

7150plus
DIGITAL
MULTIMETER

OPERATING MANUAL

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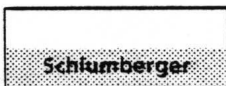
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7150plus DIGITAL MULTIMETER

Operating Manual

Issue 2B: August 1988

Part No. 71500024



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Chapter 1

General Information

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1.1 INTRODUCTION

This manual contains operating instructions and other information relevant to the 7150plus Digital Multimeter (DMM).

The operating manual is divided into two parts; Part 1 contains general information, including initial installation procedures and familiarizes the user with the DMM's controls and displays. Part 2 is required only when the DMM is to be controlled remotely – using a suitable controller. In either case it will always be necessary to read Part 1 of the manual.

The DMM will perform all common types of measurement function whether commanded directly, via its front panel controls, or remotely, via a controller. Users will find the example commands given in Part 2 – using several common types of controller – particularly useful.

For those perhaps less familiar with remotely controlled devices, some basic concepts and an in depth description of Solartron's General Purpose Interface Bus (GP-IB) are also provided in Part 2. The GP-IB Interface, an integral part of the DMM, conforms to the IEEE 488 (1978) Standard for Programmable Instrumentation, thus 7150plus is compatible with a whole family of devices which comply with this internationally recognized standard.

1.2 SAFETY

The DMM has been designed in accordance with the recommendations of IEC 348. To ensure the user's safety, and the continued safe operation of the DMM, the user is advised to read carefully the procedures and specifications given in this Operating Manual.

Care should always be exercised whenever the input leads are being connected or removed, especially where high voltages are known to exist, or high transients occur.


The DMM is protected against measurement overload, up to 1.2kV peak on voltage measurement, and 240V rms on resistance measurements. Protection against current overload is by a 2A fuse.

When using the DMM on equipment which is capable of delivering high voltages (e.g. inductive circuitry giving high back-emf's) it is strongly recommended that the equipment under test is **not** switched off while the DMM is still connected. The DMM leads should be carefully disconnected before switching off the equipment; this will help to prevent the hazards of back-emf's. The following example illustrates this. Consider the inputs connected across the secondary of a large mains transformer; the very high input impedance of the DMM is such that, in the event of the mains supply being interrupted, the resultant back emf induced in the undamped secondary could be in the order of 100kV. This is obviously hazardous to the user, and would certainly damage the DMM. User safety may be preserved by the inclusion of a switch between the DMM and the transformer secondary; the switch could then be switched on, and off, while the transformer remained powered.

Whenever it is likely that the safety of the DMM has been impaired – e.g. if it shows visible signs of damage, if it fails to perform correctly, or if the specifications have been exceeded in any way – it should be made inoperative and referred to a suitable repair depot.

1.2.1 Maintenance

Maintenance, adjustment or repair of the DMM must only be carried out by skilled personnel, in accordance with the procedures and precautions detailed in the Maintenance Manual (Part No. 71500026).

 Wherever this symbol appears on the front or rear panel it is advisable to consult the appropriate section of the Operating Manual for further information.

Instrument warranty may be breached if the unit has been subjected to any of the following conditions : mis-use by operators, damage due to incorrect storage or environmental conditions whilst in the owners possession, physical damage, repairs carried out by unauthorised personnel or third parties.

Integrity seals (plastic caps) have been placed over the cover retaining screws in order to prevent unauthorised tampering with the instrument, which may invalidate the warranty. Regular, annual recalibration can be carried out without removing the instrument cover, refer to Chapters 5 and 7 of this manual.

1.3 INSTALLATION

The DMM is fitted with a mains supply input unit (Fig 1.1) which contains the mains fuses and voltage selector. These items cannot be accessed until the mains input cable has been removed. Before applying power to the instrument, check that the voltage selector is correctly set, viz the relevant 100V, 120V, 220V or 240V appears in the aperture and that the correct fuses are in place (Para 1.3.4).

For a 220→265V input, use the 240V setting
188→230V input, use the 220V setting

110→127V input, use the 120V setting
92→115V input, use the 100V setting

The method of adjusting the voltage setting is given in Para 1.3.1.

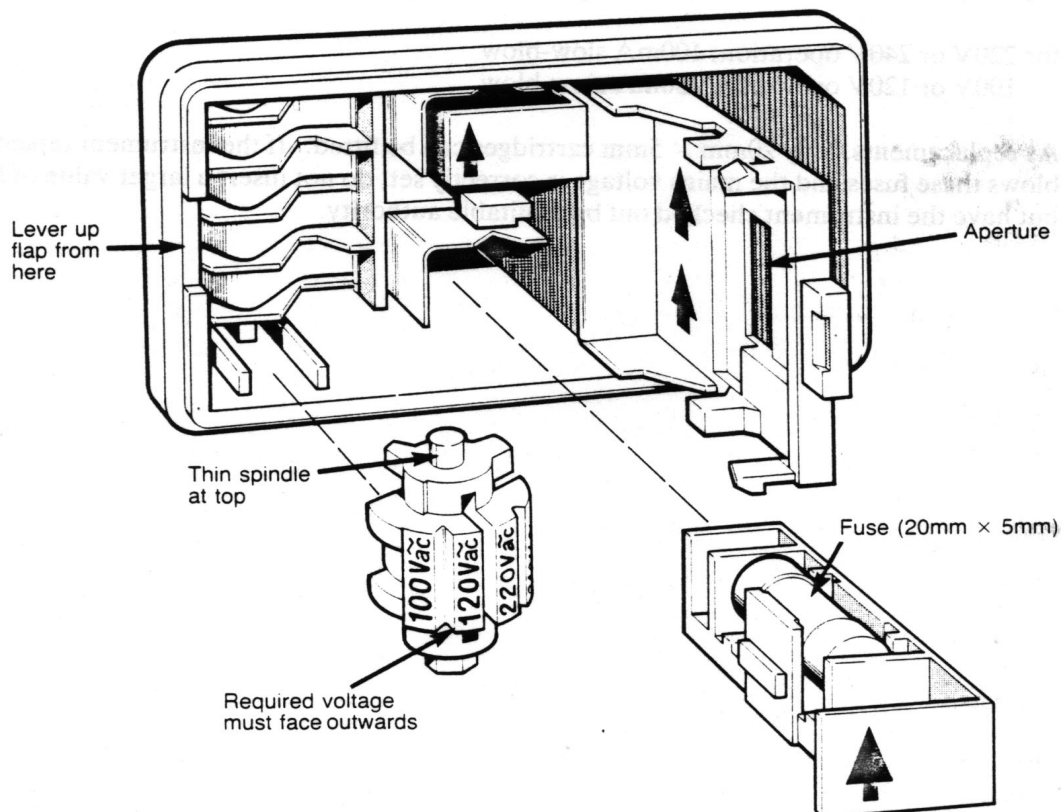


Fig. 1.1 Mains Supply Input Unit

1.3.1 Voltage Adjustment

To change the selected voltage, gently lever up the hinged flap with a screwdriver, lift out the voltage selector block and refit it such that the required voltage appears in the aperture. Close the flap securely and refit the mains connector.

1.3.2 Frequency Range

The instrument is intended for use on nominal 50Hz, 60Hz or 400Hz power supplies. However, if the frequency deviates from these values, the instrument will still operate correctly but with reduced interference rejection.

1.3.3 Mains Input Cable

The mains input cable supplied with the instrument is usually appropriate to the country of destination but should it require changing, observe the colour convention of the wires:

Connection	Colour
Line	Brown
Neutral	Blue
Earth	Green/Yellow

If rack mounting the DMM, or to obtain the best RFI performance, connect the rear panel earthing terminal to a suitable earthing point (in addition to normal earthing arrangements via the power lead).

1.3.4 Fuses

Line and neutral are both fused in the DMM. To access either of these fuses, disconnect the mains cable and gently lever up the flap of the mains power input unit (Fig 1.1). Inside are two fuse holders marked ↑ which pull out. Fuse values are:

for 220V or 240V operation: 100mA slow-blow
100V or 120V operation: 250mA slow-blow

As replacements, only 20mm × 5mm cartridges can be fitted. If the instrument repeatedly blows these fuses and the mains voltage is correctly set, do not insert a larger value of fuse but have the instrument checked out by a suitable authority.

SWITCH ON

The DMM is switched On/OFF by a rear panel switch adjacent to the mains input unit. At switch-on, 7150plus checks its internal memories, front panel display windows and status annunciators.

If the DMM is operating satisfactorily, its display will show the following at the completion of a test:

PASS

This message will be followed by the DMM's GP-IB address:

IEEE 'nn'

(where nn is the actual address set on rear panel address switch)

The DMM is now ready for use.

Should the message:

FAIL 'n'

be displayed, then the multimeter is faulty and should be returned to an authorised repair depot.

Note: The character 'n' represents a failure code; full details are given in the maintenance manual

1.5

ACCESSORIES

The 7150plus is supplied with the following accessories:

	Part Number
Mains cable - UK/USA/Europe - as applicable	359900380/390/250
Set of test leads and probes	359900360
Calibration Jack plug	351302120
Calibration Overlay	71502070A
5-Pin Din Plug	351305070
Spare fuses 100mA slow blow	360106260
2A fast blow	360100150
250 mA	360103050
Fuse Holder	360208150
Operating Manual	71500024

1.6

OPTIONS

The following Options are available for 7150plus:

Radio Frequency Probe	70457F
High Voltage Probe	70457E
Current Shunt	70457X
Temperature Probe, Insertion	71517A
Temperature Probe, Surface	71517B
Rack Mounting Kit	71501
Maintenance Manual	7150026
Nato Connection Set	71517C
Carrying Case	71509A

Chapter 2

Controls and Displays

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2.1 INTRODUCTION

This chapter describes the functions of the DMM's controls and displays. During calibration, other control functions are possible. These are fully described in Part 1, Chapter 5, 'Front Panel Calibration'.

2.2 FRONT AND REAR INPUTS

Input terminals are provided on the front and rear panels. Generally either set of terminals may be used; the choice depends on whether or not the instrument is to be rack mounted or free standing and also on the type of measurement required. As Fig 2.1 shows, front and rear terminal functions are not identical.

Front or rear inputs can be selected by a front panel switch whose action is indicated by the symbols:

-  FRONT Push button out: front inputs selected
-  REAR Push button in: rear inputs selected

The selection of front or rear inputs cannot be actioned by remote control; however a remote controller can interrogate the DMM to determine which set of terminals are in use.

(See Para 1.9.2 'Serial Polling' in Part 2 of this manual).

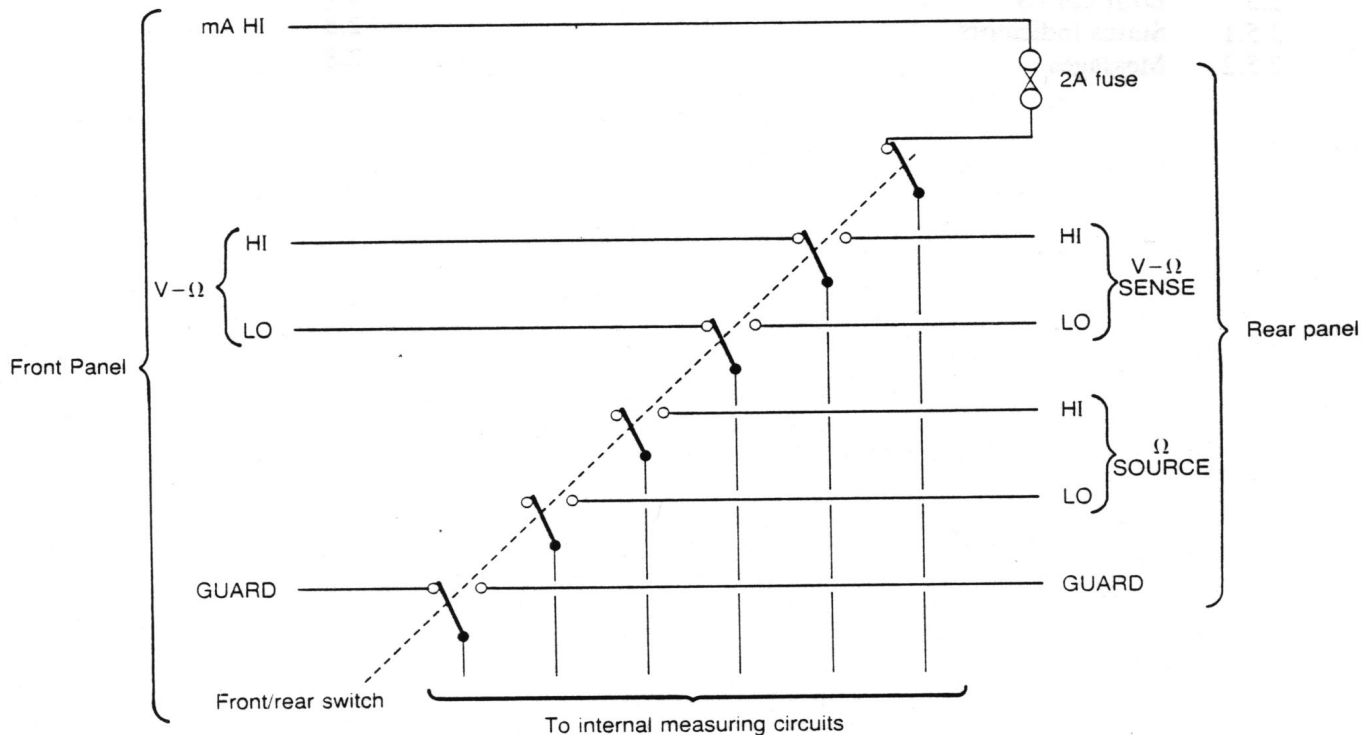


Fig. 2.1 Switching of Front/Rear Input Terminals

2.3 FRONT PANEL CONTROLS

The DMM's front panel controls can be used to select:

The type of measurement (Vdc, ohms, etc).

The type of range (auto or manual; more sensitive/less sensitive).

The measurement resolution (number of digits).

The front panel also has controls which permit:

Nulling (to offset thermal emf's).

A return to 'local' (from remote) control.

2.3.1 Measurement Selection



Voltage dc, 100nV to 1kV in 5 ranges; results in V or mV.



Voltage ac, 1 μ V to 750V in 5 ranges; results in V or mV.



Resistance, 1m Ω to 20M Ω in 5 ranges; results in k Ω .

Press again to measure diode forward volts drop, limit of 2.4V.
Uses 2Vdc volts range.

(Sequence repeats).



Current dc, 1 μ A to 2A, 1 range; results in mA.



Current ac, 10 μ A to 2A, 1 range; results in mA.



Temperature in $^{\circ}$ C. Press again for $^{\circ}$ F.

(Sequence repeats).

2.3.2 Ranging

The instrument can autorange – or ranges can be set manually. As a safety feature, the DMM defaults to autorange on power up.



Selects autoranging of the chosen measurement function.
Press again to deselect and fix on present range.



Selects more sensitive range – and deselects AUTO.



Selects less sensitive range – and deselects AUTO.

2.3.3 Resolution

Ordinarily, the time taken for the DMM to display a measurement after receiving an input is 800ms, (viz, 400ms 'integration time' plus a 400ms 'drift correction'). A result so produced is referred to as a 5½ digits result (5 significant figures plus a leading digit of either 0, 1 or 2). Faster measurements of less resolution (4½ digits) or slower measurements of greater resolution (6½ digits) are possible using the DIGITS control.



Pressing this control causes the number of digits to increase.
After 6½ digits (maximum), display reverts to 4½ digits.

(Sequence repeats).

2.3.4 Walking Window Filter

When 6½ digits is selected (DIGITS control) 'walking window' filter results are produced and a *FILT* annunciator is displayed. The filter provides a high level of immunity against interference, particularly at lower frequencies. Repeated 5½ digit measurements are taken and the display, which is refreshed every 800ms, shows the running average result. After the sixteenth reading, the result becomes the running average of the sixteen most recent readings. As each new reading is added, the earliest reading is discarded, hence the description 'walking window'.

With 5½ digits selected, a walking window filter, similar to that described for 6½ digits, is effective. In this case however, only four readings are used to produce the running average and the *FILT* annunciator remains off.

2.3.5 Nulling

The nulling facility permits small dc error voltages, superimposed on the required input signal, to be cancelled out. Typically, these may be produced by thermal effect on the connecting leads or terminations. Errors of at least the following magnitudes may be cancelled out:

voltage dc: $\pm 1\text{mV}$
current dc: $\pm 1\text{mA}$
resistance: $\pm 10\Omega$

Briefly, a null (offset) value can be measured for each range of a selected dc function. These values are then stored in memory along with the null values of any other nulled function. Thereafter, when a measurement is made in a particular function/range, the appropriate null value is recalled from memory and applied as a correction factor to the measured result. The dc error at the input is thus cancelled out. Switching off the instrument causes all null values to be destroyed.

Note: The null facility cannot be used on ac or diode ranges. To null a dc voltage or resistance range, select the required measurement (Vdc or k Ω) fit the test leads to the V- Ω Hi and Lo terminals and short the free ends together. Now press NULL.



Press once to automatically null each range in turn.

To null a dc current, carry out the same procedure but open circuit the input leads.

When NULL is pressed, nulling begins on the lowest range. The display shows *NULL 'n'* where 'n' = the number of ranges yet to be nulled. Upon completion, the *NULL* annunciator is displayed and the instrument returns to the range in use prior to nulling.

If an offset exceeds the value that can be nulled, the display shows *HI NULL* and the sequence is halted.

On return to a previously nulled function, its null values are recalled. To re-null a particular function, select the function, press NULL to reset all previous null values, then press NULL again to restart the nulling process.

2.3.6 Local/Remote Control

If the DMM is in remote control pressing the LOCAL control will restore local (front panel) control. If Local Lockout (LLO) has been asserted via the interface however, pressing LOCAL will have no effect. LLO disables the LOCAL control.



Press to regain local (front panel) control. Inoperative when interface command LLO is asserted.

Note: If single-shot measurements have been commanded remotely, using T0 (see Instruction Set in Part 2, Page 2.7 of the manual) pressing local will cause the DMM to resume tracking- providing the external HOLD facility is not being used. (see Para 2.4).

2.4 REAR PANEL MEASUREMENT CONTROL

With the 7150plus, the user is able to initiate measurements using his own external hardware. Access to the DMM's switching circuits is via 5-way Din socket SK505 which is located on the rear panel (Fig. 2.2).

The socket, which also has an output facility, uses standard TTL logic levels to activate the various control functions.

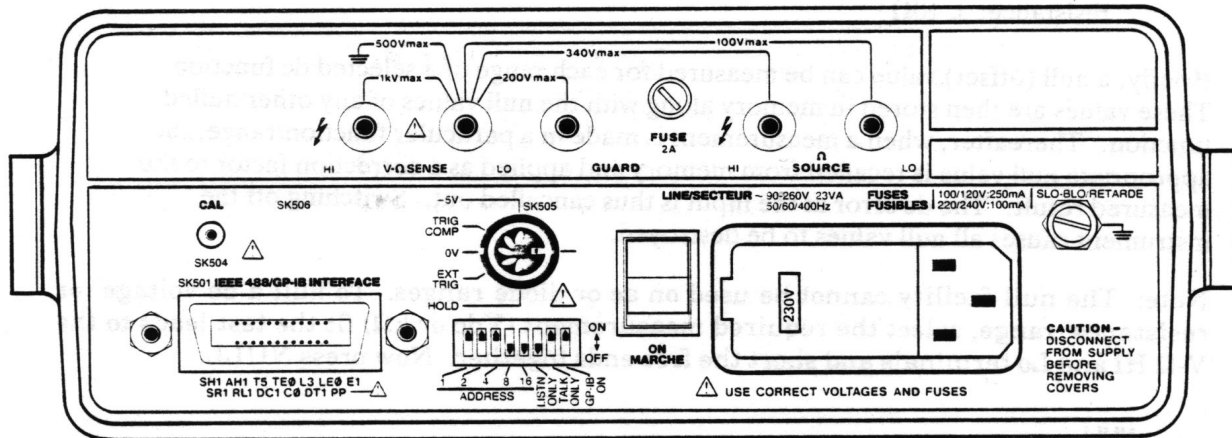


Fig. 2.2 DMM Rear Panel

The following input signals are available via SK505:

Hold

External Trigger

Following an External Trigger command, the following output is available via SK505:

Trigger Complete.

2.4.1 Hold

Usually, the DMM measures continuously. When the HOLD input (normally 'high') is connected to 0V, the Multimeter stops measuring, the *HOLD* annunciator appears and the most recent reading remains in the display.

2.4.2 External Trigger

External Trigger, which is only operative in HOLD, is used to command a single measurement. This input is normally held 'high'. To activate the measurement, the 'EXT TRIG' input must be connected to 0V. To make further measurements, the input must be returned to +5V and the above action repeated.

2.4.3 Trigger Complete

The DMM can indicate (to an external device) that a measurement has been completed. The indication is via the (normally high) 'TRIG COMP' pin which is pulled low (logic 0) for 10-20ms after a measurement has been completed.

2.5 DISPLAYS

The DMM presents data on a 6½ digit, alpha-numeric, liquid-crystal display which is back-lit to enhance clarity in poor light. The display includes a leading minus sign and a series of status annunciators to show the various operating modes.

The main part of the display shows the numeric value of a measurement, its polarity, the units of measurement and at times – messages. Messages may include for example an indication of an overload, or a user prompt to facilitate calibration of the DMM.

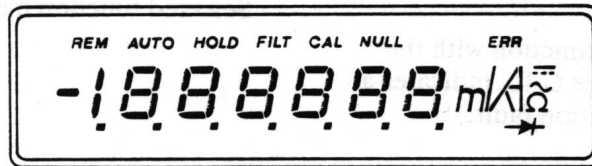


Fig. 2.3 Numeric Display and Annunciators

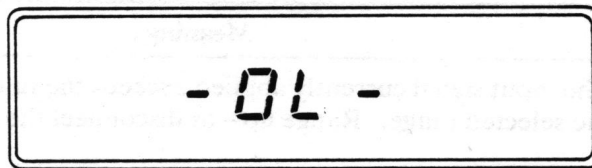


Fig. 2.4 Overload Message

2.5.1 Status Indicators

Status Indicator	Flashing Indicator	Indicator Steady
REM	-	DMM under remote control.
AUTO	-	Auto ranging is enabled.
HOLD	-	DMM is not measuring.
FILT	-	Filter (6½ digits) is selected.
CAL	Calibration Mode Enabled	Calibration mode ENTERED.
NULL	-	Selected function has been nulled.
ERR	In conjunction with the message CAL, indicates a calibration fault.	
COMP	Flashes briefly on COMPlition of each measurement.	

2.5.2 Messages

Displayed Message	Meaning
<i>Complete display flashes regardless of content</i>	The input signal currently applied exceeds the full scale value of the selected range. Range up – or disconnect the input.
- OL -	Appears in place of a measurement result to indicate that the measurement exceeded the full scale value at some point during the measurement time.
----- V	The function has been changed (eg, to Vac) but no measurement has yet been taken with the new settings. The selected units only are displayed.
NULL 'n'	Displayed during a nulling sequence. The 'n' indicates the number of ranges yet to be nulled.
HI NULL	Indicates an input signal too large to be nulled.
ILLEGAL	Appears when two conflicting modes of operation are selected; for example, attempting to null on an ac range.
ERR 'xy'	Refer to 'Error Messages' (Part 2, Page 2.8).

Chapter 3

Taking Measurements

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3.1 INPUT TERMINALS

With 7150plus, current measurement is only possible via the front panel mA HI and (common) LO terminals. Conversely, 4-terminal ohms measurement is only possible via the appropriate rear panel terminals. (See Fig. 2.1).

WARNING: Do not exceed the maximum permitted voltages between terminals as stated on the front and rear panels.

3.2 MEASUREMENT – GENERAL

For many applications, it is sufficient just to connect the unknown quantity (volts, ohms etc) to the DMM with a pair of test leads connected to the appropriate terminals (V- Ω HI and LO etc). Measurements can then be taken.

Very often however, interference is superimposed on the input signal to the instrument and if it is large enough, the displayed result may be affected, ie, the result may be unstable, or worse still, steady but incorrect.

As it is sometimes difficult to assess whether or not results will be affected by interference, it is advisable to take certain simple precautions that guard against it. Briefly, these are:

- (a) Null the dc ranges prior to their use. (With ohms measurements, nulling will also offset the value of the lead resistance).
- (b) Connect the Guard terminal to the equipment under test at the source of any suspected Common Mode interference, usually at the point of connection of the LO lead. Although slightly less effective, a compromise is to connect GUARD to LO at the instrument.

For information on the possible causes of interference, see Part 1, Chapter 4.

It is not normally too important which way round the connecting leads are arranged as the instrument can measure +ve and -ve signals. If -ve, a minus sign will precede the result. If maximum interference rejection is required, it is advisable to connect the leads in the conventional manner once the polarity of the input is known.

3.3 VOLTAGE MEASUREMENT (Via Front or Rear Panel)

Connect the test leads to the V- Ω HI and LO terminals and select V_{DC} or V_{AC} . Select AUTO ranging and connect the test leads across the unknown voltage. Connect GUARD as shown. Repeated measurements will be taken; use the HOLD facility to freeze the display if required.

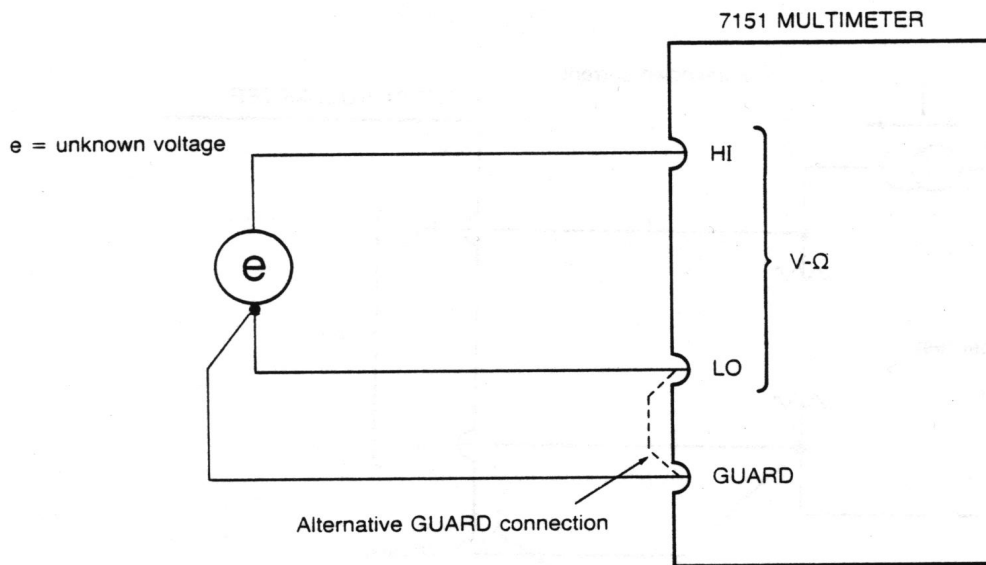


Fig. 3.1 Connections for Voltage Measurement

Note: Protection against voltages in excess of approx. 1.2kVdc or 1.2kV peak ac is afforded by a spark gap between HI and LO.

3.4 CURRENT MEASUREMENT (Via Front Panel Only)

Connect the test leads to the mA HI and LO terminals and select I_{DC} or I_{AC} . Connect the test leads to the unknown current and to the GUARD terminal as indicated in Fig. 3.2.

Repeated measurements will be taken; use the HOLD facility to freeze the display if required.

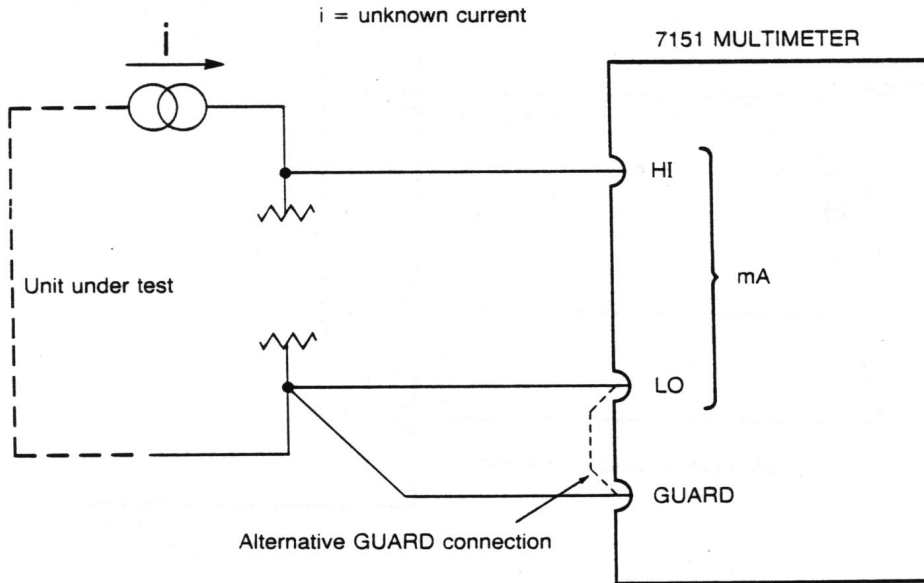


Fig. 3.2 Connections for Current Measurement

Note: Protection against currents in excess of 2A is provided by a 2A fast blow fuse mounted on the rear panel.

3.5 RESISTANCE MEASUREMENT

Resistance can be measured by using either the two or four-terminal method. For most applications the two-terminal method is satisfactory. However, as the value of unknown resistance becomes smaller, the effects of the instrument being remote from the resistance becomes more noticeable. In particular, the connecting leads always have some resistance, typically 0.25Ω . As a result, the ratio of unwanted resistance to that which is required becomes more significant.

In order to ascertain which method should be used, it is sufficient to measure the resistance of the test leads (if not already known) and then calculate their value as a percentage of the resistor under test. If this figure is unacceptable, the four-terminal method should be used.

A test current for resistance measurement is provided by a constant current generator whose output varies with the selected resistance range, viz, $100\mu\text{A}$ (for $2\text{k}\Omega$ and $20\text{k}\Omega$ ranges) $10\mu\text{A}$, $1\mu\text{A}$ and 100nA .

3.5.1 Two-Terminal Resistance Measurement (Front or Rear Panel)

Connect the test leads to the V- Ω HI and LO terminals and select Ω . Short the leads together, then null. Select AUTO ranging and connect the test leads across the unknown resistance. Connect GUARD as shown in Fig. 3.3. Repeated measurements will be made; use the HOLD facility to freeze the display if required.

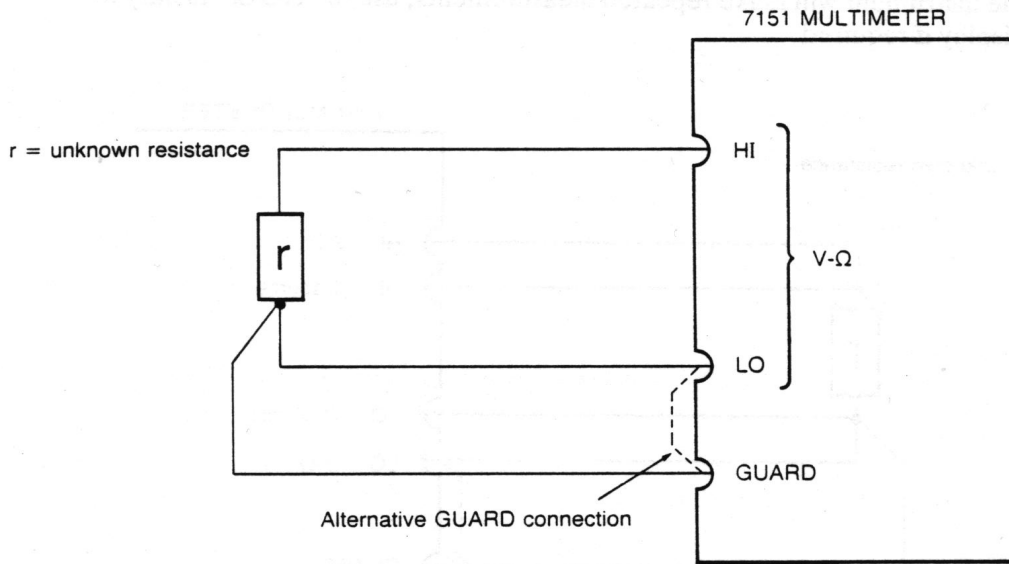


Fig. 3.3 *Two-terminal Resistance Measurement*

3.5.2 Four-Terminal Resistance Measurement (Rear Panel Only)

Connect the test leads to the rear terminals as shown in Fig. 3.4 and select Ω . Short the V- Ω test leads together and allow readings to settle, ie, allow settling time for thermals. Perform a null. Disconnect the short and connect these two leads across the unknown resistance, keeping the connections as close to the body of the resistance as possible. Now connect the Ω SOURCE HI and LO test leads. Allow thermals to settle and select AUTO ranging. The instrument will make repeated measurements; use the HOLD facility to freeze the display if required.

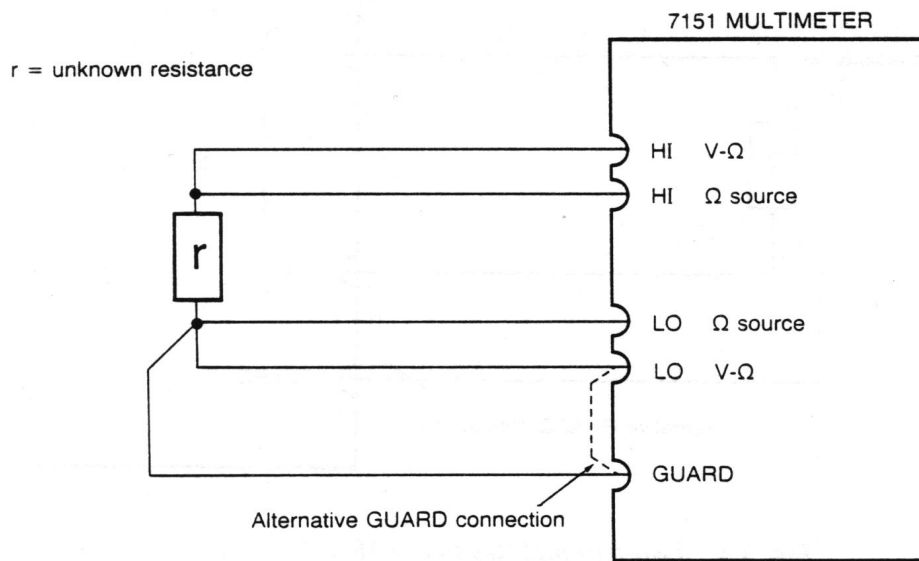


Fig. 3.4 *Four-Terminal Resistance Measurement*

Note: For nulling prior to four-terminal resistance (or temperature) measurement, connect the test leads as shown in Fig. 3.5.

3.6 TEMPERATURE MEASUREMENT

Temperature may be measured using the optional immersion or surface type Platinum Resistance Temperature (PRT) probes.

In practice, temperature measurement involves taking resistance measurements which the DMM then converts into either °C or °F. As for resistance, two-terminals may be used but four-terminal measurements will produce more accurate results. (Select rear panel inputs for four-terminal measurements).

If two-terminal measurements are to be made, it will be sufficient to use the front panel V-Ω HI and LO terminals, otherwise the probe must be connected to the rear input V-Ω SENSE and Ω SOURCE HI and LO terminals. (Match the colour of the probe leads to those of the input terminals).

When using the surface probe, a small amount of heat sink compound between the probe and the surface will ensure good thermal contact. To measure the temperature of a liquid, insert the immersion probe approximately 3in (6-7cm) into the liquid.

It is advisable to null the resistance ranges before use. For two-terminal measurements, connect a short circuit between the DMM's V-Ω HI and LO terminals. (A measured result will show a small error due to lead length).

For four-terminal measurements, short the terminals as shown in the diagram, ie, V-Ω SENSE HI to V-Ω SENSE LO, Ω SOURCE HI to Ω SOURCE LO, then join the two at the points shown.

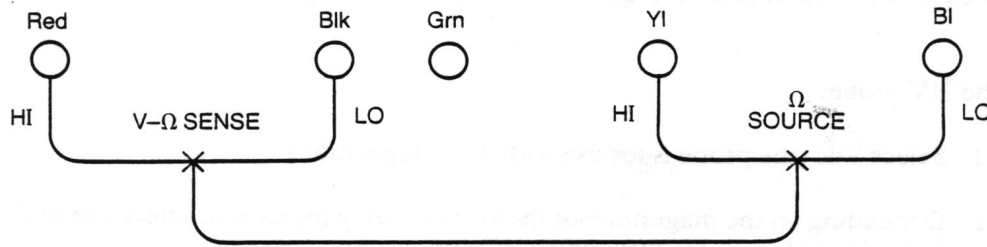


Fig. 3.5 Rear 4mm Terminals – Recommended Connections for Ohms Null

3.7 USING THE OPTIONS

The following options may be used with the DVM:

Radio Frequency Probe (70457F)

High Voltage Probe (70457E)

10A Current Shunt (70457X)

3.7.1. Radio Frequency Probe

This is a peak-sensing rms-scaled probe which extends the frequency coverage for ac voltage measurements. With the probe, the DMM may be used to measure ac voltage at frequencies between 10kHz and 750MHz. Probe inputs can be within the range 100mV to 40V.

To use the RF Probe:

1. Select Vdc (the probe gives a dc output).
2. Depending on the magnitude of the voltage being measured, select one of the following Vdc ranges: 20V or 200V.
3. Connect the probe to the V- Ω HI and LO input terminals.

3.7.2. High Voltage Probe

The probe extends measurement range of dc voltage to 40kV, giving a division ratio of 1000:1.

To use the HV probe:

1. Select Vdc (the probe is for use with dc voltages only).
2. Depending on the magnitude of the voltage being measured, select one of the following Vdc ranges: 20V, 200V.
3. Connect the probe to the V- Ω HI and LO input terminals.

Note: When using the RF or HV Probe, use only the ranges stated. This ensures that the the probe is correctly terminated by 10M Ω .

3.7.3 Current Shunt

This is a 1m Ω shunt which extends the measurement range of ac or dc current up to 10A. The input current will be read as an ac or dc voltage developed across the shunt. The voltage readings produced by the DMM must be converted by the user into current, using the conversion; 1mV/Amp.

(A 2.5mV reading for example, would indicate a current of 2.5 Amps).

To use the current shunt:

1. Select Vdc or Vac as appropriate.
2. Select the 0.2V range.
3. Connect the shunt to the V- Ω HI and LO input terminals.

Chapter 4 Interference – Some Causes & Cures

<i>Para</i>	<i>Title</i>	<i>Page</i>
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4.2	SERIES MODE INTERFERENCE	4.2
4.2.1	Series Mode DC	4.2
4.2.2	Series Mode AC	4.3
4.3	COMMON MODE INTERFERENCE	4.4
4.4	REMEDIAL ACTION	4.5

4.1 INTRODUCTION

Consider a DMM measuring a signal applied to its input terminals. The signal presented to the input comprises two components; the required input signal and an unwanted signal (no matter how small). If the unwanted signal is sufficiently large, it invariably causes a change in the DMM reading.

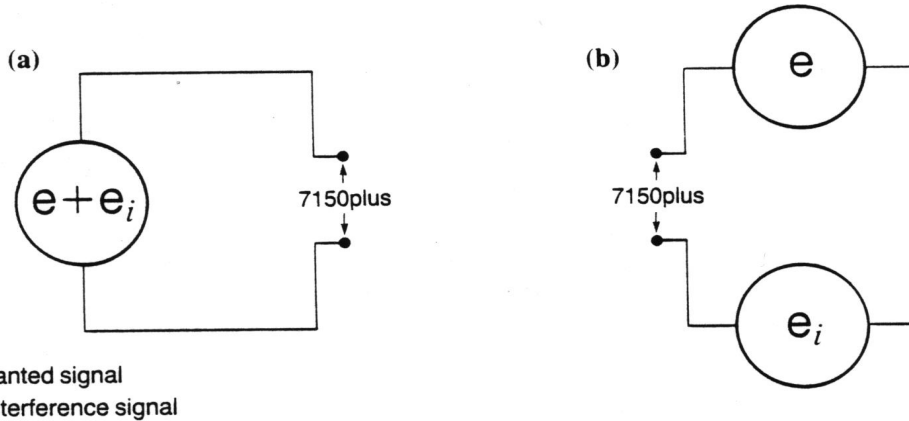
This unwanted signal, or interference, may be ac or dc. Sometimes, the presence of interference is simply indicated by a result that differs from the expected value, or perhaps the last one or two digits are unstable, due to some additional, spurious signal. Very often however, the displayed result gives no indication that the measurement has been affected by interference, and so precautions against it must be taken.

4.2 SERIES MODE INTERFERENCE

The term series mode (or normal mode) arises because the interference is effectively in series with the signal source and voltmeter input. It may arise (a) as part of the source where the signal and interference are inextricably mixed; or (b) as a separately identifiable generator.

e = wanted signal
 e_i = interference signal

In both cases the DMM sees an input = $e + e_i$



e = wanted signal
 e_i = interference signal

In both cases the DMM sees an input = $e + e_i$

Fig. 4.1 Series mode interference

4.2.1 Series Mode DC

When the interference is dc there is no way of designing the DMM to ignore it. If the interference is only of the order of microvolts then a zero, or null control may be able to compensate. For example, on Volts dc, the DMM can null out offsets of at least $\pm 1\text{mV}$. If the offset is excessive and cannot be nulled, the user can only take precautions, knowing that the problems may exist.

If the source of the offset is simply resistance in the test leads then the solution is to make the leads shorter/thicker. Often though, the offset is caused by thermal effects upon connectors, clips, and relays in the measuring path. For example, a simple reed relay with nickel-iron contacts usually has copper connections, i.e. a pair of thermocouples. Any temperature gradient across the relay then results in an emf of approximately $40 \mu\text{V}/^\circ\text{C}$.

Other sources of dc interference can result from leakage across nominally good conductors, especially under conditions of high humidity; moisture on exposed terminals may cause galvanic emf's to be generated; screened cables connected to vibrating equipment may generate electrostatic potentials; and so on.

4.2.2 Series Mode AC

The most serious form of ac interference is usually derived from the mains supply, ie 50Hz, 60Hz, etc.

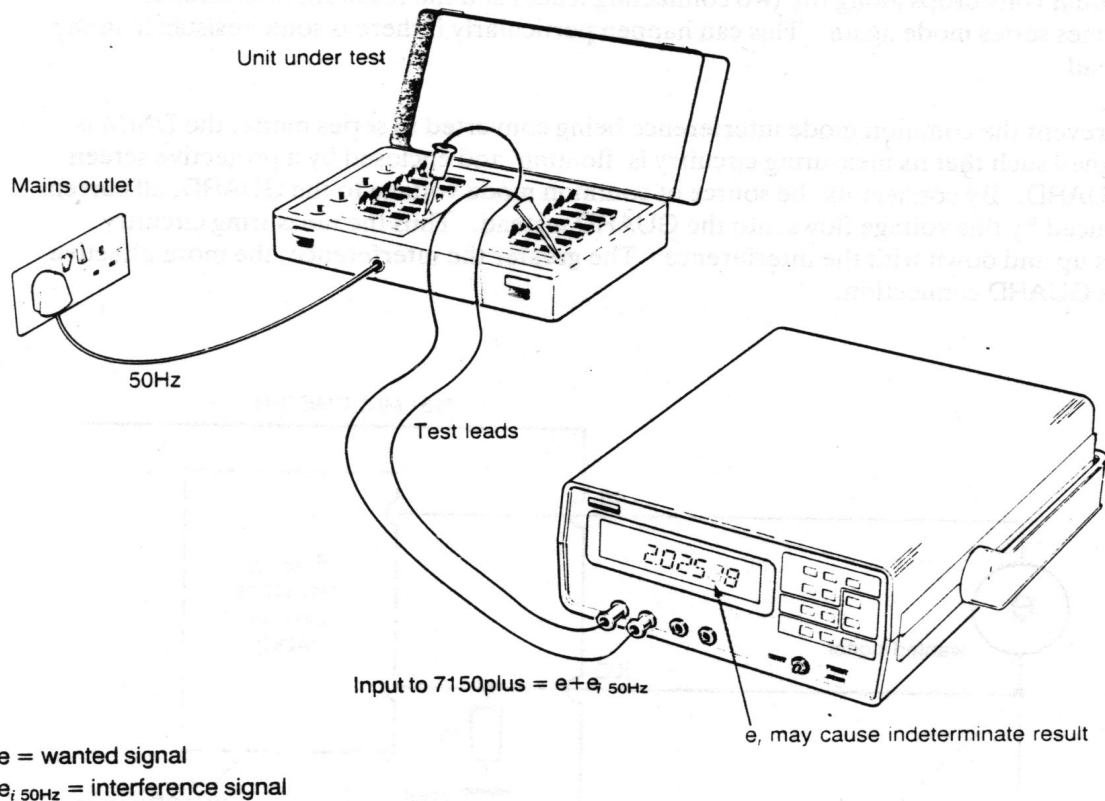


Fig. 4.2 Mains induced interference

This problem can be overcome by designing the DMM so that its measurement times are multiples of the mains frequency period. For example, for 50Hz operation, measurement times of 20ms, 40ms, 60ms ---- etc. would be suitable. Thus the 50Hz induced interference components are averaged out.

However, if the interference is other than mains induced, the most successful way of dealing with it is to use the longest practicable measurement time in order to average out the interference components. When relying on this process however, the DMM's dynamic range becomes important. Consider a DMM with a nominal range of 2.000V having an applied input of 1.700V. A series mode rejection ratio of 40dB (100:1) implies that the DMM can withstand 100mV of ac before 1mV error is displayed. But conversely, it is not true to say that a display error of say, 10mV is allowable in addition to the 1.7V input. This is because with a 40dB (100:1) rejection ratio, to display 10mV error implies an error input of 1.0V, in addition to the wanted signal of 1.7V. Consequently, at times the total input to the DMM exceeds the range maximum (2.000V). This problem can easily be avoided by ensuring that plenty of headroom is always given in the selected measurement range, i.e. range up if in doubt.

4.3 COMMON MODE INTERFERENCE

Common mode interference is brought about by a source which is common to both input leads and superimposed as a standing voltage with respect to earth. It is when this common mode voltage is converted to series mode that corruption of a measurement occurs.

If the connecting leads have identical resistances and the currents flowing through them are equal, then there is no potential difference at the DMM input terminals, apart from the input voltage proper, that is. But, in practice, these resistances and currents are unequal (unequal volts drops along the two connecting leads) and the resultant interference becomes series mode again. This can happen particularly if there is some resistance in the LO lead.

To prevent the common mode interference being converted to series mode, the DMM is designed such that its measuring circuitry is 'floating' and enclosed by a protective screen, or GUARD. By connecting the source of common mode voltage to the GUARD, all current produced by this voltage flows into the GUARD instead. Thus the measuring circuitry floats up and down with the interference. The greater the interference, the more effective is the GUARD connection.

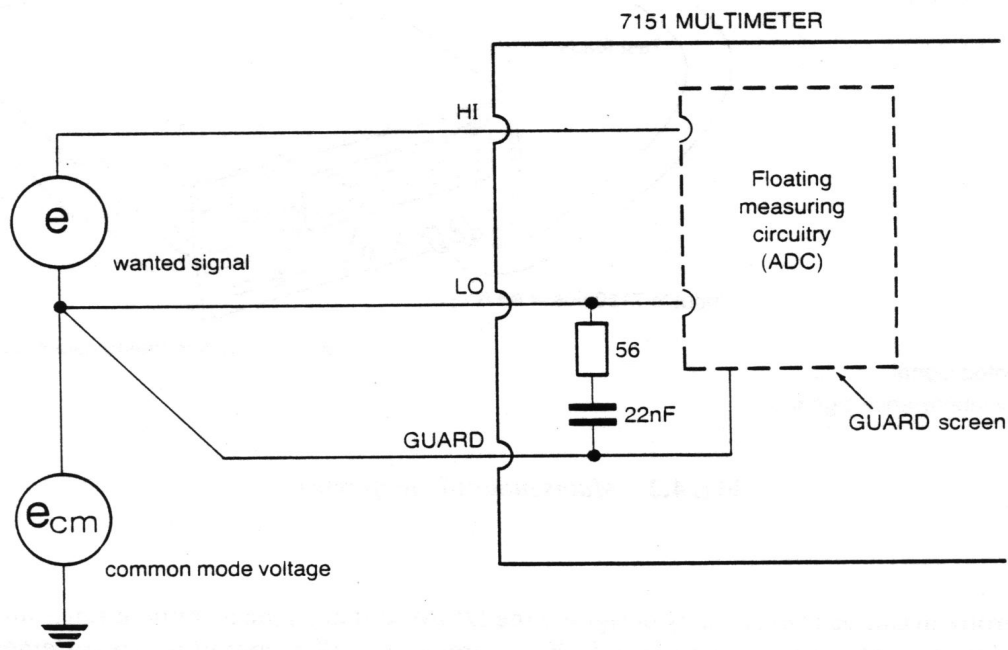


Fig. 4.3 DMM Guard Arrangement

With 7150plus, the GUARD is internally ac coupled to the LO terminal by a series RC network. This path provides adequate protection for most ac interference and the GUARD terminal need not necessarily be connected externally. However, it is good policy to always connect the GUARD to a suspected source of common mode interference, usually the point at which the LO lead is connected.

4.4 REMEDIAL ACTION

Interference can be series or common mode, ac or dc. Here is a summary of the suggested methods for dealing with the interference. In addition, keep the lengths of any connecting leads approximately equal, and to a minimum.

- | | |
|----------------------|---|
| Series mode, dc | Use the null facility to remove small offsets. Alternatively, attempt to eliminate the offset source from the measuring path. |
| Series mode, ac | Select a measurement time that is a Multiple of the mains period. For example, for 50Hz operation, use 40ms, 400ms etc. For other forms of interference (e.g. noise), use the longest practicable measurement time to average out the effects, 400ms or 1.6s etc. In practice, the higher ohms ranges may be found more susceptible to series mode ac. The real cure here is to use a screened lead where the V- Ω HI, and Ω SOURCE HI & LO leads are screened by an outer braid connected to V- Ω LO. |
| Common mode, dc & ac | Connect the GUARD terminal to the source of common mode interference, usually the point to which the LO lead is connected. If possible, use matched connecting leads. |

Chapter 5

Front Panel Calibration

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5.3	CALIBRATION PROCEDURE	5.4
5.3.1	Exit from Calibration Mode	5.5
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5.3.3	Modifying a Reference Setting	5.6
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5.1 GENERAL

The 7150plus DMM may be calibrated via its GP-IB interface, using programmable calibration standards and a suitable controller. Part 2 of the manual contains in Chapter 7, the procedure for calibrating the DMM via the GP-IB and also gives some program examples using various types of controller. As an alternative, the DMM may be calibrated via its front panel controls as described in Paras. 5.2 to 5.4 below.

Calibration of the 7150plus is possible without the use of tools or the removal of covers. Calibration coefficients are held in the DMM's non-volatile memory (EAROMS), replacing conventional potentiometers. With 'digital' calibration, the DMM can be fully calibrated in less than half the time taken, using traditional methods.

Since calibration coefficients are stored independent of each other, individual functions and ranges may be calibrated without disturbance to others. Thus with 7150plus, it would be in order to calibrate only the range required – and simply refresh coefficients for others.

Data retention times of ten years are typical with the EAROMS. It is however recommended that calibration (or a memory refresh) is carried out annually.

Fig 5.1 shows an 'actual' uncalibrated A-to-D converter characteristic alongside the calibrated 'ideal'. The characteristic represents a straight line equation, $y = mx + c$, and is typical of a DMM that uses digital calibration to convert an unknown input Voltage V_x , into a measured reading.

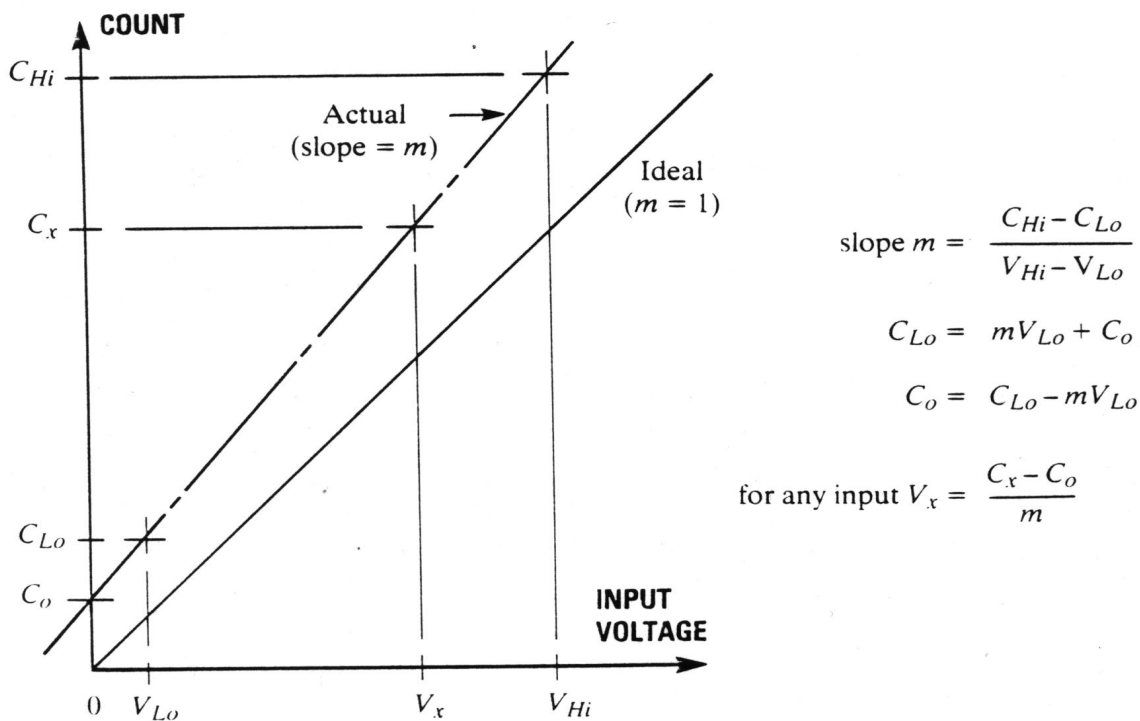


Fig 5.1 Calibration Characteristic

At calibration, a specific mode and range are selected, say dc volts and 2V range.

Two known calibration voltages, eg, 2 volts as V_{Hi} and 0.1V as V_{Lo} are then presented to the DMM in sequence and a measurement triggered in each case. The DMM will store the result of its own A-to-D conversion for these known input voltages as C_{Hi} and C_{Lo} respectively.

Because the DMM has been told that V_{Hi} should be 2V and V_{Lo} should be 0.1V, its microprocessor is able to compute the slope shown in the diagram. The offset at zero volts, C_o , can be also derived from the equation for m .

In practice (and ideally for dc) C_{Lo} can be a short circuit input (zero volts) so C_o could be measured directly. The calibration of the 2V dc range is now complete. The values of m and C_o are stored in the DMM's memory as the calibration coefficients for the 2V dc range.

For any unknown input voltage, V_x , in the 2V dc range, the DMM will measure C_x and use this value in the equation:

$$V_x = \frac{C_x - C_o}{m}$$

to compute the unknown input voltage V_x .

A similar procedure is repeated for all ranges and modes. It simply involves selecting the appropriate measurement mode, stepping through the ranges in sequence and for each range, applying an appropriate high and low reference input.

5.2 PRELIMINARIES

The following equipment will be required to calibrate the DMM:

- Standards (AC/DC Voltage, AC/DC Current, Resistance)
- Front Panel Calibration Overlay
- Calibration Enable Jack-plug

5.2.1 Standards

The standards should be able to provide reference inputs appropriate to each range and mode. Suggested reference values are shown on the DMM's display. If other values are used, refer to the procedure for modifying reference values given in paragraph 5.3.3.

For resistance and dc inputs, the low reference – usually zero – is readily obtained simply by shorting out the DMM's V- Ω HI and LO terminals. On ac ranges, the low reference value should not be less than 10% of the nominal full scale value.

For all ranges, the nominal full scale value of a range is suitable as a high reference value. A high reference of less than 50% of nominal full scale should not be used.

5.2.2 Front Panel Calibration Overlay

In calibration mode, some of the DMM's controls assume different functions; these are identified on the calibration overlay. During the calibration procedure, the overlay is placed over the control keypad.

5.2.3 Calibration Enable Jack-plug

The calibration jack-plug, when inserted in the rear panel CAL socket, 'enables' the DMM's calibration circuits. After calibration the jack-plug must be removed, to prevent unauthorized calibration and to protect the calibration constants.

Before use, the internal contacts of the jack-plug should be shorted together. (This is assumed to have been done in the following calibration procedure).

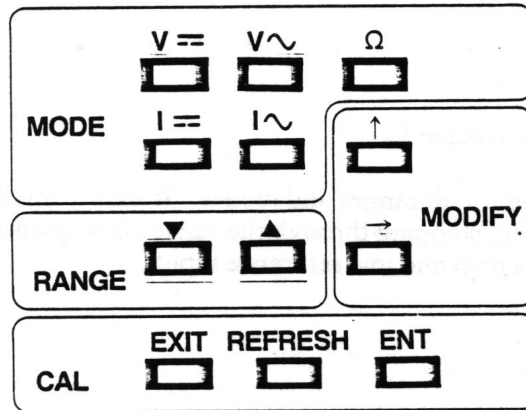


Fig. 5.2 Calibration Overlay

5.3 CALIBRATION PROCEDURE

To calibrate the DMM:

1. Insert the jack plug into the CAL socket on the rear panel.

The CAL annunciator will flash indicating that the calibration mode is enabled – though not yet entered.

2. Press LOCAL to enter CAL mode.

The CAL annunciator will stop flashing and remain solidly on.

3. Fit the calibration overlay (Fig. 5.2).

(With the jack plug inserted and LOCAL pressed, the control functions identified on the overlay become effective).

4. Select the appropriate measurement mode; Vdc or Vac, Idc or Iac, or Ω. (The display annunciator indicates the present mode).

Note that with the overlay in position, no diode or temperature controls are offered; both diode and temperature calibration are inherent in ohms calibration.

5. Select the required range using the normal range controls.

Pressing either 'range-down' or 'range-up' not only causes the range to change in the prescribed manner, but also momentarily displays its nominal full scale value. This is a convenient reminder of the range in use. Ranges may be calibrated in any order.

6. With the required mode and range selected, press ENTER.

This causes the DMM to display a sequence of prompts advising the user that the low reference value (or low point) should be applied, eg:

```
"Lo Pt.  "
"APPLY  "
"0.00000 V"      (Set low point).
```

For all ranges, a recommended value is given for the low (and high) point. However, a flashing first digit in the prompt indicates that it is possible to modify the recommended value to one which matches precisely the available input (see Para 5.3.3).

7. With the appropriate reference value set, connect the DMM to the reference source, apply the low point and allow time for the reading to settle. Once the input is steady the value may be entered.
8. Press ENTER again.

This time, pressing ENTER causes the DMM to measure the low point and commit it to memory.

A similar sequence of prompts automatically follows for the high point, eg:

```
"Hi Pt.  "
"APPLY  "
"2.00000 "      (Set high point).
```

At this stage the high point should be applied. Alternatively, the value may be modified (Para 5.3.3) and the new value applied to the DMM.

9. In either case, when the input has settled, press ENTER again.

The DMM will measure the high point and commit it to memory.

The actual value of the units entered, will depend upon the chosen range and mode. The above values are typical for the Vdc 2V range.

When both the low and high reference values have been measured, the DMM will proceed to calculate the calibration constants for that particular range and on successful completion, display a final message:

" Good "

This message indicates that the present range has been calibrated and that the calibration constants in memory have been altered accordingly. (See Para 5.4 for details of other calibration messages).

To select another range (or mode), return to steps 5 (or 4) and repeat the procedure until the required ranges are calibrated. Do *not* at this stage remove the jack-plug; it is important that the correct exit procedure be followed on completion of the required calibration task (see Para 5.3.1).

5.3.1 Exit From Calibration Mode

If only a partial calibration has been carried out (ie, not all ranges of all modes have been calibrated) it is strongly recommended that memory refresh is used *before* exiting from calibration mode. (See Para 5.3.2)

Once the required ranges have been calibrated, the multimeter may exit calibration mode as follows:

1. Press EXIT.

When EXIT is pressed, the DMM calculates an overall checksum for the calibration constants and stores the value in memory.

2. Remove the calibration overlay and withdraw the jack-plug from the CAL socket. (A flashing CAL annunciator warns if the jack-plug has been left in position).

5.3.2 Memory Refresh

When REFRESH is pressed, the DMM reads all the calibration constants held in memory and then re-writes them. Memories therefore re-acquire maximum (and thus identical) retention times.

The refresh sequence is monitored on the DMM (see 'Messages' Para 5.4).

5.3.3 Modifying a Reference Setting

Usually, when setting a low and high reference points, the DMM will prompt the user to apply the most appropriate input for the chosen range.

In some cases, the calibration equipment available may not be able to provide the value requested. It may still be possible however to calibrate a range.

Consider for example that calibration is to be carried out on the 2V dc range and that the only useful input available as a high reference is, say 1.01864V, from a standard cell.

In the normal manner, the DMM will have been programmed to expect only the value displayed in the prompt, viz, 2.00000V and would therefore reject the lower value as being outside of acceptable limits. An appropriate error message would be displayed (see Para 5.4).

For the DMM to accept 1.01864V as the high point, the value must first be set on its display using the 'MODIFY' controls.

Initially, when the high point prompt appears in the display, the first digit will flash – indicating that the value displayed may be modified if required. (Some values eg, zero on ohms, or dc ranges, may *not* be modified).

To modify a reference value:

1. Use the control marked [↑] to increment the first (flashing) digit. (Digits increment from 1 to 9, then back to 0).
2. Once the first digit has been incremented, select the next digit using the other arrowed control [→]. The newly selected digit will now flash. (This control will scroll, through the remaining digits, back to the first if required).
3. Increment the digit as described in 1 above.
4. Repeat the process for the remaining digits until the display reads 1.01864.
5. Apply 1.01864V from the standard and allow time for the input to settle.
6. Commit the value to the DMM's memory by pressing ENTER as per step 9 of the calibration procedure.

5.4 MESSAGES

During calibration, the following messages may be displayed.

Displayed Message	Meaning
<i>Good</i>	A range has been successfully calibrated.
<i>Error</i>	The calculated calibration constants for the present range exceed acceptable limits. Original calibration constants for the range will be retained. Repeat calibration for this range, ensuring that correct reference inputs are applied.
<i>Abort</i>	An inappropriate control key has been pressed during the calibration sequence. Original calibration constants will be retained. Reselect range and repeat calibration.
<i>LOC 'nn'</i>	Displayed during a REFRESH sequence. Shows the location in memory most recently refreshed. The DMM range $(0 \text{ to } 16) \times 2$ (number of constants per range) = nn.

Chapter 6

Rack Mounting the 7150plus

<i>Para</i>	<i>Title</i>	<i>Page</i>
6.1	GENERAL	6.2
6.2	ASSEMBLY INSTRUCTIONS	6.2
6.2.1	Assembling the Rack Mounting Kit	6.2
6.2.2	Preparing the DMM for Rack Mounting	6.3

6.1 GENERAL

The optional Rack Mounting Kit (71501) will be required if the DMM is to be rack mounted. Each kit will allow two DMM's to be mounted side by side in a standard 19" rack. Once the rack mounting kit has been assembled, the DMM itself must be prepared (removal of handle, trims etc) before it can be located inside the kit assembly.

If only one DMM is to be mounted, a blanking plate (included in the kit) can be fitted.

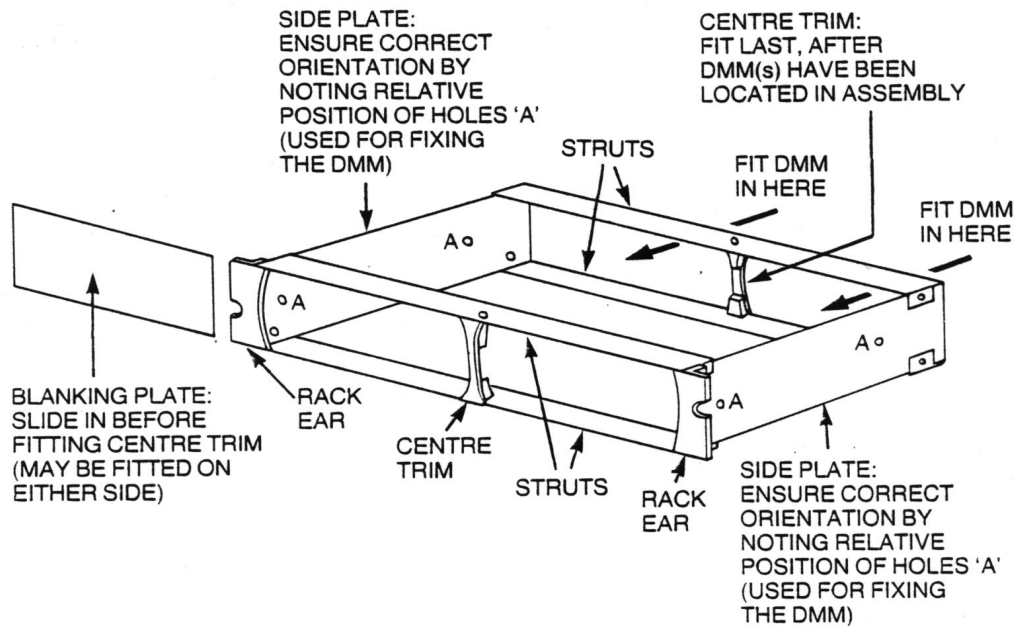
6.2 ASSEMBLY INSTRUCTIONS

Before attempting to assemble the rack mounting kit, or prepare the instrument for rack mounting, first identify the parts of the kit.

- 4 struts
- 2 sided plates
- 2 centre trims
- 2 rack ears
- 8 M4 × 8mm screws (for fitting struts and rack ears)
- 4 M3 × 10mm screws (for fitting the centre trims)
- 4 M4 × 16mm screws (for fitting the DMM's)
- 1 blanking plate
- 8 captive nuts (4 to be fitted into each DMM)

6.2.1 Assembling the Rack Mounting Kit

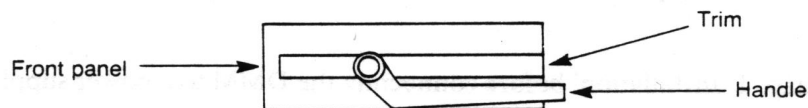
1. Fit the two rear struts to the side plates, using the M4 × 8mm screws. Ensure that the struts are fitted to the 'rear' end of the side plates. The correct orientation of the side plates is given by the relative positions of the holes marked 'A' in the assembly diagram below.



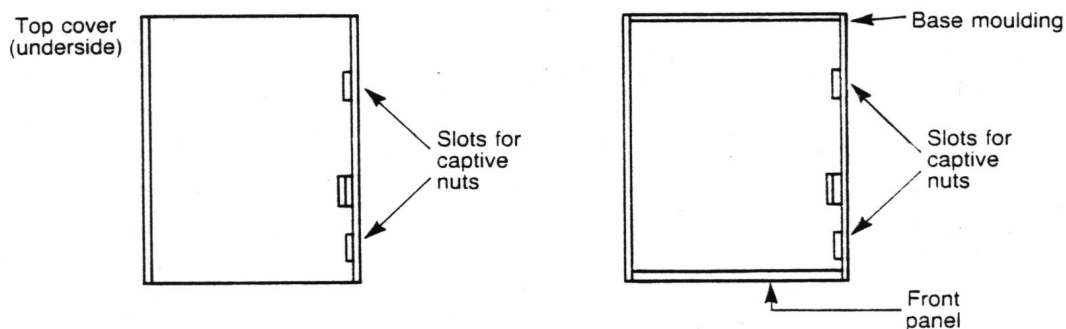
2. Fit the two front struts and two rack ears to the side plates using the same (M4) screws.
3. If only one DMM is to be fitted, locate the blanking plate into the appropriate position (left or right side) by sliding the plate into the inner recess in the rack ear.
4. Next, take a centre trim and butt it against the other edge of the blanking plate, then fix the centre trim to the front struts using the M3 screws. This will lock the blanking plate in position.
5. If two DMMs are to be fitted, fit the centre trim to the front struts using the M3 screws. (Do not fit the blanking plate).

6.2.2 Preparing the DMM for Rack Mounting

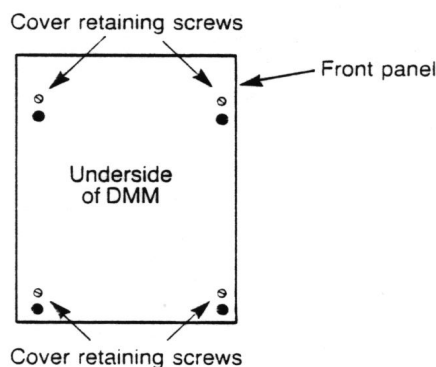
1. Raise the carrying handle shown in the diagram below to the vertical position then gently pull the handle away from the case at the pivot points. Detach the handle.
2. Peel off the trim on both sides of the DMM.



3. Remove the 4 rubber feet from the underside of the DMM, by carefully prizing out with a small screwdriver.



4. Remove the four plastic caps and cover retaining screws on the underside of the DMM and carefully lift off the top cover.



5. Fit captive nuts in the four slots indicated in the diagram below; two in the top cover and two in the base moulding.
6. Refit top cover and replace the cover retaining screws.
7. Slide (each) DMM into the finished assembly from the rear as indicated on the assembled rack diagram. The front moulding of the DMM will then butt against the front centre trim and rack ear such that it protrudes from the front of the assembly by approx. 6mm.
8. Fix the DMM to the adjacent side plate using two of the M4 × 16mm screws. Pass the screws through the holes in the side plate marked 'A' on the diagram and screw into the captive nuts within the DMM. Use only the screws provided, or ensure that screws do not exceed 16mm in length. (Longer screws may damage the DMM).
9. Fit the centre trim to the rear struts, using the M3 screws as shown in the kit assembly diagram.
10. Fit the complete assembly into a standard 19" rack. Ensure that adequate ventilation is provided.
11. See Part 1, Chap. 1 'Installation' before connecting the DMM to a power supply.

Chapter 7

Specification

Specification

Accuracy

The following applies to the Accuracy sections.

Limits of error:

Applicable after 2 hours warm up. DC and resistance measurement with null in use. The accuracy specification gives the uncertainty in measurement for the stated time and temperature range and is expressed in two parts – as a fraction of the reading, (in percentage), plus a number of counts in the least significant digit displayed. Drift will significantly reduce with increasing age of the instrument.

Temperature coefficient

Expressed as \pm [% reading + counts] / °C. Valid from 0 to 40°C. Temperature coefficient need only be applied outside the temperature span quoted with T_e .

Calibration temperature

Calibration Temperature (T_e) is the temperature of the calibration room environment. Calibration occurs at 20°C (23°C for USA) and is directly traceable to International Standards via the National Physical Laboratory or the National Bureau of Standards. Recalibration is valid at T_e from 15°C to 30°C. A 3 hour warm up time is recommended before attempting recalibration

DC Voltage

Accuracy: \pm [% rdg + counts]. 5½ digits.

Nominal Range	Sensitivity		Input Resistance	Stability $T_e \pm 1^\circ\text{C}$ 24 hrs	Limits of Error $T_e \pm 5^\circ\text{C}$	
	6½D	5½D			90 Day	1 Year
0.2V	100nV*	1µV	>10GΩ	0.002 + 3	0.006 + 4	0.008 + 4
2.0V	1µV	10µV	>10GΩ	0.002 + 3	0.005 + 4	0.006 + 4
20V	10µV	100µV	10MΩ	0.002 + 3	0.006 + 4	0.008 + 4
200V	100µV	1mV	10MΩ	0.002 + 3	0.006 + 4	0.008 + 4
1000V	1mV	10mV	10MΩ	0.002 + 3	0.006 + 4	0.008 + 4

For 6½ digits add 3 to counts error + 1µV.

3½ digit accuracy add 1 to counts error. 4½ digit accuracy divide counts error by 2.

*Over the bus only.

Readings per Second

Digits	Full Scale	Integration	Track rdg/s
3½	2300	6.67ms	25
4½	23000	40ms	13
4½	23000	50ms	12
4½	23000	100ms	7
5½	230000	400ms	1
6½	2300000	6.4s	1

Linearity: <0.001% of range

Input current: <150pA

Range of null: $> \pm 1\text{mV}$

Temperature coefficient: <0.001% rdg/°C + 0.2 µV/°C

Overload protection:

Autorange: 1.2kV peak

Fixed ranges: 0.2, 2V 750V rms

20, 200, 1000V 1.2kV peak

Resistance

Accuracy: \pm [% rdg + counts]. 5½ digits.

Nominal Range	Sensitivity		Measuring Current	Stability $T_e \pm 1^\circ\text{C}$ 24 hrs	Limits of Error $T_e \pm 5^\circ\text{C}$	
	6½D	5½D			90 Day	1 Year
2.0kΩ	1mΩ	10mΩ	100µA	0.002+4	0.015+5	0.02+5
20kΩ	10mΩ	100mΩ	100µA	0.002+3	0.015+4	0.02+4
200kΩ	100mΩ	1 Ω	10µA	0.003+3	0.025+4	0.03+4
2.0MΩ	1Ω	10 Ω	1µA	0.005+3	0.025+4	0.03+4
20MΩ	10Ω	100 Ω	100nA	0.03 +20	0.045+20	0.05+20

For 6½ digits: add 3 to counts error + 5mΩ. 3½ digit accuracy add 1 to counts error.

4½ digit accuracy divide counts error by 2.

Measurement configuration:

4-wire, or 2-wire auto-sense.

Readings per second

As for dc voltage.

Temperature

coefficient: <0.004% rdg/°C + 2mΩ/°C
20MΩ range <0.006% rdg/°C

Linearity: <0.001% of range

Maximum overload protection: 350V peak, 250V rms

Maximum open terminal voltage: <7V

Range of null: $> \pm 10\Omega$

Temperature

Using 100Ω Platinum Resistance Thermometer linearised to IEC751.

Temperature range:

-200°C to +600°C

Max Resolution: 0.01°C or °F

Conformance to IEC751: 0.1°C

Measurement current: 100µA

Resistance at 0°C: 100 ohms

Specification

AC Voltage True rms of ac component.

Accuracy: \pm [% rdg + counts]*. 5½ digits. For inputs above 10% of range.

Stability: 24 hours, $T_0 \pm 1^\circ\text{C}$

Range	40Hz-10kHz	10kHz-30kHz	30kHz-50kHz	50kHz-100kHz
0.2V	0.03 + 15	0.05 + 40	0.25 + 80	0.4 + 200
2.0V	0.03 + 15	0.05 + 40	0.25 + 80	0.4 + 200
20V	0.04 + 15	0.05 + 40	0.25 + 80	0.4 + 200
200V	0.04 + 15	0.05 + 40	0.25 + 80	0.4 + 200
1000V	0.05 + 15	0.06 + 40	0.25 + 80	0.4 + 200

Limits of error:

90 Day, $T_0 \pm 5^\circ\text{C}$

Range	40Hz-10kHz	10kHz-30kHz	30kHz-50kHz	50kHz-100kHz
0.2V	0.07 + 15	0.08 + 40	0.3 + 80	0.45 + 200
2.0V	0.06 + 15	0.08 + 40	0.3 + 80	0.45 + 200
20V	0.07 + 15	0.08 + 40	0.3 + 80	0.45 + 200
200V	0.07 + 15	0.08 + 40	0.3 + 80	0.45 + 200
1000V	0.08 + 15	0.09 + 40	0.3 + 80	0.45 + 200

1 Year, $T_0 \pm 5^\circ\text{C}$

Range	40Hz-10kHz	10kHz-30kHz	30kHz-50kHz	50kHz-100kHz
0.2V	0.09 + 40	0.35 + 80	0.5 + 200	0.8 + 200
2.0V	0.09 + 40	0.35 + 80	0.5 + 200	0.8 + 200
20V	0.09 + 40	0.35 + 80	0.5 + 200	0.8 + 200
200V	0.09 + 40	0.35 + 80	0.5 + 200	0.8 + 200
1000V	0.1 + 40	0.35 + 80	0.5 + 200	0.8 + 200

Temperature coefficient

< 0.008 rdg/ $^\circ\text{C}$ up to 20kHz

Input impedance 1M Ω , 100pf

Crest factor 10:1 add 1% of rdg

Peak input < 5 times full scale or 1.2 kV

Sensitivity Full scale (230000) 5½ digits:
1 μV on 0.2 range

Decreases by a factor of 10 for each successive range to 1000V.

Readings per second: As for dc voltage except 5½ digit rdg is 0.8/second

Maximum ratings

Autorange: $< 1\text{kHz}$ 750V rms or 1.2kV peak
 $> 1\text{kHz}$ 200V rms

Fixed range:

0.2, 2V $< 1\text{kHz}$ 500V rms
 $> 1\text{kHz}$ 120V rms
20, 200, 1000V $< 30\text{kHz}$ 750V rms or 1.2kV peak
 $> 30\text{kHz}$ 2×10^7 VHz

DC content: 400V max

counts figure by 10 to 10% of range.

DC Current

Accuracy: \pm [% rdg + counts]. 5½ digits.

Nominal Range	Sensitivity 6½D	Sensitivity 5½D	Stability 24hrs, $T_0 \pm 1^\circ\text{C}$	Limits of Error 1yr, $T_0 \pm 5^\circ\text{C}$
2000mA	1 μA	10 μA	0.02 + 5	0.04 + 5

For 6½ digits add 10 to counts error. 3½ and 4½ digits as above.

Full scale: 2300.000mA

Shunt resistor: 100 millionm

Temperature coefficient: $< 0.005\%$ rdg/ $^\circ\text{C}$

Burden: $< 0.8\text{V}$

Overload protection: 2A fuse

Range of null: $> \pm 1\text{mA}$

Readings per Second: As dc voltage

AC Current True rms of ac component

Accuracy: \pm [% rdg + counts]. 5½ digits, 40Hz to 10kHz. For inputs above 1% of range.

Nominal Range	Input Sensitivity	Stability 24hrs, $T_0 \pm 1^\circ\text{C}$	Limits of Error 1yr, $T_0 \pm 5^\circ\text{C}$
2000mA	10 μA	0.05 + 50	0.2 + 50

For 3½ and 4½ digits: divide count error by 10. Above 1kHz add 0.1% rdg.

Full scale: 2300.00mA

Readings per second: As ac voltage

Temperature coefficient: $< 0.01\%$ rdg/ $^\circ\text{C}$

Burden: $< 0.8\text{V}$

Overload protection: 2A fuse

Interference Rejection

Normal mode rejection ratio

DC measurements, 6½ to 4½ digits
Power Frequency
50/60/400Hz $\pm 0.1\%$ $> 60\text{dB}$

Effective common mode rejection ratio

With 100 Ω imbalance in either lead

DC measurement, 6½ to 4½ digits
Rejection of 50/60Hz: $> 140\text{dB}$
400Hz: $> 120\text{dB}$
dc: $> 150\text{dB}$

AC measurement, 5½ to 4½ digits
Rejection of 50/60Hz: $> 60\text{dB}$
dc: $> 150\text{dB}$

Maximum Common Mode Voltage: 500V dc or peak

Extended frequency Low frequency

Frequency	\pm [% rdg + counts]
3-5Hz	10.0
5-10Hz	8.0
10-20Hz	0.95
20-40Hz	0.3

High frequency

Frequency	\pm [% rdg + counts]
100-200kHz	5 +
(0.2V to 200V)	
200-500kHz	10 +
(0.2V to 20V)	
500kHz-1MHz	15 +
(2V only)	

* For 3½ and 4½ digits divide double counts figure for 1% typical figures.

Specification

Systems Use

Interface, provided as standard IEEE488 (1978)

Provides full talker/listener, talk only and listen only facilities and remote control of all functions. Serial and parallel poll.

Subset: SH1, AH1, T5, TE0, L3, LE0, SR1, RL1, DC1, CO, DT1, E1, and parallel poll.

Additional inputs and outputs:

- External trigger input: TTL level or contact closure
- Sample complete output: TTL pulse – active low
- Display hold: Contact closure

General Data

Power Supply

Voltage: Switch selected 100/120/220/240Vac
92 to 127V or 188 to 265V
Frequency: nominal 50/60/400Hz
Consumption: <25VA

Protection

Power Supply: fused line and neutral
Current Measurement: fused 2A
Voltage Measurement: spark gap at 1.4kV

Safety

Designed in accordance with IEC348, BS4743, and UL 1244.

Environment

Design & construction to Def Std. 66-31 Issue 1 Cat 111 and MIL-T-28800 Type III Class 5 Style E.
Operating Temperature: –5° to 55°C, RH < 30%
0° to 40°C, RH < 93%*
Storage Temperature: –40°C to +70°C

Allow a suitable recovery, warm-up and thermal stabilization period after storage or high humidity conditions.

*90% RH for 2M Ω and 20M Ω

Dimensions

Height: 88mm (3.46ins)
Width: 228mm (8.98ins)
Depth: 278mm (10.94ins)
Weight: 3kg (6.6lbs)

Optional Accessories

Temperature probes:

Four Terminal 100 Ω platinum resistance sensor to I.E.C. 751.

Insertion probe: (71517A)

Temperature range: –50 to 250°C
Error (Class A): < 0.7°C

Surface probe: (71517B)

Temperature range: –50 to 200°C
Error (Class B): < 1.5°C

Radio Frequency probe (70457F)

Peak-sensing, the probe provides 1V dc output for 1v rms sine wave input when terminated into 10 M Ω . Complete with fittings and adaptors.

Limits of Error: 1V rms sine wave
100kHz to 500MHz: \pm 1dB
100kHz to 750MHz: \pm 3dB
Voltage Range: 100mV to 40V
DC Isolation: 200V
Working Temperature: –5 to +55°C
Lead Length: 1m

High voltage probe (70457E)

Extends measurement of dc voltage to 40kV. Complete with fittings and adaptors. Input resistance 1000 M Ω , when terminated into 10 M Ω .

Voltage Range: 1kV to 40kV
Division Ratio at 20kV, 23°C: (1000:1) \pm 0.5%
Limits of Error 1kV to 40kV, 23°C: \pm 3%
Temperature Coefficient: <200ppm/°C
Working Temperature: –5 to +55°C
Lead Length: 1.8m

Current shunt, 10A (70457X)

Extends the current measuring capacity to 10A. Simple plug-in unit.

Shunt Value: 1 mV/A (1 m Ω)
Accuracy: \pm 0.9% fs
Range: 1 to 10A
Temperature Coefficient: \pm 250ppm/°C
Maximum Voltage Burden: 100mV at 10A
Absolute Max. Current: 12A

NATO connection set (71517C)

Two input leads with interchangeable alligator clips, spades, hooks and probes. NATO Stock No. 6625-99-744-2794.

Rack mounting kit (71501)

The 71501plus is a 1/2-rack width unit. Using the 71501 allows one or two DMMs to be mounted in one 19 inch width.

NOTE: 7150 SERIES MULTIMETERS

The 7150plus is one of a series of digital multimeters, the variants being identified by the addition of a suffix (eg "plus") following the product number.

Unless otherwise stated, the program examples given in Part 2 of this manual apply to all 7150 series multimeters, thus in the examples, no suffixes are shown.

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1.8.5 Service Request (SRQ)

A service request is generated from a device to the controller and it requests the controller to interrupt the controller's present task and attend to the requirements of the device. The device continues to assert the SRQ line until its requirements are serviced by the controller.

For example, if the controller sends the Q1 instruction to the DMM, the DMM generates an SRQ when it is ready to send a measurement or when an error occurs on the DMM. The controller responds to the SRQ by performing a serial poll on the DMM.

1.8.6 Device Clear (DCL and SDC)

By sending the Device Clear (DCL) command, all devices connected to the bus are set to their initialised or power-up 'default' state.

To set any one particular device to the initialised or power-up state, the Selective Device Clear (SDC) command is sent accompanied by the device listen address. All other devices remain as previously set.

The power-up state to which the DMM is set when sent a DCL or SDC command is defined in Chapter 2.

Note the difference between Device Clear and Interface Clear commands. A Device Clear command resets only the interface of a device, it does not reset the operating status of the device, e.g. on the DMM the function and range of operation would remain unchanged.

Some controllers, such as the PET 4032 or 8032, are unable to send the DCL or SDC commands and provision has been made within the DMM for such an eventuality. The DMM Instruction Set includes an 'A' command which sets all DMM parameters to the power-up state. The A command is device dependent and can be sent to the DMM whether or not the controller has the DCL/SDC capability. The 'A' command is a device clear command which operates only on the DMM addressed. A period of about two seconds should be left after sending an A command, further commands can be sent after the delay.

1.8.7 Local Lockout

Some GP-IB devices have a LOCAL key fitted on the front panel. For example, the 7150plus has a LOCAL key which can be pressed while the instrument is under remote control to regain local control, i.e. front panel control. The Local Lockout (LLO) command is used to protect a device against inadvertent or unauthorised front panel operation.

When Local Lockout is asserted, all LOCAL keys fitted to devices on the bus are made inoperative and local control cannot be obtained from the device front panel.

Note that the action of the Local Lockout command should not be confused with the action of the Remote Enable (REN) command. With respect to the DMM, the Local Lockout command disables only the operation of the single LOCAL key.

The various states of Local/Remote operation, obtained by using the Remote Control and Local Lockout commands in conjunction with the LOCAL key, are shown in Fig. 1.4.

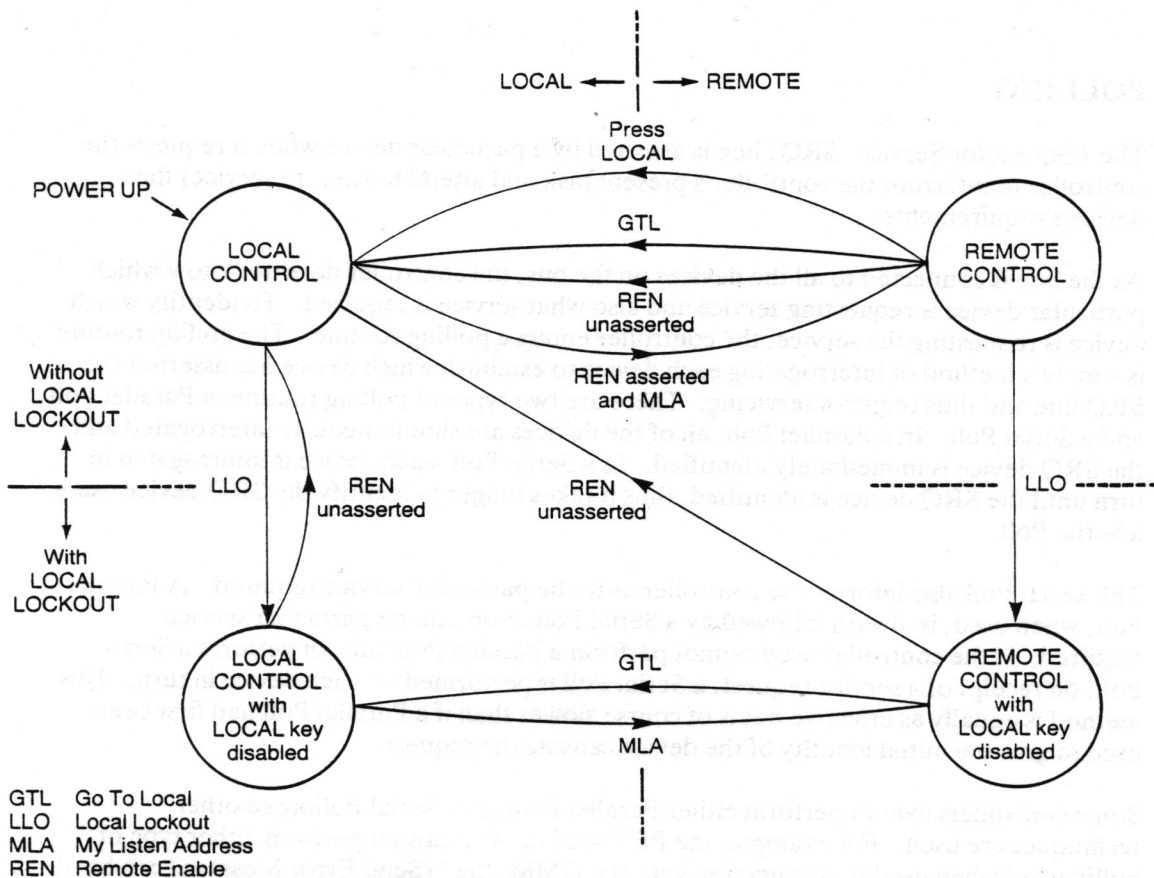


Fig. 1.4 Local/Remote Status Transfer Diagram

This diagram shows that, at power up, the device is in LOCAL CONTROL. To place the device in REMOTE CONTROL, the controller must assert the REN (Remote Enable) line and send MLA (My Listen Address) for the device. To cause the device to return from REMOTE to LOCAL control, any one of the following three actions can be used:

- Press the LOCAL key on the device front panel.
- Use the controller to send GTL (Go To Local) command.
- Use the controller to unassert the REN (Remote Enable) line.

In either LOCAL or REMOTE CONTROL, the LOCAL key can be disabled by sending the LLO (Local Lockout) command to the device.

When controlling a DMM via the GP-IB it is possible for the LOCAL key to be enabled/disabled in one of two ways by

- using the standard GP-IB commands.
To disable LOCAL key send LLO.
To enable LOCAL key unassert the REN line.
- using the K0 and K1 commands from the 7150plus Instruction Set.
To disable LOCAL key send K1.
To enable LOCAL key send K0.

The K0 and K1 commands are intended primarily for use with controllers which do not have a Local Lockout capability (such as the PET 4032 or 8032).

The standard GP-IB command LLO places all devices on the Bus in the Local Lockout state, whereas the DMM (device dependent) commands K0 and K1 enable/disable the LOCAL key only on the particular DMM addressed.

1.9 POLLING

The Request for Service (SRQ) line is asserted by a particular device when it requests the controller to interrupt the controller's present task and attend to (i.e. to service) the device's requirements.

As the line is connected to all the devices on the bus, the controller does not know which particular device is requesting service and also what service is required. To identify which device is requesting the service, the controller enters a polling routine. The polling routine is simply a method of interrogating each device to establish which device has asserted the SRQ line and thus requires servicing. There are two types of polling routine, a Parallel Poll and a Serial Poll. In a Parallel Poll, all of the devices are simultaneously interrogated and the SRQ device is immediately identified. In a Serial Poll, each device is interrogated in turn until the SRQ device is identified, thus it takes longer to identify the SRQ device using a Serial Poll.

The Serial Poll also informs the controller as to the particular service required. A Parallel Poll, when used, is always followed by a Serial Poll to obtain the particular service required. If the controller used cannot perform a Parallel Poll but can perform a Serial Poll, on receipt of a service request, a Serial Poll is performed on each device in turn. This method is equally as effective but is of course slower than if a Parallel Poll had first been used to give the initial identity of the device causing the request.

Some controllers cannot perform either Parallel Polling or Serial Polling so other techniques are used. For example, the PET 4032 or 8032 cannot perform either type of polling and when used in conjunction with the DMM, the ! (Send Error Message) can be sent to the DMM. The ! command will cause the DMM to output an error message which may be examined to ascertain if an error has occurred. If no error has occurred the message Error 00 is produced. During a long program, the ! command could be sent periodically to detect any error which may have occurred.

1.9.1 Parallel Polling

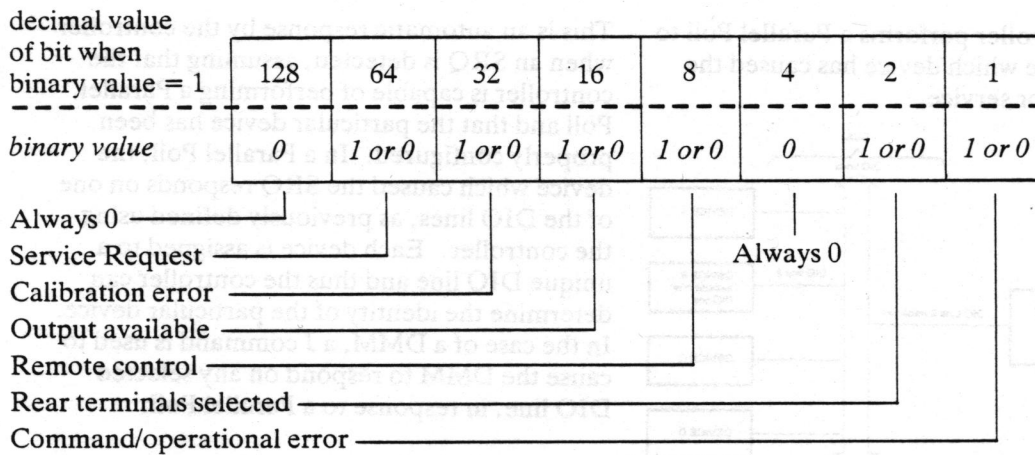
A parallel poll is configured by the controller assigning a DIO line to each device as a reply line for the device when it is interrogated by the controller during a parallel poll.

Each of the eight DIO lines, DIO1 to DIO8 is assigned to a particular device such that when a Parallel Poll command is issued by the controller, the appropriate device (e.g. Device No. 1) replies only on DIO1, Device No. 2 on DIO2, etc.

By this arrangement it is possible to interrogate up to eight separate devices in parallel and immediately establish which device is requesting service. If more than eight devices on the bus can generate a SRQ, it is possible to assign one DIO line to two or more devices.

1.9.2 Serial Polling

Every device capable of generating a SRQ contains a status register which holds information on the current operating status of the device. A device status register is examined by the controller during a Serial Poll to establish that the particular device is requesting service and also to determine the service required. The status register on the 7150plus contains eight bits which are termed the Serial Poll byte. Fig. 1.5 shows how the register is organised.



Each of the above conditions is true when the bit in question = 1,
and false when the bit in question = 0.

Fig. 1.5 DMM Serial Poll Byte

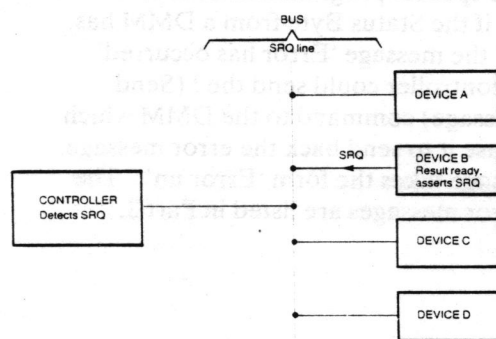
If the controller conducts a Serial Poll, the DMM responds by outputting a Serial Poll status byte into the data lines.

The controller reads the binary status byte (above) and computes its decimal representation from the relevant bit values. From this, it can deduce the status of the DMM by means of a suitable program. For example, if the decimal value of the byte is 80, SRQ was generated because an output was available (i.e. $16 + 64 = 80$).

1.9.3 Simplified Description of System Polling

A simplified description of system operation following a request for service is given below and shown in the accompanying diagrams.

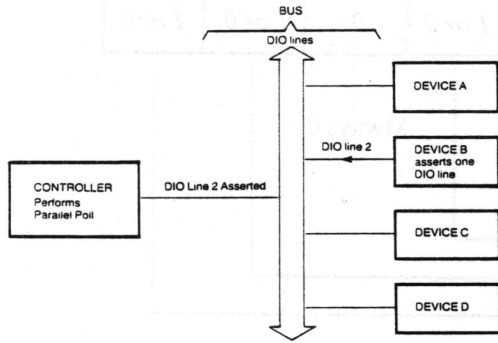
The device needing service asserts the SRQ line.



This is an automatic response by the device but some prior configuration of the device is necessary. As an example, for a DMM the SRQ can be generated on error (Q0), or on error and when a measurement is ready (Q1). This configuration is achieved by sending the appropriate command to the device prior to running the program or at the beginning of the program.

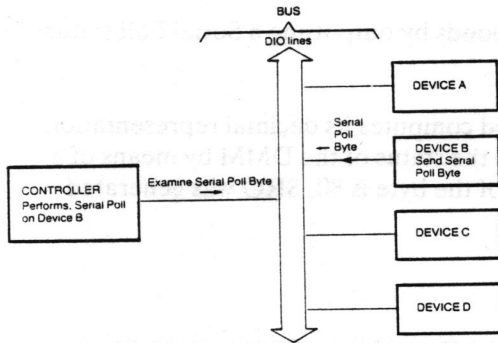
When the controller detects the SRQ it interrupts its present task.

The controller performs a Parallel Poll to determine which device has caused the request for service.



This is an automatic response by the controller when an SRQ is detected, assuming that the controller is capable of performing a Parallel Poll and that the particular device has been properly configured. In a Parallel Poll, the device which caused the SRQ responds, one of the DIO lines, as previously defined using the controller. Each device is assigned to a unique DIO line and thus the controller can determine the identity of the particular device. In the case of a DMM, a J command is used to cause the DMM to respond on any selected DIO line, in response to a Parallel Poll.

The controller performs a Serial Poll to determine the cause of the service request.



This is an automatic response by the controller providing that it is capable of performing a Serial Poll and that it has been programmed accordingly. In a Serial Poll, the controller requests the particular device to send a Status Byte held in the device Status Register. This byte contains information on the current operating status of the device and informs the controller of the service required by the device. The Status Byte from the 7150plus provides the following information, refer to Fig. 1.5.

- ★ The DMM is requesting service (SRQ)
- ★ Calibration error
- ★ Output available
- ★ Remote/Local status
- ★ Rear terminals selected
- ★ Error has occurred.

The controller can then use this information to take some specific programmed action. For example, if the Status Byte from a DMM has conveyed the message 'Error has occurred' then the controller could send the ! (Send Error Message) command to the DMM which would cause it to send back the error message. This message takes the form 'Error nn'. The DMM error messages are listed in Part 2, Chap. 2.

Table 1.2 GP-IB Commands on DIO Lines

DIO Lines	8	7	6	5	4	3	2	1										
									0	0	0	0	0	0	0	0	0	0
									0	0	0	0	1	1	1	1	1	1
									0	0	1	1	0	0	1	1	1	1
									0	1	0	1	0	1	0	1	0	1
									0	0	0	0	0	16	0	16		
									0	0	0	1	17	1	17			
									0	0	1	0	18	2	18			
									0	0	1	1	19	3	19			
									0	1	0	0	20	4	20			
									0	1	0	1	21	5	21			
									0	1	1	0	22	6	22			
									0	1	1	1	23	7	23			
									1	0	0	0	24	8	24			
									1	0	0	1	25	9	25			
									1	0	1	0	26	10	26			
									1	0	1	1	27	11	27			
									1	1	0	0	28	12	28			
									1	1	0	1	29	13	29			
									1	1	1	0	30	14	30			
									1	1	1	1	UNL	15	UNT			

Addressed Command Group (ACG)	Universal Command Group (UCG)	Listen Address Group (LAG)	Talk Address Group (TAG)
-------------------------------------	-------------------------------------	-------------------------------------	-----------------------------------

The above command groups and addresses are part of the Primary Command Group (PCG).

Table 1.3 ASCII Coding on DIO Lines

		0	0	0	0	0	0	0	0
		0	0	0	0	1	1	1	1
		0	0	1	1	0	0	1	1
		0	1	0	1	0	1	0	1
DIO Lines	8 7 6 5 4 3 2 1								
		0 0 0 0	NUL	DLE	SP	O	@	P	p
		0 0 0 1	SOH	DC1	!	1	A	Q	a q
		0 0 1 0	STX	DC2	"	2	B	R	b r
		0 0 1 1	ETX	DC3	#	3	C	S	c s
		0 1 0 0	EOT	DC4	\$	4	D	T	d t
		0 1 0 1	ENQ	NAK	%	5	E	U	e u
		0 1 1 0	ACK	SYN	&	6	F	V	f v
		0 1 1 1	BEL	ETB	'	7	G	W	g w
		1 0 0 0	BS	CAN	(	8	H	X	h x
		1 0 0 1	HT	EM	)	9	I	Y	i y
		1 0 1 0	LF	SUB	*	:	J	Z	j z
		1 0 1 1	VT	ESC	+	;	K	[	k {
		1 1 0 0	FF	FS	,	<	L		l |
		1 1 0 1	CR	GS	-	=	M	]	m }
		1 1 1 0	SO	RS	.	>	N	↑	n ~
		1 1 1 1	SI	US	/	?	O	—	o DEL

1.10.3 Initiating a Parallel Poll

Before a parallel poll command can be initiated, a DIO response line must first be allocated to each device on the bus. Response lines are allocated by using the DMM J command.

The command for a parallel poll is given by simultaneously energising ATN (Attention) and EOI (End or Identify) lines. The instrument requesting service will reply by energising one of the data lines (DIO 1–8), only one line being applicable to an instrument.

1.10.4 Initiating a Serial Poll

To initiate a serial poll, a controller sends a Serial Poll Enable (SPE) command by means of a coded message on the data lines (DIO–8). This command sets all talkers to a serial poll idle state. The talk address for a particular device is then sent. If the particular device addressed has previously sent a SRQ (Service Request) then RQS (Request Service) is enabled by energising DIO 7 of the data lines when ATN is released.

The state of the other data lines is immaterial to RQS and information regarding the condition of the interface can be sent as a Status Word on the other data lines.

To exit the Serial Poll State, Serial Poll Disable (SPD) is sent on the data lines together with ATN and bus messages may then be resumed.

When the DMM is serial polled, it de-energises its SRQ output. But, because SRQ is a wired OR function, the controller may still receive a SRQ call due to a service request by another instrument.

All listeners should be given the command UNL (Unlisten) before SPE (Serial Poll Enable).

1.10.5 Data Output

Measuring devices put results onto the bus for transmission to recorders, or perhaps to the controller where the results may be processed before transmission to a recorder. In this sense the recorder might be a system terminal such as a VDU.

When a voltmeter has made a measurement it has to tell the controller that the data is ready for transmission. It may do this by sending SRQ (Service Request) which is its way of saying, "Task finished, what next?" If there are several devices, the controller has no means of immediately knowing which has sent SRQ; hence the controller conducts a poll to establish which device has requested service. With simple systems a poll will not be necessary.

Previously assigned active talkers and listeners are disabled by the controller sending UNL (Unlisten) followed by the new listen address (recorder) and the new talk address (voltmeter). The voltmeter knows what it is measuring (e.g. Vdc) so this can be used as a header to the measured value.

1.10.6 Example of Data Transfer

To illustrate the use of the bus, a typical sequence of events leading to the transfer of information between a talker and listener is described. It is assumed that a controller is in command of the system.

The sequence of messages can be commenced by the IFC (Interface Clear) command which sets all interfaces to their initial condition. This command is also used to reset the system when the system ceases to run normally, e.g. system crash.

Following this, the ATN (Attention) command is made by signifying that there is address or command information available on the 8 data lines; this transfer of information is controlled by means of the handshake routine. The information transferred during the interval defined by ATN will set up the message route; the initial information will give the addresses of listener devices followed by the address of the talker devices (a preferred, but not obligatory, order).

On release of the ATN command (viz ATN) the talker may then place data on the data lines (DIO 1 to DIO 8). This data transfer is controlled by the handshake routine and is received by all addressed listeners. The last data byte may be accompanied by a delimiter/terminator to indicate the end of a message.

Before commencing another message sequence, the controller may switch all listeners off by the command Unlisten (UNL) and switch the talker off by the command Untalk (UNT) which will be issued in conjunction with ATN (Attention). The commands UNL and UNT are coded commands appearing on data lines (DIO 1-8).

Should a controller wish to interrupt during a message sequence it does so by energising ATN; the talker then enters a wait state. In order to avoid losing information ATN should be asserted synchronously with the handshake routine; when NRFD is energised NDAC is released.

EXAMPLE

A Talker 'P' is instructed to send a message, 1 2 3, to listener 'Q'.

	Management Lines	Data Lines
Controller sends	ATN ATN	Listen address of Q Talk address of P
P sends	— — EOI	1 2 3
Controller sends	ATN ATN	UNL UNT

Listener Q receives only messages 1 2 3.

1.10.7 Controlling an Instrument from the Bus

During manual use an operator makes decisions as to what the instrument must do and then makes selections via the front panel controls. Under remote control the same decision must be fed into the instrument as a message string from the bus.

Although the GP-IB standard defines the protocol and procedures for transferring data strings and interface commands from one device to another on the bus, it does not define the interpretation of the strings. The interpretation is dependent upon the type of device. Obviously the commands given to a voltmeter and to a frequency response analyser will be different. On the DMM each commanded function (e.g. Range) is given a letter (e.g. R), while sub-divisions of a function are given numbers (e.g. R3 for Range 3).

As an example the following table shows some of the command characters for a typical digital voltmeter.

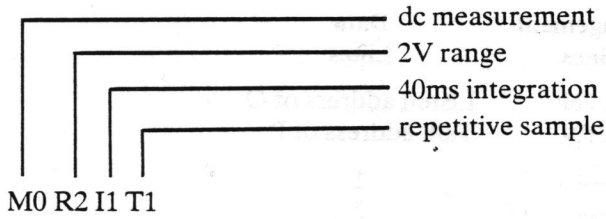
Title	Control function	Sub-division of function	
		Command Character	Title
Measurement type	M	0	Vdc
		1	Vac
		2	Ω
Range	R	0	autorange
		1	0.2V
		2	2V
Integration period	I	0	6.66ms
		1	40.0ms
		2	50.0ms
Send Service Request upon completion of each measurement	Q	0	no
		1	yes
Sample (Trigger)	T	0	single
		1	repetitive

Chapter 1

The GP-IB

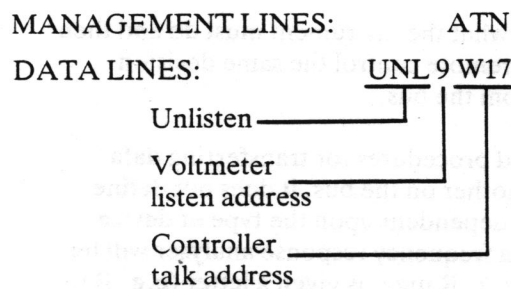
<i>Para</i>	<i>Title</i>	<i>Page</i>
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Thus a control setting for the voltmeter might be:

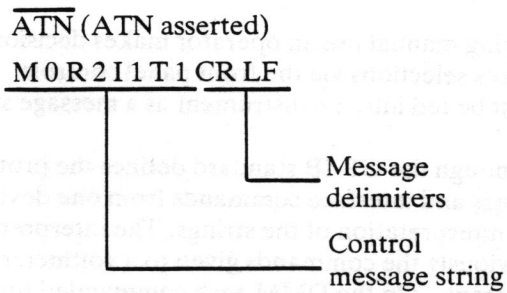


Prior to the control string, the voltmeter and its interface must be put in a state to receive the control message. Frequently this will commence by Unlisten to ensure that no other device will receive the control message should one have been left in the listen state. This is followed by the voltmeter's listen address and the controller's talk address.

Interface addressed to listen



Interface made transparent to message



All devices designed for operation on the GP-IB can be set-up in this way. Power supplies, oscillators, counters have codes for the parameters that are peculiar to their function. This is why it is essential to consult the operating manual for each device before attempting to use it on the bus.

1.1 INTRODUCTION

The 7150plus Digital Multimeter has a built-in GP-IB Interface which complies with the IEEE 488 1978 Interface Standard. GP-IB is an abbreviation for General Purpose Interface Bus which is the name used by Solartron for the IEEE 488 Standard.

The standard defines mechanical, electrical, timing and data parameters. All devices and instrumentation which comply with the standard, regardless of manufacturer, are compatible with and can be connected to the GP-IB.

All DMM facilities can be accessed and controlled remotely via the GP-IB using a suitable controller.

Part 2 of the manual contains general information about GP-IB (Chapter 1), specific 7150plus GP-IB information (Chapter 2), example programs for four particular controllers (Chapters 3 to 6) and a procedure for calibrating the DMM via its GP-IB interface (Chapter 7). The controllers used in the example programs are the:

Hewlett-Packard HP9825
Hewlett-Packard 85
Commodore Pet 4032 and 8032
Apple II

The user will require the Operating/Programming Manual(s) for the particular controller to obtain a full understanding of remote control of the DMM:

In addition, the following IEEE publication, which contains a complete description of the Standard, is recommended.

IEEE Standard Digital Interface for Programmable Instrumentation.

1.2 BASIC CONCEPTS

A bus is simply a number of separate wires which run parallel with each other and onto which electrical connections are made.

The GP-IB is a bus, constructed from special cables, whose electrical and mechanical features are standardised and are used to interconnect various devices to form a particular system required by the user. The term "device" is used for convenience and it applies to any instrument (voltmeter, logger etc.) and peripheral unit (printer, VDU etc.) which is capable of being connected to the bus.

The important point to note about the GP-IB is that devices (fitted with GP-IB interface connections) manufactured by different companies can readily be connected together to form a system without requiring special and expensive equipment or expertise.

Most GP-IB systems require a controller to regulate the activities on the bus by giving commands, as and when required, to the various devices on the bus. A low cost microcomputer usually performs the role of the controller.

A typical GP-IB system is shown in Fig. 1.1. The devices and controller in a system can be connected to the bus in any order and they each must contain a GP-IB interface which is either incorporated into the original design of the device (and also the controller) or is a separate unit which is fitted as an optional extra. With 7150plus, the GP-IB interface is incorporated into the design of the multimeter.

The basic tasks performed on the bus by the controller and devices are described as follows.

1.2.1 The Controller

As previously stated, the controller is usually a microcomputer fitted with a GP-IB interface. The controller can be operated "manually" by the operator entering each command string on the keyboard as and when required. This method has very limited use (e.g. test purposes) and in practice, the controller is loaded with an application program specially written for the tasks to be performed by the bus system. Examples of controller programs for operating the DMM are given in Chapters 3 to 6.

The controller has complete control of all the devices on the bus and it can be considered as the "master" and the devices as "slaves".

To implement computer control of the bus, a standard set of GP-IB commands are used. These commands are applicable to most types of controllers but for some controllers alternative methods may be required to perform a standard routine.

In addition to the general GP-IB commands, most devices have a unique instruction set which enables the operating facilities of the device to be remotely controlled from the bus. The GP-IB instruction set for the DMM is given in Part 2, Chapter 2. Programming statements made on the controller consist of GP-IB commands and DMM instructions entered in the controller's programming language.

The IEEE 488 Standard is divided into a number of sub-sets which define particular functions performed on the bus by a device. The sub-sets applicable to a particular device are dependent upon the functions and facilities of that device. The sub-sets implemented within the DMM are listed in Chapter 2 and annotated on the rear panel of the DMM.

1.2.2 Talker and Listener Devices

Devices connected to the bus are generally categorised as either Talkers, Listeners or Talker/Listeners.

- a) A Talker is a device (e.g. tape reader) which puts data onto the bus.
- b) A Listener is a device (e.g. printer) which receives data from the bus.
- c) A Talker/Listener (e.g. controller) device both sends and receives data to and from the bus but not simultaneously.

At any time there can only be one Active talker, including the controller, operating on the bus. However, there can be more than one Active Listener on the bus.

The term 'data' also refers to some types of controller commands received by the device, e.g. commands to select the required function and range of operation on the DMM. Refer to '1.7 Interface Commands and Device Messages' for a more precise description of Talkers and Listeners.

More than one controller can be connected to the bus but only one of them may be the Active Controller. The others must operate as an ordinary Talker/Listener. The Active Controller can, when required, pass control of the bus to a currently Inactive Controller and in doing so makes itself an Inactive Controller.

As most systems use only one controller, the information given in this manual applies only to this type of system.

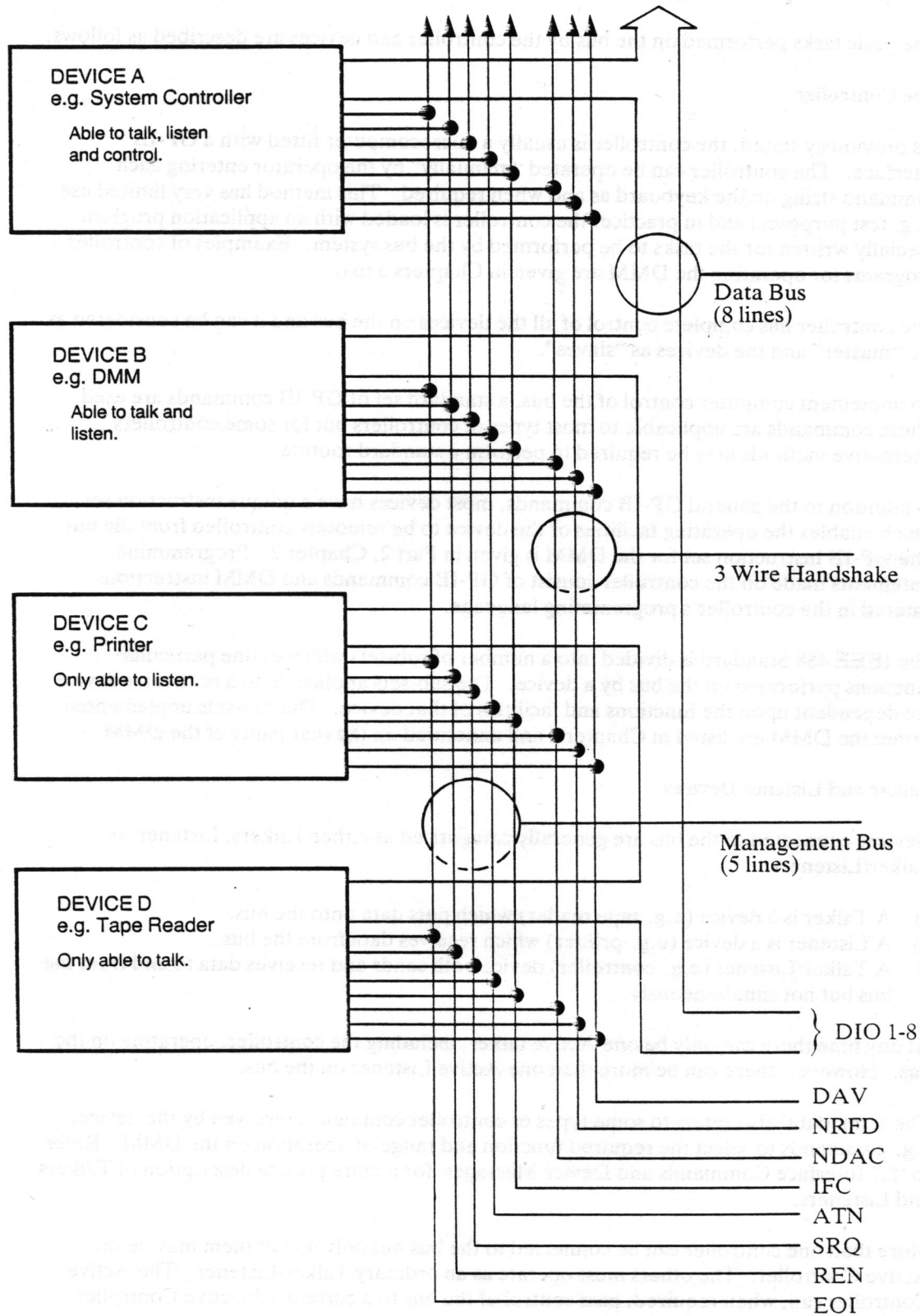


Fig. 1.1 GP-IB Bus Structure with Typical Devices Connected

1.3 BUS CONNECTIONS

The maximum cable length of the GP-IB is 20 metres and up to a maximum of 14 devices plus a controller can be connected to the bus.

A combined plug and socket connector is fitted to each end of the standard cables which form the bus. This type of connector allows a cable end to be plugged into another cable end which in turn can be plugged into a device or another cable end. This cabling facility allows the devices to be easily connected to the bus in either a daisy chain or star connections arrangements, refer to Fig. 1.2 and 1.3.

GP-IB compatible devices are fitted with a standard 24-way connector and also a group of selector switches which determine the bus address and bus mode of operation (e.g. talker) for the device.

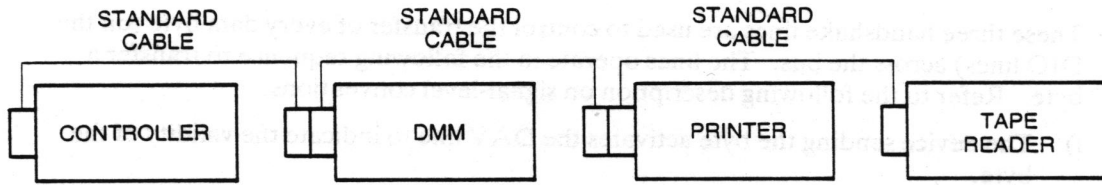


Fig. 1.2 Example of Bus Daisy-chain Connections

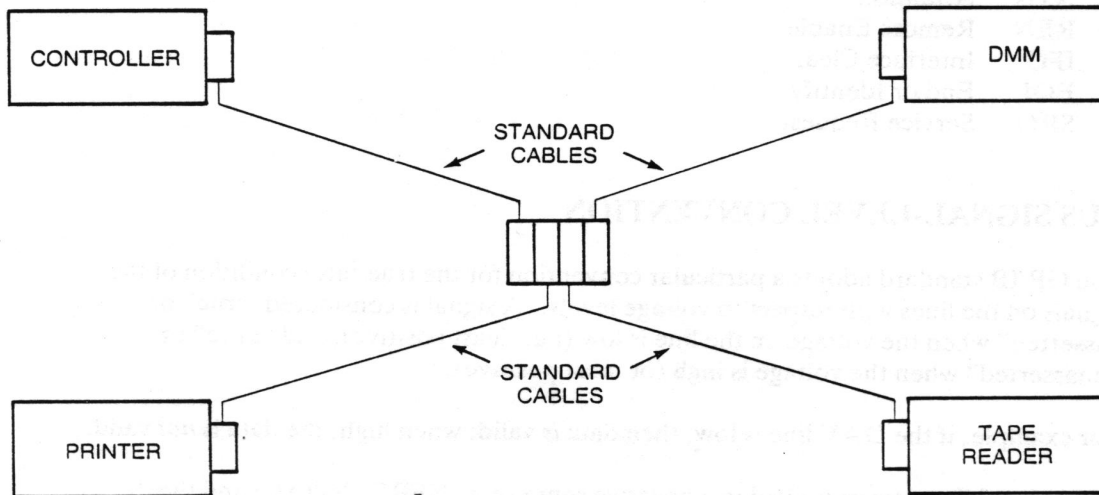


Fig. 1.3 Example of Bus Star Connections

1.4 BUS PARAMETERS

The GP-IB consists of a standard cable format of 24 lines, comprising 16 signal lines and 8 earth returns. The 16 signal lines are functionally grouped as follows, refer to Fig. 1.1.

a) *8 Data Input/Output Lines*

Data is transferred across the bus on these 8 lines in the form of 8-bit bytes, DIO1 is the least significant bit and DIO8 the most significant bit. As data is sent 8-bit (1 byte) at a time and as one byte may follow another in a serial fashion, this arrangement is referred to as a 'bit-parallel byte-serial' system.

b) *3 Handshake Lines*

DAV Data Valid
NDAC Not Data Accepted
NRFD Not Ready for Data

These three handshake lines are used to control the transfer of every data byte (on the DIO lines) across the bus. The lines operate in the following sequence to transfer a byte. Refer to the following description on signal-level conventions.

- i) The device sending the byte activates the DAV line to indicate the validity of the byte.
- ii) The device receiving the byte de-activates the NDAC line to indicate the acceptance of the byte and de-activates the NRFD line to indicate that the device is ready to receive another byte.

c) *5 Management Lines*

These lines are used to manage the bus, and they are described in '1.8 Descriptions of GP-IB Commands'.

ATN Attention
REN Remote Enable
IFC Interface Clear
EOI End or Identify
SRQ Service Request

1.5 BUS SIGNAL-LEVEL CONVENTION

The GP-IB standard adopts a particular convention for the true/false condition of the signals on the lines with respect to voltage levels. A signal is considered "true" or "asserted" when the voltage on the line is low (i.e. least positive), and "false" or "unasserted" when the voltage is high (or most positive).

For example, if the DAV line is low, then data *is* valid; when high, the data is *not* valid.

Some signal lines are described in a negative sense (e.g. NFRD, NDAC) and the convention also applies to these lines. If NRFD is low then the signal is true, i.e. *not* ready for data; if NRFD is high then the signal (Not Ready For Data) is false (i.e. *is* ready for data).

1.6 BUS ADDRESSING

To command a device to be an active talker or active listener, the controller must send that device a command. However, as the GP-IB is a parallel bus, the command message will be presented to all the devices on the bus, not just the device for which it is intended. For this reason, each device on the bus is identified by a unique number termed the ADDRESS.

Listen and talk addresses are allocated, where applicable, to each device on the bus and also to the controller.

There are 31 addresses available for active talkers and 31 for active listeners.

When communicating with a bus device, the controller sends an interface command on the DIO lines. The command contains the address of the device.

A device is fitted with address and talk/listen selector switches or links which are manually set to the required address.

1.7 INTERFACE COMMANDS AND DEVICE DEPENDENT MESSAGES

The GP-IB standard classifies all data sent on the bus into the following two distinct categories.

- a) Interface Commands
- b) Device-dependent Messages.

1.7.1 Interface Commands

Interface commands are instructions sent by the controller for the purpose of "managing" the bus system. For example, if the controller wishes to specify a device (e.g. a printer) to be an active listener it would have to send an appropriate Interface Command. A different interface command would be sent by the controller in specifying an active talker. Interface commands can be sent on the management lines (see Fig. 1.1) or the DIO lines. Those sent on the management lines (e.g. ATN, REN, IFC, etc) are sometimes referred to as "uni-line commands" as they involve only one line. Those commands sent on the DIO lines are referred to as "multi-line commands" as they involve more than one line.

Interface commands have to be recognised and understood by all interfaces on the bus and their meanings are specifically defined by the GP-IB standard. A list of common GP-IB commands is given in Table 1.1.

1.7.2 Device-dependent Messages

A device-dependent message is the correct title for what is loosely referred to as normal data. It is sent by the active talker and received by the active listener(s) and is referred to as "device dependent" because the information content of such a message depends upon the devices sending and receiving the data. For example, such a message may be a measurement result generated by a digital voltmeter or data to be printed by a printer.

Device dependent messages are sent on the DIO lines and can consist of any number of bytes. It is usual that the devices consider these bytes to represent the standard ASCII characters (one byte represents one character). Sometimes, but quite rarely, binary representation is used.

Unlike interface commands, the device-dependent messages are not interpreted by the interfaces.

Table 1.1 *List of Common GP-IB Commands*

Mnemonic	Command	Function	Comments
ATN	Attention	Indicates interface message	From controller to all devices.
DCL	Device Clear	Resets all instruments to initial state	From controller to all devices.
END	End	Indicates end of message	From talker to listeners and controller.
GET	Group Execute Trigger	Starts device actions simultaneously	From controller to all addressed listeners.
GTL	Go To Local	Instructs device to respond to local controls	From controller to all addressed listeners.
IFC	Interface Clear	Resets the interface	From controller to all devices.
LLO	Local Lockout	Inhibits manual operation of a device locally	From controller to all devices.
MLA	My Listen Address	Alerts device to receive next message. Returns talker to idle. Changes device to remote control.	From controller to accepting device. Can initiate three separate functions in conjunction with other commands.
MTA	My Talk Address	Alerts device to send next message. Returns listener to idle.	From controller to accepting device. Can initiate two separate functions.
*PPC	Parallel Poll Configure	Allocates a data line to a device for parallel polling	From controller to all devices.
*PPU	Parallel Poll Unconfigure	Removes a data line previously allocated	From controller to all devices.
REN	Remote Enable	Enables control of devices via the bus	From controller to all devices.
SDC	Selective Device Clear	Resets the selected instrument to initial state.	From controller to selected device.
SPD	Serial Poll Disable	Disables a serial poll	From controller to selected device.
SPE	Serial Poll Enable	Enables a serial poll	From controller to selected device.
SRQ	Service Request	Informs controller of availability of new information or device error message.	From talker to controller.
*TCT	Take Control	Transfers control of new controller-in-charge	Controller addressed as talker.
UNL	Unlisten	Terminates activity as listener	From controller to all devices.
UNT	Untalk	Terminates activity as a talker	From controller to all devices.

*indicates that the command is not applicable to the DMM. The DMM J command is used for parallel polling.

By defining active talkers and active listeners, the controller is essentially defining a pathway for device-dependent messages from the active talker to the active listener(s).

Reference has previously been made to talkers, listeners and talker/listeners. It is important to realise that these terms are in reference to device-dependent messages and not interface commands. All devices "listen" to interface commands.

1.8 DESCRIPTIONS OF GP-IB COMMANDS

1.8.1 The Attention Line (ATN)

As the eight DIO lines are used for both multi-line commands and device-dependent messages, there obviously must be some way of indicating which of these two types of data is currently on the DIO lines. This is done by the attention line ATN.

When the ATN line is high (false) then bytes (which are put on the bus by the active talker and accepted by the active listeners) are understood to be device dependent messages. When the ATN line is low (true), the bytes on the DIO lines are understood to be multi-line interface commands.

The ATN line is driven by the controller. When pulled low by the controller, the transfer of device dependent messages across the bus is suspended and the controller may then send multi-line commands to the interfaces.

1.8.2 Remote Enable (REN)

Most devices can either be controlled from their front panel controls or remotely controlled from the GP-IB. The REN command is used in conjunction with the My Listen Address (MLA) command to set a selected device to remote control operation. When the DMM is operating in remote control, all of the front panel controls, with the exception of the local key, are disabled and the DMM is operated under remote control from the bus. To regain local control, the LOCAL key on the DMM is operated or the Go To Local (GTL) command is sent by the controller. Refer also to the description on Local Lockout.

1.8.3 Interface Clear (IFC)

This command line is used by the controller to immediately stop any activity on the bus and to reset all device interfaces to a known state. It does not alter the current operating status of the devices.

1.8.4 End or Identify (EOI)

This command line is used for ending a message (i.e. a delimiter/terminator) and is also used in conjunction with another command for identification purposes, e.g. polling function.

A data message is usually represented on the bus by a series of bytes coded in the ASCII character set. These messages are terminated (delimited) by the Carriage Return (CR) and/or Line Feed (LF) characters. Other terminator characters can be used to suit the requirements of a particular controller.

When a data message is represented in binary format, i.e. not ASCII represented, the usual terminators are not used as they cannot be differentiated from the binary data bytes. The EOI command is used as the message terminator when the message is binary represented. It can also be used to terminate ASCII represented messages when a fast-acting terminator is required.

The EOI line is also used in conjunction with the ATN line to initiate a Parallel Poll.

Chapter 2

7150plus and the GP-IB

<i>Para</i>	<i>Title</i>	<i>Page</i>
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2.2	GP-IB SOCKET CONNECTIONS	2.2
2.3	DMM ADDRESS/STATUS SWITCH	2.3
2.4	SENDING COMMANDS TO THE DMM	2.3
2.4.1	Controller-specific Command	2.3
2.4.2	DMM Command String	2.4
2.4.3	Power-up 'Default Status'	2.4
2.4.4	Commands Entered Using the Controller	2.4
2.5	DMM OUTPUT DATA FORMATS	2.5
2.6	IEEE 488/GP-IB SUB-SET IMPLEMENTATION	2.5
2.7	7150plus INSTRUCTION SET	2.6
2.8	ERROR MESSAGES	2.8

2.1 INTRODUCTION

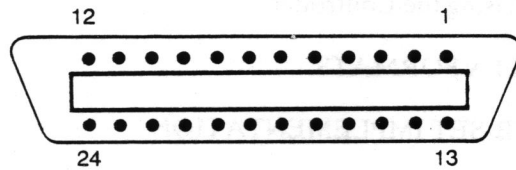
Full control of all the DMM facilities can be achieved via the GP-IB using a suitable controller. These facilities consist of all those offered at the front panel plus some additional ones.

The DMM will accept commands from the controller, initiate measurements and send results back to the controller when requested. In addition, the DMM can be programmed to interrupt the controller when a measurement or an error occurs, thereby allowing the controller to conduct other tasks until interrupted and so increase system efficiency.

Connection to the GP-IB is made using the 'IEEE 488/GP-IB INTERFACE' socket on the rear panel. The DMM address number and Talk/Listen status are selected using the adjacent switch.

2.2 GP-IB SOCKET CONNECTIONS

Pin Numbering



Front view of socket

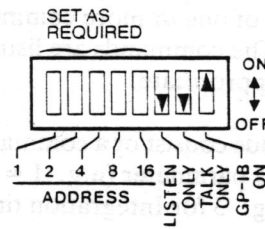
Pin Connections

PIN NO	SIGNAL
1	DIO1
2	DIO2
3	DIO3
4	DIO4
5	EOI
6	DAV
7	NRFD
8	NDAC
9	IFC
10	SRQ
11	ATN
12	Shield (0V)
13	DIO5
14	DIO6
15	DIO7
16	DIO8
17	REN
18	0V (GND)
19	0V (GND)
20	0V (GND)
21	0V (GND)
22	0V (GND)
23	0V (GND)
24	0V (GND)

2.3 DMM ADDRESS/STATUS SWITCH

For normal operation on the GP-IB (using a controller), set the selector switch on the rear panel as indicated below:

ADDRESS 1, 2, 4, 8, 16 : As required (0 to 30)
 LISTEN ONLY : OFF
 TALK ONLY : OFF
 GP-IB ON : ON



Note: Address 31 (all switched ON) is disallowed by the Standard and should never be selected.

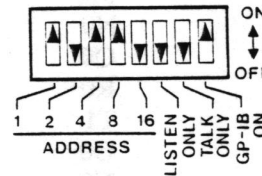
At power-up the DMM display will show all segments and annunciators (as a display test) and then show the legend 'IEEE n', where *n* is the address selected at the switch.

For operation without a controller, e.g. if a printer only is connected to the DMM, the TALK ONLY mode should be selected. To achieve this, set TALK ONLY to ON, and set other switches as shown above.

If TALK ONLY is set to ON at power-up, the DMM display will show all segments and annunciators (as a display test), and then the message 'IEEE to'. If LISTEN ONLY had been set to ON, the message 'IEEE Lo' would appear instead.

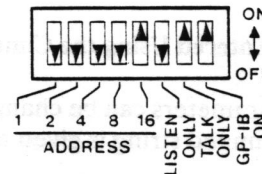
Example 1

For Address 13, Listener/Talker, GP-IB on.



Example 2

For Address 16, Talker only, GP-IB on.



2.4 SENDING COMMANDS TO THE DMM

The DMM is controlled by messages sent from the controller. This is normally achieved using statements of the form:

<Controller-specific command> <DMM command string>

e.g. PRINT # 1, "M0D0I3"
 ↑ ↑
 Controller-specific DMM command
 command string

2.4.1 Controller-specific Command

The 'controller-specific command' is an instruction to the controller, such as 'output', 'display', 'read' or 'print' which is expressed in the language appropriate for the controller being used.

2.4.2 DMM Command String

The 'DMM command string' is a device-dependent message which controls the DMM. The string consists of one or more commands from the DMM Instruction Set which is tabulated in page 2.7. The commands are listed in alphabetical order and additional information is given where appropriate.

Most commands consist of a command letter and a number (the argument), e.g. I3. The letter defines a parameter (e.g. I = Integration time); the number defines the status of the parameter (e.g. 3 for Integration time = 400 ms).

Each parameter will always assume one of its settings, by virtue of, either, (1) the 'power up' condition, or (2) the commands entered using the controller.

2.4.3 Power-up 'Default' States

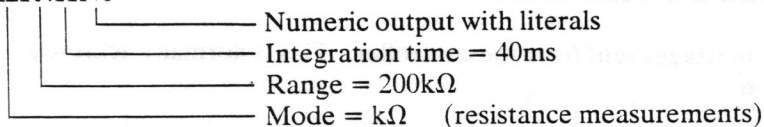
When the DMM is switched on, each parameter assumes the 'default' commanded state as shown below:

C0
D0
I3
J0
K0
M0
N0
Q0
R0
T1
U0
Y0
Z0

2.4.4 Commands Entered Using the Controller

Any or all parameters can be changed at any time using a 'DMM command string'. An example command string is given below:

"M2R4I1N0"



All other parameters would remain as previously selected.

The commands can be entered in any order, but if both the Mode (M) and Range (R) commands are to be sent, it is recommended that the M command is always sent before the R command.

Whenever the DMM makes a measurement, this will be performed according to the parameter settings which are selected when the measurement is taken.

Certain commands, such as A (Device Clear), E (Echoback) and G (Sample) do not require an argument number.

If a new command string is sent to the DMM before all outputs produced by the previous string have been read, then all the previous command string is aborted; any unread outputs are discarded and the DMM starts to action the new command string.

When the T1 Track Mode (repetitive measurements) is selected, the output buffer in the DMM will be continuously updated by each new measurement taken, whether or not any measurements are read by the controller. When the controller reads the DMM, the result of the last measurement taken will be output.

2.5 DMM OUTPUT DATA FORMATS

Measurement results

Results are presented as ASCII strings in one of two formats depending upon the commanded status of N.

For N0, the output will be of the form

+ 1.234567 _ _ V _ DC

i.e. characters 1 to 9 contain the numeric result,
character 10 is always a space,
character 11 is a space if not overload, or '!' if overload,
characters 12 to 15 indicate the measurement mode (literals),
(_ = space)

For N1, only characters 1 to 9 are presented
(i.e. overload and measurement mode do not appear).

The commanded value of U determines which of the available set of delimiter characters will be sent at the end of an output string from the DMM.

2.6 IEEE 488/GP-IB SUB-SET IMPLEMENTATION

The following sub-sets of the IEEE 488/GP-IB Standard are implemented within the DMM.

SH1	Source Handshake
AH1	Acceptor Handshake
T5	Basic Talker, serial poll, talk-only selectable, unaddressed if MLA (My Listen Address)
TE0	Extended Talker no capability
L3	Listen-only selectable, unaddressed if MTA
LE0	Extended Listener no capability
SR1	Service Request
RL1	Remote/Local
DC1	Device Clear
C0	Not a Controller
DT1	Device Trigger, full capability
PP-	See below
E1	Open collector

PP- (Parallel Poll). The DMM has a parallel poll capability, but the manner in which it is configured is not covered by any of the IEEE 488 1978 Parallel Poll sub-sets. Instead, parallel poll configuring in the DMM is achieved using the device-dependent command J (see 7150plus Instruction Set). Re-configuring is achieved using the controller itself (thereby offering an advantage over the PP2 sub-set in which configuring would be achieved using switches at the instrument).

2.7 7150plus INSTRUCTION SET

A	- Device clear	For use with a controller having no 'Device-Clear' command capability. Sets each parameter to the 'power-up' default state, refer to page 2.3.
C	0 Normal operating mode 1 Calibration mode selected	Permits the automatic calibration routine to be used.
D	0 Display on 1 Display inhibited	Normal operating state Gives a higher measurement speed by removing the display updating time. When D1 is sent the message 'OFF' appears on the display and remains visible for as long as D1 is selected.
E	- Echoback	Causes the DMM to output the present settings of all parameters (in alphabetical order) e.g. C0 D0 I3 J1 K0 M2 N1 Q0 R0 T1 U7 Y0 Z1. Use the Interrogate (?) command for individual parameters. Note: When the Range setting is output (using either E or R?), the result will be R, followed by 2 numbers, e.g. R13; the first number gives autorange status, 0 = autorange off, 1 = autorange on; the second number gives the actual range.
G	- Sample	Produces a 'single-shot' measurement.
H	Calibration High Point	For use in C1 mode only.
I	0 6.66ms (3 × 9's) 1 40.0ms (4 × 9's, 50Hz line) 2 50.0ms (4 × 9's, 60Hz line) 3 400ms (5 × 9's) 4 10 × 400ms (6 × 9's 'walking window') 5 (Reserved) 6 100ms (4 × 9s)	Sets the Integration Time For actual reading rates, see Specification in the Operating Manual. 4 cannot be used for Vac (M1) or Iac (M4) or diode (M5) measurements.
J	0 No response to Parallel Poll 1 Respond on DIO line 1 2 Respond on DIO line 2 3 Respond on DIO line 3 4 Respond on DIO line 4 5 Respond on DIO line 5 6 Respond on DIO line 6 7 Respond on DIO line 7 8 Respond on DIO line 8	Determines the DIO line which will respond in a parallel poll. This response will only occur if the DMM is generating SRQ when the parallel poll is performed.
K	0 LOCAL key operates as per IEEE 488 1 LCCAL key disabled	Normal operating mode when using a controller with Local Lockout. For use with a controller having no Local Lockout capability.
L	Calibration Low Point	For use in C1 mode only.
M	0 Vdc 1 Vac 2 kΩ 3 Idc 4 Iac 5 PRT	Selects the Mode ('Mode' is also referred to as 'Input Function' when controlled from the front panel).
N	0 Numeric output with literals 1 Numeric output only	Vdc, kΩ, etc. are output with results Vdc, kΩ, etc. are not output.
O	Refresh calibration constants	For use in C1 mode only.

(2.7 7150plus Instruction Set cont.)

Q	0	SRQ on error only	The DMM generates an SRQ when an error occurs (the controller may then determine the type of error)		
	1	SRQ on error or output available	As Q0, except that SRQ will also be generated when an output is available. This would allow the controller to conduct other tasks while the DMM was making measurements, and the tasks would be interrupted only when each result is ready.		
R	0	<i>Vdc & Vac</i> Autorange	<i>kΩ</i> Autorange	<i>Idc & Iac</i> Autorange	Selection of R1 to R6 inclusive will switch-off autoranging.
	1	0.2V (Vdc only)	Not used	Not used	
	2	2V	Not used	Not used	
	3	20V	20kΩ	Not used	
	4	200V	200kΩ	Not used	
	5	2000V	2MΩ	2A	
	6	Not used	20MΩ	Not used	
T	0	Sample mode	Sample (single-shot) measurements can be made using the G command (Internal measurement triggers are disabled).		
	1	Track mode	Allows (normal) repetitive measurements to be taken.		
U	0	CR, LF	Output Delimiters.		
	1	ETX	Selects the terminating characters to match the requirements of the particular controller.		
	2	CR, LF, ETX	EOI is not a character but a separate uniline signal and when required, will be asserted with the last character of the string eg, with LF when using U4.		
	3	(EOI)			
	4	CR, LF, (EOI)			
	5	ETX, (EOI)			
	6	CR, LF, ETX, (EOI)			
	7	CR			
	8	Space			
W		Write calibration constants	For use in C1 mode only.		
Y	0	Timed drift-corrects enabled	Drift corrects are always taken whenever Mode (input function), Range or Integration time are changed. Timed drift-corrects, taken automatically at 10 second intervals, will also be taken if Y0 is selected (normal operating condition). These timed drift-corrects can be inhibited by selecting Y2. One additional drift-correct will be taken with the next measurement if Y1 is selected, the DMM will then automatically revert back to Y0 or Y2 as previously selected.		
	1	Drift-correct with next measured result			
	2	Timed drift-corrects disabled			
Z	0	Disable Null	Cancels null on the Mode selected.		
	1	Take a new Null	New Null taken on the Mode selected.		
?		When preceded by a command letter, e.g. M?, the Interrogate command will cause the present setting of that command to be output	Use this command to determine the present status of any one parameter; for example M? might produce the result M3, indicating the DMM is currently set to I _{dc} . Can be used with any command that expects an integer argument.		
!		Send error message	Refer to Part 2, Para 2.8		

2.8 ERROR MESSAGES

If an error condition occurs, the DMM automatically generates an appropriate error message. The error message is shown on the DMM front panel display and is also available at the GP-IB Interface as detailed below.

Immediately an error is detected:

- a) The error message is displayed on the front panel in the form 'Err nn' or can be an 'Illegal' or 'Hi Null' message.
- b) An SRQ (service request) is generated at the interface. The SRQ line is consequently asserted and the controller may then conduct a Parallel and/or Serial pole. In response to a Serial pole, the DMM sends a Serial Pole Byte (see Para 1.9.2 of Part 2) which indicates its operating status. The least significant bit in this byte is a '1' if an error is present. The controller can send the ! (query) command requesting the DMM to send the error message in the form described above.

The error messages are listed in the following table.

Error Number	Displayed Message	Error Condition	Additional Information
0	-	No error	
1	Err.01	Bad command	Command letter was not recognised by the DMM
2	Err.02	Bad argument	Argument (number) for the associated command does not exist
3	Err.03	Input buffer overflow	Input string is too long and will be ignored; re-send the commands in shorter strings
4	Hi.null	Null too big	No null taken
5	Illegal	Null not allowed in this mode	Null cannot be used with Vac, Iac or diode test
6	Illegal	Filter not allowed in this mode	Filter cannot be used with Vac, Iac or diode test
7	Err.07	Cal not allowed in this mode	Cal cannot be used in diode test mode
8	Err.08	Cal inhibited	Cal command C1 has not been sent or accepted, and/or CAL plug not inserted or shorted
9	Err.09	Command not allowed in CAL mode	G, T, Z, M5 and Z1 cannot be used in Cal mode
10	Err.10	Computed Cal multiplier/offset not OK	Cal input is out of range

Chapter 3

Hewlett-Packard HP9825

Example Programs

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3.1 INTRODUCTION

The following example programs are given:

- ★ Obtaining repetitive measurements on a given range/mode
- ★ Obtaining a single-shot measurement on demand
- ★ Nulling a given range/mode
- ★ Local key enable/disable

Before using the HP9825 in conjunction with the DMM, refer to '3.2 Preliminaries'.

3.2 PRELIMINARIES

1. Ensure that the HP-IB Interface 98034A is fitted to one of the rear slots on the HP9825. The Interface 'select code', which is switchable by means of the rotary switch on the Interface, should be set to 7 (normal factory setting).
2. Ensure that the 98214A ROM cartridge is fitted in one of the 4 front slots in the HP9825 (up to 4 ROM cartridges can be fitted; the 98214A is essential for GP-IB operation).
3. Set the DMM GP-IB address to 13, as this is the address used in the various programs. If required, any other address in the range 0 to 30, with the exception of address 21, can be selected, providing that the appropriate program lines are amended accordingly. Address 21 is factory set for the HP9825. Instructions for changing this address are given in the H-P manual "Hewlett-Packard 98034A HP-IB Interface Installation and Service Manual".
4. Connect the lead from the HP-IB Interface to the DMM GP-IB socket.
5. Switch on the equipment.
6. Before entering any example programs, erase any existing programs by pressing the ERASE and EXECUTE keys.
7. Remember to press the STORE key after entering each program line.

3.3 OBTAINING REPETITIVE MEASUREMENTS ON A GIVEN RANGE/MODE

The program will set up the DMM as follows:

```

Mode       : V dc (M0)
Range      : 2V (R2)
Integration time: 400ms (I3)
Track      : (T1)
    
```

Results from the repetitive measurements produced will be read by the HP9825 and presented on the display.

3.3.1 Program Listing

```

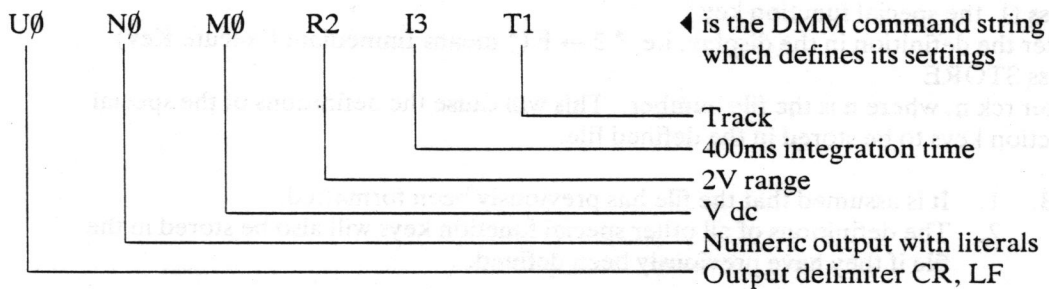
0  dim A$ [15]
1  wrt 713, "U0N0M0R2I3T1"
2  red 713, A$
3  dsp A$
4  goto 2
    
```

Press RUN to start the program.
Press STOP to stop the program.

3.3.2 Listing Description

Line 0 defines the string variable A\$, and its length (15 characters) into which the measurement results from the DMM will be placed.

Line 1 sets up the DMM
'713' defines the write destination : 7 = HP-IB Interface select code, 13 = DMM address. Note that if the address of the DMM was 06 then lines 1 and 2 would read 706.



Measurements can be made on a different range/mode by altering the command string, see the Instruction Set in Chapter 2 for other possible commands.

Line 2 causes a measurement result from the DMM to be read and placed in variable A\$.

Line 3 causes HP9825 to display the contents of A\$, i.e. the measured results. The command prt A\$ could be used instead, and this would cause the results to be output on the built-in printer.

Line 4 sets up a program loop which causes repetitive measurements.

3.4 OBTAINING A SINGLE-SHOT MEASUREMENT ON DEMAND

This program will set up the DMM as follows:

Mode : V ac (M1)
Range : 20V (R3)
Integration time: 400ms (I3)
Sample : (T0)

Single-shot measurements can be produced on demand when required by pressing the f0 (Special Function Key) on the HP9825. Each result will be read by the HP9825 and presented on the display.

Prior to running the program the f0 and f1 (Special Function Keys) must be defined as follows:

f0: * 1 → F
f1: * 2 → F

ie. when 'f0' is pressed F becomes equal to 1
when 'f1' is pressed F becomes equal to 2

3.4.1 Programming the Special Function Keys

The procedure for programming f0 and f1 is as follows:-

On the HP9825:

1. Press FETCH
2. Press f0, the special function key
3. Enter the definition in the display, i.e. * 1 → F (* means Immediate Execute Key)
4. Press STORE
5. Press FETCH
6. Press f1, the special function key
7. Enter the definition in the display, i.e. * 2 → F (* means Immediate Execute Key)
8. Press STORE
9. Enter rck n, where n is the file number. This will cause the definitions of the special function keys to be stored in the defined file.

- N.B.
1. It is assumed that the file has previously been formatted.
 2. The definitions of all other special function keys will also be stored in the file if they have previously been defined.

3.4.2 Program Listing

```

0: dim A$[17],B$[15]
1: ldk i
2: "F0=sample,F1=exit")A$
3: 0)F
4: wrt 713,"U0N0M1R3I0T0"
5: dsp A$
6: if F=2;gto 13
7: if F#1;gto 6
8: wrt 713,"G"
9: red 713,B$
10: dsp A$&B$
11: 0)F
12: gto 6
13: end

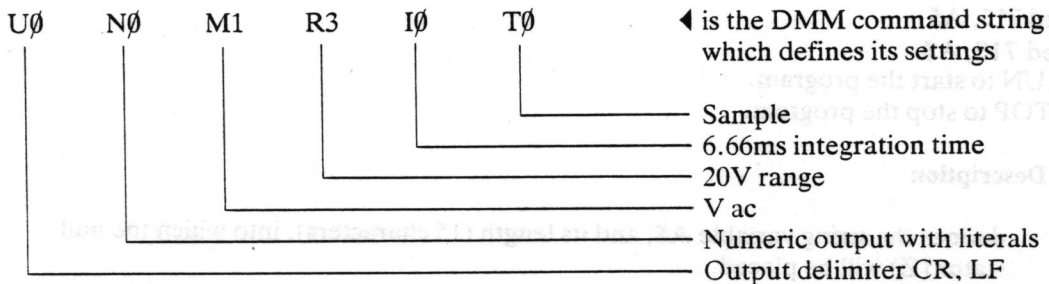
```

Press RUN to start the program.
Press STOP to stop the program.

Note. Lines 3 and 11 above
read: 0 → F

3.4.3 Listing Description

- Line 0** defines the string variable A\$ and B\$ and their respective length.
- Line 1** causes the special function key definitions (i.e. f0, f1) to be loaded.
- Line 2** defines a text string and places it in variable A\$.
- Line 3** makes the flag F equal 0, in readiness for a key press.
- Line 4** contains a write instruction which sets up the DMM
'713' defines the write destination:
7 = HP-IB Interface select code
13 = DMM address



A different mode/range can be called by altering the command string accordingly.

- Line 5** causes the contents of variable A\$ (see Line 2) to be displayed. The statement simply informs the user of the definition of keys f0 and f1 on the HP 9825. At this point, the user may press f0 (if a sample measurement is required) or f1 (to exit from the program).
- Line 6** detects if F = 2, i.e. if the key f1 (exit) has been pressed. If so, the program jumps to line 13.

- Line 7** detects if F is not equal to 1, i.e. if any key other than key f0 or f1, has been pressed. If so, the program jumps back to line 6 to again test the status of F. If F = 1, i.e. f0 (sample) has been pressed, the program continues at line 8.
- Line 8** causes the G (sample) command to be sent to the DMM, causing it to produce one single-shot measurement (on the mode/range selected).
- Line 9** contains a read instruction which causes the DMM measurement to be read by the HP9825 and stored in variable B\$.
- Line 10** causes the contents of variables A\$ and B\$ to be displayed, i.e. "F0 = sample, F1 = exit" and the measurement result.
- Line 11** makes the flag F equal to 0 in readiness for another key press. At this point the user may press either f0 key (for another sample) or f1 (to exit).
- Line 12** causes the program to jump back to line 6; the program will then determine the status of the next key press.

3.5 NULLING A GIVEN RANGE/MODE

This program will set up the DMM as follows:

```

Mode :  $\Omega$  (M2)
Range : 20k $\Omega$  (R3)
Sample : (T $\emptyset$ )

```

A null will be taken on the 20k Ω resistance range/mode; the null value will be stored in the DMM but will not be presented on the HP9825.

3.5.1 Program Listing

```

0  dim A$ [15]
1  wrt 713, "U $\emptyset$ N $\emptyset$ M2R3T $\emptyset$ "
2  wrt 713, "Z1Z?"
3  red 713, A$
4  red 713, A$

```

Press RUN to start the program.
Press STOP to stop the program.

3.5.2 Listing Description

Line 0 defines the string variable A\$, and its length (15 characters), into which the null status (Z) will be placed.

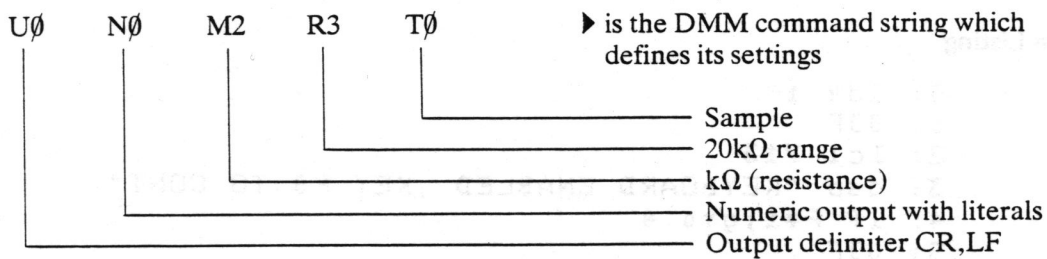
Line 1 contains a write instruction which sets up the DMM.

'713' defines the write destination:

```

7 = HP-IB interface select code
13 = DMM address

```



A different mode/range can be nulled by altering the command string. T0 (Sample) is selected to ensure that no measurements will be made before or after the null, i.e. after the T0 command is sent, measurements are automatically inhibited during a null.

- Line 2** contains a write instruction which causes a null to be taken (Z1).
- Line 3** asks for the present status of the null to be sent back (Z?). Z? is included so that further commands are not sent to the DMM until the null is completed; in effect, Z? actually causes the controller to wait until the null is finished. Any commands sent while a null is in progress will not be activated until the null is completed.
- Line 4** contains a read instruction which causes the null status to be stored in A\$.

3.6 LOCAL KEY ENABLE/DISABLE

This program causes the local key on the DMM front panel to be enabled/disabled, thereby rendering all front panel controls to be operative (permitting Local control) or non-operative (preventing Local control). The f0 (special function key) on the HP 9825 is utilised to perform toggling between the two states of the Local key; each successive press of f0 will change the state.

Prior to running this program the f0 (Special Function Key) must be defined as follows:

f0: * 1 → F
i.e. when f0 is pressed F becomes equal to 1

3.6.1 Programming the Special Function Key

The procedure for programming f0 is as follows:

On the HP9825

1. Press FETCH
2. Press f0, the special function key
3. Enter the definition in the display, i.e. * 1 → F (* means Immediate Execute Key)
4. Press STORE
5. Press FETCH
6. Enter rck n, where n is the file number. This will cause the definition of the special function key to be stored in the defined file.

- N.B. 1. It is assumed that the file has previously been formatted.
2. The definitions of all other special function keys will also be stored in the file if they have previously been defined.

3.6.2 Program Listing

```
0: ldk 1
1: 00F
2: lcl 713
3: dsp "KEYBOARD ENABLED ,KEY F0 TO CONT"
4: if F#1;gto 4
5: 00F
6: llo 7
7: rem 713
8: dsp "KEYBOARD DISABLED,KEY F0 TO CONT."
9: if F#1;gto 9
10: gto 1
```

Press RUN to start the program.
Press STOP to stop the program.

Note. Lines 1 and 5 above
read: 0 → F

3.6.3 Listing Description

- Line 0** causes the special function key definition (i.e. f0) to be loaded.
- Line 1** makes the flag F equal to 0 to ensure that f0 has not already been pressed.
- Line 2** sends the local command to the DMM.
'713' defines the destination:
7 = HP-IB Interface select code
13 = DMM address
- Line 3** causes the display to show the message 'Keyboard Enabled, Key f0 to Cont'.
'Keyboard Enabled' means that the DMM Local Key is enabled and that all DMM keys are operational. The user should now verify this by pressing various DMM keys. 'Key f0 to Cont' means that when the user wishes the program to continue, and thereby make the Local Key revert to 'being disabled', the f0 key on the HP9825 should be pressed.
- Line 4** is a wait loop, which waits for f0 to be pressed. When it is pressed, F = 1 and the program continues.
- Line 5** makes the flag F equal to 0, in readiness for a key press.
- Line 6** causes the command 'local lockout (llo) 7' to be sent to the DMM thereby disabling its Local key.
- Line 7** causes the command 'remote' to be sent to the DMM.
N.B. It is important that llo (line 6) is sent before rem so that the DMM Local Key cannot be used to regain local control before llo is sent.
- Line 8** causes the display to show the message 'Keyboard Disabled, Key f0 to Cont'.
'Keyboard Disabled' means that the DMM Local Key is disabled and all DMM keys are non-operational. The user should verify this by pressing LOCAL and then various other keys. 'Key f0 to Cont' means that when the user wishes the program to continue, and thereby make the Local Key revert to being enabled, the f0 key on the HP 9825 should be pressed.
- Line 9** is a wait loop which waits for f0 to be pressed. When it is, the flag F = 1 and the program continues.
- Line 10** causes the whole program to repeat.

4.6.1 Program Listing

```
10 !
20 ! * Serial Poll Example *
30 !
40 DIM A$(27),B$(136)
50 !
60 ! ** Read Serial Poll Byte descriptions **
70 !
80 FOR I=1 TO 8
90 J=(I-1)*17+1
100 READ B$(J,J+16)
110 NEXT I
120 !
130 ! ** Initialise 7150 & Setup Interrupts **
140 !
150 CLEAR 7 ! Send Device Clear to 7150
160 REMOTE 713
170 STATUS 7,1 ; A ! Clear SRQ from HP-85 interface
180 OUTPUT 713 ;"UONOQ1" ! Set terminator,alpha mode and enable SRQ
190 CLEAR
200 ON INTR 7 GOSUB 290
210 ON KEY# 1,"SEND" GOSUB 630
220 ON KEY# 3,"END" GOSUB 760
230 ENABLE INTR 7;8 ! Enable interrupts on SRQ only
240 !
250 ! ** Wait for interrupt **
260 !
270 GOTO 270
280 !
290 ! ** GPIB Interrupt Service Routine **
300 !
310 S=SPOLL(713) ! Get serial poll byte from 7150
320 STATUS 7,1 ; A ! Clear SRQ from HP-85 interface
330 !
340 ! Show SRQ status byte on screen
350 !
360 CLEAR
370 DISP "BIT DESCRIPTION VALUE"
380 T=0
390 FOR I=8 TO 1 STEP -1
400 J=(I-1)*17+1
410 T1=BIT(S,I-1)
420 T2=2^(I-1)
430 T3=T1*T2
440 IF T3=0 THEN 470
450 DISP USING "X,D,XX,18A,XX,D,XX,DD" ; I-1,B$(J,J+16),T1,T3
460 GOTO 480
470 DISP USING "X,D,XX,18A,XX,D,XX" ; I-1,B$(J,J+16),T1
480 T=T+T3
490 NEXT I
500 DISP USING 950
510 DISP USING 960 ; T
520 DISP USING 950
530 IF BIT(S,4)=0 THEN 570 ! Is there any data available ?
540 ENTER 713 ; A$
550 DISP " Data:"
560 DISP USING "3X,27A" ; A$
570 ON KEY# 2,"CONT" GOTO 590
580 GOTO 580 ! Wait for k2 to continue
590 OFF KEY# 2
600 ENABLE INTR 7;8 ! Enable SRQ interrupts
610 RETURN
620 !
630 ! ** Enter command Interrupt Service Routine **
640 !
650 CLEAR
660 DISP
670 DISP "Enter Command ";
680 INPUT A$
690 OUTPUT 713 ;A$ ! Send Command
700 ENABLE INTR 7;8 ! Enable SRQ interrupts
710 CLEAR
720 RETURN
730 !
740 ! ** Terminate program **
750 !
760 CLEAR
770 LOCAL 713
780 DISP
790 DISP " ** PROGRAM TERMINATED **"
800 END
```

```

810 !
820 ! Serial Poll Byte descriptions
830 !
840 DATA "Error Status"
850 DATA "Always zero"
860 DATA "Always zero"
870 DATA "Remote/Local"
880 DATA "Output Available"
890 DATA "Calibration Error"
900 DATA "Service Request"
910 DATA "Always zero"
920 !
930 ! IMAGE definitions
940 !
950 IMAGE 26X, "----"
960 IMAGE 7X, "Serial Poll Byte = ",DDD

```

Press RUN to start the program.
Press RESET to stop the program.

4.6.2 Listing Description

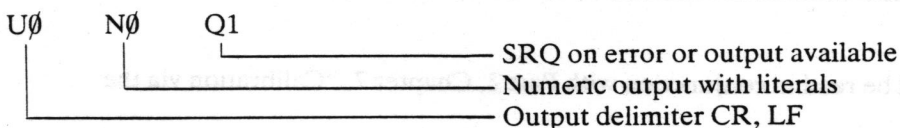
Line 40 dimensions the variables A\$ and B\$. Incoming data from the bus is entered into A\$. Variable B\$ is a dimension for the title descriptions used in the VDU display.

Lines 80 to 110 is a loop which reads the title descriptions into variable B\$. The variable J in Line 90 assigns the start position of each title.

Line 160 sets the DMM (at address 13) to Remote mode.

Line 170 clears any SRQ from the HP85 interface.

Line 180 sets up the DMM
'713' defines the write destination:
7 = HP-IB Interface select code
13 = DMM address



Lines 210 and 220 specify the subroutine and key labels for the special function keys k1 and k3.

Line 270 is a loop waiting for an SRQ or keyboard interrupt.

Line 310 The variable S contains the value of the DMM Serial Poll byte.

Lines 360 to 520 determine the status of each bit in the Serial Poll byte and display it on the VDU.

Line 530 examines the status of bit 4 (Output Available) of the Serial Poll byte. If the bit is 0 there is no data available from the DMM and the program jumps to Line 570.

Line 540 Data from the DMM is entered into variable A\$.

Lines 550 and 560 format and display the data contained in A\$.

Lines 570 and 580 form a loop waiting for the special function key k2 (continue) to be depressed.

- Line 590** breaks the loop when key k2 is pressed.
- Line 600** enables SRQ interrupts. The next request can now be read from the DMM when available.
- Line 630** starts the key k1 (enter command) routine.
- Line 650** clears the screen.
- Line 670** instructs the operator to enter the required DMM command.
- Line 680** the command from the keyboard is entered into A\$.
- Line 690** outputs the command to the DMM.
- Line 700** enables SRQ interrupts.
- Line 740** starts the key k3 (terminate) routine.
- Line 760** clears the screen.
- Line 770** sets the DMM to local control.
- Lines 840 to 910** contain data statements which are read into variable B\$.
- Lines 950 and 960** are used to format the display.

4.7 CALIBRATION OF A GIVEN RANGE/MODE

This program will calibrate the 20k Ω resistance range. No provision is made for error trapping. Although this program is only a simple example for calibrating just one range and mode, it will write calibration constants to the DMM. The calibration source used must be accurate.

This section should be read in conjunction with Part 2, Chapter 7, "Calibration via the GP-IB".

4.7.1 Program Listing

```

10 ! CALIBRATION EXAMPLE
20 DIM A$(8)
30 D=2000 ! VALUE USED FOR INTEGRATION & CALIBRATION WRITE DELAY
40 CLEAR 713 ! INITIALISE 7150
50 WAIT D ! WAIT FOR INITIALISATION TO COMPLETE
60 OUTPUT 713 ;"U0N0T0M2R3" ! SET TERMINATOR,ALPHA MODE,MODE & RANGE
70 CLEAR
80 DISP " THE 7150 IS TO BE CALIBRATED      FOR THE 20 K OHMS RANGE."
90 DISP
100 DISP " INSERT THE CALIBRATION PLUG"
110 GOSUB 620 @ IF K=1 THEN S80
120 OUTPUT 713 ;"C1" ! CHANGE TO CALIBRATION MODE
130 OUTPUT 713 ;"!" ! GET ERROR STATUS FROM THE 7150
140 ENTER 713 ; A$
150 E=VAL(A$(7,8)) ! E IS THE 7150 ERROR CODE
160 IF E=0 THEN 190 ! IF NO ERROR THE CONTINUE
170 IF E=8 THEN 60 ! IF CAL PLUG NOT INSERTED ASK THE QUESTION AGAIN
180 DISP "ERROR ";E @ STOP
190 CLEAR
200 DISP " CONNECT A 20 K OHM REFERENCE TO THE 7150"
210 GOSUB 620 @ IF K=1 THEN S80
220 ! GET CALIBRATION HIGH POINT
230 OUTPUT 713 ;"H200000" ! OHMS REFERENCE IS ASSUMED TO BE EXACTLY 20 K OHMS
240 ENTER 713 ; A$

```

```

250 H=VAL(A$) ! H IS THE 7150 CALIBRATION HIGH POINT
260 CLEAR
270 DISP " SHORT THE INPUT TERMINALS          TOGETHER"
280 GOSUB 620 @ IF K=1 THEN 580
290 ! GET CALIBRATION LOW POINT
300 OUTPUT 713 ;"L0" ! OHMS LOW VALUE IS ASSUMED TO BE ZERO
310 ENTER 713 ; A$
320 L=VAL(A$) ! L IS THE 7150 CALIBRATION LOW POINT
330 CLEAR
340 DISP " THE CALIBRATION POINTS FOR THE  20 K OHMS RANGE ARE :-"
350 DISP
360 DISP "   HIGH POINT : ";H
370 DISP "   LOW POINT  : ";L
380 DISP
390 DISP " WRITE THESE VALUES ?"
400 GOSUB 620 @ IF K=1 THEN 580
410 OUTPUT 713 ;"W" ! WRITE CALIBRATION CONSTANTS
420 CLEAR
430 WAIT D ! PAUSE SO THAT THE STATUS OF THE CALIBRATION CAN BE SEEN ON THE 7150

440 OUTPUT 713 ;"!" ! GET ERROR STATUS FROM THE 7150
450 ENTER 713 ; A$
460 E=VAL(A$[7,8])
470 IF E=0 THEN 530 ! NO ERRORS CALIBRATION CONSTANTS VALID
480 IF E(>)10 THEN DISP "ERROR ";E @ STOP
490 CLEAR
500 DISP " BAD CALIBRATION"
510 GOSUB 620 @ IF K=1 THEN 580
520 GOTO 40
530 CLEAR
540 DISP " CALIBRATION COMPLETE"
550 DISP " PRESS 'K1' TO EXIT"
560 ON KEY# 1,"EXIT" GOTO 580
570 GOTO 570
580 CLEAR
590 OUTPUT 713 ;"C0" ! RETURN FROM CALIBRATION MODE
600 END
610 ! GET 'K1' TO CONTINUE OR 'K2' TO EXIT
620 K=0
630 DISP
640 DISP " PRESS 'K1' TO CONTINUE          'K2' TO EXIT"
650 ON KEY# 1,"CONT" GOTO 680
660 ON KEY# 2,"EXIT" GOTO 690
670 GOTO 670
680 K=2 @ GOTO 700
690 K=1
700 RETURN

```

Press RUN to start the program.
Press RESET to stop the program.

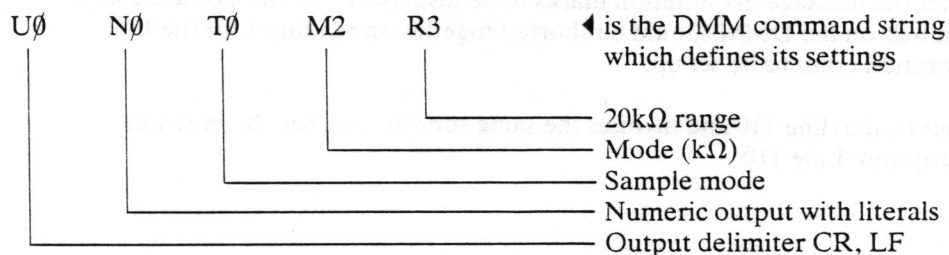
4.7.2 Listing Description

Line 20 defines the length of variable A\$, into which each result will be placed.

Line 30 sets up a 2s delay.

Line 40 initialises the DMM (Device Clear)
'713' defines the write destination:
7 = HP-IB Interface select code
13 = DMM address.

Line 60 sets up the DMM. '713' defines the output destination.



- Line 70** clears the display.
- Lines 80 to 100** contain remarks which are presented on the display. The DISP statement in line 90 gives a line space. Line 100 instructs the user to insert the Calibration Plug (with contacts shorted) at the rear of the DMM.
- Line 110** causes the program to jump to the subroutine starting at Line 620, which sets the flag K to 0.
- Line 120** causes the C1 (Calibration) command to be sent to the DMM, thereby placing it in the Calibration Mode.
- Line 130** causes the ! (send error message) command to be sent to the DMM.
- Line 140** causes the error message to be read into variable A\$.
- Line 150** causes the 7th and 8th digits in the error message (i.e. the error number) to be read from A\$; E becomes equal to the error number.
- Line 160** detects if E = 0, i.e. no error, and if so the program jumps to line 190.
- Line 170** detects if E = 8, i.e. error 8 is present (Calibration command C1 has not been sent or accepted, and/or CAL plug not inserted or shorted). In this event the program returns to line 60 and repeats the program, so that the cause of the error can be determined and rectified.
- Line 180** detects if any other error is present, and if so stops the program and displays the word 'Error' and the error number.
- Line 190** clears the display (the program has jumped from line 160, if no error was present).
- Line 200** causes the message in quotation marks to be displayed. At this point the user must connect a precise calibration source of 20k ohms to the DMM input terminals in readiness for the Hi calibration point to be set up.
- Line 210** is identical to line 110. Calls subroutine 620 to invoke a function key to continue or exit and act accordingly.
- Line 230** causes the Hi point command and value (H200 000) to be sent to the DMM. (If the calibration source is not exactly 20k ohms, the number must be amended accordingly).
- Line 240** causes the measured value of the calibration source (Hi point) to be read into variable A\$.
- Line 250** makes variable H equal to the value of A\$.
- Line 260** clears the screen.
- Line 270** causes the message in quotation marks to be displayed. At this point the input terminals on the DMM should be shorted together in readiness for the Lo calibration point to be set up.
- Line 280** is identical to line 110 and invokes the same subroutines, see the previous description 'Line 110'.

Line 300 causes the Lo calibration point command and value 'LO' to be sent to the DMM. (This assumes that the effective resistance of the input, which is shorted, is zero).

Line 310 causes the measured value of the Lo value resistance to be read into variable A\$.

Line 320 makes variable L equal to the value of A\$.

Lines 340 to 370 cause the calibration Hi and Lo points to be displayed.

Line 390 asks the user if these calibration Hi and Lo points (values) are to be written into the DMM.

Line 400 is identical to line 110 and invokes the same subroutines, see the previous description 'Line 110'.

Line 410 causes the 'W' (Write Calibration Constants) command to be sent to the DMM; the Hi and Lo point values are thereby written into the DMM memory and become the new calibration constants for the measurement mode/range selected (the previous constants are overwritten).

Line 430 causes a delay of 2 seconds; this allows the user time to read the DMM display which will display 'Good' or 'Bad' indicating if the constants have been accepted or not.

Line 440 causes the ! (send error message) command to be sent to the DMM.

Line 450 causes the error message to be read into variable A\$.

Line 460 causes the 7th and 8th digits in the error messages (i.e. the error number) to be read from A\$; E becomes equal to the error number.

Line 470 detects if $E = 0$, i.e. no error, and if so the program jumps to line 530.

Line 480 detects if the error is not error 10 (i.e. error 1 to 9), in which case the display shows Error E ($E =$ error number) and the program stops. In this event the error must be rectified and the calibration procedure repeated.

If the error detected at line 480 was error 10, then the program continues at line 490 which clears the display.

Line 500 causes 'Bad Calibration' to be displayed.

Line 510 causes the program to call the subroutine starting at line 620 which checks for either of the special function keys k1 or k2. If, in this subroutine, the k1 key ("Continue") is pressed, $K = 2$; if the k2 key ("Exit") is pressed, $K = 1$.

If k2 has been pressed then $K = 1$ and the program exits. This is achieved by the IF statement which follows the GOSUB statement and directs the program to line 580 to terminate the program. If k1 has been pressed then $K = 2$ and the program continues to line 520.

Line 520 as the previously pressed key must have been k1 ("Continue") the program proceeds to line 40 to start another calibration.

Line 530 clears the display, and lines 540 and 550 cause the messages in quotation marks to be displayed.

Line 560 defines key 1 as "Exit", and when the key is pressed the program jumps to line 580.

Line 570 is a wait loop which waits for the key 1 to be pressed.

Line 580 clears the display.

Line 590 sends the CO (Normal Operating Mode) command to the DMM, and program ends at line 600.

If in Line 110, K is not equal to 1, then the program continues at line 120.

Line 630 provides another space between the lines.

Line 640 causes an instruction to the user to be displayed.

Line 650 defines Key 1 as 'Continue', and when the key is pressed, causes the program to jump to line 680.

Line 660 defines Key 2 as 'Exit', and when the key is pressed, causes the program to jump to line 690.

Line 670 is a wait loop which will be interrupted by a key press ('Continue' or 'Exit').

If 'Continue' is selected, the program jumps to line 680 which makes $K = 2$ and the program then returns (via line 700) to line 110. If 'Exit' is selected, the program jumps to line 690 which makes $K = 1$ and the program then returns (via line 700) to line 110. The second statement in line 110 detects if the flag $K = 1$. If it is, this implies that 'Exit' has been selected and the program jumps to Line 580.

Line 680 causes the program to jump to line 700 when the k1 ("Continue") key is pressed.

4.8 OBTAINING ECHOBACK

This program will cause the DMM to output an echoback string indicating the present setting of all parameters. The echoback string will show the parameters in alphabetical order and will take the form of the following example.

```
COD0I3J1K0M2N0Q0R3T1U0Y0Z0
```

The meaning of each command letter/argument number is defined in the Instruction Set in Chapter 2.

4.8.1 Program Listing

```
5   DIM A$ [30]
10  OUTPUT 713; "UØE"
15  ENTER 713; A$
20  DISP A$
30  END
```

Press RUN to start the program.
Press RESET to stop the program.

4.8.2 Listing Description

- Line 5** defines the string variable A\$, and its length (30 characters) into which the echoback string from the DMM will be placed.
- Line 10** causes the echoback command E to be sent to the DMM.
UØ is the delimiter CR, LF.
'713' defines the 'write' address:
7 = HP-IB Interface select code,
13 = DMM address.
- Line 15** causes the echoback string to be returned and placed in variable A\$.
- Line 20** causes the HP85 to display the echoback string.

Chapter 4

Hewlett-Packard HP85

Example Programs

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4.1 INTRODUCTION

The following example programs are given:

- ★ Obtaining repetitive measurements on a given range/mode
- ★ Obtaining a single-shot measurement on demand
- ★ Parallel Polling
- ★ Serial Polling
- ★ Calibration of a given range/mode
- ★ Using Echoback

Before using the HP85 with the DMM, refer to '4.2 Preliminaries'.

4.2 PRELIMINARIES

1. Ensure that the module ports at the rear of the HP85 contain the following modules
HP-IB Interface Module 82937
ROM Drawer, Type 82936A containing the I/O ROM.
2. Set the DMM GP-IB address to 13 as this is the number defined in the various programs. If desired, any other address in the range 0 to 30, with the exception of address 21, can be selected, providing that the appropriate program lines are amended accordingly. Address 21 is factory set for the HP85. Instructions for changing this address are given in the H-P manual, "HP-IB Peripheral Installation Instructions".
3. Connect the lead from the HP-IB Interface to the DMM GP-IB socket.
4. Switch on the equipment.
5. Before entering any example programs, erase any existing programs by pressing the SHIFT and SCRATCH keys and then ENDLINE.
6. Remember to press the ENDLINE key after entering each program line.
7. Once running, the program can be paused by pressing the PAUSE key, and stopped by pressing RESET or any alpha key.

4.3 OBTAINING REPETITIVE MEASUREMENTS ON A GIVEN RANGE/MODE

This program will set up the DMM as follows:

Mode : V dc (M0)
Range : 2V (R2)
Integration time: 400ms (I3)
Track : (T1)

Results from the repetitive measurements produced will be read by the HP85 and presented on the display.

4.3.1 Program Listing

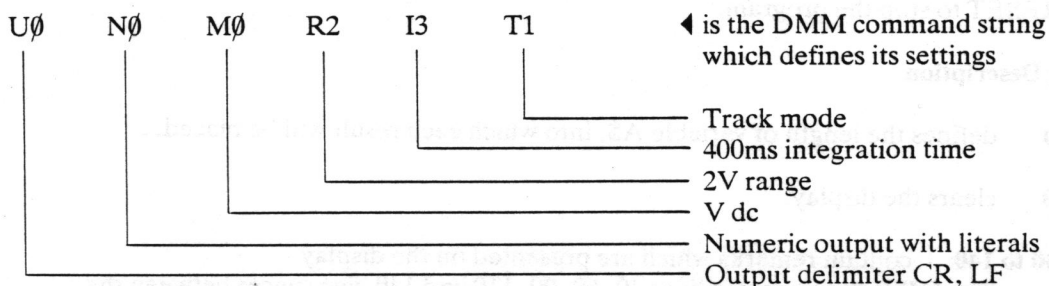
```
5 DIM A$ [15]
10 OUTPUT 713; "U0N0M0R2I3T1"
15 ENTER 713; A$
20 DISP A$
25 GOTO 15
30 END
```

Press RUN to start the program.
Press RESET to stop the program.

4.3.2 Listing Description

Line 5 defines the string variable A\$ and its length (15 characters) into which the measurement results from the DMM will be placed.

Line 10 sets up the DMM
'713' defines the write destination:
7 = HP-IB Interface select code,
13 = DMM address.



Measurements can be made on a different range/mode by altering the command string, see the Instruction Set in Chapter 2 for other possible commands.

Line 15 causes a measurement result from the DMM to be read and placed in variable A\$.

Line 20 causes the HP85 to display the contents of A\$, i.e. the measured result; 'PRINT' could be used instead; this would cause measurements to be sent to the system printer and not to the display.

Line 25 sets up a program loop which causes repetitive measurements.

4.4 OBTAINING A SINGLE-SHOT MEASUREMENT ON DEMAND

This program will set up the DMM as follows:

Mode : V ac (M1)
Range : 20V (R3)
Integration time: 400ms (I3)
Sample : (T0)

Single-shot measurements can be produced on demand when required by pressing the K1 Key. Each result will be read by the HP85 and presented on the display. To exit from this program press the K2 key. (K1 and K2 are special function keys).

4.4.1 Program Listing

```
10 ! SAMPLE MODE EXAMPLE
20 DIM A$(15) ! DESIGNATE SPACE FOR STRINGS
30 CLEAR
40 DISP @ DISP
50 DISP "THE 7150 HAS BEEN PROGRAMMED FOR"
60 DISP
70 DISP " 20 VOLTS AC 6.66 MILLISECONDS"
80 DISP "          INTEGRATION"
90 DISP @ DISP
100 DISP "          PRESS FUNCTION KEY "
110 DISP
120 DISP "          'K1' TO SAMPLE"
130 DISP "          'K2' TO EXIT"
140 DISP @ DISP @ DISP
150 OUTPUT 713 ;"U0N0M1R3I0T0" @ ! SET MODE,RANGE,INTEGRATION & SAMPLE MODE
160 ON KEY# 1,"SAMPLE" GOTO 190
170 ON KEY# 2,"EXIT" GOTO 230
180 GOTO 180 @ ! WAIT FOR KEY
190 OUTPUT 713 ;"G" @ ! SEND SAMPLE COMMAND
200 ENTER 713 ; A$
210 DISP "          ";A$
220 GOTO 160
230 CLEAR
240 END
```

Press RUN to start the program.
Press RESET to stop the program.

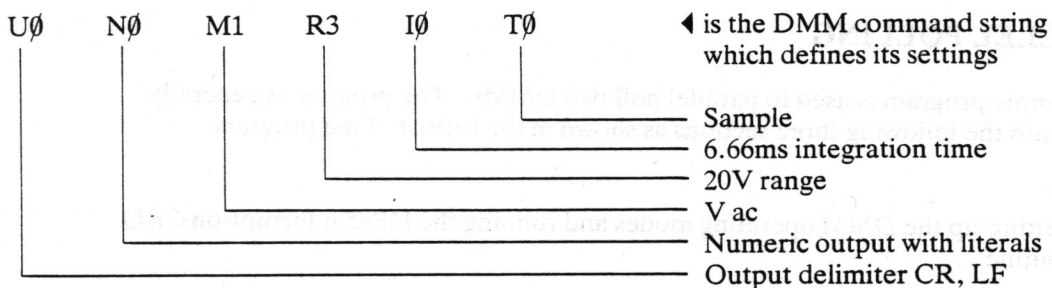
4.4.2 Listing Description

Line 20 defines the length of variable A\$, into which each result will be placed.

Line 30 clears the display.

Lines 40 to 140 contain remarks which are presented on the display.
The DISP statements in lines 40, 60, 90, 110 and 140 give spaces between the lines of remarks.

Line 150 sets up the DMM
'713' defines the write destination:
7 = HP-IB Interface select code
13 = DMM address



Measurements can be made on a different range/mode by altering the command string, see the Instruction Set in Chapter 2 for other possible commands.

Line 160 defines the KEY 1 as "SAMPLE", and when the key is pressed, causes the program to jump to line 190.

Line 170 defines KEY 2 as "Exit", and when the key is pressed, causes the program to jump to line 230.

The action of lines 160 and 170 is to 'sample' or 'exit', but the keys are labelled 'sample' or 'exit' for convenience so that the function name may be displayed.

Line 180 is a wait loop which will be interrupted by a key press ("Sample" or "Exit").

Line 190 causes the G command to be sent to the DMM, following a program jump from line 160.

Line 200 causes the result of 'G' measurement to be read into variable A\$.

Line 210 causes the result to be displayed.

Line 220 sets up a program loop which makes the program jump back to line 160 in readiness for the next "Sample" key press.

Line 230 clears the display, following a program jump from line 170.

Line 240 terminates the program.

4.5 PARALLEL POLLING

This example program is used to parallel poll two DMMs. The program is generally divided into the following three sections as shown in the format of the program listing.

1. Setting-up the DMM operating modes and running the HP85 interrupt-on-SRQ routine.
2. Servicing an SRQ received from a DMM.
3. A simple serial poll routine.

The DMMs are identified as DMMs 7150A and 7150B and their modes of operation and bus configuration are set-up by the program as follows:

7150A	7150B
DC voltage autoranging	DC current range
Integration time of $10 \times 400\text{ms}$ ("walking window")	Integration time of 400ms
Responds on DIO Line 1	Responds on DIO Line 2
Bus address 13	Bus address 14

The outputs from the two DMMs are displayed on two separate columns on the HP85 VDU display. The left column displays the A measurements and the right column the B measurements. The display scrolls-up to accommodate each new measurement.

When the program is initially run, only the B measurements are displayed. Due to the "walking window" filter input selected for the 7150A, the A measurements are displayed only when the eleventh measurement is received.

4.5.1 Program Listing

```
10 !
20 ! * Parallel Poll Example *
30 !
40 DIM A$(15),B$(15),C$(15) ! Designate space for strings
50 CLEAR 7 ! Device clear
60 ON INTR 7 GOSUB 190
70 CLEAR
80 ! Set up 7150 'A'
90 OUTPUT 713 ;"U0N0J1Q1M0R0I4T1"
100 ! Set up 7150 'B'
110 OUTPUT 714 ;"U0N0J2Q1M3R5I3T1"
120 ! Enable interrupts on SRQ only
130 ENABLE INTR 7;8
140 GOTO 140 ! Loop until interrupt received.
150 END
160 !
170 ! *** Service SRQ ***
180 !
190 A$="" ! Erase old data
200 B$=""
220 D=PPOLL(7) ! Discover which device requires servicing
230 IF D(2) THEN 290
240 ! 7150 'B' has caused service request
250 D=D-2 ! Acknowledge that 7150 'B' has been serviced
260 A=14 ! Address of device is 14
270 GOSUB 390 ! Service device
280 ! Check for request from 7150 'A'
290 IF D(1) THEN 330
300 ! 7150 'A' has caused service request
310 A=13 ! Address of device is 13
320 GOSUB 390 ! Service device
```

```

330 DISP A$;B$ ! Display data
335 STATUS 7,1 ; A ! Clear SRQ from interface
340 ENABLE INTR 7;8 ! Enable SRQ interrupts
350 RETURN
360 !
370 ! *** Service routine ***
380 !
390 S=SPOLL(700+A) ! Get status from interrupting device
400 ! Check for data available
410 IF BIT(S,4)=0 THEN 470
420 ! Data available so read it from 7150
430 ENTER 700+A ; C$
440 ! Transfer data to correct string
450 IF A=13 THEN A$=C$ @ GOTO 470
460 IF A=14 THEN B$=C$
470 RETURN

```

Press RUN to start the program.
Press RESET to stop the program.

4.5.2 Listing Description

Line 40 dimensions the three variables A\$, B\$ and C\$. All measurements from the bus are first entered into C\$ and then transferred to the appropriate variable, A\$ for the 7150A and B\$ for the 7150B.

Line 50 clears all devices on the bus. "(7)" refers to HP85 Interface.

Line 60 instructs the HP85 to direct the interrupts received from peripheral 7 to the subroutine at line 190.

Line 70 clears the screen.

Line 90 sets-up the 7150A (address 13) with the following command string.

```

UØ Output delimiter CR, LF
NØ Numeric output with literals
J1 Respond to Parallel Poll on DIO line 1
Q1 Enables SRQ on error and output available
MØ Volts d.c.
RØ Autorange
I4 10 × 400ms (6 × 9s 'walking window') integration
T1 Track mode

```

Line 110 sets-up the 7150B (address 14) with the following command string.

```

UØ Output delimiter CR, LF
NØ Numeric output with literals
J2 Respond to Parallel Poll on D10 line 2
Q1 Enables SRQ on error and output available
M3 d.c. current
R5 2A range
I3 400ms integration
T1 Track mode

```

Line 130 enables the SRQ interrupts from the bus.

Line 140 is a loop waiting for a SRQ interrupt.

Lines 190 and 200 clear the variables A\$ and B\$.

- Line 220** identifies the device which requires servicing by returning the value of the DIO lines, after a parallel poll, to variable D. "(7)" refers to the HP85 GP-IB interface.
- Line 230** Depending on the value of D (1 for 7150A, 2 for 7150B and 3 for 7150A and B) the program either continues to line 240 (B or A and B requires service) or 290 (A requires service).
- Line 250** decrements D by 2 to indicate that the 7150B is going to be serviced.
- Line 260** sets the variable A to the address of 7150B
- Line 270** directs the program to the service subroutine at Line 390.
- Line 290** detects if there is another device to service. If there is not ($D = 0$) then the program jumps to Line 330 to display the data.
- Line 320** the service routine, Line 390, services the device.
- Line 330** displays A and B measurements or spaces if no data is available.
- Line 335** clears the SRQ from the HP 85 GP-IB interface.
- Line 340** enables SRQ interrupts so that another interrupt can be accepted.
- Line 390** reads the serial poll byte from the selected 7150 whose address (13 or 14) is held in variable A.
- Line 410** checks bit 4 of the 7150 Serial Poll byte for an available output. If no output is available (bit 4 set to 0) then the program returns.
- Line 430** enters available data from the selected 7150 into variable C\$.
- Lines 450 and 460** transfer data from variable C\$ into the correct string for the device serviced. Data is transferred from C\$ to A\$ for a 7150A measurement response and to B\$ for 7150B.

4.6 SERIAL POLLING

This program demonstrates the programming techniques used to serial poll a DMM connected to the bus. The program displays the status of each bit of the Serial Poll byte in the DMM.

A typical display produced by the program is shown as follows:

BIT	DESCRIPTION	VALUE	
7	Always zero	0	
6	Service Request	1	64
5	Calibration Error	0	
4	Output Available	1	16
3	Remote/Local	1	8
2	Always zero	0	
1	Always zero	0	
0	Error Status	0	

Serial Poll Byte = 88

Data:
-.0005530 V DC

The binary value and corresponding weighting of each bit of the Serial Poll byte show the operating status of the DMM. If data is available from the DMM it is shown at the bottom of the VDU display.

The three function keys k1, k2 and k3 are used to control the program as follows:

- k1 Enters a DMM command
- k2 Enables SRQ ready for the next DMM response
- k3 Terminates the program

To enable measurements from the DMM, type k1 to enter a command and then type, for example, T1 (Track Mode) to generate SRQs from the DMM. To allow the operator time to interpret the DMM results, the HP85 does not respond to every SRQ generated by the DMM. To obtain the next measurement, the operator must depress function key k2. Other DMM commands which can be entered by the operator to generate SRQs from the DMM are G (Single Sample), E (Echoback), M? (Interrogate) and ! (Error Response). In this demonstration Serial Polling program, the Q1 (SRQ on error and on output available) command is used to generate a stream of SRQs from the DMM.

To obtain an example error status message from the DMM, the operator can send an illegal command. For example, sending a command such as S or requesting C1 (Calibration mode) without having a calibration plug inserted into the rear of the DMM.

Only the U \emptyset command should be used as the output delimiter as the other U commands will not terminate the lines correctly and may subsequently affect the running of the program. Also the A (Device Clear) command should not be used as it resets the DMM to the 'power-up' default state.

Line 450 detects if an error other than Error 10 is present. If so, the message Error n (= 1 to 9) will be displayed and the program will be stopped by the STOP statements. The user must rectify the error condition and then re-run the program. If Error 10 is present (Calibration input is out of range), line 460 causes the message 'Bad Calibration' to be displayed.

Line 470 causes the program to jump to the subroutine starting at line 570. This routine detects if 'C' (to continue), 'E' (to exit) or an invalid key has been pressed (see description for lines 580 to 610).

If "E" was pressed $K = 1$ and the program returns to the second statement in line 470. The program then jumps to line 530 which clears the screen. Line 540 then sends the C0 (Normal mode) command to the DMM, line 550 closes file 1 and line 560 ends the program.

If C was pressed $K = 2$ and the program returns to the second statement in line 470 then to line 480. This causes the program to return to line 40 and the program is repeated.

Lines 490 and 500 respectively cause the 'Calibration Complete' and 'Press E to Exit' messages to be displayed.

Line 510 is a wait loop. The program will advance only when a key is pressed.

Line 520 detects if the key pressed was not an 'E'. If any key except E was pressed, the program returns to line 510 and waits for another key to be pressed. If E was pressed the program advances to line 530 which clears the screen. Line 540 sends the C0 command (normal operating mode) to the DMM. Line 550 closes file 1 and the program ends at line 560.

Line 530 clears the screen.

Line 540 sends the C0 command (normal operating mode) to the DMM.

Line 550 closes file 1.

Line 560 ends the program.

Line 580 causes text to be presented on the screen preceded by a 3 line gap.

Line 590 is a wait loop waiting for a key to be pressed. The program will advance only when a key is pressed.

Line 600 the action taken for each key is as follows:

- a) If key E (exit) is pressed, the program is ended in the following manner. When E is pressed, $K = 1$ and the program returns, via line 630, to the second statement in line 100. Since $K = 1$ the program jumps to line 530 which clears the screen. Line 540 sends the C0 command (normal operating mode) to the DMM, line 550 closes file 1 and the program ends at line 560.
- b) If key C (continue) is pressed, the program will detect this at line 590. K will be made equal to 2 at line 620 and the program will return (via line 630) to line 100 and then to line 110 which will send the C1 (calibration mode) command to the DMM.
- c) Any other key pressed is invalid and this is detected at line 610 and the program returns to line 590 to await next key press.

Line 610 detects if the key pressed was not "C" (for continue). If so an invalid key was pressed and the program returns to line 590 to await the next key press.

5.7 USING LOCAL LOCKOUT

As the PET does not have a Local Lockout (LLO) or Go To Local (GTL) capability, the DMM commands K1 and K0 must be used to disable/enable the LOCAL key on the DMM front panel.

The program below shows how the K1 and K0 commands may be used. In this program the 'C' key on the PET is used to 'toggle' the state of the LOCAL key (disable/enable). In each state, the user can verify that the DMM front panel controls are enabled or disabled.

5.7.1 Program Listing

```
10 REM LOCAL KEY ENABLE / DISABLE EXAMPLE
20 OPEN 1,13 : REM THE 7150 MUST BE SET TO ADDRESS 13
30 PRINT#1,"K0" : REM ENABLE KEYBOARD
40 PRINT "J" : REM CLEAR SCREEN
50 PRINT:PRINT:PRINT
60 PRINT "THE 7150 KEYBOARD IS NOW ENABLED AND CAN"
70 PRINT "BE PROGRAMMED FROM THE FRONT PANEL."
80 PRINT:PRINT:PRINT
90 PRINT "PRESS THE 'LOCAL' KEY TO GAIN CONTROL"
100 PRINT
110 PRINT "AND THEN CHANGE MODE OR RANGE TO VERIFY"
120 PRINT
130 PRINT "THAT THE KEYBOARD IS ACTIVE."
140 PRINT:PRINT:PRINT
150 PRINT "      PRESS 'C' TO CONTINUE"
160 GET A$: IF A$ = "" THEN 160 : REM WAIT FOR A KEY TO BE PRESSED
170 IF A$ <> "C" THEN 160 : REM KEY IS NOT A 'C' THEREFORE IT MUST BE AN INVALID
180 PRINT#1,"K1" : REM DISABLE KEYBOARD
190 PRINT "J" : REM CLEAR SCREEN
200 PRINT:PRINT:PRINT
210 PRINT"THE 7150 KEYBOARD HAS NOW BEEN"
220 PRINT
230 PRINT"DISABLED BY THE 'K1' COMMAND."
240 PRINT
250 PRINT "ATTEMPT TO PROGRAM THE 7150 BY USING"
260 PRINT
270 PRINT "THE 'LOCAL' KEY."
280 PRINT:PRINT:PRINT
290 PRINT "PRESS 'C' TO CONTINUE OR 'E' TO EXIT"
300 GET A$: IF A$="" THEN 300 : REM WAIT FOR A KEY TO BE PRESSED
310 IF A$ = "C" THEN 30 : REM 'C' FOR CONTINUE , ENABLE KEYBOARD AGAIN
320 IF A$ <> "E" THEN 300 : REM KEY PRESSED WAS NOT 'E' THEREFORE,GET ANOTHER KE
Y
330 REM EXIT PROGRAM
340 PRINT#1,"K0" : REM ENSURE THAT THE KEYBOARD IS ENABLED ON EXIT
350 CLOSE 1 : REM CLOSE GPIB OUTPUT
360 PRINT "J" : REM CLEAR SCREEN
370 END
```

Type RUN to start the program.
Press STOP to stop the program.

5.7.2 Listing Description

- Line 20** opens file 1 and assigns to it the device at GP-IB address 13 (i.e. the DMM).
- Line 30** causes the K0 command to be sent to the DMM thereby enabling the its LOCAL key.
- Line 40** clears the screen.
- Lines 50 to 150** contain text which is presented on the screen. The PRINT statements in lines 50, 80, 100, 120 and 140 give spaces between the lines of text.

- Line 160** is a wait loop. The program will advance only after a key has been pressed. Pressing C causes the program to continue.
- Line 170** detects if the key pressed was C. If a key other than C was pressed (i.e. an invalid key), the program returns to line 170.
- Line 180** causes the K1 command to be sent to the DMM thereby disabling its LOCAL key.
- Line 190** clears the screen.
- Lines 200 to 290** contain text which is presented on the screen. The PRINT statements in lines 200, 220, 240, 260 and 280 give spaces between the lines of text.
- Line 300** is waiting for a key. The program will advance only after a key has been pressed. Pressing C causes the program to continue, pressing E to exit from the program.
- Line 310** detects if the key pressed was C; if so the program returns to line 30. This allows the DMM to be toggled again between the LOCAL key enabled/disabled status using the K0 and K1 commands.
- Line 320** detects if the key pressed was an E, if not an invalid key must have been pressed and the program returns to line 300. If an E was pressed, the program continues.
- Line 340** causes the K0 command to be sent to the DMM thereby enabling its LOCAL key on exit.
- Line 350** closes file 1.
- Line 360** clears the screen.

5.8 OBTAINING ECHOBACK

This program will cause the DMM to output an echoback string indicating the present setting of all parameters. The echoback string will show the parameters in alphabetical order, and will take the form of the following example:

```
'CØDØI3J1KØM2NØQ2R1ØT1UØYØZØ'
```

The meaning of each command letter/argument number is defined in the Instruction set in Chapter 2.

5.8.1 Program Listing

```
10 OPEN 1, 13
20 PRINT #1, "E"
30 INPUT #1, A$: IF ST <> 0 THEN 30
40 PRINT A$
50 CLOSE 1
60 END
```

Type RUN to start the program.
Press STOP to stop the program.

5.8.2 Listing Description

- Line 10** opens up file 1 and assigns to it the device at GP-IB address 13 (i.e. the DMM).
- Line 20** causes the echoback command E to be sent to the DMM.
- Line 30** causes the echoback string to be read from the DMM and placed in variable A\$, refer to para. 5.1.4.
- Line 40** causes the PET to display the echoback of A\$, i.e. the echoback string.
- Line 50** closes file 1.

Chapter 5

Commodore PET 4032 and 8032

Example Programs

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5.1 INTRODUCTION

The following example programs are given:

- ★ Obtaining repetitive measurements on a given range/mode
- ★ Obtaining a single-shot measurement on demand
- ★ Using Device Clear
- ★ Calibration of a given range/mode
- ★ Using Local Lockout
- ★ Obtaining Echoback

The example programs given will operate on both the PET 4032 and 8032 computers.

Before using the PET in conjunction with the DMM refer to the following paragraphs and to '5.2 Preliminaries'.

5.1.1 Polling

As the PET 4032 and 8032 do not have a normal polling facility, it may be helpful to incorporate the DMM command ! (send error message) into a program. The ! command will cause the DMM to output an error message which can then be examined to ascertain if an error has occurred. If no error is detected the message "ERROR 00" is produced. When an error is indicated, the user may then take appropriate action. During a long program the ! command could be sent periodically to detect any error which may have arisen in the DMM.

5.1.2 Lockout

As the PET 4032 and 8032 do not have a 'Local Lockout' (LLO), or 'Go to Local' (GTL) command, the DMM commands K1 and K0 must be used to disable/enable the LOCAL key on the front panel.

5.1.3 Output Delimiter

The output delimiter must be CR, i.e. the U7 command must be sent. Other delimiters, such as LF, would not be cleared from the DMM output buffer after a measurement and would thus corrupt the subsequent reading.

5.1.4 Bus Transfers

In practice, the PET may attempt to read data from the DMM before a measurement result is ready and thus a zero reading would be produced. To avoid this, the IF statement is included with the bus transfer statement. This will cause the program to keep repeating the INPUT instruction until a reading is available. At this point the status of the PET will change from 1 to 0 and the program will continue.

Status = 1 means no output is available, status = 0 means that an output is available.

5.1.5 Cursor Control Characters

Cursor control characters are used within the programs. Special symbols associated with these cursor control characters are echoed on the VDU and printed on the hardcopy listing, e.g. the CLR character echoes a heart-shaped symbol in reverse video.

5.1.6 DMM Addressing

Only the addresses, 5, 6, 7 and 9 to 30 inclusive, from the range 0 to 30, can be used for the DMM when a PET is used as the controller. The remaining addresses are allocated to the PET as follows:

0	Keyboard
1	Cassette 1
2	Cassette 2
3	VDU
4	IEEE Device 4 (Printer)
8	Disk Drives

5.2 PRELIMINARIES

1. Set the DMM GP-IB address to 13, as this is the number defined in the various programs.
2. Connect the lead from the GP-IB port on the 4032/8032 (port nearest the mains switch) to the DMM GP-IB socket.
3. Switch on equipment.

5.3 OBTAINING REPETITIVE MEASUREMENTS ON A GIVEN RANGE/ MODE

The program will set up the DMM as follows:

Mode	:	V dc (M0)
Range	:	2V (R2)
Integration time	:	400ms (I3)
Track	:	(T1)

Results from the repetitive measurements produced will be read by the PET and presented on the display.

5.3.1 Program Listing

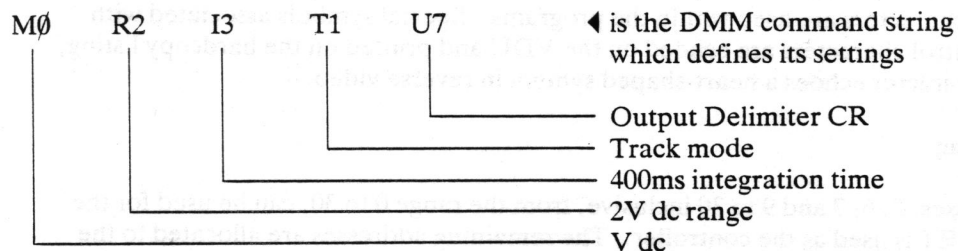
Listing to go here

Type RUN to start the program.
Press STOP to stop the program.

5.3.2 Listing Description

Line 10 opens file 1, and assigns to it the device at GP-IB address 13 (i.e. the DMM).

Line 20 sets up the DMM



Measurements can be made on a different range/mode by altering the command string, see the Instruction Set in Chapter 2 for other possible M and R commands.

Line 30 causes the measurement result to be read from the DMM and placed in variable A\$, refer to para 5.1.4.

Line 40 causes the PET to display the contents of A\$, i.e. the measured results.

Line 50 sets up a program loop which causes repetitive inputs from the DMM.

5.4 OBTAINING A SINGLE-SHOT MEASUREMENT ON DEMAND

This program will set up the DMM as follows:

Mode : V ac (M1)
Range : 20V (R3)
Integration time : 6.66ms (I3)
Sample : (T0)

Single-shot measurements can be produced on demand when required by pressing the SPACEBAR. Each result will be read by the PET and presented on the display.

5.4.1 Program Listing

```
10 REM SAMPLE MODE EXAMPLE
20 PRINT "C":REM CLEAR SCREEN
30 PRINT:PRINT
40 PRINT "THE 7150 HAS BEEN PROGRAMMED FOR :-"
50 PRINT
60 PRINT "20 VAC 6.66 MILLISECONDS INTEGRATION"
70 PRINT:PRINT:PRINT
80 PRINT "PRESS THE 'SPACEBAR' TO TAKE A SAMPLE."
90 PRINT
100 PRINT " 'E' TO EXIT."
110 PRINT:PRINT:PRINT
120 OPEN 1,13:REM THE 7150 MUST BE SET TO ADDRESS 13
130 PRINT#1,"U7M1R3I0T0":REM SET TERMINATOR,MODE,RANGE,INT. TIME & SAMPLE MODE
140 GET A$:IFA$=""THEN140:REM WAIT FOR A KEY TO BE PRESSED
150 IF A$="E" THEN 200:REM 'E' FOR EXIT PRESSED
160 IFA$<>" "THEN140:REM NOT 'SPACEBAR' THEREFORE IT MUST BE AN INVALID KEY
170 PRINT#1,"G":REM SEND SAMPLE COMMAND
180 INPUT#1,A$:IFST<>0THEN180:REM WAIT FOR BUS TRANSFER
190 PRINT " "A$
200 PRINT "C":REM RE-POSITION CURSOR FOR NEXT MEASUREMENT
210 GOTO140:REM GET ANOTHER KEY
220 REMEXIT PROGRAM
230 CLOSE 1:REM CLOSE GPIB OUTPUT
240 PRINT "C":REM CLEAR SCREEN
250 END
```

Type RUN to start the program.
Press STOP to stop the program.

5.5 USING DEVICE CLEAR

As the PET 4032 and 8032 do not have a Device Clear command, the DMM command 'A' must be used instead. The 'A' command will set all parameters to their power-up state, see 'Sending Commands to the DMM' in Part 2, Chapter 2. Immediately after sending the 'A' command, a delay of approximately two seconds must be allowed for the DMM parameters to assume their new settings. Further commands can then be sent to the DMM.

A Device Clear command must not immediately follow a C1 (calibration mode) operation as this will induce a calibration error. Command C1 is followed by C0 (normal operating mode) and then the Device Clear command.

The program below uses the A command to set up all the DMM parameters to the power-up state.

5.5.1 Program Listing

```
10 OPEN 1, 13
20 PRINT #1, "A"
30 FOR I = 1 TO 2000 : NEXT I : REM WAIT APPROXIMATELY 2 SECONDS
40 CLOSE 1
50 END
```

Type RUN to start the program.
Press STOP to stop the program.

5.5.2 Listing Description

Line 10 opens up file 1 and assigns to it the device at GP-IB address 13 (i.e. the DMM).

Line 20 sends the 'A' command to the DMM.

Line 30 gives the necessary delay of approximately 2 seconds.

Line 40 closes file 1.

5.6 CALIBRATION OF A GIVEN RANGE/MODE

This section should be read in conjunction with Part 2, Chapter 7, "Calibration via the GP-IB".

This program will calibrate the 20k Ω resistance range. Although this program is only a simple example for calibrating just one range and mode, it will write the calibration constants to the DMM. A precision 20k Ω calibration source must be used.

Refer to para. 5.5 regarding the use of a Device Clear command.

5.6.1 Program Listing

```
10 REM CALIBRATION EXAMPLE
20 D=2000 : REM VALUE USED FOR INITIALISATION AND CALIBRATION WRITE DELAY.
30 OPEN 1,13 : REM THE 7150 MUST BE SET TO ADDRESS 13
40 PRINT#1,"A" : REM INITIALISE 7150
50 FOR I = 1 TO D : NEXT I : REM WAIT FOR INITIALISATION TO COMPLETE
60 PRINT#1,"UPTOM2R3" : REM SET TERMINATOR,HOLD,SAMPLE,MODE AND RANGE
70 PRINT "THE 7150 IS TO BE CALIBRATED FOR"
80 PRINT "THE 20 K OHMS RANGE."
90 PRINT "INSERT THE CALIBRATION PLUG"
100 GOSUB 570 : IF K=1 THEN 530
110 PRINT#1,"C1" : REM CHANGE TO CALIBRATION MODE
120 PRINT#1,"!" : REM GET ERROR STATUS FROM THE 7150
130 INPUT#1,A# : IF ST <> 0 THEN 130
```

```

140 E = VAL(MID$(A$,7,2)) : REM E IS THE 7150 ERROR CODE
150 IF E = 0 THEN 180 : REM IF NO ERROR THEN CONTINUE
160 IF E = 8 THEN 60 : REM IF CAL PLUG NOT INSERTED THEN ASK QUESTION AGAIN
170 PRINT "ERROR ";E : STOP
180 PRINT "CONNECT A 20 K OHM REFERENCE TO THE"
190 PRINT "7150."
200 GOSUB 570 : IF K=1 THEN 530
210 REM GET CALIBRATION HIGH POINT
220 PRINT#1,"H200000" : REM OHMS REFERENCE IS ASSUMED TO BE EXACTLY 20 K OHMS
230 INPUT#1,A$ : IF ST <> 0 THEN 230 : REM WAIT FOR BUS TRANSFER
240 H=VAL(A$) : REM H IS THE 7150 CALIBRATION HIGH POINT
250 PRINT "SHORT THE INPUT TERMINALS TOGETHER"
260 GOSUB 570 : IF K=1 THEN 530
270 REM GET CALIBRATION LOW POINT
280 PRINT#1,"L0" : REM OHMS LOW VALUE ASSUMED TO BE ZERO
290 INPUT#1,A$ : IF ST<>0 THEN 290 : REM WAIT FOR BUS TRANSFER
300 L=VAL(A$) : REM L IS THE 7150 CALIBRATION LOW POINT
310 PRINT "THE CALIBRATION POINTS FOR THE 20 K OHMS"
320 PRINT "RANGE ARE :-"
330 PRINT "HIGH POINT : ";H
340 PRINT "LOW POINT : ";L
350 PRINT "WRITE THESE CALIBRATION VALUES ?"
360 GOSUB 570 : IF K=1 THEN 530
370 PRINT#1,"W" : REM WRITE CALIBRATION CONSTANTS
380 PRINT "C" : REM CLEAR SCREEN
390 FOR I=1 TO 0 : NEXT I
400 REM PAUSE SO THAT THE STATUS OF THE CALIBRATION CAN BE SEEN ON THE 7150
410 PRINT#1,"!" : REM GET ERROR STATUS FROM THE 7150
420 INPUT#1,A$:IF ST <> 0 THEN 420
430 E = VAL(MID$(A$,7,2))
440 IF E = 0 THEN 490 : REM NO ERRORS CALIBRATION CONSTANTS VALID
450 IF E<>10 THEN PRINT "ERROR ";E:STOP
460 PRINT "BAD CALIBRATION"
470 GOSUB 570 : IF K=1 THEN 530
480 GOTO 40
490 PRINT "CALIBRATION COMPLETE"
500 PRINT "PRESS 'E' TO EXIT"
510 GET A$ : IF A$ = "" THEN 510 : REM WAIT FOR A KEY TO BE PRESSED
520 IF A$ <> "E" THEN 510
530 PRINT "C" : REM CLEAR SCREEN
540 PRINT#1,"C0" : REM RETURN FROM CALIBRATION MODE
550 CLOSE 1
560 END
570 REM GET KEY 'C' TO CONTINUE OR 'E' TO EXIT
580 PRINT "PRESS 'C' TO CONTINUE OR 'E' TO EXIT"
590 GET A$:IF A$ = "" THEN 590 : REM WAIT FOR A KEY TO BE PRESSED
600 IF A$ = "E" THEN K=1 : GO TO 630
610 IF A$<>"C"THEN590: REM KEY IS NOT A 'C' THEREFORE INVALID SO GET ANOTHER
620 K=2
630 RETURN

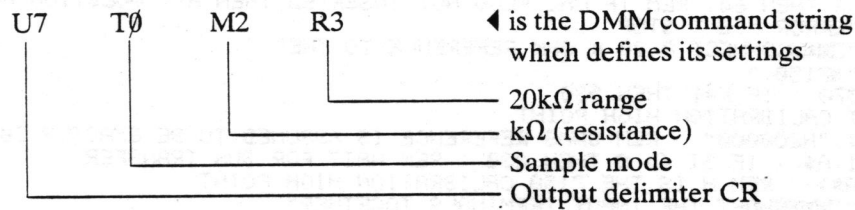
```

Type RUN to start program.
Press STOP to stop program.

5.6.2 Listing Description

- Line 20** defines the length of delay time as 2000ms.
- Line 30** opens file 1 and assigns to it the device at GP-IB address 13 (i.e. the DMM).
- Line 40** sends the command A (Device Clear) to the DMM, this sets its DMM parameters to the power-up (initialised) state.
- Line 50** is a delay which causes the program to wait for 2 seconds, as defined in line 20; this allows the DMM parameters to settle at the initialised state before another command is sent.

Line 60 sets up the DMM.



Any other mode/range can be calibrated by altering the M and R commands, see the Instruction Set in Chapter 2. A highly accurate voltage/current/resistance standard must be used.

Lines 70 to 90 incorporate cursor control symbols, refer to para. 5.1.5. Line 90 contains a message instructing the operator to insert the calibration plug, with shorted links, into the rear of the DMM.

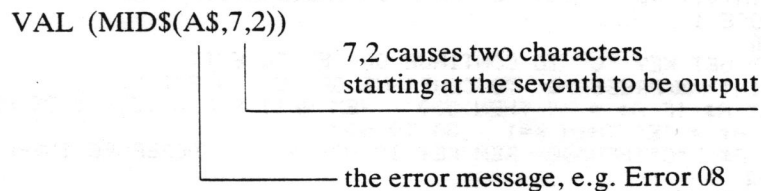
Line 100 causes the program to jump to the subroutine starting at line 570 to get one key to continue or another to exit.

Line 110 will send the C1 (calibration mode) command to the DMM.

Line 120 will send the ! (send error message) command to the DMM.

Line 130 causes the error message to be read from the DMM and places it in variable A\$. Refer to para. 5.1.4, Bus Transfers.

Line 140 makes E equal to the error code number.



Line 150 detects if no error was present, i.e. E = 00. If so, the program jumps to line 180.

Line 160 detects if Error 8 was present, i.e. the Calibration plug was not inserted. In this event, the program jumps to line 60 and repeats the request to insert the plug.

Line 170 causes the number of any other error detected (i.e. 1 to 7 inclusive or 9 and 10) to be displayed. If any such error is detected, the program is stopped by the STOP statement. The user must rectify the fault and then re-run the program starting at line 10.

Lines 180 and 190 contain text which is presented on the display.
N.B. an accurate 20k ohm calibration source must be connected to the DMM input, at this stage.

Line 200 causes the program to jump to the subroutine starting at line 570. This subroutine detects if 'C' (to continue), 'E' (to exit) or an invalid key has been pressed (see description for lines 580 to 610).

Assuming 'C' has been pressed, the program then advances to line 210, otherwise if E has been pressed then the program will go to line 530.

- Line 220** sends the H (calibration High Point) value to the DMM. If necessary, this value may be changed to suit the precise value of the calibration source if it is not exactly 20k Ω .
- Line 230** causes the measured value of resistance to be read from the DMM, and placed in A\$. The IF statement is described under Line 130.
- Line 240** makes H equal to the numeric value of A\$.
- Line 250** contains text which is presented on the screen requesting that the 20k ohms calibration source be removed and the input terminals shorted together.
- Line 260** causes the program to jump to the subroutine starting at line 570. This subroutine detects if 'C' (to continue) 'E' (to exit) or an invalid key has been pressed (see description for lines 580 to 610).
- Assuming C has been pressed, the program advances to line 270, otherwise if E has been pressed the program will go to line 530.
- Line 280** sends the L (Calibration Low Point) value to the DMM.
- Line 290** causes the measured value of resistance to be read from the DMM and placed in A\$.
- Line 300** makes L equal to the numeric value of A\$.
- Lines 310 to 340** cause the calibration high and low point values measured to be displayed on the screen.
- N.B. at this point the user must decide whether or not to write these calibration values into memory in the DMM.
- Line 360** causes the program to jump to the subroutine starting at line 570. This subroutine detects if 'C' (to continue), 'E' (to exit) or an invalid key has been pressed (see description for lines 580 to 610).
- If C to continue has been pressed then the program continues onto line 370, otherwise if the E to exit key has been pressed, the program then jumps to line 530.
- Line 370** sends the (Write) command to the DMM, thereby causing the calibration values to be written into memory.
- Line 380** clears the screen.
- Line 390** is a delay loop which gives a 2 second delay; this allows the status of the calibration, e.g. 'good' or 'bad' to be read on the DMM display.
- Line 410** causes the ! (Send error message) command to be sent to the DMM.
- Line 420** causes the error message to be read from the DMM and places it in A\$, refer to para. 5.1.4, Bus Transfer.
- Line 430** makes E equal to the error code number.
- Line 440** detects if no error was present, i.e. E = 0. If so, the program jumps to line 490. No error indicates that the calibration constants are valid, otherwise the program continues at line 450 because an error has occurred.

Chapter 6

Apple II Example Programs

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6.1 INTRODUCTION

The following example programs are given:

- ★ Obtaining repetitive measurements on a given range/mode
- ★ Obtaining a single-shot measurement on demand
- ★ Nulling a given range/mode
- ★ Using Device Clear

The reader is referred to the APPLE II IEEE-488 Interface User's Guide which describes in detail the operation of the APPLE in conjunction with the GP-IB bus.

Before using the APPLE in conjunction with the DMM, refer to '6.2 Preliminaries'.

6.1.1 DMM Addressing

An example listing for addressing a DMM is given as follows:

```
10 ADDR = 13: REM DMM ADDRESS
20 ZL$ = CHR$(ADDR+32) + CHR$(26)
30 ZT$ = CHR$(ADDR+64) + CHR$(26)
```

In this example, the DMM GP-IB address is 13 but it can be easily changed by amending line 10 only. The listen address is defined by the string ZL\$ in line 20.

The listen address is formed by adding on offset of 32 to the required IEEE address to give the relevant ASCII character. The special character "control Z" [CHR\$(26)] indicates the end of the address list. In a similar way, the talk address is defined by the string ZT\$ in line 30 and uses an offset of 64.

The address zero is not usually used for the DMM as this address is allocated to the APPLE. If required, the address range 0 to 30 can be selected by using the DEVICE command on the APPLE, refer to the APPLE II IEEE-488 Interface User's Guide.

6.1.2 Poke Commands

In general terms, the APPLE operating system intervenes between the application program and the software monitor and it intercepts BASIC commands directed to the monitor. Operating systems commands are prefaced by the CHR\$(4), control D, characters. Using these CHR\$(4) commands to select and activate an input/output device means that the device is initialised every time the appropriate CHR\$(4) command is generated.

To avoid this happening to the GPIB interface card in slot 3, the input and output vectors are manually changed to different locations by POKE commands to avoid the repeated initialisation of the bus interface.

6.2 PRELIMINARIES

1. Ensure that a GP-IB Interface card is fitted in the APPLE, normally in slot 3; refer to the APPLE II IEEE-488 Interface User's Guide for further information. Ensure that the VDU is connected to the Video Output slot and the Disk Drive(s) to slot 6.
2. Set the DMM GP-IB address to 13, as this is the number defined in the various programs. If required any other address in the range 1 to 30 can be selected, refer to para 6.1.1.
3. Connect the lead from the APPLE GP-IB Interface to the DMM GP-IB socket.
4. Insert the operating system disk into Disk Drive 1.
5. Switch on the equipment. The APPLE will automatically load the operating system from the disk and run the first program found on the diskette catalogue which is normally the "Greetings" program and is titled "HELLO".
6. Before entering any example programs, erase any existing programs from memory by typing the command NEW.
7. Remember to press the RETURN key after entering each program line.

6.3 OBTAINING REPETITIVE MEASUREMENTS ON A GIVEN RANGE/ MODE

The program will set up the DMM as follows:

Mode	:	V dc (M0)
Range	:	2V (R2)
Integration time	:	400ms (I3)
Track	:	(T1)

Results from the repetitive measurements produced will be read by the APPLE and presented on the display.

6.3.1 Program Listing

```
10 ADDR = 13: REM 7150 ADDRESS
20 ZL$ = CHR$ (ADDR + 32) + CHR$ (26)
30 ZT$ = CHR$ (ADDR + 64) + CHR$ (26)
40 PRINT CHR$ (4); "PR#3"
50 PRINT CHR$ (4); "IN#3"
60 PRINT "SC0"
70 PRINT "RA"
80 PRINT "WT"; ZL$; "U7N0M0R2I3T1"
90 PRINT "RD"; ZT$;
100 INPUT A$
110 PRINT CHR$ (4); "PR#0"
120 PRINT CHR$ (4); "IN#0"
130 PRINT A$
140 POKE 54,6: POKE 55,195: POKE 56,3: POKE 57,195
150 CALL 1002
160 GOTO 90
```

Type RUN to start the program.
Press RESET to stop the program.

6.3.2 Listing Description

Lines 10 to 30 define the DMM address, refer to para 6.1.1.

Line 40 causes all output data to be sent to slot 3.

Line 50 causes all input data to be sent to slot 3.

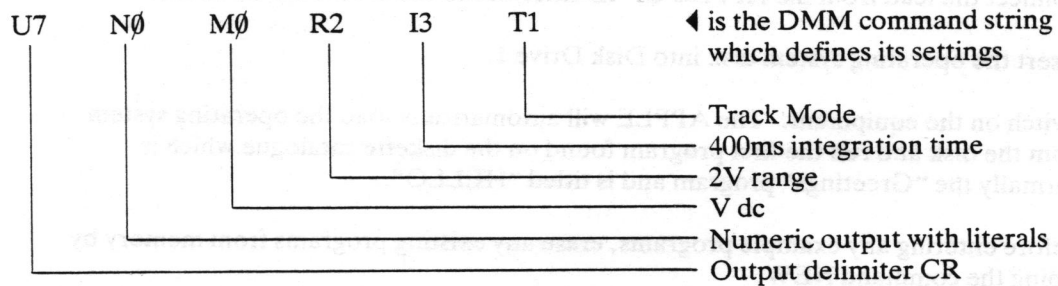
Line 60 switches off the debug mode and stops echo onto the screen.

Line 70 puts the DMM into remote control.

Line 80 causes a command string to be sent to the DMM.

PRINT "WT" causes a string to be output.

ZL\$ is the listen address of the DMM as defined in line 20.



Measurements can be made on a different range/mode by altering the command string, see the Instruction Set in Chapter 2 for other possible M and R commands.

Line 90 prepares the APPLE Interface card (in slot 3) to read from talk address ZT\$ as defined in line 30.

Line 100 causes the APPLE to read data from the DMM.

Line 110 causes data to be sent to the VDU.

Line 120 re-enables the APPLE to read from the keyboard.

Line 130 causes results from the DMM to be shown on the VDU.

Lines 140 and 150 set up the GP-IB Interface ready for another measurement without further initialisation. CALL 1002 relinks the operating system.

Line 160 sets up a program loop which causes repeated measurements to occur.

6.4 OBTAINING A SINGLE-SHOT MEASUREMENT ON DEMAND

This program will set up the DMM as follows:

Mode : V ac (M1)
Range : 20V (R3)
Integration time: 400ms (I3)
Sample : (T0)

Single shot measurements can be produced on demand when required by pressing the SPACEBAR. Each result will be read by the APPLE and presented on the VDU. Press E to exit from the program.

6.4.1 Program Listing

```
10 REM SAMPLE MODE EXAMPLE
20 HOME
30 PRINT : PRINT
40 PRINT "THE 7150 HAS BEEN PROGRAMMED FOR :-"
50 PRINT
60 PRINT "20 V AC 400 MILLISECONDS INTEGRATION"
70 PRINT : PRINT : PRINT
80 PRINT "PRESS THE 'SPACEBAR' TO TAKE A SAMPLE"
90 PRINT
100 PRINT "          'E'          TO EXIT"
110 PRINT : PRINT : PRINT
120 REM INITIALISE APPLE INTERFACE CARD
130 PRINT CHR$(4);"PR#3"
140 PRINT "SC0"
150 PRINT "RA"
151 ZL$ = CHR$(32 + 13) + CHR$(26): REM IEEE LISTEN ADDRESS = 13
152 ZT$ = CHR$(64 + 13) + CHR$(26): REM IEEE TALK ADDRESS = 13
160 PRINT CHR$(4);"PR#0"
170 PRINT CHR$(4);"IN#0"
180 A$ = "U7N0M1R3I3T0": GOSUB 340: REM SET DELIMITER, ALPHA O/P, MODE, RANGE,
                                     INTEGRATION TIME & SAMPLE MODE

190 VTAB 18: HTAB 12: GET A$
200 IF A$ = "E" THEN 260: REM 'E' FOR EXIT PRESSED
210 IF A$ < > " " THEN 190: REM KEY IS NOT 'SPACEBAR'
                                     THEREFORE IT MUST BE AN INVALID KEY

220 A$ = "G": GOSUB 340: REM SEND SAMPLE COMMAND
230 GOSUB 400: REM GET MEASUREMENT FROM 7150
240 HTAB 12: VTAB 18: PRINT A$: REM POSITION CURSOR & PRINT MEASUREMENT
250 GOTO 190
260 HOME
270 END
280 REM CHANGE I/O TO IEEE
290 POKE 54,6: POKE 55,192 + 3: REM IEEE CARD IS ASSUMED TO BE IN SLOT 3
300 POKE 56,3: POKE 57,192 + 3: REM I/O IS NOW VIA IEEE CARD
310 CALL 1002: REM RE-LINK THE OPERATING SYSTEM
320 RETURN
330 REM SEND IEEE COMMAND
340 GOSUB 290: REM CHANGE I/O TO IEEE
350 PRINT "WT";ZL$;A$: REM SEND COMMAND TO IEEE
360 PRINT CHR$(4);"PR#0": REM RETURN I/O TO VDU & KBD
370 PRINT CHR$(4);"IN#0"
380 RETURN
390 REM INPUT FROM 7150
400 GOSUB 290: REM CHANGE I/O TO IEEE
410 PRINT "RD";ZT$;
420 INPUT " ";A$: REM INPUT FROM IEEE
430 PRINT CHR$(4);"PR#0": REM I/O TO VDU & KBD
440 PRINT CHR$(4);"IN#0"
450 RETURN
```

Type RUN to start the program.
Press RESET to stop the program.

6.4.2 Listing Description

Line 20 clears the screen.

Lines 40 to 100 contain text which is presented on the display. The PRINT statement in lines 30, 50, 70, 90, and 110 give spaces between the lines of text.

Lines 130 causes all output data to be sent to slot 3 and switches the Input/Output to the GP-IB interface.

Line 140 switches off the debug mode and stops echo onto the screen.

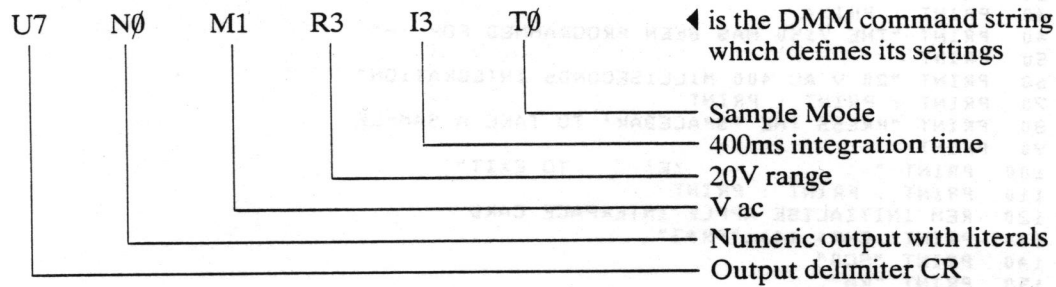
Line 150 puts the DMM into remote control.

Lines 150 to 152 define the DMM address, refer to para. 6.1.1.

Line 160 causes data to be sent to the VDU and switches I/O to the keyboard VDU.

Line 170 re-enables the APPLE to read from the keyboard.

Line 180 places the DMM command string in A\$.



Measurements can be made on a different range/mode by altering the command string, see the Instruction Set in Chapter 2 for other possible commands.

Line 190 obtains the input from the tabulated positions of line 18 and column 12 of the display.

Line 200 detects if 'E' (for exit) has been pressed. If so the program jumps to line 260 (which clears the screen) and 270 (which ends the program).

Line 210 detects if the key pressed was not the SPACEBAR, i.e. an invalid key. If an invalid key was pressed the program returns to line 190 in readiness for the next key to be pressed.

Line 220 enters G, the sample command, into A\$. (The SPACEBAR will have been pressed for the program to have reached this line.) The program will then gosub to line 340 and line 290.

Line 240 sets up the vertical and horizontal cursors and causes the DMM measurement to be printed.

Line 250 returns the program to line 190 in readiness for the next measurement command (press SPACEBAR) or exit command (Press E).

Lines 290 and 300 change vectors in order to re-direct the Input/Output to the GP-IB card which is assumed to be in slot 3 (hence the '+3' part in the statement).

Line 310 re-links the operating system.

Line 320 causes the program to return to line 350.

Line 350 causes the G command to be sent to the GP-IB interface.
PRINT "WT" causes a string to be output.
ZL\$ is the listen address of the DMM as defined in line 151.
A\$ contains the G command.

Line 360 causes the data to be sent to the VDU and returns Input/Output to the VDU and Keyboard.

Line 370 re-enables the APPLE to read from the keyboard.

Line 380 causes the program to return to line 230 and then gosub to line 400.

Line 410 prepares the Interface card (in slot 3) to read from talk address ZT\$ as defined in line 152.

Line 420 causes the input from the Interface card (i.e. the DMM results) to be read into A\$.

Line 430 causes data to be sent to the VDU.

Line 440 re-enables the APPLE to read from the keyboard.

Line 450 causes the program to return to line 240.

6.5 NULLING A GIVEN RANGE/MODE

This program will set up the DMM as follows:

Mode : $k\Omega$ (M2)
Range : $20k\Omega$ (R3)
Sample : (T \emptyset)

A null will be taken on the $20k\Omega$ resistance range/mode; the null value will be stored in the DMM but will not be presented on the APPLE value.

6.5.1 Program Listing

```
10 ADDR = 13 : REM 7150 ADDRESS
20 ZL$ = CHR$ (ADDR + 32) + CHR$ (26)
30 ZT$ = CHR$ (ADDR + 64) + CHR$ (26)
40 PRINT CHR$ (4); "PR#3"
50 PRINT CHR$ (4); "IN#3"
60 PRINT "SCO"
70 PRINT "RA"
80 PRINT "WT"; ZL$; Z$; "U7N0M2R3T0"
90 PRINT "WT"; ZL$; Z$; "Z1"
100 PRINT "WT"; ZL$; Z$; "Z?"
110 PRINT "RD"; ZT$; Z$
120 INPUT A$
130 PRINT CHR$ (4); "PR#0"
140 PRINT CHR$ (4); "IN#0"
150 END
```

Type RUN to start the program.

Press RESET to stop the program.

6.5.2 Listing Description

Lines 10 to 30 define the DMM address, refer to para. 6.1.1.

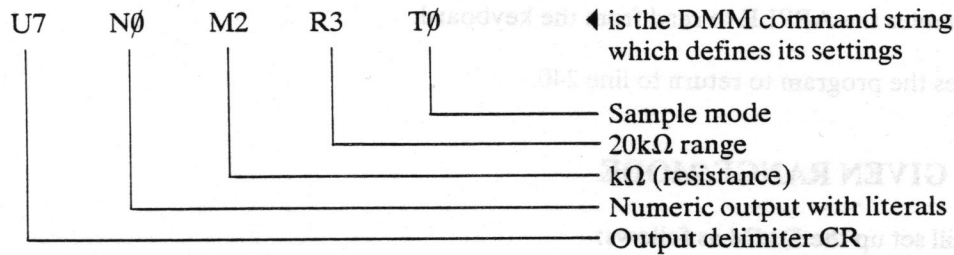
Line 40 causes all output data to be sent to slot 3.

Line 50 causes all input data to be sent to slot 3.

Line 60 switches off the debug mode and stops echo onto the screen.

Line 70 puts the DMM into remote control.

Line 80 causes a command string to be sent to the DMM.
 PRINT "WT" causes a string to be output
 ZL\$ is the listen address of the DMM as defined in line 20.
 Z\$ is the listen address terminator.



A different range/mode can be nulled by altering the command string see the Instruction Set in Chapter 2 for other possible commands.

Line 90 Z1 causes a new null to be taken.

Line 100 Z? requests the present state of Z to be sent back as verification that the particular range has been nulled.

PRINT "WT" ; ZL\$; Z\$; are as used in line 80.

Line 110 prepares the Interface card (in slot 3) to read from talk address ZT\$ as defined in line 20. Z\$ is the talk address terminator.

Line 120 causes results from the DMM to be shown on the VDU.

Line 130 causes data to be sent to the VDU.

Line 140 re-enables the APPLE to read from the keyboard.

6.6 USING DEVICE CLEAR

The program below sets up all of the DMM parameters to the power-up state, see 'Sending Commands to the DMM' in Part 2, Chapter 2. The standard IEEE command (CL) is used for Device Clear.

When the A command (DMM instruction set) is used for device clear it must be followed by a delay period of approximately two seconds.

A device clear command must not immediately follow a C1 (calibration mode) operation as this will induce a calibration error. Command C1 is followed by C0 (normal operating mode) and then the device clear command.

6.6.1 Program Listing

```

10 ADDR = 13: REM 7150 ADDRESS
20 ZL$ = CHR$(ADDR + 32) + CHR$(26)
30 ZT$ = CHR$(ADDR + 64) + CHR$(26)
40 PRINT CHR$(4); "PR#3"
50 PRINT CHR$(4); "IN#3"
60 PRINT "SC0"
70 PRINT "RA"
80 PRINT "CL"; ZL$
90 PRINT CHR$(4); "PR#0"
100 PRINT CHR$(4); "IN#0"
110 END

```

Type RUN to start the program.
 Press RESET to stop the program.

6.6.2 Listing Description

- Lines 10 to 30** define the DMM address, refer to para. 6.1.1
- Line 40** causes all output data to be sent to slot 3.
- Line 50** causes all input data to be sent to slot 3.
- Line 60** switches off the debug mode and stops echo onto the screen.
- Line 70** puts the DMM into remote control.
- Line 80** causes a Device Clear command to be sent to the DMM.
'CL' is the IEEE Device Clear command as used on the APPLE IEEE interface card.
ZL\$ is the listen address of the DMM as defined in line 20.
- Line 90** causes data to be sent to the VDU.
- Line 100** re-enables the APPLE to read from the keyboard.

Chapter 7 Calibration via the GP-IB

<i>Para</i>	<i>Title</i>	<i>Page</i>
7.1	GENERAL	7.2
7.2	PRELIMINARIES	7.2
7.3	CALIBRATION PROCEDURE	7.2
7.3.1	Memory Research	7.4
7.3.2	Exit Calibration Mode	7.4

7.1 GENERAL

The 7150plus DMM may be calibrated via the GP-IB interface.

Calibration of the DMM by this method involves the use of a controller rather than of the front panel controls. The principle used to derive calibration constants however remains the same as that described in Part 1, Chapter 5, 'Front Panel Calibration'.

7.2 PRELIMINARIES

The following equipment will be required to calibrate the DMM via the GP-IB:

Standards (for ac/dc voltage, ac/dc current, resistance).

Controller (IEEE 488/GP-IB compatible).

Calibration Enable Jack-plug (with remote switch if required).

The DMM address switch on the rear panel should be set as indicated below:

ADDRESS 1,2,4,8,16 : As required (0 to 30)
LISTEN ONLY : OFF
TALK ONLY : OFF
GP-IB ON : ON

7.3 CALIBRATION PROCEDURE

To calibrate the DMM:

1. With the DMM switched on, insert the calibration plug into the CAL socket on the rear panel. The CAL annunciator will flash indicating that the calibration mode is enabled.

Note: The jack-plug should be shorted before use. Alternatively, the plug may be inserted and the contacts closed remotely, via a switch connected to the plug.

2. Send "C1" command to enter calibration mode. (Error code 08 on the display would indicate that no calibration plug is fitted). The CAL annunciator should appear in the display.

With the DMM in the calibration mode, the following conditions apply:

- a. The Z (null) command cannot be used.
- b. Commands H (high ref.) L (low ref.) W (write constants) and O (memory refresh) become available for use.

3. Send commands M (measurement mode) and R (range) for the particular mode and range to be calibrated.

eg, for Vdc, 2V, send "M0R2"

The DMM must now be supplied with two reference inputs. One input, usually the nominal full scale value of a range, is known as the 'high' reference. The other, at zero, the 'low' reference. In the case of Iac and Vac, the low reference value should not be less than 10% of nominal full scale rather than zero.

After a reference input is applied, the DMM must be informed of its precise value. This is achieved using the H command for the high reference and L for the low reference. These commands, which may be sent in any order, must be accompanied by an integer (argument) of up to six digits in length, which expresses the applied input in terms of a 5-digits count. This may be calculated using the formula below.

H or L integer to be entered = applied input $\times 10^{(7-R)}$
where R = commanded range number (1 to 6)

eg, for a 2V input on the 2V range, enter 200000
for a 0.3V input on the 200V range, enter 000300

4. Apply the high reference input to the DMM for the particular mode/range.

eg, 2.00000V on 2Vdc range.

5. Using the controller, send the H command to the DMM.

eg, H200000

The DMM will respond by displaying '*Hi Pt*' for approximately 1½ seconds, during which time it will measure the applied reference input. When finished, the DMM will display and output its measured count. The result may differ from the applied input; this is quite normal.

6. Apply the low reference input to the DMM, eg, 0V short circuit for non-ac ranges.

7. Using the controller, send the L command to the DMM.

eg, LO (leading zeros need not be specified).

The DMM will respond by displaying '*Lo Pt*' for approx 1½ seconds, during which time it will measure the applied reference input. When finished, the DMM will display and output the measured count. The result may differ from the applied input; this is quite normal.

8. Having specified high and low reference points (which may be repeated if necessary) send the command W to the DMM. The W command, which has no argument, causes the DMM to compute and store the appropriate values of calibration constants for the mode/range selected. The display will show the message '*Good*' on successful completion of a W command. If W is not successfully completed, an error message will be displayed and output to the controller.

9. Repeat instructions 1 to 8 for each range to be calibrated.

7.3.1 Memory Refresh

If only a partial calibration has been carried out (ie, not all ranges calibrated) it is essential to execute a memory refresh before exiting from calibration mode. This causes all calibration constants held in memory to be read and re-written.

To refresh:

1. Send the command O via the controller to re-write calibration constants.

7.3.2 Exit Calibration Mode

Once the required ranges have been calibrated/refreshed, the DMM may exit calibration mode as follows:

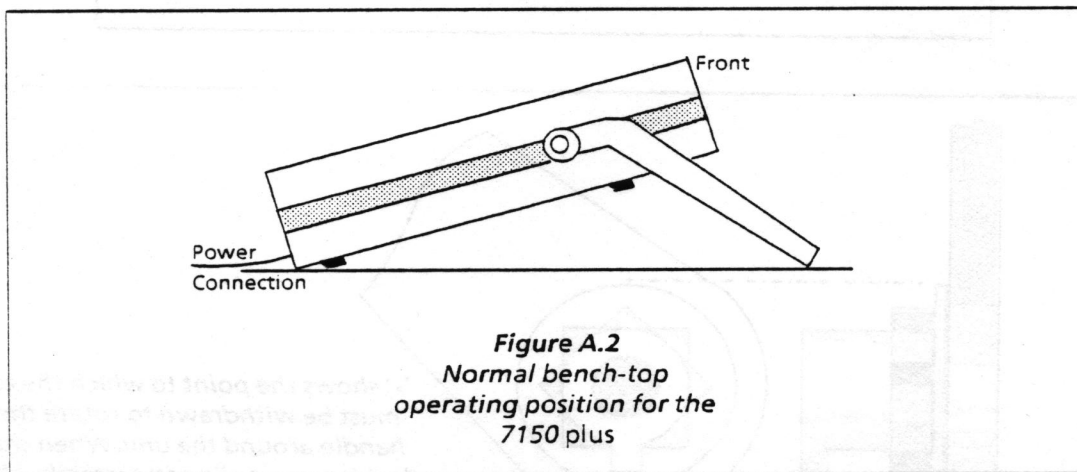
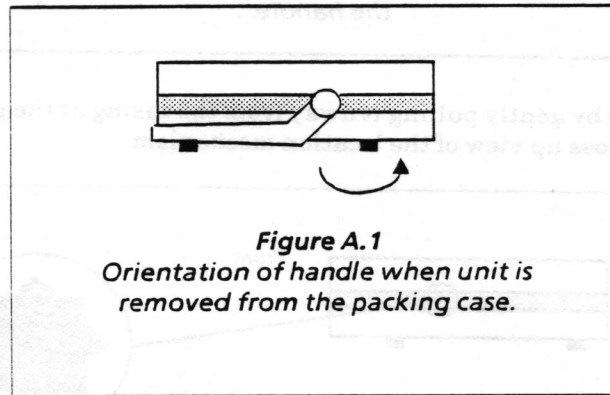
1. Send the command CO via the controller. The DMM will exit calibration mode and the CAL annunciator will flash, warning that the calibration jack-plug is still in position.
2. Remove the jack-plug. The flashing CAL annunciator will now no longer be visible.

The DMM is now ready for use.

Appendix A

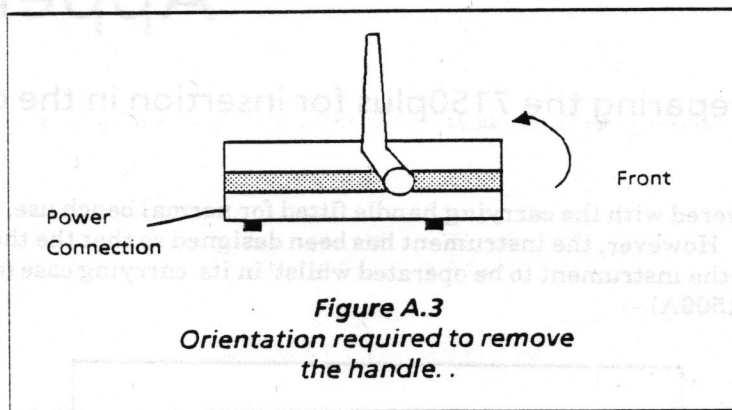
Preparing the 7150plus for insertion in the carrying case.

The 7150 plus is delivered with the carrying handle fitted for normal bench use, as shown in Figures A.1 and A.2. However, the instrument has been designed so that the the handle can be repositioned to allow the instrument to be operated whilst in its carrying case (optional accessory, Part No 71509A).-

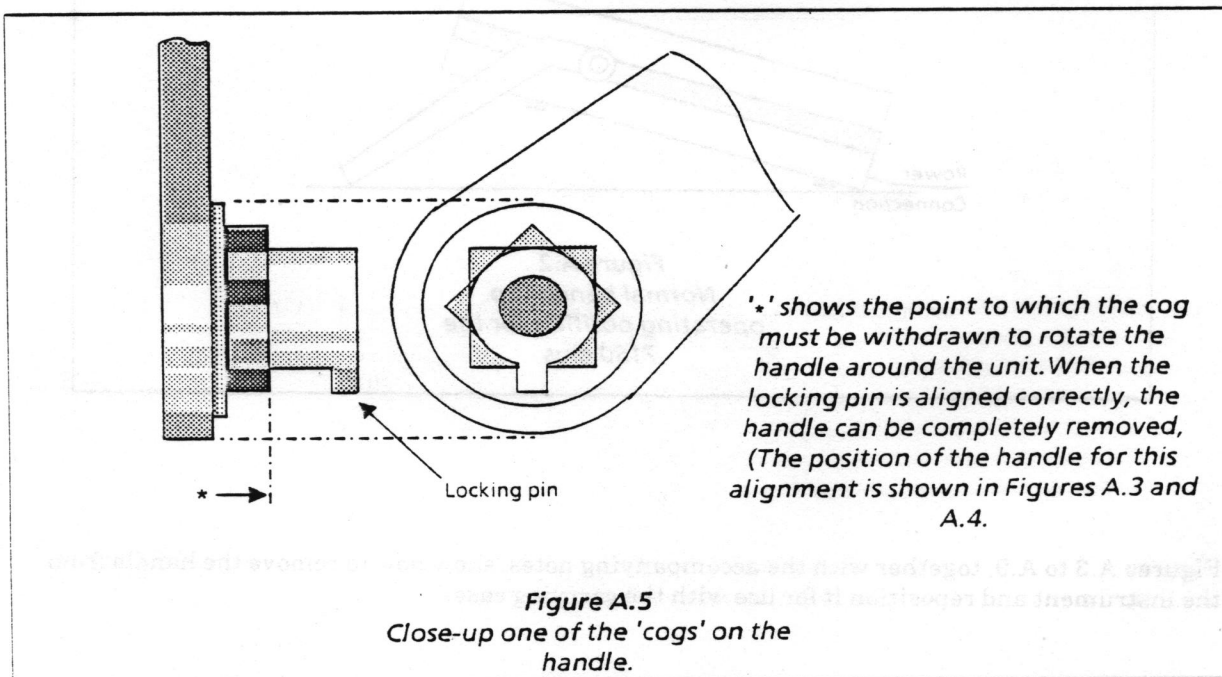
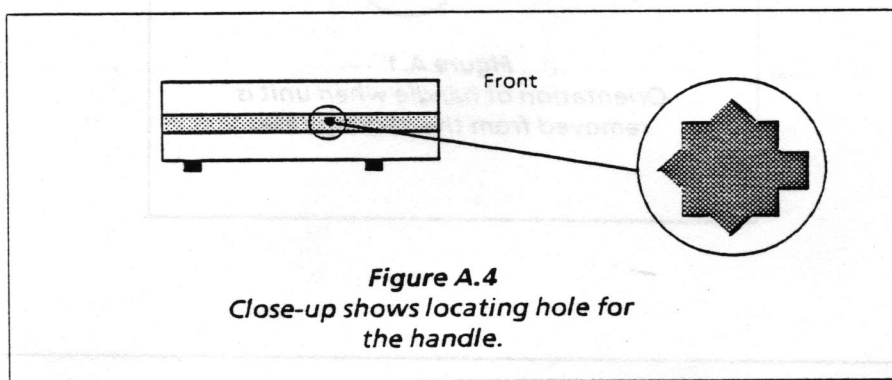


Figures A.3 to A.9, together with the accompanying notes, show how to remove the handle from the instrument and reposition it for use with the carrying case.

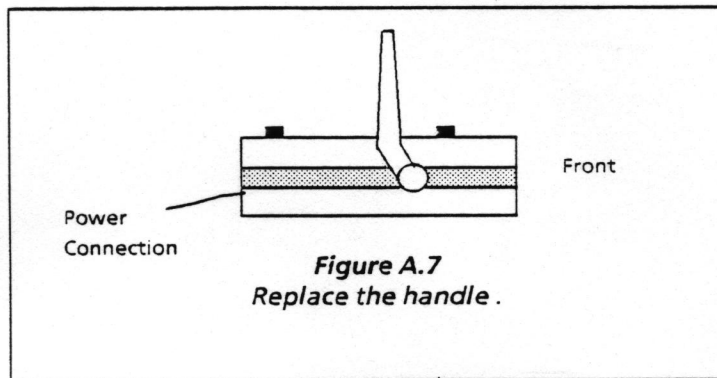
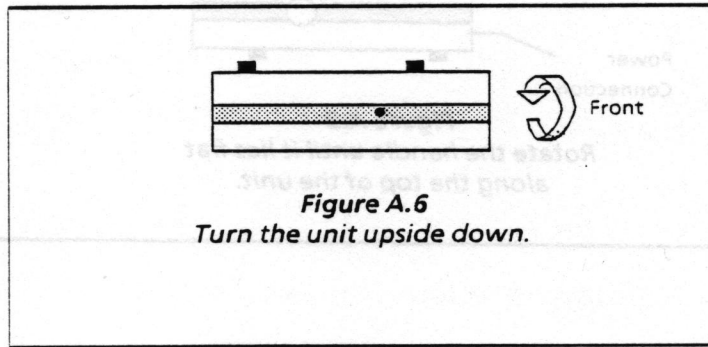
1. Rotate the handle to the position shown in Figure A.3.



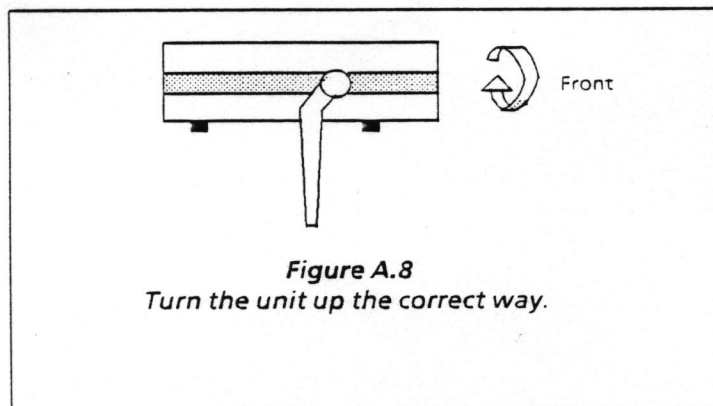
2. Remove the handle by gently pulling it away from the casing at the pivot point. Figures A.4 and A.5 show close up view of the location mechanism.

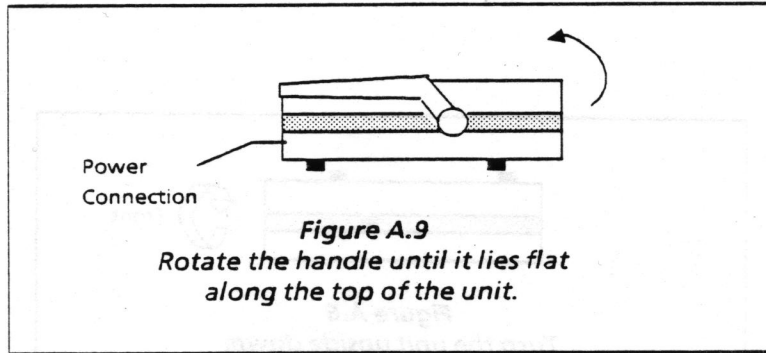


3. Turn the unit upside down and replace the handle with the same orientation as it had when it was removed, as shown in Figures A.6, and A.7.



4. Turn the unit the correct way up and rotate the handle through 270° so that the handle lies flush with the casing., see Figures A 8 and A.9.





5. The unit may now be placed in the carrying case and the power supply connected through the aperture in the rear of the carrying case.

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