

Model 251 I-V Test Software

Instruction Manual

Contains Operating Information

KEITHLEY

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**Instruction Manual
Model 251
I-V Test Software**

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Model 251 I-V Test Software

OVERVIEW

INSTRUMENTS CONTROLLED: Model 236/237/238 Source Measure Units (SMU), Model 213 Quad Voltage Source, Model 707 Matrix Switch. Model 2361 Trigger Controller is required for 2 or more SMUs.

TESTS: Control instruments to source and measure current or voltage. **Curve Family:** SWEEP, SYNCHSWEEP, STEP, and up to 3 BIAS channels, Linear, log, linear pulsed and log pulsed sweeps.

DC Source-Measure: Up to 6 BIAS Channels.

GPIB CONTROL: Provides basic control of any GPIB instrument. Useful for controlling sources, switch matrices, hot chucks, and probers.

707 MATRIX SUPPORT: Upload and download setups (up to 100 memories).

DATA DISPLAY: Graphic or list display.

XY or XYY Graph Axes: Manual or auto scale, linear or log, labeled, X-axis and Y-axis invert.

Overlay two sets of reference data on original.

GRAPHIC ANALYSIS: Dual data curve markers with data value readout.

Line Display: Between markers. Readout slope, 1/slope, X- and Y-intercept. Zoom between markers. Filter data curve.

Gain/Ratio Calculation: DC or differential. Data array or point. Graphic display or readout referenced to marker position. Used for Beta, β_m or resistance.

PRINT/PLOT: Hardcopy output of any screen to printer, or output graphic display to plotter.

FILES: **Data File:** Contains Data, test, GPIB and display parameters.

Test Setup File: Contains Test, GPIB and display parameters.

Instrument Configuration File: Contains Instrument names, GPIB addresses, Trigger Controller channels.

Test Sequence Files: Contains the user's pre-programmed test sequence (ASCII file).

707 File: Contains 707 matrix setups.

Data Export/Import: Contains Data, array names and units. Lotus (.WK1) and ASCII (.ASC).

AUTOMATIC TEST SEQUENCES: Program any sequence of tests, prints, plots, 707 downloads, data save/export, prompts and display, for attended or unattended operation. Printing or plotting can be done off-line (after acquisition).

MEASUREMENT CAPACITY LIMITS: A curve in the Curve Family Test may contain up to 1000 points. Up to six source arrays and up to six measurement arrays can be created by each test. Each array is limited to 4000 points. The maximum number of arrays and tests is limited only by the available disk storage space.

HELP: On-line, context sensitive, with index.

SYSTEM REQUIREMENTS

MINIMUM HOST COMPUTER: IBM compatible 80386, 640kb Conventional RAM (530k or 542720 bytes free) plus 1Mb of LIM expanded memory, hard drive (2MB free), 720kb 3 $\frac{1}{2}$ inch or 1.2Mb 5 $\frac{1}{4}$ inch floppy drive, Intel 80387 math coprocessor, EGA color monitor and graphics card, parallel port.

OPERATING SYSTEM: MS-DOS or PC-DOS 3.2 (minimum).

GRAPHICS ADAPTER: EGA or VGA color, VGA monochrome.

COMPATIBLE PRINTERS: IBM Graphics Printers, Epson or compatible, HP LaserJet, IBM Proprinter, and Okidata Microline 182.

COMPATIBLE PLOTTERS: HP7440, HP7470, HP7475.

COMPATIBLE MOUSE: Microsoft or Logitech.

IEEE-488 (GPIB) INTERFACE CARDS SUPPORTED

Advantech PCL 748

B&C PC488A

BBS GPIB-1000

Capital Equipment PC<>48, 4x488, PS<>488

Contec GPIB (PC)

Hewlett Packard HPIB

IBM GPIB board

ICS 488-PC1

IOtech GP488, GP488/2

Keithley PC-488-CEC, 4-488-CEC-0M, 4-488-CEC-1M, PS-488-CEC

MetraByte IE-488

National Instruments GPIB-PC, GPIB-PCII, GPIB-PCIIA, GPIB-PCIII,

MC-GPIB, AT-GPIB

Qua Tech MXI-100, MXI-1000

Scientific Solutions IEEE 488 LM, MC-IEEE 488

Ziatech ZT 1444, ZT/2

SUPPLIED TEST LIBRARY

The Test Library provides default settings for the Test, 707 Matrix, GPIB Control, Data Display and Graphic Analysis screens.

FET TESTS: Curve Family, Threshold Voltage, Transconductance, Breakdown, and Leakage.

BIPOLAR TESTS: Curve Family, Gummel Plot, Current Gain, Breakdown, and Leakage (linear and pulsed sweeps).

DIODE TESTS: I-V Curve, Reverse Breakdown, Zener Voltage.

COMPONENT TESTS: Capacitor Leakage, Resistor Voltage Coefficient.

EXAMPLE GPIB CONTROL: 213 Quad Voltage Source, 707 Switching Matrix and hot chuck.

TEST SEQUENCES: Bipolar tests, multiple diodes.

MATERIALS PROVIDED

Instruction Manual

Diskettes: 720kb 3 $\frac{1}{2}$ inch and 1.2Mb 5 $\frac{1}{4}$ inch containing installation, program, test library, and sample data.

Specifications subject to change without notice.

Model 251 Addendum

INTRODUCTION

This addendum to the Model 251 Instruction Manual is being provided to supply you with the latest information in the least possible time. Please incorporate the following information into the manual.

LOADING AND SAVING FILES

An enhancement to the Model 251 I-V Test Software is its ability to perform file operations from the CURVE FAMILY TEST and DC SOURCE-MEASURE TEST forms. You no longer have to return to the main menu to load/save data, test setup, instrument configuration, and 707 files, or import/export ASCII and Lotus formatted files. (Loading sequence files remains a main menu operation.)

This load/save enhancement is implemented with function keys. The <F2> key loads (and imports) files and the <F3> key saves (and exports) file.

When the <F2> key is pressed from the CURVE FAMILY TEST or DC SOURCE-MEASURE TEST form, the following pop-up is displayed:

Load Data File
Load Test File
Load Inst. Cfg. File
Load 707 File
Import ASCII File
Import Lotus File

Use the cursor to select the desired operation and press <Enter>. When loading test setup and data files, you are reminded that loading overwrites old test parameters and data. If you continue, the next screen prompts for a file name in the usual manner. After the file is loaded or imported you are returned to the appropriate test form.

When the <F3> key is pressed from the CURVE FAMILY TEST or DC SOURCE-MEASURE TEST form, the following pop-up is displayed:

Save Data File
Save Test File
Save Inst. Cfg. File
Save 707 File
Import ASCII File
Import Lotus File

Use the cursor to select the desired operation and press <Enter>. The next screen prompts for a file name in the usual manner. After the file is saved or exported you are returned to the appropriate test form.

SEQUENCER DELAY COMMAND

A DELAY command has been added to the test sequencer. It forces the sequencer to wait a specified interval before processing the next command. This allows for thermal settling between tests or sending GPIB commands to other instruments. The DELAY command has the form:

DELAY: delay_value

where delay_value may be specified in seconds or dd:hh:mm:ss for days, hours, minutes, and seconds (expressed in positive integers). There is a maximum of three colons in the delay_value field, plus one that must follow the DELAY command.

During the time delay, the screen displays the seconds remaining. You can press <Esc> to stop the delay. The following examples show legal and illegal forms:

DELAY: 0	zero seconds
DELAY:	illegal value
DELAY: :	zero seconds
DELAY:3::120:100	3 days, 120 minutes, 100 seconds

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SECTION 1

General Information

1.1 INTRODUCTION

This section contains overview information for the Model 251 I-V Test Software system and is arranged as follows:

1.2 Features

1.3 Warranty Information

1.4 Manual Addenda

1.5 Safety Symbols and Terms

1.7 Computer Requirements

1.2 FEATURES

Model 251 I-V Test Software is a program that controls a system of instruments designed to measure I-V characteristics of semiconductors. Model 251 can be configured to support the following instruments:

- Model 236/237/238 Source Measure Units
- Model 2361 Trigger Controller
- Model 213 Quad Voltage Source
- Model 707 Switching Matrix

Other Keithley and non-Keithley instruments are supported with user-programmed device-dependent commands.

Key Model 251 features include:

- The menu-driven software allows easy data collection of parameters from semiconductors and other components. No computer programming knowledge is necessary to operate the system.
- The data is displayed on the computer monitor and can be printed or plotted on a hardcopy peripheral.
- Graphical analysis capabilities include markers, line slope, zooming, and smoothing.
- A library of tests is included for resistors, capacitors, diodes, bipolar transistors, and FETS. Test setup and sample data files are included on disk.
- A test sequencing procedure lets you chain multiple tests without operator interventions.
- Full Model 213 support provides an easy method of interfacing a four-channel voltage bias source.
- Model 707 support for uploading and downloading of up to 100 setups expands the capability to run multiple tests on multiple devices.
- The Model 2361 Trigger Controller that is available simplifies trigger connections and optimizes trigger response times among the source measure units.

1.3 WARRANTY INFORMATION

Warranty information is located on the inside front cover of this instruction manual. Should you require warranty service, contact your Keithley representative or the factory for further information.

1.4 MANUAL ADDENDA

Any improvements or changes concerning Model 251 I-V Test Software or this instruction manual will be explained on a separate addendum supplied with the documentation. Please be sure to note these changes and incorporate them into the manual before operating the system.

1.5 SAFETY SYMBOLS AND TERMS

The following safety symbols and terms may be found on the instruments or used in this manual:

The  symbol on an instrument indicates that you should consult the operating instructions in the associated manual.

The  symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

A **WARNING** heading in this and other manuals cautions against possible hazards that could lead to personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

A **CAUTION** heading outlines dangers that could damage an instrument. Such damage may invalidate the warranty.

1.6 UNPACKING AND INSPECTION

1.6.1 Unpacking Procedure

Upon receiving the Model 251, carefully unpack it from the shipping carton and inspect all items for any obvious physical damage. Report any such damage to the shipping agent at once. Save the original packing carton for possible future reshipment.

1.6.2 Shipment Contents

The following items are included with every Model 251 order:

- Model 251 distribution disks (1.2M-byte, 5-1/4" and 720K-byte, 3-1/2")
- Copy protection block
- Model 251 Instruction Manual

NOTE

Model 251 distribution disks are available upon request in the 360K-byte, 5-1/4" format. Contact Keithley's Applications department.

1.6.3 Instruction Manual

If an additional instruction manual is required, order the manual package, 251-901-00. The manual package includes an instruction manual and any applicable addenda.

1.7 COMPUTER REQUIREMENTS

The following paragraphs discuss minimum and recommended computer requirements, supported interface cards, printers, and plotters.

1.7.1 Computer Hardware

Model 251 I-V Test Software is intended to run on an IBM Personal System/2 (80386) or IBM compatible 80386 computer. Table 1-1 summarizes the computer configuration.

NOTE

Although Model 251 software will run on an 80286-based computer, an 80386-based computer is recommended for speed considerations.

1.7.2 IEEE-488 Interfaces

The computer must be equipped with a suitable IEEE-488 interface so that it can communicate with the instruments. IEEE-488 interfaces supported by Model 251 software are listed below:

Advantech PCL 748
 B&C PC488A
 BBS GPIB-1000
 Capital Equipment PC<>488, 4x488, PS<>488
 Contec GPIB (PC)
 Hewlett Packard HPIB

IBM GPIB board
 ICS 488-PC1
 IOtech GP488, GP488/2
 Keithley PC-488-CEC, 4-488-CEC-0M, 4-488-CEC-1M, PS-488-CEC
 MetraByte IE-488
 National Instruments GPIB-PC, GPIB-PCII, GPIB-PCIIA, GPIB-PCIII, MC-GPIB, AT-GPIB
 Qua Tech MXI-100, MXI-1000
 Scientific Solutions IEEE 488 LM, MC-IEEE 488
 Ziatech ZT 1444, ZT/2

1.7.3 Printers and Plotters

To obtain hard copies of your curves, it will be necessary for you to connect a suitable printer (serial or parallel) or plotter (serial or IEEE-488) to your computer. Compatible printers and plotters for Model 251 software are as follows:

Printers

IBM Graphics Printer, Epson or compatible
 HP LaserJet
 IBM Proprinter
 Okidata Microline 182

Plotters

HP 7440
 HP 7470
 HP 7475

Table 1-1. Computer Hardware Requirements

Description	Requirements
Computer	IBM compatible 80386 with parallel port
RAM	640KB conventional memory (530KB free), 1MB of LIM expanded memory
Coprocessor	Intel 80387
Disk drives	Hard drive, 720KB 3-1/2" or 1.2MB 5-1/4" floppy drive
Monitor/graphics card	EGA or VGA color, VGA monochrome
Mouse	Microsoft or Logitech mouse
Operating system	MS-DOS or PC-DOS 3.2

SECTION 2

Getting Started

2.1 INTRODUCTION

Section 2 contains introductory information to help you get your system up and running as quickly as possible. Section 3 contains more detailed information on using the Model 251 I-V Test Software.

Section 2 is organized as follows:

2.2 Hardware Configuration: Details the system hardware configuration, cable connections, and trigger controller.

2.3 System Power-up: Covers the power-up procedure for a typical system, environmental conditions, and warm-up periods.

2.4 Computer Hardware and Software Installation: Outlines installing the IEEE-488 interface and Model 251 software, including configuring the software for a graphics adapter, printer, and plotter.

2.5 Operation Overview: Describes the overall structure of the Model 251 I-V Test Software and details configuring the software for the IEEE-488 interface and instruments.

2.6 System Checkout: Gives the procedure for checking out the system to ensure that everything is working properly, including running sample tests.

2.2 HARDWARE CONFIGURATION

2.2.1 System Block Diagram

An overall block diagram of a system for running Model 251 software is shown in Figure 2-1. This configuration with two source measure units, a quad voltage source, and a switching card and mainframe, is a typical system with switching, yours may differ. The various system components perform the following functions:

Model 236/237/238 Source Measure Units — Each source measure unit can source voltage and simultaneously measure current, or source current and simultaneously measure voltage. One unit is necessary to run two-terminal device tests, while two units are required to run bipolar transistor and FET tests. If a substrate bias is required, a third source measure unit, a quad voltage source, or a current or voltage source will be necessary.

Model 2361 Trigger Controller — A Model 2361 Trigger Controller is a bus-programmable instrument that is required for all tests where more than one source measure unit is configured to measure (including synchronized sweeps). The unit can handle the triggering needs of up to six source measure units. It not only simplifies system trigger connections, but it also coordinates the trigger schemes needed for all tests. The front and rear panels of the Model 2361 are shown in Figure 2-2. Refer to Appendix C for more information on the Model 2361.

Model 213 Quad Voltage Source — The Model 213 is a quad output digital to analog converter interface for the IEEE-488 bus. Each port can be programmed for full scale output of $\pm 1V$, $\pm 5V$, or $\pm 10V$.

Model 707 Switching Matrix — The Model 707 is a programmable switch for connecting signal paths in a matrix or multiplex topology. It is for large-scale switching applications (up to 576 crosspoints per mainframe). Plug-in cards are available for general purpose and special purpose switching.

Model 8006 Component Test Fixture — The test fixture is the interface between the DUT (device under test) and the instruments. The Model 8006 includes sockets for axial-component, TO packages, and 24-pin DIP package devices. A Model 8007 Semiconductor Test Fixture or a user-supplied test fixture could also be used.

Computer — An IBM PS/2 (or compatible), or a 386-based computer, equipped with an IEEE-488 interface card, controls the test system.

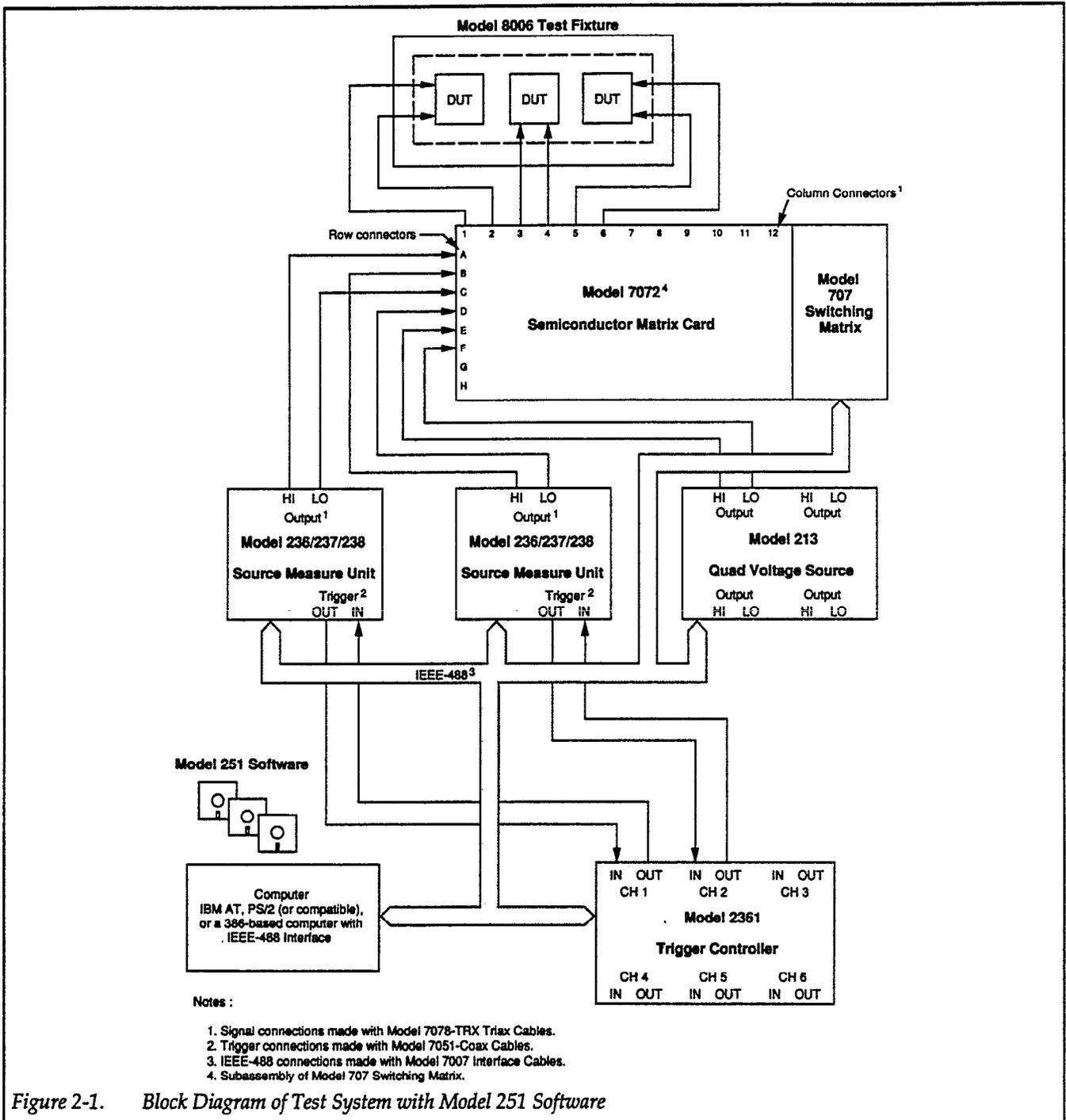


Figure 2-1. Block Diagram of Test System with Model 251 Software

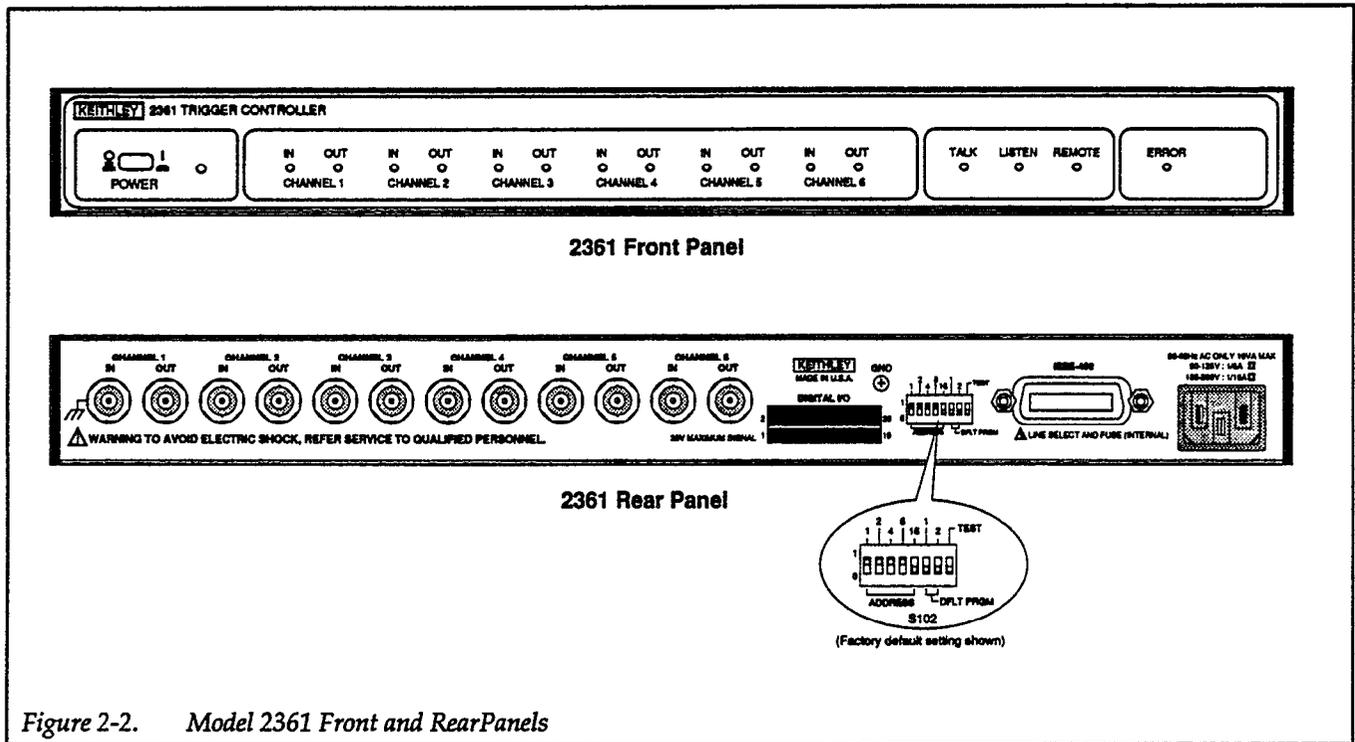


Figure 2-2. Model 2361 Front and Rear Panels

Table 2-1. Signal and Interlock Cables

Model	Description	Application
7078-TRX	0.9m (also 3m or 6m) low noise triax cable	Signal connections between 236/237/238, 7072 and 8006 or 8002A
236-ILC-3	3m shielded cable	Interlock connections between 236/237/238 and 8006 or 8002A
7051	0.6m (also 1.5m or 3m) BNC cable (RG-58C)	Trigger connections between 236/237/238 and 2361; unguarded signal connections
7078-TRX-BNC	3-slot male triax to BNC adapter	Unguarded signal connections between 236/237/238, 7072 and coax cables
7007	1m (also 2m) shielded IEEE-488 cable	IEEE-488 instrument bus

2.2.2 System Connections

Table 2-1 summarizes the necessary cables for a test system with Model 236/237/238 Source Measure Units, a Model 2361 Trigger Controller, a Model 707 Switching Mainframe with a Model 7072 Semiconductor Matrix Card, and a Model 8006 or 8002A Test Fixture.

Using Figure 2-3 and Figure 2-4 as a guide for a single source measure unit, and Figure 2-5 through Figure 2-7 for multiple source measure units, connect the equipment together as shown. For test systems using a Model 213 Quad Voltage Source or a Model 7072 Semiconductor Matrix Card, see Figure 2-8 and Figure 2-9.

WARNING

All equipment should be turned off when making connections.

WARNING

Safety interlocks must be used to protect the operator from potentially lethal voltages that could result in injury or death. Keithley source measure units are designed to be used with test fixtures that incorporate a safety interlock switch, such as the Keithley Model 8006 Test Fixture. By using the interlock, the source measure unit cannot source current or voltage when the lid of the test fixture is open. Refer to paragraph 2.3 in the Model 236/237/238 Operator's Manual for more information on interlock usage for the Model 8006 and custom test fixtures.

WARNING

The test fixtures must be connected to safety earth ground using #18 AWG or larger wire.

To simplify test connections, most examples in this manual use local sensing for the source measure units. Local

sensing requires connecting only two signal cables between the source measure unit and the test fixture (OUTPUT HI and OUTPUT LO). Also, the appropriate jumpers between the test fixture signal panel and the component test module must be installed.

To optimize accuracy, you should use remote sensing in any of the examples (remote sensing is recommended for optimal accuracy with currents above 1mA). To use remote sensing, connect SENSE HI and SENSE LO to the test fixture, and add the necessary jumpers to the DUT. See Section 2 of the Model 236/237/238 Operator's Manual for complete details on test connections.

WARNING

With remote sensing enabled, an open sense lead will result in lethal voltages appearing at OUTPUT HI and GUARD. This voltage can cause injury or death, and damage external circuitry. Always make sure that the sense leads are properly connected before enabling remote sense. NEVER change connections with power applied. Be sure to always discharge and/or disconnect external power sources.

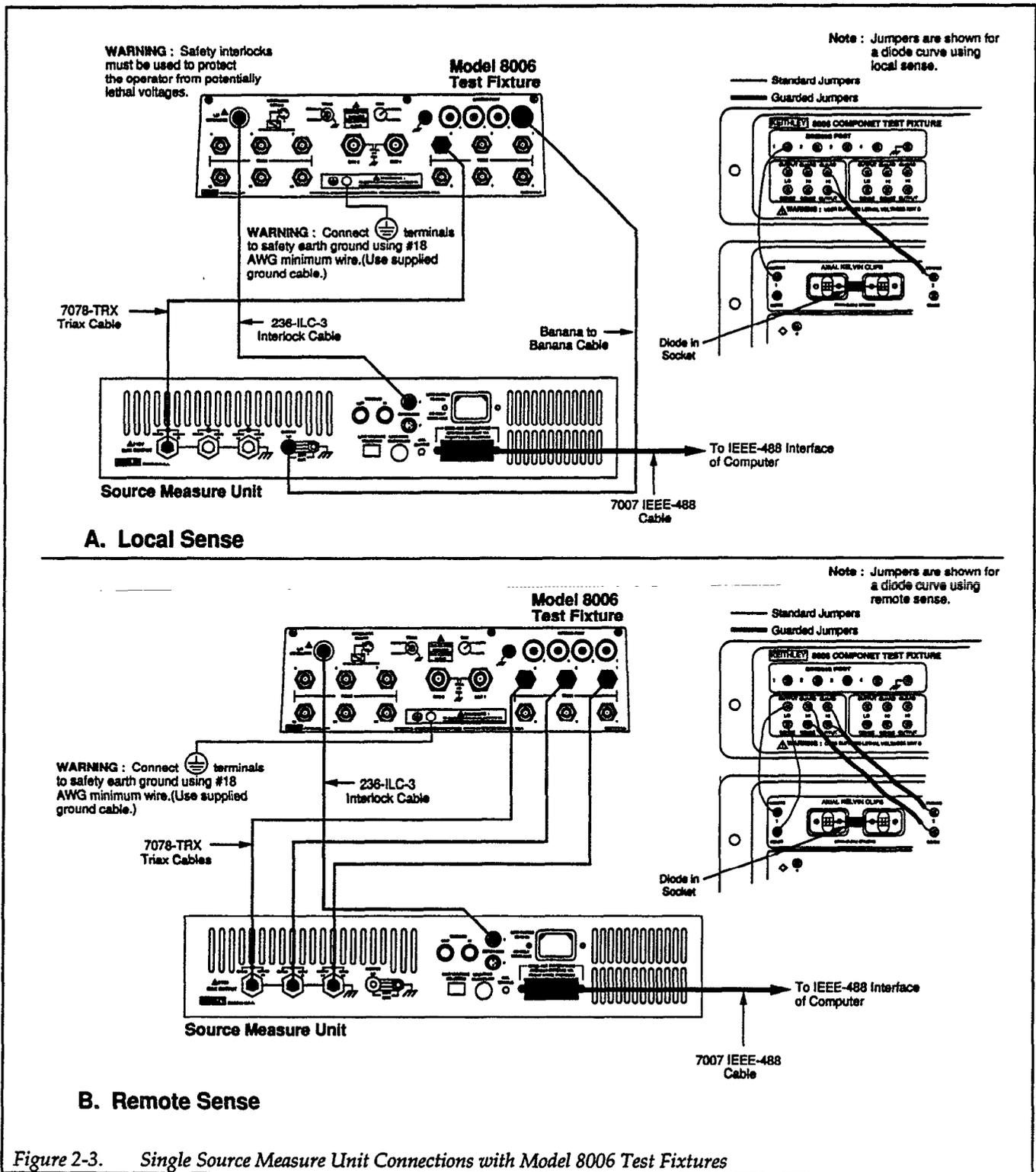


Figure 2-3. Single Source Measure Unit Connections with Model 8006 Test Fixtures

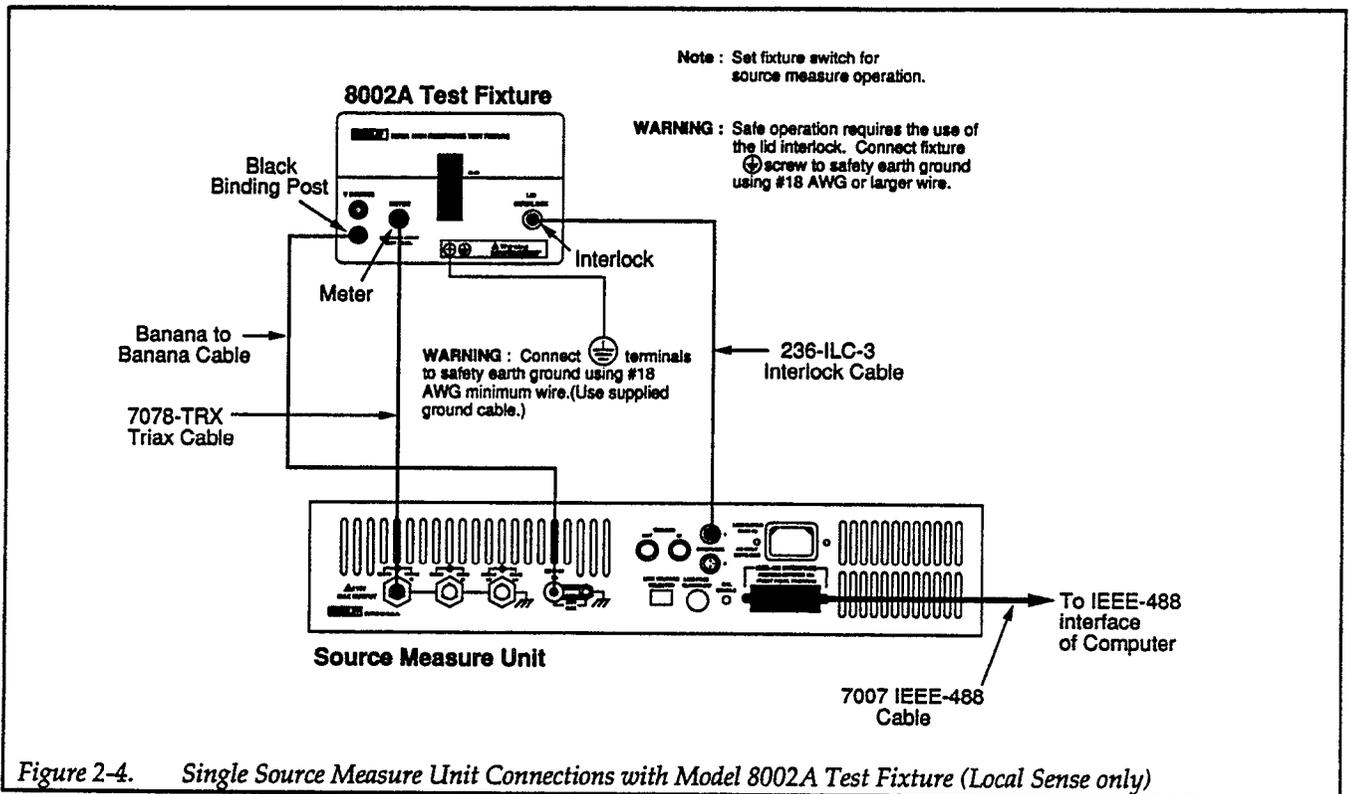


Figure 2-4. Single Source Measure Unit Connections with Model 8002A Test Fixture (Local Sense only)

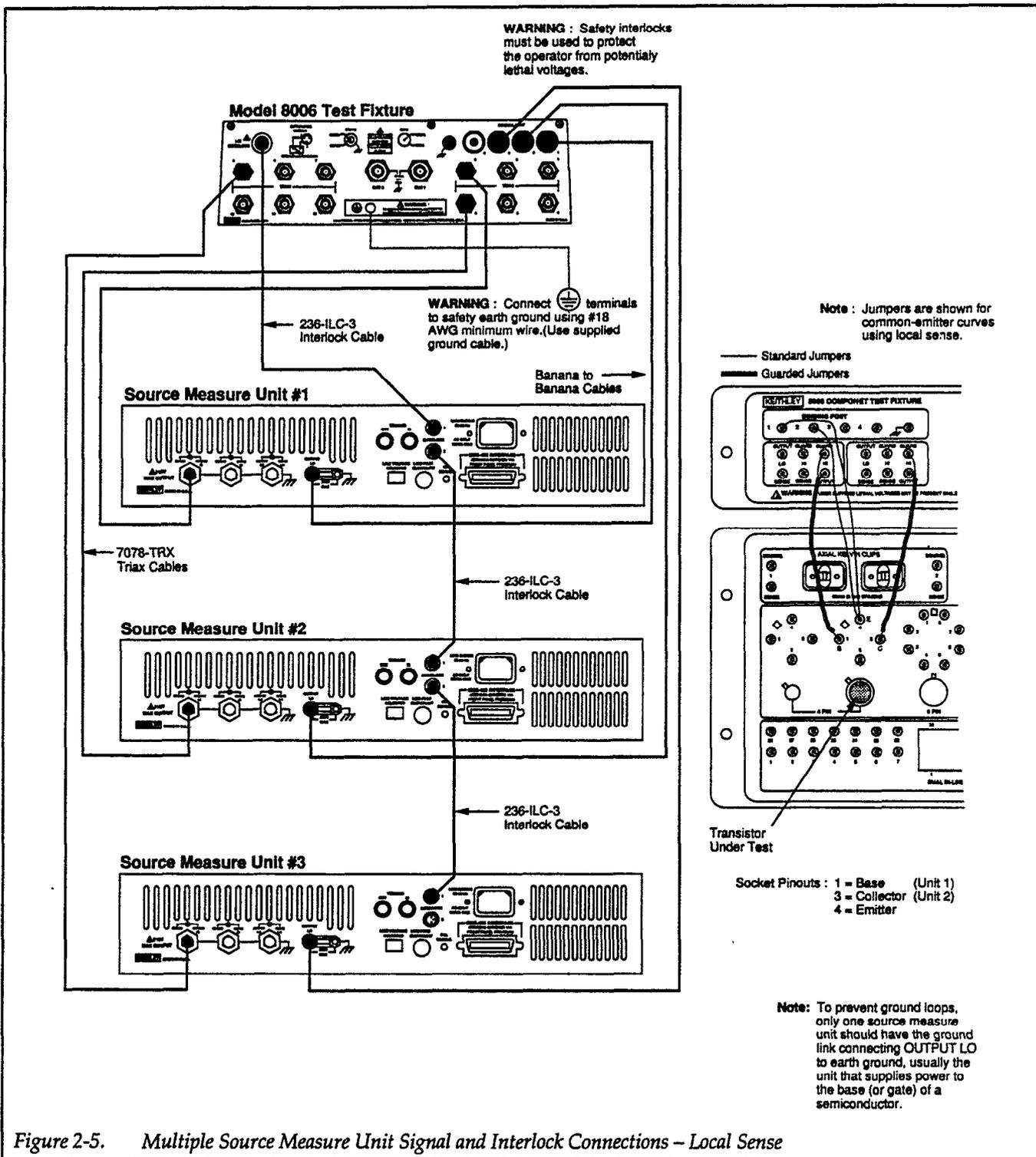


Figure 2-5. Multiple Source Measure Unit Signal and Interlock Connections – Local Sense

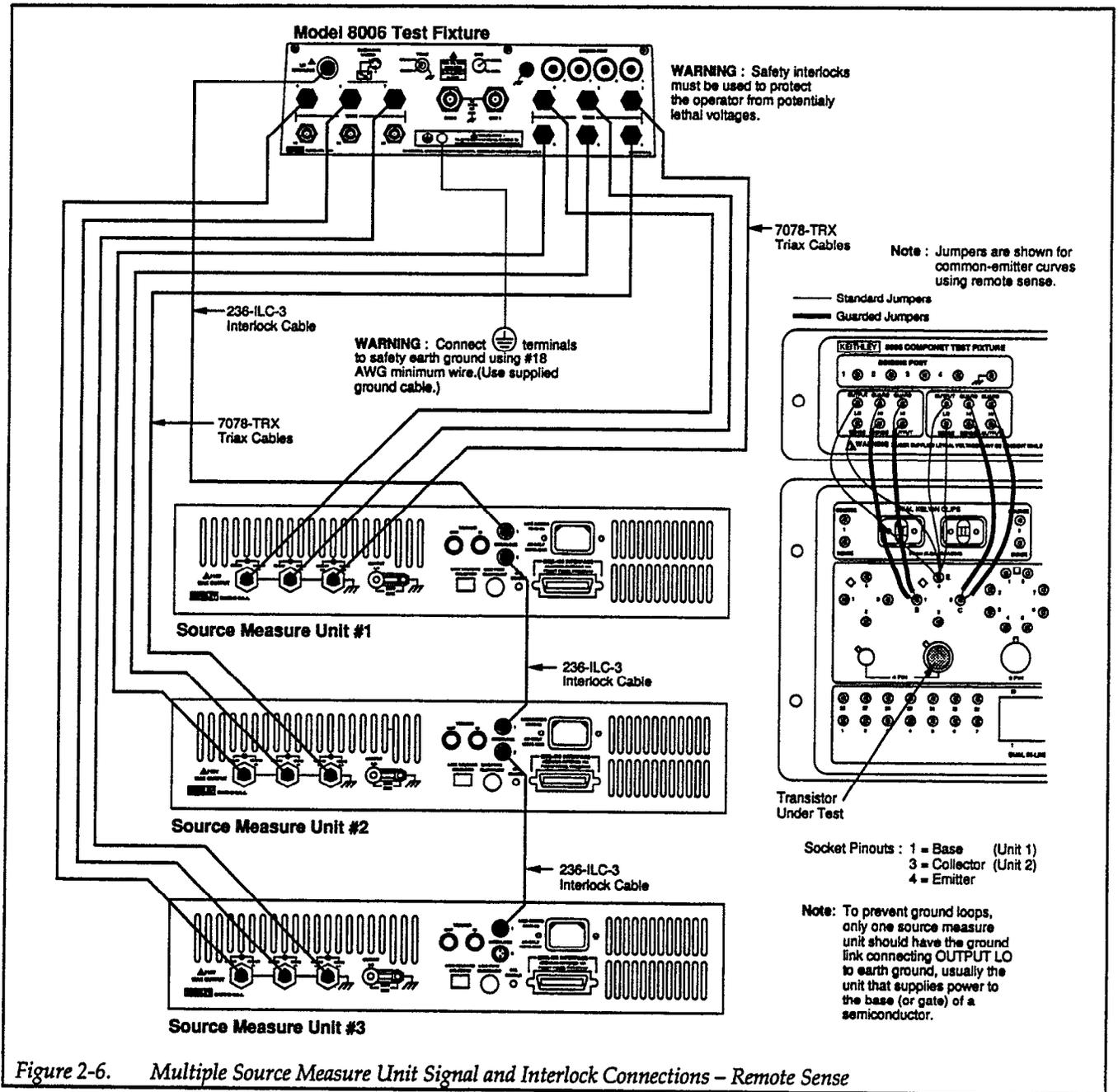


Figure 2-6. Multiple Source Measure Unit Signal and Interlock Connections – Remote Sense

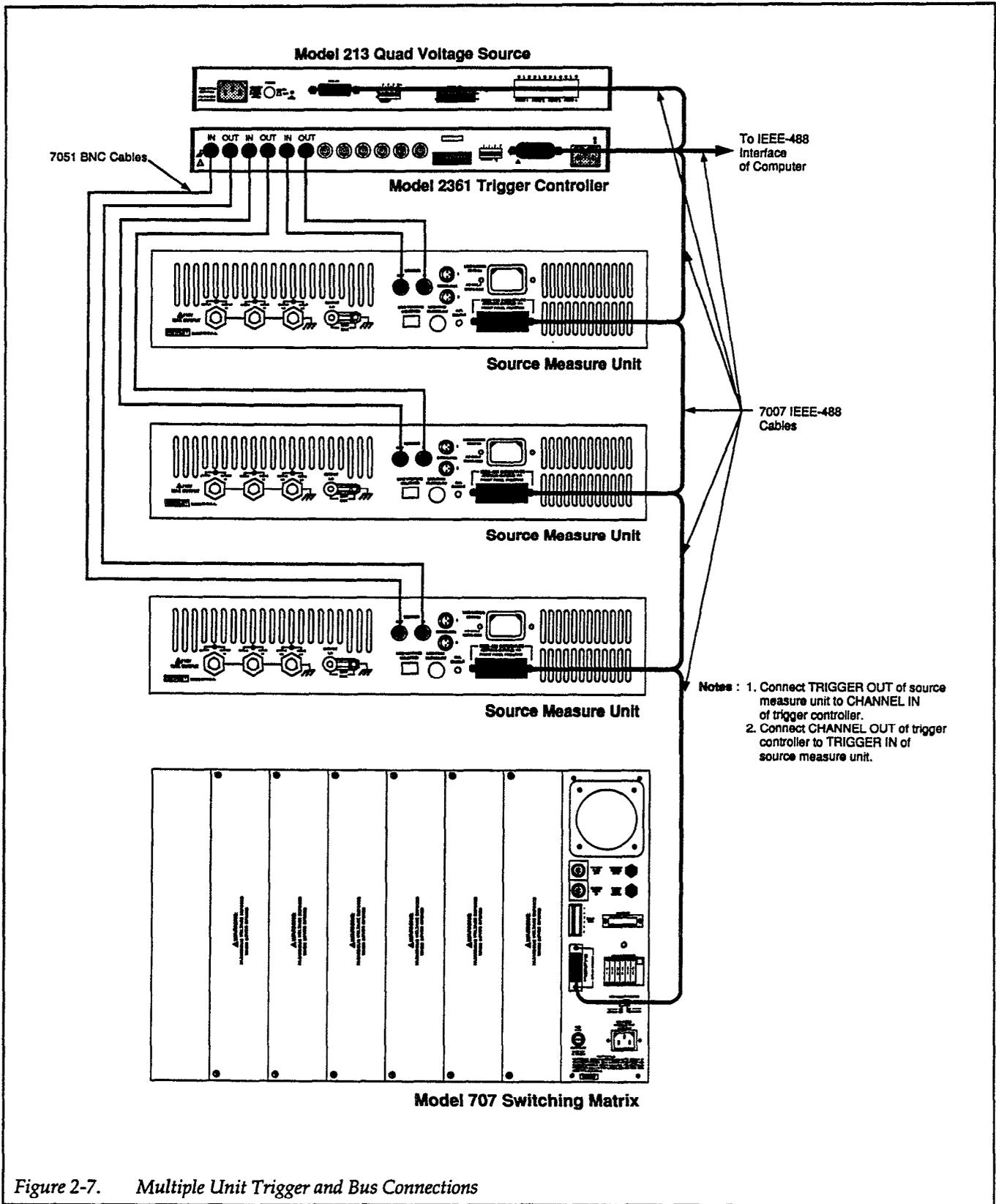


Figure 2-7. Multiple Unit Trigger and Bus Connections

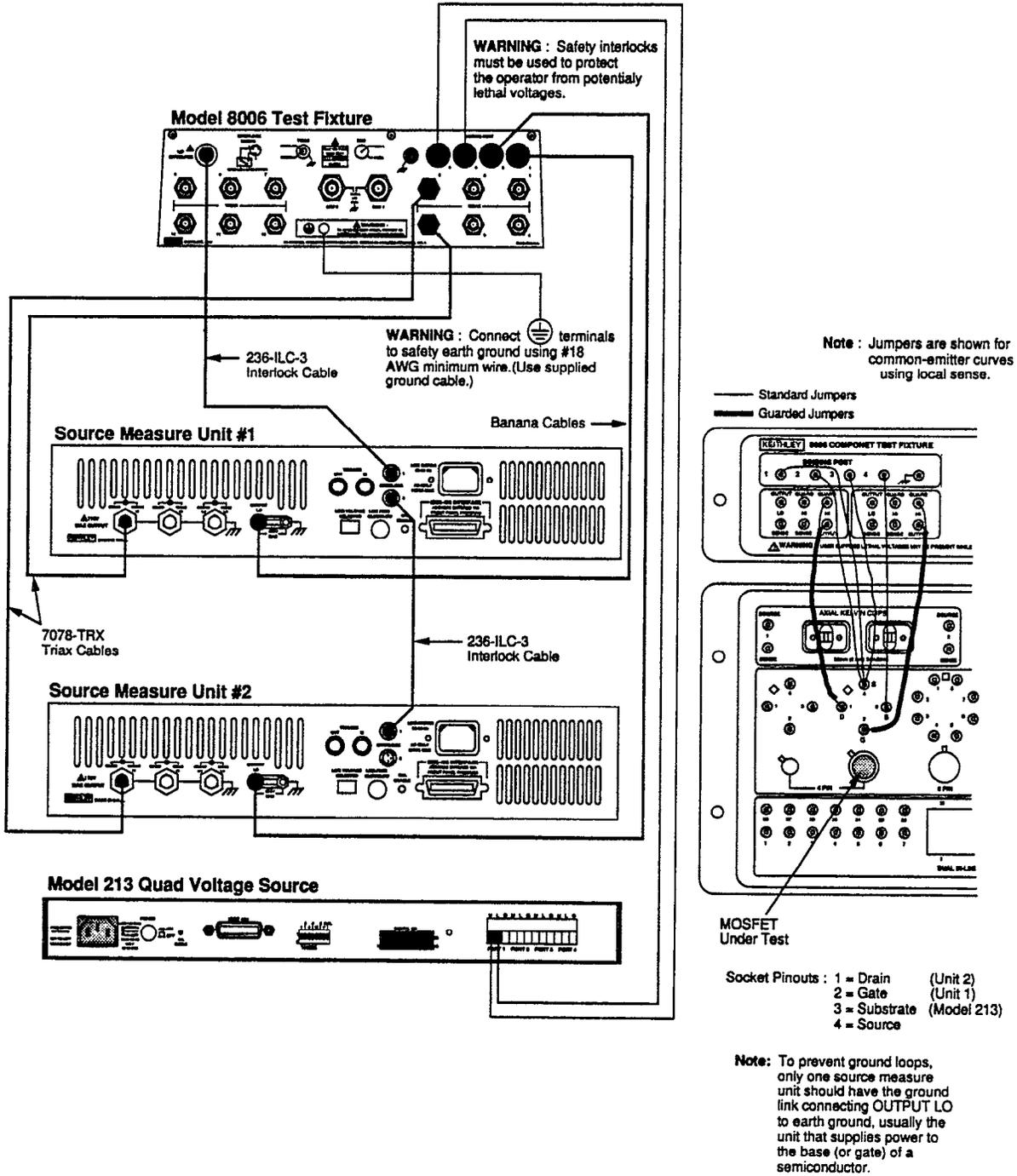


Figure 2-8. Example Signal Connections with Model 213

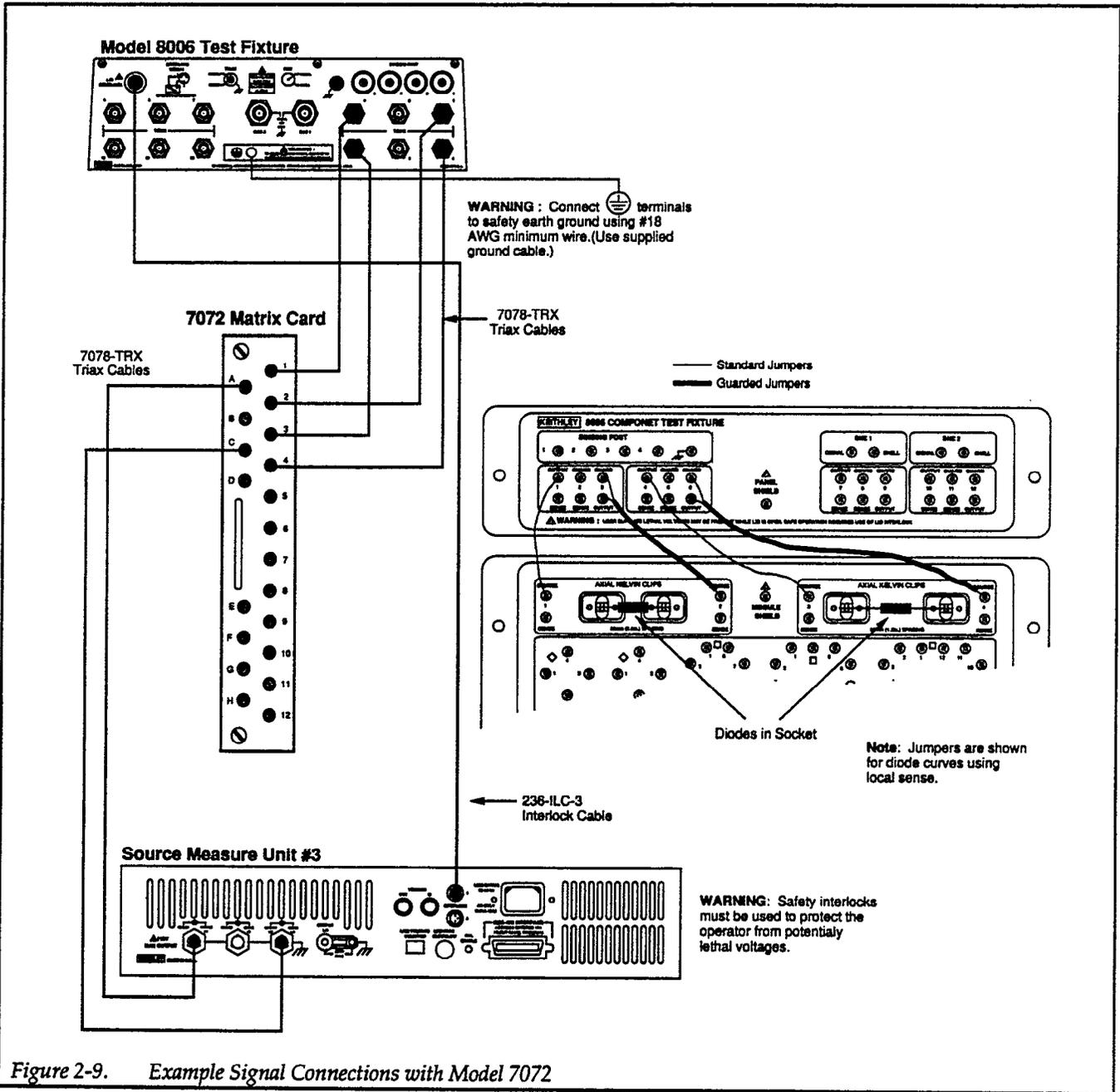


Figure 2-9. Example Signal Connections with Model 7072

2.3 SYSTEM POWER-UP

2.3.1 Instrument Power Requirements

The Model 236/237/238 Source Measure Units are designed to operate from 105-125V or 210-250V line power ranges. A special transformer may be installed (at the factory) for 90-110V and 195-235V ranges. A slide switch on the rear panel indicates the present operating voltage. If the line voltage needs to be changed, refer to the Model 236/237/238 Operator's Manual.

Both the Model 2361 Trigger Controller and Model 213 Quad Voltage Source operate from 90-125V or 180-250V line power ranges. The present operating voltage is indicated on the rear panel. If the line voltage needs to be changed, a slide switch is located inside the unit (refer to Appendix B or the appropriate instruction manual).

The Model 707 Switching Matrix operates from 105-125V or 210-250V line power ranges. It can be rewired at the factory for the 90-110V and 180-220V ranges. A slide switch on rear panel indicates the selected line voltage. To change the selection, refer to the Model 707 Switching Matrix Instruction Manual.

CAUTION

Do not attempt to operate an instrument on a supply voltage outside the allowed range, or instrument damage may occur.

2.3.2 Power Connections

Each instrument should be connected to a grounded AC outlet using the supplied AC power cord or the equivalent.

WARNING

Each instrument must be connected to a grounded outlet to ensure protection from electric shock. Failure to use a grounded outlet and a 3-wire power cord may result in personal injury or death because of electric shock.

WARNING

As a safety precaution, it is recommended that all instruments in a rack be connected to a single power outlet strip. The strip should be wired to a panel-mounted emergency stop switch within easy access of the user. A red push-pull mushroom switch should be mounted to the top front of the instrument rack. The switch must be UL recognized and have sufficient break current capacity for the load. To specify the break current of the switch, add up the total VA of the rack instruments and divide by the line voltage. Multiply the total by 125% to yield the minimum break current specification for an inductive load.

2.3.3 Environmental Conditions

For maximum accuracy, all measuring instruments and the test fixture must be operated at an ambient temperature between 18 and 28°C at a relative humidity less than 70%. (See specifications in Models 236/237/238 Operator's Manual.)

2.3.4 Warm-up Period

The system can be used immediately when all instruments are first turned on, however, to achieve rated system accuracy, all instruments should be turned on and allowed to warm up for at least one hour before use.

2.3.5 Power-up Procedure

Follow the general procedure below to power up a Model 251 I-V Test system:

1. Connect the instruments together as outlined in paragraph 2.2.3.
2. Examine the rear panel DIP switches on the Model 2361 and Model 213. Set switches to desired IEEE-488 bus addresses. The factory default setting (15) of the Model 2361 is shown in Figure 2-2. The default setting (9) of the Model 213 is shown in Figure 2-10.
3. Turn on each instrument by pressing in its power switch. Verify that each instrument goes through its normal power-up routine, as described below.

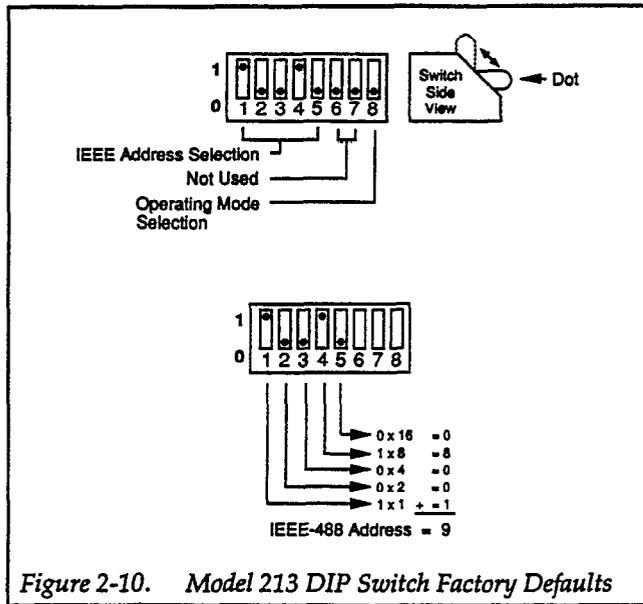


Figure 2-10. Model 213 DIP Switch Factory Defaults

WARNING

In a multiple source measure unit test system, make sure all the Model 236/237/238s remain powered up. Turning off one or more Model 236/237/238s may result in erratic interlock operation. For example, if any unit is turned off, an operational Model 236/237/238 may not go into standby when the lid of the system test fixture is opened. This condition exposes the operator to potentially lethal voltages that could result in injury or death.

Model 2361 Power-up

The instrument first turns on all LEDs. If the self-test diagnostic passes, all LEDs but the one for POWER turn off, and the unit is ready for normal operation. If the self-test diagnostic fails, the LEDs will indicate the problem, as explained in Appendix C.

Model 236/237/238 Power-up

The source measure units perform a self-test at power-up, then display a model number, software revision, and IEEE-488 address.

The MANUAL TRIGGER LED on the front panel should be blinking when the source measure unit completes its

self test. If it is not, cycle power on the instrument. (Complete details on the power-up sequence are in the Model 236/237/238 Operator's Manual.)

The instrument will operate at a line frequency of 50 or 60Hz. To check the line frequency setting, press the MENU button and rotate the knob until the line frequency is displayed. The alternate line frequency can be selected by displaying it with the SELECT buttons and then pressing ENTER. To exit from the menu, press the MENU button.

To change the IEEE-488 bus address, press the MENU button and rotate the knob until the bus address is displayed. Key in the desired address and press ENTER. Examples in this manual will assume unit #1 at address 16, unit #2 at address 17, and unit #3 at address 18. To exit from the MENU, press the MENU button.

Model 213 Power-up

All the front panel LEDs should light for approximately one second while the unit performs an internal ROM and RAM self-test. At the end of this self-test, all indicators should turn off except POWER. Flashing LEDs or the ERROR LED indicate failure of the self-test. Refer to the Model 213 Instruction Manual for details.

Model 707 Power-up

The Model 707 will perform a power-up self-test to check ROM, RAM, card configuration, stored setups, master/slave loop, indicators, and displays. It will then show the software revision level and IEEE-488 bus address. (See the Model 707 Instruction Manual for a listing of error messages.) When the self-test has completed, the Model 707 is configured with:

- All relays opened.
- RELAYS indicator lit.
- RELAY STEP to 000.
- MEMORY STEP to 001.

To change the IEEE-488 bus address, press the MENU key until the present address is displayed. Use the data entry keys to key in a new value, then press ENTER. This action will also exit menu mode.

2.4 COMPUTER HARDWARE AND SOFTWARE INSTALLATION

2.4.1 IEEE-488 Interface Card Installation

Model 251 software can be used with the IEEE-488 interfaces listed in Table 2-2.

Note the configuration settings of your IEEE-488 interface card (also referred to as a GPIB card). If necessary, see the documentation supplied with the interface card for interpretation of the switch and jumper settings. Depending on the particular card, you will be prompted for

these parameters when Model 251 software is configured for an IEEE-488 card:

- I/O port address
- Memory address
- System controller setting
- Interrupt line number
- Interrupt level

After noting the card configuration, install it in the computer. See the interface card documentation for detailed installation procedures.

Table 2-2. IEEE-488 Boards and Default Configurations

Board Name	Factory Default Setting		
	I/O Address	IRQ #	DMA #
Advantech PCL-748	C000 (MEM)	NC	1
B&C PC488A	2E1	NC	NC
BBS GPIB-1000	390	NC	NA
Capital Equipment PC<>488	2B8	NC	1
Capital Equipment PS<>488	2B8	3	1
Capital Equipment 4 x 488	2B8	NC	1
Contect GPIB (PC)	2E1	7	1
Hewlett-Packard HPIB	DC00 (MEM)	5	2
IBM GPIB board	2E1	7	1
ICS 488-PC1	C000 (MEM)	NC	1
IOtech GP488	2E1	NC	NC
IOtech GP488/2	2B0	NC	4
Keithley PC-488-CEC	2B8	NC	1
Keithley 4-488-CEC-0M, 4-488-CEC-1M	2B8	NC	1
Keithley PS-488-CEC	2B8	3	1
MetraByte IE-488	300	5	3
National Instruments AT-GPIB	2C0	11	5
National Instruments GPIB-PC	2B8	7	1
National Instruments GPIB-PCII	2B8	7	1
National Instruments GPIB-PCIIA	2E1	7	1
National Instruments GPIB-PCIII	280	7	1
National Instruments MC-GPIB	E00	3	0
Qua Tech MXI-100	318	2	3
Qua Tech MXI-1000	200	3	3
Scientific Solutions IEEE 488 LM	2E1	7	1
Scientific Solutions MC-IEEE 488	2B8	5	0
Ziatech ZT 1444	210	NC	NC
Ziatech ZT/2	800	NC	1

NA = feature not available on this board
NC = not configured from factory

NOTE: Only Micro Channel boards can use multiple DMA channels. Non-Micro Channel boards must use DMA channel number 1 except for the Hewlett-Packard board which uses DMA channel 2. Also note that the Ziatech ZT/2 board cannot use DMA channels 4-7.

2.4.2 Copy Protection Block

Model 251 I-V Test software is copy protected. To run Model 251 software, you must install the copy protection block that was shipped with the software. The copy protection block attaches to any parallel port on the back of your computer. Figure 2-11 shows a block installed on a computer.

To install the copy protection block, first remove from the parallel port any device cable, such as a printer cable, if one is currently attached. Then insert the block into the port and re-attach the device cable. The block will not interfere with the performance of the device attached to the parallel port. Note that a device does not need to be connected to the block in order to run Model 251 software.

2.4.3 Software Backup

Before installing Model 251 software on your hard disk, make backup copies of each of the distribution floppy disks. To do so, boot up DOS, then use the DOS command

DISKCOPY, which automatically formats blank disks. (Remember that the DISKCOPY command file must be in the current directory or path.) For systems with two floppy disks, the command syntax is:

```
DISKCOPY A: B: <Enter>
```

Follow the prompts on the screen to complete copying of all supplied disks.

Similarly, the command for systems with one floppy disk is:

```
DISKCOPY A: A: <Enter>
```

Again, follow the prompts on the screen to copy all supplied disks.

After copying, put the original disks away for safekeeping.

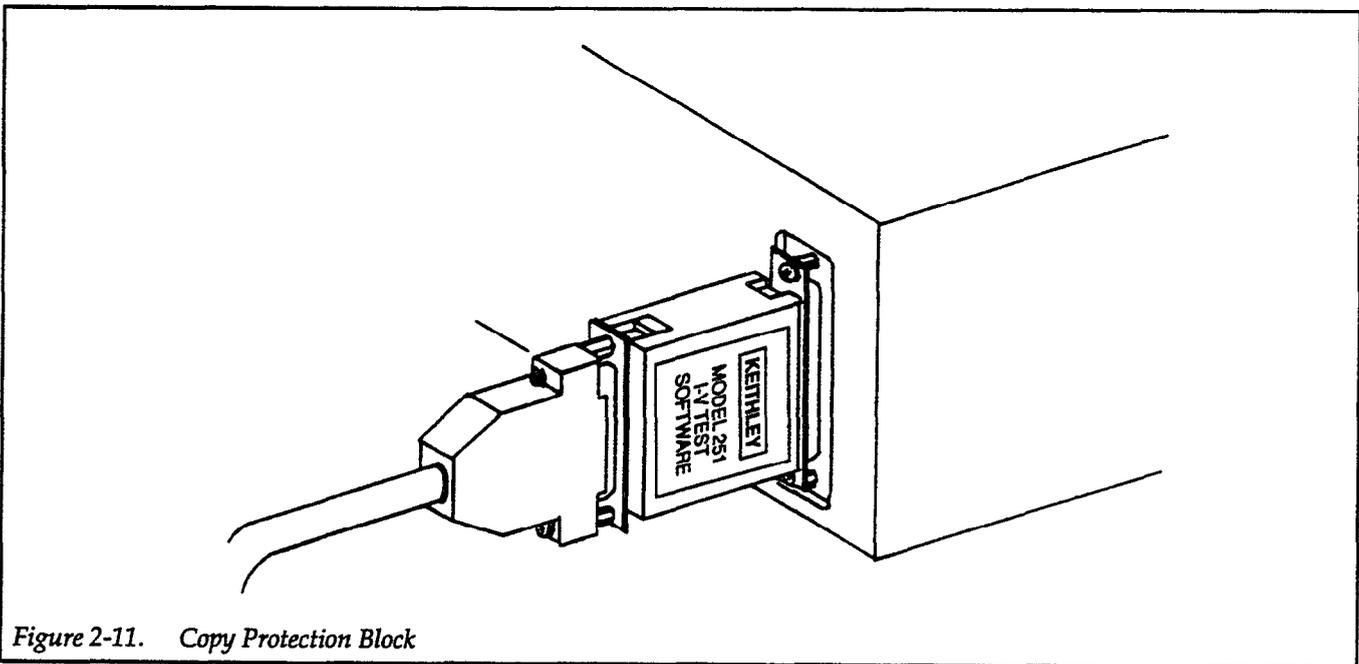


Figure 2-11. Copy Protection Block

2.4.4 Software Installation and Configuration

Model 251 software is installed on a hard disk drive by the program called `INSTALL`, which is supplied on the distribution floppy disks. This program creates subdirectories and copies files for initial installation. It may also be used to reconfigure the software after a change in the computer configuration (see paragraph 2.4.5). Follow the procedure below in the order presented to install the software. Press `<Esc>` at any time to abort installation.

1. Place the backup copy of the Model 251 Installation Disk in drive A and enter the following:

```
A: <Enter>
TYPE README.DOC <Enter>
```

This file explains the latest changes and how experienced DOS users can install the software without reading the following instructions.

2. Type in:

```
INSTALL <Enter>
```

The title screen of the `INSTALL` program is displayed.

At this time, the program checks for a minimum computer configuration:

- EGA or VGA graphics adapter
- DOS version 3.2 or higher
- Math coprocessor
- At least 640K-bytes RAM

If minimum requirements are not present, the `INSTALL` program will display an error message.

3. Press `<Esc>` to quit or any other key to continue. The next screen asks you if this is a first-time installation or a reconfiguration of previously installed software.

Select the first option to install Model 251 for the first time. The second option is used when it is necessary to reconfigure Model 251 software for different default directories, graphics adapter, IEEE-488 card, printer, or plotter.

4. You are then prompted to choose a target hard disk drive for Model 251 software. The listed options depend on what is available on your computer. The `INSTALL` program will display an error message if the selected drive does not have at least 3M-bytes of free disk space.

5. The next series of questions asks you to select directories for the Model 251 software. The default names for the root directory and three subdirectories are:

```
\MODEL251
\MODEL251\DATA    (for data files)
\MODEL251\TESTS  (for test setup files)
\MODEL251\CONFIG  (for instrument configuration files)
\MODEL251\707    (for Model 707 files)
\MODEL251\SEQ     (for test sequencer files)
```

6. You are then prompted for your computer's graphics adapter type:

```
EGA or VGA
```

7. You are next prompted to select an IEEE-488 (GPIB) interface card from a displayed list. The `INSTALL` procedure will copy the necessary IEEE-488 driver. The card parameters (I/O port address, memory address, etc.) are not entered until Model 251 software is run.
8. The printer and plotter types are then requested. Select appropriate models, and if a plotter was chosen, the interface type (serial or GPIB) and address.

NOTE

Printer and plotter configuration is further discussed in paragraph 2.5.3.

After your response, the `INSTALL` program creates directories and copies files as they are listed on the computer screen.

9. As the `INSTALL` program is copying files, you will be prompted to insert Model 251 Program Disks. When the program has completed, remove any disks and put them away.

Unless the `INSTALL` procedure was aborted, you will be returned to the drive and directory where Model 251 Software is installed.

2.4.5 Software Reconfiguration

As part of a first-time installation, the text file MODEL251.CFG is created by the INSTALL program to define the selected subdirectories and computer hardware configuration. MODEL251.CFG is placed in the Model 251 root directory (default name is \MODEL251). An example file is shown in Figure 2-12.

If any changes are made in the computer hardware, the "Reconfigure" option of the INSTALL program must be selected to change the parameters of the MODEL251.CFG file. (Although MODEL251.CFG is an

ASCII file, do not attempt to edit it as line and character spacing are exact.)

Since the INSTALL program minimizes the hard disk space required by only copying the IEEE-488 driver software that is needed, it also may be necessary to run the INSTALL program after changing the IEEE-488 card. As explained in paragraph 2.5.6, the IEEE-488 card must be configured through a menu selection. If the desired interface card is not highlighted in the list of available cards, run the INSTALL program to select the new card before configuring it through the menu selection.

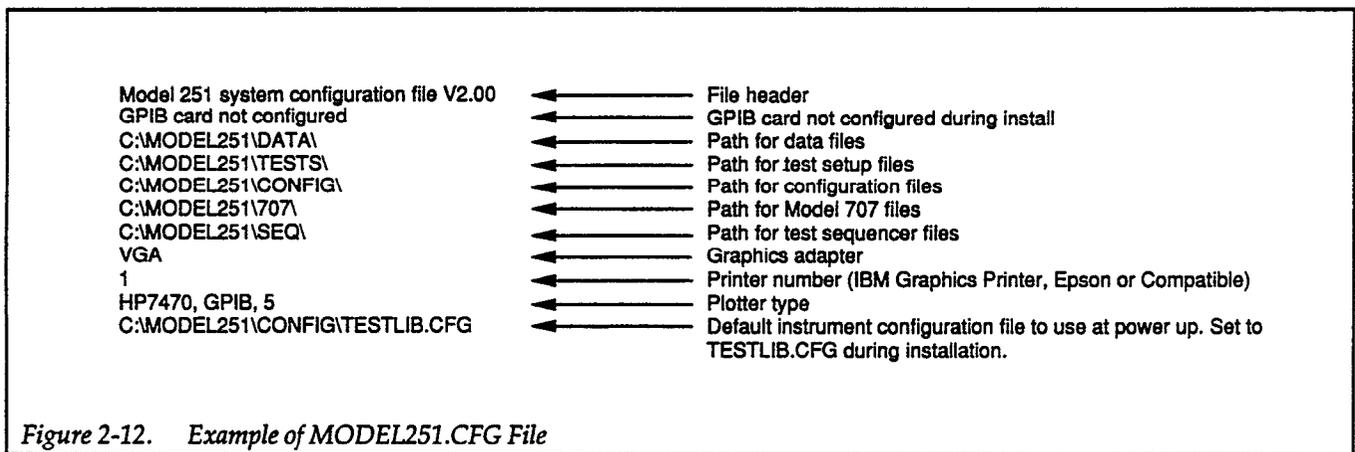


Figure 2-12. Example of MODEL251.CFG File

Operation Overview

2.5 OPERATION OVERVIEW

2.5.1 Running the Software

Once the software is installed, running the program is simply a matter of typing in the following from the MODEL251 (or other) subdirectory:

MODEL251 <Enter>

The Model 251 software will read the MODEL251.CFG file to configure itself to the computer hardware selections made during installation, then, if everything checks out, display a logo screen and then the screen shown in Figure 2-13.

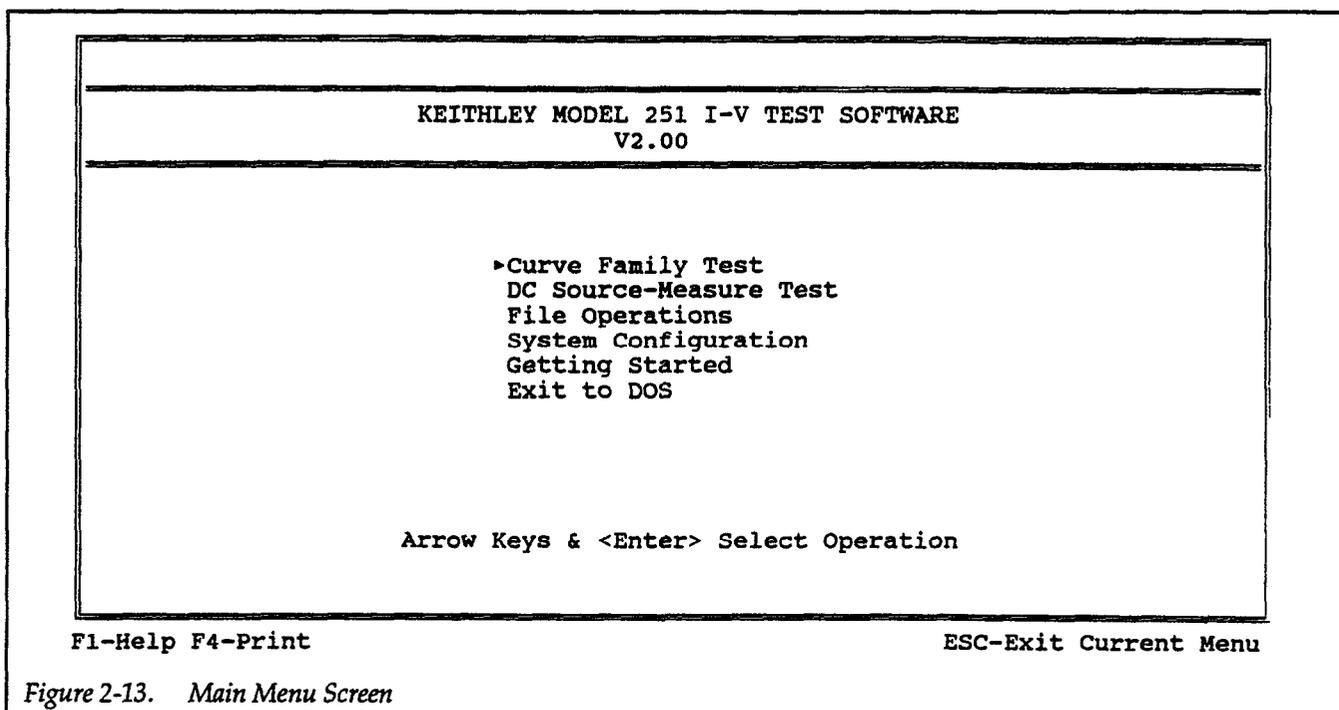


Figure 2-13. Main Menu Screen

Table 2-3. Model 251 Errors Messages on Start-up

Message	Cause
Can't find parallel port copy protect block – exiting ASYST.	The copy protect block is missing or is not securely attached to a parallel port of the computer.
Not enough free DOS memory to run Model 251. Suggestion – Remove any memory resident programs not necessary for operation to free up more memory.	The computer must have 530K-bytes(542, 720 bytes) of free DOS memory. See paragraph 2.5.2.
System does not have enough expanded memory to boot. Model 251 requires a minimum of 1M-byte of expanded memory to operate.	The computer must have 1M-byte of free expanded memory. See paragraph 2.5.3.
System file (file name) not found. Run INSTALL to ensure all system files are present.	A Model 251 file is missing. You must re-install the software.
None	Computer must have 530K-bytes of free DOS memory. (Computer may lock up if this memory is not available; see paragraph 2.5.2.) Or, the copy protect block is missing or is not securely attached to a parallel port of the computer.

NOTE

The first time Model 251 software is executed, a screen telling you that a GPIB card must be selected is displayed before the main menu screen. Refer to paragraph 2.5.8.

Note that the version number of the software is listed in the title bar. Knowing the software version is useful when discussing problems with the Applications Department at Keithley Instruments.

Possible error conditions for software start-up are listed in Table 2-3.

2.5.2 DOS Memory Requirement

Model 251 software needs 530K-bytes (542, 720 bytes) of free DOS memory to run. If you must free up more memory to run Model 251 software, follow these guidelines:

1. Examine your present AUTOEXEC.BAT and CONFIG.SYS files to determine which device drivers and terminate and stay resident (TSR) programs are necessary. For example, a mouse driver, an IEEE-488 board driver, and a LIM expanded memory driver

are probably necessary. A network driver or a batch file for a DOS shell are probably not necessary.

2. Copy your present AUTOEXEC.BAT and CONFIG.SYS files to make backups:

```
COPY AUTOEXEC.BAT AUTOEXEC.SAV
COPY CONFIG.SYS CONFIG.SAV
```

3. Create an AUTOEXEC.251 and a CONFIG.251 in your root directory to run Model 251 software, including any lines determined necessary in Step 1 and the following suggested lines:

```
AUTOEXEC.251  echo Model 251 Boot Up
CONFIG.251    buffers = 20
              files = 20
```

4. Create batch files to switch back and forth between boot up configurations:

```
M251.BAT  copy autoexec.251 autoexec.bat
          copy config.251 config.sys
MINE.BAT  copy autoexec.sav autoexec.bat
          copy config.sav config.sys
```

5. To configure the computer to run Model 251 software enter the following command:

```
M251
```

This batch file copies the AUTOEXEC and CONFIG files you just created with a 251 extension to ones that will be read on boot up.

6. Reboot the computer.
7. Enter the following from the MODEL251 subdirectory to start Model 251 software:

```
MODEL251 <Enter>
```

To configure the computer with your original AUTOEXEC and CONFIG files, follow this procedure:

1. Return to the root directory of your computer's boot up drive and type in:

```
MINE
```

This batch file copies your original AUTOEXEC and CONFIG files to ones that will be read on boot up.

2. Reboot the computer.

2.5.3 Expanded Memory Requirement

Model 251 software is compatible with Lotus/Intel/Microsoft (LIM) Expanded Memory, versions 3.2 and 4.0. Model 251 needs 1M-byte of free expanded memory to run. There are numerous combinations of hardware and software to attain this requirement. Among them are:

- DOS 4.0 contains built-in LIM 4.0 support.
- Add-in memory boards offer LIM support in hardware or software.
- Computers purchased with 2M-byte RAM often include a utility program to convert extended memory to LIM expanded memory. A free utility for this purpose is available from many computer bulletin boards.
- Commercially available memory management utilities include QEMM-386 (Quarterback Office Systems) for 386-based computers.

2.5.4 Setting Up Printers and Plotters

Model 251 software supports only the peripheral devices and communications ports shown in Table 2-4.

Table 2-4. Supported Configurations for Peripheral Devices

Printer	Plotter
None	None
None	Serial
None	IEEE-488
Parallel	None
Parallel	Serial
Parallel	IEEE-488
Serial	None
Serial	IEEE-488

Parallel printers and IEEE-488 plotters are completely configured during the INSTALL program. Serial printers and plotters need additional configuration.

After installing or reconfiguring Model 251 software for serial output devices, it is necessary to properly configure a serial port for the device and, in the case of printers, to redirect output from a parallel port to a serial port. This is accomplished by using the DOS MODE command in your AUTOEXEC.251 file.

Example 1. Connecting an HP 7470A plotter with a serial interface.

Your AUTOEXEC file will need a MODE command to configure the baud rate, parity, data bits, and stop bits of serial port COM1. Assuming 2400 baud, no parity, 8 data bits, and 1 stop bit, the MODE command in your AUTOEXEC file would be one of the following:

```
mode com1: 2400, n, 8, 1, p      (for DOS version 3.3)
mode com1: 2400, n, 8, 1, b      (for DOS version 4.0)
```

Example 2. Connecting an Epson compatible printer with a serial interface.

Your AUTOEXEC file will need two MODE commands, the first to configure serial port COM1, and the second to redirect printer output from parallel port LPT1 to serial port COM1. Assuming 2400 baud, no parity, 8 data bits, and 1 stop bit, the MODE command would be one of the following pairs:

```
mode com1: 2400, n, 8, 1, p      (for DOS version 3.3)
mode lpt1: = com1:
```

```
mode com1: 2400, n, 8, 1, b      (for DOS version 4.0)
mode lpt1: = com1:
```

The exact format of the MODE commands should be verified by referring to your DOS Reference Manual.

2.5.5 Main Menu Options

Figure 2-14 shows the hierarchy of functions accessed by main menu options, including submenus and forms.

When the software is started, the cursor defaults to the first menu item, Curve Family Test. To move the cursor through a menu, use the up and down arrow keys. To select an operation, use the <Enter> key. For some operations, a submenu pops up; the up/down arrows and <Enter> keys function the same way in a submenu. To return to the main menu from one of its submenus or forms, use the <Esc> key to close the submenu or form and return to the previous screen.

Hot keys are also present, where a single keypress will select a menu item. At each menu level, the first letter of an item is treated as a hot key.

Model 251 software supports the Microsoft mouse and the Logitech mouse. The button assignments depend on the mouse driver software, but are commonly the following:

Left Button	Right Button
<Enter>	<Escape>

For a 3-button mouse, the middle button can be assigned to the <F1> key for accessing Model 251 help screens.

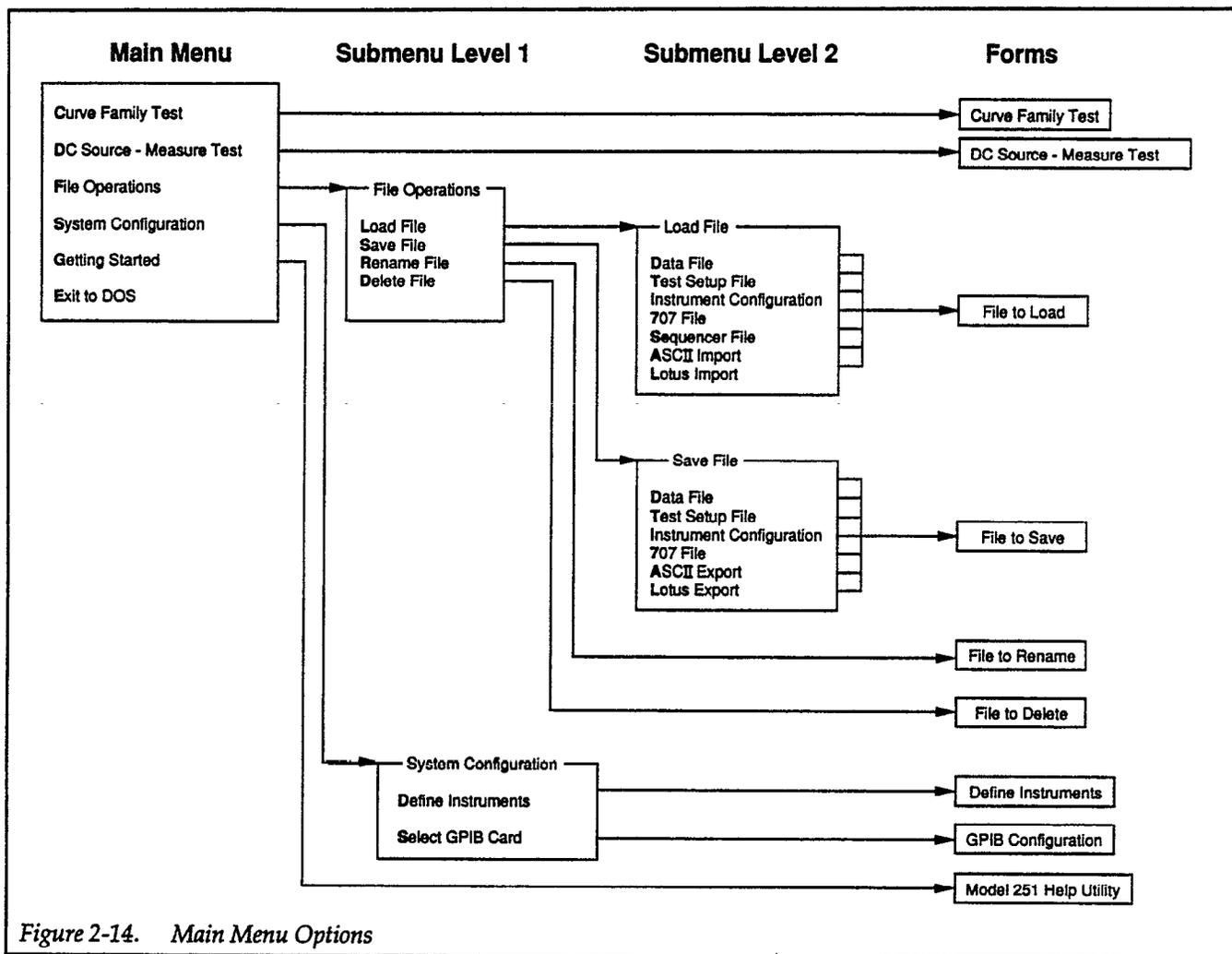


Figure 2-14. Main Menu Options

An explanation of each item on the main menu follows:

- **Curve Family Test** — This selection sets the parameters of up to three source measure units for a curve family test. This can be either a single sweep (e.g., diode I-V curve), a subordinate sweep (e.g., common emitter curves), or a synchronous sweep (e.g., Gummel plot). Also, up to three additional source measure units can be configured as measuring or non-measuring bias channels.
- **DC Source-Measure Test** — This menu selection configures up to six source measure units as dc voltage or current sources. Optionally, each channel can measure.
- **File Operations** — File operations include loading and saving data files, test setup files, instrument configuration files, 707 files, sequencer files (load only), and data import/export files (ASCII or Lotus WK1 formats). The location and contents of these files are shown in Table 2-5.
- **System Configuration** — This selection is used to configure Model 251 software to the hardware: the source measure units, the trigger controller, and the IEEE-488 interface card.
- **Getting Started** — This selection takes you to a topic in the Help file that lists the steps required for running an example curve family test.
- **Exit to DOS** — This selection returns you to the DOS command line after prompting you to save data and parameters.

Table 2-5. Load and Save File Types

File Type	Default Path and File Extension	Contents
Data	\MODEL251\DATA*.DAT	GPIB I/O parameters, test parameters, display parameters, data.
Test Setup	\MODEL251\TESTS*.TST	GPIB I/O parameters, test parameters, display parameters.
Instrument Configuration	\MODEL251\CONFIG*.CFG	Source measure unit, trigger controller, quad voltage source, and switching matrix parameters.
707	\MODEL251\707*.707	Matrix setup.
Sequencer	\MODEL251\SEQ*.SEQ	Commands to run a series of tests.
Data in ASCII File Format	\MODEL251\DATA*.ASC	Data, array names, and units.
Data in Lotus File Format	\MODEL251\DATA*.WK1	Data, array names, and units.

2.5.6 Using Function Keys

In addition to the screens showing pop-up submenus and forms accessed by main menu selections, other screens are accessed by using the function keys. Each screen lists the available function keys on the bottom line. (See Table 2-6.) The screens accessed by the function keys are summarized below:

- **Help** — Pressing the <F1> key brings up a context sensitive help screen. Pressing <F1> again or the <Enter> key displays an index of help topics. Pressing <Esc> returns you to the current screen.
- **Goto Point** — When the VIEW LIST form is displayed, the <F2> key brings up a pop-up form called Goto Specified Point. You can enter a curve number and an index into the curve array.
- **Plot** — The <F3> key plots a hardcopy of the graphical representation of the data on a plotter.
- **Print** — The <F4> key prints a hardcopy of the current screen to a printer.
- **GPIB** — The GENERAL GPIB OUTPUT form is used to send device dependent commands to bus instruments, usually those not directly supported by Model 251 software.
- **Disp.Param** — The <F7> key brings up the display parameters form where you can set the parameters for displaying source and measure data arrays and calculated arrays.
- **View** — If data arrays were previously specified on the display parameters form, the <F8> key shows a list or graphical representation of the data. A menu of graphical analysis tools is also available on this screen.
- **Execute** — The <F10> key initiates test execution, either a curve family of a dc source measure test. From the GENERAL GPIB OUTPUT form, the <F10> key initiates device dependent command execution (after highlighting the desired function).
- **Delete** — When the DEFINE INSTRUMENTS form is displayed, the key will remove the definition of the instrument at the present cursor position after prompting you for confirmation.
- **Exit** — The <Esc> key returns you to the previous screen.

Table 2-6. Available Function Keys

Menu/Form	Function Keys Available									
	<F1> Help	<F2> Goto Point	<F3> Plot	<F4> Print	<F5> GPIB	<F7> Disp. Param	<F8> View	<F10> Execute	<Esc> Exit	 Delete
Main Menu	X			X					X	
Curve Family Test Form	X	*	*	X	X	X	X	X	X	
DC Source-Measure Test Form	X	*	*	X	X	X	X	X	X	
Define Instruments Form	X			X					X	X
General GPIB Output Form	X			X				X	X	
Display Parameters Form	X			X			X	X	X	
View Graphics	X		X	X		X		X	X	
View List	X	X		X		X		X	X	

* <F2> is Load File and <F3> is Save File from these forms only.

2.5.7 How to Get Help

Model 251 I-V Test software contains a context sensitive help function. It is accessed from any text screen by pressing the <F1> key. The first help topic displayed is specific to the menu or form where help was requested. The up/down arrow keys scroll the display. <PgUp> and <PgDn> scroll through the help file to present related topics.

The <Enter> or <F1> keys display an index of help topics. (See Figure 2-15.) Use the arrow keys to move around the index, then press <Enter> or <F1> to select the topic. One of the topics is Help: Usage of Keys. It explains what keys are active for the help index and help topic screens.

Use the <Escape> key to exit help. You are returned to the menu or form screen where you requested help.

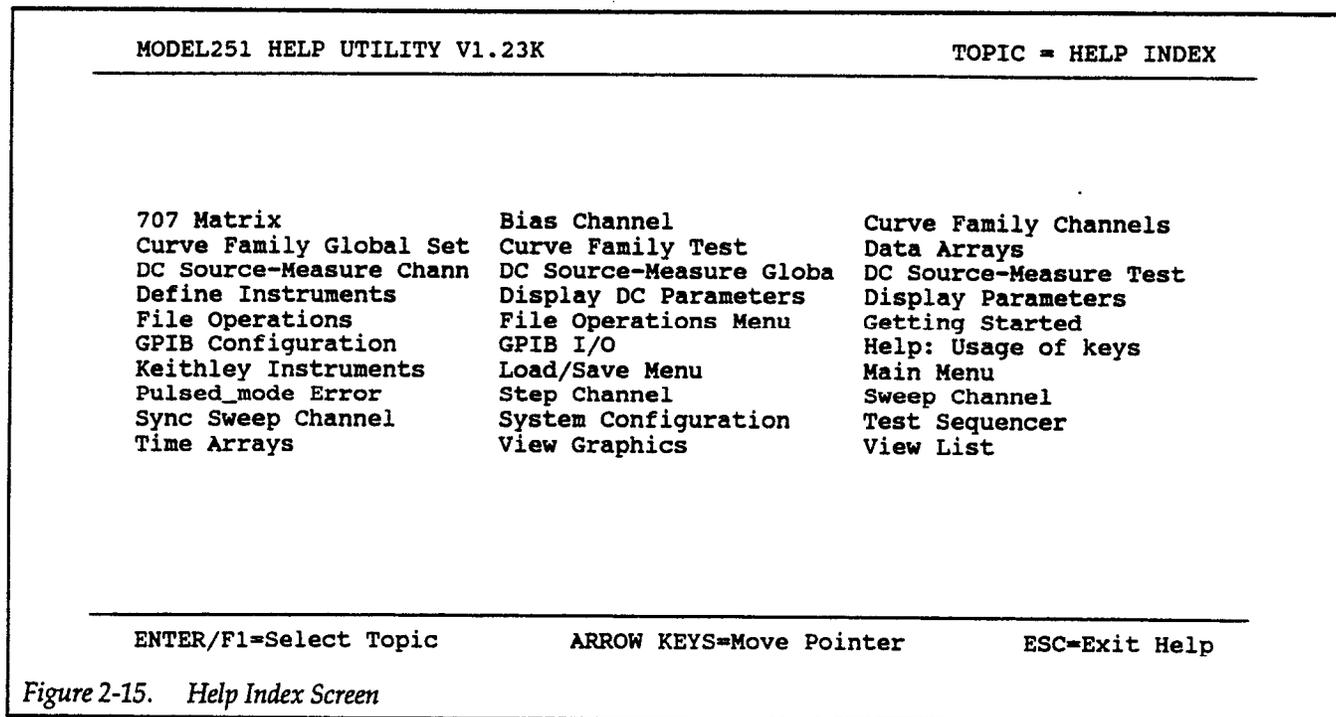


Figure 2-15. Help Index Screen

2.5.8 Configuring the IEEE-488 Card

During the INSTALL procedure, you selected an IEEE-488 (GPIB) driver overlay for your interface card. Before running any tests, Model 251 software must be configured with the hardware specific information of that IEEE-488 card. Follow this procedure:

1. From the main menu of Model 251 software, select the System Configuration option.
2. From the System Configuration pop-up, choose Select GPIB Card. After an opening screen explaining how to get help, you will see the GPIB Configuration form, an example of which is shown in Figure 2-16.
3. You will be asked:

Which bus do you want to configure? (0,1,2,or3):

Always respond with: 0

Model 251 software must be configured to bus 0.

4. The next screen displays a list of supported IEEE-488 cards. Use the <PgUp> and <PgDn> keys to see the complete list. Your IEEE-488 card should be highlighted in the list. (If it is not, the INSTALL program must be run again; this time choose the Reconfigure option.)

Enter the appropriate number for your card.

NOTE

If you have a CEC 4 × 488, Keithley PC-488-CEC, Keithley 4-488-CEC-0M, or Keithley 4-488-CEC-1M card, select the CEC PC<>488 from the list. If you have a Keithley PS-488-CEC, choose the CEC PC<>488.

5. You will be asked:

Enter primary address for ME:

Always respond with: 0

6. The next prompt depends on which card type you have. For NEC type cards, enter the hexadecimal I/O address. For Hewlett Packard cards, enter the hexadecimal memory segment address. Responses depend on how the card jumpers and switches are configured, which should have been noted in paragraph 2.4.1. Also, refer to Table 2-2 for factory default settings.

7. The next question is:

Is the board the system controller? (Y/N):

Always respond with: Y

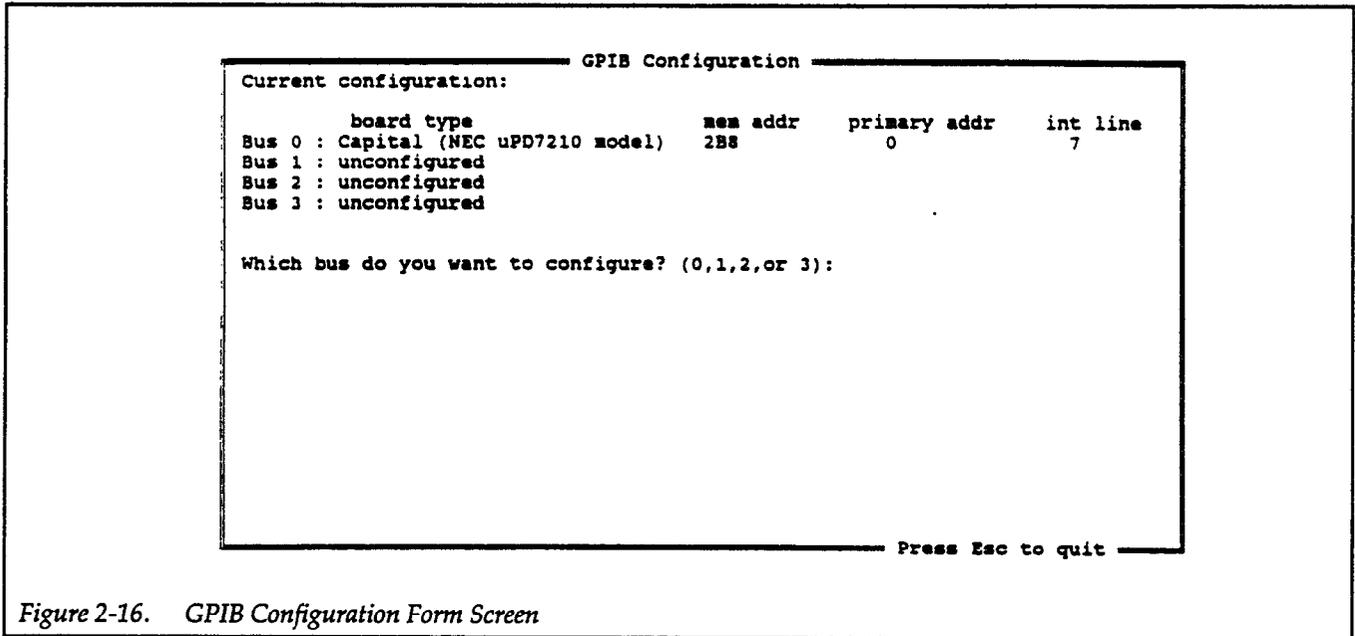


Figure 2-16. GPIB Configuration Form Screen

8. The next prompt is:

Enter interrupt line# used by board (2-7):

Respond with an unused interrupt line after referring to Table 2-7. Your choice must match that chosen by jumpers or switches on the IEEE-488 card.

NOTE

The Hewlett Packard card only allows interrupt lines 3-6 to be used.

9. If needed for your card, you are prompted with:

Enter interrupt level (0-7):

Respond with a number that is not used by any other board in your computer. Normally, the same value as the interrupt line number will work.

10. The last prompt is:

Configure another board? (Y/N)

Model 251 software can only be configured for one board.

If you think you made a wrong entry to one of the previous prompts, enter a "Y" here to go through the configuration again. Enter "N" if you are satisfied

with your configuration. You will be returned to the main menu of Model 251 software.

Table 2-7. Typical Interrupt Line Assignments

Interrupt (IRQ) Line Number	Description
2	Access to interrupts 8-15
3	Serial port 2
4	Serial port 1
5	Parallel port 2
6	Floppy disk
7	Parallel port 1

2.5.9 Configuring the Instruments

Before running any tests, the Model 251 software has to be configured for the bus instruments (source measure units, trigger controller, and other instruments). The DEFINE INSTRUMENTS form is accessed through a main menu item as described in the following procedure:

1. Select System Configuration from the main menu.
2. Select Define Instruments from the SYSTEM CONFIGURATION pop-up submenu. The DEFINE INSTRUMENTS form will be displayed. Figure 2-17 shows a completed form.

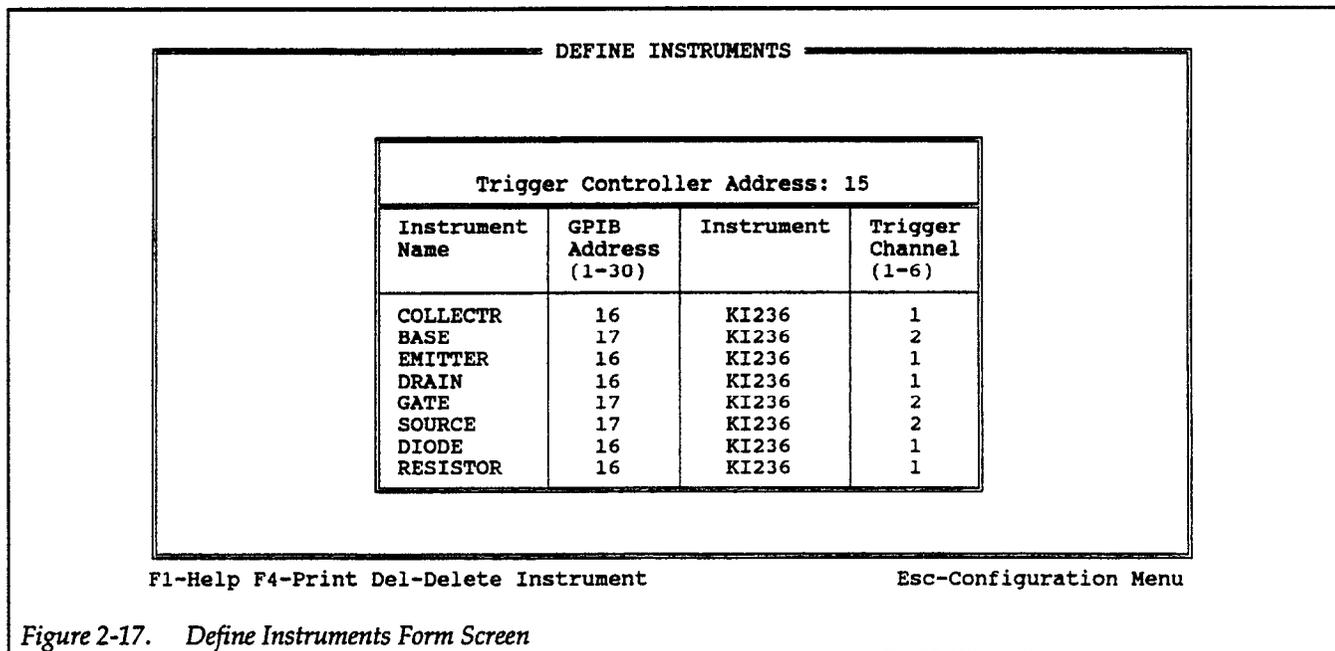


Figure 2-17. Define Instruments Form Screen

3. The cursor first appears in the Instrument Name field. Type in a name (up to 8 characters) for the unit. The name will be used on the test setup form to identify the instrument on each channel.
4. Press <Enter>. The cursor advances to the GPIB Address field. Type in the address for the unit. (Refer to paragraph 2.3.5 if the source measure unit address is unknown.)

The address may be set to any value between 1 and 30 as long as address conflicts with other instruments are avoided.

5. Press <Enter>. The cursor goes to the Instrument field. Press <Enter> again. A pop-up menu appears listing possible choices. Use the up/down arrow keys and the <Enter> key to select the instrument type.
6. Use the right arrow key to advance to the Trigger Channel field. Type in the trigger channel assignment for the source measure unit and press <Enter>.
7. Repeat steps 3 through 6 for remaining bus instruments. Recall that only source measure units are assigned to trigger channels.
8. Use the up arrow key to go to the Trigger Controller address field. Type in the address selected by the rear panel DIP switch (see Figure 2-2) on the trigger controller and press <Enter>.
9. Press <Esc>. You will be prompted with:

Initialize instrument table (Y/N) ?

If the IEEE-488 card is connected to the bus cable, and all instruments are on, press <Y>, otherwise press <N>. The screen will display:

Performing instrument initialization

Model 251 software will send a device dependent command to each source measure unit restoring it to factory default conditions. You will be prompted if any error or warning conditions exist.

10. After initialization has finished, pressing any key returns you to the main menu.

It is recommended that you save the present instrument configuration in a file stored in the CONFIG subdirectory. This procedure follows:

1. Select File Operations from the main menu.
2. Select Save File from the pop-up submenu.
3. Select Instrument Configuration from the pop-up submenu.

4. At the File to Save prompt, type in a file name to complete the path. Optionally, use a CFG file extension, such as:

\\SAMPLE.CFG

5. Press <Enter>. You will be prompted when the file has been saved. Press any key to return to the main menu screen.

The name of the instrument configuration file will be stored in the MODEL251.CFG file. When Model 251 software is next started, it will load that instrument configuration as a default.

2.6 SYSTEM CHECKOUT

There are two modes of operation with Model 251 software: the interactive mode and the test sequencer mode. All examples use the interactive mode, unless otherwise specified. The test sequencer is described in Section 6.

There are four steps involved when interactively running an I-V test with Model 251 software:

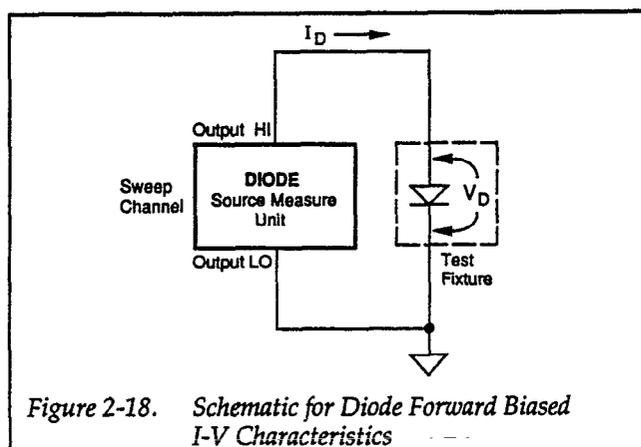
1. Defining the instrument parameters, test parameters, and display parameters.
2. Executing the test.
3. Printing or plotting the results.
4. Saving the instrument parameters, test parameters, display parameters, and test data.

The following examples will lead you through step-by-step procedures. The examples will also check out Model 251 software to determine if the system is operational, to show that all instruments and the software are functioning normally.

2.6.1 Running Simple Tests

The two examples given here will run I-V curves on a diode and a transistor. The first example explains in detail the hierarchical structure of the menus and forms; the second will assume familiarity with the structure.

Example #1 — This example outlines a test procedure for diode forward biased I-V characteristics. It is based on the test library called DIODELIN for a 1N914 diode (see Appendix D). Connect a source measure unit to a diode as shown in the schematic of Figure 2-18.



DEFINE

Select File Operations from the main menu.

1. Select Load File from the FILE OPERATIONS submenu.
2. Select Instrument Configuration from the LOAD FILE submenu.
 - A. Press <Enter> when prompted for "FILE TO LOAD".
 - B. Select TESTLIB.CFG from the listing of the CONFIG subdirectory.
 - C. Hit any key after the file has been loaded.
3. Select Test Setup File from the LOAD FILE submenu.
 - A. Press <Enter> when prompted for "FILE TO LOAD".
 - B. Select DIODELIN.TST from the listing of the TESTS subdirectory.
 - C. Hit any key after the file has been loaded.
 - D. Press <Esc> twice to return to the main menu

Select System Configuration from the main menu.

1. Select Define Instruments from the SYSTEM CONFIGURATION submenu.
2. Modify the DEFINE INSTRUMENTS form, if needed, to match your setup. (No trigger controller is needed for a single unit setup.)
 - A. Press <Esc> to exit the form.
 - B. Press <Y> to initialize the instrument table.
 - C. Hit any key at the "SMU Initialization Finished" prompt.
 - D. Press <Esc> to return to the main menu.

Select Curve Family Test from the main menu.

1. Modify the CURVE FAMILY TEST parameters form, if needed, to match your source measure unit and diode characteristics.

2. Press <F7> for Disp.Param (DISPLAY PARAMETERS form).
3. Modify the DISPLAY PARAMETERS form to match your test parameters.

EXECUTE

1. Press <F10> for Execute test.
2. Compare test results with the curve shown in Figure 2-19.

PRINT

1. Press <F4> to Print (or <F3> to Plot) the curve, if desired.
2. Press <Esc> twice to return to the main menu.

SAVE

Select File Operations from the main menu.

The instrument parameters, test parameters, display parameters, and test data are optionally saved in three files:

- An instrument configuration file contains instrument parameters.
- A test setup file contains test and display parameters.
- A data file contains test and display parameters and data.

NOTE

Data can also be saved in an export file in either ASCII or Lotus WK1 format.

1. Select Save File from the FILE OPERATIONS submenu.
2. Select Instrument Configuration from the SAVE FILE submenu.
 - A. Type in: \MYDIODE.CFG <Enter> when prompted for "FILE TO SAVE".
 - B. Hit any key after the file has been saved.
3. Select Test Setup File from the SAVE FILE submenu.
 - A. Type in: \MYDIODE.TST <Enter> when prompted for "FILE TO SAVE".
 - B. Hit any key after the file has been saved.
4. Select Data File from the SAVE FILE submenu.
 - A. Type in: \MYDIODE.DAT <Enter> when prompted for "FILE TO SAVE".
 - B. Hit any key after the file has been saved.
 - C. Press <Esc> twice to return to the main menu.

Marker 1 [X=
 Marker 2 [X=
 Line [X-int=
 >Markers
 Line
 Horiz. zoom
 Vertical zoom
 Restore
 Autoscale
 Filter
 Overlay
 X-Invert
 Y-Invert

Marker1: Home
 Marker2: End
 Step[]: +/-
 PgUp/PgDn
 Y1/Y2: Tab
 F1-Help
 F3-Plot
 F4-Print
 F7-Disp Par.
 F10-Exec/Stop
 Esc-Test Form

Y=] Beta(Mkr1)=
 Y=] gm(Mkr1)=
 Y-int= Slope= 1/Slope=]

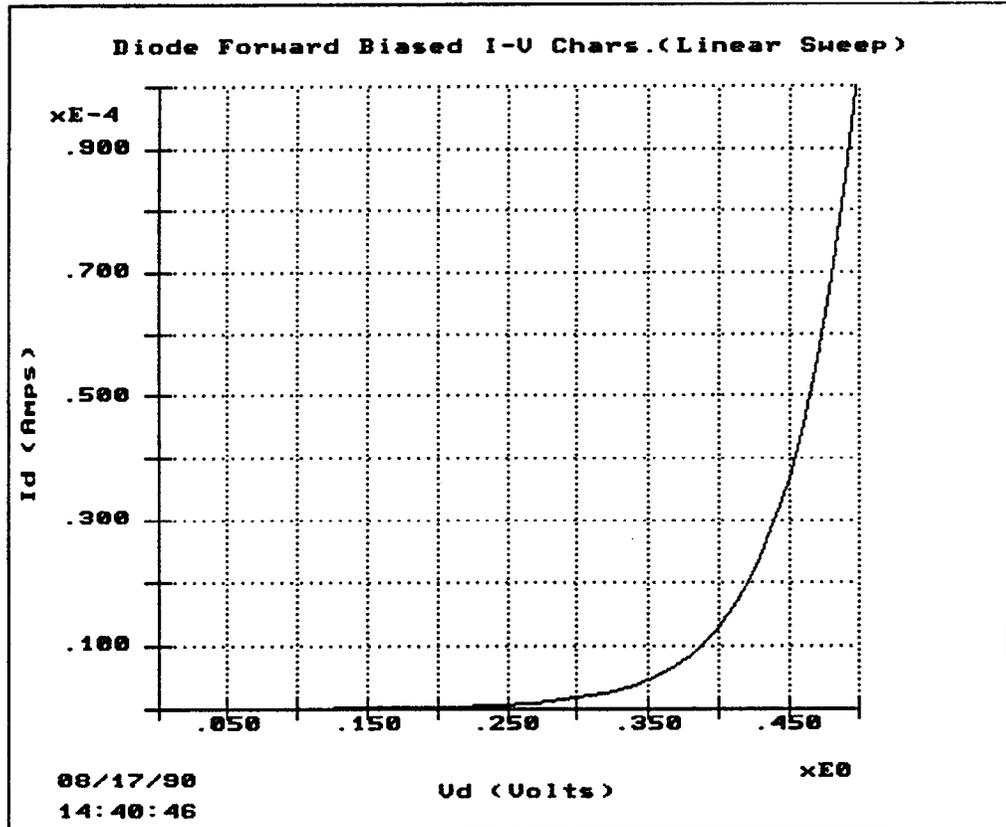


Figure 2-19. Diode Forward Biased I-V Characteristics

Example #2 — This example is a test procedure for NPN transistor common emitter curves. It is based on the test library called NPNCRV for a 2N3904 transistor (see Appendix D). Connect two source measure units as shown in the schematic of Figure 2-20.

DEFINE

1. Load the instrument configuration file called TESTLIB.CFG.
2. Load the test setup file called NPNCRV.TST.
3. Modify the DEFINE INSTRUMENTS form, if needed, to match the parameters of your source measure units and trigger controller.
4. Modify the CURVE FAMILY TEST form, if needed, to match your transistor characteristics.
5. Modify the DISPLAY PARAMETERS form to match your test parameters.

EXECUTE

6. Execute the test.
7. Compare test results with the curves shown in Figure 2-21.

PRINT

8. Print or plot the curves, if desired.

SAVE

9. Save the instrument configuration file, test setup file, and data file under new names, if desired.

2.6.2 System Troubleshooting

Troubleshoot any system problems using the basic procedure shown in Table 2-8. Also refer to the error messages of Table 2-3 and Appendix B. For information on troubleshooting individual instruments, refer to the respective instruction manual(s).

Use of the GENERAL GPIB OUTPUT form to troubleshoot instruments is described in paragraph 3.7.7.

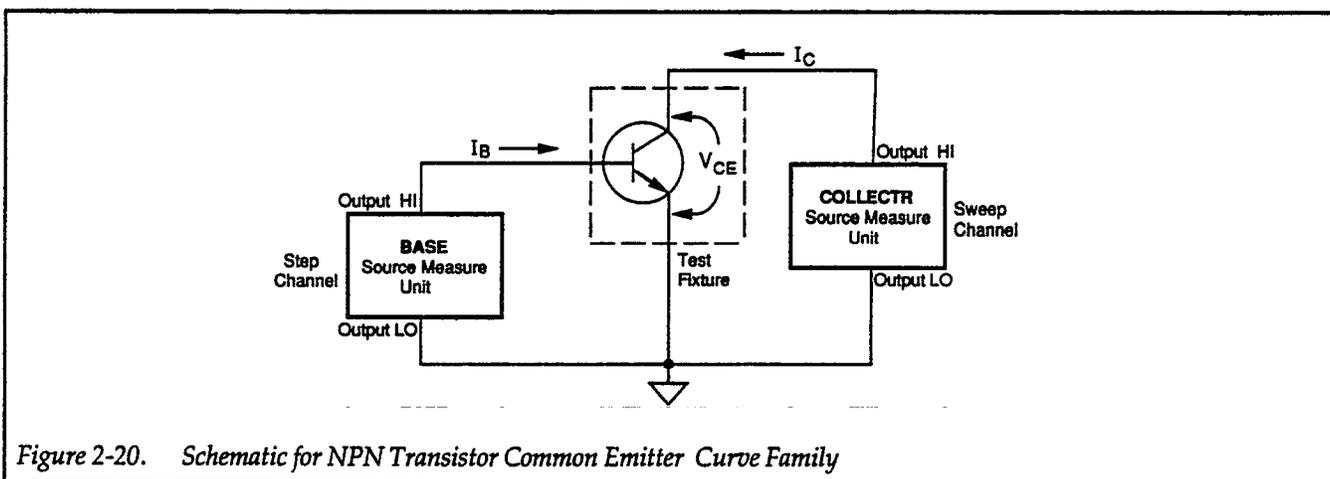


Figure 2-20. Schematic for NPN Transistor Common Emitter Curve Family

Table 2-8. System Troubleshooting Summary

Symptom	Possible Cause(s)
No instrument responds over bus.	Units not connected to system controller, units not configured, system controller defective, improper card configuration.
One instrument fails to respond.	Unit not connected to bus, improper configuration, unit defective.
Instruments not triggered.	Unit not connected to trigger controller.
Excessive leakage current.	Wrong cables used, dirty jacks, test fixture contamination.
Erratic readings.	EMI interference, poor connections.

SECTION 3

Measurements

3.1 INTRODUCTION

This section describes interactive data acquisition, including instrument configuration, test parameter entry, and test execution. Section 3 contains the following topics:

3.2 Measurements Overview: Provides an overview of data acquisition and gives a basic procedure for acquisition operation.

3.3 Data Entry: Lists guidelines for entering data and using edit keys.

3.4 Instrument Configuration: Describes using the DEFINE INSTRUMENTS form to configure Model 251 software for a test instrument setup.

3.5 Curve Family Tests: Details use of all of the channels on the CURVE FAMILY TEST form to acquire single curve and curve family data.

3.6 DC Source and Measure Tests: Covers use of bias channels on the DC SOURCE-MEASURE TEST form to acquire DC data.

3.7 GPIB Input/Output: Explains using the GENERAL GPIB OUTPUT form to support testing with instruments other than Models 236/237/238 Source Measure Units and Model 213 Quad Voltage Sources and troubleshooting with all bus instruments.

Error messages associated with measurement operations are described in Appendix B.

3.2 MEASUREMENTS OVERVIEW

Once Model 251 software is configured for your instrument setup, acquiring measurement data is done simply by loading (and modifying, if necessary) a test setup file and executing the test. The step-by-step procedure is outlined below:

Step 1: Define Instruments

Model 251 software must be configured for the instruments in your test system. This is done on the DEFINE INSTRUMENTS form. For an instrument to be used in any test, it must be defined and named on this form. You specify bus address, instrument type, trigger channel, and assign a name to this set of parameters.

Step 2: Define Test

There are two tests available from the main menu of Model 251 software:

- **Curve Family Test** — Source measure units operate in the sweep function to acquire a single curve or a curve family. Additional source measure units use the DC function to provide voltage or current biasing. A quad voltage source can provide voltage biasing.
- **DC Source-Measure Test** — Source measure units operate in the DC function to source and measure dc data. A quad voltage source can also be used.

Each test has a corresponding test form to define the parameters of up to six source measure units.

An additional test, GPIB input/output, can be accessed from the CURVE FAMILY TEST form or the DC SOURCE-MEASURE TEST form. It is used primarily to interface instruments other than the Keithley Model 236/237/238 units or Model 213 with the software.

Step 3: Select Display Arrays

Before a test can be run, the software must know how to display the source and measure data. This is done on a display parameters form (one for curve data, another for DC data). As a minimum requirement, you must select which source and measurement arrays you want to graph or list. All other selections are discussed in Section 4, Data Display.

Step 4: Execute Test

From a test form or display parameters form, a test can be executed to acquire curve family or DC measurement data. The results will be displayed in the mode (graphics or list) selected on a display parameters form.

3.3 DATA ENTRY

Model 251 software is structured with menus and forms. Where data entry is required, some basic guidelines are followed for the functions of editing keys, as summarized in Table 3-1. Other guidelines for data entry are as follows:

- Name entries can be alphanumeric (up to eight characters) as long as the first character is a letter. Two additional characters, the ampersand (&) and underscore (_) are also legal for names.
- Source and measure values (up to five significant digits) can be entered with an exponent and/or an engineering unit and multiplier prefix. The values are displayed with an engineering unit and prefix. If no engineering unit is entered, the unit defaults to volts, amps, or seconds, depending on the field. (An exception to this is in the calculated arrays, where no units need to be specified.)

- A multiplier prefix for the engineering unit is optional. For example, in the SOURCE Start field for a current sweep, the following entries are equivalent to 3.4 μ A:

3.4e-6 .0000034 3.4u 3.4uA 3.4e-3mA 3.4e-9k

Note that in the two rightmost entries above, when an exponent and multiplier prefix are both specified, they are multiplied together.

- A rough range checking is performed when a source or compliance value is entered. The entry is compared with the following limits:

Volts -1100V to -100 μ V; 0V; 100 μ V to 1100V
 Amps -1A to -100fA; 0A; 100fA to 1A
 Seconds 1msec to 65sec

Entered values between zero and the minimum resolution are changed to the minimum resolution. Entered values that are greater than the upper limit are changed to the upper limit.

- When entering numerical entries with engineering units, the following prefixes are recognized:

Exponent	Entered Prefix	Displayed Prefix	Exponent	Entered Prefix	Displayed Prefix
10 ¹⁵	P	P	10 ⁻³	m	m
10 ¹²	T	T	10 ⁻⁶	u or U	μ
10 ⁹	G	G	10 ⁻⁹	n or N	n
10 ⁶	M	M	10 ⁻¹²	p	p
10 ³	K or k	k	10 ⁻¹⁵	f or F	f

Note that there are four case-sensitive prefixes: P, p and M, m.

Table 3-1. Editing Key Functions

	Keys	Actions
Form	Backspace	None
	Delete	On data field, selects field and deletes leftmost character. On DEFINE INSTRUMENTS form, removes definition of selected instrument.
	End	Moves cursor to bottom of column.
	Enter	Toggles a parameter, or displays a pop-up menu, or selects a field.
	Esc	Returns to previous screen.
	Home	Moves cursor to top of column.
	Insert	On data field, selects field and inserts space before leftmost character.
	Left/Right Cursors	Moves cursor to next column left/right.
	Page Down	On DEFINE INSTRUMENTS form, displays next page.
	Page Up	On DEFINE INSTRUMENTS form, displays next page.
	Space	On data field, selects field and clears data.
	Tab	Moves cursor one column to the right.
	Up/Down Cursors	Moves cursor up/down within a column.
	<Alt> <C>	Clears test form and data
Pop-up Menu	Backspace	None
	Delete	On array name pop-up, deletes the array.
	End	Moves cursor to bottom of menu.
	Enter	Selects highlighted item and returns to form.
	Esc	Returns to form with no item change.
	Home	Moves cursor to top of menu.
	Insert	None
	Left/Right Cursors	None
	Page Down	On name pop-up, moves cursor to bottom of menu.
	Page Up	On name pop-up, moves cursor to top of menu.
	<S>	On array name pop-up, lists size of array.
	Space	None
Tab	None	
Up/Down Cursors	Moves cursor up/down within menu.	
Data Entry Field	Backspace	Deletes character to left of cursor.
	Delete	Deletes character at present cursor position.
	End	Moves cursor to right of data.
	Enter	Selects field for entry, or completes data entry and returns to form at next row.
	Esc	Returns to form with no data change.
	Home	Moves cursor to beginning of field.
	Insert	Inserts space at present cursor position.
	Left/Right Cursors	Moves cursor to left/right within a field.
	Page Down	None
	Page Up	None
	Space	Clears field from present cursor position to end of field.
	Tab	Moves to next subfield or completes data entry moves to next column to right.
	Up/Down Cursors	Completes data entry and moves cursor up/down to next row.

3.4 INSTRUMENT CONFIGURATION

3.4.1 DEFINE INSTRUMENTS Form

The DEFINE INSTRUMENTS form allows you to configure Model 251 software for the instruments in your test setup. For an instrument to be used in any test (curve family, DC source-measure, or GPIB input/output), its bus address, instrument type and, optionally, trigger channel must be defined on this form. This definition process does not have to be performed before every test, but only when your instrument setup changes.

NOTE

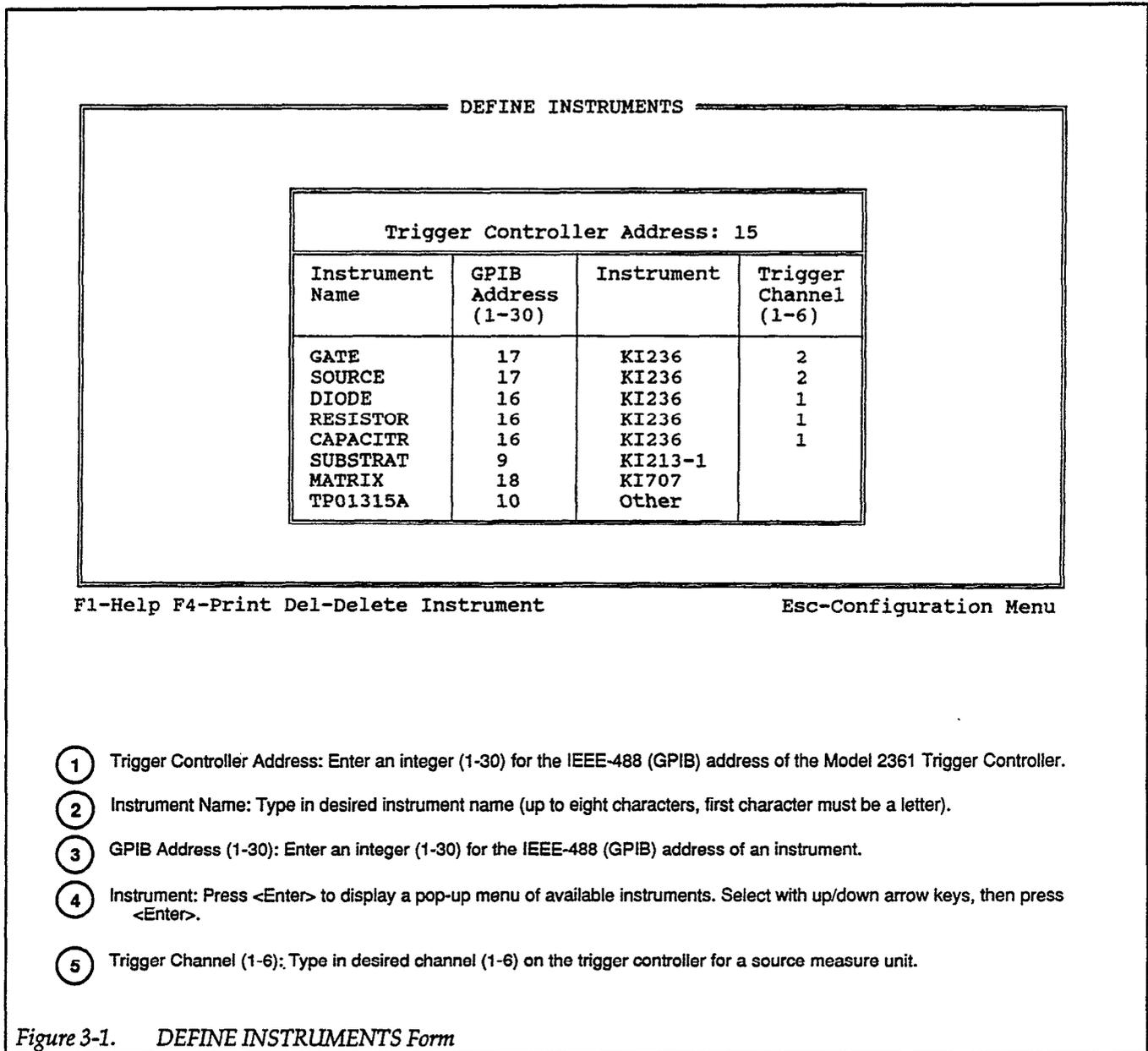
Parameters on the DEFINE INSTRUMENTS form can be saved in an instrument configuration file. When Model 251 software is started, it loads the form with the parameters from the last loaded or saved instrument configuration file.

Entering the DEFINE INSTRUMENTS Form

To access the DEFINE INSTRUMENTS form, select System Configuration from the main menu. The SYSTEM CONFIGURATION pop-up menu will be displayed. Press <Enter> at the Define Instruments option.

DEFINE INSTRUMENTS Screen Format

The general format of the DEFINE INSTRUMENTS form is shown in Figure 3-1, which shows eight entries from a sample instrument configuration file (TESTLIB.CFG). The top field concerns the bus address for the Model 2361 Trigger Controller, while the remaining fields of the screen concern parameters for the test instruments. There can be a maximum of 64 instrument names defined.



Active Function Keys

The following function keys are active while in the DEFINE INSTRUMENTS form:

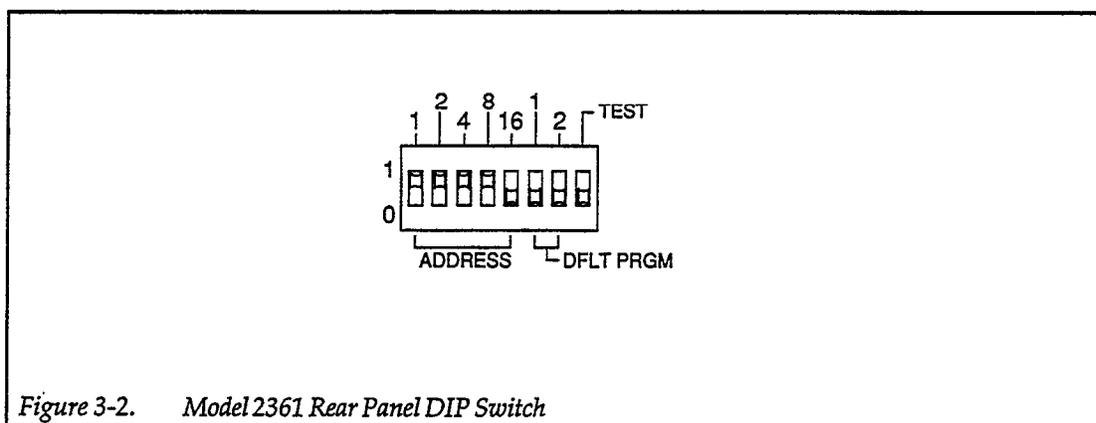
- | | |
|-----------------------|--|
| F1-Help | Provides on-line help information. |
| F4-Print | Prints the screen to a defined printer. |
| Del-Delete Instrument | Removes the instrument definition. You will be prompted for confirmation. |
| Esc-System Config. | Exits DEFINE INSTRUMENTS form. You will be asked whether you want the instruments initialized. With a "Y" answer, all Model 236/237/238 units that are turned on and connected to the bus will be initialized. |

3.4.2 Parameter Description

Trigger Controller

This field contains the IEEE-488 (GPIB) address of the Model 2361 Trigger Controller. The bus address of the Model 2361 is set with its rear panel DIP switch. Figure 3-2 shows the factory default setting of 15, which is selected by simple binary weighting.

The Trigger Controller field can be left blank when the test system consists of a single source measure unit configured to measure, without a trigger controller.



Instrument Name

Each line of instrument parameters is assigned a unique Instrument Name. This name is used to refer to the parameters of a source measure unit or other instrument in the CURVE FAMILY TEST form, DC SOURCE-MEASURE TEST form, and GENERAL GPIB OUTPUT test form.

The instrument name can be alphanumeric as long as the first character is a letter. Two additional characters, the ampersand (&) and underscore (_) are also legal for name entry. Trailing numbers can be used to differentiate like names.

GPIB Address (1-30)

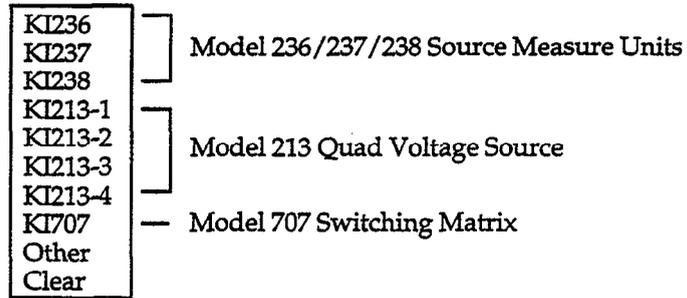
The GPIB (IEEE-488) Address field contains the address of each instrument interfaced with Model 251 software. This can be any value between 1 and 30 as long as conflicts with other instruments on the bus are avoided. Paragraph 2.3.5 describes verifying and changing IEEE-488 addresses of source measure units.

Each address must have a unique Instrument type and Trigger Channel, but it is possible to assign more than one Instrument Name to the same set of parameters.

Instrument

The Instrument field has a pop-up menu listing the model numbers for Keithley instruments supported by Model 251.

Pressing <Enter> brings up a pop-up menu of available instruments:



Use the up/down arrows to select an instrument, then press <Enter>. Use the <Esc> key to keep the present instrument selection. Specify "Other" for instruments other than those listed. Selecting "Clear" deletes any present instrument from the field.

Trigger Channel (1-6)

Up to six trigger channels can be configured for Keithley source measure units.

Trigger channels are used only for KI236, KI237, and KI238. The Trigger Channel field can also be left blank when the test system consists of a single source measure unit configured to measure, without a trigger controller.

Curve Family Tests

3.5 CURVE FAMILY TESTS

3.5.1 CURVE FAMILY TEST Form

The CURVE FAMILY TEST form configures Model 251 software to perform voltage and current sweeps with single or multiple source measure units. Three channels support single, subordinate, and synchronous sweeps. Three additional channels are available to supply voltage or current biasing from source measure units or a quad voltage source.

NOTE

Parameters on the CURVE FAMILY TEST form, along with GPIB I/O parameters and display parameters, can be saved in a test setup file. This is done from the File Operations selection of the main menu and is discussed in Section 5.

Entering CURVE FAMILY TEST Form

To access the CURVE FAMILY TEST form, select Curve Family Test from the main menu and press <Enter>. The CURVE FAMILY TEST form will be displayed.

CURVE FAMILY TEST Screen Format

An example of a CURVE FAMILY TEST form is shown in Figure 3-3, which is a test form for NPN transistor common emitter curves. (The form is that for NPNCRV.TST from the test library of Appendix D.) The top portion of the form lists parameters that apply to all channels (global). The lower portion of the form lists channel specific parameters of the six available channels.

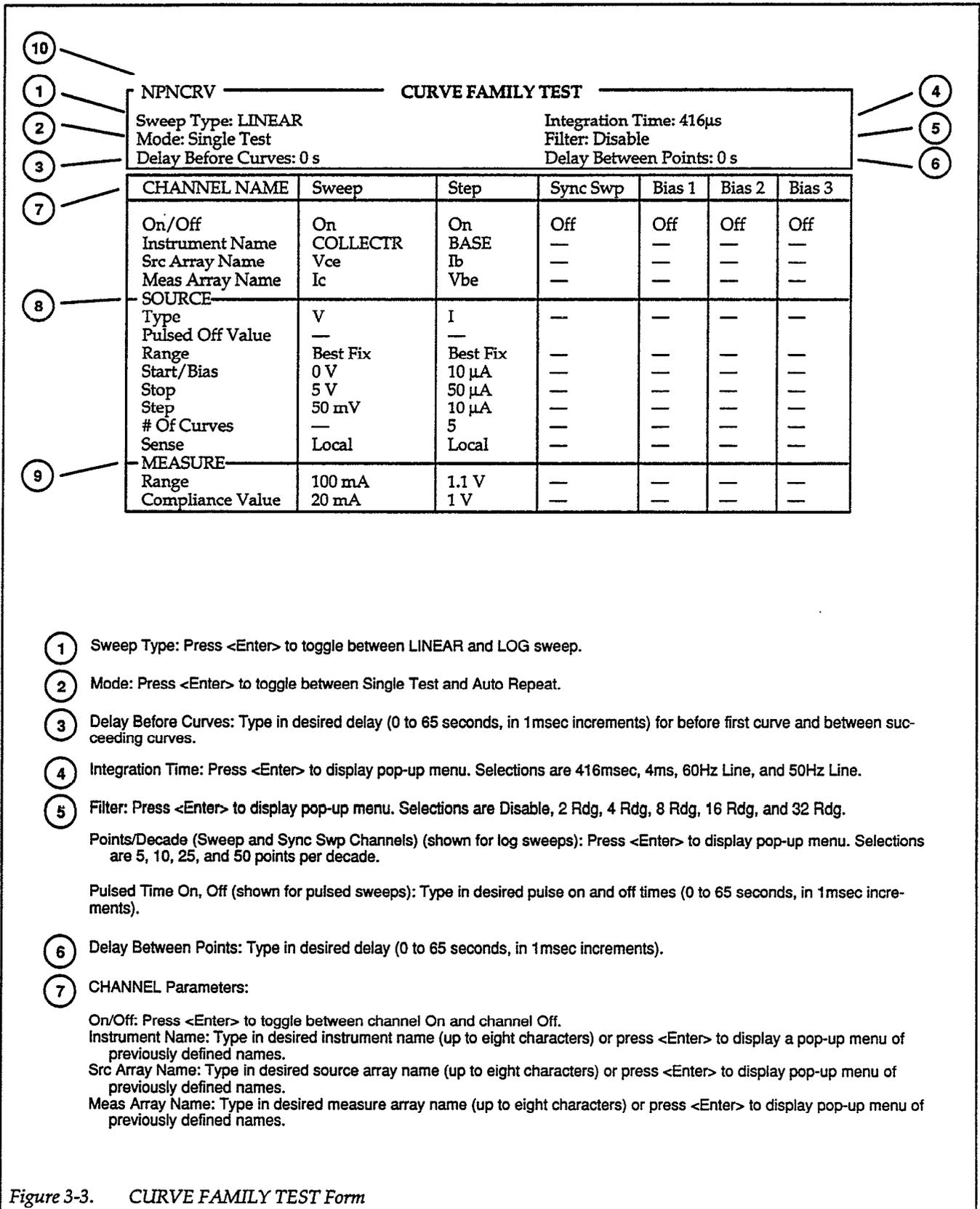


Figure 3-3. CURVE FAMILY TEST Form

8 SOURCE Parameters:

Type: Press <Enter> to display pop-up menu. Selections are V (source voltage), I (source current), V Pulsed (source pulsed voltage), and I Pulsed (source pulsed current).
 Pulsed Off Value (shown for pulsed sweeps): Type in desired voltage or current level for between pulses.
 Range: Press <Enter> to toggle between Auto source range and Best Fix source range.
 Start/Bias: Type in desired starting voltage or current value of a sweep. For bias channels, type in desired voltage or current bias level.
 Stop: Type in ending voltage or current level of sweep.
 Step: Type in desired incremental value between linear sweep points (1000 points/curve maximum).
 # of Curves: Type in desired number of curves in a curve family (2-32).
 Sense: Press <Enter> to toggle between Local and Remote sense.

9 MEASURE Parameters:

Range: Press <Enter> to display a pop-up menu of measure ranges. Selections depend on source type and model of source measure unit.
 Compliance Value: Type in desired compliance limit for current or voltage.

10 Test Title: Name of the test setup file that was loaded or saved.

CURVE FAMILY TEST Form (cont.)

Active Function Keys

F1-Help	Provides on-line help information.
F4-Print	Prints the screen to a defined printer.
F5-GPIB	Takes you to the GENERAL GPIB OUTPUT form.
F7-Disp.Param	Takes you to the DISPLAY PARAMETERS form.
F8-View	Takes you to the VIEW screen, if data is available and data arrays have been specified on the DISPLAY PARAMETERS form.
F10-Execute Test	Performs the sweep if data arrays have been specified on the DISPLAY PARAMETERS form, then takes you to the VIEW screen.
ESC-Main Menu	Exits CURVE FAMILY TEST form and returns you to the main menu.

3.5.2 Parameter Description

Global Parameters

Sweep Type	Press the <Enter> key to toggle between LINEAR and LOG sweeps. Linear sweeps are the default selection. Log sweeps are generally preferred for wider sweep ranges (over three decades or more). If LINEAR is chosen, any selected sweep channel (Sweep, Step, or Sync Swp) will perform a linear sweep. If LOG is chosen, the Sweep channel, and Sync Swp if selected, will perform log sweeps.
Mode	Press the <Enter> key to toggle between the two test modes: Single Test and Auto Repeat. With Single Test, the test will be executed once, then the data will be graphed or listed. With Auto Repeat, the test will be executed and the data will be graphed or listed continually. Pressing <Escape> will immediately abort a test. If Auto Repeat is selected, the <F10> key will interrupt the test repetition after the present test has completed.

Delay Before Curves Specifies the time before the start of the first sweep, and between successive sweeps of a curve family, to allow the source output to settle.

NOTE

A Model 213 Quad Voltage Source requires at least 750 μ s to settle.

Integration Time Press the <Enter> key to display the following pop-up menu:

416 μ s
4ms
60Hz Line
50Hz Line

Your selection specifies the speed for A/D conversions within the source measure units and subsequent usable measurement resolution, with 60Hz Line as the default selection. The integration times have the following measurement resolutions: 416 μ sec (4 digits), 4msec (5 digits), 60Hz line (16.7msec, 5 digits), and 50Hz line (20msec, 5 digits). If one of the line cycle selections is chosen, match your power line frequency or noisy readings are possible.

Filter Filtering is used to reduce measurement noise. Pressing the <Enter> key displays the following pop-up menu:

Disable
2 Rdg
4 Rdg
8 Rdg
16 Rdg
32 Rdg

Your selection specifies the number of reading conversions that will be averaged to yield a final measurement. The default selection, Disable, is synonymous to averaging one reading conversion. Since filtering increases measurement time, use only as much as necessary.

Delay Between Points Specifies the time between successive points in a sweep, to allow the source output to settle.

Points/Decade (Sweep Channel) This parameter is displayed for log sweeps. Pressing <Enter> will display the following pop-up menu:

5
10
25
50

The default value is five. Your selection specifies the number of measurement points per logarithmic decade for the Sweep and Sync Swp channels.

Pulsed Time On, Off These parameters are shown for pulsed sweeps. The on and off times define the entire period for each pulse waveform. Pulse Time On is the duration of the pulse at the sweep level. Pulse Time Off is time between pulses at the level set by Pulsed Off Value.

The on and off times include the effects of integration time, filtering, and autoranging. If the source measure unit is configured such that it cannot run fast enough to output pulses at the programmed on and off times, you are informed with the "Pulse times are approximate" message and given the opportunity to change test parameters.

Channel Parameters

CHANNEL NAME To execute a single curve or curve family test, six channels are available. The channel named Sweep performs a single curve test (e.g., a diode I-V curve) and is always required. The Step channel is used in combination with the Sweep channel to generate a curve family (e.g., bipolar common emitter curves).

A synchronous sweep, where two source measure units trigger each other back and forth until a sweep is completed, is accomplished with the Sweep and Sync Swp channels. A typical application for a synchronous sweep is a Gummel plot. The sync sweep list will have the same number of points as the primary sweep, and have a slope determined by the Start and Stop values of the Sync Swp channel.

The three bias channels source a constant DC voltage or current, and optionally measure. The bias channels are commonly used to provide a bias voltage or current for a semiconductor's substrate terminal, to supply device power, or to set an operating point for a test.

On/Off Press the <Enter> key to toggle between the two choices. A channel must be turned on to configure it for a test and use it during test execution. Only the Instrument Name field can be modified if the channel is turned off. The source and measure parameters are saved through a channel On-Off-On cycle.

Instrument Name Press the <Enter> key to display a pop-up menu of the Instrument Names previously specified on the DEFINE INSTRUMENTS form. Select the name of a Keithley source measure unit for any of the channels, or a Keithley quad voltage source for a bias channel. Each channel that is turned on must have a unique Instrument Name and address.

Src Array Name This field is the name of an array where the source values will be stored. Pressing <Enter> before modifying the field will display a pop-up menu of previously created array names.

Meas Array Name This field (source measure unit only) is the name of an array where the measure values will be stored. Pressing <Enter> before modifying the field will display a pop-up menu of previously created array names.

Time arrays are created when measure arrays are named on the CURVE FAMILY TEST form. The time arrays are called SWPTIME, STEPTIME, SYNCTIME, B1TIME, B2TIME, and B3TIME for the respective channels. They are filled with elapsed time data during acquisition for channels with measure array names. They can be specified on the DISPLAY PARAMETERS form to view data versus time.

NOTE

Since a test will run faster with fewer arrays, specify only those that require stored data. A measure array for the Sweep channel must be specified.

SOURCE Parameters

Type Pressing <Enter> will display the following pop-up menu (source measure units only):



The default selection, V, is for sourcing a voltage sweep (and measuring current). The next selection, I, is for sourcing a current sweep (and measuring voltage). The last two selections are for pulsed voltage or current sweeps. Source and measure parameters are saved when the source type is changed.

Pulsed Off Value This parameter is shown for pulsed sweeps. It is the desired voltage or current level during the pulse off times.

Range Pressing <Enter> toggles between Auto, the default, and Best Fix for the source range. With Auto range, the source measure unit may change ranges during a sweep, depending on the Start and Stop values. With Best Fix range, the source range is dictated by the highest range needed for the sweep parameters.

Start/Bias For the Sweep, Step, and Sync Swp channels, this is the starting voltage or current value of a sweep. For bias channels, this is the voltage bias level or current (source measure units only) bias level.

Stop For the Sweep, Step, and Sync Swp channels, this is the ending voltage or current value of a sweep.

Step

For linear sweeps, this is the incremental value between consecutive sweep points. If a negative value is entered, the absolute value is displayed, as the direction of the sweep is determined by the Start and Stop levels. Changes to the Step field are reflected in the # of Curves field for the Step channel.

The maximum number of points per data array is 4000. As shown in Figure 3-4, it is the product of curves per family and points per curve. 1M-byte of LIM expanded memory, up to 24 data arrays of this size or smaller can be created.

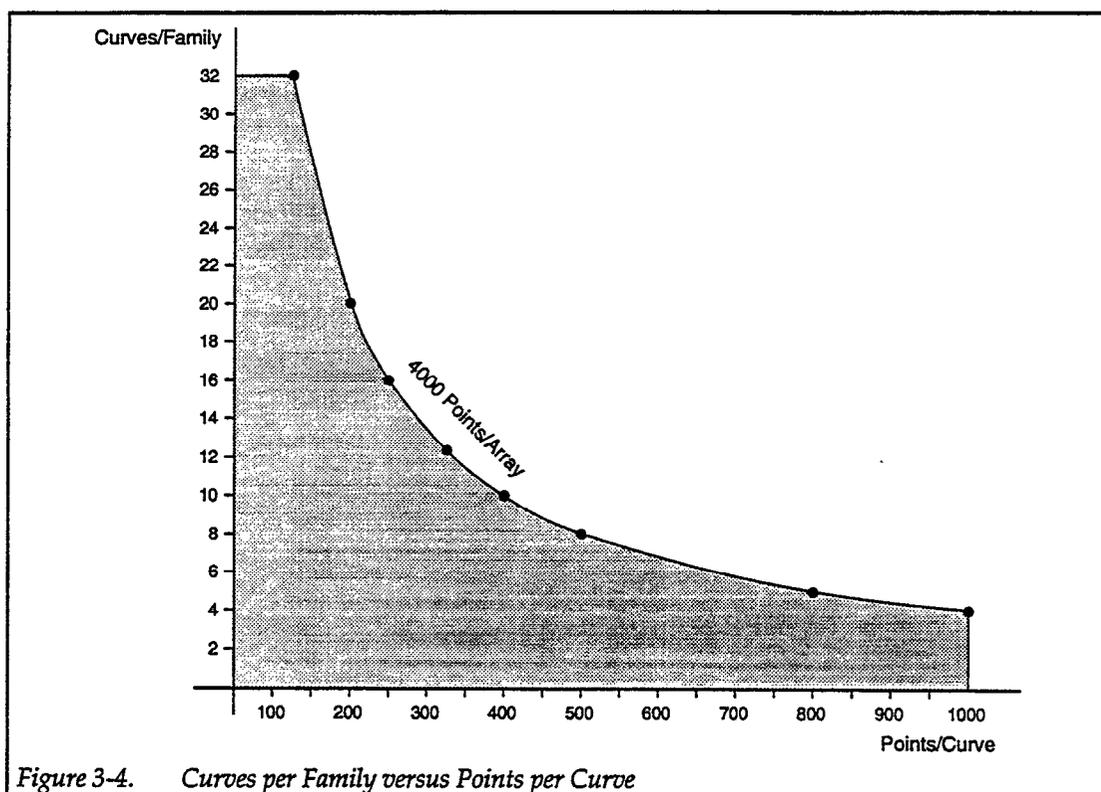


Figure 3-4. Curves per Family versus Points per Curve

For pulsed sweeps, the Step parameter determines the number of pulses. Since measurements are taken during the pulse on and pulse off times, the maximum number of pulses is 500 (this yields a 1000-point curve).

of Curves

For the Step channel, this field specifies the number of curves in a family. Changes to # of curves are reflected in the Step field. Once all four parameters (Start, Stop, Step, and # of Curves) are entered, changes to Start or Stop cause recalculation of Step according to # of Curves.

Sense

This field is active for source measure units only. Press the <Enter> key to toggle between Local sense, the default selection, and Remote sense. Use remote sensing when sourcing or measuring over 1mA. Refer to the instrument connection diagrams in Section 2, Getting Started.

WARNING

With remote sensing enabled, an open sense lead will result in lethal voltages appearing at OUTPUT HI and GUARD of the source measure units. This voltage can cause injury or death, and damage external circuitry. Always make sure that the sense leads are properly connected before enabling remote sense. NEVER change connections with power applied. Be sure to always discharge and/or disconnect external power sources.

MEASURE Parameters

- Range** Press the <Enter> key to display a pop-up menu of auto and fixed ranges of measure for the model of source measure unit specified by Instrument Name. Auto is the default selection.
- Compliance Value** This field (source measure units only) specifies the compliance limit that is set to protect external circuitry (i.e., the device under test) from damage. When sourcing voltage, a current compliance is set; when sourcing current, a voltage compliance is set.

3.5.3 Curve Family Test Examples

The test library of Appendix D contains curve family test examples, including sample data in the DAT files. This paragraph will describe modifying test examples to meet your needs. Listed below are the various types of curve family tests from the library.

Test Type	Trigger Controller	Example Test Setup File	Instruments and Channel Names
Linear sweep	No	DIODELIN.TST	236 – Sweep
Log sweep	No	DIODELOG.TST	236 – Sweep
Linear sweep with bias	Yes	NJFETTIG.TST	236 – Sweep 236 – Bias I
Linear subordinate sweep	Yes	NPNCRV.TST	236 – Sweep 236 – Step
Linear synchronous sweep	Yes	NPNFGUML.TST	236 – Sweep 236 – Sync Swp
Linear subordinate pulsed sweep	Yes	NPNPULS1.TST	236 – Sweep 236 – Step

Single Channel Sweep

This example is for a simple test system consisting of one source measure unit and no trigger controller. If you choose to run the test, refer to Diode Forward Biased I-V Characteristic Linear Sweep (DIODELIN.TST) in the test library for a schematic.

Step 1: Define the Instruments

Before you can run a test, Model 251 software must be configured for the instruments in your test system.

NOTE

Since Model 251 software defaults to the last loaded or saved instrument configuration file on start-up, all parts of this step may not be necessary.

1. From the main menu, select File Operations, then press <Enter>.
2. Select Load File <Enter>.
3. Select Instrument Configuration <Enter>.
4. Press <Enter>, then use the up/down arrow keys to highlight the instrument configuration file called TESTLIB.CFG.

NOTE

If TESTLIB.CFG does not appear in the directory listing, the Model 251 software may not be properly installed; refer to paragraph 2.4 for details on installation.

5. Press <Esc> three times to return to the main menu.
6. Select System Configuration and press <Enter>. Select Define Instruments and press <Enter>. The DEFINE INSTRUMENTS form should appear on the screen.
7. If necessary, modify the form to match the setup of your test system. Delete lines that refer to instruments with bus addresses not present.
8. Press <Esc> when done. Press <Y> at the Initialize Instruments prompt. You will be returned to the main menu after source measure units are initialized.

Step 2: Load the Test Setup File

Load a test setup file, which contains test parameters, display parameters, and GPIB I/O parameters.

1. From the main menu, select File Operations, then press <Enter>.
2. Select Load File <Enter>.
3. Select Test Setup File <Enter>.
4. Press <Enter>, then use the up/down arrow keys to highlight the test setup file called DIODELIN.TST, then press <Enter>.
5. Press <Esc> three times to return to the main menu.

Step 3: Set Up the Test Parameters

Examine the test parameters and modify them, if necessary, for your device and source measure unit.

1. From the main menu, select Curve Family Test, then press <Enter>.
2. Edit the CURVE FAMILY TEST form to correctly test your device with your source measure unit. You should be able to test a 1N914 diode with a Model 236 without modifying the test parameters shown in Figure 3-5.

DIODELIN		CURVE FAMILY TEST				
Sweep Type: LINEAR Mode: Single Test Delay Before Curves: 0 s			Integration Time: 416 μ s Filter: Disable Delay Between Points: 0 s			
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	DIODE					
Src Array Name	Vd	—	—	—	—	—
Meas Array Name	Id	—	—	—	—	—
SOURCE						
Type	V	—	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	—	—	—	—
Start/Bias	0 V	—	—	—	—	—
Stop	500 mV	—	—	—	—	—
Step	10 mV	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	1 mA	—	—	—	—	—
Compliance Value	1 mA	—	—	—	—	—

Figure 3-5. Sample Single Channel Test Parameters

Step 4: Set Up the Display Parameters

The display parameters, loaded along with the test parameters in the test setup file, may require modification.

NOTE

Parameters on the DISPLAY PARAMETERS screen are saved with a test setup or data file. Thus, it is not necessary to access this screen after loading a test setup or data file, unless, of course, you wish to make changes to the way your data is displayed.

1. Press <F7> from the CURVE FAMILY TEST form to get to the DISPLAY PARAMETERS form.
2. The display parameters may need editing if you are not testing a 1N914 diode. (See Section 4 for editing details.)

NOTE

With no test setup or data file loaded, the default values on the DISPLAY PARAMETERS form will display a graph, as long as you specify what Array Names to plot.

Step 5: Execute the Test

1. From the DISPLAY PARAMETERS form, press the <F10> key. This will initiate test execution.
2. When the test has completed, a graph of the I-V characteristics will be displayed on the screen.

Multichannel Sweep

This example will use two source measure units and a trigger controller to acquire curve family data. If you choose to run the test, refer to NPN Transistor Common Emitter Curve Family (NPNCRV.TST) in the test library for a schematic.

Step 1: Define the Instruments

1. From the main menu, select File Operations, then press <Enter>.
2. Select Load File <Enter>.
3. Select Instrument Configuration <Enter>.
4. Press <Enter>, then highlight the TESTLIB.CFG file and press <Enter>.
5. Press <Esc> three times to return to the main menu.
6. Select System Configuration and press <Enter>. Select Define Instruments and press <Enter>.
7. Modify the DEFINE INSTRUMENTS form to match your test system. This test needs two source measure units and a trigger controller
8. Press <Esc> when done. Press <Y> at the Initialize Instruments prompt. You will be returned to the main menu.

Step 2: Load the Test Setup File

1. From the main menu, select File Operations, then press <Enter>.
2. Select Load File <Enter>.
3. Select Test Setup File <Enter>.
4. Press <Enter>, then highlight the NPNCRV.TST file and press <Enter>.
5. Press <Esc> three times to return to the main menu.

Step 3: Set Up the Test Parameters

1. From the main menu, select Curve Family Test, then press <Enter>.
2. Examine the test parameters. Edit them for your device and source measure units, if necessary. The parameters shown in Figure 3-6 are set for a 2N3904 NPN transistor with two Model 236 Source Measure Units.

Step 4: Set Up the Display Parameters

1. Press <F7> from the CURVE FAMILY TEST form to get to the DISPLAY PARAMETERS form.
2. The display parameters may need editing if you are not testing a 2N3904 transistor.

Step 5: Execute the Test

1. From the DISPLAY PARAMETERS form, press the <F10> key. The sweeps will start.
2. When the sweeps have completed, a graph of the common emitter characteristics will be graphed on the screen.

NPNCRV		CURVE FAMILY TEST				
Sweep Type: LINEAR Mode: Single Test Delay Before Curves: 0 s			Integration Time: 416µs Filter: Disable Delay Between Points: 0 s			
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	On	Off	Off	Off	Off
Instrument Name	COLLECTR	BASE	—	—	—	—
Src Array Name	Vce	Ib	—	—	—	—
Meas Array Name	Ic	Vbe	—	—	—	—
SOURCE						
Type	V	I	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	Best Fix	—	—	—	—
Start/Bias	0 V	10 µA	—	—	—	—
Stop	5 V	50 µA	—	—	—	—
Step	50 mV	10 µA	—	—	—	—
# Of Curves	—	5	—	—	—	—
Sense	Local	Local	—	—	—	—
MEASURE						
Range	100 mA	1.1 V	—	—	—	—
Compliance Value	20 mA	1 V	—	—	—	—

Figure 3-6. Sample Multichannel Test Parameters

Multichannel Pulsed Sweep with Calculation

This example is a continuation of the previous one. It uses pulsed sweeps and performs a calculation on the acquired data. If you wish to run the test, refer to NPN Transistor Curve Family and Beta Using Pulsed Sweep and Step (NPNPULS1.TST) in the test library.

Step 1: Define the Instruments

This step has the same parts as the Multichannel Sweep example and does not need to be repeated.

Step 2: Load the Test Setup File

Perform the same parts as in the previous example, except specifying the NPNPULS1.TST.

Step 3: Set Up the Test Parameter

Examine the test parameters of Figures 3-7 and modify for your device and instruments, if necessary.

Step 4: Set Up the Display Parameters

1. Press <F7> from the CURVE FAMILY TEST form to get to the DISPLAY PARAMETERS form.
2. The display parameters may need editing if you are not testing a 2N3904 transistor. Note that beta will be plotted on the Y2 axis.
3. Move the cursor down to DC-Gain (Ratio) and press <Enter>. A pop-up form will be displayed.
4. Note that the collector and base current arrays are specified in the form and that the calculation is enabled.
5. Press <Esc> to return to the DISPLAY PARAMETERS form.

Step 5: Execute the Test

1. From the DISPLAY PARAMETERS form, press the <F10> key. The pulsed sweeps will start.
2. When the sweeps have completed, the common emitter characteristics and beta will be graphed on the screen.

DC Source and Measure Tests

3.6 DC SOURCE AND MEASURE TESTS

3.6.1 DC SOURCE-MEASURE TEST Form

The DC SOURCE-MEASURE TEST form configures Model 251 software to source, and optionally measure DC voltage or current. Up to six channels are available for source measure units.

NOTE

Parameters on the DC SOURCE-MEASURE TEST form, along with GPIB I/O parameters and display parameters, can be saved in a test setup file. This is done from the File Operations selection of the main menu and is discussed in Section 5.

Entering DC SOURCE-MEASURE TEST Form

To access the DC SOURCE-MEASURE TEST form, select DC Source-Measure Test from the main menu and press <Enter>. The DC SOURCE-MEASURE TEST form will be displayed.

DC SOURCE-MEASURE TEST Screen Format

An example of a DC SOURCE-MEASURE TEST form is shown in Figure 3-7, which is a test form for a capacitor leakage test. (The form is for the DCCAPAC.TST from the test library of Appendix D.) The top portion of the form lists parameters that apply to all channels. The lower portion of the form lists channel specific parameters of the six bias channels.

8	DCCAPAC ————— DC SOURCE-MEASURE TEST —————							3
1	Mode: Single Test			Integration Time: 60Hz Line				4
2	Delay Time: 10 s			Filter: Disable				
5	CHANNEL NAME	Bias 1	Bias 2	Bias 3	Bias 4	Bias 5	Bias 6	
	On/Off	On	Off	Off	Off	Off	Off	
	Instrument Name	CAPACITR						
	Src Array Name	Vc						
	Meas Array Name	Ic						
6	SOURCE							
	Type	V						
	Range	Best Fix						
	Value	2 V						
	Sense	Local						
7	MEASURE							
	Range	1 μ A						
	Compliance Value	1 μ A						

- 1 Mode: Press <Enter> to toggle between Single Test and Auto Repeat.
- 2 Delay Time: Type in desired delay (0 to 65 seconds, in 1msec increments).
- 3 Integration Time: Press <Enter> to display pop-up menu. Selections are 416 μ sec, 4ms, 60Hz Line, and 50Hz Line.
- 4 Filter: Press <Enter> to display pop-up menu. Selections are Disable, 2 Rdg, 4 Rdg, 8 Rdg, 16 Rdg, and 32 Rdg.
- 5 CHANNEL Parameters
 - On/Off: Press <Enter> to toggle between channel On and channel Off.
 - Instrument Name: Type in desired instrument name (up to eight characters) or press <Enter> to display a pop-up menu of previously defined names.
 - Src Array Name: Type in desired source array name (up to eight characters) or press <Enter> to display pop-up menu of previously defined names.
 - Meas Array Name: Type in desired measure array name (up to eight characters) or press <Enter> to display pop-up menu of previously defined names.
- 6 SOURCE Parameters:
 - Type: Press <Enter> to toggle between V (source voltage) and I (source current).
 - Range: Press <Enter> to toggle between Auto source range and Best Fix source range.
 - Value: Type in desired voltage or current bias value for DC operation.
 - Sense: Press <Enter> to toggle between Local and Remote sense.
- 7 MEASURE Parameters:
 - Range: Press <Enter> to display a pop-up menu of measure ranges. Selections depend on source type and model designation of named instrument.
 - Compliance Value: Type in desired compliance limit for current or voltage.
- 8 Test Title: Name of the test setup file that was loaded or saved.

Figure 3-7. DC SOURCE-MEASURE Test Form

Active Function Keys

F1-Help	Provides on-line help information.
F4-Print	Prints the screen to a defined printer.
F5-GPIB	Takes you to the GENERAL GPIB OUTPUT form.
F7-Disp.Param	Takes you to the DISPLAY DC PARAMETERS form.
F8-View	Takes you to the VIEW screen, if data is available and data arrays have been specified on the DISPLAY DC PARAMETERS form.
F10-Execute Test	Performs the DC source/measure if data arrays have been specified on the DISPLAY DC PARAMETERS form, then takes you to the VIEW screen.
ESC-Main Menu	Exits DC SOURCE-MEASURE TEST form and returns you to the main menu.

3.6.2 Parameter Description

Global Parameters

Mode	Press the <Enter> key to toggle between the two test modes: Single Test and Auto Repeat. With Single Test, the test will be executed once, then the data will be listed. With Auto Repeat, the test will be executed and the data will be listed continually. Pressing <Escape> will immediately abort a test. If Auto Repeat is selected, the <F10> key will interrupt the test repetition after the present test has completed.
Delay Time	Specifies the dc delay, the time between source and measure phases of a source-delay-measure cycle, to allow the source output to settle. The DC delay is in addition to the default delay.

NOTE

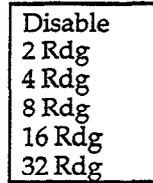
A Model 213 Quad Voltage Source requires at least 750 μ s to settle.

Integration Time	Press the <Enter> key to display the following pop-up menu:
------------------	---

416 μ s
4ms
60Hz Line
50Hz Line

Your selection specifies the speed for A/D conversions and subsequent usable measurement resolution, with 60Hz Line as the default selection. The integration times have the following measurement resolutions: 416 μ sec (4 digits), 4msec (5 digits), 60Hz line (16.7msec, 5 digits), and 50Hz line (20msec, 5 digits). If one of the line cycle selections is chosen, match your power line frequency or noisy readings are possible.

Filter Filtering is used to reduce measurement noise. Pressing the <Enter> key displays the following pop-up menu:



Your selection specifies the number of reading conversions that will be averaged to yield a final measurement. With the filter disabled, only one reading is taken. Since filtering increases measurement time, use only as much as necessary.

Channel Parameters

CHANNEL NAME To execute a DC test, up to six bias channels source a constant DC voltage or current, and optionally measure.

On/Off Press the <Enter> key to toggle between the two choices. A channel must be turned on to configure it for a test and use it during test execution. Only the Instrument Name field can be modified if the channel is turned off. The source and measure parameters are saved through a channel On-Off-On cycle.

Instrument Name Press the <Enter> key to display a pop-up menu of the Instrument Names previously specified on the DEFINE INSTRUMENTS form. Select the name of a Keithley source measure unit or quad voltage source. Each channel that is turned on must have a unique Instrument Name and address.

Src Array Name This field is the name of an array where the source values will be stored. Pressing <Enter> before modifying the field will display a pop-up menu of previously created array names.

Meas Array Name This field (source measure units only) is the name of an array where the measure values will be stored. Pressing <Enter> before modifying the field will display a pop-up menu of previously created array names.

NOTE

Since a test will run faster with fewer arrays, specify only those that require stored data.

SOURCE Parameters

Type	Pressing <Enter> toggles between two choices (source measure units only): V, the default selection, for sourcing DC voltage (and measuring current), and I, for sourcing DC current (and measuring voltage). Source and measure parameters are saved when the source type is toggled back and forth.
Range	Pressing <Enter> toggles between Auto, the default, and Best Fix for the source range. With Auto range, the source measure unit may change ranges. With Best Fix range, the source range is dictated by the highest range needed for the source value.
Value	This is the voltage bias level or current (source measure units only) bias level.
Sense	This field is active for source measure units only. Press the <Enter> key to toggle between Local sense, the default selection, and Remote sense. Use remote sensing when sourcing or measuring over 1mA. Refer to the instrument connection diagrams in Section 2, Getting Started.

WARNING

With remote sensing enabled, an open sense lead will result in lethal voltages appearing at OUTPUT HI and GUARD of the source measure units. This voltage can cause injury or death, and damage external circuitry. Always make sure that the sense leads are properly connected before enabling remote sense. NEVER change connections with power applied. Be sure to always discharge and/or disconnect external power sources.

MEASURE Parameters

Range	Press the <Enter> key to display a pop-up menu of auto and fixed ranges of measure for the model of source measure unit specified by Instrument Name. Auto is the default selection.
Compliance Value	This field (source measure units only) specifies the compliance limit that is set to protect external circuitry (i.e., the device under test) from damage. When sourcing voltage, a current compliance is set; when sourcing current, a voltage compliance is set.

3.6.3 DC Source-Measure Test Examples

The test library of Appendix D contains DC source-measure test examples, including sample data in the .DAT files. This paragraph will describe modifying a test example to meet your needs.

This example is for a simple test system consisting of one source measure unit and no trigger controller. If you choose to run the test, refer to Capacitor Leakage Test (DCCAPAC.TST) in the test library for a schematic.

Step 1: Define the Instruments

Model 251 software must be configured for your test system.

NOTE

Since Model 251 software defaults to the last loaded or saved instrument configuration file on start-up, all parts of this step may not be necessary.

1. From the main menu, select File Operations, then press <Enter>.
2. Select Load File, then press <Enter>.
3. Select Instrument Configuration, then press <Enter>.
4. Press <Enter>, then use the up/down arrow keys to highlight the instrument configuration file called TESTLIB.CFG.

NOTE

If TESTLIB.CFG does not appear in the directory listing, the Model 251 software may not be properly installed; refer to paragraph 2.4 for details on installation.

5. Press <Esc> three times to return to the main menu.
6. Select System Configuration and press <Enter>. Select Define Instruments and press <Enter>. The DEFINE INSTRUMENTS form should appear on the screen.
7. If necessary, modify the form to match the setup of your test system. Delete lines that refer to instruments with bus addresses not present.
8. Press <Esc> when done. Press <Y> at the Initialize Instruments prompt. You will be returned to the main menu after source measure units are initialized.

Step 2: Load the Test Setup File

Load a test setup file, which contains test parameters, display parameters, and GPIB I/O parameters.

1. From the main menu, select File Operations, then press <Enter>.
2. Select Load File, then press <Enter>.
3. Select Test Setup File, then press <Enter>.
4. Press <Enter>, then use the up/down arrow keys to highlight the test setup file called DCCAPAC.TST, then press <Enter>.
5. Press <Esc> three times to return to the main menu.

Step 3: Set Up the Test Parameters

Examine the test parameters and modify them, if necessary, for your device and source measure unit.

1. From the main menu, select DC Source-Measure Test, then press <Enter>.
2. Edit the DC SOURCE-MEASURE TEST form to correctly test your device with your source measure unit. You should be able to test a 1 μ F capacitor with a Model 236 without modifying the test parameters shown in Figure 3-8.

DCCAPAC		DC SOURCE-MEASURE TEST				
Mode: Single Test Delay Time: 10 s		Integration Time: 60Hz Line Filter: Disable				
CHANNEL NAME	Bias 1	Bias 2	Bias 3	Bias 4	Bias 5	Bias 6
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	CAPACITR					
Src Array Name	Vc	—	—	—	—	—
Meas Array Name	Ic	—	—	—	—	—
SOURCE						
Type	V	—	—	—	—	—
Range	Auto	—	—	—	—	—
Value	2 V	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	1 μ A	—	—	—	—	—
Compliance Value	1 μ A	—	—	—	—	—

Figure 3-8. Sample DC Source-Measure Test Parameters

Step 4: Set Up the Display Parameters

The display parameters, loaded along with the test parameters in the test setup file, may require modification.

NOTE

Parameters on the DISPLAY PARAMETERS screen are saved with a test setup or data file. Thus, it is not necessary to access this screen after loading a test setup or data file, unless, of course, you wish to make changes to the way your data is displayed.

1. Press <F7> from the DC SOURCE-MEASURE TEST form to get to the DISPLAY DC PARAMETERS form.
2. The display parameters may need editing if you are not testing a 1 μ F capacitor. (See Section 4 for editing details.)

NOTE

As long as you specify Select All, the default values on the DISPLAY DC PARAMETERS form will run properly with no test setup or data file loaded.

Step 5: Execute the Test

1. From the DISPLAY DC PARAMETERS form, press the <F10> key. This will initiate test execution.
2. When the test has completed, a list of the source and measure values, and any calculated value, will be displayed on the screen.

3.7 GPIB INPUT/OUTPUT

3.7.1 GENERAL GPIB OUTPUT Form

The GENERAL GPIB OUTPUT form is used to control any named instrument on the DEFINE INSTRUMENTS form. These can be instruments other than Keithley. If the first output string has been defined on the GENERAL GPIB OUTPUT form, it is sent before a curve family or DC source-measure test is executed. The string can be used, for example, to set a bias voltage level, or trigger a matrix relay setup, or set the temperature of a hot chuck.

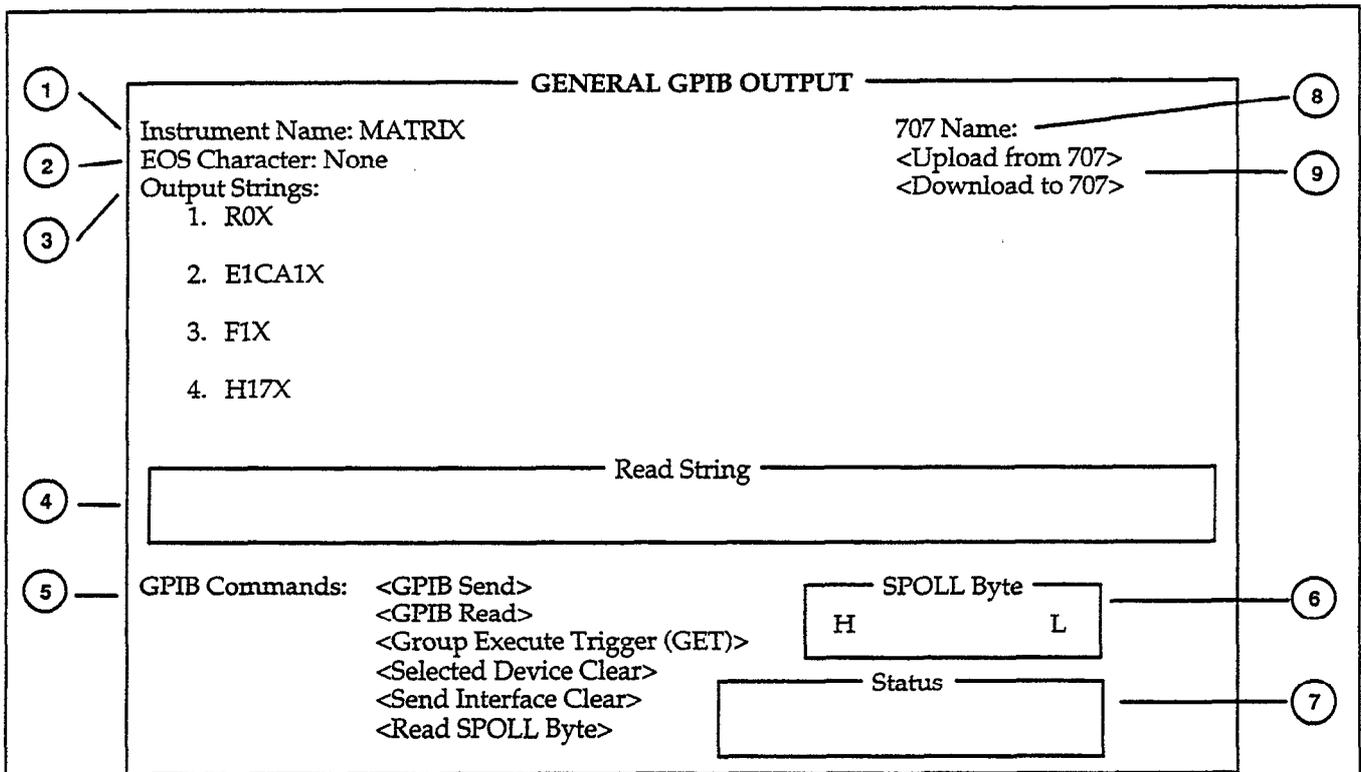
The output strings can also be sent by themselves to troubleshoot specific named instruments. Responses from bus instruments are displayed on the form.

Entering GENERAL GPIB OUTPUT Form

The GENERAL GPIB OUTPUT form is accessed by pressing the <F5> key from the CURVE FAMILY TEST form or the DC SOURCE-MEASURE TEST form. When the GENERAL GPIB OUTPUT form is exited, you are returned to the appropriate test form.

GENERAL GPIB OUTPUT Screen Format

An example of a GENERAL GPIB OUTPUT form is shown in Figure 3-6, which is configured to trigger a matrix relay setup on a Keithley Model 707 Switching Matrix. The top portion of the form lists the output strings to send. The lower portion of the screen lists the available GPIB commands that are executed with the <F10> key.



- 1 Instrument Name: Type in desired instrument name (up to eight characters) or press <Enter> to display a pop-up menu of previously defined names.
 - 2 EOS Character: Press <Enter> to display pop-up menu of end of string characters. Selections are None, CRLF, CR, and Decimal.
 - 3 Output String: Type in up to four device-dependent command strings to output to the named instrument (up to 60 characters).
 - 4 Read String: This window displays responses from the named instrument (up to 70 characters, including terminators).
 - 5 GPIB Commands: These are the commands that can be sent to the named instrument. Select a command with the cursor, then press <F10> to execute a command.
 - 6 SPOLL Byte: This window displays the serial poll byte response from the named instrument after the Read SPOLL Byte command is executed.
 - 7 Status: This window displays the status of the requested operation, either pending or complete.
- Enter string # to send: A pop-up is displayed when the <F10> key is passed with the cursor on <GPIB Send>. Valid responses are 1-4 (sends single string) and * (sends all strings)..
- 8 707 Name: Type in desired instrument name (up to eight characters) or press <Enter> to display a pop-up menu of previously defined names.
 - 9 707 Commands: These are the commands that support uploading and downloading for the Model 707 Switching Matrix. Select a command with the cursor, then press <F10> to execute.

Figure 3-9. GENERAL GPIB OUTPUT Form

Active Function Keys

F1-Help	Provides on-line help information.
F4-Print	Prints the screen to a defined printer.
F10-Execute GPIB	Performs the selected GPIB command. If GPIB Send, prompts you to enter string number to send.
ESC-Test Form	Exits GENERAL GPIB OUTPUT form and returns you to a test form (curves or DC).

3.7.2 Parameter Description

Instrument Name	Press the <Enter> key to display a pop-up menu of the Instrument Names previously specified on the DEFINE INSTRUMENTS form. You can select the name of any instrument.
EOS Character	Press the <Enter> key to display a pop-up menu listing the valid end of string (EOS) characters. Select from the following, where "None" is the default:

None CRLF CR Decimal

Output Strings	This field specifies the strings to be sent to the named instrument (up to 60 characters). After entering the strings, move the cursor to the the GPIB Send command and press <F10>. You will be prompted to enter the individual string number or an asterisk (*) to send all strings. The strings are sent as data along with the selected EOS character after each string.
----------------	---

NOTE

The parameter values of Instrument Name, EOS Character, and the first Output String are saved within .TST and .DAT files.

3.7.3 GPIB Commands

Use the cursor and <F10> keys to execute the following commands:

GPIB Send	Sends the desired output string(s) to the named device.
-----------	---

NOTE

Up to four output strings can be sent when the GENERAL GPIB OUTPUT form is displayed. Only the first output string is sent when a curve test or DC test is performed.

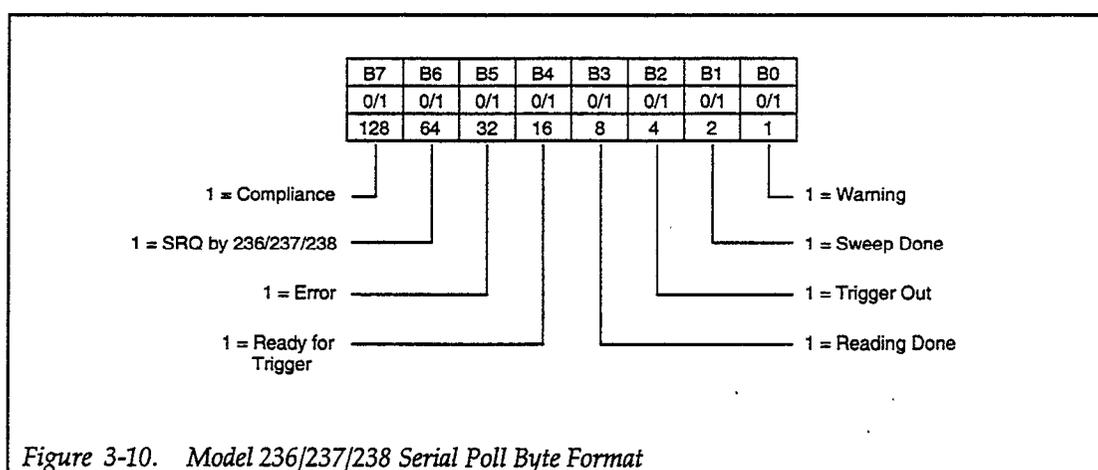
GPIB Read	Reads a string from the named device and displays the result in the Read String window (up to 70 characters, including terminators).
-----------	--

- Group Execute Trigger (GET) Sends a trigger to the named device. For example, GET initiates a sweep if a Model 236/237/238 is configured for an IEEE GET input trigger origin.

- Selected Device Clear Clears a named instrument; returns it to power-up default conditions.

- Send Interface Clear Places all bus instruments in the local, talker idle and listener idle state.

- Read SPOLL Byte Obtains the serial poll byte from the named instrument and displays it in the SPOLL Byte display field. See Figure 3-10 for the format of the SPOLL byte for a Model 236/237/238.



3.7.4 GPIB Display Fields

- Read String If the GPIB Read command is selected, the response from the instrument is displayed in this field (up to 70 characters, including terminators). This could be a status word or measurement string, for example.

- SPOLL Byte When the Read SPOLL byte command is selected, the serial poll byte response is displayed in this field.

- Status The status of the requested command, either Operation Pending or Operation Complete, is displayed in this field.

3.7.5 Model 707 Fields

- . 707 Name Press the <Enter> key to display a pop-up menu of the Instrument Names previously specified on the DEFINE INSTRUMENTS form. You can select the name of any instrument. However, <Upload from 707> is permitted only for type KI707.

Upload from 707

Use the cursor and <F10> keys to execute this command. It uploads either the current relay setup or up to 100 stored setups from the Model 707 to computer memory. (See Figure 3-11.)

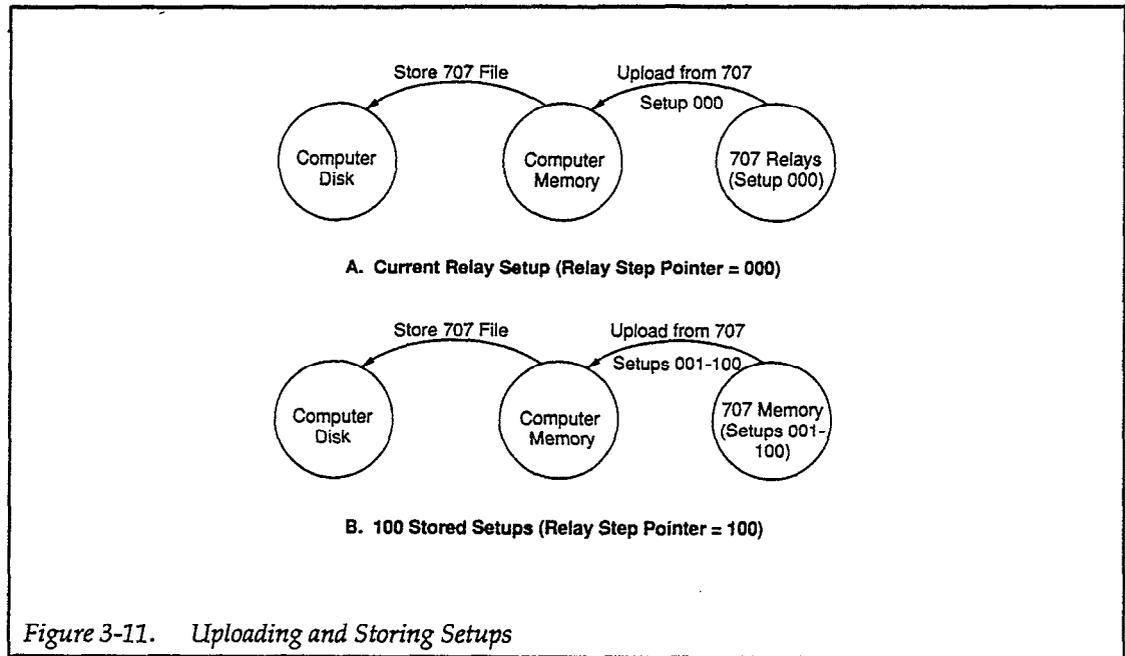


Figure 3-11. Uploading and Storing Setups

Download to 707

Use the cursor and <F10> keys to execute. It downloads either the current relay setup or up to 100 stored setups from computer memory to the Model 707. (See Figure 3-12.)

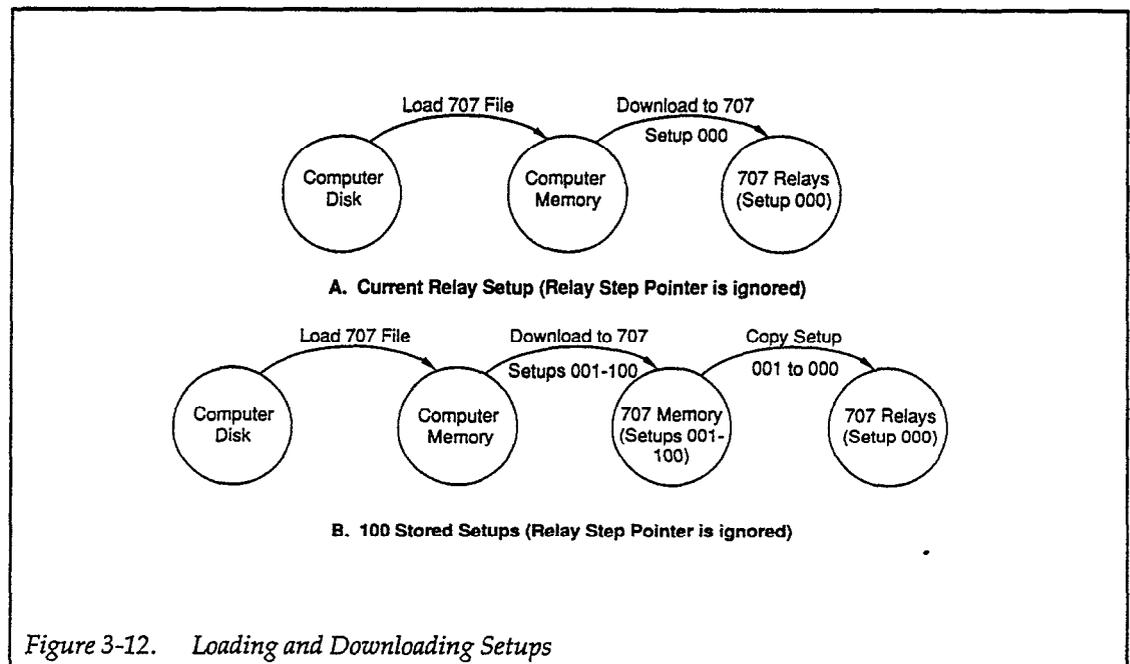


Figure 3-12. Loading and Downloading Setups

3.7.6 Uploading and Downloading

Relay setups from a standalone Model 707 or a Model 707 master/slave system can be uploaded and downloaded through the previously described fields. This includes the required Model 707 handshaking if the instrument type for the named instrument (in the 707 Name field) is KI707. There are several rules of operation for this feature:

1. The value of the RELAY STEP pointer on the Model 707 determines how many setups are uploaded. If the RELAY STEP equals 000, only the current relay setup is uploaded. If the RELAY STEP equals from 001-100, that is how many stored setups are uploaded. The RELAY STEP pointer is ignored on downloads.
2. The order of user actions affects the current relay setup in the Model 707 according to Table 3-2.
3. Model 251 software waits until the Model 707 reports that it has settled before sending the first Output String. The Delay Before Curves will occur after the first Output String is sent.
4. Although setups are downloaded in binary format, the Model 707 determines the format by checking the first byte for binary or ASCII data.
5. You can specify another instrument type in the 707 Name field. In this case, only downloading is supported, with no handshaking or status checking. (See Table 3-3.)
6. A 707 file can have anything in it, including device-dependent commands for another instrument. This can include binary data, although if the last character in the file is Control-Z (hex 1A), it is considered end-of-file and is not sent. As long as the first line contains an instrument name, the file is sent over the GPIB bus to that instrument.

Table 3-2. Order of User Actions

User Action	Model 251 Response
CASE 1	
A. Change RELAY STEP to 050 on 707 front panel.	A. None
B. Select <Upload from 707> and <F10> from GPIB OUTPUT form.	B. Uploads 50 setups.
C. Select <F10>-Execute Test from a test form.	C. Executes test with setup 050.
CASE 2	
A. Select Load 707 File.	A. Loads a 707 file that was previously created. (Assume 50 setups for this example.)
B. Select <Download to 707> and <F10> from GPIB OUTPUT form.	B. Downloads 50 setups, copies setup 001 to setup 000 (relays), sets RELAY STEP to 000.
C. Select <F10>-Execute Test from a test form.	C. Executes test with setup 000.

NOTE: In Case 1, if the GPIB OUTPUT form contains a command to trigger the 707, the test is executed with setup 051. In Case 2, the test is executed with setup 001, which was previously copied to setup 000.

Table 3-3. Uploading and Downloading Support for Instruments

Instrument Type	Handshaking	Uploading	Downloading
KI236, KI237, KI238			X
KI213-1, KI213-2, KI213-3, KI213-4			X
KI707	X	X	X
Other			X

Uploading and Storing Setups

Refer to Figure 3-11A for the current relay setup and Figure 3-11B for up to 100 stored setups.

1. On the Model 707 front panel, set the RELAY STEP pointer to the desired number of setups. (Enter number on keypad, then press RELAYS key.)

For example: 000 — selects the current relay setup
001 — selects the stored setup 001
050 — selects stored setups 001-050
100 — selects stored setups 001-100

2. From the Model 251 GPIB OUTPUT form, press <Enter> at the 707 Name field to see a pop-up of instrument names. Select the instrument name of the Model 707 and press <Enter>.
3. Upload setup(s) from the Model 707 by selecting the <Upload from 707> command and pressing <F10>.
4. Press <Esc> until you return to the main menu. Save the setups to a 707 file by selecting File Operations - Save File - 707 File, and by naming it when prompted. Or, press <Esc> to a test form and <F3> to save a file. Select Save 707 File and name it when prompted.
5. Press <Esc> to return to the main menu.

Loading and Downloading of Setups

Refer to Figure 3-12A for the current relay setup and Figure 3-12B for up to 100 stored setups.

1. From the Model 251 main menu, load a 707 file by selecting File Operations -Load File - 707 File.
2. Press <Enter> at the File To Load prompt. Select a 707 file from the directory and press <Enter>. Press <Esc> until you return to the main menu.

NOTE

As an alternative to steps 1 and 2, load a file by pressing the <F2> key from a test form.

3. Go to a test form, then press <F5> for the GPIB OUTPUT form.
4. Press <Enter> at the 707 Name field to see pop-up of instrument names. Select the instrument name of the Model 707 and press <Enter>.
5. Download the setups contained in the 707 file by selecting the <Download to 707> command and pressing <F10>.

3.7.7 System Troubleshooting with the GPIB Form

In addition to controlling instruments other than Keithley Source Measure Units, the GENERAL GPIB OUTPUT form can be used to troubleshoot any instrument that is connected to the IEEE-488 bus. You can send device-dependent commands (DDCs) and read data from the instrument named on the form.

Before using this form to troubleshoot, you should verify that the instruments are properly connected and configured, as follows:

1. On the IEEE-488 card, check the cable connection and hardware configuration. (See paragraph 2.2.3 for connections and paragraph 2.4.1 for configuration.)
2. On each instrument, check the bus cable connection and bus address. (See paragraph 2.2.3 for connections and paragraph 2.3.5 for addresses.)

3. Within Model 251 software, check that the parameters on the GPIB CONFIGURATION form match those of your IEEE-488 card. (See paragraph 2.5.8.)
4. Also within Model 251 software, check that the parameters on the DEFINE INSTRUMENTS form match those of your instrument setup. (See paragraph 2.5.9.)

If the instruments still do not respond, use the GENERAL GPIB OUTPUT form to clear the bus and attempt to communicate with one instrument:

1. If the Instrument Name field on the form is blank, move the cursor there and press the <Enter> key to display the previously defined instruments. Use the cursor and <Enter> keys to select a name.
2. Move the cursor to the <Send Interface Clear> GPIB Command and press the <F10> key to execute the command. This places all bus instruments in the local, talker idle, and listener idle state.
3. Move the cursor to the <Selected Device Clear> command and press the <F10> key. This places the named instrument in the power-up, device clear, selected device clear default conditions.
4. Try to get a simple response from the named instrument, such as the serial poll (SPOLL) byte. Do this by moving the cursor to the <Read SPOLL Byte> command and pressing <F10>. The SPOLL Byte field should display a byte of data.
5. If unsuccessful, return to the previous procedure to verify connections and configurations with a single instrument. If successful, continue with the next procedure.

The following example checks whether a Model 213 Quad Voltage Source outputs a specified voltage, but it can be adapted to send DDCs and read the status of any bus instrument:

1. Enter the output strings shown in Figure 3-13. The first string programs port 1 of the Model 213 for 3 volts on the $\pm 5V$ range; the second string requests the port 1 status.
2. Move the cursor to <GPIB Send> and press <F10>. At the prompt for string number, type in “*”. The output strings are sent to the Model 213.
3. Move the cursor to <GPIB Read> and press <F10>. The status word for port 1 of the Model 213 is displayed in the Read String display field.

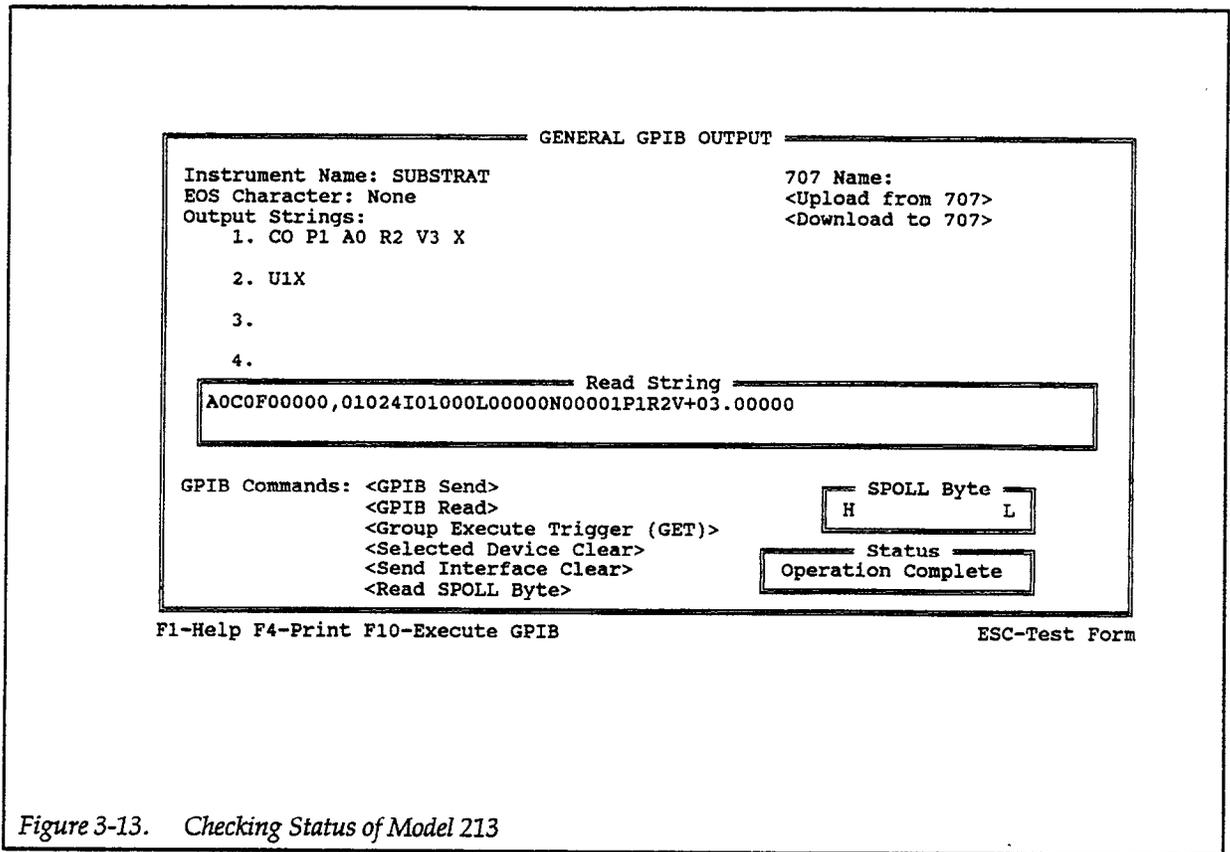


Figure 3-13. Checking Status of Model 213

SECTION 4

Data Display

4.1 INTRODUCTION

This section includes detailed information on displaying data in various forms. Section 4 contains the following information:

4.2 Display Overview: Provides overview information on data display and gives a basic step-by-step procedure for display operation.

4.3 Display Parameters: Details programming of the display parameters, which are to define the way data is displayed.

4.4 Graphics Display: Describes data plotting and the available graphical analysis tools.

4.5 List Data: Covers methods to list numeric data from both DC and curve tests on the computer screen.

4.6 Printing and Plotting: Gives procedures for obtaining hard copy of data display information using a printer or plotter.

4.7 Display Examples: Summarizes step-by-step procedures for performing common display tasks.

Error messages associated with display operations are covered in Appendix B.

4.2 DISPLAY OVERVIEW

The general steps below outline the basic procedure for graphing or listing data. Detailed information for each step is located in the remainder of this section. These steps assume that you have already set up system hardware and software as discussed in Sections 2 and 3. Detailed procedures for typical graphics applications are covered in paragraph 4.7.

Step 1: Acquire Data

You must, of course, have your data in computer memory before attempting to display it. If you have already acquired data in a previous session and have saved it on disk, use the Load Data selection in the FILE OPERATIONS menu to load the desired data file. If you are executing a test, the data will be automatically displayed as part of the test procedure.

Step 2: Choose Display Parameters

From a test form screen, press the F7 key to bring up the DISPLAY PARAMETERS screen. You can use the various parameters on this screen to tailor the way your data is displayed. For example, the Mode parameter allows you to choose between Graphics and List (The Graphics mode graphs data, while List displays data in numeric form). See paragraph 4.3 for details on the various parameters for the graphics mode. Display parameters for the list mode are covered in paragraph 4.5.

Step 3: Display Data

From the DISPLAY PARAMETERS screen, press the F8 key to display your data. If you have chosen the Graphics mode, your data will be plotted on the screen. With the List mode, the numeric values of arrays or variables will be displayed. Paragraph 4.4 covers the graphics screen mode in detail, while information on the list mode may be found in paragraph 4.5.

Step 4: Analyze Data

If you have graphed your data, you can use a variety of graphical analysis tools to manipulate and analyze that data. For example, you can use the Markers and Lines tools to determine data point values, curve slopes and axis intercept points. The Vertical zoom and Horiz. zoom tools allow you enlarge a portion of the graph for more detailed analysis, while the Filter tool can be used to smooth curves, minimizing noise. Graphical analysis tools are covered in detail in paragraph 4.4.

Step 5: Print or Plot Data

You can obtain a hard copy of your data by pressing F3 to plot (graphics screen only) or F4 to print on your printer while data is being displayed. In order to plot or print properly, you must have the software properly configured (paragraph 2.4). Paragraph 4.6 gives more information on printing and plotting.

4.3 DISPLAY PARAMETERS

4.3.1 Display Parameters Screen

The DISPLAY PARAMETERS screen allows you to program various aspects of your data display, such as selecting graphics or data list mode, arrays to plot, and grid, axis, and line parameters (labels, colors and type).

NOTE

Parameters on the DISPLAY PARAMETERS screen are saved with a test setup or data file. Thus, it is not necessary to access this screen after loading a test setup or data file, unless, of course, you wish to make changes to the way your data is displayed.

The following paragraphs discuss each of these aspects in detail.

Entering the DISPLAY PARAMETERS Screen

To access the DISPLAY PARAMETERS screen, press F7 from the Graphics Display screen, a List Display screen, or the CURVE FAMILY TEST screen. Note that you cannot display the graphics mode screen from the DC SOURCE-MEASURE TEST screen.

DISPLAY PARAMETERS Screen Format

The general format of the DISPLAY PARAMETERS screen in the Graphics mode is shown in Figure 4-1, which shows the default values for the various selections on the screen. The top part of the screen includes prompts for general graphics parameters, while the form at the center left of the screen includes selections for specific parameters for both X and Y axes. The bottom of the screen includes selections for additional graphics parameters that control grids, labels, colors, and gain values.

DISPLAY PARAMETERS

1 Mode: Graphics

2 Graph Title:

3 Scale: Auto

Axis	X	Y1	Y2
Array Name			
Linear/Log	Linear	Linear	--
Min	--	--	--
Max	--	--	--
# of Divisions	--	--	--

5 Grid: On

6 X Label:

7 Y1 Label:

7 Y2 Label:

7 Colors/Curve Labels

8 DC-Gain(Ratio)

9 Differential Gain

9 Overlay Form

10 F1-Help F4-Print F6-View F10-Execute Test ESC-Test Form

- 1 Mode: Select Graphics to graph (curve test only); List to list numeric data.
- 2 Graph Title: Type in desired graph title (50 characters maximum).
- 3 Scale: Select Auto to auto-scale axes maximum, minimum, and number of divisions. Select manual to manually set scaling (set parameters as below).
- 4 Axis: Type in parameters for X, Y1, and Y2 (optional) axis. Linear/Log and # of Div of Y2 are the same as those chosen for Y1.
 Array Name: Defines array to plot along selected axis.
 Linear/Log: Selects linear or base 10 log plotting.
 Min: Defines X, Y1, or Y2 axis minimum value (Manual scaling only).
 Max: Sets X, Y1, or Y2 axis maximum value (Manual scaling only).
 # of Div: Sets number of major divisions, 1-15 (Manual scaling only).
- 5 Grid: Select Grid On (Dotted grid lines) or Grid Off (tick marks on axis).
- 6 Labels: Type in desired labels for each axis (default labels are array names).
- 7 Colors/Curve Labels: Select to choose graph colors and step value labels (Figure 4-2).
- 8 DC-Gain: Select to calculate DC gain of user-defined arrays (Figure 4-3).
- 9 Differential Gain: Select to calculate small-signal gain (Figure 4-4).
- 10 Overlay Form: Choose to define filename and arrays to overlay data on existing graph (Figure 4-5).

Figure 4-1. DISPLAY PARAMETERS Screen (Graphics Mode)

Entering Parameters

You can control cursor movement around the screen by using the cursor keys. Use the up and down cursor keys to move the cursor among the various individual parameter selections, and use the left and right cursor keys or the Tab key to move from left to right for lines which have multiple selections.

Once the cursor is on the desired parameter, you can select that parameter by pressing the <Enter> key. The parameter will either become highlighted to show that it is selected, or (with some parameters), pressing <Enter> will toggle between parameter selections or display a pop-up menu. For example, placing the cursor on Mode and pressing <Enter> will toggle the display mode between Graphics and List. With others parameters, you must type in names or numeric values and then press <Enter> to complete the process. Examples of parameters which require numeric entry are the Min and Max parameters which are the minimum and maximum scaling parameters used when manually-scaling the X and Y axes. Keep in mind that engineering unit symbols are case sensitive. For example, "M" = mega, "m" = milli, "P" = peta and "p" = pico.

While entering these names or numeric value parameters, you can use the standard editing keys (left and right cursor, Backspace, Delete, Insert, Home, and End) to edit your entry, and you can use the <Esc> key to cancel a new entry and leave the parameter unchanged. After entering the parameter, press <Enter> to complete the entry process; pressing up or down cursor will also complete parameter entry and move the cursor to the next parameter. If entering an array name that doesn't exist, the pop-up array list will be displayed. From that list, you can select a valid array.

To blank an entry field, first position the cursor over the desired parameter, and press the <Space> key.

Selecting Pop-Up Menu Parameters

You can move among several parameters in pop-up menus in the same manner. For all pop-up windows that require two or more parameters, pressing the <Esc> key accepts all parameters in the window and closes the window.

Active Function Keys

The following functions keys are active while in the DISPLAY PARAMETERS screen:

F1-Help	Provides online help information.
F4 (Print)	Prints the screen to a defined printer.
F8-View	Displays graph of data, accesses graphical analysis tools.
F10-Execute Test	Executes test based on selected test parameters.
Esc-Test Form	Exits DISPLAY PARAMETER screen and returns to test form.

NOTE

The functions keys are not active while a pop-up menu is being displayed. You must first close the window by pressing <Esc> before using a function key.

4.3.2 Parameter Description

General Graphics Parameters

Mode Press the <Enter> key to toggle between two basic display modes: Graphics or List.

The Graphics mode is the default display mode for curve family tests, and it is used to display data in graphical form (the Graphics mode is not available for DC tests). You can display your graph by pressing F8 after editing display parameters (refer to paragraph 4.4 for details). The List mode allows you to list your data in numeric form on the screen. See paragraph 4.5. for complete details on using List.

Graph Title Selecting Graph Title will allow you to type in a string of up to 50 characters to title your graph. You can use the standard cursor and editing keys to edit your entry. Press <Enter> after typing in the desired characters to complete the entry process. The Graph Title will be displayed at the top of the graph.

Scale Press <Enter> to toggle between the two scale selections: Manual and Auto.

Choosing Manual scaling give you the flexibility of selecting the maximum and minimum values and the number of divisions for both the X and Y axes (see below). The Auto scale mode provides for optimum display of the graph based on measurement results.

NOTE

When Manual scaling is selected, a curve will be graphed on the screen after each sweep. With Auto, however, the graph will not be generated until all data is taken.

Axes Parameters

The parameters discussed below can be individually selected for the X and Y axes of the graph. You can specify parameters for two Y axes called Y1 and Y2. In most cases, you would use only the Y1 axis parameters, but some plots (for example, Gummel plots) require that the Y2 parameters be specified. The Y2 axis will be displayed only if you specify an array name in the Y2 column.

To select a parameter for a specific axis, be certain you are selecting the parameter in the appropriate column (X, Y1, or Y2). Place the cursor over the desired parameter, then press <Enter> to select it.

Only the array name and the minimum and maximum values can be selected for the Y2 axis. The Y2 linear/log status and number of divisions will be the same as those selected for the Y1 axis.

Array Name This parameter specifies the names of the X, Y1, and Y2 axis arrays to graph. The Array Name should be specified as a string of up to eight characters.

You can either type in the desired name directly, or simply press the <Enter> key to pop up a list of available array names (as when editing a test form). Use the cursor keys to select the Array Name, then press <Enter> to complete the selection.

Time arrays are created when measure arrays are named on the CURVE FAMILY TEST form. The time arrays are called SWPTIME, STEPTIME, SYNCTIME, B1TIME, B2TIME, and B3TIME for the respective channels. They are filled with elapsed time data during acquisition for channels with measure array names. They can be specified on the DISPLAY PARAMETERS form to view data versus time.

Up to 24 array names can be defined, but only eight will be displayed at a time. Use the up and down cursor keys to scroll among array names, or use Page Up and Page Down to select the three pages.

Linear/Log Use the <Enter> key to toggle between Linear and Log (base 10 Logarithmic) axis formats.

The Linear option is the default mode for the X, Y1 and Y2 axes. Note that you can select Linear for the X axis and Log for the Y1 axis (or vice versa), if desired. Note that the Y2 axis follows the selection for the Y1 axis.

NOTE

Negative or zero values cannot be graphed using the log axis. The absolute value of negative values will be used for the graph. For a zero value, a value that corresponds to the minimum resolution of the selected measurement function of the Source Measure Unit will be used for the graph.

Min Min is the minimum endpoint for the X, Y1, or Y2 axis. To enter Min, type in the desired numeric value in floating-point format, then press <Enter>. Note that Min can be programmed only when manual scaling is selected.

Max Max is the maximum endpoint for the X, Y1, or Y2 axis. Enter Max by typing in the desired number in floating point format and then pressing the <Enter> key. Max can be selected only if manual scaling is selected.

Notes:

1. When manually setting the axes of the graph, it is typical to select Min and Max values that will accommodate all expected data. Otherwise, data that falls outside the defined axes will not be displayed. Keep in mind that Min and Max axis values can be changed after a test is exe-

cuted. After modifying the Min and Max values, the new graph can then be displayed <F8>.

2. Maximum resolution for Min and Max values is five digits.
3. Min values must be less than Max values, otherwise an Invalid Scaling Parameters error will result.
4. Engineering unit symbols are case sensitive (i.e., "P" = peta, "p" = pico, "M" = mega, "m" = milli).

of Div

of Div defines the number of major divisions for each axis and is programmed as a positive integer. This option is not valid for an axis that is defined as having a log format specified. Note that the number of divisions can be defined only for manual scaling. The minimum value for # of Div is 1 and the maximum value is 15.

Additional Graphics Parameters

Grid

This option allows you to turn the grid on or off. Use the <Enter> key to toggle between Grid Off and Grid On (default is Grid On). Note that grid lines are dotted (not solid) lines. When the grid is turned off, tick marks will appear on the X and Y axes.

X Label/
Y1 Label/
Y2 Label

These options allow you to enter X axis and Y1 and Y2 axis label string up to a maximum of 30 characters. The entered string will be used to label the corresponding axis instead of the default label string, which is the array name chosen in the Axis parameters table (and assigned when you set up your test form).

If you change the array name after entering a label, the corresponding label will be automatically replaced with the new array name.

Colors/
Curve Labels

Selecting Colors/Curve Labels will open the pop-up menu shown in Figure 4-2.

You can select Axes, and Markers colors by placing the cursor over the desired selection and then pressing the <Enter> key to cycle through the various color selections. Press cursor down or cursor up after displaying your selection to move on to the next parameter.

The curve attributes can be individually selected for both Y1 and Y2 and include:

Multiple Colors (for more than one curve): If selected, multiple curves will be plotted in different colors, as selected by the software. Colors used for the background and axes will not be used for curves.

One Color: All curves will be plotted using one color. You can cycle through the available colors by using the <Enter> key.

Axis Labels: You can individually select the desired color for each label; press the <Enter> key to cycle through available colors.

Step Value Labels: Enabling this attribute will label one end of each curve on a multiple-curve graph. The graph will be labeled with values from the step array. For example, when plotting common-emitter characteristics, curves would typically be labeled with base current values.

Line Symbols: The Line Symbols attribute allows you to select the type of line used for the graph itself. Both solid and dashed lines are available, and they can be selected with the <Enter> key.

DISPLAY PARAMETERS

Mode: Graphics

Graph Title:
Scale: Auto

Axis

Array Name

Linear/Log

Min

Max

of Divisions

Grid: On
X Label:
Y1 Label:
Y2 Label:
Colors/Curve Labels
DC-Gain(Ratio)
Differential Gain
Overlay Form

Colors/Curve Labels

Axes: Brt White } 1

Markers: Yellow }

Curve Attributes	Y1	Y2
Multiple Colors	Yes	Yes
One color	Brt White	Brt White
Axis Labels	Brt White	Brt White
Step Value Labels	Yes	Yes
Line Symbols	Solid	Dashed

F1-Help F4-Print F8-View F10-Execute Test ESC-Test Form

- 1 Axes and Markers Colors: Use Enter key to cycle through available colors for axes and markers.
- 2 Color Attributes: Use Enter to choose multiple colors or one color parameters and axis label colors.
- 3 Step Value Labels: Select Yes to turn on curve step value labeling (curves will be labeled with values from step array).
- 4 Line Symbols: Use enter key to choose desired line type: solid or dashed

NOTE: Press <Esc> to accept displayed parameters and close window.

Figure 4-2. Colors/Curve Labels Window

DC-Gain

As the name implies, DC-Gain provides calculation of DC Gain. You can use this feature to calculate the beta of a bipolar transistor or to display the ratio between any two variables (DC tests) or variable arrays (curve tests). The results of the DC gain computation will be appended to the list of variables on the DISPLAY PARAMETERS screen. You can then graph or list the results as you would any other array or variable. The arrays of the calculated values for CURVE FAMILY test can be displayed on the graph or listed on the List Display if you select it for the display.

The entire formula may be modified. Any name may be substituted for beta, the numerator or the denominator. The system sees the equation as follows:

$$\text{NAME} = (\text{ARRAY1} / \text{ARRAY2}) * \#$$

where name is your choice of a legal name, ARRAY1 and ARRAY2 are any arrays you choose, and # can be any value from $-1e32$ to $1e32$.

This equation will allow you to perform flexible, general computations.

When displaying a graph, moving Marker 1 provides a readout of calculated values at the top of the screen. The calculated values for DC test can be listed on the Data points List Display. See paragraph 4.5 for listing details.

To use this feature, position the cursor over DC-Gain, then press <Enter>. The window shown in Figure 4-3 will then pop up on the screen.

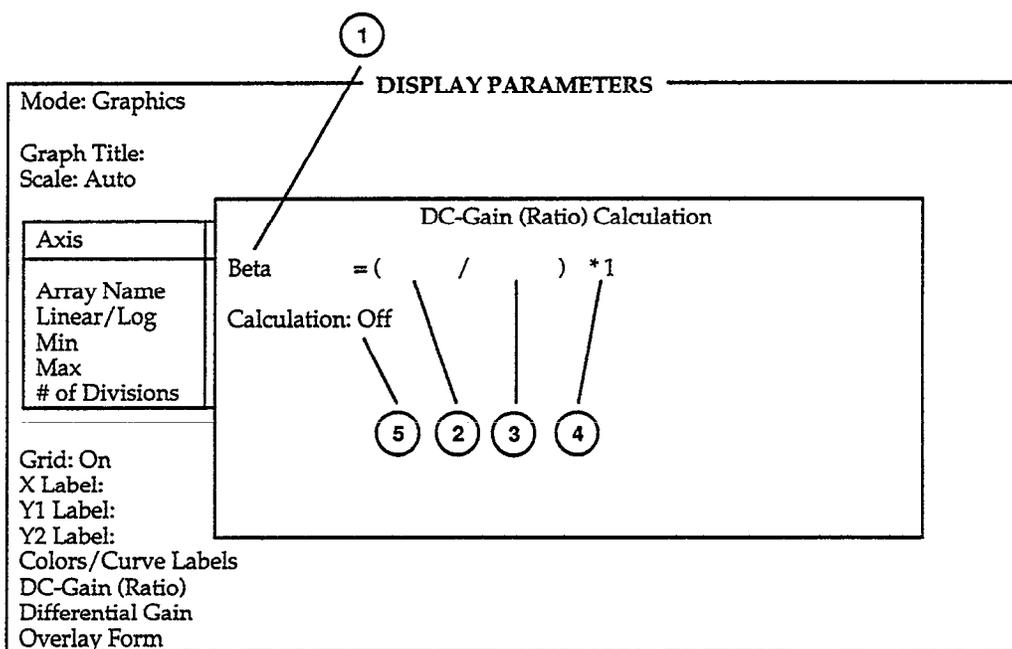
The DC gain is actually the ratio between two user-defined variables or arrays. You can change the word "Beta" to any desired name of eight characters or less by selecting the "Beta" field (position the cursor, then press <Enter>).

You can enter the array or variable names by typing them in, or by pressing the <Enter> key after positioning the cursor over the desired variable field. A list of available variable or array names will then pop up on the screen. Use the cursor keys to select the desired variable name, then press the <Enter> key.

After entering the array or variable names, enable the calculation by selecting "Calculation: On", and execute the test to acquire DC gain data. Whenever the calculation is changed, be sure to re-execute the test to update the DC gain data.

NOTE

Any calculation with zero in the denominator results in a reading of $1e32$.



- ① DC Gain Array Name: Defines DC gain array name to plot or list. Default is Beta, but name can be changed, if desired (Four characters maximum).
- ② Numerator: Select desired numerator array for DC gain calculation (either type in name or press Enter to view available array names).
- ③ Denominator: Select denominator array for calculation (type in name or press Enter to view names).
- ④ Multiplier: Equation may incorporate any value within the range from zero to 1e32.
- ⑤ Calculation: Select On to enable calculation, Off to disable calculation. When enabled, DC gain array will be available for listing and graphing, and DC gain value will appear at top of graphics screen.

NOTE: Press <Esc> to accept displayed parameters and close window.

Figure 4-3. DC Gain Window

Differential Gain

The differential gain parameter allows you to calculate the small signal gain for a device. The default name is gm (transconductor) for FETs but can be changed to a different name. You can differentiate Along Curves or differentiate Between Curves.

You can enter this selection by positioning the cursor over Differential Gain, and pressing <Enter>. The pop-up window shown in Figure 4-4 will appear on the screen.

Parameter entry is similar to that discussed for DC-Gain above. The displayed differential gain name (gm) can be changed to a new name up to eight characters long. The new name will be added to the pop-up array list when the test is executed. The numerator and denominator array names used for the calculation can be typed in or selected from the pop-up array list. The pop-up array list is displayed by pressing <Enter> while the cursor is positioned over the desired variable field.

Alternate differentiation type (Between Curves or Along Curves) is selected by placing the cursor over the Differentiate field and pressing <Enter>. The display will toggle to the alternate selection. Like DC-gain, Differential Gain is enabled by selecting "Calculation: On". Note that the test must be executed to acquire differential gain data. Any time the calculation is changed, be sure to re-execute the test to update the differential gain data.

Most arrays are valid for differentiation calculations. The exceptions are as follows.

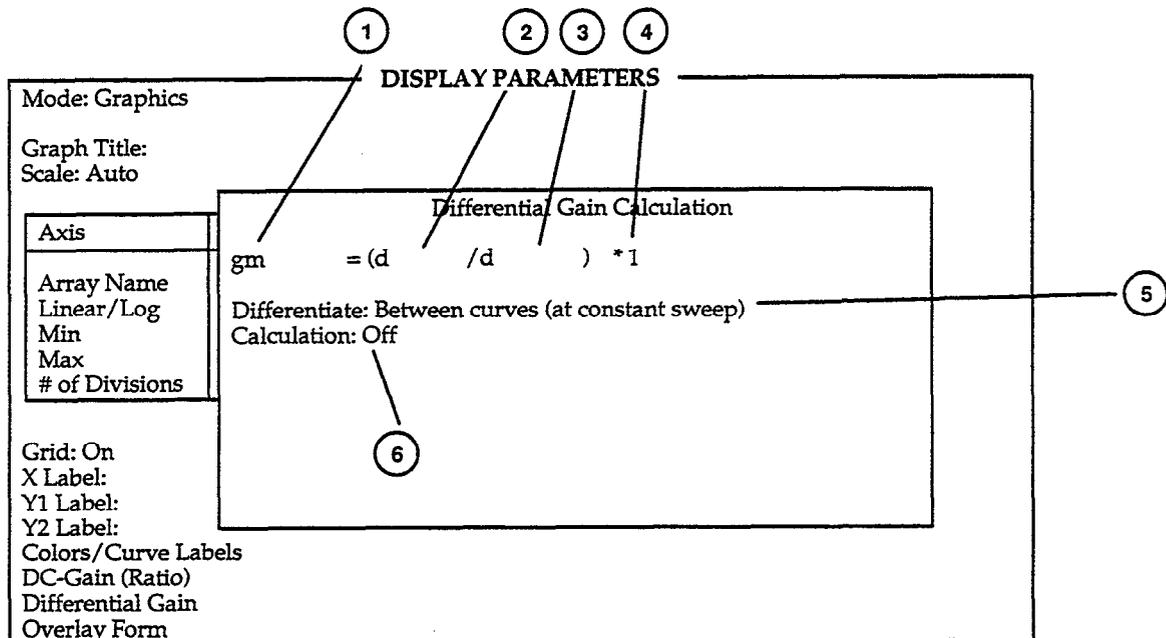
Differentiate Between Curves — you cannot use a SWEEP_SOURCE array or BIAS_SOURCE array in the calculation.

Differentiate Along Curves — You cannot use a STEP_SOURCE array or BIAS_SOURCE array in the calculation.

The following example shows how gm (along curves) is calculated if the array names are Id (STEP_MEASURE array) and Vgs (SWEEP_SOURCE array):

$$gm = (d(Id)/d(Vgs)) *1$$

If an invalid calculation is entered an error message will appear and you will not be able to exit (<Esc>) from the "Differential Gain Calculation" mode. Either enter a valid calculation or disable the calculation (Calculation: Off).



- ① Differential Gain Array Name: Defines differential gain array to plot or list. Default is gm, but name can be changed, if desired (for characters maximum).
- ② Numerator: Select desired numerator array for gm calculation (either type in name or press Enter to view available names).
- ③ Denominator: Select denominator array for calculation (type in name or press Enter to view names).
- ④ Multiplier: Equation may incorporate any value within the range from $-1e32$ to $1e32$.
- ⑤ Differentiate: Select differentiation type; Between Curves or Along Curves.

Calculation: Select On to enable calculation, Off to disable calculation. When enabled, differential gain array will be available for listing and plotting, and DC gain value will appear at top of graphics screen.

NOTE: Press <Esc> to accept displayed parameters and close window.

Figure 4-4. Differential Gain Menu

After acquiring differential gain data, use Marker 1 (on the Graphics Display Screen) to provide a readout of the calculated gm gain values. The readout is located at the top right-hand side of the screen. The gain data can be graphed by entering the array name in the "DISPLAY PARAMETERS" graphics screen then viewing it (F8).

You can also list the calculated array as discussed in paragraph 4.5.

Notes:

1. For best accuracy when calculating gain between curves, you should program the step source for as small a value as possible if using the step source array in the equation.
2. A graph must contain at least three curves in order to calculate differential gain between curves.
3. Any calculation with zero in the denominator results in a reading of 1e32.

Overlay Form

Overlay Form allows you to compare sets of data by overlaying their plots on the same graph. The data currently residing in memory can be compared with similar data in disk files that you specify. For example, you may wish to compare the common-source curves for two similar transistors to note similarities among various samples of the same type or compare a curve to high and low limit curves previously acquired, or compare a curve to theoretical data imported from spreadsheet.

To use this feature, place the cursor over the Overlay Form and then press <Enter>. The Overlay Data window shown in Figure 4-5 will appear on the screen and the cursor will be located on the first Data File field. Notice that the path names are automatically included in the data file fields. To enter a data file name, first press <Enter> to position the cursor after the path name and then type in the name of the data file (be sure to include the .DAT extension). With the complete path and data file name displayed, again press <Enter>. Enter the X and Y array names to overlay by typing in each desired array name and pressing <Enter>. Repeat the process for the second overlay data set, if desired.

Once you have selected your overlay data, you can display the complete graph, including the overlay data by using the Overlay tool available from the graphical analysis screen (see paragraph 4.4). Note that if an invalid data file or array name is entered in the overlay form, nothing will happen when the overlay tool is used.

In order to distinguish between the main and overlay data on the graphs, the overlay data uses different line types. A long dashed line will be used for the first data set, and a shorter dashed line will be used for the second data set.

Selecting Horizontal Zoom, Vertical Zoom, Restore, Autoscale, Filter, X-Invert or Y-Invert will remove the overlaid graph(s) from the display.

DISPLAY PARAMETERS

Mode: Graphics

Graph Title:

Sc

Overlay Data

Data File: C:\MODEL251\DATA\ _____

X Array: _____

Y Array: _____

Data File: C:\MODEL251\DATA\ _____

X Array: _____

Y Array: _____

Gr

X

Y1 Label:

Y2 Label:

Colors/Curve Labels

DC-Gain(Ratio)

Differential Gain

Overlay Form

F1-Help F4-Print F8-View F10-Execute Test ESC-Test Form

- ① Data File: Type in desired data filename for overlay curve 1 (be sure to use .DAT extension).
 - ② X Array Name: Type in X array name for overlay #1.
 - ③ Y Array Name: Enter Y array name for overlay #1.
 - ④ — ⑥ Parameters for second overlay are similar to the first using a different data file.
- NOTE: Press <Esc> to accept displayed parameters and close window.

Figure 4-5. Overlay Form Menu

However, after selecting one of these options, Overlay can again be selected. The overlaid graph, like the original graph, will be affected by the selected option. For example, if the original graph is inverted, the overlay graph(s) will also be inverted when Overlay is selected. An exception to this is the Filter option. The original graph will be filtered but the subsequent overlay graph(s) will not.

A displayed graph that includes the overlay(s) can be printed (F4). However, the overlay(s) will not be included in a plot (F3) of the graph.

A test configuration that includes a defined overlay can be saved as a data file. When this file is later loaded, the Overlay option will automatically be functional.

Graphing Area

The graphing area takes up the major portion of the screen and allows graphing using standard X-Y coordinates. The date and time appears at the lower lefthand portion of the screen. If defined, the graph title will appear at the top. The X and Y axes will be labeled either with array names (and appropriate units), or with different labels chosen with the DISPLAY PARAMETERS screen. The Y1 axis will be labeled at the left side of the graph, and the Y2 axis (if used) will appear on the right side of the graph. The resolution of the step source curve labels is two digits.

Graphics Analysis Tools

The graphics analysis tools displayed on the screen allow you to manipulate the graphed data and see the results on the display immediately.

Briefly, these tools perform the following functions:

Markers	Places two markers on the screen. Marker axis coordinates appear at the top of the screen.
Line	Connects a line between the two markers at the curve intercepting points. For linear scales, line slope and axis intercepts are displayed at the top of the screen. For log scale formats, the line equation and its parameters are instead displayed.
Horiz. zoom	Allows you to horizontally zoom in on (enlarge) a desired portion of the graph.
Vertical zoom	Allows you to zoom in vertically on desired curves.
Restore	Cancel all other analysis tools except Filter and restores original graph.
Autoscale	Automatically scales the graph to conform with test data.
Filter	Filters curve data to reduce noise.
Overlay	Overlays one or two sets of curve data on the graph for comparison.
X-Invert	Inverts X axis.
Y-Invert	Inverts Y axis.

Selecting Graphical Analysis Tools

You can select the graphical analysis tools in one of two ways:

1. Press the highlighted letter for the tool you wish to choose. For example, press the M key to activate markers.
2. Use the up and down cursor keys to place the highlighted cursor over the menu selection, then press <Enter>. For example, to invert the X axis, highlight X-Invert, then press the <Enter> key.

Marker Keys Area

The Marker Keys area summarizes the keys that control marker operation. Briefly, these keys are:

Home	Selects Marker 1.
------	-------------------

End	Selects Marker 2.
+ or -	Increments/decrements marker step index.
Page Up/ Page Down	Selects individual curve on family of curves.
Tab	Selects Y1 or Y2 axis curve(s) for marker.

Data Display Area

Three lines at the top of the screen will display data associated with some of the tools including, X and Y marker position, line X and Y intercept, and slope and 1/slope. Note that data will be displayed in these areas only after the associated tool has been activated.

In addition, beta and gm values will be displayed in the data area at the top of the screen when these calculation features have been turned on using the corresponding parameters on the DISPLAY PARAMETERS screen.

Active Function Keys

The following function keys are active while the Graphics Display screen is activated:

F1-Help	Provides on-screen operational information.
F3 (Plot)	Plots the screen graph on a defined plotter.
F4 (Print)	Allows you to print the screen on a defined printer.
F7-Disp. Par.	Displays the DISPLAY PARAMETERS screen, which allows you to control various graphics parameters (paragraph 4.3).
F10-Exec/Stop	Starts and stops test execution.
Esc-Test Form	Exits the graphics screen and returns to the test form screen.

4.4.2 Analysis Tool Description

The following paragraphs discuss each of the analysis tools in detail.

Markers	The Markers tool allows you to place two markers on the graph. The left marker is Marker 1, and the right marker is Marker 2. These markers can be moved among data points on the screen. You can toggle markers on or off either by pressing the M key, or by positioning the cursor over Markers and pressing the <Enter> key.
---------	--

Figure 4-7 shows an example plot with markers activated.

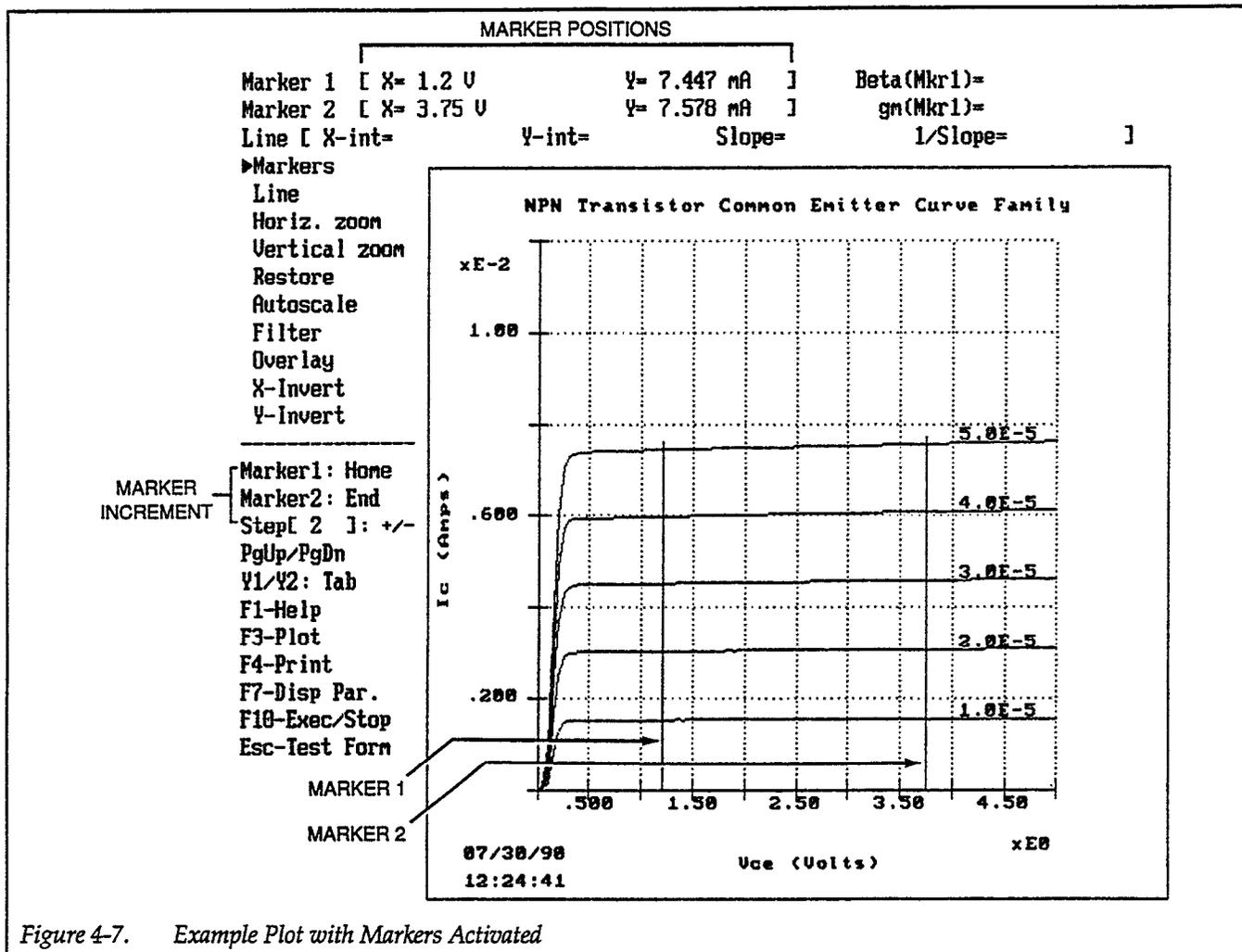


Figure 4-7. Example Plot with Markers Activated

Controlling Markers

The following keys affect marker operation:

Left cursor	Moves the selected marker to the left.
Right cursor	Moves the selected marker to the right.
+	Increments marker step index.
-	Decrements marker step index.
Home	Selects left marker as active marker.
End	Selects right marker as active marker.
Page Up	Moves markers up to next curve.
Page Down	Moves markers down to previous curve.
Tab	Selects Y1 or Y2 curve.

Marker Step Index (Step []: +/-)

The marker step index is the number of data points that the marker will move each time you press the left or right cursor key. You can control its

value by pressing + or -. Press + to increase the marker step index value, and press - to decrease it.

Marker Selection

Use the Home and End keys to select the active marker (the marker affected by other marker control keys). Press Home to select Marker 1, and press End to activate Marker 2.

Curve Selection

With multiple-curve graphs, you can place the markers on the desired curve with Page Up and Page Down. Pressing Page Up moves the markers up one curve per key press, and pressing Page Down moves the markers down, also one curve per key press.

Y1 and Y2 Axis Selection

If you are using both Y1 and Y2 axes, you can place the markers on the curve(s) for the desired axis by pressing the Tab key. Pressing Tab alternates markers between Y1 and Y2.

Marker Position Display

The current X and Y positions of both Marker 1 and Marker 2 will be displayed in the corresponding fields at the top of the screen. These values will be displayed only if markers were activated

Beta and Gm Display Values

The calculated values of Beta and gm will be displayed only if they had been specified using the DC Gain or Differential Gain parameters on the DISPLAY PARAMETERS screen. The values for beta and gm on the graphics display screen are determined by the Marker 1 position.

Initial Marker Positions

When markers are selected, they will be positioned on the first curve. If the markers are switched off, and then back on, they will be displayed at the last position at which they had been switched off.

Turning Markers Off

To turn the markers off, either press the M key, or position the cursor over Markers, then press the <Enter> key. Markers can also be turned off by using Restore, but marker positions will be lost if the markers are turned off with Restore.

Line

The Line tool connects the two markers with a straight line. This feature allows you to measure slopes of plotted curves and their intercepts with the X and Y axes. The slope and intercept values will be displayed in the Line section of the data display area at the top of the screen. The slope and intercept values will be displayed only after the Line tool has been selected. Figure 4-8 shows an example plot with the Line feature activated.

In order to use the Line tool first enable markers by pressing M, then set the markers to the desired positions. Enable the Line tool either by pressing L, or by positioning the cursor over Line and then pressing <Enter>. You can reposition the line by moving the markers, if desired.

Log Scale

If Line is enabled with a Log scale selected, the appropriate line equation is displayed along with its calculated parameters (X-int, Y-int, A and m). The following table provides the line equations for the three possible log scale combinations. Note that logarithms used in the following equations and calculations are natural (ln).

Axis		Line Equation
X	Y	
Linear	Log	$Y=Ae^{mx}$
Log	Linear	$Y=A\ln x+m$
Log	Log	$Y=Ax^m$

The following calculations show how the parameters for the three line equations are determined. For all calculations. . .

X1, Y1 are the coordinates of the first point of the line
X2, Y2 are the coordinates of the second point of the line

$Y=Ae^{mx}$ (X lin, Y log format):

$$Y\text{-int} = e^{((X2 \cdot \ln Y1 - X1 \cdot \ln Y2) / (X2 - X1))}$$

Y-int represents a value of the line intercept with the Y-axis (X=0)

$$A = Y\text{-int}$$

$$m = (\ln Y2 - \ln Y1) / (X2 - X1)$$

$$X\text{-int} = e^{(-m/A)}$$

X-int represents a value of the line intercept with the X-axis
(ln Y=0, or Y=1)

$Y=A\ln x+m$ (X log, Y lin format):

$$a = (Y2 - Y1) / (\ln X2 - \ln X1)$$

$$m = ((Y1 \cdot \ln X2) - (Y2 \cdot \ln X1)) / (\ln X2 - \ln X1)$$

$$Y\text{-int} = m$$

Y-int represents a value of the line intercept with the Y-axis
(ln X=0, or X=1)

$$X\text{-int} = e^{(-m/A)}$$

X-int represents a value of the line intercept with the X-axis
(Y=0)

$Y = Ax^m$ (X log, Y log format):

$Y\text{-int} = e^b$ where; $b = ((\ln Y1 * \ln X2) - (\ln Y2 * \ln X1)) / (\ln X2 - \ln X1)$

Y-int represents a value of the Line intercept with the Y-axis
($\ln X = 0$, or $X = 1$)

$A = Y\text{-int}$

$m = (\ln Y2 - \ln Y1) / (\ln X2 - \ln X1)$

$X\text{-int} = A^{(-1/m)}$

X-int represents a value of the Line intercept with the X-axis
($\ln Y = 0$, or $Y = 1$)

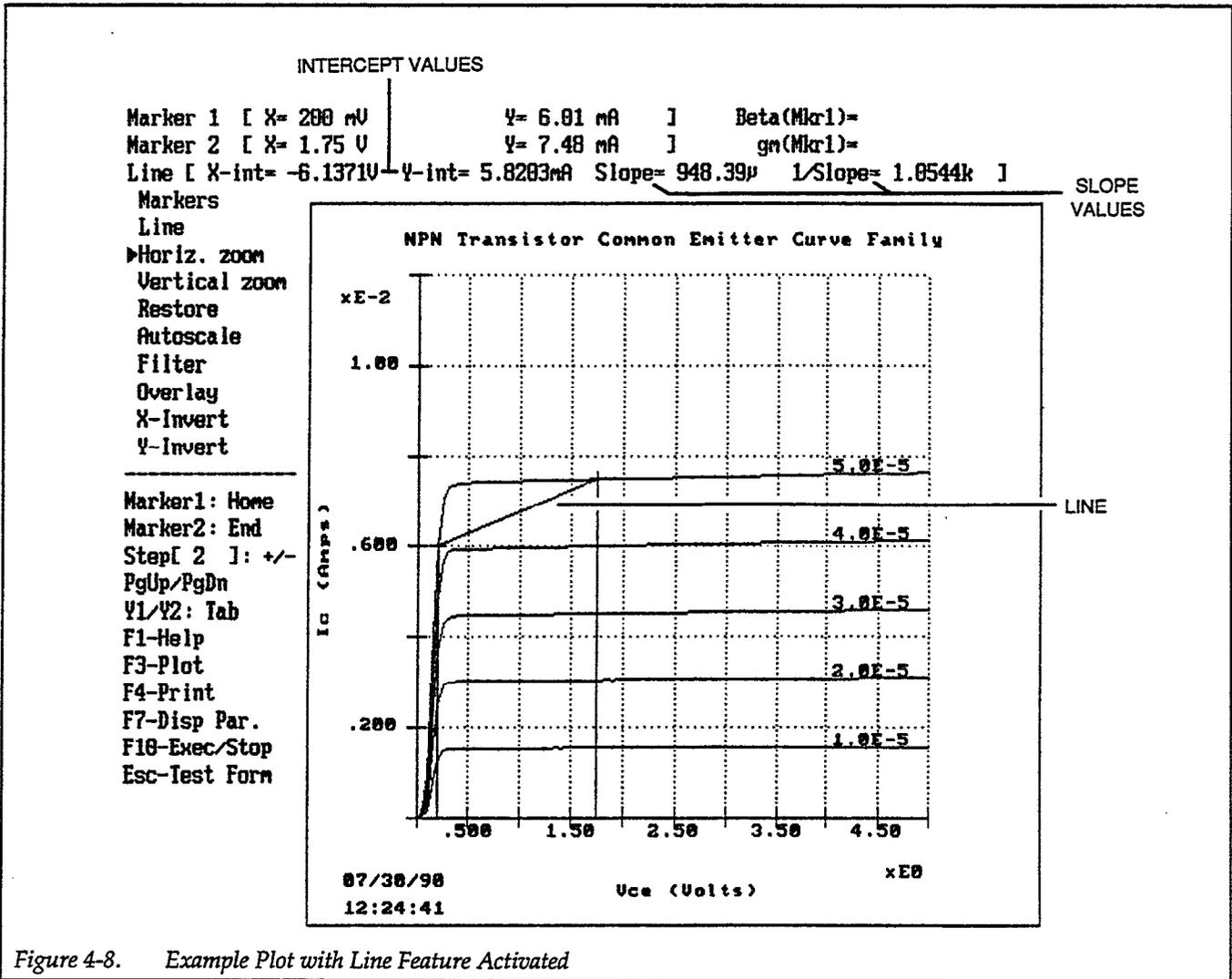


Figure 4-8. Example Plot with Line Feature Activated

Horiz. zoom The Horiz. zoom tool allows you to zoom in on a desired portion of the graph horizontally. You can use this feature with both single-curve and multiple-curve graphs.

In order to use Horiz. zoom, first activate markers, then position Marker 1 and Marker 2 to indicate the horizontal portion of the graph to be enlarged. Activate zoom either by pressing H, or by positioning the cursor over Horiz. zoom and pressing <Enter>. The selected portion will then be expanded to fill the display area horizontally.

Both markers will still be active and can be controlled with the left and right cursor keys as usual. You can reposition the markers and then repeat the zoom operation, if desired. Horiz. zoom can be repeated until fewer than two data points will be displayed on the screen, and it can be canceled by using Restore discussed below.

Horiz. zoom can be used with the Vertical zoom tool (discussed below) to enlarge only one or two curves on a multiple-curve graph.

Figure 4-9 shows an example of multiple-curve zoom operation.

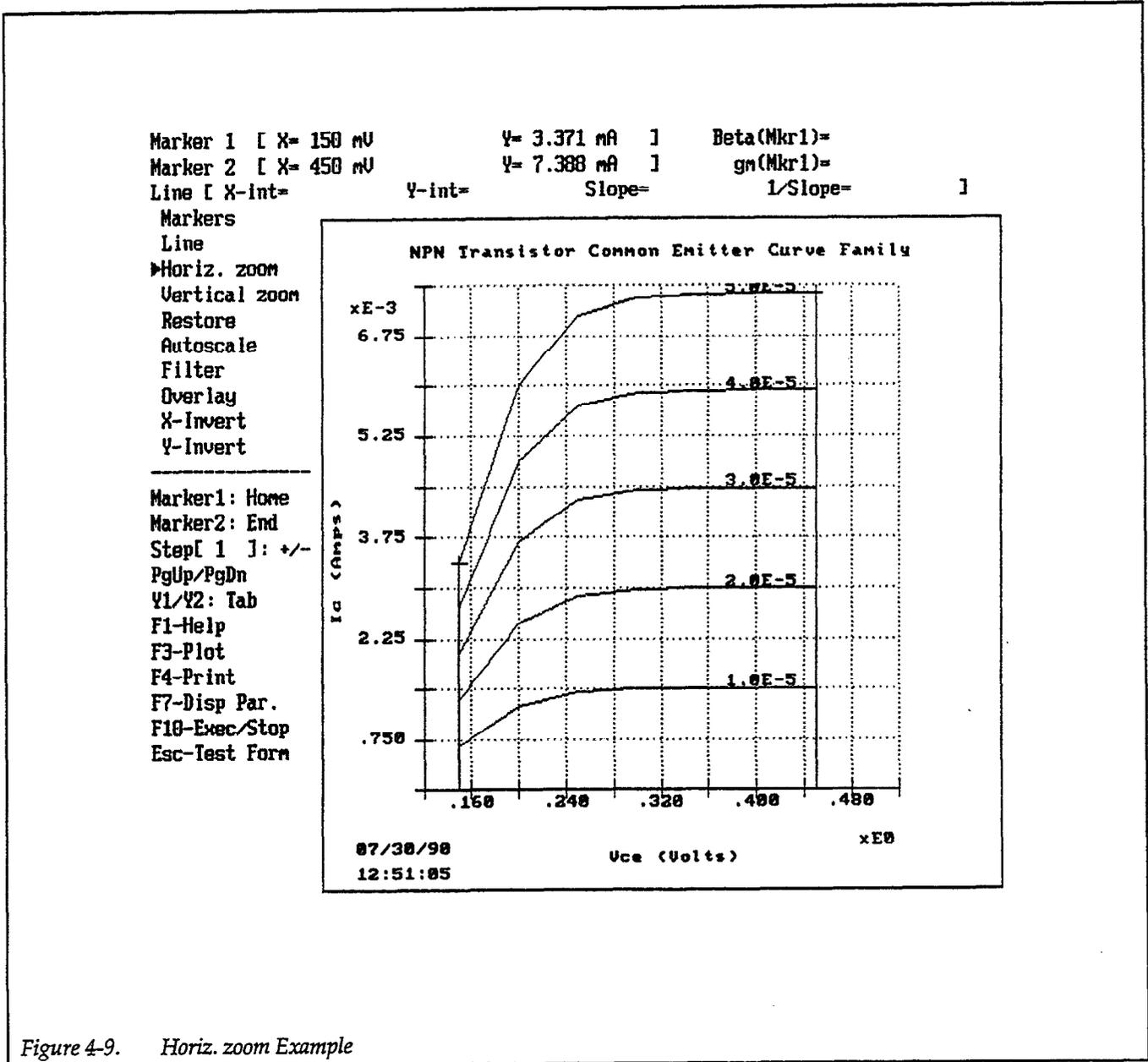
Vertical zoom Just as Horiz. zoom allows you to expand the graph horizontally, Vertical zoom allows you to enlarge a vertical section of the graph. This feature is useful for selecting one or more curves of a multiple-curve graph for display.

To use Vertical zoom, first enable markers, then press V (or highlight Vertical zoom, then press <Enter>). Use Page Up or Page Down to place the markers on the curve which will act as the upper or lower boundary of the vertical cross section, then press <Enter> (or press <Esc> to cancel the operation). Use Page Up or Page Down again to select the curve to be the lower or upper boundary, then press <Enter> (or <Esc> to cancel). The graph will be expanded vertically using the selected curves as the upper and lower boundaries.

Use Restore to return the graph to normal.

Restore Restore cancels all other analysis tools except Filter and returns the graph to normal. Canceled tools include: Markers, Line, Horiz. zoom, Vertical zoom, Autoscale, and X-Invert and Y-Invert. Note that Restore also cancels the current marker positions.

To use Restore, either press R, or place the cursor over Restore, then press <Enter>.



Autoscale

Autoscale rescales the graph, providing optimum display of measurement results based on the existing test data in memory. To use this feature, either press the A key, or place the cursor over Autoscale, then press <Enter>.

To cancel automatic scaling, select Restore. Graph scaling will revert to the Min and Max values set in the DISPLAY PARAMETERS screen.

NOTE

If Scale: Auto is selected on the DISPLAY PARAMETERS screen, the Autoscale tool will have no effect since the

graph will already be automatically scaled. Also, you cannot disable autoscale with Restore if Scale: Auto is selected.

Filter

The Filter tool allows you to enter a number of points to filter and redraw the graph using smoothed data. This feature is useful for minimizing any noise that might be present in your measurement data.

NOTE

Using FILTER will overwrite original data in memory. If you wish to save your old data, save it as a data file before selecting Filter. Also, you can save the filtered data, if desired use the Save Data selection in the FILE OPERATIONS menu.

To enable filtering, either press F, or place the cursor over Filter, then press <Enter>. A prompt, asking you to type in the number of points to filter, will appear on the screen. Type in the number of points to filter (within the displayed limits), then press the <Enter> key.

The number of points filtered represents the period length of the signal to filter out. All frequencies with periods shorter than the selected number of filter points will be eliminated. The cutoff frequency of the filter is simply the reciprocal of the number of points filtered. The default number of points to filter is 4, which corresponds to a cutoff frequency of 0.25.

The allowable range for filtering is 2-30 points; however, the maximum number of points is restricted by the number of points in the measurement. The maximum number of points for a given measurement sweep is equal to $n/2$, where n represents the number of points in the measurement. For example, if your data has 50 points per curve, the maximum number of filter points is: $50/2 = 25$. You will not be able to choose a filter value outside the displayed allowable range.

If Filter is enabled, all curves in a family of curves will be smoothed using the selected filter parameters.

Filter cannot be disabled by using Restore. To restore your original data, you must reload it from an existing data file.

Overlay

The Overlay tool allows you to overlay one or two sets of similar curves on a set of existing curves, thus allowing you to compare the characteristics of up to three similar devices. Figure 4-10 shows a typical overlay example.

In order to use Overlay, first type in the file and array names to overlay using the Overlay Form window on the DISPLAY PARAMETERS screen. Note that the complete path must be used when typing in file names (i.e.

C:\MODEL251\DATA\FILENAME.DAT). Display the first graph by pressing F8, then press O (or highlight Overlay then press <Enter>) to overlay the overlay graph(s) on the first. The overlay curves will be made up of long dotted lines for the first curve(s) and short dotted lines for the second curve(s), if defined.

Use Restore to return to normal graph operation after using the overlay tool.

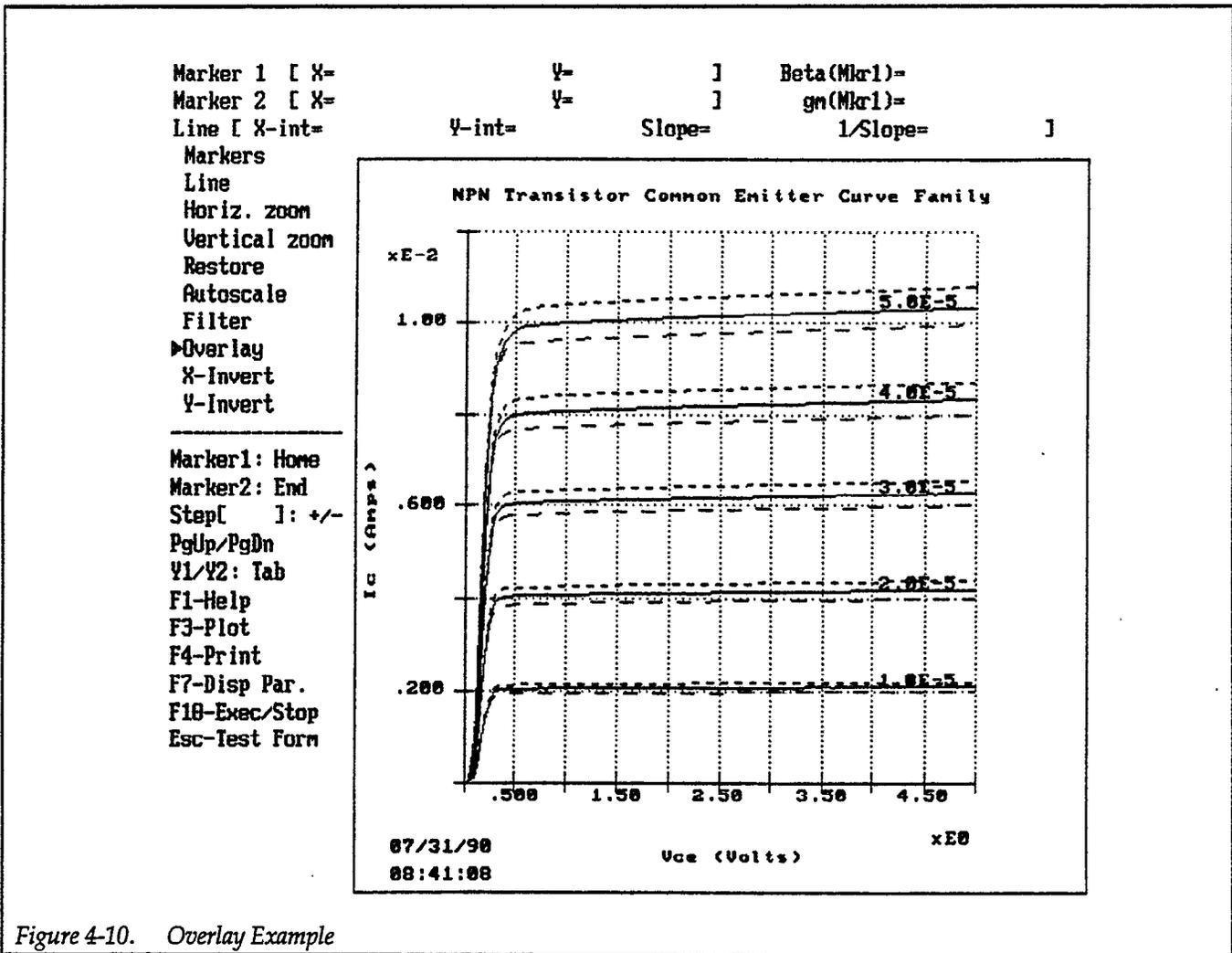


Figure 4-10. Overlay Example

X-Invert

The X-Invert option allows you to invert the X axis end-to-end. To use this feature, either press X, or position the cursor over X-Invert, then press <Enter>.

To return the graph to normal (not inverted status), select X-Invert a second time (or use Restore).

Y-Invert

Y-Invert allows you to invert the Y axis end to end. Either press Y, or select Y-Invert, then press <Enter> to activate this feature. Select Y-Invert a second time to return the graph to normal display.

Y-Invert and X-Invert can be used together to display third-quadrant curves in the first quadrant. For example, this feature will allow you to display PNP transistor curves, which actually occur in the third quadrant, to be displayed in the first quadrant, resulting in the expected plot appearance. Figure 4-11 shows a comparison for inverted and noninverted curves. Figure 4-11(A) shows a set of PNP curves without inversion, and Figure 4-11(B) shows the same curves with both the X and Y axes inverted. Note that log scales cannot be inverted.

4.5 LIST DATA

The List Data option allows you to display your data as columns of numeric values. Variables from both DC and curve family tests can be listed using this feature. The following paragraphs discuss entering the list mode as well as procedures for listing both DC and curve data.

4.5.1 Listing Curve Data

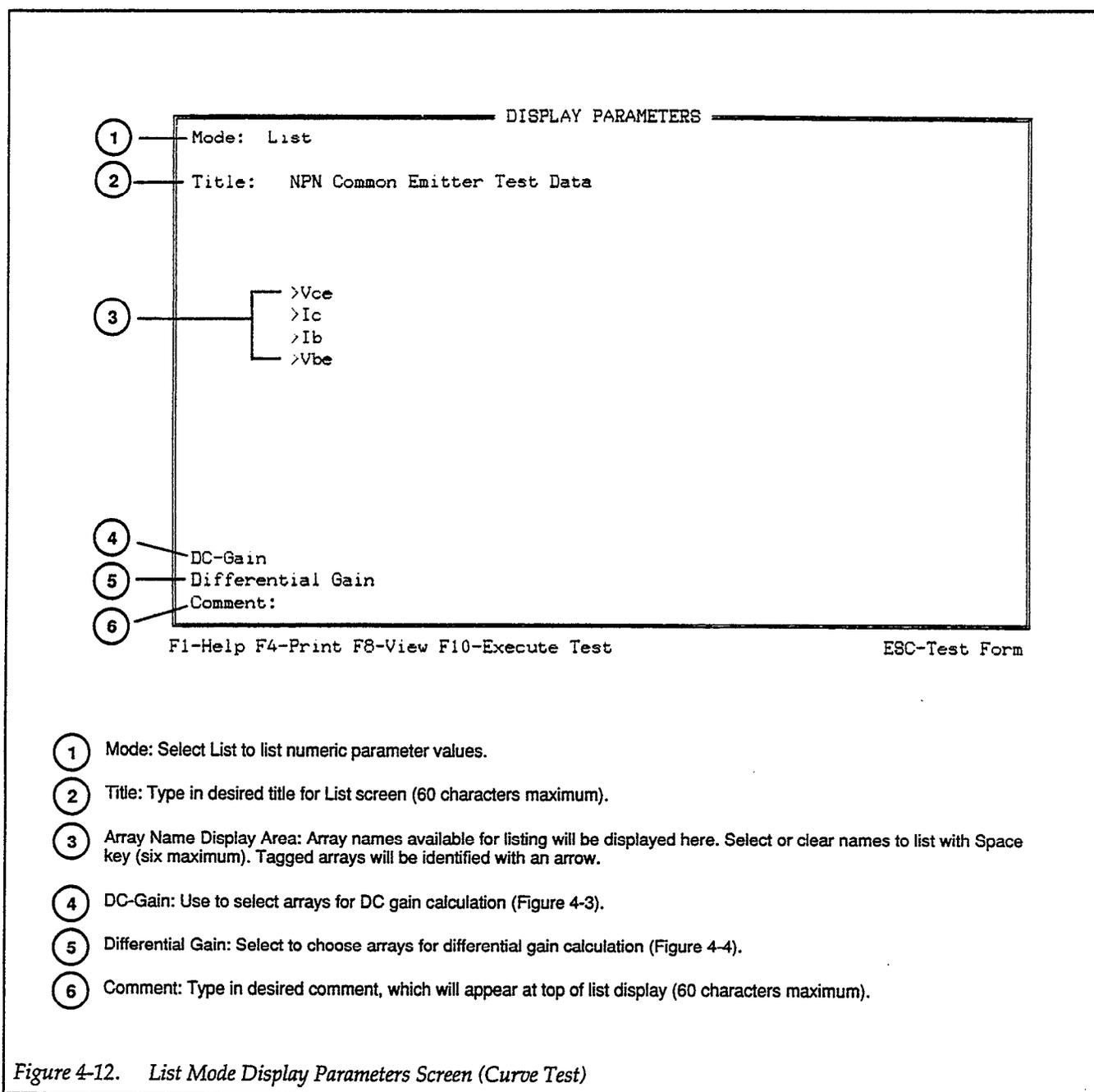
Selecting List Array Names

To enter the list mode, first make sure that a curve test data file is loaded into memory, then press the F7 key to bring up the DISPLAY PARAMETERS screen. Place the cursor over Mode:, then press the <Enter> key to change the displayed parameter to Mode: List. The DISPLAY PARAMETERS screen (list mode) shown in Figure 4-12 will appear on the display.

Screen parameters include:

- | | |
|-------------------|--|
| Mode: List | The Model 251 software must display Mode: List in order to list parameters. Use the <Enter> key to toggle between Graphics and List. |
| Title: | You can type in a title for your data list using this selection (60 characters maximum). In order to do so, place the cursor over this parameter, then press <Enter>. Type in the desired title, then press <Enter>. Press <Enter> again after you have typed in the title. |
| Array Name Area | Available array names are displayed in the area immediately below the title line. Choose arrays to list by placing the highlighted cursor over the array name and pressing the <Space> key. Selected names will be indicated by an arrow (>). You can clear a name by pressing <Space> with the cursor located over a selected array name.

You can choose up to six array names for simultaneous list display. If you select more than six names, a warning message will be displayed. Select multiple array names with the <Space> Bar; selected arrays will remain indicated by arrows (>). |
| DC-Gain | Selecting DC-Gain will allow you to select two array names to calculate beta or other user-defined ratio. The calculated gain array will then be added to the list of arrays that can be listed. You can then select the calculated gain array for listing as described above. Paragraph 4.3.2 covers DC gain parameters in detail. |
| Differential Gain | Selecting Differential Gain allows you to calculate the small signal gain of a device. The calculated array will be added to the list of array names. You can then choose to list the calculated gain array as outlined above. See paragraph 4.3.2 for details on differential gain. |
| Comment: | Comment allows you to type in a string of up to 60 characters containing additional information about the test or graph. The comment string will appear in the data list area. |



Curve Data Listing

Once you have selected the arrays to list, press the F8 key to display the data list on the screen. Figure 4-13 shows the overall format of the CURVE LIST DISPLAY. The title and comment appears at the top of the screen, while the array names are listed at the top of each data column. The first column lists the index, which is the number of the individual data point or step for each curve, and the second column lists the curve number for multiple-curve tests. The corresponding data points are listed under the appropriate array names with units. Note that up to six columns of array data can be listed.

You can scroll through individual rows of data by using the up and down cursor keys. Use Page Up and Page Down to select other pages of data, if available. Use Home to return to the beginning, and use End to go to the end.

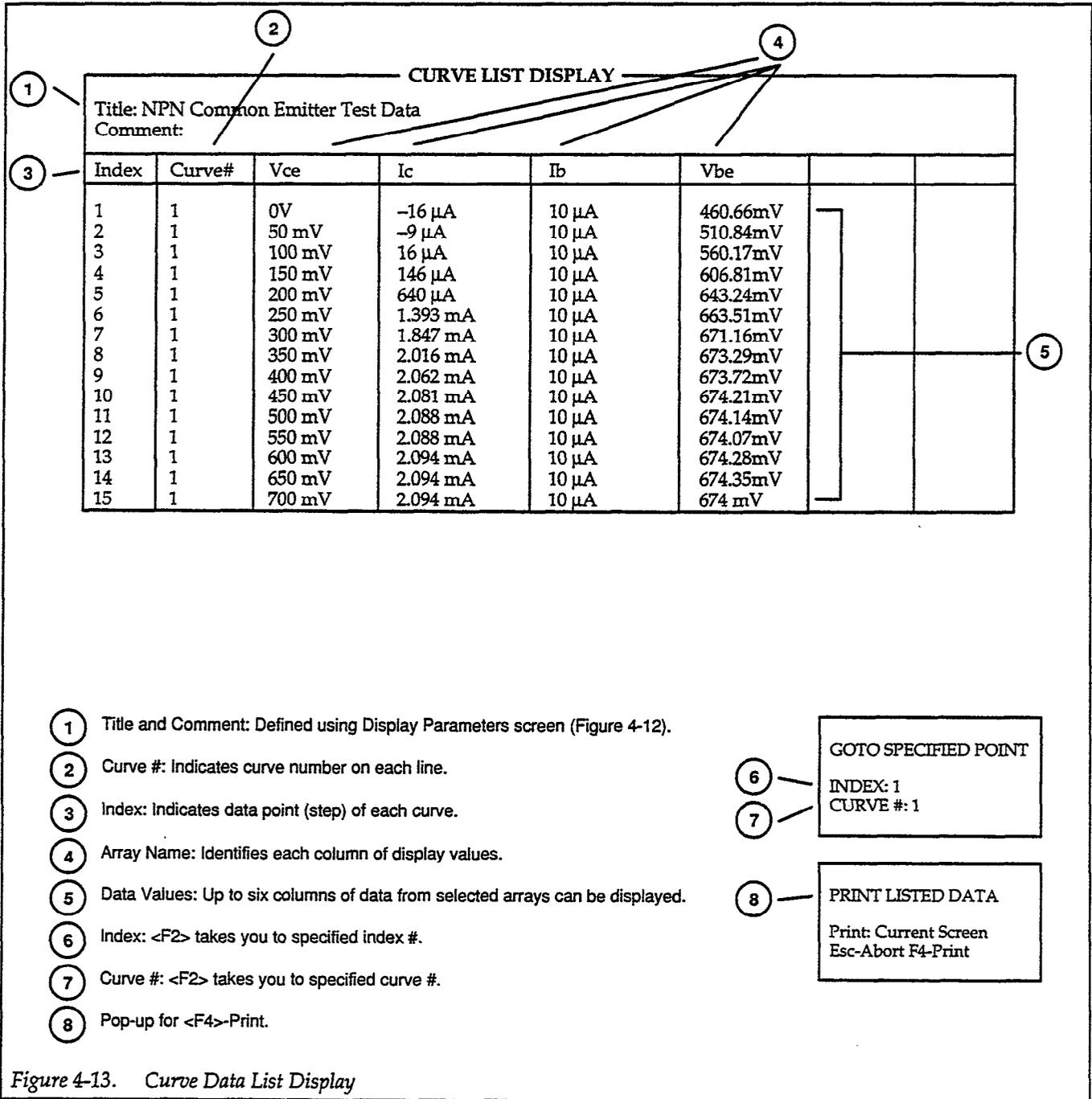
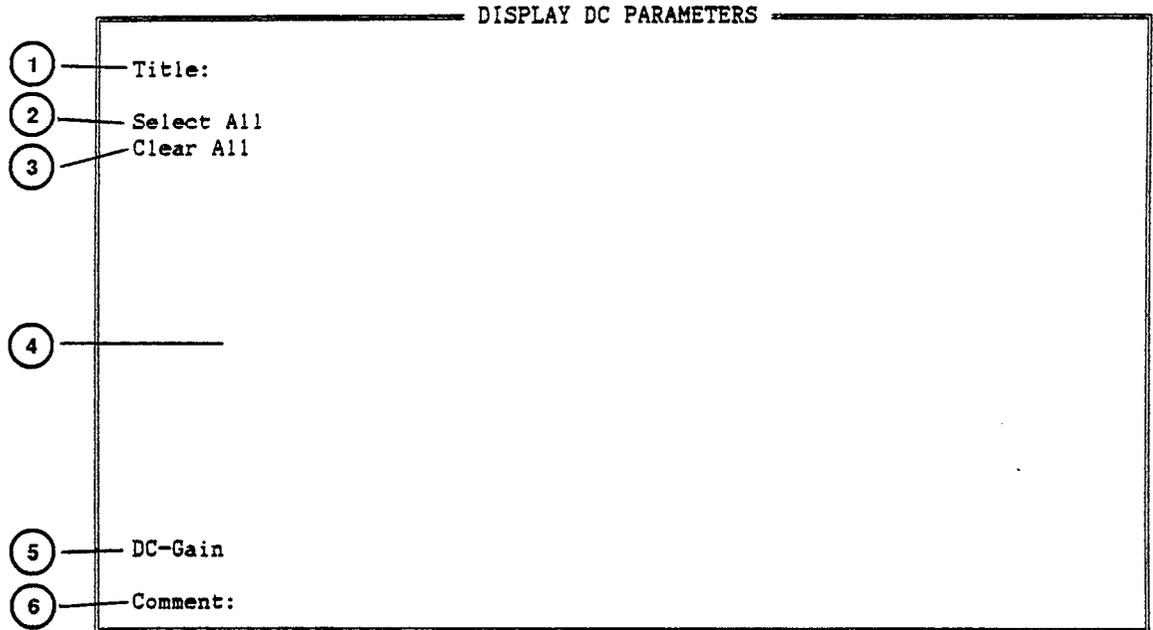


Figure 4-13. Curve Data List Display

4.5.2 Listing DC Data

Selecting Variable Names

To enter the list mode, first make sure that a DC test data file is loaded into memory, then return to the DC SOURCE-MEASURE TEST form. Press the F7 key to bring up the DISPLAY DC PARAMETERS screen, which is shown in Figure 4-14.



The screenshot shows a terminal window titled "DISPLAY DC PARAMETERS". On the left side, there are six numbered callouts (1-6) pointing to specific elements: 1 points to the "Title:" label; 2 points to the "Select All" option; 3 points to the "Clear All" option; 4 points to a large empty rectangular area; 5 points to the "DC-Gain" option; and 6 points to the "Comment:" label. At the bottom of the window, there is a footer with the text "F1-Help F4-Print F8-View F10-Execute Test" on the left and "ESC-Test Form" on the right.

1 Title:
2 Select All
3 Clear All
4
5 DC-Gain
6 Comment:

F1-Help F4-Print F8-View F10-Execute Test ESC-Test Form

- 1 Title: Type in desired title for list display (60 characters maximum).
- 2 Select All: Choose to select all displayed variable names simultaneously.
- 3 Clear All: Use to clear all selected variable names simultaneously.
- 4 Variable Name Display Area: Available variable names will be displayed in this area. Use Space bar to select or clear individual variables for listing. Selected names will be identified with an arrow.
- 5 DC-Gain: Select to choose DC gain parameters (Figure 4-3).
- 6 Comment: Enter desired comment for top of list display (60 characters maximum).

Figure 4-14. List Mode Display DC Parameters Screen

Screen parameters include:

Title: You can type in a title up to 60 characters using this selection. The title will appear at the top of the DC data list.

Select All This selection allows you to select all listed variables for display simultaneously.

Clear All This selection clears all selected variable names.

Variable Names All available variable names are displayed in this area. You can choose variables to list by placing the highlighted cursor over the variable name and pressing <Space>. Selected names will be indicated with an arrow (>). You can clear a selected name by pressing <Enter> a second time.

Select multiple variable names with the <Space> Bar; selected variables will remain tagged with arrows. Use Select All to select all variables simultaneously, or use Clear All to clear all selected variables at the same time.

DC-Gain Selecting DC-Gain will allow you to select variable names to calculate beta or other user-defined ratio. You can then select the calculated gain variable name for listing as described above. Paragraph 4.3 covers DC gain in detail.

Comment Comment allows you to type in a string of up to 60 characters containing additional information about the test or graph. The comment string will appear in the data list area.

DC Data Listing

After selecting the variables to list, press F8 to generate the list. Figure 4-15 shows the general format of the DC test LIST DISPLAY screen. The title and comments are located at the top of the screen, while the individual variables are listed on the remainder of the screen. Note that variable names appear above the variables themselves.

Printing and Plotting

4.6 PRINTING AND PLOTTING

The following paragraphs discuss printer plotter configuration and procedures for printing and plotting from display screens.

4.6.1 Printer/Plotter Configuration

Before printing or plotting, the Model 251 software must be properly configured to operate with your printer or plotter, as discussed in paragraph 2.4. In addition, the device must be properly connected to the serial port, parallel port, or GPIB (IEEE-488) bus, as the case may be. The primary address of a GPIB device must be the same as that chosen during Model 251 software installation or configuration, and the primary address must be different from the primary address of all other devices connected to the IEEE-488 bus. For serial port devices, transmission parameters such as baud rate, parity, and number of data and stop bits must be agree with those chosen during installation or reconfiguration.

4.6.2 Printing or Plotting from a Graphics Screen

You can plot or print directly from a graphics screen by pressing F3 (Plot) or F4 (Print) while displaying a graph. The F3 (Plot) generates a plot of the graph area only on a defined plotter, while the F4 (Print) selection will dump the entire graphics display screen to your printer.

F3 (Plot)

To generate a plot on a plotter, press F3 (Plot). The graph title, the axes with Labels, Grid (or tick marks), time and date, and the graph itself will be plotted.

Figure 4-16 shows an example generated by F3 (Plot).

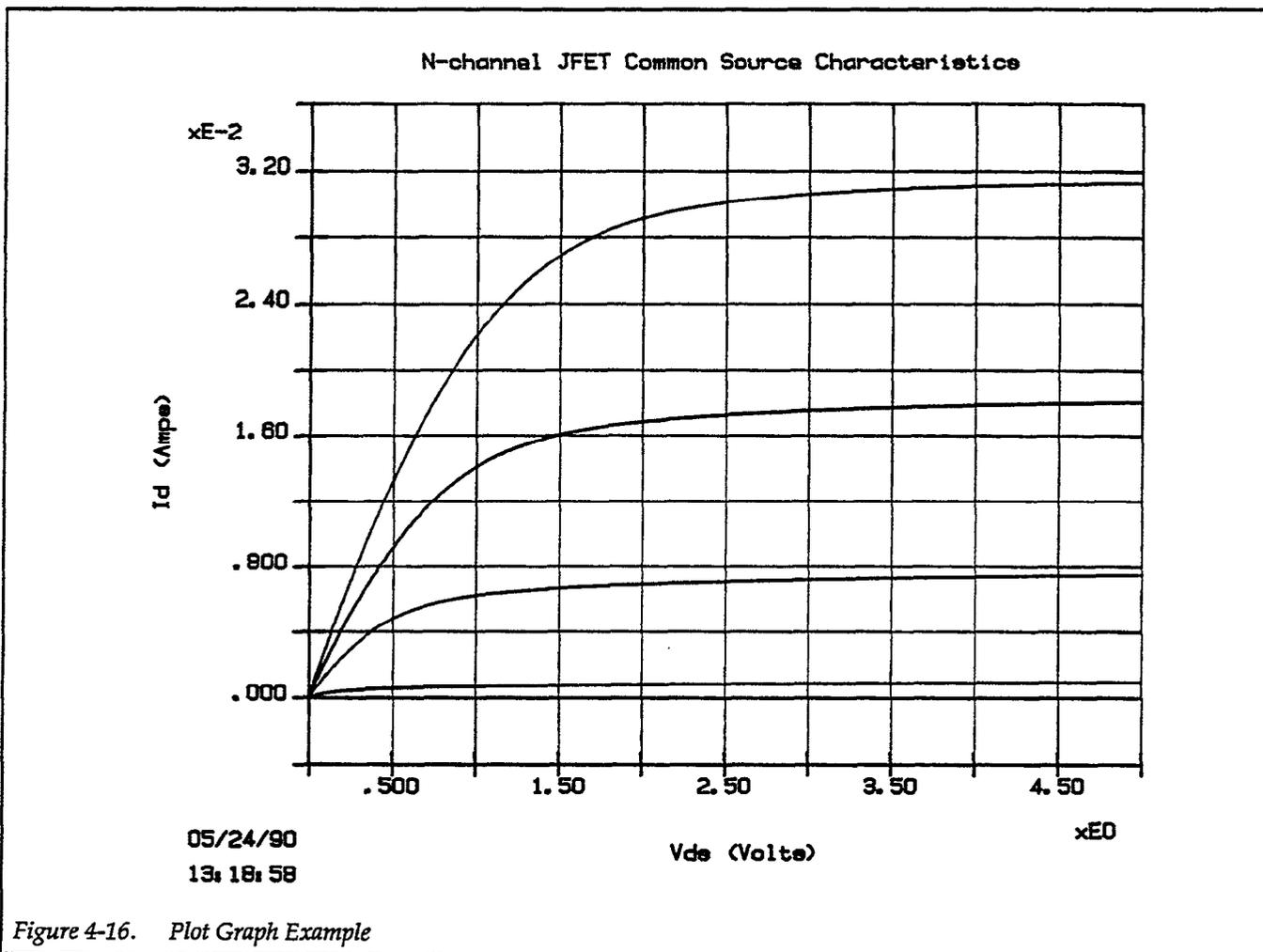


Figure 4-16. Plot Graph Example

Certain plotter defaults, which depend on the type of the plotter (number of pens), are assumed:

Two-pen plotter:

The plotter will change pens after plotting the axes and the grid, after writing the labels and the graph title, and again after plotting each curve in a multiple-curve plot. You can vary colors manually by changing pens between curves, if desired (if you are fast enough).

Four, six, and eight-pen plotters:

The default pen colors will match graph colors that you programmed for the screen using the Colors/Curve Labels parameter on the Display Parameters screen. If there are fewer available pen colors than screen colors, the plotter will go through the color sequence again, excluding the grid colors.

Color Plotting with a Monochrome Display

If you are using a monochrome display but wish to obtain a plot with colors, use the Colors/Curve Labels parameter on the DISPLAY PARAMETER to turn multiple colors on. Press F7 to access the DISPLAY PARAMETERS screen.

F4 (Print)

Pressing F4 (Print) will perform a bit-mapped graphics dump of the entire screen to your printer, including markers and lines (if enabled). For proper results, it is especially important that the proper printer type is specified (paragraph 2.4). The quality of the resulting hard copy will depend on the type of video display you are using. For best print quality, VGA graphics is recommended.

Figure 4-17 shows a typical example of an F4 (Print) printer dump from a graphics screen. The aspect ratio and overall size of the printed results may vary somewhat and will depend both on the particular printer used, as well as the video graphics mode (EGA or VGA).

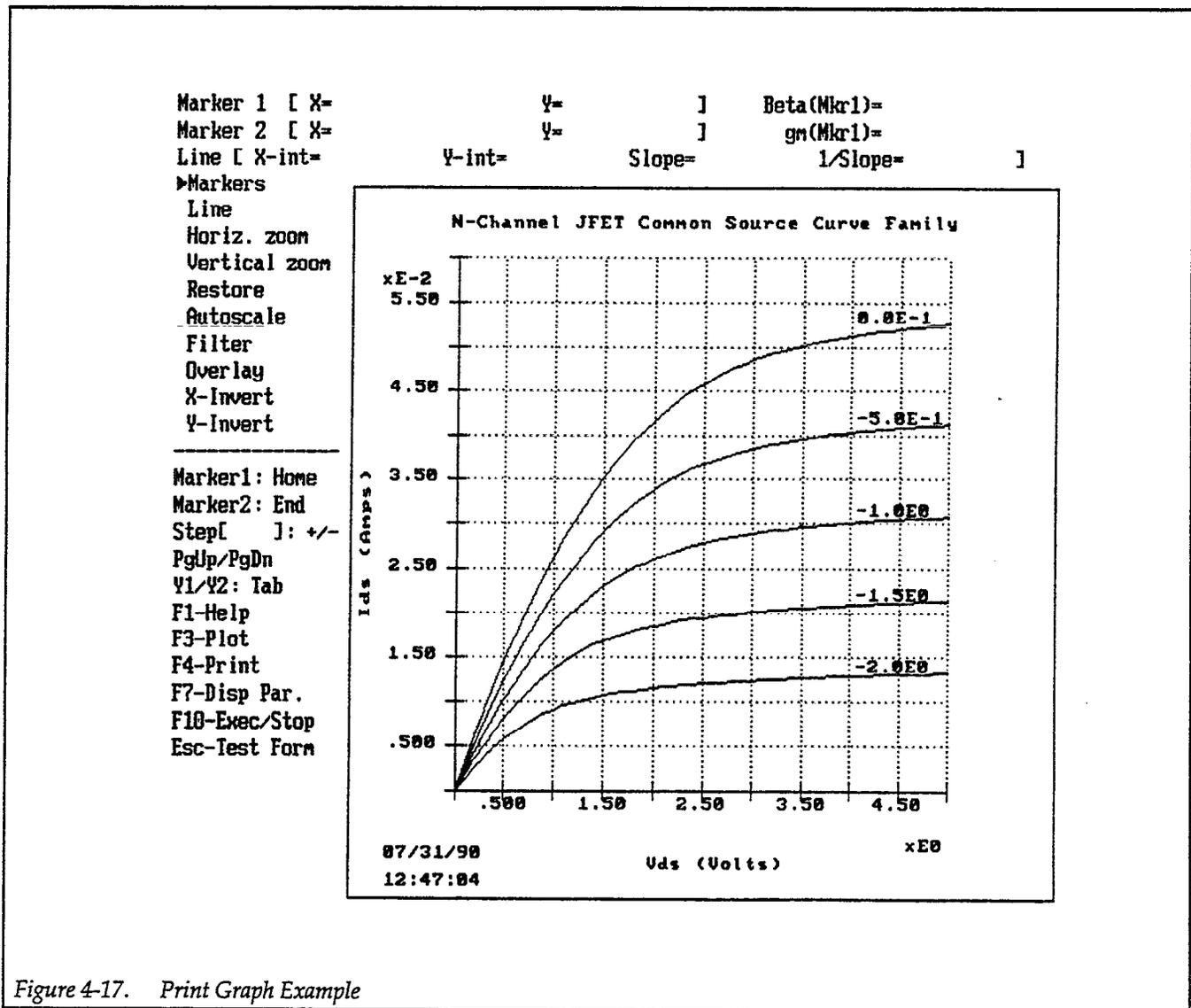


Figure 4-17. Print Graph Example

4.6.3 Printing from a Display List Screen

You can print out the data from a DISPLAY LIST screen by pressing F4 (Print) while display listing your data. The displayed screen will be printed on your printer exactly as it is displayed. To print out multiple pages of data, simply repeat the print operation after displaying the new data elements. Use Page Up and Page Down select data pages, and use the up and down cursor keys to scroll through individual rows of data.

4.6.4 Printing or Plotting from Other Screens

You can also print out information from other display screens such as the test forms by pressing the F4 (Print) key. Doing so will perform a basic screen dump to a printer. Note that you cannot use the F4 key while a pop-up window is being displayed; you must press <Esc> to close the window before using F4 to print from one of these screens.

4.6.5 Using GRAPHICS.COM for Graphics Screen Dump to Printer

Those who are using MS-DOS version 4.01 or later (or PC-DOS version 4.0 or later) can use the keyboard Print Screen key to obtain a direct graphics dump of the entire screen to an IBM graphics-compatible printer. Earlier versions of MS-DOS or PC-DOS do not have this capability because the GRAPHICS.COM utility supplied with those versions does not support EGA or VGA graphics.

In order to do so, load GRAPHICS.COM before starting the Model 251 software. After displaying the desired graph on the screen, simply press <Print Screen> (Shift <Print Screen> on some systems) to dump graphics. Note, however, that some systems may not have enough memory to run the Model 251 software with GRAPHICS.COM resident.

4.7 DISPLAY EXAMPLES

The following paragraphs list step-by-step procedures using typical examples for displaying Model 251 data. These examples assume that the Model 251 software is properly configured, as discussed in paragraph 2.4. Note that it is not necessary to run tests to use most of these examples, and all the examples use data or test setup files from the test library, which is summarized in Appendix D.

4.7.1 Displaying a Graph from a Data File

Follow the steps below to load a data file, setup the display parameters, and graph data.

Step 1: Load the Data File

Before you can graph data, that data must, of course, be located in computer memory. Test data are stored on disk in data files, which have a .DAT extension. Data files can be loaded as follows:

1. From the main menu, select File Operations, then press <Enter>.
2. Select Load File, then press <Enter>.
3. Select Data File, then press <Enter>.
4. At the "FILE TO LOAD" prompt, press <Enter>, then use the up and down cursor keys to highlight the data file called NPNCRV.DAT, then press <Enter>. (NOTE: If NPNCRV.DAT does not

appear in the directory listing, the Model 251 software may not be properly installed; refer to paragraph 2.4 for details on installation.)

5. Press <Esc> three times to return to the main menu, then select Curve Family Test, and press <Enter>. The test form should appear on the screen.

Step 2: Modify Display Parameters (Optional)

Since the display parameters are saved with data and test setup files, it is not necessary to modify display parameters before graphing data on the screen. Thus, you can skip this step and proceed to step 3. However, you may find it desirable to modify some of these parameters before graphing the data in order to customize the display to your liking. The steps below will take you through a typical display parameter screen editing.

1. From the CURVE FAMILY TEST screen, press F7 to bring up the DISPLAY PARAMETERS screen.
2. With the Display Parameters screen in the Graphics mode, use the down cursor key to highlight Graph Title, then press <Enter> and edit or type in a new graph title, if desired.
3. Move the cursor down to Scale. Use the <Enter> key to toggle between "Scale: Manual" and "Scale: Auto."
4. Move the cursor down to the Array Name row. If desired, select an array name for each axis by placing the cursor over the corresponding array name and pressing <Enter> to view a list of available array names. To select an alternate array name, place the cursor over the desired name in the list and press <Enter>.
5. For Linear/Log, place the cursor over the appropriate selection, and press <Enter> to toggle between "Linear" and "Log."
6. If manual scaling is selected, you can choose the Min and Max axis limits. Simply place the cursor over the appropriate Min/Max limit, type in the new value, and then press <Enter>. Keep in mind that a Min value must be less than a Max value.
7. Place the cursor over Colors/Curve Labels, then press <Enter> to pop up the colors menu. Select the colors for the axes, labels, and curves for the X and Y1 axes as desired. You can select colors by placing the cursor over the appropriate parameter and using the <Enter> key to cycle through the various colors. You can also choose whether or not to label each curve with the base current value by selecting Yes under Step Value Labels for the Y1 axis. Finally, select the line type (solid or dashed), if desired.
8. Press <Esc> to return to the DISPLAY PARAMETERS screen.

Step 3. Display the Graph

From the DISPLAY PARAMETERS screen, press the F8 key to display the graph. The graph will be generated using the selected display parameters. Figure 4-18 shows a typical example using NPNCRV.DAT from the supplied test library.

Step 2: Setup Display Parameters and Display Graph

1. Press F7 to access the DISPLAY PARAMETERS screen.
2. Make any desired changes on the DISPLAY PARAMETER screen. Use the cursor keys to move around the screen, and use the <Enter> key to select parameters. Be sure that Mode: Graphics is selected.
3. Press F8 to display the graph on the screen.

Step 3: Enable Markers and Lines

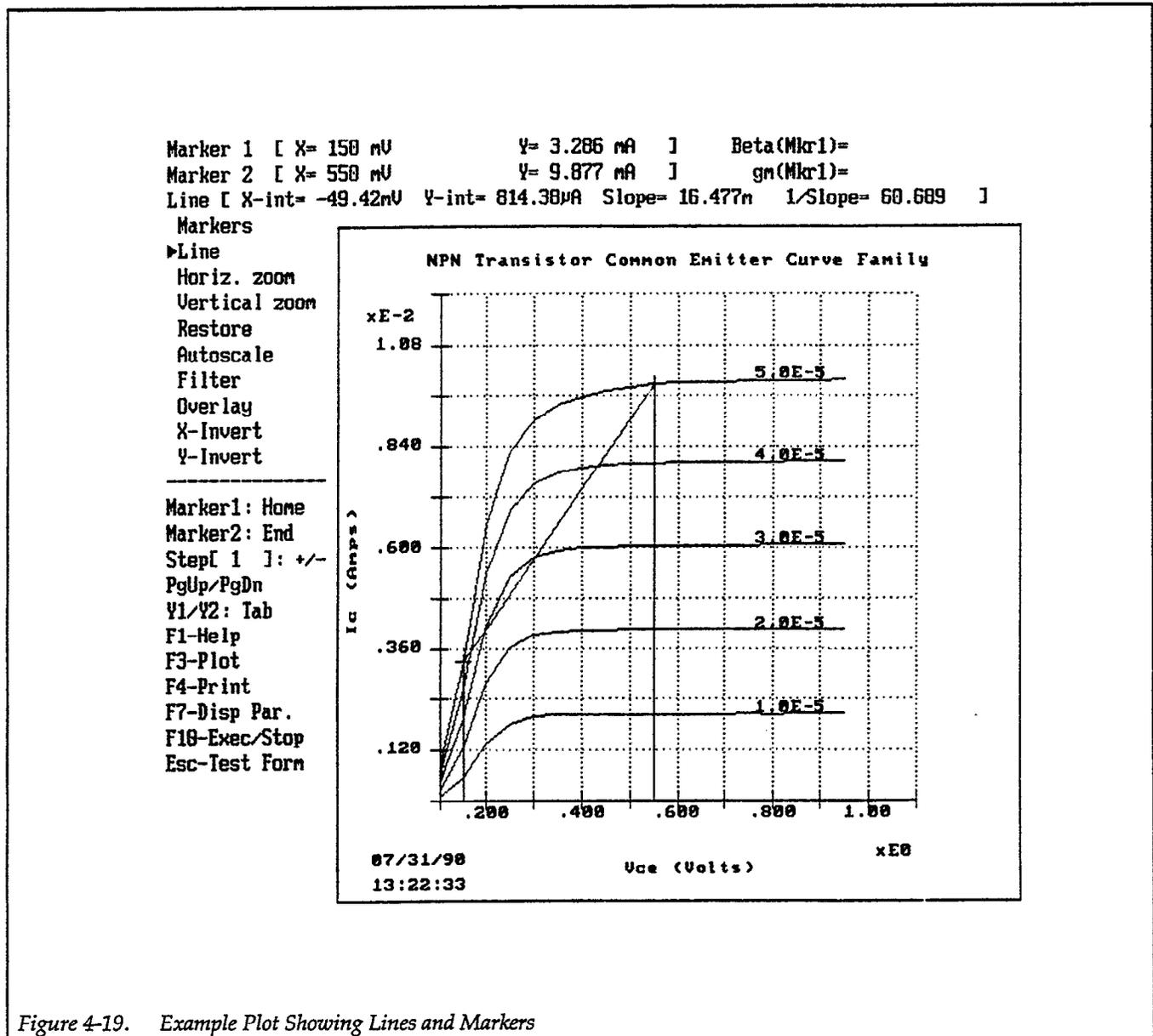
1. Press M to turn on display markers. Note that marker X and Y positions are displayed at the top of the screen.
2. Use Page Up and Page Down to place the markers on the desired curve.
3. Use the Home key to select Marker 1, or press the End key to enable Marker 2.
4. Use the left and right cursor keys to position the selected marker at the desired point of the curve. Marker step can be adjusted by using + or -.
5. Select the other marker using the Home or End key, and position the marker as appropriate by repeating steps 2 and 3.
6. Press L to connect a line between the markers, and note that the X and Y intercepts, and slope values are displayed at the top of the screen. If a log scale is selected, the line equation along with its parameters will instead be displayed. Figure 4-19 shows an example with lines and markers activated.
7. Pressing L a second time will cancel the line mode.

Step 4: Enlarge a Portion of Graph

1. Press M to enable markers if not already enabled.
2. Press V, then use Page Up and Page Down to place the markers on the curve to act as the upper or lower curve boundary. Press <Enter> to complete the selection, then use Page Up and Page Down to select the opposite curve boundary by placing the markers on the corresponding curve. Press <Enter> to complete vertical zoom boundary selection.
3. Position Marker 1 and Marker 2 on a curved portion of the graph using the left and right cursor keys.
4. Press the H key to zoom in horizontally on the selected area of the graph.
5. If desired, reposition the markers and zoom in again.
6. When finished, press R to restore the graph to normal.

Step 5: Invert graph

1. Press X, and note that the X axis is now inverted.
2. Press Y, and note that the Y axis is inverted.
3. Press both X and Y (or R) to return the graph to normal.



4.7.3 Graph Overlay

The graph overlay feature allows you to display two or three sets of similar data on the same graph. In order to demonstrate this feature, it will be necessary for you to perform two curve family test procedures using the steps below.

Step 1: Load Test and Configuration Files

1. From the main menu, select File Operations, then press <Enter>
2. Choose Load File, then press <Enter>.
3. Select Test Setup File, then press <Enter>.
4. Press <Enter> to view a list of test files.
5. Select the desired test file with the cursor keys, then press <Enter>. For this example, use the supplied library file NPNCRV.TST to test two similar NPN transistors.

6. Press <Esc>, select Instrument Configuration file, and then press <Enter>.
7. Press <Enter> to view a list of instrument configuration files.
8. Select the TESTLIB.CFG file, then press <Enter> to load it.
9. Return to the main menu, select Curve Family Test, then press <Enter> to display the test form.

Step 2: Take Two Similar Sets of Data

1. If necessary, edit the test form to correctly test your device. A 2N3904 NPN transistor is a typical transistor to use for this example. You should be able to test this device without modifying the test setup file.
2. Perform a test on the first device by pressing F10.
3. Save the data file using the File Operations, Save File, and Data File menus.
4. Repeat the test on the second device, which should have characteristics similar (but not identical) to those of the first device.

Step 3: Select Display Parameters

1. Press F7 to access the DISPLAY PARAMETERS screen.
2. Make sure that Mode: Graphics is selected. If not, use the <Enter> key to switch from Mode: List to Mode: Graphics.
3. If desired, modify other display parameters.
4. Select the Overlay Form parameter, then press <Enter>.
5. Type in the filename for the second data set where indicated in the pop-up Overlay Data menu (be sure to include the .DAT extension).
6. Type in the X and Y array names to plot as overlay data. If you used the NPNCRV.TST test file without alterations, the array names should be Vce and Ic for the X and Y axes respectively.
7. Press <Esc> to return to the DISPLAY PARAMETERS screen.

Step 4: Plot Data Sets

1. From the DISPLAY PARAMETERS screen, press F8 to graph the data.
2. The first set of data will be graphed on the screen.
3. Press O to enable the Overlay Tool. The second data set will be overlaid on the graph using dotted lines to distinguish between the two data sets. Figure 4-20 shows an example using graph overlay.

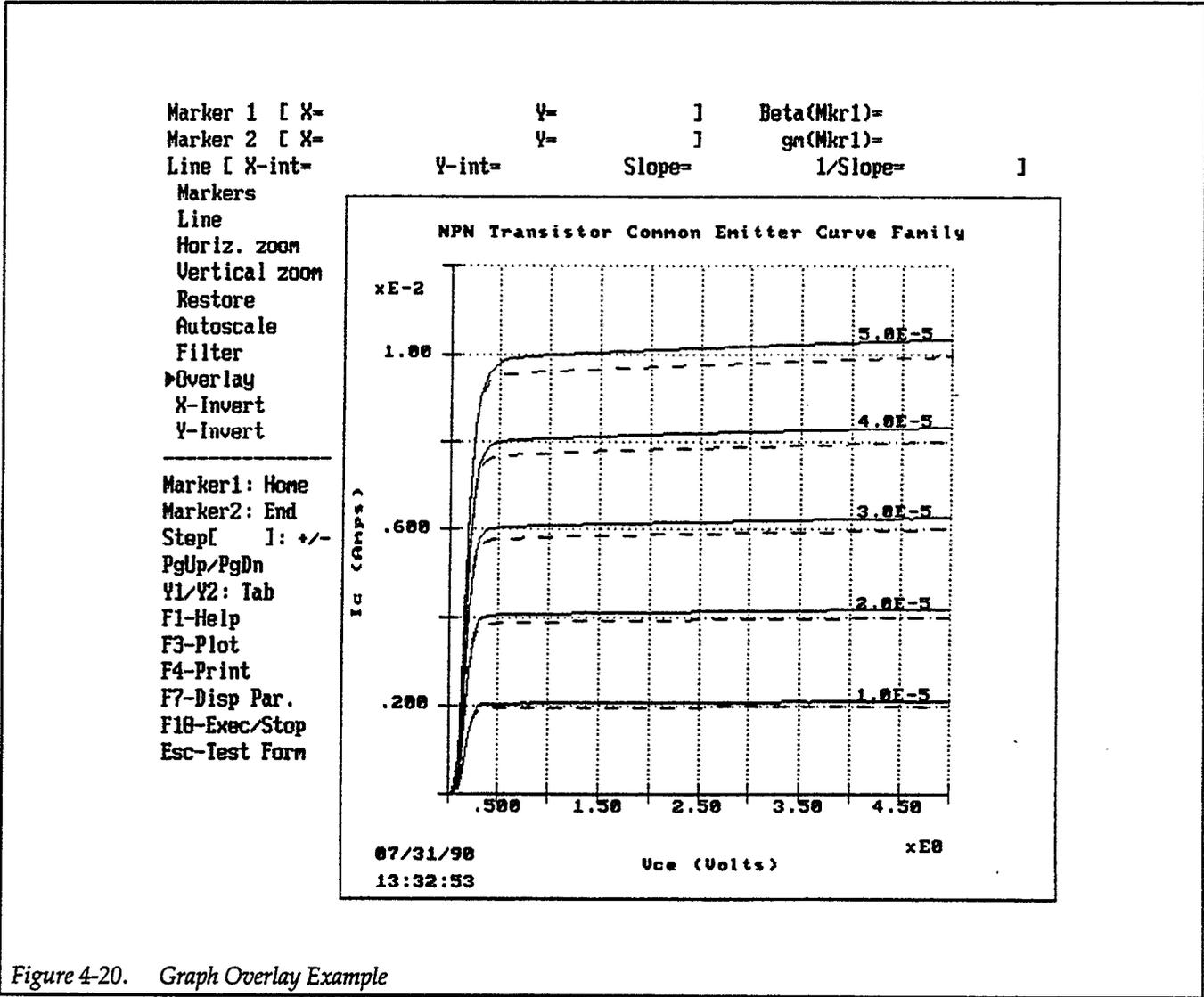


Figure 4-20. Graph Overlay Example

4.7.4 Second Y-Axis (Y2) Graphing

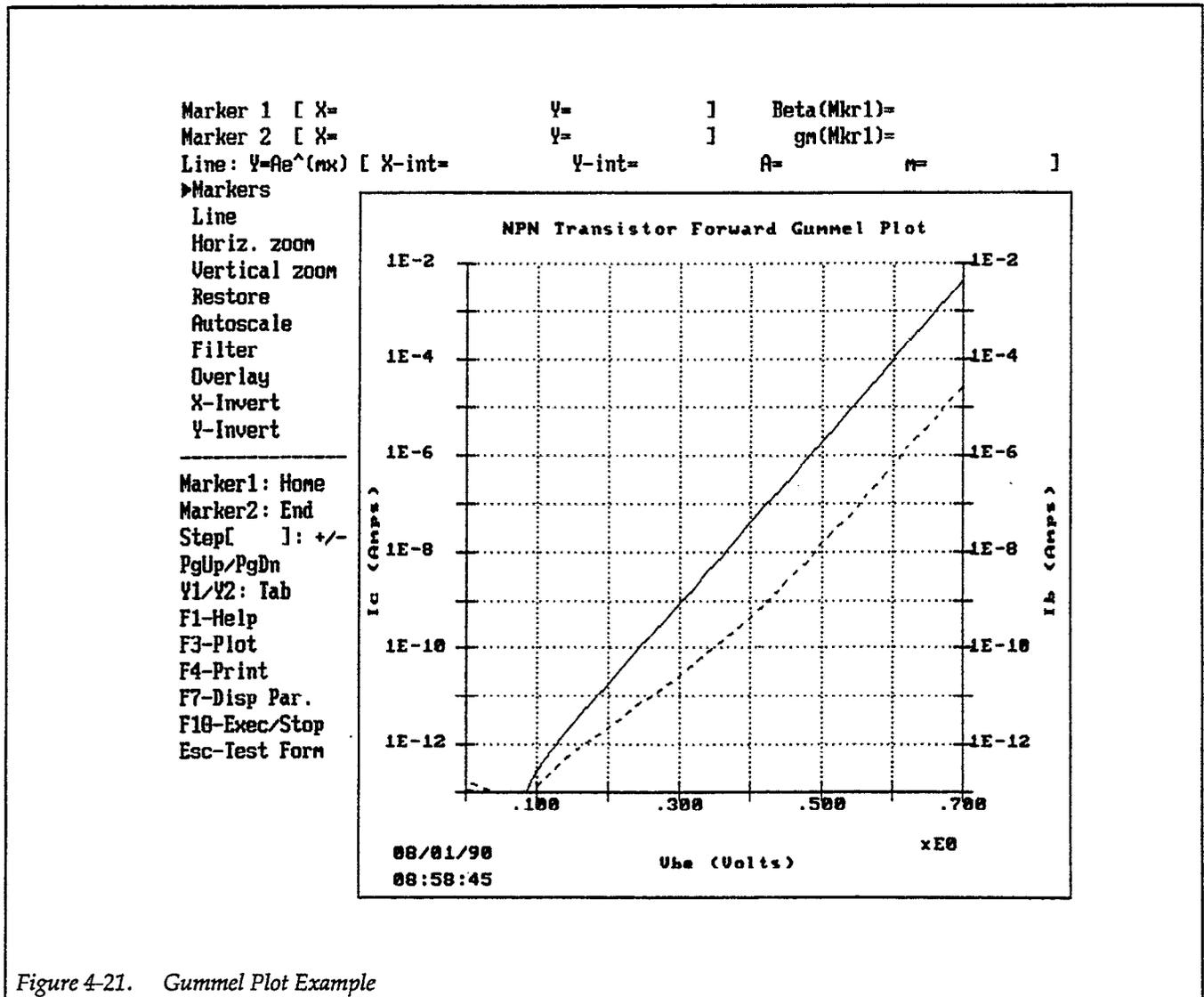
By choosing appropriate parameters on the DISPLAY PARAMETERS screen, you can plot two Y axes (Y1 and Y2). An example of a test type that requires using both Y1 and Y2 is the Gummel plot, which graphs both I_B and I_C vs. V_{BE} . The steps below demonstrate the basic procedure for generating a Gummel plot using data from the test library.

Step 1: Load the Data File

1. Select File Operations on the main menu, then press <Enter>.
2. Select Load File, then press <Enter>.
3. Select Data File, then press <Enter>.
4. Press <Enter>, select the file called NPNFGUML.DAT, then press <Enter> again to load the indicated file.
5. Return to the main menu, then select Curve Family Test to bring up the test form.

Step 2: Select Display Parameters and Graph Data

1. Press F7 to bring up the DISPLAY PARAMETERS screen.
2. Note in particular the axis parameters display near the center of the screen. The X axis is set up to plot V_{be} , the Y1 axis is set up for I_c , and the Y2 axis is configured to plot I_b .
3. If desired, change the grid, labels, line types, and colors, but do not alter the axis parameters.
4. Press F8 to generate the graph. Figure 4-21 shows an example of the Gummel plot from the data in NPNFGUML.DAT.



4.7.5 Listing Data

Follow the steps below to list numeric data values from a specified file on the computer screen.

Step 1: Load Data File

1. Select the FILE OPERATIONS menu, then press <Enter>.
2. Select Load File, then press <Enter>.
3. Select Data File, then press <Enter>.
4. Press <Enter>, then use the cursor keys to choose the data file to load (use a curve test data file for this example). Press <Enter> to load the file once you have made your selection.
5. Return to the main menu, then select Curve Family Test to display the test form.

Step 2: Select List Mode and List Data

1. Press F7 to access the DISPLAY PARAMETERS screen.
2. Select Mode: List using the <Enter> key.
3. Select the arrays to list using the cursor and <Space> keys. Selected arrays will be tagged with arrows (>).
4. Press F8 to list the selected arrays on the screen. Listed values will include the curve number, index (data point or step), as well as the individual array elements (see Figure 4-13 for an example).
5. Use up and down cursor to scroll through lines of data, or use Page Up or Page Down to page through data.

4.7.6 Printing/Plotting Data

Follow the steps below the print or plot a graph on your printer or plotter. Keep in mind that the printer or plotter must be properly connected, and the software must be properly installed and configured in order to print or plot (see paragraph 2.4).

Step 1: Load the Data File

1. Select File Operations on the main menu, then press <Enter>.
2. Select Load File on the subsequent pop-up menu, then press <Enter>.
3. Select Data File, then press <Enter>.
4. Press <Enter> to display a list of available data files.
5. Select the file to load, then press <Enter> to load it. Make sure you load curve family-type data for this example (for example NPNCRV.DAT).
6. Return to the main menu, select Curve Family Test, then press <Enter>.

Step 2: Setup Display Parameters and Plot Graph

1. Press F7 to display the DISPLAY PARAMETERS screen.
2. Make sure that Mode: Graphics is selected.
3. Select other display parameters, as required.
4. Press F8 to display the graph on the screen.

Step 3: Print or Plot the Graph

1. Press F3 to plot the graph on a plotter, or press F4 to dump the screen to your printer.
2. The graph will be printed on your printer, or plotted on your potter, depending on your selection.
3. With F3 (Plot), only the graph area with no markers or lines will be plotted. With F4 (Print), the entire graph, including markers and lines (if enabled) will be printed. Figure 4-16 and Figure 4-17 show plotting and printing examples.

SECTION 5

File Operations

5.1 INTRODUCTION

This section of the Model 251 Instruction Manual contains detailed information on file operations. Section 5 includes information on:

- 5.2 **File Types:** Covers the various types of files and directories for the Model 251.
- 5.3 **Loading Files:** Details procedures for loading all seven file types.
- 5.4 **Saving Files:** Covers methods for saving the six savable file types.
- 5.5 **Renaming Files:** Describes how to rename all file types.
- 5.6 **Deleting Files:** Gives the procedure for deleting all file types.
- 5.7 **Export/Import Data:** Describes how to export data to and import data from ASCII and Lotus 123 file formats.

Error messages associated with file operations are covered in Appendix B.

5.2 FILE TYPES

There are seven basic file types you can access using the File Operations menu, as summarized in Table 5-1. The basic file types can be identified by the filename extension as follows:

- Data File (.DAT)
- Test Setup File (.TST)
- Instrument Configuration (.CFG)
- 707 File (.707)
- Sequencer File (.SEQ)
- ASCII Import/Export (.ASC)
- Lotus Import/Export (.WK1)

The following paragraphs discuss the file types and default directories. Import/export files are discussed separately in paragraph 5.7.

Table 5-1. File Type

File Type	Filename Format	Comments
Data	Filename.DAT	User specified filename
Test Setup	Filename.TST	User specified filename
Instrument Configuration	Filename.CFG	Contains instrument configuration table.
707 File	Filename.707	Contains binary setup data
Sequencer File	Filename.SEQ	May be loaded/not saved
ASCII Import/Export File	Filename.ASC	ASCII data file
Lotus Import/Export File	Filename.WK1	Release 2 format (or later)

Note: Filenames are subject to the standard DOS restrictions. Filenames must use extension shown for each file type.

5.2.1 Test Setup Files

The test setup files include the following information:

- The test parameters you select in your DC or curve test form.
- The display parameters selected with the DISPLAY PARAMETERS screen (accessed with the F7 key).
- The parameters you select with the GENERAL GPIB OUTPUT screen (accessed with the F5 key).

Note that test setup files contain no data.

These files can be saved and loaded using the corresponding selections in the file control menu. When accessing test setup files, Model 251 supplies the .TST extension. Typical test setup filenames include:

SETUP1.TST
GUMMEL.TST

5.2.2 Data Files

Data files include the following information:

- The test parameters you select in your DC or curve test form.
- The display parameters selected with the DISPLAY PARAMETERS screen (accessed with the F7 key).
- The parameters you select with the GENERAL GPIB OUTPUT screen (accessed with the F5 key).
- The data arrays filled with data taken during the test procedure.

These files can be saved or loaded with appropriate menu selections. Note that Model 251 supplies the .DAT extension when loading or saving data files. The following are examples of typical data filenames:

MYFILE.DAT
TEST1.DAT

5.2.3 Instrument Configuration Files

An instrument configuration file can have any valid name that you choose, but it must use the .CFG extension. When the new configuration is saved, the MODEL251.CFG file is also updated so that the latest instrument configuration file is automatically loaded at startup.

You can load or save any alternate instrument configuration files by using the load or save file menus discussed below. Loading a new instrument configuration file will flag that file as the default instrument configuration file in MODEL251.CFG so that the last loaded instrument configuration file will become the default at software startup. Typical filenames are:

SETUP1.CFG
INSTR.CFG
TEST4.CFG

NOTE

You should not attempt to load or modify the Model 251 configuration file called MODEL251.CFG using the Load File menu. This file contains important software configuration parameters and is created or modified during installation or configuration (see paragraph 2.4.5).

5.2.4 Import/Export Format Files

ASCII and Lotus files must conform to specific formats, as described in paragraph 5.7.

ASCII format files must end with the .ASC extension. These files are accessed through the appropriate Load File (import) or Save File (export) selections.

Typical ASCII import/export filenames are:

```
TEST4.ASC
LEAKAGE.ASC
FORMTEST.ASC
```

Lotus 123 files are accessed through the Export/Import selection on the file menu and must use the .WK1 extension. Note that the format used is for Lotus 123 release 2 or later. Other formats such as .WKS (release 1) and Symphony (.WRK) cannot be used. See paragraph 5.7 for details on exporting and importing Lotus 123 files, and the required formats.

Typical import/export filenames are:

```
TEST4.WK1
LEAKAGE.WK1
FORMTEST.WK1
```

5.2.5 Default Directories

During operation, the Model 251 assumes that the various files will appear in specific default directories unless you specify otherwise when accessing these files. The names of these directories are defined when you install or configure the software and are stored in the MODEL251.CFG file (see paragraph 2.4).

Table 5-2 summarizes default names for the various directories. In this example, the default subdirectories for data and test setup files are called \MODEL251\DATA and \MODEL251\TESTS respectively, while the configuration files are placed in the directory \MODEL251\CONFIG. Example directory names shown are installation defaults.

If you wish to access files in other (non-default) directories, you can do so by typing in a new path name at a file-

Table 5-2. Typical Default Directories

File Type	Default Directory
Configuration	\MODEL251\CONFIG
Test Setup	\MODEL251\TESTS
Data	\MODEL251\DATA
707 File	\MODEL251\707
Sequencer	\MODEL251\SEQ
ASCII Export/Import	\MODEL251\DATA
Lotus Export/Import	\MODEL251\DATA

name prompt. The procedures for doing so are covered in the following paragraphs.

5.3 LOADING FILES

Follow the steps below to load instrument configuration, data, or test setup files.

1. From the main menu, select File Operations using the up and down cursor keys, then press <Enter>.
2. The FILE OPERATIONS menu, which allows you to access the various file operations, will pop up on the screen:

```
FILE OPERATIONS
Load File
Save File
Rename File
Delete File
```

3. Press <Enter> to access the LOAD FILE menu:

```
LOAD FILE
Data File
Test Setup File
Instrument Configuration
707 File
Sequencer File
ASCII Import
Lotus Import
```

4. Select the file type to load, then press <Enter>.

NOTE

If you are attempting to load a data or test setup file, you may be asked if you wish to continue. Select 'Y' to load the new file without saving the old file; choose 'N' to return to the previous menu to avoid overwriting the old file. Loading a data file will automatically load the test parameters into your test form, as well as display parameters.

At this point, you can choose to load a file using one of three methods:

- A. Press <Enter> to view files in the displayed default directory with a matching extension for the file type selected (.DAT, .TST, or .CFG, etc.). Select the file to load with the cursor keys, then press <Enter> to load it.
 - B. Type in a new path or directory, then press <Enter> to view files with the correct extension in that directory. Select the file to load, then press <Enter>.
 - C. Type in the filename (you need not include the extension as it will be automatically assigned), then press <Enter>. If the file is found, it will be loaded. If the file cannot be found, or if you use the wrong extension, an error message will be displayed.
5. If the file is loaded successfully, a message to that effect will be displayed; if, however, the file cannot be loaded (for example, file or path not found), an appropriate error message will be displayed.
 6. If desired, repeat step 4 for other file types, or press <Esc> to return to the previous menu. Keep in mind that you can have only one data, test setup, instrument configuration, 707, or sequencer file in memory at any given time.

5.4 SAVING FILES

Follow the steps below to save instrument configuration, data, test setup, or 707 files.

1. From the main menu, select File Operations using the up and down cursor keys, then press <Enter>.
2. The FILE OPERATIONS menu, which allows you to access the various file operations, will pop up on the screen:

```
FILE OPERATIONS
Load File
Save File
Rename File
Delete File
```

3. Using the cursor keys, select Save File, then press <Enter> to access the SAVE FILE menu:

```
SAVE FILE
Data File
Test Setup File
Instrument Configuration
707 File
ASCII Export
Lotus Export
```

4. Select the file type to save, then press <Enter>. You can now save the selected file type using one of the following three basic methods:
 - A. Press <Enter> to view files in the displayed default directory with a matching extension for the file type selected. Select the file to save with the cursor keys, then press <Enter> to save it.
 - B. Type in a new path or directory, then press <Enter> to view files with the matching extension in that directory. Select the file to save, then press <Enter>.
 - C. Type in the filename up to eight characters in length (you need not include the extension, as it will be automatically assigned), then press <Enter>. If you use the wrong extension, an error message will be displayed.

NOTE

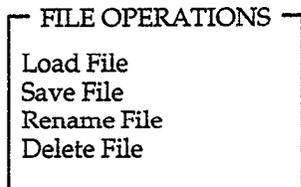
The Model 251 does not automatically save file backups. In order to save backups, you must first rename an existing file before saving a replacement file using the existing filename. Otherwise, any existing file with the selected name will be overwritten.

5. If desired, repeat step 4 for other file types, or press <Esc> to return to the previous menu.

5.5 RENAMING FILES

Rename files as follows:

1. From the main menu, select File Operations to select the FILE OPERATIONS menu:



2. Select Rename File on the FILE OPERATIONS menu.
3. You can now select the file to rename using one of the following four basic methods:
 - A. Type in the name of the directory (i.e. DATA, TESTS, CONFIG, etc.) and press <Enter> to view all files in that directory. Select the file to rename with the cursor keys, then press <Enter> to select it.
 - B. Type in the name of the directory and the complete file name including the correct extension, then press <Enter>.
 - C. Type in a new path and directory, then press <Enter> to view all files in that directory. Select file to rename and press <Enter>.
 - D. Type in a new path name, directory and the file name (including extension) to rename, then press <Enter>.
4. Type in the new filename and extension when prompted to do so. The file will be renamed as selected.
5. Repeat steps 3 and 4 for other files if required, or press <Esc> to return to the previous menu.

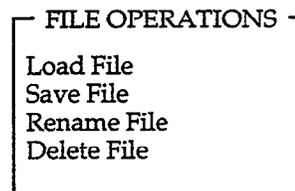
NOTES

1. Be sure to use the correct extension when renaming files. Data files must have the .DAT extension, instrument configuration files require the .CFG extension, and test setup files must have a .TST extension. See the file types list at the beginning of paragraph 5.2 for all applicable extensions.
2. Attempting to rename a file using an existing filename will result in an error message.

5.6 DELETING FILES

Delete files as follows:

1. From the main menu, select File Operations to select the FILE OPERATIONS menu:



2. Select Delete File on the FILE OPERATIONS menu, then press <Enter>.
3. You can now select the file to delete using one of the following four basic methods:
 - A. Type in the name of the directory (i.e. DATA, TESTS, CONFIG, ETC.) and press <Enter> to view all files in that directory. Select the file to delete with the cursor keys, then press <Enter> to select it.
 - B. Type in the name of the directory and the complete file name including the correct extension, then press <Enter>.
 - C. Type in a new path and directory, then press <Enter> to view all files in that directory. Select file to delete and press <Enter>.
 - D. Type in a new path name, directory and the file name (including extension) to delete, then press <Enter>.
4. A prompt, verifying your file selection, will now be displayed. Press 'Y' to delete the file, or press 'N' to cancel the deletion process.

NOTE

You cannot recover a file once you have deleted it.

5. If the deletion process is successful, a message indicating the selected file has been deleted will be displayed.

5.7 EXPORT/IMPORT DATA

Model 251 I-V Test Software has the capability to export data to, or import data from, files using these two formats:

- Lotuse 123 file format (release 2, or later), with the .WK1 extension, as explained in paragraph 5.7.3.

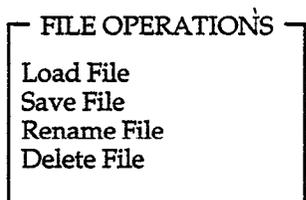
- ASCII file format, with the .ASC extension, as explained in paragraph 5.7.4.

The following describes the import and export procedure for Lotus files. However, the basis is the same for both Lotus and ASCII file types.

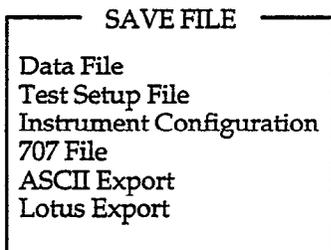
5.7.1 Export Data

The steps below provide an example of how to export data to a file in Lotus 123 format:

1. From the main menu, select File Operations to access the following FILE OPERATIONS menu:



2. Using the cursor keys, select Save File, then press <Enter>. The following menu will then be displayed:



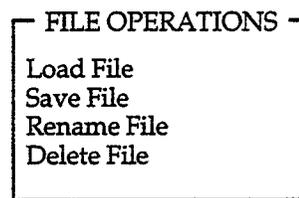
3. Select Lotus Export, then press <Enter>.
4. To export use one of these methods:
 - A. Press <Enter> to view files in the displayed default directory with a .WK1 extension. Select the file to export with the cursor keys, then press <Enter> to export it.
 - B. Type in a new path or directory, then press <Enter> to view files with the matching .WK1 extension in that directory. Select the file to export, then press <Enter>.
 - C. Type in the filename (you need not include the .WK1 extension), then press <Enter>. If you use the wrong extension, an error message will be displayed.

5. The file will be converted to Lotus 123 format and saved with the .WK1 extension. The file can then be retrieved by Lotus 123 or other spreadsheet programs compatible with .WK1 files; see paragraph 5.7.3 for format details.

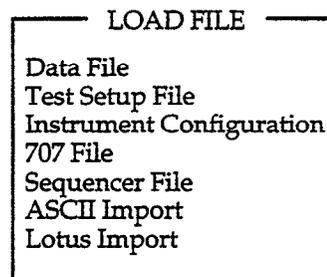
5.7.2 Import Files

Lotus 123 format files (release 2 and later) can be imported by the Model 251 using the procedure below. These files use the .WK1 extension, and they must also conform to the format discussed in paragraph 5.7.3 below.

1. From the main menu, select File Operations to select the FILE OPERATIONS menu:



2. Select Load File, then press <Enter>. The following menu will be displayed:



3. Select Lotus Import, then press <Enter>.
4. You can now import in one of several ways:
 - A. Press <Enter> to view files in the displayed default directory with a .WK1 extension. Select the file to import with the cursor keys, then press <Enter> to import it.
 - B. Type in a new path or directory, then press <Enter> to view files with the matching extension in that directory. Select the file to import, then press <Enter>.
 - C. Type in the filename (you need not include the .WK1 extension), then press <Enter>. If you use the wrong extension, an error message will be displayed.

5. If successful, the file will be imported and converted to Model 251 format. Data arrays can be viewed or plotted in the usual manner (see Section 4).

NOTE

Before you can graph imported data, you must define the arrays using the DISPLAY PARAMETER screen. This step is necessary because export/import files do not save display, test, or GPIB parameters.

5.7.3 Lotus Export/Import Data Format

The Lotus Export function stores all data arrays associated with the current data set to the named Lotus 123 type file, as outlined above. Note that the test setup informa-

tion, which is stored with conventional Model 251 data files, is not included with exported data. Similarly, the import function recalls data from the selected Lotus 123 format file and stores it in the named arrays in active memory.

The various data elements are stored in cells using the standard Lotus spreadsheet column-row format. Columns are lettered A, B, C, etc., and the rows are numbered 1, 2, 3, etc. Each cell is referred to by its column-row designation. For example, cell C2 means column C, row 2.

Each line of the Lotus .WK1 file corresponds to a row of spreadsheet information. The various lines (rows) of the file are defined as outlined below. Figure 5-1 shows an example spreadsheet using a simple file.

	A	B	C	D	E	F	G	H	I	J
1										
2			CREATED BY KEITHLEY MODEL251							
3										
4			TEST =	CURVE.TEST						
5										
6			4	DATA ARRAYS						
7										
8			ARR.NAME	AA	X DIM	2	Y DIM	2	UNITS:	AMPS
9			1	1						
10			1	1						
11										
12			ARR.NAME	AB	X DIM	2	Y DIM	3	UNITS:	VOLTS
13			2	2	2					
14			2	2	2					
15										
16			ARR.NAME	BB	X DIM	3	Y DIM	3	UNITS	AMPS
17			3	3	3					
18			3	3	3					
19			3	3	3					
20										
21			ARR.NAME	BA	X DIM	3	Y DIM	4	UNITS	VOLTS
22			4	4	4	4				
23			4	4	4	4				
24			4	4	4	4				

Figure 5-1. File Export Format

Line 1: Left blank.

Line 2: Contains the string: "CREATED BY KEITHLEY MODEL 251"
This string occupies cell C2 in the spreadsheet.

Line 3: Left blank.

Line 4: Cell C4 contains the string "TEST="
Cell D4 contains a string representing the test type (ie. "CURVE.TEST" or "DC.TEST")

Line 5: Left blank.

Line 6: Cell C6 contains the number of data arrays {number}
Cell D6 contains the string "DATA.ARRAYS" {string}

Line 7: Left blank.

Line 8: Cell C8 contains the string "ARR.NAME" {string}
Cell D8 contains the name of the first array {string}
Cell E8 contains the string "X DIM" {string}
Cell F8 contains the X dimension of the first array

{number}

Cell G8 contains the string "Y DIM" {string}
Cell H8 contains the Y dimension of the first array {number}

Cell I8 contains the string "UNITS:"
Cell J8 contains the string "Volts" for voltage or "Amps" for current.

Line 9: Data array values are stored beginning with line 9. X and Y dimensions of the first array are specified in cells E8 and G8. Array[1,1] is stored in C9, Array[2,1] is stored in C10, and so on. Array[1,2] will be stored in D9, Array[1,3] in E9, etc. Thus, each row in the spreadsheet corresponds to one curve, with the first data point appearing in column C, the second data point in column D, and so on with each data point taking up one column in the row.

Once an array is completed, the format described in Lines 7 through 9 is repeated for the next array(s) with a blank line between arrays. Unused cells are filled with blanks to make the resulting file presentable on the spreadsheet screen.

Actual Spreadsheet Example

2V with 100mV steps. The V_{CE} data is located in row 9 of the spreadsheet, while the measured I_C data is contained in row 12.

Figure 5-2 shows an actual example of an exported file from an I_{CEO} test. For this test, V_{CE} was swept from 0V to

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1														
2			CREATED BY KEITHLEY MODEL 251											
3														
4			TEST=	CURVE.TEST										
5														
6			3 DATA ARRAYS											
7														
8			ARR.NAME	Vd	X DIM	1	Y DIM	51	UNITS:	Volts				
9			0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.09999999	0.11
10														
11			ARR.NAME	Id	X DIM	1	Y DIM	51	UNITS:	Amps				
12			1.4E-07	2E-08	8E-08	2E-08	2E-08	8E-08	2E-08	8E-08	8E-08	8E-08	8E-08	8E-08
13														
14			ARR.NAME	SWPTIME	X DIM	1	Y DIM	51	UNITS:	Seconds				
15			0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009	0.01	0.011	0.012	0.013

	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1														
2														
3														
4														
5														
6														
7														
8														
9	0.12	0.13	0.14	0.14999999	0.16	0.17	0.17999999	0.19	0.19999999	0.20999999	0.22	0.22999999	0.23999999	0.25
10														
11														
12	8E-08	8E-08	8E-08	1.4E-07	1.4E-07	2E-07	2E-07	2.7E-07	2.7E-07	3.3E-07	3.9E-07	4.6E-07	5.8E-07	7.1E-07
13														
14														
15	0.014	0.015	0.016	0.017	0.018	0.019	0.02	0.021	0.022	0.023	0.024	0.025	0.026	0.027

	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
1														
2														
3														
4														
5														
6														
7														
8														
9	0.25999999	0.26999998	0.28	0.28999999	0.29999998	0.31	0.31999999	0.32999998	0.34	0.34999999	0.35999998	0.37	0.38	0.38999999
10														
11														
12	8.3E-07	1.02E-06	1.21E-06	1.53E-06	1.84E-06	2.16E-06	2.72E-06	3.35E-06	4.11E-06	4.93E-06	6E-06	7.51E-06	9.34E-06	1.148E-05
13														
14														
15	0.028	0.029	0.03	0.031	0.032	0.033	0.034	0.035	0.036	0.037	0.038	0.039	0.04	0.041

	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA
1											
2											
3											
4											
5											
6											
7											
8											
9	0.39999998	0.41	0.41999999	0.42999998	0.44	0.44999999	0.45999998	0.47	0.47999999	0.48999998	0.5
10											
11											
12	1.419E-05	1.746E-05	2.156E-05	2.666E-05	3.308E-05	4.102E-05	5.097E-05	6.325E-05	7.837E-05	9.733E-05	0.00012107
13											
14											
15	0.042	0.043	0.044	0.045	0.046	0.047	0.048	0.049	0.05	0.051	0.052

Figure 5-2. Actual Example of File Export

5.7.4 ASCII Export/Import Data Format

The ASCII format file must conform to the following format.

The Model 251 I-V Test Software system requires a main header which must look exactly like the following string:

```
Model 251 V2.00 ASCII import/export file
```

The system searches the ASCII file until it finds the above string. If the string is not loaded, an error message is generated. However, this string does not have to be on the first file line, nor does it have to be the first string. But, if the system locates data before it finds the main header string, that data will not be recognized.

After the system successfully locates the above main header string, the routine recognizes the following array name string:

```
Arrays in this file: name1, name2, name3, name4, ...
```

where name(#) represents an array name such as Vce, Ib, Ic, or Vbe. There is a limit of six array names per line. The array name string is not required.

The third string is the array header. It is required and looks like this:

```
Array: name, units, dim1 x dim2
```

where name is the array name, units is the type of array (volts, current, etc.), and dim1 and dim2 are the dimensions of the array. One dimensional arrays require only dim1.

A typical array header might look like this:

```
Array: Vce, Volts, 5 x 101
```

which would indicate:

- An array named Vce
- Of the type voltage
- Five sweeps
- 101 points per sweep

The file data would follow directly below the array header.

The following is an example of a Model 251 I-V Test Software compatible ASCII format file. It assumes the following:

- Four data arrays, showing Vce, Vbe, Ic, and Ib
- Five sweeps
- 101 points per sweep
- Sweeps starting at 0.0V
- Sweep steps of 0.050V

The above file might look like this:

```
{your optional identifying text}
```

```
Model 251 V2.00 ASCII import/export file  
{required string}
```

```
{more optional identifying text}
```

```
Arrays in this file: Vce, Vbe, Ic, Ib, ... {not required}
```

```
Array: Vce, Volts, 5 x 101 {required string}
```

```
0.0000E-1, 0.0000E-1, ... (five columns: 0.000V)  
5.0000E-2, 5.0000E-2, ... (five columns; 0.050mV  
step)
```

```
1.0000E-1, 1.0000E-1, ...
```

```
1.5000E-1, ...  
(next 97 points) ...
```

```
Array: Ic, Amps, ... {third array}
```

Note the commas following each field in the three headers and the data arrays.

There is a complete ASCII format file in the test library which contains a full set of data. From your ASCII editor or word processor, load NPN.ASC to check out the full file. Since this is a library file, make sure you back it up, or copy it to a disk, before using or modifying it.

This file format, as shown, is flexible to allow you to put other necessary information in the file. Therefore, you may put text or other identifying information before the array headers, or at the beginning of the file. This information will be ignored because the system recognizes only the prescribed strings in the specified order. Until these are matched, the system does not recognize data.

Therefore, the system recognizes only contiguous sets of data that immediately follows the third specified string.

When data are imported, you will be asked if you wish to clear all existing data arrays. If you respond with "yes", a new set of data are imported into the file you specify (Filename.ASC). If you respond "no", imported data are appended to the end of the specified ASCII file. If the named file already exists, you will be asked for permission to overwrite. You may accept or refuse file overwrite.

During import/export, you may abort the procedure at any time, by pressing <Esc>. If import/export is aborted,

the system will complete the operation for the array it is working on, then display an error message. All arrays being imported/exported will appear in the appropriate file up to, and including, the one being imported or exported at the moment <Esc> was pressed.

The above information applies only to the ASCII format file. However, whether you wish to import/export ASCII or LOTUS format files, the file operations procedure is the same.

An example ASCII format file is shown in Figure 5-3.

```

Model 251 V2.00 ASCII import/export file

Arrays in this file:
Vce      , Ic      , Ib      , Vbe

Array: Vce , Volts , 5 x 101
0.0000E-1 , 0.0000E-1 , 0.0000E-1 , 0.0000E-1 , 0.0000E-1
5.0000E-2 , 5.0000E-2 , 5.0000E-2 , 5.0000E-2 , 5.0000E-2
1.0000E-1 , 1.0000E-1 , 1.0000E-1 , 1.0000E-1 , 1.0000E-1
1.5000E-1 , 1.5000E-1 , 1.5000E-1 , 1.5000E-1 , 1.5000E-1
2.0000E-1 , 2.0000E-1 , 2.0000E-1 , 2.0000E-1 , 2.0000E-1
...

Array: Ic , Amps , 5 x 101
-1.6000E-5 , -2.2000E-5 , -3.5000E-5 , -4.2000E-5 , -5.5000E-5
-9.0000E-6 , -1.6000E-5 , -1.6000E-5 , -2.2000E-5 , -1.6000E-5
1.6000E-5 , 4.9000E-5 , 9.4000E-5 , 1.5300E-4 , 2.1800E-4
1.4600E-4 , 4.0600E-4 , 7.1100E-4 , 1.0620E-3 , 1.4060E-3
6.4000E-4 , 1.5360E-3 , 2.5030E-3 , 3.4510E-3 , 4.3600E-3
...

Array: Ib , Amps , 5 x 101
1.0000E-5 , 2.0000E-5 , 3.0000E-5 , 4.0000E-5 , 5.0000E-5
1.0000E-5 , 2.0000E-5 , 3.0000E-5 , 4.0000E-5 , 5.0000E-5
1.0000E-5 , 2.0000E-5 , 3.0000E-5 , 4.0000E-5 , 5.0000E-5
1.0000E-5 , 2.0000E-5 , 3.0000E-5 , 4.0000E-5 , 5.0000E-5
1.0000E-5 , 2.0000E-5 , 3.0000E-5 , 4.0000E-5 , 5.0000E-5
...

Array: Vbe , Volts , 5 x 101
4.6066E-1 , 4.8844E-1 , 5.0510E-1 , 5.1729E-1 , 5.2700E-1
5.1084E-1 , 5.3848E-1 , 5.5521E-1 , 5.6719E-1 , 5.7704E-1
5.6017E-1 , 5.8767E-1 , 6.0419E-1 , 6.1616E-1 , 6.2573E-1
6.0681E-1 , 6.3346E-1 , 6.4926E-1 , 6.6068E-1 , 6.6975E-1
6.4324E-1 , 6.6783E-1 , 6.8215E-1 , 6.9271E-1 , 7.0093E-1
...

```

Figure 5-3. Model 251 V2.00 ASCII Import/Export File

SECTION 6

Test Sequencer

6.1 INTRODUCTION

This section contains information on the operation of the Test Sequencer portion of the Model 251 I-V Test Software system. Section 6 is organized as follows:

- 6.2 **Test Sequence Overview:** Provides an overview of the sequence operation and gives a basic look at the procedures for using the sequencer.
- 6.3 **Test Sequence File:** Shows the format of the test sequence file and explains the syntax details for creating an executable test.
- 6.4 **Parser:** Explains parser functions and how it helps the operator build a working test file. Parser errors are also explained.
- 6.5 **Error Files:** Explains error file management and how to understand error messages.
- 6.6 **Sample Test Sequence:** This section takes you step-by-step through the creation of a sample test sequence file.

6.2 TEST SEQUENCER OVERVIEW

The test sequence file is an ASCII file which you create with an ASCII editor or a word processor with ASCII ca-

pability. The Model 251 I-V Test Software does not support this editing process.

In the following paragraphs the descriptions and definitions will be provided to show an accurate technical overview of the commands, parameters, files, and operations of the system. Following that will be some techniques that will enhance the way you work with the system.

The test sequence file will be loaded in the normal manner from the File Operations menu at the main menu. The file may be named anything you wish, but it must end with the SEQ extension. The SEQ file will reside in the sequence subdirectory (C:\MODEL251\SEQ by default).

When you have written and successfully loaded the SEQ file, you will be given three options:

- Execute the test sequence file with <F10>.
- Parse the file to detect syntax errors with <Enter>.
- Abort the test sequence with <Esc>.

If execute is chosen, the system will attempt to execute the file. The user may halt execution with <Esc>. This may or may not cause immediate system halt, depending on where the system is currently operating. It must complete the current operation first.

The system checks for <Esc> during sequencer operation at the same points it does during interactive operation, plus between sequence commands.

NOTE

If a Loop command is being executed when the <Esc> key is pressed, EXIT Loop is an option.

If the execution attempt is unsuccessful, an error message is displayed (if the STOPONERROR metacommand is set) and you are given a chance to continue or to abort the sequence. If STOPONERROR is not set, the error is logged to a file and the sequencer continues.

The sequencer can be run unattended by setting the UN-ATTENDED metacommand. In unattended mode, the system runs without stopping for errors or prompts. Pause is overridden and errors are logged to a file.

Attended and unattended mode operation are discussed in paragraph 6.3.3, META Commands.

6.3 TEST SEQUENCE FILE

A test sequence file increases the system operating modes to a total of three:

- Interactive, without sequencer
- Attended sequencer
- Unattended sequencer

In the attended or unattended operating mode of the test sequencer, a warning message will be displayed for two seconds if a test uses remote sensing.

WARNING

With remote sensing enabled, an open sense lead will result in lethal voltages appearing at OUTPUT HI and GUARD of the source measure units. This voltage can cause injury or death, and damage external circuitry. Always make sure that the sense leads are properly connected before enabling remote sense. NEVER change connections with power applied. Be sure to always discharge and/or disconnect external power sources.

A test sequence file has a specific format. However, not all types of information are used every time.

A test sequence file can be of any length. File size limits are dictated by disk space, only. The file has the following general layout:

- META command
- LOOP . . . ENDLOOP command
- CONFIG command
- TEST command
- 707FILE command
- PROMPT command

Note that each command identifier may be shortened to three letters or more.

Either a TEST command or a 707 command must be present for the system to perform a meaningful process.

META commands are not required, but if they are present, they must appear as the first non-white space line used. If the 707FILE command is used, a relay setup must have been uploaded previously from a Model 707 and saved to a 707 file, or an existing 707 file must have been created on a disk.

6.3.1 Test Sequence Grammar

The test sequence file has the following grammar:

METACOMMANDS: STOPONERROR, MAXERRORS = n, OVERWRITE, AUTOREPEAT-OK, UNATTENDED

LOOP: (nnnnnnn) . . . ENDLOOP

CONFIGURATION: filename

TEST: filename, ASCIIFILE = filename, DATAFILE = filename, LOTUSFILE = filename, NOEXECUTE, PRINT, PLOT, PAUSE, REPEAT = nnnn

707FILE: filename

PROMPT: "Optional prompt text."

The syntax is composed of the following elements:

- Fields
- Tokens
- Commands
- Parameters
- White space

Tokens are non-splittable constructs. Parser recognized tokens are:

- Filenames
- Commas (,)
- Colon mark (:)
- Equal mark (=)
- Quoted strings
- The number n
- METACOMMANDS
- STOPONERRORS
- MAXERRORS
- OVERWRITE
- AUTOREPEAT-OK
- UNATTENDED
- LOOP...ENDLOOP
- CONFIGURATION
- TEST
- DATAFILE
- ASCIIFILE
- LOTUSFILE
- PROMPT
- NOEXECUTE
- PRINT
- PLOT
- PAUSE
- REPEAT
- 707FILE

NOTE

All keyword tokens may be shortened (three letter minimum).

Fields within a command are separated by commas. Notice in the section on grammar that each command is separated by white space.

White space can be any of the following:

- Space
- Tab
- Line feed

- Form feed
- Carriage return
- Comments

Comments may appear anywhere, but with the following considerations:

1. Any comment begins with an exclamation mark (!).
2. Anything to the right of the ! is considered a comment until the end of the line.

White space may precede any command/parameter field, and may follow any comma. Here is an example of a correct META command:

```
META: STOP, MAXERRORS=14,
```

```
OVERWRITE
```

Here is an incorrect version of the same command:

```
META : STOP , MAX ERRORS = 14
```

```
OVERWRITE
```

There are two errors in the previous command. The token MAXERRORS should not be split with white space and there should be a comma after the "4".

When the parser comes to the end of a recognizable command field, it expects to see one of three things:

- A comma followed by a recognized parameter
- White space followed by a recognizable command (TEST, CON, 707, or PROMPT)
- White space, then the end of the file

Without the comma, the parser expects the next field to be a command, such as TEST, LOOP, or PROMPT. Thus, the parser becomes unsynchronized. Therefore, from that error point, the parser will not understand anything until it reaches something to put it back in synchronization.

If the error is detected within a META command sequence, the parser will attempt to find a correct sequence for the rest of that command. If it is within one of the other command fields, it will ignore all tokens that follow

commas, until the first token that does not follow a comma.

- 707FILE
- CONFIG
- PROMPT

Strings may contain white space. Everything within a pair of double quotation marks is viewed as a single token. Within a string, a pair of double quote marks (""") is viewed as a literal double quote mark.

A command must start with one of the six keywords listed below:

- META
- LOOP... ENDLOOP
- TEST

NOTE

All commands must be followed by colon (:); all command parameters which use filenames or counters (ASCII, DATA, LOTUS, MAXERRORS, REPEAT) must be followed by an equal sign (=).

Here is an example using the correct statement above:

```
META: STO, MAX=14,      ! the OVER command may be on this line
      OVER              ! or this one
                        ! note that not all of the command name
                        ! is required; in fact, only the first
                        ! three letters are necessary.
                        ! comment alignment is not required

TEST: myfile.tst, mydata.dat

                        ! note that white space is ignored,
                        ! so comment as required to make the
                        ! file readable

PROMPT: "He said, ""anything in paired double quotes is a literal"" "
"" ""quote"           ! balanced quote marks
                        ! are not required
"but there is a limit of 8 prompt lines"
"and this is the fourth one."
```

Keep in mind, the parser does not see "lines", (it is not line based). It sees white space, commands, command parameters, prompts, and delimiters. Also, as with other software, comments are for your purposes and will not print to screen except during ASCII file editing.

The system looks at prompts this way:

- The prompt window is 60 characters wide.
- Lines will be wrapped to the next physical line at character position 61.
- The window will hold eight lines; excess lines will scroll out of the window.
- The total prompt character length is 255, regardless of the actual number of lines used. The window's total space of 480 characters (60x8) is there to allow some flexibility in laying out the prompts for clarity.

The LOOP...ENDLOOP function is designed to contain any part of the test sequence file within its boundaries, with two exceptions:

- META commands, which must appear first and only once.
- REPEAT = nnn

REPEAT = nnn and LOOP...ENDLOOP are mutually exclusive. Thus, a TEST command may not specify a REPEAT >1 if TEST command is in the LOOP...ENDLOOP command. REPEAT = 1 is the default and can be in a loop.

6.3.2 Message Screens

When a test sequence is operating, the system will flash brief message screens showing one of the following:

- A test, data, 707, or configuration file has been loaded
- Or, a data file has been saved

Also, it will show a number that corresponds to the test line it was on when it displayed the screen. When executing commands in a loop, it will also show the loop iteration counter.

6.3.3 META Commands

META commands are the global commands for the test sequencer system. The following guidelines apply to these commands:

- META commands are not required in a file.
- The META command must be the first command in a file, if used.
- All META commands must be stated together; once the initial sequence of the META command and the listed parameters is completed, no more META commands may be stated in that file.
- All commands and parameters (including META), may be stated by using the first three letters of the name, at a minimum.

The five META command parameters are:

- | | |
|-----------------|-----------|
| • STOPONERROR | (STO) |
| • MAXERRORS=nnn | (MAX=nnn) |
| • OVERWRITE | (OVE) |
| • AUTOREPEAT-OK | (CON) |
| • UNATTENDED | (UNA) |

STOPONERRORS is a flag that allows the software to halt whenever the system encounters an error condition. The system displays an error screen and pauses for operator intervention. Enabling this flag (default is disabled) usually limits the system to attended operation.

The exception is that the UNATTENDED metaccommand overrides the STOPONERRORS command, setting that flag to false. Errors will be logged to an error log file, but the system will not stop for errors.

If STOPONERRORS is not specified, and the system is in attended mode, the system will log any errors to a file called 251ERROR.LOG, and will continue without waiting for operator permission.

MAXERRORS=n specifies the maximum number of parsing and execution errors permitted when STOP is disabled. The permissible range is from 0 to 32767 errors. Setting n to 0 disables the limit checking sequence. This allows an unlimited number of errors. Zero is the default.

OVERWRITE allows the sequencer to overwrite data files without warning the operator. The sequencer will never overwrite files, even in unattended mode, unless this flag is set.

AUTOREPEAT-OK allows continuous execution if a test or data files calls for AUTOREPEAT. This operation will continue until the software encounters an <F10> or

<Esc> command. AUTOREPEAT-OK disabled is the default setting.

UNATTENDED is the META command parameter that provides a shortcut from attended sequencer to unattended sequencer mode.

Since the Model 251 I-V Test Software does not demand any particular sequence in listing the META command parameters, it is strongly suggested that you insert the UNATTENDED parameter, as a matter of course. It may be commented out (!), easily. The only change required to change this file from attended sequencer to unattended sequencer operation (vice versa), is to insert or delete the !.

To implement this, place the UNATTENDED statement on its own line of the META command string, so the comment will work without disabling other parameters.

NOTE

The above procedure, commenting out commands, works for all command parameters. Therefore, it is advantageous to place all command fields on individual lines, so that commenting them out is simplified. A detailed explanation is provided, along with specific formatting, in paragraph 6.6, Sample Test Sequence.

The UNATTENDED command does the following:

- Sets STOPONERROR to false; disables STOP.
- Disables all PAUSE parameters of TEST commands.
- Skips over all PROMPTS.
- Sets AUTOREPEAT-OK to false.

6.3.4 TEST Command

Although the test sequence file does not require any specific information, a TEST command or a 707FILE command must be present for the system to perform any meaningful process. The minimum required command format is:

TEST : <filename>

and/or

707FILE : <filename>

Any other parameters associated with the TEST command can follow in any order, although some preferred techniques will be shown later in this section.

Syntax must be correct, regardless of the order of instruction.

There may be as many TEST command sequences in the TEST.SEQ file as needed.

Although the TEST command parameters may follow in any order, the software system executes in a specific order. The order of execution is:

- GPIB Line 1
- Execute Test
- Display Data Results
- Pause
- Print
- Plot
- Save Data File

This sequence will repeat only if the REPEAT parameter is specified in the TEST command, and the iteration count must be >1 (1 is the default).

The sequence from GPIB Line 1 to Save Data File will always execute in the given order, although one or more steps may be skipped.

GPIB Line 1 refers to the first line in the GPIB OUTPUT form, which you access from the Curve Family Test Form or DC Source-Measure Test Form, via <F5>. This line is sent automatically when filled in.

Execute Test performs data acquisition. This step is skipped if NOEXECUTE is specified.

Display Data Results means the system will display the appropriate screen at this point. The sequencer will always display the screens, regardless of whether you are running the attended or unattended mode. The display will be a graph or list as specified in the DISPLAY PARAMETERS form. This step cannot be skipped.

Pause (when specified) will temporarily halt execution until the operator signals to continue or abort. A single line, generic prompt will display at the top or bottom of the screen. Pause will be ignored if the UNATTENDED metacommand was specified.

Print will send the data display to the printer, if specified.

Plot will send the graphics output to the plotter, if specified.

Save Data File will save the data in a Model 251 .DAT file, an ASCII file, a Lotus file, or any specified combination.

Depending on the number of repeat cycles set, the system may repeat this sequence.

Figure 6-1 shows the sequencer flow, which depends on whether or not NOEXECUTE is set in the TEST command section.

Test

TEST : must be followed by a filename and must appear as the first field in this command. The filename must have an extension of either TST or DAT (.TST is the default).

ASCIIFILE = is optional, but when used, it must be followed by a filename. The ASC extension is assumed by default. No other extension may be appended to ASCII = files, or an error is generated.

DATAFILE = is optional, but when used, it must be followed by a filename. The DAT extension is assumed by default. No other extension may be appended to DATA = files, or an error is generated.

LOTUSFILE = is optional, but when used, it must be followed by a filename. The WK1 extension is assumed by default. No other extension may be appended to LOTUS = files, or an error is generated.

NOEXECUTE is optional. It specifies NOT to execute the TEST and GPIB, even if the proper forms are filled out. This allows you to load a DAT file, with option to print or plot the data, only. This is useful for printing or plotting data in unattended mode.

PRINT is optional. If used, data are printed. The operator can specify, from the GRAPH DISP form, to display either a graphic version of the data, or simply a listing of data points. Either type of data may be printed.

PLOT is optional. Plotting data is limited to graphic presentation. You must have selected GRAPHICAL DISPLAY before loading the file. An error results if LIST was specified on the DISPLAY PARAMETER form.

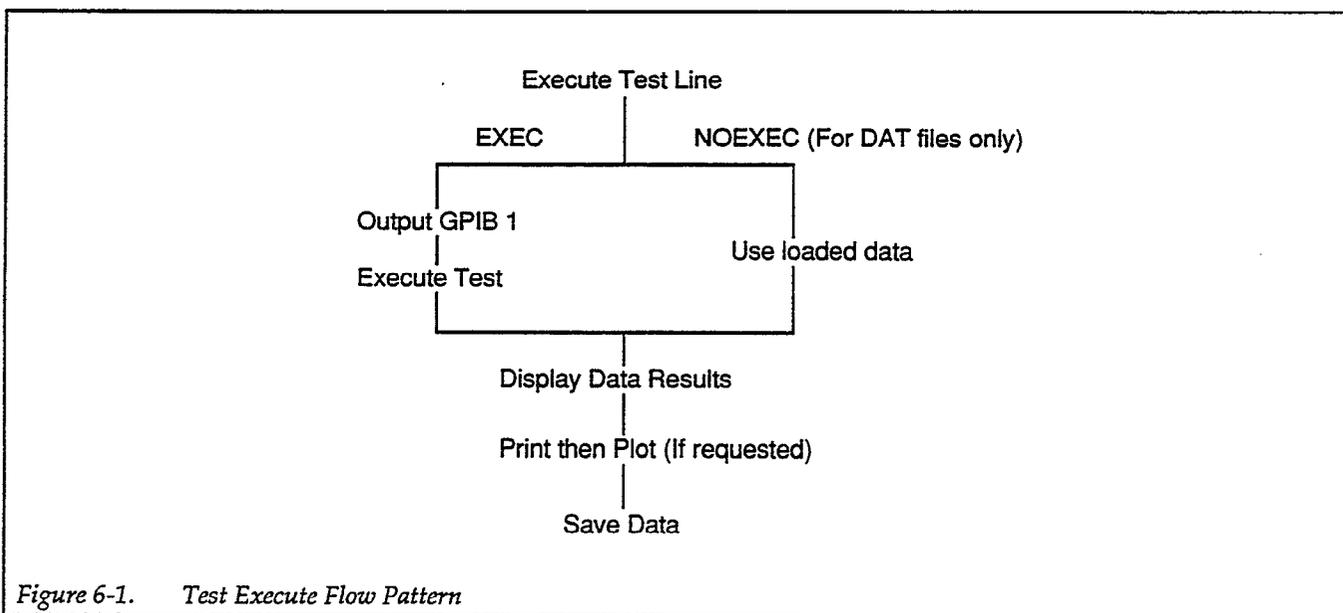


Figure 6-1. Test Execute Flow Pattern

PAUSE is optional. PAUSE will temporarily halt execution. When UNATTENDED metacommand is specified, the PAUSE parameter is ignored. During PAUSE, the operator is given the choice of continuing execution, or aborting the test.

REPEAT = (nnn) is optional. This parameter tells the system to repeat this test <n> times. The repeat range is from 1 (default) to 999 times. The default is operative if the statement is omitted. An error is generated if <nnn> is <1 or >999. A REPEAT iteration count >1 may not be used within a LOOP...ENDLOOP command.

NOTE

REPEAT is slightly faster than LOOP. .
.ENDLOOP, because the <TEST :> file is loaded once only.

6.3.5 LOOP...ENDLOOP Command

The LOOP...ENDLOOP command provides a powerful method for repeating a group of various commands in a TEST file and all the attendant features surrounding it (PROMPT, 707, CON, etc.).

NOTE

META commands may not be specified within a LOOP...END command.

LOOP is a control flow command, and, as such, it looks for the logical END command. This allows one potential problem: it will view everything as a valid loop statement until it reaches the END command, or the end of the file. Thus, if ENDLOOP is not found, it will not perform any iterations. Also, if it sees another LOOP command, before it finds an ENDLOOP command, this will appear as an attempt to nest LOOP commands, which is not permitted and a nesting error message will be generated.

The structure of the command is as follows:

```
LOOP : nnnnnnn  
  
Other commands  
  
END (LOOP)
```

First, notice the seven n's following the logic command LOOP. These n's represent a figure up to 9,999,999; the maximum number of loops you may specify. Thus, with this command it is possible to run a test, or sequence of tests, almost ten million times without operator intervention.

The primary thing to watch for is that any legal filename may contain only eight characters, so multiple passes through the test will produce restrictions on the possible filenames.

For example, you choose to run the maximum number of loops, but you want to save each data file from each run. The procedure then must take into account that you want to save 9,999,999 files with different names. The loop will either overwrite the same files or create new files for each iteration.

To save data for each iteration, the system requires the operator to place one or more pound (#) characters in the filename, to allow the loop counter to insert iteration numbers. The pound character will be replaced by the loop iteration number, thus creating a unique file name for each loop. Therefore, to run 1,234 loops, you would have to place four "#s" in the filename.

If you were running a test 1,234 times, and saving each data file, the format for the data filename would like this:

XXXX####.DAT

where XXXX is the allowable character space that you would use for the filename. The #### would be the area used by the system to insert a number showing the loop iteration count.

Assuming you wish to test a wafer 1,234 times, you might name the original file

WAFR####.DAT

Thus, the data filenames, when you retrieve them from the data library, would look like this:

```
WAFR0001.DAT (loop one)  
WAFR0002.DAT ... (loop two)  
WAFR0101.DAT ... (loop 101)  
WAFR1234.DAT (loop 1,234)
```

The system does not require that the # sign be located in any particular position within the eight character spaces. The only requirement is that the # signs are contiguous.

Therefore, the following format is equally correct:

```
XXX####Z.DAT
```

A second option allows you to use all eight character spaces for a normal style filename, eliminating all pound signs. This will prevent the system from inserting an incremental iteration number. This makes the system attempt to overwrite the file, so OVERWRITE must be set to true or an error will result.

Assume that you want to run a diagnostic on several similar devices to look for a specific device that matches characteristics which you pre-defined. This option allows you to run numerous tests without saving data until you find the device that matches your specifications.

To find the specific device, use the following procedure:

- Set the OVERWRITE flag
- Comment out the UNATTENDED command
- Create an appropriate PROMPT to allow the system to halt after each iteration
- Use <Esc> only when system halts and the display shows data to match your desired specifications
- The saved data file contains the specifications you want

This feature is available only from the LOOP command. The REPEAT command always creates new data files.

If the loop function were used without regard to the possibility for error, and you ran 1,234 loops, the system would generate 1,234 error messages for a single syntax or execution error.

Therefore, it is recommended that the PARSE ONLY function be selected before any attempt is made to execute a test. The parser does not loop when checking for syntax, so it will generate only one set of parser errors when set for parsing only, no matter how many times the loop is set for.

However, the run-time execution errors could mount up, if there are several execution errors. Therefore, it is advantageous to run a short sample test loop to check for execution errors.

Initially then, it is recommended that the loop function be set to 2, so that only two sets of error messages are generated during a trial run-through. Two iterations is the smallest number of loops which will check for overwrite conflicts.

It is a simple matter to change the loop number to the desired number after the trial execution. The structure of the filename for the data you want to save doesn't affect the parser or execution errors, as long as the name accommodates the number of specified loop iterations, as described above.

Keep in mind, if the loop command does not see the ENDLOOP directive, it will not iterate and an error message will be generated.

It is recommended that you always write the loop command by combining the front and back of the command at the very beginning. You may avoid problems if you write the command this way:

```
LOOP : (nn..n)
ENDLOOP
```

And then insert whatever you want in the space between the numbers and ENDLOOP. That way, you will not forget to end the command.

The LOOP. . .ENDLOOP function is designed to contain any part of the sequencer file within its boundaries, with three restrictions:

- META commands, which must appear first and only once, may not be included in a LOOP statement.
- LOOP functions may not be nested.
- REPEAT = nnn and LOOP. . .ENDLOOP are mutually exclusive if REPEAT = NNN is greater than 1 (the default).

That is, a TEST command within a LOOP may not specify a REPEAT nnn statement when nnn >1. An error message will be generated.

You may specify any number of TEST commands outside a LOOP statement, and the attendant REPEAT = NNN parameters may contain any legal value.

LOOP is more powerful than REPEAT. LOOP permits you to choose whether you will increment the saved data filename (XXXX####.DAT) or you may choose to OVERWRITE files. However, LOOP is slightly slower than REPEAT when iterating one TEST only, because LOOP loads the file for each iteration.

Choose LOOP over REPEAT:

- When you need to repeat commands other than TEST
- For high iteration rates (>999).
- When you need to execute more than one TEST.

Choose REPEAT instead of LOOP:

- When only one TEST is repeated, and for <1,000 iterations.
- For faster iteration

The placement of LOOP within the test sequence file is arbitrary, except that it must come after any META command string. The number of LOOP commands in a sequencer file is not restricted, but they may not be nested. A LOOP . . .END command may be followed by other commands, or another complex LOOP . . .END sequence.

6.3.6 CONFIG Command

CONFIG loads a new instrument configuration file. This file remains in effect for the duration of the sequencer execution, or until a new configuration file is loaded. The last configuration file loaded remains in effect following sequencer execution.

CONFIG does not effect the default configuration filename in MODEL251.CFG. If CONFIG is not specified in the TEST sequence file, the default configuration file specified in MODEL251.CFG or the previously loaded instrument configuration file is used for the entire test sequence.

6.3.7 PROMPT Command

PROMPT may occur anywhere in the test sequence file. The operator may use a maximum of 255 characters for any prompt string. Message lines are limited to sixty characters.

The prompt screen may contain up to eight lines, keeping in mind that the parser will read from the first double quote mark to the next double quote mark and regard this as a single line. The following rules apply to parsing strings:

1. Strings are enclosed by double quote marks.
2. A pair of double quote marks within a string is treated as a literal double quote mark.
3. A pair of double quote marks outside a string is treated as a null (blank line).

Failure to observe line length or number of lines, will cause text to scroll off screen, with the resulting loss of prompt information. A parser error message will be generated when the total number of prompt characters exceeds 255. Lack of an intended ending double quote mark may cause the parser to get out of synchronization temporarily.

The structure of the prompt screen is:

- Sixty character window width
- Eight line window height
- 255 character total prompt length
- Automatic character-wrap to next line at 61st character
- For each prompt, add two system characters (for <CR> and <LF>) to total prompt count
- A single prompt may take first full 255 characters or be spread randomly over eight lines

Although the prompt window reserves space for 480 characters (60x8), you are limited to 255. The 255 character limit allows you to place prompts in any fashion, thus making the prompts more readable.

The 255 maximum includes carriage returns <CR> and line feed <LF> characters for each line. Be sure that you add two characters to every prompt line length to count to the actual number of characters between the quote marks.

This is an example of the way the system looks at prompts:

```

"This prompt contains 37 characters." "" ""11 here""
""
"This line takes 30 characters."

```

Notice that the example contains a pair of double quote marks without a space, like this: "".

The "" is a null string and it causes a blank line to be inserted. Don't confuse this null string with the paired quote (") marks used inside a quote string. Inside the

string, these paired double quotes indicate a literal quote character. Compare prompt two, line three, of the example below, with the same statement above (""11 here"). In this case, the whole prompt is a literal string quote, so the string prints with quote marks surrounding it. The other prompts don't print with quotes.

Since the system sees each consecutive pair of double quote marks as a prompt line, and a null string as a blank line, the example creates five prompt lines; three messages and two blank, separation lines.

The above example will print this way:

<i>This prompt contains 37 characters.</i>	<i>(prompt one, line one)</i>
""11 here"	<i>(null prompt, line two)</i>
"	<i>(prompt two, line three)</i>
"	<i>(null prompt, line four)</i>
<i>This line takes 30 characters.</i>	<i>(prompt three, line five)</i>

The total character count is the actual number of letters, numbers and spaces, plus two system characters for each prompt. The quote marks that define the prompt string do not count. Therefore, the total count in the example is: 82 (35+2, +2, 9+2, +2, 30). The last line will not have the added characters (CR and LF).

6.3.8 707FILE Command

This command is the Model 707 relay setup file that is to be downloaded. If this file is specified, Model 251 I-V Test Software will download the file information, using the <DOWNLOAD to 707> command of the GENERAL GIPB OUTPUT form. The GPIB commands in the specified file will be sent over the IEEE-488 bus.

Several features inherent in this command provide powerful enhancements to the Model 251 I-V Test Software system. The major feature is that the system will operate in two ways when it is operating with the 707FILE command.

First, the system recognizes the KI707 when listed on the DEFINE INSTRUMENTS form. This means that the system will perform handshaking, instrument checks, and other bus functions when the table specifies a KI707 as the instrument type.

The second method is when a 707 file specifies an instrument which is defined as a non-KI707 in the instrument table. In this case, the system sends the GPIB commands in the file to the specified instrument, with no Model 707 handshaking.

This blind acceptance and the fact that no instrument checks are performed, makes it possible to control non-707 instruments. This means that you may put virtually any GPIB commands in the 707 file and the software will send the file contents over the bus to whatever instrument is there.

Operation of the Model 707 in this system are detailed in paragraph 3.7. Included in that material are the details on using the 707 file to operate non-707 instruments.

The file format for a 707 file is:

- First line must be instrument name defined on the DEFINE INSTRUMENTS form.
- Remainder can contain any GPIB command, and may include binary data.

However, keep in mind, a Control-Z (^Z, hex 1A) is interpreted as an end of file (EOF) character when it is the last character in a file. Control-Z within a file is accepted as binary data.

Parser

6.4 PARSER

The parser is the interface between the test sequence file and the auto sequencer portion of the Model 251 I-V Test Software system. The parser interprets commands from the test sequence file and puts the commands in a format that can be executed by the auto sequencer.

The parser operates in two modes. One is the parse only mode, which can check syntax without executing the file. The other is execution mode.

The Model 251 I-V Test Software allows the LOOP ... ENDLOOP command structure, which makes it important that the parser be used prior to test execution.

For example, if the LOOP...ENDLOOP function were set to perform 1,000 iterations, any syntax errors inside the logic loop would generate 1,000 syntax error messages. Therefore, it is recommended that the operator run the parser in the parse only mode prior to executing a test sequence.

Further, it is recommended that the LOOP...ENDLOOP function be set for an initial execution loop of two passes, only.

After the parser has checked for syntax errors, and the operator has corrected these errors, a trial run of two passes can be performed. If these do not generate execution errors, and do not create file overwrite conflicts, the loop iteration number can be set to the desired figure.

The parser in the Model 251 I-V Test Software system operates the same way other language parsers do, but it is useful to have a basic knowledge of its operating methods.

Assuming the parser is set for parse only mode, the method used to check for syntax errors is:

- Open the test sequence file and find the first recognizable command.
- Generate, and present, any applicable syntax errors, indicating the type of error and its line location.
- Find the next recognizable command string.
- Repeat this sequence until end of file is reached.
- Close the file.

If the test sequence file is being executed, the parser uses a different procedure, as shown here:

- Open the file to the previously saved location or start of file, and obtain a command.
- If an error is found, report or log error until a valid command is found.
- Save location of end of command.
- Close the file.
- Pass information to the processor, which will execute the command.

- Repeat until the end of the file is reached.

Since the parser is merely passing information to the processor, without regard to the order of presentation, the order of execution is fixed. Execution order is discussed in paragraph 6.3.4, Test Command.

6.5 ERROR FILES

The software logs two types of errors to the error file:

- Syntax errors
- Execution errors

Errors found during a parse only check will be syntax errors only.

Errors found when executing the test sequence file may be both parser and execution errors.

Each type of error will be identified according to specific type.

NOTE

If STOPONERROR is set to true, all errors will be sent to the screen, rather than to an error log file.

Parser and sequencer error messages, and their definitions, are given in Appendix B, Error Messages.

6.6 SAMPLE TEST SEQUENCE

This section will show you how to run the following sample test sequences:

- NPN curve test with beta
- NPN curve test
- Non-executed test that displays data only

The test equipment required is:

- Two source measure units

- Trigger controller
- Model 8006 or equivalent test fixture
- Appropriate cables

The files you use will come from the test library, which is resident in the Model 251 I-V Test Software system. The procedures for loading, creating, and implementing these files are described in Section 3.

Test Sequence File

This next section will help you become familiar with the test sequence file.

Creation of this sample test sequence file is based on the following assumptions:

- You have the necessary equipment (listed above).
- You have the requisite semiconductor devices to test.
- You have already installed and configured the system according to Section 2, Getting Started.
- You have a text editor or word processor that will create an ASCII file.

Setting Up the Instruments

In setting up this test, feel free to use equivalent devices or make any changes, as long as you compensate for hardware or electrical differences.

Connect the system as shown in Figure 2-1, Block Diagram of Test System with Model 251 I-V Test Software.

Creating a Test Sequence File Template

This section will show you how to create a boilerplate, or template, that can be used as the basis for creating your own test files. If your text editor or word processor has sufficient capability, you can import this file to a new blank file and create a fully operational test sequence file without having to write everything from scratch.

From your text editor or word processor, open a ASCII file and name it MYSEQNCR.TST, or some other unique name of your choice.

Start the file as follows:

```
META :
  STOPONERROR,
  OVERWRITE,
  AUTOREPEAT-OK,
  UNATTENDED,
  MAXERRORS = 0
```

It is suggested that you indent command line parameters five or six character spaces. Note that MAXERRORS=0 is the default, so this line serves as the last parameter, which is always present.

The order of the parameters between META and MAX is up to you. The reason for this layout is to allow you to comment out any combination of parameters, except MAX = 0, and still have a legal, operating META command.

The principle is this:

Put a ! at the left of any parameter that you do not want to use in the existing test file. Since the parser sees everything to the right of the ! as white space extending to the end of the line, that command parameter becomes transparent to the processor. Leaving MAXERRORS = 0 (the default) at the end produces a final statement that is actually a NOP. That means that nothing happens when that statement is used, but its presence fulfills the parser requirement that the last parameter must not have a comma at the end. If a comma followed the MAX statement, the parser would generate an error. Keep in mind, anytime you wish to set MAXERRORS to a higher number, simply replace the zero with the desired number.

The next part of the test sequence file will be the CONFIG : command. Although the system does not require that CONFIG be placed here, it is suggested that you place a configuration file prior to a test sequence to ensure that the instruments are correctly set up before execution.

You may find that within a LOOP sequence you may have several CONFIG setups in various positions. You may find that you need one in other positions, as well.

Next, leave a couple of free lines below the MAX statement, and indent to insert the TEST command sequence. Again, lay out the command, and its six associated pa-

rameters, in the same manner as you did with the META command sequence. The difference between the META section and this TEST section is that you want to make the REPEAT = 1 parameter the last one. The reasoning is the same as for the META sequence, but in this case REPEAT=1 is the last parameter. The sequence of the middle parameters is optional, again.

NOTE

The default for the REPEAT parameter is 1 (one). Since this is the default, its presence within a LOOP statement is permitted. Keep in mind, REPEAT may not be zero, or a parser error will be generated, and, within a LOOP, a number >1 causes an error because it is not the REPEAT default.

At this point, you should have a file that is similar to the following:

```
META :
  ... (your sequence of parameters)
  MAX = 0
CONFIG :
TEST :
  ...
  REPEAT = 1
```

The next section of the test sequence file is going to be the LOOP command statement. This statement may include anything you wish, except for the META command sequence, or a REPEAT parameter with a iteration number other than 1.

Add the LOOP statement in the way you did with the two statements above. Set the command for 2 iterations (LOOP : 2). At this point, don't add anything inside the LOOP statement boundaries.

Now, move down the file and add the PROMPT command.

Next, add the 707FILE command.

At this point, your file should look like this:

```
META :
  ...
  MAX = 0
CONFIG :
```

```
TEST :  
  ...  
  REPEAT = 1  
LOOP : 2  
  ...  
ENDLOOP  
PROMPT : "Your prompt "" with embedded quotes."" "  
707FILE :
```

This test file can be filled in to run any test sequence operation by simply filling in the details and moving blocks around to suit the requirements. Of course, you may comment out any unused commands, or simply delete them from the actual files you create with this boilerplate.

Test Sequence File with Loops and Repeats

In this section, you will view a sample test sequence file from the test library. You may run it if you wish. You may import the file to your ASCII editor or word processor

and modify the file before running it. It is strongly suggested that you make a backup copy of the original library file before you make any changes or deletions. See your DOS instruction manual for details on making backups.

The following file is a slightly modified version of an ASCII library file called: NPNTTEST.SEQ.

This is an example of a test sequencer file. It uses the test files provided in the resident libraries. This sequencer file executes some of the tests; therefore, the instruments must be connected properly, as specified in Section 2, Getting Started.

Below are examples of most of the commands. The unused commands and parameters are commented out with a "!" at the left side of the line. All commands are shown in their longest form, but may be shortened to the first three letters of the command name.

```

metacommands:
  autorepeat-ok,      ! Allows continuous execution; <F10> or <Esc> stops.
  overwrite,          ! Allows overwriting of existing files.
  stoponerror,        ! Stops and displays every error; if stoponerror is omitted, errors are
                      ! written to 251error.log.
!  unattended,        ! Don't pause for anything; write errors to log file; not used here.
  maxerrors=0         ! A NOP (default; no effect); must be last META parameter to allow pre
                      ! vious meta commands to be commented out without worrying about
                      ! extra or missing commas. Last parameter may not end with a comma.

Prompt:              "This test will execute several NPN Transistor tests from"
                    "the test library and collect a set of parameters for NPN"
                    "Transistor."
                    "" ! NOP; creates blank line.
                    "The first test will acquire and display NPN Curve"
                    "Family characteristics."

CONFIG:              TESTLIB ! Load the configuration supplied with the libraries.
! Use ruler below to ensure prompt lines are ≤60 characters
!12345678-10-345678-20-345678-30-345678-40-345678-50-345678-6

Prompt:              "Connect NPN Transistor according to the schematics drawn"
                    "in the Appendix D of the Model 251 Manual under"
                    "the NPN Transistor Common Emitter Curve Family test."
                    "The test NPNCRV.TST will be run, and the data will be"
                    "saved in the data file FAMILY1.DAT."

TEST:                NPNCRV,
                    PAUSE, ! At PAUSE, you must tell system to continue or abort; you may want to
                      ! run the actual file, and use these pauses to compare this text file with the
                      ! screen displays and prompts in the library file.
                    DATA=FAMILY1, ! data file FAMILY1 is saved.
! ASCII =           ! ASCII file not used this time.
! LOTUS =           ! LOTUS file not used this time.
! NOEXECUTE,       ! Command is set false (default; will execute).
                    REPEAT=1 ! A NOP (see METACOMMANDS above).

Prompt:              "The next test will acquire data, calculate and display"
                    "the NPN Transistor DC-gain."
                    "The test NPNBETA.TST from the Test Library will now be run."
                    "The data will be saved in the data file BETA1.DAT"

TEST:                NPNBETA,
                    PAUSE,
                    DATA=BETA1,
! NOEXECUTE,
                    REPEAT=1

Prompt:              "The next test will acquire data, calculate and display"
                    "the NPN Transistor Small Signal Gain."
                    "The test NPNHFE.TST from the Test Library will now be run."
                    "The data will be saved in the data file HFE1.DAT"

TEST:                NPNHFE,
                    PAUSE,
                    DATA=HFE1,
! NOEXECUTE,
                    REPEAT=1

Prompt:              "The next test will acquire and display"
                    "the NPN Transistor Forward Gummel Plot."
                    "The test NPNFGUML.TST from the Test Library will now be run."
                    "The data will be saved in the data file GUMMEL1.DAT"

```

```

TEST:      NPNFGUML,
           PAUSE,
           DATA=GUMMEL1,
!          NOEXECUTE,
           REPEAT=1
Prompt:    "The next test will acquire and display the NPN Transistor"
           "Collector Emitter Breakdown data."
           "DISCONNECT THE BASE PIN of THE TRANSISTOR (leave it open)."
Prompt:    "The test NPNBVCEO.TST from the Test Library will be run"
           "two times to show an example of using the REPEAT feature."
           "The data will be saved in BVCEO001.DAT and BVCEO002.DAT."
TEST:      NPNBVCEO,
           PAUSE,
           DATA=BVCEO,      ! Since this test repeats, system automatically makes filename look like
!                               ! this: BVCEO001.DAT and BVCEO002.DAT.
           NOEXECUTE,
           REPEAT=2         ! A valid parameter this time; will execute 2x; therefore, not permitted in
!                               ! LOOP sequence.
Prompt:    "The next test will display NPN Collector Emitter"
           "Breakdown data from the NPNBVCEO.DAT data file."
           "The next two tests will be run two times to show"
           "an example of using the LOOP feature."
LOOP:2     ! This illustrates the use of LOOP...ENDLOOP; any permissible part of
           ! test sequencer file may be inserted here, except a META command and
           ! REPEAT with an iteration number >1.
           TEST:      NPNBVCEO.DAT,
           PAUSE,
           DATA=BVCEO###, ! This file name will allow 999 loops; all #'s automatically replaced with
!                               ! 0's and then incremented.
           NOEXECUTE,     ! Set true; don't want to execute data files.
           REPEAT=1
           Prompt:    "The next test will display NPN Transistor Collector"
           "Leakage data from the NPNICEO.DAT data file."
           TEST:      NPNICEO.DAT
           PAUSE,
!          DATA=ICEO1,
           NOEXECUTE,
           REPEAT=1
ENDLOOP    ! Must locate this command or may create problems
Prompt:    "The next test will acquire and display "
           "NPN Transistor Collector Leakage data."
           "The test NPNICEO.TST from the Test Library will now be run."
           "The data will be saved in the data file ICEO1.DAT".
TEST:      NPNICEO,
           PAUSE,
           DATA=ICEO1,     ! Saves NPNICEO test data as ICEO1.DAT; <.DAT> automatically
!                               ! appended
!          NOEXECUTE,
           REPEAT=1
Prompt:    "This ends NPNTTEST.SEQ. You now have 8 new data files:"
           "FAMILY1.DAT" "BETA1.DAT" "HFE1.DAT" "GUMMEL1.DAT"
           "BVCEO001.DAT" "BVCEO002.DAT" "ICEO1.DAT"

```

The above file shows several combination examples of sequences that may be run, using the test sequence file system. You may wish to call up the test library files called: NPNTTEST.SEQ and NPNDATA.SEQ, and run them to see how the actual prompts, pauses, and so forth, operate.

The test sequence files listed above are fixed so that you need a minimum of cabling, instruments, and DUTs. There is only one modification required in the wiring

during the operation sequence, and you are prompted for that change.

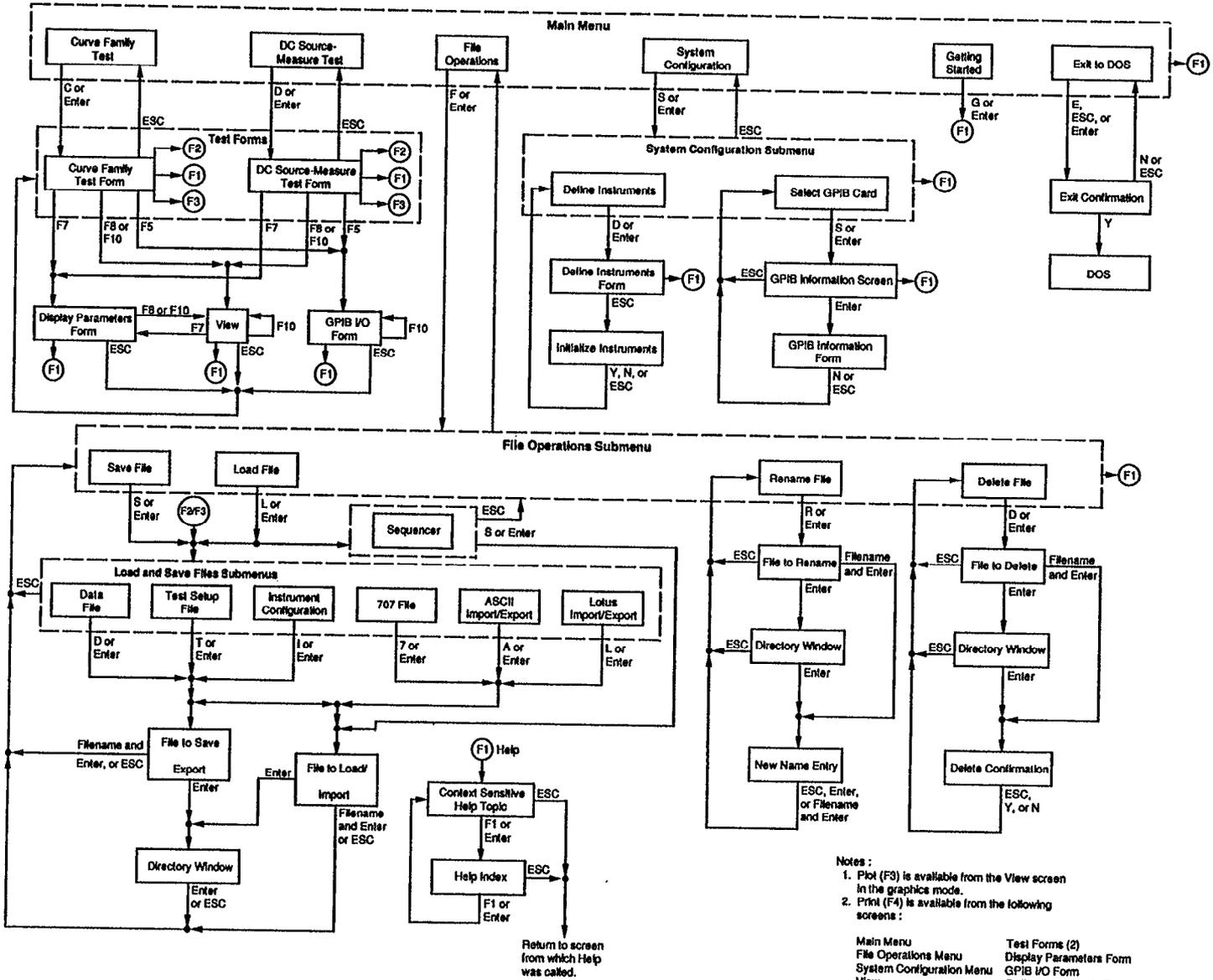
You may use the actual sequence given above, if you import your boilerplate test form into a new file and fill in the appropriate blanks. Or you may modify the two mentioned library files, using your text editor.

You may add a Model 213 and a Model 707 to the system and check them out, as well.

APPENDIX A

Software Structure

Figure A-1 shows the structure of the menus, forms, and windows of Model 251 software.



- Notes:
1. Plot (F3) is available from the View screen in the graphics mode.
 2. Print (F4) is available from the following screens:
- | | |
|---------------------------|-------------------------|
| Main Menu | Test Forms (2) |
| File Operations Menu | Display Parameters Form |
| System Configuration Menu | GPIB I/O Form |
| View | Define Instruments Form |
3. Load File (F2) and Save File (F3) are available from the test forms.

Return to screen from which Help was called.

Figure A-1. Model 251 I-V Test Software Structure

APPENDIX B

Error Messages

Model 251 error messages are, for the most part, self-explanatory. They are listed here, in alphabetical order, with the following format:

Error Message	Type of Test or Operation
<i>Action Taken</i>	

If you encounter an error message with an error number, of the form:

Error nnn – (error message text)

contact Keithley Instruments Applications Department.

A

A matrix setup has been loaded from the 707 and has not yet been saved to disk. Loading a 707 setup file will destroy this information. Press <Esc> to abort and save the matrix setup. Press <Enter> to load a new 707 file.	File Operation
<i>This error can occur when loading or saving 707 files. You are returned to the File Load or Save menu.</i>	

APPENDIX B
Error Messages

A matrix setup must be uploaded from 707 through the GPIB window, or must be loaded from a file on disk, before a 707 file can be saved.	File Operations
<i>This error can occur when loading or saving 707 files. You are returned to the File Load or Save menu.</i>	

A maximum of 8 characters allowed for a file name!	Sequencer Parser
<i>The maximum legal character count was exceeded.</i>	

A null extension is not allowed! Don't specify dot if default extension desired.	Sequencer Parser
<i>A dot ends the filename, but no extension follows the dot. Either delete the dot to allow the system to append the default extension, or specify the extension.</i>	

A number was expected after "token".	Sequencer Parser
<i>A non-digit character was found where a digit was expected. "Token" is replaced with appropriate character (: or =).</i>	

A 707 setup file cannot be saved until a 707 Name is entered in the GPIB form. Even if you do not have a matrix instrument connected at this time, define the name of the matrix instrument in the instrument configuration table, and enter that name in the "707 name" field of the GPIB form.	File Operation
<i>This error can occur when loading or saving 707 files. You are returned to the File Load or Save menu.</i>	

Address not specified for TCU or SMU. Check instrument configuration and make sure all devices have a valid address.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form.</i>	

Array name specified for graph not found. Check array names.	Curve Family Test View Graphics
<i>After this error, you are returned to the appropriate form.</i>	

Array name(s) "name1 & name2" not found in this file: (filename). Check array names in overlay form.	View Graphics
<i>After this error, you are returned to the menu of graphic analysis tools beside the graph.</i>	

Array size of one or more variables not compatible. Run test to make sure all arrays are dimensioned correctly.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form.</i>	

Array size too large. Largest allowable array is 4000 points. Decrease number of points in sweep or number of curves so that the product of the two is 4000 or less.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form.</i>	

Array specified for graph does not contain any data. Check display parameter form.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form. If you are trying to display the results of a DC or differential gain calculation, the array is not filled until after the test has finished. Use auto scaling if you want the results displayed immediately after test.</i>	

Array specified for graph does not contain any data. Run test to ensure arrays in test are filled with data.	View Graphics
<i>You are returned to the DISPLAY PARAMETERS form.</i>	

Arrays specified for graph are different lengths. The larger arrays have been truncated to allow graphing.	View Graphics
<i>After this message is shown, the graph is displayed with truncated data.</i>	

ASCII import file header not found. Header must read (main header string is displayed).	File Operations
<i>This error can occur when importing or exporting ASCII files. You are returned to the File Load or Save menu.</i>	

At least one SMU must measure for the DC test. Check DC test form and make sure at least one SMU has a measure array specified.	DC Source-Measure Test
<i>You are returned to the DC SOURCE-MEASURE TEST form.</i>	

Auto repeat mode for curve test is not valid with list display. Either switch to graph display, or use single test mode.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form.</i>	

B

Bus timeout on GPIB device at address (address of device).	GPIB I/O Test
<i>You are returned to the GPIB OUTPUT form or a test form.</i>	

Bus timeout on 707 device at address (address of 707).	GPIB I/O Test
<i>This error can occur when uploading or downloading setups. You are returned to the GPIB I/O form.</i>	

C

Can't find parallel port copy protect block – exiting ASYST.	Model 251 Startup
<i>You are returned to DOS. Refer to paragraph 2.4.2.</i>	

Can't open Error Log File.	Sequencer Parser
<i>The file 251ERROR.LOG can't be opened.</i>	

Can't open Sequence File.	Sequencer Parser
<i>The specified sequence file (.SEQ) cannot be opened.</i>	

Can't save (file name).	File Operations
<i>This occurs when a file cannot be saved, either due to an incompatible format or the disk being full. You will be returned to the SAVE FILE submenu.</i>	

D

Data file name must contain enough pounds signs (#) to hold revision number, or no pounds to overwrite data file.	Sequencer Parser
<i>A TEST command within a LOOP contains a DATA filename with insufficient pound signs to contain the specified LOOP count. LOOP replaces the pound signs in a filename with the current LOOP counter value. There must be enough pound signs in the name for the maximum loop count if any pound signs are used. NO pound signs in a filename directs LOOP to overwrite the same filename. The META command OVERWRITE parameter should be specified in this case.</i>	

DC Gain calculation failed. Check array names to make sure they exist.	DC Source-Measure Test
<i>You are returned to the DC SOURCE-MEASURE TEST form.</i>	

Device timeout on GPIB device at address (address of device).	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form.</i>	

Duplicate array name (name) in Test, DC, or differential gain forms. All array names must be unique.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form</i>	

Duplicate GPIB addresses or KI 213 ports for devices in test form. Check test form for duplicate names and instrument configuration for devices with same address.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form.</i>	

E

ENDLOOP not preceded by a LOOP statement.	Sequencer Parser
<i>An ENDLOOP was found without a LOOP command in effect. Either a syntax error in an attempted LOOP statement created an unrecognized LOOP command, or you forgot LOOP statement.</i>	

End of file before end of string!	Sequencer Parser
<i>An end of file was encountered before end of string.</i>	

Error performing DC gain calculation. Check form parameters.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form.</i>	

Error performing differential gain calculation. Check form parameters. Note: when performing differential gain between curves at least 3 curves must be acquired.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form. When performing differential gain between curves, at least three curves must be acquired.</i>	

Error writing Log File	Sequencer Parser
<i>An attempt to write an error message to 251ERROR.LOG failed. System sets STOPONERROR to TRUE, allowing you to see error.</i>	

Errors in 707 Matrix Switch: (Possible errors): IDDC, IDDCO, Not in Remote, Selftest Failed, Trigger Overrun, Trigger Received Before Settling Time, Master/Slave Loop Error, Powerup Initialization Failed, Setup Checksum Error	GPIB I/O Test
<i>This error can occur when uploading or downloading setups. You are returned to the GPIB I/O form.</i>	

Expected a file name to follow drive:path!	Sequencer Parser
<i>A drive or path was specified without a filename.</i>	

Expected a metacommand	Sequencer Parser
<i>A META: was found without any valid parameter, or a comma follows the last meta parameter. Flagged token usually is next command. Generates at least one more syntax error until the parser re-synchronizes.</i>	

Expected a TEST command!	Sequencer Parser
<i>Similar to previous error.</i>	

Expected { “;” “=” } and a filename to follow “keyword”.	Sequencer Parser
<i>A token and a filename are missing after a command (or the DATA/ASCII/LOTUS parameter of the TEST command) requiring a filename. “Keyword” will be replaced with the appropriate keyword.</i>	

F

File Exists In Directory. Replace (Y/N)?	File Operations
<i>This occurs while saving a file with the same name as an existing file. If you type “Y”, it will replace the previous file with the new one. If you type “N”, you will be brought back to the default directory to type a new name</i>	

File name more than 8 characters. Please retype (up to 8 characters).	File Operations
<i>This occurs when you try to load/save a file name with more than an eight character length. You will be returned to the default directory to type a new name.</i>	

File name too long.	Sequencer Parser
<i>The test sequencer allows 78 characters maximum for specifying a filename, including: drive designator (2 characters, if specified), complete path (65 character, if specified), filename (8 character, if specified), filename extension (3 characters, if specified).</i>	

G

Graphing error. If using manual graphing, check parameters and ensure that data does not go beyond axis of graph.	View Graphics
<i>After this error, you are returned to the DISPLAY PARAMETERS form.</i>	

I

Illegal (Data, Test Setup, or Configuration) File Format in (file name).	File Operations
<i>This occurs if the format of the selected file is not the same as the file type. You will be returned to the LOAD FILE submenu.</i>	

Import/Export operation aborted.	File Operations
<i>This error can occur when importing or exporting ASCII files. You are returned to the GPIB I/O form.</i>	

Incompatible file format in (file name).	File Operations
<i>This occurs while loading a file. If it is a corrupt file, or a file with an older format, this message is generated and you will be returned to the LOAD FILE submenu.</i>	

Incorrect Extension Typed.	File Operations
<i>This occurs if you type in a different file extension from the one expected for a certain file type (i.e., .DAT for a data file, .TST for a test setup file, .CFG for instrument configuration file). You will be returned to the default directory to type a new file name.</i>	

Incorrect extension: .XXX expected!	Sequencer Parser
<i>You specified an extension other than the default. This message will show the expected extension. For example, TEST: command allows either .TST or .DAT.</i>	

Instrument specified by 707 Name not found. Check instrument name.	GPIB I/O Test
<i>This error can occur when uploading or downloading setups. You are returned to the GPIB I/O form.</i>	

Instrument specified by 707 name is not a type KI 707; cannot upload from non-707 instruments.	GPIB I/O Test
<i>This error can occur when uploading setups. You are returned to the GPIB I/O form.</i>	

APPENDIX B
Error Messages

Insufficient Disk Space.	File Operations
<i>This occurs if there are fewer than 2000 bytes of free disk space while trying to select a file name for load/save operations from the directory menu. You will be returned to the LOAD/SAVE menu without the loss of any data.</i>	

Integer too large: seven digits max allowed!	Sequencer Parser
<i>Seven decimal digits is the maximum for any number entered in the sequencer. Plus (+), minus (-), decimal point (.) and comma (,) are not allowed as part of the number and will generate an unrecognized token message.</i>	

Invalid address for specified GPIB I/O instrument. Check instrument address.	GPIB I/O Test
<i>You are returned to the GPIB OUTPUT form or a test form.</i>	

Invalid array header found. Array header format is Array: name, units, dim1 × dim2.	File Operations
<i>This error can occur when importing or exporting ASCII files. You are returned to the File Load or Save menu.</i>	

Invalid Directory/Path typed.	File Operations
<i>This occurs if you try to change to an invalid directory to look for files in the filing section. You are returned to the default directory.</i>	

Invalid File/Path or duplicate file typed.	File Operations
<i>This occurs if you try to rename a file to an already existing one, or to any invalid file name or path. You will be returned to the default directory to type in a new file name.</i>	

Invalid File/Path Typed.	File Operations
<i>This occurs if you type in an invalid or incorrect file and/or path name. You are returned to the default directory for a new file name.</i>	

Invalid format code from overlay file.	View Graphics
<i>You are returned to the DISPLAY PARAMETERS form.</i>	

Invalid format code in file.	File Operations
<i>This occurs when the file has a format code other than one. You are returned to the LOAD/SAVE menu.</i>	

Invalid format for data from SMU. Contact Keithley Instruments.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form. Contact Keithley's Applications Department.</i>	

Invalid instrument type in test form. All instruments in test form must be Keithley 236, 237, or 238 SMU's or 213 QVS's for bias channels. Check instrument names in test form and configuration table.	Curve Family Test DC Source-Measure Test
<i>You are returned to the CURVE FAMILY TEST form.</i>	

Invalid length for one dimensional array. Only single element arrays are allowed for one dimensional arrays.	File Operations
<i>This error can occur when importing or exporting ASCII files. You are returned to the File Load or Save menu.</i>	

APPENDIX B
Error Messages

Invalid log sweep parameters. For both Sweep and Sync Sweep, the start and stop values must be different and must not cross or be equal to zero.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form.</i>	

Invalid manual scaling parameters. Check display form.	Curve Family Test View Graphics
<i>You are returned to the appropriate form.</i>	

Invalid response from sweep SMU when reading number of sweep points.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form.</i>	

Invalid response from 707 when reading number of memories.	GPIB I/O Test
<i>This error can occur when uploading or downloading setups. You are returned to the GPIB I/O form.</i>	

Invalid response reading output value from KI 213.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form.</i>	

Invalid step parameters. Check step channel setup. The start and stop must be different values. The step must be non-zero. The # of curves must be 2 or greater. If you wish to have one step, turn the Step channel off and use a bias channel if a bias is needed.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form.</i>	

K

KI 213 Calibration Switch Not Closed.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form.</i>	

KI 213 Invalid Command parameter.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form.</i>	

KI 213 Non-volatile RAM Error, system defaults or cal constants may be lost.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form.</i>	

KI 213 Trigger Overrun Error.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form.</i>	

L

Loop count must be greater than zero.	Sequencer Parser
<i>LOOP: 0 was found. LOOP count must be >1.</i>	

Lotus File Not Compatible With Model 251.	File Operations
<i>This occurs if the Lotus file is not of the format expected by Model 251. You will be returned to the EXPORT/IMPORT DATA menu.</i>	

M

Manual scaling area too small for data. Either change axis endpoints or use auto plotting.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form.</i>	

Maxerrors must be ≤ 32767 .	Sequencer Parser
<i>You specified a MAXERRORS value > 32767.</i>	

Metacommand must appear at beginning of file!	Sequencer Parser
<i>A metacommand was found after any other command or parameter had been found.</i>	

Missing ENDLOOP; no iterations performed on last LOOP.	Sequencer Parser
<i>System found LOOP statement, then found end of file without finding matching ENDLOOP.</i>	

Missing end quote! For multi line quotes, "each line must be a separate quoted string".	Sequencer Parser
<i>An end of line was found before end of string.</i>	

Missing X after Y!	Sequencer Parser
<i>A token (X) was expected following (Y), but was not found. Examples: A colon doesn't follow one of the five commands; or an equals sign doesn't follow a REPEAT or MAXERRORS parameter.</i>	

N

Nested LOOPS are not allowed! LOOP statement ignored.	Sequencer Parser
<i>An existing LOOP command must find an ENDLOOP before it finds any other LOOP command.</i>	

No dimensions specified for array in array header.	File Operations
<i>This error can occur when importing or exporting ASCII files. You are returned to the File Load or Save menu.</i>	

No files are specified to be overlaid. To overlay data, go to the display parameters form. Choose "Overlay Form" option, and fill in the file and array names desired for overlay.	View Graphics
<i>After this error, you are returned to the menu of graphic analysis tools beside the graph.</i>	

No files in (Data, Test, or Config) directory.	File Operations
<i>This occurs when you try to rename or delete a file in an empty directory or subdirectory.</i>	

No setups have been uploaded from the 707; there is nothing to download to the 707! 707 setups are loaded into computer memory by either loading a 707 setup file from the file menu, or executing the <Uploading from 707> GPIB command.	GPIB I/O Test
<i>This error can occur when uploading or downloading setups. You are returned to the GPIB I/O form.</i>	

No (.DAT, .TST, or .CFG) Files in (Data, Test, or Config) Directory.	File Operations
<i>This occurs when there are no .DAT, .TST, or .CFG files in the directory specified for file selection through the menu.</i>	

No 707 instrument name has been specified. Fill in the 707 name in GPIB form and try again.	GPIB I/O Test
<i>This error can occur when uploading or downloading setups. You are returned to the GPIB I/O form.</i>	

NOEXECUTE specified with .TST file: Nothing to do! Must allow execution or load a .DAT file.	Sequencer Parser
<i>You specified NOEXECUTE while trying to load a test (.TST) file. NOEXECUTE can be used only with data files. You may have failed to specify .DAT extension; .TST is assumed by default.</i>	

Not enough free DOS memory to run Model 251. Suggestion – Remove any memory resident programs not necessary for operation to free up more memory.	Model 251 Startup
<i>You are returned to DOS.</i>	

Not enough memory to create array. Either delete unwanted arrays or change form settings so a smaller array will be used.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form. Delete arrays by using Delete key on array name pop-up.</i>	

No variables are tagged for display. Use space bar to tag the variables for display.	View Curve Family List DC Source-Measure Test
<i>After this error, you are returned to the DISPLAY PARAMETERS form. Tag variables with the space bar.</i>	

Number of points read from the file does not match the number of points specified in array header.	File Operations
<i>This error can occur when importing or exporting ASCII files. You are returned to the File Load or Save menu.</i>	

O

Out of available arrays. Delete unwanted arrays to make room for test arrays.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form. Delete arrays by using Delete key on array name pop-up.</i>	

Overlay file: (filename) not found.	View Graphics
<i>After this error, you are returned to the menu of graphic analysis tools beside the graph.</i>	

Q

Quoted string too long!	Sequencer Parser
<i>A quoted string exceeds maximum 255 characters length, which includes two unseen characters (<CR> <LF>) for each line.</i>	

R

Remote sensing is enabled. An open sense lead will result in lethal voltages at Output High and Guard. Hit <Esc> to return to test form, or any other key to execute test.	Curve Family Test DC Source-Measure Test
<i>This warning is displayed when a DC test or Curve Family test is run and remote sensing was enabled on the test form. You are given the options of continuing with the test or returning to the test form.</i>	

Repeat clause requires data file name length to be ≤5!	Sequencer Parser
<i>This is generated on a TEST line with REPEAT >1, where the DATA parameter specifies a file name of length >5. REPEAT will always append a 3 digit version number to name, so five characters (not including .DAT extension) is the maximum.</i>	

Repeat count must be between 1 and 999. Use LOOP . . . ENDLOOP for more iterations.	Sequencer Parser
<i>The specified REPEAT count is out of range (1 minimum; 999 maximum).</i>	

Repeat parameter not allowed in a LOOP.	Sequencer Parser
<i>A TEST command within a LOOP has a REPEAT count >1. REPEAT count >1 is not allowed within a LOOP because both REPEAT and LOOP attempt to append version numbers to data files.</i>	

Replacing (file name). Replace (Y/N)?	File Operations
<i>This occurs while saving a file with the same name as an existing file. If you type "Y", the previous file will be replaced with a new one. If you type "N", you are returned to the default directory to type a new name.</i>	

S

Seek Error in Sequence File	Sequencer Parser
<i>A fatal parser file error, which prevents further parser operation.</i>	

Specified GPIB I/O device not found. Check instrument name.	GPIB I/O Test
<i>You are returned to the GPIB OUTPUT form or a test form.</i>	

<p>Status error: (Possible errors)</p> <table border="0"> <tr> <td>Trigger Overrun</td> <td>IOU EEROM Failed</td> </tr> <tr> <td>IDDC</td> <td>IOU Cal Checksum Error</td> </tr> <tr> <td>IDDCO</td> <td>DPRAM Lockup</td> </tr> <tr> <td>Interlock Present</td> <td>DPRAM Link Error</td> </tr> <tr> <td>Illegal Measure Range</td> <td>Cal ADC Zero Error</td> </tr> <tr> <td>Illegal Source Range</td> <td>Cal ADC Gain Error</td> </tr> <tr> <td>Invalid Sweep Mix</td> <td>Cal SRC Zero Error</td> </tr> <tr> <td>Log Cannot Cross Zero</td> <td>Cal SRC Gain Error</td> </tr> <tr> <td>Autorangeing Source with Pulse Sweep</td> <td>Cal Common Mode Error</td> </tr> <tr> <td>In Calibration</td> <td>Cal Compliance Error</td> </tr> <tr> <td>In Standby</td> <td>Cal Value Error</td> </tr> <tr> <td>Unit is a 236</td> <td>Cal Constants Error</td> </tr> <tr> <td>IOU DPRAM Failed</td> <td>Cal Invalid Error</td> </tr> </table>	Trigger Overrun	IOU EEROM Failed	IDDC	IOU Cal Checksum Error	IDDCO	DPRAM Lockup	Interlock Present	DPRAM Link Error	Illegal Measure Range	Cal ADC Zero Error	Illegal Source Range	Cal ADC Gain Error	Invalid Sweep Mix	Cal SRC Zero Error	Log Cannot Cross Zero	Cal SRC Gain Error	Autorangeing Source with Pulse Sweep	Cal Common Mode Error	In Calibration	Cal Compliance Error	In Standby	Cal Value Error	Unit is a 236	Cal Constants Error	IOU DPRAM Failed	Cal Invalid Error	<p>Curve Family Test DC Source-Measure Test</p>
Trigger Overrun	IOU EEROM Failed																										
IDDC	IOU Cal Checksum Error																										
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In Calibration	Cal Compliance Error																										
In Standby	Cal Value Error																										
Unit is a 236	Cal Constants Error																										
IOU DPRAM Failed	Cal Invalid Error																										
<p><i>You are returned to the appropriate test form. Refer to Section 3 of Model 236/237/238 Operator's Manual for details on status errors.</i></p>																											

<p>Status warning: (Possible errors)</p> <p>Uncalibrated Temporary Cal Value Out of Range Sweep Buffer Filled No Sweep Points, Must Create Sweep Points Pulse Times Not Met Not In Remote Measure Range Changed Due to 1kV/100mA or 110V/1A Range Select Measurement Overflow (OFLO) / Sweep Aborted Pending Trigger</p>	<p>Curve Family Test DC Source-Measure Test</p>
<p><i>You are returned to the appropriate test form. Refer to Section 3 of Model 236/237/238 Operator's Manual for details on status warnings.</i></p>	

<p>Sweep channel must be "ON" for this test and must collect both source and measure data.</p>	<p>Curve Family Test</p>
<p><i>You are returned to the CURVE FAMILY TEST form.</i></p>	

APPENDIX B
Error Messages

System file (file name) not found. Run INSTALL to ensure all system files are present.	Model 251 Startup
<i>You are returned to DOS.</i>	

System does not have enough expanded memory to boot. Model 251 requires a minimum of 1 Mbytes of expanded memory to operate. Hit any key to return to DOS.	Model 251 Startup
<i>You are returned to DOS. The system requires 1 Mbyte of free expanded memory.</i>	

T

TCU not responding. This test requires a TCU. Check that TCU is on and that its address is set properly.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form. Check Model 2361 Trigger Controller address switch and DEFINE INSTRUMENTS form.</i>	

Test aborted by user.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form.</i>	

The values entered for Curve Delay & Point Delay total up to more than 65 seconds. Reduce one or both of the delays so the total is 65 seconds or less.	Curve Family Test
<i>You are returned to the CURVE FAMILY TEST form.</i>	

Token too long!	Sequencer Parser
<i>The parser found a token (usually a string) longer than 255 characters.</i>	

Two instruments of different addresses have the same TCU channel assigned. This is not allowed! This must be corrected before you can exit the instrument configuration.	Define Instruments
<i>This occurs if you try to exit the DEFINE INSTRUMENTS form with two instruments having the same trigger channel and different bus addresses. You are returned to the DEFINE INSTRUMENTS form.</i>	

U

Unable to create array. Out of available arrays.	File Operations
<i>This error can occur when importing or exporting ASCII files. You are returned to the File Load or Save menu.</i>	

Unable to filter data. Try using fewer # of pts or using smaller data array.	View Graphics
<i>After this error, you are returned to the menu of graphic analysis tools beside the graph.</i>	

Unable to load configuration file: (filename)	Sequencer Execution
<i>This error can occur when loading or saving files during sequencer execution. If STOPONERROR is set in the sequencer file, you are given the following options: Re-execute, Next line, or Abort. If not, the error message will be logged into the error file.</i>	

Unable to load file: (filename)	Sequencer Execution
<i>This error can occur when loading or saving files during sequencer execution. If STOPONERROR is set in the sequencer file, you are given the following options: Re-execute, Next line, or Abort. If not, the error message will be logged into the error file.</i>	

Unable to load 707 file: (filename)	Sequencer Execution
<i>This error can occur when loading or saving files during sequencer execution. If STOPONERROR is set in the sequencer file, you are given the following options: Re-execute, Next line, or Abort. If not, the error message will be logged into the error file.</i>	

Unable to read string from instrument. Note: The maximum length string that can be read back from an instrument is 140 characters long.	GPIB I/O Test
<i>You are returned to the GPIB OUTPUT form or a test form.</i>	

Unable to save file – Insufficient disk space.	File Operations
<i>This error can occur when importing or exporting ASCII files. You are returned to the File Load or Save menu.</i>	

Unable to save sequencer data file: (filename)	Sequencer Execution
<i>This error can occur when loading or saving files during sequencer execution. If STOPONERROR is set in the sequencer file, you are given the following options: Re-execute, Next line, or Abort. If not, the error message will be logged into the error file.</i>	

Undefined GPIB instrument in test form! Check GPIB device names and make sure they match the names defined in instrument setup.	Curve Family Test DC Source-Measure Test
<i>You are returned to the appropriate test form.</i>	

Unexpected X	Sequencer Parser
<i>An unexpected single character token found. X represents the unexpected single character token (comma, colon, equals sign or quote mark). usually occurs after a syntax error.</i>	

Unrecognized command: . . .	Sequencer Parser
<i>A command token of less than 3 characters was found. Only file names, numbers, and the special single character tokens may be less than 3 characters long.</i>	

Unrecognized or misplaced Sequencer command: . . .	Sequencer Parser
<i>An unrecognized or misplaced token was found; but token is of proper length (>3). May occur after a missing comma.</i>	

APPENDIX C

Model 2361

Trigger Controller

INTRODUCTION

The Model 2361 controls the routing of TTL-compatible trigger signals among a maximum of six instruments. A simple trigger programming language is included to specify what combination of trigger inputs cause an output.

Shipment Contents

The following items are included with every Model 2361:

Description	Keithley Part No.
Line Cord	CO-19
Feet (4)	FE-24-1
Rack Ears (2)	2361-311
Screws (4), for rack ears	10-32×3/8PFHBLKOX
Screws (8), nylon	10-32×1/4PBHBLKNY
20-pin Digital I/O Connector	CS-444-2
20-pin Digital I/O Self-test Connector	2361-314
BNC Interconnect Cable (4)	7051-2

Optional Accessories

Model 7051 BNC Interconnect Cables — Model 7051 cables are used for making connections to trigger in and trigger out connections on the Model 2361 rear panel. The Model 7051-2 is a 50Ω BNC to BNC cable (RG-58C), which is 0.6m (2 ft.) long. The Models 7051-5 and 7051-10 are similar, but 5 feet and 10 feet in length respectively.

Model 7007 Shielded IEEE-488 Cables — A Model 7007 connects the Model 2361 to the IEEE-488 bus using shielded cables to reduce electromagnetic interference (EMI). The Model 7007-1 is one meter (3.3 ft.) long and has an EMI shielded IEEE-488 connector at each end. The Model 7007-2 cable is identical to the Model 7007-1, but is 2m (6.6 ft.) long.

FRONT PANEL INDICATORS

The Model 2361 front panel is shown in Figure C-1.

Trigger Channel In/Out Indicators

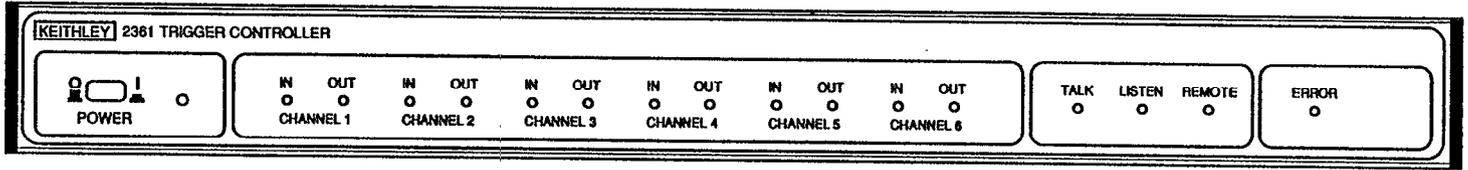
Each of the six trigger channels has two LEDs on the front panel, IN and OUT. An IN LED will blink when a trigger is received on that channel; an OUT LED will blink when a trigger is sent to that channel.

If a channel is used in a “Cumulative AND” expression on the input side of a relation, the IN LED will remain lit until the expression evaluates true.

If a trigger is received on a channel that is not used in an input expression, the IN LED will turn on and remain lit until that channel is cleared.

IEEE-488 Status Indicators

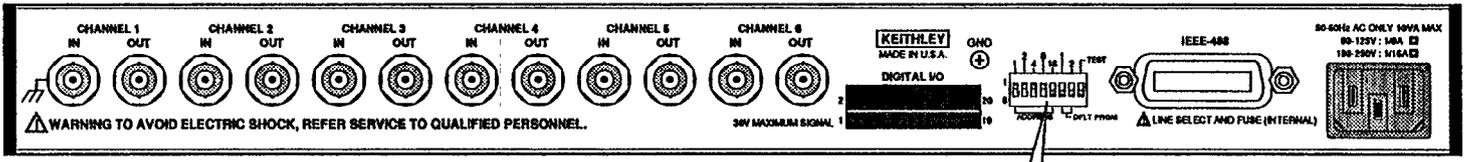
The TALK, LISTEN, and REMOTE indicators show the present IEEE-488 status of the instrument. Each of these indicators is briefly described below.



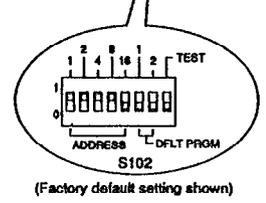
2361 Front Panel

Figure C-1. Model 2361 Front Panel

C-2



2361 Rear Panel



(Factory default setting shown)

Figure C-2. Model 2361 Rear Panel

TALK — This indicator is on when the instrument is in the talker active state. The unit is placed in this state by addressing it to talk. TALK is off when the unit is in the talker idle state.

LISTEN — This indicator is on when the Model 2361 is in the listener active state. LISTEN is off when the unit is in the listener idle state.

REMOTE — This indicator shows when the instrument is in the remote state. When REMOTE is turned off, the instrument is in the local state.

Error Indicator

The ERROR LED will light when one of the following error conditions occurs:

- Trigger test failed
- Digital I/O test failed
- ROM test failed
- RAM test failed
- Illegal device-dependent command option (IDDCO)
- Illegal device-dependent command (IDDC)

CONFIGURATION

The Model 2361 has one 8-position DIP switch (S102) accessible from the rear panel (see Figure C-2 and Figure C-3). This switch determines the unit's IEEE address, default trigger I/O program, and test mode. The switch is read only when the unit is powered on and should be set prior to applying power.

The factory default settings of the switch are shown in Figure C-3. To modify any of these defaults, turn the instrument off and change the switch setting using a small screwdriver.

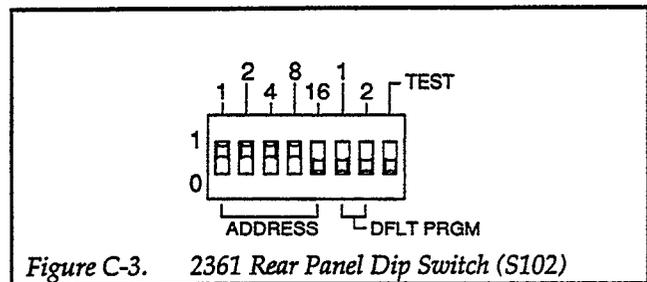


Figure C-3. 2361 Rear Panel Dip Switch (S102)

IEEE-488 Address Selection

The IEEE-488 bus address is set by S102. The address can be set from 0 through 30 and is read only at power on. The address is selected by simple binary weighting with switch 1 being the least significant bit and switch 5 the most significant bit. The factory default address is 15.

Trigger I/O Program Selection

Up to three trigger I/O programs can be stored in EEPROM. The following switch settings of S102 determine the program that is loaded on power-up.

DFLT PRGM Switch

DFLT PRGM Switch		
1	2	
0	0	
1	0	Program #1 (EEPROM)
0	1	Program #2 (EEPROM)
1	1	Program #3 (EEPROM)

Test Selection

The TEST position of S102 selects a power-up self-test that checks trigger and digital I/O signal paths (see power-up procedure).

CONNECTIONS

Trigger Channels

The Model 2361 has six trigger channels; each channel uses two BNC connectors; one for the input and one for the output. Trigger signals are connected with Model 7051-2 BNC cables.

The normal connection scheme has an external instrument's trigger out signal going to a CHANNEL IN connector on the Model 2361 rear panel. To complete the loop, a BNC cable is connected from a Model 2361 CHANNEL OUT to the instrument's trigger in. An example connection schematic is shown in Figure C-4.

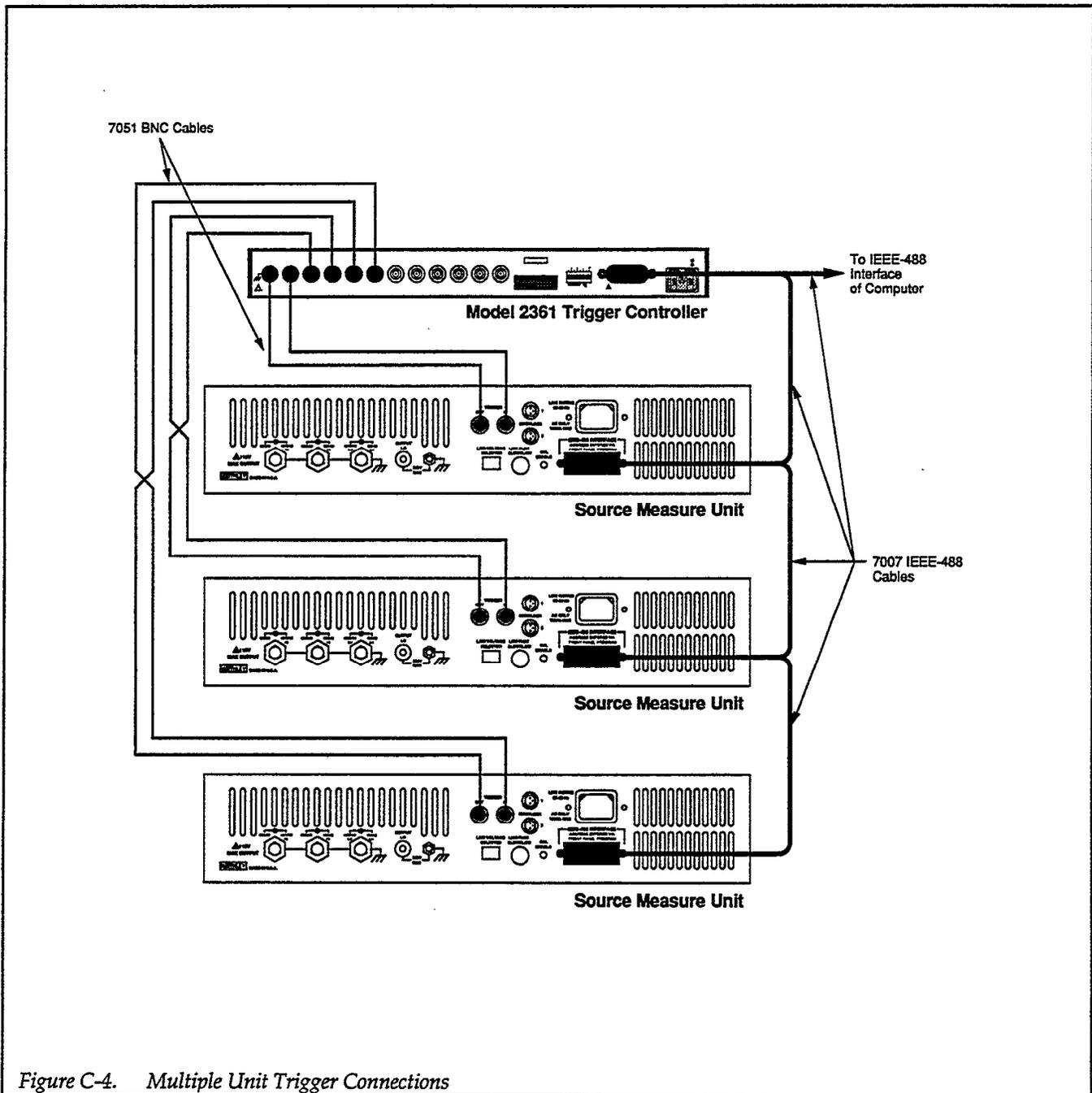


Figure C-4. Multiple Unit Trigger Connections

Digital I/O

The DIGITAL I/O port located on the rear panel is shown in Figure C-5. It is a 20-pin card-edge connector. Sixteen pins are used for the eight digital channels, with input pins located on the top row of the connector and output pins located on the bottom row. The eight digital channels are identified on the drawing. Also note that two pins are used to access +5V and two pins are used to access digital ground. The connector pinout is also provided by Table C-1.

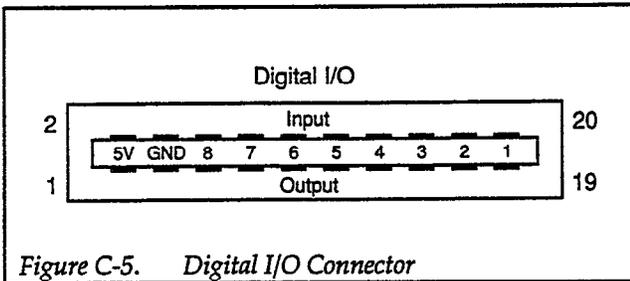


Figure C-5. Digital I/O Connector

Table C-1. Digital I/O Port Pinout

Pin	Signal	Pin	Signal
1	+5 volts	11	Digital Output 5
2	+5 volts	12	Digital Input 5
3	Digital Ground	13	Digital Output 4
4	Digital Ground	14	Digital Input 4
5	Digital Output 8	15	Digital Output 3
6	Digital Input 8	16	Digital Input 3
7	Digital Output 7	17	Digital Output 2
8	Digital Input 7	18	Digital Input 2
9	Digital Output 6	19	Digital Output 1
10	Digital Input 6	20	Digital Input 1

The Digital I/O connector will mate with the supplied 20-pin Digital I/O connector. This connector is equipped with solder lugs to accommodate cable connections.

In order to minimize susceptibility to electromagnetic interference (EMI) and radio frequency interference (RFI), use shielded wires for digital input and output lines. The shields should then be connected directly to the GND (ground) screw on the rear panel.

HARDWARE INSTALLATION

Included with the Model 2361 are accessories for rack or bench use. If rack mount installation is desired, install the two rack ears using the enclosed screws. These ears can be installed so either the front or rear of the unit faces the front of the rack fixture (see Figure C-6).

NOTE

The front and rear rack mount holes may contain 10-32 × 1/4" nylon screws. Remove the four appropriate nylon screws and attach the rack ears using the four 10-32 × 3/8" screws.

WARNING

A potential shock hazard will exist if screws longer than those supplied (10-32 × 3/8") are used to attach the rack ears.

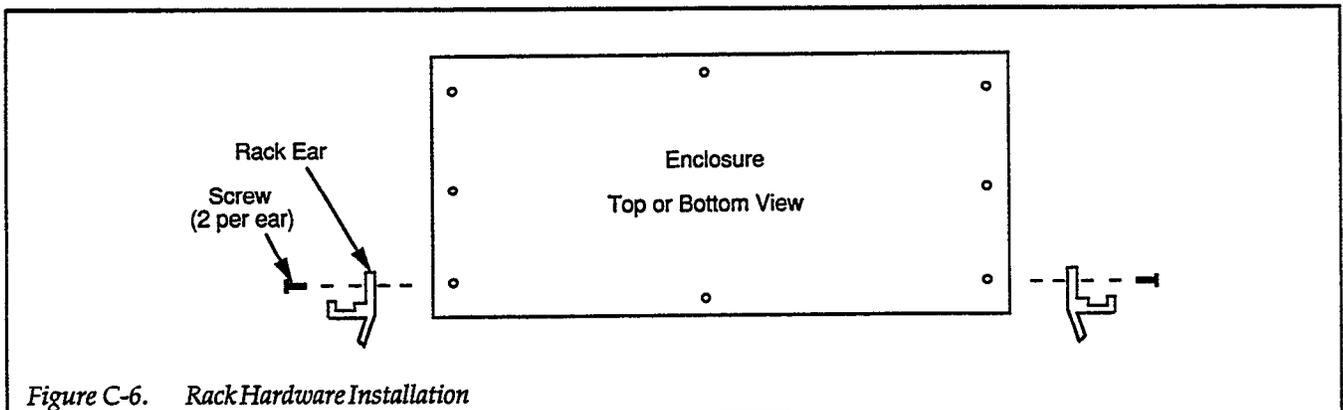


Figure C-6. Rack Hardware Installation

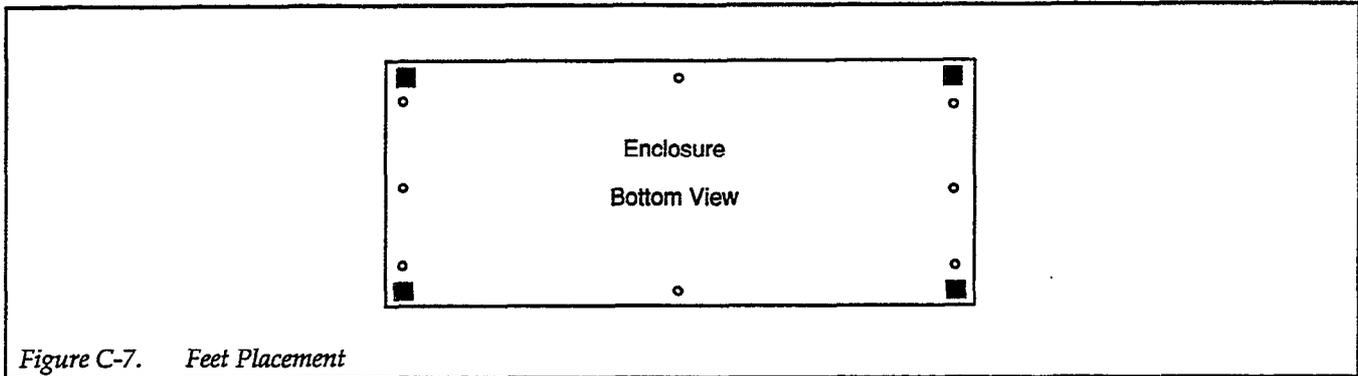


Figure C-7. Feet Placement

If bench installation is desired, the rubber feet can be installed on the underside of the unit near each corner (see Figure C-7).

POWER-UP PROCEDURE

Line Power

Use the following procedure to connect the Model 2361 to line power and power up the instrument.

1. Check that the instrument is set to correspond to the available line power. When the instrument leaves the factory, the internally selected line voltage is marked on the rear panel near the power jack. Ranges are 90-125V or 180-250V, 50-60Hz ac. If the line voltage setting of the instrument needs to be changed, a procedure is located in paragraph B.8.

CAUTION

Be sure that the line voltage agrees with the indicated range on the rear panel of the instrument. Failure to observe this precaution may result in instrument damage.

2. Connect the female end of the power cord to the ac receptacle on the rear panel of the instrument. Connect the other end of the cord to a grounded ac outlet.

WARNING

The Model 2361 is equipped with a 3-wire power cord that contains a separate ground wire and is designed to be used with

grounded outlets. When proper connections are made, instrument chassis is connected to power line ground. Failure to use a grounded outlet may result in personal injury or death because of electric shock.

3. The instrument can be turned on by pressing in the front panel POWER switch. The switch will be at the innermost position (1) when the instrument is turned on.

Tests

The trigger controller has two power-up self tests. The start-up (and default) test proceeds as follows:

1. All front panel LEDs flash once when power is turned on.
2. The unit performs a ROM check. If this test fails, the LEDs corresponding to trigger channels 1, 2, and 3 (both in and out) will flash.
3. A RAM test is conducted by the instrument. Failure of this test causes LEDs corresponding to channels 4, 5, and 6 to flash.
4. The EEPROM is examined. The in and out LEDs of all six channels will flash if this test fails.

The self-test is optional and is initiated by setting DIP switch S102 to the TEST position (see Figure C-3) before turning on the power. For normal operation, this switch should be set to "0". The Model 2361 will operate normally if the switch remains in the TEST position following completion of the self-test; however, the self-test will be executed if any power glitch occurs.

Connections

The self-test requires that all inputs (trigger and digital) be connected to their respective outputs as follows:

1. Using six BNC cables, connect IN to OUT for all six trigger channels.
2. Mate the supplied Digital I/O Self-test Connector to the DIGITAL I/O connector on the rear panel.

Self-Test

With S102 set for TEST, the self-test proceeds as follows:

1. The start-up test is performed.
2. Trigger channel rising edge test — A rising edge is generated at CHANNEL 1 OUT. When the edge is detected at CHANNEL 1 IN, both CHANNEL 1 LEDs are flashed. The remaining trigger channels are tested in order.
3. Trigger channel falling edge test — This test is the same as the previous step, but with a falling edge.
4. Digital I/O rising edge and high level test — A rising edge is generated at Digital Output 1 and detected at Digital Input 1. The Digital I/O channel 1 level line is then tested for a high level. When both edge and level are detected at Digital Input 1, the CHANNEL 1 IN LED is flashed. The remaining Digital INs/OUTs are tested in order in a similar manner.
5. Digital I/O falling edge and low level test — This test is the same as the previous, but with a falling edge and a low level.

The order in which all signals are tested is given in Table C-2

IEEE-488 BUS PROGRAMMING

Trigger I/O Programs

The trigger I/O program provides the means for the Model 2361 Trigger Controller to determine when and where to send output triggers. Trigger I/O programs are sent to the trigger controller just like device-dependent commands.

A program consists of up to six trigger I/O relations, each of which relates specified inputs to specified outputs.

Table C-2. Order of Channel Testing for Self-test

Signal Channel	LED in Self-test
Trigger 1	CHANNEL 1 IN and OUT
Trigger 2	CHANNEL 2 IN and OUT
Trigger 3	CHANNEL 3 IN and OUT
Trigger 4	CHANNEL 4 IN and OUT
Trigger 5	CHANNEL 5 IN and OUT
Trigger 6	CHANNEL 6 IN and OUT
Digital 1	CHANNEL 1 IN
Digital 2	CHANNEL 1 OUT
Digital 3	CHANNEL 2 IN
Digital 4	CHANNEL 2 OUT
Digital 5	CHANNEL 3 IN
Digital 6	CHANNEL 3 OUT
Digital 7	CHANNEL 4 IN
Digital 8	CHANNEL 4 OUT

Each relation consists of an input expression and an output expression separated by the greater than (>) character.

Trigger input expressions specify what combination of trigger inputs will cause a trigger output. Trigger output expressions specify what combination of trigger outputs will occur after the corresponding input expression has evaluated true.

Valid relations contain channel numbers (1-6) and operators, which specify output trigger conditions dependent upon the states of the input channels. The legal operators are as follows:

- * Logical "AND" for inputs and outputs, cumulative for inputs (See Note 5.)
- + Logical "OR", for inputs only
- > I/O separator, separates the input expression from the output expression
- ; Relation separator, delimits relation in a multiple relation command string

Examples

OUTPUT 715;"1>2X"	!If 1 triggered, trigger out 2.
OUTPUT 715;"1*2>1X"	!If 1 and 2 are triggered, trigger out 1.
OUTPUT 715;"1*2*3>1*6X"	!When inputs 1, 2 and 3 are triggered, trigger out 1 and 6.
OUTPUT 715;"1+2*3>4X"	!If 1 or (2 and 3) are triggered, trigger out 4.

OUTPUT 715;"1*2+3>4X" !If (1 and 2) or 3 are triggered, trigger out 4.

OUTPUT 715;"1>1;2>2;3>3;4>4;5>5;6>6X" !All channels act as a throughport, i.e., when 1 is triggered, trigger out 1, when 2 is triggered, trigger out 2, etc.

OUTPUT 715;"6+1>3;4>1*3X" !If 6 or 1 is triggered, trigger out 3. Also, if 4 is triggered, trigger out 1 and 3.

OUTPUT 715;"1>1*6U2;2>2X" !If 1 is triggered, trigger out 1 and 6. Obtain the present program. Then, if 2 is triggered, trigger out channel 2.

OUTPUT 715;"1*2*3>1*2*3X" !If 1 and 2 and 3 are triggered, trigger out 1 and 2 and 3.

Note: An illegal relation generates an IDDCO error and turns on the front panel "ERROR" indicator.

DEVICE-DEPENDENT COMMANDS

The program instructions covered in this section use examples written with Hewlett Packard BASIC version 4.0. This language was chosen because of its versatility in controlling the IEEE-488 bus.

Order of Command Execution

Device-dependent commands are not necessarily executed in the order they are received. Rather, the instrument always executes them in a specific order, as summarized in Table C-3

Table C-3. Order of Command Execution

Notes

1. The maximum number of characters in any relation string is 46. More characters results in an error.
2. Inclusion of a trigger I/O program in a IEEE-488 command string will overwrite any previously defined program upon receipt of the next X command.
3. Each input channel may be used in only one of the input expressions in the program.
4. A program string must contain no more than six relations. This is a direct result of Note 3, since each of the six input channels may be used in only one relation.
5. Each output channel may be used in any number of the output expressions in the program.
6. Any output channels ANDed together in an output expression will produce output pulses simultaneously when the input expression evaluates true. However, if any input channels are ANDed together, the input pulses received by the individual channels are latched and held, one by one, until the input expression evaluates true. Only then are the latches cleared and the outputs produced.
7. All * operators are evaluated first, from left to right. All + operators are evaluated second, from left to right.

Order	Command	Description
1	Z	Clear programs from EEPROM
2	C	Clear present program
3	program	Trigger I/O program
4	W	Delay
5	E	Enable/disable trigger response
6	F	Detect trigger input on falling edge
7	R	Detect trigger input on rising edge
8	S	Store program in EEPROM
9	K	Bus hold-off
10	L	Load program from ROM or EEPROM
11	M	SRQ mask format
12	O	Digital I/O
13	D	Digital input change mask
14	I	Clear trigger inputs
15	T	Trigger input change mask
16	U	Status
17	Y	Terminator
18	P	Immediate mode pulse
19	H	Detect digital input on rising edge
20	B	Detect digital input on falling edge
21	J	Restore factory default settings

Examples of Illegal Relations

OUTPUT 715;"1>1;1>2X" ! Input channel 1 is used twice.

OUTPUT 715;"1>2+3X" ! An OR operator appears on the output side of the relation.

If you wish to force a particular order of execution, simply include the execute (X) character after each command in the string. For example, the following string would be executed in the order received:

L1XS2X

This forced sequence will load Program 1 from EEPROM and then store it as Program 2 in EEPROM. If the X after the L1 command is omitted (L1S2X), the S2 command will be executed first. In that case, the current active program will be stored as Program 2 in EEPROM, and then Program 1 will be loaded as the active program.

Device-dependent Command Summary

All Model 2361 device-dependent commands are summarized in Table C-4.

Table C-4. Device-dependent Command Summary

Command	Code	Description
Detect Digital Input on Falling Edge	Bn	Set digital input channels to detect an input on its falling edge (0-8).
Clear Present Program	C0	Clear present program from memory.
Digital Input Change Mask	Dn	Determine which digital input channels will set DIGCHNG bit in serial poll byte (0-255).
Trigger Response	En	Enable (E0) or disable (E1) input trigger channels.
Detect Trigger Input on Falling Edge	Fn	Detect an input trigger on its falling edge (0-6).
Detect Digital Input on Rising Edge	Hn	Set a digital input to detect an input on its rising edge (0-8).
Clear Trigger Inputs	In	Initialize a trigger input latch(es) to the non-triggered state (0-6).
Restore Factory Defaults	J0	Restore factory default settings.
Bus Hold-off	Kn	Enable (K0) or disable (K1) bus hold-off on X.
Load Program from ROM or EEPROM	Ln	Recall a previously stored program (0-3).
SRQ Mask Format	Mn	Program which conditions generate an SRQ (service request). M0 = SRQ disabled M1 = Digital input change M2 = Trigger input change M16 = Ready for input M32 = Error
Digital I/O	On	Assert the digital output lines (0-255).
Immediate Mode Pulse	Pm	Send a pulse to specified trigger output(s) (0-6).
Detect Trigger Input on Rising Edge	Rn	Set trigger input channel to detect on rising edge (0-6).
Store Program in EEPROM	Sn	Store present program in EEPROM (1-3).
Trigger Input Change Mask	Tn	Determine which trigger input channels will set the TRGCHNG bit in serial poll byte (0-63).
Status	Un	Obtain instrument status and configuration information. U0 = Send machine status word U1 = Send error status word (0-255) U2 = Send present active program U3 = Send latched trigger input state (0-63) U4 = Send latched digital input state and clear latches U5 = Send DIP switch setting (0-255) U6 = Send trigger and digital input edge detection polarities U7 = Send firmware revision level
Delay	Wn	Delay in 500µsec increments between input expression evaluating true and sending output pulse (0-255).
Execute	X	Execute command string.
Terminator	Yn	Select ASCII terminator sequence for strings. Y1 = CR LF Y2 = LF CR Y3 = CR Y4 = LF
Clear All Programs	Z0	Clear all programs from EEPROM.

B Detect Digital Input On Falling Edge

Purpose	To set specified digital input(s) to detect a trigger on its falling edge.	
Format	Bn	
Parameters	n = 0; Set all digital inputs to detect triggers on falling edges. n = 1 to 8; The digital input(s) "n" that is to detect an input on its falling edge.	
Default	Upon power-up, or after a DCL or SDC command, all digital inputs are set to detect input triggers on falling edges (B0).	
Description	The B command sets a digital input line(s) (via DIGITAL I/O port) to detect an incoming trigger on its falling edge.	
Programming Notes	<ol style="list-style-type: none">1. This command, along with the H command, also controls the polarity of the edge which triggers an SRQ on a digital input change for those inputs that are set to generate an SRQ in the DIGCHNG mask (see M command).2. Any time a B or H command is used, the corresponding digital input channel latch is cleared.	
Programming Examples	OUTPUT 715;"B1X" OUTPUT 715;"B2XB3X"	! Detect falling edge of trigger on input #1. ! Detect falling edge of triggers on inputs #2 and #3.

C Clear Present Program

Purpose	To clear the present program from memory.
Format	C0
Parameters	C0 Clear present program from memory
Description	The C command clears the active program from the trigger controller's RAM. Programs stored in EEPROM are not affected.
Programming Notes	<ol style="list-style-type: none">1. The C command does not clear either the digital or the or trigger input latches. For the latches to be cleared, the I command must be used.2. The zero in the command string may be omitted.
Programming Examples	OUTPUT 715;"C0X" ! Clear present program

D Digital Input Change Mask

Purpose To determine which digital input channel(s) will set the DIGCHNG bit in the serial poll byte when the appropriate trigger edge occurs.

Format Dn

Parameters * n = 0 to 255; An integer value that is the decimal weighted sum of the selected bits in the digital input change mask.

Default Upon power-up, or after receiving a DCL or SDC command, the digital input change mask will default to D0.

Description The digital input change mask determines which digital input channels (via DIGITAL I/O port) will cause the DIGCHNG bit, located in the serial poll byte, to be set when the appropriate edge (rising or falling as determined by the H and B commands) is detected.

The bits of this 8-bit mask (see Figure C-8) represent the eight digital input channels. The MSB (B7) represents digital input #8, and the LSB (B0) represents digital input #1.

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Decimal Weighting	128	64	32	16	8	4	2	1
Digital Input Channel	8	7	6	5	4	3	2	1

Figure C-8. Digital Input Change Mask

The desired channels are selected by simply setting the corresponding bit in the mask. To program the mask, the decimal weighted sum of the set bits are sent with the D command. For example, to set the mask for digital input channels 8 and 1, send D129X over the bus.

Then, when an edge is latched at any of the specified channels, DIGCHNG in the serial poll byte (see M command) is set. The DIGCHNG bit is cleared when all digital input latches are cleared by a U4 status request.

Programming Examples

```

10 REMOTE 715
20 OUTPUT 715;"D1X"           ! Set DIGCHNG on digital
                               channel 1 state change
30 OUTPUT 715;"M1X"         ! Set to SRQ on DIGCHNG
40 S=SPOLL(715)             ! Serial poll the 2361
50 IF NOT BIT(S,6) THEN 40  ! Wait for SRQ
60 PRINT "Change in state
   occurred at ch. 1"
70 END

```

E Trigger Response

Purpose To enable/disable the input trigger channels.

Format En

Parameters E0 Enable input triggers.
E1 Disable input triggers.

Default Upon power-up, or after receiving a DCL or SDC command, the instrument triggers are enabled (E0).

Description The E command determines whether or not the input trigger channels will be examined. If the inputs are enabled, the outputs will be determined by the current active program. If the inputs are disabled, all input triggers will be ignored.

Programming Notes

1. Trigger channel input latches can still be set by an incident trigger with the input triggers disabled. The relations of set triggers will be executed when the E0 command is sent over the bus.
2. Any time a new trigger program is sent on the IEEE-488 bus, the trigger response defaults to the enabled condition (E0).
3. A trigger program can be installed with trigger response disabled by loading it from EEPROM using the L command if it was stored with trigger response disabled (E1).

Programming Examples

```

10 REMOTE 715
20 OUTPUT 715;"10X"           ! Clear input latches
30 OUTPUT 715;"1*2>3X"       ! Trigger out 3 if inputs 1 and 2 are triggered
40 OUTPUT 715;"E1X"          ! Disable input triggers
50 END

```

F Detect Trigger Input On Falling Edge

Purpose To detect an input trigger on its falling edge.

Format Fn

Parameters n = 0; Set all trigger channels to detect an input on its falling edge
n = 1 to 6; Trigger channel number to be triggered on a falling edge input.

Default All trigger inputs default to a falling edge trigger status (F0) on power-up, or a DCL or SDC command.

Description With the F command, you can specify which, if any, input trigger channel(s) will latch an input on its falling edge.

Programming Notes

1. This command, along with the R command, also controls the polarity of the edge that triggers an SRQ on trigger input for those channels that are set to generate an SRQ in the TRGCHNG mask.
2. Any time an F or R command is used, the corresponding trigger input channel latch is cleared.

Programming Examples

```
10 REMOTE 715
20 OUTPUT 715;"F1XF2X"           ! Falling edge detection on 1 and 2
30 OUTPUT 715;"1+2>3X"          ! If 1 or 2 is triggered, trigger out 3
40 END
```

H Detect Digital Input On Rising Edge

Purpose	To set a digital input to detect an input on its rising edge.
Format	Hn
Parameters	n = 0; Set all channels to detect a trigger on its rising edge. n = 1 to 8; Digital channel which is to detect an input trigger on its rising edge.
Default	On power-up, or after receiving a DCL or SDC command, all digital input lines default to a falling edge detection state (B0).
Description	The H command sets a digital input line(s) to detect an incoming trigger on its rising edge.
Programming Notes	<ol style="list-style-type: none">1. This command, along with the B command, also controls the polarity of the edge that triggers an SRQ on a digital input change for channels that are set for an SRQ in the DIGCHNG mask (see M command).2. Any time a B or H command is used, the corresponding digital input channel latch is cleared.
Programming Examples	OUTPUT 715;"H1XH2X" ! Rising edge detection on 1 and 2

I Clear Trigger Inputs

Purpose To initialize a trigger input latch(es) to the non-triggered state.

Format In

Parameters n = 0; Clear all trigger latches
n = 1 to 6; Trigger channel latch to be cleared

Default All latches are cleared (I0) on power-up, or after receiving a DCL or SDC command.

Description The I command initializes the specified trigger input latch to a non-triggered state, i.e., sets the desired latch output to a logical "0" state.

Programming Note For the command string IOX (clear all the trigger latches), the "0" parameter may be omitted. Thus, instead of sending IOX over the bus, simply send IX.

Programming Examples

```
10 REMOTE 715
20 OUTPUT 715;"R1XR2X"           ! Detect triggers 1 and 2 on rising edge
30 OUTPUT 715;"1*2>3IOX"        ! Trigger out 3 if inputs 1 and
40 END                             2 are triggered, and clear all latches
```


K Bus Hold-Off

Purpose To enable or disable bus hold-off on X.

Format Kn

Parameters K0 Enables bus hold-off on X.
K1 Disables bus hold-off on X.

Default The default on power-up, or after a DCL or SDC command is K0.

Description Bus hold-off allows the instrument to temporarily hold up bus operation via the NRFD line when it receives the X character until all commands are processed. The advantage of using bus hold-off is that commands are not missed while the instrument is processing previously received commands.

Programming Examples OUTPUT 715;"K0X" ! Enable bus holdoff

L Load Program From EEPROM

Purpose To load a previously stored program from EEPROM.

Format Ln

Parameters

- L0 Clear current program (no active program).
- L1 Load Program 1 from EEPROM.
- L2 Load Program 2 from EEPROM.
- L3 Load Program 3 from EEPROM.

Description The L1 through L3 commands allow the user to load a program from EEPROM and make it the active program. The three programs stored in EEPROM may be programs defined and saved by the user (see S command), or may be factory default programs (see J command).

The L0 command clears the program that was currently active. With no active program, the trigger controller ignores external trigger inputs.

When the unit is powered up, one of the three programs can be automatically loaded from EEPROM. This is accomplished by setting the rear panel DFLT PRGM switches (see Figure C-3) to the proper configuration. The switch settings correspond to the following programs:

DFLT PRGM Switch		
1	2	
0	0	No active program
1	0	Program 1
0	1	Program 2
1	1	Program 3

Programming Note The trigger input edge polarity status and the trigger response status are loaded along with the trigger I/O program.

Programming Examples OUTPUT 715;"L1X" ! Load program 1

M SRQ Mask and Serial Poll Byte Format

Purpose To program which conditions generate an SRQ (service request).

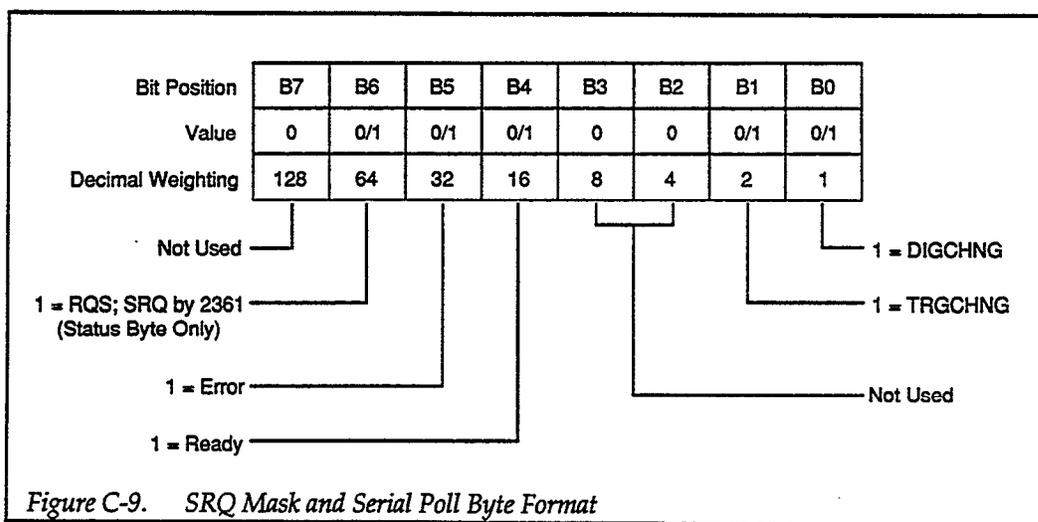
Format Mn

Parameters n = Sum of bits in the SRQ mask

- M0 Disable SRQ
- M1 Digital Input Change
- M2 Trigger Input Change
- M16 Ready
- M32 Error

Default The instrument defaults to an M0 state on power-up, or after receiving a DCL or SDC command.

Description **SRQ Mask** — The Model 2361 uses an internal mask to determine which conditions will cause an SRQ (service request) to be generated. Figure C-9 shows the general format of this mask, which is made up of eight bits.



SRQ can be programmed by sending the ASCII letter "M" followed by a decimal number to set the appropriate bit in the SRQ mask. Decimal values for the various bits are included in Figure C-9 and also listed in the "Parameters" section. Note that the instrument may be programmed for more than one set of conditions simultaneously. To do so, simply add up the decimal bit values for the required SRQ conditions. For example, to enable SRQ under trigger input change and error conditions, send M34. To disable SRQ, send M0X. This command clears all bits in the SRQ mask.

Available SRQ conditions include:

- Digital Input Change (M1) — Program for an SRQ on a digital input change.
- Trigger Input Change (M2) — Program for an SRQ on a trigger input change.
- Ready (M16) — Program for SRQ when ready to accept additional commands.
- Error (M32) — Program for SRQ when an error condition has occurred.

Serial Poll Byte Format — The serial poll byte contains information relating to data and error conditions within the instrument. The general format of this status byte is shown in Figure C-9. Note that the various bits correspond to the bits in the SRQ mask as described above.

The bits in the serial poll byte have the following meaning:

Bit 0 DIGCHNG (Digital Input Change) — Set when the appropriate edge has been detected at a digital input channel, and that the bit in the digital input change mask corresponding to that channel has been set (see D command – Digital Input Change Mask).

Bit 1 TRGCHNG (Trigger Input Change) — Set when the appropriate edge has been detected at a trigger input channel, and that the bit in the trigger input change mask corresponding to that channel has been set (see T command – Trigger Input Change Mask).

Bit 4 Ready — Set when the instrument has processed all previously received commands, and is ready to accept additional commands. Cleared while the instrument is processing commands.

Bit 5 Error — Set when one of the following error conditions has occurred:

1. Power-up test (RAM/ROM) failure
2. Operational self test (Digital I/O, Trigger I/O) failure
3. Illegal device-dependent command (IDDC)
4. Illegal device-dependent command option (IDDCO)

This bit is cleared when the U1 status word is read to determine the type of error (see U command – Status).

Bit 6 RQS (Request for service) — Set if the instrument asserted SRQ. Cleared when the instrument is serial polled.

Programming Note

If SRQ is disabled (M0), then the serial poll byte reflects the real-time state of the instrument:

- The TRGCHNG and DIGCHNG bits are reset by resetting the appropriate latches, either with the I command or under control of the active trigger program.
- The READY bit is reset whenever the unit is ready for another IEEE-488 byte.
- The Error bit is reset by a U1 status request.

**Programming
Examples**

```
10 DIM Error$ [50]
20 REMOTE 715
30 OUTPUT 715;"M32X"           ! Program for SRQ on error
40 OUTPUT 715;"E2X"           ! Program illegal option
50 S=SPOLL(715)                ! Serial poll the 2361
60 IF NOT BIT(S,6) THEN 50     ! Wait for SRQ
70 PRINT"B7 B6 B5 B4 B3      ! Label bit positions
   B2 B1 B0"
80 FOR I=7 TO 0 STEP -1       ! Loop 8 times
90 PRINT BIT(S,I)             ! Display the bit positions
100 NEXT I
110 PRINT
120 OUTPUT 715;"U1X"          ! Get status byte
130 ENTER 715;Error$
140 PRINT Error$              ! Display status byte
150 END
```

O Digital I/O

Purpose To assert the digital output lines high.

Format On

Parameters n = 0 to 255; Sum of bits in digital output byte.

Default Upon power-up, or after receiving a DCL or SDC command, all eight digital output lines are at 0V (00).

Description The O command specifies which of the eight digital output lines will be asserted high by using a binary output byte representation (see Figure C-10). Each of the eight digital output channels are assigned a bit. The least significant bit represents output channel 1, while the most significant bit represents output channel 8. An output channel is asserted high by sending the decimal equivalent of the appropriate bit position with the O command. For example, to assert digital output channel 3 high, send O4X. To assert multiple channels high, add up the decimal equivalents of the appropriate bit positions. For example, to assert output channels 5 and 7, send O80X.

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Decimal Weighting	128	64	32	16	8	4	2	1
Digital Output Channel	8	7	6	5	4	3	2	1

Figure C-10. Digital Output Byte

Programming Note The digital output pattern is a level output only. Any bit pattern specified with the O command will output a steady state until the next O command.

Programming Examples

<pre>10 REMOTE 715 20 OUTPUT 715;"T63X" 30 OUTPUT 715;"M2X" 40 OUTPUT 715;"1>1" 50 S=SPOLL(715) 60 IF NOT BIT(S,6) THEN 50 70 OUTPUT 715;"O1X" 80 END</pre>	<pre>! Set TRGCHNG on any trigger state change ! SRQ on TRGCHNG ! If 1 triggered, trigger out 1 ! Serial poll the 2361 ! Wait for SRQ ! Set digital output 1 high on a trigger state change</pre>
--	---

P Immediate Mode Pulse

Purpose To send an immediate pulse to a specified output(s).

Format Pn

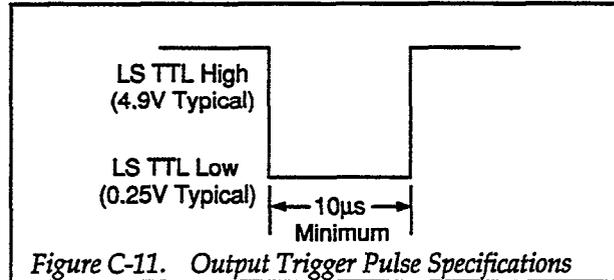
Parameters n = Any valid expression specifying the desired trigger output channel(s).

Description The P command sends an immediate trigger pulse to the specified output channel or channels. The channels are specified in the output expression following the P command. The output expression can simply be a single decimal digit 1 to 8 that corresponds to the specified channel. For example, to send a trigger pulse to output channel 6, send P6X.

To send a trigger pulse to multiple channels use the "*" operator as shown in the following example to send a trigger pulse to output channels 3 and 4:

P3*4X

The specifications of the output trigger pulse are shown in Figure C-11.



Programming Note The P command does not affect the active trigger I/O program. It is an immediate mode output only.

Programming Examples

OUTPUT 715; "P1X"	! Immediate trigger 1
OUTPUT 715; "P2*3"	! Immediate trigger 2 and 3

R Detect Trigger Input on Rising Edge

Purpose To set a trigger input channel to detect on its rising edge.

Format Rn

Parameters n = 0; Set all trigger input channels to detect an input trigger on its rising edge.
n = 1 to 6; Set the specified trigger input channel to detect an input trigger on its rising edge.

Default All trigger input channels default to a falling edge trigger state (F0) upon power-up, or after receiving a DCL or SDC command.

Description The R command allows the user to program an input trigger channel to latch an input on its rising edge.

Programming Notes

1. This command, along with the F command, also controls the polarity of the edge which triggers an SRQ for those channels which are set to generate an SRQ using the TRGCHNG mask (see T and M commands).
2. Any time an F or R command is used, the corresponding trigger input channel latch is cleared.

Programming Examples

```

10 OUTPUT 715;"R1X"           ! Detect 1 on rising edge
20 OUTPUT 715;"R2X"           ! Detect 2 on rising edge
30 OUTPUT 715;"1+2>3"         ! If 1 or 2 is triggered, trigger out 3
40 END

```

S Store Program in EEPROM

Purpose To store the current (active) program in EEPROM.

Format Sn

Parameters
S1 Store program in memory as Program 1.
S2 Store program in memory as Program 2.
S3 Store program in memory as Program 3.

Description The S command stores the currently active user program (which may be user defined) into EEPROM. Up to three programs can be stored and later recalled using the L command.

Programming Notes

1. One of the three stored programs may be loaded from EEPROM when the instrument is powered up. The particular program (Program 1, 2 or 3) is specified by setting DIP switches on rear panel (see L command).
2. The trigger input edge polarity status and the trigger response status are stored along with the program.
3. If it is desired to store a user defined program with the trigger response disabled (E1), then the E1 command must be sent after the program is created. When a user defined program is created, trigger response is enabled (E0).

Programming Examples

```
10 REMOTE 715
20 OUTPUT 715;"R1X"           ! Detect inputs 1 and 2 on
30 OUTPUT 715;"R2X"           rising edge input
40 OUTPUT 715;"1*2>3X"       ! If 1 and 2 are triggered, trigger out on 3
50 OUTPUT 715;"S1X"         ! Store as program 1
60 END
```

T Trigger Input Change Mask

Purpose To determine which trigger input channels will set the TRGCHNG bit in the serial poll byte when they receive a trigger.

Format Tn

Parameters n = 0 to 63; An integer value that is the decimal weighted sum of the selected bits in the trigger input change mask.

Default Upon power-up, or after receiving a DCL or SDC command, the digital input change mask will default to T0.

Description The digital input change mask determines which trigger input channels will cause the TRGCHNG bit, located in the serial poll byte, to be set when an input trigger is received.

Bits 0 through 5 of this mask (see Figure C-12) represent the six trigger input channels. The MSB (B5) represents trigger input #6, and the LSB (B0) represents trigger input #1.

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Decimal Weighting	128	64	32	16	8	4	2	1
Trigger Input Channel	-	-	6	5	4	3	2	1

Figure C-12. Trigger Input Change Mask

The desired channels are selected by simply selecting the corresponding bit in the mask. To program the mask, the decimal weighted sum of the selected bits are sent with the T command. For example, to set the mask for trigger input channels 6 and 1, send T33X over the bus.

Then, when a trigger is received at the specified channels, TRGCHNG in the serial poll byte (see M command) is set.

Programming Examples

```

10 REMOTE 715
20 OUTPUT 715;"T1X"           ! Set TRGCHNG bit on channel 1 state change
30 OUTPUT 715;"1>2X"         ! If 1 triggered, trigger out 2
40 OUTPUT 715;"M2X"          ! Set to SRQ on TRGCHNG
50 S=SPOLL(715)               ! Serial poll the 2361
60 IF NOT BIT(S,6) THEN 50    ! Wait for SRQ
70 PRINT "Change in state
   occurred at ch. 1"
80 END

```

U Status

Purpose To obtain instrument status and configuration information.

Format Un

Parameters

- U0 Send machine status word.
- U1 Send error status word (0-255).
- U2 Send present active program.
- U3 Send latched trigger input state (0-63).
- U4 Send latched digital input state and clear latches.
- U5 Send DIP switch setting (0-255).
- U6 Send trigger and digital input edge detection polarities.
- U7 Send firmware revision level.

Description By sending the proper U command and then addressing the instrument to talk as with normal data, you can obtain information on machine status, error conditions and other data. The information is transmitted only once for each U command.

U0 Send Machine Status Word

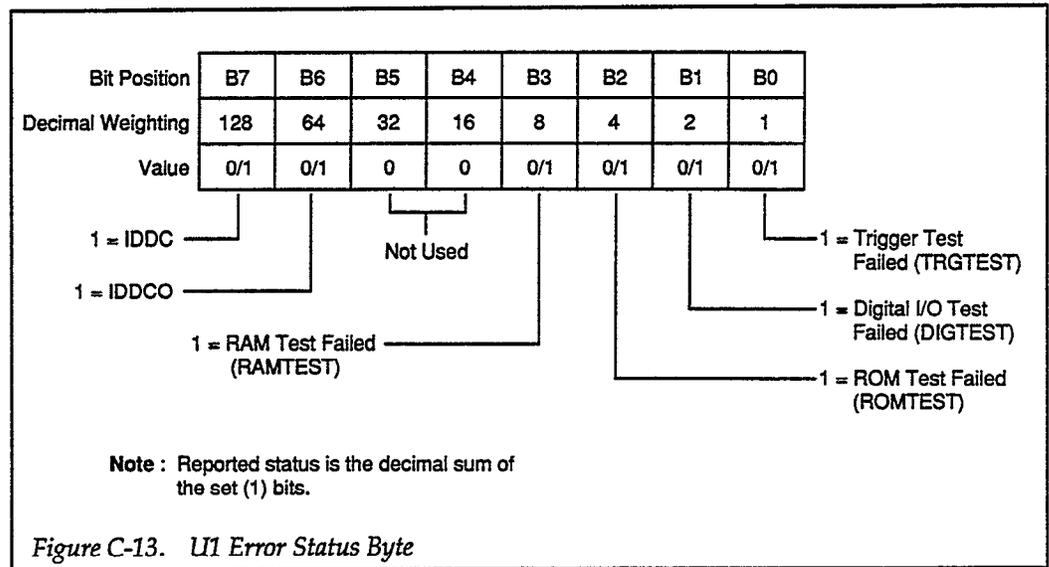
The U0 command lists the current modes programmed by the device-dependent commands. All returned values correspond to the last received values. On power-up, or after a DCL or SDC command is sent over the bus, the instrument will return to the following default conditions:

```
B0D000E1F0H0I0K0L0M00000R0S0T00W000Y0
```

U1 Send Error Status Byte

The U1 command permits access to the trigger controller's error byte. The error byte is a decimal number representing binary positions (see Figure C-13) that provides information about the machine's error status. For example, if the RAM and ROM tests failed, reading the U1 status byte will send the decimal value 12 (B2 and B3 set) to the computer.

An error condition will set the error bit in the SRQ serial poll status byte. If desired, the instrument can be programmed to generate an SRQ if an error condition occurs. Reading the U1 error status byte clears the error bit in the serial poll status byte (see M command).

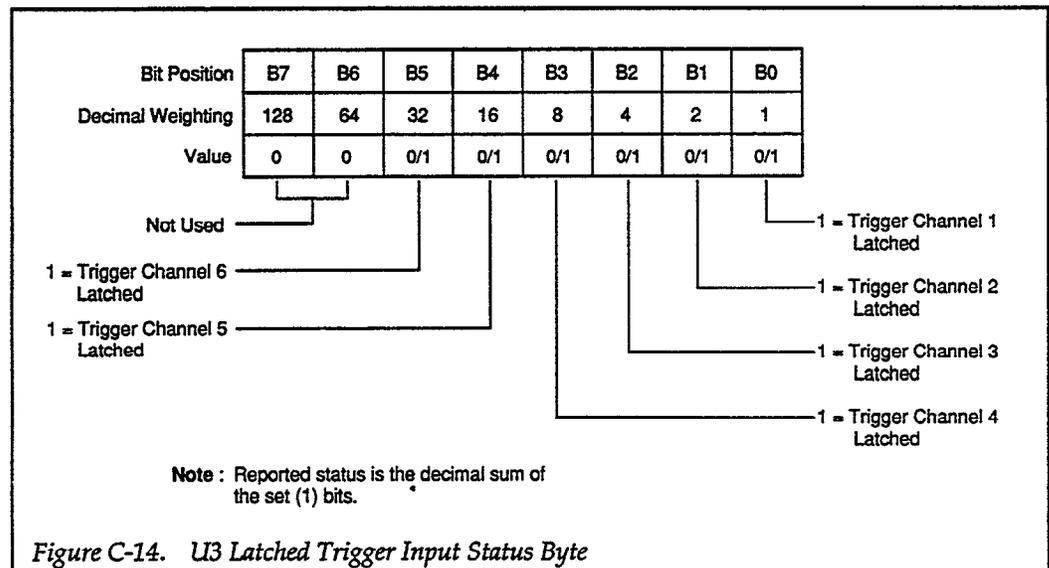


U2 Send Present Active Program

The U2 command allows the user to obtain the active program relation(s) from the trigger controller.

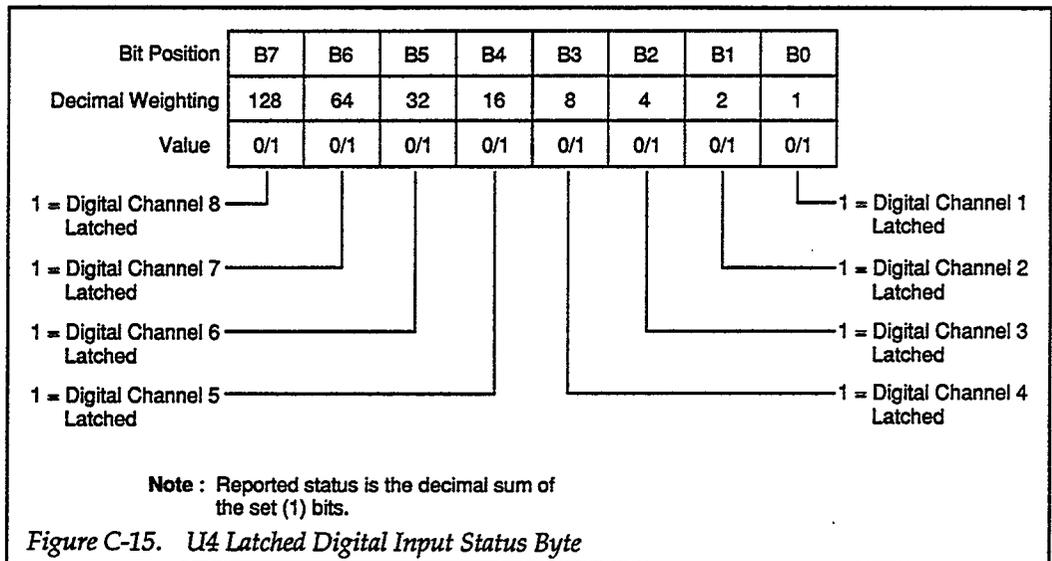
U3 Send Latched Trigger Input State

The U3 command is used to determine the current state of the input trigger channel latches. The argument is the decimal sum of the set bits in the binary byte which represents the six trigger inputs (see Figure C-14).



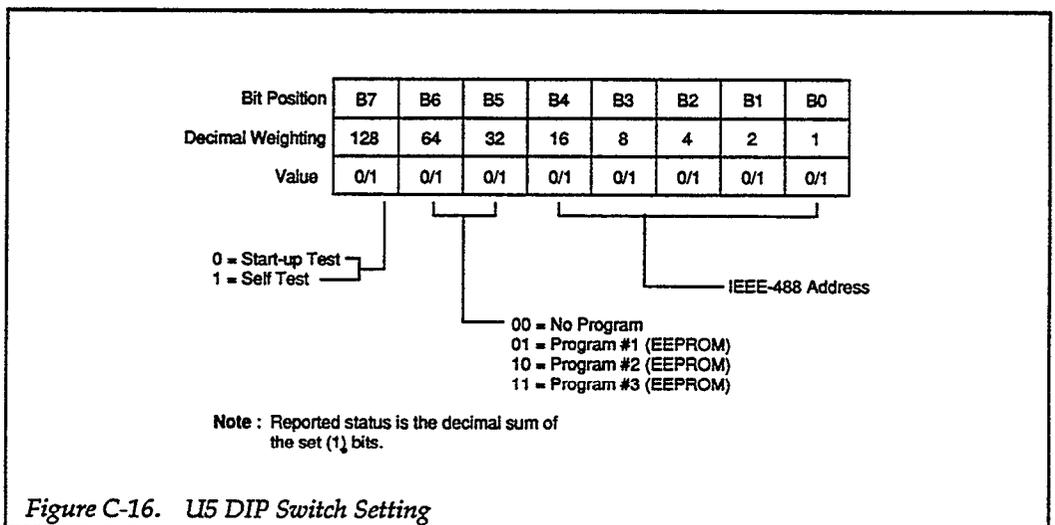
U4 Send Latched Digital Input State and Clear

The U4 command is used to determine the current state of the digital input channel latches. The argument is the decimal sum of the set bits in the binary byte which represents the eight digital inputs (see Figure C-15). Any set bit represents a channel that has detected an edge (trigger) of the polarity specified with the B or H command. When the U4 status is read, the latches are cleared.



U5 Send DIP Switch Setting

The U5 command is used to read the rear panel DIP switch setting. The decimal value (0-255) represents the switch positions as shown in Figure C-16.



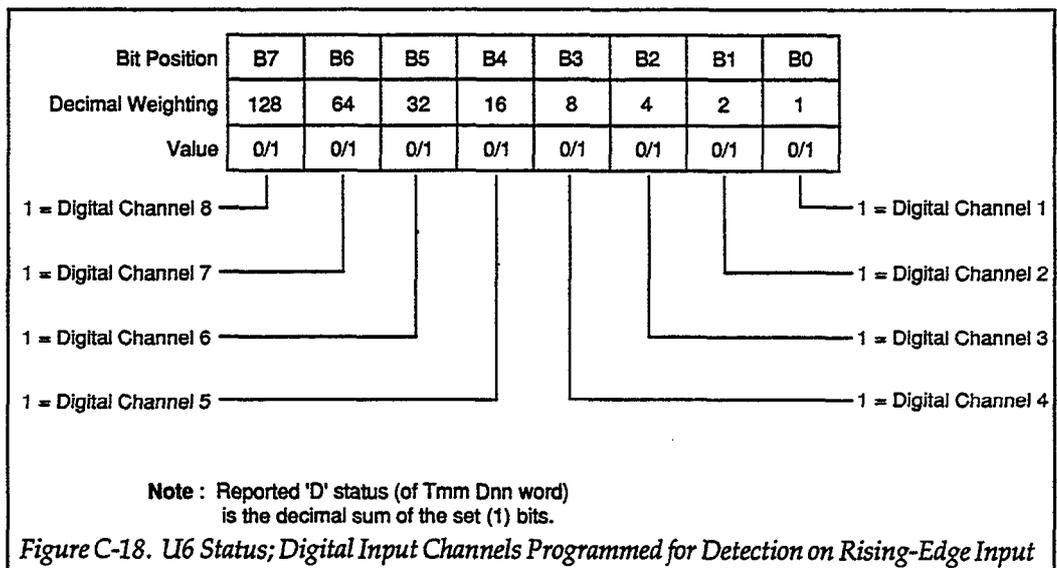
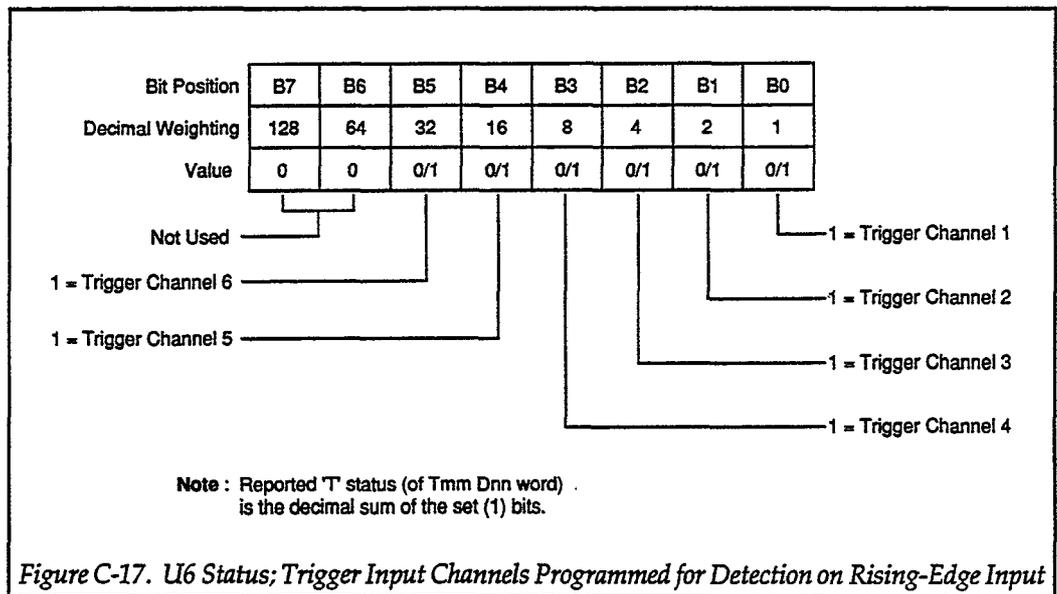
U6 Send Trigger and Digital Input Rising Edge Detection Status

The U6 command is used to determine which trigger and digital channels are programmed to detect rising-edge input. The U6 status word is sent in the following form:

TmmDnnn

where; mm = 00 to 63; Decimal value of set bits in a binary byte that represents trigger input channels that were programmed for detection on rising edges using the R command (see Figure C-17).

nnn = 000 to 255; Decimal value of set bits in a binary byte that represents digital input channels that were programmed for detection on rising edges using the H command (see Figure C-18).



For example, the U6 status word T03D000 indicates that trigger channels 1 and 2 are programmed to detect rising-edge input.

U7 Send Firmware Revision Level

The U7 command is used to obtain the revision level of the instruments firmware.

Programming Note

To send a status word (or byte) to the controller, the Model 2361 must be addressed to talk immediately after sending the desired U command. If a U command is not first sent, the current digital levels on the eight digital input lines (0-255) will instead be sent to the controller when addressed to talk.

Programming Examples

```
10 DIM Command$ [50]           ! Dimension command string
20 DIM Status$ [50]           ! Dimension status string
30 REMOTE 715
40 PRINT "Enter U Command"     ! Get desired U command
50 INPUT Command$
60 IF LEN(Command$)=0 THEN 120 ! Check for null
70 OUTPUT 715; Command$&"X"   ! Program with U command
80 ENTER 715; Status$         ! Get status
90 PRINT Status$              ! Print status
100 PRINT CHR$(128)           ! Print blank line
110 GOTO 40                   ! Return for next U
120 END
```

W Delay

Purpose To delay the output pulse after an input expression evaluates true.

Format Wn

Parameters n = 0 to 255; where "n" is the delay in 500µsec increments.

Default Upon power-up, or after a DCL or SDC command, the programmable delay defaults to 0msec.

Description The W command programs a delay between the input expression evaluating true and sending the output pulse(s) specified in the corresponding output expression. The delay period equals the value of "n" times 500µsec. For example, sending W100X programs a delay of 50msec ($100 \times 500\mu\text{sec} = 50\text{msec}$).

Programming Examples

OUTPUT 715;"W20X"	! Delay 10msec
OUTPUT 715;"W0X"	! Clear delay

X Execute

Purpose Execute DDC's or create an active program.

Format X

Parameters none

Description The execute command is implemented by sending an ASCII "X" over the bus. Its purpose is to direct the unit to execute all device-dependent commands received since the last X. Also, a user defined I/O program is created by using the X command.

Programming Examples

OUTPUT 715; "M32X"	! Execute M command
OUTPUT 715; "I0"	! Send I0 command
OUTPUT 715; "X"	! Execute I0 command
OUTPUT 715; "1>2X"	! Create program; if channel 1 triggered, trigger out on channel 2.

Y Terminator

Purpose To select the ASCII terminator sequence that marks the end of the instrument's data string.

Format Yn

Parameters
Y0 <CR><LF>
Y1 <LF><CR>
Y2 <CR>
Y3 <LF>

Default The default terminator on power-up, or a SDC or DCL command is Y0.

Description By using the Y command, you can program the number and type of terminator character(s) the instrument sends at the end of its data string. Available terminator characters are the commonly used CR (carriage return, ASCII 13) and LF (line feed, ASCII 10) characters.

These terminators are recognized by most controllers. Selecting the wrong terminator for the controller could cause the bus to hang.

Programming Examples

OUTPUT 715; "Y1X"	! Terminate on LF CR
OUTPUT 715; "Y0X"	! Terminate on CR LF

Z Clear All Programs

Purpose To clear all programs from EEPROM.

Format Z0

Parameters none

Description The Z command clears all programs from EEPROM. The memory can contain up to three user programs. The Z command has no effect on the currently active program (stored in RAM).

Programming Examples OUTPUT 715;"Z0X" ! Clear all programs from EEPROM memory

SERVICE INFORMATION

Ordering Information

To obtain information concerning replacement parts, contact your Keithley representative or the factory. See the inside front cover for addresses. When ordering replacement parts, include the following information:

- Instrument model number
- Instrument serial number
- Parts description
- Circuit designation (if applicable)

Factory Service

If the instrument is to be returned to the factory for service, please complete the service form, which follows this appendix, and return it with the instrument.

WARNING

The servicing procedures included in this appendix are for use by qualified service personnel only. Do not perform these procedures unless qualified to do so. Never open the Model 2361 case while it is connected to the AC line. Internal voltage potentials exist which could cause personal injury or death.

Line Voltage Selection

The Model 2361 may be operated from 90-125V or 180-250V, 50-60Hz AC. The operational voltage is set by an internal switch (S101). The trigger controller was shipped from the factory set for the operating voltage marked on the rear panel. To change the operating voltage, it is necessary to open the enclosure and change the setting of S101 according to the following instructions:

WARNING

Disconnect the power cord from the AC line and from the Model 2361. Disconnect any cables prior to disassembly. Never open the case while it is connected to the AC line. Internal voltage potentials exist which could cause injury or death.

1. Place the trigger controller on a flat surface. Remove the eight screws on top of the case and remove the top cover. Located next to the main power supply transformer is the line voltage selection switch S101.
2. Insert the tip of a small screwdriver into the slot of the switch and move the switch to the left or right so that the desired line voltage selection appears on the switch.
3. Install a power line fuse appropriate for the line voltage. See the following paragraph for the fuse replacement procedure.
4. Make a note of the new voltage setting on the rear panel of the trigger controller and carefully reassemble the unit.

Fuse Replacement

The Model 2361 contains an internal AC line fuse. The fuse is located next to the internal line voltage switch (S101). This fuse may be replaced by using the following procedure:

Table C-5. Line Fuse Values

Line Voltage	Fuse Type	Keithley Part No.
105-125V	1/8A, 250V, 3AG, Slo Blo	FU-20
180-250V	1/16A, 250V, 3AG, Slo Blo	FU-21

WARNING

Disconnect the power cord from the AC line and from the Model 2361. Disconnect any cables prior to disassembly.

1. Turn off the power and disconnect the line cord and all other cables from the unit.
2. Place the unit on a flat surface. Remove the eight screws on top of the case and remove the top cover.
3. The fuse is located next to the line voltage selection switch (S101). Gently pull upward on the plastic fuse housing until it separates from the fuse holder on the pc board.
4. Open the fuse housing by pushing up on the tab on the bottom of the housing.
5. Remove the fuse, and replace it with the proper type using Table C-5 as a guide.

CAUTION

Do not use a fuse with a higher rating than specified or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse.

6. Close the housing and insert it into the fuse holder.
7. Make note of the fuse rating for later reference and carefully re-assemble the unit.

Schematic, Component Layout, and Replaceable Parts

The schematic and component layout drawing are shown following the parts list

Model 2361 Digital Board, Parts List

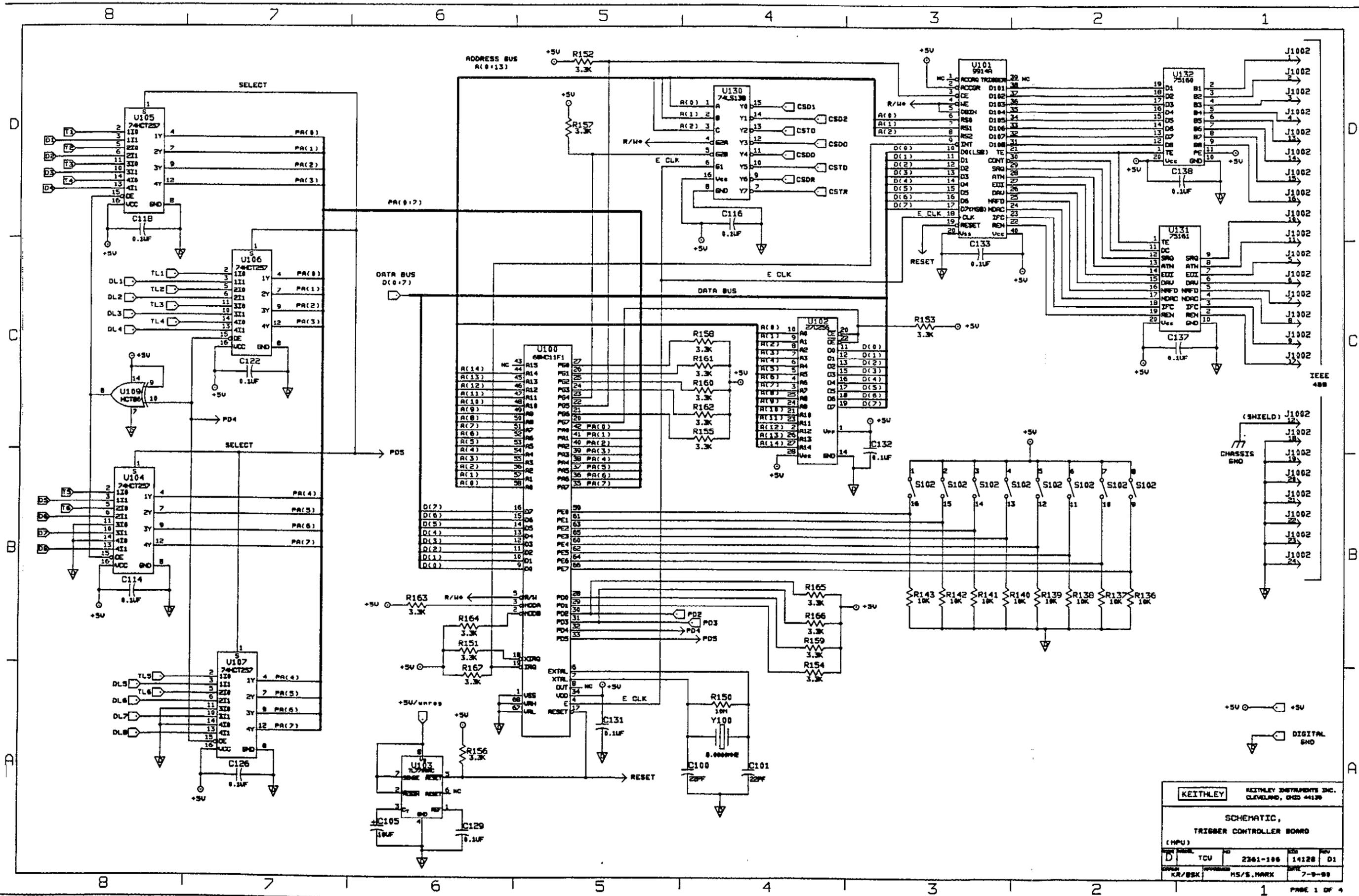
Circuit Desig.	Description	Keithley Part No.
	FUSE HOLDER	FH-29
	CONN,MALE,5 PIN	CS-288-5
	FUSE CLIPS	FH-12
C100,101	CAP,22PF,20%,500V,CERAMIC	C-22-22P
C102,103	CAP,1UF,20%,50V, CERAMIC	C-237-1
C104	CAP,4700UF, -10%+100%,16V, ELECTROLYTIC	C-290-4700
C105	CAP, 10UF,-20+100%,25V,ALUM ELEC	C-314-10
C106..138	CAP,.1UF,20%,50V,CERAMIC	C-365-.1
CR100..155	DIODE,SILICON,IN4148 (DO-35)	RF-28
CR156	DIODE, BRIDGE PE05	RF-48
DS100..116	PILOT LIGHT RED, HI-INTENSITY LED	PL-88-1
F100	(FU-21 1/16A FOR EUROPE) FUSE, .125A, 250V,3AG SLO-BLO	FU-20
J1002	CONN,RIGHT ANGLE,24 PIN	CS-501
J1004..1015	CONN, BNC	CS-547
J1016	MODIFIED CONNECTOR	236-329
R100..127	RES,100,5%,1/4W,COMPOSITION OR FILM	R-76-100
R128..149	RES,10K,5%,1/4W,COMPOSITION OR FILM	R-76-10K
R150	RES,10M,5%,1/4W,COMPOSITION OR FILM	R-76-10M
R151..167	RES,3.3K,5%,1/4W, COMPOSITION OR FILM	R-76-3.3K
R168	RES, 33, 5%,1/4W, COMPOSITION OR FILM	R-76-33
R169..185	RES,390,5%,1/4W,COMPOSITION OR FILM	R-76-390
S100	SWITCH,PUSHBUTTON (6 POLE)	SW-466
	PUSHBUTTON, RED	29465-3
S101	SWITCH, SLIDE (DPDT)	SW-484
S102	SWITCH, HORIZONTAL MOUNT, DIP, SPST	SW-449-8
T100	TRANSFORMER	TR-275
U100	IC,8-BIT MICROCONTROLLER,MC68HC11F1	LSI-98
U101	IC,GPIB ADAPTER,9914A	LSI-49
U102	EPROM PROGRAM	2361-800-**
U103	IC, SUPPLY VOLTAGE SUPERVISOR, TL7709AC	IC-715
U104..107	IC, QUAD 2 INPUT MULTI, 74HCT257	IC-709
U108..114	IC, QUAD 2 INPUT EXCLUSIVE-OR, 74HCT86	IC-707
U115..122	IC, OCTAL D-TYPE FLIP-FLOP, HCT574	IC-629
U123..129	IC,DUAL D FLIP FLOP W/SET & RESE,74HCT74	IC-515
U130	IC,DECODER/DEMUX,74LS138	IC-182
U131	IC,OCTAL INTERFACE BUS TRANSCEIVER,75161	IC-299
U132	IC,OCTAL INTERFACE BUS,75160	IC-298

**ORDER CURRENTLY INSTALLED FIRMWARE REVISION LEVEL.

	4-40X5/16 PHILLIPS PAN HD	4-40X5/16PPH
	6-32 PEM NUT	FA-135
	6-32X3/8 PHILLIPS PAN HD	6-32X3/8PPH
	SOCKET,I.C. 28 PIN	SO-69
	SOCKET, 68-PIN QUAD	SO-128-68
VR100	IC, POS VOLTAGE REG +5V,500MA,309	IC-34
	HEAT SINK	HS-32
	MOUNTING KIT	MK-20
	MOUNTING KIT	MK-16
Y100	CRYSTAL,8.0000MHZ	CR-24-1

Model 2361 Mechanical, Parts List

Description	Keithley Part No.
BNC TO BNC CABLY ASSEMBLY	CA-19-1
CONNECTOR CARD EDGE	CS-444-2
COVER, TOP AND BOTTOM	2361-307A
DIGITAL BOARD TO FRONT PANEL BRACKET	2361-313A
FEET	FE-24-1
FRONT PANEL	2361-304A
GND LUG	LU-88
HOUSING, CONNECTOR	CS-287-5
IEEE MTG HARDWARE	CS-378
KEY	CS-474
LINE FILTER	LF-6-1
OVERLAY, FRONT PANEL	2361-303B
POWER CORD	CO-19
P1016 CONNECTOR	CS-276
P1016 POLARIZING KEY	CS-345
RACK EAR	2361-311A
REAR PANEL	2361-306C
SELF-TEST CONNECTOR	2361-314B
SIDE PANEL	2361-308A
SPACER PLATE	2361-309A
TINNERMAN CLIP	FA-231-1
1/2-28 UNEF SMALL NUT	FA-234-1

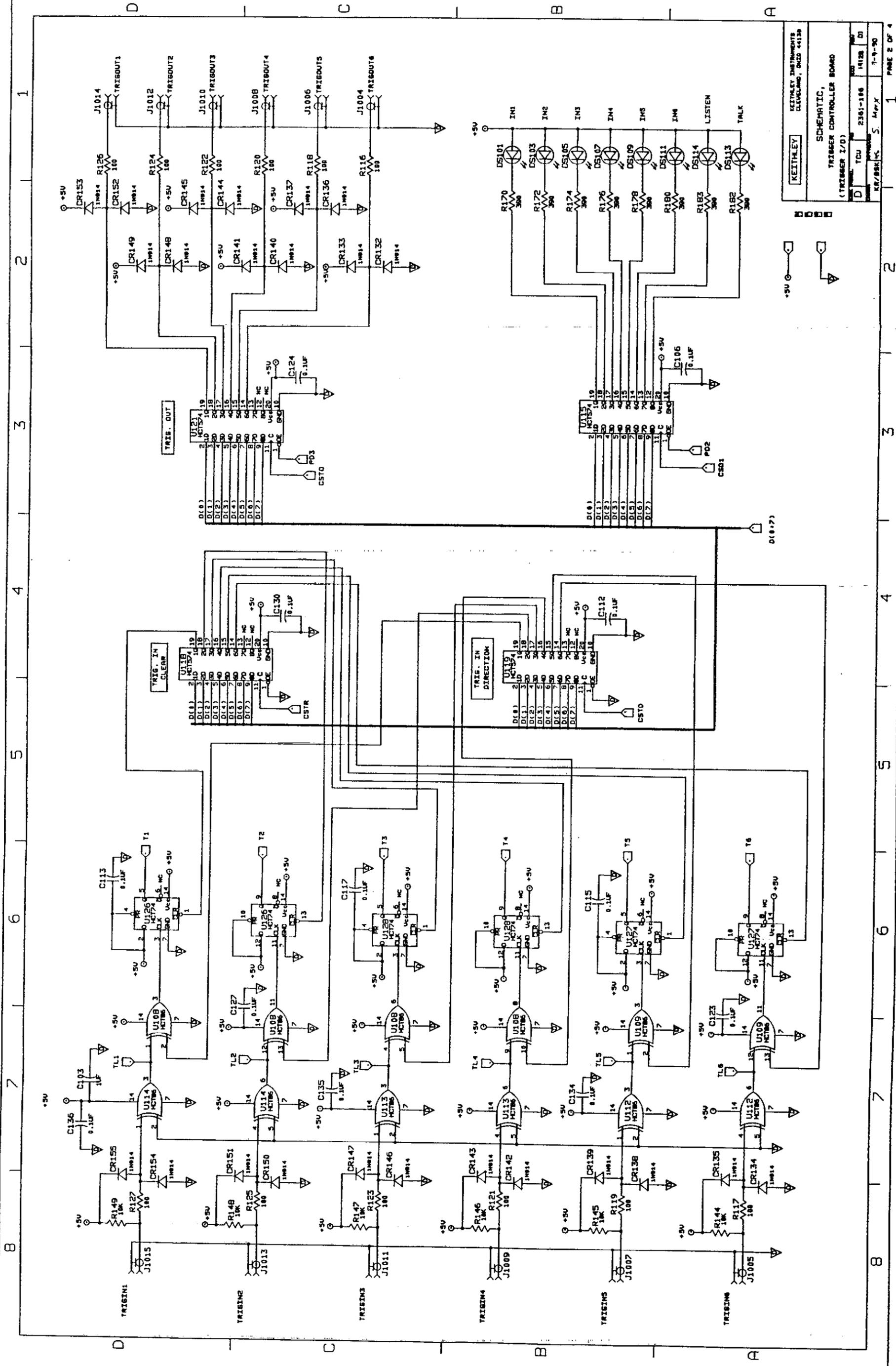


KEITHLEY KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44129

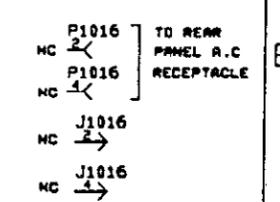
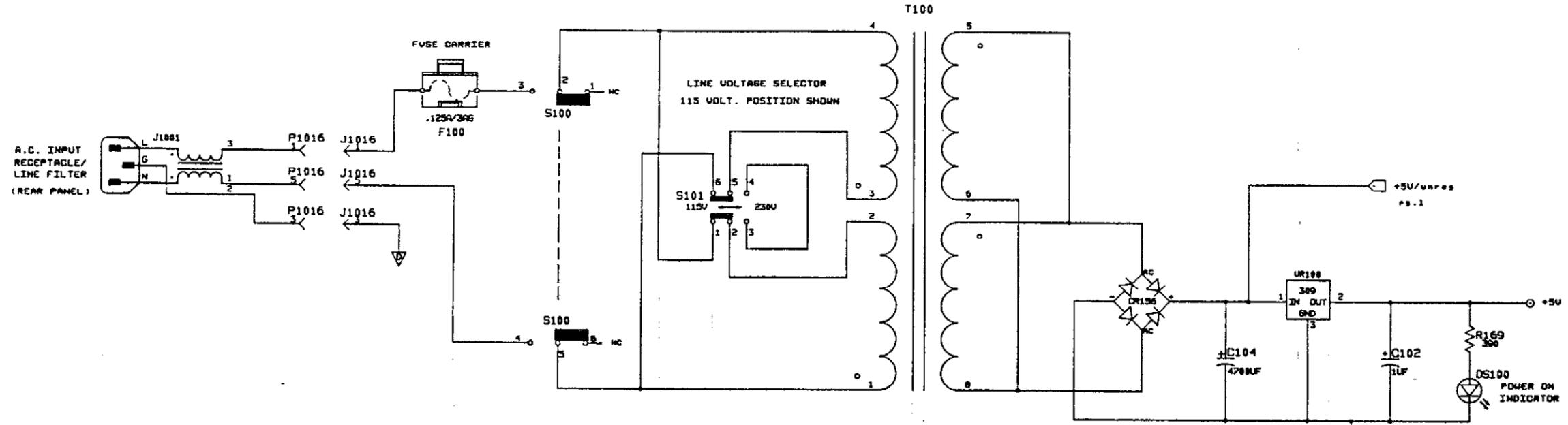
SCHEMATIC, TRIGGER CONTROLLER BOARD (MPU)

REV	TCU	NO	2361-106	REV	14128	REV	D1
DATE	KS/SBK	APPROVED	HS/S.MARK	DATE	7-9-88		

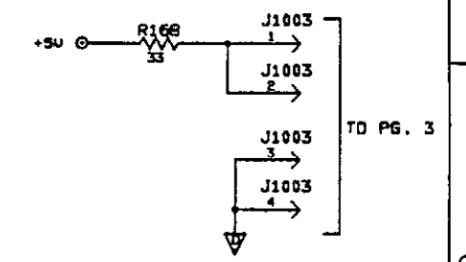
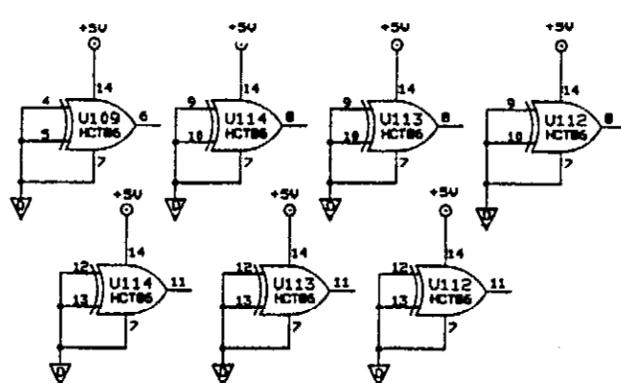
PRIME 1 OF 4



8 7 6 5 4 3 2 1



SPARES



KEITHLEY		KEITHLEY INSTRUMENTS CLEVELAND, OHIO 44139	
SCHEMATIC, TRIGGER CONTROLLER BOARD (POWER SUPPLY)			
REV	DATE	BY	CHK
D	TCU	2361-196	14128 D1
DRWN	APPROVED	DATE	
KR/BSK	S. Marx	7-9-90	

8 7 6 5 4 3 2 1

APPENDIX D

Test Library

INTRODUCTION

This appendix contains a collection of common tests for Model 251 software. Most tests are described on two pages, including a connection schematic, sample curves, and all of the test forms. The instrument configuration file, test setup files, sample data files, sequence files, and 707 files for these tests were copied to the CONFIG, TEST, DATA, SEQ, and 707 (default) subdirectories during the Install procedure.

The library is divided into six sections:

- Component tests
- Diode tests
- Bipolar tests
- FET tests
- Example GPIB control
- Test Sequences

Page numbers were omitted so additions can be easily inserted as the library is expanded.

The tests were written to use Model 236 Source Measure Units. If sourcing or measuring requirements exceed 110V for your tests, use a Model 237 (up to 1100V); if requirements exceed 100mA, use a Model 238 (up to 1A).

The TESTLIB.CFG file contains the instrument configurations needed to run all the tests in this library. It assumes an instrument rack with two Model 236 Source Measure Units, a Model 2361 Trigger Controller, a Model 213 Quad Voltage Source, a Model 707 Switching Matrix, and a Temptronic Model TP0315A thermal chuck. The trigger channels, IEEE-488 address, and instrument name assignments are as shown in Table D-1. Instrument names were chosen to correspond to device under test (DUT) terminals.

Before running tests from the library, it will be necessary to make changes in the instrument configuration if your rack does not contain the same complement. This is described in Section 3, Measurements.

Table D-1. Assignments for Test Library Instrument Configuration

Trigger Channel	Instrument	IEEE-488 Address	Instrument Names				Example GPIB
			Component Tests	Diode Tests	Bipolar Tests	FET Tests	
1	KI236	16	RESISTOR CAPACITR	DIODE	COLLECTR EMITTER	DRAIN	
2	KI236	17			BASE	GATE SOURCE	
	KI213-1	09					SUBSTRAT
	Other (KI213)	11					QVS213
	Other (KI707)	18					MATRIX
	Other (Hot chuck)	10					TP0315A

Most of the three-terminal device tests are run with NPN bipolar transistors or N-channel JFETs. When testing other bipolars or FETs, the polarities of the current and voltage parameters need to be changed. Tables D-2 through D-4 list polarities for the common parameters.

Table D-2. Parameter Polarities for Bipolar Transistor Tests

Parameter	NPN Transistor	PNP Transistor
I_B	+	-
I_C	+	-
I_E	+	-
V_{BC}	+	-
V_{BE}	+	-
V_{CE}	+	-
V_{EC}	+	-

Table D-3. Parameter Polarities for JFET Tests

Parameter	N-channel JFET	P-channel JFET
I_D	+	-
I_D (self-bias test)	-	+
I_G	-	+
V_{DS}	+	-
V_{GS}	-	+
V_{SD}	-	+
V_{SG}	+	-

Table D-4. Parameter Polarities for MOSFET Tests

Parameter	N-channel Enhancement Mode MOSFET	P-channel Enhancement Mode MOSFET	N-channel Depletion Mode MOSFET
I_D	+	-	+
I_D (self-bias test)	-	+	-
I_G	+	-	-/+
I_G (gate leakage test)	+	-	-
V_{DS}	+	-	+
V_{GS}	+	-	-/+
V_{GS} (gate leakage test)	+	-	-
V_{SD}	-	+	-
V_{SG}	-	+	-/+
V_{SUB}	-	+	-

Component Tests

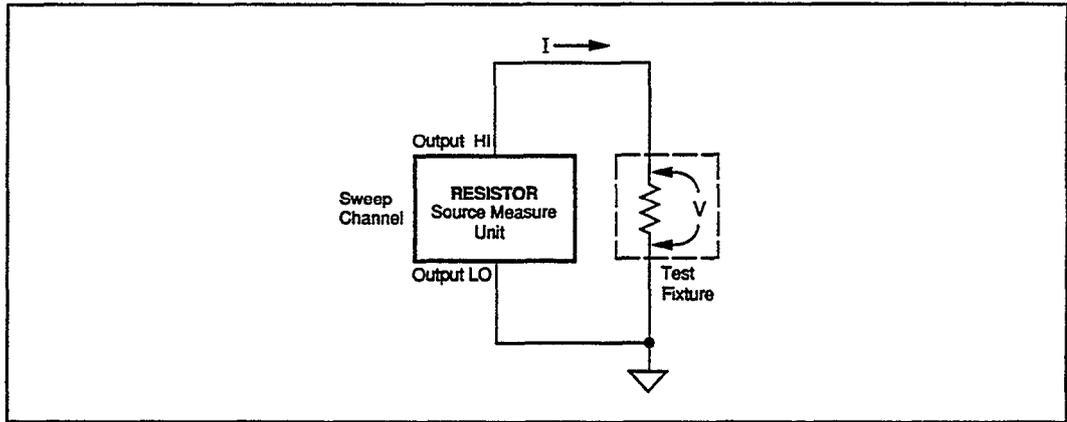
Resistor Voltage Coefficient
Capacitor Leakage Test

Resistor Voltage Coefficient

File Names TESTLIB.CFG, RESISTOR.TST, RESISTOR.DAT

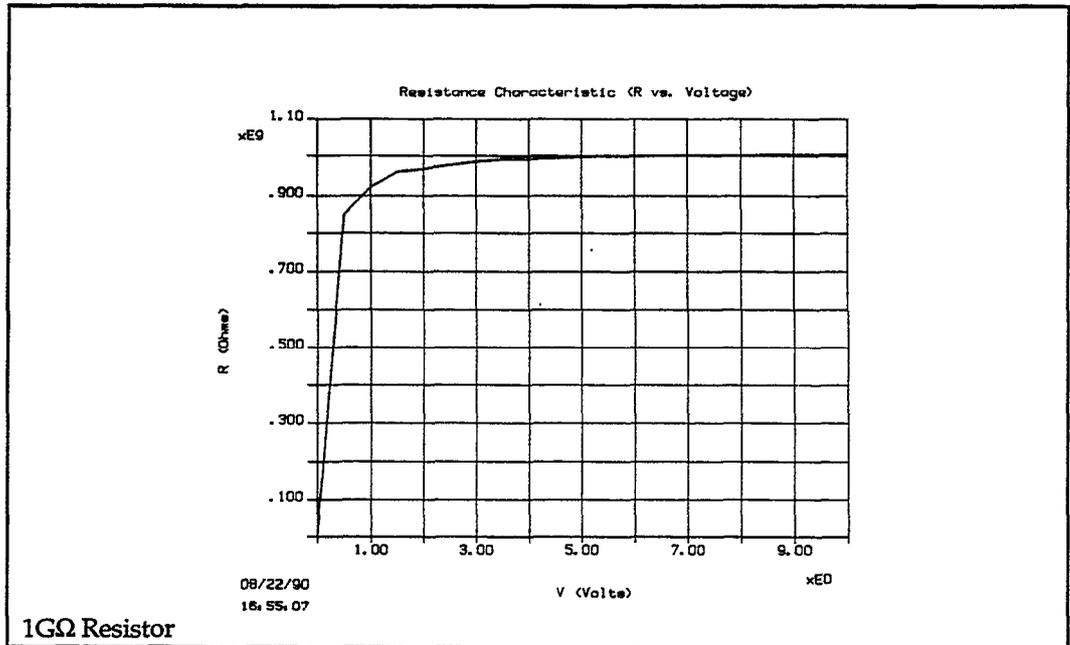
Test Description

Graphs resistance value versus voltage. From the graph, the resistor voltage coefficient can be determined.



Test Method

- A 1GΩ resistor is connected between the OUTPUT HI and OUTPUT LO terminals of a source measure unit.
- The source measure unit sweeps V from 0 to 10V and measures I.
- OUTPUT LO of the source measure unit is grounded.
- The slope value of the line placed on the linear part of the graph determines the resistor voltage coefficient.



DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
RESISTOR	16	KI236	1

RESISTOR CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 416µs				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	RESISTOR					
Src Array Name	V	—	—	—	—	—
Meas Array Name	I	—	—	—	—	—
SOURCE						
Type	V	—	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	—	—	—	—
Start/Bias	0 V	—	—	—	—	—
Stop	10 V	—	—	—	—	—
Step	500 mV	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	100 nA	—	—	—	—	—
Compliance Value	100 nA	—	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: Resistance Characteristic (R vs. Voltage)

Scale: Manual

Axis	X	Y1	Y2
Array Name	V	R	
Linear/Log	Linear	Linear	—
Min	0V	0	0
Max	10V	1.1G	1
# of Divisions	10	11	—

Grid: On
X Label: V (Volts)
Y1 Label: R (Ohms)
Y2 Label:
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

DC Gain (Ratio) Calculation

$R = (V / I) * 1$

Calculation: On

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
CAPACITR	16	KI236	1

DCCAPAC

DC SOURCE-MEASURE TEST

Mode: Single Test Delay Time: 10 s		Integration Time: 60Hz Line Filter: Disable				
CHANNEL NAME	Bias 1	Bias 2	Bias 3	Bias 4	Bias 5	Bias 6
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	CAPACITR					
Src Array Name	Vc	---	---	---	---	---
Meas Array Name	Ic	---	---	---	---	---
SOURCE						
Type	V	---	---	---	---	---
Range	Auto	---	---	---	---	---
Value	2 V	---	---	---	---	---
Sense	Local	---	---	---	---	---
MEASURE						
Range	1 μ A	---	---	---	---	---
Compliance Value	1 μ A	---	---	---	---	---

DISPLAY DC PARAMETERS

Title: Capacitor Leakage Test
Select All
Clear All
▶ Vc
▶ Ic
▶ R
DC-Gain
Comment: 1uF capacitor is used for the test.

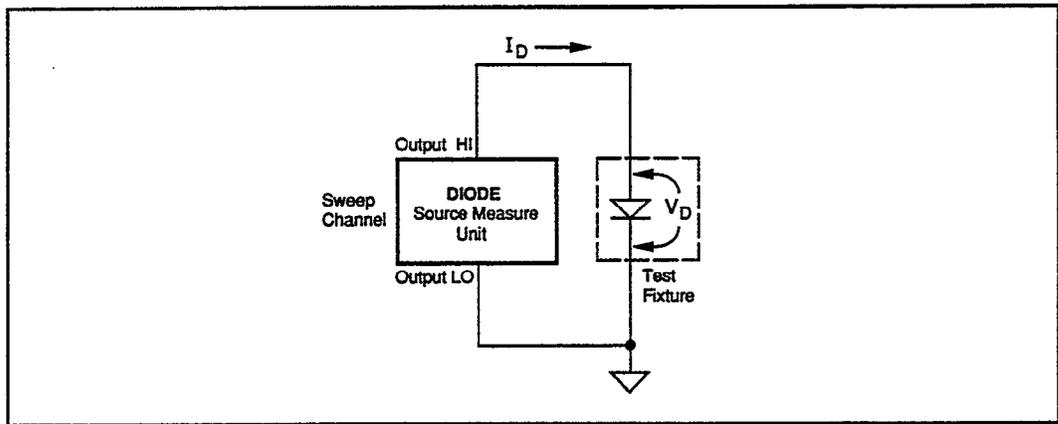
Diode Tests

Diode Forward Biased I-V Characteristic Linear Sweep
Diode Forward Biased I-V Characteristic Log Sweep
Diode Reverse Breakdown Voltage
Zener Diode Resistance Test
Zener Diode Voltage Test

Diode Forward Biased I-V Characteristic Linear Sweep

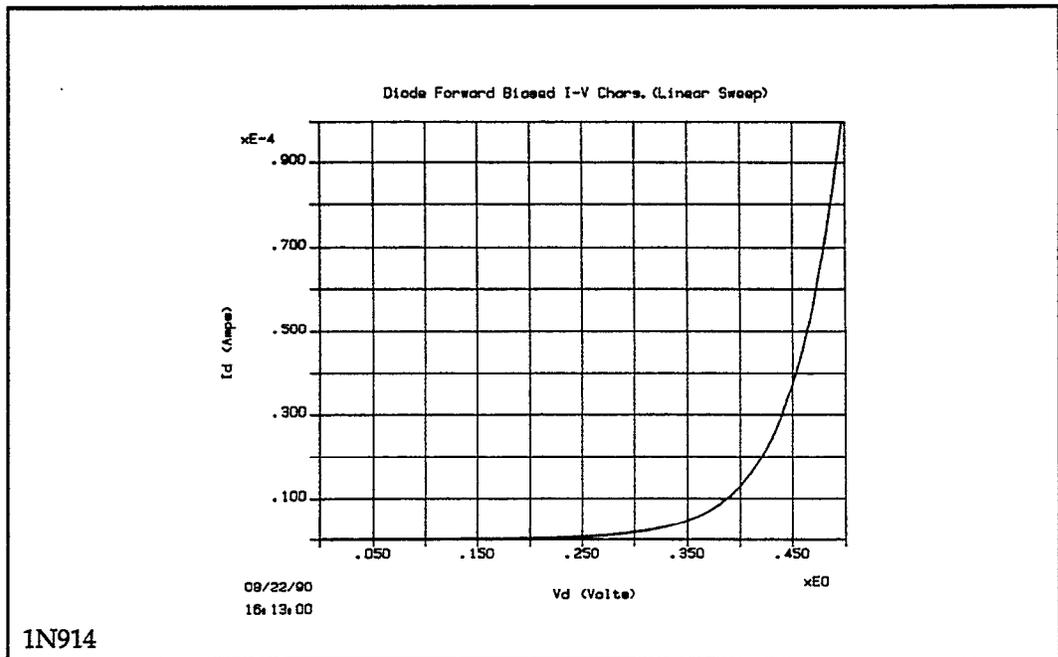
File Names TESTLIB.CFG, DIODELIN.TST, DIODELIN.DAT

Test Description Graph of I_D versus V_D for a diode. (Alternative V_D could be graphed vs. I_D .)



Test Method

- The source measure unit sweeps V_D from 0V to +500mV and measures I_D .
- The OUTPUT LO terminal of the source measure unit is connected to the cathode and grounded.



See Also DIODELOG.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DIODE	16	KI236	1

DIODELIN

CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 416µs				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	DIODE	—	—	—	—	—
Src Array Name	Vd	—	—	—	—	—
Meas Array Name	Id	—	—	—	—	—
SOURCE						
Type	V	—	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	—	—	—	—
Start/Bias	0 V	—	—	—	—	—
Stop	500 mV	—	—	—	—	—
Step	10 mV	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	1 mA	—	—	—	—	—
Compliance Value	1 mA	—	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: Diode Forward Biased I-V Chars. (Linear sweep)

Scale: Manual

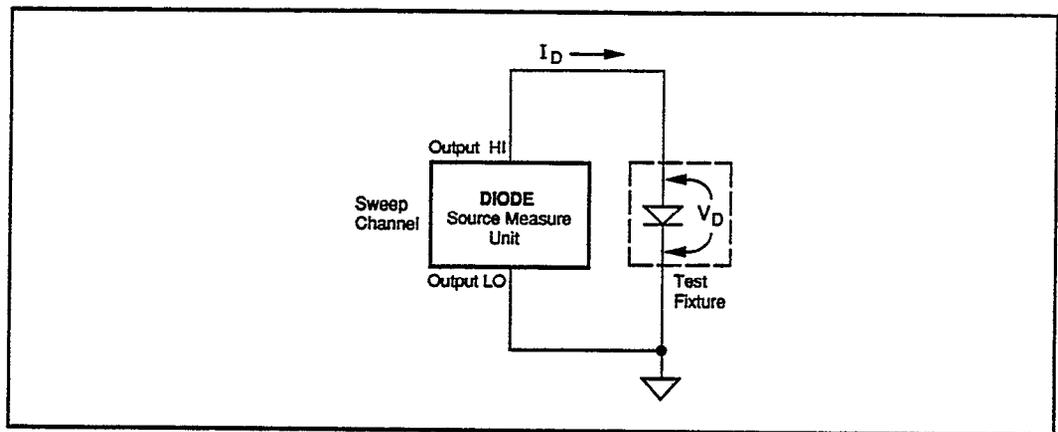
Axis	X	Y1	Y2
Array Name	Vd	Id	—
Linear/Log	Linear	Linear	—
Min	0	0	0
Max	500 mV	100 µA	1
# of Divisions	10	10	—

Grid: On
X Label: Vd (Volts)
Y1 Label: Id (Amps)
Y2 Label:
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

Diode Forward Biased I-V Characteristic Log Sweep

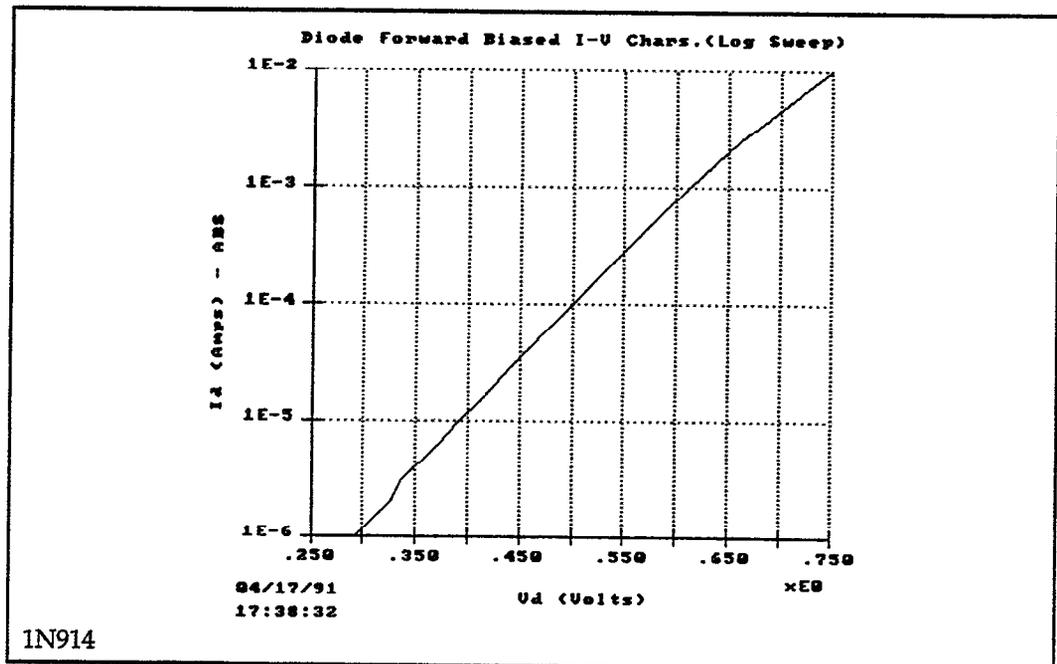
File Names TESTLIB.CFG, DIODELOG.TST, DIODELOG.DAT

Test Description Graph of I_D versus V_D . A log sweep is used to source I_D .



Test Method

- The source measure unit sweeps I_D from $1\mu\text{A}$ to 10mA and measures V_D .
- The OUTPUT LO terminal of the source measure unit is connected to the cathode and grounded.



See Also DIODELIN.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DIODE	16	KI236	1

DIODELOG

CURVE FAMILY TEST

Sweep Type: LOG		Integration Time: 416µs				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	DIODE					
Src Array Name	Id	—	—	—	—	—
Meas Array Name	Vd	—	—	—	—	—
SOURCE						
Type	I	—	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Auto	—	—	—	—	—
Start/Bias	1 µA	—	—	—	—	—
Stop	10 mA	—	—	—	—	—
Step	—	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	Auto	—	—	—	—	—
Compliance Value	10 V	—	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: Diode Forward Biased I-V Chars. (Log sweep)

Scale: Manual

Axis	X	Y1	Y2
Array Name	Vd	Id	
Linear/Log	Linear	Log	—
Min	250 mV	1 µA	0
Max	750 mV	10 mA	1
# of Divisions	10	—	—

Grid: On
X Label: Vd (Volts)
Y1 Label: Id (Amps)
Y2 Label:
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

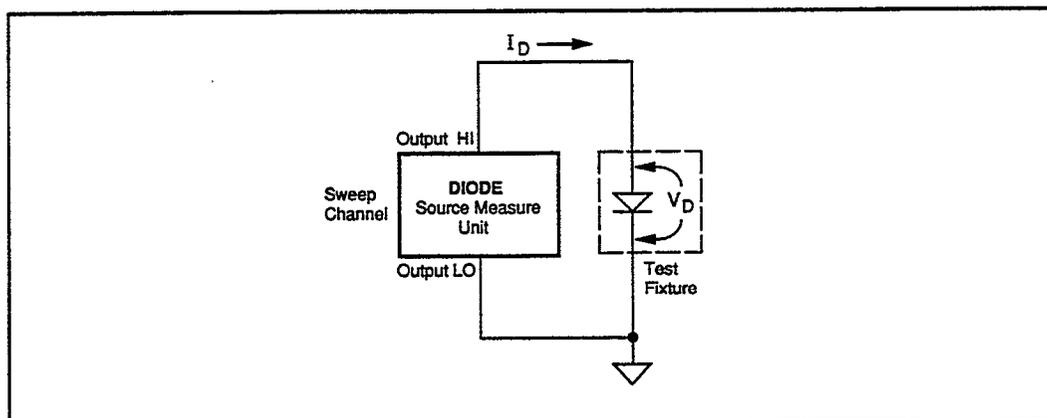
Diode Reverse Breakdown Voltage

File Names

TESTLIB.CFG, DIODERBV.TST, DIODERBV.DAT

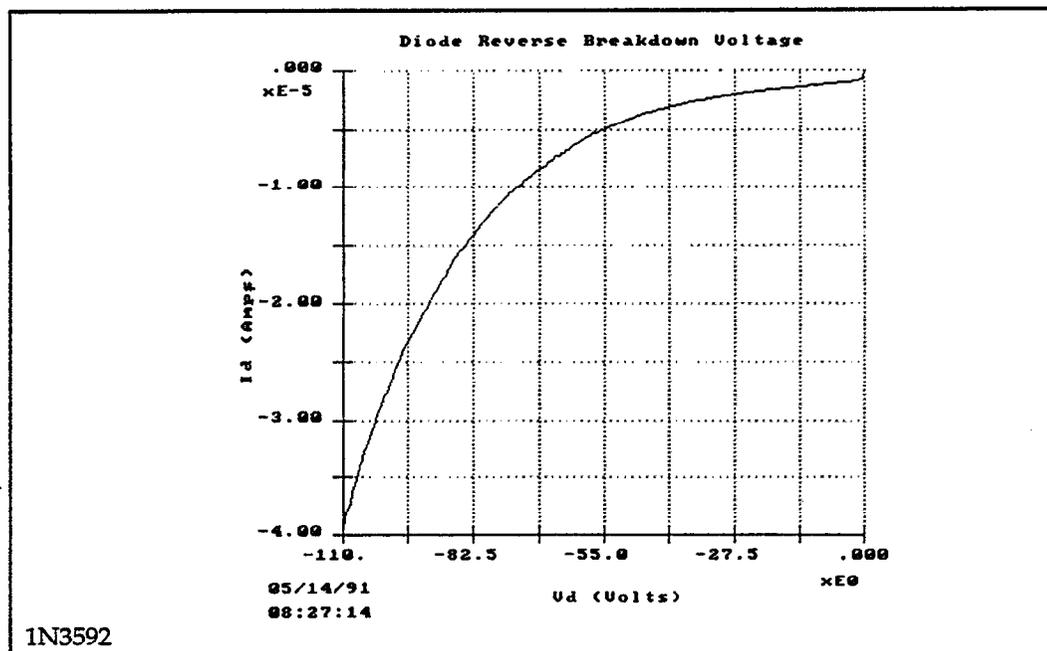
Test Description

Graph of I_D versus V_D . From the graph, the reverse breakdown voltage of a diode can be determined.



Test Method

- The source measure unit sweeps V_D from 0 to $-85V$ and measures I_D .
- The OUTPUT LO terminal of the source measure unit is connected to the cathode and grounded.



DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DIODE	16	KI236	1

DIODERBV CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 416µs				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	DIODE					
Src Array Name	Vd	—	—	—	—	—
Meas Array Name	Id	—	—	—	—	—
SOURCE						
Type	V	—	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	—	—	—	—
Start/Bias	0 V	—	—	—	—	—
Stop	-85 V	—	—	—	—	—
Step	500 mV	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	Auto	—	—	—	—	—
Compliance Value	1 mA	—	—	—	—	—

DISPLAY PARAMETERS

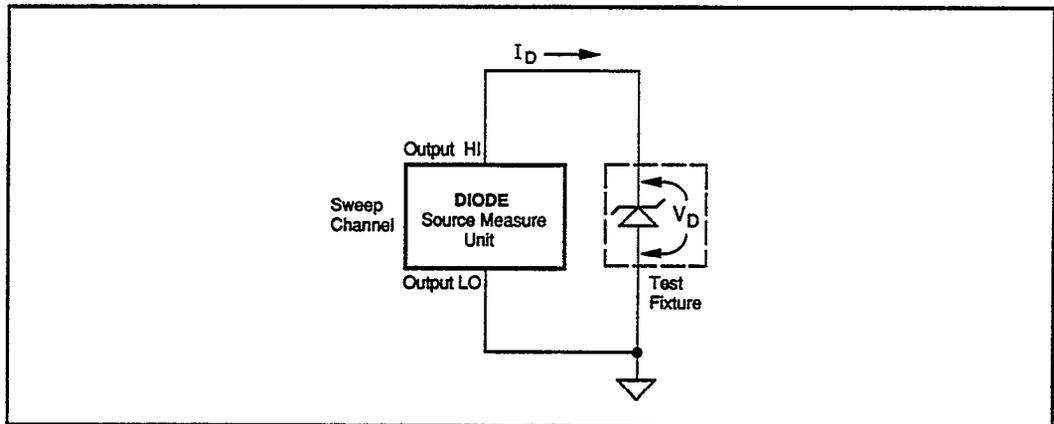
Mode: Graphics			
Graph Title: Diode Reverse Breakdown Voltage			
Scale: Manual			
Axis	X	Y1	Y2
Array Name	Vd	Id	
Linear/Log	Linear	Linear	—
Min	-90 V	-140 µA	0
Max	0 V	0 A	1
# of Divisions	10	14	—
Grid: On			
X Label: Vd (Volts)			
Y1 Label: Id (Amps)			
Y2 Label:			
Colors/Curve Labels			
DC-Gain (Ratio)			
Differential Gain			
Overlay Form			

Zener Diode Resistance Test

File Names TESTLIB.CFG, ZENERRES.TST, ZENERRES.DAT

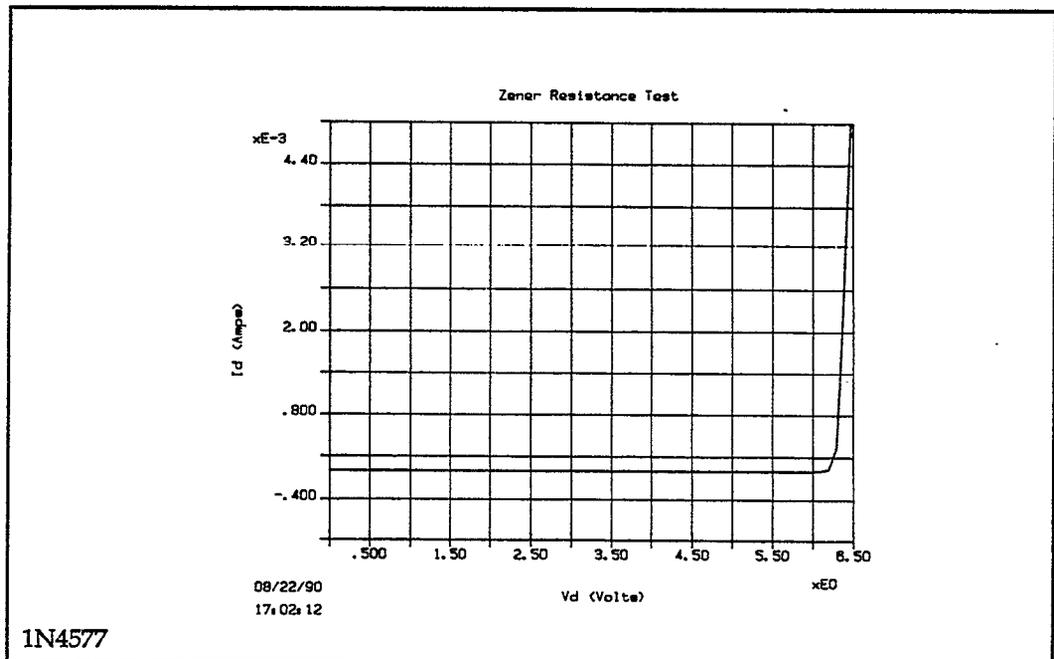
Test Description

Graph of I_D versus V_D . From the graph, zener resistance can be determined.



Test Method

- The source measure unit sweeps V_D from 0 to 6.5V and measures I_D .
- The OUTPUT LO terminal of the source measure unit is connected to the anode and grounded.
- The 1/Slope value of the line placed on the linear part of the graph determines the resistance of the zener.



DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DIODE	16	KI236	1

ZENERRES CURVE FAMILY TEST

Sweep Type: LINEAR
Mode: Single Test
Delay Before Curves: 0 s
Integration Time: 416µs
Filter: Disable
Delay Between Points: 0 s

CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	DIODE	—	—	—	—	—
Src Array Name	Vd	—	—	—	—	—
Meas Array Name	Id	—	—	—	—	—
SOURCE						
Type	V	—	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	—	—	—	—
Start/Bias	0 V	—	—	—	—	—
Stop	6.5 V	—	—	—	—	—
Step	100 mV	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	10 mA	—	—	—	—	—
Compliance Value	10 mA	—	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics
Graph Title: Zener Resistance Test
Scale: Manual

Axis	X	Y1	Y2
Array Name	Vd	Id	—
Linear/Log	Linear	Linear	—
Min	0 V	-1 mA	0
Max	6.5 V	5 mA	1
# of Divisions	13	12	—

Grid: On
X Label: Vd (Volts)
Y1 Label: Id (Amps)
Y2 Label:
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DIODE	16	KI236	1

ZENERVLT DC SOURCE-MEASURE TEST

Mode: Single Test Delay Time: 0s		Integration Time: 416µs Filter: Disable				
CHANNEL NAME	Bias 1	Bias 2	Bias 3	Bias 4	Bias 5	Bias 6
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	DIODE					
Src Array Name	Id	—	—	—	—	—
Meas Array Name	Vd	—	—	—	—	—
SOURCE						
Type	I	—	—	—	—	—
Range	Best Fix	—	—	—	—	—
Value	2 mA	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	11 V	—	—	—	—	—
Compliance Value	10 V	—	—	—	—	—

DISPLAY DC PARAMETERS

Title: Zener Diode Voltage Test

Select All
 Clear All

▶ Id
 ▶ Vd

DC-Gain

Comment:

Bipolar Transistor Tests

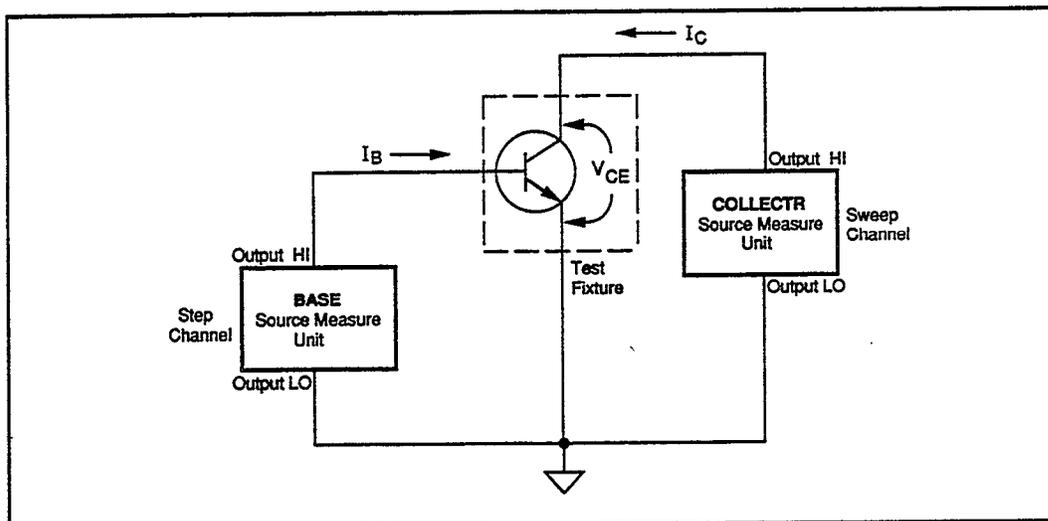
NPN Transistor Common Emitter Curve Family
NPN Transistor Beta (DC-Gain) Plot
NPN Transistor Small Signal Gain Plot
NPN Transistor Collector Emitter Breakdown Test
NPN Transistor Collector Leakage Test
NPN Transistor Forward Gummel Plot
NPN Transistor Reverse Gummel Plot
NPN Transistor Curve Family and Beta (Pulsed Sweep and Step)
NPN Transistor Collector Emitter Breakdown Test (Pulsed Sweep)

NPN Transistor Common Emitter Curve Family

File Names TESTLIB.CFG, NPNCRV.TST, NPNCRV.DAT

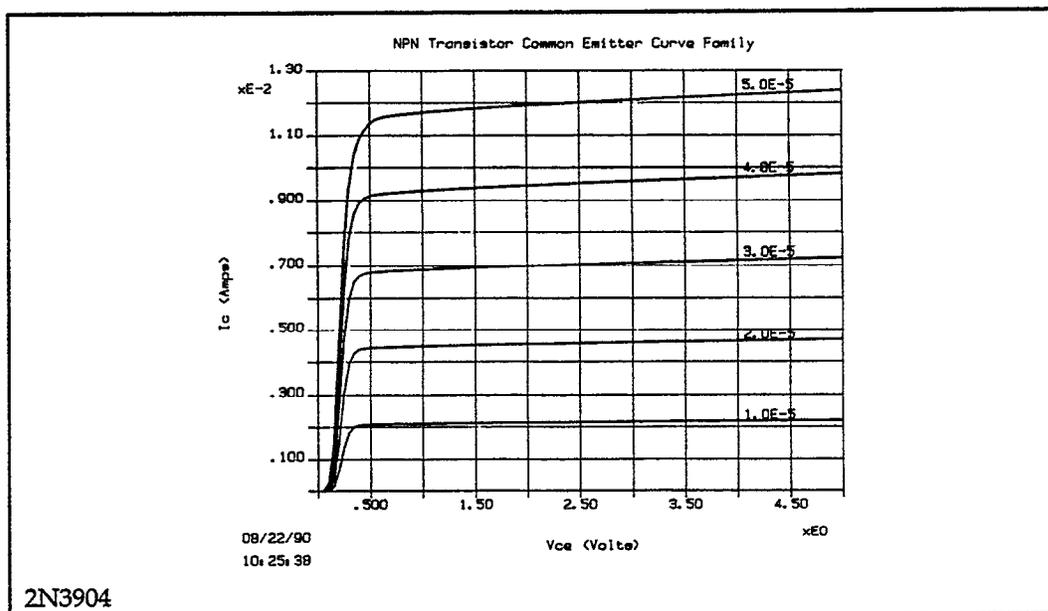
Test Description

Graph of I_C versus V_{CE} for five different values of I_B for an NPN transistor.



Test Method

- The COLLECTR source measure unit sweeps V_{CE} from 0V to 5V and measures I_C .
- The BASE source measure unit steps I_B from $10\mu A$ to $50\mu A$ with $10\mu A$ increments.
- The OUTPUT LO terminals of both source measure units are grounded.



See Also NPNPULS1.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
COLLECTR	16	KI236	1
BASE	17	KI236	2

NPNCRV

CURVE FAMILY TEST

Sweep Type: LINEAR
Mode: Single Test
Delay Before Curves: 0 s

Integration Time: 416 μ s
Filter: Disable
Delay Between Points: 0 s

CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	On	Off	Off	Off	Off
Instrument Name	COLLECTR	BASE				
Src Array Name	Vce	Ib	—	—	—	—
Meas Array Name	Ic	Vbe	—	—	—	—
SOURCE						
Type	V	I	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	Best Fix	—	—	—	—
Start/Bias	0 V	10 μ A	—	—	—	—
Stop	5 V	50 μ A	—	—	—	—
Step	50 mV	10 μ A	—	—	—	—
# Of Curves	—	5	—	—	—	—
Sense	Local	Local	—	—	—	—
MEASURE						
Range	100 mA	1.1 V	—	—	—	—
Compliance Value	20 mA	1 V	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: NPN Transistor Common Emitter Curve Family
Scale: Manual

Axis	X	Y1	Y2
Array Name	Vce	Ic	
Linear/Log	Linear	Linear	—
Min	0 V	0 A	0
Max	5 V	11 mA	1
# of Divisions	10	13	—

Grid: On

X Label: Vce (Volts)

Y1 Label: Ic (Amps)

Y2 Label:

Colors/Curve Labels

DC-Gain (Ratio)

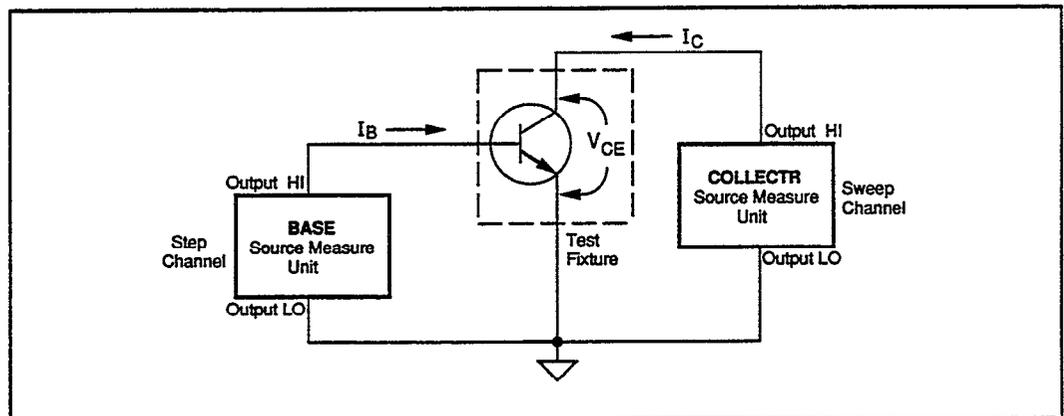
Differential Gain

Overlay Form

NPN Transistor Beta (DC-Gain) Plot

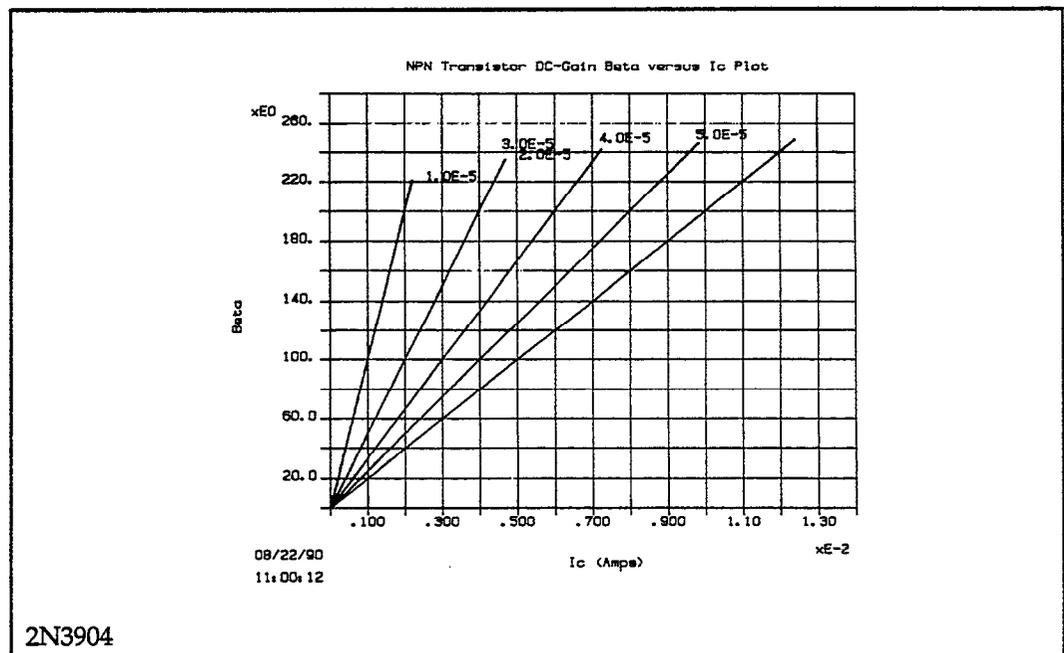
File Names TESTLIB.CFG, NPNBETA.TST, NPNBETA.DAT

Test Description Graphs $\beta = I_c/I_B$ versus I_c .



Test Method

- The COLLECTR source measure unit sweeps from 0 to 5V and measures I_c .
- The BASE source measure unit steps I_B from $10\mu A$ to $50\mu A$ with $10\mu A$ increments.
- $\beta = I_c/I_B$ is calculated and graphed versus I_c .
- The OUTPUT LO terminals of both source measure units are grounded.



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DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
COLLECTR	16	KI236	1
BASE	17	KI236	2

NPNBETA

CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 416µs				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	On	Off	Off	Off	Off
Instrument Name	COLLECTR	BASE	—	—	—	—
Src Array Name	Vce	Ib	—	—	—	—
Meas Array Name	Ic	Vbe	—	—	—	—
SOURCE						
Type	V	I	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	Best Fix	—	—	—	—
Start/Bias	0 V	10 µA	—	—	—	—
Stop	5 V	50 µA	—	—	—	—
Step	50 mV	10 µA	—	—	—	—
# Of Curves	—	5	—	—	—	—
Sense	Local	Local	—	—	—	—
MEASURE						
Range	100 mA	1.1 V	—	—	—	—
Compliance Value	20 mA	1 V	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics			
Graph Title: NPN Transistor DC-Gain Beta versus Ic Plot			
Scale: Manual			
Axis	X	Y1	Y2
Array Name	Ic	Beta	—
Linear/Log	Linear	Linear	—
Min	0 A	0	0
Max	10 mA	220	1
# of Divisions	14	14	—
Grid: On			
X Label: Ic (Amps)			
Y1 Label: Beta			
Y2 Label:			
Colors/Curve Labels			
DC-Gain (Ratio)			
Differential Gain			
Overlay Form			

DC Gain (Ratio) Calculation

Beta = (Ic / Ib) * 1

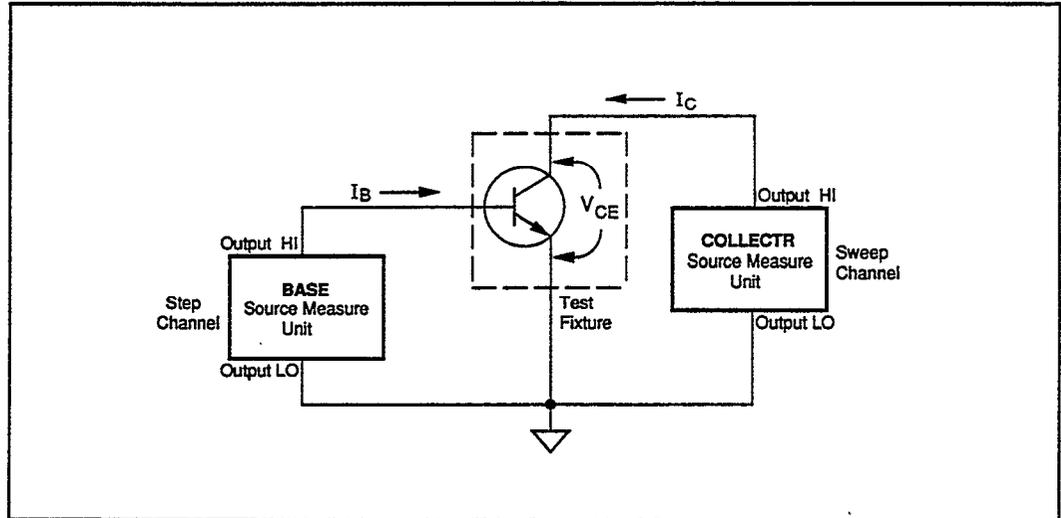
Calculation: On

NPN Transistor Small Signal Gain Plot

File Names TESTLIB.CFG, NPNHFE.TST, NPNHFE.DAT

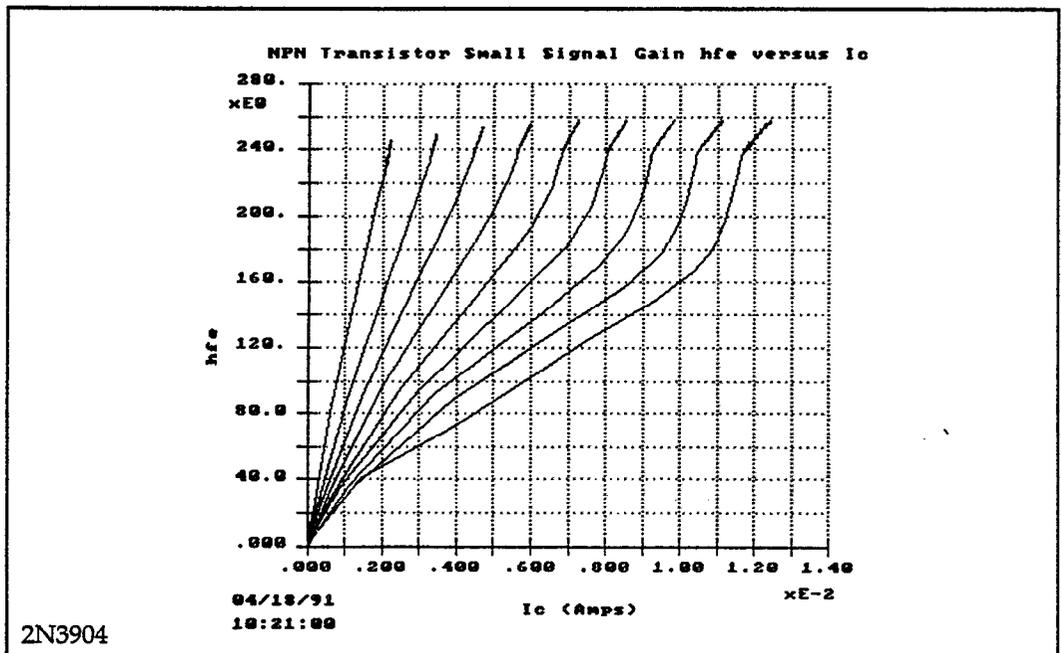
Test Description

Graphs $h_{FE} = d I_C / d I_B$ versus I_C .



Test Method

- The COLLECTR source measure unit sweeps from 0 to 5V and measures I_C .
- The BASE source measure unit steps I_B from $10\mu A$ to $50\mu A$ with $5\mu A$ increments.
- $h_{FE} = d I_C / d I_B$ is calculated and graphed versus I_C .
- The OUTPUT LO terminals of both source measure units are grounded.



DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
COLLECTR	16	KI236	1
BASE	17	KI236	2

NPNHFE

CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 416µs				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	On	Off	Off	Off	Off
Instrument Name	COLLECTR	BASE	—	—	—	—
Src Array Name	Vce	Ib	—	—	—	—
Meas Array Name	Ic	Vbe	—	—	—	—
SOURCE						
Type	V	I	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	Best Fix	—	—	—	—
Start/Bias	0 V	10 µA	—	—	—	—
Stop	5 V	50 µA	—	—	—	—
Step	50 mV	5 µA	—	—	—	—
# Of Curves	—	9	—	—	—	—
Sense	Local	Local	—	—	—	—
MEASURE						
Range	100 mA	1.1 V	—	—	—	—
Compliance Value	20 mA	1 V	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: NPN Transistor Small Signal Gain hfe versus Ic

Scale: Manual

Axis	X	Y1	Y2
Array Name	Ic	hfe	
Linear/Log	Linear	Linear	—
Min	0 A	0	0
Max	10 mA	200	1
# of Divisions	14	14	—

Grid: On
X Label: Ic (Amps)
Y1 Label: hfe
Y2 Label:
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

Differential Gain Calculation

$$hfe = (d Ic / d Ib) * 1$$

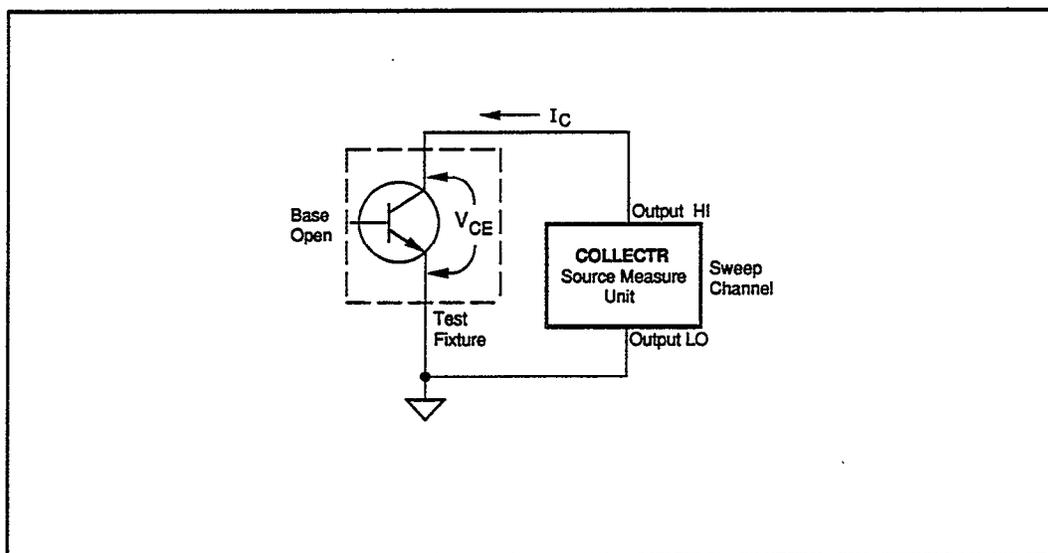
Differentiate: Between curves (at constant sweep)
Calculation: On

NPN Transistor Collector Emitter Breakdown Test

File Names TESTLIB.CFG, NPNBVCEO.TST, NPNBVCEO.DAT

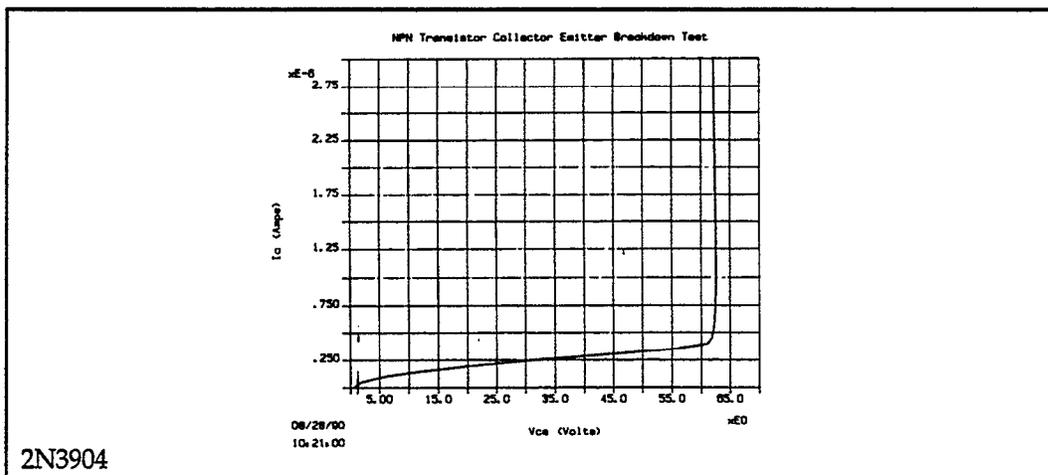
Test Description

Graph of I_C versus V_{CE} for $I_B = 0$. From the graph, the breakdown voltage of the collector/emitter junction can be determined.



Test Method

- The source measure unit sweeps I_C from 0 to $5\mu A$ and measures V_{CE} .
- The emitter is grounded and the base is open.
- The OUTPUT LO terminal of the source measure unit is grounded.



See Also NPNPULS2.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
COLLECTR	16	KI236	1

NPNBVCEO

CURVE FAMILY TEST

Sweep Type: LINEAR
Mode: Single Test
Delay Before Curves: 0 s

Integration Time: 416µs
Filter: Disable
Delay Between Points: 0 s

CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	COLLECTR	—	—	—	—	—
Src Array Name	Ic	—	—	—	—	—
Meas Array Name	Vce	—	—	—	—	—
SOURCE						
Type	I	—	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	—	—	—	—
Start/Bias	0 A	—	—	—	—	—
Stop	5 µA	—	—	—	—	—
Step	50 nA	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	110 V	—	—	—	—	—
Compliance Value	80 V	—	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: NPN Transistor Collector Emitter Breakdown Test
Scale: Manual

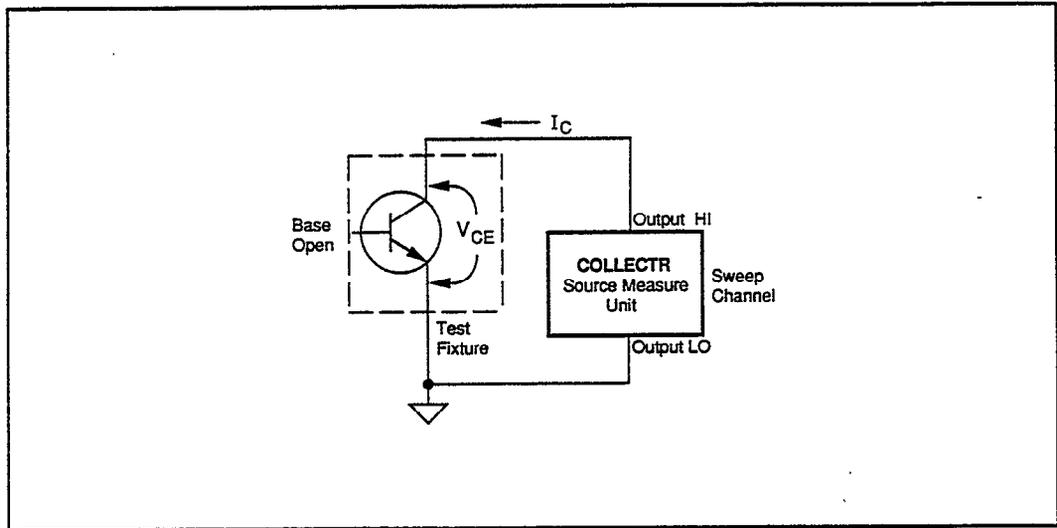
Axis	X	Y1	Y2
Array Name	Vce	Ic	—
Linear/Log	Linear	Linear	—
Min	0 V	0 A	0
Max	55 V	3 µA	1
# of Divisions	14	12	—

Grid: On
X Label: Vce (Volts)
Y1 Label: Ic (Amps)
Y2 Label:
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

NPN Transistor Collector Leakage Test

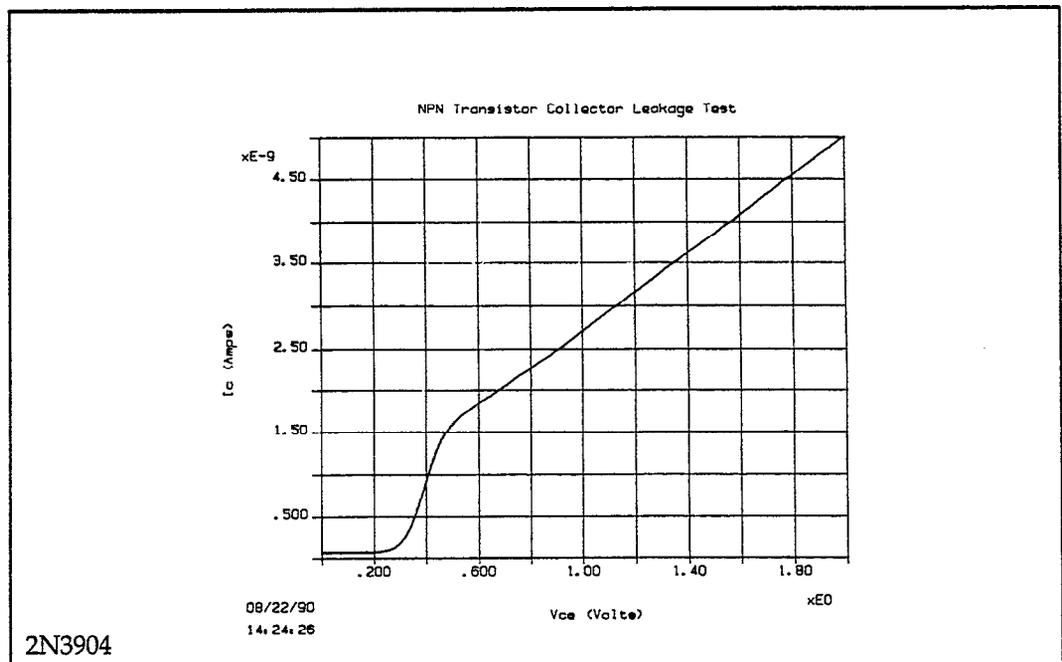
File Names TESTCFG.TST, NPNICEO.TST, NPNICEO.DAT

Test Description Graph of I_C versus V_{CE} for $I_B=0$ measured at low values of V_{CE} .



Test Method

- The source measure unit sweeps V_{CE} from 0 to 2V and measures I_C .
- The collector is reversed biased and the base is open.
- The OUTPUT LO terminal of the source measure unit is grounded.



DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
COLLECTR	16	KI236	1

NPNICEO

CURVE FAMILY TEST

Sweep Type: LINEAR Mode: Single Test Delay Before Curves: 0 s			Integration Time: 416 μ s Filter: Disable Delay Between Points: 0 s			
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	COLLECTR	—	—	—	—	—
Src Array Name	Vce	—	—	—	—	—
Meas Array Name	Ic	—	—	—	—	—
SOURCE						
Type	V	—	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	—	—	—	—
Start/Bias	0 V	—	—	—	—	—
Stop	2 V	—	—	—	—	—
Step	20 mV	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	Auto	—	—	—	—	—
Compliance Value	20 nA	—	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: NPN Transistor Collector Leakage Current Test
Scale: Manual

Axis	X	Y1	Y2
Array Name	Vce	Ic	—
Linear/Log	Linear	Linear	—
Min	0 V	0 A	0
Max	2 V	1 nA	1
# of Divisions	10	10	—

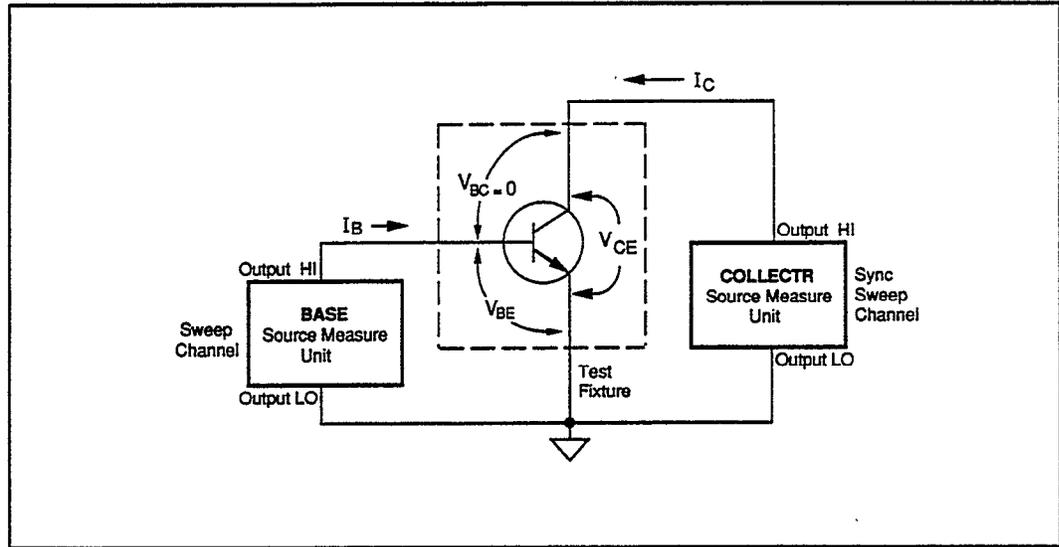
Grid: On
X Label: Vce (Volts)
Y1 Label: Ic (Amps)
Y2 Label:
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

NPN Transistor Forward Gummel Plot

File Names TESTLIB.CFG, NPNFGUML.TST, NPNFGUML.DAT

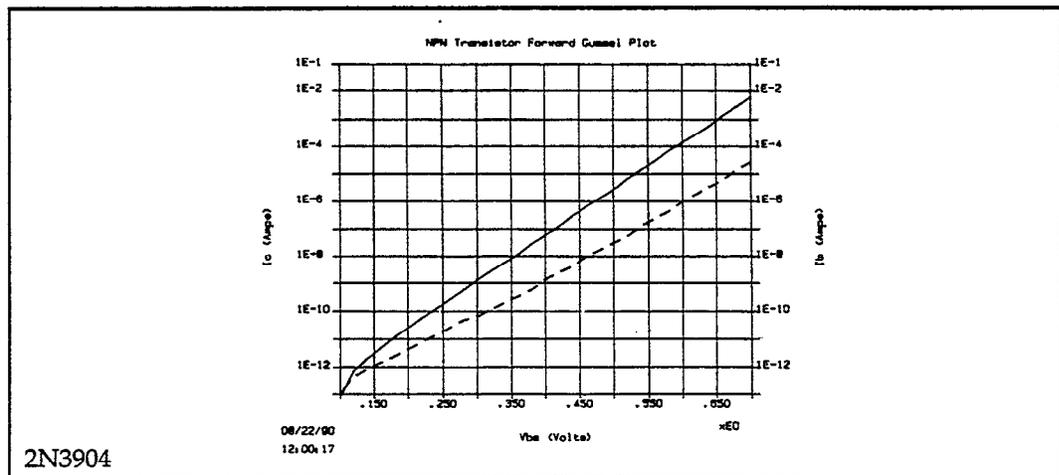
Test Description

Graph of I_C and I_B versus V_{BE} in Lin/Log/Log coordinates.



Test Method

- The BASE source measure unit sweeps V_{BE} from 700mV to 0V and measures I_B , and at the same time, the COLLECTR source measure unit sync sweeps V_{CE} from 700mV to 0V and measures I_C .
- The base/emitter junction is forward biased and the base/collector junction is off.
- The OUTPUT LO terminals of both source measure units are grounded.
- I_C is plotted along Y1 axis and I_B is plotted along Y2 axis. Both I_C and I_B are plotted in Log scale.



See Also NPNRGUML.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
COLLECTR	16	KI236	1
BASE	17	KI236	2

NPNFGUML CURVE FAMILY TEST

Sweep Type: LINEAR
Mode: Single Test
Delay Before Curves: 0 s

Integration Time: 416µs
Filter: Disable
Delay Between Points: 0 s

CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	On	Off	Off	Off
Instrument Name	BASE		COLLECTR			
Src Array Name	Vbe	—	Vce	—	—	—
Meas Array Name	Ib	—	Ic	—	—	—
SOURCE						
Type	V	—	V	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	Best Fix	—	—	—
Start/Bias	700 mV	—	700 mV	—	—	—
Stop	0 V	—	0 V	—	—	—
Step	20 mV	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	Local	—	—	—
MEASURE						
Range	Auto	—	Auto	—	—	—
Compliance Value	20 mA	—	100 mA	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: NPN Transistor Forward Gummel Plot
Scale: Manual

Axis	X	Y1	Y2
Array Name	Vbe	Ic	Ib
Linear/Log	Linear	Log	—
Min	100 mV	100 fA	100 fA
Max	700 mV	100 mA	100 mA
# of Divisions	12	—	—

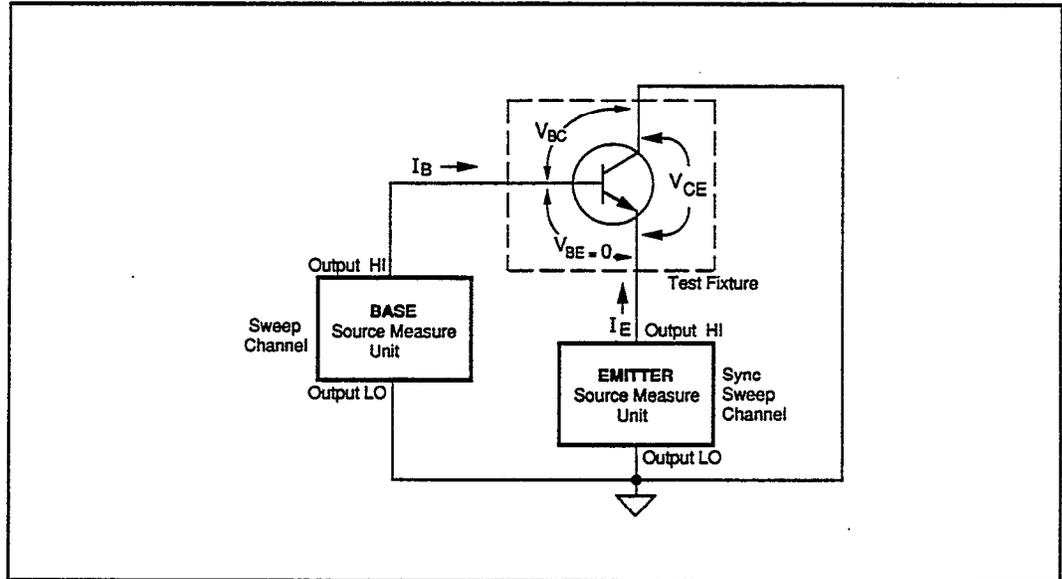
Grid: On
X Label: Vbe (Volts)
Y1 Label: Ic (Amps)
Y2 Label: Ib (Amps)
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

NPN Transistor Reverse Gummel Plot

File Names TESTLIB.CFG, NPNRGUML.TST, NPNRGUML.DAT

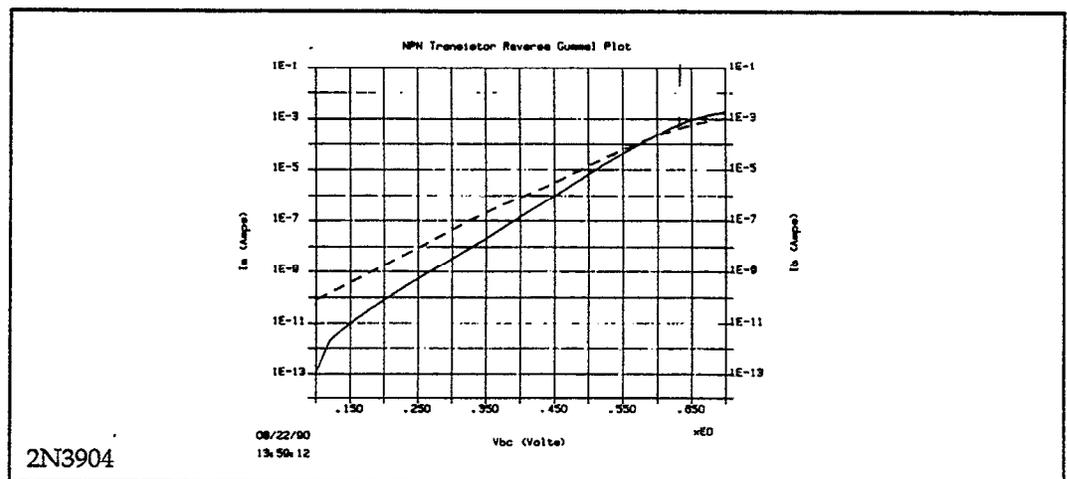
Test Description

Graph of I_E and I_B versus V_{BC} in Lin/Log/Log coordinates. (The collector and emitter pins are reversed compared to the Forward Gummel Plot.)



Test Method

- The BASE source measure unit sweeps V_{BC} from 700mV to 0V and measures I_B , and at the same time, the EMITTER source measure unit sync sweeps V_{EC} from 700mV to 0V and measures I_E .
- The base/collector junction is forward biased and the base/emitter junction is off.
- The OUTPUT LO terminals of both source measure units are grounded.
- I_B is plotted along the Y1 axis and I_E is plotted along the Y2 axis. Both I_B and I_E are plotted in Log scale.



See Also NPNFGUML.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
EMITTER	16	KI236	1
BASE	17	KI236	2

NPNRGUML CURVE FAMILY TEST

Sweep Type: LINEAR
Mode: Single Test
Delay Before Curves: 0 s

Integration Time: 416 μ s
Filter: 16 Rdg
Delay Between Points: 0 s

CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	On	Off	Off	Off
Instrument Name	BASE		EMITTER			
Src Array Name	Vbc	—	Vec	—	—	—
Meas Array Name	Ib	—	Ie	—	—	—
SOURCE						
Type	V	—	V	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	Best Fix	—	—	—
Start/Bias	700 mV	—	700 mV	—	—	—
Stop	0 V	—	0V	—	—	—
Step	20 mV	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	Local	—	—	—
MEASURE						
Range	Auto	—	Auto	—	—	—
Compliance Value	10 mA	—	100 mA	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: NPN Transistor Reverse Gummel Plot
Scale: Manual

Axis	X	Y1	Y2
Array Name	Vbc	Ie	Ib
Linear/Log	Linear	Log	—
Min	0 V	10 fA	10 fA
Max	700 mV	100 mA	100 mA
# of Divisions	12	—	—

Grid: On
X Label: Vbc (Volts)
Y1 Label: Ie (Amps)
Y2 Label: Ib (Amps)
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

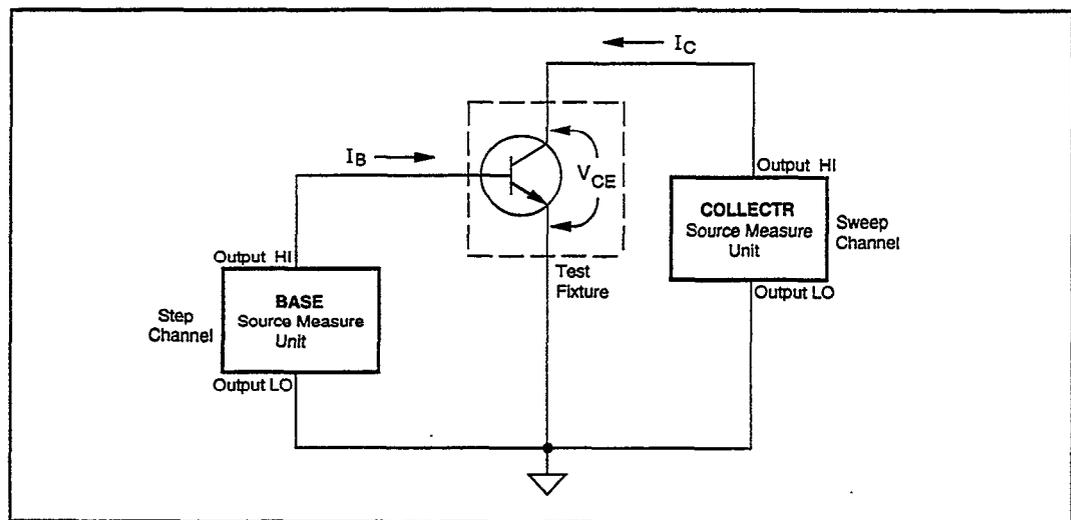
NPN Transistor Curve Family and Beta (Pulsed Sweep and Step)

File Names

TESTLIB.CFG, NPNPULS1.TST, NPNPULS1.DAT

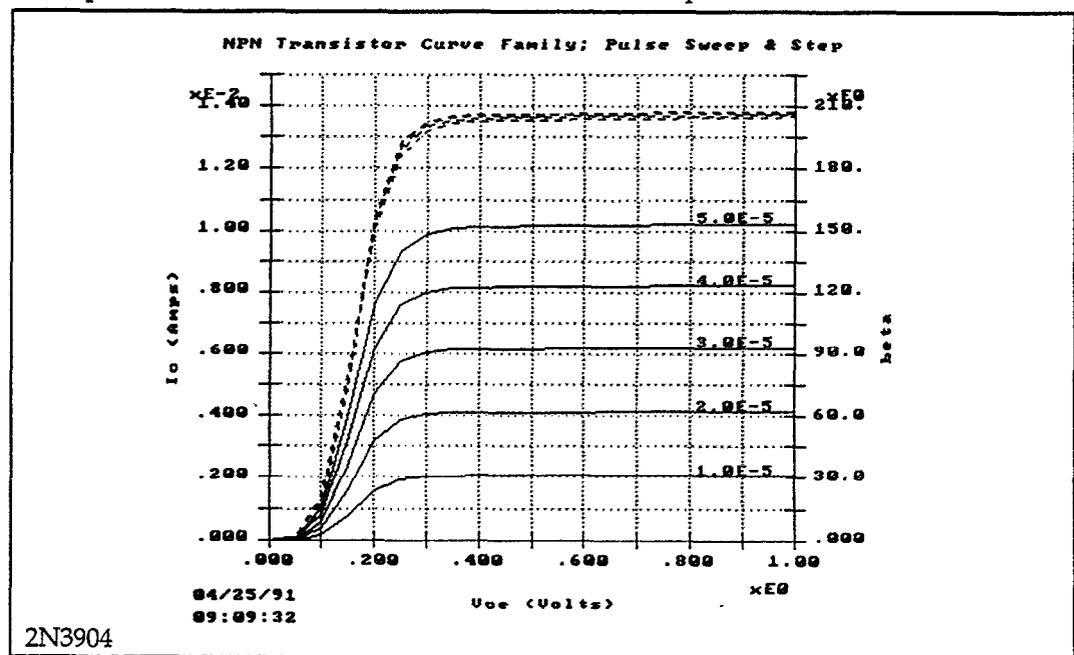
Test Description

Graph of I_C and beta versus V_{CE} for five different values of I_B .



Test Method

- The COLLECTR source measure unit sweeps V_{CE} from 0V to 1V and measures I_C .
- The BASE source measure unit sweeps I_B from $10\mu A$ to $50\mu A$ with $10\mu A$ increments.
- The pulse on/off times are 2msec/50msec for both sweeps.



See Also

NPNCRV.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
COLLECTR	16	KI236	1
BASE	17	KI236	2

NPNPULS1 CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 416µs				
Mode: Single Test		Filter: Disable				
Delay Between Curves: 0 s		Pulsed Time On: 2ms Off: 50ms				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	On	Off	Off	Off	Off
Instrument Name	COLLECTR	BASE	—	—	—	—
Src Array Name	Vce	Ib	—	—	—	—
Meas Array Name	Ic	—	—	—	—	—
SOURCE						
Type	V Pulsed	I Pulsed	—	—	—	—
Pulsed Off Value	0V	1 µA	—	—	—	—
Range	Best Fix	Best Fix	—	—	—	—
Start/Bias	0 V	10 µA	—	—	—	—
Stop	1 V	50 µA	—	—	—	—
Step	50 mV	10 µA	—	—	—	—
# Of Curves	—	5	—	—	—	—
Sense	Local	Local	—	—	—	—
MEASURE						
Range	100 mA	1.1 V	—	—	—	—
Compliance Value	20 mA	1 V	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: NPN Transistor Curve Family; Pulse Sweep & Step

Scale: Manual

Axis	X	Y1	Y2
Array Name	Vce	Ic	beta
Linear/Log	Linear	Linear	—
Min	0V	0A	0
Max	1V	15mA	225
# of Divisions	10	15	—

Grid: On
X Label: Vce (Volts)
Y1 Label: Ic (Amps)
Y2 Label: beta
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

DC-Gain (Ratio) Calculation

$$\text{beta} = (Ic / Ib) * 1$$

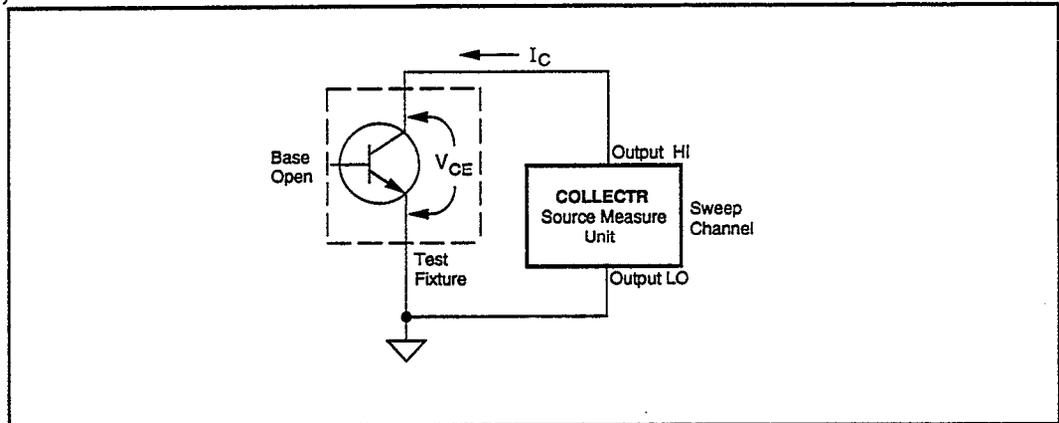
Calculation: On

NPN Transistor Collector Emitter Breakdown Test (Pulsed Sweep)

File Names TESTLIB.CFG, NPNPULS2.TST, NPNPULS2.DAT

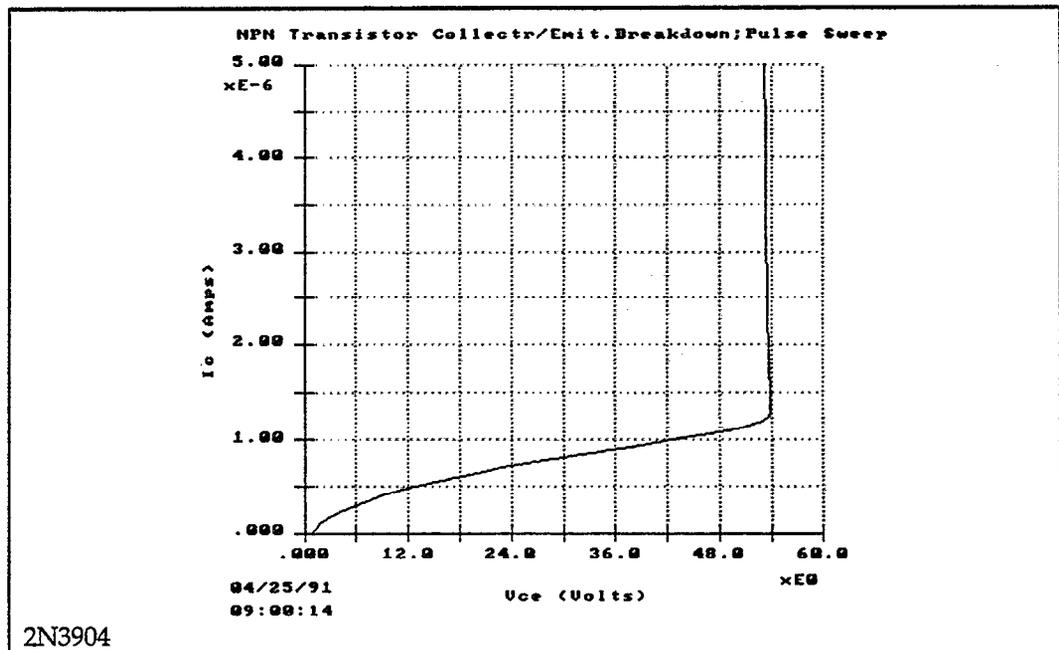
Test Description

Graph of I_C versus V_{CE} for $I_B=0$. From the graph, the breakdown voltage of the collector/emitter junction can be determined.



Test Method

- The source measure unit sweeps I_C from 0 to $5\mu A$ and measures V_{CE} .
- The pulse on/off times are 2ms/50ms.
- The emitter is grounded and the base is open.
- The OUTPUT LO terminal of the source measure unit is grounded.



See Also

NPNBVCEO.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPiB Address (1-30)	Instrument	Trigger Channel (1-6)
COLLECTR	16	KI236	1

NPNPULS2

CURVE FAMILY TEST

Sweep Type: Linear

Mode: Single Test

Delay Between Curves: 0 s

Integration Time: 416µs

Filter: Disable

Pulsed Time On: 2ms Off: 50ms

CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	COLLECTR	—	—	—	—	—
Src Array Name	Ic	—	—	—	—	—
Meas Array Name	Vce	—	—	—	—	—
SOURCE						
Type	I Pulsed	—	—	—	—	—
Pulsed Off Value	0A	—	—	—	—	—
Range	Best Fix	—	—	—	—	—
Start/Bias	0 A	—	—	—	—	—
Stop	5 µA	—	—	—	—	—
Step	50 nA	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	110 V	—	—	—	—	—
Compliance Value	60 V	—	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: NPN Transistor Collector/Emit. Breakdown; Pulse Sweep

Scale: Manual

Axis	X	Y1	Y2
Array Name	Vce	Ic	
Linear/Log	Linear	Linear	—
Min	0V	0A	0
Max	60V	5µA	1
# of Divisions	10	10	—

Grid: On

X Label: Vce (Volts)

Y1 Label: Ic (Amps)

Y2 Label:

Colors/Curve Labels

DC-Gain (Ratio)

Differential Gain

Overlay Form

FET Tests

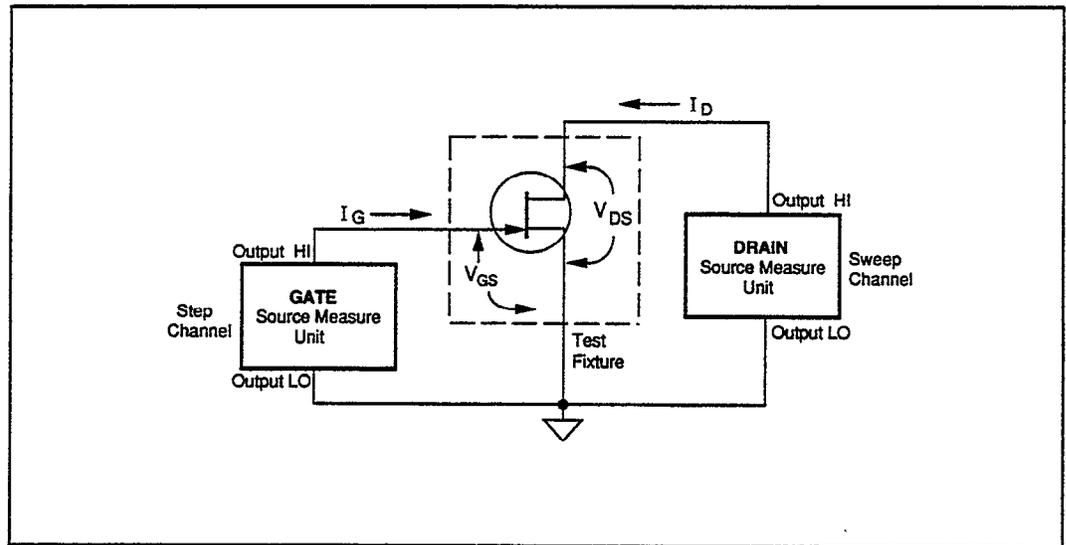
N-channel JFET Common Source Curve Family I_D vs. V_{DS}
N-channel JFET Common Source Curve Family I_D vs. V_{GS}
N-channel JFET Drain Source Breakdown Voltage (BV_{DS})
N-channel JFET Gate Leakage Current
N-channel JFET g_m vs. V_{GS} Plot
N-channel JFET Self Bias g_m vs. I_D
N-channel JFET Self Bias Threshold Voltage
P-channel Enhancement Mode MOSFET Common Curve Family (Method 1)

N-channel JFET Common Source Curve Family I_D vs. V_{DS}

File Names TESTLIB.CFG, NJFETVDS.TST, NJFETVDS.DAT

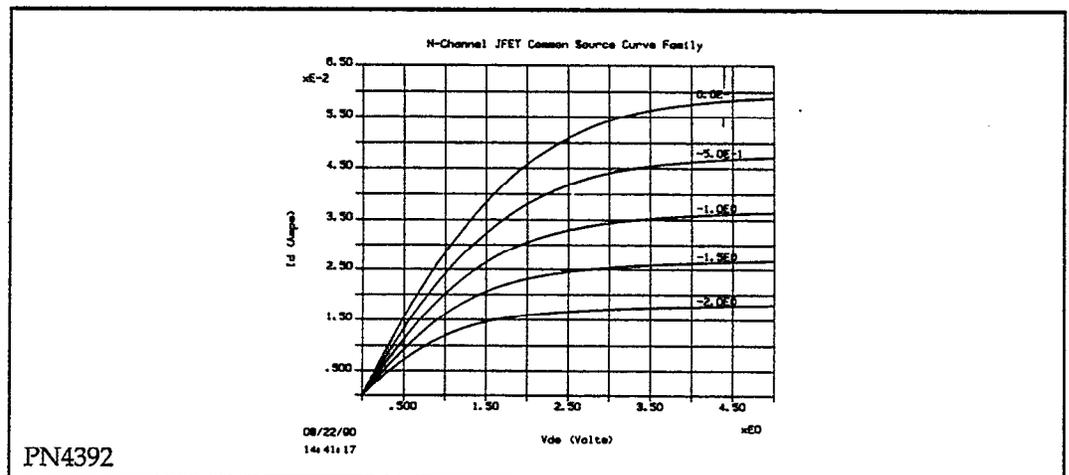
Test Description

Graph of I_D versus V_{DS} for five different values of V_{GS} for an N-channel JFET.



Test Method

- The DRAIN source measure unit sweeps V_{DS} from 0V to +5V and measures I_D .
- The GATE source measure unit steps V_{GS} from 0V to -2V with 0.5V increments.
- The OUTPUT LO terminals of both source measure units are grounded.



See Also

NJFETVGS.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DRAIN	16	KI236	1
GATE	17	KI236	2

NJFETVDS CURVE FAMILY TEST

Sweep Type: LINEAR
Mode: Single Test
Delay Before Curves: 0 s

Integration Time: 416 μ s
Filter: Disable
Delay Between Points: 0 s

CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	On	Off	Off	Off	Off
Instrument Name	DRAIN	GATE				
Src Array Name	Vds	Vgs	—	—	—	—
Meas Array Name	Id	Ig	—	—	—	—
SOURCE						
Type	V	V	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	Best Fix	—	—	—	—
Start/Bias	0 V	0 V	—	—	—	—
Stop	5 V	-2 V	—	—	—	—
Step	100 mV	500 mV	—	—	—	—
# Of Curves	—	5	—	—	—	—
Sense	Local	Local	—	—	—	—
MEASURE						
Range	100 mA	1 mA	—	—	—	—
Compliance Value	80 mA	1 mA	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: N-Channel JFET Common Source Curve Family
Scale: Manual

Axis	X	Y1	Y2
Array Name	Vds	Id	
Linear/Log	Linear	Linear	—
Min	0 V	0 A	0
Max	5 V	65 mA	1
# of Divisions	10	13	—

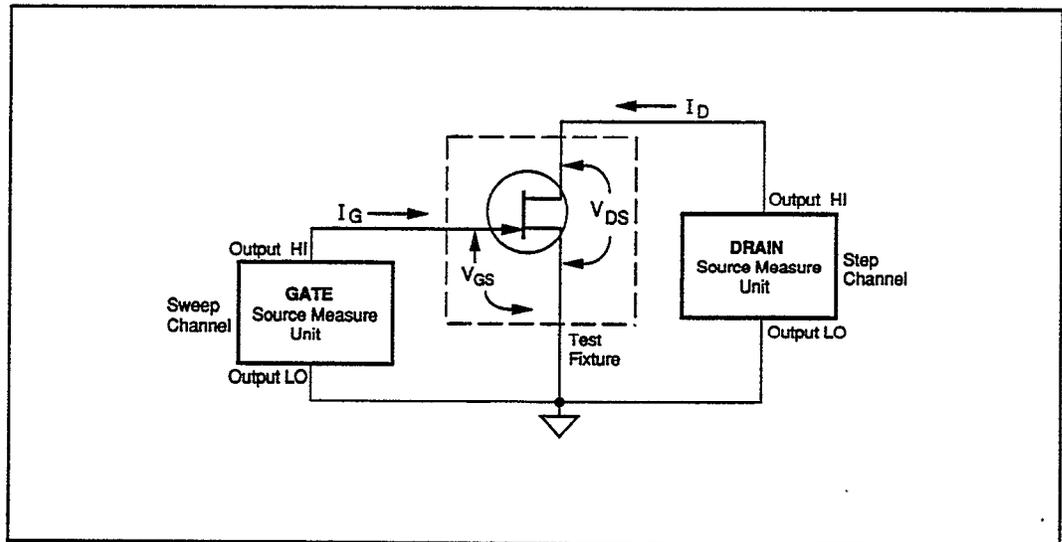
Grid: On
X Label: Vds (Volts)
Y1 Label: Id (Amps)
Y2 Label:
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

N-channel JFET Common Source Curve Family I_D vs. V_{GS}

File Names TESTLIB.CFG, NJFETVGS.TST, NJFETVGS.DAT

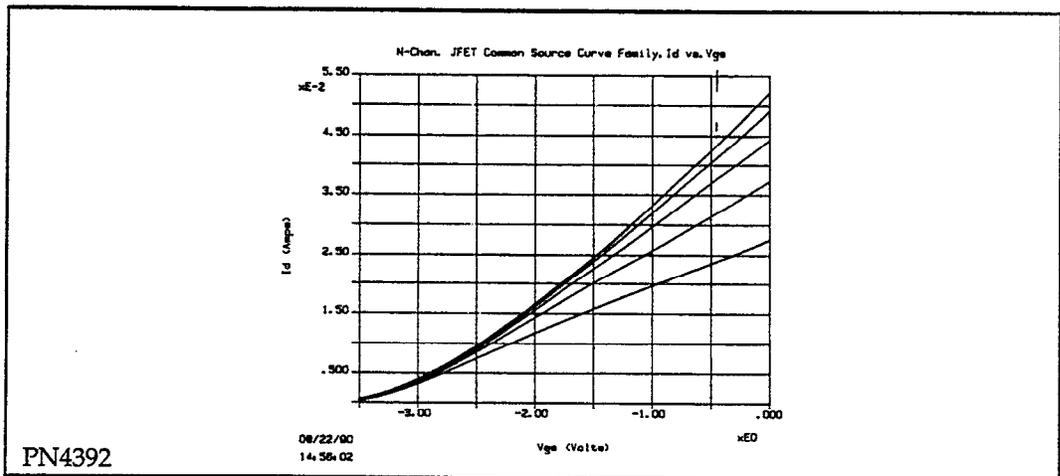
Test Description

Graph of I_D versus V_{GS} for five different values of V_{DS} for an N-channel JFET.



Test Method

- The GATE source measure unit sweeps V_{GS} from 0V to -3.5V and measures I_G .
- The DRAIN source measure unit steps V_{DS} for 1V to 3V with 0.5V increments and measures I_D .
- The OUTPUT LO terminals of both source measure units are grounded.



See Also NJETVDS.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DRAIN	16	KI236	1
GATE	17	KI236	2

NJFETVGS

CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 416 μ s				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	On	Off	Off	Off	Off
Instrument Name	GATE	DRAIN				
Src Array Name	Vgs	Vds	—	—	—	—
Meas Array Name	Ig	Id	—	—	—	—
SOURCE						
Type	V	V	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	Best Fix	—	—	—	—
Start/Bias	0 V	1 V	—	—	—	—
Stop	-3.5 V	3 V	—	—	—	—
Step	50 mV	500 mV	—	—	—	—
# Of Curves	—	5	—	—	—	—
Sense	Local	Local	—	—	—	—
MEASURE						
Range	1 mA	100 mA	—	—	—	—
Compliance Value	1 mA	100 mA	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: N-Chan. JFET Common Source Curve Family, Id vs. Vgs

Scale: Manual

Axis	X	Y1	Y2
Array Name	Vgs	Id	
Linear/Log	Linear	Linear	—
Min	-3.5 V	0 A	0
Max	0 V	55 mA	1
# of Divisions	7	11	—

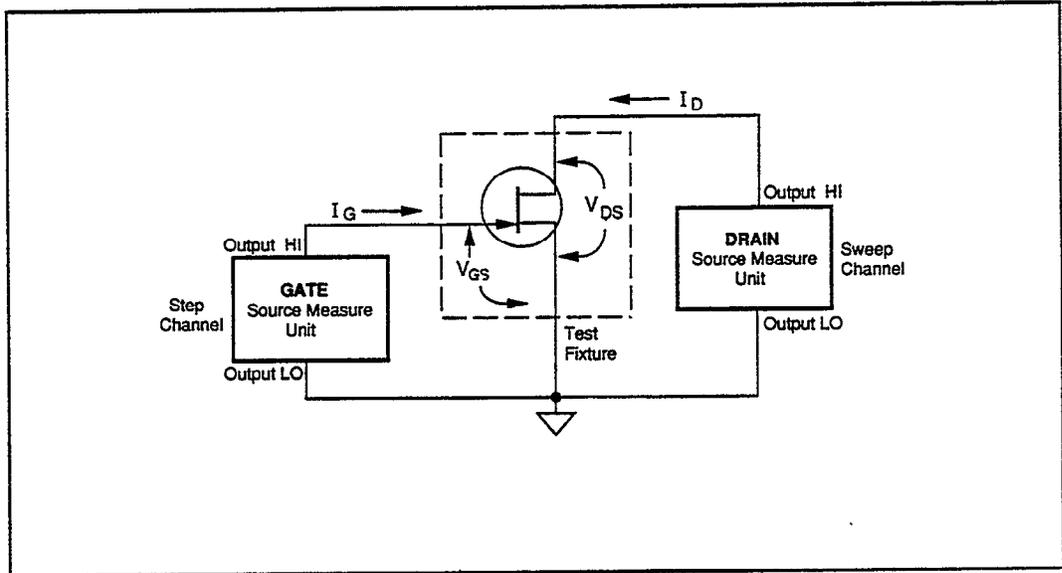
Grid: On
X Label: Vgs (Volts)
Y1 Label: Id (Amps)
Y2 Label:
Colors/Curve Label
DC-Gain (Ratio)
Differential Gain
Overlay Form

N-channel JFET Drain Source Breakdown Voltage (BV_{DS})

File Names TESTLIB.CFG, NJFETBV.TST, NJFETBV.DAT

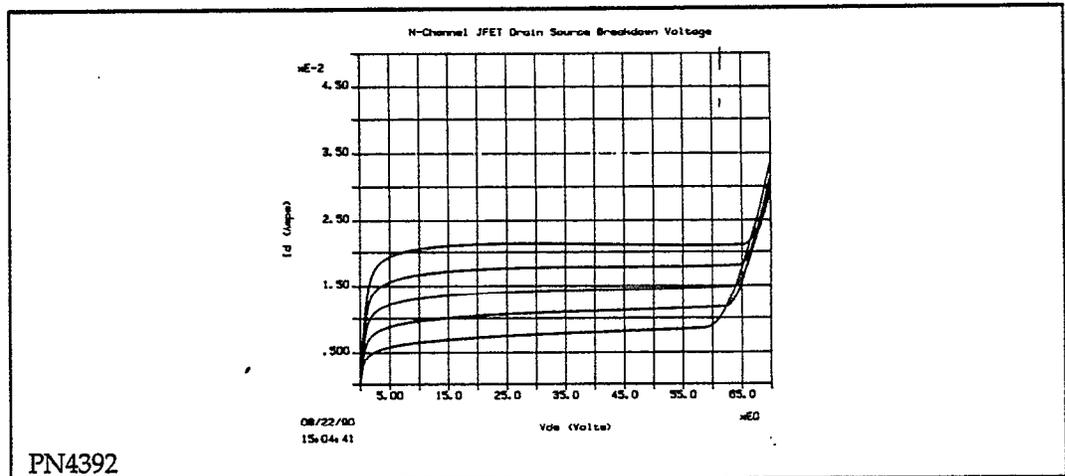
Test Description

Graph of I_D versus V_{DS} for five different values of V_{GS} . From the graph the breakdown voltage of the drain/source junction can be determined.



Test Method

- The DRAIN source measure unit sweeps V_{DS} from 0V to 70V and measures I_D .
- The GATE source measure unit steps V_{GS} from -3V to -2V with 0.25V increments.
- The OUTPUT LO terminals of both source measure units are grounded.



DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DRAIN	16	KI236	1
GATE	17	KI236	2

NJFETBV

CURVE FAMILY TEST

Sweep Type: LINEAR Mode: Single Test Delay Before Curves: 0 s			Integration Time: 416µs Filter: Disable Delay Between Points: 0 s			
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	On	Off	Off	Off	Off
Instrument Name	DRAIN	GATE	---	---	---	---
Src Array Name	Vds	Vgs	---	---	---	---
Meas Array Name	Id	Ig	---	---	---	---
SOURCE						
Type	V	V	---	---	---	---
Pulsed Off Value	---	---	---	---	---	---
Range	Best Fix	Best Fix	---	---	---	---
Start/Bias	0 V	-3 V	---	---	---	---
Stop	70 V	-2V	---	---	---	---
Step	500 mV	250 mV	---	---	---	---
# Of Curves	---	5	---	---	---	---
Sense	Local	Local	---	---	---	---
MEASURE						
Range	100 mA	1 mA	---	---	---	---
Compliance Value	100 mA	1 mA	---	---	---	---

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: N-Chan. JFET Drain Source Breakdown Voltage
Scale: Manual

Axis	X	Y1	Y2
Array Name	Vds	Id	
Linear/Log	Linear	Linear	---
Min	0 V	0 A	0
Max	70 V	50 mA	1
# of Divisions	14	10	---

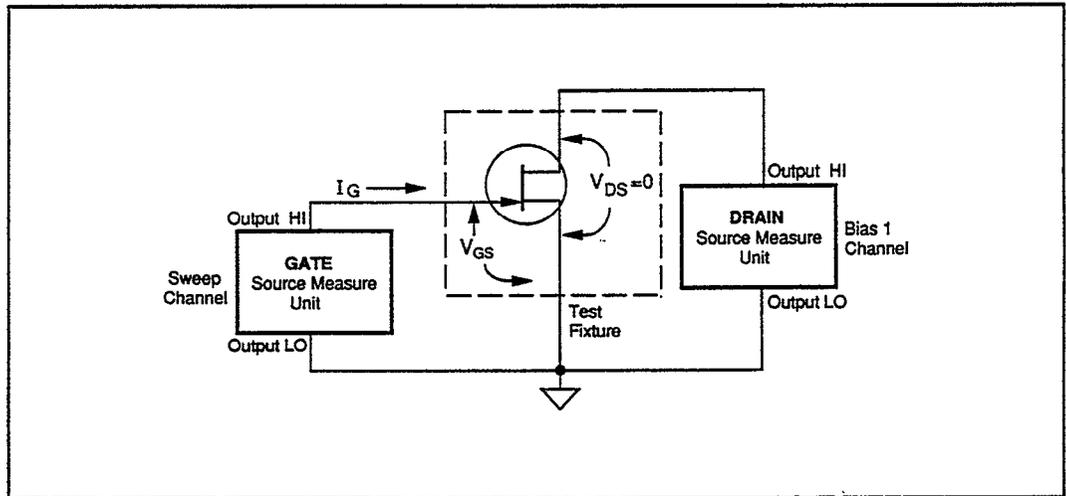
Grid: On
X Label: Vds (Volts)
Y1 Label: Id (Amps)
Y2 Label:
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

N-channel JFET Gate Leakage Current

File Names TESTLIB.CFG, NJFETIG.TST, NJFETIG.DAT

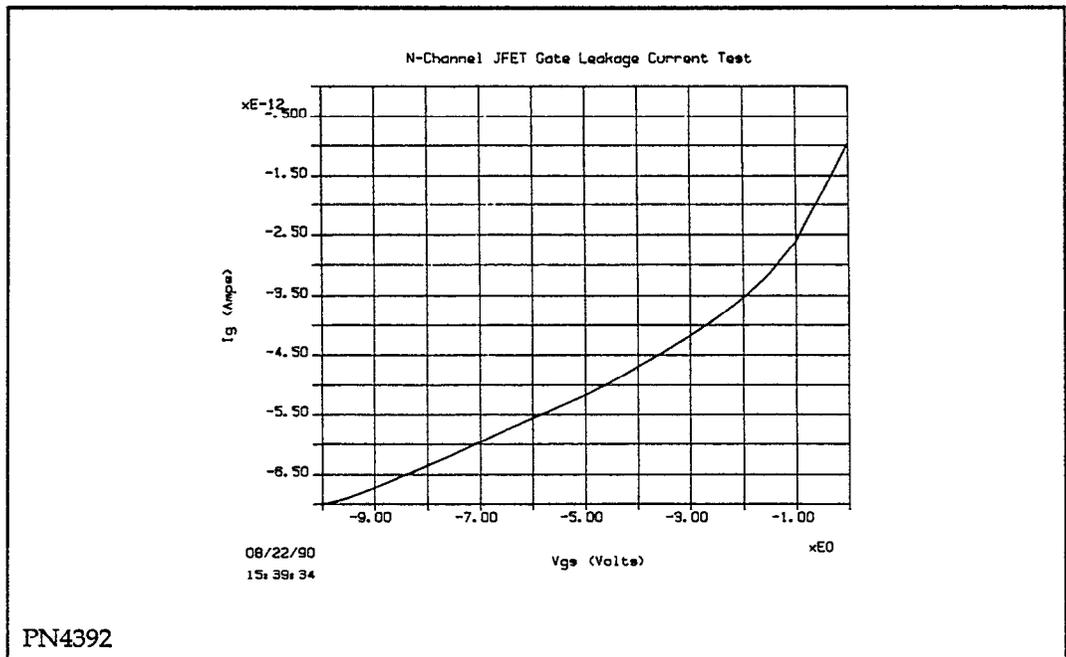
Test Description

Graph of I_G versus V_{GS} at $V_{DS} = 0$.



Test Method

- The GATE source measure unit sweeps V_{GS} from 0 to $-10V$ and measures I_G .
- The DRAIN source measure unit applies $0V$ bias to V_{DS} .
- The OUTPUT LO terminals of both source measure units are grounded.



DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DRAIN	16	KI236	1
GATE	17	KI236	2

NJFETIG

CURVE FAMILY TEST

Sweep Type: LINEAR Mode: Single Test Delay Before Curves: 0 s				Integration Time: 60Hz Line Filter: 4 Rdg Delay Between Points: 0 s		
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	On	Off	Off
Instrument Name	GATE			DRAIN		
Src Array Name	Vgs	—	—	Vds	—	—
Meas Array Name	Ig	—	—		—	—
SOURCE						
Type	V	—	—	V	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	—	Best Fix	—	—
Start/Bias	0 V	—	—	0 V	—	—
Stop	-10 V	—	—	—	—	—
Step	500 mV	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	Local	—	—
MEASURE						
Range	1 nA	—	—	1mA	—	—
Compliance Value	1 nA	—	—	1 mA	—	—

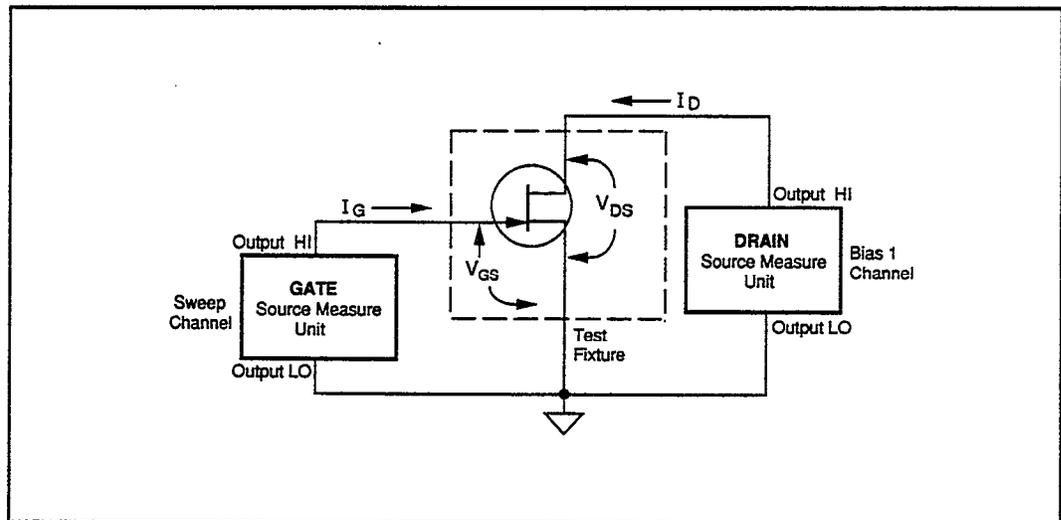
DISPLAY PARAMETERS

Mode: Graphics			
Graph Title: N-Channel JFET Gate Leakage Current Test			
Scale: Manual			
Axis	X	Y1	Y2
Array Name	Vgs	Ig	
Linear/Log	Linear	Linear	—
Min	-10 V	-7 pA	0
Max	0 V	0 A	1
# of Divisions	10	14	—
Grid: On			
X Label: Vgs (Volts)			
Y1 Label: Ig (Amps)			
Y2 Label:			
Colors/Curve Labels			
DC-Gain (Ratio)			
Differential Gain			
Overlay Form			

N-channel JFET g_m vs. V_{GS} Plot

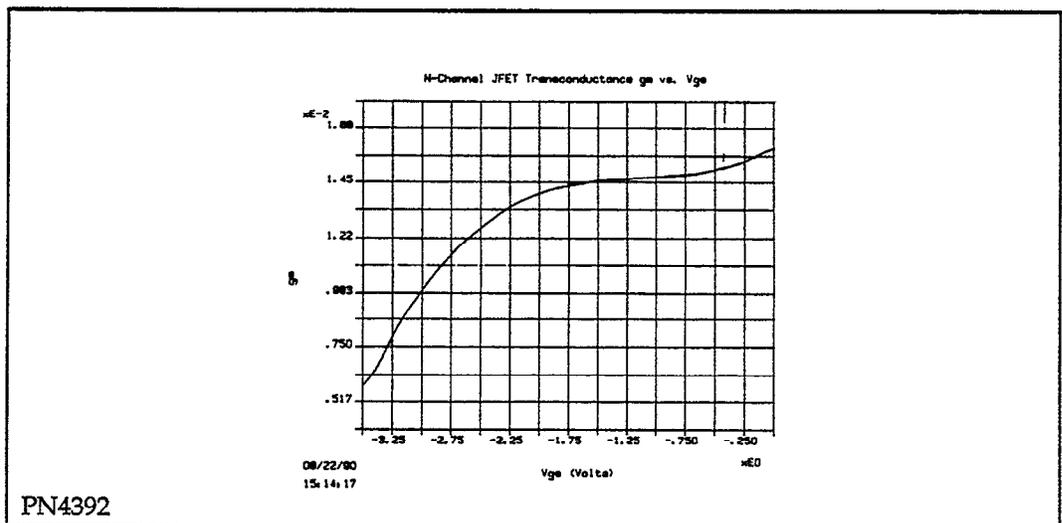
File Names TESTLIB.CFG, NJFETGM.TST, NJFETGM.DAT

Test Description Graph of I_D versus $g_m = dI_D/dV_{GS}$ versus V_{GS} at $V_{DS} = \text{constant}$.



Test Method

- The GATE source measure unit sweeps V_{GS} from 0 to $-3.5V$ and measures I_G .
- The DRAIN source measure unit applies $2V$ bias to V_{DS} and measures I_D .
- Calculated $g_m = dI_D/dV_{GS}$.
- The OUTPUT LO terminals of both source measure units are grounded.



Note The parameter g_m also can be calculated from the graph I_D vs V_{GS} using Line on the graphics display: g_m is equal to the Slope value displayed as a line parameter.

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DRAIN	16	KI236	1
GATE	17	KI236	2

NJFETGM

CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 416µs				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	On	Off	Off
Instrument Name	GATE	—	—	DRAIN	—	—
Src Array Name	Vgs	—	—	Vds	—	—
Meas Array Name	Ig	—	—	Id	—	—
SOURCE						
Type	V	—	—	V	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	—	Best Fix	—	—
Start/Bias	0 V	—	—	2 V	—	—
Stop	-3.5 V	—	—	—	—	—
Step	50 mV	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	Local	—	—
MEASURE						
Range	10 mA	—	—	100 mA	—	—
Compliance Value	10 mA	—	—	100 mA	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: N-Channel JFET Transconductance gm vs. Vgs
Scale: Manual

Axis	X	Y1	Y2
Array Name	Vgs	gm	
Linear/Log	Linear	Linear	—
Min	-3.5V	3m	0
Max	0V	18m	1
# of Divisions	7	12	—

Grid: On
X Label: Vgs (Volts)
Y1 Label: gm
Y2 Label:
Colors/Curve labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

Differential Gain Calculation

$$gm = (d Id / d Vgs) * 1$$

Differentiate: Along curves (at constant step)
Calculation: On

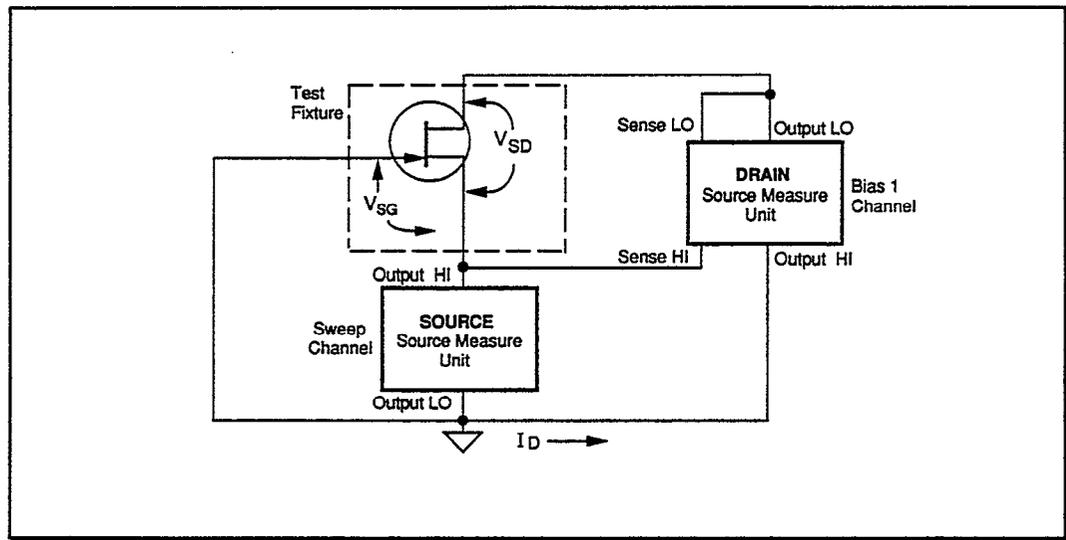
N-channel JFET Self Bias g_m vs. I_D

File Names

TESTLIB.CFG, NJFETGM2.TST, NJFETGM2.DAT

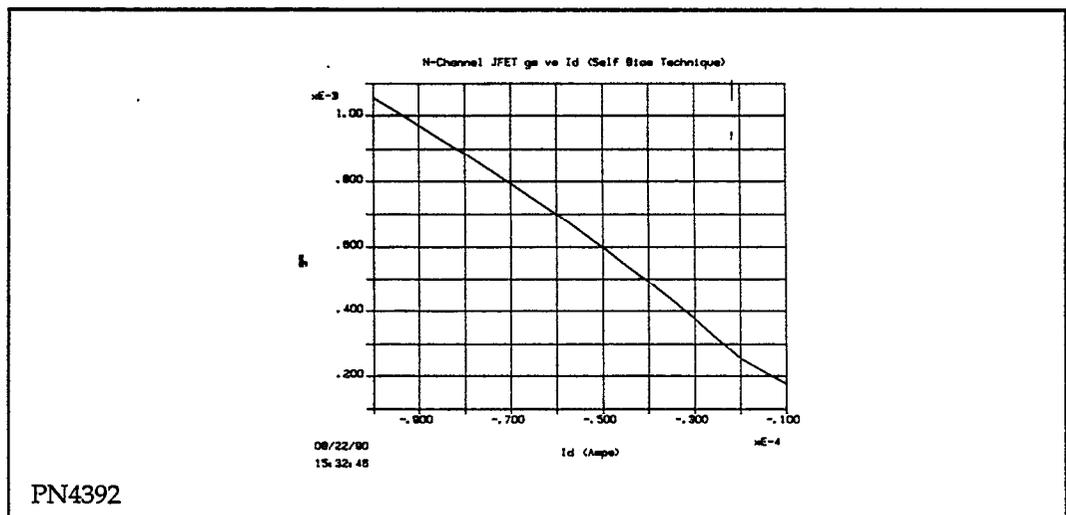
Test Description

Graphs g_m versus I_D .



Test Method

- The SOURCE source measure unit sweeps I_D ($I_D = I_S$) from $-10\mu A$ to $-100\mu A$ and measures V_{SG} ($V_{GS} = -V_{SG}$).
- The DRAIN source measure unit applies $V_{SD} = -10V$.
- $g_m = dI_D/dV_{SG}$ is calculated and plotted versus I_D .
- The OUTPUT LO of the DRAIN unit is not grounded. (Remove ground link between OUTPUT LO and earth ground.)
- The SENSE LO terminal of DRAIN source measure unit is connected to the drain and the SENSE HI is connected to the source.



DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DRAIN	16	KI236	1
SOURCE	17	KI236	2

NJFETGM2

CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 60Hz				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	On	Off	Off
Instrument Name	SOURCE			DRAIN		
Src Array Name	Id			Vsd		
Meas Array Name	Vsg					
SOURCE						
Type	I			V		
Pulsed Off Value						
Range	Best Fix			Best Fix		
Start/Bias	-10 μ A			-10 V		
Stop	-100 μ A					
Step	10 μ A					
# Of Curves						
Sense	Local			Remote		
MEASURE						
Range	11 V			100 mA		
Compliance Value	10 V			100 mA		

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: N-Channel JFET gm vs Id (Self Bias Technique)

Scale: Manual

Axis	X	Y1	Y2
Array Name	Id	gm	
Linear/Log	Linear	Linear	
Min	-100 μ A	100 μ	0
Max	-10 μ A	1.3 m	1
# of Divisions	9	12	

Grid: On
X Label: Id (Amps)
Y1 Label: gm
Y2 Label:
Colors/Curve labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

Differential Gain Calculation

$$gm = (d Id / d Vsg) * 1$$

Differentiate: Along curves (at constant step)
Calculation: On

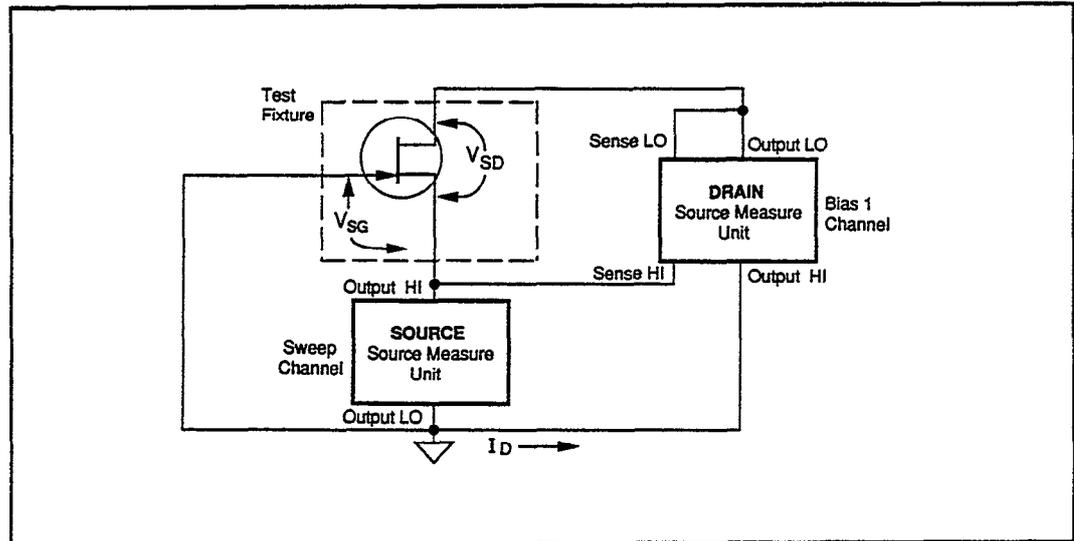
N-channel JFET Self Bias Threshold Voltage

File Names

TESTLIB.CFG, NJFETSBT.TST, NJFETSBT.DAT

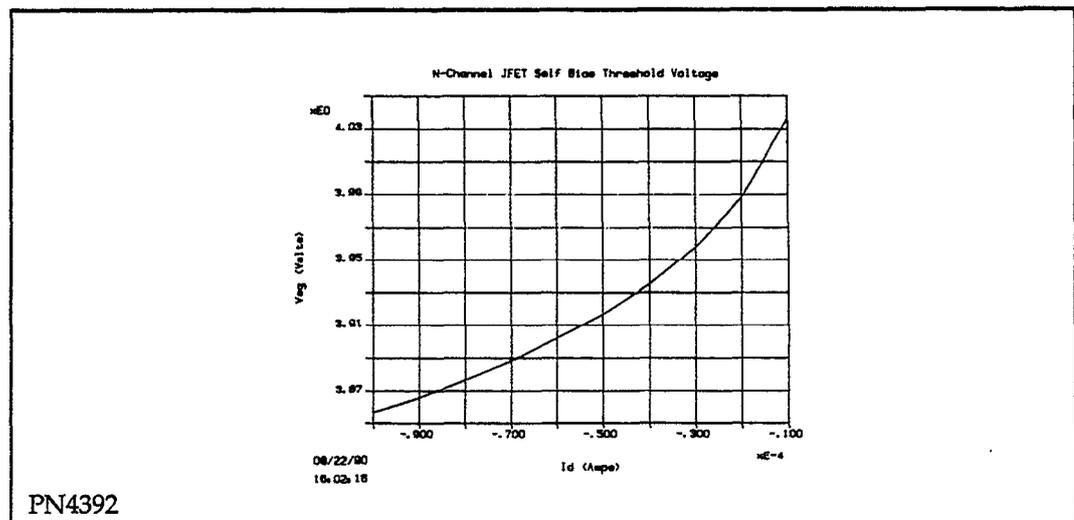
Test Description

Graphs V_{GS} voltage versus I_D . From the graph, V_T can be determined for a specified value of I_D .



Test Method

- The SOURCE source measure unit sweeps I_D ($I_D = I_S$) from $-10\mu A$ to $-100\mu A$ and measures V_{SG} ($V_{GS} = -V_{SG}$).
- The DRAIN source measure unit applies $V_{SD} = -10V$.
- The OUTPUT LO of the DRAIN unit is not grounded. (Remove ground link between OUTPUT LO and earth ground).
- V_{SG} is plotted vs. I_D . $V_T = -V_{SG}$ can be found from the graph for any plotted I_D value.
- The SENSE LO terminal of DRAIN source measure unit is connected to the drain and the SENSE HI terminal is connected to the source.



DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DRAIN	16	KI236	1
SOURCE	17	KI236	2

NJFETSBT

CURVE FAMILY TEST

Sweep Type: LINEAR
Mode: Single Test
Delay Before Curves: 0 s

Integration Time: 416µs
Filter: Disable
Delay Between Points: 0 s

CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	On	Off	Off
Instrument Name	SOURCE			DRAIN		
Src Array Name	Id	—	—	Vsd	—	—
Meas Array Name	Vsg	—	—		—	—
SOURCE						
Type	I	—	—	V	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	—	Best Fix	—	—
Start/Bias	-10 µA	—	—	-10 V	—	—
Stop	-100 µA	—	—	—	—	—
Step	10 µA	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	Remote	—	—
MEASURE						
Range	11 V	—	—	100 mA	—	—
Compliance Value	10 V	—	—	100 mA	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: N-Channel JFET Self Bias Threshold Voltage
Scale: Manual

Axis	X	Y1	Y2
Array Name	Id	Vsg	
Linear/Log	Linear	Linear	—
Min	-100 µA	3.05 V	0
Max	-10 µA	3.25 V	1
# of Divisions	9	8	—

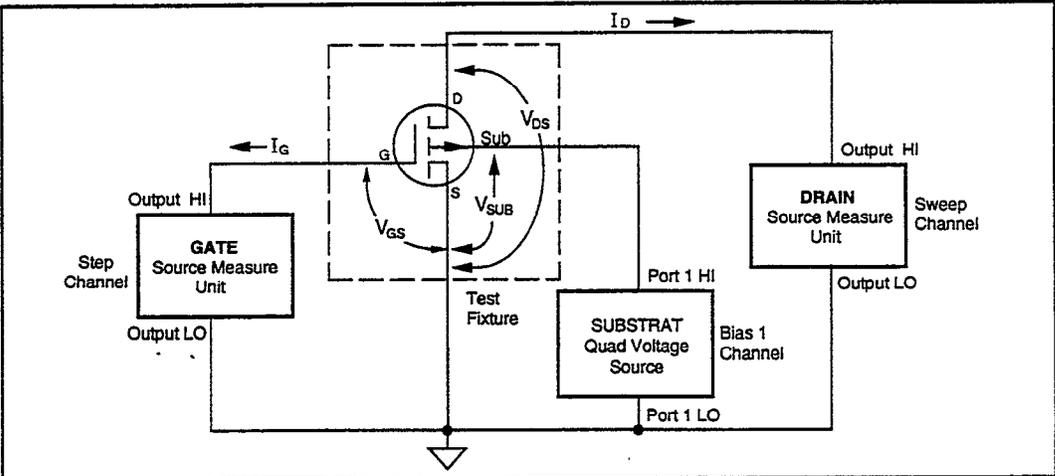
Grid: On
X Label: Id (Amps)
Y1 Label: Vsg (Volts)
Y2 Label:
Colors/Curve labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

P-channel Enhancement Mode MOSFET Common Source Curve Family

File Names TESTLIB.CFG, 213BIAS.TST, 213BIAS.DAT

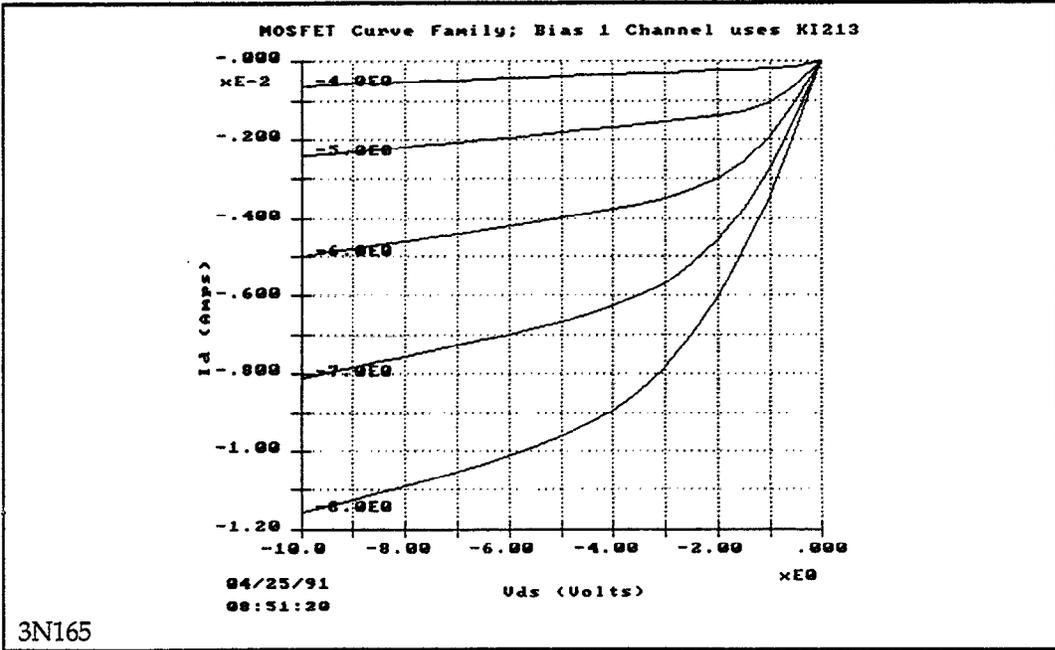
Test Description

Graph of I_D versus V_{GS} for a P-channel enhancement mode MOSFET. A Model 213 Quad Voltage Source is used to apply a bias voltage to the substrate and program as a bias channel.



Test Method

- The Model 213 applies a 3V bias to the substrate.
- The DRAIN source measure unit sweeps V_{DS} from 0 to $-10V$ and measure I_D .
- The GATE source measure unit steps V_{GS} from -4 to $-8V$ with $1V$ increment.
- The OUTPUT LO connections of both source measure units and the PORT 1 LO connection of Model 213 are grounded.



See Also 213QVS.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DRAIN	16	KI236	1
GATE	17	KI236	2
SUBSTRAT	9	KI213-1	

213BIAS CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 416 μ s				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	On	Off	On	Off	Off
Instrument Name	DRAIN	GATE		SUBSTRAT		
Src Array Name	Vds	Vgs	—	Vsub	—	—
Meas Array Name	Id	Ig	—	—	—	—
SOURCE						
Type	V	V	—	V	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	Best Fix	—	Best Fix	—	—
Start/Bias	0 V	-4 V	—	3V	—	—
Stop	-10 V	-8 V	—	—	—	—
Step	500 mV	1 V	—	—	—	—
# Of Curves	—	5	—	—	—	—
Sense	Local	Local	—	—	—	—
MEASURE						
Range	100 mA	1 μ A	—	—	—	—
Compliance Value	60 mA	1 μ A	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: MOSFET Curve Family; Bias 1 Channel uses KI213

Scale: Manual

Axis	X	Y1	Y2
Array Name	Vds	Id	
Linear/Log	Linear	Linear	—
Min	-10V	-12mA	0
Max	0V	0A	1
# of Divisions	10	12	—

Grid: On
X Label: Vds (Volts)
Y1 Label: Id (Amps)
Y2 Label:
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

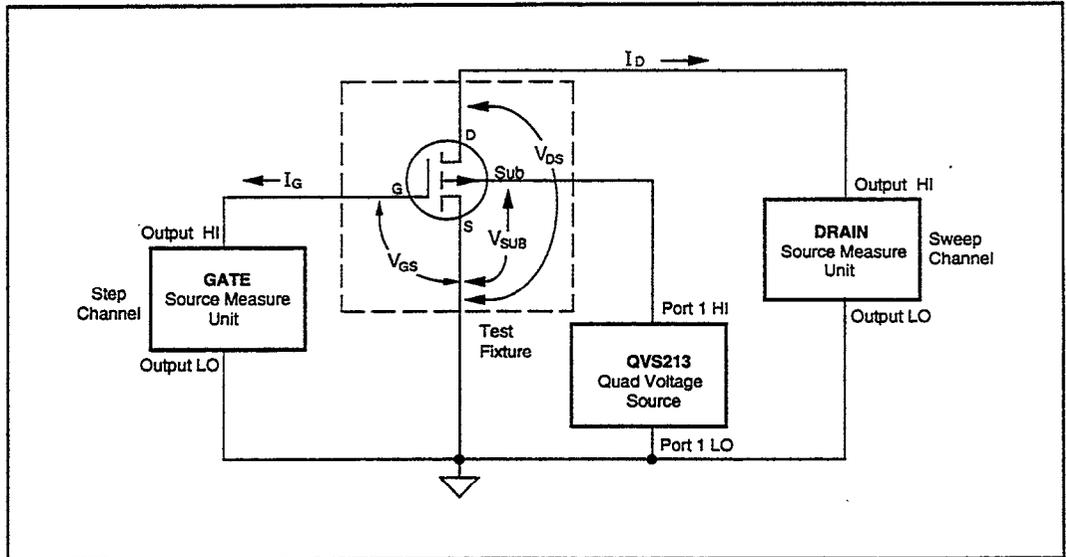
GPIB Tests

- P-channel Enhancement Mode MOSFET Common Curve Family (Method 2)
- Forward Biased I-V Characteristics of Multiple Diodes
- Forward Biased I-V Characteristics of Multiple Diodes (with 707 Matrix Setup File)
- GPIB Control of a Hot Chuck

P-channel Enhancement Mode MOSFET Common Source Curve Family

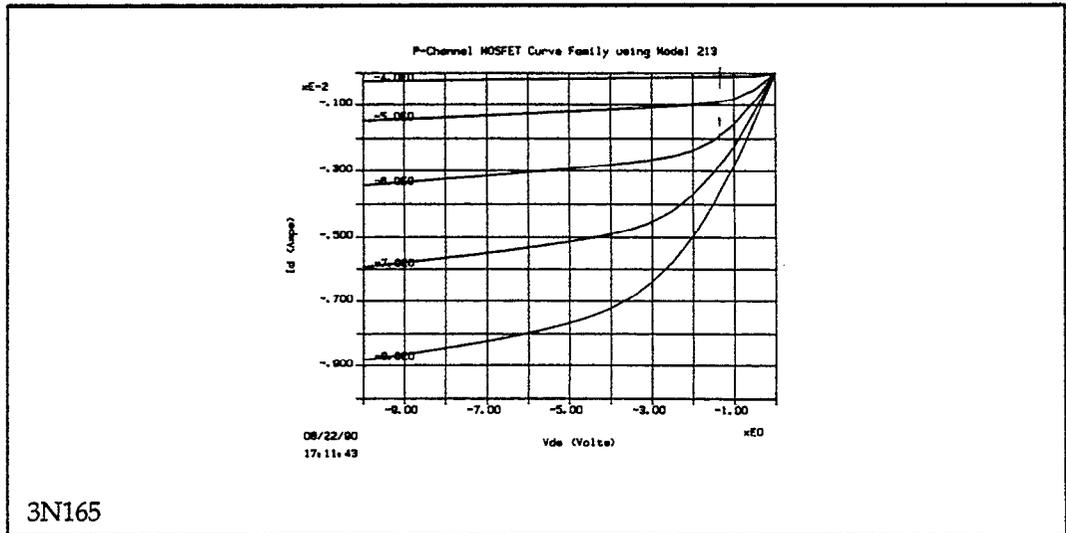
File Names TESTLIB.CFG, 213QVS.TST, 213QVS.DAT

Test Description Graph of I_D versus V_{GS} for a P-channel, enhancement mode MOSFET. A Model 213 Quad Voltage Source, under GPIB control, is used for applying a bias voltage to the substrate.



Test Method

- The Model 213 applies a 3V bias to the substrate. The instrument is controlled from the GENERAL GPIB OUTPUT form.
- The DRAIN source measure unit sweeps V_{DS} from 0 to $-10V$ and measures I_D .
- The GATE source measure unit steps V_{GS} from -4 to $-8V$ with a $1V$ increment.
- The OUTPUT LO connections of both source measure units and the PORT 1 LO connection of the Model 213 are grounded.



3N165

See Also 213BIAS.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DRAIN	16	KI237	3
GATE	17	KI236	1
QVS213	11	Other	

213QVS

CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 416 μ s				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	On	Off	Off	Off	Off
Instrument Name	DRAIN	GATE				
Src Array Name	Vds	Vgs	—	—	—	—
Meas Array Name	Id	Ig	—	—	—	—
SOURCE						
Type	V	V	—	—	—	—
Pulse Off Value	—	—	—	—	—	—
Range	Best Fix	Best Fix	—	—	—	—
Start/Bias	0 V	-4 V	—	—	—	—
Stop	-10 V	-8 V	—	—	—	—
Step	500 mV	1 V	—	—	—	—
# Of Curves	—	5	—	—	—	—
Sense	Local	Local	—	—	—	—
MEASURE						
Range	100 mA	1 μ A	—	—	—	—
Compliance Value	60 mA	1 μ A	—	—	—	—

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: P-channel MOSFET Curve Family using Model 213

Scale: Manual

Axis	X	Y1	Y2
Array Name	Vds	Id	—
Linear/Log	Linear	Linear	—
Min	-10 V	-13 mA	0
Max	0 V	0 A	1
# of Divisions	10	10	—

Grid: On

X Label: Vds (Volts)

Y1 Label: Id (Amps)

Y2 Label:

Colors/Curve Labels

DC-Gain (Ratio)

Differential Gain

Overlay Form

GENERAL GPIB OUTPUT

Instrument Name: QVS213

EOS Character: None

Output Strings:

1. C0 P1 A0 R2 V3 X

2.

3.

4.

707 Name:

<Upload From 707>

<Download to 707>

Read String

GPIB Commands: <GPIB Send>
 <GPIB Read>
 <Group Execute Trigger (GET)>
 <Selected Device Clear>
 <Send Interface Clear>
 <Read SPOLL Byte>

SPOLL Byte

H

L

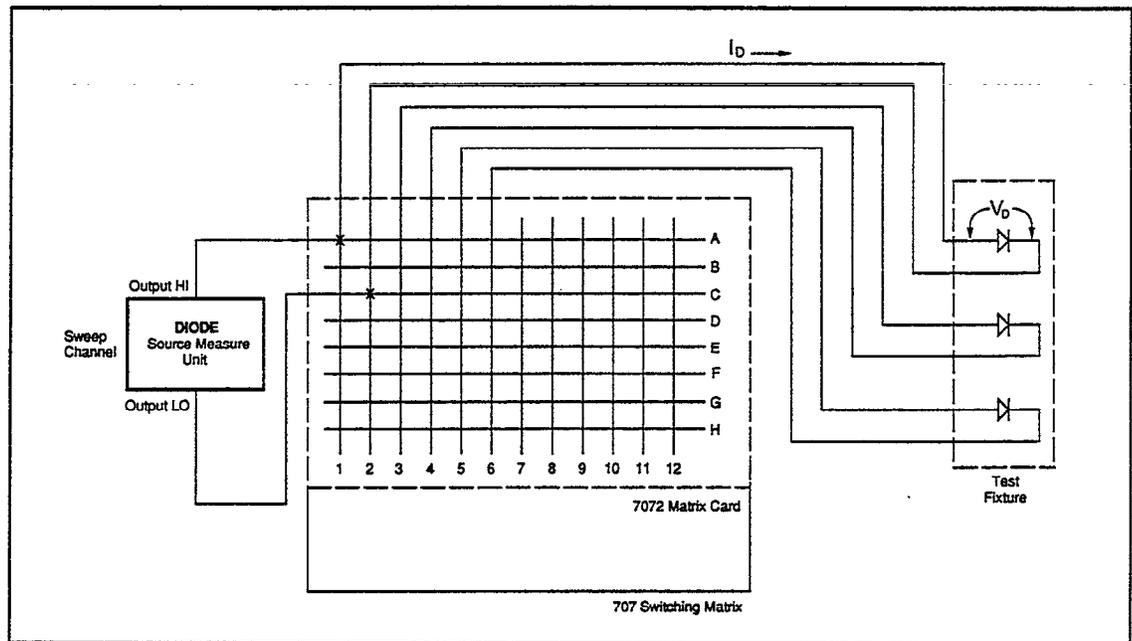
Status

Forward Biased I-V Characteristics of Multiple Diodes

File Names TESTLIB.CFG, MATRIX.TST, MATRIX.DAT

Test Description

Graphs of I_D versus V_D for multiple diodes. A Model 707 Switching Matrix, under GPIB control, is used to switch signals among the diodes.



Test Method

- Go to the GENERAL GPIB OUTPUT form and confirm that the device-dependent commands P0CA1, C2X appear in the Output String #1 field. These commands will open all crosspoints, then close crosspoints A1 and C2.
- Return to the CURVE FAMILY TEST form and execute the test. Before the curve test is started, the commands are sent to the Model 707. They will connect the OUTPUT HI and LO terminals of the source measure unit to the anode and cathode of the first diode.
- The source measure unit sweeps V_D from 0V to 500mV and measures I_D .
- When the test has completed, save the data, then return to the GENERAL GPIB OUTPUT form. Edit the Output String #1 field to the following:

$$P0CA3, C4X$$
- Return to the CURVE FAMILY TEST form and execute the test. The Model 707 will close the crosspoints for the second diode before the curve test is run. Save the second set of data, then edit the Output String #1 for the third diode:

$$P0CA5, C6X$$
- Execute the test a third time from the CURVE FAMILY TEST form. You can compare the three sets of data by using the Overlay function.

See Also

DIODELIN.TST, 707DIODE.TST

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DIODE	16	KI236	1
MATRIX	18	Other	

MATRIX

CURVE FAMILY TEST

Sweep Type: LINEAR		Integration Time: 416 μ s				
Mode: Single Test		Filter: Disable				
Delay Before Curves: 0 s		Delay Between Points: 0 s				
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	DIODE					
Src Array Name	Vd					
Meas Array Name	Id					
SOURCE						
Type	V					
Pulsed Off Value	—					
Range	Best Fix					
Start/Bias	0 V					
Stop	500 mV					
Step	10 mV					
# Of Curves	—					
Sense	Local					
MEASURE						
Range	1 mA					
Compliance Value	1 mA					

DISPLAY PARAMETERS

Mode: Graphics

Graph Title: Diode IV Chars. using Model 707 Switching Matrix

Scale: Manual

Axis	X	Y1	Y2
Array Name	Vd	Id	
Linear/Log	Linear	Linear	—
Min	0 V	0	0
Max	500 mV	100 μ A	1
# of Divisions	10	10	—

Grid: On
X Label: Vd (Volts)
Y1 Label: Id (Amps)
Y2 Label:
Colors/Curve Labels
DC-Gain (Ratio)
Differential Gain
Overlay Form

GENERAL GPIB OUTPUT

Instrument Name: MATRIX

EOS Character: None

Output Strings:

1. P0CA1, C2X
2. P0CA3, C4X
3. P0CA5, C6X
- 4.

707 Name:

<Upload from 707>

<Download to 707>

Read String

GPIB Commands:

- <GPIB Send>
- <GPIB Read>
- <Group Execute Trigger (GET)>
- <Selected Device Clear>
- <Send Interface Clear>
- <Read SPOLL Byte>

SPOLL Byte

H

L

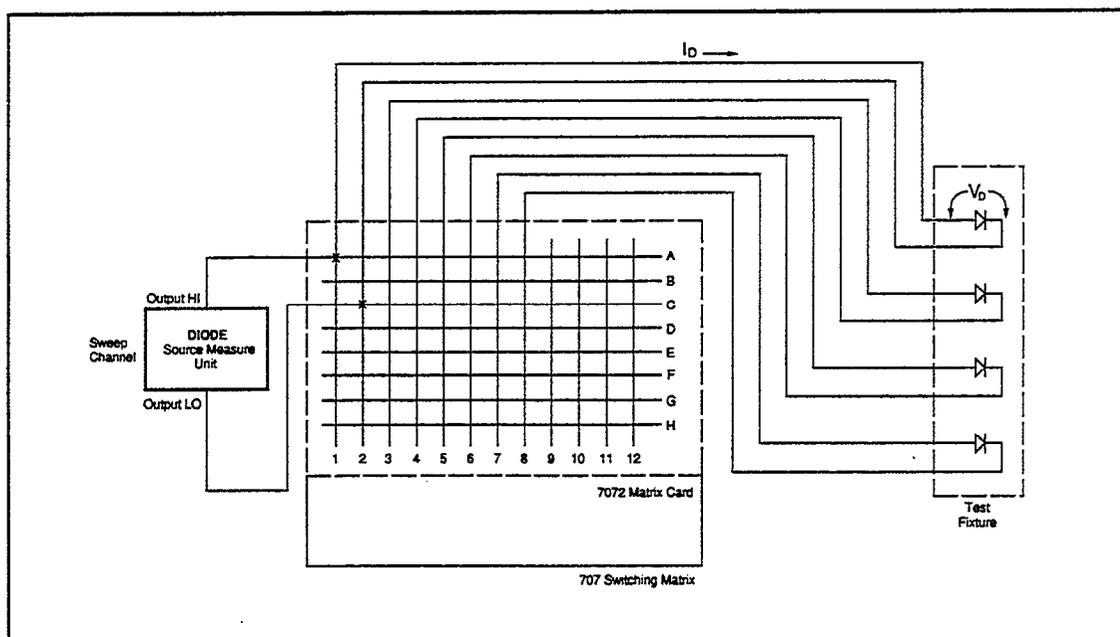
Status

Forward Biased I-V Characteristics of Multiple Diodes (with 707 Matrix Setup File)

File Names TESTLIB.CFG, 707DIODE.TST, 707DIODE.DAT, 707DIODE.707

Test Description

Graphs of I_D versus V_D for multiple diodes. A Model 707 Switching Matrix is used to switch signals among the diodes.



Test Method

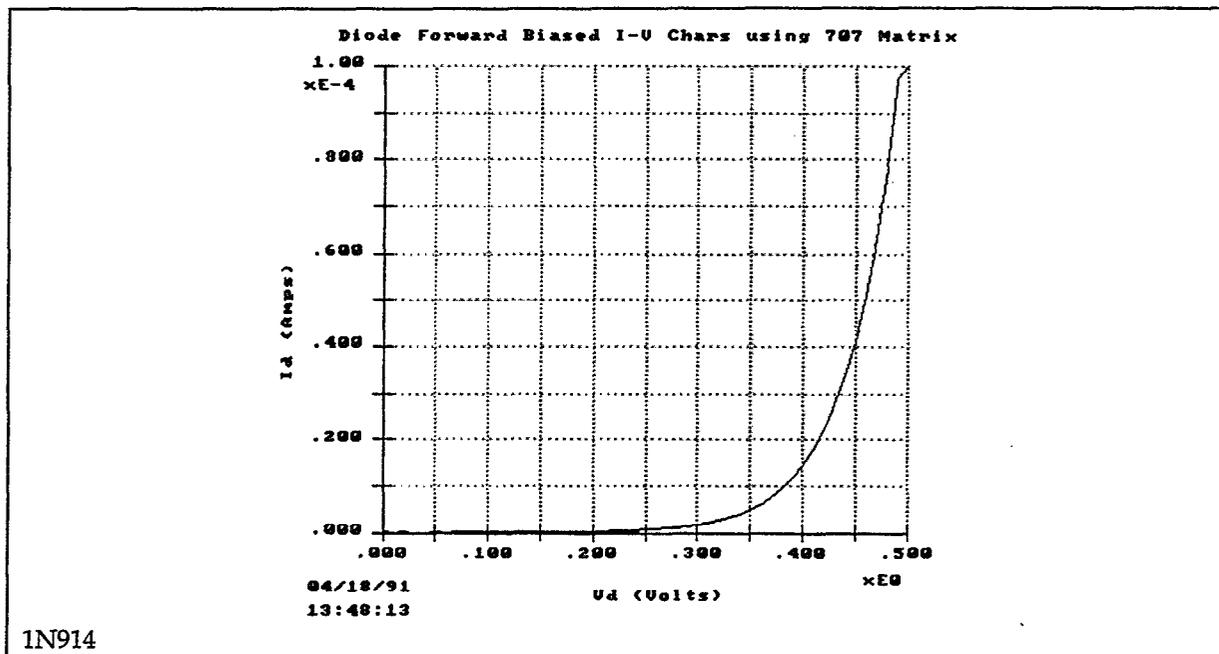
- After configuring your instruments and loading present the test setup file (707DIODE.TST), load the 707DIODE.707 file from the 707 directory. It contains previously saved relay setups for the Model 707 Switching Matrix.
- From the CURVE FAMILY TEST form, press <F5> for the GENERAL GPIB OUTPUT form. The name MATRIX is displayed in the Instrument Name and 707 Name fields. The commands shown in the first output string trigger the Model 707 at test execution.
- Select <Download to 707> and press <F10>. The setups are downloaded and SETUP 001 is copied to the relays. This closes crosspoints A1 and C2, connecting the first diode.
- To test Diode 1, return to the CURVE FAMILY TEST form and press <F10>. This sends the first output string from the GENERAL GPIB FORM, triggering SETUP 001 to the relays, and runs the test.

NOTE

Each time a Model 707 is triggered, the next stored setup is copied to the relays. Since a <Download to 707> already copied SETUP 001 to the relays, the first trigger is effectively a NOP (no operation).

- When the test has completed, save the data. If this is not done, the data for the second diode will overwrite it.
- To test Diode 2, return to the CURVE FAMILY TEST form and press <F10>. This triggers

- SETUP 002 to the Model 707 relays, which connects the second diode, and runs the test again.
- Save the data for the second diode. Continue testing the remaining diodes, saving after each test.
 - If the test sequencer file 707DIODE.SEQ is loaded prior to the first test, the four diodes are tested without operator intervention. The acquired data is saved in the files DIODE001.DAT through DIODE004.DAT.



See Also DIODELIN.TST, 707DIODE.SEQ

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
DIODE MATRIX	16 18	KI236 KI707	1

707DIODE		CURVE FAMILY TEST				
Sweep Type: LINEAR Mode: Single Test Delay Before Curves: 0 s			Integration Time: 416µs Filter: Disable Delay Between Points: 0 s			
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	On	Off	Off	Off	Off	Off
Instrument Name	DIODE					
Src Array Name	Vd	—	—	—	—	—
Meas Array Name	Id	—	—	—	—	—
SOURCE						
Type	V	—	—	—	—	—
Pulsed Off Value	—	—	—	—	—	—
Range	Best Fix	—	—	—	—	—
Start/Bias	0 V	—	—	—	—	—
Stop	500 mV	—	—	—	—	—
Step	10 mV	—	—	—	—	—
# Of Curves	—	—	—	—	—	—
Sense	Local	—	—	—	—	—
MEASURE						
Range	1 mA	—	—	—	—	—
Compliance Value	1 mA	—	—	—	—	—

DISPLAY PARAMETERS			
Mode: Graphics			
Graph Title: Diode Forward Biased I-V Chars using Model 707 Matrix			
Scale: Manual			
Axis	X	Y1	Y2
Array Name	Vd	Id	
Linear/Log	Linear	Linear	—
Min	0 V	0	0
Max	500 mV	100 µA	1
# of Divisions	10	10	—
Grid: On			
X Label: Vd (Volts)			
Y1 Label: Id (Amps)			
Y2 Label:			
Colors/Curve Labels			
DC-Gain (Ratio)			
Differential Gain			
Overlay Form			

GENERAL GPIB OUTPUT

Instrument Name: MATRIX

EOS Character: None

Output Strings:

1. F1T4X
- 2.
- 3.
- 4.

707 Name: MATRIX

<Upload from 707>

<Download to 707>

Read String

- GPIB Commands:
- <GPIB Send>
 - <GPIB Read>
 - <Group Execute Trigger (GET)>
 - <Selected Device Clear>
 - <Send Interface Clear>
 - <Read SPOLL Byte>

SPOLL Byte

H

L

Status

GPIB Control of a Hot Chuck

File Names TESTLIB.CFG, HOTCHUCK.TST

Test Description This test library file shows an example of GPIB control. A Temptronic Model TP0315A thermal chuck (with an IEEE-488 option) is used to control the temperature of a device under test.

Test Method The four output strings on the GENERAL GPIB OUTPUT form can be sent one at a time using the GPIB Send command:

- The first string sets the hot chuck to the ambient temperature of 23°C with a window of 1°C.
- The second string sets the hot chuck to 250°C with a window of 1°C.
- The third string clears the service request mask. After it is sent, use the Read SPOLL Byte command to perform a serial poll. If the hot chuck reached the programmed temperature, the least significant bit will be set.
- The fourth string requests the present temperature. After it is sent, use the GPIB Read command to read the temperature.

GENERAL GPIB OUTPUT	
Instrument Name: TP0315A EOS Character: None Output Strings: 1. ;RS23;RW1 2. ;RS250;RW1 3. ;RMO 4. ;ST	707 Name: <Upload from 707> <Download to 707>
<div style="border: 1px solid black; width: 80%; margin: 0 auto; height: 40px; display: flex; align-items: center; justify-content: center;"> Read String </div>	
GPIB Commands: <GPIB Send> <GPIB Read> <Group Execute Trigger (GET)> <Selected Device Clear> <Send Interface Clear> <Read SPOLL Byte>	<div style="border: 1px solid black; width: 100%; text-align: center; margin-bottom: 5px;"> SPOLL Byte H L </div> <div style="border: 1px solid black; width: 100%; text-align: center; margin-bottom: 5px;"> Status </div>

DEFINE INSTRUMENTS

Trigger Controller Address: 15			
Instrument Name	GPIB Address (1-30)	Instrument	Trigger Channel (1-6)
TP0315A	10	Other	

HOTCHUCK

CURVE FAMILY TEST

Sweep Type: LINEAR			Integration Time: 60Hz Line			
Mode: Single Test			Filter: Disable			
Delay Before Curves: 0 s			Delay Between Points: 0 s			
CHANNEL NAME	Sweep	Step	Sync Swp	Bias 1	Bias 2	Bias 3
On/Off	Off	Off	Off	Off	Off	Off
Instrument Name	---	---	---	---	---	---
Src Array Name	---	---	---	---	---	---
Meas Array Name	---	---	---	---	---	---
SOURCE						
Type	---	---	---	---	---	---
Pulsed Off Value	---	---	---	---	---	---
Range	---	---	---	---	---	---
Start/Bias	---	---	---	---	---	---
Stop	---	---	---	---	---	---
Step	---	---	---	---	---	---
# Of Curves	---	---	---	---	---	---
Sense	---	---	---	---	---	---
MEASURE						
Range	---	---	---	---	---	---
Compliance Value	---	---	---	---	---	---

DISPLAY PARAMETERS

Mode: Graphics

Graph Title:

Scale: Auto

Axis	X	Y1	Y2
Array Name			
Linear/Log	Linear	Linear	---
Min	---	---	---
Max	---	---	---
# of Divisions	---	---	---

Grid: On

X Label:

Y1 Label:

Y2 Label:

Colors/Curve Labels

DC-Gain (Ratio)

Differential Gain

Overlay Form

Test Sequences

NPN Transistor Tests (Data Display Only)
NPN Transistor Tests (with Test Execution)
Forward Biased I-V Characteristics of Multiple Diodes

NPN Transistor Tests (Data Display Only)

File Names	NPNDATA.SEQ
Test Description	Displays NPN transistor curves from the test library.
Test Method	<ul style="list-style-type: none">• Load the test sequence file called NPNDATA.SEQ. Follow the user prompts.• The test sequence file is listed below.
See Also	NPNCRV.TST, NPNBETA.TST, NPNHFE.TST, NPNFGUML.TST, NPNBVCEO.TST, NPNICEO.TST.

Sequence File

```
! This is an example of a Test Sequence file, which uses the data
! files provided in the supplied libraries. It should work if your
! system is installed with the provided libraries. This sequence file
! will not execute the tests, but only display the data, and therefore
! does not require any instruments to be connected.

! Below are examples of all metacommands; the unused ones are
! commented out with a "!" at the start of line. All commands are shown
! in their longest form, but may be shortened to 3 characters.

metacommands:
  autorepeat-ok,          ! This allows auto repeat mode; F10 or ESC to stop.
  overwrite,              ! This allows overwriting existing files.
  stoponerror,           ! This stops and displays every error; if stoponerror
                        ! is omitted, errors are written to 251error.log
! unattended,            ! Don't pause for anything, and write errors to log file
  maxerrors=0             ! This is a NOP (it's the default; has no effect), and
                        ! serves only as a place holder, so previous meta
                        ! commands can be commented out as needed without
                        ! worrying about extra/missing commas, since the
                        ! last included parameter may not end in comma.

CONFIG: TESTLIB          ! Load the configuration supplied with the libraries

!
! The ruler below can be used to ensure lines are <= 60 characters
! 12345678-10-345678-20-345678-30-345678-40-345678-50-345678-6

Prompt:  "This test sequence will display NPN Transistor data"
         "collected and saved in the Test Library data files."
         ""
         "The first test will display a NPN Curve Family"
         "Characteristics from NPNCRV.DAT file."

TEST: NPNCRV.DAT,
      PAUSE,
! DATA=FAMILY1,
      NOEXECUTE,
      REPEAT=1          ! Once again, this is a NOP (see metacommands above)

Prompt:  "The next test will display the calculated DC-gain."
         "from NPNBETA.DAT data file."

TEST: NPNBETA.DAT,
      PAUSE,
! DATA=BETA1,
      NOEXECUTE,
      REPEAT=1          ! Once again, this is a NOP (see metacommands above)

Prompt:  "The next test will display the NPN Transistor Small Signal"
         "Gain from the NPNHFE.DAT data file."
```

```
TEST: NPNHFE.DAT,  
      PAUSE,  
!     DATA=HFE1,  
      NOEXECUTE,  
      REPEAT=1 ! Once again, this is a NOP (see metacommands above)
```

```
Prompt:    "The next test will display the NPN Transistor"  
           "Forward Gummel Plot from the NPNFGUML.DAT data file."
```

```
TEST: NPNFGUML.DAT,  
      PAUSE,  
!     DATA=GUMMEL1,  
      NOEXECUTE,  
      REPEAT=1           ! Once again, this is a NOP (see metacommands above)
```

```
Prompt:    "The next test will display NPN Collector Emitter"  
           "Breakdown data from the NPNBVCEO.DAT data file."  
           "The next two tests will be run two times to show"  
           "an example of using the LOOP feature."
```

```
LOOP:2           ! This illustrates the use of LOOP...ENDLOOP
```

```
TEST: NPNBVCEO.DAT,  
      PAUSE,  
      DATA=BVCEO###,  
      NOEXECUTE,  
      REPEAT=1           ! Once again, this is a NOP (see metacommands above)
```

```
Prompt:    "The next test will display NPN Transistor Collector"  
           "Leakage data from the NPNICEO.DAT data file."
```

```
TEST: NPNICEO.DAT,  
      PAUSE,  
!     DATA=ICEO1,  
      NOEXECUTE,  
      REPEAT=1           ! Once again, this is a NOP (see metacommands above)
```

```
ENDLOOP
```

```
Prompt:    "End of the Test Sequence NPNDATA.SEQ."
```


NPN Transistor Tests (with Test Execution)

File Names	NPNTTEST.SEQ
Test Description	Executes NPN transistor tests from the test library.
Test Method	<ul style="list-style-type: none">• Load the test sequence file called NPNTTEST.SEQ. Follow the user prompts.• The test sequence file is listed below.
See Also	NPNCRV.TST, NPNBETA.TST, NPNHFE.TST, NPNTGUGML.TST, NPNBVCEO.TST, NPNICEO.TST.

Sequence File

```
! This is an example of a Test Sequence file, which uses the test
! files provided in the supplied libraries. It should work if your
! system is installed with the provided libraries. This sequence file
! will execute the tests, and therefore requires instruments that are
! connected properly (as specified in the manual).

! Below are examples of all metacommands; the unused ones are
! commented out with a "!" at the start of line. All commands are shown
! in their longest form, but may be shortened to 3 characters.

metacommands:
  autorepeat-ok,          ! This allows continuous execution; F10 or ESC to stop. overwrite,
                          ! This allows overwriting existing files. stoponerror,
                          ! This stops and displays every error; if stoponerror
                          ! is omitted, errors are written to 251error.log.
! unattended,            ! Don't pause for anything, and write errors to log file
  maxerrors=0            ! This is a NOP (it's the default; has no effect), and
                          ! serves only as a place holder, so previous meta
                          ! commands can be commented out as needed without
                          ! worrying about extra/missing commas, since the
                          ! last included parameter may not end in comma.

Prompt:                  "This test will execute several NPN Transistor tests from"
                          "the test library and collect a set of parameters for NPN"
                          "Transistor."
                          ""
                          "The first test will acquire and display NPN Curve"
                          "Family characteristics."

CONFIG: TESTLIB          ! Load the configuration supplied with the libraries.

!                          The ruler below can be used to ensure lines are <= 60 characters
!                          12345678-10-345678-20-345678-30-345678-40-345678-50-345678-6

Prompt:                  "Connect NPN Transistor according to the schematics drawn"
                          "in the Appendix D of the Model 251 Manual under"
                          "the NPN Transistor Common Emitter Curve Family test."
                          "The test NPNCRV.TST will be run, and the data will be"
                          "saved in the data file FAMILY1.DAT."

TEST: NPNCRV,
  PAUSE,
  DATA=FAMILY1,
! NOEXECUTE,
  REPEAT=1              ! Once again, this is a NOP (see metacommands above)

Prompt:                  "The next test will acquire data, calculate and display"
                          "the NPN Transistor DC-gain."
                          "The test NPNBETA.TST from the Test Library will now be run."
                          "The data will be saved in the data file BETA1.DAT"
```

```
TEST: NPNBETA,
      PAUSE,
      DATA=BETA1,
!     NOEXECUTE,
      REPEAT=1           ! Once again, this is a NOP (see metacommands above)
```

```
Prompt:  "The next test will acquire data, calculate and display"
          "the NPN Transistor Small Signal Gain."
          "The test NPNHFE.TST from the Test Library will now be run."
          "The data will be saved in the data file HFE1.DAT"
```

```
TEST: NPNHFE,
      PAUSE,
      DATA=HFE1,
!     NOEXECUTE,
      REPEAT=1           ! Once again, this is a NOP (see metacommands above)
```

```
Prompt:  "The next test will acquire and display"
          "the NPN Transistor Forward Gummel Plot."
          "The test NPNFGUML.TST from the Test Library will now be run."
          "The data will be saved in the data file GUMMEL1.DAT"
```

```
TEST: NPNFGUML,
      PAUSE,
      DATA=GUMMEL1,
!     NOEXECUTE,
      REPEAT=1           ! Once again, this is a NOP (see metacommands above)
```

```
Prompt:  "The next test will acquire and display the NPN Transistor"
          "Collector Emitter Breakdown data."
          "DISCONNECT THE BASE PIN of THE TRANSISTOR (leave it open)."
```

```
Prompt:  "The test NPNBVCEO.TST from the Test Library will be run"
          "two times to show an example of using the REPEAT feature."
          "The data will be saved in BVCEO001.DAT and BVCEO002.DAT."
```

```
TEST: NPNBVCEO,
      PAUSE,
      DATA=BVCEO,
!     NOEXECUTE,
      REPEAT=2
```

```
Prompt:  "The next test will acquire and display "
          "NPN Transistor Collector Leakage data."
          "The test NPNICEO.TST from the Test Library will now be run."
          "The data will be saved in the data file ICEO1.DAT"
```

```
TEST: NPNICEO,
      PAUSE,
      DATA=ICEO1,
!     NOEXECUTE,
      REPEAT=1           ! Once again, this is a NOP (see metacommands above)
```

```
Prompt:  "This ends NPNTTEST.SEQ. You now have 7 new data files:"
          "FAMILY1.DAT" "BETA1.DAT" "HFE1.DAT" "GUMMEL1.DAT"
          "BVCEO001.DAT" "BVCEO002.DAT" "ICEO1.DAT"
```


Forward Biased I-V Characteristics of Multiple Diodes

File Names	707DIODE.SEQ
Test Description	Executes 707DIODE.TST for 4 diodes.
Test Method	<ul style="list-style-type: none">• Load the test sequence file called 707DIODE.SEQ. Follow the user prompts.• The test sequence file is listed below.
See Also	707DIODE.TST, 707DIODE.707 (relay setup file), DIODELIN.TST

Sequence File

! This is a Test Sequence file, which provides the execution of
! the 707diode.tst as an automatic sequence. The 707diode.tst is supplied
! in the Model251 library of tests. It will measure consecutively the
! forward biased characteristics of four diodes connected to the SMU
! using the 707 Matrix switch.

meta: over, stop
CONFIG: TESTLIB

Prompt: "Connect four diodes to the SMU and 707 Matrix according"
"to the schematics shown in the description of the test:"
"Forward Biased I-V Characteristics of Multiple Diodes"
"using 707 MATRIX Setup File. (Model251 Manual, Appendix D)"

707FILE: 707diode.707
TEST: 707diode, DATA=DIODE, REPEAT=4

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Service Form

Model No. _____ Serial No. _____ Date _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

- | | | |
|--|--|--|
| <input type="checkbox"/> Intermittent | <input type="checkbox"/> Analog output follows display | <input type="checkbox"/> Particular range or function bad; specify |
| <input type="checkbox"/> IEEE failure | <input type="checkbox"/> Obvious problem on power-up | <input type="checkbox"/> Batteries and fuses are OK |
| <input type="checkbox"/> Front panel operational | <input type="checkbox"/> All ranges or functions are bad | <input type="checkbox"/> Checked all cables |

Display or output (check one)

- | | |
|-----------------------------------|--|
| <input type="checkbox"/> Drifts | <input type="checkbox"/> Unable to zero |
| <input type="checkbox"/> Unstable | <input type="checkbox"/> Will not read applied input |
| <input type="checkbox"/> Overload | |

Calibration only Certificate of calibration required

Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

What power line voltage is used? _____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

Be sure to include your name and phone number on this service form.

KEITHLEY

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Cleveland, Ohio 44139