USER'S HANDBOOK

4000
4000A

datron
INSTRUMENTS

AUTOCAL STANDARD

USER'S HANDBOOK

for

THE DATRON 4000 & 4000A
AUTOCAL STANDARD

850050 Issue 3 (JULY 1987)

For any assistance contact your nearest Datron Sales and Service office.
Addresses can be found at the back of this handbook.

Due to our policy of continuously updating our products, this handbook may contain minor differences in specification, components and circuit design to the instrument actually supplied. Amendment sheets precisely matched to your instrument serial number are available on request.

DANGER

HIGH VOLTAGE

THIS INSTRUMENT IS CAPABLE OF DELIVERING

A LETHAL ELECTRIC SHOCK!

FRONT or REAR terminals carry the Full Output Voltage.

THIS CAN KILL!

Guard terminal is sensitive to over-voltage

It can damage your instrument!

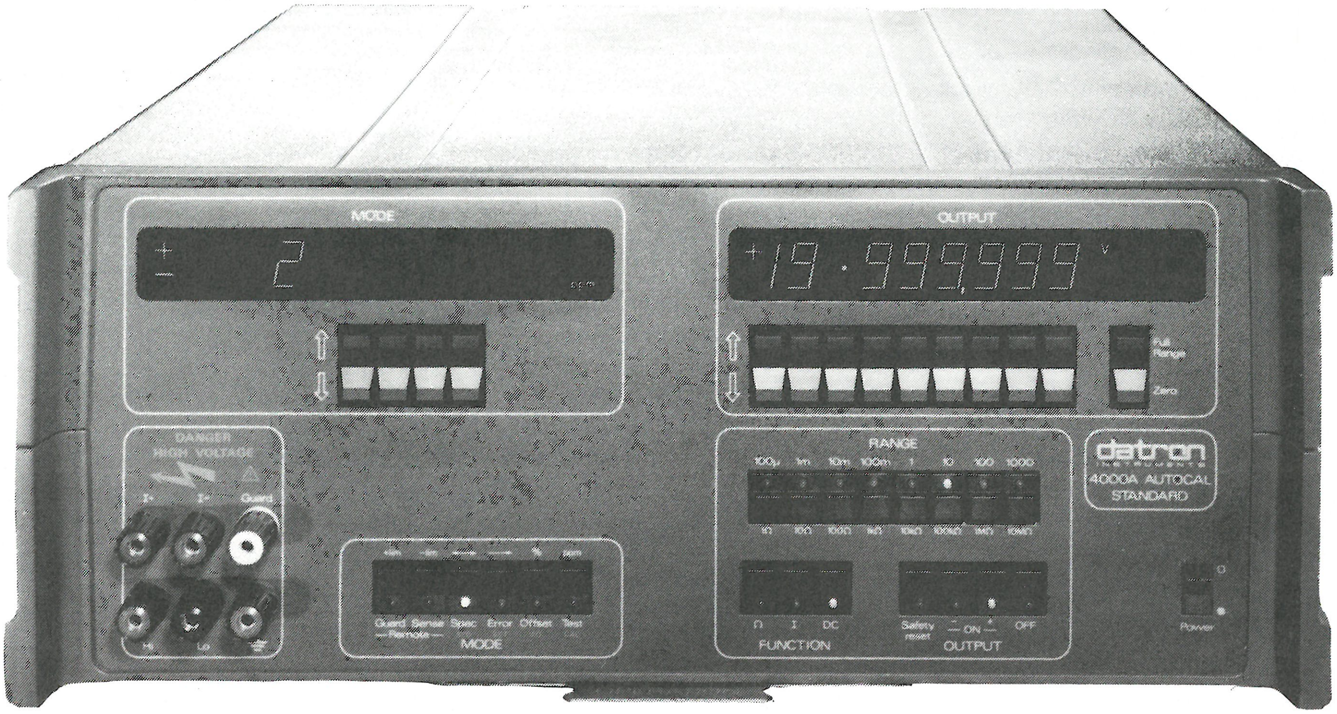
Unless **you** are **sure** that it is **safe** to do so,

DO NOT TOUCH the **I+ I− Hi** or **Lo leads** and **terminals**

DANGER

CONTENTS

SECTION 1 THE DATRON 4000 AND 4000A AUTOCAL STANDARDS



General View of Datron 4000A Autocal Standard

Introduction

The Datron 4000 and 4000A Autocal Standards are high-precision calibrators which feature exceptionally high stability and full systems capability. They are characterized by a wide-range coverage of DC Voltage, DC Current and Resistance functions in a single unit.

Both versions incorporate a reference module containing precision temperature-compensation elements, maintaining a high accuracy specification over the ambient range of 23°C ±5°C. The 4000A achieves a higher level of stability and accuracy by the use of super-selected components and ultra-stable gain-defining resistors. The "Autocal" feature ensures that their 24-hour specifications are usable realities, not merely figures of merit.

Complex manual operations (such as calibration of high-quality digital multimeters) are simplified by the use of a microprocessor for control management. The IEEE 488 interface provides a comprehensive remote programming capability, featuring programmed calibration of the instruments themselves.

Except where differences are noted; all the facilities and operation details described in this Handbook for the 4000, apply equally to the 4000A.

Standard Facilities

DC Voltage Ranges. The basic instrument provides DC voltage calibration facilities in eight decade ranges from ±100μV to 1000V. 100% overrange is incorporated except on 1000V range, when the output is limited to 1200V.

Resolution and Accuracy. The maximum resolution is 7½ digits with a unique facility for displaying the specified accuracy of any output voltage. The 4000 and 4000A specifications are in Section 6.

Autocal. All Datron AUTOCAL instruments are designed to make the removal of the covers for calibration unnecessary, as full calibration of all ranges and functions can be carried out from the front panel.

Accidental or unauthorised use of the calibration routine is prevented by a key-operated switch on the instrument rear panel. The procedure for calibrating this instrument is contained in Section 8.

Output Deviation. A user may deviate the output voltage from the output display value by introducing a gain 'Error' within the range ± 9.9999%. Additionally, the output may be 'Offset' by up to ± 2% of the range in use, or 200μV, whichever is greater.

Self-test. On power-up, the internal calibration memory is automatically checked. At any time when the output is off, a user may conduct a sequenced test of the displays, keyboard, safety circuitry and Safety Reset function.

Remote Sense. The specified output voltage may be sensed at the load by selection on the keyboard and the use of 4-wire connections.

Remote Guard. This facility allows the instrument's internal guard shields to be externally connected.

Message Readout. Messages to the user are presented on the MODE display. Two main groups are:

Fail: when an internal fault condition has been detected.

Error: when a user has selected a task which is outside the instrument's capability.

Systems Use. The instrument can form part of a system by means of the IEEE 488 standard digital interface. The method of connecting to the system, and programming details for the system controller can be found in Section 5.

SAFETY

For protection of the user, safety trip circuits are fitted to switch the Output OFF in the event of instrument failures which might generate dangerous Output voltages.

UNDER NO CIRCUMSTANCES SHOULD USERS TOUCH ANY OF THE OUTPUT, SENSE OR GUARD TERMINALS UNLESS THEY ARE FIRST SATISFIED THAT NO DANGEROUS VOLTAGE IS PRESENT.

Optional Facilities

The capability of the 4000 may be extended by the addition of one or more of the following options:

Option 20: 4-wire resistance Calibrator (a single precision resistor is connected to the output terminals for each front panel RANGE key)
DC current Calibrator (max output 2 Amp).

Option 41: Rear Output (as a factory-wired alternative to front panel output).

Accessories

The instrument is supplied with the following accessories:

Description	Part Number
Power Cable	920012
Set of Calibration keys	700068
User's Handbook	850050
Calibration and Servicing Handbook	850055

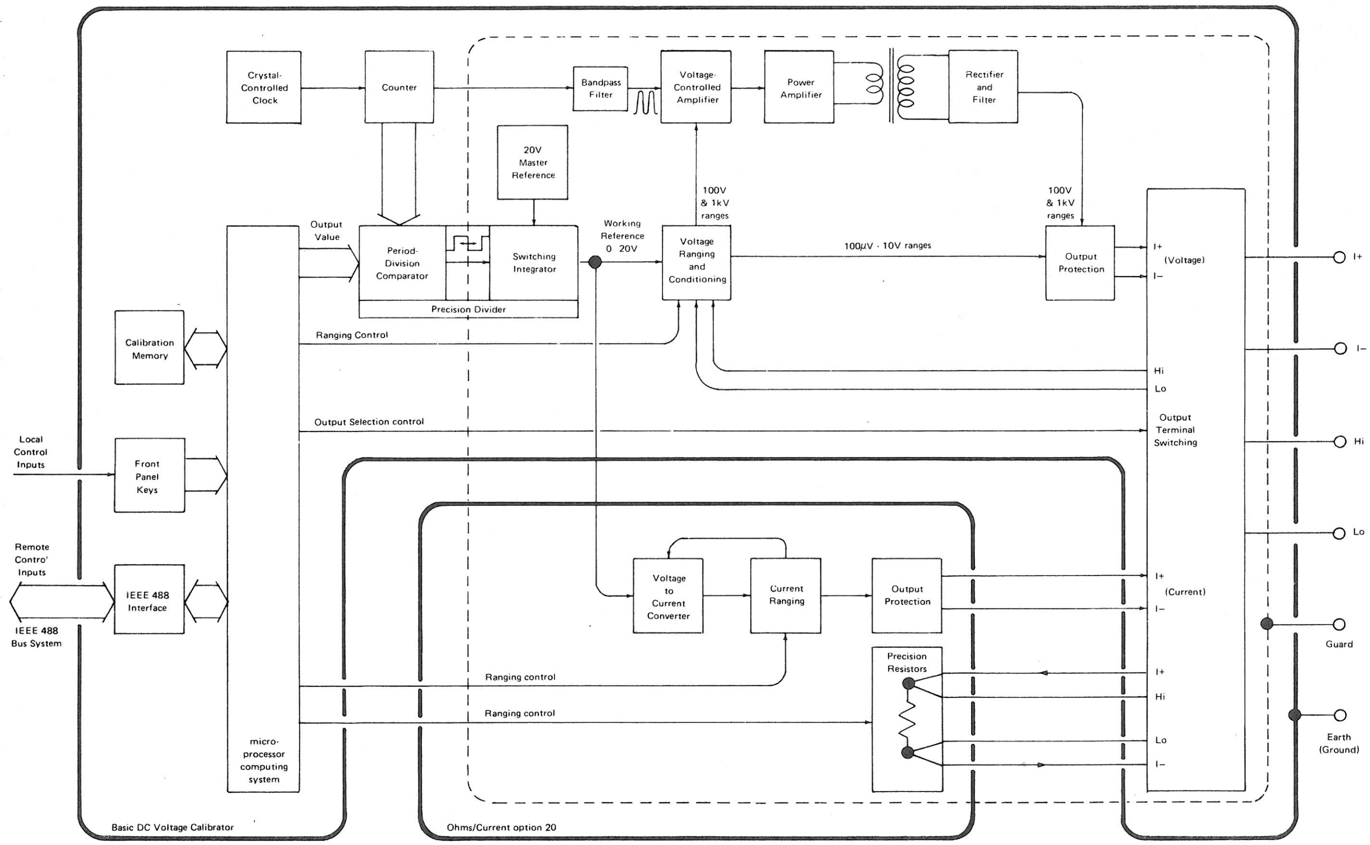
In addition the following accessories are available for use with the 4000 instrument:

Description	Part Number
RMK Rack mounting kit (Option 90)	440094
de luxe lead kit	440070

Additional Documentation

The Calibration and Servicing Handbook contains information required to adjust and service the 4000 instrument. It contains detailed descriptions of the circuits, trouble-shooting diagrams, calibration procedures, parts lists and circuit diagrams.

Principles of Operation



Simplified Functional Diagram. The diagram illustrates the division and flow of functions within the 4000 in general terms.

Inputs. The 6802 microprocessor system accepts inputs from three main sources:–

i) The front panel keys give full control of the functions.

ii) In remote operation, the IEEE 488 bus messages assume control instead of instructions from the keyboard.

iii) The values input from keyboard or bus are modified by corrections stored in the non-volatile calibration memory. These account for the accumulated gain and offset errors of the analogue circuitry, updated at the most recent calibration.

After processing, the computing system changes the output of the instrument to respond to the input instructions.

Reference Voltages. The fundamental accuracy of the 4000 is established by a "Master" Voltage Reference of 20 Vdc. From this, a precision divider derives a "Working Reference" voltage, variable between 0 and ± 20V. The value of the working reference voltage depends on digital inputs from front panel keys and calibration memory.

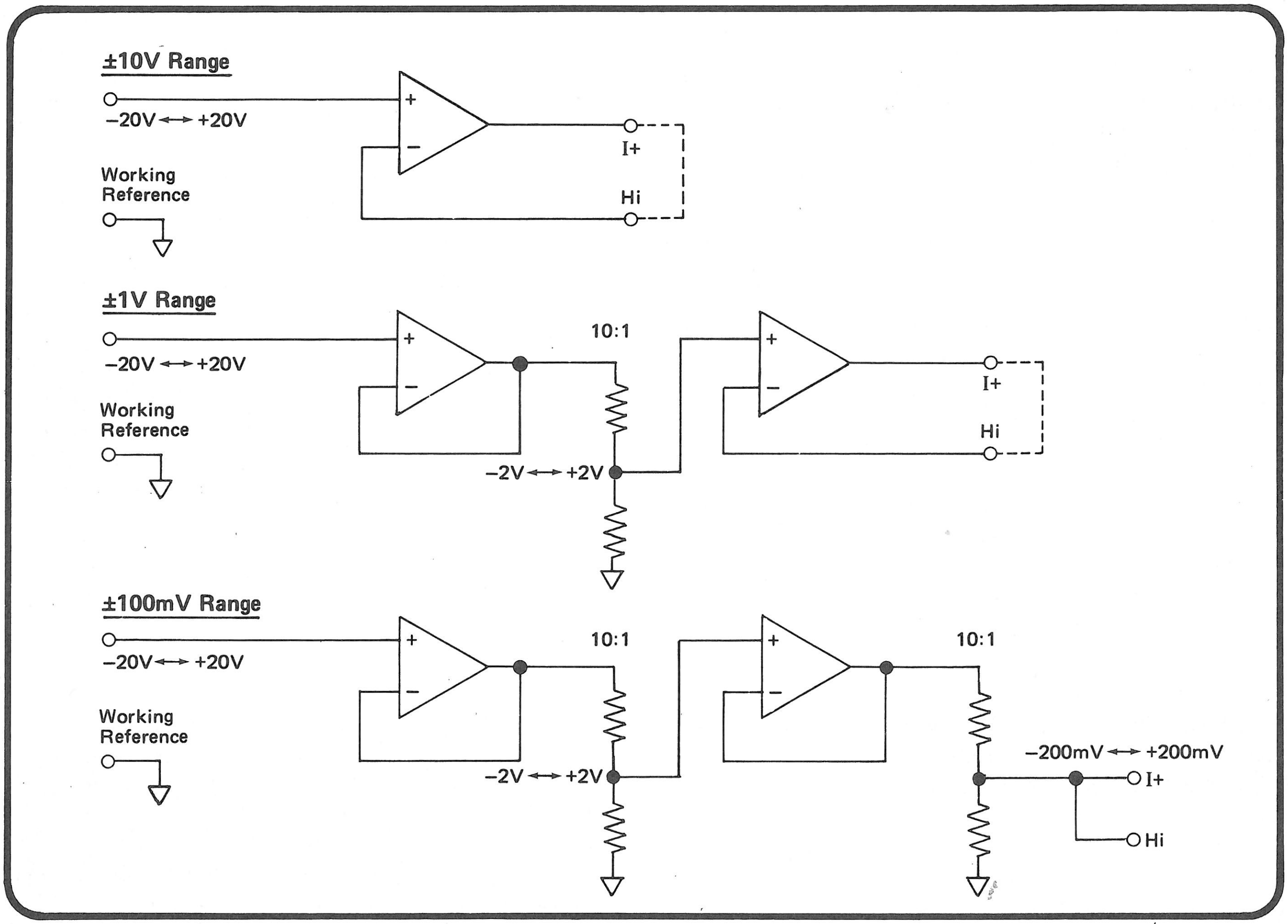
Precision Divider. The out-guard section is a 25-bit, processor-controlled, crystal-stabilized comparator which produces an accurately-variable mark-space-ratio square wave. The ratio mark : period represents the selected output value as the square wave is transferred into guard to chop the Master Reference voltage. The resultant square wave is integrated by a 7-pole active low-pass filter with high rejection at the chopping frequency, to generate the Working Reference.

Thus the working reference is a stable DC voltage, accurately variable at high resolution between 0 and +20V.

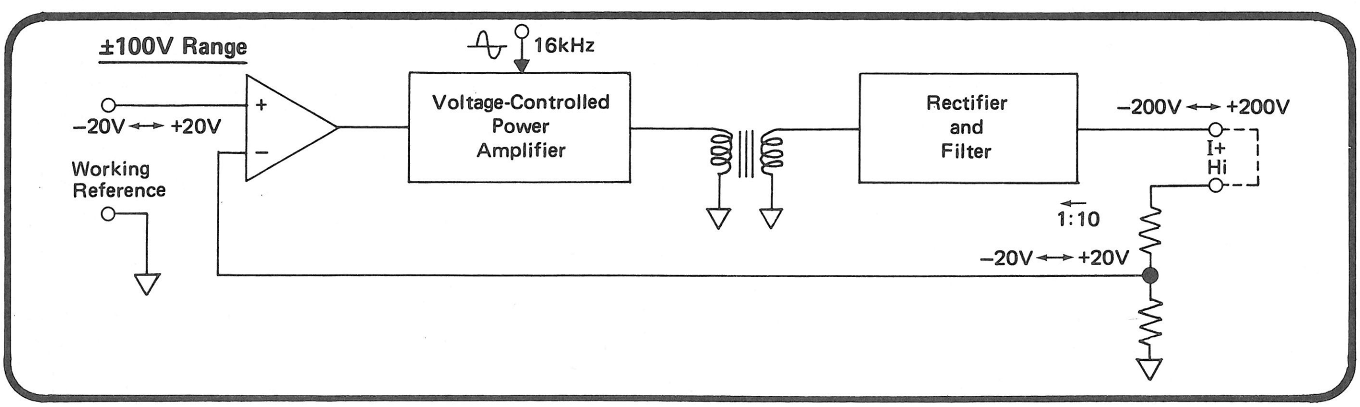
Low Voltage Ranges (100μV – 10V FR). The basic range of the 4000 is ± 10V Full Range (± 19.999999V Full Scale), derived directly from the working reference. The 1V and 100mV ranges are achieved by attenuation:

The 100mV range attenuator is also used for 10mV, 1mV and 100μV ranges, and the digital input to the precision divider is scaled to provide the correct working reference values:

Range	Working reference values
10mV	–2V ↔ +2V
1mV	–200mV ↔ +200mV
100μV	–20mV ↔ +20mV



High Voltage Ranges (100V and 1000V). The 100V range employs step-up AC transformation to provide output DC voltages in the range –200V ↔ +200V. The sense signal is attenuated by 10:1 before being compared with the –20V ↔ +20V working reference to control the output voltage value:



On the 1000V range the step-up ratio is increased and the attenuation ratio is 60:1, so that the −20V ↔ +20V working reference produces outputs between −1200V ↔ +1200V Full Scale. The digital input to the precision divider is scaled for the −20V ↔ +20V working reference to represent **OUTPUT** display selections of −1200V ↔ +1200V.

Output Switching. In addition to switching between functions, the output switching circuits isolate terminals on **OUTPUT OFF**. Remote/Local Sense and Guard switching is incorporated.

Autocalibration. With the calibration enable key switch on the rear panel turned to the **ENABLE** position, the calibration procedure (see Section 8) may take place during which measurements are taken and the results stored in the non-volatile memory. These values are then used as reference for future use when the instrument is in the normal **RUN** mode.

Processor. The internal control of the instrument is performed by a 6802-series microprocessor using 20K bytes of program memory. With the exception of the **Power** ON/OFF switch and **Safety Reset** key all front and rear panel operating controls provide an input to the microprocessor, which translates the information to command the analogue and calibration sections.

1K bytes of memory are used for stack and work space, and 256 bytes are made non-volatile by a battery-powered back-up supply, to act as a calibration store. The processor also controls the display, the IEEE 488 Interface Bus and the operation of the restart and error circuitry.

Option 20 Current Output

On changing functions to Current, the Working Reference voltage is switched to drive a voltage-to-current converter, and the **OUTPUT** display legend is changed to μA, mA or A. Over-voltage protection is provided, and the Output lines are fused.

Option 20 Resistance

Remote Sense. One of a set of eight precision resistors is internally 4-wire connected to the **I+**, **I−**, **Hi** and **Lo** terminals by operation of each **RANGE** key. Simultaneously the 4-wire calibrated value of the resistor is displayed (**OUTPUT** display). Pressing the **OUTPUT Zero** key connects a true 4-wire short to the terminals, and the **OUTPUT** display indicates zero. This zero display value cannot be recalibrated.

Local Sense (Remote Sense LED Unlit). The connections to the resistor remain the same, but the displayed value includes the resistance of the connections from the Hi and Lo terminals to the resistor. The arrangement provides a calibrated 2-wire facility with external connection to the **Hi** and **Lo** terminals. The **Zero** key shorts the **Hi** and Lo terminals, in this case the resistance between the terminals is displayed and may be recalibrated. When **Ω** is selected from any other function, the 4000 is forced into **Remote Sense**, but this may be deselected for 2-wire operation.

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DANGER

SECTION 2 INSTALLATION

This section contains information and instructions for unpacking and installing the Datron 4000.

Unpacking and Inspection

Every care is taken in the choice of packing materials to ensure that your equipment will reach you in perfect condition.

If the equipment has been subject to excessive mishandling in transit, the fact will probably be visible as external damage to the shipping carton. In the event of damage, the shipping container and cushioning material should be kept for the carrier's inspection.

Unpack the equipment and check for external damage to the case, sockets, keys etc. If damage is found notify the carrier and your sales agent immediately.

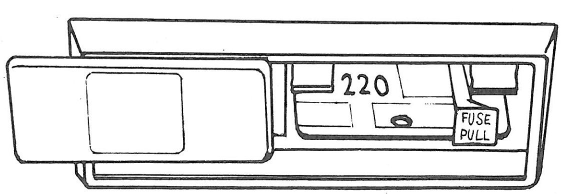
Standard accessories supplied with the instrument are as described in Section 1.

Preparation for Operation

DANGER

> THIS INSTRUMENT IS CAPABLE OF DELIVERING A LETHAL ELECTRIC SHOCK. THE I+, I–, Hi and Lo TERMINALS ARE MARKED WITH ⚡ SYMBOL TO WARN USERS OF THIS DANGER.
> UNDER NO CIRCUMSTANCES SHOULD USERS TOUCH ANY OF THE FRONT TERMINALS UNLESS THEY ARE FIRST SATISFIED THAT NO DANGEROUS VOLTAGE IS PRESENT.

Power input. The recessed **POWER INPUT** plug, **POWER FUSE** and **Line Voltage Selector** are contained in an integral filtered module at the centre of the rear panel.

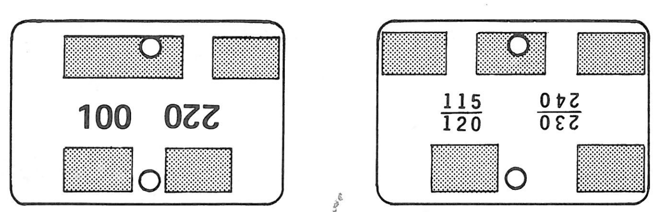


The protective window allows the fuse rating and line voltage selection to be inspected with the power socket connected. This window slides to the left once the socket has been disconnected, for access to the fuse and voltage selector printed circuit board.

Power cable. The detachable supply cable, comprising two metres of 3-core PVC sheath cable permanently moulded to a fully-shrouded 3-pin socket, fits in the **POWER INPUT** plug recess, and should be pushed firmly home.

The supply lead should be connected to an earthed outlet ensuring that the earth lead is connected. Connect Brown lead to Line, Blue lead to Neutral, and Green/Yellow lead to Earth (Ground).

Line voltage. The 4000 is operative within the line voltage ranges 100/120/220/240 ± 10%. 50 or 60Hz. To accommodate the ranges, a small PC selector board is housed beneath the **POWER FUSE.**



Operating Voltage Selection

Ensure **POWER CABLE** removed
Slide window to left to reveal fuse and PC selector board
Draw fuse extractor to left and remove fuse
Remove PC selector board and rotate until desired voltage is on left side of upper surface.
Reinsert selector board firmly into the module slot. The desired voltage is visible in cut-out below fuse.
Return fuse extractor to normal position.
Insert appropriate **POWER FUSE** (see below)
Slide window to right and insert **POWER CABLE.**

Power Fuse. The fuse rating is:
3.0A on 220/240V ranges
6.25A on 100/120V ranges
It is located behind the window in the **POWER INPUT** module on the rear panel, and should be of the anti-surge type.

WARNING
MAKE SURE THAT ONLY FUSES WITH THE REQUIRED RATED CURRENT AND OF THE SPECIFIED TYPE ARE USED FOR REPLACEMENT. THE USE OF MENDED FUSES AND THE SHORT CIRCUITING OF FUSE-HOLDERS SHALL BE AVOIDED, AND RENDERS THE WARRANTY VOID.

Bench Mounting

The instrument is fitted with six rubber-covered plastic feet. It is intended to stand flat on a bench, positioned so that the cooling-air inlet and exhaust apertures are not obstructed.

Rack Mounting

Option 90 permits the instrument to be mounted in a standard 19 inch cabinet.

The method of fitting this option is described below, but on no account should the upper and lower covers be removed.

To Fit Option 90:

Note that the 4000 is designed to be supported at front and rear. **AT NO TIME** should the 4000 be supported only by the front brackets.

Remove the two rear spacers from the case sides by releasing six screws.

Fit the two-rack mounting slides to the rear of the case sides and secure using six of the shorter screws in the option kit.

N.B. The slides may be reversed to give rearward extension.

Fit the two front rack-mounting ears using six of the shorter screws in the option kit.

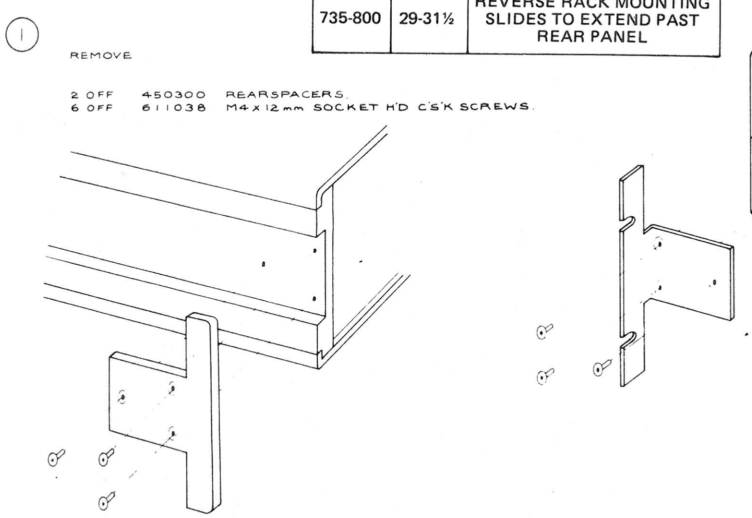
Fit the two rear rack-mounting ears to the rear of the cabinet, with tongues facing forward. In shallow cabinets it may be necessary to trim the tongue.

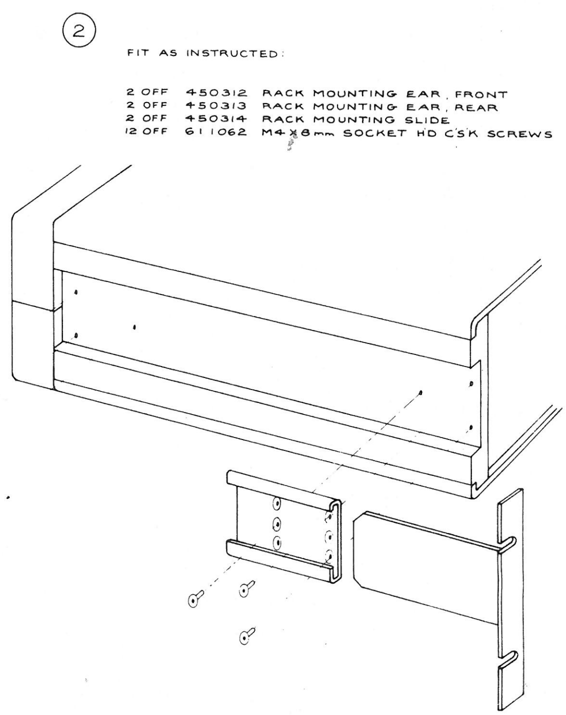
CAUTION. Assistance is required to fit the 4000 into the cabinet.

Lift the 4000 into position in the cabinet, locate the tongues in the slides, and carefully slide backwards until the front ears butt up against the cabinet front. Secure the front ears to the cabinet.

SUITABLE RACK DEPTHS

DEPTH mm	DEPTH ins	NOTES
< 635	< 25	SHORTEN REAR RACK MOUNTING EARS
635-735	25-29	FIT AS SHOWN BY DRAWING
735-800	29-31½	REVERSE RACK MOUNTING SLIDES TO EXTEND PAST REAR PANEL



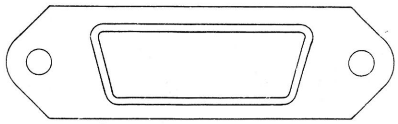


Rack Mounting — Fitting of Option 90

Connectors and Pin Designations

IEEE 488 Input/Output Socket J27. The IEEE input/output is a 24-way connector that is directly compatible with the IEEE defined system.

Pin Layout



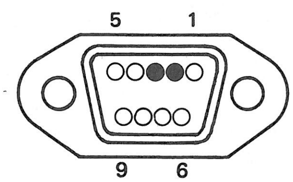
24-Pin Socket

Pin Designations

J27 Pin No.	Name	Description
1	DIO 1	Data Input Output Line 1
2	DIO 2	Data Input Output Line 2
3	DIO 3	Data Input Output Line 3
4	DIO 4	Data Input Output Line 4
5	EO1	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	SHIELD	Screening on cable-connected to 4000 Safety Ground
13	DIO 5	Data Input Output Line 5
14	DIO 6	Data Input Output Line 6
15	DIO 7	Data Input Output Line 7
16	DIO 8	Data Input Output Line 8
17	REN	Remote Enable
18	GND 6	Gnd wire of twisted pair with DAV
19	GND 7	Gnd wire of twisted pair with NRFD
20	GND 8	Gnd wire of twisted pair with NDAC
21	GND 9	Gnd wire of twisted pair with IFC
22	GND 10	Gnd wire of twisted pair with SRQ
23	GND 11	Gnd wire of twisted pair with ATN
24	GND	4000 Logic Ground (Internally connected to 4000 Safety Ground)

Socket J53 External Reset. This D-type plastic socket is located next to the cooling air intake filter. It may be used to input an external reset to restore the 4000 to its power-up state of DCV, 10V range etc. if required.

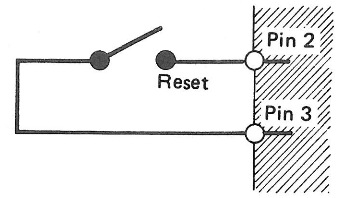
Pin Layout



Pin Designation

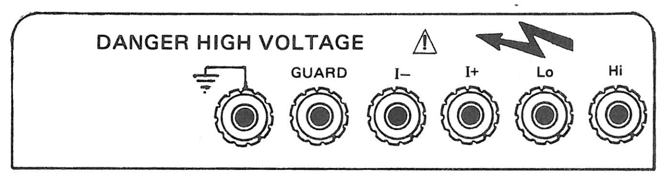
J53 Pin No	Signal
1	Not used
2	Reset Common
3	Reset line
4–9	Not used

External Reset Switch Wiring



Rear Output Terminals

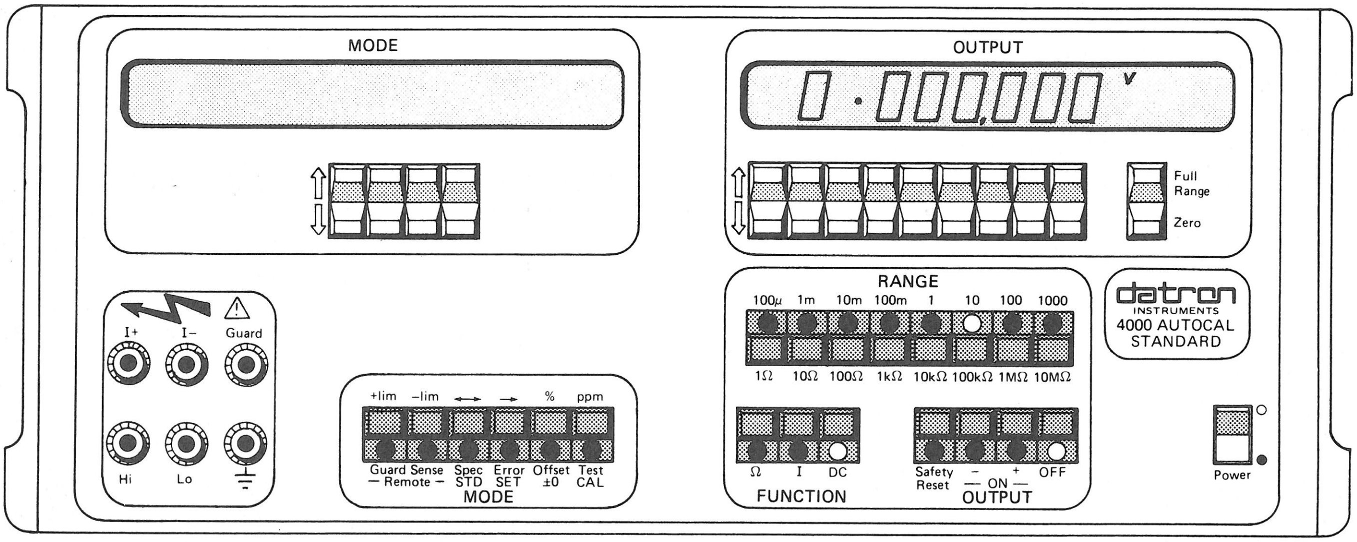
The 4000 is fitted with either six front panel output terminals or six rear output terminals. The Rear Output alternative is fitted at the customer's request only at manufacture:



The functions of the six terminals are identical to those normally fitted on the front panel, and the external leads are connected in the same way (See Section 4 for details).

SECTION 3 OPERATING CONTROLS

Front Panel Power-up state



The controls are outlined in blocks, left and right, associated with the appropriate display. The right-hand blocks generally deal with function and output definition, whereas the left-hand blocks are concerned with mode and terminal configurations.

Front Panel Keys

All user commands from front panel keys (except **Safety Reset**) are executed through main program firmware. A Key LED lit signifies that conditions are valid for the selected operation, and not merely that the key has made contact.

Power Switch

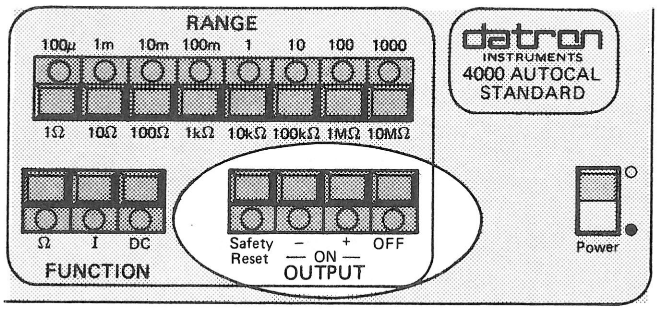
WARNING

THE POWER SWITCH SHOULD NOT BE SET TO ON UNTIL THE LINE VOLTAGE AND POWER FUSE RATING HAVE BEEN SELECTED AS DETAILED IN SECTION 2 INSTALLATION

When set to the (OFF) position, the 2-pole Power switch isolates the instrument from the supply. When switched to (ON) the instrument powers up, runs a self-test program and is configured into the following state:

OUTPUT	OFF
FUNCTION	DC
RANGE	10
OUTPUT DISPLAY	0.000,000 V
MODE DISPLAY	Blank
MODES	Not selected
Guard	Local connection
Sense	Local connection
Key LEDs Lit	OUTPUT OFF, DC, 10.

Output Switching



OUTPUT ON/OFF. With the **OUTPUT OFF**, **I+**, **I–**, **Hi** and **Lo** terminals are isolated from the internal circuitry, regardless of **RANGE**, **FUNCTION** or **MODE** selections. The **OUTPUT OFF** LED is lit.

The instrument is normally set up with **OUTPUT OFF**. Selecting one of the **OUTPUT ON** keys connects the **I+**, **I–**, **Hi** and **Lo** terminals to their energised internal circuits.

OUTPUT OFF default. The instrument status is described at any time by the combination of LED states, display values and display messages. Certain combinations are prohibited, and some transfers between states are regulated by main program firmware. For safety reasons, some of these combinations result in the Output being switched **OFF**. These include:

1. Changing functions.
2. When 1000V range is selected, or when 1000V range polarity is reversed.
3. When the internal temperature exceeds its specified limit. A time limit guard (approx. 2 mins) also operates to prevent reselection of **OUTPUT ON** until the instrument has cooled.
4. Most 'FAIL' messages.

Generally, if an invalid condition is selected, either the nearest valid condition is activated, or the command is ignored and the 4000 remains in its previous state.

Output polarity. On DC Voltage or current, the polarity at the Output terminals is determined by the Key used to switch the output on, as labelled. In addition, polarity may be reversed by using the ↑|↓ keys to step the output across zero value. The **ON** LEDs describe the polarity **AT THE OUTPUT TERMINALS**, not on the **OUTPUT** display. (In "offset" mode these two could be opposite).

In **Ω** function, either the **ON+** key or the **ON–** key causes the selected precision resistor to be connected to the terminals. The **ON+** LED is lit, but the **ON–** LED is inoperative.

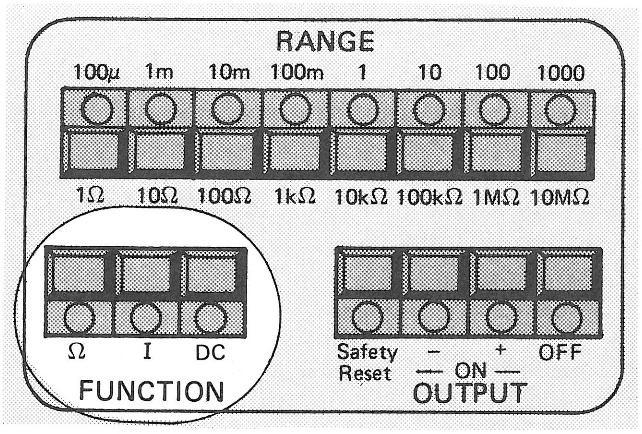
Safety Reset key. Under certain abnormal conditions (e.g. if a user injects a voltage across the Output terminals), the 4000 output will trip **OFF**, accompanied by a **Fail 5** message on the **MODE** display. Control is removed from the front panel keys.

If the **Fail 5** message is present, there is no automatic recovery from the tripped state whether internal conditions have returned to normal or not.

The **Safety Reset key** allows a user to reset the safety trip to test whether conditions have returned to normal. If they have, the **Fail 5** message will disappear; the previous instrument state will be restored but with **OUTPUT OFF**, and front panel control will be returned to the user. If conditions are still abnormal the **Fail 5** state will persist, and a further attempt may be made after a suitable interval. The **Safety Reset** LED is inoperative except in "Test" mode.

A full analysis of 4000 messages appears in Section 4.

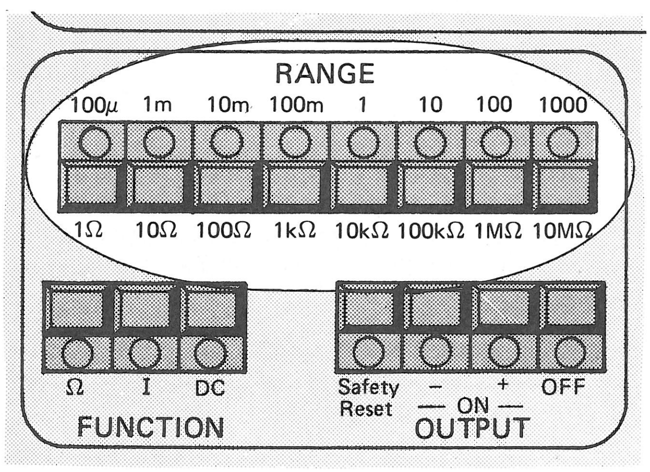
FUNCTION Keys



Selection	Specified Output
DC	DC Voltage
I	DC Current
Ω	Resistance

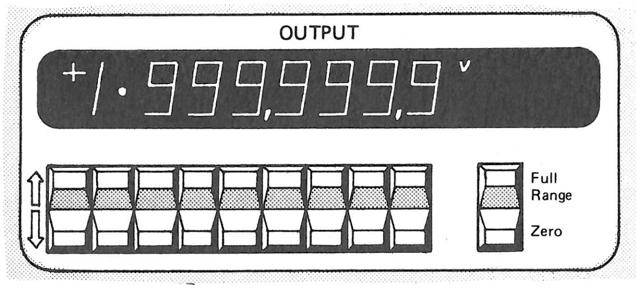
(**Ω** selection also forces the 4000 into Remote sense, for 4-wire operation). When changing from one function to another, the output is automatically set to **OFF**. When changing from **Ω** to **DC** or **I**, the **OUTPUT** value is automatically set to zero.

RANGE Keys



Each **RANGE** key scales the output as selected by the user, setting the legend and decimal point on the **OUTPUT** display to match. Full-range values for DC voltage and current are marked above the keys, the actual output value being selected by use of the **OUTPUT** display ↑|↓ keys. In the **Ω** function, the nominal value of each precision resistor is labelled below its corresponding **RANGE** key.

OUTPUT Display and ↑|↓ Keys



The **OUTPUT** display is supplemented by legends. These always indicate the correct units for the range and function selected.

Each vertical pair of ↑|↓ keys is assigned to the display digit above it. Thus the value registered on the display may be set within the range permitted by the function selected. Each momentary press of the ↑ key adds +1 to its digit, and each ↓ key adds −1. On Ω ranges, only the **overrange**↑|↓ keys are operative. These duplicate the action of the **Full Range/Zero** Keys.
The Resistance value displayed is the calibrated value of the standard internal resistor selected (not the nominal value). This may be updated during periodic calibration. The value displayed depends on the selection of **Local** (2-wire) or **Remote** (4-wire) **Sense**, and should be recalibrated in the correct Sense mode (See Section 8).

Auto-increment/decrement. When a ↑|↓ key is pressed for more than ½ second its digit is increased or decreased at a rate of approximately 6 digits per second until the key is released.

Overflow and underflow. As a digit is stepped from 9 to 0, the value of the next higher-order digit is increased by 1. Stepping from 0 to 9 decreases the value by 1. The whole display therefore acts as a counter, with full "carry" and "borrow" action. The display is limited to its full-scale reading of ±19999(999).

DC ZERO and polarity. On DC voltage and current, a polarity sign is present except at zero. The numerical display represents the magnitude of the output.

As the display value is stepped to zero, the polarity sign disappears, and the opposite sign appears as stepping continues in the same direction. If the **OUTPUT** is **ON** during the sequence, the change in output polarity is signalled by a changeover from one polarity **ON** LED to the other.

N.B. If the 4000 is in **Offset** Mode, with an offset present, the display and output zeros do not coincide. It is therefore possible to have a **positive** sign on the display, and the **ON–** LED Lit; and vice-versa.

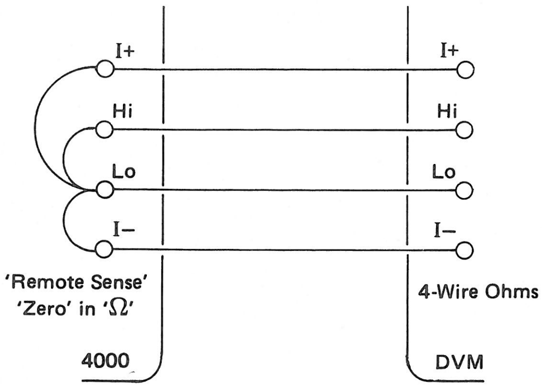
When using the ↑|↓ keys or **Zero** key to obtain a zero, the polarity is not changed over and the same **OUTPUT ON** LED remains lit. The polarity LEDs change over only when the opposite polarity appears <u>at the output terminals</u>.

Full Range/Zero keys. When the **Full Range** key is pressed, the display reverts to the Full Range value of the range selected.
The **Zero** key reduces the the display value to zero.

If **OUTPUT** is **ON** when the **Full Range** key is pressed, the terminal value follows the display value unless:

1. 4000 is in **1000V** range: The High Voltage interlock procedure <u>must</u> be observed (described later in this section).
2. **Offset** or **Error** Mode is selected: The user-input offset or gain error is not cancelled.

On Ω ranges in **Remote Sense** with **OUTPUT ON**, the **Zero** key connects a true 4-wire internal short circuit to the **OUTPUT** terminals as shown below. With **Remote Sense** LED UNLIT, the same short is connected, but the actual resistive value of this short may be calibrated (see section 8).



TRUE 4-wire Ohms Zero

Selection of high voltage outputs. The 4000 is capable of delivering LETHAL output voltages so program interlocks are used to ensure that users do not inadvertently select outputs in excess of 110V. On **100V** and **1000V** ranges, the instrument uses two overlapping voltage states:

Low voltage	$-110V \leqslant V \leqslant +110V$
High voltage	$-1200V \leqslant V \leqslant -90V$ and
	$+90V \leqslant V \leqslant +1200V$

Details of the High Voltage selection procedure are given in Section 4.

Display resolution. The maximum number of digits available depends on the range and function, detailed in the tables below.

DC Voltage Ranges	100μV	1mV	10mV	100mV	1	10	100	1000
Maximum Resolution (digits)	4½	5½	6½	7½	7½	7½	7½	7½

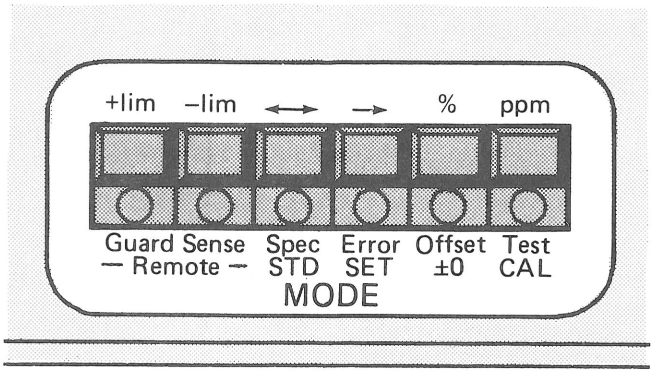
DC Current Ranges	100μA	1mA	10mA	100mA	1	10	100	1000
Maximum Resolution (digits)	6½	6½	6½	6½	6½	–	–	–

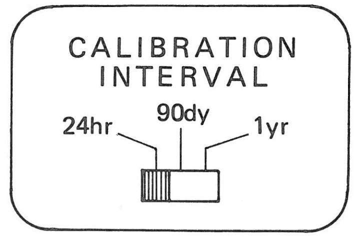
Ohms Ranges	1Ω	10Ω	100Ω	1kΩ	10kΩ	100kΩ	1MΩ	10MΩ
Maximum Resolution (digits)								
Remote Sense (4-wire)	7½	7½	7½	7½	7½	7½	7½	7½
Local Sense (2-wire)	3½	4½	5½	6½	7½	7½	7½	7½

Lower-order digit suppression. Unless Error or Offset Mode is selected, the user may reduce the resolution of the display by removing unwanted lower-order digits. The Zero key is held down and an increment (↑) key is pressed. The digits above the keys to its right (i.e. lower-order digits) will disappear. Only the digits above the four right-hand keys may be suppressed. Any number of those suppressed may be recovered by repeating the operation for the required degree of resolution. These operations naturally reset the display value to zero.

N.B. On **1000V** Range, minimum resolution is obtained by pressing the ↑ key to the left of the decimal point.

MODE Selection Keys





Rear Panel CALIBRATION INTERVAL switch used in conjuction with **Spec** mode.

The **MODE** Selection Keys are located on the lower left of the front panel. The Remote-Guard and Sense keys are described under "I+, I−, Hi, Lo, Guard and ⏚"

STD, SET, ±0, and **CAL** are calibration modes, printed in red and described in Section 8.

Spec mode

The **Spec** key controls the toggle-action "Specification" function. By pressing the key, its green LED lights and the 4000 specification tolerances are displayed on the **MODE** display, referred to its current **FUNCTION, OUTPUT** and **CALIBRATION INTERVAL** selection. A second press cancels the function and the LED goes off. For **24 hour** calibration intervals, the figures displayed are relative to the calibration standards used, but for **90 days** and **1 year** intervals they are absolute tolerances.

Whilst the **Spec** LED is lit, all primary functions of **MODE** keys are cancelled although the selected Guard and Sense connections remain. The secondary key functions **+ lim, − lim, %** and **ppm** become active. On selection of **Spec** the secondary mode **ppm** or **%** is automatically selected, depending on the magnitude of the tolerance specified. The arrow ↔ above the key indicates that all four secondary modes are available.

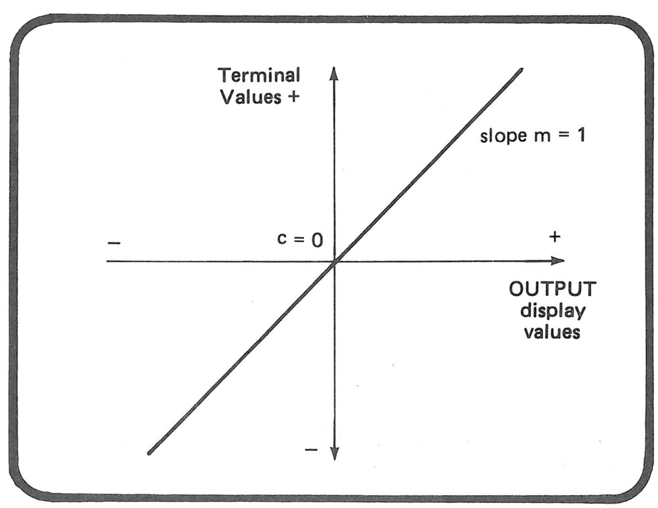
Full details of the operation of Specification mode are given in Section 4.

Error and Offset modes

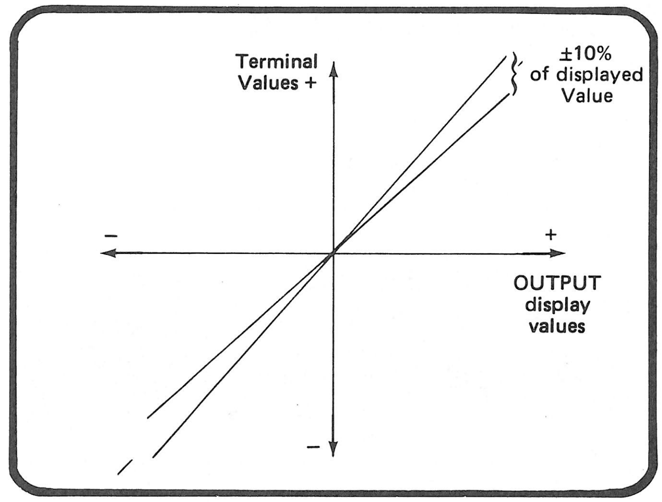
These keys are used to deviate the OUTPUT at the terminals from the value on the OUTPUT display. The two modes may be selected together.

Error and Offset modes not selected. The terminal value is a linear function of the OUTPUT DISPLAY value:

terminal value = (m x OUTPUT DISPLAY value) + c
where m = 1 and c = 0

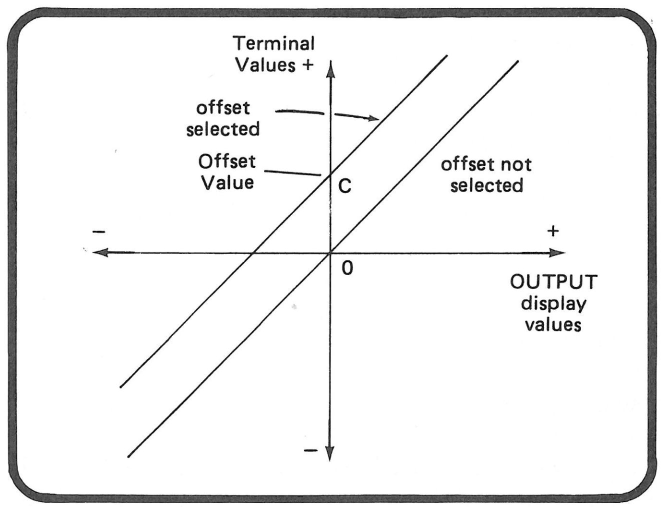


Error mode selected. In Error mode, the slope (m) may be adjusted within ±10% of displayed value. To increase resolution, ppm may be selected below 0.1%.



Offset mode selected. In **Offset** mode, the intercept (c) may be adjusted to any value within the Offset limit.

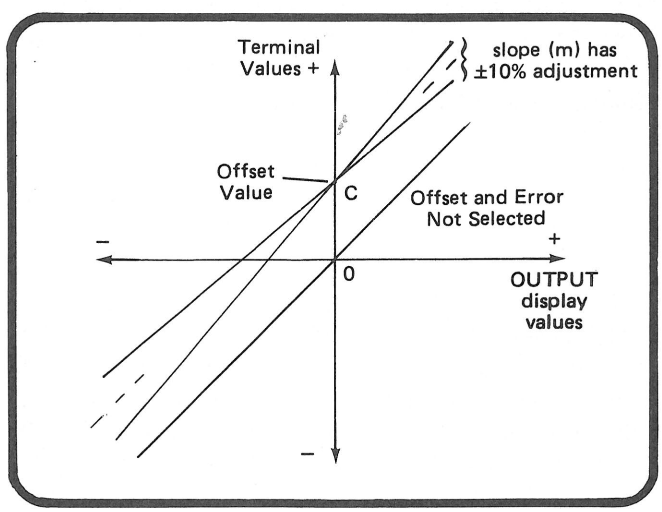
Offset Limits: 100μV and 1mV Ranges: ±200μV
Other Ranges: ±2% of Full Range value



Offset and Error Mode Combination. Offset cannot be selected or deselected when the 4000 is already in **Error** Mode.

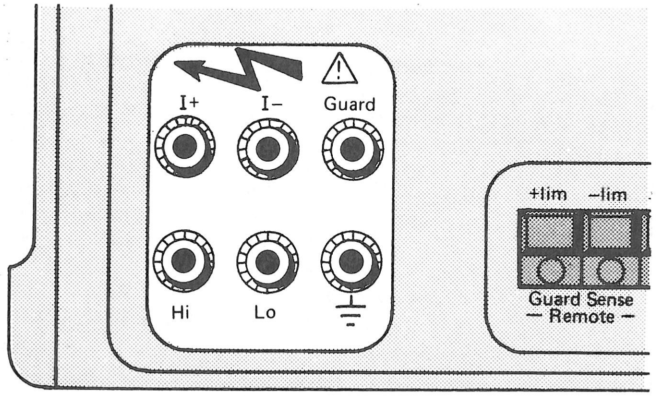
The intercept (c) is established first in **Offset** mode, then the slope (m) is adjusted in **Error** mode.

Full details of the operation of Error, Offset and the combined mode are given in Section 4.



Test mode selected. Full details of the operations in Test mode are given in Section 4. The **Test** key runs a program which allows a user to check front panel keys and displays, and checks the **Safety Reset** operation.

I+, I–, Hi, Lo, Guard and ⏚ (Ground)



These terminals are located on the lower left of the front panel.

The I+ and I– terminals are connected to the internal power circuits, and the Hi and Lo terminals are used for sensing the output voltage.

Remote Sense. The specified voltage output of the 4000 may be produced either at its output terminals (Local sense for high impedance loads) or at the load terminals (Remote sense for cases in which lead resistance and load impedance produce a significant effect). With **Remote Sense OFF**, the **Hi** and **Lo** terminals are internally connected to the **I+** and **I–** terminals, and with **Remote Sense** LED **lit** the output voltage must be sensed externally, using leads connected to the **Hi** and **Lo** terminals.

Remote Sense is not available on Current ranges and 100μV – 100mV ranges; on **Ohms** ranges, **Local Sense** is used for 2-wire connections, and **Remote Sense** for 4-wire. (Changing **FUNCTION** into **Ω** forces the 4000 into **Remote Sense**, but this may be deselected for 2-wire operation). the **Remote Sense** LED always indicates the true connection:

Lit = Remote; Unlit = Local.

The **Guard** terminal is permanently connected to the internal guard shields:

With **Remote Guard OFF**, it is also internally connected to the **I–** terminal.

With **Remote Guard** LED lit, the internal link to **I–** is removed. The **Guard** terminal can then be connected to the load to reduce common mode interference.

Both **Remote Guard** and **Remote Sense** keys have a toggle action e.g. A key-press when in Remote will revert to Local.

N.B. **Guard and Sense connections may only be switched with OUTPUT OFF.**

The ⏚ (Earth or Ground) terminal connects directly to the 4000 internal Ground shields and to Safety Ground via the power-cable.

Connections to the output terminals may be made with wire leads or with a shrouded connector.

N.B. For DC Voltage outputs in local sense the two leads should be attached to the Hi and Lo terminals. (In Section 8, Local Sense DC Voltage is calibrated with a Null Detector connected to the Hi and Lo terminals).

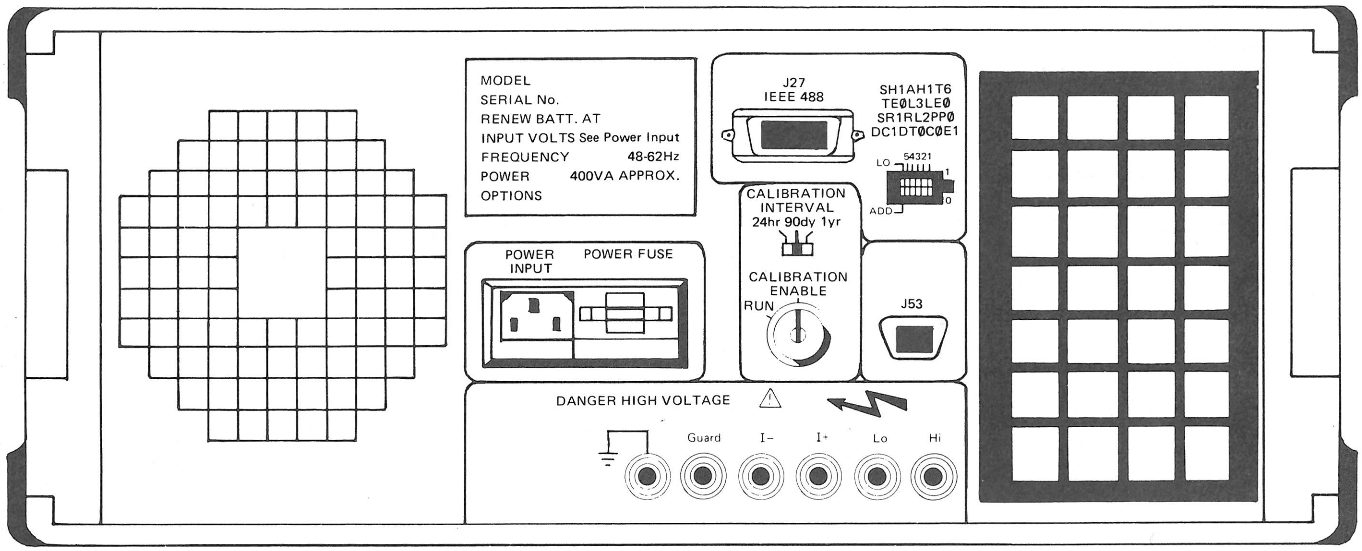
Various configurations of 4000 Load connections are detailed in Section 4.

Output Impedance

With Remote Sense ON (4-wire) and the proper external connections made, the output impedances are as stated in Section 6.

With Remote Sense OFF (2-wire), the output impedance at the terminals depends on internal wiring and connections. It is recommended that Remote Sense be used in high accuracy applications when the load is less than a few hundred kilohms.

Rear Panel (Shown with alternative Rear Output terminals)



Power Input

The recessed power input plug, power fuse and line voltage selector are located in the centre of the rear panel, contained within a single moulded unit. Details of connections, selection of line voltage and fuse are given in Section 2.

Rear Output Alternative

This can be incorporated at manufacture, to provide six output terminals on the rear panel instead of the six on the front. Their functions and connections are identical.

Socket J53 – External Reset

This D type plastic socket is located next to the cooling air intake filter. It may be used to input an external reset to restore the 4000 to its power-up state of DCV, 10V Range etc. if required.

Pin Layout, Pin Designation and Switch Wiring

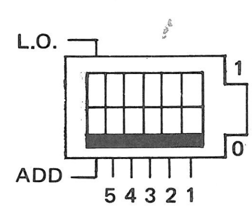
These are given in Section 2.

IEEE 488 Input/Output. Socket J27

The IEEE 488 Input/output socket J27 is a 24-way micro-ribbon connector that is directly compatible with the IEEE 488 interface and the IEC-defined system (D-type).

J27 is located at the top of the rear panel, outlined with the IEEE 488 address switch. The pin layout and designations are given in Section 5.

IEEE 488 Address Switch



The 4000 may be addressed for use on the IEEE 488 interface bus. The address settings are given in Section 5.

DANGER

HIGH VOLTAGE

THIS INSTRUMENT IS CAPABLE OF DELIVERING

A LETHAL ELECTRIC SHOCK!

FRONT or REAR terminals carry the Full Output Voltage.

THIS CAN KILL!

Guard terminal is sensitive to over-voltage

It can damage your instrument!

Unless **you** are **sure** that it is **safe** to do so,

DO NOT TOUCH the **I+ I– Hi** or **Lo leads** and **terminals**

DANGER

SECTION 4 USING THE DATRON 4000

Preliminaries

Before using the instrument it is important that it has been correctly installed as detailed in Section 2.

Limiting Characteristics

The following details are given in Section 6.

Function	Characteristics
All functions	Peak terminal voltages
DC Voltage	Output resistance and current limit
DC Current	Maximum load resistance and maximum compliance
Resistance	Maximum currents and accuracy de-rating factors

SAFETY

The 4000 is designed to be Class 1 equipment as defined in IEC Publication 348 and UL 1244 concerning safety requirements.

Protection is provided by a direct connection via the power cable from earth (ground) to exposed metal parts and internal earth screens.

The line connection must only be inserted in a socket outlet provided with a protective earth contact, and continuity of the earth conductor must be assured between the socket and the instrument.

WARNING:
ANY INTERRUPTION OF THE PROTECTIVE EARTH CONDUCTOR INSIDE OR OUTSIDE THE INSTRUMENT OR DISCONNECTION OF THE PROTECTIVE EARTH TERMINAL MAY MAKE THE APPARATUS DANGEROUS. INTENTIONAL INTERRUPTION IS PROHIBITED.

THE TERMINALS MARKED WITH THE ⚡ SYMBOL CARRY THE OUTPUT OF THE 4000. THESE TERMINALS AND ANY OTHER CONNECTIONS TO THE LOAD UNDER TEST COULD CARRY LETHAL VOLTAGES.

UNDER NO CIRCUMSTANCES SHOULD USERS TOUCH ANY OF THE FRONT (OR REAR) PANEL TERMINALS UNLESS THEY ARE FIRST SATISFIED THAT NO DANGEROUS VOLTAGE IS PRESENT.

The ⚠ symbol is used to remind the user of special precautions detailed in this Handbook and is placed adjacent to terminals and switches that are sensitive to overvoltage conditions. See Section 6.

Interconnections

The Datron 4000 has the capability to be used as an accurate source for precision calibration. Unless care is taken in making connections to the load the overall specification may be severely degraded.

Sources of error

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

Noisy or intense electric, magnetic and electro-magnetic effects in the vicinity can disturb the measurement circuit. Some typical sources are:

- Proximity of large static 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 may intensify the disturbances.

Lead Resistance may drop significant voltages in the source-load connections, particularly if the leads are long or the current in them is high.

Lead Insulation Leakage may cause significant errors in measurement circuits at high voltages, high resistances or current. Some insulating materials suffer greater losses than others e.g. PVC has more leakage than PTFE.

Avoidance Tactics

Thermal EMFs: Screen thermal junctions 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 Aluminium. 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 circuit.

Balance one thermal junction with another in opposition, where possible. (Switch and relay contacts, terminals etc.)

E-M Interference: Choose as 'quiet' a site 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.

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

Lead Resistance: 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 possible to establish the 4000 output specification at the load.

Use 4-wire connections for values of resistance below 1kΩ.

Lead Insulation Leakage: Choose low loss insulated leads – PTFE is preferred 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 4000 terminals are configured as follows:

Voltage ranges 100μV, 1mV, 10mV, 100mV
– Local sense only
1V, 10V, 100V, 1000V
– User selects Local or Remote sense

All Current ranges
– Local sense only

All Resistance ranges
– Remote Sense gives 4-wire connection
– Local Sense gives 2-wire connection

The key LED indicates the true connection:
Lit = Remote, Unlit - Local

N.B. When changing to Ω function, the 4000 is automatically forced into **Remote Sense** for 4-wire operation.

Typical Lead Connections

Seven arrangements are shown below, using connections to a dvm as an example:

Simple 2-wire connection. Use for the majority of 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	$V \geqslant 100\text{mV}$
Current	$1\text{mA} \leqslant I \leqslant 1\text{A}$
Resistance	$1\text{k}\Omega \leqslant R \leqslant 1\text{M}\Omega$

N.B. After selecting Ω, Remote Sense must be cancelled for 2-wire operation

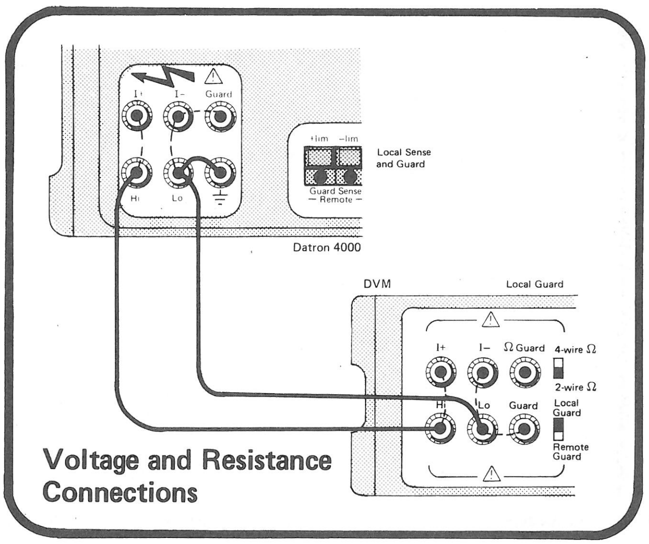
Guard-screened 2-wire connection. Use where:

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

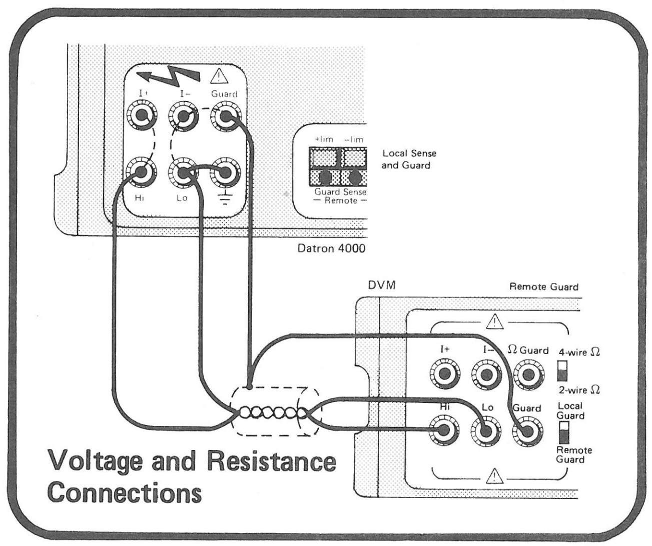
Use for measurements in the following ranges

Voltage	$V \geqslant 10\mu V$
Current	$I \geqslant 10\mu A$
Resistance	$1\text{k}\Omega \leqslant R \leqslant 1\text{M}\Omega$

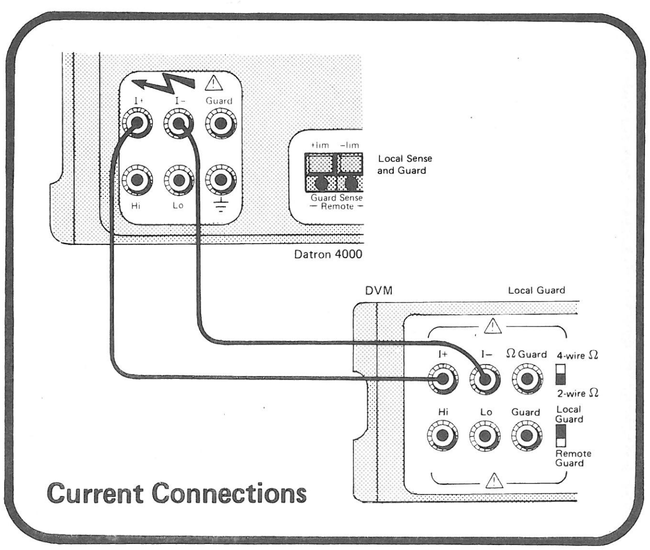
N.B. After selecting Ω, Remote Sense must be cancelled for 2-wire operation.



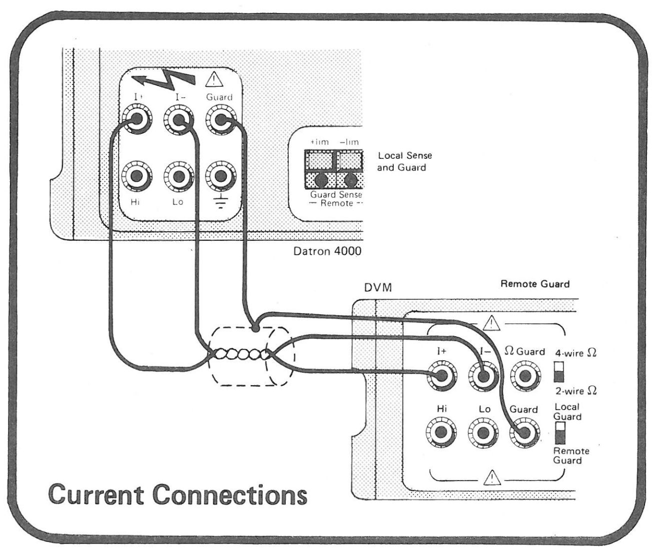
Voltage and Resistance Connections



Voltage and Resistance Connections



Current Connections



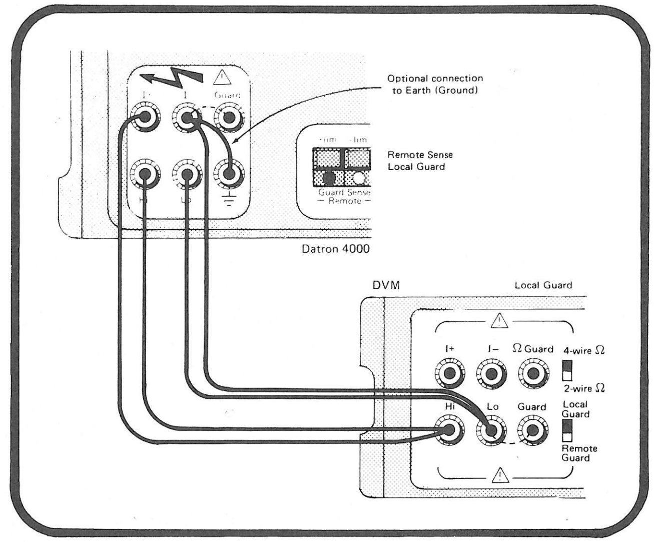
Current Connections

4-wire Remote Sense connection. Use where:

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

Use for measurements in the following ranges:

Voltage: 200mV ⩽ V ⩽ 1200V (1V, 10V, 100V and 1kV ranges only)
Current: not applicable (No remote sense)
Resistance: not appropriate

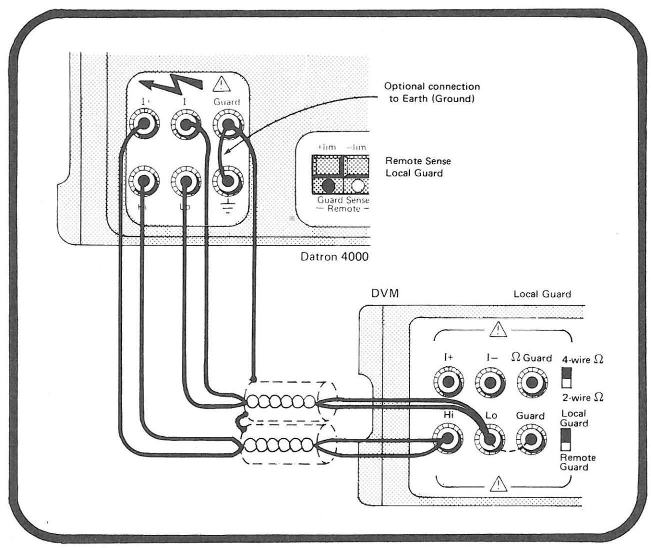


Guard-screened 4-wire Remote Sense. Use where:

The voltage drop in the leads is significant
The E-M environment is relatively 'noisy'
External common-mode voltages are insignificant

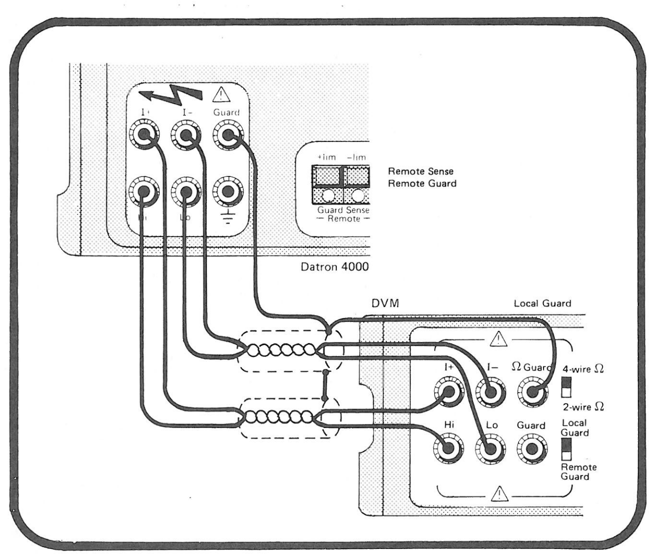
Use for measurements in the following ranges:

Voltage: 200mV ⩽ V ⩽ 1200V (1V, 10V, 100V and 1kV ranges only)
Current: not applicable (no remote sense)
Resistance: not appropriate

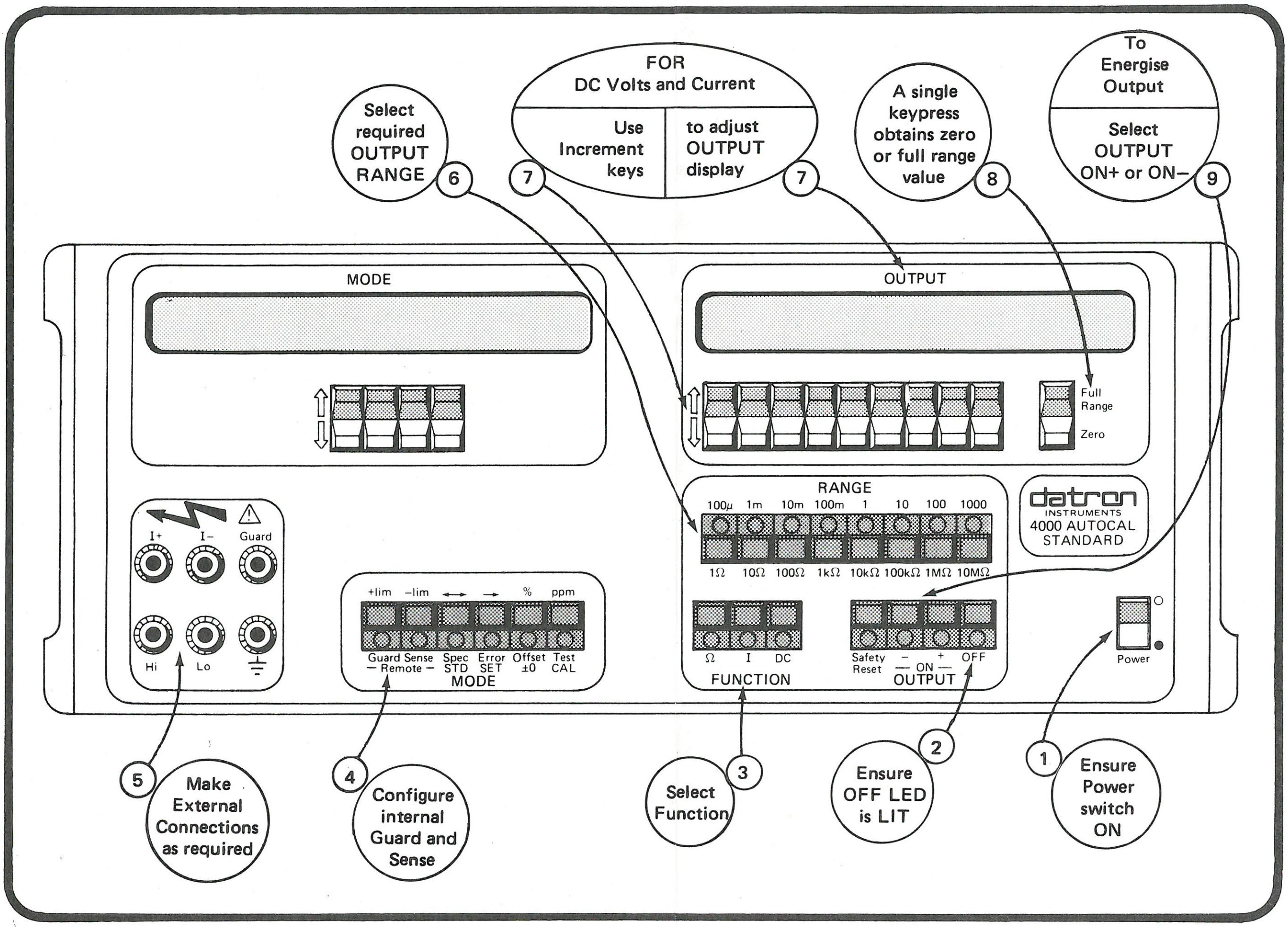


4-wire Resistance measurements: Use is specific to resistance measurement and may be used for all values. At values of 1Ω, 10Ω, 100Ω: 4-wire is necessary to eliminate the effects of lead resistance. Guard and screen are not required unless the E-M environment is very noisy.

At values of 1MΩ and 10MΩ, it is suitable for measuring high resistance with long cables, since the effects of leakage and capacitance between leads are eliminated. The resistors in the 4000 are surrounded by a guard screen to reduce any errors due to noise. PTFE-insulated cables must be used for values greater than 10kΩ, otherwise accuracy may be seriously degraded.



General Sequence of Operations



Display Messages (See full list at end of this section)

Error 1 / Spec mode	%	:	Tolerance > 100%
	± lim	:	Off-scale limit
Error 2	: Cal. mode	:	Output not ON
Error 3	: Cal. mode	:	Incorrect range or Function for mode
Error 4	: Cal. mode	:	Correction exceeds Store capacity
Error 5	: Error or Offset Mode	:	Requested output would have been off-scale
Error 6	: Cal. mode	:	Resistance value selected exceeds calibration limit
Error OL	: Voltage	–	output is current-limited
	Current	–	compliance limit reached

Fail 1	:	Excessive internal temperature
Fail 2	:	Over-voltage
Fail 3	:	Control data corrupted
Fail 4	:	Precision divider fault
Fail 5	:	Safety circuits tripped
Fail 6	:	Calibration store fault
Fail 7	:	PA 15V/50V power failure or 50V regulator over-temperature – Suspect excessive Power Input line voltage
'B'	:	Processor busy
SAFETY	:	Forced safety trip in Test Mode
PASS (Test Mode)	:	Calibration Memory and Over-voltage tests – No failure

DANGER
HIGH VOLTAGE

THIS INSTRUMENT IS CAPABLE OF DELIVERING

A LETHAL ELECTRIC SHOCK!

FRONT or REAR terminals carry the Full Output Voltage.

THIS CAN KILL!

Guard terminal is sensitive to over-voltage

It can damage your instrument!

Unless **you** are **sure** that it is **safe** to do so, **DO NOT TOUCH** the **I+ I− Hi** or **Lo leads** and **terminals**

DANGER

Operating Routines

The 4000 has been designed for ease of operation. The use of a processor for internal management allows the operator to concentrate on the work in progress.

Legend B appears on both displays when the processor is "busy".

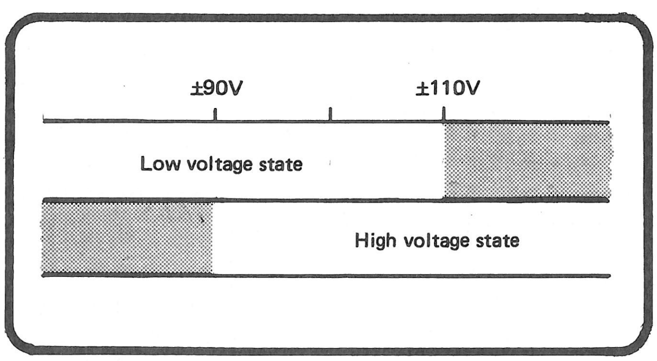
The following operating routines are subdivided into two main types:

Standard operating sequences
Additional facilities

Standard operating sequences.
To a large extent, a common routine can be used for Voltage, Current and Resistance operation. The diagram opposite shows the general sequence of operations. It should be used in conjunction with the instructions for individual functions to be found in the following pages.

DC Voltage

There are two overlapping voltage states. The 20V overlap allows ±10% adjustment about the typical full range value of 100V without changing state.



In the Low voltage state, the output may be switched ON directly but to transfer from Low to High voltage state, deliberate user-actions are required.

N.B. The 4000 switches its output voltage **OFF** every time the **1000V RANGE** is selected and when 1000V RANGE polarity is reversed.

Low Voltage selections (up to ±110V). Use the general sequence:

At operation ③: Select DC.

At operations ④ and ⑤: **No Remote Sense** on **100μ, 1m, 10m** and **100m** ranges

High Voltage selections (above ±110V). Use the general sequence:

At operation ③: Select DC

At operation ⑦: **RANGE** LED **flashes** for selections **above ±110V**

At operation ⑨: **Audible warning** – 5 pulses/sec for 3 secs.
After 3 second warning – 4000 switches OUTPUT ON
Whilst OUTPUT ON – Audible reminder pulses at approx. 1 sec. invervals, and **RANGE** LED **continues flashing**

Transfer into High Voltage State with OUTPUT ON

By changing **RANGE**:
- The **OUTPUT** is switched **OFF**, and the selected **RANGE** LED **flashes**.

User reselects **OUTPUT ON**:
- **3 sec audible warning**
- 4000 switches **OUTPUT ON**
- Audible reminder whilst **OUTPUT ON**
- **RANGE** LED **flashing**.

By use of ↑|↓ keys in **100V** or **1000V** range:
- **OUTPUT** remains **ON** at previous voltage
- **OUTPUT** display shows selected (High Voltage) value
- **RANGE** and **OUTPUT ON** LEDs **flash**.

User reselects **OUTPUT ON**:
- **3 sec audible warning**
- 4000 increases **OUTPUT** voltage to **OUTPUT** display value
- Audible reminder whilst in High voltage state
- **RANGE** LED **flashing**
- **OUTPUT ON** LED **lit continuously**

Transfer out of High Voltage state with OUTPUT ON

By pressing **OUTPUT OFF** key:
ON+ or **ON–** LED remains lit until the **OUTPUT Voltage** has decayed into Low Voltage State (Approx. 1 sec from 1000V).

By use of ↑|↓ keys or by changing **RANGE** down:
Transfer to Low Voltage State is automatic when the **OUTPUT Voltage** falls below **90V**.
– **RANGE** LED stops flashing – stays lit
– **OUTPUT ON** LED stays lit
– Audible reminder is silent.

Changing voltage state when in Error or Offset Mode

For safety reasons, the thresholds are always defined with respect to voltage levels at the OUTPUT terminals. Therefore, if the instrument is in Error or Offset mode, the threshold indications may not coincide with 110V and 90V on the OUTPUT display.

Option 20 – DC Current

Use the General Sequence:

At operation ③: select I

At operations ④ and ⑤: Remote Sense not available

N.B. Maximum compliance 3V on all ranges.

Option 20 – Resistance

Use the General Sequence:

At operation ③ : Select **Ω** – **Remote Sense** LED lights as 4000 is forced into 4-wire

At operation ④ : If 2-wire Ohms is required, press **Remote Sense** to deselect

At operation ⑤ : 4-wire Ohms – use **I+** and **I–** terminals for energising current. Measure at **Hi** and **Lo**.
2-wire Ohms – use **Hi** and **Lo** terminals.
(**I+** and **I–** terminals internally fused at 1.0A, **Hi** and **Lo** terminals fused at 3.75mA; on **Ω** function).

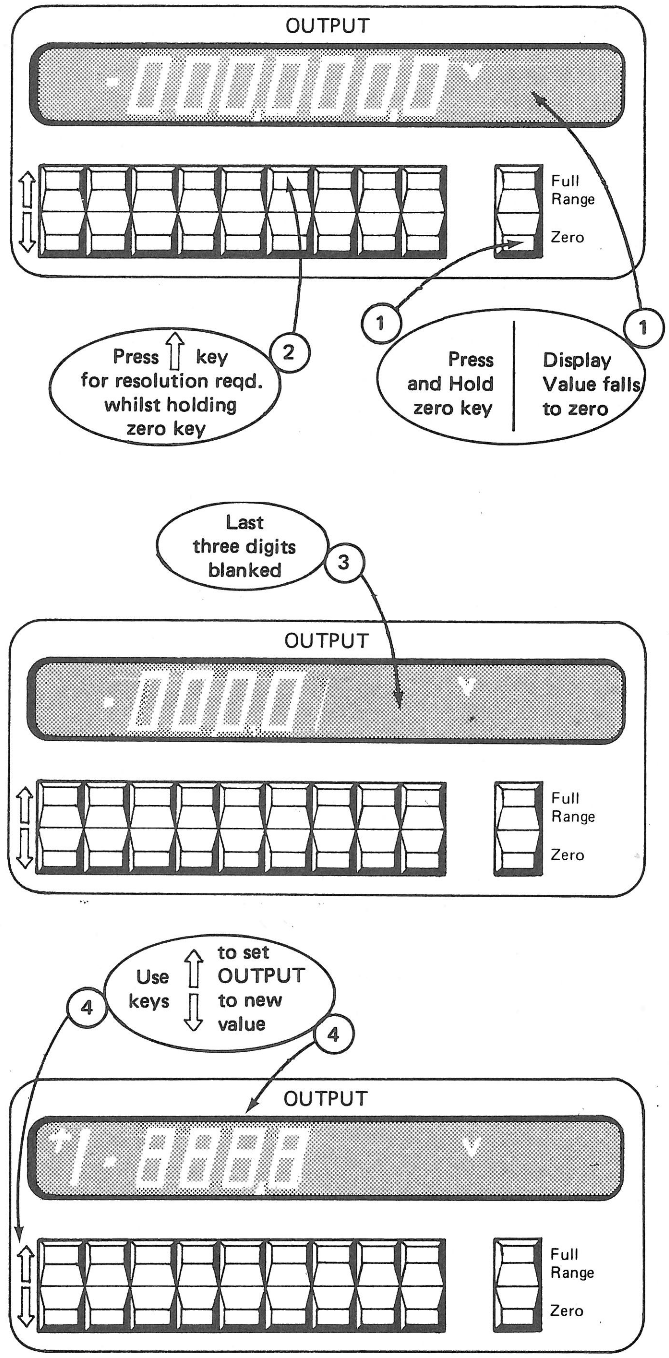
At operation ⑥ : **RANGE** key value is **nominal**. **OUTPUT display** value is as previously calibrated (At Full Range only, for 4-wire; at Full Range and Zero for 2-wire).

At operation ⑦ : **Left hand** (overrange) pair of ↑|↓ keys have the same functions as **Full Range/Zero** keys.
The other ↑|↓ keys are inoperative except in Calibration function (See Section 8).

Display Resolution

Change of OUTPUT display resolution (Not available in Offset or Error Mode)

If high resolution is not required, the unnecessary digits can be removed from the display by the following procedure. Up to four of the least significant digits may be suppressed, leaving a resolution of 3½ digits. In the example shown, just the last 3 digits are blanked:



The procedure can be repeated to set any required resolution in the available range; so to restore full resolution, press the **least significant** digit ↑ key whilst holding the **Zero** key.

Selection of **Error** and **Offset** modes, and transfer to Remote Operation on the IEEE interface, will restore full resolution for the range. Full resolution will persist when these modes are deselected.

Selection of **Test** mode does not restore full resolution; and when **Test** mode is terminated or aborted, any previously-truncated **OUTPUT** display will reappear.

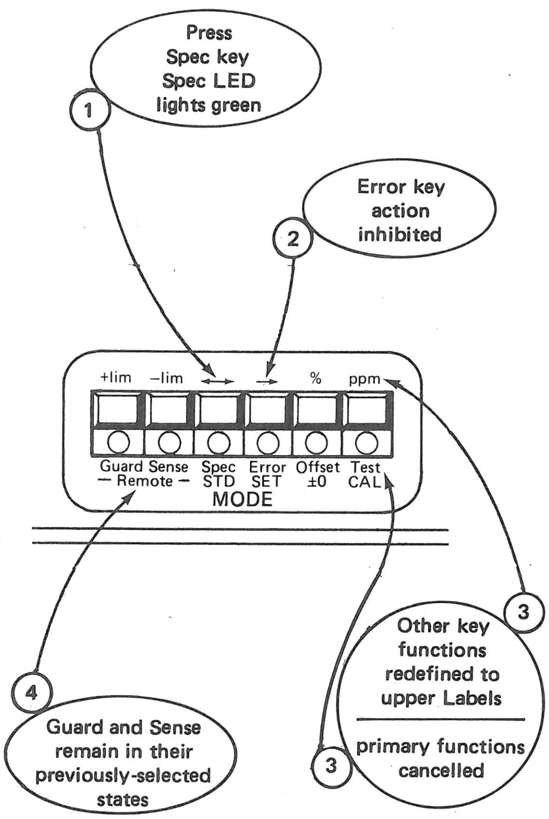
Additional Facilities

'Spec' Mode

Spec Key. This key allows a user to avoid constantly referring to the data sheet specifications, when it is necessary to determine the uncertainty tolerance for any set value.

The full range of specification offset and gain tolerances is held in internal memory. In 'Spec' mode the 4000 selects the appropriate stored data and calculates the overall uncertainty tolerance for the selected Function, Range, Set Value and Calibration Interval.

To initiate 'Spec' mode: first select the required **Calibration Interval** (Rear Panel switch), then:



On pressing the Spec key the tolerance appears on the MODE display. Initially the presentation is as shown in the following table:

Tolerance	Display Units
⩽ 1,999 ppm of set value	ppm
> 1,999 ppm of set value	%
Not displayable or > 100%	Error 1

Secondary 'Spec' Modes. Once 'Spec' mode has been selected, there is a choice of four secondary modes:

ppm, %, +lim, or −lim

ppm or % tolerance (of displayed value). From 1ppm to 1999 ppm, the tolerance may be displayed in ppm. From 0.001% to 100%, the tolerance may be displayed in %. Above 100%, the message "Error 1" is displayed.

Example of Error 1 condition (Calibration Interval set to 24 Hrs)

Tolerance figures derived from Section 6.

Range = 100mV
Tolerance ≃ 0.5μV (0.0005mV)
Setting = +0.0006mV
Mode display is 83.4%

Setting = +0.0004mV
Mode display is **Error 1** (125% tolerance)

+Lim or −Lim. To obtain a reading of an absolute limit of tolerance, merely press the **+Lim** or **−Lim** key. The **MODE** display will switch to the same resolution as the **OUTPUT** display and its reading will be the positive or negative absolute limit of tolerance (i.e. the **OUTPUT** reading plus or minus the absolute tolerance error limit for that output).

As the reading approaches full scale, one of its limits may exceed full scale. If this limit is selected, "Error 1" is displayed.

Examples of Error 1 condition (Calibration Interval set to 24 Hrs)

Tolerance figures derived from Section 6.

	Example 1	Example 2
Range	1V	10V
Setting	+1.9999950V	−19.999980V
24 Hr tolerance	±6μV	±30μV
+Lim	+2.0000010V (Error 1)	−19.999950V (displayed)
−Lim	+1.9999890V (displayed)	−20.000010V (Error 1)

4000 & 4000A 'Spec' Data

Section 6 breaks down the specification into:

a) Stability.
b) Accuracy relative to Cal. Standards (23°C ±1°C).
c) Accuracy relative to Cal. Standards (23°C ±5°C).
d) Datron's Calibration Uncertainty.

The CALIBRATION INTERVAL switch on the rear panel of both models is labelled: '24hr', '90dy', and '1yr'. The stored tolerance data is selected from (a), (b), (c) and (d) above, as follows:

4000 24hr (a) : Stability.
90dy } (b) + (d) : 1°C Accuracy plus
1yr } Uncertainty

4000A 24hr (a) : Stability.
90dy } (c) + (d) : 1°C Accuracy plus
1yr } Uncertainty

Thus the accuracy figures displayed for 90dy and 1yr are relative to National Standards (traceable).

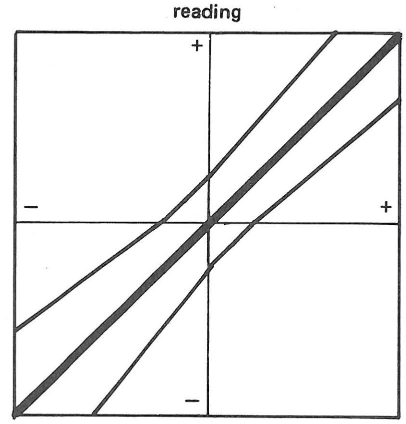
Users are able to display the 'Spec' limits on receipt of a 4000 or 4000A, to verify the instrument's traceability against their own Calibration Standards; but these must be of sufficiently low uncertainty.

Refer to Section 7, Specification Verification.

'Error' and 'Offset' Modes

(DC Voltage and Current Only)

The specification of a high accuracy dvm (and of other electrical measuring equipment) relates its display readings to its input values. A perfectly calibrated dvm would have an exact 1:1 correspondence, and the specification lays down acceptable tolerances of deviation from this direct relationship. Plotted as a graph, the ideal case is a straight line at 45° through the origin. The tolerances, Plotted on the graph, enclose an area on both sides of this line.



There are three major causes of deviation from the ideal case:

Zero offset – the line does not pass through the origin. Most dvms have a front panel adjustment to correct this.

Gain error – the slope of the line is not 45°

Linearity error – the slope of the line varies. (A common variation is a "dog's leg" at zero)

Each of these elements could cause large enough deviations to place the instrument out of tolerance, sometimes a combination of elements being responsible.

The "Error" and "Offset" modes allow a user to deviate the output of the 4000 in specific ways, so as to identify directly the causes of excessive deviation.

Resolution remains at maximum in Offset or Error Modes. It cannot be reduced whilst the modes are set, and any previous reduction is cancelled by entering either mode.

'Error' Mode

Error Key

The "Error" mode allows the **OUTPUT terminal value** to be deviated from the **set value** according to a predetermined **gain ratio**, entered on the **MODE** display.

The maximum gain resolution available in Error mode is 0.1ppm of Full Range, for Voltage ranges with 7½ digit resolution.

On both Voltage and Current ranges, Error mode resolution is reduced in proportion to the set value below the Full Range value.

Example of the use of "Error" mode

To measure the linearity of a dvm, a user needs to:

Remove any zero offset.

Detect and measure any inherent gain error ratio (usually from its response to a full-range input).

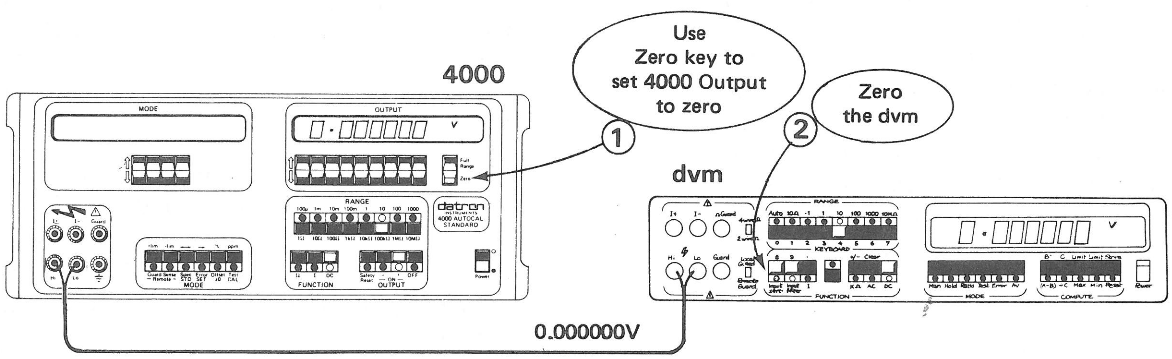
Calculate compensating deviations for each of the inputs for the linearity measurement, based on the measured ratio.

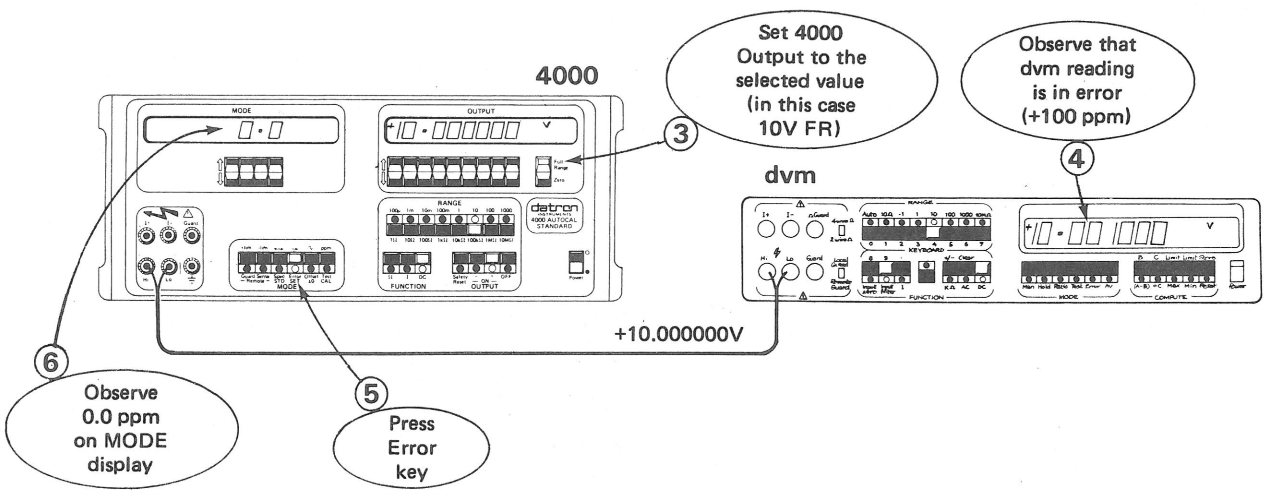
and

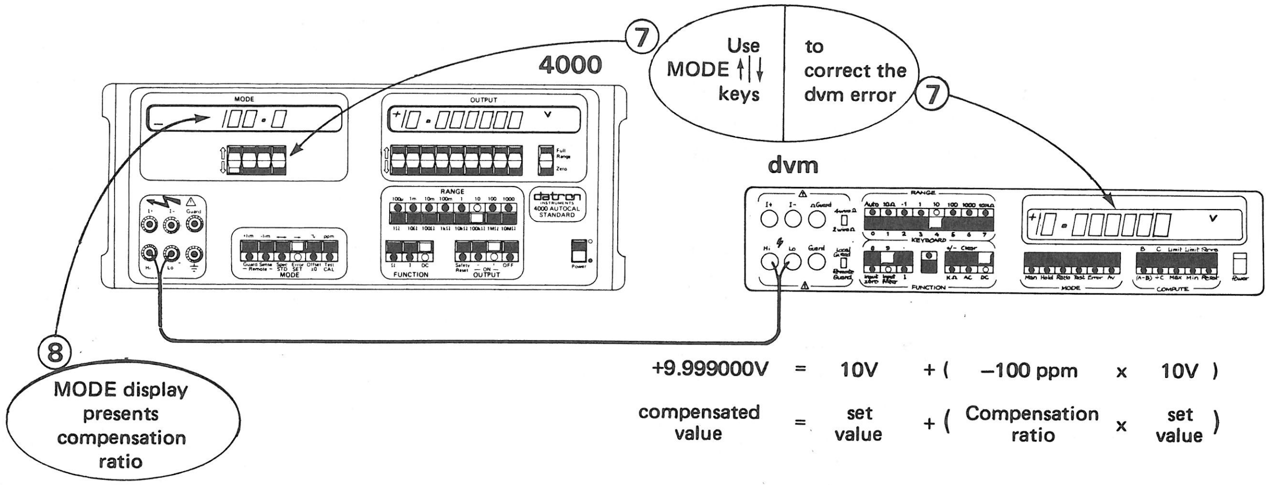
Compensate each input to the dvm so that the linearity errors may be measured.

In "Error" mode, once the gain error has been measured, the 4000 automatically calculates and applies the compensating deviation to all its outputs on that range and function; whilst displaying both the nominal (uncompensated) value of output and the compensation ratio. Only if the dvm response is linear, will each dvm reading agree with the corresponding 4000 OUTPUT display value.

In the following sequence a dvm is checked for linearity. For purposes of explanation, it is assumed that linearity is correct, but the dvm has a gain error of +100.0 ppm.







The 4000 output has now been compensated for the gain error of the dvm. All selected output values will be compensated in the same ratio on this range and function until either the ratio is changed or Error mode is deselected. The Mode display presents the compensation ratio directly. Note that the compensation polarity is shown, not the error polarity, therefore the true output is the sum of both displayed values – in this case +10.000000V – 100ppm = +9.999000V.

The linearity of the dvm may now be checked by directly comparing its reading with the **OUTPUT** display settings.

e.g. at +5V on this range, both 4000 and dvm read +5.000000V, although the terminal voltages are +4.999500V

Other linearity check values could be:

Nominal Check Point	4000 set Value	dvm Reading	Terminal Voltages
–0.5V	–0.500000V	–0.500000V	–0.499950V
+0.1V	+0.100000V	+0.100000V	+0.099990V
+0.01V	+0.010000V	+0.010000V	+0.009999V

Full Scale Limiting. The **OUTPUT display** cannot be raised to a value which sets its overrange digit to greater than 1, and the **Error MODE display** cannot be raised above ±9.9999% (±999.9 ppm).

Nevertheless, a combination of **OUTPUT display value** and **gain error** could result in an off-scale value. The 4000 prevents this by rejecting any demand for an error-corrected Output Voltage in excess of full scale. The user is informed by "**Error 5**" message on the **MODE** display with no change to the **OUTPUT** display.

Either **OUTPUT** ↑|↓ or **MODE** ↑|↓ keys may be used to bring the actual output within scale; the Error message will be replaced by the compensation ratio.

Deselection of Error Mode clears the **MODE** display, turns the green **Error** LED **OFF** and restores the 4000 gain factor to unity. Normally the mode is deselected by repressing the **Error** key, but it is also turned off by changing **FUNCTION** or **RANGE.**

After leaving Error mode, the **OUTPUT** display resolution remains at maximum for the Function and Range selected.

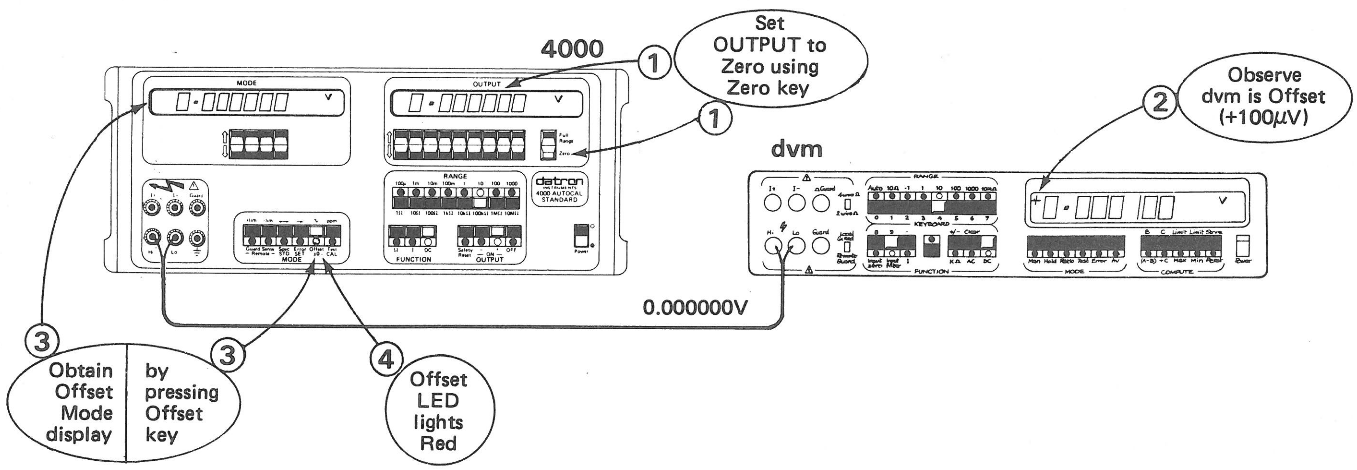
'Offset' Mode

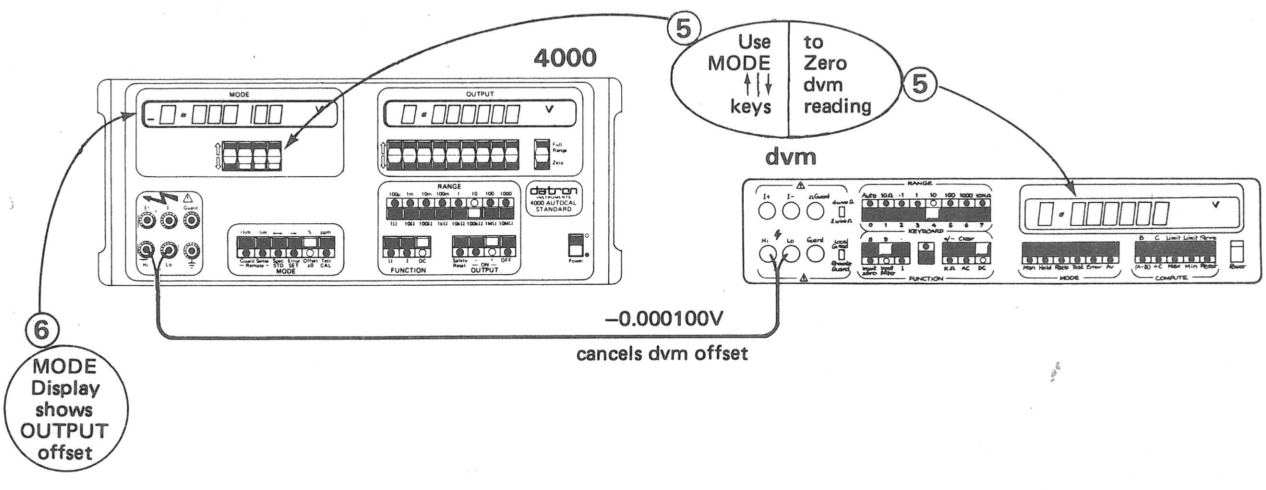
Offset key

A device being checked against the 4000 (say a dvm) may have an inherent zero offset error. Nevertheless, a user may wish to perform other measurements before removing the offset error. The 4000 "Offset" Mode is used for this purpose.

The following example generates an offset of $-100\mu V$ on the 10V range of a dvm, for all set values (unless the 4000 would be driven off-scale).

Connect the dvm to the 4000, both set to **10V** range, ensuring that 4000 **Error** and **Offset** LEDs are **UNLIT**.



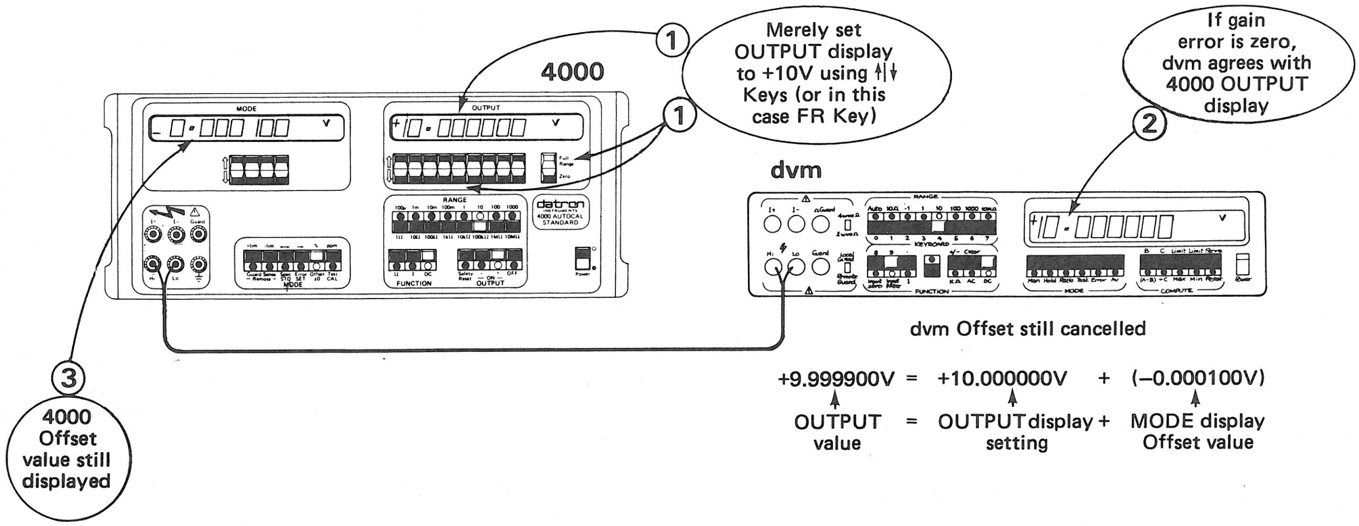


N.B. The **MODE** ↑|↓ keys have an automatic action: If a key is held pressed, the display will increment or decrement continuously until the key is released. For overflow digits the running speed is increased.

The value of output at the 4000 terminals is now the **sum** of the **OUTPUT display value** and the **MODE display offset value.**

Note that the negative polarity of the Offset value shown on the MODE display indicates that the Output voltage is more negative than the value on the OUTPUT display, i.e. the 4000 offset polarity is displayed, not the polarity of the dvm offset error.

Now the dvm gain error only may be measured:



Full Scale Limiting. The 4000 will reject any combination of set value and zero offset which would result in an off-scale output.

e.g. if −19.999950V is set together with −100μV offset, the user is requesting an offscale output of −20.000050V and the combination is invalid. The 4000 causes **Error 5** to appear on the **MODE** display as a signal to the user, and continues to output its previous (valid) value. The next valid selection will be accepted and Error 5 is replaced by the Offset value.

The **OUTPUT display** cannot be set to a value greater than Full Scale. The **Offset MODE display** cannot be set to a value greater than the Offset span for the Range in use.

i.e. 100μV and 1mV Ranges: < 200μV
Other Ranges: < 2% of Full Range value

Deselection of Offset Mode clears the **MODE** display, turns the red **Offset** LED **OFF** and reduces the 4000 offset to zero. Normally the mode is deselected by repressing the **Offset** key, but it is also turned off by changing **FUNCTION** or **RANGE**.

After leaving Offset mode, the **OUTPUT** display resolution remains at maximum for the Function and Range selected.

Combining Offset and Error modes

By combining Offset and Error modes it is possible to carry out a rapid analysis of a measuring instrument's linearity (e.g. for a dvm or A-D converter) without the need to correct its zero offset and gain errors.

This is done by using **Offset Mode** to compensate the 4000 output for the dvm's zero offset, and then using **Error Mode** to compensate for the dvm's gain error with the offset compensation still present.

In this condition, any residual deviations in dvm readings from the 4000 OUTPUT display settings represent non-linearities which would still be present if the dvm were corrected for offset and gain errors.

This facility also permits a user to quantify the linear response of the instrument to its input values in the form y = mx + c

in which y = instrument reading
x = input value
m = gain ratio
c = zero offset value

e.g. for a dvm on its 10 Volt range:

if y = 9.999956x – 0.000084,
then the dvm needs a gain compensation of +4.4ppm and a zero offset compensation of +84μV

These compensation figures can be read directly from the 4000 MODE display, during the following procedure.

Combination procedure (See Note below)

1. Use Offset-mode to compensate for input offset error and record the 4000 **MODE display value** at operation ⑥→(γ)
2. With Offset LED still lit, press **Error** key. Use Error mode to compensate for the instrument's gain error and record the 4000 **MODE display value** (ppm or %) at operation⑧→(μ)
3. Use suitable values of **OUTPUT display setting** to check the linearity of the instrument under test. If the instrument has a perfect linear response, then its readings will agree with those of the 4000 OUTPUT display and its linear transfer function is:

   either: Instrument reading

$$= \left[1 - \frac{\mu \text{ (in ppm)}}{10^6}\right] \text{x Input value} - \gamma \equiv y = mx + c$$

or:

$$= \left[1 - \frac{\mu \text{ (in \%)}}{100}\right] \text{x Input value} - \gamma \equiv y = mx + c$$

4. Deselect in reverse sequence.

NOTE: For these equations to be valid, the procedure must follow the above sequence. therefore the 4000 has been designed to inhibit any other sequence.

i.e. Offset mode cannot be selected or deselected when the Error LED is lit, and the Offset key operates in its secondary function of '%'.

Test Key

Tests available

There are two stages of 'Test' mode. The first stage, Safety and Memory checks, cannot be omitted from any 'Test' sequence.

Safety and Memory checks

On first pressing the Test key, the 4000 carries out three checks:

1. Operation of the Safety trip and reset circuitry.
2. Calibration Memory integrity.
3. Over-voltage check. (High voltage when not in HV state).

Messages appear on the MODE display, and completion is signalled by the Test LED going OFF. The remainder of the sequence may be omitted by pressing any key other than Test.

Display and key checks

If the Test Key is re-pressed before pressing any other key, a visual sequence commences to test the front panel:

1. Gas discharge displays
2. Key LEDs
3. Key contacts

The 4000 remains in the key-contact check mode until the Zero Key is pressed. It may then be used normally.

NOTE: At any time during this stage, the Test sequence may be aborted by pressing Test Key again.

Test Sequence

The Front or Rear panel terminals are not energised during Test sequence.

Safety and Memory checks.

1. Initial Conditions.

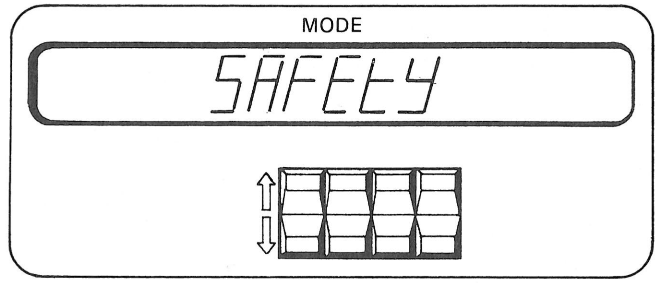
   Ensure that **OUTPUT OFF** LED is lit, **Error** and **Spec** LEDs are **unlit**. Check that **Test** LED is **unlit**.

2. Press Test Key:

   Test LED lights as the checks begin.

3. **Safety trip check.** The 4000 tests the safety trip circuits.

   The **SAFETY** message appears on the **MODE** display when the trips have operated.



4. **Safety Reset check** ensures that a user tests the Safety Reset action.

   Press **Safety Reset** Key:

   The SAFETY message disappears. Relay operation can be heard during the following automatic checks.

5. **Calibration Memory check** is a sum-check of the Non-Volatile RAM. If the check fails, the Message **FAIL 6** appears, otherwise no message.

6. **Over-voltage check** automatically tests the over-voltage detector threshold levels in Low Voltage state.
   If the check fails, the message FAIL 2 appears, otherwise PASS message indicates all 3 tests completed successfully.

7. The **Test** LED goes **OFF**

The following table summarises the MODE display messages:

Message	**Reason**
PASS	No failures discovered
FAIL 6 only	Parity error in Calibration Memory check
FAIL 2 only	High voltage can be present in Low Voltage state
FAIL 6 followed by **FAIL 2** (**FAIL** 2 remains)	Calibration Parity error and over-voltage detector failure

8. **To terminate Test** before the Display and Key checks

   Press any key other than Test:

   4000 reverts to initial conditions except that if Offset Mode were selected it is now cancelled.

   Operate 4000 normally.

Display and Key checks

Visual Check Sequence – read this information before pressing Test Key to start.

NOTE: After pressing Test Key, the Visual Check Sequence commences.

During this sequence observe that:

(a) No display segments or blocks are missing or incomplete.

(b) Segments and blocks do not appear spuriously.

(c) Inter-digit and inter-segment 'streaming' does not occur.

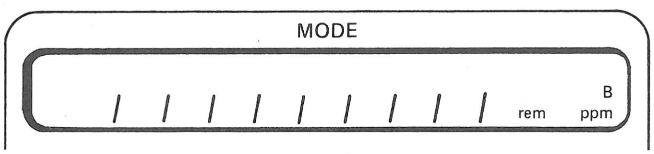
(d) All LEDs are lit in their correct sequence.

(e) LEDs are not lit spuriously.

1. **Press Test key** – **Test** LED lights
   All other LEDs unlit
   displays cleared momentarily, then:

2. **MODE** display

   (a) Initial presentation:



nine segments and legends are presented.

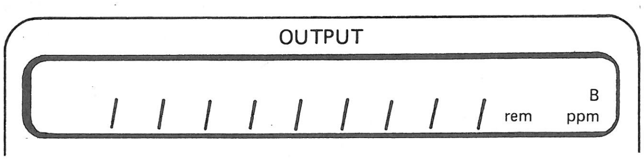
   (b) Progressively, all seven-segment digits and legends are displayed segment by segment.

N.B. Commas are not presented in the MODE display sequence.

   (c) **MODE** display cleared.

3. **OUTPUT display**

   (a) Initial presentation:



nine segments and legends are presented

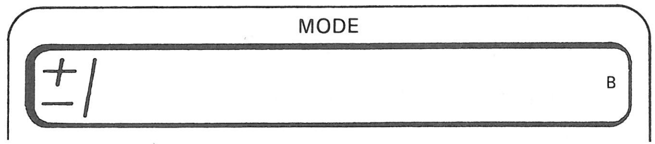
   (b) Progressively, all seven-segment digits and legends are displayed segment by segment.

   (c) Final presentation: Nine commas are displayed on **OUTPUT** display then all 18 commas are displayed on **OUTPUT** and **MODE** displays.

   (d) **OUTPUT** and **MODE** displays cleared.

4. **MODE display**

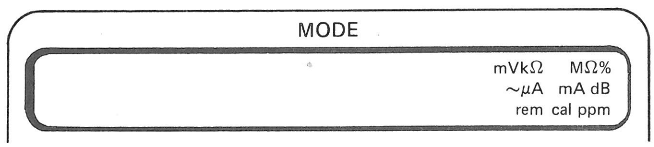
   (a) Initial presentation:



Polarity signs and overrange digit displayed.

   (b) Progressively, seven-segment digits are presented digit by digit.

   (c) Final presentation.



First, then second block of legends are displayed.

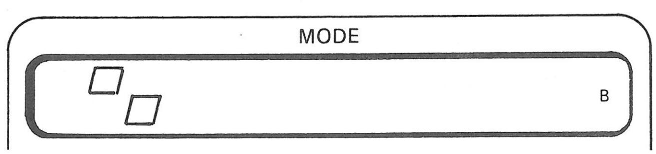
   (d) **MODE** display cleared.

5. **OUTPUT** display digits are presented next, in the same order as for the **MODE** display

6. **LED Check sequence commences:**

   (a) Test LED stays on, and key LEDs are lit in Left to Right sequence starting at 100μ key and ending at OFF

   (b) **MODE** display



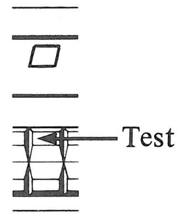
Symbol shown indicates that the keys are ready to be checked.

7. **Key Check**

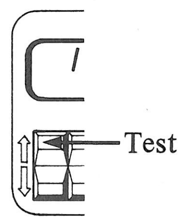
N.B. The Zero key should not be pressed until it is desired to terminate the Test Sequence.

(a) **↑|↓ Keys**

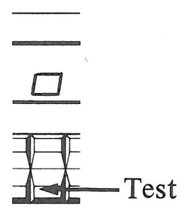
Each ↑ key should light the **upper** half of the digit immediately above it.



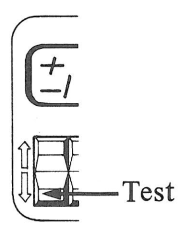
OUTPUT Display **overrange** digit ↑ key.



Each ↓ key should light the **lower** half of the digit immediately above it.



OUTPUT Display **overrange** digit ↓ key.



(b) **MODE, RANGE, FUNCTION** and **OUTPUT** keys should cause their LEDs to light with the exception of the **Safety Reset** Key, which is inoperative, and **Test** Key, which aborts the test.

(c) In these tests the key-press operates a latch so that the display or LED remains lit until another key is pressed. Only one key-press at a time is recognised.

(d) To terminate the **Test** sequence.

Press **Zero** Key

4000 reverts to initial conditions except that if Offset Mode were selected it is now cancelled.

(e) **Test** LED goes **OFF**

(f) Operate 4000 normally

Messages and Warnings

Mode Display

Error 1	– Spec Mode +Lim, – Lim	– Tolerance >100% – The selected limit is off-scale
Error 2	– Calibrate Mode	– Output not 'ON'
Error 3	– Calibrate Mode	– Incorrect range or function for this calibration mode
Error 4	– Calibrate Mode	– Correction exceeds store capability
Error 5	– Offset or Error Mode	– The selected deviation would have caused the output to exceed full-scale value, and has been prevented.
Error 6	– Calibrate Mode (Resistance)	– The resistance value entered on the OUTPUT display exceeds the calibration limit for this Range and Sense selection.
Error OL	– DC	– Output current limited to 25mA. (Output is also set OFF on 100V and 1000V ranges)
	– I	– Compliance limited to 3V.

FAIL 1 – Excessive internal temperature
FAIL 2 – Over-voltage
FAIL 3 – Control data corrupted
FAIL 4 – Precision divider fault
FAIL 5 – Safety circuits tripped
FAIL 6 – Calibration memory sum check non-parity
FAIL 7 – PA 15V/50V power failure or 50V regulator over-temperature – Suspect excessive Power Input line voltage.

SAFETY	– Test Mode	– Safety circuits tested by tripping: User should press Safety Reset Key to continue test.
PASS	– Test Mode	– Fail 6 and Fail 2 did not occur during tests of Calibration memory parity and over-voltage thresholds.

Audible Warning (a) Sounds at rate of approx 5 pulses per second during the 3 second delay between selection of OUTPUT ON and the High Voltage being connected to the terminals, when the OUTPUT TERMINAL VOLTAGE WILL EXCEED 110V

(b) Sounds at approx 1 second intervals with OUTPUT ON in high voltage state (>110V)

Key LEDs

Basic Indications

Lit : The labelled facility is selected and active

Unlit : The labelled facility is not selected.

Lit Green : (Spec Mode and Error Mode Only): Other MODE Keys' facilities are changed to secondary modes printed ABOVE the Keys as directed by the arrows – no secondary LED indications.

Warnings :

With DC Voltage Selected, 100 or 1000 RANGE LEDs Flashing — A voltage in excess of ±110V has been selected. (Whether OUTPUT is ON or OFF).

ON+ or ON– LED Flashing — Whilst in Low Voltage state with OUTPUT ON, an attempt to select an in excess of ±110V has been prevented. Repressing the key whose LED is flashing will switch the high voltage ON.

Processor "Busy"

Mode and Output displays — Legend 'B' indicates that the 4000 processor is busy.

Recalled Messages

ISSUE XX – Firmware issue number (selected by pressing Error then –Lim)

Addr XX – IEEE 488 Bus Address as set on Address switch (selected by pressing Error then +Lim).

SECTION 5 SYSTEMS APPLICATION VIA THE IEEE 488 INTERFACE

Introduction

Interface Capability

The 4000 conforms to the standard specification IEEE Std 488 – 1978 "IEEE Standard Digital Interface for Programmable Instrumentation". If may be connected to the IEEE 488 Interface Bus and set into programmed communication with other bus-connected devices under the direction of a system controller. The standard specification is detailed in the publication ANSI./IEEE Std. 488-1978.

The instrument may be programmed via the IEEE Interface, to:

(1) Change its operational state (Range, Function. Mode, Output etc.)

(2) Transmit its own 'status' data to other devices on the bus.

(3) Request service from the system controller.

Capability Codes

Although the interface specification is called a standard, variations in implementation within the specification are permitted. These variations determine the capabilities of the particular interface and a list of abbreviations are defined in the standard document to indicate to a user which interface capabilities have been designed in. These abbreviations appear on the rear of the instrument beneath the interface connector and are shown in table 5.1. A fuller description of each code appears in appendix C of the IEEE Standard.

Code	Interface Function
SH1	Source Handshake Capability
AH1	Acceptor Handshake Capability
T6	Talker (basic talker, serial poll, unaddressed to talk if addressed to listen)
TEØ	No Address Extension Talker Mode
L3	Listener (basic listener, listener only mode, unaddressed to listen if addressed to talk)
LEØ	No Address Extension Listener Mode
SR1	Service Request Capability
RL2	Remote/Local Capability (without Local Lockout)
PPØ	No Parallel Poll Capability
DC1	Device Clear Capability
DTØ	No Device Trigger Capability
CØ	No Controller Capability
E1	Open – Collector Drivers

Table 5.1
IEEE Interface capability

Bus Addresses

If a system comprises several instruments, the controller is able to communicate with the instruments indivually through the assignment to each of a different 'address'. One address is sufficient for a Datron instrument as the controller adds information to the address to define either talk or listen.

The 4000 may be preset, by means of a switch on its rear panel, either to 'Listen' only (L.O.), or to be addressed to 'talk' or 'listen' by the controller (codes T6 and L3 in Table 5.1).

Interconnections

Instruments fitted with an IEEE interface are connected together to form a system by using an interconnecting cable as specified in the IEEE Standard 488-1978 document. The connector and pin designations are also standardised and shown in Fig. 5.1 and Table 5.2.

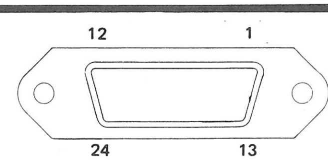


Fig. 5.1 J27 Pin Layout

Table 5.2 IEEE 488-1978 Connector — Pin Designations

J27 Pin No.	Name	Description
1	DIO 1	Data Input Output Line 1
2	DIO 2	Data Input Output Line 2
3	DIO 3	Data Input Output Line 3
4	DIO 4	Data Input Output Line 4
5	EOI	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	SHIELD	Screening on cable-connected to Safety Ground
13	DIO 5	Data Input Output Line 5
14	DIO 6	Data Input Output Line 6
15	DIO 7	Data Input Output Line 7
16	DIO 8	Data Input Output Line 8
17	REN	Remote Enable
18	GND 6	Gnd wire of twisted pair with DAV
19	GND 7	Gnd wire of twisted pair with NRFD
20	GND 8	Gnd wire of twisted pair with NDAC
21	GND 9	Gnd wire of twisted pair with IFC
22	GND 10	Gnd wire of twisted pair with SRQ
23	GND 11	Gnd wire of twisted pair with ATN
24	GND	4000 Logic Ground (Internally connected to 4000 Safety Ground)

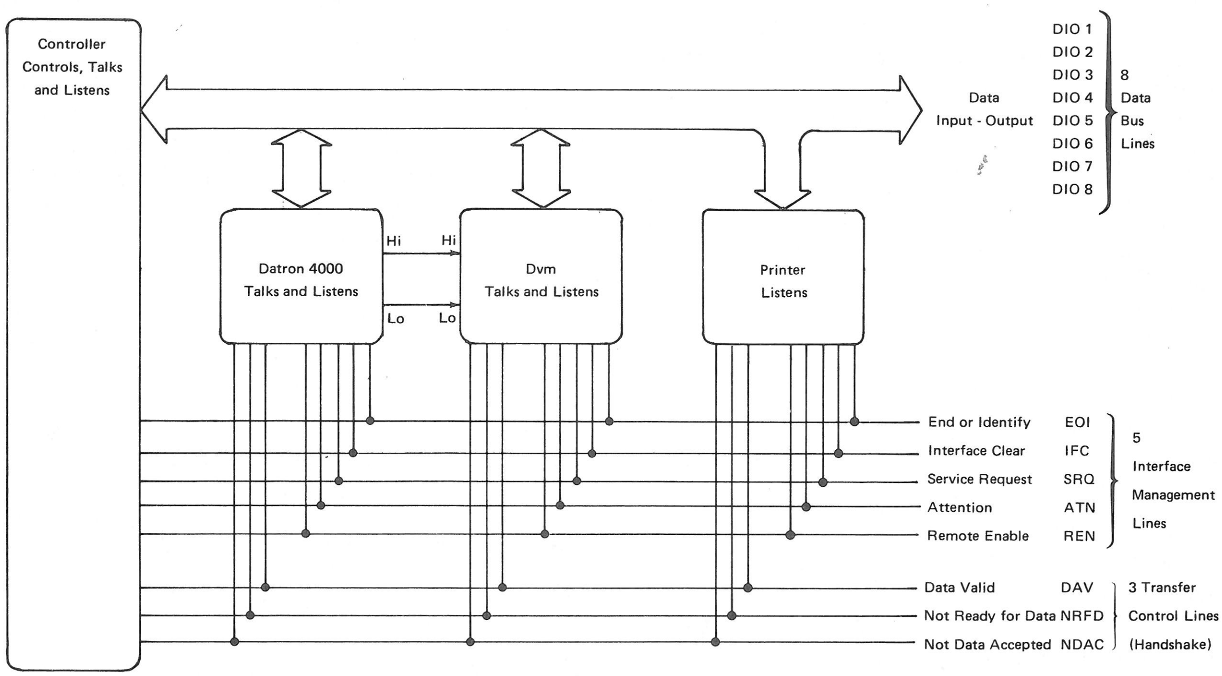


Fig 5.2. Typical System

Typical System

A typical system is shown in Fig. 5.2. The system is directed by a controlling device able to:

(a) Issue commands (controller)

(b) Receive data (listener)

and (c) Transmit data (talker)

Example of a system in operation

In the system example (Fig. 5.2) the programmed task could be to check the dvm calibration against the 4000, and print out the results.
The following is a typical sequence of events:

(1) The controller needs to instruct the 4000 to set its output to a calibration point for the dvm. These instructions must not be received by the dvm or the printer and so the controller sends the general bus message 'Unlisten'

(2) To enable the 4000 to receive its instructions the controller sends the listen address which has been assigned uniquely to this device. It follows this with the instructions required to configure the 4000 correctly for the task. The instructions are passed along the IEEE Bus data lines as coded messages (bytes). The code most normally used is ASCII (American Standard Code for Information Interchange). These instructions would include the "Output disable" message, to ensure that the DVM does not receive an inappropriate analogue input.

(3) Although the 4000 will accept the instructions as they are passed, their physical implementation will take a period of time. The controller may have been programmed to carry out other tasks during this period. In the example case it will pass configuring instructions to the dvm, after the general 'unlisten' message and the dvm 'listen' address have been sent.

(4) The dvm will also take time to settle into stable operation after accepting its instructions, so again the controller may have been programmed for other tasks during the wait, such as to pass configuration instructions to the printer.

(5) The controller then generates the 'unlisten' message, addresses the 4000 as a Listener, and re-configures its Analogue Output On by an "Output Enable" message. If the 4000 has already finished acting upon its previous instructions, it sets OUTPUT ON immediately, otherwise the OUTPUT is set ON as soon as the previous instructions have been executed.

In either case, the instrument sends a message back to the controller via the SRQ (Service Request) management line.

(6) The controller does not know which device generated the SRQ message, since the SRQ is used by all devices. (Wired – OR FUNCTION). To determine the originator, the controller can, by sending messages via the interface, ask or 'poll' all the devices one by one (serial poll).

(7) The controller will determine that the 4000 is the SRQ source and that its output is ON. It addresses the dvm as listener and the Group Execute Trigger message (GET) is passed to the dvm via the data bus, to initiate the reading.

(8) The dvm requires a period of time to take a measurement and prepare data. It generates an SRQ message to the controller when its data is ready for transfer.

(9) The controller must again determine which of the devices sent the SRQ message by conducting a poll.

(10) With the reading available, the controller activates the printer with its listen address, and the dvm with its talk address.

(11) When the controller signals the beginning of the transfer, using another of the bus management lines, the dvm will send the data, byte by byte, to the printer using the three data-byte transfer-control lines (handshake lines) to ensure orderly transfer of data between the instruments.

(12) Usually the controller is also listening to this data transfer to determine when it is complete. As an aid to the controller and printer, the dvm can send with the last byte to be transferred another message (EOI-end or identify) using another of the bus management lines.

(13) The sequence is complete and the controller is able to start again at another calibration point.

The program to check the dvm at all calibration points is built up from sequences such as that given above; changing functions, ranges and output levels as designed by the user. The program would also include "display" messages to complete the printout in a recognisable form for the user's convenience.

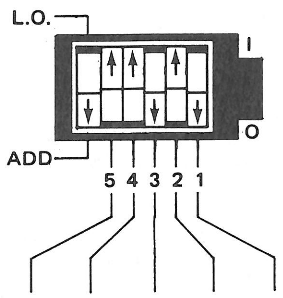
With an Autocal dvm, the program may include sequences which cause the dvm errors to be reduced until they are within specification, if it is set in its 'calibrate' mode.

Using the 4000 in a System

Address Selection — See Table 5.3

The instrument address is set manually using a six way miniature switch near the interface connector on the rear panel. Five of the switches are used to set the address, and using a binary code, this enables any address in the range 00 to 30 to be used. e.g. 11010 is address 26.

e.g. Switch setting – ADD 11010 = ADDRESS 26



A5	A4	A3	A2	A1	Decimal Code
0	0	0	0	0	00
0	0	0	0	1	01
0	0	0	1	0	02
0	0	0	1	1	03
0	0	1	0	0	04
0	0	1	0	1	05
0	0	1	1	0	06
0	0	1	1	1	07
0	1	0	0	0	08
0	1	0	0	1	09
0	1	0	1	0	10
0	1	0	1	1	11
0	1	1	0	0	12
0	1	1	0	1	13
0	1	1	1	0	14
0	1	1	1	1	15
1	0	0	0	0	16
1	0	0	0	1	17
1	0	0	1	0	18
1	0	0	1	1	19
1	0	1	0	0	20
1	0	1	0	1	21
1	0	1	1	0	22
1	0	1	1	1	23
1	1	0	0	0	24
1	1	0	0	1	25
1	1	0	1	0	26 (e.g. above)
1	1	0	1	1	27
1	1	1	0	0	28
1	1	1	0	1	29
1	1	1	1	0	30

Table 5.3. Address Selection

'Listener Only' (L.O.)

The sixth switch when set to L.O. causes the 4000 to become a 'Listener only', meaning it can only receive programming data. This may be useful in a simple system for remote control. When set to ADD, the normal bus address may be used.

Address 31 (Illegal bus address)

Address 31 configures the 4000 as a bench instrument. Only at this address is a manual calibration possible.

Addresses 0 — 30

With an address selected in the range 0 to 30, the instrument may be controlled manually, or remotely as part of a system on the Bus. The address selected must be the same as that used in the controller program to activate the 4000.

Remote Operation

When the 4000 is under the direction of the controller, the legend "rem" appears on the mode display and all front panel controls are disabled except "Power" and "Safety Reset".

The two facilities 'Error' and 'Offset' must be performed by the controller when in remote operation, and not by the 4000. (These facilities have been deleted in order to increase the speed of operation and reduce bus activity). On entering remote, any earlier selection of 'Error' or 'Offset' is cancelled. 'Spec' mode is also cancelled, but can be reselected by bus command. There is no 'Spec' mode display on the front panel in remote operation.

The 4000 power-up sequence is performed as for manual operation. In addition, an SRQ is generated for the controller, and a special 'status' byte is prepared for transmission as a response to the subsequent serial poll.

Calibration Enable

The selection of any address 0 –30 inhibits the manual calibration of the 4000, as a 'Calibration Enable' message via the bus is required to set the instrument into its Calibration mode. (For manual calibration of the 4000 the address 31 must be set on the rear panel switches, together with the CALIBRATION ENABLE keyswitch set to ENABLE).

Local Operation within a System

It is possible for the system controller to switch the 4000 for "Local" operation as part of its program. In this condition the user can control the 4000 from its front panel.

The controller can still assume overriding control, imposed by the following commands:

DCL or SDC – Specific "Device Clear" commands transmitted over the bus which return the instrument to a pre-determined state (described later in this section).

LAD with REN true – The controller addresses the 4000 as a listener with the "Remote Enable" management line true (Low). This returns the 4000 from Local to Remote control. Any commands which had been sent during the period under Local control will then be executed.

Programming Instructions

Programming Strings

From the example given earlier in this section it may be seen that the 4000 requires an address command followed by a series of device-dependent messages or commands to change the various range, function and operating modes.

A series of these commands can be sent together as a 'program string', each programming instruction being position-independent.

e.g. R4 F∅ 01 =

programming instructions (R4, F∅, 01) — string terminator (=)

Each string will contain at least one programming instruction, details of which are given later, but before the instrument can take any action on the instructions, it must receive a "terminate" signal at the end of any string.

The required terminator is the ASCII character "=".

To assist in obtaining a correct set of programming instructions, the 4000 checks for errors in the string, and generates a service request (SRQ) if a syntax error occurs or if an option was called for but not fitted.

Device-dependent commands

To give maximum scope for system programming, the bus operation of the 4000 differs in detail from manual operation, which is organised for ease of front panel use. Some functions of the 4000 firmware are deleted for bus operation, as they are easily programmed into the system controller; and extra functions have been made available to take advantage of the controller's added computing power.

The following Alphabetic codes are used to establish the required functioning of the 4000 as a calibration source:

Full Range/Zero:	A
Safety Delay Override:	D
Output ON/OFF:	O
Function DCV, DCI, Ω:	F
Range in all Functions:	R
Value:	M
Sense:	S
Guard:	G
"Calibrate" trigger:	C
Calibration Mode Enable:	W

The following Alphabetic codes are used to select and configure the messages to be passed by the 4000 via the IEEE Bus:

Output string terminators:	K
Notation of output values:	L
Specification tolerances (relative: ppm or %):	P
Specification tolerances (absolute limits):	U
Recall/Verify:	V
Service request origination:	Q
Diagnostic (Used only in manufacture):	X

Fig 5.3 summarises the way that front panel functions are transferred to system operation, and **Table 5.4** lists the range of device-dependent command codes available.

Local Operation within a System

It is possible for the system controller to sw the 4000 for "Local" operation as part of program. In this condition the user can con the 4000 from its front panel.

The controller can still assume overriding cont imposed by the following commands:

DCL or SDC – Specific "Device Clear" comma transmitted over the bus wl return the instrument to a determined state (described l in this section).

LAD with REN true – The controller addresses the 4 as a listener with the "Rem Enable" management line (Low). This returns the 4000 fı Local to Remote control. A commands which had been s during the period under Lo control will then be executed.

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From the example given earlier in this sec it may be seen that the 4000 requires an add command followed by a series of device-depen messages or commands to change the var range, function and operating modes.

A series of these commands can be sent toge as a 'program string', each programming instruc being position-independent.

e.g. R4 FØ 01 =

programming instructions ——— st termin

Each string will contain at least one programm instruction, details of which are given later, before the instrument can take any action on instructions, it must receive a "terminate" si at the end of any string.

The required terminator is the ASCII chara "=".

To assist in obtaining a correct set of programm instructions, the 4000 checks for errors in string, and generates a service request (Sl if a syntax error occurs or if an option was ca for but not fitted.

CONTROL	CODE	DESCRIPTION
FULL RANGE/ZERO	AØ A1	Zero Full Range } (Not recognised in RØ)
CALIBRATION MODE	CØ C1 C2 C3	"CAL" – Calibration Trigger "SET" "STD" } See Section 8 "±0"
SAFETY DELAY	↑ DØ D1	Safety delay active Safety delay overridden
FUNCTION	↑ FØ F2 F4	DC Voltage DC Current Resistance (also forces S1)
GUARD	↑ GØ G1	Local Guard Remote Guard
OUTPUT STRING TERMINATORS	↑ KØ K1 K2 K3 K4 K5 K6 K7	Cr, followed by Lf with EOI Cr, followed by Lf Cr with EOI Cr Lf with EOI Lf EOI with last character No terminator
VALUE NOTATION	↑ LØ L1 L2 L3	Scientific – with legends Scientific – no legends Engineering – with legends Engineering – no legends
MAIN REGISTERED VALUE	M±***. . . ↑M (Zero)	Numeric value of 4000 Analogue Output Default State
OUTPUT	↑ OØ O1	4000 Output OFF 4000 Output ON
SPECIFICATION TOLERANCE (ppm or % relative to 4000 Output value)	PØ P1 P2	24 hr 90 day } Tolerance of output value presented to bus 1 yr
SERVICE REQUEST	↑ QØ Q1 Q2	SRQ on all specified states SRQ on Overload and Fail only No SRQs
RANGE	↑ RØ R1 R2 R3 R4 R5 R6 R7 R8	Autorange (notes 1 and 2) 100μV 100μA 1Ω 1mV 1mA 10Ω 10mV 10mA 100Ω 100mV 100mA 1kΩ 1V 1A 10kΩ 10V 1A 100kΩ 100V 1A 1MΩ 1000V 1A 10MΩ
SENSE	↑ SØ S1	Local Sense Remote Sense
SPECIFICATION TOLERANCE (Absolute limits)	UØ U1 U2 U3 U4 U5	24 Hr 90 day } Output Low Limit to bus 1 yr 24 hr 90 day } Output High Limit to bus 1 yr
RECALL/VERIFY	VØ V2 V3	4000 Analogue Output value 4000 Status (as command codes) Software Status (Part/Issue number)
CALIBRATION	↑ WØ W1	Calibration Mode disable Calibration Mode Enable (With Calibration Key set to ENABLE)
DIAGNOSTIC	X*	Manufacturer's use only

NOTES 1. Autorange control not available in manual operation.
2. No Autorange in Ω Function.
↑. Power-up Default State codes.

Table 5.4 IEEE 488 Remote Programming Commands

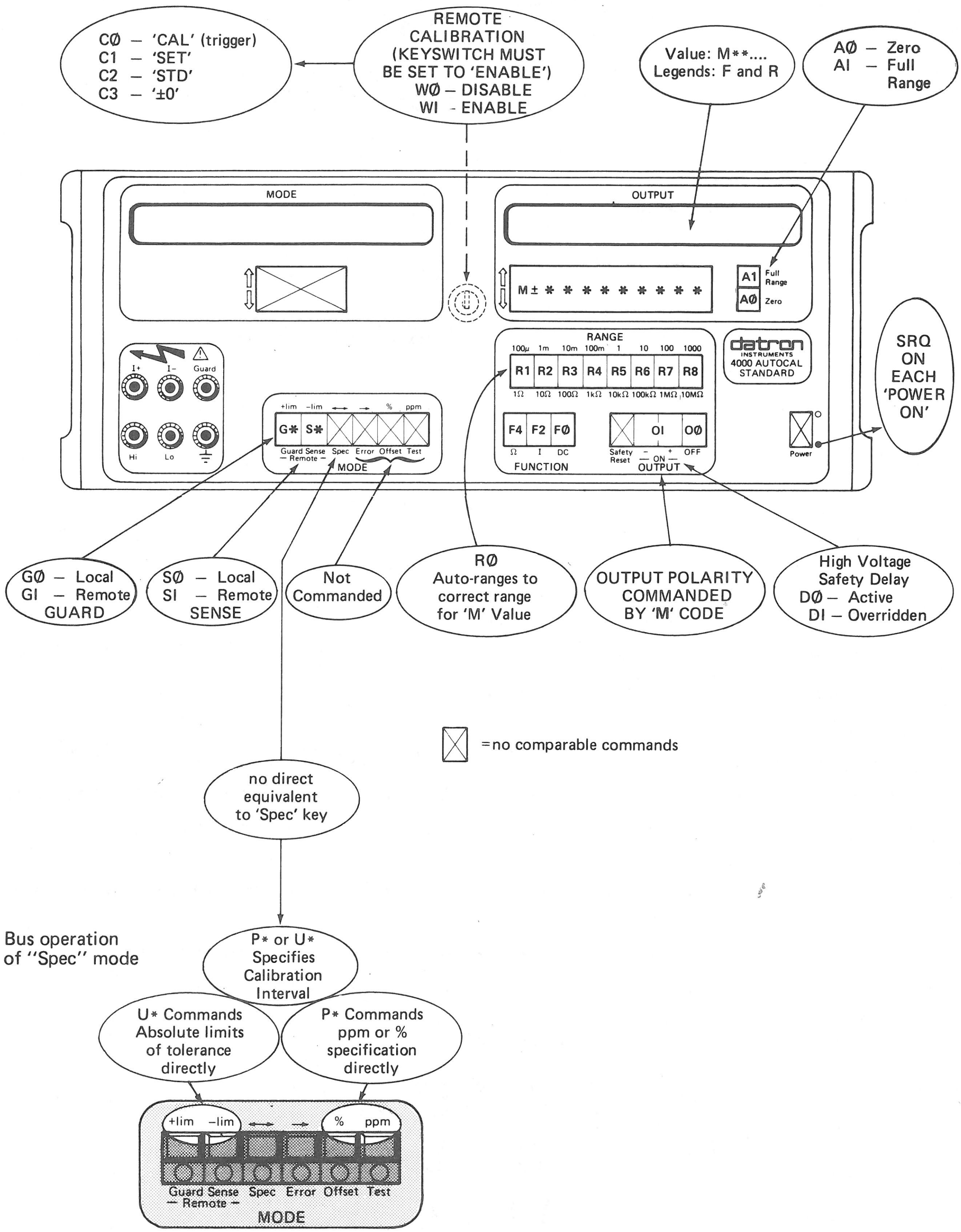


Fig. 5.3 Transfer of Front Panel Controls to System Operation

DANGER

HIGH VOLTAGE

FRONT or REAR
terminals carry the
Full Output Voltage.

THIS CAN KILL !

READ THIS: For manual operation, the 4000 High Voltage Interlocks ensure that users employ deliberate actions before voltages in excess of 110V are generated at the OUTPUT terminals. In System applications, the same interlocks require the same deliberate commands to be received from the system controller. (But see Safety Delay Override command D1 in the text).

In manual operation the user who is exposed to danger from high voltages also has direct control of the 4000 output, but it is not possible to give the same degree of built-in protection to exposed users when the instrument is under remote program control. This danger is intensified by the high speed of remote programming, so it is ESSENTIAL that WHENEVER THE 4000 IS BEING USED IN A SYSTEM TO GENERATE VOLTAGES IN EXCESS OF 110V, THERE MUST BE NO ACCESS TO THE 4000 FRONT PANEL OR REAR PANEL OUTPUT TERMINALS.

Unless **you** are **sure** that
it is **safe** to do so,
DO NOT TOUCH the
I+ I– Hi or **Lo leads**
and **terminals**

DANGER

Programming of Operational Functions

OUTPUT ON/OFF. The analogue OUTPUT is switched off by command **OØ** (output disable), and switched on to the selected value by **O1**. The polarity of the output is derived from the data used to set the main register (Output display). The appropriate LED is lit for the output terminal polarity.

Safety Delay. The High Voltage Safety delay (3 seconds) is normally active (**DØ**). It may be overriden by command D1, but the use of this command sets up potentially dangerous situations. **DØ** is enforced by any Function or Range change (including Autorange changes).

DO NOT USE D1 UNLESS ESSENTIAL FOR HIGH SPEED OPERATION. TAKE SAFETY PRECAUTIONS TO PROTECT PERSONNEL IN THE VICINITY.

Function. **FØ** (DC Voltage) **F2** (DC Current) and **F4** (Resistance) configure the instrument to the required function. **F4** forces the 4000 into **S1** (Remote Sense), but **SØ** may be used to command Local Sense. Programming out of **F4** forces the 4000 into **SØ**.

Range. **R1** through to **R8** configure the 4000 to specific ranges as shown in Table 5.4. **RØ** places the instrument in auto-range function, which allows the OUTPUT value to be specified as a number without setting the actual range. Upranging occurs at full scale, down-ranging at 20% of range, i.e. full scale value of next lower range. **RØ** is not applicable to Resistance Function (**F4**). Commands **AØ** and **A1** are not recognised in autorange.

Output Display Value (Main Register). In remote programming, the incremental (↑|↓) method of setting the output value is not used. Instead, each main register value is input explicitly by Code M********* in numeric, scientific or engineering notation. If the resolution is too high for the range in use the value is truncated to the selected resolution and the controller is informed by SRQ Status byte (see SRQ status byte formats later in this section).

The change from Low to High voltage state is controlled by the same interlocks which govern the manual changeover. To effect the changeover, the command string "M (followed by voltage code) O1 =" must be used whether the Output is already enabled (O1) or disabled (OØ). [When the M code alone is attempted (Mxxxx...=) the 4000 responds by entering the new value in the Main Register (Output display). If Output is already enabled the output voltage does not change until it receives commands "O1=", then it ramps to the high voltage. If Output is already disabled, it needs the enabling command in any case].

A delay of 200mS is incurred on sign change and the slew rate of the ramp up or down is adjusted to match that of the analogue circuitry involved.

During these processes, the front panel warnings of flashing LEDs and pulsing tones operate as for manual operation. **Nevertheless, access to the front panel should be restricted because the high speed of programming on the IEEE interface adds to the safety hazard.**

Examples of valid M codes:

Value	Function	Range	M Code	Output Display
−153V	FØ	R7	M− 153	− 153.0000V
+1.6212574V	FØ	R5	M+ 1.6212574	+ 1.6212574V
+1.6212574V	FØ	R5	M+ 16212574E−7	+ 1.6212574V
+1.6212574V	FØ	RØ	M+ 1621.2574E−03	+ 1.6212574V (Autorange to R5 = 1V)
0.002563A	F2	RØ	M.002563	+ 2.56300mA (Autorange to R3 = 10mA)

Resolution. For normal use the 4000 resolution is set as follows for the Function and Range selections:

Range		100μ / 1Ω	1m / 10Ω	10m / 100Ω	100m / 1kΩ	1 / 10kΩ	10 / 100kΩ	100 / 1MΩ	1000 / 10MΩ
Range Code		R1	R2	R3	R4	R5	R6	R7	R8
Functions:									
DC Voltage	FØ	4½	5½	6½	7½	7½	7½	7½	7½
DC Current	F2	6½	6½	6½	6½	6½	—	—	—
Resistance and Remote Sense	F4 S1	7½	7½	7½	7½	7½	7½	7½	7½
Resistance and Local Sense	F4 SØ	3½	4½	5½	6½	7½	7½	7½	7½

Guard and Sense. These are configured into Local or Remote by G and S codes:

- GØ Local guard
- G1 Remote guard
- SØ Local sense (If in F4, SØ programs for 2-wire resistance).
- S1 Remote sense (Programming F4 automatically forces S1 for 4-wire resistance).

These bus commands are subject to the constraints of the 4000 firmware.
Invalid commands (e.g. Remote Sense when in 100mV range) will be rejected and ignored. Sense changes when in F4 (Resistance) alter the resolution and value on the OUTPUT display (Refer to "Resolution" above).

Programming of Bus Transmissions

Format Output (Codes K and L)

Codes KØ to K7 are used to adapt the Interface Output of the 4000 for systems which employ different output-string terminators.

The terminators used could be any combination of carriage return (Cr) and Line Feed (Lf) on the data bus, with the **EOI** management line held true or false with the last character. To accommodate these variations, the system programmer uses the K codes:

Code KØ – No suppression (Cr. Lf and EOI all present as terminators)
K1 – Suppress EOI (Terminator Cr Lf)
K2 – Suppress Lf (Terminator Cr with EOI)
K3 – Suppress Lf and EOI (Terminator Cr)
K4 – Suppress Cr (Terminator Lf with EOI)
K5 – Suppress Cr and EOI (Terminator Lf)
K6 – Suppress Cr and Lf (Terminator EOI with last character)
K7 – Suppress Cr, Lf and EOI (No terminators used)

Each output string will be terminated as defined by the K code.

Codes LØ to L3 configure the output string notation:

LØ – Scientific notation with legends
L1 – Scientific notation, no legends
L2 – Engineering notation with legends
L3 – Engineering notation, no legends

Service Request

The 4000 can asynchronously request service from the controller by putting the **SRQ** line true (low) **SRQ** is always generated by the action of switching the 4000 power **ON**, as the power-up default mode is **QØ**.

A user can program the 4000 to generate SRQs (or not) using command code Q:

QØ – SRQ on any of the states in table 5.5
Q1 – SRQ on overload and any FAIL state in table 5.5
Q2 – No SRQs generated

Serial Poll and RQS Status Byte. If programmed for SRQ response, the bus controller will pause in its operation to attend to the service request. It first conducts a serial or parallel poll to determine which device initiated the SRQ. The 4000 does not react to parallel poll, but responds to serial poll, during which each device is addressed in turn. The instrument responds to its serial-poll address by releasing a prepared "RQS Status Byte" on to the bus. The **RQS Request Bit** (bit b7 of its status byte) is set true (Low) only if the 4000 has generated the SRQ. This validates the remainder of the byte, which describes the causal condition by the state codes listed in Table 5.5.

RQS Status byte is composed as follows:

bit b8: indicates an option or syntax error when true
bit b7: the RQS request bit, which when true admits that the 4000 was the SRQ originator. The RQS status byte is not valid unless bit b7 is true
bit b6 false: bits b5-1 <u>each</u> represent separate functional states within the 4000 so that the RQS byte represents several states as listed in Table 5.5

Example with bit b6 false: RQS status byte 010x0001 represents:

0 – No option or Syntax error
1 – This instrument originated the SRQ
0 – The following bits each represent separate states
x – This bit has no significance, x = 1 or 0
0 – No High voltage warning
0 – Auxiliary register not at limit
0 – Main register not at limit
1 – Output is ON

Bit b6 true: Each <u>combination</u> of bits b5-1 represents a single state as listed in Table 5.5

The RQS status byte should not be confused with other status messages (e.g. 'calibrator' or 'software' status, described later under 'Recall/Verify') which are called up by the system controller's program.

Table 5.5 lists the possible RQS status bytes which may be transmitted by the 4000.

N.B. The information in the byte is valid only if bit b7 (request bit) is true.

Legend 1 = True, 0 = False, x = Either 1 or 0.

1 = True   0 = False   x = 1 or 0

bits	b8	b7	b6	b5	b4	b3	b2	b1	
	1	x	x	x	x	x	x	x	Option or Syntax error
	x	1	x	x	x	x	x	x	RQS Request-for-service bit
Combination Status Messages									
	x	1	0	x	x	x	x	1	Output ON
	x	1	0	x	x	x	1	x	Main Register limit reached
	x	1	0	x	x	1	x	x	Auxiliary Register limit reached
	x	1	0	x	1	x	x	x	High Voltage Warning
Individual Status Messages									
	x	1	1	0	0	0	0	0	Recall message available
	x	1	1	0	0	0	0	1	Error 1 Specification not displayable
	x	1	1	0	0	0	1	0	Error 2 CAL mode : Output not ON
	x	1	1	0	0	0	1	1	Error 3 CAL mode : Incorrect Range/Function
	x	1	1	0	0	1	0	0	Error 4 CAL mode : Insufficient store span
	x	1	1	0	0	1	0	1	Error 5 Offset/Error : Overscale output requested
	x	1	1	0	0	1	1	0	Error 6 CAL mode : Selected resistance value exceeds calibration limits
	x	1	1	1	0	0	0	0	Fail 0 Fault condition rectified
	x	1	1	1	0	0	0	1	Fail 1 Over-temperature
	x	1	1	1	0	0	1	0	Fail 2 Over-Voltage
	x	1	1	1	0	0	1	1	Fail 3 Analogue Control fault
	x	1	1	1	0	1	0	0	Fail 4 Precision divider fault
	x	1	1	1	0	1	0	1	Fail 5 Safety alarm
	x	1	1	1	0	1	1	0	Fail 6 Cal. store sum check non-parity
	x	1	1	1	0	1	1	1	Fail 7 Power supply fault
	x	1	1	1	1	1	1	0	Overload – Current or voltage limited
	x	1	1	1	1	1	1	1	Power-on

Table 5.5 Status Byte Coding

FAIL Messages. The 4000 needs to react quickly to internally-generated FAIL messages and is programmed to take rapid protective action. A fault condition may generate a train of internal FAIL messages, which occur too quickly for some controllers to detect. Such a train may be terminated by a FAIL 5 message, which is detected by the controller. Therefore the receipt of a FAIL 5 message by a controller should be taken as a final default condition, and not as indicating the origin of the fault.

Specification tolerance (ppm or %).

The **Spec** mode is accessible over the bus, including setting the calibration interval:

- **PØ** – 24 hour
- **P1** – 90 day
- **P2** – 1 year

On being commanded by 'P' code, the 4000 calculates its Output tolerance (in % or ppm) and generates an output string formatted as commanded by K and L codes.

Absolute limits of tolerance.

In this case, the U commands cause the 4000 to calculate the high or low **spec limit** of its output value against the nominated calibration interval:

UØ	– Low limit	24 hour
U1	– Low limit	90 day
U2	– Low limit	1 year
U3	– High limit	24 hour
U4	– High limit	90 day
U5	– High limit	1 year

On being commanded, the calculated value is output by the 4000 in an output string formatted by K and L codes.

Recall/Verify.

By programming a V code the controller effectively interrogates the 4000 to identify its present status:

- VØ – Output value
- V2 – Functional status
- V3 – Software status

Code VØ recalls the output value, as an ASCII string.

The response to V2 is an ASCII string:

(space R*F*O*G*S*W*Q*D*L*K*terminator)

The functions are represented by the same numerics as for programming. In addition the Range is identified by a lower case 'r' if the 4000 is programmed in autorange.

The software status is the part number and issue number of the internal program. This is formatted as follows, in response to command code V3:

space	890044	-	numeric	terminator
	Part No.		Issue No.	

(This status report is also available manually by pressing the **Error** key and then the **Lim** + key. The firmware issue-number is presented on the **MODE** display)

Recall/Verify bus transmissions. Once the appropriate ASCII output string has been assembled in the 4000 Output registers it may be released onto the bus by addressing the 4000 as a talker. Alternatively, if **QØ** or **Q1** is set, the SRQ line will be set true, and the "Recall" SRQ status byte made available (x1100000) for the subsequent serial poll. On receiving the status byte the controller addresses the 4000 as a talker, and the output string is transferred via the IEEE data bus to the programmed listener(s).

Calibration Enable (W codes) and Calibrate (C codes).

These are available for "Autocal" calibration of the 4000 on the IEEE bus:

- **WØ** – disable
- **W1** – enable (only if CALIBRATION ENABLE keyswitch set to **ENABLE**)

CØ	– Calibration Trigger – equivalent to **CAL** key	Refer to Section 8
C1	– as **SET** key	
C2	– as **STD** key	
C3	– as **±O** key	

Diagnostic.

The range of 'X' codes is reserved for the manufacturer's diagnosis during production, and is not available for general use.

Activation of Commands

Use of terminator. The 4000 does not activate commands, whether single or multiple, unless the recognised terminator is received. This is the ASCII character "=".

Commands or command strings may be received while the instrument is in Local control, but will not be activated even if a terminator is present, until the instrument is set to remote control. The two "Clear" messages (DCL and SDC) will be activated even when in Local control.

Multiple Commands

Activation sequences. The input buffer has a capacity of 128 characters. Commands in a multiple string may be entered in any order, provided correct character syntax is observed. They are extracted from the buffer in received sequence and sorted by alpha character into command stores. Any existing commands in the stores are over-written and lost.

When a string terminator is received the commands in the store are activated. To ensure that the operational and safety constraints of the 4000 are observed, new commands are executed in the following defined sequence:

K	Output terminator format
L	Output notation
Q	SRQ Mode
W	Calibration Enable
S	Sense
G	Guard
F	Function
R	Range
D	Safety Delay override
A	Full Range/zero
M	Main register value
C	Calibrate Mode
O	OUTPUT ON/OFF
P	Specification tolerance
U	Specification limits
V	Recall/Verify

A programmer may elect to change the sequence by inserting terminators between commands, but the basic constraints of the 4000 will still be imposed. For example, if the function is changed as a single command (e.g. F2 =) the main program firmware will set Output OFF as a result, and it must then be re-programmed ON by the user.

Succession of multiple commands. If the input buffer is not full, new commands are accepted to await their turn for processing, and are extracted string by string. The input system design makes it extremely unlikely that the buffer will overflow, unless the 4000 is in "Local control" (REN false) and the command input is excessive.

If the buffer does fill up, the IEEE bus handshake sequence is held until the string in Command Store has been activated and the extraction process has restarted. Then the handshake is released and commands may once again be passed into the input buffer.

Input Errors. Any non-printing characters are ignored and not entered in the input buffer. Other unwanted commands are entered but later rejected. Certain syntax errors will abort individual commands leaving other commands in the string to be activated. (The whole string is not aborted). Any incorrect command may be over-written by entering the correct command and terminator.

"Read" commands.

Before addressing the 4000 as a talker, it is essential that is has been programmed by a P, U or V command. Otherwise it will have no data to transmit.

Universal commands.

The following commands are actioned as described below:

LLO (Local Lockout)	– ignored, no capability
PPU (Parallel Poll Unconfigured)	– ignored, no capability for parallel poll
SPE (Serial Poll Enable)	– will set the instrument to serial poll mode state, and when addressed will respond with RQS status byte. This byte contains the condition of the request service bit (bit 7). If the 4000 is requesting service this bit will be true, and the associated bits will describe the service requested.
SPD (Serial Poll Disable)	– returns the instrument to serial poll idle state.

Addressed commands

PPC (Parallel Poll configure)	– ignored, no capability
GET (Group Execute Trigger)	– ignored, no capability
TCT (Take Control)	– ignored, no capability
GTL (Go To Local)	– instrument returns to Manual Control. The controller regains remote control by addressing the 4000 as a listener with REN line true.

Clear commands (DCL and SDC)

When the 4000 receives either of the two 'Clear' messages, (DCL is universal and SDC is addressed to a selected device) it will default to the pre-determined state defined below. During the time taken to default, the IEEE interface handshake is held. These commands are effective even in "Local" control.

A?	Not Active (see M code)
FØ	dc volts
RØ	autorange 10V dc default
M (value)	where value is zero
GØ	local guard
SØ	local sense
OØ	off state
QØ	SRQ on all specified states
DØ	Safety delay active
WØ	calibration disabled
C?	not active – disabled by WØ
P?	not active
U?	not active
V?	not active
X?	not active
K*	unchanged
L*	unchanged

Operational Sequence Guidelines

Most inferface communication tasks require sequences of coded messages to be sent over the interface. Many controllers assign a single programming instruction to a complete sequence, so it is advisable to study the available controller capabilities carefully before attempting to program a system. Because the IEEE Std 488 (1978) allows a certain latitude in bus protocol, considerable differences may be found between programming instructions and operating sequences from one make of controller to another.

Consequently, the following sequences are recommendations only.

Data Transfer

UNL	Inhibits all current listeners
LAD_1 ⋮ LAD	Each address sent enables a specific device to receive future data bytes. More than one address may be sent if multiple listeners desired.
TAD	The address sent enables a specific device to send data. NB The 4000 must be already programmed to prepare data.
DAB_1 ⋮ DAB_n	Data bytes sent by currently-enabled talkers to all currently-enabled listeners.
UNT	Disables the talker on receipt of last character.

UNL = unlisten
LAD = listen address of specific device
TAD = talk address of specific device
DAB = data bytes
UNT = untalk

Serial Poll

UNL	Prevents other devices listening to status sent.
SPE	Puts interface into serial poll mode during which all devices send status instead of data when addressed.
TAD_n	Enable a specific device to send status. Within this loop devices should be sequentially enabled.
SBN or SBA	Status byte sent be enabled device: If SBN, loop should be repeated. If SBA sent, the enabled device is identified as having sent SRQ and will automatically remove it.
SPD	Disables serial poll mode.
UNT	Disable last talker.

SPE = Serial poll enable
SPD = Serial poll disable
SBN = Status byte negative where bit 7 = Ø
SBA = Status byte affirmative where bit 7 = 1

Untalk. It is highly desirable that a sequence which causes a device to be addressed as a talker should be terminated by an "untalk" command.

SECTION 6 SPECIFICATIONS

General

POWER SUPPLY

Voltage	:	100/120/220/240V ±10%
Line Frequency	:	48 to 62Hz
Consumption	:	<300 Watts
Fuses 220/240V	:	3.0A
100/120V	:	6.25A

CLIMATE CONDITIONS

Operating Temperature	:	0°C to +50°C (except where specified)
Storage Temperature[1]	:	–40°C to +70°C
Maximum Relative Humidity	:	75% @ 40°C
Warm-up Time	:	Four hours to meet all specifications

MECHANICAL

Dimensions	:	Height 178mm (7") Width 454mm (17.9") Depth 563mm (22.2")
Weight	:	30 Kg (66 lbs)

OPERATING INDICATIONS

Scale length	:	Output display – 7½ digits max. e.g. 1.9999999V. Mode display – 7½ digits max. in Offset Mode. For other modes see Section 4
Indication	:	Symbols lit on display and illuminated keys

AUTORANGE : Available on IEEE 488 interface only. See Sect. 5

SAFETY : The 4000 has been designed to meet BSI 4743, IEC 348, and UL 1244 specifications.

PEAK TERMINAL VOLTAGES

Guard to Ground	:	920V
Lo to Guard or Ground	:	920V
Hi to Guard or Ground	:	1556V
Rear panel digital inputs to Ground	:	0V to +5V. NB. Digital Common is internally strapped to Ground.
to Lo or Guard	:	920V
to Hi	:	1556V

[1] External Temperature stress may affect calibration stability

DC Voltage

Stability and Accuracy

MODEL	RANGE	STABILITY [2] ±(ppm Output + ppm FS) [4]		ACCURACY RELATIVE TO CALIBRATION STANDARDS ±(ppm Output + ppm FS) [4]		
		10 Mins	24 Hours	24 Hours	23°C ±1°C 90 Days	1 Year
4000A	100.00μV - to - 100.00000mV	0.3 + 0.3μV	0.6 + 0.3μV	2.0 + 0.4μV	4 + 0.4μV	8 + 0.4μV
	1.0000000V	0.2 + 0.25	0.5 + 0.25	1.0 + 0.4	3 + 0.4	6 + 0.4
	10.000000V	0.2 + 0.05	0.3 + 0.05	0.5 + 0.25	2 + 0.25	4 + 0.25
	100.00000V	0.2 + 0.13	0.5 + 0.13	1.0 + 0.5	3 + 0.5	6 + 0.5
	1000.0000V	0.3 + 0.1	0.5 + 0.1	2.0 + 0.25	4 + 0.25	8 + 0.25
4000	100.00μV - to - 100.00000mV	0.3 + 0.3μV	1.5 + 0.3μV	3.0 + 0.5μV	6 + 0.5μV	12 + 0.5μV
	1.0000000V	0.2 + 0.25	1.2 + 0.25	2.0 + 1.0	4 + 1.0	8 + 1.0
	10.000000V	0.2 + 0.05	0.6 + 0.05	1.0 + 0.5	3 + 0.5	6 + 0.5
	100.00000V	0.2 + 0.13	1.2 + 0.13	2.0 + 1.0	4 + 1.0	8 + 1.0
	1000.0000V	0.3 + 0.1	1.2 + 0.1	3.0 + 1.5	6 + 1.5	11 + 1.5

Noise

(For 10kHz-wide band, multiply 2.5kHz figures by 2)

(For DC-10Hz, multiply DC-2Hz figures by 2)

(For RMS, divide pk-to-pk figures by 6)

BANDWIDTH / RANGE	2.5kHz (RMS)	Average over 1 Line Period (pk-to-pk)	Average over 10 Line Periods (pk-to-pk)	DC - 2Hz Typical Null Detector (pk-to-pk)
100μV - 100mV	2μV	0.2μV	0.05μV	0.1μV
1V	4μV	1.5μV	0.5μV	0.5μV
10V	10μV	5μV	2μV	2μV
100V	400μV	50μV	25μV	25μV
1000V	2.5mV	500μV	150μV	150μV

Notes:

[2] Stability figures repeatable only in the same environmental conditions.
[3] Datron Instruments traceability to National Standards.
[4] FS (Full Scale) = 2 x Nominal Range.

ACCURACY RELATIVE TO CALIBRATION STANDARDS ±(ppm Output + ppm FS) [4]			CALIBRATION UNCERTAINTY ±ppm [3]	TEMPERATURE COEFFICIENT ±ppm Output/°C 13°C - 18°C 28°C - 33°C	OUTPUT	
24 Hours	23°C ±5°C 90 days	1 Year			IMPEDANCE	COMPLIANCE
4.0 + 0.5µV	6.0 + 0.5µV	10 + 0.5µV	5	1.4	100Ω	—
2.5 + 0.5	4.5 + 0.5	8 + 0.5	3	0.8	<0.1mΩ	25mA
1.0 + 0.25	2.5 + 0.25	5 + 0.25	2	0.3	<0.1mΩ	25mA
2.5 + 0.5	4.5 + 0.5	8 + 0.5	4	0.8	<1mΩ	25mA
3.5 + 0.25	5.5 + 0.25	10 + 0.25	4	0.8	<10mΩ	25mA
7 + 0.5µV	10 + 0.5µV	16 + 0.5µV	5	2.4	100Ω	—
5 + 1.0	7 + 1.0	11 + 1.0	3	1.4	<0.1mΩ	25mA
3 + 0.5	5 + 0.5	8 + 0.5	2	1.0	<0.1mΩ	25mA
5 + 1.0	7 + 1.0	11 + 1.0	4	1.6	<1mΩ	25mA
7 + 1.5	10 + 1.5	15 + 1.5	4	2.0	<10mΩ	25mA

Other Specifications

Overrange	100% On 100µV to 100V Ranges; 20% on 1000V range (1200V).
True Bipolar Output	Capable of delivering ±1200V with respect to Output Lo at up to 25mA.
Settling Time	0.1s / 1s / 5s Proximity to step size: 100ppm / 10ppm / 1ppm
Remote / Local Sensing	Selectable remote or local voltage sensing on 1V to 1000V ranges.
Remote / Local Guarding	Selectable remote or local guard connection Maximum Guard to Ground voltage: 650Vrms (2.5kV flash test).
Common Mode Rejection Ratio	140dB at DC - 400Hz

Current

Accuracy

MODEL	RANGE	ACCURACY RELATIVE TO CALIBRATION STANDARDS ±(ppm Output + ppm FS) [4]					
			23°C ±1°C			23°C ±5°C	
		24 Hours	90 Days	1 Year	24 Hours	90 Days	1 Year
4000/4000A	100.0000μA	5 + 5	20 + 5 50	40 + 5	15 + 5	30 + 5	50 + 5
	1.000000mA	5 + 5	20 + 5 50	40 + 5	15 + 5	30 + 5	50 + 5
	10.00000mA	5 + 5	20 + 5 50	40 + 5	15 + 5	30 + 5	50 + 5
	100.0000mA	5 + 5	20 + 5 50	40 + 5	15 + 5	30 + 5	50 + 5
	1.000000A[5]	10 + 10	50 + 10 125	75 + 10	40 + 10	80 + 10	100 + 5

Notes:
[3] Datron Instruments traceability to National Standards.
[4] FS (Full Scale) = 2 x Nominal Range.
[5] Accuracy figures are "typical" for outputs in excess of 1 Ampere.

Resistance

Accuracy

MODEL	RANGE [1]	ACCURACY RELATIVE TO CALIBRATION STANDARDS ±(ppm Output + ppm FS) [4]					
			23°C ±1°C			23°C ±5°C	
		24 Hours	90 Days	1 Year	24 Hours	90 Days	1 Year
4000/4000A	1.0000000Ω	10	15 50	25	30	35	45
	10.000000Ω	4	10 30	15	15	20	25
	100.00000Ω	1.5	3 12	5	5	7	9
	1.0000000kΩ	1.5	3 12	5	5	7	9
	10.000000kΩ	1.5	3 12	5	5	7	9
	100.00000kΩ	1.5	3 19	8	5	7	12
	1.0000000MΩ	4	10 40	15	15	20	25
	10.000000MΩ	10	25 65	35	30	40	50

x) tatsächliche Werte im Standard

Notes:
[1] Range figures are nominal. Actual calibrated values are displayed.
[3] Datron Instruments traceability to National Standards.
[4] FS (Full Scale) = 2 x Nominal Range.

Noise

CALIBRATION UNCERTAINTY ±ppm [3]	TEMPERATURE COEFFICIENT ±ppm Output/°C 13°C - 18°C 28°C - 33°C	OUTPUT IMPEDANCE	OUTPUT COMPLIANCE
10	6	> 20GΩ	1.5 volts to full specification - 3 volts maximum
10	6	> 2GΩ	
10	6	>200MΩ	
10	6	> 20MΩ	
25	15	> 1MΩ	

BANDWIDTHS 2.5kHz (RMS)	BANDWIDTHS Average over 1 Line Period (pk-to-pk)	BANDWIDTHS Average over 10 Line Periods (pk-to-pk)
500pA	300pA	200pA
5nA	3nA	2nA
50nA	30nA	20nA
1μA	500nA	400nA
25μA	25μA	10μA

For LF RMS noise divide pk-pk figures by 6.

Other Specifications

Overrange	100% on all ranges
True Bipolar Output	Capable of delivering ±2 Amperes
Settling Time	1 second to specification
Sense and Guard	Local only - Remote not available

CALIBRATION UNCERTAINTY ±ppm [3]	TEMPERATURE COEFFICIENT ±ppm Output/°C 13°C - 18°C 28°C - 33°C	SPECIFIED CURRENT (Is)	MAXIMUM CURRENT (Im)	ADDITIONAL UNCERTAINTY for Is < I < Im (ppm)
15	10	100mA	250mA	$100.I^2$
10	6	10mA	100mA	$(10x10^2).I^2$
5	2	10mA	25mA	$(8.5x10^3).I^2$
5	2	1mA	10mA	$(8.5x10^4).I^2$
5	2	100μA	2.5mA	$(8.5x10^5).I^2$
12	2	100μA	1mA	$(8.5x10^6).I^2$
20	6	10μA	100μA	$(10x10^7).I^2$
25	10	1μA	10μA	$(15x10^8).I^2$

Other Specifications

Connection	Selectable 2 or 4 wire connection to resistors. In 2 wire, displayed value includes lead resistance.
Guarding	Selectable remote or local guard connection.
Protection	All resistors fuse-protected to max applied voltage of 120V rms.

SECTION 7 SPECIFICATION VERIFICATION

Introduction

This section contains the procedures used to verify that the 4000 is working within its specification. They may be used to check the instrument during a "goods inwards" inspection, or for a routine performance test.

Verification upon receipt of a 4000 Autocal Standard

Each instrument leaving the factory is calibrated to its nominal values in DC Voltage. If Option 20 is fitted, it is also calibrated to nominal in DC Current, and to actual values in Resistance. The Accuracy specifications can be made relative (ie. Traceable) to National Standards, by the addition of Datron's Calibration Uncertainty figures printed in the specifications. Thus either the 90-day or 1-year accuracy specification is verifiable by comparison with traceable Reference Standards.

The 10-minute and 24-hour stability specifications can only be verified following a calibration operation or calibration check against the user's Reference Standards.

Equipment Requirements

DC Voltage

- A Standard DC Voltage source of suitable accuracy
  Example: Series bank of 10 standard cells and Datron 4904 Standard Cell buffer.
- A Precision Divider.
  Example: Datron 4902 High Voltage divider and Datron 4903 DC Switching Unit
- A battery-operated null detector with variable sensitivity, able to withstand 1200V across its input terminals
  Example: Keithley Instruments Model 155

DC Current

- A DC Voltage source, calibrated to suitable accuracy at approximately 1V and 100mV
  Example: The standard voltage source used for DC Voltage, with the Datron 4903 DC Switching Unit.
- The battery-operated null detector used for DC Voltage.
- A set of calibrated current shunts of suitable accuracy.

N.B. To allow the same value to be set on the DC Voltage source for each range, the shunts may be of five decade values. Then the same Null Detector sensitivity can be used on each range.

CAUTION When choosing a set of current shunts ensure that their power dissipation ratings are sufficient to avoid permanent degradation from the self-heating effects of the current being checked. This applies particularly to the 1 Amp shunt.

- alternatively, a dmm of sufficient accuracy may be used to measure the voltage across the set of calibrated current shunts
  Example: Datron 1081 using "compute" mode.

Resistance

- a set of standard resistors covering 1Ω to 10MΩ. The 1Ω to 10kΩ should be 4-wire type.
- an accurate resistance bridge, or other ratiometric device for measuring resistance to the required accuracy.
- a Datron 1081 used as a transfer-measurement device.

Notes on the Use of the Null Detector

The null detector is connected in the **Hi** lead between the DC Voltage Source and the 4000. A high-impedance-input device should be chosen to reduce off-null currents due to differences in the outputs of the DC voltage source and the 4000. A battery-operated instrument is preferred to ensure adequate isolation. Some null detectors possess high input impedance only when their readings are on-scale, so care should be taken to ensure that drain currents from the DC Voltage source do not become excessive. This applies particularly if the DC source is a standard cell or a bank of cells. Five points are important:

1. The null detector should be connected to the 4000 (or 4000 load resistor in Current function) only when the 4000 **OUTPUT OFF** LED is lit. (With Output **OFF**, the **I+**, **I–**, **Hi** and **Lo** terminals are at high impedance).

2. Always set the null detector to its lowest sensitivity before connecting up, and increase sensitivity only when the voltages output by the DC Voltage source and the 4000 are close in value.

3. Do not change polarity of the 4000 or DC Voltage source without first switching the 4000 OUTPUT **OFF**. Care must be taken to ensure that the correct-polarity **ON** key is pressed, to avoid excessive voltages being connected across the null detector, particularly when checking the 4000 directly against a standard cell.

4. WARNING **During Performance checks and calibration a common mode voltage equal to the full range voltage is present at the Null Detector input terminals. On ±1000V checks this voltage is potentially lethal, so EXTREME CAUTION must be observed when making adjustments to the null detector sensitivity.**

5. CAUTION The Null Detector used must be able to withstand voltages up to 1200V between its input terminals. Such voltages will be present during the time that the 4000 is ramping from zero to 1000V Full Range after setting OUTPUT ON.

Specification Verification Report Sheet

The verification procedures in this section use the **+Lim** and **–Lim** facilities of **Spec** mode, so a written table of tolerance limits is unnecessary. In most cases, users will wish to verify against Reference Standards at non-cardinal values, so a table of Full Range limits would have little value.

Instead of Limit tables, a Report Sheet is provided at the end of this Section. This can be used for recording the results of verifying any of the three stored specifications. Spaces are provided to record the displayed limits as well as the measured values. The sheet may be used as a master to generate duplicate copies for future use.

Stored Specifications

Three specifications are stored within each 4000 and 4000A instrument's non-volatile memory:

24-hour stability,
90-day accuracy + Datron's Calibration Uncertainty
1 year accuracy + Datron's Calibration Uncertainty

These are selectable by the CALIBRATION INTERVAL switch on the rear panel, and are accessible to users by selecting 'Spec' mode (Refer to Sections 3 and 4). Thus 'Spec' mode provides tolerance and limit figures which are traceable to National Standards.

4000 & 4000A Tolerance Limits

In each model, the 'Spec' mode 24-hour stability limits are computed from their specifications in Section 6. The displayed 90-day and 1-year Accuracy limits for the 4000 are given at 23°C, 1°C, whereas for the 4000A they are at 23°C, 5°C. They include Datron's calibration uncertainty, but not temperature-coefficient corrections nor the user's calibration uncertainties. These should be taken into account if appropriate.

Non-Verification

If an instrument is found to be out of specification, refer to the Routine Autocalibration in Section 8, or contact your nearest Datron Servicing Center.

N.B. It is recommended that the Blank Report Sheets be duplicated to give copies for future use.

Verification Procedures

A full verification should be carried out in the sequence appearing on the Specification Verification Report Sheet. The instructions which follow are divided into 4 procedures:

DC Voltage Full Range
DC Voltage Linearity (10V Range only)
DC Current Full Range
Resistance

The displayed limits do not include temperature-coefficient corrections or the user's calibration uncertainties which should be taken into account if this is appropriate.

DANGER
HIGH VOLTAGE

THIS INSTRUMENT IS CAPABLE OF DELIVERING

A LETHAL ELECTRIC SHOCK!

FRONT or REAR terminals carry the Full Output Voltage.

THIS CAN KILL!

Guard terminal is sensitive to over-voltage

It can damage your instrument!

Unless **you** are **sure** that it is **safe** to do so, **DO NOT TOUCH** the **I+ I− Hi** or **Lo leads** and **terminals**

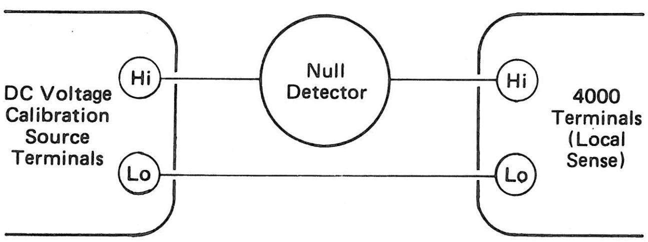
DANGER

4000 DC Voltage Performance

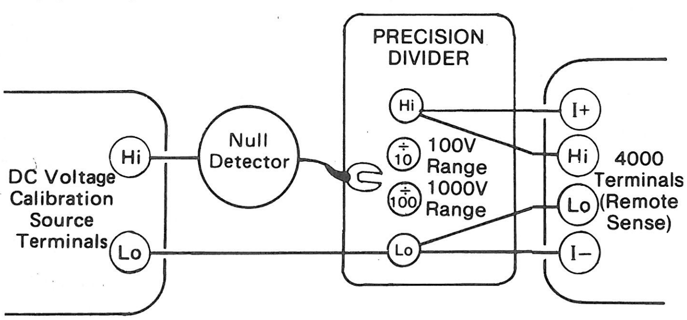
CAUTION: First read the notes on the use of the Null Detector

1. Turn on the instrument to be checked and allow a minimum of 4 hours to warm-up in the specified environment.
2. Cancel any MODE keys, set OUTPUT **OFF** and check that **cal** is not present on the MODE display.
3. Select **Test** to carry out the test routine described in Section 4. Terminate the test routine.
4. Select **DC** and connect the DC Voltage source and Null Detector to the 4000 **Hi** and **Lo** terminals as shown. Use short leads.

(a) Low Voltage: 100µV – 10V Ranges



(b) High Voltage: 100V and 1000V Ranges



Turn the voltage source down to zero and allow the circuit to stabilize thermally.

NOTE When changing polarity during the checks; if leads are reversed it will be necessary to allow time for thermal effects to stabilize in the reversed connection before proceeding with the check.

5. **Full Range Checks:**
Press **Spec** Key, check each range in turn in the following order to reduce the stabilization time for thermal effects at the terminals:
±100µV, ±1mV, ±10mV, ±100mV, ±1V, ±10V, ±100V, ±1000V

The checks may be carried out either at Full Range voltage or at a user's Reference standard voltage close to Full Range. For each check use the routine detailed in para 7. Use Report Sheet Table 1a to record the results.

6. **Linearity Check**
This is performed on the 10V range. Press **Spec** Key. Check each pair of values in turn in the following order to reduce the stabilization time for thermal effects at the terminals:
±10mV, ±100mV, ±1V, ±10V, ±19V.

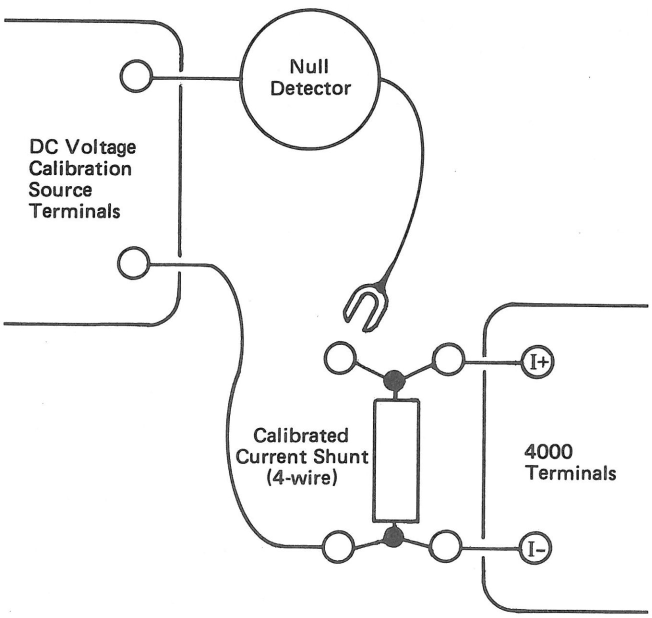
The checks may be carried out either at the above values or at user's Reference standard voltages close to the above values. For each check use the routine detailed in para 7. Use Report Sheet Table 1b to record the results.

7. To check each value against its specification limits use the following routine:

a) Null Detector	Set to low sensitivity.
b) 4000	Switch OUTPUT **OFF**
c) DC Voltage Source	Set to correct polarity and voltage.
d) 4000	Select **DC** and correct **RANGE**
e) 4000	Use OUTPUT ↑|↓ keys to set correct polarity and voltage on OUTPUT display. Press **+Lim**: Record the displayed positive limit. Press **−Lim**: Record the displayed negative limit
f) 4000	Press the correct-polarity **ON** Key. **CAUTION.** Pressing the wrong ON Key will result in approximately twice the OUTPUT voltage being connected across the null detector.
g) Null Detector	Increase sensitivity to give an off-null reading and use 4000 ↑|↓ keys to back off to null, until the null lies between two consecutive values of the OUTPUT display least-significant digit.
h) 4000 OUTPUT display	Record the value closest to null and check against the specification limits.

4000 DC Current Performance

1. Carry out the DC Voltage performance checks 1 to 3 if the DC voltage performance has not been verified.
2. Select I and connect the DC Voltage source, null detector and calibrated current shunt to the 4000 **I+** and **I–** terminals as shown below. Do not connect null detector to shunt yet.



Preferred shunt values are as follows:

100μA range	–	10kΩ	1mW min
1mA range	–	1kΩ	10mW min
10mA range	–	100Ω	100mW min
100mA range	–	10Ω	1W min
1A range	–	0.1Ω	1W min

An output voltage of 1V from the DC Voltage source now represents full range values of 4000 Output current, except on 1A range where self-heating is reduced by using an output voltage of 100mV.

Turn the DC Voltage source down to zero and allow the circuit to stabilize.

3. **Full Range checks**
   Press **Spec** Key. Check each range in turn, in the following order to reduce thermal stabilization time:
   ±100μA, ±1mA, ±10mA, ±100mA, ±1A

   These checks may be carried out either at Full Range current or at a value close to full-range represented by a user's Reference standard voltage. For each check use the routine detailed in para 4. Use Report Sheet Table 2 to record the results.

4. To check each value against its specification limits use the following routine:

a) Null Detector	Set to low sensitivity
b) 4000	Switch OUTPUT **OFF**
c) DC Voltage source	Set to correct polarity and voltage
d) 4000	Select **I** and correct **RANGE**
e) 4000	Use OUTPUT keys to set correct polarity and current on OUTPUT display. Press **+Lim**: Record the displayed positive limit Press **–Lim**: Record the displayed negative limit
f) 4000	Press the correct-polarity **ON** key and allow 5 minutes to stabilize. **CAUTION**: Pressing the wrong ON key can result in approximately twice the DC voltage source output voltage being connected across the null detector.
g) Null Detector	Connect to the shunt terminal. Increase sensitivity to give an off-null reading and use 4000 ↑↓ keys to back off to null again. Continue increasing sensitivity and backing off until the null lies between two consecutive values of the OUTPUT display least-significant digit. Ensure that the null obtained is stable.
h) 4000 OUTPUT display	Record the value closest to null and check against the specification limits.
j) Null Detector	Set to low sensitivity. Disconnect from the shunt terminal.
k) DC Voltage source	Set output to zero.
l) 4000	Switch OUTPUT **OFF**

4000 Resistance Performance

1. Carry out the DC Voltage performance checks 1 to 3 if the DC Voltage performance has not been verified.

2. For each resistance (RANGE) selection, three checks are required:
   a) Remote Sense (4-wire) at **Full Range** (Resistor Value)
   b) Local Sense (2-wire) at **Full Range** (Resistor plus internal wiring)
   c) Local Sense (2-wire) at **Zero** (internal wiring only)

   The displayed values were obtained at the most recent calibration, except 10MΩ zero and Full Range in Local Sense which are the same as in Remote Sense.

3. For each verification check, the measured value should lie between the 90-day specification limits taken about the displayed value. The upper and lower test limits should be determined using Spec mode and secondary modes **+Lim** and **–Lim**, with the **CALIBRATION INTERVAL** switch on the rear panel set to **90-day** (see section 4 for operation of Spec mode). Space to record these limits, is reserved in Table 3 (Resistance) on the Specification Verification Report Sheet at the end of this Section.

N.B. It is assumed that the specified energising currents will be used to verify the resistance specification, so the displayed limits have been calculated directly from the specification figures in Section 6 and are not modified by accuracy derating factors. The displayed limits refer to the 90-day Accuracy specification. The Stability specification should only be referred to, when checking against the same standard used for the previous calibration.

4. Press **Spec** Key

   Carry out the checks in the order listed in Table 3 (Resistance) on the Verification Report Sheet at the end of this section, to minimise waiting time for thermal stabilization.

Perform each check in the following order

Set 4000 **OUTPUT OFF**

Select resistor value (**RANGE** Key) (If Local Zero press OUTPUT **Zero** Key)

Select **Local/Remote** Sense (OUTPUT must be **OFF**)

Record OUTPUT displayed value on Table 3.

Press **+Lim** and record value on Table 3.

Press **–Lim** and record value on Table 3.

Connect measuring equipment (2-wire to **Hi** and **Lo** Terminals, or 4-wire energising current to **I+** and **I–** Terminals, voltage measurement across **Hi** and **Lo** Terminals)

Set 4000 OUTPUT **ON**

Measure Resistance value and record on Table 3

Check that this value is between +Lim and –Lim values recorded.

Specification Verification Report Sheet

(Use as master for duplicate copies)

Datron Model . . . . Date . . . .

Serial Number . . . . Tested By . . . .

Calibration Interval . . . . Stability/Accuracy

Note: 1) The comparison between OUTPUT display readings for null and the Spec Mode Limits is Valid if zero errors have first been nulled out.

2) DC Current & Resistance table on reverse

1 DC Voltage

a) Full Range Checks

Polarity/ Range	DC Calibration Source Voltage	Spec Mode Limits +Lim	–Lim	OUTPUT display reading for null
+ 100μV				
– 100μV				
+ 1mV				
– 1mV				
+ 10mV				
– 10mV				
+ 100mV				
– 100mV				
+ 1V				
– 1V				
+ 10V				
– 10V				
+ 100V				
– 100V				
+1000V				
–1000V				

b) 10V Range Linearity

Polarity/ Nominal Value	DC Calibration Source Voltage	Spec Mode Limits +Lim	–Lim	OUTPUT display reading for null
+ 10mV				
– 10mV				
–100mV				
+100mV				
+ 1V				
– 1V				
– 10V				
+ 10V				
+ 19V				
– 19V				

2 DC Current: Full Range Checks

Polarity/ Range	Shunt Value	DC Calibration Source Voltage	Spec Mode Limits +Lim	−Lim	OUTPUT display reading for null
+100μA					
−100μA					
+ 1mA					
− 1mA					
+ 10mA					
− 10mA					
+100mA					
−100mA					
+ 1A					
− 1A					

3 Resistance: Value Measurements

Method Used: . . . .

Range/Sense	Specified Current	Current Used	Displayed Value	Spec Mode +Lim	−Lim	Measured Value
10MΩ Remote	1μA					
Local						
Local Zero						
1MΩ Remote	10μA					
Local						
Local Zero						
100kΩ Remote	100μA					
Local						
Local Zero						
10kΩ Remote	100μA					
Local						
Local Zero						
1kΩ Remote	1mA					
Local						
Local Zero						
100Ω Remote	10mA					
Local						
Local Zero						
10Ω Remote	10mA					
Local						
Local Zero						
1Ω Remote	100mA					
Local						
Local Zero						

SECTION 8 ROUTINE AUTOCALIBRATION

Introduction

For full information on calibration of the 4000 against in-house reference standards, see the Calibration and Servicing Handbook. Section 1.

The 4000 possesses excellent short and long term stability. Some users will wish to maintain the highest accuracy by recalibrating at short intervals (e.g. every 24 Hours). In these cases, recalibration of the 4000 becomes a routine task. For this reason the calibration procedures are presented in this section of the User's Handbook. It is emphasised that the 4000 can be used immediately after recalibration.

The 4000 Autocal Feature

Full or part calibration may be carried out for all routine purposes from the front panel. Removal of covers is unnecessary, therefore avoiding thermal disturbance. Calibration corrections are stored in an internal memory which remains energised by a battery even when the instrument power supply is switched off. The life of the battery is estimated at 7–10 years, so it should not need changing at less than 5-year intervals. On power-up, the 4000 performs a self-test which includes a check of the contents of the calibration memory.

Equipment Requirements

DC Voltage
- A Standard DC Voltage source of suitable accuracy
  Example: Series bank of 10 standard cells and Datron 4904 Standard Cell buffer.
- A Precision Divider:
  Example: Datron 4902 High Voltage divider and Datron 4903 DC Switching Unit
- A battery-operated null detector with variable sensitivity, able to withstand 1200V across its input terminals
  Example: Keithley Instruments Model 155

DC Current
- A DC Voltage source, calibrated to suitable accuracy at approximately 1V and 100mV
  Example: The standard voltage source used for DC Voltage, with the Datron 4903 DC Switching Unit.
- The battery-operated null detector used for DC Voltage.
- A set of calibrated current shunts of suitable accuracy.

N.B. To allow the same value to be set on the DC Voltage source for each range, the shunts may be of five decade values. Then the same Null Detector sensitivity can be used on each range.

CAUTION When choosing a set of current shunts ensure that their power dissipation ratings are sufficient to avoid permanent degredation from the self-heating effects of the current being checked. This applies particularly to the 1 Amp shunt.

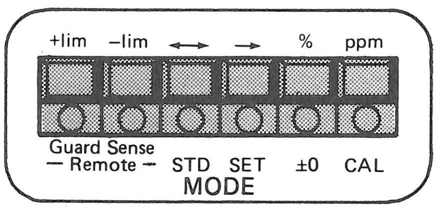
- alternatively, a dmm of sufficient accuracy may be used to measure the voltage across the set of calibrated current shunts.
  Example: Datron 1081 using "compute" mode.

Resistance
- a set of standard resistors covering 1Ω to 10MΩ. The 1Ω to 10kΩ should be 4-wire type.
- an accurate resistance bridge, or other ratiometric device for measuring resistance to the required accuracy.
- a Datron 1081 used as a transfer-measurement device.

Interconnections

Interconnection instructions in this section are necessarily simple and basic, and are mainly intended to show connections to the 4000. It is recognised that they may need to be adapted to meet an individual user's requirements. It is assumed that users will possess knowledge of the operation and use of standards equipment such as that mentioned above.

Calibration Modes



Four of the Mode Keys have 'Autocal' functions:

STD, SET, ±0 and CAL

These are printed in red below the keys and are activated only when the **cal** legend is present on the **MODE** display. The normal key modes, (Spec, Error, Offset and Test) are disabled by the selection of **CALIBRATION ENABLE** on the rear-panel keyswitch. The **STD**, **SET** and **±0** keys have toggle action (e.g. when a mode is set it may be deselected by a second key-press).

General Procedure

The OUTPUT display is set to the Calibration Standard value, the 4000 output is switched **ON**, and one of the calibration mode preselector keys (**SET**, **STD** or **±0**) is pressed. The 4000 output is adjusted to obtain a null at the Calibration Standard value, and the **CAL** key is pressed to execute the calibration.

Autocal Facilities

The following facilities are provided by the selection of CALIBRATION ENABLE on the rear panel keyswitch with OUTPUT ON.

SET The SET key allows calibration to any value in the selected Range (e.g. at a standard cell voltage):

Before selecting SET, the ↑|↓ keys are operated to place the Calibration Standard value on the OUTPUT display and set the 4000 output level. Pressing SET then informs the 4000 that calibration is to be carried out at this value. The instrument acknowledges by duplicating the value on the MODE display.

Next, the ↑|↓ keys are manipulated to null the 4000 output against the Calibration Standard (the OUTPUT display changes during this adjustment).

Pressing the CAL key executes the calibration. The 4000 memorizes the difference between the two display values, and exits from SET mode. This is shown by transfer of the Standard value from the MODE display to the OUTPUT display. The instrument uses the difference to modify stored constants, which in "RUN" mode correct both positive and negative outputs on the calibrated range only.

If the Calibration Standard value is below 2% of Full Range, the 4000 assumes a request for "Offset" correction; but if at 2% or above, "Gain" correction is assumed.

±0 The ±0 key is used to align the ON+ and ON− zeros of all voltage and current ranges, by a two-part calibration on the 10V range. The ±0 Alignment Routine (Item 4 on page 8.6) is necessary only when the ON+ and ON− zeros on the 10V range do **not** coincide at the same null.

STD STD calibration is carried out on the 1V or 10V range, and differs from the "SET" procedure only in the use of the STD key instead of the SET key.

It changes the gain of all voltage and current ranges in the same ratio, and thus performs the same function as trimming the internal Master Reference voltage. The facility can be used to avoid a full recalibration of the 4000 when Laboratory References have been re-standardized (or for instance when a 4000 has been moved from one country to another).

CAL The CAL key executes the preselected Autocal facility, as described in "SET" above. Alternatively, it can be used without first pressing SET, ±0, or STD to calibrate Voltage or Current ranges, but only at Zero or Full Range values:

Before selecting CAL, the Zero or Full Range key is pressed to set the 4000 output level.

Next, the ↑|↓ keys are manipulated to null the 4000 output against the Calibration Standard (the OUTPUT display changes during this adjustment).

Pressing CAL commands the 4000 to calibrate. The instrument decides on "Zero Offset" or "Full Range Gain" from the OUTPUT display value (defined by the same limits as for "SET"), and executes the calibration. The difference between the OUTPUT display value and the value chosen by the 4000 is used to modify the stored constants mentioned in "SET" above.

Autocal Availability

As the Autocal keys perform specific tasks, they are available only as defined by Table 8.1. The message "**Error 3**" appears on the **MODE** display for any attempt to select an inappropriate mode.

<table>
<tr><th colspan="2" rowspan="2">AUTOCAL Mode</th><th rowspan="2">DC Voltage
(DC)</th><th rowspan="2">DC Current
(I)</th><th colspan="2">Resistance (Ω)</th></tr>
<tr><th>Local Sense
(2-wire)</th><th>Remote Sense
(4-wire)</th></tr>
<tr><td rowspan="2">SET
and
CAL</td><td>Zero offset for range at User's selected value</td><td>All Ranges</td><td rowspan="2">All
Ranges</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Gain for range at User's standard value</td><td>100mV–1000V Ranges only</td></tr>
<tr><td>+0
and
CAL</td><td>Alignment of internal ON+ and ON– zeros</td><td>10V Range only</td><td></td><td></td><td></td></tr>
<tr><td>STD
and
CAL</td><td>Internal Reference gain at User's Standard value</td><td>1V and 10V Range only</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">CAL
Only</td><td>Zero offset for range</td><td>All Ranges</td><td rowspan="2">All
Ranges</td><td rowspan="2">1Ω–1MΩ
Ranges only</td><td></td></tr>
<tr><td>Gain for range at Full Range Value</td><td>10mV–1000V Ranges only</td><td>All Ranges</td></tr>
</table>

Table 8.1 Autocal availability

Zero Calibration

It is common practice to accept a small offset in the output of a voltage calibration standard, providing that the same offset is present at all output values, including zero.

The output of the 4000 is fully floating, so its output may be referred to any common mode voltage within the range specified on page 6.1. In particular, its zero may be aligned to absolute zero in Local Sense by calibration to a null across its Hi and Lo (Sense) terminals. But if it is then gain-calibrated against an offset standard without re-zeroing to that standard's offset zero, normal mode gain errors will result.

It is therefore essential that on each voltage and current range, the standard's offset is adjusted out using a null detector zero adjustment, before using that standard to calibrate the range gain.

DANGER

HIGH VOLTAGE

THIS INSTRUMENT IS CAPABLE OF DELIVERING

A LETHAL ELECTRIC SHOCK!

FRONT or REAR terminals carry the Full Output Voltage.

THIS CAN KILL!

Guard terminal is sensitive to over-voltage

It can damage your instrument!

Unless **you** are **sure** that it is **safe** to do so, **DO NOT TOUCH** the **I+ I– Hi** or **Lo leads** and **terminals**

DANGER

Calibration Sequence

The sequence of operations for full calibration of a 4000 Autocal Standard is given below:

Preparation
DC Voltage
DC Current
Resistance
Return to Use

If only a partial recalibration is to be done, step 1 of the DC Voltage sequence should be carried out immediately after the preparation.

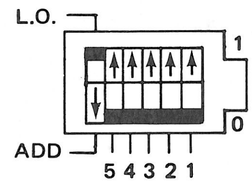
WARNING **During Performance checks and calibration a common mode voltage equal to the full range voltage may be present at the Null Detector input terminals. On ±1000V checks this voltage is potentially lethal, so EXTREME CAUTION must be observed when making adjustments to the null detector sensitivity.**

CAUTION The Null Detector used must be able to withstand voltages up to 1200V between its input terminals. Such voltages will be present during the time that the 4000 is ramping from zero to 1000V Full Range after setting OUTPUT ON. Inadvertent disconnection of the Precision Divider terminals can transfer full output across the Null detector.

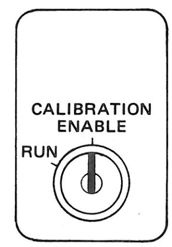
Preparation: Before any calibration from the front panel is carried out, prepare the 4000 as follows:

1. Turn on the instrument to be checked and allow minimum of 4 hours to warm-up in the specified environment.

2. IEEE 488 Address switch: Set to **ADD 11111** as shown (Address 31)



3. CALIBRATION ENABLE key switch: Insert Calibration Key and turn to **ENABLE.**



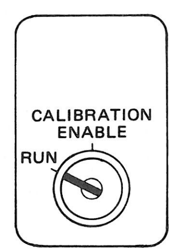
These actions activate the four calibration modes (labelled in red) and present the **cal** legend on the MODE display.

4. Ensure that OUTPUT OFF LED is lit.

Return to Use: When any calibration is completed, return the 4000 to use as follows:

1. Ensure that OUTPUT **OFF** LED is **lit.**

2. CALIBRATION ENABLE key switch: Turn to **RUN** and withdraw calibration key.



3. IEEE 488 Address switch: Restore to **correct address** if the 4000 is to be used in an IEEE 488 system.

4000 DC VOLTAGE CALIBRATION

1. Initial Setup

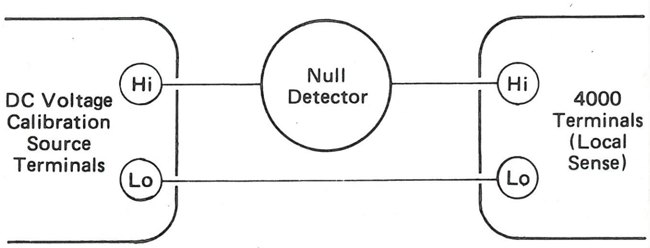
CAUTION: First read the Notes on the use of the Null Detector in Section 7.

Carry out the Preparation as detailed on Page 8-5.

Select **DC** and connect the DC Voltage Calibration Source and Null Detector to the 4000 terminals as shown in Fig. 8.1(a).

Use short leads, ensure that the Calibration Source voltage is set to zero and that the inter-connecting circuit has thermally stabilized.

(a) Low Voltage: 100μV – 10V Ranges



(b) High Voltage: 100V and 1000V Ranges

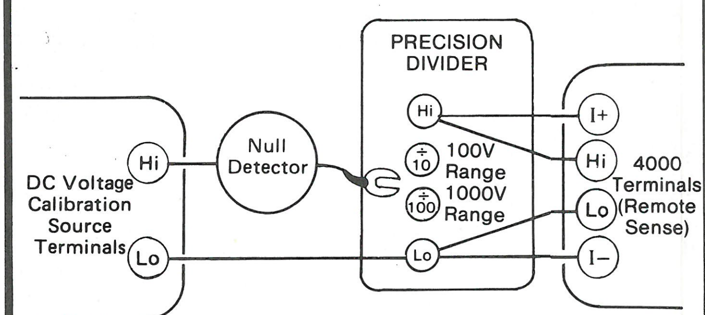


Fig. 8.1
4000 connections for DC Voltage Calibration

2. Calibrate as follows:

a) Full Calibration

Calibrate the DC Voltage ranges in the step sequence of Table 8.2, using the Calibration Routine at each step (except steps 2 and 3). For steps 10 - 13, reconnect as Fig. 8.1(b).

b) Partial Calibration

Carry out Step 1 of Table 8.2.

Proceed with the desired steps of Table 8.2, using the Calibration Routine at each step (except steps 2 and 3). For steps 10 - 13, reconnect as Fig. 8.1(b)

c) Re-standardizing using "STD"

To re-standardize all DC Voltage and Current ranges in the same ratio, carry out steps 1, 2, 3, then either 6 and 7, or 8 and 9. In operation (g) of the Calibration Routine, substitute "STD" for "SET". (Refer to earlier description of "STD").

3. Calibration Routine: Calibration of DC Voltage to a Standard voltage calibration source.

NOTES:

A For calibration at any value, this routine may be used as printed.

B For calibration at zero or positive nominal Full Range only, operation (g) may be omitted.

C In Table 8.2(a), use interconnections as Fig. 8.1(a) (Low Voltage), obtaining the correct calibration voltage from the source.

In Table 8.2(b), use interconnections as Fig. 8.1(b) (High Voltage) selecting ÷10 at steps 10 and 11, ÷100 at steps 12 and 13.

CAUTION: Below 2% of Range, the 4000 corrects for an assumed offset error, at 2% of Range and above the correction is for an assumed gain error.

3. **Calibration Routine (contd.)**

a) Null Detector	Set to **Low** sensitivity
b) 4000	Ensure OUTPUT **OFF**
c) DC Source	Set to the required polarity and value
d) 4000	Select correct FUNCTION and RANGE
e) 4000	Use **Full Range**, **Zero** or OUTPUT ↑|↓ keys to set the required polarity and value on OUTPUT display.

N.B. Operation (f) must be carried out before operation (g)

f) 4000	Press the correct-polarity **ON** key

Omit Operation (g) if calibrating at **zero** or **Full Range** value

g) 4000	Press **SET** Key: **SET LED** lights green OUTPUT display reading also appears on **MODE** display
h) Null Detector	Increase sensitivity to give an off-null reading and use 4000 OUTPUT ↑|↓ keys to back off to null. Repeat until null lies between two values of the OUTPUT display least-significant digit.
j) Null Detector	Set to **LOW** sensitivity
k) 4000	Press **CAL** key

Not applicable if operation (g) omitted:
- **CAL LED** flashes once
- **MODE** display value is transferred to **OUTPUT** display
- **MODE** display is cleared
- **SET LED** goes **OFF**

The 4000 is now calibrated at this value.

4. **±0 Alignment Routine**: Alignment of 10V Range positive and negative zeros if necessary at step 3 of Table 8.2

a) Null Detector	Set to **low** sensitivity
b) 4000	Ensure OUTPUT **OFF** on **DC 10V** Range.
c) Calibration Source	Ensure set to **zero** and thermally stable.
d) 4000	Press OUTPUT **Zero** Key Press **ON+** Key Press **±0** Key: **±0 LED** lights, OUTPUT display at **zero**
e) Null Detector	Increase sensitivity to give an off-null reading and use 4000 OUTPUT↑|↓ keys to back off to null. Repeat until null lies between two values of the OUTPUT display least-significant digit.
f) 4000	Press **CAL** key: **CAL LED** lights No change to OUTPUT display
g) 4000	Press **ON–** key
h) Null Detector	Obtain accurate null as in (e) above
j) 4000	Press **CAL** key: **CAL LED** goes **OFF** **±0 LED** goes **OFF** OUTPUT display falls to **zero**

The 4000 positive and negative zeros are now both aligned to the Calibration Source zero.

Table 8.2 STEPS in DC VOLTAGE CALIBRATION

(a) Low Voltage – connect as Fig. 8.1(a)

Step	Calibration Operation	4000 Range	Calibration Source Voltage	4000 Output Setting (Nominal value)[1]	AUTOCAL Key Used[2]
1	10V Range ON+ zero	10	0.000000V	(ON+) 0.000000V	–
2	10V Range ON– zero check only – do not calibrate	10	0.000000V	(ON–) 0.000000V	Check only 0.000000V
3	±0 Alignment	10	0.000000V	Refer to ±0 Alignment Routine	'±0'
4	100mV Range zero	100m	0.00000mV	0.00000mV	–
5	100mV Range gain	100m	+100.00000mV	(ON+) 100.00000mV	'SET' for non-nominal
6	1V Range zero	1	.0000000V	(ON+) .0000000V	–
7[3]	1V Range gain	1	+1.0000000V	(ON+) 1.0000000V	'SET' for non-nominal
8	10V Range zero	10	0.000000V	(ON+) 0.000000V	–
9[3]	10V Range gain	10	+10.000000V	(ON+) 10.000000V	'SET' for non-nominal

(b) High Voltage – connect as Fig. 8.1(b)

Step	Calibration Operation	4000 Range	Calibration Source Voltage	Precision Divider Select	4000 Output Setting (Nominal value)[1]	AUTOCAL Key Used[2]
10	100V Range zero	100	0.00000V	÷10	(ON+) 0.00000V	–
11	100V Range gain	100	+10.000000V	÷10	(ON+) 100.00000V	'SET' for non-nominal
12	1000V Range zero	1000	0.0000V	÷100	(ON+) 0.0000V	–
13	1000V Range gain LETHAL VOLTAGE	1000	+10.000000V	÷100	(ON+) 1000.0000V* *Enter High Voltage state using interlock procedure (User's Handbook Sect. 4)	'SET' for non-nominal

NOTES [1] It is expected that many users will wish to calibrate Range gains at values other than the nominals shown. In these cases set the Calibration Source voltage and 4000 OUTPUT display to in-house standard values near nominal.

[2] Except for Step 2, use CAL key as trigger (Refer to Calibration Routine).

[3] To trim the internal Master Reference voltage, substitute 'STD' for 'SET' for 1V or 10V Range (Refer to Calibration Routine and description of 'STD').

4000 DC CURRENT CALIBRATION

1. Ensure that the 4000 OUTPUT **OFF** LED is **lit.** Select I and connect the DC Voltage calibration source, null detector and calibrated current shunt to the 4000 OUTPUT terminals as shown below. **Do not connect** null detector to shunt until the voltage across the shunt and the source voltage are close in value.

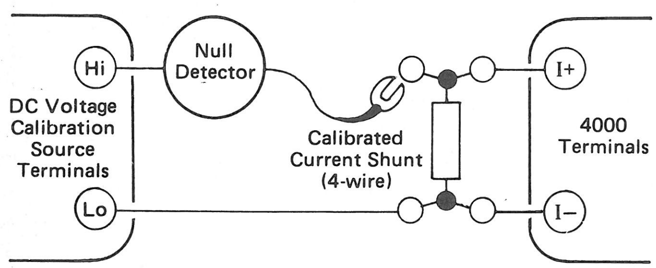


Fig. 8.2
4000 connections for DC Current Calibration

Preferred shunt values are as follows:

			Calibration Source Output Voltage for Full Range
100μA range -	10kΩ	1mW min	1V
1mA range -	1kΩ	10mW min	1V
10mA range -	100Ω	100mW min	1V
100mA range -	10Ω	1 Watt min	1V
1A range -	0.1Ω	1 Watt min	100mV

Ensure that the calibration source voltage is set to zero and that the interconnecting circuit has thermally stabilized.

2. Calibrate the DC Current ranges in the step sequence of Table 8.3, using the Calibration Routine at each step.

3. **Calibration Routine:** Calibration of DC Current using a DC Voltage Calibration Source and a series of calibrated current shunts.

NOTES: A. For calibration at <u>any</u> value, the routine may be used as printed.
B. For calibration at **zero** or positive nominal **Full Range** only, operation (g) may be omitted.

CAUTION: Below 2% of Range, the 4000 corrects for an assumed offset error, at 2% of Range and above the correction is for an assumed gain error.

a) Null Detector — Set to **Low** sensitivity

b) 4000 — Ensure OUTPUT **OFF**

c) DC Source — Set to the required polarity and value

d) 4000 — Select correct FUNCTION and RANGE

e) 4000 — Use **Full Range, Zero** or OUTPUT ↑|↓ keys to set the required polarity and value on OUTPUT display

N.B. Operation (f) must be carried out before operation (g)

f) 4000 — Press the correct polarity ON key

CAUTION: Pressing the wrong ON key will result in twice the OUTPUT being connected across the null detector.

Omit operation (g) if calibrating at Zero or Full Range value

g) 4000 — Press **SET** key:
SET LED lights **green**
OUTPUT display reading also appears on **MODE** display

h) Null Detector — Increase sensitivity to give an off-null reading and use 4000 OUTPUT ↑|↓ keys to back off to null. Repeat until null lies between two values of the OUTPUT display least-significant digit.

j) Null Detector — Set to **LOW** sensitivity

k) 4000 — Press **CAL** key
CAL LED flashes once

Not applicable if operation (g) omitted:
- **MODE** display value is transferred to **OUTPUT** display
- **MODE** display is cleared
- **SET LED** goes **OFF**

Step	Calibration Operation	Shunt Value	Calibration Source Voltage [1]	4000 OUTPUT Current		AUTOCAL Key Used [2]
				Range	OUTPUT Setting [1]	
1	100μA Range zero	10kΩ	.0000000V	100μ	0.0000μA	–
2	100μA Range gain	10kΩ	+ 1.0000000V	100μ	+100.0000μA	'SET' for non-nominal
3	1mA Range zero	1kΩ	.0000000V	1m	.000000mA	–
4	1mA Range gain	1kΩ	+ 1.0000000V	1m	+ 1.000000mA	'SET' for non-nominal
5	10mA Range zero	100Ω	.0000000V	10m	0.00000mA	–
6	10mA Range gain	100Ω	+ 1.0000000V	10m	+ 10.00000mA	'SET' for non-nominal
7	100mA Range zero	10Ω	.0000000V	100m	0.0000mA	–
8	100mA Range gain	10Ω	+ 1.0000000V	100m	+100.0000mA	'SET' for non-nominal
9	1A Range zero	0.1Ω	0.00000mV	1	.000000A	–
10	1A Range gain	0.1Ω	+100.00000mV	1	+ 1.000000A	'SET' for non-nominal

Table 8.3 STEPS in DC CURRENT CALIBRATION

NOTES: [1] It is expected that most users will wish to calibrate Range gains at values other than the nominals shown. In these cases set the Calibration Source voltage and the 4000 OUTPUT display to in-house standard values near nominal.

[2] At each step, use **CAL** key as a trigger (Refer to Calibration Routine).

4000 RESISTANCE CALIBRATION

1. **Calibration Memory**
In Ω function, each RANGE key selects a nominal-value standard resistor. Routine adjustment of the resistor is not necessary. During calibration the actual value is **measured** and **stored** in the calibration memory to be displayed whenever that range is selected. Separate memory stores exist for Remote Sense (4-wire), Local Sense (2-wire) and Local Sense zero.

2. **4-Wire Calibration Limits**
The value measured in 4-wire **Remote Sense** does not include the resistance of internal or external wiring. The 4000 accepts any value within ±200 ppm of nominal as a valid calibration.

3. **2-Wire Calibration Limits**
The value measured in 2-wire **Local Sense** is greater than for 4-wire Remote Sense, as it includes the resistance of internal wiring and relay contacts. The 4000 will not accept any 2-wire value less than the stored value for 4-wire, so the 4-wire Remote Sense calibration must be carried out before attempting 2-wire Local Sense. The extra internal resistance depends on Range, so the 4000 accepts the following values (x) as valid 2-wire calibrations:

Zero calibration.
1Ω – 1MΩ Ranges:
$0 \leqslant x \leqslant 0.900\Omega$

Value calibrations.
1Ω Range:
4-wire value $\leqslant x \leqslant$ (4-wire value + 0.999Ω)
10Ω – 1MΩ Ranges:
4-wire value $\leqslant x \leqslant$ (4-wire value + 1.999Ω)

4. **"Error 6" message**
"Error 6" appears on the MODE display for any attempt to enter a value outside the 4-wire or 2-wire limits quoted above.

NOTE: When resistance is calibrated in Remote Sense, the 4000 overwrites the Local Sense calibration memory with the new 4-wire value.

5. **4-wire and 2-wire Connections**

4-wire calibration

Remote Sense

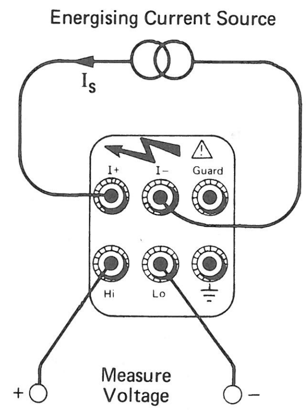


Fig. 8.3 (a)

2-wire calibration
(using 4-wire method externally)

Local Sense

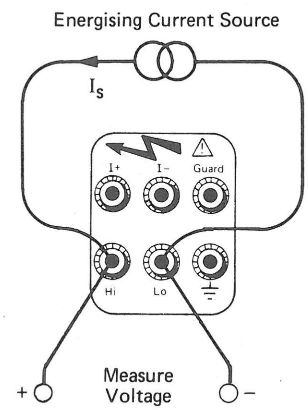


Fig. 8.3 (b)

6. **Calibration sequence**
Press Ω key and calibrate the resistors in the step sequence of Table 8.4 (a and b), using the Calibration Routine at para 7 (a or b). Refer to para 5 for connections to the measuring equipment. For 4-wire connections in Remote Sense, only the value of the internal Standard Resistor is measured. In Local Sense, a 4-wire method is used to exclude the resistance of the external leads from the measured value.

7. **Calibration Routine:** Measurement and Storage of the values of an internal resistor.

a) **Remote Sense** (Internal 4-wire, connected as Fig 8.3 a)
Full Range values – Routine for Table 8.4 a)

i)	4000	Select OUTPUT **OFF** and Ω Select **Remote Sense**
ii)	4000	Press required resistor (RANGE) key: The previously-calibrated value appears on the OUTPUT display
iii)	4000 and resistance-measuring equipment	Press OUTPUT **ON+** and measure the value of the internal resistor
iv)	4000 OUTPUT ↑↓ Keys	Set the **measured value** on the OUTPUT display
v)	4000 CAL Key	Press to store OUTPUT display value
vi)	4000	Set OUTPUT **OFF**
vii)	Repeat operations (ii) to (vi) for each step of Table 8.4 a)	

b) **Local Sense** (Internal 2-wire, connected as Fig 8.3 b), Remote Sense **OFF**)
Full Range and Zero values – Routine for table 8.4 b)

i) 4000 — Select OUTPUT **OFF** and **Ω**. **Deselect** Remote Sense

ii) 4000 — Press required resistor (RANGE) Key: The previously-calibrated value appears on the OUTPUT display.

iii) 4000 and resistance-measuring equipment — Press OUTPUT **ON+** and measure the value of the internal resistance

iv) 4000 OUTPUT ↑|↓ Keys — Set the **measured value** on the OUTPUT display

v) 4000 **CAL** Key — Press to **store** OUTPUT display value

vi) 4000 **Zero** Key — Press and repeat operations (iii) to (v) for this RANGE selection.

vii) 4000 — Set OUTPUT **OFF**

viii) Repeat operations (ii) to (vii) for each step of Table 8.4 b).

Table 8.4 STEPS IN RESISTANCE CALIBRATION (Internal resistor value measurement and storage).

a) **Remote Sense** (Internal 4-wire, connect as Fig. 8.3 a)
Calibration at **Full Range**. Resolution 7½ digits, Tolerance ±199.9ppm (±1999 digits).

Step	Range	Measured resistance value, Calibration Limits
1	10MΩ	9.998,001 to 10.001,999 MΩ
2	1MΩ	.999,800,1 to 1.000,199,9 MΩ
3	100kΩ	99.980,01 to 100.019,99 kΩ
4	10kΩ	9.998,001 to 10.001,999 kΩ
5	1kΩ	.999,800,1 to 1.000,199,9 kΩ
6	100Ω	99.980,01 to 100.019,99 Ω
7	10Ω	9.998,001 to 10.001,999 Ω
8	1Ω	.999,800,1 to 1.000,199,9 Ω

b) **Local Sense** (Internal 2-wire, connect as Fig. 8.3 b), Remote Sense OFF)
Calibration at **Full Range** and **Zero**. Resolution as listed in table.
Tolerances – 0Ω + 0.999Ω on 1Ω Range, –0Ω + 1.999Ω on 10Ω - 1MΩ Ranges, –0Ω + 0.900Ω for zero on 1Ω - 1MΩ Ranges.

Step	Range	Resolution (digits)	Resistance value Limits	Zero Limits
9	1MΩ	7½	Step 2 value, –0 +19 digits	.000,000,0 to .000,000,9 MΩ
10	100kΩ	7½	Step 3 value, –0 +199 digits	0.000,00 to 0.000,90 kΩ
11	10kΩ	7½	Step 4 value, -0+1999 digits	0.000,000 to 0.000,900 kΩ
12	1kΩ	6½	Step 5 value, –0+1999 digits	.000,000 to 0.000,900 kΩ
13	100Ω	5½	Step 6 value, –0+1999 digits	0.000 to 0.900 Ω
14	10Ω	4½	Step 7 value, –0+1999 digits	0.000 to 0.900 Ω
15	1Ω	3½	Step 8 value, –0 +999 digits	.000 to .900 Ω

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HANDBOOK AMENDMENT SHEET

Ref No 850050-3.3

4000/A User's Handbook - Issue 3

INTRODUCTION

SECTION 8

On page 8-3, autocal availability on DC Voltage is incorrectly stated.

CORRECTION

Page 8-3: The definitions of autocal availability, set out in Table 8.1 on page 8-3, are in error. The text of the table should be amended as follows:

Existing

AUTOCAL DC Mode		DC Voltage (DC)
SET and Cal	Zero Offset for range at User's selected value	All Ranges
	Gain for range at User's standard value	100mV - 1000V Ranges only

Change to read

AUTOCAL DC Mode		DC Voltage (DC)
SET and Cal	Zero Offset for range at User's selected value	100mV - 1000V Ranges only
	Gain for range at User's standard value	100mV - 1000V Ranges only

CONTENTS LIST: No Change