Metrology

Interconnections and Guarding

DMC.D1.4.H3

INTERCONNECTIONS AND GUARDING

Importance of Correct Connections

The 4800, 4805 and 4808 calibrators have been designed for use as accurate sources for precision calibration. To match the external circuitry to their superior specifications, it is essential to take great care in making connections to the load.

Sources of Error

Thermal EMFs

Thermal EMFs can give rise to series (normal) mode interference, particularly for low voltage outputs or in situations where large currents have a heating effect at thermo-electric junctions. Draughts can also cause unbalanced cooling in an otherwise thermo-electrically balanced measuring circuit.

E-M Interference

Noisy or intense electric, magnetic or electromagnetic fields in the vicinity of the calibration set-up can disturb the measurement circuit.

Some typical sources are:

- Proximity of large electric fields
- Fluorescent lighting
- Inadequate screening, filtering or grounding of power lines
- Transients from local switching
- Induction and radiation fields of local E-M transmitters
- Excessive common mode voltages between source and load

The disturbances may be magnified by the user's hand capacitance. Electrical interference has greatest effect in high impedance circuits. Separation of leads and creation of loops in the circuit can intensify the disturbances.

Lead Impedance

The impedance of the connecting leads can cause significant voltage drops between the source and load, and generate adverse phasing effects, particularly if the leads are long or the current in them is high.

Lead Insulation Leakage

Leakage currents in lead insulation can cause significant errors in measurement circuits at high voltages. Some insulating materials suffer greater losses than others e.g. PVC has more leakage than PTFE.

Avoidance Tactics

Thermal EMFs

Screen thermal juntions from draughts.

Allow time for thermal equilibrium to be reached before taking readings.

Use conductors, joints and terminals with a good margin of current-carrying capacity.

Avoid thermo-electric junctions where possible.

e.g. Use untinned single-strand copper wire of high purity. Avoid making connections through Nickel, Tin, Brass and Aluminum. If oxidation is a problem use gold-plated copper terminals, and replace the terminals before the plating wears off. If joints must be soldered, low-thermal solders are available, but crimped joints are preferred. Use low-thermal switches and relays where they form part of the measuring circuits.

Balance one thermal EMF against another in opposition, where possible (switch and relay contacts, terminals, etc.).

E-M Interference

Choose a site as 'electrically quiet' as possible (a screened cage may be necessary if interference is heavy).

Suppress as many sources as possible.

Always keep interconnecting leads as short as possible, especially unscreened lengths.

Run leads together as twisted pairs in a common screen to reduce loop pick-up area, but beware of leakage problems and excessive capacitance.

Where both source and load are floating, connect I- to ground at the source to reduce common mode voltages.

Lead Impedance

Keep all leads as short as possible.

Use conductors with a good margin of current-carrying capacity.

Use Remote Sense and 4-wire connections where necessary to establish the calibrator's output specification at the load. Always use 4-wire connections for values of resistance below 1kΩ.

Lead Insulation Leakage

Choose low-loss insulated leads - PTFE is preferable to PVC.

When running leads together in screened pairs, avoid large voltages between leads in the same screen, especially if using PVC insulation.

Remote/Local Sense Configurations

The calibrator terminals are configured as follows:

Voltage ranges 100μV, 1mV, 10mV and 100mV
- Local sense only.

Voltage ranges 1V, 10V, 100V and 1000V
- user selects Local or Remote sense

Current ranges - Local sense only.

Resistance ranges
- Remote Sense gives 4-wire connection
- Local Sense provides 2-wire connection cap-ability.

The **Rem sense** key LED indicates the true connection:
Lit = Remote Unlit = Local

N.B. When changing to Ω function, the calibrator is automatically forced into **Remote Sense** for 4-wire operation.

Connections to the Load

General Considerations

The choice of connection method is influenced by several factors:

a. Loading Effects

4-wire connections should be used for low load impedances. For high impedance loads, 2-wire connections can be employed.

The ratio : $\frac{\text{Total Lead Resistance}}{\text{Load Resistance}}$

gives the approximate error for 2-wire connection at low frequencies.

e.g. Two 0.5Ω leads with a load of 100kΩ produce an error of approximately 10ppm.

At frequencies higher than about 100kHz, the error is also modified by reactive effects.

b. Noise and Output Level

Providing the E-M environment is reasonably quiet, interference due to noise pickup in the load connection is insignificant for outputs of more than about 100mV, so unscreened leads can be used. But at lower signal levels, or in noisier environments, it is advisable to use screened cable.

c. High Frequency Effects

i. Voltage.

Up to about 100kHz, for outputs above 100mV, it is possible to use pairs of unscreened wires, provided that the E-M environment is quiet. Twist or run leads together; keep length less than 1 meter.

Above 100kHz, both lead and load capacitances reduce the load impedance. Similarly, lead and load inductances combine to increase the load impedance with frequency (heavily reactive loads should be avoided). It is therefore advisable to make leads from low-capacitance coaxial or twin-axial cable. To avoid mutual coupling, sense and power leads should not run together in the same screen.

ii. Current

Above about 1kHz, with low output currents, high lead capacitance can introduce shunt errors. To reduce these errors, the leads should be kept as short as possible, and be of low-capacitance.

d. Common Mode Disturbances

When in Local Guard, the guard shields and tracks for the sense circuitry are connected internally to 'I-', the low impedance terminal of the calibrator's output power source. This classical connection effectively guards out internal common mode disturbances. To reduce external disturbances it is advisable to make only one ground connection to the measurement circuit, and in the case of a guarded DMM, to make use of its external guard facilities. Also, where a line-powered load (such as a DMM being calibrated) has a ground connection, it should be to the same line ground as the calibrator.

DANGER

THE 4800, 4805 and 4808's OUTPUT CIRCUITS ARE NOT INTERNALLY CONNECTED TO GROUND. USERS ARE STRONGLY ADVISED TO CONNECT Lo OR I- EXTERNALLY TO GROUND (PREFERABLY AT THEIR COMMON JUNCTION), WHEN THE CALIBRATORS ARE TO BE USED ON THE 100V OR 1000V RANGE. THIS ELIMINATES THE RISK OF Lo AND I- FLOATING TO HIGH VOLTAGE.

Suggested Lead Connections

Because of:

a. the variety of environmental conditions and loads likely to be encountered when using the calibrator

b. the extensive set of combinations of outputs from the instrument

c. the accuracy required

it is unrealistic to describe a definitive 'best' general method of connection to the load.

Combinations of the above factors can lead to conflicting requirements, and users may be faced with a choice between methods. In these cases it is sometimes necessary to arrive at a compromise solution by setting priorities.

Six suggestions for connecting the 4800, 4805 or 4808 calibrators to a load are illustrated on the following pages 4-8 to 4-13. Each has found use with the combination of factors described, and together they cover the majority of predicted requirements.

Typical Lead Connections

Voltage and Resistance Outputs

Simple 2-wire Connection

Use for many applications where:

The voltage drop in the leads is insignificant.
The E-M environment is 'quiet'.
External common-mode voltages are insignificant.

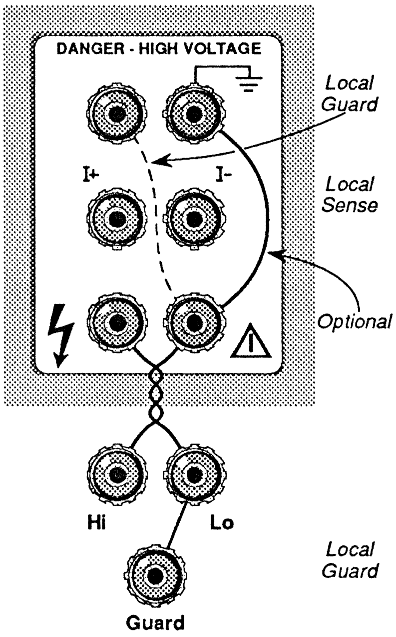
Use for measurements in the following ranges:

Voltage	DCV ≥ 100mV
	ACV ≥ 100mV
Frequency	F < 100kHz
Resistance	1kΩ ≤ R < 1MΩ

Select Local Sense and Local Guard.

Keep leads as short as possible(no longer than 1 meter). Twisted pair is preferable.

Calibrator Terminals



Load Terminals

* CAUTION

ALL LEADS AND CABLES MUST BE PROOFED TO AT LEAST 2kV.

ON 100V/1000V RANGES, GROUND THE Lo LINE FOR SAFETY

Two-wire Connection using Coaxial Cable

Use where:

The voltage drop in the leads is insignificant.
Sensitive measurements are being made.
The E-M environment is relatively 'noisy'.
External common-mode voltages are insignificant.

Use for measurements in the following ranges:

Voltage	DCV ≥ 10μV
	ACV > 90μV
Frequency	F ≤ 1MHz
Resistance	Not appropriate

Select Local Sense and Local Guard.

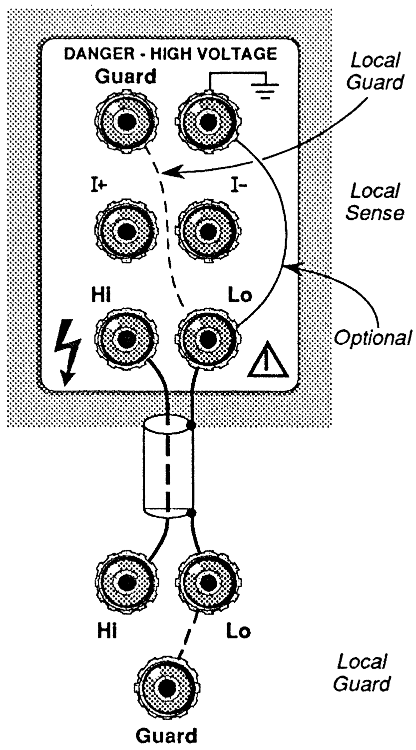
Keep leads as short as possible (no longer than 1 meter).

* CAUTION

ALL LEADS AND CABLES MUST BE PROOFED TO AT LEAST 2kV.

ON 100V/1000V RANGES, GROUND THE Lo LINE FOR SAFETY

Calibrator Terminals



Load Terminals

Screened 2-wire Connection

Use where:

Sensitive measurements are being made.
The E-M environment is relatively 'noisy'.
External common-mode voltages are significant.

Use for measurements in the following ranges:

Voltage	DCV ≥ 10μV
	ACV > 90μV
Frequency	F ≤ 1MHz
Resistance	1kΩ ≤ R < 1MΩ

Select Local Sense and Local Guard.

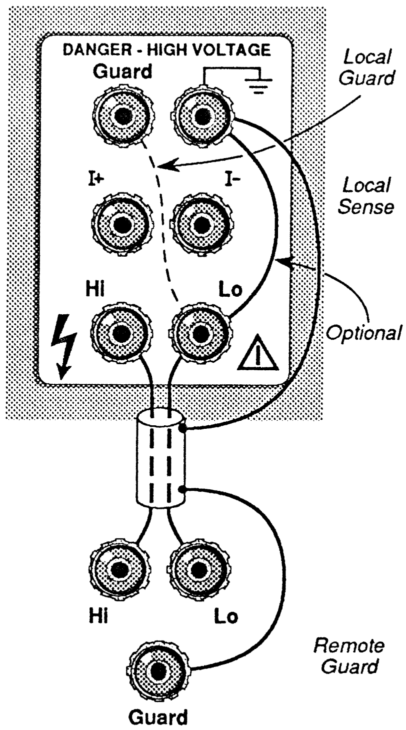
Keep leads as short as possible (no longer than 1 meter).

* CAUTION

ALL LEADS AND CABLES MUST BE PROOFED TO AT LEAST 2kV.

ON 100V/1000V RANGES, GROUND THE Lo LINE FOR SAFETY

Calibrator Terminals



Load Terminals

Screened 4-wire Connection Using Coaxial Cable.

Use where:

The load resistance is low enough to cause a significant voltage drop in the output connection.
Sensitive measurements are being made.
The E-M environment is relatively noisy.
External common-mode voltages are significant.

Use for measurements in the following ranges:

Voltage	DCV ≥ 90mV
	ACV ≥ 90mV
Frequency	F ≤ 1MHz
Resistance	Not appropriate

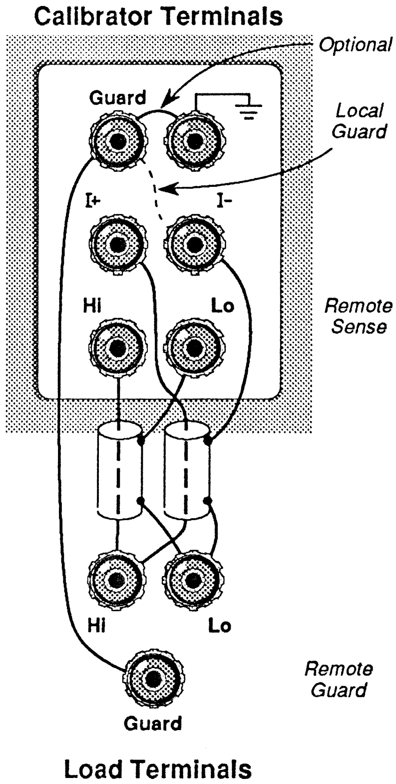
Select Remote Sense and Local Guard.

Keep leads as short as possible (no longer than 1 meter).

*** CAUTION**

ALL LEADS AND CABLES MUST BE PROOFED TO AT LEAST 2kV.

ON 100V/1000V RANGES, GROUND THE Lo LINE FOR SAFETY



Alternative Screened 4-wire Connection Using Twin-axial Cable.

Use where:

The load resistance is low enough to cause a significant voltage drop in the output connection.
Sensitive measurements are being made.
The E-M environment is relatively noisy.
External common-mode voltages are significant.

Use for measurements in the following ranges:

Voltage	DCV ≥ 90mV
	ACV ≥ 90mV
Frequency	F ≤ 1MHz
Resistance	Not appropriate

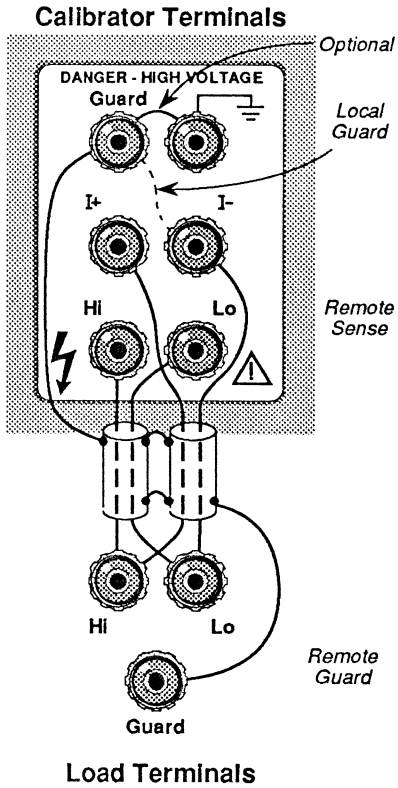
Select Remote Sense and Local Guard.

Keep leads as short as possible (no longer than 1 meter).

*** CAUTION**

ALL LEADS AND CABLES MUST BE PROOFED TO AT LEAST 2kV.

ON 100V/1000V RANGES, GROUND THE Lo LINE FOR SAFETY



Current Outputs

Simple 2-wire Connection

Use for the majority of applications where:

The E-M environment is 'quiet'.
External common-mode is insignificant.

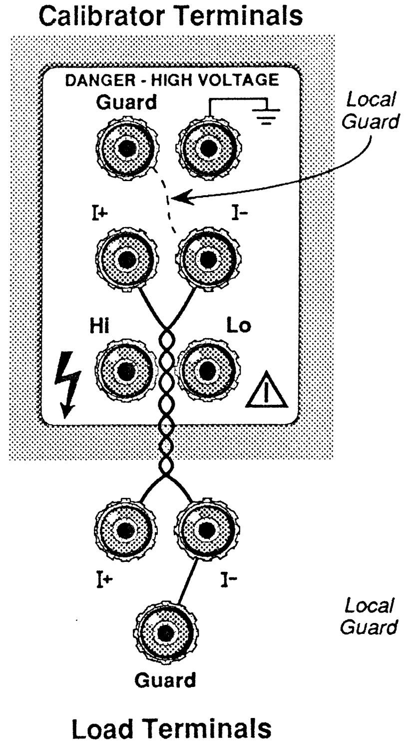
Use for measurements in the following ranges:

Current	DCI > 1mA	
	ACI > 100mA	
Frequency	F < 5kHz	

Local Sense selected automatically.

Select Local Guard.

Keep leads as short as possible (no longer than 1 meter). Twisted pair is preferable.



Screened 2-wire Connection

Use where:

Sensitive measurements are being made.
The E-M environment is relatively 'noisy'.
External common-mode is significant.

Use for measurements in the following ranges:

Current	DCI > 9µA	
	ACI > 9µA	
Frequency	F < 5kHz	

Local Sense selected automatically.

Select Local Guard.

Keep leads as short as possible (no longer than 1 meter). Co-axial or Twin-axial is preferable.