REMOTE CONTROL INTERFACES

FOR

DO5000 SERIES

DIGITAL MICROHMMETERS

USER MANUAL

Issue 7.0

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MANUAL HISTORY

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Includes minor variations for the DO5003 model.

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Includes Settling Algorithm for inductive measurement.
Includes MEDIUM speed mode.
Includes adjustable Reference Temperature in Temperature Compensation mode.

CONTENTS

1. **INTRODUCTION**

Two different types of Remote Interface permit full remote control of the microhmmeter by an external computer using either the RS-232 serial interface or the IEEE-488 parallel interface. The measured value and instrument status can also be read by the computer.

The software commands are common to both interfaces and generally follow the IEEE488.2/SCPI format. Either or both interfaces can be fitted to the instrument, however, only one of these can be in use at any one time.

An additional interface can be fitted which permits more basic control of the microhmmeter by a Programmable Logic Controller (PLC) or similar device. The Analogue Output feature is also included on the PLC card.

Selection of the optional interfaces, together with additional features such as Baud Rate and addresses, are set from the front panel menu.

All interface connectors are accessible on the rear panel.

The RS-232 interface requires Ver 2.0 software, or higher.

The IEEE-488 interface requires Ver 3.0 software, or higher.

The PLC interface requires Ver 4.0 software, or higher.

2. **RS-232 SERIAL INTERFACE**

2.1 Connection

This conforms to specification ANSI/EIA/TIA-232-E-1991 "Interface Between Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange." A list of pin assignments is given in Appendix II.

| Signal levels; | MARK (logical "1"); | -3V to -15V |
| | SPACE (logical "0"); | +3V to +15V |

Data is transferred using the TXD and RXD lines.

Hardware handshaking for each character transfer uses the RTS and CTS lines.

RTS is an output from the microhmmeter which indicates its receiver status. When asserted (low) it indicates that it is ready to receive another character. When negated (high) the microhmmeter receiver buffer is full and cannot receive another character until the buffer is processed (if the PC sends one it may be lost). As soon as space becomes available in the receiver buffer, RTS is re-asserted to allow the PC to send the next character.

When the microhmmeter detects receipt of a line terminator character, RTS is negated whilst the command line buffer is read and validated. This is to prevent the PC sending further characters whilst a command is being validated. Following validation, RTS is re-asserted to permit the next command to be transmitted by the PC.

CTS is an input to the microhmmeter and controls the transmission of characters. If the PC asserts CTS (low) then the microhmmeter will transmit the next character from the output buffer (if one is waiting). If the PC negates CTS (high) then the microhmmeter will not transmit the character, but will wait until CTS is re-asserted. TXD will remain in the mark (low) condition whilst CTS is negated. Note that changing CTS during transmission of a character will not disrupt the transmission of that character.

If a 3-wire (TXD, RXD, GND) connection is to be used, connect RTS to CTS at the microhmmeter end. But take care; sending characters too quickly to the microhmmeter could cause its receiver buffer (4 characters) to overflow and subsequent characters may be lost. Always use a time delay between transmitted characters, or better still, use the full 5-wire connection for reliable hardware handshaking of each character.

It is recommended that Cropico cable assembly (Pt. No. 100031) be used for connecting the microhmmeter to a PC. This has the 5-wire connection and will maintain EMC integrity.

2.2 Front Panel Set-up

Press "MENU" on the front panel and select "Rem I/F". On the next menu, select "RS-232". A further menu allows selection of Talk Only mode and Baud Rate.

*If RS-232 option is not fitted, the warning message "** OPTION NOT AVAILABLE **" is displayed.*

Talk Only Mode

This mode is useful for sending results directly to a printer without the need for a PC.

Select "ON" to set the Talk Only mode. In this mode, the interface will ignore all incoming interface commands, and the instrument will remain in LOCAL control mode. The result of each measurement is sent to the interface output with the resolution as per the main display. If the Temperature Compensation is selected, then the compensated resistance will be sent. See section 4.1 for output data format.

Baud Rate

On selecting Baud Rate, the current setting is displayed. This defaults to 9600 following a RESET operation, and is the usual setting on shipment. If this is acceptable press "OK".

To change, press the up/down arrow keys until the required rate is displayed.

Valid rates are 75, 110, 150, 300, 600, 1200, 2400, 4800, 9600 & 19200 Baud.

These set the Baud rate for both transmit and receive.

The data word format is fixed at;

Start bit;	1
Data word length;	8 bits
Parity checking;	None
Stop bit;	1

Software handshaking using XON/XOFF is not implemented.

2.3 Communicating

In order to communicate with the DO5000 using RS-232, the command "SYSTem:REMote" must first be sent (see "RS-232 Interface Commands").

3. <u>IEEE-488 PARALLEL INTERFACE</u>

3.1 <u>Connection</u>

This conforms to specification ANSI/IEEE Std 488.1-1987 "Digital Interface for Programmable Instrumentation." A list of pin assignments is given in Appendix III.

3.2 <u>Front Panel Set-up</u>

Press "MENU" on the front panel and select "Rem I/F". On the next menu, select "IEEE". A further menu allows selection of Talk Only mode or Address.

*If no IEEE card is fitted the warning message "** OPTION NOT AVAILABLE **" is displayed.*

<u>Talk Only Mode</u>

This mode is useful for sending results directly to a printer without the need for a PC.

Select "ON" to set the Talk Only mode. In this mode, the interface will ignore all incoming interface commands, and the instrument will remain in LOCAL control mode. The result of each measurement is sent to the interface output with the same resolution as the main display. If the Temperature Compensation is selected, then the compensated resistance will be sent. See section 4.1 for output data format.

<u>Addressable Mode</u>

On selecting Address ("Addr"), the current setting is displayed. This defaults to 8 following a RESET operation and is the usual setting on shipment. If this is acceptable press "OK".

To change the value, press "Chg" and enter the new address (0-31).

Addresses 0 to 30 are recognised as valid addresses for full bus communication.

Address 31 is used to isolate an instrument from the bus without the need to disconnect it physically.

3.3 <u>Interface Functions</u>

The interface performs the following functions;

 SH1, AH1, T5, TE0, L3, LE0, SR1, RL1, PP0, DC1, DT1, C0, E2

These have the following meanings;

SH1   Source Handshake
      The device can send multiline messages.

AH1   Acceptor Handshake
      The device can receive multiline messages.

T5   Talker Capability
      The device; can act as a basic talker
                ; can respond to a serial poll
                ; can perform a talk only mode
                ; unaddresses if MLA sent

TE0   Extended Talker Capability
      Extended talker addressing is not implemented.

L3   Listener Capability
      The device; can act as a basic listener
                ; can be set to listen only mode
                ; becomes unaddressed if MTA sent

LE0   Extended Listener Capability
      Extended listener addressing is not implemented

SR1   Service Request Function
      The device can asynchronously assert the SRQ line to request the attention of
      the system controller.

RL1   Remote/Local Function
      The device has full remote/local switching capability. There is no manual
      switch on the instrument.

PP0   Parallel Poll Function
      The parallel poll function is not implemented.

DC1   Device Clear Function
      The device may be set to the default state by the appropriate command, and
      includes a selective device clear.

DT1   Device Trigger Function
      The device may be triggered by the appropriate commands.

C0   Controller Function
      The controller function is not implemented, and hence the instrument cannot
      behave as a system controller. Talk Only mode is available for minimal bus
      use.

E2   Driver Electronics
      All lines are tri-state outputs except SRQ, NRFD and NDAC which are open-
      collector.

3.4   Single Wire Interface Messages

The IEEE bus consists of 8 data lines, 5 General Interface Management Lines and 3
Handshake lines.

The 3 Handshake lines are;

DAV   Data Valid
      Asserted by the talker to indicate that data has been put onto the data bus.

NRFD Not Ready For Data
      Asserted by the listener to indicate that it is busy and is not ready to receive
      data.

NDAC Not Data Accepted
      Negated by the listener to confirm receipt of a data byte.

The 5 General Interface Management Lines are;

REN   Remote Enable
This is used only by the System Controller to enable devices to be subsequently placed in the remote programming mode. When true, all listeners capable of remote operation are placed in remote when addressed to listen. When false, all devices return to local operation. All devices capable of both remote and local operation must monitor REN at all times. Devices must respond to REN within 100uS.

The REN command is the only command that will put the instrument into remote mode. The front-panel keys are disabled, and the 'Rem' legend appears on the display. The 'Lstn' and 'Talk' legends indicate when the instrument is addressed.

The instrument may be returned to local operation by sending the GTL command while the instrument is addressed to listen.

IFC   Interface Clear
This is used only by the System Controller to halt current operations (communications) on the bus (i.e. unaddress all talkers and listeners and disable Serial Poll - the idle state). All devices must monitor IFC at all times and respond within 100uS (minimum pulse width for IFC).

EOI   End Or Identify
When ATN is true the EOI line is used by a controller to execute a parallel poll. When ATN is false, the EOI line is used by an active talker to indicate the last byte of a data message.

SRQ   Service Request
This is used by one or more devices to indicate the need for attention and can act as an interruption of the current sequence of events. Typically SRQ indicates data is ready to transmit and/or an error condition (e.g. syntax error, overload, trigger too fast etc.) exists. The controller can mask the SRQ interrupt and must perform a Serial Poll of devices (when there is more than one) to determine who requested service and why.

ATN   Attention
All devices must monitor ATN at all times and respond to it within 200nS. When true ATN places the interface in the Command Mode where all devices accept (handshake) data on the DIO lines and interpret it as it Commands (see Multi-wire Interface Messages below). When false ATN places the interface in the Data Mode where the active talker sources device dependent Data to all active listeners. Addresses are sent over the bus during the Command Mode.

3.5 Multiwire Interface Messages (ATN True)

Data transferred on the DIO lines while the controller asserts the ATN line (low) are bus management commands and device addressing information. This is known as Command Mode.

GTL   Go To Local
This causes the addressed listener to return to local panel control (exit the REMOTE state). The device will return to remote when REN is sent again.

SDC   Selective Device Clear
This causes the addressed listener to reset to a device-dependent state. This is the same as DCL (Device Clear) but only affects the addressed device.

PPC   Parallel Poll Configure
Parallel Poll is not implemented. This command is ignored.

GET   Group Execute Trigger
This causes all devices which have the GET capability and are currently addressed to listen to initiate a pre-programmed action (e.g. trigger, take a sweep etc.). Some devices may also recognise a device-dependent data character or string for this function (equivalent but requires entry into Data Mode).

Sending either GET or *TRG will make the microhmmeter perform the INITiate command and take a measurement. The command must be sent as a single message. Sending either GET or *TRG within a command string will result in a 'command error' and the trigger will be ignored.

TCT   Take Control
This instructs the addressed device to become the bus controller. The microhmmeter is not capable of this function. The command is ignored.

LLO   Local Lockout
This disables return-to-local control (push button) on devices that recognise the command. Recognising devices accept the command whether they are addressed or not. REN must be set false to re-enable the push button, this also replaces all devices under local control. The microhmmeter does not have a manual "local" button, so this command is equivalent to the single-wire REN function.

DCL   Device Clear
This command causes all recognising devices to return to a pre-defined device-dependent state. Recognising devices respond whether they are addressed or not.

The effect of DCL is as follows:

- The parser is reset to await a new command.
- The output queue is flushed.
- The instrument is put into the Operation Complete Command Idle State and the Operation Complete Query Idle State.

PPU   Parallel Poll Unconfigure
Parallel Poll is not implemented. This command is ignored.

SPE   Serial Poll Enable
This establishes serial poll mode for all responding talker devices on the bus. When they are addressed to talk, each responding device will return a single 8-bit byte of status from each device. Devices which recognise this command must have Talker interface capabilities to allow the device to output the status-byte.

SPD   Serial Poll Disable
This terminates serial poll mode for all responding devices, returning the devices to their normal talker state when they output device-dependent data rather than status information.

MLA   My Listen Address
This is sent by a controller to indicate to all other bus devices that it has become a listener.

UNL   Unlisten
This unaddresses all current listeners on the bus. Single listeners cannot be unaddressed without unaddressing all listeners. It is necessary that this command be used to guarantee that only desired listeners are addressed. The 'Lstn' legend is turned off. (Device address 31 is illegal and is the address sent by UNL to unaddress the device).

MTA   My Talk Address
This is sent by a controller to indicate that it will be the talker from now on. All other bus devices must "un-talk" on receiving this command.

UNT   Untalk
This unaddresses the current talker. Sending an unused talk address would accomplish the same thing. This command is provided for convenience since addressing one talker automatically unaddresses another. (Device address 31 is illegal and is the address sent by UNT to unaddress the device). The 'Talk' legend is turned off.

PPE   Parallel Poll Enable
Parallel Poll is not implemented. This command is ignored.

PPD   Parallel Poll Disable
Parallel Poll is not implemented. This command is ignored.

3.6 Device Dependent Messages (ATN False)

Data transferred on the DIO lines while the controller negates the ATN line (high) are Device Dependent Messages. This is known as Data Mode. These messages are described fully in Section 4.

3.7 Serial Poll

A Serial Poll is a sequence which enables the controller to learn if a device or group of devices requires service and/or determine multi bit status of devices on the interface.

Devices which can be Serial Polled will return a Status Byte (requires Talker subset) to the controller to indicate their status under program control. The controller sequentially polls each individual device on the interface (sends a SPE if IFC is false and sequentially addresses devices to talk) and evaluates each status byte in turn. Therefore, this procedure can be lengthy in larger systems, but does provide the nature of the request at the same time as the identity of the requestor.

It is advisable, though not mandatory, to poll every device to be sure to find every requestor and also to send Serial Poll Disable (SPD) and Untalk (UNT) at the end of the procedure.

3.8 Parallel Poll

Parallel Poll is not implemented.

4. **PROGRAMMING THE RS-232 & IEEE INTERFACES**

4.1 Introduction

These interfaces are programmed in a common language which is based on SCPI (Standard Commands for Programmable Instruments). Although similar in style, full conformance to the SCPI and IEEE488.2 standards is not guaranteed.

The following is a brief guide to the structure and syntax of the programming language.

Command Tree

Commands are arranged as a hierarchical "tree", similar to the filing system trees found in personal computers. Commands start at the root level and progress down each level in more detail. The complete path must be specified to access the lower level commands.

Colon (:)

The colon is used to separate command keywords and automatically move the path down to the next level.

All new command lines automatically start at the root-level.

For the microhmmeter, a colon must not be sent as the first character. This is treated as a non-recognised character and the 'command error' bit (5) of the Standard Event Register is set.

Semicolon (;)

The semicolon is also used to separate command keywords, but in this case the path remains at the same level. This is to enable more than one command to be included in a single command line.

This is not implemented for the microhmmeter as only one command per line can be accepted. The semicolon is treated as a non-recognised character and the 'command error' bit (5) of the Standard Event Register is set.

Whitespace (TAB or SPACE)

A whitespace character must be used to separate the first parameter from a command keyword. If omitted, the 'command error' bit (5) of the Standard Event Register is set.

The microhmmeter will not accept whitespace characters in the subsequent parameter list. These will set the 'command error' bit (5) of the Standard Event Register.

Comma (,)

If a command requires multiple parameters, a comma must be used to separate parameters from one another in the parameter list.

<u>Query (?)</u>

Commands ending in a query (?) indicate that a response is expected from the instrument. This is usually a measured value or status message. Commands sent without a query instruct the instrument to perform a function. The instrument will not output a response without a query command (except in Talk Only mode).

<u>Common Commands (*)</u>

Commands beginning with a "*" are called common commands and have a precise function as defined by the IEEE-488.2 standard. All instruments behave in an identical way. These commands are primarily concerned with control, reset, self-test and status.

<u>Command Syntax</u>

Most command keywords have both a long and short form. The bus controller can send commands in either form and also in any combination of upper and lower case characters. Instrument responses, however, are always in the short form, upper case.

If extra, redundant parameters are sent in a parameter list they are simply ignored. No error is produced.

> <u>e.g.</u>   SENSe:FRESistance:RANGe 30OHM,300OHM
> {ignored}

In the description of commands that follows, various symbols are used for different features:

> < *parameter* >   represents a field name.
>
> < ON|OFF >   the vertical bar indicates OR
>
> [optional]   square brackets indicate optional commands or parameters.
>
> "string"   indicates an ASCII text string.

<u>Data Types</u>

The bus controller can also send data in a range of formats, but the instrument always responds in a precise format. There are four principal data types;

Numeric Parameters are decimal numbers which include an optional sign, mantissa, decimal point and exponent. Engineering suffix units are not accepted.

Discrete Parameters have limited values e.g. SINGle, INFinite, and like command keywords they can have long and short forms, upper and lower case.

Boolean Parameters have a single binary value. The controller can send OFF or 0, ON or 1, but the instrument response is always 0 or 1.

String Parameters contain ASCII characters which are placed between a pair of double quotation marks, i.e. "   ".

<u>Input Data Format</u>

Numeric data sent to the instrument should be in Ohms or degrees unless stated otherwise. The value can be in any standard scientific format.

<u>e.g.</u>   3KOHM can be sent as: 3000, 3E3, 3.000E3, 0.3E4 etc.

The units are not sent.

<u>Output Data Format</u>

Non- Measurement queries   ASCII character string

Measurement queries   IEEE   SDDDD.DDDESDD <lf>
                                RS-232   SDDDD.DDDESDD <cr><lf>

Where   S = sign (+/-)
                                D = decimal digit (0-9)
                                E = Exponential
                            <cr> = carriage return character
                            <lf> = linefeed character

Note: In IEEE mode the EOI line is also asserted with the transmission of the <lf> terminator.

Measurement queries always return values expressed in Ohms or Degrees, but the units are omitted. Resistance values are returned with engineering exponents reflecting the resolution and units displayed on the LCD screen.

<u>e.g.</u>   <u>Display</u>   <u>Returned Value</u>

        30.321 Ω 30.321   (30Ω range)
        29.657 KΩ 29.657E+3   (30KΩ range)
        106.45 mΩ 106.45E-3   (200mΩ range)

If a query (?) command results in a "command" or "execution" error, the error value +9.90E+37 is sent to the output buffer.

<u>Input Message Terminators</u>

In RS-232 mode, all messages sent to the instrument must terminate with either a <lf> character or a <cr> character. It is also permitted to send both <cr><lf> to terminate a message; the <lf> is ignored.

For IEEE-488 mode, messages can be terminated in one of two ways;

        - by sending a <lf> character at the end of the message
        - by asserting the EOI line with the last character sent

It is also permitted to combine these, and assert EOI when sending the <lf> character.

Message termination always forces the command path back to the root-level ready for the next command message.

The instrument receives messages into an input buffer and only starts executing commands after receipt of a message terminator. The buffer can store up to 100 characters including separators and terminator.

Sending a new command before the existing command is executed may cause unreliable operation. It is advisable to query the Status Byte (*STB?) to check on the current status of the microhmmeter before sending a new command.

Sending a command whilst the microhmmeter is transmitting (following a ? command) may result in the transmitted response being corrupted. It is advisable to wait for the expected response to be transmitted before sending a new command.

4.2 RS-232 Interface Commands

SYSTem:LOCal
> Returns the instrument to the local mode from RS-232 operation. All keys on the front panel are fully functional. This is the default at power-up.

SYSTem:REMote
> Places the instrument in the remote mode for RS-232 operation. All keys on the front panel are disabled.

> *These commands will produce a "command error" in IEEE mode. The commands are ignored.*

4.3 Configuration & Measurement Commands

Configuration Group

These commands allow the measurement configuration to be set up, but they do not trigger a measurement.

SENSe:FRESistance:RANGe *<range>*
> Sets the resistance measurement according to the following parameters. The current measurement is aborted.

DO5000 & DO5001:

<range>		
	3MOHM	(3 mOhm)
	30MOHM	(30 mOhm)
	200MOHM	(200 mOhm)
	3OHM	(3 Ohm)
	30OHM	(30 Ohm)
	300OHM	(300 Ohm)
	3KOHM	(3 KOhm)
	30KOHM	(30 KOhm)
	AUTO1	(Autorange1 - top range first)
	AUTO2	(Autorange2 - last-used range first)

DO5002:

<range>		
	300MOHM	(300 mOhm)
	3OHM	(3 Ohm)
	30OHM	(30 Ohm)
	300OHM	(300 Ohm)
	3KOHM	(3 KOhm)
	30KOHM	(30 KOhm)
	AUTO1	(Autorange1 - top range first)
	AUTO2	(Autorange2 - last-used range first)

DO5003:

<range>	3OHM	(3 Ohm)
	30OHM	(30 Ohm)
	300OHM	(300 Ohm)
	3KOHM	(3 KOhm)
	30KOHM	(30 KOhm)
	AUTO1	(Autorange1 - top range first)
	AUTO2	(Autorange2 - last-used range first)

AUTO1 and AUTO2 are not available if Open Circuit Limiting is enabled. The 3KOHM and 30KOHM ranges are also not available if Open Circuit Limiting is enabled.

Sending these commands in these conditions will generate an "execution error". The command will be ignored and the microhmmeter will remain in the original range.

SENSe:FRESistance:RANGe?

Returns the resistance range currently in force, together with the Autorange mode. The response is an ASCII string containing the appropriate parameter values as above. The current measurement is not affected.

The response is an ASCII string of the form:

"*< range >*, *< auto mode >*"

where,   range   = 3MOHM to 30KOHM (as in tables above)
            auto mode = AUTO OFF, AUTO1, AUTO2

SENSe:FRESistance:MODE <SLOW|MED|FAST>

Sets the measurement mode. Slow mode produces approximately two readings per second, gives the best noise immunity, and all features are available. Medium mode gives a 1.5x to 2x improvement in speed. Fast mode can produce up to 50 readings per second, but some features are not available:

Average Current Mode: Forced to +I mode
Temperature Compensation: Forced OFF
Settling Algorithm: Forced OFF

SENSe:FRESistance:MODE?

Returns the measurement mode currently in force. The response is an ASCII string: "SLOW", "MED" or "FAST".

SOURce:CURRent *<magnitude>,<current-mode>*

Sets the measuring current magnitude and mode according to the following parameters. The current measurement is aborted.

<magnitude>	10 - 100	(%)
<current mode>	+I, -I, AVE	

AVE current mode is not available in FAST mode. Sending this command will generate an "execution error". The command is ignored and the microhmmeter will remain in the original current mode. The Settling Algorithm will be set to OFF if AVE current mode is selected.

For the DO5003 model, which has fixed current, a magnitude of 10 - 100 must be entered, but will be ignored.

SOURce:CURRent?

Returns the measuring current magnitude and mode currently in force. The response is of the following form:

<magnitude>,<"current mode">

containing the appropriate parameter values as above. The current measurement is not affected.

Trigger & Measure Group

These commands trigger measurements, and allow the results to be output to the bus.

INITiate

This initiates single measurements. The Measurement Available bit (8) of the Operation Condition Register is set on completion. The reading is stored internally and is not sent to the output buffer. Use FETCh? to transfer the value to the output buffer and clear the Measurement Available bit.

This command is not available when the CONTinuous triggering mode is on, nor when DATAlogging mode is on, in which cases, an "execution error" will occur.

*TRG

This is identical to the INITiate command

FETCh[:FRESistance|:TEMPerature|:TCOMpensate]?

Returns the value of the last measurement made. This is normally used in conjunction with the INITiate command. If CONTinuous triggering is "off", then INITiate followed by FETCh? will be needed for each measurement. If CONTinuous triggering is "on", then repeated FETCh? commands can be made to return the most recent measurement.

One of three optional functions can be included with this command:

FRESistance - Returns the uncompensated resistance and is the default for the first FETCh?

TEMPerature - Returns the temperature value of the external Pt100 probe, providing that temperature compensation is "ON" and set to "EXT" mode. Otherwise, an "execution error" is generated and the error value is returned.

TCOMpensate - Returns the compensated resistance value at the reference temperature, providing that temperature compensation is "ON". Otherwise, an "execution error" is generated and the error value is returned.

If no function is subsequently entered, then the function used in the previous FETCh? or READ? command is used.

INITiate:CONTinuous <ON|OFF> or <1|0>

Setting to OFF means that any subsequent READ?, or INIT followed by FETCh?, will take one reading and send it to the output buffer.

If set to ON, the microhmmeter will perform continuous measurements, which will be initiated immediately, and FETCh? will send the most recent value to the output buffer. The measurements can be stopped by setting CONTinuous to OFF.

(For the DO5001 model operating on battery power, continuous mode is not available, and INITiate:CONTinuous ON will cause an "execution error" to be generated).

INITiate:CONTinuous?
> Returns "0" (OFF) or "1" (ON).

READ[:FRESistance|:TEMPerature|:TCOMpensate]?
> Triggers and returns a measurement. It is identical to INITiate, followed by FETCh?. See the FETCh? command above, for use of additional functions.
>
> *This command is not available when the CONTinuous triggering mode is "on", nor when DATAlogging mode is "on", in which cases, an "execution error" will be generated and the error value returned.*

ABORt
> Stops the current measurement and clears the input and output buffers.
>
> *ABORt works for RS-232 only. If sent in IEEE-488 mode, it will generate a "command error".*

4.4 Data Operation Commands

DATAlogger Group

These commands store and retrieve measurement values using the data logging memory. This memory is non-volatile and can store up to 4000 readings. When the datalog mode is enabled, triggering is controlled by the special DATAlogger commands.

*The usual READ?, INITiate and *TRG commands are not available and will generate an "execution error".*

DATAlogger:CLEAr
> Clears the datalog memory. Take care; all the current stored values will be lost!

DATAlogger:COUNt <*No. of readings*>
> Sets the maximum number of readings to be stored. Valid range is 1 to 4000.

DATAlogger:COUNt?
> Returns the maximum number of readings to be stored.

DATAlogger:STATe <ON|OFF> or <1|0>
> Enables or disables the datalog function. When turned on, triggering is controlled by STARt, STOP and STEP, and all readings are sent to the datalog memory.

DATAlogger:STATe?
> Returns "0" (OFF) or "1" (ON).

DATAlogger:STARt
> Forces the continuous measuring mode, with all readings being sent to the datalog memory. Readings are stored sequentially up to the value set by COUNt. To start the log at location 1, use CLEAr first.
>
> *If the log has reached the COUNt value, any further STARt commands will generate an "execution error", and the command will be ignored.*
>
> *(For the DO5001 model operating on battery power, continuous mode is not available, and DATAlogger:STARt will cause an "execution error" to be generated).*

DATAlogger:STOP
> Forces the microhmmeter to 'STOP' mode. The current measurement is aborted. If the log has not reached the COUNt value, STARt or STEP can be used to continue the log from this point.

DATAlogger:STEP
Forces a single measurement only, which is stored in the next datalog location. The microhmmeter then returns to single trigger mode.

If the log has reached the COUNt value, any further STEP commands will generate an 'execution error'. The command will be ignored, and the microhmmeter will remain in the single trigger mode.

DATAlogger:VALue? <*value number|ALL*>
Transfers a datalog reading from the memory to the output buffer. A value number of between 1 and POINts will output one reading from that location. If ALL is used, all readings are sent sequentially to the output buffer from location 1 to POINts. Sending ABORt will cancel the operation. The output format is:

<*record no.*>,<*"range"*>,<*resistance*>,<*"date"*>,<*"time"*>

The "range" will include the letter 'z' if the Zero function was used on a measurement, and the letter 'T' if Temperature Compensation was used.

DATAlogger:POINts?
Returns the number of readings actually stored in the datalog memory. The response will be between 0 and COUNt.

CALCulate:DATA Group

These commands perform statistical calculations on the current contents of the data log. A minimum of 2 readings must be stored otherwise an 'execution error' is generated, i.e. bit (4) of the Standard Event Register is set. This error is also generated if the log contains inconsistent entries, e.g. readings taken on different ranges.

CALCulate:DATA:MINimum?
Returns the minimum resistance value stored in the data log.

CALCulate:DATA:MAXimum?
Returns the maximum resistance value stored in the data log.

CALCulate:DATA:AVERage?
Returns the average of all resistance values stored in the data log.

CALCulate:DATA:PTPeak?
Returns the peak-to-peak value of the resistance values stored in the data log, i.e. max to min.

CALCulate:DATA:SDEViation?
Returns the standard deviation of the resistance values stored in the data log. This is effectively a measure of rms noise.

CALCulate:LIMit Group

These commands are used to set and query the lower and upper limit values used to test the measured resistance. Exceeding these limits is reported in the Questionable Data Register (bits 11 & 12).

CALCulate:LIMit:LOWer <*value*>
Sets the lower measurement limit. The value is in Ohms (0 - 30,000).

CALCulate:LIMit:LOWer?
Returns the lower measurement limit in Ohms.

CALCulate:LIMit:UPPer <*value*>
Sets the upper measurement limit. The value is in Ohms (0 - 30,000).

CALCulate:LIMit:UPPer?
　　Returns the upper measurement limit in Ohms.

CALCulate:LIMit:STATe <ON|OFF> or <1|0>
　　Enables or disables the measurement limit facility.

CALCulate:LIMit:STATe?
　　Returns "0" (OFF) or "1" (ON).

CALCulate:LIMit:ALARm <ON|OFF> or <1|0>
　　Enables or disables the 'failed limit' audible alarm.

CALCulate:LIMit:ALARm?
　　Returns "0" (OFF) or "1" (ON).

4.5 Other function Commands

Temperature Compensation Group

SENSe:TCOMpensate:STATe <ON|OFF> or <1|0>
　　Enables or disables the temperature compensation facility.

　　Temperature compensation is not available in FAST mode. Attempting to set the state "ON" will generate an "execution error".

SENSe:TCOMpensate:STATe?
　　Returns "0" (OFF) or "1" (ON).

SENSe:TCOMpensate:MODE <EXT> or <MAN,*manual temperature*>
　　Sets the temperature of the test-piece to either an external Pt100 probe measurement, or to a fixed, manually-entered temperature, the unit of which is the current temperature unit (°C or °F). Range is 0 - 100 °C (32 - 212°F)

SENSe:TCOMpensate:MODE?
　　Returns "EXT", or "MAN",*<manual temperature>*.

SENSe:TCOMpensate:REFerence *<temperature value>*
　　Sets the reference temperature. This is the temperature to which resistance measurements are compensated (normally 20°C). It is entered in the current temperature unit (°C or °F). Range is 0 - 50°C (32 - 122°F), in integer values of °C, or the °F equivalent.

SENSe:TCOMpensate:REFerence?
　　Returns the reference temperature in the current temperature unit.

SENSe:TCOMpensate:COEFficient <CU|AL>or <USER,*user coefficient*>
　　Sets the temperature coefficient to Copper, Aluminium or to a user-defined value, which is entered in ppm/°C (0 - 9999).

SENSe:TCOMpensate:COEFficient?
　　Returns "CU",<fixed copper coefficient>, or "AL",<fixed aluminium coefficient>, or "USER",<user coefficient>. The coefficients are quoted in ppm/°C.

UNIT:TEMPerature <C|CEL|F|FAR>
　　Sets the temperature unit to °Celsius or °Farenheit.

UNIT:TEMPerature?
　　Returns "CEL" or "FAR".

<u>Filter (Averaging) Group</u>

SENSe:AVERage:STATe <ON|OFF> or <1|0>
Enables or disables the filter (rolling average) facility.

SENSe:AVERage:STATe?
Returns "0" (OFF) or "1" (ON).

SENSe:AVERage:COUNt *<No. of readings>*
Sets the number of readings to be filtered or averaged (1 - 32).

SENSe:AVERage:COUNt?
Returns the number of readings to be filtered (averaged).

Selecting Filter on will automatically deselect the Settling facility.

<u>Settling Algorithm Group</u>

SENSe:SETTling:STATe <ON|OFF> or <1|0>
Enables or disables the Settling facility.

SENSe:SETTling:STATe?
Returns "0" (OFF) or "1" (ON).

SENSe:SETTling:COUNt *<No. of readings>*
Sets the maximum number of readings to be taken (2 - 999).

SENSe:SETTling:COUNt?
Returns the maximum number of readings selected.

SENSe:SETTling:LIMit *<No. of digits>*
Sets the maximum number of display digits by which two consecutive readings may differ, for the measurement to be defined as 'settled'.

SENSe:SETTling:LIMit?
Returns the maximum number of display digits selected.

Selecting the Settling facility will:
  Deselect the Filter facility.
  Change Average (AVE) Current mode to Positive (+I) Current mode.
  Cause an error message if in Fast mode.

Selecting Filter on, Average Current or Fast mode will automatically deselect the Settling facility.

<u>Open Circuit Voltage Limit Group</u>

SOURce:VOLTage:LIMit:LEVel <OFF|0|20|50>
Sets the open circuit limit to OFF, 20mV or 50mV.

Open Circuit Limits are not available if the 3KOHM or 30KOHM range is selected, and attempting to set 20mV or 50mV will generate an "execution error" and the command will be ignored.

Attempting to set 20mV or 50mV with AUTO1 or AUTO2 selected will be successful, but autorange mode will be turned off and the instrument forced to the current manual resistance range.

The DO5003 does not have this facility, and attempting to set it will generate an "execution error" and the command will be ignored.

SOURce:VOLTage:LIMit:LEVel?
    Returns "0" (OFF), "20" (20mV) or "50" (50mV).

    The DO5003 does not have this facility, and sending this query will generate a "query error".

4.6 System Related Commands

DISPlay:BRIGhtness <ON|OFF> or <1|0>
    Turns the front-panel display backlight on or off. Default at power-up is on.

DISPlay:BRIGhtness?
    Returns "0" (OFF) or "1" (ON).

SYSTem:BEEPer
    Issues a single beep immediately.

SYSTem:BEEPer:STATe <ON|OFF> or <1|0>
    Enables or disables the front-panel beeper.

SYSTem:BEEPer:STATe?
    Returns "0" (OFF) or "1" (ON).

SYSTem:VERSion?
    Queries the SCPI version to which the instrument conforms.

    The DO5000 is not compliant and returns the message "NOT SCPI COMPLIANT".

SYSTem:TIME <hh>,<mm>,<ss>
    Set the system clock time. Use 24 hour clock format.

SYSTem:TIME?
    Queries the system clock time. Returns "hh,mm,ss" in 24 hour clock format.

SYSTem:DATE <yyyy>,<mm>,<dd>
    Set the system calendar date.

SYSTem:DATE?
    Queries the system calendar date. Returns "yyyy,mm,dd".

*IDN?
    Read the instrument's identification string. This is of the form:

        "*<manufacturer>,<model no.>,<serial no.>,<software version>*"

    The serial no. field is not used.
                    e.g.   "Cropico,DO5000,0,Ver3.0"

*RST
    Clears all pending operations, and resets the instrument to the default RESET
    condition as described in the instrument user manual with two exceptions:

    1) No change is made to the remote interface parameters (interface type,
       baud rate and IEEE address).

    2) The trigger mode is set to SINGLE (INITiate:CONTinuous OFF).

    For IEEE only, this also resets the Operation Complete Command State and
    Operation Complete Query State (clears bit 0 of Standard Event Register).

The default conditions that are forced are:

Range:	30KOHM, AUTO1
Current:	100%, +I
Read Rate:	SLOW
Trigger Mode:	CONT:OFF (Single), STOP
Measurement Limits:	OFF, Alarm ON, Lower Limit = 0, Upper Limit = 30KΩ
Filter:	OFF, 10 readings
Settling Algorithm:	OFF, 10 readings, 10 digits limit
Open Circuit Limit:	OFF
Temp Compensation:	OFF, MAN, +20°C, Cu, USER = 3980, Ref Temp = +20°C
Data Logger:	OFF, Count = 10, Datalog Memory unchanged.
READ? or FETCh?:	Set to FRESistance.
Talk Only mode:	OFF
Analogue Output	OFF

All other functions and parameters are left unchanged by *RST.

*TST?
Always returns '0' to indicate self-test OK.

*WAI
This command is accepted by both interfaces, but ignored as all commands are executed sequentially. It is provided only for compatibility with IEEE-488.2.

4.7 Status Reporting Commands

There are five groups of registers involved.

The Questionable Data and Operation groups each consist of three registers;

- The Condition Register contains the current status of the instrument and is continuously updated. The register value can be read at any time using the appropriate query (?) command.

- The Event Register detects '0' to '1' transitions in the Condition Register and the appropriate bit is set. The register value can be read at any time using the appropriate query (?) command. Reading an Event Register results in all the bits of that register being cleared.

- The Enable Register is a mask which allows any of the bits from the Event Register to set the appropriate bit in the Status Byte. Setting an enable bit to '1' enables the event bit; clearing the enable bit inhibits the corresponding event bit. The register value can be read at any time using the appropriate query (?) command.

The Standard Event group is similar, but consists only of the Event and Enable Registers. There is no Condition Register.
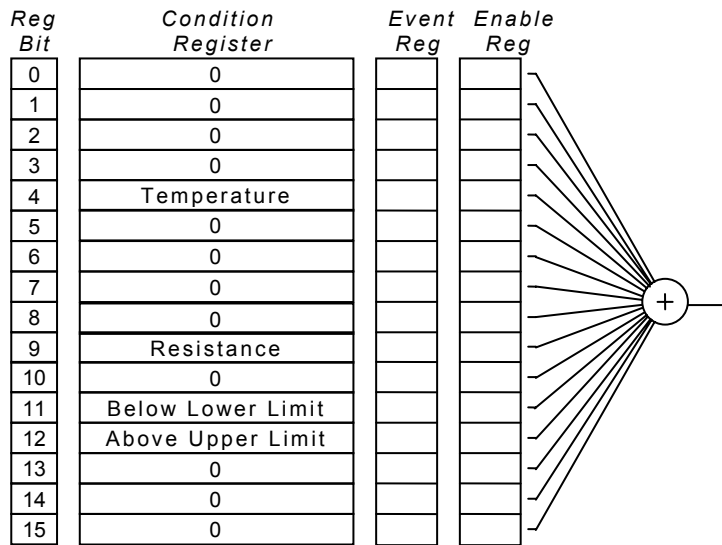
The Output Buffer stores a single line message to be transmitted to the bus. This can be up to 80 characters long. The message is normally the result of a query (?) command.

The Status Byte group is used to read a summary of the other registers.

Note that all Event Registers are cleared after reading, but the Condition Registers, Enable Registers, and Status Byte are left unchanged after reading.
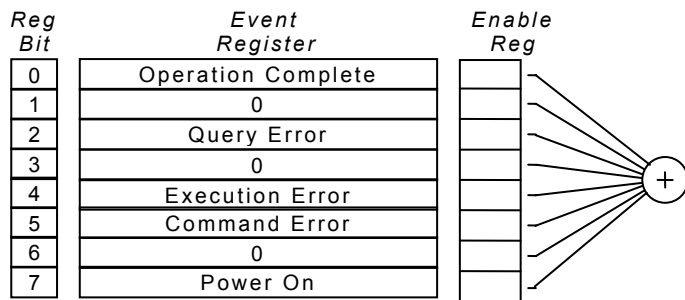
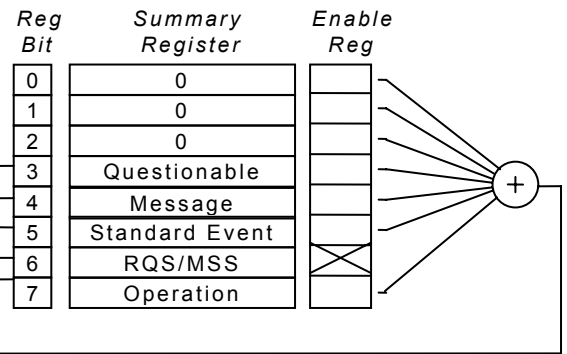The Status Reporting System is summarised in the following diagram.
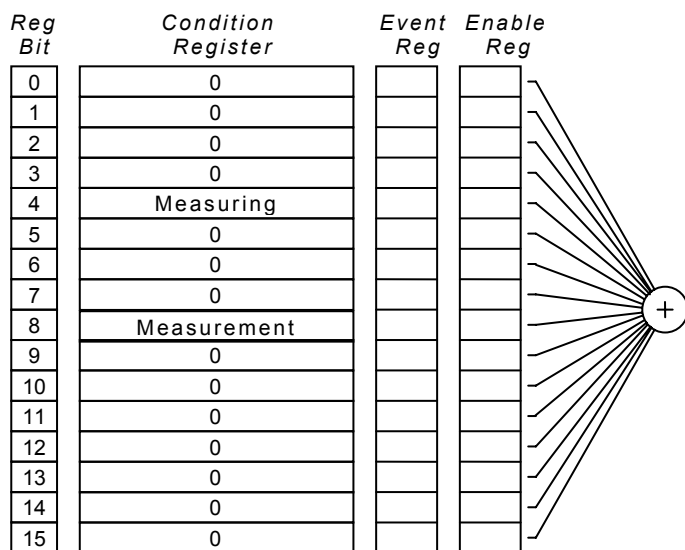
Questionable Data

Reg Bit	Condition Register	Event Reg	Enable Reg
0	0		
1	0		
2	0		
3	0		
4	Temperature		
5	0		
6	0		
7	0		
8	0		
9	Resistance		
10	0		
11	Below Lower Limit		
12	Above Upper Limit		
13	0		
14	0		
15	0		

Output Buffer

Standard Event

Reg Bit	Event Register	Enable Reg
0	Operation Complete	
1	0	
2	Query Error	
3	0	
4	Execution Error	
5	Command Error	
6	0	
7	Power On	

Status Byte

Reg Bit	Summary Register	Enable Reg
0	0	
1	0	
2	0	
3	Questionable	
4	Message	
5	Standard Event	
6	RQS/MSS	
7	Operation	

Operation

Reg Bit	Condition Register	Event Reg	Enable Reg
0	0		
1	0		
2	0		
3	0		
4	Measuring		
5	0		
6	0		
7	0		
8	Measurement		
9	0		
10	0		
11	0		
12	0		
13	0		
14	0		
15	0		

This reporting system follows the style of SCPI, and the unused bits are allocated to other functions which allow for expansion and compatibility with other SCPI compliant devices.

Questionable Data Registers

Temperature Range (bit 4)
This bit is set when the last measurement resulted in a temperature measurement error (eg. out of range).

Resistance (bit 9)
This bit is set when the last measurement resulted in a resistance measurement error (eg. over-range, polarity error, excess resistance in current leads).

Below Lower Limit (bit 11)
This bit is set when the limits facility is on, and the last measurement was less than the lower limit.

Above Upper Limit (bit 12)
This bit is set when the limits facility is on, and the last measurement was greater than the upper limit.

The following commands are used to access these registers;

STATus:QUEStionable:CONDition?
Query the Questionable Data Condition Register. The instrument returns a binary-weighted decimal value representing the bits set in the condition register.

STATus:QUEStionable:EVENt?
Query the Questionable Data Event Register. The instrument returns a binary-weighted decimal value representing the bits set in the event register, and clears it.

STATus:QUEStionable:ENABle *<enable value>*
Enable bits in the Questionable Data Enable Register. The selected bits are then reported to the Status Byte.

STATus:QUEStionable:ENABle?
Query the Questionable Data Enable Register. The instrument returns a binary-weighted decimal value representing the bits set in the enable register.

Standard Event Registers

Operation Complete (bit 0)
This bit is set in response to the *OPC command. It indicates that the instrument has completed all pending operations.

This works for IEEE only - the bit is indeterminate for RS-232.

Query Error (bit 2)
This bit is set when either an attempt has been made to read data from the output queue when no data is present or pending, or data in the queue has been lost.

This works for IEEE only - the bit is indeterminate for RS-232.

Execution Error (bit 4)
This bit is set when a valid command has been received and recognised, but could not be executed at the time. This could be either an out-of-context command or an out of range parameter. The command is ignored.

Command Error (bit 5)
   This bit is set when the command line is not recognised by the parser. This could be an invalid command, parameter or syntax. The command is ignored.

Power On (bit 7)
   Indicates that an off-on transition has occurred in the instrument's power supply.

The following commands are used to access these registers;

*ESR?
   Query the Standard Event Register. The instrument returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register, and clears it.

*ESE *<enable value>*
   Enable bits in the Standard Event Enable Register. The selected bits are then reported to the Status Byte.

*ESE?
   Query the Standard Event Enable Register. The instrument returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

Operation Registers

Measuring (bit 4)
   This bit is set when a new measurement starts and is cleared when complete.

Measurement Available (bit 8)
   This bit is set when a new measurement started by the INITiate command has completed. The bit is cleared when the FETCh? command is used to transfer the value to the output buffer.

The following commands are used to access these registers:

STATus:OPERation:CONDition?
   Query the Operation Condition Register. The instrument returns a binary-weighted decimal value representing the bits set in the condition register.

STATus:OPERation:EVENt?
   Query the Operation Event Register. The instrument returns a binary-weighted decimal value representing the bits set in the event register, and clears it.

STATus:OPERation:ENABle *<enable value>*
   Enable bits in the Operation Enable Register. The selected bits are then reported to the Status Byte.

STATus:OPERation:ENABle?
   Query the Operation Enable Register. The instrument returns a binary-weighted decimal value representing the bits set in the enable register.

Status Byte Registers

The Status Byte Register contains summary bits from the Questionable Data, Standard Event and Operation Registers, and also has a single bit reporting the Service Request function for IEEE.

The Service Request function allows the instrument to request service from the system controller. If the same bit is set simultaneously in both the Status Byte Register and the Service Request Enable Register, the RQS bit is set in the Status Byte Register and the SRQ (service request) bus signal is asserted. In response to the Service Request, the controller will normally be instructed to perform a serial poll sequence on all devices. The instrument returns its Status Byte with SRQ set when it is polled. The action of reading the Status Byte via the serial poll clears RQS and negates SRQ.

The following describes the Status Byte Register Messages.

Questionable Data Summary (bit 3)
This bit is set when an enabled Questionable-Data event has occurred. It is cleared by reading the Questionable Data Event Register or by clearing relevant bits in the Questionable Data Enable Register.

Message Available Summary (bit 4)
This bit indicates that the Output Queue contains response data. It is cleared by reading all data from the output queue or, the output queue being flushed by a Query Error or, by the *CLS command. This works for IEEE only - the bit is always 0 for RS-232.

This bit is particularly useful for synchronising data transfers from the instrument. The application programme can poll the bit to detect when a measurement is complete and data is available. Alternatively, for IEEE, the corresponding enable bit in the Service Request Enable Register can be set so that a Service Request (SRQ) interrupt will occur.

Standard Event Summary (bit 5)
This bit Indicates that an enabled Standard Event has occurred. It is cleared either by reading the Standard Event Status Register, by clearing relevant bits in the Standard Event Enable Register, or by the *CLS common command.

Request for Service/Master Summary Status (bit 6)
The meaning of this bit depends on how the Status Byte Register is read. This works for IEEE only - the bit is always 0 for RS-232.

RQS
This bit forms part of the IEEE-488.1 Service Request function and is valid only during Serial Poll. It indicates that the instrument is requesting service. It is set when an enabled bit in the Status Byte Register becomes set and cleared by a Serial Poll. Assuming no 'new reason for service' occurs, the bit will be set for one Serial Poll and clear for subsequent Polls. RQS is also cleared if the reason for service disappears, for instance when a status register is read.

MSS
When the Status Byte Register is read with *STB? this bit indicates that an enabled bit in the Status Byte Summary Register is set. The bit is cleared when all summary-messages are clear.

Operation Summary Message (bit 7)
This bit is set when an enabled Operation event has occurred. It is cleared by reading the Operation Event Register or by clearing the relevant bits in the Operation Enable Register.

The following commands are used to access these registers;

*STB?

    Query the Status Byte Summary Register. The instrument returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

*SRE <*enable value*>

    Enable bits in the Service Request Enable Register. The selected bits are then reported to the Status Byte.

*SRE?

    Query the Service Request Enable Register. The instrument returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

Other Related Commands

*CLS

    Clears the Status Byte Summary Register and all event registers, and also resets the Operation Complete Command State and Operation Complete Query State.

*OPC

    This command sets the instrument's 'Operation Complete Command State' active. When any 'in-progress' command is completed, the state returns to idle and the Operation Complete bit (0) is set.

    The command should only be used in conjunction with non-query commands and is only available for IEEE. If the *OPC is sent in RS-232 mode it will generate a "command error" and the command is ignored.

    Example

    Data logging can take an appreciable time to execute, so it is useful to program the instrument to generate a service request on completion of the logging function. The following command sequence can be used:

    *ESE 1   Enables Operation Complete to set the Standard Event bit
    *SRE 32   Enables Standard Event to trigger service request
    *CLS   Clears the Operation Complete bit
    DATA:START   Initiates data logging
    *OPC   Sets RQS on completion of the log

*OPC?

    This command sets the instrument's 'Operation Complete Query State' active. When any 'in-progress' command is completed, the state returns to idle, a '1' is placed in the output queue and therefore the Message Available bit (4) is set. The command should only be used in conjunction with non-query commands and is only available for IEEE.

    If *OPC? is sent in RS-232 mode it will generate a "command error" and the command is ignored.

Example

Data logging can take an appreciable time to execute, so it is useful to program the instrument to generate a service request on completion of the logging function. The following command sequence can be used:

*SRE 16	Enables the Message Available bit to trigger a service request
*CLS	Clears the Message Available bit
DATA:START	Initiates data logging
*OPC?	Sets RQS on completion of the log

Alternatively, the application programme can continuously poll the Message Available bit using *STB?.

The Status Byte Register can also be read by an IEEE-488.1 serial poll sequence.

4.8 Front Panel Operations

The currently selected interface is indicated by the "RS-232" or "IEEE" legend.

Talk Only mode is indicated by the "Talk" legend.

The "REM" legend indicates that the microhmmeter is under control of the remote interface. The front panel keys will be locked out.

The "MEAS" legend indicates that a measurement cycle is in progress.

For the IEEE-488 interface, the "TALK/LSTN" legends indicate that the device has been addressed by the system controller. Operation, however, may be local or remote.

5. **PLC INTERFACE**

5.1 Connection

Connection to the PLC or similar device is made via the 25-way 'D' connector on the rear panel. See Appendix IV for pin details.

5.2 Front Panel Set-up

Press MENU on the front panel, select Rem I/F, then press PLC. The PLC is now selected, and the option to select the Analogue Output is given. This should be OFF if not required, as it will cause a small increase in measurement times. For this reason, it defaults to OFF at power up. Note that once the Analogue Output is ON, there is no need for the PLC interface to remain selected, if it is not required.

*If no PLC card is fitted, the warning message "** OPTION NOT AVAILABLE **" is displayed.*

5.3 Interface Functions

The PLC interface allows basic remote control of the microhmmeter by a Programmable Logic Controller or similar device. The facilities it provides are:

Triggering of measurements.

Selection from 10 stored set-up memories, which are user-programmable via the front panel (See main Operation Manual for details).

Outputs give indication of 'End of Test', 'Measurement within limits', 'Measurement too Low/High' and 'Error'.

25VDC output available to drive inputs and outputs for a self-contained system. (For the DO5001 model, it is only available when the instrument is connected to the mains, and is not supplied by the internal batteries).

The analogue Output produces a voltage proportional to the measured resistance value. If the Temperature Compensation is selected, then this value will be the compensated resistance.

5.4 Electrical Characteristics

Inputs:

Number	7
Type	optoelectronic
Input resistance	1.5 kohms
Minimum voltage	11 VDC or 8 VAC
Maximum voltage	43 VDC or 30 VAC

Outputs:

Number	6
Type	dry contacts
Maximum voltage	70 VDC
Switch rating	30 W
Maximum current	0.15 ADC

<u>Logic states:</u>

Input - High state   DC or AC voltage with an amplitude between Vmin & Vmax
Input - Low state   no voltage
Output - High state   *closed contact
Output - Low state   *open contact

*Note: these can be reversed by altering the position of links on the PLC card.

<u>25VDC output:</u>

This is provided to drive the PLC inputs/outputs, and is rated at 1.25 ADC. (For the DO5001 model, it is only available when the instrument is connected to the mains, and is not supplied by the internal batteries).

<u>Measurement time:</u>

For a basic resistance measurement, the approximate time from the rising edge of the MEASURE line to the EOT (end of test) signal is:

Slow mode   700 mS
Medium mode   450 mS
Fast mode   240 mS

5.5 <u>Description of Input/Output signals</u>

<u>Inputs:</u>

COM IN   Common line for all inputs.

CTRLIN   Requests remote control of the microhmmeter, and locks the keyboard. When released, control will revert to the front panel.

N0-N3   Binary-coded data inputs for selection of set-up memories:

N3	N2	N1	N0	Memory No.
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
:	:	:	:	:
1	0	0	1	9

MEASURE   Triggers a measurement. If closed momentarily, a single measurement will result. If left permanently closed, continuous measurements will result.

<u>Outputs:</u>

The links on the PLC card are factory fitted such that the relay contacts will close when an output signal is asserted, These can be reversed if required.

COM OUT   Common line for all outputs.

ACK   This signal acknowledges the CTRLIN signal, but not until the first MEASURE input is received. It then remains asserted as long as CTRLIN is asserted.

EOT	End of Test. This is asserted when a measurement cycle is completed.	
PASS	If the measurement limits are in use, then this signal will be asserted with EOT to indicate that the resistance value was within the limits set.	
FAIL LOW/HIGH	If the measurement limits are in use, then this signal will be asserted with EOT to indicate that the resistance value was below/above the limits set.	
ERROR	This indicates that an error condition occurred during the previous measurement:	

Cause	EOT	ERROR
Overange	Yes	Yes
Polarity error	Yes	Yes
Excess resistance in Current leads	Yes	Yes
Open Circuit detected	Yes	Yes
Temperature out of range	Yes	Yes
Settling Algorithm failed to settle	Yes	Yes
Measurement attempted with empty memory	No	Yes
Measurement attempted when Datalog is ON, and maximum No. of readings has been reached	No	Yes

5.6 Using the PLC Interface

IMPORTANT:
The PLC must be selected as the Remote Interface (See Front Panel Set-up).
When CTRLIN is asserted, the Keyboard is locked.

(If no Remote Interface is selected when CTRLIN is asserted, then the PLC will be selected automatically. If the RS-232 or IEEE is selected, a warning message will be displayed, together with an intermittent beep, and the keyboard remains locked until CTRLIN is released.)

See Figures 1 and 2 for connection details, using the internal supply or an external supply.

To take a measurement

Make sure that the microhmmeter is displaying the normal measurement screen.
Assert CTRLIN - 'Rem' appears on the screen.
Set N0-N3 to select the required set-up memory (See 'Description of Input/Output signals').
Assert MEASURE (Min 10mS) - CTRLOUT is asserted and remains asserted until CTRLIN is negated. The N0-N3 inputs are read, the appropriate memory is selected, and the measurement commences. Note that if MEASURE remains asserted, continuous measurements will occur.
At the end of the measurement, the outputs will be set (See 'Description of Input/Output signals').
Negating CTRLIN will remove 'Rem' from the display and unlock the keyboard.

The PLC interface uses SINGLE trigger mode only. If a set-up memory which has CONTINUOUS trigger mode stored is selected when using the PLC interface, then this will be changed to SINGLE at the start of the first measurement. As one of the stored parameters has been altered, the MEM number will be removed from the display, but all other parameters for that memory will remain correctly set.

See Figures 3 and 4 for examples of the input and output behaviour during measurement.

5.7 Analogue Output

This is selected from the Remote Interface, PLC menu (see Front Panel Set-up). When fitted and selected ON, it produces an output voltage proportional to the measured resistance. If the Temperature Compensation is selected, then this value will be the compensated resistance. For the nominal full-scale value for each range (30,000 count), this is $\pm$ 3.00V, depending on the current direction.

This facility increases the measurement time by a small amount, only significant in FAST mode. To avoid it being left ON inadvertently, it defaults to OFF at power-up.

Figure 1 - Initial measurement using Memory 5 - Test failed, resistance too high

CTRLIN

N0

N1

N2

N3

MEASURE

CTRLOUT

PASS

FAIL HIGH

FAIL LOW

EOT

ERROR
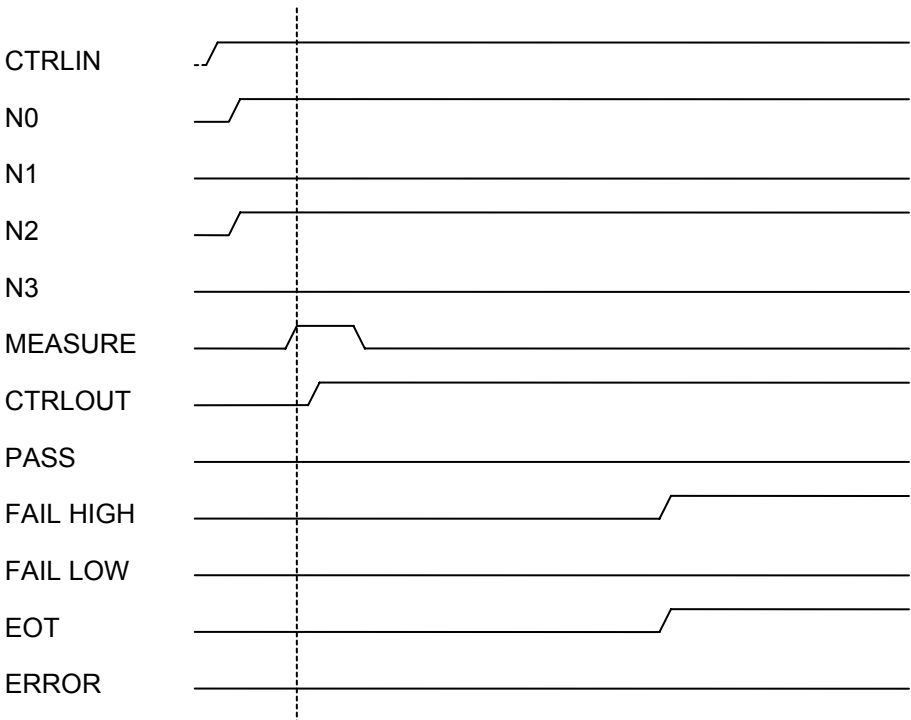
Figure 2 - Subsequent measurement using Memory 3 - Test passed

CTRLIN

N0

N1

N2

N3

MEASURE

CTRLOUT

PASS

FAIL HIGH

FAIL LOW

EOT

ERROR
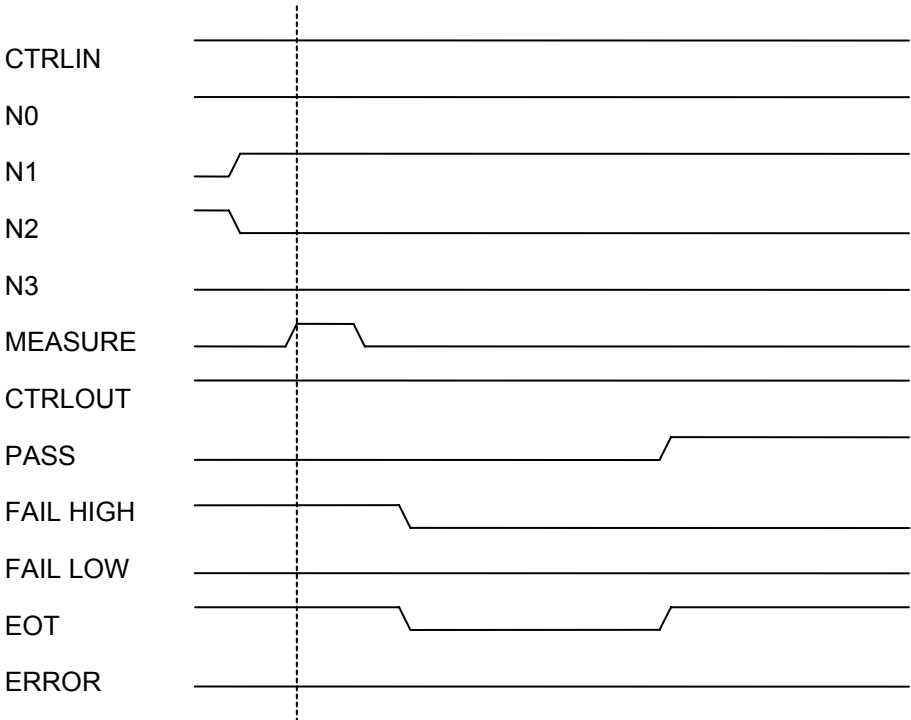
Figure 3 - Connecting the unit with the internal supply

PLC SYSTEM

DO5000

CTRLIN (4)

N0 (17)

N1 (5)

N2 (18)

N3 (6)

MEASURE (7)

+25V (3)

0V (2)

COM IN (16)

COM OUT (8)

CTRLOUT (21)

EOT (22)

PASS (10)

FAIL HIGH (9)

FAIL LOW (20)

ERROR (23)

+25V -
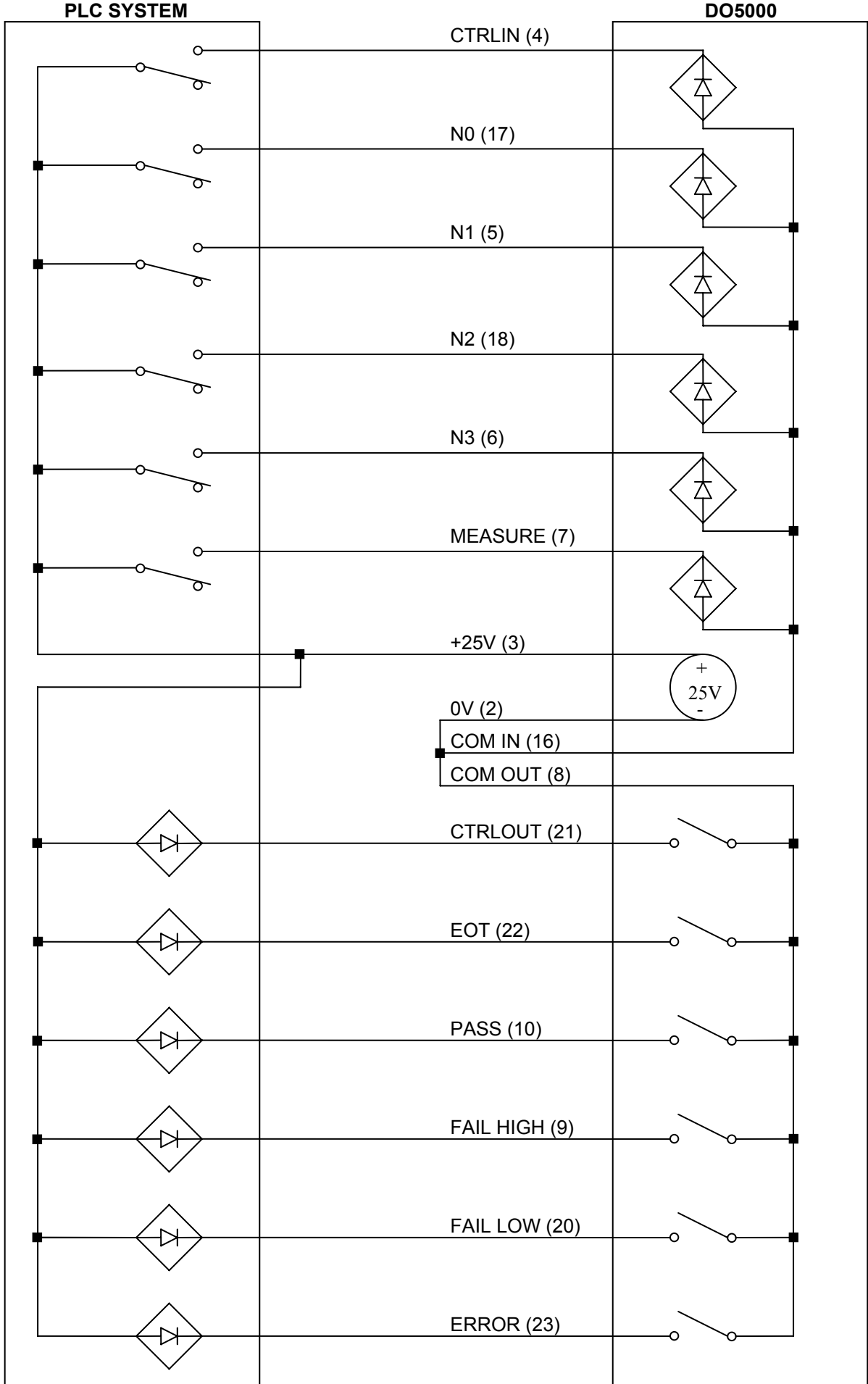
Figure 4 - Connecting the unit with an external supply

PLC SYSTEM

DO5000

CTRLIN (4)

N0 (17)

N1 (5)

N2 (18)

N3 (6)

MEASURE (7)

+25V (3)

$+$
25V
$-$

0V (2)

COM IN (16)

25V

COM OUT (8)

CTRLOUT (21)

EOT (22)

PASS (10)

FAIL HIGH (9)

FAIL LOW (20)

ERROR (23)
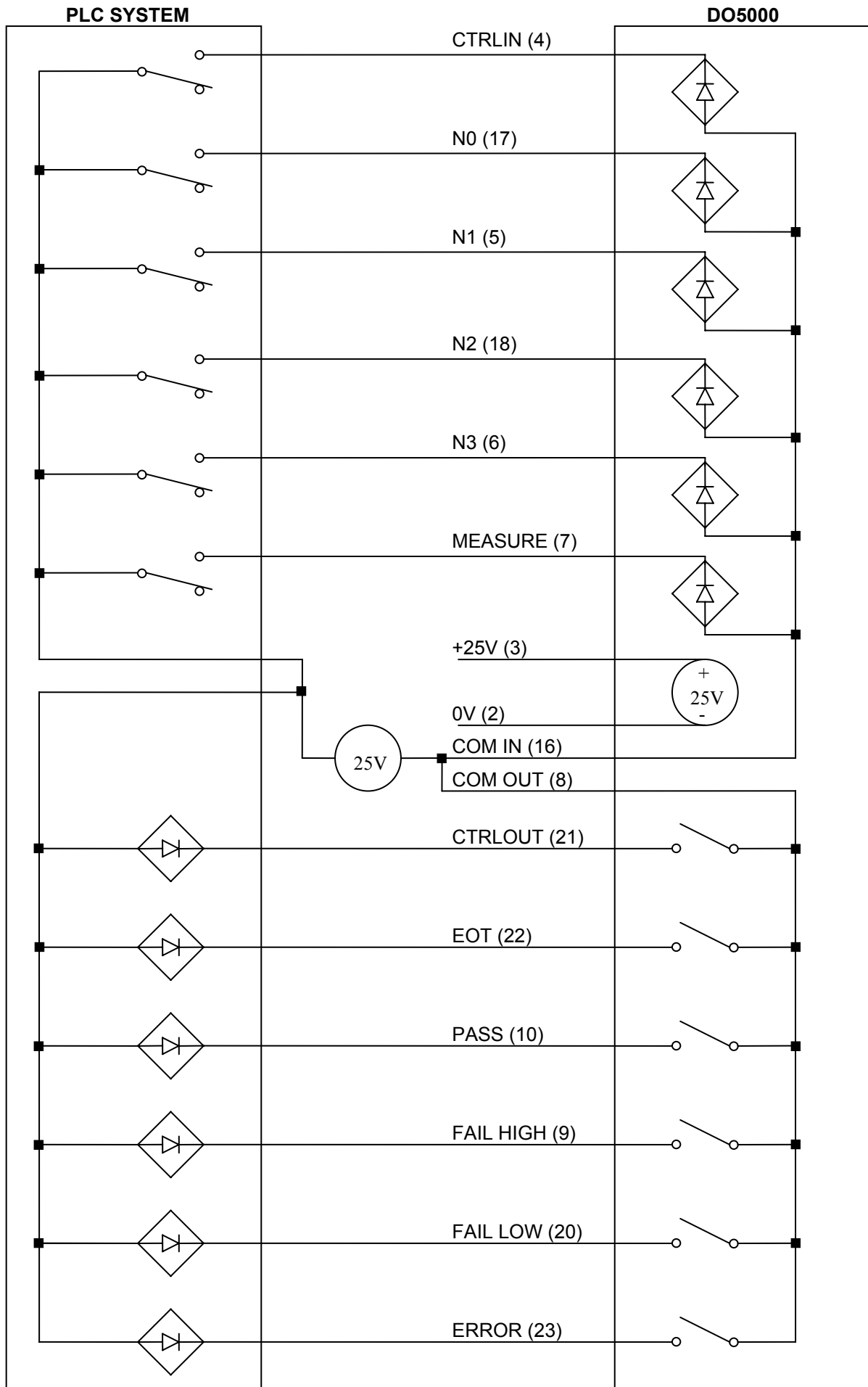
APPENDIX I

RS-232/IEEE-488 COMMAND SUMMARY

Single Wire Interface Messages (IEEE-488 Only)

DAV   Data Valid
NRFD   Not Ready For Data
NDAC   Not Data Accepted
REN   Remote Enable
IFC   Interface Clear
EOI   End Or Identify
SRQ   Service Request
ATN   Attention

Multi Wire Interface Messages (ATN=Low) (IEEE-488 Only)

GTL   Go To Local
SDC   Selective Device Clear
GET   Group Execute Trigger
DCL   Device Clear
SPE   Serial Poll Enable
SPD   Serial Poll Disable
MLA   My Listen Address
UNL   Unlisten
MTA   My Talk Address
UNT   Untalk

Programming Language

Both interfaces use the same commands.

For the RS-232 interface these commands are sent as part of a serial string.

For the IEEE-488 interface these commands are sent as a Multi-wire Interface Message (with ATN=High).

Configuration Commands

SENSe:
  FRESistance:RANGe *<range>*
  FRESistance:RANGe?
  FRESistance:MODE <SLOW|MED|FAST>
  FRESistance:MODE?

SOURce:CURRent *<magnitude>*,*<current mode>*
SOURce:CURRent?

Trigger and Measurement Commands

INITiate
*TRG
FETCh[:FRESistance|:TEMPerature|:TCOMpensate]?

INITiate:CONTinuous <ON|OFF> or <0|1>
INITiate:CONTinuous?

READ[:FRESistance|:TEMPerature|:TCOMpensate]?
ABORt

Data Operation Commands

DATAlogger:
  CLEAr
  COUNt *<No. of readings>*
  COUNt?
  STATe <ON|OFF> or <1|0>
  STATe?
  STARt
  STOP
  STEP
  VALue? *<value number|ALL>*
  POINts?

Mathematical Operation Commands

CALCulate:
  DATA:MINimum?
  DATA:MAXimum?
  DATA:AVERage?
  DATA:PTPeak?
  DATA:SDEViation?

CALCulate:
  LIMit:LOWer *<value>*
  LIMit:LOWer?
  LIMit:UPPer *<value>*
  LIMit:UPPer?
  LIMit:STATe <ON|OFF> or <1|0>
  LIMit:STATe?
  LIMit:ALARm <ON|OFF> or <1|0>
  LIMit:ALARm?

Temperature Compensation Commands

SENSe:
  TCOMpensate:STATe <ON|OFF> or <1|0>
  TCOMpensate:STATe?
  TCOMpensate:MODE <EXT> or <MAN,*manual temperature*>
  TCOMpensate:MODE?
  TCOMpensate:REFerence *<temperature value>*
  TCOMpensate:REFerence?
  TCOMpensate:COEFficient <CU|AL> or <USER,*user coefficient* >
  TCOMpensate:COEFficient?

UNIT:
  TEMPerature <C|CEL|F|FAR>
  TEMPerature?

Filter (Averaging) Commands

SENSe:
  AVERage:STATe <ON|OFF> or <1|0>
  AVERage:STATe?
  AVERage:COUNt *<No. of readings>*
  AVERage:COUNt?

Settling Algorithm Commands

SENSe:
  SETTling:STATe <ON|OFF> or <1|0>
  SETTling:STATe?
  SETTling:COUNt *<No. of readings>*
  SETTling:COUNt?
  SETTling:LIMit *<No. of digits>*
  SETTling:LIMit?

Open Circuit Voltage Limit Commands

SOURce:
      VOLTage:LIMit:LEVel <OFF|0|20|50>
      VOLTage:LIMit:LEVel?

System Related Commands

DISPlay:BRIGhtness <ON|OFF> or <1|0>
DISPlay:BRIGhtness?

SYSTem:
  BEEPer
  BEEPer:STATe <ON|OFF> or <1|0>
  BEEPer:STATe?
  VERSion?
  TIME *<hh>*,*<mm>*,*<ss>*
  TIME?
  DATE *<yyyy>*,<mm>,*<dd>*
  DATE?

*IDN?
*RST
*TST?
*WAI

Status Reporting Commands

STATus:
  QUEStionable:CONDition?
  QUEStionable:EVENt?
  QUEStionable:ENABle *<enable value>*
  QUEStionable:ENABle?

*ESR?
*ESE *<enable value>*
*ESE?

STATus:
  OPERation:CONDition?
  OPERation:EVENt?
  OPERation:ENABle *<enable value>*
  OPERation:ENABle?

*STB?
*SRE <enable value>
*SRE?
*CLS
*OPC
*OPC?

RS-232 Interface Commands

SYSTem
 :LOCal
 :REMote

APPENDIX II

RS-232 Pin Connections

1	DCD	Data Carrier Detect	(not connected)
2	RXD	Received Data	(input)
3	TXD	Transmitted Data	(output)
4	DTR	Data Terminal Ready	(not connected)
5	GND	Signal Ground	
6	DSR	Data Set Ready	(not connected)
7	RTS	Request To Send	(output)
8	CTS	Clear To Send	(input)
9	RI	Ring Indicator	(not connected)

APPENDIX III

IEEE-488 Pin Connections

1	DIO1	Data Input/Output 1
2	DIO2	Data Input/Output 2
3	DIO3	Data Input/Output 3
4	DIO4	Data Input/Output 4
5	EOI	End Or Identify
6	DAV	Data Valid
7	NRFD	Not Ready For Data
8	NDAC	Not Data Accepted
9	IFC	Interface Clear
10	SRQ	Service Request
11	ATN	Attention
12	CABLE SHIELD	
13	DIO5	Data Input/Output 5
14	DIO6	Data Input/Output 6
15	DIO7	Data Input/Output 7
16	DIO8	Data Input/Output 8
17	REN	Remote Enable
18	DAV ground	
19	NRFD ground	
20	NDAC ground	
21	IFC ground	
22	SRQ ground	
23	ATN ground	
24	LOGIC ground	

APPENDIX IV

PLC Pin Connections

1	No Connection
2	0VDC
3	+25VDC
4	CTRLIN
5	N1
6	N3
7	MEASURE
8	COM OUT
9	FAIL HIGH
10	PASS
11	ANALOGUE OUTPUT - LOW
12	CASE
13	No Connection
14	No Connection
15	No Connection
16	COM IN
17	N0
18	N2
19	Spare Input
20	FAIL LOW
21	CTRLOUT
22	EOT
23	ERROR
24	ANALOGUE OUTPUT - HIGH
25	No Connection