TECHNICAL MANUAL

FOR

MODEL 7130A

"DIGITAL AC/DC TRANSFER STANDARD"

NOTICE

TM7130A-D-00

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1 INTRODUCTION

1.1 SCOPE

This manual contains technical specifications, detailed description and maintenance information, and diagrams for the Guildline Instruments 7130A Digital AC/DC Transfer Standard.

1.2 DESCRIPTION

The 7130A Digital AC/DC Transfer Standard is a microprocessor based, fully automated digital AC/DC Transfer Standard. It combines the established Differential Multijunction Thermal Converter (DMJTC)[1] technique with the latest advances in microprocessor technology and digital design. The ppm performance achieved in the earlier 7100A AC/DC Transfer Standard using the DMJTC has been extended over a wider voltage and frequency range by means of a new wideband auto ranging attenuator.

This attenuator is the result of extensive work carried out by Guildline engineers in our Research and Development laboratories.

The main features of the 7130A Digital AC/DC transfer Standard are:

- Fully programmable
- Autoranging voltage from 1 mV to 1200 Vrms.
- Wide frequency range DC, 10 Hz to 1 MHz.
- Precision AC voltmeter mode.
- Direct reading of Voltage, Voltage Difference and ppm.
- Self balancing operation with built in precision DC supply.
- Automatic DC reversal.
- Overload protection circuit, up to 3½ times nominal rms input on the low voltage input. HV protection = 1.75

[1]The Guildline DMJTC is based on F.J. Wilkins' original thermal converter designed at the National Physical Laboratory (NPL) in England. This design was enhanced by N. Kusters and L. Cox at the National Research Council of Canada (NRCC) in co-operation with Guildline's engineers.

kVrms. Instantaneous crowbar protection provided for sudden over voltages >3½ times nominal input.

- GPIB/IEEE-488 interface built in.
- RS-232C interface.
- Built-in frequency counter and display.

1.3 APPLICATIONS

The 7130A Digital AC/DC Transfer Standard is a precision AC measuring instrument. Its main applications are:

- A prime standard of AC/DC transfer from 1 mV to 1200 V over the frequency band 10 Hz to 1 MHz and at DC.
- Calibration and monitoring of short and long term drift characteristics of AC power supplies.
- Calibration of AC analogue and digital voltmeters.
- Calibration of AC bridges.
- Calibration of other AC measuring instruments, e.g. lower accuracy AC/DC transfer devices.
- Calibration of AC calibrators and AC sources.
- Calibration of audio frequency generators.
- Integration into automatic calibration systems and mobile calibration facilities.

1.4 GENERAL THEORY

(Refer to Figure 1.1)
Essentially the 7130A acts like a traditional AC/DC Transfer Standard in that it compares the unknown input with an internally generated, highly stable, DC reference. Comparison is done by utilizing a DMJTC (Differential Multijunction Thermal Converter) [See footnote page 1], manufactured by Guildline. The latter thermally compares the two voltages and generates an error voltage proportional to power difference. This voltage is fed via an A/D converter to the internal microprocessor which updates the internal DC reference to zero the error voltage prior to the next measurement.

Equilibrium is achieved after a number of measurements. The DC reference value is then read out after appropriate compensation.

The 7130A adds additional refinements to the above model to compensate for imperfections in the amplifier and DMJTC.

As shown in Figure 1.1, one refinement involves the application of the internal DC reference voltage to heater H1 of the thermal converter in place of the input voltage, via an accurate, stable DC Attenuator/Inverter. To obtain a fully compensated AC difference value the DC reference is applied to H1 in normal and inverted polarity and the input applied twice to form a four sample measurement cycle. Error voltages obtained for each sample are stored in the microprocessor, which then computes the true AC/DC difference, _ V, prior to updating the DC reference for the next
4 cycle comparison.

The calculation involved is shown in Equation (1).

The displayed value is the final DC reference voltage with the various compensation applied as described in Section 4.7.

Conceptually, the 7130A uses the DMJTC (Differential Multijunction Thermal Converter) to compare the rms (or DC) input with a precision variable DC reference voltage that is internally generated and controlled by the microprocessor. The value of this internal voltage is used as the final displayed value after application of previously characterised compensating constants. (e.g. frequency response).

Under normal, stable operation, (after input acquisition), the unknown input is attenuated or amplified via the input attenuator and programmable gain amplifier to present a normalized voltage at H1 of the thermal converter. (2 Vrms represents full scale of the range selected).

Concurrently the microprocessor applies to heater H2 of the thermal converter the previously derived DC reference voltage that is equivalent to the input. The output of the servo loop/thermal converter comparison, forms the AC/DC difference voltage (or error voltage).

This voltage is presented to the microprocessor at the end of a measurement interval of approximately 2½ seconds, via the 12 bit A/D converter.

The microprocessor performs 3 subsequent measurements in which the effective variable DC reference is applied to heater H1, in both polarities, as well as repeating once more a measurement using the input.

The AC difference voltages for the four measurements are then used as follows to determine _V, final AC/DC difference.

The four measurements performed in sequence are shown below:

1. N_{ac1} = Input applied (first sample)

2. R^{+}_{dc} = Internal DC applied with positive polarity

3. N_{ac2} = Input applied (second sample)

4. R^{-}_{dc} = Internal DC applied with negative polarity.

The AC/DC difference is calculated as per the equation:

$$\Delta V = \frac{N_{ac}1 + N_{ac}2}{2} - \frac{R^{+}_{dc} + R^{-}_{dc}}{2} \qquad \textbf{(1)}$$

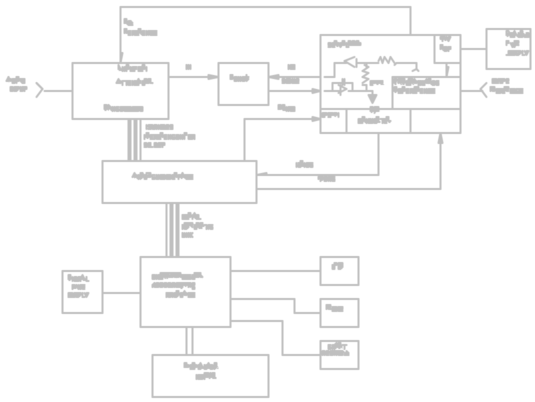


Figure 1.1: Block Diagram

When the unknown rms signal is applied to H1 and the proportional DC applied to H2, the servo circuit adds or subtracts the negative feedback from the DC applied to H2 to maintain the output of the DMJTC very close to zero. The negative feedback to maintain the null is scaled and fed to the A/D converter input. The output from the A/D converter goes to the microprocessor. The microprocessor waits for four complete readings and calculates Delta V as per Equation 1. The setting of the DC source is combined with _V and the microprocessor refreshes the variable DC supply with this value. This DC value is displayed as measured rms volts. The display is updated every 2 cycles after the first sequence of four measurements if the instrument is in 2 cycle update mode. It updates every 4 cycles if the instrument is in 4 cycle update mode.

The update rates are shown in Table 4.2.

2 SPECIFICATIONS

Specifications for Guildline Instruments 7130A Digital AC-DC Transfer Standard		
Operating Temperature	23 ± 5	°C
	70 ± 8	°F
Max. Relative Humidity	70% at 40°C(non-condensing)	R.H
Storage Temperature	0-50	°C
	32-122	°F
Storage Humidity	15-80	%R.H
Power Requirements	40	VA
Voltage Requirements	100,120,220,240 ± 10%	VAC
Line Frequency	50, 60	Hz
Dimensions	44.2 X 45.7 X 8.9 high	cm
	17.4 X 18 X 3.5 high	in
Weight	9	kg
	20	lbs

Table 2.1: Basic Instrument Specifications

Other features include:

- Bench top mounting or rack mount with extra flanges provided separately.
- Hidden Power selection switch on rear panel.
- GPIB Bus Address selectable from switches on rear panel.
- Front panel (local) or GPIB (remote) calibration.

All specifications apply between 33% and 120% of nominal range.

Table 2.2: AC/DC TRANSFER ACCURACY (90 Days) @ 23°C ±5°C Relative To Calibration Standards

Voltage Range	Limits of Error ± % Reading								
	DC	10Hz-30Hz	30Hz-1kHz	1kHz-10kHz	10kHz-20kHz	20kHz-50kHz	50kHz-100kHz	100kHz-400kHz	400kHz-1MHz
3 mV	0.361	0.022	0.0040	0.0050	0.0055	0.0065	0.0065	0.012	0.042
10 mV	0.112	0.022	0.0035	0.0040	0.0045	0.0045	0.0050	0.027	0.052
30 mV	0.039	0.021	0.0030	0.0040	0.0045	0.0055	0.0055	0.011	0.041
100 mV	0.015	0.021	0.0025	0.0030	0.0035	0.0035	0.0040	0.026	0.051
0.3 V	0.003	0.02	0.0020	0.003	0.0035	0.0045	0.0045	0.01	0.04
1 V	0.003	0.02	0.0015	0.002	0.0025	0.0025	0.003	0.025	0.05
3 V	0.0015	0.02	0.0015	0.002	0.0025	0.0025	0.003	0.025	0.05
10 V	0.0015	0.02	0.0015	0.002	0.002	0.0025	0.0035	0.03	0.05
30 V	0.0015	0.02	0.0015	0.002	0.002	0.0025	0.004	0.03	0.04**
100 V	0.0015	0.02	0.0015	0.002	0.0025	0.0035	0.004	0.05**	-
300 V	0.0020	0.02	0.0020	0.0025	0.003	0.0085	0.020**	-	-
1000 V	0.0035	0.02	0.0035	0.0130	0.060	-	-	-	-

** MAX. V ? Hz = 2×10^7

All Specifications apply between 33% and 120% of nominal range.

These uncertainties are relative to calibration standards and include stability, temperature coefficient and linearity.

NOTE: 1. Using internal DC reference add ±0.0005% of Reading to all values.
2. External DC reference must be +10 volts ±0.1% (standard cells with a suitable buffer may be used).

Table 2.3: Absolute AC/DC Transfer Accuracy (90 Days) @ 23°C ±5°C

Voltage Range	Limits of Error ± % Reading								
	DC	10Hz-30Hz	30Hz-1kHz	1kHz-10kHz	10kHz-20kHz	20kHz-50kHz	50kHz-100kHz	100kHz-400kHz	400kHz-1MHz
3 mV	0.363	0.242	0.165	0.165	0.166	0.167	0.197	0.262	0.54
10 mV	0.114	0.054	0.032	0.032	0.033	0.035	0.055	0.098	0.20
30 mV	0.041	0.049	0.018	0.019	0.019	0.026	0.051	0.077	0.17
100 mV	0.017	0.042	0.008	0.008	0.009	0.011	0.020	0.056	0.086
0.3 V	0.0042	0.04	0.0075	0.0085	0.008	0.015	0.02	0.06	0.100
1 V	0.0042	0.04	0.0035	0.004	0.0045	0.007	0.0085	0.037	0.096
3 V	0.0026	0.04	0.003	0.0035	0.004	0.007	0.0085	0.037	0.096
10 V	0.0026	0.04	0.004	0.0045	0.0045	0.007	0.009	0.043	0.099
30 V	0.0026	0.04	0.0035	0.004	0.004	0.007	0.0095	0.043	0.089**
100 V	0.0026	0.04	0.005	0.0055	0.006	0.0105	0.0115	0.064**	-
300 V	0.0031	0.04	0.005	0.006	0.006	0.0155	0.028**	-	-
1000 V	0.0046	0.04	0.008	0.0165	0.066	-	-	-	-

** MAX. V ? Hz = 2×10^7

All Specifications apply between 33% and 120% of nominal range.

This table lists absolute uncertainites when calibrated with Guildline's reference standards, which are traceable to National Standards.

NOTE: 1. Using internal DC reference add ±0.0005% of Reading to all values.
2. External DC reference must be +10 volts ±0.1% (standard cells with a suitable buffer may be used).

Table 2.4: AC/DC TRANSFER ACCURACY (1 Year) @ 23°C ±5°C Relative To Calibration Standards

Voltage Range	Limits of Error ± % Reading								
	DC	10Hz-30Hz	30Hz-1KHz	1KHz-10KHz	10KHz-20KHz	20KHz-50KHz	50KHz-100KHz	100KHz-400KHz	400KHz-1MHz
3 mV	0.365	0.025	0.0072	0.0082	0.0087	0.0097	0.0097	0.015	0.045
10 mV	0.115	0.025	0.0066	0.0072	0.0077	0.0077	0.0082	0.030	0.055
30 mV	0.041	0.023	0.0052	0.0062	0.0067	0.0077	0.0077	0.013	0.043
100 mV	0.017	0.023	0.0046	0.0052	0.0057	0.0057	0.0062	0.028	0.053
0.3 V	0.0042	0.021	0.0032	0.0042	0.0047	0.0057	0.0057	0.011	0.041
1 V	0.0042	0.021	0.0026	0.0032	0.0037	0.0037	0.0042	0.026	0.051
3 V	0.0026	0.021	0.0026	0.0032	0.0037	0.0037	0.0042	0.026	0.051
10 V	0.0026	0.021	0.0026	0.0032	0.0032	0.0037	0.0047	0.031	0.051
30 V	0.0026	0.021	0.0026	0.0032	0.0032	0.0037	0.0052	0.031	0.041**
100 V	0.0026	0.021	0.0026	0.0032	0.0037	0.0047	0.0052	0.051**	-
300 V	0.0055	0.024	0.0055	0.006	0.0065	0.012	0.024**	-	-
1000 V	0.0075	0.024	0.007	0.017	0.064	-	-	-	-

** MAX. V ? Hz = 2×10^7

All Specifications apply between 33% and 120% of nominal range.

These uncertainties are relative to calibration standards and include stability, temperature coefficient and linearity.

NOTE: 1. Using internal DC reference add ±0.0005% of Reading to all values.
2. External DC reference must be +10 volts ±0.1% (standard cells with a suitable buffer may be used).

Table 2.5: Absolute AC/DC Transfer Accuracy (1 Year) @ 23°C ±5°C

Voltage Range	Limits of Error ± % Reading								
	DC	10Hz-30Hz	30Hz-1KHz	1KHz-10KHz	10KHz-20KHz	20KHz-50KHz	50KHz-100KHz	100KHz-400KHz	400KHz-1MHz
3 mV	0.367	0.245	0.168	0.169	0.169	0.170	0.200	0.265	0.550
10 mV	0.117	0.058	0.035	0.036	0.036	0.038	0.059	0.10	0.210
30 mV	0.043	0.052	0.020	0.021	0.021	0.028	0.053	0.079	0.173
100 mV	0.019	0.044	0.010	0.011	0.011	0.013	0.022	0.060	0.090
0.3 V	0.0054	0.041	0.0087	0.0097	0.0092	0.0162	0.0212	0.061	0.101
1 V	0.0054	0.041	0.0046	0.0052	0.0057	0.0082	0.0097	0.038	0.097
3 V	0.0037	0.041	0.0041	0.0047	0.0052	0.0082	0.0097	0.038	0.097
10 V	0.0037	0.041	0.0051	0.0057	0.0057	0.0082	0.0102	0.044	0.100
30 V	0.0037	0.041	0.0046	0.0052	0.0052	0.0082	0.0102	0.044	0.09**
100 V	0.0037	0.041	0.0061	0.0067	0.0072	0.0117	0.0127	0.065**	-
300 V	0.0066	0.044	0.0085	0.0095	0.0095	0.019	0.032**	-	-
1000 V	0.0086	0.044	0.0115	0.0205	0.070	-	-	-	-

** MAX. V ? Hz = 2 x 10^7

All Specifications apply between 33% and 120% of nominal range.

This table lists absolute uncertainties when calibrated with Guildline's reference standards, which are traceable to National Standards.

NOTE: 1. Using internal DC reference add ±0.0005% of Reading to all values.
2. External DC reference must be +10 volts ±0.1% (standard cells with a suitable buffer may be used).

3 OPERATING INSTRUCTIONS

3.1 INSTALLATION

Place the Digital AC/DC Transfer Standard on a solid bench. Where the Digital AC/DC Transfer Standard is to be used in a rack, attach the mounting brackets provided. "To attach the rackmounting flanges (brackets), the original screws holding the handles to the instrument are removed and the flanges attached over the handles with the longer screws supplied. The instrument has to be supported in the rack/cabinet with adjustable support angles or a support bar. In case of interference with other equipment mounted directly below the instrument, the 4 feet must be removed. This requires that the bottom skin of the instrument is lowered to get access to the nuts which hold the feet." Install the unit in the rack.

Check the voltage selector (see section 3.7) on the back of the cabinet for correct voltage. Connect the line cord to an electrical outlet. Disconnect all cables from the input connector. Press POWER push button and observe that the display runs through a self test pattern then ranges down from 1000 V range to 3 mV range and then goes to standby.

3.2 FRONT PANEL LOCKOUT

A facility known as FRONT PANEL LOCKOUT is not apparent from the front panel legends. Under the control of an external command applied via the IEEE-488 or RS-232C interfaces, the action of all the front panel membrane switch controls can be inhibited. This command signal even disables LOCAL and can be used to prevent unauthorized use of the 7130A when it is committed within a system.

The 7130A has two forms of FRONT PANEL LOCKOUT. In the first form all programmable controls, except the LOCAL key, are disabled. This is known as PARTIAL FRONT PANEL LOCKOUT. In the second form all programmable controls, including the LOCAL key, are disabled. This is known as FULL FRONT PANEL LOCKOUT. See section 5.5 for more details.

3.3 FRONT PANEL CONTROLS

All the front panel controls are of the membrane switch type with the exception of the POWER ON/OFF and FRONT/REAR switches. Incorporated in some of the membrane switches is an LED as a status indicator; all the membrane switches are programmable via the IEEE-488 and RS-232C interfaces. Some of the switches have multiple functions working in a shift key mode in Sofcal.

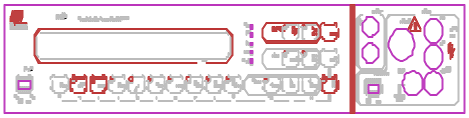
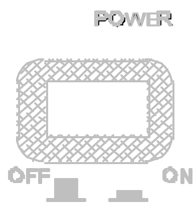


Figure 3.1: Typical Front Panel

3.3.1 POWER ON/OFF



This alternate action push button (Push on - push off) applies AC line power to the instrument. This control is not programmable from the remote interfaces.

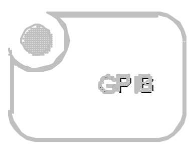
3.3.2 LOCAL

This key will deselect either the GPIB or RS-232C talk/only modes if either are selected, or if the remote controller has locked out the local keyboard then the local key may return control to the keyboard.

In Sofcal mode this key selects the numeral "0" or the EXIT menu item.

NOTE: Local control of the instrument cannot be restored with this key if the remote controller has locked out the entire keyboard (See section 3.2).

3.3.3 GPIB

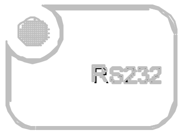


This key performs several functions on the 7130A.

If the 7130A is configured such that the IEEE-488 bus is in Talk/Only mode then, the instrument will output measurement results to a remote device. Depressing the key will enable the Talk/Only mode, the Talk/Only mode may be disabled by depressing the LOCAL key (See section 3.3.2).

In Sofcal mode this key selects the numeral "1" or the first menu item.

3.3.4 RS-232C



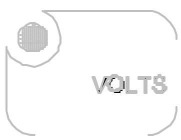
This key/LED indicator combination performs several functions on the 7130A.

If the 7130A is configured as part of a test and measurement system with a remote controller, then the LED indicator in this key is used to indicate that a remote RS-232C controller is in charge of the instrument.

If the 7130A is configured such that the RS-232C interface is in Talk/Only mode then, when the LED indicator is lit this indicates that the instrument will output measurement results to a remote device (such as a printer). Depressing the key will enable the Talk/Only mode. The Talk/Only mode may be disabled by depressing the LOCAL key (See section 3.3.2).

In Sofcal mode this key selects the numeral "2" or the second menu item.

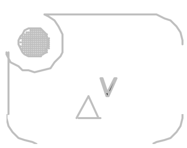
3.3.5 VOLTS



When the 7130A is powered on, the default display mode is the VOLTS display mode. It is possible to select display modes other than the VOLTS display mode (such as PPM mode or _V mode, see sections 3.3.7 and 3.3.6), depressing this will return the instrument to the VOLTS mode.

In Sofcal mode this key selects the numeral "3" or the third menu item.

3.3.6 _V



When the 7130A is powered on, the default display mode is the VOLTS display mode. It is possible to select display modes other that the VOLTS display mode, depressing this key will select the _V display mode.

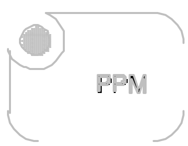
The _V display uses the measurement voltage (obtained at the time the _V key was depressed) as a reference voltage, and subtracts this voltage from all subsequent measurements and displays the _ voltage, or change, instead of the actual voltage. This display mode is useful for monitoring the drift of a precision supply. The LED indicator integral to the key switch will be lit to indicate that the _V display mode has been selected.

If the difference between the input voltage and the reference voltage exceeds 0.1% of the nominal full scale voltage the display will show:

OVER _V

In Sofcal mode this key selects the numeral "4" or the fourth menu item.

3.3.7 PPM



When the 7130A is powered on, the default display mode is the VOLTS display mode. It is possible to select display modes other that the VOLTS display mode, depressing this key will select the PPM display mode.

The PPM display mode uses the measurement voltage (obtained at the time the PPM key was depressed) as a reference voltage, and subtracts this voltage from all subsequent measurements and displays the change in voltage, in parts per million of the reference voltage, instead of the actual voltage (See also section 3.3.6). This display mode is useful for monitoring the drift of a precision supply.

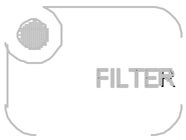
The LED indicator integral to the key switch will be lit to indicate that the PPM display mode has been selected.

If the difference between the input voltage and the reference voltage exceeds 1000 ppm the display will show:

OVER PPM

In Sofcal mode this key selects the numeral "5" or the fifth menu item.

3.3.8 FILTER



This key is an alternate action switch which will enable a software low pass digital filter (when the LED is lit), or disable the low pass digital filter (when the LED is extinguished). Each time the key is depressed the enabled/disabled status of the Filter will change.

The time roll-off frequency and the slope of the roll-off of the digital filter depends upon the filter factor and filter type selected (see section 4.6). When the filter is OFF (LED extinguished) normal integration is selected.

In Sofcal mode this key selects the numeral "6" or the sixth menu item.

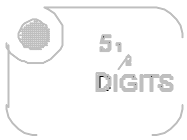
3.3.9 4½ DIGITS

When the 7130A is powered on, the default display mode is the 6½ digit display mode. It is possible to select display modes other than the 6½ digit display mode, (such as 5½ and 4½ digit display mode) depressing the 4½ key will select the 4½ digit display mode.

This display mode is useful when the full accuracy of the 7130A is not required (such as when a check of a power supply is desired). The LED indicator integral to the key switch will be lit to indicate that the 4½ digit display mode has been selected.

In Sofcal mode this key selects the numeral "7" or the seventh menu item.

3.3.10 5½ DIGITS

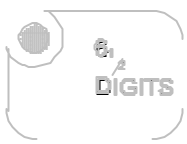


When the 7130A is powered on, the default display mode is the 6½ digit display mode. It is possible to select display modes other than the 6½ display mode, (such as 5½ and 4½ digit display mode) depressing the 5½ key will select the 5½ digit display mode.

This display mode is useful when the full accuracy of the 7130A is not required (such as when a check of a power supply is desired). The LED indicator integral to the key switch will be lit to indicate that the 5½ display mode has been selected.

In Sofcal mode this key selects the numeral "8" or the eighth menu item.

3.3.11 6½ DIGITS

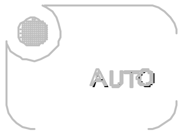


When the 7130A is powered on, the default display mode is the 6½ digit display mode. It is possible to select display modes other that the 6½ digit display mode, (such as 5½ and 4½ digit display mode) depressing the 6½ digit key will select the 6½ digit display mode.

This display mode is useful when the full accuracy of the 7130A is required (such as when an accurate check of a precision power supply is desired). The LED indicator integral to the key switch will be lit to indicate that the 6½ digit display mode has been selected.

In Sofcal mode this key selects the numeral "9" or the ninth menu item.

3.3.12 AUTO



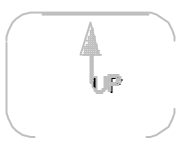
Depressing this key will alternately enable (LED lit) or disable (LED extinguished) the AUTORANGING function of the instrument. When the autoranging mode is selected (LED lit) the instrument will automatically select the appropriate range for the measurement of voltage.

When the autoranging mode is disabled (LED extinguished) the instrument will not automatically change ranges to the appropriate range for a given input voltage.

The autoranging mode of the instrument will be disabled if the operator manualy changes the measurement range (see sections 3.3.13 and 3.3.14).

In Sofcal mode this key "DEL" is used to delete the current (flashing) character.

3.3.13 - UP



This key is used to select the next larger measurement range, for example if the current measurement range is the 10 volt range depressing the -UP key will cause the 30 volt range to become the current measurement range.

Depressing the -UP key will disable the autoranging feature of the instrument (see section 3.3.12). If the current measurement range is the 1000 volt range depressing the -UP key will have no effect on the selected measurement range (however autoranging will be disabled).

In Sofcal mode, depressing this key will step through the available menu items, or if Sofcal numeric entry mode is selected depressing this key will enter a decimal point ".".

3.3.14 ? DOWN

This key is used to select the next lower measurement range, for example if the current measurement range is the 30 volt range depressing the ?DOWN key will cause the 10 volt range to become the current measurement range.

Depressing the ?DOWN key will disable the autoranging feature of the instrument (see section 3.3.12). If the current measurement range is the 300 millivolt range, depressing the ?DOWN key will have no effect on the selected measurement range (however autoranging will be disabled).

In Sofcal mode, depressing this key will step through the available menu items, or if the Sofcal-numeric entry mode is selected depressing this key will change the sign of the number being entered "±".

3.3.15 SOFT CAL

This key alternately selects (LED lit) or deselects (LED extinguished) the Sofcal mode of operation refer to Section 4 for complete explanation of all the sofcal functions, levels and subsets.

NOTE: When the Sofcal mode of operation is selected (and the LED is lit) the normal functions of the keyboard keys are disabled and the special Sofcal keyboard mode is enabled. When Sofcal is enabled depressing the SOFT CAL key will return the 7130A to its normal operating mode (LED extinguished).

3.3.16 STANDBY

The STANDBY key allows the instrument to be safely connected to an unknown voltage source, and then measured. This key is an alternate action key which when depressed will either put the instrument into standby mode (LED lit) or measurement mode (LED extinguished).

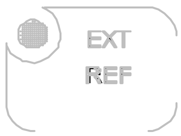
If the instrument is in measurement mode (LED extinguished), depressing this key will place the instrument into standby mode (LED lit), when the instrument is in standby mode, it is safe for the instrument operator to connect or disconnect the input lead from the voltage source, since the measurement circuitry of the instrument is effectively disconnected.

If the instrument is in standby mode (LED lit), depressing this key will connect the internal measurement circuitry to the voltage source. If the autoranging mode is enabled (see section 3.3.12) the instrument will try the 1000 volt measurement range first, then subsequently lower measurement modes until the appropriate range for measuring the unknown input voltage is found. If the 7130A is not in the autoranging mode (LED extinguished), then the range most recently used will be selected.

CAUTION

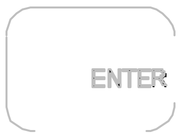
The input circuitry of the 7130A may be damaged when the instruments operating mode is changed from the standby mode to the measurement mode if the input voltage is substantially greater than the previously measured voltage and the autoranging mode has been disabled by the operator.

3.3.17 EXT REF



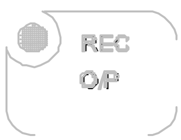
Selects an externally connected 10 V reference (LED lit). If there is no signal connected to the (REF), the 7130A will not operate correctly.

3.3.18 ENTER



The ENTER key is used only in the Sofcal mode of operation (See section 4).

3.3.19 REC O/P



Switches the analogue recorder output on (LED lit).

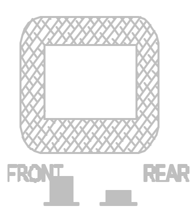
3.3.20 REC CAL

Selects fixed analogue output signals, (0 V, +5 V, -5 V, +10 V, and -10 V) to enable calibration of chart recorders or verify zero at any time during a recording.

3.3.21 RESET

Reinitializes the microprocessor and simulates a power up sequence.

3.3.22 FRONT REAR



Selects the front or rear inputs.

3.3.23 120 V MAX INPUT

This input is to be used when measuring input signals less than 120 V. If the input signal exceeds 120 V the 7130A will enter STANDBY mode and disconnect this input connector from the analogue circuitry. When the 120 V MAX INPUT rear input connector is used and the Front/Rear Switch is depressed, the signal at the rear connector also appears at the 120 V MAX INPUT front panel connector.

3.3.24 1200 V MAX INPUT HI/LO

Signals between 100 V and 1200 V can be measured at these input terminals (Hi, Lo). If the input signal between the HI and LO terminals exceeds 1200 V the 7130A will enter STANDBY mode and disconnect the HI input terminal from the analogue circuitry. When using the rear 1200 V MAX INPUT HI, LO terminals with the FRONT/REAR switch depressed, the front panel 1200 V max HI terminal is disconnected from all active circuitry.

3.3.25 GUARD

This terminal when used with the GND terminal provides for single ground point configurations while using a grounded source. The GUARD terminal is connected to the analogue shielding network and is not connected to digital or chassis ground. The recommended guarding technique is to connect GUARD to the LO input terminal on the front panel.

The GUARD input should never be left disconnected from either LO or GND input terminals unless it is being driven by an active GUARD signal generated by the signal source. The GUARD/GND connection is not a recommended configuration since this defeats the effect of the power line guarding and isolation circuitry. However, the GUARD/GND terminals can be connected when using the 7130A to measure power line frequency signals.

3.3.26 GND

This terminal when used with the GUARD terminal provides for single ground point configurations while using a grounded signal source. This terminal is connected to the power line input safety ground, chassis and digital ground.

3.3.27 EXT REF

Two binding posts are provided for use when an external 10 VDC reference is to be used in place of the internal 10 VDC reference. When the EXT REF option is enabled (pressing switch EXT REF a 10 VDC (±1000 ppm) source must be connected to the REF terminals.

3.4STATUS INDICATORS

There are five LED's to the right of the display. TALK, SRQ, LISTEN and REMOTE are GPIB/IEEE-488 status indicators while

BUSY indicates that the instrument is taking a reading.

3.5REAR PANEL CONTROLS

3.5.1 EIGHT POSITION DIP SWITCH

Switches 1 to 5 allow an IEEE-488 address between 0 and 31 to be selected. Switch 6 selects talk only or talk/listen mode. Switch 7 selects interface enable/disable and switch 8 selects audible annunciator on/off.

3.5.2 REAR INPUTS

See sections 3.3.23 and 3.3.24

3.5.3 EXT REF

See section 3.3.27

3.5.4 RECORDER OUT

An analogue output voltage proportional to the last three digits of the displayed voltage, which can be connected to chart recorders.

3.5.5 GPIB INTERFACE (IEEE-488)

This connector is used for connecting the instrument to other devices/controllers on a General Purpose Interface Bus (GPIB) IEEE-488 STD (1978 Revision).

3.5.6 RS-232C INTERFACE

Connects to other devices/controllers configured to operate via the RS-232CC interface.

3.5.7 POWER RECEPTACLE

Selects line voltage of 100, 120, 230 or 240 V and accepts a standard three wire moulded line cord. The receptacle also has a built in line filter.

3.5.8 NORMAL/CAL KEY SWITCH

Selects normal mode or sofcal calibration mode. In the NORMAL mode of operation the instrument will display a corrected input voltage (from the A/D conversion process). In the CAL mode of operation the instrument will display the input voltage directly without performing any compensation. The CAL mode of operation also allows for the modification of the entered compensation coefficients (See section 4.7).

3.6CONTROLS SUMMARY

Control	Function	Alpha Numeric Character
POWER	Line on/off	
LOCAL	Return to local	0
GPIB	Enable GPIB Talk/Only	1
RS-232C	Enable Talk/Only	2
VOLTS	Display Volts	3
_V	Deviation in Volts	4
PPM	Deviation in PPM	5
FILTER	Filter on/off	6
4½	4½ Digit Resolution	7
5½	5½ Digit Resolution	8
6½	6½ Digit Resolution	9
SOFCAL	Sofcal on/off	
AUTO	Autorange on/off	DEL
- UP	Manual up range	.
? DOWN	Manual Down range	±
STANDBY	Standby on/off	
EXT REF	External DC Ref	
ENTER		Enter
REC O/P	Recorder Output	
REC CAL	Recorder Calibrate	
RESET	Reinitialize	
FRONT REAR	Front/Rear Input Switch	
KEY SWITCH	Normal/Cal Switch	

Table 3.1: Controls Summary

3.7 PRELIMINARIES

3.7.1 VOLTAGE SELECTION DRUM

This drum allows the 7130A operator to select the input voltage of the instrument from one of 100, 120, 220 or 240 volts. It is important that the correct input voltage be selected before any attempt is made to operate the instrument. To change the selected input voltage, after removing the line cord from the receptacle, pry open the power receptacle as shown in Figure 3.2.

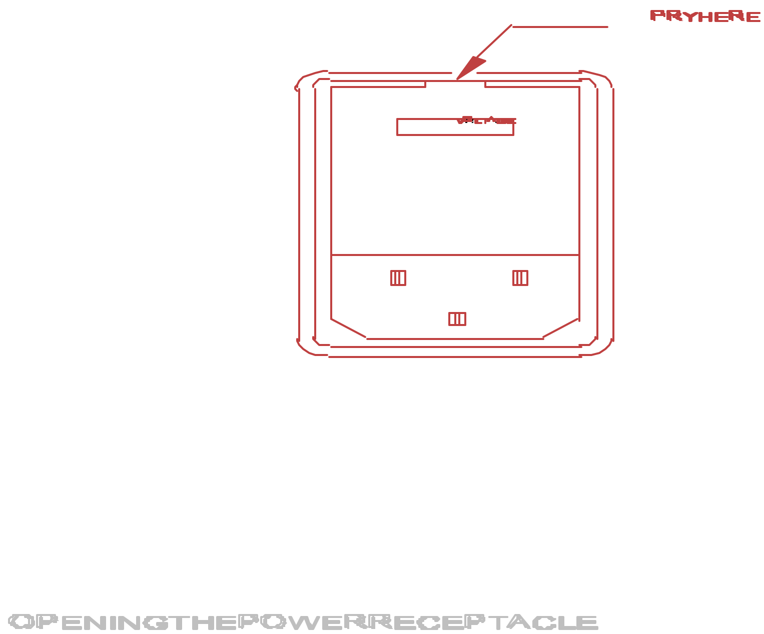


Figure 3.2: Opening the Power Receptacle

Check to see that the fuses inserted in the receptacle correspond to the type specified in Table 3.2. Only fuses of the specified type should be used.

Line Voltage	Fuse Type Required
100 Volts 120 Volts	0.5 Amp Slo-Blo (MDL-½ A 250 V)
220 Volts 240 Volts	0.25 A Slo-Blo (MDL-¼ A 250 V)

Table 3.2: Recommended Fuses

In order to rotate the drum it must be removed completely from the receptacle. Set the voltage selector drum so that the proper line voltage indication will be visible through the receptacle window when the cover is closed.

Where the supplied line cord does not match the power outlet receptacle, the plug may be removed from the line cord and replaced with a grounded plug of the correct type. The plug should be wired as shown in Table 3.3.

Cord Wire Colour	Potential Voltage
Brown	High Voltage
Blue	Neutral
Green/Yellow	Ground (Earth)

Table 3.3: Line Cord Wiring

The supplied moulded line cord should be plugged into the 3 pin power receptacle on the left hand side rear of the instrument. Ensure that the other end of the cord is plugged into a wall socket provided with a protective ground for safe operation of the instrument; this also applies to the use of an extension cable. Where 3-contact supply outlets are not available a suitable protective ground connection must be made before switching the instrument on.

Any interruption of the protective ground may possibly render the instrument unsafe.

3.8 PRECAUTIONS

The instrument should be disconnected from the line supply before any attempt is made to remove the cover.

Make sure that the voltage to be measured is applied to the appropriate input connector. The low voltage input has a 120 V maximum and the high voltage input has a 1200 V maximum.

3.9 OPERATING PROCEDURES

The following procedures describe how to use the 7130A Digital AC-DC Transfer Standard. To turn on the instrument press in the white button at the far left of the front panel marked POWER. The instrument will beep, all segments of the display will be illuminated and all the LED annunciators will be lit. Then each 14 segment character will be illuminated in sequence from left to right. The instrument will then automatically range down from
1000 V.

If there is an input voltage the 7130A will find the appropriate range and display the readings in volts and the frequency of the signal. If there is no input voltage the instrument, after down ranging to 3 mV, will go to `STANDBY' mode.

During the initial power up the instrument runs a self test program and is configured into the following state:

- Autoranging is enabled (see section 3.3.12).
- Voltage display mode is selected (see section 3.3.5).
- 6½ display digits (see section 3.3.11).

3.10 MEASUREMENT OF VOLTAGE

Switch the instrument 'ON'.

Apply the unknown AC or DC volts to the appropriate low or high voltage input of the instrument. Check that the input is connected to the front or rear connector as per the position of the FRONT REAR selector switch. If using the low voltage connector, it is strongly recommended that a shorting bar (provided in accessories kit) be used on the high voltage input.

The instrument will automatically down range to the optimum range and will display the 3 most significant digits of the AC or DC signal applied. For example if a 0.999 999 volt at 1 kHz signal is applied the display will indicate:

- After about 4-5 seconds delay the busy LED will go dark and the display will be updated as follows:

- The display will update every 2 or 4 cycles dependent on the update mode selected. See Sofcal section 4 to select or change update rate.
- If the readings displayed are noisy due to external interference the digital filter can be selected to increase the measurement time and stabilize the readings. The filter can be adjusted between 3 and 20 readings by means of a filter factor. To select or change the filter factor refer to section 4.6 for details.

3.11 MEASUREMENT OF VOLTAGE DEVIATION

When _V or PPM is selected the 7130A will display the deviation between the input signal and the last measurement made in the volts mode. It can be displayed as either voltage difference in volts (_V mode) or in parts per million (PPM mode) depending on which mode has been selected. The deviation mode is particularly useful for measuring the drift in AC or DC sources. A typical display will be as follows:

If the input signal deviates by more than 1000 ppm (0.1%) of nominal full scale voltage the display will show "OVER PPM" or "OVER _V".

In order to monitor a signal that is drifting, it may be convenient to use the analogue recording facilities of the 7130A in conjunction with the _V and PPM modes. Refer to

Analogue Recording in section 3.12.

3.12 ANALOGUE RECORDING

To record deviations of an AC or DC signal on a chart recorder, connect a suitable recorder to the outputs on the rear of the 7130A making sure the instrument is in the volts mode and the recorder output is on. This is the default condition on power up and there is no output at the recorder terminals in the volts mode; an analogue output signal is only present in the _V or PPM modes. Before proceeding, the chart recorder will need to be calibrated and this can be achieved using the 7130A's built-in recorder calibration facilities.

Recorder Calibration is performed as follows:

1. With the 7130A switched on and in the volts mode with REC O/P (Recorder Output) LED lit there will be no output at the recorder output terminals. This would normally be the status of the instrument straight after power up.

2. Press REC O/P once.

3. Observe that the REC CAL (Recorder Calibration) LED is illuminated and REC O/P LED is extinguished. There is now a 0 V calibration signal being output which is confirmed on the display of the 7130A.

4. Adjust the chart recorder zero (or datum) to the required position on the paper.

5. Press REC CAL once and a +5 V signal is output and confirmed in the display. If the chart recorder in use has linearity controls adjust for ½ full scale positive deflection. If there are no linearity controls go to step 6.

6. Press REC CAL once again and a +10 V signal is output and confirmed in the display. Adjust the chart recorder for positive full scale deflection on the recorder paper.

7. Press REC CAL again and the +5 V signal is repeated and linearity can again be checked.

8. Press REC CAL again and the 0 V signal is repeated. Recheck the chart recorder datum.

9. Press REC CAL 3 more times and -5 V, -10 V and -5 V signals will be output for adjusting the chart recorder for negative deflections.

10. Pressing REC CAL a final time returns the recorder output

to 0 V and the datum can be checked again.

11. Press REC O/P.
12. Observe that the REC O/P LED is illuminated and REC CAL has been extinguished. The 7130A is now ready to output analogue signals proportional to the deviations displayed in either the _V or PPM modes of measurement.

13. Select either _V or PPM and begin recording.

The effective resolution of the analogue output on the various ranges of measurement of the 7130A are as follows:

- _V Mode

Measurement Range	Full Scale Deflection	Sensitivity
3 mV	±10 V	±1 µV
10 mV and 30 mV	"	±10 µV
100 mV	"	±100 µV
300 mV	"	±100 µV
1 V and 3 V	"	±1 mV
10 V and 30 V	"	±10 mV
100 V and 300 V	"	±100 mV
1000 V	"	±1 V

- PPM Mode

The recorder output of ±10 V fsc is equivalent to ±1000 ppm i.e. 10 mV of analogue output is equivalent to 1 ppm displayed.

3.13 EXTERNAL DC REFERENCE

Although the internal reference of the 7130A is extremely stable (<5 ppm per year), it may be replaced by the use of a very high stability known 10 volt DC to improve measurement performance. Such an external reference should be connected to the EXT REF terminals and the EXT REF mode selected (press EXT REF key).

An external reference must be within ±0.1% of 10 volts.

Software correction is provided which will permit a deviation from 10 V to be entered as a correction. (See section 4.)

4 SOFCAL

SOFCAL is proprietary firmware developed by Guildline and provides the onboard intelligence built into the 7130A. The selection of available functions are accessed by descending through layers until the desired function is reached. The uppermost layer contains the selections shown in Table 4.1.

In order to access any of the SOFCAL layers first depress the key marked SOFT CAL, followed by the number of desired layer key
followed by ENTER. For example to setup the RS-232C interface first depress the key marked SOFT CAL, then depress the key marked "2" then the key marked ENTER.

Since it is often inconvenient to have the manual present when changing one of the instrument operating parameters (such as the RS-232C interface baud rate) the 7130A will prompt the operator with all of the possible selections on a given layer if the -UP or ?DOWN keys are depressed repeatedly, when the desired layer is displayed the operator can depress the ENTER key to select the desired layer. It should also be noted that there will be a SETUP EXIT prompt available, when the ENTER key is depressed the 7130A will return to the previous level.

Depressing the SOFT CAL key a second time will cause the 7130A to return to it's normal operating mode, and the LED in the SOFT CAL key will be extinguished. The SOFT CAL key can be used to exit from SOFCAL mode at any time.

When a SOFCAL numeric parameter is to be changed the step by step
procedures below always show the -UP and ?DOWN keys being used to select the value of the numeric parameter. It is possible to enter the direct numeric entry mode when changing numeric parameters, in this mode the numeric keys, the decimal point key and the "±" key are all active. In order to enter direct numeric entry mode simply depress one of the numeric keys (0-9), the displayed number will be cleared and the first digit of the number will be displayed, followed by an underscore cursor. Continue to depress digit keys (as well as the decimal point key and the "±" key) until the desired number is displayed, then press ENTER.

Key	Display	Description
1	SETUP GPIB	This menu layer allows the user to examine and verify the GPIB interface address and mode settings which have been setup using rear panel DIP Switch (See Section 3.5.1).
2	SETUP RS-232C	This menu layer allows the user to examine and change the RS-232C interface parameters such as 'Baud Rate', 'Parity', and 'Stop Bits'.
3	SETUP SELF-TESTS	This menu layer allows the technician to diagnose problems with the analogue measurement module.
4	SETUP PRINTER	When a printer is connected to either the GPIB interface or the RS-232C interface (and the interface is configured as Talk/Only) each measurement can be recorded, the data to be logged can be selected, in addition the quality of data to be logged can be selected.
5	SETUP UPDATE	The 7130A has several different measurement update modes, this menu layer allows selection of

4.1 SOFCAL SETUP GPIB

This menu layer allows the user to examine and verify the GPIB interface address and mode settings which were setup using the rear panel DIP switch (See section 3.5.1).

1. Depress the SOFT CAL key. The LED in the SOFT CAL key will become lit, and the display will show SETUP GPIB with the word GPIB flashing.

2. Depress the ENTER key. The display will show the currently selected GPIB address. Changing the DIP switches which select the GPIB address on the rear panel will cause the displayed address to change. Note: the GPIB address to which the 7130A will respond to will not be changed until after the instrument has been reset (See section 3.3.21).

3. Depress the ENTER key. The display will show the currently selected operational mode for the GPIB interface. Changing the DIP switches on the rear panel which affect the operational mode will cause the displayed mode to change. This is useful for setting the GPIB mode. Note: the GPIB operating mode will not be changed until after the instrument has been reset (See section 3.3.21).

4. Depress the ENTER key. The display will return to the display SETUP GPIB with the word GPIB flashing.

5. Depress the SOFT CAL key. The 7130A will return to its normal operating mode.

4.2 SOFCAL SETUP RS-232C

This menu layer allows the user to examine and change the RS-232C interface parameters such as Baud Rate, Parity, and Stop Bits. The following step by step procedure illustrates how to set up the RS-232C interface from the front panel. The meanings of the various parameters which can be configured are discussed in the following sections.

1. Depress the SOFT CAL key. The LED in the SOFT CAL key will become lit, and the display will show SETUP GPIB with the word GPIB flashing.

2. Depress the 2 key. The display will show SETUP RS-232C with the word RS-232C flashing.

3. Depress the ENTER key. The display will show the currently selected baud rate, with the current rate

flashing.

4. Depress the -UP key to select a higher baud rate or the ?DOWN key to select a lower baud rate, continue to depress the -UP and ?DOWN keys until the desired baud rate is displayed.

5. Depress the ENTER key to select the baud rate shown. The 7130A will now display the current RS-232C interface parity selection.

6. Depress the -UP or the ?DOWN key to select an alternate parity choice, continue to depress the -UP and ?DOWN keys until the desired parity is displayed. Available choices are none, odd, and even.

7. Depress the ENTER key to select the parity displayed. The 7130A will now display the current RS-232C interface stop bits selection.

8. Depress the -UP or the ?DOWN key to select an alternate stop bit choice, continue to depress the -UP and ?DOWN keys until the desired number of stop bits are displayed. Available choices are 1, 1.5, and 2.

9. Depress the ENTER key to select the stop bits displayed. The 7130A will now display the current RS-232C interface data bits selection.

10. Depress the -UP or the ?DOWN key to select an alternate data bit choice, continue to depress the -UP and ?DOWN keys until the desired number of data bits are displayed. Available choices are 7, and 8.

11. Depress the ENTER key to select the data bits displayed. The 7130A will now display the current RS-232C interface echo mode selection.

12. Depress the -UP or the ?DOWN key to select an alternate echo mode choice, continue to depress the -UP and ?DOWN keys until the desired echo mode is displayed. Available choices are ON, and OFF.

13. Depress the ENTER key to select the echo mode displayed. The 7130A will now display the current RS-232C interface flow control mode selection.

14. Depress the -UP or the ?DOWN key to select an alternate flow control mode choice, continue to depress the -UP and ?DOWN keys until the desired flow control mode is displayed. Available choices are NONE, RTC/CTS, and XON/XOFF.

15. Depress the ENTER key to select the flow control mode displayed. The 7130A will now display the current RS-232C interface operation mode.

16. Depress the -UP or the ?DOWN key to select an alternate interface operational mode choice, continue to depress the -UP and ?DOWN keys until the desired interface operational mode is displayed. Available choices are TALK/ONLY, and TALK/LISTEN.

17. Depress the ENTER key to select the interface operational mode displayed. The display will return to the display SETUP RS-232C with the word RS-232C flashing.

18. Depress the SOFT CAL key. The 7130A will return to its normal operating mode.

NOTE: The RS-232C parameters will not be changed until after the instrument has been reset (See section 3.3.21).

4.2.1 Baud Rate

The baud rate on an RS-232C interface determines the time that will be taken to transmit each bit of information. Common baud rates are 300, 1200, and 9600 baud. The 7130A has a wide range of available baud rates which can be used. The higher baud rates allow information to be passed between the controller and the instrument more quickly, however the higher baud rates require faster processing and hence are not always an advantage. For the 7130A a baud rate of 1200 is satisfactory to move all information to and from the instrument with no delays, this is due to the fact that the 7130A only performs 1 reading every 2 seconds at its fastest.

4.2.2 PARITY

The parity bit in a serial communications data byte is used as a quick check of the correctness of the data transmitted. The parity is computed by adding up the bits in the data byte and appending one final bit which makes the total number of 1 bits either even (as in EVEN parity) or odd. The 7130A does not check the parity of incoming data, however any data transmitted to the remote controller should have the correct parity since many controllers require the correct parity otherwise data will not be accepted. The parity feature can be disabled by selecting a parity setting of NONE.

4.2.3 STOP BITS

In an asynchronous communications system (ie. RS-232C) there is a variable delay between each character transmitted, the minimum delay between each byte is set by the number of stop bits. If no data is being transmitted this is equivalent to sending more stop bits (often hundreds or thousands of stop bits are sent). Usually 1 stop bit is sufficient to separate transmitted characters but some devices require more than 1 stop bit therefore the 7130A allows the choice of 1, 1.5, or 2 stop bits.

4.2.4 DATA BITS

The entire ASCII character set can be represented with 7 data bits, but some controllers require the eighth data bit to be sent. The 7130A will ingore the eigth bit on any received data, and will always transmit a zero for bit 8 if 8 bit data mode has been selected. Normally 7 bits of data are all that are required.

4.2.5 ECHO

If the 7130A is used with a dumb terminal, or if the controller wishes to confirm that data sent was received correctly the 7130A can be programmed to echo back any received data. The echo can be turned on or off.

4.2.6 FLOW CONTROL

When data is being sent to or from a controller there may be times when the controller is not prepared to receive data, during these times the controller signals to the 7130A that it is not able to receive data, and that data should not be transmitted. There are several common methods of controlling the flow of data (flow control). The most desirable method is to not use flow control (NONE), this allows the smoothest flow of data possible. When flow control is required the 7130A recognizes two methods of restricting the flow of data, hardware handshaking, and software flow control.

The hardware handshaking technique (RTS/CTS) uses the RS-232C control lines, request to send (RTS) is set true by the controller when the controller is requesting permission to send data to the 7130A, the 7130A will activate the clear to send (CTS) signal to indicate that data may be sent from the controller to the 7130A. To control the flow of data from the 7130A to the controller, the controller must activate the data terminal ready (DTR) signal line to indicate that the controller is ready to receive data.

The software flow control technique uses two characters from the ASCII character set to halt the data flow, and to re-enable the data flow. These two characters are normally named XON and XOFF (transmitter (X) on and transmitter (X) off). The two characters which the 7130A will accept and send are -S (ASCII Device Control 3 (DC3)) to stop transmission, and -Q (ASCII Device Control 1 (DC1)) to enable transmission.

4.2.7 MODE

The 7130A provides for two modes of operation on the RS-232C interface, Talk/Only and Talk/Listen. The Talk/Only mode is used for devices (such as printers) which will only log data sent to them. The Talk/Listen mode is used for devices (such as computers) which will send commands to the 7130A and expect replies from the 7130A.

4.3 SOFCAL SETUP SELF-TESTS

This menu layer allows a technician to diagnose problems with the analogue measurement module.

These self tests are invaluable in allowing a qualified technician to trouble shoot and partially calibrate the analogue module.

4.3.1 FIBRE LINK TEST

This test continuously cycles through 8 different bit patterns to see if the full duplex serial link is running and this results in one of two messages:

1. LINK NOT RUNNING; something is wrong with the optical fibres or link hardware

2. LINK OK; serial communications are O.K.

4.3.2 FREQUENCY

This test continuously monitors the output of the zero-crossing detector and puts the calculated frequency on the display.

4.3.3 SET DAC OUTPUT

This test sets the DC voltage connected to the amplifier/attenuator module.

The range is any number between 0 and 2.5 inclusive, where 2.0 is 100% of range and 2.5 represents 25% over range.
This test, in conjunction with DMJTC Adjust is indispensable in checking the operation of the servo loop and the null on the thermal converter.

4.3.4 ADC

This test checks the 8 channels on the A/D converter in the analogue module.

4.3.4.1 RMS

This test checks and reports the output of the 3½ digit RMS-DC converter, where 1.0 represents full scale input.

4.3.4.2 +5

This test checks and reports the +5 volt digital supply in the analogue module, where +4.6 V is nominal. This supply is checked on power up and an error message results if it is below nominal.

4.3.4.3 +15

This test checks and reports the +15 volt analogue supply in the analogue module, where +14 V is nominal. This supply is checked on power up and an error message results if it is below nominal.

4.3.4.4 -15

This test checks and reports the -15 volt analogue supply in the analogue module, where -14 V is nominal. This supply is checked on power up and an error message results if it is below nominal.

4.3.4.5 1 ms FILTER

This channel test of the multiplexer looks at the output of the integrator in the servo loop through a 1 ms time constant filter. Full scale is ±5.000 (volts). This channel is used in making measurements above 1 kHz.

4.3.4.6 10 ms FILTER

This channel looks at the output of the integrator in the servo loop through a 10 ms time constant filter. This channel is used in making measurements between 100 Hz and l kHz.

4.3.4.7 100 ms FILTER

This channel looks at the output of the integrator in the servo loop through a 100 ms time constant filter. This channel is used in making measurements below 100 Hz.

4.3.4.8 CAL

This channel looks at analogue ground and is a check on the 12 bit A/D converter calibration and two representations are given, decimal and binary.

The converter is in calibration if one of the two following binary numbers are displayed:

    1000...00   (11 zeros)
or
    0111...11   (11 ones)

4.3.5 DMJTC ADJUST

This checks the balance of the thermal converter at the two sensitivity levels of the servo loop, High (H) sensitivity and Low (L) sensitivity, as well as at both polarities (+ and -) of the DC level set in the routine DAC OUTPUT. The four possible combinations are cycled through by selecting the arrow - or ? keys and the output of the integrator in the servo loop is displayed in volts.

4.4 SOFCAL SETUP PRINTER

When a printer is connected to either the GPIB interface or the RS-232C interface (and the interface is configured as Talk/Only) each measurement can be recorded, the data to be logged can be selected, in addition the quantity of data to be logged can be selected. The following step by step procedure outlines how to set up the printer output format.

1. Depress the SOFT CAL key. The LED in the SOFT CAL key will become lit, and the display will show SETUP GPIB with the word GPIB flashing.

2. Depress the "4" key. The display will show SETUP PRINTER with the word PRINTER flashing.

3. Depress the ENTER key. The display will show the currently selected print rate, with the current rate flashing. A print rate of 1/3 will print 1 result every 3 readings, a print rate of 1/1 will print every result. Normally a print rate lower than 1/1 is used (such as 1/10) so that the amount of paper used over a long period of time (i.e. 24 hours) is reduced.

4. Depress the -UP key to select a lower print rate or the ?DOWN key to select a higher printer rate. Continue to depress the -UP and ?DOWN keys until the desired print rate is displayed.

5. Depress the ENTER key to select the print rate shown. The 7130A will now display the current print error selection. The print error selection allows the output of the four individual error voltages from the four submeasurements to be output along with the final result.

6. Depress the -UP key or the ?DOWN key to change the selection of print error, continue to depress the -UP and ?DOWN keys until the desired print error mode (ON or OFF) is displayed.

7. Depress the ENTER key to select the print error mode shown. The 7130A will now display the current print frequency selection. The print frequency selection allows the output of the frequency measured by the frequency counter in the 7130A.

8. Depress the -UP key or the ?DOWN key to change the selection of print frequency, continue to depress the -UP and ?DOWN keys until the desired print frequency mode (ON or OFF) is displayed.

9. Depress the ENTER key. The display will return to the display SETUP PRINTER with the word PRINTER flashing.

10. Depress the SOFT CAL key. The 7130A will return to its normal operating mode.

11. Toggle the printer on and off by pushing the front panel RS-232C key.

4.5 SOFCAL SETUP UPDATE

The 7130A has several different measurement update modes, this menu layer allows selection of the update modes. Normally the 7130A automaticaly selects the optimum trade-off between display update rate and reading stability, however it is possible to decrease the display update rate in order to improve reading stability. In addition it is possible to have the 7130A update the displayed reading after only two of the four measurement cycles, at the expense of a reduced reading accuracy and stability.

The time for a display update can be computed by knowing the measurement cycle time, the number of displayed digits, and the number of cycles per update (see Table 4.2). To determine display update time simply multiply the cycle time (from Table 4.2) by the number of cycles per display update (2 or 4).

It is also possible to increase the cycle time above the times given in Table 4.2 by setting the update time as directed below:

1. Depress the SOFT CAL key. The LED in the SOFT CAL key will become lit, and the display will show SETUP GPIB with the word GPIB flashing.

2. Depress the "5" key. The display will show SETUP UPDATE with the word UPDATE flashing.

3. Depress the ENTER key. The display will show the currently selected update rate, with the current rate flashing. An update rate of 2 cycles will update the display every 2 cycles, a update rate of 4 cycles will update the display every 4 cycles. Normally an update rate of 4 cycles is selected for best reading accuracy and stability.

4. Depress the -UP or the ?DOWN key to select the desired update rate, continue to depress the -UP and ?DOWN keys until the desired update rate is displayed.

5. Depress the ENTER key to select the update rate shown. The 7130A will now display the current cycle time in milliseconds. The cycle time actually used by the 7130A is the greater of the cycle time shown and the cycle time shown in Table 4.2.

6. Depress the numeric keys (0-9) followed by ENTER to select the new desired cycle time. Valid cycle times are 1000 mS to 8000 mS.

7. Depress the ENTER key to confirm the displayed cycle time. The display will return to the display SETUP UPDATE with the word UPDATE flashing.

8. Depress the SOFT CAL key. The 7130A will return to its normal operating mode.

Frequency Range	Display Digits	Measurement Cycle Time
DC	6½	4.0
	5½	3.0
	4½	2.0
10-100 Hz	6½	5.0
	5½	3.0
	4½	2.5
100-10 kHz	6½	4.5
	5½	3.0
	4½	2.5
>10 kHz	6½	4.5
	5½	3.0
	4½	2.5

Table 4.2: Display Resolution and Update Times

4.6 SOFCAL SETUP FILTER

The 7130A has several different measurement filters available. This menu layer allows the selection of the desired filter.

4.6.1 FILTER TYPE

4.6.1.1 ROLLING AVERAGE

This filter takes the last N measurements, where N is the number chosen for the filter constant, divides the result by N and puts this on the display.

4.6.1.2 DECIMALIZATION

This filter takes the present measurement and multiplies it by 1/N, where N is the number chosen for the filter constant, and adds this to (N-1)/N times the present displayed value and this number becomes the new displayed value.

4.6.1.3 FILTER CONSTANT

A whole number between 3 and 20 and is used as described above in Filter types.

4.7 SOFCAL SETUP COMP

The 7130A has several corrections which are made to the data after the data is collected from the analogue measurement hardware and before the result is displayed. This menu layer allows the modification of the various compensation coefficients.

4.7.1 SOFCAL SETUP FREQ COMP

For each measurement voltage range and each frequency range within the voltage measurement range there is a software compensation coefficient. This menu layer allows the modification of the compensation coefficients.

The compensation points are shown in Table 4.3.

-DC
+DC
10 Hz
20 Hz
60 Hz
100 Hz
1 kHz
3 kHz
6 kHz
10 kHz
20 kHz
30 kHz
60 kHz
100 kHz
200 kHz
400 kHz
600 kHz
800 kHz
1 MHz

Table 4.3: Frequency Compensation Points

At each frequency an error term is entered (in parts per million (ppm)). The 7130A corrects the measurements at each of the compensation points before displaying the result. The compensation is not performed if the NORMAL/CAL key switch is in the CAL position (See 3.5.9).

For example, if the following (partial) table of error terms were entered for the 10 volt range:

Partial Table of Frequency Compensation Coefficients		
Range (Volts)	Frequency (Hz)	Frequency Compensation (ppm)
10	60	400
	100	200
	1000	0
	3000	-100

If the input frequency were 100 Hz the measured voltage would be increased by 200 ppm before being displayed, if the input frequency were 1 kHz the measured voltage would be displayed with no modifications. If the input frequency is between 100 Hz and 1 kHz the amount of compensation would be linear interpolated between 200 and 0 ppm compensation. The linear interpolation formula is shown in Equation (2).

$$V_{displayed} = V_{measured} \, x \left\{ 1 + \left(\frac{C_{high} - C_{low}}{f_{high} - f_{low}} x (f_{in} - f_{low}) + C_{low} \right) x \, 10^{-6} \right\} \qquad \textbf{(2)}$$

C_{low} Compensation from table at frequency below input frequency

C_{high} Compensation from table at frequency above input frequency

f_{in} Input frequency

f_{low} Table frequency below input frequency

f_{high} Table frequency above input frequency

In order to change the frequency calibration coefficients follow the step-by-step procedure given below:

1. Turn the NORMAL/CAL key switch to the CAL position. If the key switch is in the NORMAL position it is possible to review the compensation coefficients, but it will not be possible to change the compensation coefficients.

2. Depress the SOFT CAL key. The LED in the SOFT CAL key will become lit, and the display will show SETUP GPIB with the word GPIB flashing.

3. Depress the 7 key. The display will show SETUP COMP with the word COMP flashing.

4. Depress the ENTER key. The display will show SETUP FREQ COMP, with the words FREQ COMP flashing.

5. Depress the ENTER key. The display will show COMP RANGE 100 mV with the word 3 mV flashing.

6. Depress the -UP or the ?DOWN key to select the desired range, continue to depress the -UP and ?DOWN keys until the desired range is displayed.

7. Depress the ENTER key to select the range shown. The display will show COMP FREQ -DC with the word -DC flashing.

8. Depress the -UP or the ?DOWN key to select the desired frequency, continue to depress the -UP and ?DOWN keys until the desired frequency is displayed.

9. Depress the ENTER key to select the frequency shown. The display will show COMP <PPM> XXX with the number XXX flashing.

10. Depress the numeric keys (0-9) and the ± key followed by ENTER to select the new desired compensation. Valid compensation values are from -9999 ppm to +9999 ppm.

11. Depress the ENTER key to confirm the displayed compensation coefficient. The display will return to the display COMP FREQ nnnHz with the word nnnHz flashing.

12. Depress the SOFT CAL key. The 7130A will return to its normal operating mode.

13. Turn the NORMAL/CAL key to the NORMAL position, then the selected compensation will be applied to the readings.

4.7.2 SOFCAL SETUP REF COMP

This menu layer allows for modification of the compensation coefficients associated with the internal DC reference.

$$V_{displayed} = V_{measured} \; x \left(1 + \frac{C_{reference}}{10^6} \right) \qquad \textbf{(3)}$$

where $V_{measured}$ is the measured voltage
$V_{displayed}$ is the displayed voltage
$C_{reference}$ is the coefficient entered for the reference compensation

$C_{reference}$ may be positive or negative.

When the 7130A measures a voltage, the voltage is a ratio between the input voltage and the internal reference. It is possible for the internal reference to have a slight error (normally only a few parts per million (ppm)), it is possible to correct the displayed readings for this error by entering a correction factor. As shown in Equation (3) the magnitude of the value displayed is increased (or decreased) by the number of parts per million entered as the Reference Compensation factor. The compensations shown in Equation (3) will not be performed unless the following conditions are met:

- The NORMAL/CAL key switch must be in the NORMAL position (see section 3.5.9).
- The internal DC reference must be selected (see section 3.3.17).

In order to change the reference compensation coefficient follow the step-by-step procedure given below:

1. Turn the NORMAL/CAL key switch to the CAL position. If the key switch is in the NORMAL position it is possible to review the compensation coefficient, but it will not be possible to change the compensation coefficient.

2. Depress the SOFT CAL key. The LED in the SOFT CAL key will become lit, and the display will show SETUP GPIB with the word GPIB flashing.

3. Depress the 7 key. The display will show SETUP COMP with the word COMP flashing.

4. Depress the ENTER key. The display will show SETUP FREQ COMP, with the words FREQ COMP flashing.

5. Depress the 2 key. The display will show SETUP REF COMP with the words REF COMP flashing.

6. Depress the ENTER key to display the reference compensation. The display will show COMP <PPM> XXX with the number XXX flashing.

7. Depress the numeric keys (0-9) and the ± key followed by ENTER to select the new desired compensation. Valid compensation values are from -9999 ppm to +9999 ppm.

8. Depress the ENTER key to confirm the displayed compensation coefficient. The display will return to the display SETUP REF COMP with the words REF COMP flashing.

9. Depress the SOFT CAL key. The 7130A will return to its normal operating mode.

10. Turn the NORMAL/CAL key to the NORMAL position, then if the internal DC reference is selected the selected compensation will be applied to the readings.

4.7.3 SOFCAL SETUP DAC COMP

This menu layer allows for modification of the compensation coefficients associated with the internal DAC which scales the DC reference.

When the 7130A measures a voltage, the voltage is a ratio between the input voltage and the internal reference. The ratio between the reference and the input is performed through a Digital to Analogue Converter (DAC). The DAC is not perfectly linear, and in order to compensate for the non-linearities in the DAC it is possible to enter a set of linearizing coefficients. The coefficients are:

1. an offset term to correct for the DAC output not passing through zero, when a zero output is

selected.

2. a gain correction term to correct between an ideal DAC gain of 1.0 and the actual DAC gain.

3. a linearity term to correct for a slight bend in the DAC gain.

The compensation is performed using Equation (4).

$$V_{displayed} = \frac{C_{offset}}{10^6} + V_{measured}\, x \left(1.0 + \frac{C_{gain}}{10^6}\right) + (V_{fs} - V_{measured})^2\, x \left(\frac{C_{linearity}}{10^6}\right) \qquad \textbf{(4)}$$

where $V_{measured}$ is the measured voltage
$V_{displayed}$ is the displayed voltage
V_{fs} is the full scale voltage for the range on which the measurement is made
C_{offset} is the coefficient entered for offset compensation
C_{gain} is the coefficient entered for gain compensation
$C_{linearity}$ is the coefficient entered for linearity compensation

C_{offset}, C_{gain}, and $C_{linearity}$ may be positive or negative.

The three coefficients (C_{offset}, C_{gain}, and $C_{linearity}$) can be modified using the following step-by-step procedure:

1. Turn the NORMAL/CAL key switch to the CAL position. If the key switch is in the NORMAL position it is possible to review the compensation coefficient, but it will not be possible to change the compensation coefficient.

2. Depress the SOFT CAL key. The LED in the SOFT CAL key will become lit, and the display will show SETUP GPIB with the word GPIB flashing.

3. Depress the 7 key. The display will show SETUP COMP with the word COMP flashing.

4. Depress the ENTER key. The display will show SETUP FREQ COMP, with the words FREQ COMP flashing.

5. Depress the 3 key. The display will show SETUP DAC COMP with the words DAC COMP flashing.

6. Depress the ENTER key. The display will show DAC OFFSET, with the word OFFSET flashing.

7. Depress the -UP or the ?DOWN key to select the desired coefficient (OFFSET, GAIN, or LINEARITY). Continue to depress the -UP and ?DOWN keys until the desired coefficient is displayed.

8. Depress the ENTER key. The display will show one of DAC OFF XXX, DAC GAIN XXX, or DAC LIN XXX with the coefficient value XXX flashing.

9. Depress the numeric keys (0-9) and the ± key followed by ENTER to select the new desired compensation. Valid compensation values are from -9999 ppm to +9999 ppm.

10. Depress the ENTER key to confirm the displayed compensation coefficient.

11. Depress the SOFT CAL key. The 7130A will return to its normal operating mode.

12. Turn the NORMAL/CAL key to the NORMAL position, then if the internal DC reference is selected the selected compensation will be applied to the readings.

4.8 COMPENSATION COEFFICIENTS

4.8.1 WORKSHEETS

The following empty tables are provided to allow recording of the compensation coefficients entered into the 7130A for a permanent record.

Internal Reference Compensation Coefficient	
	(ppm)
$C_{reference}$	

Digital To Analogue Converter Compensation Coefficients	
	(ppm)
C_{offset}	
C_{gain}	
$C_{linearity}$	

Frequency Compensation Coefficients (ppm)								
Range Volts Frequency	0.3	1	3	10	30	100	300	1000
$-DC_{offset}$								
$-DC_{gain}$								
AC_{offset}								
$+DC_{offset}$								
$+DC_{gain}$								
10 Hz								
20 Hz								
60 Hz								
100 Hz								
1 kHz								
3 kHz								

6 kHz								
10 kHz								
20 kHz								
30 kHz								
60 kHz								
100 kHz								
200 kHz								
400 kHz								
600 kHz								
800 kHz								
1 MHz								

NOTE: See section 6.3.2 for calculation of coefficients.

Frequency Compensation Coefficients (ppm)				
Frequency	Range millivolts			
	3	10	30	100
$-DC_{offset}$				
$-DC_{gain}$				
AC_{offset}				
$+DC_{offset}$				
$+DC_{gain}$				
10 Hz				
20 Hz				
60 Hz				
100 Hz				
1 kHz				
3 kHz				
6 kHz				
10 kHz				
20 kHz				
30 kHz				
60 kHz				
100 kHz				
200 kHz				
400 kHz				
600 kHz				
800 kHz				
1 MHz				

NOTE: See section 6.3.2 for calculation of coefficients.

4.8.2 CALCULATIONS

The compensation coefficients are used in the following manner when calculating the displayed value of the input:

For AC measurements, the measurement cycle repeats the sequence step 1, step 2, step 4 where the output for step 1 ($V^1_{internal}$) is used as the input to step 2 and the output from step 2 used as the input to step 4.

For DC measurements, the measurement cycle repeats the sequence step 1, step 2, step 3.

Step 1: Reference Compensation

$$V^1_{internal} = V_{measured} \, x \left(1 + \frac{C_{reference}}{10^6} \right)$$

Step 2: DAC Compensation

$$V^2_{internal} = \frac{C_{offset}}{10^6} + V^1_{internal} \, x \left\{ V_{fs} + \frac{C_{gain}}{10^6} + (V^1_{internal})^2 \, x \left(\frac{C_{linearity}}{10^6} \right) \right\}$$

Step 3: DC Measurement

$$V^{3}_{displayed} = \frac{C_{DCoffset}}{10^{6}} + V^{2}_{internal}\, x \left(1.0 + \frac{C_{DCgain}}{10^{6}} \right)$$

Step 4: AC Measurement Frequency Compensation

$$V^{4}_{displayed} = V^{2}_{internal}\, x \left(1.0\, \frac{\frac{C_{high} - C_{low}}{f_{high} - f_{low}}\, x (f_{in} - f_{low}) + c_{low}}{10^{6}} \right) + C_{ACoffset}$$

5 REMOTE CONTROL

The 7130A Digital AC/DC Transfer Standard operates directly from the front panel or under remote control of an instrument controller, computer or terminal. Remote control can be interactive, with the user controlling each step from a terminal, or under the control of a computer running the 7130A in an automated system. It is also possible to connect a printer to the remote interface of the 7130A and have the 7130A output some or all of the measurements taken to the printer for a permanent record.

This chapter describes the interfaces and the commands to which
the 7130A will respond. The setting of the GPIB address and mode is
described in Section 4.1.

5.1 INTERFACES

The model 7130A has two interfacing standards available:

1. A GPIB interface conforming to IEEE-488.2.

2. A serial interface conforming to RS-232C.

The GPIB address switch and connector are on the rear panel and the GPIB can be configured by the dip switch. Setting up the DIP switch is explained in Section 3.5.1.

The RS-232C connector is on the rear but it has to be configured from the front panel as explained in Section 4.2.

The 7130A can be operated in a system where both RS-232C and IEEE interfaces are being used. It can be controlled with an IEEE bus and a printer connected to the RS-232C output for permanent records of measurements.

In a system containing more than one controller, only one controller can exercise control while the other stays in dormant state until control is transferred.

5.2 IEEE-488 (GPIB) INTERFACE

The 7130A is fully programmable for use on the IEEE standard 488.1 interface bus (IEEE-488 bus). The interface is also designed in compliance with the supplemental standard IEEE-488.2. Devices connected to the bus in a system are designated as talkers, listeners, talker/listeners, or controllers. The 7130A can be operated on the IEEE-488 bus as a talker or under the control of an instrument controller as a talker/listener.

This manual assumes that the user is familiar with the basics of the IEEE-488 interface bus.

The IEEE-488 interfacing standard applies to interface of instrumentation systems or portions of them, in which the:

1. Data exchanged among the interconnected apparatus is digital.

2. Number of devices that may be interconnected by one contiguous bus does not exceed 15.

3. Total transmission path lengths over interconnecting cables does not exceed the lesser of either 20 meters or 2 times the number of devices on the bus.

4. Data rate across the interface on any signal line does not exceed 1 megabit per second.

5.2.1 CONTROLLER

There can be only one designated controller in charge on the GPIB bus. This device exercises overall bus control and is capable of both receiving and sending data. The rest of the devices can be designated as listener, talker or talker/listener.

The controller can address other devices and command them to listen, address one device to talk and wait till the data is sent. Data routes are set by the controller but it need not take part in the data interchange.

5.2.2 GPIB RESPONSES

The reply to any GPIB query command will be a sequence of ASCII characters followed by a Line-Feed character (0x0A). The Line-Feed character may also be expressed as $0A_{16}$ or 10_{10} or 12_{8} or control-J. Throughout this manual we will use the "C" programming language notation for expressing numbers in base 16, specifically 0x0A indicates that 0A is to be interpreted in base 16 (hex).

5.2.3 INTERCONNECTING CABLE AND GPIB CONNECTOR

The interconnecting cable of IEEE-488 1978 consists of 24 conductors, 16 conductors are for carrying signals and 8 for grounding. Individual cable assembly should be up to 4 meters long and should have both a plug and a receptable connector type at each end of the cable. Each connector assembly is fitted with a pair of captive locking screws.

5.2.4 TYPICAL SYSTEM

Data Input/Output Lines - The 8 data I/O lines form the data bus over which data between the various devices is transmitted under the supervision of the controller. The message bytes are carried on Data I/O signal lines in a bit parallel byte serial form, asynchronously and generally in a bidirectional manner.

Handshake or Data Byte Control - The three interface signals are used to effect the transfer of each byte of data on the DIO signal lines from a talker or controller or one or more listeners.

1. DAV (DATA VALID) is used to indicate the condition of (availability and validity) information on the DIO signal lines.

2. NRFD (NOT DATA ACCEPTED) is used to indicate the condition of readiness of devices to accept data.

3. SRQ (SERVICE REQUEST) is used by a device to indicate the need for attention and to request an interruption of the current sequence of events.

4. REN (REMOTE ENABLE) is used (by a controller) in conjunction with other messages to select between two alternate sources of device programming data.

5. EOI (END OF INDENTIFY) is used (by a talker) to indicate the end of a multiple byte transfer sequence or in conjunction with ATN (by a controller) to execute a polling sequence.

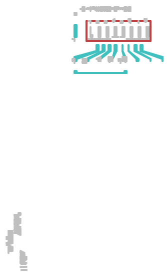


Figure 5.1: Address/Talk/Listen Selection

5.2.5 ADDRESS AND TALK/LISTEN SELECTION

Switches mounted on the rear panel enable the GPIB Address and Talk/Listen status to be set as desired.

If there is no controller and the 7130A is hooked up to a printer for hard copy then Talk Only mode should be selected. Also for the GPIB interface to be enabled the Interface Enable switch should be in the 'ON' position.

5.2.6 GPIB ELECTRICAL INTERFACE

The 7130A meets the subsets of the GPIB interface specification IEEE-488.1 shown in Table 5.2. The pin connections on the GPIB interface connector are shown in Table 5.1.

SH1 the 7130A has complete source handshake capabilities.
AH1 the 7130A has complete acceptor handshake capabilities.

T5 the 7130A has talker capabilities with a single primary address in the range 0 to 30. Extended addressing is not implemented.

L3 the 7130A supports basic listener with unaddress if MTA
(My Talk Address) is received. The talk and listen addresses will always be the same. The 7130A does not support extended listen addresses.

SR1 the 7130A has complete service request generation capabilities.
RL1 all functions (except POWER and RESET) on the front panel of the 7130A can be locked out by the GPIB controller.

PP0 the 7130A has no parallel poll capabilities.

DC1 the 7130A full device clear capabilities.

DT1 the 7130A full device trigger capabilities.

C0 the 7130A can never become the bus controller.

E2 the 7130A has all required electrical interface capability.

PIN	NAME	DESCRIPTION
1	DIO1	Data Input Output Line 1
2	DIO2	Data Input Output Line 2
3	DIO3	Data Input Output Line 3
4	DIO4	Data Input Output Line 4
5	EIO	End or Identify
6	DAV	Data Valid
7	NRFD	Not Ready for Data
8	NDAC	Not Data Accepted
9	IFC	Interface Clear
10	SRQ	Service Request
11	ATN	Attention
12	SHEILD	Screening on Cable (connected to safety ground
13	DIO5	Data Input Output Line 5
14	DI06	Data Input Output Line 6
15	DIO7	Data Input Output Line 7
16	DIO8	Data Input Output Line 8
17	REN	Remote Enable
18	GND6	Ground wire of twisted pair with DAV
19	GND7	Ground wire of twisted pair with NRFD
20	GND8	Ground wire of twisted pair with NDAC
21	GND9	Ground wire of twisted pair with IFC
22	GND10	Ground wire of twisted pair with SRQ
23	GND11	Ground wire of twisted pair with ATN
24	GND	Logic Ground

Table 5.1: IEEE-488.1 Pin Designations

Source Handshake	SH1
Acceptor Handshake	AH1
Talker	T5
Listener	L3
Service Request	SR1
Remote Local	RL1
Parallel Poll	PP0
Device Clear	DC1
Device Trigger	DT1
Controller	C0
Electrical Interface	E2

Table 5.2: GPIB Device Capabilities

5.2.7 GPIB INPUT BUFFERING

The GPIB input buffer is 256 bytes long. The input full bit is set when the buffer is above 75% full (64 bytes remaining), hence if the programmer limits messages sent to the 7130A to 32 bytes and checks the IFL bit in the status register before sending each message, then under normal operating conditions the buffer should never overflow. If the buffer is full and the programmer sends more data, the 7130A will perform the necessary handshaking as per usual, but the data will be lost, this is done for two reasons:

1. if the buffer is full, the system programmer is probably in error since the 7130A should never become full (the 7130A interprets most commands in under 150 milliseconds).

2. the 7130A will never lock up the GPIB bus.

5.2.8 GPIB OUTPUT BUFFERING

Output from query commands are placed into a 256 byte output buffer. When the controller reads data from the 7130A the responses will come from the output buffer in, first in first out order. If for some reason the controller does not read the responses from its query commands the output buffer will overflow, in this case the first data into the buffer will still be valid and the later data will be lost. When output data is lost the query error bit in the status register will be set. When the output buffer is not empty then the message available (MAV) bit will be set in the status register.

5.2.9 GPIB DEADLOCK

If the controller demands a byte of data from the 7130A and the buffer is empty and this condition persists for a period of 8 seconds, the 7130A will place the current voltage (see Voltage? command) into the output buffer and use this data to satisfy the controllers demand for data. The format of the data is set by the current state of the Terse/Verbose flag (see TErse and VErbose commands).

5.3 RS-232C INTERFACE

The 7130A has an RS-232C interface which can be connected to a controller or to a simple printer. The controller (which can be almost any computer with an RS-232C interface) can control the 7130A through a variety of commands which allow setting the instruments operating parameters, and analyzing the measurements made by the 7130A. The simple printer interface can be used to log any or all of the measurements taken by the 7130A during normal operation.

When using the RS-232C port to remotely control the 7130A, either interactively with a terminal or under computer control, operation is the same as using an IEEE-488 controller connected to the IEEE-488 port for control, with the following exceptions:

1. The end of line input terminator is Carriage Return (0x0D).

2. There is no SRQ capability when using serial remote control. The status registers still behave as described in this chapter, but the 7130A serial interface does not have a way to perform the SRQ function.

3. There is no direct way to perform GPIB hardware interface functions such as DCL (Device CLear) or SDC (Selected Device Clear).

5.3.1 RS-232C - PIN DESIGNATIONS

Pin		Function	Direction
1	CHG	CHassis Ground	IN
2	TxD	Transmit Data	OUT
3	RxD	Receive Data	IN
4	RTS	Request To Send	OUT
5	CTS	Clear To Send	OUT
6	DSR	Data Set Ready	OUT
7	GND	Signal Ground	OUT
8	DCD	Data Carrier Detect	IN
All other pins not used or connected.			

Table 5.3: RS-232C Pin Designations

The 7130A Digital AC/DC Transfer Standard is a data communication equipment (DCE) so TxD is an input (the data which the modem is to transmit).

5.3.2 RS-232C RESPONSES

The reply to any RS-232C query command will be a sequence of ASCII characters followed by a Carriage-Return character (0x0D) and then a Line-Feed character (0x0A). The Line-Feed character may also be expressed as $0A_{16}$ or 10_{10} or 12_{8} or control-J. Throughout this document we will use the "C" programming language notation for expressing numbers in base 16, specifically 0x0A indicates that 0A is to be interepreted in base 16 (hex).

5.4 COMMAND LANGUAGE

The commands for GPIB and RS-232C mainly correspond to the labels assigned to the front panel pushbuttons. Throughout this document when examples are given they apply to commands through the RS-232C interface or through the GPIB interface. The examples will not show the termination characters since these differ for each of the interfaces (See sections 5.2.2 and 5.3.2).

5.4.1 GENERAL SYNTAX FOR COMMANDS

The 7130A uses a sophisticated command parser which can usually determine which command was desired, even if the command is entered incorrectly. The commands Voltage? and Volts? will be considered by the command parser as identical, some care should be taken when sending commands such as RAnge? and RomChecksum since the parser may not be able to decide which command was desired in the event of a gross misspelling (such as using Rance instead of RAnge).

No command used in the 7130A has an embedded space in its name, spaces (0x20) are used only to separate command names from their parameters, and to separate parameters from each other.

Throughout this manual some of the command names will have an UPPER case portion and a lower case portion. The command may be shortened such that only the portion of the command name which was presented in UPPER case characters is present. The command parser of the 7130A is case insensitive (ie. the letter case of commands sent to the 7130A does not matter), both UPPER case letters and lower case letters may be used.

5.4.2 GENERAL SYNTAX FOR NUMBERS

Numeric parameters may have up to 30 characters, and although the 7130A will accept numeric parameters in the range ±2.2E-308 through ±1.8E308, the useful range of numbers is between ±1.0E-8 and 1.0E5.

The portion of the command parser which interprets numeric input will correctly recognize most common forms of numeric input, for example the following are all valid methods of expressing the number 123.4:

```
123.4
123.4e00
0.1234E3
1234e-1
0000123.4
```

The following are examples of invalid forms of expressing a number:

123.4 e00	space between mantissa and exponent letter
1234D-1	exponent not e or E
n123.4	letter in front of the first digit
e34	missing mantissa

Multipliers (such a µ, m, k, and M) are not permitted on commands, all numbers must be entered in the base units, for example 100 mV can be expressed as 100e-3 or 0.100.

Expressions (for example 7 + 20 X 3) are not allowed as parameters.

5.5 REMOTE AND LOCAL OPERATION

The 7130A can be operated using the front panel keys or it can be operated remotely using a remote controller. In addition the 7130A can be placed in a local lockout condition at any time by a command from the controller. When combined, the local, remote, and lockout conditions yield four possible operating states:

5.5.1 LOCAL

The 7130A responds to local and remote commands. This is also called "Front Panel Operation". Only remote commands that do not affect the state of the 7130A are allowed to execute. (For example the command Voltage? is allowed to operate but the command Range 1 000.0 which would change the instrument state is not allowed.) If the controller sends a command which would affect the instrument state while in local, the command will be ignored, and no error indication will be given.

5.5.2 LOCAL WITH LOCKOUT

Local with lockout is identical to Local except that the 7130A will go into remote with lockout instead of the remote state when the 7130A receives a remote command. The local with lockout state is entered by sending an IEEE-488 LLO+REN command from the controller, or by sending the {\tt LOCKOUT} command to the 7130A.

5.5.3 REMOTE

When the Remote Enable (REN) line is asserted and the controller addresses the 7130A as a listener, the 7130A enters the remote state. The REMOTE LED on the front panel of the 7130A will be lit when the 7130A is in the remote state.

Front panel operation is restricted to the use of the Power Switch and the LOCAL key. Pressing the LOCAL key or sending the GTL (Go To Local) interface message returns the 7130A to the local state.

5.5.4 REMOTE WITH LOCKOUT

The remote with lockout state can be entered from remote or local with lockout, but not directly from local. Remote with lockout is similar to the remote state but

restricted: the LOCAL key will not return to the local state. To return the 7130A to the local with lockout state the controller must send a GTL interface command. To return the 7130A to the local state the controller must unassert the REN control line.
Table 5.4 summarizes the possible Remote/Local state transitions.

From	To	IEEE-488 Interface Command	RS-232C Interface Command
Local	Remote	MAL + REN	REMOTE
	Local/ Lockout	LLO	LOCKOUT
Remote	Local	GTL or LOCAL key	LOCKOUT
	Remote/ Lockout	LLO + REN	LOCKOUT
Local/ Lockout	Remote/ Lockout	MLA + REN	REMOTE
Remote/ Lockout	Local	REN	LOCAL
	Local/ Lockout	GTL	None

Table 5.4: Remote/Local State Transitions

5.6 REMOTE COMMANDS

5.6.1 *ESE - SET EVENT STATUS ENABLE REGISTER

This command sets the standard event status enable register bits. When the bits in the Event Status Enable (ESE) register are "ANDed" with the bits in the Event Status Register (ESR) if the result is non-zero then the Event Status Bit (ESB) in the Status Byte (STB) register is set.

The values accepted for the *ESE command are between 0 and 255, all other values are considered to be an error. The default value for The Event Status Enable (ESE) register at power on is zero (0).

Figure 5.2: Event Status Bit Operation

5.6.2 ESE? - EVENT STATUS ENABLE QUERY

This command reports the current value of the Event Status Enable Register. The value returned will be between 0 and 255.

5.6.3 *ESR? - EVENT STATUS REGISTER QUERY

This query allows the programmer to determine the current contents of the event status register. Reading the Event Status Register clears it.

5.6.4 *IDN? - IDENTIFCATION QUERY

This command causes the 7130A to reply with an identification string. The identification string is built up of four (4) fields delimited by commas (,). The first field is the manufacturer (i.e. Guildline Instruments), the second field is the model (i.e. 7130A), the third field is the serial number (i.e. 55065), and the final field is the firmware revision (i.e. A). A typical response might read:

Guildline Instruments, 7130A, 55065, A

The reply string will be shorter than 73 characters.

5.6.5 *OPC - OPERATION COMPLETE

This command will cause the 7130A to set the Operation Complete bit (bit 0) in the Event Status Register. Since the 7130A processes all commands sequentially, the operation complete bit will be set as soon as the command is parsed.

5.6.6 *OPC? - OPERATION COMPLETE QUERY

This query will place a numeric 1 in the output buffer indicating that all pending operations are complete.

Bit Location		Name	Description
0	LSB	OPC	OPeration Complete. This event bit is generated in response to the *OPC or *OPC? command. It indicates that the 7130A has completed any pending operations and that the parser is ready to accept more program messages.
1		RQC	ReQuest Control. This event bit indicates to the GPIB controller that the 7130A is requesting permission to become the controller in charge. The 7130A will never set this bit.
2		QYE	QuerY Error. This bit indicates that an attempt is being made to read data from the output queue when no output is either present or pending, or that data in the output queue has been lost (queue overflow). See also GPIB Deadlock.
3		DDE	Device Dependent Error. Not Used.
4		EXE	EXecutive Error. Set when 1)a program data element is evaluated to be outside the legal input range or is inconsistent with the 7310A's capabilities, 2)a valid program message could not be properly processed.
5		CME	CoMmand Error. Set when l)a syntax error has been detected by the parser, 2)a semantic error has occurred indicating that an unrecognized header has been received, 3)A Group Execute Trigger was entered into the input buffer inside of a program message.
6		URG	User Request. Set when any key is depressed on the 7130A keyboard.
7	MSB	PON	Power ON. This bit is set after the 7130A is powered up.

Table 5.5: Event Status Register

5.6.7 *RST - DEVICE RESET

This command is intended to return the 7130A to a known state, specifically a return to terse mode. This command will not affect the following:

1. The output queue.

2. The state of the IEEE-488 interface.

3. The selected address of the 7130A.

4. The *SRE setting.

5. The *ESE setting.

6. Calibration data that affects device specifications.

The *RST command will perform the following actions:

1. Autoranging mode will be selected.

2. The Voltage display mode will be selected.

3. The Volts display mode will be selected.

4. The 7130A will be placed in standby mode.

*RST is a MANDATORY IEEE-488.2 command.

The *RST command shall perform the following:

1. Set the device dependant functions to a known state that is independant of the past-use history of the device. Device dependant commands may be provided to a different reset state than the original factory supplied one.

2. Set GET of *TRG macro defined by *DDT to a "do-nothing" state.

For those devices not implementing the *DDT command, the *RST shall set the GET or *TRG to the default as specified by the manufacturer.

3. Reset *EMC setting to zero and disable macros.

4. Clear pending operations.

The *RST command explicitly shall not affect the following:

1. The output queue.
2. The state of the IEEE-488 interface.
3. The selected IEEE-488.1 address of the device.
4. The *SRE setting.
5. The *ESE setting.
6. The *PSC setting.
7. Macros defined with the *DMC command.
8. Calibration data which affects device specifications.
9. The *PUD? response.
10. The *RDT? response.

5.6.8 *SRE - SERVICE REQUEST ENABLE COMMAND

The service request enable command allows the 7130A to generate a service request on the GPIB interface under a limited set of conditions. The limitations on the conditions are defined by the numeric parameter following the *SRE command. The numeric parameter is a decimal integer in the range 0-255. The numeric parameter when expressed in base 2 (binary) represents the bit values of the Service Request Enable Register. For all bits (except bit 6) a bit value of one (1) indicates an enabled condition and a bit value of zero (0) represents a disabled condition. *SRE? is the companion query command.

5.6.9 *SRE? - SERVICE REQUEST ENABLE QUERY

This command allows a programmer to determine the current contents of the Service Request Enable Register. A decimal number between 0 and 63 or between 128 and 191 will be returned.

5.6.10 *STB? - READ STATUS BYTE QUERY

This command allows the programmer to read the status byte and master summary bits (shown in Figure 5.6.).

The response from this command is a decimal integer in the range 0-255. This decimal integer when expressed in base 2 (binary) represents the bit values in the Status Byte Register. Note that the Master Summary Status bit and Not RSQ is reported in bit 6.

The Status Byte Register can also be read with the Read Serial Poll hardware command on the GPIB interface.

This Register can be read by Serial Poll or by the *STB? command.

LOCATION		NAME	DESCRIPTION
0	LSB	OVR	OVeRload. Will always be cleared to zero when unit returns to standby.
1		RDY	ReaDY. Set when the unit has a stable reading and cleared with radical change in input. Its sense is opposite to busy LED on front panel.
2		CHK	CHecKsum computation complete. This bit is set once, after instrument power on and the completion of the computation of the ROM checksum is cleared by the RomChecksum? command.
3		IFL	Input FuLl. This bit is set when the input queue is over 75% full and cleared when the queue drops below 25% full.
4		MAV	Message AVailable. This bit is set when the output queue is not empty.
5		ESB	Event Summary Bit. This bit is set when the result of a bitwise AND of the Event Status Enable register is not zero.
6		RQS	ReQuest for Service. This bit is set when the result of a bit-wise AND of the Status Byte Register and the Service Request Enable register is not zero.

5.6.11 *TRG - GROUP EXECUTE TRIGGER

This command performs the same action as a group execute trigger on the GPIB interface. Since the 7130A is not capable of starting any action on command, this command will set the execution error bit in the event status register (bit 4).

5.6.12 *TST? - QUERY RESULTS OF SELF TEST

This command is intended to report the status of any self-tests performed by the 7130A. If the 7130A passes all of its self-tests then the reply will be:

    0

If any failures are detected then the result will be an integer number (between -32768 and 32767) indicating which test failed.

5.6.13 DISPLAY - SET THE CURRENT DISPLAY MODE

This command allows a system programmer to set the display mode. For example the command:

    DIsplay 0

will select the voltage display mode (see section 3.3.5). The other display modes can be selected by using a numeric parameter as selected from Table 5.7.

Numeric Parameter	Display Mode
0	Volts
1	_V
2	ppm

Table 5.7: DIsplay Command Numeric Parameter

If the numeric parameter to the command is missing or unrecognizable the CME (CoMmand Error) bit in the Event Status Register will be set. If the numeric value is out of range (i.e. not 0, 1, or 2) then the EXE (EXecution Error) error bit will be set for a program data element out of range error.

5.6.14 Display? - QUERY THE CURRENT DISPLAY MODE

This query command displays the value of the currently selected display mode. In verbose mode the reply will be:

DIsplay 0

or in terse mode the reply will be:

0

where the value 0 is dependant upon the current display mode selected. The display modes are turned into a numeric reply as shown in Table 5.6.7.

5.6.15 Extdc - SET EXTERNAL DC REFERENCE MODE

The Extdc command will turn the External DC Reference Input on or off depending upon the value of the parameter to the command. For example the command:

Extdc 1

will set the External DC Reference Input as the instruments reference input (disabling the internal DC reference), and the command:

Extdc 0

will cause the 7130A to use its own internal DC reference. The allowable values for the numeric parameters are shown in Table 5.8.

Numeric Parameter	DC Reference Source
0	Internal
1	External

Table 5.8: Extdc Command Numeric Parameters

If the numeric parameter to the command is missing or unrecognizable the CME (CoMmand Error) bit in the Event Status Register will be set. If the numeric value is out of range (i.e. not 0 or 1) then the EXE (EXecution Error) will be set for a program data element out of range error.

5.6.16 Extdc? - QUERY EXTERNAL DC INPUT STATUS

This query command displays the value of the currently selected DC reference. In verbose mode the reply will be:

```
Extdc 0
```

or in terse mode the reply will be:

```
0
```

where the value 0 is dependant upon the current DC reference selected. The allowable values for the numeric response are shown in Table 5.8.

5.6.17 FIlter - SELECT DIGITAL FILTER

The FIlter command will turn the filter on or off depending upon the value of the parameter to the command. For example the command:

```
FIlter 10
```

will turn the filter ON with a filter factor of 10, and the command:

```
FIlter 0
```

will turn the filter OFF. The numeric parameter can be between 3 and 20.

If the numeric parameter to the command is missing or unrecognizable the CME (CoMmand Error) bit in the Event Status Register will be set. If the numeric value is out of range (i.e. not 0 or 3-20) then the EXE (EXecution Error) error bit will be set for a program data element out of range error.

5.6.18 FIlter? - DISPLAY FILTER STATUS

This query command displays the value of the currently selected filter. In verbose mode the reply will be:

```
FIlter 0
```

if the filter is disabled or in terse mode the reply will be:

```
0
```

where the value 10 is dependant upon the current filtering selected. If the filter is turned on the numeric reply will be between 3 and 20 otherwise, if the filter is turned off the numeric reply will be 0.

5.6.19 Frequency? - DISPLAY CURRENT INPUT FREQUENCY

The Frequency? command causes the output of the most recent voltage measurement. In verbose mode the response will be:

    1002 Hertz

and in the terse mode the response will be:

    1002

where the number will change to reflect the actual measured frequency. The number of significant digits reported is always 4. If the input is a DC voltage the frequency reported will be either +DC or -DC depending upon the polarity of the input.

5.6.20 Key? - REPORT LAST KEY PRESSED

This query command will report the value of the key most recently pressed on the keyboard. The key command will always report the letter "K" when in CAL mode. In terse mode the response will be one of:

    0, 1, 2, 3, 4, 5, 6, 7, 8, 9, S, X, U, D, E, B, A,
    C, O, L, R, K, ?

where ? indicates that no keys have been pressed since the 7130A was last RESET. The verbose mode reply will be preceeded with "KEY". The meanings of the various key characters are shown in Table 5.9.

5.6.21 Key <keyname> - ENTER A KEYSTROKE

The Key command causes the 7130A to perform actions similar to the actions performed when a front panel key is pressed. Allowable values for <keyname> are:

    0, 1, 2, 3, 4, 5, 6, 7, 8, 9, S, X, U, D, E, B, A,
    C, O, L, R, K

where each of these is a single ASCII character. Multiple <keynames> may be placed on the key command line and they will be processed in the order given.

Character	Key Name
0-9	numeric digits
0	LOCAL
1	GPIB
2	RS232
3	VOLTS
4	_V
5	ppm
6	FILTER
7	4½
8	5½
9	6½
S	SOFT CAL
N	RANGE
X	DELETE

Character	Key Name
X	AUTO
U	DECIMAL
U	-UP
D	±
D	?DOWN
E	ENTER
B	STANDBY
A	DC EXT
C	RECORDER
O	REC O/P
L	REC CAL
R	RESET
K	CAL

Table 5.9: Keyboard Character Designations

5.6.22 LOCAL - ENABLE THE LOCAL STATE

This command will place the 7130A into the local state. This command duplicates the IEEE-488 GTL (Go To Local) message. Normally this command is only sent from a RS-232C controller, if this command is received from a IEEE-488 controller it will be ignored.

There are no parameters for the LOCAL command. For example the command:

LOCAL

will enter the local state (See section 5.5).

5.6.23 LOCKOUT - ENABLE THE LOCAL/LOCKOUT STATE

This command will place the 7130A into the local lockout state. This command duplicates the IEEE-488 LLO (Local Lock Out) message. Normally this command is only sent from a RS-232C controller, if this command is received from an IEEE-488 controller it will be ignored.

There are no parameters for the LOCKOUT command. For example the command:

    LOCKOUT

will enter the lockout state (See section 5.5).

5.6.24 MEasure - BEGIN MEASUREMENTS

This command will take the 7130A out of Standby mode (see section 5.6.35) and commence measurements.

5.6.25 RAnge - SELECT MEASUREMENT RANGE

This command changes the currently selected measurement range. For example the command:

    RAnge 30.0

will select the 30 volt range of measurement where the value 30 is dependant upon the range desired.

Almost any value can be specified, however the instrument only has a limited set of available ranges (1 volt, 3 volts, and 10 volts etc.), therefore the closest available range will be selected. After a range has been selected the autoranging feature will be disabled.

In order to enable the autoranging function enter the command:

    RAnge 0.0

After a Range command has been executed care should be taken to ensure that the range desired is actually selected.

If the numeric parameter to the command is missing or unrecognizable the CME (CoMmand Error) bit in the Event Status Register will be set. If the numeric value is out of range (i.e. greater than 1200 V) then the EXE (EXecution Error) error will be set for a program data element out of range error.

5.6.26 RAnge? - DISPLAY CURRENTLY SELECTED RANGE

This query command displays the value of the currently selected range. In verbose mode the reply will be:

RAnge 30.0 Volts

or in terse mode the reply will be:

30.0

where the value 30.0 is dependant upon the current range selected. If the instrument is in standby the response terse will be 0.0.

5.6.27 REference - SELECT REFERENCE VOLTAGE

This command changes the currently selected reference voltage in the _V and ppm modes. For example the command:

REference 27.5002

will select a reference voltage of 27.5002 volts.

Almost any value can be specified, however the range of valid values is between 30% and 120% of full scale and must be within 0.1% of the current displayed reading or overrange will be displayed.

If the numeric parameter to the command is missing or unrecognizable the CME (CoMmand Error) bit in the Event Status Register will be set. If the numeric value is out of range (i.e. greater than 120% of full scale or less than 33% of full scale) then the EXE (EXecution Error) error will be set for a program data element out of range error.

5.6.28 REference? - QUERY REFERENCE VOLTAGE

This command reports the currently selected reference voltage. In terse mode a typical reply might be:

27.5002

and in verbose mode a typical reply might be:

27.5002 Volts

Almost any value can be specified, however the range of valid values will be between 30% and 120% of full scale.

5.6.29 REMOTE - ENABLE THE REMOTE STATE

This command will place the 7130A into the remote state. This command duplicates the IEEE-488 REN (Remote ENable) message. Normally this command is only sent from a RS-232C controller, if this command is received from a IEEE-488 controller it will be ignored.

There are no parameters for the REMOTE command. For example the command:

REMOTE

will enter the remote state (See section 5.5).

5.6.30 SerialNumber - SET SERIAL NUMBER

This command accepts an integer in the range -200 000 to +200 000, this number will be reported in the serial number field of the *IDN? command.

5.6.31 SOFCAL - SET CALIBRATION COEFFICIENTS

The SOFCAL command allows the programmer to change the instrument calibration.

WARNING

Great care should be taken when using this command since the 7130A cannot check that the values of the parameters are correct.

Read the frequency compensation coefficients by entering the command:

SOFCAL FREQUENCY? N_1,N_2

where N_1 represents the range and N_2 represents the frequency as given in the following tables.

N_1	Range
0	1000 V
1	300 V
2	100 V
3	30 V
4	10 V
5	3 V
6	1 V
7	300 mV
8	100 mV
9	30 mV
10	10 mV
11	3 mV
12	null

N_2	Frequency
0	$-DC_{offset}$
1	$-DC_{gain}$
2	AC_{offset}
3	$+DC_{offset}$
4	$+DC_{gain}$
5	10 Hz
6	20 Hz
7	60 Hz
8	100 Hz
9	1 kHz
10	3 kHz
11	6 kHz
12	10 kHz
13	20 kHz
14	30 kHz
15	60 kHz
16	100 kHz
17	200 kHz
18	400 kHz
19	600 kHz
20	800 kHz
21	1 MHz

As an example SOFCAL FREQUENCY? 5,10 would give you the 3 kHz coefficient on the 3 V range.

Similarly you can set frequency coefficients (in the CAL MODE of operating) by the command:

SOFCAL FREQUENCY N_1,N_2,N_3

where (1) N_1 stands for the range
(2) N_2 stands for the frequency
(3) N_3 is the desired coefficient

As an example SOFCAL FREQUENCY 5,10,-61 would set the 3 kHz coefficient on the 3 V range to -61.

The commands:

SOFCAL DAC N_1,N_2,N_3

and

SOFCAL DAC?

are used for writing and reading the DAC_{offset} (N_1), gain (N_2) and linearity (N_3) coefficients.

The commands:

SOFCAL REFERENCE N

and

SOFCAL REFERENCE?

are used for writing and reading the coefficient (N) for the internal reference.

5.6.32 SOFCAL? - REVIEW CALIBRATION COEFFICIENTS

The SOFCAL command allows the programmer to review the current values stored for instrument calibration.

Normally this command is to review the calibration values which are used when a range is selected.

5.6.33 STandby - ENABLE STANDBY MODE

This command allows the system programmer to place the 7130A into standby mode. The 7130A can be placed into measurement mode with the MEasure command (see section 5.6.25).

For example the command:

STandby

will place the 7130A into standby mode, effectively disconnecting the input connection from the measurement circuitry.

5.6.34 STandby? - QUERY STANDBY MODE STATUS

This command allows the system programmer to determine if the instrument is in standby mode or measure mode (see sections 5.6.34 and 5.6.25).

The terse reply will be:

0

and the verbose reply will be:

0 Measure

or

1 Standby

where the values displayed are dependant upon the actual instrument mode. The value 1 indicates the instrument is in standby mode, and the value 0 indicates the instrument in measure mode.

5.6.35 TErse - DISABLE VERBOSE MODE

This is the default mode for the 7130A after reset. Typically query commands will return very little extraneous information in terse mode.

For example the command:

TErse

will place the 7130A into terse mode.

5.6.36 VErbose - SET VERBOSE MODE

The VErbose command causes the output of all subsequent commands to contain additional information. This mode should be used for determining problems with programs and when the instrument is being used interactively.

For example the command:

VErbose

will place the 7130A into verbose mode.

5.6.37 Voltage? - DISPLAY CURRENT INPUT VOLTAGE

The Voltage? command causes the output of the most recent voltage measurement. In verbose mode the response will be:

1.000 013 Volts

and in the terse mode the response will be:

1.000 013

where the number will change to reflect the actual measured voltage. The voltage displayed will be the filtered voltage if the FILTER is enabled.

5.7 PROGRAMMING HINTS

In general, a simple way to get this instrument to select a voltage range, or to program a calibration coefficient, is to use the KEY command (see section 5.6.22) sending the same keystrokes that would be used from the front panel. This technique allows the system programmer to easily try out the command sequences from the front panel before coding the necessary controller routines.

6 CALIBRATION

6.1 CALIBRATION

The calibration should be performed once a year or whenever the Analogue Module has been altered. The following calibration procedure provides the highest level of accuracy by directly transferring traceability through a thermal converter set - calibrated to National Standards - to the model 7130A. See Figure 6.1 for the recommended calibration setup for the "volts" ranges and Figure 6.2 for the recommended calibration setup for the "millivolts" ranges.

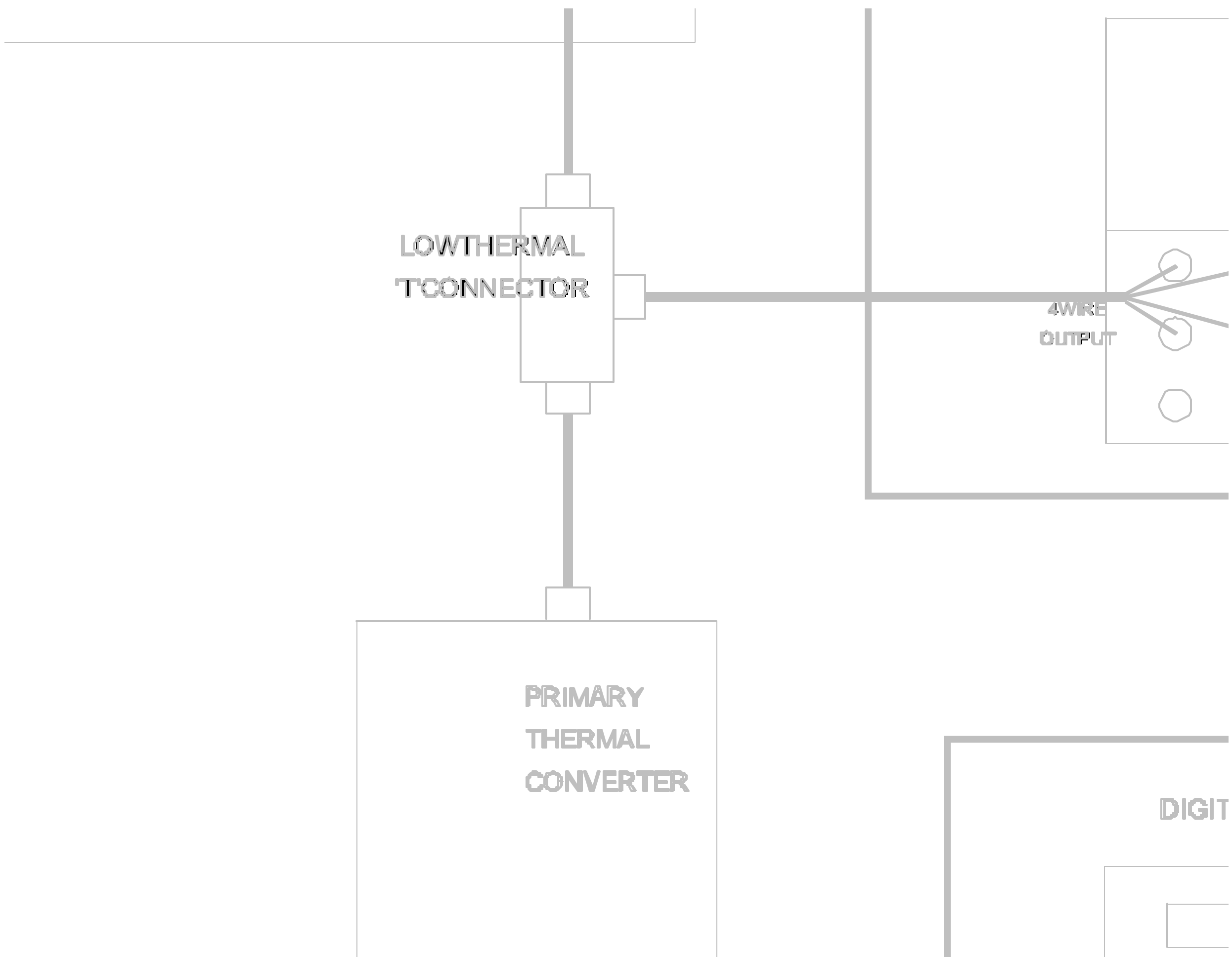


Figure 6.1: Calibration System Configuration - 7130A Volt Ranges

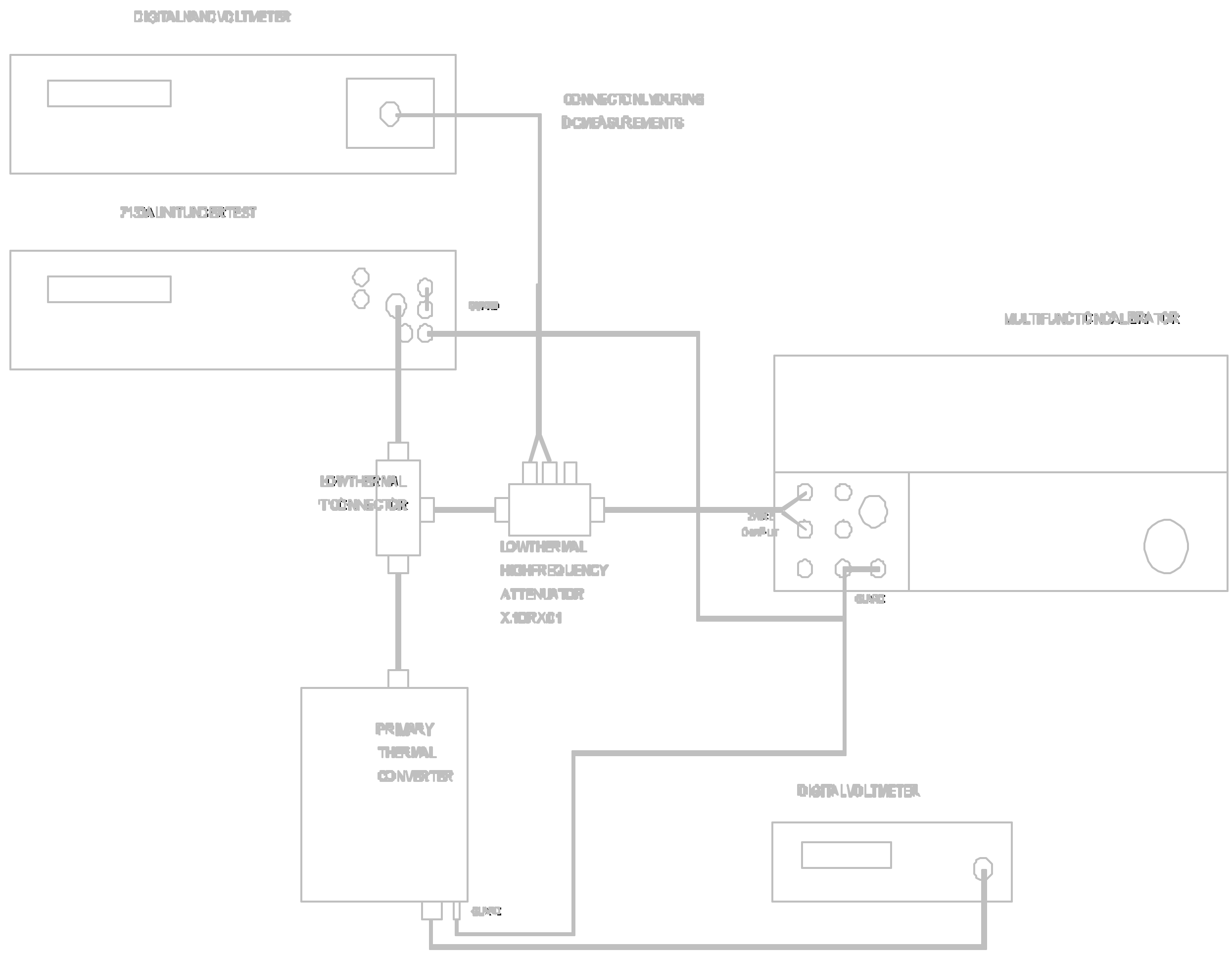


Figure 6.2: Calibration System Configuration - 7130A mV Ranges

6.2 OVERVIEW

Measurements are made using a set of AC/DC standard thermal converters over the bandwidth of 10 Hz to 1 MHz and the range of 2 mV to 1000 V. A multifunction calibrator having a DC absolute accuracy of at least 6 ppm and a short term DC and AC stability better than 5 ppm/hr is recommended for the voltage source.

For both the "volt" and "mV" calibration setups, a GR874 tee is used as the junction between the thermal converter, 7130A, and the output of the multifunction calibrator. Four-wire sensing is to the input of the tee during calibration of the "volt" ranges. The measurement of the output of the thermal converter is accomplished with either a Guildline 4880 or 4880A nanovoltmeter used as a null meter.

All cabling is kept to a minimum length and guarding techniques are employed.

6.2.1 ADDITIONAL SETUP INFORMATION

This calibration should be done in an environmentally controlled laboratory and sound metrology techniques employed, as follows:

- One AC ground in the system
- Thermal converter shielded from air currents
- Short cabling
- Proper shielding of cables, and guarding
- Connectors from the tee to the 7130A and the thermal converter protected from air currents.
- 1 to 2 hours warm up time for all instruments, or until stabilization is reached.

6.2.2 LOW VOLTAGE TESTING

Put a shorting bar, supplied with the 7130A accessory kit, across the high voltage input terminals when attempting to calibrate the low voltage input connector of the 7130A. Remember to remove this link when calibrating the high voltage ranges. To calibrate the 7130A unit under test on its "volt" ranges (i.e. all low voltages greater than 100 mV), the AC-DC differences of the calibrator output (at the frequencies and voltages of interest) at the input to the tee connector are computed using the primary thermal converter and digital voltmeter. The readings of the unit under test are also noted with its NORMAL/CAL key set to the CAL position.
To calibrate the unit under test on its "mV" ranges (i.e. all low voltages less than or equal to 100 mV), the AC-DC differences of the attenuated calibrator output at the input to the tee connector is computed using the primary thermal converter, digital voltmeter and nanovoltmeter. The nanovoltmeter is used to set the DC levels at nominal fullscale to optimise the unit's frequency response and at 40% of nominal fullscale to optimise for linearity. For example, on the 10 mV range, using the X 0.01 attenuator, the calibrator DC output is adjusted at 1 V and 400 mV so that the nanovoltmeter reads 10.00000 mV and 4.00000 mV respectively. The readings of the unit under test are also noted with it's NORMAL/CAL key switch set to the CAL position.

6.3 7130A CALIBRATION FORMULAE

This section details the calculations to be performed when calibrating the 7130A unit under test. For each range and associated points of interest, a coefficient is calculated and entered into the non-volatile memory of the unit under test.

6.3.1 LINEARITY COEFFICIENT FOR AC,DC+ and DC-

The following calculations are used to calculate the coefficients entered into memory as:

$+DC_{gain}$, $-DC_{gain}$, $+DC_{offset}$, $-DC_{offset}$, 1 kHz gain and AC_{offset}.

If:

D_{nom} = displayed value on unit under test when 100% nominal input is applied at 1 kHz, DC+ and DC-

D_{40} = displayed value on unit under test when 40% nominal input is applied at 1 kHz, DC+ and DC-

FS_{nom} = full scale nominal value of the 7130A range under test.
(i.e. FS_{nom} = 100% full scale = 30.00000 V on the 30 V range).

Then :

$$C_{offset} = \left[\frac{4x\,D_{nom} - 10x\,D_{40}}{6} \right] (ppm)$$

and :

$$C_{gain} = \left[\frac{6x\,FS_{nom}}{10x(D_{nom} - D_{40})} - 1 \right] x10^{6} (ppm)$$

6.3.2 FREQUENCY COMPENSATION COEFFICIENT (FCC(ppm))

To calculate the frequency compensation coefficients used by the 7130A the following definitions and formulae apply.

Let :

V_{meas} = AC input voltage as measured by the primary thermal converter (PTC).

V_{dis} = AC input voltage measured by the 7130A unit under test with the NORMAL/CAL key switch in the CAL position.

V_{DC+} = reading of the voltmeter connected to the PTC at a calibrator setting of DC+ volts (nominal full scale positive).

V_{DC-} = reading of the voltmeter connected to the PTC at a calibrator setting of DC- volts (nominal full scale negative).

V_f = reading of the voltmeter connected to the PTC at a calibrator frequency setting of f Hz (nominal full scale).

PTC_{AC-DC} = primary thermal converter AC-DC difference in ppm at the calibration point of interest.

FCC_f = frequency compensation coefficient for the 7130A unit under test at the test frequency f Hz.

AC_{offset} = offset of the 7130A as measured at a test frequency of 1 kHz.

Then :

$$V_{meas} = \left[\frac{2xV_f}{V_{DC+} + V_{DC-}} + \frac{PTC_{AC-DC}}{10^6} \right] xDC +$$

and for frequency f Hz (where f is not equal to 1 kHz) :

$$FCC_f = \left[\frac{V_{meas}}{V_{dis}} - 1 \right] x\, 10^6 - AC_{offset}$$

See section 4.7.1 Sofcal Setup Freq Comp detailing the procedure to enter the derived calibration coefficients into the 7130A non-volatile memory.

7 THEORY OF OPERATION

7.1 SYSTEM OPERATION

System operation is described in section 1.5.

Individual circuit and subsystem operation is described below.

Figure 7.1 is a functional block diagram of the 7130A. The 7130A can be partitioned into an analogue module and a digital module. The latter contains the controlling processor, display and the RS-232C and GPIB bus controllers. The former consists of the analogue circuits and associated data conversion and interfacing functions.

On power up the instrument runs a self test program and then reverts to the STANDBY mode with no input applied.

With the application of an input voltage and the selection of the VOLTS mode, depressing STANDBY causes the unit to go into its input acquisition mode.

In this mode the input sensed by the UNDER/OVER RANGE DETECT circuits causes the microprocessor to select the highest range (1000 V) and then "down range" until the output of the RMS-DC Converter is within range of the 12 Bit A/D. The output of the latter is then fed to the microprocessor via the O/P BUFFER REGISTER.

The microprocessor now selects a DC reference voltage approximately equal to the sensed rms input. The appropriate word is fed to the DAC via the I/P BUFFER REGISTER.

In the next cycle this reference voltage is applied to heater H1 via the DC ATTENUATOR and the PROGRAMMABLE GAIN AMPLIFIER.

The microprocessor now configures the instrument to perform the four cycle measurement described in section 1.4. to calculate _V. For the first measurement of _V the DMJTC error voltage is fed to the A/D at approximately 1/10 of its final gain, to ensure that A/D range is not exceeded. In subsequent calculations of _V, error voltage gain is increased to its final "High Sensitivity" value.

Thus after input acquisition the unknown rms signal is applied to H1 and the proportional DC applied to H2, the servo circuit adds or subtracts the negative feedback from the DC applied to H2 to maintain the output of the DMJTC very close to zero. The negative feedback to maintain the null is scaled and fed to the A/D converter input. The output from the A/D converter goes to the microprocessor. The microprocessor waits for four complete readings and calculates _V as per Equation (1) of section 1.4. The setting of the DC source is combined with _V and the microprocessor refreshes the variable DC supply with this value. This DC value is displayed as a measured rms volts. The display is updated every 2 cycles after the first sequence of four measurements if the instrument is in 2 cycle update mode. It updates every 4 cycles if the instrument is in 4 cycle update mode.

The update rates are shown in Table 4.2.

When measuring a DC input the DC reference polarity is not reversed. It is however set to maintain the same polarity at H1 of the thermal converter as the input.

This compensates for any drift in the PROGRAMMABLE GAIN AMPLIFIER and thermal converter error channel.

System operation as described above, both for AC as well as DC inputs, compensates for:

- Thermal converter reversal errors, square law non-conformance and nulling errors (or H1/H2 tracking)

- Amplifier drift and non-linearity

Additional compensation for frequency response of amplifier and thermal converter, gain and offset errors in the attenuator, amplifier and DC reference circuit, are compensated by software compensation constants. (See section 4.7.)

The UNDER/OVER RANGE detector circuit generates the O/L (overload signal) when it sees a 350% of full scale over voltage at the input. This causes the microprocessor to go into the OVERLOAD mode. In this mode it tries to reset the overload flip-flop of the above circuit and indicates overload on the display until the overload is removed. As this circuit will only see the overload when the input is being sampled its response time is slow.

Additional protection is therefore provided by the use of surge voltage protectors (SVPs) to provide an instantaneous crowbar protection of the attenuator, when the input voltage is suddenly increased by a magnitude greater than the above.

The 7130A also provides for the application (by the user) of an External DC Reference, as shown in the Block Diagram. Here the INT/EXT Multiplexer is operated by the microprocessor to substitute the External DC in place of the internal reference diode supply (INT. REF) that drives the DAC Reference (See section 7.2.1.4)

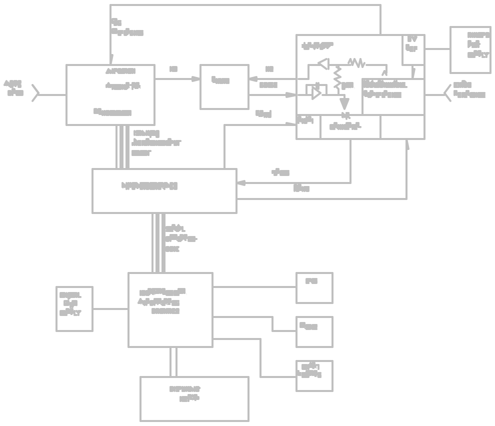


Figure 7.1: 7130A Block Diagram

7.2 CIRCUIT DESCRIPTIONS

7.2.1 ANALOGUE MODULE

The sensitive Analogue Module circuity is contained in a fully shielded enclosure that has no permanent electrical connection to the main chassis of the unit.

In addition the only signal connections to the digital module or Card File are provided by four fibre-optic links as shown in Figure 7.1. This permits complete isolation from the digital module as well as providing maximum protection from spurious radiated signals.

The shield of the analogue module is connected to the front and rear panel GUARD terminals. This permits versatility in measurement configurations. (i.e. when measuring a source that has one end referenced to AC ground, GUARD and LO terminals only strapped together to ensure a single AC ground connection). If the source is effectively isolated from ground, LO GUARD and GROUND terminals are strapped together.

Front and rear panels are also isolated from the analogue module. Controls and terminals are brought out through clearance holes in the front and rear panel to implement this feature.

An N Type connector is used as the input connection for "low voltage" inputs up to 120 V. Excellent high frequency characteristic plus low leakage led to its choice.

HV standoffs are used for the higher voltage inputs to accommodate peak voltage rating at the maximum input of 1200 Vrms.

7.2.1.1 CIRCUIT BOARDS

The Analogue Module circuitry is contained in three printed circuit boards (pcbs). These are listed below:

- Amplifier/Attenuator pcb.
- Data Conversion pcb.
- Analogue Interface pcb.

Partitioning of circuits is as follows:

The input AC/DC attenuator, range and reference selection plus front/rear panel selection relays together with the programmable gain amplifier of Figure 7.1 are contained in the Amplifier/Attenuator pcb. The I/P and O/P buffer registers, range function selection and relay drivers together with fibre optic drivers, receivers and associated circuitry are contained in the Analogue Interface pcb. These circuits can be considered as the digital interfacing circuits of the analogue module.

All remaining circuits are contained on the Data Conversion pcb.

The thermal converter is hardwired to both the Data Conversion pcb and the Amplifier/Attenuator pcb to form one assembly prior to being integrated with the rest of the module.

In order to minimize IR volt drops to a very low level it has been found necessary to use extra heavy wire (#8 AWG) for connections carrying heater currents H1 and H2 of the thermal converter and the supply currents of the amplifier to the star ground point located on the Data Conversion pcb.

7.2.1.2 AMPLIFIER/ATTENUATOR pcb

Figure 7.2 is a simplified schematic of the Amplifier/Attenuator pcb.

The configuration is that of a current to voltage converter with a 3 dB bandwidth of approximately 20 MHz.

Input current on all ranges is 1 mA at nominal full scale input. The exceptions are the 0.3 V, 30 mV and 3 mV ranges where 0.3 mA is nominal full scale. The input attenuator forms an "L" attenuator at any range with the selected range resistor forming the series element and all other range resistors in parallel forming the parallel component.

This configuration results in a constant attenuator output impedance for all ranges seen at the amplifier summing junction.

For the 100 mV ranges and below, a low noise, high input impedance amplifier is switched in. The amplified signal is fed into the 1 volt or 300 mV range. The gain is 10 for the 100 mV and 30 mV ranges, and 100 for the 10 mV and 3 mV ranges.

The grounding of unused inputs removes the effect of parallelled complex leakage impedances produced by the unused range resistors together with the open contact capacitance and conductance of unselected range relays.

The wideband amplifier converts the 1 mA nominal full scale input current into a 2 V nominal output voltage for all ranges except the 0.3 V, 30 mV and 3 mV ranges. Here the feedback network is modified with a T-network to increase its gain by a factor of 3.333, thus delivering the standard 2 Vrms to the thermal converter load.

The selection of the internal DC Reference voltage would normally result in a reduced input current as the attenuator output is no longer seeing the virtual ground of the summing junction of the amplifier. This would introduce a square wave input current component which would result in a disturbance of the source being measured. The addition of the ATTENUATOR.FET (Q1) ensures a constant current input at all times. The F GATE signal is timed to turn on the FET prior to the switchover to REF and to hold it on after the switch lock to NORM mode when the input is reconnected.

The DC REF input is fed through an attenuator that presents the same output impedance as the attenuator, while maintaing the full scale input current of 1 mA (nominal), for ranges ³ 1 volt and 0.3 mA for the 0.3 range.

Individual range resistors are used for all ranges in the input attenuator except for the 1 V and 0.3 V ranges. For the latter two ranges a 1.5 kO resistor is switched in parallel with the 3 kO resistor of the 3 V range. This provides the required 1 mA/volt input impedance required for these ranges. This is done to maintain a reasonably high range resistance value thus minimizing the effect of range relay contact resistance variations.

All range selection relays are low thermal emf latching type. The use of latching allows for reduced coil current consumption. The employment of mercury contacts in input relays K4 thru K8 and K10, K11 minimize contact resistance and provide maximum stability for this parameter.

In addition all range relays except the 300 V and 1 kV units are equipped with electrostatic shields to minimize any noise, coupling from the relays supplies, that may be present.

Extensive guarding of tracks is provided at the amplifier summing junction to minimize noise coupling and also spurious input coupling to the summing junction.

The latter effect is greatly minimized by grounding all unused inputs.

NOTE: To illustrate the effect of input coupling, a leakage conductance equivalent to 10^{11} O constitutes a 10 ppm gain error on the 1 kV range.

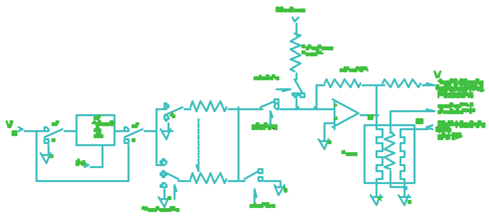


Figure 7.2: Amplifier/Attenuator

Vacuum surge suppressors are provided for the protection of range resistors to momentary excessive voltages which are too fast for the automatic switchover provided by the processor to higher ranges.

The wideband amplifier U1, U2 and associated components employs a transimpedance, 2000 V/µs slew rate operational amplifier (AD844) followed by a fast buffer (EL2003) to drive the 100 O impedance of H1 heater of the thermal converter. The output is also fed out via a 10 O resistor for the rms DC converter channel on the Data Conversion pcb.

7.2.1.3 ANALOGUE INTERFACE pcb

Refer to the attached functional block diagram Figure 7.3, and the Timing Chart, Figure 7.4.

The Analogue Interface pcb forms the digital interface between the microprocessor and the Analogue Module. Its operation is controlled by the microprocessor.

The Analogue Interface pcb also accepts the inputs from the front and rear panels and switches them into the amplifier/attenuator pcb.

The clock burst received from the microprocessor on the CLOCK channel is used by the Timing Logic circuit to control the input register (U4, U5, U9, U10, U17) which converts the serial data stream received from the microprocessor into a latched data word. The latter is fed out to the DAC (on the Data Conversion Board) at the termination of the data stream.

The Timing/Control Logic circuit also controls the A/D converter on the Data Conversion Board. The A/D output from the Data Conversion Board is latched into the OUTPUT REGISTER at the start of the clock burst. The output of this register is fed out as a serial pulse stream coincidentally with the incoming data stream. (Refer to Timing Chart.) Four data bits from the INPUT REGISTER are decoded in U18 to generate the range relay control signals that feed the RELAY DRIVERS circuit. The latter, drive the relays of the Amplifier/Attenuator board both latching and non-latching units. Latching pulses are generated in the TIMING/CONTROL LOGIC function circuits. U/R, O/R and O/L (Under range, Over range and Overload) logic inputs from the Data Conversion Board are latched into the Output Register with the A/D output, to form part of the outgoing data word. In addition the O/L signal is fed to the Timing Logic to inhibit relay operation on an overload.

Figure 7.3: Analogue Interface

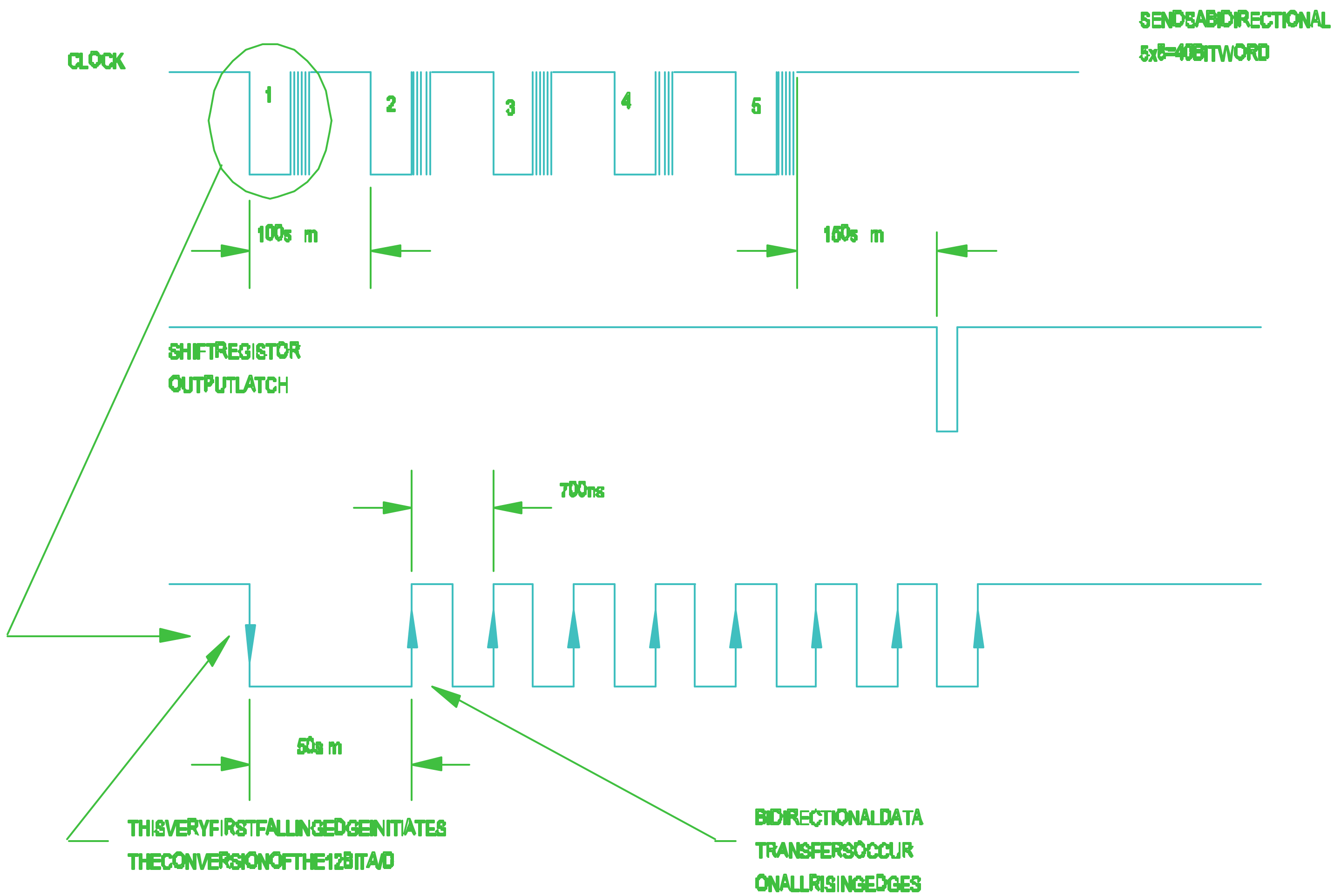


Figure 7.4: Timing Chart

7.2.1.4 DATA CONVERSION pcb

Refer to the attached simplified schematic, Figure 7.1.

The Data Conversion pcb consists of 4 subsections:

1) A precision tracking power supply to provide a clean and stable supply to the wideband I/V converter on the amplifier/attenuator pcb.

2) A programmable ±DC reference that can be locked to either an internally generated 10 V reference or to an externally supplied 10 V reference.

3) Supervisory circuits consisting of an eight channel multiplexer and a 12 bit A/D converter, the overload, overrange and underrange comparators, and a 3½ digit solid state rms/DC converter.

4) A servo loop (which requires microprocessor control to close) that is used to null the output of the sense winding in the DMJTC.

The resistors used in the servo loop and the programmable ±DC reference are all precision metal film and were burned in to ensure long term stability in the resistance values. As well all operational amplifiers used in the reference circuit were chosen for low temperature drift and very high gain linearities.

In the ±DC reference circuit a custom design resistor network is used in order that all critical resistors thermally track each other and so further reduce the thermal drifts in our generated reference.

The way this board is used in conjunction with the amplifier/attenuator board by the microprocessor to make a measurement is as follows (assuming autoranging mode of operation!).

The autoranging software selects the 1 kV range first on the amplifier/attenuator board and monitors the output of the underrange detector on the data conversion board.

It then ranges down until the output of the underrange detector is no longer true. Once the correct range has been found, the output of the solid state 3½ digit rms/DC converter is checked to set the upper 12 bits of the +DC reference and a 3½ digit result is shown on the front panel display.

Now the software selects the "ERROR" channel, the output of the integrator in the servo loop. (the integrator is in low res mode). If the integrator is pegged at either supply, the +DC reference is moved up (or down) 1000 ppm at a time (and this is done 6 times at most) until the output of the integrator is within the range of the 12 bit A/D converter. The reading from the integrator is used to set the remaining 6 bits on the precision reference and a 4½ digit result is shown on the display.

A cycle of 4 readings is now taken from the amplifier/attenuator board to make up 1 measurement in low resolution mode (with the DAC fixed).

1)	AC_{in}	these inputs are all compared to the
2)	+DC	+DC reference via the "ERROR"
3)	AC_{in}	channel output of the servo loop.
4)	-DC	

and V_{in} is computed by

$$V_{in} = \left[\frac{1+3}{2}\right] - \left[\frac{2+4}{2}\right]$$

A 5½ digit result is now displayed on the front panel. The DAC is reset to this new value and the integrator is put into high resolution mode. The same cycle of 4 readings is now taken to complete V_{in}, with a little more time allotted for the integrator to settle. The measurement result is shown as a 6½ digit result on the front panel.

The software will continue in this high resolution mode of measurement until it looses lock with the input, in which case it will back up one step at a time to reacquire a lock on the input, or if the input is overloaded, it will range up and restart the whole sequence.

If a DC signal is detected at the input to the amplifier/attenuator board, the usual 4 cycle measurement is modified somewhat in that only the same polarity signals are compared.

7.2.2 CENTRAL PROCESSING UNIT (CPU)

The internal central processing unit (Guildline Drawing Number 18221.02.04 and hereafter referred to as the CPU) in the model 7130A Digital AC/DC Transfer Standard is built up from conventional digital circuitry and is based on the Intel iAPX8088 processor.

After the power is turned on the first step the microprocessor performs is to fetch its first instruction from location OxFFFFO. The first section of code executed is a power on diagnostic routing which validates the correct operation of the processor, the on-board ROM, RAM, interrupt controller, the parallel port and the timer. The correct completion of this test is seen as all sixteen vacuum-fluorescent displays being on for about one second.

The power up self-tests are performed entirely on the CPU pcb and require a reasonably functional display as an output device. The detailed steps for the power up CPU self-test are as follows:

1. Initialize the 81C55.

2. Turn on all of the LED indicators on the display card
(including the audible indicator).

3. Perform a simple read/write test of the Ox100 bytes of RAM located in the 81C55.

4. Turn off the audible indicator on the display card.

5. Initialize the 82C59 interrupt controller, and place interrupt vectors into the tested memory.

6. Turn on all of the vacuum-fluorescent displays.

7. Turn on the seven segment LED displays.

8. Wait for one half second by counting interrupts from the 81C55 timer.

9. Turn off all the vacuum-fluorescent displays and LEDs on the display card.

10. Start execution of the system diagnostics program.

If any of the above steps should fail, the program will halt and the display indicators will remain as they have been set, hence giving an indication of the failure cause. As an example if step 1 should fail then all of the displays will be in their power up condition (randomly on or off) and the program will not proceed.

7.2.2.1 PROCESSOR

The microprocessor on the CPU pcb is a CMOS version of the iAPX8088 processor. The microprocessor has an 8 bit wide data bus and has a 20 bit wide address bus. The microprocessor can address up to 1 million bytes of memory. In addition there exists a separate address space which allows for up to 64k bytes of input/output devices.

All of the start up routines for the microprocessor self-test are contained in the on-board EPROM.

7.2.2.2 ADDRESS MAP

A portion of the addressing range of the microprocessor is used by devices located on the CPU pcb. These devices include memory (both RAM and ROM) as well as input/output devices.

Address	Function
0xFFFFF 0xF0000	On board Rom 64K bytes
0x00100 0x00000	On board RAM 256 bytes

Table 7.1: CPU Memory Address Allocations

Address	Function
0xFFFF	
0x0203 0x0202 0x0201 0x0200	82C52 Baud Rate Control Register 82C52 Modem Control Register 82C52 Control/Status Register 82C52 Data Register
0x0101 0x0100	82C59 Control Register 1 82C59 Control Register 0
0x0005 0x0004 0x0003 0x0002 0x0001 0x0000	81C55 Timer Count Register (Low Byte) 81C55 Timer Count Register (High Byte) 81C55 Port C 81C55 Port B 81C55 Port A 81C55 Control/Status Register

Table 7.2: CPU Input/Output Address Allocations

The chip selects for each of the devices on the CPU pcb are generated by decoding the control and address signals. This decode function is performed within the PAL decoder (U1) and the three input OR gate U12.

7.2.2.3 CLOCK GENERATOR

The CPU oscillator and microprocessor clocks are generated by the 82C84 clock chip which operates with a 14.745 600 MHz crystal. This operating frequency has been selected since it is an integer multiple of the frequency of the RS-232C baud rate. The microprocessor operates with a clock that has a 33% duty cycle (the waveform is high 33% of the time). This clock is easily generated by dividing the crystal frequency by three, hence the microprocessor clock frequency of 4.915 200 MHz. The peripheral clock (PCLK) frequency is one-half of the microprocessor clock rate and hence is 2.457 600 MHZ. The 82C84 IC generates a power-on reset which is compatible with the 80C88 timing requirements. In addition the 82C84 can generate a wait signal which will slow the rate of memory access for slow memories or peripherals.

Correct operation of the 82C84 can be verified with an oscilloscope by examining pin 8 to see a 33% duty cycle clock at 4.912 200 MHz (203.5 ns period). At pin 2 the oscilloscope should see a 2.467 60 MHz square wave (407 ns period) and at pin 10 an active high pulse with a period of about 1 second should be observed after power up.

7.2.2.4 MEMORY

The on-board memory of the CPU pcb is made up of 64k bytes of EPROM and 256 bytes of RAM. The EPROM is a 27C512 and the RAM is contained in the 81C55 chip.

Correct operation of the memory chips is verified by the diagnostic programs after power is applied.

7.2.2.5 INTERRUPT CONTROL UNIT

The interrupt control integrated circuit is a type 82C59. This chip has 8 interrupt inputs. When one of the interrupt inputs becomes active (rising edge) the interrupt controller interrupts the microprocessor. After the microprocessor completes its current instruction it acknowledges the interrupt. During the interrupt acknowledge cycle the interrupt controller generates an interrupt vector which the CPU uses to determine which section of code to execute.

Normally only the Tx ready and the Rx ready outputs of the 82C52 and the interrupts from the timer in the 81C55 are wired to the interrupt controller. All other interrupt sources come from external cards through the external bus interface.

Correct operation of the interrupt controller and the timer input is determined by the power on diagnostic routine.

7.2.2.6 RS-232C INTERFACE

The RS-232C interface on the CPU pcb is controlled by U5 which is an 82C54. This chip has a built in baud rate generator and the transmit and receive rates are derived from the PCLK. The internal logic levels on the CPU pcb are not compatible with the required signal levels of the RS-232C Interface ICs U6 and U9, which are type 1489 receivers and 1488 drivers respectively. These IC's translate the signal levels on the RS-232C lines to a level compatible with the CPU.

The RS-232C interface is configured as data communications equipment (DCE), hence pin 2 (TxD) of the RS-232C connector is an input. The RS-232C pinouts and signal directions are given in Table 5.3.

7.2.2.7 PARALLEL INTERFACE

The CPU parallel interface is part of U3 which is an 81C55. The parallel port is configured by the initialization software to operate with ports A and B as outputs and port C as an input.

Since the parallel port drives the display its correct operation can be readily determined by visually observing the display.

7.2.2.8 BUS INTERFACE

The CPU bus interface (for communication with the other pcb's in the system) is through the 96 pin DIN connector on the pcb. The configuration of the outer two pin rows (rows A and C) correspond to the pinout, level and timing requirements of the National Semiconductor Cimbus. The center row of contacts (row B) is configured to the Guildline extensions of this bus.

The address, data and control signals on the bus are driven by 74HC245 drivers/receivers. The address and control buses are bidirectional so that other bus masters (such as DMA controllers) can access the memory and input/output devices on the CPU pcb, however this feature is not used in the 7130A system.

7.2.3 KEYBOARD AND DISPLAY

The keyboard and display pcb (Guildline Drawing Number 18225.01.04) provide an input/output facility for the model 7130A CPU. The sixteen digit/sixteen segment vacuum-fluorescent display provides an easy to read general purpose output device. This display is augmented by a number of special purpose LED indicators and a four digit/seven segment LED display.

The circuitry on the display pcb is as simple as possible and the CPU is expected to generate all of the control signals necessary to refresh the display. The keyboard is a simple matrix keyboard and the CPU provides the scan functions.

7.2.3.1 VACUUM-FLUORESCENT DISPLAY

The vacuum-fluorescent display is a glass envelope with a heater and is similar to a classical vacuum tube triode. The heater requires 8 volts and each anode and cathode require 28 volts drive. The high voltage (28 V) is generated by a switching power supply module (ERG Inc. E705-.28V8.). The anodes and cathodes are driven by four Exar 6118P (U8, U9, U12 and U13) driver chips.

The scan rate selected for the 16 segments is 55 hertz. If the scan rate is slower, the display appears to flicker; if the scan rate is higher, the CPU cannot handle the processing load. In order for the CPU to illuminate a given segment of a given digit of the display it is necessary to perform several steps.

1. Put the data for the lower 8 segments onto the port A outputs.

2. Set port B bit 3 low (this disables the display) and set port B bits 0-2 to 5 (this causes U11 to sample the data output in step 1).

3. Set port B bits 0-3 to 0 (this causes U11 to hold the data output in step 1).

4. Put the data for the upper 8 segments onto the port A outputs.

5. Set port B bits 0-3 to 6 (this causes U7 to sample the data output in step 4).

6. Set port B bits 0-2 to 0 (this causes U7 to hold the data output in step 4), set port B bits 4-7 to the number of the digit to be lit (digit 0 is the rightmost display and digit 16 is the leftmost display), and set port B bit 3 to 1 to enable the display.

The circuitry associated with U14 (D1, R5, R6 and C1) is a retriggerable one-shot integrated circuit which will extinguish the vacuum-fluorescent display if the CPU is not periodically refreshing the display.

Correct operation of the vacuum-fluorescent display can be determined visually by observing its behaviour during the power up sequence.

7.2.3.2 LED INDICATORS

There is provision for up to 28 LED indicators on the display card however not all are used. The LEDs are arranged in four banks of eight LEDs. In order for the CPU to turn on any one of the LEDs the following steps must be taken.

1. Output the data for the bank of 8 LEDs to port A. All 8 LEDs must be set at the same time. If the data bit is zero for a given LED then that

LED will be turned ON.

2. Output the number of the LED bank on bits 0-3 of port B, where 1 selects U5, 2 selects U6, 3 selects U3 and 4 selects U2 (this causes the latch to sample the data output in step 1).

3. Output 0 on bits 0-3 of port B (this causes the LED bank to hold the data output in step 1).

It should be noted that there is no way for the CPU to read back the data on the LED displays therefore it is up to the CPU to maintain a list of current settings. The 7130A operational software keeps such a list and refreshes the LED latches as it refreshes the vacuum-fluorescent displays.

7.2.3.3 LED DISPLAY

The data from the LED display is presented to the inputs of the 7 segment decoder (U1) during S0, S1, S2 and S3 display times. The lower 3 parts of the LED display are standard 7 segment displays and are handled by the 7 segment decoder. The most significant digit can display +/-1. In order to display -1 the number 3 is output, +1 uses an 8 as output and 1 uses a 1 as output.

7.2.3.4 AUDIBLE INDICATOR

The audible indicator is wired the same as one of the LEDs, internally the indicator contains an oscillator so only power need be applied for a tone output.

7.2.3.5 KEYBOARD

The keyboard is a 4 ? 6 matrix. In order to scan the keys the microprocessor outputs one of the PB4-PB7 lines low and reads back the PC0-PC5 signals. Each of the four columns are scanned 60 times per second, and a key must be scanned as low on two consecutive scans to be considered pressed. This effectively debounces the switch action.

7.2.3.6 EXTERNAL TRIGGER CIRCUIT

The 4N26 opto-isolator (U15) is wired such that when pins 1 and 2 of J5 are shorted, a key (column 4, row 0) appears to be pressed. The same rules for scanning keys outlined in paragraph 8.4.5 apply to the opto-isolator input.

7.2.4 MEMORY INPUT/OUTPUT PCB

The memory input/output pcb (Guildline Drawing Number 18222.02.04 and hereafter called the MIO pcb) contains a GPIB bus interface, a twelve (12) bit digital to analogue converter, a parallel interface, and three (3) sockets which can each be configured as one of random access memory (RAM), electrically programmable read only memory (EPROM) or electrically erasable programmable read only memory (EEROM).

7.2.4.1 ADDRESS MAP

A portion of the addressing range of the microprocessor is used by devices located on the MIO pcb. These devices include memory (RAM or ROM) as well as input/output devices.

The chip select for each of the devices on the MIO pcb are generated by decoding the control signals and the address signals. This decode function is performed within the PAL decoder (U9) and the four input OR gate (U12).

Address	Size	Use/Device
0xFFFFF		
0x10000		
0x08000	32K bytes	On board ROM
0x04000	16K bytes	Available but not used memory
0x02000	8K bytes	On board Non-volatile memory
0x00100	8K bytes	On board RAM
0x00000	256 bytes	Not available (used on CPU card)
0xFFFF		
0xC037 0xC036 0xC035 0xC034 0xC033 0xC032 0xC031 0xC030		GPIB data register GPIB parallel poll register GPIB instrument status register GPIB address register GPIB auxilary command register GPIB mode register GPIB interrupt cause GPIB interrupt register
0xC013 0xC012 0xC011 0xC010		82C55 command/status register 82C55 port C 82C55 port B 82C55 port A
0xC001 0xC000		ADC567 high byte ADC567 low byte
0x0000		

Table 7.3: Address Allocations for Memory Input/Output Circuit Boards

7.2.4.2 MEMORY INTEGRATED CIRCUITS

A factory programmed ROM is installed at U5. The software contained in this memory is the invariant operating instructions for the instrument. A RAM memory device is installed at U10. This IC stores the temporary decision information created by the operator as various modes of operation are selected. This information is erased each time the power is applied or the instrument is reset. A RAM memory is also installed at U14, but it is mounted on a lithium battery powered smart socket that prevents data loss when power is turned off. In effect, the IC is thereby made to have a non-volatile memory. This IC is used to store calibration coefficients. The expected life of the lithium battery is approximately 10 years. When the battery is eventually depleted, the entire socket (Dallas Semiconductor part number DS1213) is replaced and calibration coefficients are re-entered. The circuit board has nine configuration pins located beside each memory (U5, U10 and U14). Jumper wires are connected between the pins to configure the circuit board for the memory IC's used. A map of the pin locations is shown in Table 7.4 (due to board space limitations, not all of the pins are labelled).

Memory Input/Output				
Pin 27				
WR	0	0	0	A14
Pin	0	0 ---	0	+5 V
A13	0	0	0	Pin 1
RDY				

Table 7.4: Map of Memory Configuration Pins

Note: Center pin is also +5 V.

Table 7.5 shows which pins are connected together for the three memories used.

Reference Designator	Part Number	Jumper	Memory Application
U5	Typically Intel 27C256 with Guildline Software	14 to 27	ROM with operating software (non-volatile)
U10	Toshiba TC5565PL or equivalent	WR to 27 26 to +5V	RAM with mode selection data (volatile)
U14	TC5565PL-12L in smart socket (see text)	WR to 27 26 to +5V	RAM with calibration coefficients (non-volatile)

Table 7.5: Memory Configuration Jumpers

A factory programmed logic array (PAL) is placed at U9. This IC manages the addressing of the memory and input/output (I/O) IC's.

Correct operation of the RAM devices on the MIO pcb is determined by the diagnostic software at the time power is applied. The correct operation of the ROM on the MIO pcb can be determined by using the checksum test under SOFCAL(TM) (see paragraph 8.2).

7.2.4.3 GPIB INTERFACE

The GPIB interface is made up of a Motorola 68488 GPIB controller (U11), two MC3447 drivers (U3 and U7) and a 74HC373 transparent latch (U2). The controller and drivers are connected to the GPIB bus as described in their data sheets and the 74HC373 transparent latch is connected to the bank of switches on the rear panel. These four chips form a complete functional GPIB interface.

The GPIB controller can be used with the direct memory access (DMA) interface. In the Model 7130A the DMA request is not used.

The GPIB interface hardware is tested by connecting a system controller to the GPIB bus and exercising the instrument from the bus. The switch register can be tested by examining the GPIB address with the SOFCAL(TM) (see paragraph 5.6) and toggling each of the switches while watching the instrument display.

7.2.4.4 PARALLEL INTERFACE

The parallel interface on the MIO pcb is controlled by an Intel 82C55 parallel port chip.

The operation of this chip is checked by the self-test software as part of the fast ADC check when power is first applied.

7.2.4.5 DIGITAL TO ANALOGUE CONVERTER

The MIO pcb has provision for a twelve (12) bit digital to analogue converter (Analogue Devices ADC567), which is used for a chart recorder output.

8 TROUBLE SHOOTING AND MAINTENANCE

8.1 PREVENTATIVE MAINTENANCE

Preventative maintenance consists of cleaning and visual inspection of the instrument. Preventative maintenance performed on a regular basis will prevent instrument breakdown and will improve the reliability of this instrument. The severity of the environment to which the 7130A is subjected determines the frequency of maintenance. A convenient time to perform preventative maintenance is prior to recalibration of the instrument.

The 7130A should be cleaned as often as operating conditions require. Accumulation of dirt in the instrument can cause overheating and component breakdown. Dirt on components acts as an insulating blanket and prevents efficient heat dissipation. It also provides an electrical conduction path which may result in instrument failure. The dress skins provide protection against dust in the interior of the instrument. Operation without these panels in place necessitates more frequent cleaning.

CAUTION

Avoid the use of chemical cleaning agents which might damage the plastics used in this instrument. In particular, avoid chemicals which contain benzene toluene, xylene or similar solvents.

Periodically inspect the instrument for general cleanliness. Remove the cover and clean out any accumulated dust with a soft brush, at the same time check for discoloured or damaged wiring. Check all screws and hardware for tightness.

8.2 NON VOLATILE MEMORY CHECKSUM

The model 7130A Digital AC/DC Transfer Standard contains a bank of memory into which certain operating data are written and stored. This memory is non-volatile (NV) in that data are kept even when power is removed from the instrument.

The integrity of the data in this memory is checked on power up and on an instrument RESET by comparing a stored checksum value with a calculated value. The two checksum values should agree. Occasionally, the stored checksum value may not agree with the newly calculated value (on RESET or Power Up) due to an operator error in entering new data into the NV RAM or when the NV RAM battery is low.

When this occurs the 7130A will display the message "EEROM DATA BAD" and will beep 10 times. This message will then be replaced with the alternating message prompts "CORRECT CHKSUM" or "0 - NO 1 - YES". Pressing the 1 (one) key (responding yes) will accept the NV RAM data as valid, causing the 7130A to calculate a new checksum, overwrite the old stored value accept NV RAM data, and continue to the measurement mode of operation.

Pressing the 0 (zero) key (responding NO) will cause the alternating messages "CLEAR EEROM ?" and "0 - NO 1 - YES" to appear in the display window. Responding NO by pressing the 0 (zero) key will cause the 7130A to accept the bad checksum and continue to the measurement mode of operation. Pressing the 1 (one) key will cause the 7130A to clear to zero all data stored in the NV RAM prior to continuing to the measurement mode of operation.

8.3 TROUBLESHOOTING

Symptom	Possible Cause
No Display	Instrument not plugged into source of AC power. Instrument not powered ON. Power Supply fuse blown. Cable between CPU Card and Display Card Loose. Faulty connector on cable between CPU and Display Card. Faulty Display Card. Faulty CPU Card. Faulty Power Supply Card.
Display On but No Keyboard Response	Keyboard switches locked out by remote controller. Cable between CPU and Display Card loose. Faulty Connector on cable between CPU and Display Card. Faulty Display Card.
Display On but only partial Keyboard Response	Cable between CPU and Display Card faulty. Faulty display Card.
Instrument Does not Beep when Key switch pressed GPIB No Response	Audible configuration switch on rear panel in closed position. Jumper E4 not installed on Display Card. Faulty Display Card. Incorrect address set on rear panel switches. Talk/Listen mode not selected. GPIB cable not connected to instrument properly. Cable from rear panel address switch to MIO card faulty. Faulty MIO Card. Faulty CPU Card.
RS-232C No Response	Incorrect baud rate set. Talk/Listen mode not selected. RS-232C Cable not connected to instrument properly. Cable from rear panel RS-232C Connector to CPU card faulty. Faulty CPU Card.

9 PARTS LISTS (can be ordered from Guildline)

Model 7130A

PL18850.02.02	General Assembly
PL18826.02.02	Data Conversion PCB
PL18848.01.02	Fibre Optic Interface PCB
PL19304.01.02	Analogue Interface PCB
PL18221.04.02	CPU PCB
PL18222.04.02	Memory I/O PCB
PL18225.03.02	Display PCB
PL19280.01.02	Amplifier/Attenuator PCB
PL19200.01.02	Analogue Sub Assembly

10 DRAWINGS (can be ordered from Guildline)

18850.02.02	General Assembly
18850.02.04	General Assembly Schematic
18826.02.02	Data Conversion PCB
18826.01.04	Data Conversion PCB Schematic
18848.01.02	Fibre Optic Interface PCB
18848.01.04	Fibre Optic Interface PCB Schematic
19304.01.02	Analogue Interface PCB
19304.01.04	Analogue Interface PCB Schematic
18221.03.02	CPU PCB
18221.03.04	CPU PCB Schematic
18222.03.02	Memory I/O PCB
18222.03.04	Memory I/O PCB Schematic
18225.03.02	Display PCB
18225.03.04	Display PCB Schematic
19280.01.02	Amplifier Attenuator PCB
19280.01.04	Amplifier Attenuator Schematic