

M2000

Operator's Manual



Table of Contents

I.	INTRODUCTION	3
II.	STANDARD EQUIPMENT	3
III.	OPTIONS AND ACCESSORIES	3
IV.	UNPACKING	3
V.	NOMENCLATURE	3
VI.	GETTING STARTED	6
VII.	VOLTAGE OUTPUT	6
VIII.	CURRENT OUTPUT	7
IX.	SETPOINTS	8
X.	REMOTE INTERFACE	8
XI.	REMOTE COMMANDS	19
XII.	SPECIFICATIONS	
	<i>General Specifications</i>	<i>26</i>
	<i>DC Voltage, Output</i>	<i>26</i>
	<i>DC Current, Output</i>	<i>27</i>

I. INTRODUCTION

The Martel series M2000 calibrator is designed to be an accurate DC calibrator for R & D, manufacturing and calibration lab applications. The units simple design and ease of operation allows users to quickly familiarize themselves with its operations and features. Time saving functions like the ability to save, recall and automatically cycle through setpoints for each output range and a complete remote interface are several key features the M2000 offers.

II. STANDARD EQUIPMENT

- Power cord (for 120 VAC versions)
- Manual
- Certificate of Calibration

III. OPTIONS AND ACCESSORIES

- Panel mount kit (Martel P/N M2000-PMK)
- Low EMF Beryllium copper test leads

IV. UNPACKING

Upon receipt of shipment, inspect the container and equipment for any signs of damage. Take particular note of any evidence of rough handling in transit. Immediately report any damage to the shipping agent.

NOTE: The carrier will not honor any claims unless all shipping material is saved for their examination.

After examining and removing contents, save packing material and carton in the event re-shipment is necessary.

Remove the Packing List and verify that all equipment has been received. If there are any questions about the shipment, please call Martel Electronics at 1-800-821-0023.

Check to see if your calibrator is complete. It should include:

- M2000 Calibrator
- Instruction Manual
- AC Line Cord

V. NOMENCLATURE

Front Panel Controls and Functions (Refer to **Figure 1** for locations)

Fig. 1 Location	Description	Function
1	Cursor Control Keys	Left and Right arrows control cursor placement. Up and Down arrows increment or decrement the selected decade.
2	Enter Key	Used to acknowledge or accept a value entered through the keypad. Note: The output will only go to the new value after the enter key is pressed.
3	Data Entry Keys	This numeric keypad is used to set the calibrator to a specific output. Several of the keys also act as "second function" keys.

4	Primary Function Keys	
	VOLTS/mA	Toggles through the Voltage and mA output ranges.
	STBY/OPR	Toggles between standby and operate modes.
	2nd	The "second function" key allows the use of the features described by the second function keys.
	CE	The "clear entry" will clear the display if a mistake is made during data entry.
5	Secondary Function Keys	These keys perform second functions after the 2nd key has been pressed.
	CAL	Used to set LCD contrast, backlight and interface parameters RS-232 or GPIB (2001A). For a complete electrical calibration the RS-232 mode is used. Contact factory for more information.
	SET	Used to set a setpoint.
	RCL	Used to recall a setpoints.
	AUTO	Used to initiate auto setpoint.
	LOCAL	Used to regain local control.
6	Output Binding Posts	These binding posts are made of a special copper alloy to reduce thermal EMF's. These posts support the use of both standard banana plugs or discreet wires.
7	Display	The 16 character by 2 line display is backlit and provides all visual user feedback.
7A	Range Field	Displays the range and setpoint number if applicable.
7B	OPR/STBY	Displays the output state.
7C	Unit Field	Displays output units.
7D	Value Field	Displays output value.

See
Section IX

See Section X

Refer to Figure 2 for locations

Fig. 2 Location	Description	Function
1	Voltage Selector and Fuse Holder	Removing this door allows the user to access the input voltage selector switch and the two (2) user replaceable fuses.
2	On/Off Rocker Switch	This is the main power switch for the M2000. It is a double pole designed for safety.
3	AC Power Inlet	This is a standard IEC universal AC input power connector for worldwide line cord usage.
4	RS-232 Connector	The male 9 pin "D" connector allows the M2000 to be connected to any computers serial interface.
5	IEEE 488.2 Connector	This connector is only installed on the M2000A for connection to an IEEE 488.2 (GPIB) Bus.

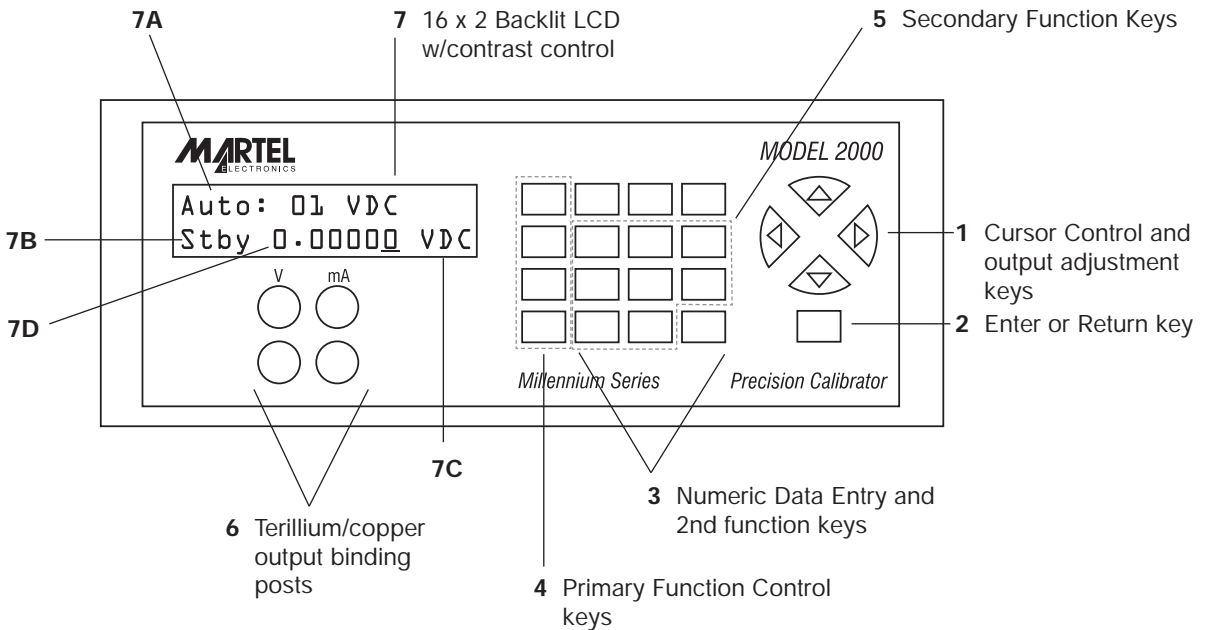


Figure 1
Front Panel Layout

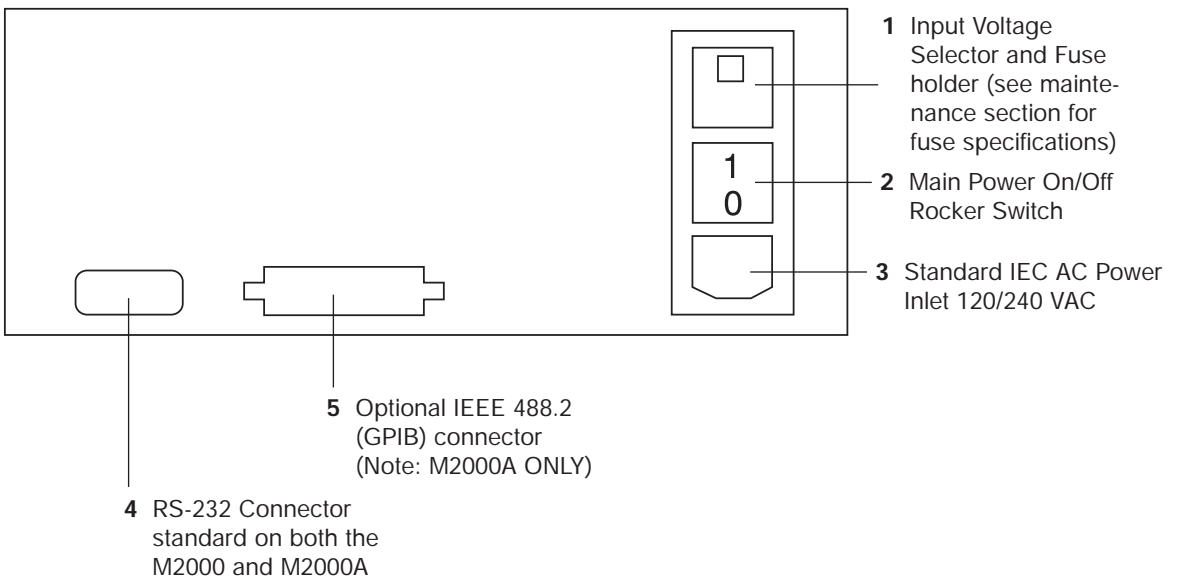


Figure 2
Rear Panel Layout

VI. GETTING STARTED

1. After unpacking the M2000 and becoming familiar with the nomenclature of the unit as described in the previous section, the M2000 is ready to be operated.
2. **Before** attaching the power cord to the rear connector the voltage selector must be set to the proper line voltage. To do this, remove the rear fuse cover found just above the On/Off rocker switch (see Figure 2, item #1). Pull out the voltage selector connector and set it for the proper line voltage using the following guidelines:

Line Voltage (50/60Hz)	Selector Position
90 to 135 VAC	120 VAC position
220 to 250 VAC	240 VAC position



WARNING – To prevent electrical shock, only set the line voltage with the power cord removed.

3. Once the voltage selection has been made, making sure the power switch is off, connect the AC power cord to the M2000. (See figure 2, item #3 for reference).
4. Turn on the M2000 using the rear panel mounted rocker switch. The M2000 should power up within a few seconds. For good stability it is best to leave the M2000 on all the time.

NOTE: If power up does not occur within 30 seconds re-power the unit.

VII. VOLTAGE OUTPUT

1. To output a voltage, enter voltage mode by pressing the **Volts/mA** key. The calibrator will auto-range in voltage source based on the value of the outputted value. If you want to lock the calibrator in a specific voltage range press the **Shift** key followed by the **Volts/mA** key.
2. Connect the unit under test (UUT) to the voltage output jacks of the M2000. See figure 3.

CAUTION

For best accuracy on the mV range use only test leads with copper plugs. This will minimize thermal EMFs.

3. Using either cursor keys or numeric keypad, enter the desired output value. If the numeric keypad is used for data, all entries must be acknowledged by pressing the **Enter** key.
4. When selecting an output on a new range the M2000 will be in the standby (STBY) mode which puts the positive (+) output jack in a high impedance state (>100k ohm) for safety.

The output can be placed into the active state by pressing the **STBY/OPR** key which toggles between the standby and operate modes.

NOTE: The standby mode is also activated if a fault occurs during operation such as an overload or short circuit condition. For safety the standby mode is activated for the first output over 30 VDC. Refer to the product specification section of this manual for maximum drive currents.

5. When small changes to an output value are required or if specific decades need to be incremented or decremented the cursor controls offers a simple solution. The left and right arrow keys move a cursor that is used to underscore any digit of the output. The up/down arrow keys allow the digit to be incremented and decremented.

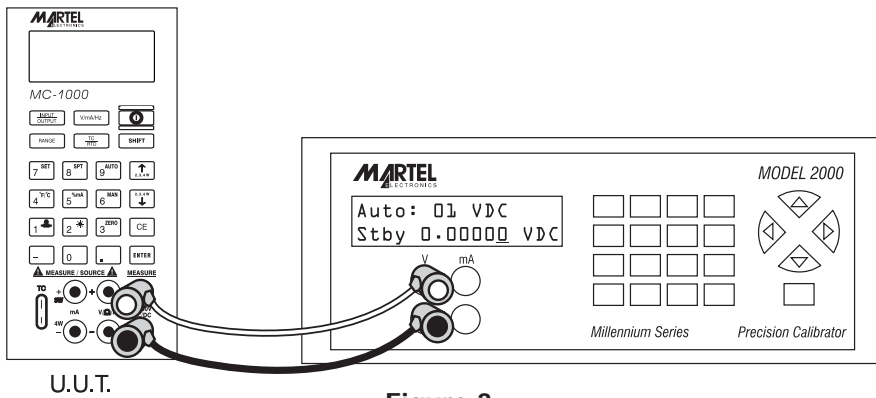


Figure 3

Connections for Outputting DC Voltage

VIII. CURRENT OUTPUT

1. To output currents of up to 100mA press the key until the milliamp output range appears on the display.
2. Operation of the mA output is similar to voltage, operating where output values can be selected or manipulated by using the numeric data entry keys or cursor controls.

NOTE: Standby mode is activated if the voltage compliance for a given output current is exceeded. Trying to output a current with no connection made to the output jacks will force the M2000 into standby mode.

See Figure 4.

3. The M2000 has a typical voltage compliance of 10V so that 4-20mA application loads up to 500 ohms can be driven. At maximum current (100mA) the maximum load is 100 ohms.

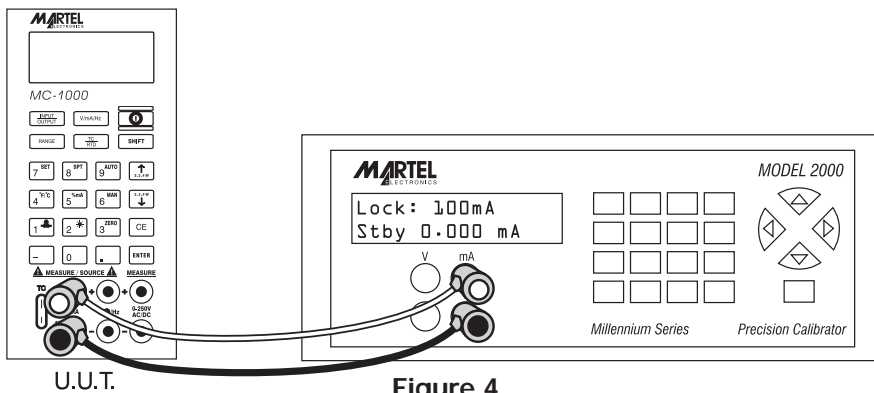


Figure 4

Connections for Outputting DC Current

IX. SETPOINTS

The M2000 offers functionality which allows the user to store and recall output levels (setpoints). Additional functionality allows the user to automatically step through a number of setpoints at a configurable interval. Up to 9 setpoints can be programmed for each range.

A. Setting a Setpoint

1. To set a setpoint go to the desired range and enter the desired output value.
2. Once you have entered the output value press the **2nd** key followed by the **SET** key.
3. Select the number of the setpoint in which the present output value is to be stored.

B. Recalling a Setpoint

1. To recall a setpoint press the **2nd** key followed by the **RCL** key.
2. Select the number of the setpoint you wish to recall.

C. Auto Setpoints

1. To initialize auto setpoint functionality, press the **2nd** key followed by the **AUTO** key.
2. Select the number of setpoints to be recalled. Setpoints step up from setpoint one to the setpoint selected and then down.
3. Select the interval (in seconds) between setpoints.

NOTE: During auto setpoint mode the **STBY/OPR** can be used. Pressing any other key will cause the unit to exit this mode.

CAUTION

When in auto setpoint mode the unit does not go to standby even if the output goes above 30V.

X. REMOTE INTERFACE

Setting up the RS-232 Port for Remote Control

The M2000 is fully programmable over an RS-232 link with a PC.

The RS-232 cable length for the port should not exceed 15 meters (50 feet), although longer cable lengths are permitted if the load capacitance measured at a connection point (including signal terminator) does not exceed 2500 pF.

RS-232 Port Setup Procedure

Serial parameters are fixed with the values shown below:

- 9600 baud
- 8 data bits
- 1 stop bit
- no parity
- Xon/Xoff
- EOL (end-of-line) character CR (Carriage Return)

A typical connection is shown in Figure 5. Note the use of a null modem cable for connection.

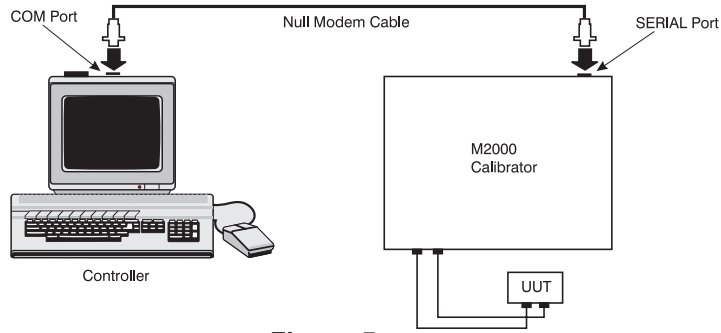


Figure 5

RS232 Remote Control connections

Setting up the IEEE-488 Port for Remote Control

The M2000 is fully programmable for use on the IEEE Standard 488 interface bus. The IEEE-488 interface is also designed in compliance with supplemental standard IEEE-488.2, which describes additional IEEE-488 features. Devices connected to the IEEE-488 bus are designated as talkers, listeners, talker/listeners, or controllers. Under remote control of an instrument, the M2000 operates as a talker/listener.

A PC equipped with an IEEE-488 interface controls the M2000. Compatible software for IEEE-488 operation, MET/CAL, may be purchased from Fluke.

When using the IEEE-488 remote control interface, there are two restrictions:

1. **Number of Devices** A maximum of 15 devices can be connected in a single IEEE-488 bus system.
2. **Cable Length** The total length of IEEE-488 cables used in one IEEE-488 system is 2 meters times the number of devices in the system, or 20 meters, whichever is less.

IEEE-488 Port Setup Procedure

Complete the following procedure to set up the M2000 for remote operations using the IEEE-488 remote control port. The purpose is to select GPIB as the interface and to select the GPIB address for the interface.

To set up the IEEE-488 port

1. Turn the M2000 power on and wait until the initialization procedure completes. You may operate the M2000 during warm-up, but specifications are not guaranteed until warm-up is complete.
2. Press SETUP (+ .
3. Press until Remote Interface: is displayed.
4. Press the or key to select GPIB, if not already selected.
5. Press to accept the interface choice.
6. Press the or key to select the desired address. The factory default is 4.
7. Press to accept the address choice and exit the Setup menu.

See Figure 6 for a typical IEEE-488 connection

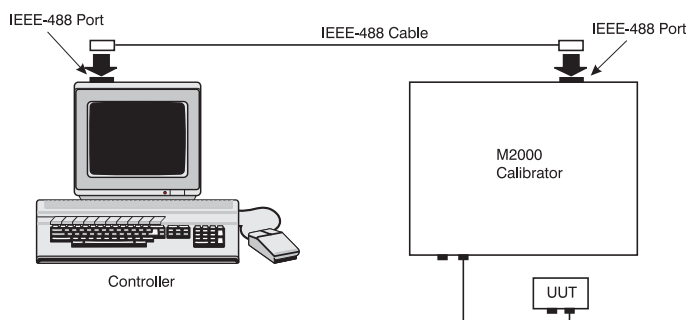


Figure 6

Typical IEEE-488 connections

Changing Between Remote and Local Operation

In addition to Local mode (front panel operation) and remote, the M2000 can be placed in a local lockout condition at any time by command of the controller. Combined, the local, remote, and lockout conditions yield four possible operating states described as follows.

Local State

The M2000 responds to local and remote commands. This is normal front panel operation. All remote commands are allowed to execute.

Local with Lockout State

Local with lockout is identical to local, except the M2000 will go into the remote with lockout state instead of the remote state when it receives a remote command.

Remote State

When the M2000 is placed in remote, either via RS-232 REMOTE command, or via IEEE-488 asserting the REN line, it enters the remote state. The top line of the display changes to: **REM**.

Front panel operation is disabled except for the **LOCAL** ("–" key). Pressing "–", using RS-232 to send the command LOCAL, or IEEE-488 to send the GTL (Go To Local) message returns the M2000 to the local state.

Remote with Lockout State

When the M2000 is placed in lockout, either via RS-232 LOCKOUT command, or via the IEEE-488 message LLO, the M2000 front panel controls are totally locked out. The top line of the display changes to: **REM**.

To return the M2000 to the local with lockout state, send the RS-232 LOCAL command or the IEEE-488 GTL (Go To Local) message.

Table 3 summarizes the possible Operating state transitions. (For more information on IEEE-488 GPIB messages, see "IEEE-488 Overview.")

Table 3. Operating State Transitions

From	To	Front Panel	GPIB Message	Serial Command
Local	Remote Local with Lockout		MLA (REN True) LLO LOCKOUT	REMOTE
Remote	Local Remote with Lockout	Local key	GTL or REN False LLO LOCKOUT	LOCAL
Local with Lockout	Local Remote with Lockout		REN False MLA (REN True)	LOCAL REMOTE
Remote with Lockout	Local		REN False GTL	LOCAL

IEEE-488 Interface Overview

The IEEE-488 parallel interface sends commands as data and receives measurements and messages as data. The maximum data exchange rate is 1 Mbyte, with a maximum distance of 20 meters for the sum length of the connecting cables. A single cable should not exceed 4 meters in length. Some commands are reserved for RS-232 serial operation because these functions must be implemented as IEEE messages per the IEEE Standards. For example, the command REMOTE could be sent as data over the IEEE-488 interface to place the M2000 into remote, but it is not because the IEEE Standards call for the remote function to be sent to the device as the uniline message REN. This is also true for several other commands and functions, as shown below, with their equivalent RS-232 emulation. A summary of IEEE-488 messages is shown in Table 4.

Table 4. RS-232 Emulation of IEEE-488 Messages

IEEE-488 Message	RS-232 Equivalent
GTL	LOCAL command
GTR	REMOTE command
LLO	LOCKOUT command
SDC, DCL	(not emulated on RS-232)
GET	(not emulated on RS-232)
SPE, SPD	(not emulated on RS-232)
UNL, UNT	(not emulated on RS-232)

The IEEE-488 interface is based on the IEEE Standards 488.1 and 488.2. For detailed information, refer to the IEEE-488.1 and IEEE-488.2 standards.

Using Commands

Communications between the controller and the M2000 consists of commands, queries, and interface messages. Although the commands are based on the 488.2 standard, they can be used on either the IEEE-488 or RS-232 interface, except for a few specialized RS-232 commands described in "Commands for RS-232 Only." (For more information on command structures, see the IEEE 488.2 standard.)

Refer to Chapter XI, "Remote Commands" when you require additional information about command references used in this chapter.

All commands and units may be entered in UPPER or lower case.

Types of Commands

The commands for the M2000 can be grouped into one or more categories, depending on how they function. Each category is described below.

Device-Dependent Commands

Device-dependent commands are unique to the M2000. An example of a device-dependent command is,

OUT 1 V

instructing the M2000 to source 1 volt dc.

Common Commands

Common commands are defined by the IEEE 488.2 standard and are common to most bus devices. Common commands always begin with an * character. Common commands are available whether you are using the IEEE-488 or RS-232 interface for remote control. An example of a common command is,

*IDN?

instructing the M2000 to return the instrument identification string.

Query Commands

Query commands request information, which is returned as the command executes, or placed in a buffer until requested. An example of a query, which always ends with a question mark, is,

RANGE?

returning the M2000 dc voltage output range.

Interface Messages (IEEE-488)

Interface messages manage traffic on the IEEE-488 interface bus. Device addressing and clearing, data handshaking, and commands to place status bytes on the bus are all directed by interface messages. Some of the interface messages occur as state transitions of dedicat-

ed control lines. The rest of the interface messages are sent over the data lines with the ATN signal true. (All device-dependent and common commands are sent over the data lines with the ATN signal false.)

An important thing to note about interface messages is that unlike device-dependent and common commands, interface messages are not sent literally (in a direct way).

IEEE-488 standards define interface messages. Interface messages are handled automatically in most cases.

Compound Commands

A compound command is two or more commands in a single command line. For example, the following two commands could be entered individually,

```
OUT 1 V
OPER
```

where the M2000 sources 1 V dc, and then goes into operate, or they could be combined into a compound command,

```
OUT 1 V ; OPER
```

using a semi-colon as a separator.

Overlapped Commands

Commands that begin execution but require slightly more time to complete are called overlapped commands, because they can be overlapped by the next command before they have completed execution.

The command graphic Overlapped shows a check for overlapped commands.

You can use the command *WAI to wait until the overlapped command has completed execution before executing the next command. For example,

```
OUT 1 V ; *WAI
```

You can also use the status commands *OPC and *OPC? to detect completion of overlapped commands. (See "Checking M2000 Status.")

Sequential Commands

Commands that execute immediately are called sequential commands.

The command graphic Sequential shows a check for sequential commands.

The majority of the commands are sequential.

Commands for RS-232 Only

The command graphic IEEE-488 RS-232 indicates RS-232 interface commands.

The IEEE-488 and RS-232 interfaces both send commands to the M2000 as data, except for those IEEE-488 functions that must be implemented as a message as specified in the IEEE-488 standards. For example, the RS-232 interface uses the command REMOTE to place the M2000 in the Remote mode. Although the IEEE-488 interface could also send a command REMOTE as data, it does not because this is one of the functions that must be implemented per IEEE-488 Standards. The relationship between these IEEE-488 messages and the equivalent RS-232 emulation is shown in Table 5.

Table 5. Commands for RS-232 Only

IEEE-488 Message [1]	RS-232 Equivalent
GTL	LOCAL command
GTR	REMOTE command
LLO	LOCKOUT command

Commands for IEEE-488 Only

The command graphic IEEE-488 indicates commands that are used for the IEEE-488 interface. This is all the commands, except for those used for RS-232 operations. (See "Commands for RS-232 Only.") All commands are transferred over the IEEE-488 as data,

except for the commands LOCAL, REMOTE, and LOCKOUT, which are implemented per IEEE Standards as messages.

Command Syntax

The following syntax rules apply to all the remote commands. Information about syntax of response messages is also given.

Parameter Syntax Rules

Table 6 lists the units accepted in command parameters and used in responses. All commands and units may be entered in upper or lower case.

Table 6. Units Accepted in Parameters and Used in Responses

Units	Meaning
uV	Volts in units of microvolts ¹
mV	Volts in units of millivolts ¹
V	Volts in units of volts
kV	Volts in units of kilovolts ¹
uA	Current in units of microamperes ¹
mA	Current in units of milliamps ¹
A	Current in units of amps
1. Parameter only	

General Rules The general rules for parameter usage is as follows:

1. Numeric parameters may have up to 15 significant digits and their exponents can be in the range +/-1.0E +/-20.
2. Including too many or too few parameters causes a command error.
3. Null parameters cause an error, e.g., the adjacent commas in OUT 1V, ,;OPER.
4. Expressions, for example 4+2*13, are not allowed as parameters.

Extra Space or Tab Characters

In the command descriptions, parameters are shown separated by spaces. One space after a command is required (unless no parameters are required). All other spaces are optional. Spaces are inserted for clarity in the manual and may be left in or omitted as desired. You can insert extra spaces or tabs between parameters as desired. Extra spaces within a parameter are generally not allowed, except for between a number and its associated multiplier or unit.

Terminators

Table 7 summarizes the terminator characters for both the IEEE-488 and RS-232 remote interfaces.

Table 7. Terminator Characters

Terminator	ASCII Character		Control Command	Language Command
Function	Number	Program	Terminator	Terminator
Carriage Return (CR)	13	Chr(13)	<Cntl> M	\n
Line Feed (LF)	10	Chr(10)	<Cntl> J	\r
Examples: RS-232 Mode using a terminal OUT 1 V <Enter> RS-232 Mode using a program Comm1.Output = "OUT 1 V" + Chr(10) IEEE-488 Mode OUT 1 V				

IEEE-488 Interface The M2000 sends the ASCII character Carriage Return with the EOI control line held high as the terminator for response messages. The M2000 recognizes the following as terminators when encountered in incoming data:

- ASCII CR character
- Any ASCII character sent with the EOI control line asserted

RS-232 Interface The M2000 returns a Carriage Return (CR) character with each response. The M2000 recognizes the following as terminators when encountered in incoming data:

- ASCII CR character
- ASCII LF character

Incoming Character Processing

The M2000 processes all incoming data as follows:

1. The most significant data bit (DIO8) is ignored.
2. All data is taken as 7-bit ASCII.
3. Lower-case or upper-case characters are accepted.

Response Message Syntax

In the command descriptions responses from the M2000 are described wherever appropriate. In order to know what type of data to read in, refer to the first part of the entry under "Response" in the tables.

Checking M2000 Status

You have access to status registers, enable registers, and queues in the M2000 to indicate various conditions in the instrument as shown in Figure 7. Some registers and queues are defined by the IEEE-488.2 standard. The rest are specific to the Calibrator. In addition to the status registers, the Service Request (SRQ) control line, and a 16-element buffer called the Error Queue provide status information. Table 8 lists the status registers and gives the read/write commands and associated mask registers.

Table 8. Status Register Summary

Status Register	Read Command	Write Command
Serial Poll Status Byte (STB)	*STB?	—
Service Request Enable Register (SRE)	*SRE?	*SRE
Event Status Register (ESR)	*ESR?	—
Event Status Enable Register (ESE)	*ESE?	*ESE

Each status register and queue has a summary bit in the Serial Poll Status Byte. Enable registers are used to mask various bits in the status registers and generate summary bits in the Serial Poll Status Byte. For IEEE-488 interface operation, the Service Request Enable Register is used to assert the SRQ control line on detection of any status condition or conditions the programmer chooses. For RS-232 interface operation, the SRQSTR string is sent over the serial interface when the SRQ line is set. (See the SRQSTR command description for more information.)

Serial Poll Status Byte (STB)

The Calibrator sends the serial poll status byte (STB) when it responds to a serial poll. This byte is cleared (set to 0) when the power is turned on. The STB byte is defined as shown in Figure 7. Refer to the *STB? Command for RS-232 interface operation for more information.

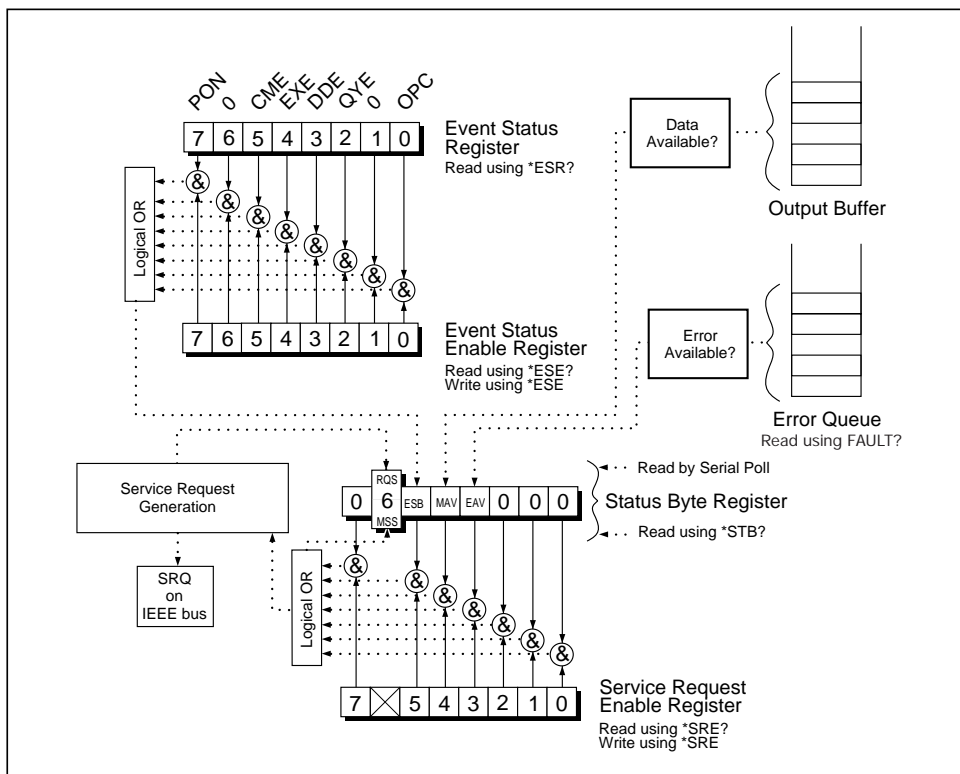


Figure 7
Status Register Overview

7	6	5	4	3	2	1	0
0	RQS	ESB	MAV	EAV	0	0	0
	MSS						
RQS	Requesting service. The RQS bit is set to 1 whenever bits ESB, MAV, EAV, or ISCB change from 0 to 1 and are enabled (1) in the SRE. When RQS is 1, the M2000 asserts the SRQ control line on the IEEE-488 interface. You can do a serial poll to read this bit to see if the M2000 is the source of an SRQ.						
MSS	Master summary status. Set to 1 whenever bits ESB, MAV, EAV, or ISCB are 1 and enabled (1) in the SRE. This bit can be read using the *STB? command in serial remote control in place of doing a serial poll.						
ESB	Set to 1 when one or more ESR bits are 1.						
MAV	Message available. The MAV bit is set to 1 whenever data is available in the M2000's IEEE-488 interface output buffer.						
EAV	Error available. An error has occurred and an error is available to be read from the error queue by using the FAULT? query.						

Figure 8. Serial Poll Status Byte (STB) and Service Request Enable (SRE)

Service Request (SRQ) Line

IEEE-488 Service Request (SRQ) is an IEEE-488.1 bus control line that the M2000 asserts to notify the controller that it requires some type of service. Many instruments can be on the bus, but they all share a single SRQ line. To determine which instruments set SRQ, the Controller normally does a serial poll of each instrument. The calibrator asserts SRQ whenever the RQS bit in its Serial Poll Status Byte is 1. This bit informs the controller that the M2000 was the source of the SRQ.

The M2000 clears SRQ and RQS whenever the controller/host performs a serial poll, sends *CLS, or whenever the MSS bit is cleared. The MSS bit is cleared only when ESB and MAV are 0, or they are disabled by their associated enable bits in the SRE register being set to 0.

Service Request Enable Register (SRE)

The Service Request Enable Register (SRE) enables or masks the bits of the Serial Poll Status Byte. The SRE is cleared at power up. Refer to Figure 7 for the bit functions.

Programming the STB and SRE

By resetting (to 0) the bits in the SRE, you can mask (disable) associated bits in the serial poll status byte. Bits set to 1 enable the associated bit in the serial poll status byte.

Event Status Register (ESR)

The Event Status Register is a two-byte register in which the higher eight bits are always 0, and the lower eight bits represent various conditions of the M2000. The ESR is cleared (set to 0) when the power is turned on, and every time it is read.

Many of the remote commands require parameters. Improper use of parameters causes command errors to occur. When a command error occurs, bit CME (5) in the Event Status Register (ESR) goes to 1 (if enabled in ESE register), and the error is logged in the error queue.

Event Status Enable (ESE) Register

A mask register called the Event Status Enable register (ESE) allows the controller to enable or mask (disable) each bit in the ESR. When a bit in the ESE is 1, the corresponding bit in the ESR is enabled. When any enabled bit in the ESR is 1, the ESB bit in the Serial Poll Status Byte also goes to 1. The ESR bit stays 1 until the controller reads the ESR or does a device clear, a selected device clear, or sends the reset or *CLS command to the M2000. The ESE is cleared (set to 0) when the power is turned on.

Bit Assignments for the ESR and ESE

The bits in the Event Status Register (ESR) and Event Status Enable register (ESE) are assigned as shown in Figure 9.

15	14	13	12	11	10	9	8
0	0	0	0	0	0	0	0
7	6	5	4	3	2	1	0
PON	0	CME	EXE	DDE	QYE	0	OPC

PON	Power on. This bit is set to 1 if line power has been turned off and on since the last time the ESR was read.
CME	Command error. The M2000's IEEE-488 interface encountered an incorrectly formed command. (The command FAULT? fetches the latest error code in the error queue, which contains error codes for the first 15 errors that have occurred.)
EXE	Execution error. An error occurred while the M2000 tried to execute the last command. This could be caused, for example, by a parameter being out of range. (The command FAULT? fetches the latest error in the error queue, which contains error codes for the first 15 errors that have occurred.)
DDE	Device-dependent error. An error related to a device-dependent command has occurred.
QYE	Query error. The M2000 was addressed to talk when no response data was available or appropriate, or when the controller failed to retrieve data on the output queue.
OPC	Operation complete. All commands previous to reception of a *OPC command have been executed, and the interface is ready to accept another message.

Figure 9. Event Status Register (ESR) and Event Status Enable (ESE)

Programming the ESR and ESE

To read the contents of the ESR, send the remote command, *ESR?. The ESR is cleared (set to 0) every time it is read. To read the contents of the ESE, send the remote command, *ESE?. The ESE is not cleared when it is read. When you read either register, the M2000 responds by sending a decimal number that when converted to binary represents bits 0 through 15.

Output Queue

The output queue is loaded whenever a query is processed, and holds up to 250 characters. The controller reads it with a statement such as a BASIC INPUT statement, removing what it reads from the queue. If the queue is empty, the M2000 does not respond to the INPUT statement from the controller. The Message Available (MAV) bit in the Serial Poll Status Byte is 1 if there is something in the output queue and 0 if the output queue is empty.

Error Queue

When a command error, execution error, or device-dependent error occurs, its error code is placed in the error queue where it can be read by the FAULT? command. (See Chapter 5 for a list of error messages.) Reading the first error with the FAULT? command removes that error from the queue. A response of 0 means the error queue is empty. The error queue is cleared when you turn off the power, and when you use the *CLS (Clear Status) common command. The error queue contains up to 15 entries. If more than 15 errors occur, only the first 15 errors are kept in the queue. A 16th entry in the queue is always an "error queue overflow" error, and all later errors are discarded until the queue is at least partially read. The first errors are kept,

because if many errors occur before the user can acknowledge and read them, the earliest errors are the most likely to point to the problem. The later errors are usually repetitions or consequences of the original problem.

Input Buffer Operation

As the M2000 receives each data byte from the controller, it places the bytes in a portion of memory called the input buffer. The input buffer holds up to 250 data bytes and operates in a first in, first out fashion.

IEEE-488 The M2000 treats the EOI IEEE-488 control line as a separate data byte and inserts it into the input buffer if it is encountered as part of a message terminator. Input buffer operation is transparent to the program running on the controller. If the controller sends commands faster than the M2000 can process them, the input buffer fills to capacity. When the input buffer is full, the M2000 holds off the IEEE-488 bus with the NRD (Not Ready For Data) handshake line. When the M2000 has processed a data byte from the full input buffer, it then completes the handshake, allowing the controller to send another data byte. The calibrator clears the input buffer on power-up and on receiving the DCL (Device Clear) or SDC (Selected Device Clear) messages from the controller.

RS-232 Under RS-232-C serial port remote control using ^ S (<Cntl> S) XOFF protocol, the M2000 issues a ^ S XOFF when the input buffer becomes 80% full. The calibrator issues a ^ Q (<Cntl> Q) XON when it has read enough of the input buffer so that it is less than 40% full.

XV. REMOTE COMMANDS

Introduction

Remote commands duplicate activities that can be initiated from the front panel in local operation. Following the summary table is a complete alphabetical listing of all commands complete with protocol details. Separate headings in the alphabetical listing provide the parameters and responses, plus an example for each command. For information on using commands, see "Remote Operation."

Command Summary by Function

Common Commands

Command	Description
*CLS	(Clear status.) Clears the ESR, the error queue, and the RQS bit in the status byte. This command terminates pending operation complete commands (*OPC or *OPC?).
*ESE	Loads a byte into the Event Status Enable register.
*ESE?	Returns the contents of the Event Status Enable register.
*ESR?	Returns the contents of the Event Status register and clears the register.
*IDN?	Identification query. Returns the manufacturer, model number, and firmware revision level of the Calibrator.
*OPC	Enables setting of bit 0 (OPC for "Operation Complete") in the Event Status Register to 1 when all pending device operations are complete.
*OPC?	Returns a 1 after all pending operations are complete. This command causes program execution to pause until all operations are complete. (See also *WAI.)
*OPT?	Returns a list of the installed hardware and software options.
*RST	Resets the state of the instrument to the power-up state. This command holds off execution of subsequent commands until it is complete. (Overlapped command.)
*SRE	Loads a byte into the Service Request Enable register (SRE).
*SRE?	Returns the byte from the Service Request Enable register.
*STB?	Returns the status byte.
*TST?	Initiates a series of self-tests, then returns a "0" for pass or a "1" for fail. If any faults are detected, they are logged into the fault queue where they can be read by the FAULT? query.
*WAI	Prevents further remote commands from being executed until all previous remote commands have been executed.

Output Commands

Command	Description
FUNC?	Returns the present output, measurement, or calibration function.
OPER	Activates the M2000 output if it is in standby.
OPER?	Returns the operate/standby setting.
OUT	Sets the output of the M2000.
OUT?	Returns the output amplitude of the M2000.
RANGE?	Returns the present output range. (Voltage only).
RANGELCK	Locks the present output range (Voltage only).
RANGELCK?	Returns the RANGELOCK state (Voltage only).
STBY	Deactivates the M2000 output if it is in Operate mode.

RS-232 Port Commands

Command	Description
LOCAL	Puts the M2000 into the local state and disables lockout.
LOCKOUT	Puts the M2000 into the lockout state. This command duplicates the
IEEE-488 LLO	(Local Lockout) message.
REMOTE	Puts the M2000 into the remote state. This command duplicates the
IEEE-488 REN	(Remote Enable) message.

Status Commands

Command	Description
FAULT?	Returns the most recent error code in the M2000 error queue, then removes that error code from the queue.

Error Code Listing

Error Number	Message Class	Description
1	DDE	Error queue overflow.
101	CME	A non-numeric entry was received in a field that should contain a numeric entry.
102	EXE	The numeric field exceeds 10 characters.
105	EXE	Entry is above upper limit for the selected output range.
106	EXE	Entry is below lower limit for the selected output range.
107	EXE	OUT? was received when the M2000 was not in a Source mode.
108	CME	A required command parameter was missing.
110	CME	An invalid RANGELCK parameter (not ON or OFF) was received.
111	EXE	RANGELCK ON was received when the M2000 is not in Volts mode.
117	CME	An unrecognizable command was received.
118	CME	An invalid parameter was received.
120	EXE	The serial input buffer overflowed
121	EXE	The command string buffer overflowed.
122	QYE	The serial output buffer overflowed.
123	DDE	The output overloaded.
124	DDE	M2000 is out of tolerance. This error is set after a failed initialization or a failed *TST?.
125	DDE	M2000 has a ADC failure. This error is set after a failed initialization or a failed *TST?.

Remote Command Listing

The following is an alphabetical list of all M2000 commands and queries, including common commands and device-dependent commands. Each command title includes a graphic that indicates remote interface applicability, IEEE-488 and RS-232, and command group: Sequential and Overlapped.

*CLS IEEE-488 RS-232 Sequential Overlapped

(Clear Status command) Clears the ESR, the error queue, and the RQS bit in the status byte. This command terminates pending operation complete commands (*OPC or *OPC?).

Parameter: (None)

Example: *CLS

Clear the ESR, the error queue, and the RQS bit in the status byte.

***ESE** IEEE-488 RS-232 Sequential Overlapped

(Event Status Enable command) Loads a byte into the Event Status Enable (ESE) register. (See "Event Status Enable Register (ESE)")

Parameter: <value> (decimal equivalent of the ESE byte, 0 to 255)

Example: *ESE 140

Load decimal 140 (binary 10001100) to enable bits 7 (PON), 3 (DDE) and 2 (QYE).

***ESE?** IEEE-488 RS-232 Sequential Overlapped

(Event Status Enable query) Returns the contents of the Event Status Enable (ESE) register. (See "Event Status Enable Register (ESE)")

Response: <value> (decimal equivalent of the ESE byte, 0 to 255)

Example: *ESE? returns 133

Returns decimal 133 (binary 10000101) when bits 7 (PON), 2 (QYE), 1 (OPC) are enabled.

***ESR?** IEEE-488 RS-232 Sequential Overlapped

(Event Status Register query) Returns the contents of the Event Status Register (ESR) and clears the register. (See Event Status Register (ESR)")

Response: <value> (decimal equivalent of the ESR byte, 0 to 255)

Example: *ESR? returns 189

Returns decimal 189 (binary 00111101) when bits 5 (CME), 4 (EXE), 3 (DDE), 2 (QYE) and 0 (OPC) are enabled.

FAULT? IEEE-488 RS-232 Sequential Overlapped

Returns the most recent error code from the error queue. If the queue is empty (no errors have occurred) it returns 0. The command can be used when the previous command did not do what it was intended to do.

For example, if a value for current output above 100 mA is entered, the FAULT? command would return error code 105, entry is above upper limit for the selected output range.

FUNC? IEEE-488 RS-232 Sequential Overlapped

(Function query) Returns the present output, measurement, or calibration function. See the response below for output and measurement modes. Responses:

DCV (dc volts function)

DCI (dc current function)

Example: FUNC? returns DCV

Returns DCV when the M2000 output function dc volts.

***IDN?** IEEE-488 RS-232 Sequential Overlapped

(Identification query) Returns instrument model number, serial number, and firmware revision levels for the main, encoder, and inguard CPUs.

Responses: (Indefinite ASCII) A message containing four fields separated by commas as follows:

1. Manufacturer
2. Model number
3. Serial number (always 0)
4. Firmware revision levels for the main, front panel, and inguard CPUs.

Example: *IDN? returns MARTEL, M2000,0,1.2

Returns Martel manufacturer, model M2000, serial number 0, firmware version 1.2.

LOCAL IEEE-488 RS-232 Sequential Overlapped

(Local command) Puts the M2000 into the local state, clearing the remote state (see the REMOTE command) and front panel lockout (see the LOCKOUT command). This command duplicates setting the IEEE-488 REN line to false.

Parameter: (None)

Example: LOCAL

Set the instrument into the local state, clearing the remote state and front panel lockout (if enabled).

LOCKOUT IEEE-488 RS-232 Sequential Overlapped

(Lockout command) Puts the M2000 into the lockout state when in remote control (see the REMOTE command). This means no local operation at the front panel is allowed during remote control. To clear the lockout condition, use the LOCAL command. This command duplicates the IEEE-488 LLO (Local Lockout) message.

Parameter: (None)

Example: LOCKOUT

Set the instrument into the front panel lockout state. The front panels controls cannot be used.

***OPC** IEEE-488 RS-232 Sequential Overlapped

(Operations Complete command) Sets bit 0 (OPC) of the Event Status Register to 1 when all pending device operations are complete. Also see the *ESR? command.

Parameter: (None)

Example: *OPC

Set bit 0 of the Event Status Register to 1 when all pending device operations are done.

***OPC?** IEEE-488 RS-232 Sequential Overlapped

(Operations Complete query) Returns a 1 after all pending operations are complete. This command causes program execution to pause until operations are complete. (See *WAI.)

Response: 1 (all operations are complete)

Example: *OPC? returns 1

Returns 1 when all pending operations are complete.

OPER IEEE-488 RS-232 Sequential Overlapped

(Operate command) Activates the M2000 output if it is in standby. This is the same as pressing the M2000 front panel STBY
OPR key.

Parameter: (None)

Example: OPER

Connect the selected output to the M2000 front panel terminals. Also indicates OPR on the display.

OPER? IEEE-488 RS-232 Sequential Overlapped

(Operate query) Returns the operate/standby setting.

Response: 1 (Operate)

0 (Standby)

Example: OPER? returns 1

Returns 1 when the M2000 is in operate.

***OPT?** IEEE-488 RS-232 Sequential Overlapped

(Options command) Returns a list of the installed hardware and software options.

Responses: <option string>, <option string>, (options list, separated by commas)
0 (no options are installed)

Example: *OPT? Returns 0

This command is reserved for future use.

OUT IEEE-488 RS-232 Sequential Overlapped

(Output command) Sets the output of the M2000 and establishes a new reference point for the error mode. To source or measure a temperature, select the desired sensor and sensor parameters first. (See the TSENS_TYPE, RTD_TYPE, and TC_TYPE commands.)

Use multipliers, k, m, u with the OUT command, as desired.

Parameters: <value> V Volts dc
<value> A Current dc

Examples: OUT 15.2 V (volts; 15.2 V)
OUT 1.2 mA (current; 1.2 mA)

Each example shows a value and unit, e.g., -15.2 V. If a value is entered without a unit, the value of the existing output is changed, when logically allowed.

OUT? IEEE-488 RS-232 Sequential Overlapped

(Output query) Returns the output amplitude of the M2000. Multipliers (e.g., K or M) are not used in the response.

Response: <amplitude value>, <units>

Examples: OUT? returns -1.520000E+01,V
OUT? returns 1.88300E-02,A
OUT? returns 1.23000E+00,V
OUT? returns 1.52000E+01,V

The respective values for the above examples are:

-15.2 V
18.83 mA
1.23 V
15.2 V

RANGE? IEEE-488 RS-232 Sequential Overlapped

(Range query) Returns the present voltage output range.

Response: <range>

Examples: V_0.1V (dc volts 100 mV range)
V_1V (dc volts 1V range)
V_10V (dc volts 10 V range)
V_100V (dc volts 100 V range)

Returns the symbolic name of the voltage output range.

RANGELCK IEEE-488 RS-232 Sequential Overlapped

(Range lock command) Locks or unlocks the present voltage range.

Parameter: ON Locks the present voltage range
OFF Unlocks the present voltage range.

RANGELCK? IEEE-488 RS-232 Sequential Overlapped

(Range command) Returns the RANGELOCK state 1 for ON or 0 for OFF.

Parameter: (None)

REMOTE IEEE-488 RS-232 Sequential Overlapped

(Remote command) Places the M2000 into the remote state. This command duplicates the IEEE-488 REN (Remote Enable) message. When the M2000 is in the remote state, and not locked out, only the LOCAL key is active. If the front panel is locked out, no front panel keys are active. See the LOCKOUT command. To unlock the front panel, use the LOCAL command, or cycle the M2000 power switch.

Parameter: (None)

Example: REMOTE

***RST** IEEE-488 RS-232 Sequential Overlapped

(Reset Instrument command) Resets the M2000 to the power-up state. *RST holds off execution of subsequent commands until the reset operation is complete.

A reset action evokes the following commands and values:

Command	Value
OUT	0 V
RANGE	0.1 V
STBY	(No output)

Response: (None)

Example: *RST

Place the M2000 in a reset condition, evoking the commands and values shown above.

***SRE** IEEE-488 RS-232 Sequential Overlapped

(Service Request Enable command) Loads a byte into the Service Request Enable (SRE) register. (See "Service Request Enable Register (SRE)". Since bit 6 is not used (decimal value 64), the maximum entry is $255 - 64 = 191$.

Parameter: <value> (the decimal equivalent of the SRE byte, 0 to 191)

Example: *SRE 48

Enable bits 4 (MAV), and 5 (ESR).

***SRE?** IEEE-488 RS-232 Sequential Overlapped

(Service Request Enable query) Returns the byte in the Service Request Enable (SRE).

Response: <value> (the decimal equivalent of the SRE byte, 0 to 191)

Example: *SRE? returns 48

Returns 48 when bits 4 (MAV), and 5 (ESR) are enabled.

***STB?** IEEE-488 RS-232 Sequential Overlapped

(Status Byte Register query) Returns the byte for the Status Byte Register. See "Status Byte Register (STB)" in Chapter 4.

Response: <value> (the decimal equivalent of the STB byte, 0 to 255)

Example: *STB? returns 96

Returns 96 if bits 5 (ESR) and 6 (MSS) are set.

STBY IEEE-488 RS-232 Sequential Overlapped

(Standby command) Deactivates the M2000 output if it is in operate. This is the same as pressing the M2000 front panel A key.

Parameter: (None)

Example: STBY

Disconnect the selected output from the M2000 front panel terminals.

***TST?** IEEE-488 RS-232 Sequential Overlapped

(Self Test command) Initiates self-test and returns a 0 for pass or a 1 for fail. If any faults are detected, they are displayed on screen (Terminal mode) or are logged into the fault queue where they can be read by the FAULT? query (Computer mode).

Responses: 0 (fail self test)
 1 (pass self test)

Example: *TST? returns 1

Returns 1 when self test passes.

***WAI** IEEE-488 RS-232 Sequential Overlapped

(Wait-to-Continue command) Prevents further remote commands from being executed until all previous remote commands have been executed. For example, if you send an OUT command, you can cause the M2000 to wait until the output has settled before continuing on to the next command if you follow OUT with a *WAI command. The *WAI command is useful with any overlapped command, preventing the M2000 from processing other commands until the overlapped command is processed.

Example: *WAI

Process all existing commands before continuing.

XVI. SPECIFICATIONS

General Specifications

Warm up time	Twice the time since last warmed up, to a maximum of 30 minutes.
Settling time	Less than 5 seconds for all functions and ranges except as noted.
Standard interface	RS-232
Optional interface	IEEE-488 (GPIB)
Temperature performance	Operating 0 °C to 50 °C Calibration (tcal) 18 °C to 28 °C Storage -20 °C to 70 °C
Electromagnetic compatibility	CE: Conforms to EN61326
Temperature coefficient	Temperature coefficient for temperatures outside tcal ± 5 °C is 10 % of the 90 day specification (or 1 year if applicable) per °C
Relative humidity	Operating <80 % to 30 °C, <70% to 40 °C, <40 % to 50 °C Storage <95 % noncondensing
Altitude	Operating 3,050 m (10,000 ft) maximum Nonoperating 12,200 m (40,000 ft) maximum
Safety	EN 61010 Second, ANSI/ISA-S82.01-1994, CAN/CSA-C22.2 No. 1010.1-92, NRTL
Analog low isolation	20 V
Line power	Line Voltage (selectable) 100 V/120 V or 220 V/240 V Line Frequency 47 to 63 Hz Line Voltage Variation ± 10 % about line voltage setting
Power consumption	15 VA maximum
Dimensions	Height 13.3 cm (5.25 in) plus 1.5 cm (0.6 in) four feet on bottom Width $\frac{3}{4}$ standard rack width Depth 47.3 cm (18.6 in) overall
Weight (without options)	4 kg (9 lb)

DC Voltage Specifications, Output

Ranges ¹	Absolute Uncertainty, tcal ± 5 °C \pm (ppm of output $+\mu\text{V}$)				Stability 24 hours, ± 1 °C \pm (ppm of output $+\mu\text{V}$)	Resolution	Maximum Burden ²
	90 days		1 year				
0 to 100.000 mV	25	3	30	3	5 ppm +2	1 μV	10 mA
0 to 1.00000 V	25	20	30	20	4 ppm +20	10 μV	10 mA
0 to 10.0000 V	25	200	30	200	4 ppm +200	100 μV	10 mA
0 to 100.000 V	25	2 mV	30	2 mV	5 ppm +1 mV	1 mV	1 mA

1. All outputs are positive only.
2. Remote sensing is not provided. Output resistance is $< 1\Omega$.

Ranges	Noise	
	Bandwidth 0.1 to 10 Hz p-p \pm (ppm of output $+\mu\text{V}$)	Bandwidth 10 Hz to 10 kHz rms μV
0 to 100.000 mV	1 μV	6 μV
0 to 1.00000 V	10 μV	60 μV
0 to 10.0000 V	100 μV	600 μV
0 to 100.000 V	10 ppm+1 mV	20 mV

DC Current Specifications, Output

Ranges ¹	Absolute Uncertainty, tcal ± 5 °C \pm (ppm of output + μ A)				Resolution	Maximum Compliance Voltage	Maximum Inductive Load
	90 days		1 year				
0 to 100.000 mA	85	2	100	2	1 μ A	10 V	100 mH
1. All outputs are positive only.							

Ranges	Noise	
	Bandwidth 0.1 to 10 Hz p-p	Bandwidth 10 Hz to 10 kHz rms μ V
0 to 100.000 mA	2000 nA	20 μ A

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