D5000M SERIES USERS MANUAL

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D5000M modules are not intrinsically safe devices and should not be used in an explosive environment unless enclosed in approved explosion-proof housings.

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WARRANTY

DGH warrants each D5000M series module to be free from defects in materials and workmanship under normal conditions of use and service and will replace any component found to be defective, on its return to DGH, transportation charges prepaid within one year of its original purchase. DGH assumes no liability, expressed or implied, beyond its obligation to replace any component involved. Such warranty is in lieu of all other warranties expressed or implied.

WARNING

The circuits and software contained in D5000M series modules are proprietary. Purchase of these products does not transfer any rights or grant any license to the circuits or software used in these products. Disassembling or decompiling of the software program is explicitly prohibited. Reproduction of the software program by any means is illegal.

As explained in the setup section, all setups are performed entirely from the outside of the D5000M module. There is no need to open the module because there are no user-serviceable parts inside. Removing the cover or tampering with, modifying, or repairing by unauthorized personnel will automatically void the warranty. DGH is not responsible for any consequential damages.

RETURNS

When returning products for any reason, contact the factory and request a Return Authorization Number and shipping instructions. Write the Return Authorization Number on the outside of the shipping box. DGH strongly recommends that you insure the product for value prior to shipping. Items should not be returned collect as they will not be accepted.

Shipping Address:

DGH Corporation
Hillhaven Industrial Park
146 Londonderry Turnpike
Hooksett, NH 03106

Default Mode

All D5000M modules contain an EEPROM (Electrically Erasable Programmable Read Only Memory) to store setup information and calibration constants. The EEPROM replaces the usual array of switches and pots necessary to specify baud rate, address, parity, etc. The memory is nonvolatile which means that the information is retained even if power is removed. No batteries are used so it is never necessary to open the module case.

The EEPROM provides tremendous system flexibility since all of the module's setup parameters may be configured remotely through the communications port without having to physically change switch and pot settings. There is one minor drawback in using EEPROM instead of switches; there is no visual indication of the setup information in the module. It is impossible to tell just by looking at the module what the baud rate, address, parity and other settings are. It is difficult to establish communications with a module whose address and baud rate are unknown. To overcome this, each module has an input pin labeled DEFAULT*. By connecting this pin to Ground, the module is put in a known communications setup called Default Mode.

The Default Mode setup is: 300 baud, one start bit, eight data bits, one stop bit, no parity, any address is recognized.

Grounding the DEFAULT* pin does not change any of the setups stored in EEPROM. The setup may be read back with the Read Setup (RS) command to determine all of the setups stored in the module. In Default Mode, all commands are available.

Each channel of the D5000M has its own channel address and all four channels are enabled in Default Mode. The addresses assigned to a module must be four consecutive ASCII values, such as 0, 1, 2, 3. A module in Default Mode will respond to any address except the six identified illegal values (NULL, CR, $, #, {, }). A dummy address must be included in every command for proper responses. The ASCII value of the module's first channel address may be read back with the RS command. A properly addressed channel can read data values and can modify calibration values, such as trim span in the Default Mode. However it must be noted that in Default Mode a module that is addressed with any value other than the four proper addresss values assigned to it will always respond with the data from its first channel. For example if a module as described above is addresses with any character other than 0, 1, 2, 3, it will respond with or modify data from channel 0.

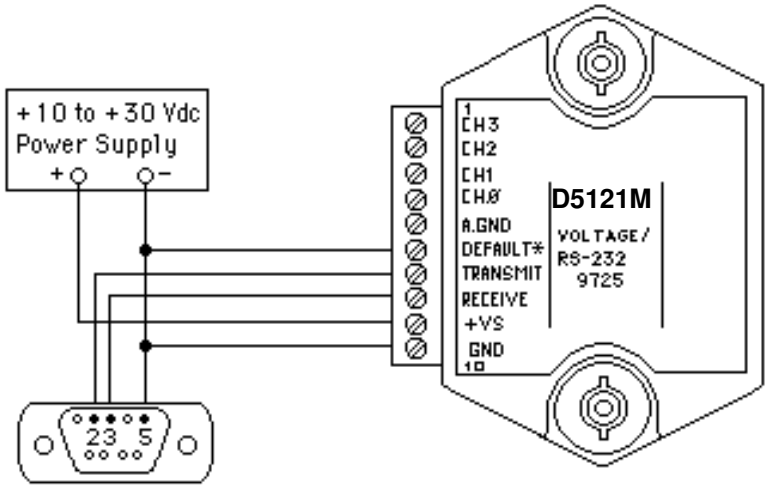
Setup information in a module may be changed at will with the SetUp (SU) command. Baud rate and parity setups may be changed without affecting the Default values of 300 baud and no parity. When the DEFAULT* pin is released, the module automatically performs a program reset and configures itself to the baud rate and parity stored in the setup information.

The Default Mode is intended to be used with a single module connected to a terminal or computer for the purpose of identifying and modifying setup values. In most cases, a module in Default Mode may not be used in a string with other modules.

RS-232 & RS-485 Quick Hook-Up

Software is not required to begin using your D5000M module. We recommend that you begin to get familiar with the module by setting it up on the bench. Start by using a dumb terminal or a computer that acts like a dumb terminal. Make the connections shown in the quick hook-up drawings, Figures 1.1 or 1.2. Put the module in the Default Mode by grounding the Default* terminal. Initialize the terminal communications package on your computer to put it into the “terminal” mode. Since this step varies from computer to computer, refer to your computer manual for instructions.

Begin by typing $1RD and pressing the Enter or Return key. The module will respond with an * followed by the data reading at the input. The data includes sign, seven digits and a decimal point. For example, if you are using a thermocouple module and measuring room temperature your reading might



Note: If using a DB-25 connector ground is tied to pin 7. Pin 3 is tied to TRANSMIT and pin 2 is tied to RECEIVE on the module.

Figure 1.1 RS-232C Quick Hook-Up.

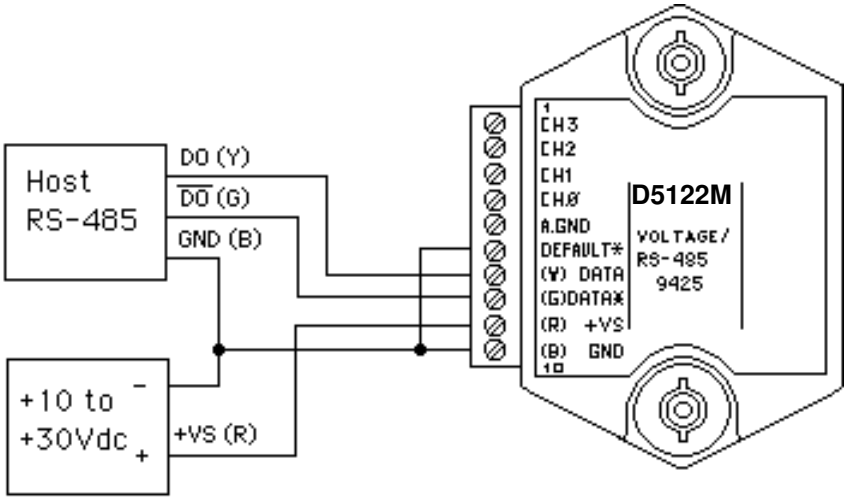


Figure 1.2 RS-485 Quick Hook-Up.

be *+00025.00. The temperature reading will be in °C. Once you have a response from the module you can turn to the Chapter 4 and get familiar with the command set.

All modules are shipped from the factory with a setup that includes a channel address of 1, 300 baud rate, no linefeeds, no parity, alarms off and two-character delay. Refer to the Chapter 5 to configure the module to your application.

RS-485 Quick Hook-up to a RS-232 port

An RS-485 module may be easily interfaced to an RS-232C terminal for evaluation purposes. This connection is only suitable for benchtop operation and should never be used for a permanent installation. Figure 1.3 shows the hook-up. This connection will work provided the RS-232C transmit output is current limited to less than 50mA and the RS-232C receive threshold is greater than 0V. All terminals that use 1488 and 1489 style interface IC's will satisfy this requirement. With this connection, characters generated by the terminal will be echoed back. To avoid double characters, the local echo on the terminal should be turned off.

If the current limiting capability of the RS-232C output is uncertain, insert a 100Ω to 1kΩ resistor in series with the RS-232 output.

In some rare cases it may be necessary to connect the module's DATA pin to ground through a 100Ω to 1kΩ resistor.

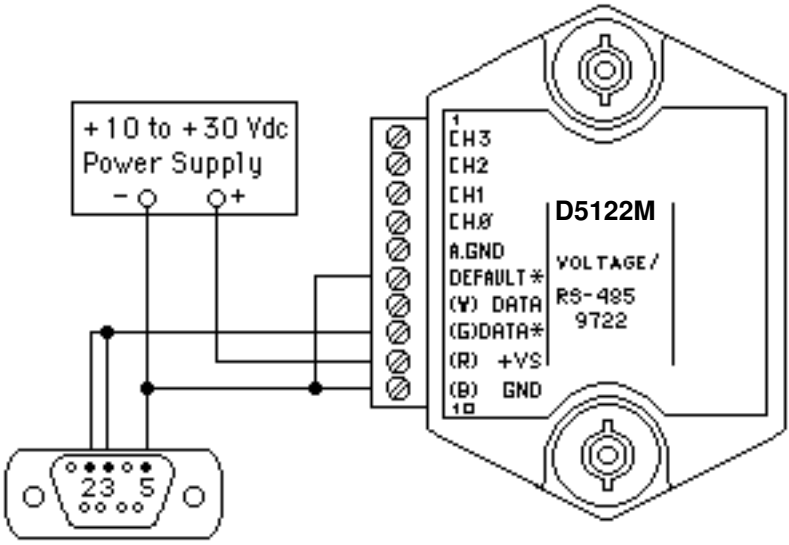


Figure 1.3 RS-485 Quick Hook-Up with RS-232C Port.

Software Quick Start

The D5000M series modules are initialized at the factory to communicate using the D5000M ASCII protocol. This allows for all setup and configurations to be easily performed using the setup software. After the setup process has been completed the D5000M can be placed in Modbus RTU protocol mode using the “MBR” command. Disable the Modbus RTU mode using the Modbus Disable (“MBD”) command.

Windows Quick-Start Steps:

1. Locate the DGH Utility Software CD-ROM and place it in your computer CD-ROM drive.
2. Using Windows 95 or higher operating systems, click on the “Start” button in the lower left hand corner. When the menu pops up, select “Run” and the “Browse” to the CD-ROM drive in your machine.
3. Select the “Setup.exe” file and “Run” it. This will begin installation of the DGH Windows Utility Software.

4. The installation program will run and you can select the default installation settings by pressing the “Next” button thru most of the prompt screens.

5. Once the installation is completed, you can review the “readme.txt” file. Or simply “Finish” the process.

6. A “Utility Software” icon will be placed on your Windows desktop. Click on this icon to run the Utility Software.

7. All DGH Users Manuals were installed during the Utility Software installation process. The Users Manuals can be found on a new menu by pressing the Windows “Start” button and selecting “Programs”. Next, select “DGH Data Acquisition” and then select “Manuals”. Click on the D5000M Users Manual to open it.

8. Connect a power supply to the D5000M between the +VS terminal and the GND terminal. The power supply voltage must be between +10 and +30Vdc.

9. Properly connect the D5000M to a computer serial port using the “Quick Hook-Up” diagrams in Chapter #1 of this manual using either an RS-232 or RS-485 Serial port.

10. An optional CA-3 serial cable and wiring diagram may be used to connect an RS-232 module to a DB-9 serial port.

11. At the Utility Software main menu, select “Setup” and then select “Modules”. A new dialog screen will open.

12. Using the drop down list box screen object, select the proper serial port that the module is connected to.

13. Press the “Settings” button to display the serial port settings. Select the proper COM port, set the baud rate for ‘300’. Press the “Advanced” button and ensure that the Parity Type is set to “Mark”, Data bits is “Seven”, Flow Control is “RTS Only” and the Stop Bits are “One”. Press the “Open” or “Update” button.

14. Select the proper device Model Number from the drop down list box screen object. Use only the four digits. For example, a D5121M should be a “5121”.

15. Specify the device address. If the “Default*” terminal on the module is connected to the “GND” terminal then any device address is acceptable. If the “Default*” terminal is not connected to the “GND” terminal then you must select the correct device address in the “Address” list box.

16. Press the “Read Setup” button at the bottom of the dialog screen. If no errors were detected then a new dialog screen will appear with all the current module setup values.
17. To configure the device for a Modbus system, the only values that need to be changed are the Baud Rate, possibly the Parity type and the Modbus Slave Address. Most Modbus systems use No Parity.
18. Set the Baud rate to the same baud rate as the Modbus master device that this module will be connected to.
19. Select the new Modbus Slave address and check the “Enable” box. Then press the “Apply” button to download the changes to the module. The setup is complete.

Modbus Installation/Verification:

1. The DGH module is now configured for the proper Baud Rate and Modbus Slave Address. The module can now be connected directly to the Modbus Master. Or it can be functionally checked.
2. To functionally verify the operation of the Modbus protocol make sure that the “Default*” terminal is no longer connected to the “GND” terminal.
3. From the Utility Software main menu select “Tools” and then select “Evaluation Screens” and then “Modbus I/O Screen”.
4. Click on the “Settings” button and change the Baud Rate to the value that the module is configured for.
5. Press the “Advanced” button. Select “8 Data bits”, “RTS Only”, “No Parity” and “2 Stop Bits”. Press the “Update” or “Open” button.
6. Select the Modbus Slave Address to the same value as the module is configured for.
7. Select Modbus function ‘04’ and register ‘000’.
8. Press the “Transmit” button.
9. Hexadecimal numbers will appear in the “Response” box. These numbers are hexadecimal between the values of ‘0000’ and ‘ffff’. They represent a percentage of the full scale value. If your getting readings back that move as your input moves then the Modbus protocol is working successfully. For more information how to compute these values consult the DGH Users Manual for your product.

DOS Quick start steps:

1. Connect a power supply to the D5000M between +Vs terminal and GND terminal. The supply voltage must be between +10 and +30Vdc.

2. Properly connect the D5000M series to a computer using the “quick hook-up” diagrams in chapter #1 of this manual using either an RS-232 or RS-485 serial port.

3. Locate the S1000 Utility software diskette and copy files from the S1000 sub-directory on the computer hard drive and run the 1000.bat file.

4. Configure the main menu “Host” RS-232 Port settings and correct COMx: port baud rate. Note: If the “Default*” pin on D1000M is connected to GND then select 300 baud as host computer baud rate and select no parity.

5. Select main menu “Setup” and enter the D5000M device address and four digit model number. For example, enter 5112 for a D5112M analog input module.

6. At the next configuration screen make alterations to Baud Rate, Parity type and any other required parameters. Press the <F10> function key to transmit the new setup values. Once the values have been transmitted press the <ESC> key back to the program main menu.

7. Select “Misc” followed by “Enable Modbus Mode” to specify the Modbus Slave address. Using the <+><-> keys, or left mouse button, increment the screen address value to desired Modbus Slave address and press <F10> to transmit the value.

8. Remove the connection between “Default*” and GND, which performs internal reset, to enable Modbus RTU mode. If there was no connection between “Default*” and GND then cycle the power on device to force a reset and enable Modbus Mode.

The device is now configured for Modbus RTU mode and can be connected to a RS-485 based Modbus master system.

Modbus Installation/Verification:

1. The D5000M module is now configured for the proper Baud Rate and Modbus Slave Address. The module can now be connected directly to the Modbus Master. Or it can be functionally checked.
2. To functionally verify the operation of the Modbus protocol make sure that the “Default*” terminal is no longer connected to the “GND” terminal.
3. From the Utility Software main menu select “Tools” and then select “Evaluation Screens” and then “Modbus I/O Screen”.
4. Click on the “Settings” button and change the Baud Rate to the value that the module is configured for.
5. Press the “Advanced” button. Select “8 Data bits”, “RTS Only”, “No Parity” and “2 Stop Bits”. Press the “Update” or “Open” button.
6. Select the Modbus Slave Address to the same value as the module is configured for.
7. Select Modbus function ‘04’ and register ‘000’.
8. Press the “Transmit” button.
9. Hexadecimal numbers will appear in the “Response” box. These numbers are hexadecimal between the values of ‘0000’ and ‘ffff’. They represent a percentage of the full scale value. If your getting readings back that move as your input moves then the Modbus protocol is working successfully. For more information on how to compute these values consult the Users Manual for your product. For more information D5000M Modbus portocol and scaling of data see Chapter 4 and Appendix C respectively.

Chapter 2
Functional Description

A functional diagram of a typical module is shown in Figure 2.1. It is a useful reference that shows the data path in the module and to explain the function of many of the module's commands.

The first step is to acquire the sensor signal and convert it to digital data. In Figure 2.1, all the signal conditioning circuitry has been lumped into one block, the analog/digital converter (A/D). Autozero and autocalibration is performed internally and is transparent to the user.

The full-scale output of each channel may be trimmed using the Trim Span (TS) command. The TS command adjusts the calibration values for each channel that stored in the internal EEPROM. The TS command should only be used to trim the accuracy of the unit with a laboratory standard reference applied to the sensor input.

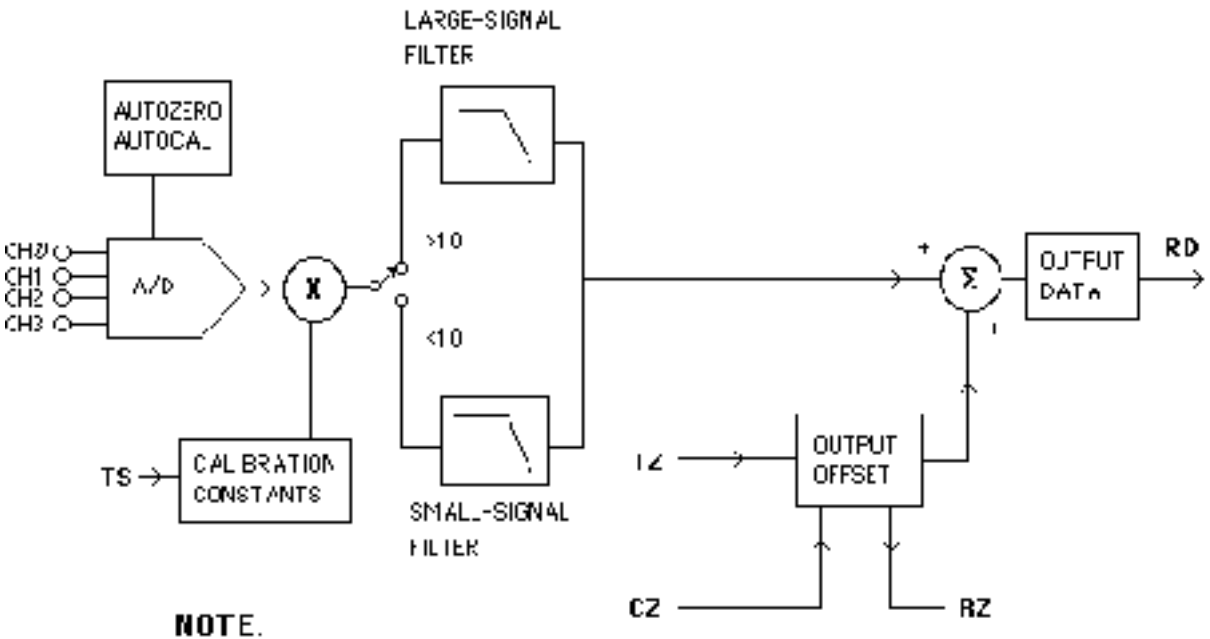
The trimmed data flows into either of two digital filters. The filter selection is performed automatically by the microprocessor after every A/D conversion. The filter selection depends on the difference of the current A/D output data and the previous data stored in the output data register. If the least significant decimal digit from the A/D differs from the old output data by more than 10 counts, the large signal filter is selected. If the change is less than 10 counts, the small signal filter is used.

The two-filter system allows for different degrees of filtering depending on the rate of the input change. For steady-state signals, the small-signal filter averages out noise and small input changes to give a stable steady-state output. The large-signal filter is activated by step changes or very noisy input signals. The time constants for the two filters can be specified independently with the SetUp (SU) command. The filter values are stored in nonvolatile memory. Typically, the small-signal filter is set to a larger time constant than the large-signal filter. This gives very good noise rejection along with fast response to step inputs.

The scaled data is summed with data stored in the Output Offset Register to obtain the final output value. The output offset is controlled by the user and has many purposes. The data in the Output Offset Register may be used to trim any offsets caused by the input sensor. It may be used to null out undesired signal such as a tare weight. The Trim Zero (TZ) command is used to adjust the output to any desired value by loading the appropriate value in the offset register. The offset register data is nonvolatile.

The output data may be read with the Read Data (RD) command.

Figure 2-1 Block Diagram



NOTE:

BOLDFACE=COMMANDS

Chapter 3
Communications

Introduction

The D5000M modules has been carefully designed to be easy to interface to all popular computers and terminals. All communications to and from the modules are performed with printable ASCII characters. This allows the information to be processed with string functions common to most high-level languages such as BASIC. For computers that support RS-232C, no special machine language software drivers are necessary for operation. The modules can be connected to auto-answer modems for long-distance operation without the need for a supervisory computer. The ASCII format makes system debugging easy with a dumb terminal.

This system allows multiple modules to be connected to a communications port with a single 4-wire cable. Up to 30 RS-485 modules may be strung together on one cable.

The modules communicate with the host on a polling system; that is, each module responds to its own unique address and must be interrogated by the host. A module can never initiate a communications sequence. A simple command/response protocol must be strictly observed to avoid communications collisions and data errors.

Communications to the D5000M modules is performed with two-character ASCII command codes such as RD to Read Data from the analog input. A complete description of all commands is given in the Chapter 4. A typical command/response sequence would look like this:

Command: **$1RD**
Response: ***+00123.00**

A command/response sequence is not complete until a valid response is received. The host may not initiate a new command until the response from a previous command is complete. Failure to observe this rule will result in communications collisions. A valid response can be in one of three forms:

1) a normal response indicated by a ' * ' prompt
2) an error message indicated by a ' ? ' prompt
3) a communications time-out error

When a module receives a valid command, it must interpret the command, perform the desired function, and then communicate the response back to the host. Each command has an associated delay time in which the module is busy calculating the response. If the host does not receive a response in an appropriate amount of time specified in Table 3.1, a communications time-out error has occurred. After the communications time-out it is assumed that no response data is forthcoming. This error usually results when

an improper command prompt or address is transmitted. The table below lists the timeout specification for each command:

Mnemonic	Timeout
RD	10 mS
All other commands	100 mS

Table 3.1 Response Timeout Specifications.

The timeout specification is the turn-around time from the receipt of a command to when the module starts to transmit a response.

Data Format

All modules communicate in standard NRZ asynchronous data format. This format provides one start bit, seven data bits, one parity bit and one stop bit for each character.

RS-232C

RS-232C is the most widely used communications standard for information transfer between computing equipment. RS-232C versions of the D5000 will interface to virtually all popular computers without any additional hardware. The advantages offered by the RS-232C standard are:

1) widely used by all computing equipment
2) no additional interface hardware in most cases
3) separate transmit and receive lines ease debugging
4) compatible with dumb terminals

However, RS-232C suffers from several disadvantages:

1) low noise immunity
2) short usable distance
3) greater communications delay in multiple-module systems
4) less reliable–loss of one module; communications are lost
5) wiring is slightly more complex than RS-485
6) host software must handle echo characters

RS-232 Module Connection

Figure 1.1 shows the connections necessary to attach one module to a host. Use the Default Mode to enter the desired address, baud rate, and other setups (see Setups).

Software Considerations
If the host device is a computer, it must be able to handle the echoed command messages on its Receive input along with the responses from the module. This can be handled by software string functions by observing that a module response always begins with a ' * ' or ' ? ' character and ends with a carriage return.

RS-485
RS-485 is a communications standard to satisfy the need for multidropped systems that can communicate at high data rates over long distances. RS-485 is similar to RS-422 in that it uses a balanced differential pair of wires switching from 0 to 5V to communicate data. RS-485 receivers can handle common mode voltages from -7V to +12V without loss of data, making them ideal for transmission over great distances. RS-485 differs from RS-422 by using one balanced pair of wires for both transmitting and receiving. Since an RS-485 system cannot transmit and receive at the same time it is inherently a half-duplex system. RS-485 offers many advantages over RS-232C:

1) balanced line gives excellent noise immunity
2) can communicate with D5000M modules at 115200 baud
3) communications distances up to 4,000 feet.
4) true multidrop; modules are connected in parallel
5) can disconnect modules without losing communications
6) up to 247 modules on one line using RS-485 repeaters
7) no communications delay due to multiple modules
8) simplified wiring using standard telephone cable

RS-485 does have disadvantages. Very few computers or terminals have built-in support for this new standard. Interface boards are available for the IBM PC and compatibles and other RS-485 equipment will become available as the standard gains popularity. An RS-485 system usually requires an interface.

We offer the A1000 and A2000 interface converters that will convert RS-232 signals to RS-485 or repeat RS-485 signals. The A1000 converters also include a +24Vdc, one amp power supply for powering D5000M series modules. The A1000 or A2000 connected as an RS-485 repeater can be used to extend an existing RS-485 network on one serial port.

RS-485 Multidrop System
Figure 3.1 illustrates the wiring required for multiple-module RS-485 system. Notice that every module has a direct connection to the host system. Any number of modules may be unplugged without affecting the remaining modules. Each module must be setup with a unique address and the

addresses can be in any order. All RS-485 modules must be setup for no echo to avoid bus conflicts (see Setup). Also note that the connector pins on each module are labelled with notations (B), (R), (G), and (Y). This designates the colors used on standard 4-wire telephone cable:

Label	Color
(B) GND	Black
(R) V+	Red
(G) DATA* (-)	Green
(Y) DATA (+)	Yellow

This color convention is used to simplify installation. If standard 4-wire telephone cable is used, it is only necessary to match the labeled pins with the wire color to guarantee correct installation.

DATA* on the label is the complement of DATA (negative true).

To minimize unwanted reflections on the transmission line, the bus should be arranged as a line going from one module to the next. 'Tree' or random structures of the transmission line should be avoided. When using long transmission lines and/or high baud rates, the data lines should be terminated at each end with 200 ohm resistors. Standard values of 180 ohms or 220 ohms are acceptable.

During normal operation, there are periods of time where all RS-485 drivers are off and the communications lines are in an 'idle' high impedance condition. During this condition, the lines are susceptible to noise pickup which may be interpreted as random characters on the communications line. To prevent noise pickup, all RS-485 systems should incorporate 1K ohm bias resistors as shown in Figure 3.1. The resistors will maintain the data lines in a 'mark' condition when all drivers are off.

A1000 series converter boxes have the 1KΩ resistors built-in. The resistors are user-selectable via dip switch located on the rear panel of the A1000.

Special care must be taken with very long busses (greater than 1000 feet) to ensure error-free operation. Long busses must be terminated as described above. The use of twisted cable for the DATA and DATA* lines will greatly enhance signal fidelity. Use parity and checksums along with the '#' form of all commands to detect transmission errors. In situations where many modules are used on a long line, voltage drops in the power leads becomes an important consideration. The GND wire is used both as a power

connection and the common reference for the transmission line receivers in the modules. Voltage drops in the GND leads appear as a common-mode voltage to the receivers. The receivers are rated for a maximum of -7V. of common-mode voltage. For reliable operation, the common mode voltage should be kept below -5V.

To avoid problems with voltage drops, modules may be powered locally rather than transmitting the power from the host. Inexpensive 'calculator' type power supplies are useful in remote locations. When local supplies are used, be sure to provide a ground reference with a third wire to the host or through a good earth ground. With local supplies and an earth ground, only two wires for the data connections are necessary.

Communications Delay

All D5000M modules with RS-485 outputs are setup at the factory to provide two units of communications delay after a command has been received (see Chapter 5). This delay is necessary when using host computers that transmit a carriage return as a carriage return-linefeed string. Without the delay, the linefeed character may collide with the first transmitted character from the module, resulting in garbled data. If the host computer transmits a carriage return as a single character, the delay may be set to zero to improve communications response time.

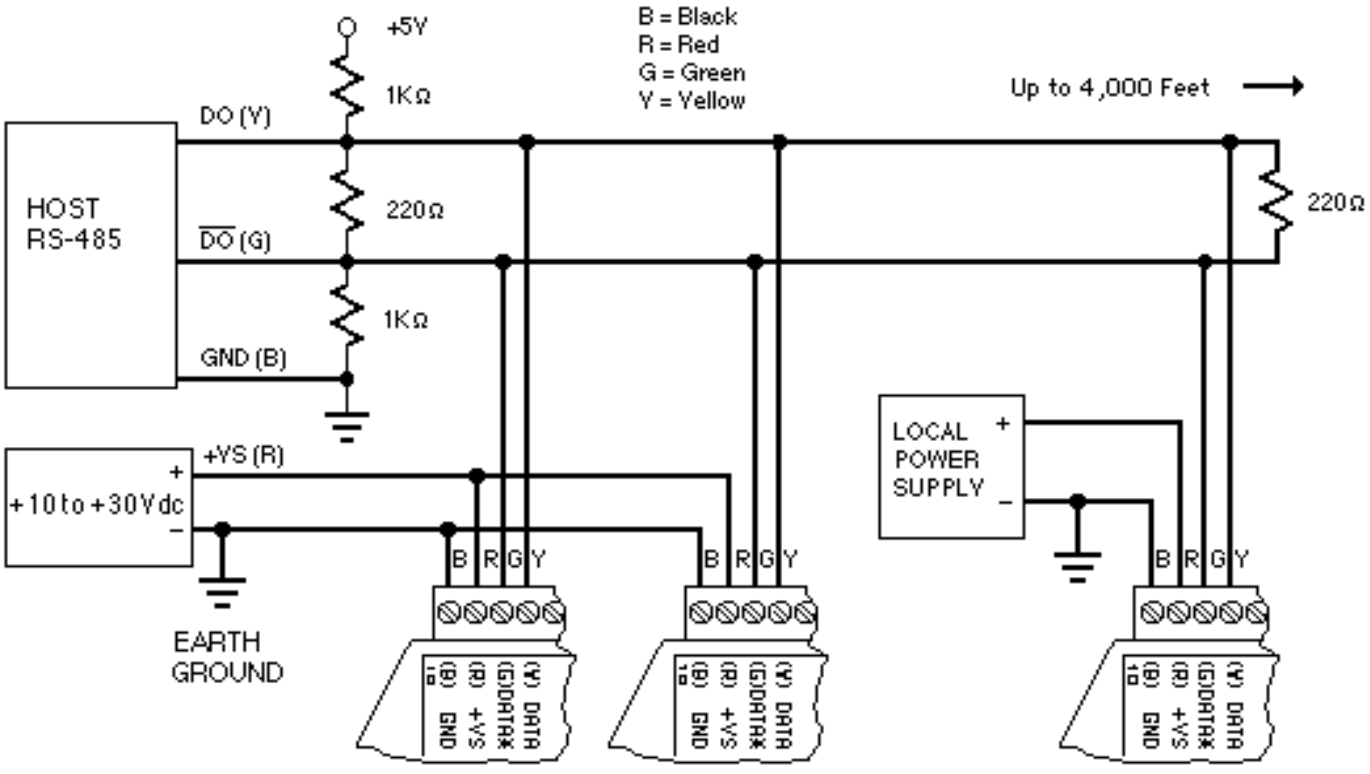


Figure 3.2 RS-485 Network.

Chapter 4
Function Codes/Command Set

Intrduction

The D5000M uses Modbus RTU protocol for communication and the D5000M ASCII protocol for setup,configuration and default settings. The begining of Chapter 4 explains the Mobus RTU protocl, usable D5000M Modbus function codes and exception responses. The end of the chapter explains the ASCII protocol, usable D5000M ASCII commands and error messages. The user should become familiar with both of these potocols.

Modbus Protocol Overviw

This document describes the Modbus RTU protocol option included in the D5000M series of data acquisition modules. This implementation of the Modbus protocol is a subset of the protocol as described in the Modicon Modbus Protocol Reference Guide PI-MBUS-300 Rev F. Only the RTU version of the protocol has been implemented.

Modbus RTU mode communicates in standard NRZ asynchronous format with one start bit, eight data bits, one parity bit, and one stop bit. Even and odd parity is supported. If no parity is specified, the number of stop bits can be user configured for either one or two stop bits.

Baud rates supported at this time are: 300, 600, 1200, 2400, 4800, 9600, 19,200, 38,400, 57,600 and 115,200 baud.

Modbus uses RS-485 for multidrop communications. RS-232 is supported for one module per serial port.

Modbus is a registered trademark of AEG Modicon Inc.

The Modbus RTU protocol transmits data in 8-bit binary bytes (not ASCII). To illustrate the data in this document, the 8-bit byte is described as two hexadecimal nibbles. For example, the binary byte value “0101 1101” will be written as 5D.

A typical Modbus RTU command may look like this:

01 04 00 00 00 01 31 CA

Remember, this command string and others throughout this document are actually transmitted to a module as eight 8-bit binary characters.

The actual format of the data is dependent on the type of command desired. The example above is the Modbus 'Read Input Registers' function.

The '01' is the address of the slave device (D5000M module) being commanded. Each slave device must have its own unique address.

The '04' specifies the Modbus 'Read Input Registers' function. This is equivalent to the 'Read Data' command to obtain analog input data.

The next two characters '00 00' specify the starting address of the registers to be read. The first Modicon input register 30001 is addressed as '00 00'. Register 30004 is addressed as '00 03', etc.

The next two characters of this command specify the number of registers to be read, including the starting register. In this case the two binary characters '00 01' indicates only one register is to be read.

The final two characters of the command string make up the Cyclical Redundancy Check (CRC), used to check for errors in the message.

There are no prompt or terminating characters in the messages. All messages must be transmitted as continuous strings. Messages are terminated by a 'silent' interval of at least 3.5 character times. A 'silent' interval of more than 1.5 character times marks the beginning of the next message. Therefore it is mandatory that the RS-485 bus must be biased in the MARK condition during the 'silent' interval. This is usually accomplished by pull-up and pull-down resistors on the communications line.

A typical response to this example command could be:

01 04 02 80 00 D8 F0

The '01' and '04' characters echo the slave address and the command function.

For this particular command function, the '02' character indicates the number of data characters to follow, in this case, 2 characters.

The two character string '80 00' is the value read from Modicon input register 30001. Register data is read back as 16 bits.

The remaining two characters, 'D8 F0' is the CRC for the response.

The A1000 series of RS-232 to RS-485 protocol converters and repeaters will not operate with the 9-bit data characters used by the Modbus protocol.

Modbus Function Codes

Modbus protocol compatible devices communicate using a master-slave technique similar to that used in ASCII protocol. In a master-slave communications system only one device (the master) can initiate a communications sequence. All others devices (the slaves) respond when requested by the master. Typical master devices can be personal computers or PLCs. Typical slave devices are D5000M modules.

The master can address any slave device. Slave devices return a message to any command that was addressed specifically to them. The returned messages are considered response messages.

The Modbus protocol format used by a master consists of a device address, a command function code which defines the operation to be performed, data required with the command, and an error checking value. The slave response message contains any required data and an error checking value. If an error occurs, an exception code will be generated. The supported master function codes are discussed below.

04 - Read Input Register (Analog Inputs)
06 - Preset Single Register (Return to D5000M ASCII protocol)

Function (04) - Read Input Register (Analog Inputs)

Read Input Register function (04) is the primary command to acquire analog input data. This command function supports reading of up to 4 input registers starting from Modbus slave register 30001 thru 3004. The registers are addressed starting from zero meaning registers 1-4 are addressed as 0-3. The D5000M contains four analog inputs defined as channels 0 thru 3. Each of the four analog input channels are converted into Modbus data values. These data values are then mapped and stored into registers that can be read using the Modbus Function 04.

The response data for each channel is returned as two bytes that represent a 16-bit binary value. The 16-bit value is scaled as a percentage of the full scale input range. The first byte contains the high order bits and the second contains the low order bits. The binary analog values for each channel can range from 0000-FFFF (hexadecimal).

A typical command and response to read the analog input value from Modbus device address 01 is:

Command: 01 04 00 00 00 04 F1 C9
Response: 01 04 08 7F FD 80 02 80 02 7F FE 00 16

In the command string:
01 is the slave address
04 is the Read Input Registers command
00 00 is the starting register to be read (Modbus address 30001)
00 04 specifies the number of registers to be read, in this case, four registers.
F1 C9 is the CRC for this message

In the response string:
01 is the slave address
04 is the command
08 is the number of data bytes in the message, in this case, two bytes
7FFD is the analog data from Modbus register 30001 (module channel 0)
8002 is the analog data from Modbus register 30002 (module channel 1)
8002 is the analog data from Modbus register 30003 (module channel 2)
7FFE is the analog data from Modbus register 30004 (module channel 3)
0016 is the CRC for this message

If we add a second module to the string (must be RS-485) the slave address in the command would be 02. The rest of the command is the same except the CRC.

The analog data from the D5000M is scaled so that 00 01 represents the Negative Full Scale value programmed into the module. FF FE represents the Positive Full Scale value programmed into the module.

For example, for a ±10 volt input module:
00 01 corresponds to -10 volts
80 00 corresponds to 0 volts
FF FE corresponds to +10 volts

A negative overload where the analog input exceeds minus full scale value is represented by 00 00 (hexadecimal).

A positive overload where the analog input exceeds the positive full scale value is represented by FF FF (hexadecimal).

See Appendix C for a more thorough explaination of D5000M scaling of data in Modbus.

Function (06) - Preset Single Register (Return to D5000M ASCII Protocol)
The Preset Single Register function (06) can be used to temporarily suspend the Modbus RTU protocol and force the module into D5000M ASCII protocol. Write a value of 0000 to Modbus register 40001 to temporarily suspend Modbus RTU mode. The module will then communicate using the D5000M ASCII protocol only.

Modbus Exception Responses
The following standard Modbus exception codes (error messages) are supported:

01 Illegal Function
This exception code is generated when the function code is not recognized by the module.

02 Illegal Data Address
This code is generated when the specified data address in the command is not supported by the module.

03 Illegal Data Value
This exception code is returned if the command data is out of range for the function.

06 Slave Device Busy
After the module is reset by power-up, a 'RR' command, or return from Default Mode, the module performs an initial self-calibration for a period of about 3 seconds. During this time any command sent to the module will result in a 'busy' exception response.

D5000M ASCII Protocol
The D5000M modules operate with a simple command/response protocol to control all module functions. A command must be transmitted to the module by the host computer or terminal before the module will respond with useful data. A module can never initiate a communications sequence. A variety of commands exists to exploit the full functionality of the modules. A list of available commands and a sample format for each command is listed in Table 4.1.

Command Structure
Each command message from the host must begin with a command prompt character to signal to the modules that a command message is to follow. There are four valid prompt characters; a dollar sign character ($) is used to generate a short response message from the module. A short response is the minimum amount of data necessary to complete the command. The

second prompt character is the pound sign character (#) which generates long responses (will be covered later in this chapter).

The prompt character must be followed by a single address character identifying the channel of the module to which the command is directed. Each module attached to a common communications port must be setup with its own unique addresses so that commands may be directed to the proper unit. Module addresses are assigned by the user with the SetUp (SU) command. Printable ASCII characters such as '1' (ASCII $31) or 'A' (ASCII $41) are the best choices for address characters. Each D5000 module requires from one to four addresses.

The address character is followed by a two or three-character command that identifies the function to be performed by the module. All of the available commands are listed in Table 4.1 along with a short function definition. All commands are described in Chapter 4. Commands must be transmitted as upper-case characters.

A two-character checksum may be appended to any command message as a user option. See 'Checksum' in Chapter 4 .

All commands must be terminated by a Carriage Return character (ASCII $0D). (In all command examples in this text the Carriage Return is either implied or denoted by the symbol 'CR'.)

Data Structure

Many commands require additional data values to complete the command definition as shown in the example commands in Table 4.1. The particular data necessary for these commands is described in full in the complete command descriptions.

The most common type of data used in commands and responses is analog data. Analog data is always represented in the same format for all models in the D5000M series. Analog data is represented as a nine-character string consisting of a sign, five digits, decimal point, and two additional digits. The string represents a decimal value in engineering units. Examples:

+12345.68
+00100.00
-00072.10
-00000.00

When using commands that require analog data as an argument, the full nine-character string must be used, even if some digits are not significant. Failure to do this results in a SYNTAX ERROR.

Analog data responses from the module will always be transmitted in the nine-character format. This greatly simplifies software parsing routines since all analog data is in the same format for all module types.

In many cases, some of the digits in the analog data may not be significant. For instance, the D5300 thermocouple input modules feature 1 degree output resolution. A typical analog data value from this type of module could be +00123.00. The two digits to the right of the decimal point have no significance in this particular model. However, the data format is always adhered to in order to maintain compatibility with other module types.

The Setup command uses hexadecimal representations of data. The data structure for this command is detailed in the command description.

Write Protection

Many of the commands listed in Table 4.1 are under the heading of 'Write Protected Commands'. These commands are used to alter setup data in the module's EEPROM. They are write protected to guard against accidental loss of setup data. All write-protected commands must be preceded by a Write Enable (WE) command before the protected command may be executed.

Miscellaneous Protocol Notes

The address character must transmitted immediately after the command prompt character. After the address character the module will ignore any character below ASCII $23 (except CR). This allows the use of spaces (ASCII $20) within the command message for better readability if desired.

The length of a command message is limited to 20 printable characters. If a properly addressed module receives a command message of more than 20 characters the module will abort the whole command sequence and no response will result.

If a properly addressed module receives a second command prompt before it receives a CR, the command will be aborted and no response will result.

Response Structure

Response messages from the module begin with either an asterisk ' * ' (ASCII $2A) or a question mark ' ? ' (ASCII $3F) prompt. The ' * ' prompt indicates acknowledgment of a valid command. The ' ? ' prompt precedes an error message. All response messages are terminated with a CR. Many commands simply return a ' * ' character to acknowledge that the command has been executed by the module. Other commands send data information following the ' * ' prompt. The response format of all commands may be found in the detailed command description.

The maximum response message length is 20 characters.

A command/response sequence is not complete until a valid response is received. The host may not initiate a new command until the response from a previous command is complete. Failure to observe this rule will result in communications collisions. A valid response can be in one of three forms:

1) a normal response indicated by a ' * ' prompt
2) an error message indicated by a ' ? ' prompt
3) a communications time-out error

When a module receives a valid command, it must interpret the command, perform the desired function, and the communicate the response back to the host. Each command has an associated delay time in which the module is busy calculating the response. If the host does not receive a response in an appropriate amount of time specified in Table 3.1, a communications time-out error has occurred. After the communications time-out it is assumed that no response data is forthcoming. This error usually results when an improper command prompt or address is transmitted.

Long Form Responses
When the pound sign ' # ' command prompt is used, the module responds with a 'long form' response. This type of response will echo the command message, supply the necessary response data and will add a two-character checksum to the end of the message. Long form responses are used when the host wishes to verify the command received by the module. The checksum is included to verify the integrity of the response data. The ' # ' command prompt may be used with any command. For example:

Command:	**$1RD**	**(short form)**
Response:	***+00072.10**	
Command:	**#1RD**	**(long form)**
Response:	***1RD+00072.10A4**	**(A4=checksum)**

Checksum
Checksum is a two character hexadecimal value appended to the end of a message. It verifies that the message received is exactly the same as the message sent. The checksum ensures the integrity of the information communicated.

Command Checksum
A two-character cumulative checksum may be appended to any command transmitted to the module as a user option. When a module interprets a command, it looks for the two extra characters and assumes that it is a checksum. If the checksum is not present, the module will perform the

command normally. If the two extra characters are present, the module calculates the checksum for the message. If the calculated checksum does not agree with the transmitted checksum, the module responds with a 'BAD CHECKSUM' error message and the command is aborted. If the checksums agree, the command is executed. If the module receives a single extra character, it responds with 'SYNTAX ERROR' and the command is aborted For example:

Command: $1RD (no checksum)
Response: *+00072.10

Command: $1RDEB (with checksum)
Response: *+00072.10

Command: $1RDAB (incorrect checksum)
Response: ?1 BAD CHECKSUM

Command: $1RDE (one extra character)
Response: ?1 SYNTAX ERROR

Response Checksums

If the long form ' # ' version of a command is transmitted to a module, a checksum will be appended to the end of the response. For example:

Command: $1RD (short form)
Response: *+00072.10

Command: #1RD (long form)
Response: *1RD+00072.10A4 (A4=checksum)

Checksum Calculation

The checksum is calculated by summing the hexadecimal values of all the ASCII characters in the message. The lowest order two hex digits of the sum are used as the checksum. These two digits are then converted to their ASCII character equivalents and appended to the message. This ensures that the checksum is in the form of printable characters.

Example: Append a checksum to the command #1RD

Characters:	#	1	R	D	
ASCII hex values:	23	31	52	44	
Sum (hex addition)	23 +	31 +	52 +	44	= EA

The checksum is EA (hex). Append the characters E and A to the end of the message: #1RDEA

Example: Verify the checksum of a module response *1RD+00072.10A4

The checksum is the two characters preceding the CR: A4

Add the remaining character values:

```
*   1   R   D   +   0   0   0   7   2   .   1   0
2A + 31 + 52 + 44 + 2B + 30 + 30 + 30 + 37 + 32 + 2E + 31 + 30 = A4
```

The two lowest-order hex digits of the sum are A4 which agrees with the transmitted checksum.

The transmitted checksum is the character string equivalent to the calculated hex integer. The variables must be converted to like types in the host software to determine equivalency.

If checksums do not agree, a communications error has occurred.

If a module is setup to provide linefeeds, the linefeed characters are not included in the checksum calculation.

Parity bits are never included in the checksum calculation.

Table 4.1 D5000M Command Set

Command and Definition	Typical Command Message	Typical Response Message ($ prompt)
RD Read Data	$1RD	*+00072.00
RMA Read Modbus Address	$1RMA	*0101
RS Read Setup	$1RS	*31070142
RZ Read Zero	$1RZ	*+00000.00
WE Write Enable	$1WE	*
Write Protected Commands		
CZ Clear Zero	$1CZ	*
MBD Modbus Disable	$1MBD	*
MBR Modbus Enable	$1MBR01	*RR
Remote Reset	$1RR	*
SU Setup Module	$1SU31070142	*
TS Trim Span	$1TS+00600.00	*
TZ Trim Zero	$1TZ+00000.00	*

D5000M User Commands
Note that in all command and response examples given below, a carriage return is implied after every character string.

Clear Zero (CZ)
The Clear Zero command clears the channel output offset register value to +00000.00. The D5000M series modules contain an output offset register for each channel. Specify the correct channel address with this command to clear the proper output offset register. This command clears any data resulting from a Trim Zero (TZ).

Command: **$1CZ**
Response: *

Command: **#1CZ**
Response: ***1CZF8**

Modbus RTU Enable (MBR)
To place any D5000M module in Modbus protocol mode use the Modbus RTU (MBR) command. The MBR command must be used to specify the Modbus device address and enable the Modbus protocol mode. The device address consists of a two character hexadecimal value and is stored in EEPROM. The two byte address specified is translated to a one byte, 8 bit address required by the Modbus protocol. The example below can be used to specify a Modbus device address of “01”.

Command: **$1MBR01**
Response: *

Command: **#1MBR01**
Response: ***1MBR019D**

After the Modbus address is specified, a reset is necessary to activate the Modbus protocol mode. The reset may be accomplished in one of three ways:

1) Removing power for about 10 seconds to perform a power-up reset.

2) Momentarily grounding the Default* pin.

3) Issue a Write Enable (WE) command followed by a Remote Reset (RR) command.

After a reset is performed, the module is in Modbus protocol mode.

Modbus Disable (MBD)
The Modbus Disable (MBD) command is used to disable the Modbus protocol. Any D5000M series module in Modbus mode can be returned to D1000 ASCII protocol mode by connecting a jumper wire between module pins GND and Default* pin. This places the module in Default Mode, where the module will only communicate at 300 baud, no parity, D5000 ASCII protocol, and answer to any address. While in Default mode, transmit an MBD command to internally disable the Modbus protocol.

Following the MBD command a device reset must occur. The reset is necessary to activate the D5000M ASCII protocol. A reset can occur by removing the Default* jumper, performing a power-up reset or by transmitting a Write Enable (WE) and Remote Reset (RR) command sequence.

After a reset is performed, the module is in D5000M ASCII protocol mode.

Command: **$1MBD**
Response: *****

Command: **#1MBD**
Response: ***1MBD2E**

Read Data (RD)
The Read Data command is the basic command used to read the buffered sensor data. The output buffer (Figure 2.1) allows the data to be read immediately without waiting for an input A/D conversion. For example:

Command: **$1RD**
Response: ***+00072.00**

Command: **#1RD**
Response: ***1RD+00072.10A4**

Since the RD command is the most frequently used command in normal operation, a special shortened version of the command is available. If a module is addressed without a two-letter command, the module interprets the string as an RD command.

Command: **$1**
Response: ***+00072.10**

Command: **#1**
Response: ***1RD+00072.10A4**

Read Modbus Address (RMA)
The Read Modbus Address command is only used for toubleshooting purposes. The RMA command tells you if the Modbus protocol is enabled or disabled and the Modbus slave address in the module. This

command should only be used when the module is in the DEFAULT mode.

Command: $1RMA
Response: *0001

Command: #1RMA
Response: *1RMA0001FC

The response contains two bytes. The second byte contains the Modbus slave address, in this example 01. The first byte indicates whether the Modbus protocol is enabled or not enabled. In this example 00 indicates that the Modbus protocol is not enabled. If the first byte were 01 the Modbus protocol is enabled.

Remote Reset (RR)
The reset command allows the host to perform a program reset on the module's microprocessor. This may be necessary if the module's internal program is disrupted by static or other electrical disturbances. Once a reset command is received, the module will recalibrate itself. The calibration process takes approximately 3 seconds. For example:

Command: $1RR
Response: *

Command: #1RR
Response: *1RRFF

Any commands sent to the module during the self-calibration sequence will result in a NOT READY error.

Read Setup (RS)
The read setup command reads back the setup information loaded into the module's nonvolatile memory with the SetUp (SU) command. The response to the RS command is four bytes of information formatted as eight hex characters.

Command: $1RS
Response: *31070142

Command: #1RS
Response: *1RS3107014292

The response contains the module's channel address, baud rate and other parameters. Refer to the setup command (SU), and Chapter 5 for a list of parameters in the setup information.

When reading the setup with a checksum, be sure not to confuse the checksum with the setup information.

Read Zero (RZ)
The Read Zero command reads back the value stored in the Output Offset Register.

Command: **$1RZ**
Response: ***+00000.00**

Command: **#1RZ**
Response: ***1RZ+00000.00B0**

The data read back from the Output Offset Register may be interpreted in several ways. The commands that affect this value are: Trim Zero (TZ) and Clear Zero (CZ).

Setup Command (SU)
Each D5000M module contains an EEPROM (Electrically Erasable Programmable Read Only Memory) which is used to store module setup information such as address, baud rate, parity, etc. The EEPROM is a special type of memory that will retain information even if power is removed from the module. The EEPROM is used to replace the usual array of DIP switches normally used to configure electronic equipment.

The SetUp command is used to modify the user-specified parameters contained in the EEPROM to tailor the module to your application. Since the SetUp command is so important to the proper operation of a module, a whole section of this manual has been devoted to its description. See Chapter 5.

The SU command requires an argument of eight hexadecimal digits to describe four bytes of setup information:

Com**mand:** **$1SU31070182**
Response: *

Command: **#1SU31070182**
Response: ***1SU3107018299**

Trim Span (TS)
The Trim Span command is the basic means of trimming the accuracy of a D5000M module. The TS command loads a calibration factor into nonvolatile memory to trim the full-scale output of an analog input channel. The D5000M series modules contain a seperate calibration span trim for each channel. This command is intended only to compensate for long-term drifts due to aging of the analog circuits, and has a useful trim value of ±10% of the nominal calibration set at the factory. It is not to be used to change the

basic transfer function of the module. Full information on the use of the TS command may be found in Chapter 8.

Command: **$1TS+00500.00**
Response: *

Command: **#1TS+00500.00**
Response: ***1TS+00500.00B0**

Caution! TS is the only command associated with the span trim. There is no provision to read back or clear errors loaded by the TS command. Misuse of the TS command may destroy the calibration of the unit which can only be restored by using laboratory calibration instruments in a controlled environment. An input signal must be applied when using this command.

Trim Zero (TZ)
The Trim Zero command is used to load a value into a channel Output Offset Register and null out an offset errors in the output data. Each D5000M series module contains four output offset registers. Specifiy the correct channel address in the command string for trim values to be loaded into the proper output offset register and trim offsets created by sensors. It may also be used to null out data to create a deviation output.

Example: Assume a D5111M voltage input module is being used and an initial reading with no input signal applied reveals an initial offset error:

Command: **$1RD**
Response: ***+00005.00**

With no signal applied, trim the output to read zero. To trim, use the TZ command and specify the desired output reading:

Command: **$1TZ+00000.00** **(zero output)**
Response: *

The TZ command will load a data value into the Output Offset Register to force the output to read zero. The module will compensate for any previous value loaded into the Output Offset Register. If another output reading is taken, it will show that the offset has been eliminated:

Command: **$1RD**
Response: ***+00000.00**

Although the TZ command is most commonly used to null an output to zero, it may be used to offset the output to any specified value. Assume that with

the previously nulled system we performed this command:

Command: **$1TZ-00100.00**
Response: *

The new data output with no signal applied would be:

Command: **$1RD**
Response: ***-00100.00**

The output is now offset by -100.

The offset value stored by the TZ command is stored in nonvolatile memory and may be read back with the Read Zero (RZ) command and cleared with the Clear Zero (CZ) command.

Write Enable (WE)
Each module is write protected against accidental changing of setup, or span and zero trims. To change any of these write protected parameters, the WE command must precede the write-protected command. The response to the WE command is an asterisk indicating that the module is ready to accept a write-protected command. After the write-protected command is successfully completed, the module becomes automatically write disabled. Each write-protected command must be preceded individually with a WE command. For example:

Command: **$1WE**
Response: *

Command: **#1WE**
Response: ***1WEF7**

If a module is write enabled and the execution of a command results in an error message other than WRITE PROTECTED, the module will remain write enabled until a command is successfully completed resulting in an ' * ' prompt. This allows the user to correct the command error without having to execute another WE command.

ERROR MESSAGES
The D5000M modules feature extensive error checking on input commands to avoid erroneous operation. Any errors detected will result in an error message and the command will be aborted.

All error messages begin with "**?**", followed by the channel address, a space and error description. The error messages have the same format for either the ' $ ' or ' # ' prompts. For example:

?**1 SYNTAX ERROR**

There are eight error messages, and each error message begins with a different character. It is easy for a computer program to identify the error without having to read the entire string.

ADDRESS ERROR
There are six ASCII values that are illegal for use as a module address: NULL ($00), CR ($0D), $ ($24), # ($23), { ($7B) and } ($7D). The ADDRESS ERROR will occur when an attempt is made to load an illegal address into a module with the SetUp (SU) command. An attempt to load an address greater than $7F will produce an error.

BAD CHECKSUM
This error is caused by an incorrect checksum included in the command string. The module recognizes any two hex characters appended to a command string as a checksum. Usually a BAD CHECKSUM error is due to noise or interference on the communications line. Often, repeating the command solves the problem. If the error persists, either the checksum is calculated incorrectly or there is a problem with the communications channel. More reliable transmissions might be obtained by using a lower baud rate.

COMMAND ERROR
This error occurs when the command is not recognized by the module. Often this error results when the command is sent with lower-case letters. All valid commands are upper-case.

NOT READY
If a module is reset, it performs a self-calibration routine which takes 2-3 seconds to complete. Any commands sent to the module during the self-calibration period will result in a NOT READY error. When this occurs, simply wait a couple seconds and repeat the command.

The module may be reset in three ways: a power-up reset, a Remote Reset (RR) command, or an internal reset. All modules contain a 'watchdog' timer to ensure proper operation of the microprocessor. The timer may be tripped if the microprocessor is executing its program improperly due to power transients or static discharge.

If the NOT READY error persists for more than 30 seconds, check the power supply to be sure it is within specifications.

PARITY ERROR
A parity error can only occur if the module is setup for 'even' or 'odd' parity. Usually a parity error results from a bit error caused by interference on the communications line. Random parity errors are usually overcome by simply

repeating the command. If too many errors occur, the communications channel may have to be improved or a slower baud rate may be used.

A consistent parity error will result if the host parity does not match the module parity. In this situation, the easiest solution may be to change the parity in the host to obtain communication. At this point the parity in the module may be changed to the desired value with the SetUp (SU) command.

The parity may be changed or turned off by using Default Mode.

SYNTAX ERROR
A SYNTAX ERROR will result if the structure of the command is not correct. This is caused by having too few or too many characters, signs or decimal points missing or in the wrong place. Table 4.1 lists the correct syntax for all the commands.

VALUE ERROR
This error results when an incorrect character is used as a numerical value. Data values can only contain decimal digits 0-9. Hex values used in the SetUp (SU) can range from 0-F.

WRITE PROTECTED
All commands that write data into nonvolatile memory are write-protected to prevent accidental erasures. These commands must be preceded with a Write Enable (WE) command or else a WRITE PROTECTED error will result.

Chapter 5
Setup Information/SetUp Command

The D5000M modules feature a wide choice of user configurable options which gives them the flexibility to operate on virtually any computer or terminal based system. The user options include a choice of baud rate, parity, address, and many other parameters. The particular choice of options for a module is referred to as the setup information.

The setup information is loaded into the module using the SetUp (SU) command. The SU command stores 4 bytes (32 bits) of setup information into a nonvolatile memory contained in the module. Once the information is stored, the module can be powered down indefinitely (10 years minimum) without losing the setup data. The nonvolatile memory is implemented with EEPROM so there are no batteries to replace.

The EEPROM has many advantages over DIP switches or jumpers normally used for option selection. The module never has to be opened because all of the options are selected through the communications port. This allows the setup to be changed at any time even though the module may be located thousands of feet away from the host computer or terminal. The setup information stored in a module may be read back at any time using the Read Setup command (RS).

The following options can be specified by the SetUp command:

Channel address
Linefeeds
Parity (odd, even, none)
Baud rate (300 to 115,200)
Communication delay (0-6 characters)
Number of displayed digits
Large-signal filter constant
Small-signal filter constant

Each of these options will be described in detail below. For a quick look-up chart on all options, refer to Tables 5.1-4.

Command Syntax
The general format for the SetUp (SU) command is:

$1SU[byte1][byte 2][byte 3][byte 4]

A typical SetUp command would look like: $1SU31070182.

Notice that each byte is represented by its two-character ASCII equivalent. In this example, byte 1 is described by the ASCII characters '31' which is the equivalent of binary 0011 0001 (31 hex). The operand of a SU command must contain exactly 8 hex (0-F) characters. Any deviation from this format will result in a SYNTAX ERROR. The Appendix contains a convenient hex-

to-binary conversion chart.

For the purposes of describing the SetUp command, 'bit 7' refers to the highest-order bit of a byte of data. 'Bit 0' refers to lowest-order bit:

'bit number':	7	6	5	4	3	2	1	0
binary data:	0	0	1	1	0	0	0	1 = $31 (hex)

The SU command is write protected to guard against erroneous changes in the setup data; therefore each SU command must be preceded by a Write Enable (WE) command. To abort an SU command in progress, simply send a non-hex character (an 'X' for example) to generate a SYNTAX ERROR, and try again.

CAUTION: Care must be exercised in using the SU command. Improper use may result in changing communications parameters (address, baud rate, parity) which will result in a loss of communications between the host and the module. In some cases the user may have to resort to using Default Mode to restore the proper setups. The recommended procedure is to first use the Read Setup (RS) command to examine the existing setup data before proceeding with the SU command.

Byte 1

Byte 1 contains the module (base-channel) address. The module contains four channels but only the base channel or channel 0 address is specified in the SetUp message. The microprocessor automatically assigns the next three consecutive ASCII values as channel addresses for channels one thru 3. The address is stored as the ASCII code for the string character used to address channel 0 of the module. In our example command $1SU31070080 , the first byte '31' is the ASCII code for the character '1'. If our sample command is sent to a module, the EEPROM will be loaded with the address '1', which in this particular case remains unchanged. To change the module base-channel address to '2' , byte 1 of the SetUp command becomes '32', which is the ASCII code for the character '2'. Now the command will look like this: $1SU32070080. When this command is sent, the module base-channel address is changed from '1' to '2' and will no longer respond to address '1'. Keep record of module addresses in order to avoid overlaps in channel addressing.

When using the SU command to change the address of a module, be sure to record the new address in a place that is easily retrievable. The only way to communicate with a module with an unknown address is with the Default Mode. Note that when communicating with a D5000M module in Default Mode the module will respond with the address value of channel 0 unless the channel was properly addressed. Therefore if address 'a' is sent to a module in default mode that is addressed as 0 thru 3, channel 0 data is

returned. But if the same module is addressed as '2', channel 2 data is returned.

The most significant bit of byte 1 (bit 7) must be set to '0'. In addition, there are six ASCII codes that are illegal for use as an address to any channel. These codes are $00, $0D, $24, $23, $7B, $7D which are ASCII codes for the characters NUL, CR, $, #, { and }. Using these codes for an address will cause an ADDRESS ERROR and the setup data will remain unchanged. This leaves a total of 122 possible addresses that can be loaded with the SU command. Take care not to assign channel 0 values within three values of an illegal address value as the microprosser automatically assigns the next three consecutive vales to the channel 0 value. It is highly recommended that only ASCII codes for printable characters be used ($21 to $7E) which greatly simplifies system debugging with a dumb terminal. Refer to Appendix A for a list of ASCII codes. Table 5.1 lists the printable ASCII codes that may be used as addresses.

Table 5.1 Byte 1 ASCII Printable Characters.

HEX	ASCII	HEX	ASCII	HEX	ASCII	HEX	ASCII
21	!	3A	:	51	Q	68	h
22	"	3B	;	52	R	69	i
25	%	3C	<	53	S	6A	j
26	&	3D	=	54	T	6B	k
27	'	3E	>	55	U	6C	l
28	(	3F	?	56	V	6D	m
29	)	40	@	57	W	6E	n
2A	*	41	A	58	X	6F	o
2B	+	42	B	59	Y	70	p
2C	,	43	C	5A	Z	71	q
2D	-	44	D	5B	[	72	r
2E	.	45	E	5C	\	73	s
2F	/	46	F	5D	]	74	t
30	0	47	G	5E	^	75	u
31	1	48	H	5F	_	76	v
32	2	49	I	60	`	77	w
33	3	4A	J	61	a	78	x
34	4	4B	K	62	b	79	y
35	5	4C	L	63	c	7A	z
36	6	4D	M	64	d	7B	{
37	7	4E	N	65	e	7C	|
38	8	4F	O	66	f	7D	}
39	9	50	P	67	g	7E	~

Byte 2
Byte 2 is used to configure some of the characteristics of the communications channel; linefeeds, parity, and baud rate.

Linefeeds
The most significant bit of byte 2 (bit 7) controls linefeed generation by the module. This option can be useful when using the module with a dumb terminal. All responses from the D5000M are terminated with a carriage return (ASCII $0D). Most terminals will generate a automatic linefeed when a carriage return is detected. However, for terminals that do not have this capability, the D5000M module can generate the linefeed if desired. By setting bit 7 to '1' the module will send a linefeed (ASCII $0A) before and after each response. If bit 7 is cleared (0), no linefeeds are transmitted.

When using the '#' command prompt, the linefeed characters are not included in the checksum calculation.

Parity
Bits 5 and 6 select the parity to be used by the module. Bit 5 turns the parity on and off. If bit 5 is '0', the parity of the command string is ignored and the parity bit of characters transmitted by the module is set to '1'.

If bit 5 is '1', the parity of command strings is checked and the parity of characters output by the module is calculated as specified by bit 6.

If bit 6 is '0', parity is even; if bit 6 is '1', parity is odd.

If a parity error is detected by the module, it will respond with a PARITY ERROR message. This is usually caused by noise on the communications line.

If parity setup values are changed with the SU command, the response to the SU command will be transmitted with the old parity setup. The new parity setup becomes effective immediately after the response message from the SU command.

Stop Bits
Bit 4 specifies the number of stop bits when no parity is used in the Modbus protocol mode.When bit 4 is '0' the module uses two stop bits as required by the Modbus RTU protocol. In cases where one stop bit is required bit 4 can be set to '1' to use one stop bit. Bit 4 is only used when the Modbus Protocol is enabled. It has no affect when the module is in the ASCII protocol.

Baud Rate
Bits 0-3 specify the communications baud rate. The baud rate can be selected from ten values between 300 and 115200 baud. Refer to Table 5.2 for the desired code.

The baud rate selection is the only setup data that is not implemented directly after an SU command. In order for the baud rate to be actually changed, a module reset must occur. A reset is performed by sending a Remote Reset (RR) command (see Communications) or powering down. This extra level of write protection is necessary to ensure that communications to the module is not accidently lost. This is very important when changing the baud rate of an RS-232C string. For more information on changing baud rate, refer to Chapter 3.

Let's run through an example of changing the baud rate. Assume our sample module contains the setup data value of '31070080'. Byte 2 is '07'. By referring to the SU command chart we can determine that the module is set for no linefeeds, no parity, and baud rate 300. If we perform the Read Setup command with this module we would get:

Command: **$1RS**
Response: ***31070080**

Let's say we wish to change the baud rate to 9600 baud. The code for 9600 baud is '0010' (from Table 5.2). This would change byte 2 to '02'. To perform the SU command we must first send a Write Enable command because SU is write protected:

Command: **$1WE**
Response: *

Command: **$1SU31020080**
Response: *

This sequence of messages is done in 300 baud because that was the original baud rate of the module. The module remains in 300 baud after this sequence. We can use the Read Setup (RS) command to check the setup data:

Command: **$1RS**
Response: ***31020080**

Notice that although the module is communicating in 300 baud, the setup data indicates a baud rate of 9600 (byte 2 = '02'). To actually change the baud rate to 9600, send a Remote Reset (RR) command (RR is write protected):

Command: **$1WE**
Response: *

Command: **$1RR**
Response: *

Up to this point all communications have been sent at 300 baud. The module will not respond to any further communications at 300 baud because it is now running at 9600 baud. At this point the host computer or terminal must be set to 9600 baud to continue operation.

If the module does not respond to the new baud rate, most likely the setup data is incorrect. Try various baud rates from the host until the module responds. The last resort is to set the module to Default Mode where the baud rate is always 300.

Setting a string of RS-232C modules to a new baud rate requires special consideration. Refer to Chapter 3 for instructions.

Table 5.2 Byte 2: Linefeed, Parity, Addressing and Baud Rate.

FUNCTION	DATA BIT							
	7	6	5	4	3	2	1	0
LINEFEED	1							
NO LINEFEED	0							
NO PARITY		0	0					
NO PARITY		1	0					
EVEN PARITY		0	1					
ODD PARITY		1	1					
TWO STOP BITS				0				
ONE STOP BIT				1				
115200 BAUD					1	0	0	0
57600 BAUD					1	0	0	1
38400 BAUD					0	0	0	0
19200 BAUD					0	0	0	1
9600 BAUD					0	0	1	0
4800 BAUD					0	0	1	1
2400 BAUD					0	1	0	0
1200 BAUD					0	1	0	1
600 BAUD					0	1	1	0
300 BAUD					0	1	1	1

Byte 3

The default value for this byte is '01'.

Channel Enable/Disable

Input channels may be enabled and disabled at will by using the SetUp command. The factory setting for the D5000M series is all four channels enabled. However the user can choose to disable one to three unnecessary channels (channel 0 is always enabled). Disabling channels increases the sampling rate, for example two channels sample at four times per second instead of twice per second for four channels. Disabling channels effects the digital filter, see byte 4 four details. This feature can also be useful in long

term experiments where one or two inputs may not need to be monitored for a length of time those inputs could simply be disabled until such time as they were needed again. Note that if a disabled channel in a D5000M is addressed with a valid command it will not respond.

Disable CJC

This function pertains only to the D5300M series thermocouple input modules. If the bit is set to '1' the Cold Junction Compensation is disabled. The module calculates the temperature output with a fixed cold junction temperature of 0° Celsius. This setup is useful for calibrating the module or in cases where remote CJC is used. Normally this bit is cleared to '0'.

Delay

Bits 0 and 1 specify a minimum turn-around delay between a command and the module response. This delay time is useful on host systems that are not fast enough to capture data from quick-responding commands such as RD. This is particularly true for systems that use software UART's. The specified delay is added to the typical command delays listed in the Software Considerations section of Chapter 3. Each unit of delay specified by bits 0 and 1 is equal to the amount of time required to transmit one character with the baud rate specified in byte 2. For example, one unit of delay at 300 baud is 33.3 mS; for 38.4 kilobaud the delay is 0.26 mS. The number of delay units is selectable from 0 to 6 as shown in Table 5.3.

In some systems, such as IBM BASIC, a carriage return (CR) is always followed by a linefeed (LF). The D5000 modules will respond immediately after a command terminated by a CR and will ignore the linefeed. To avoid a communications collision between the linefeed and the module response, the module should be setup to delay by 2 units.

Table 5.3 Byte 3 Options.

FUNCTION	DATA BIT 7	6	5	4	3	2	1	0
CHANNEL 3 DISABLE	0							
CHANNEL 3 ENABLE	1							
CHANNEL 2 DISABLE		0						
CHANNEL 2 ENABLE		1						
CHANNEL 1 DISABLE			0					
CHANNEL 1 ENABLE			1					
CJC (D5300'S)				0				
NO CJC (D5300'S)				1				
NOT USED					X			
NOT USED						X		
NO DELAYS							0	0
2 BYTE TIME DELAYS							0	1
4 BYTE TIME DELAYS							1	0
6 BYTE TIME DELAYS							1	1

Byte 4
This setup byte specifies the number of displayed digits and the digital filter time constants.

Number of displayed digits
For ease of use, the data outputs of all modules are standardized to a common 7-digit output consisting of sign, 5 digits, decimal point, and two more digits. Typical output data looks like: +00100.00. However, best-case resolution of the A/D converter is 1 part in 32,768. In some cases, the resolution of the output format is much greater than the resolution of the measurement system. In such cases, the trailing digits of the response would display meaningless information. Bits 6 and 7 are used to insert trailing zeros into the output data to limit the output resolution and mask off meaningless digits.

Bit 7	Bit 6		
0	**0**	**XXXX0.00**	**(4 displayed digits)**
0	**1**	**XXXXX.00**	**(5 displayed digits)**
1	**0**	**XXXXX.X0**	**(6 displayed digits)**
1	**1**	**XXXXX.XX**	**(7 displayed digits)**

For example, the D5311M model for thermocouples has 1.0 degree output resolution. The appropriate number of digits for this module is 5, to mask off the 0.xx digits which have no meaningful data. In some cases, the user may want to limit the output resolution to 10 degrees. To do this, select bits 6 and 7 to display 4 digits. With this selection, the right-most three digits will always be set to '0'.

The number of displayed digits affects only data received from an RD command.

Large Signal Filter, Bits 3,4,5
Small Signal Filter, Bits 0,1,2
The modules contain a versatile single-pole, low-pass digital filter to smooth out unwanted noise caused by interference or small signal variations. The digital filter offers many advantages over traditional analog filters. The filtering action is done completely in firmware and is not affected by component drifts, offsets, and circuit noise typically found in analog filters. The filter time constant is programmable through the SetUp (SU) command and can be changed at any time, even if the module is remote from the host.

The digital filter features separate time constants for large and small signal variations. The Large Signal Filter time constant is controlled by bits 3,4,5. This time constant is used when large signal variations are present on the input. The Small Signal Filter time constant is controlled by bits 0,1,2. This filter time constant is automatically selected when input signal variations are small. The microprocessor in the module automatically selects the correct

filter constant after every A/D conversion. The constant selected depends on the magnitude of the change of the input signal and the setup for the number of digits displayed. The microprocessor always keeps the value of the last calculated output to compare to a new data conversion. If the new data differs from the last output by more than ten counts of the last displayed digit, the large signal time constant is used in the digital filter. If the result of the most recent A/D conversion differs from the last output value by less than ten counts of the last displayed digit, the small signal time constant is used. Let's look at an example:

The D5451M thermistor module has been changed from a standard resolution of 0.01 degrees to an output resolution of 0.1 degrees. The number-of-displayed-digits setup for this module is now 6 digits, from byte 4 of the setup data. Therefore, the large signal filter will be selected if a new input conversion differs from the previous value by > 1.0 degree:

Previous data	New data	Filter selected
+00098.00	+00098.50	small
+00098.00	+00099.50	large
+00099.00	+00099.90	small
+00099.00	+00097.90	large
-00050.50	-00050.00	small
-00050.50	-00060.00	small

If the number of displayed digits is changed to reduce output resolution, filter selection is also affected. If the number of displayed digits in the previous example is changed to 5, the output resolution becomes 1.0 degree.

In this case the large signal time constant is used if the new reading differs from the old by more than 10.0 degrees:

Previous data	New data	Filter selected
+00090.00	+00095.00	small
+00089.00	+00100.00	large
+00090.00	+00091.00	small
+00090.00	+00075.00	large
-00050.00	-00045.00	small
-00050.00	-00039.00	large

Large Signal Time Constant

The large signal filter time constant is specified by bits 3,4,5 of byte 4. It may be specified from 0 (no filter) to 64 seconds. The time constant for a first-order filter is the time required for the output to reach 63% of its final value for a step input.

Small Signal Time Constant

Bits 0,1, 2 specify the filter time constant for small signals. Its values are similar to the ones for the large signal filter. Most sensors can benefit from a small amount of small signal filtering such as T = 1 second. In most applications, the small signal time constant should be larger than the large signal time constant. This gives stable readings for steady-state inputs while providing fast response to large signal changes.

Table 5.4 Byte 4 Displayed Digits and Filter Time Constants.

BYTE 4

FUNCTION	DATA BIT 7	6	5	4	3	2	1	0
+XXXX0.00 DISPLAYED DIGITS	0	0						
+XXXXX.00 DISPLAYED DIGITS	0	1						
+XXXXX.X0 DISPLAYED DIGITS	1	0						
+XXXXX.XX DISPLAYED DIGITS	1	1						
NO LARGE SIGNAL FILTERING			0	0	0			
1 SECOND TIME CONSTANT			0	0	1			
2 SECOND TIME CONSTANT			0	1	0			
4 SECOND TIME CONSTANT			0	1	1			
8 SECOND TIME CONSTANT			1	0	0			
16 SECOND TIME CONSTANT			1	0	1			
NO SMALL SIGNAL FILTERING						0	0	0
1 SECOND TIME CONSTANT						0	0	1
2 SECOND TIME CONSTANT						0	1	0
4 SECOND TIME CONSTANT						0	1	1
8 SECOND TIME CONSTANT						1	0	0
16 SECOND TIME CONSTANT						1	0	1

Disabled channels and filtering time constants

Disabling channels will change the digital filter time constants the table below describes the changes.

Large and Small Signal Filter Time Constants	Channels Enabled 1	2	3	4
0	0	0	0	0
1	.25	.5	.65	1
2	.5	1	1.3	2
3	1	2	2.6	4
4	2	4	5.2	8
5	4	8	10.4	16
6	8	16	20.8	32
7	16	32	41.6	64

Setup Hints

Until you become completely familiar with the SetUp command, the best method of changing setups is to change one parameter at a time and to verify that the change has been made correctly. Attempting to modify all the setups at once can often lead to confusion. If you reach a state of total confusion, the best recourse is to reload the factory setup shown in Table 5.5 and try again, changing one parameter at a time. Use the Read Setup (RS) command to examine the setup information currently in the module as a basis for creating a new setup.

By using the RS command and changing one setup parameter at a time, any problems associated with incorrect setups may be identified immediately. Once a satisfactory setup has been developed, record the setup value and use it to configure similar modules.

If you commit an error in using the SetUp command, it is possible to lose communications with the module. In this case, it may be necessary to use the Default Mode to re-establish communications.

Table 5.5 Factory Setups by Model.

(All modules from the factory are set for address '1', 300 baud, no parity)

Model	Setup Message
D511XM, D515XM, D525XM	310701C2
D512XM	31070182
D513XM, D514XM	31070142
D53XXM,	31070142
D545XM	31070182

Chapter 6
Power Supply

D5000M modules may be powered with an unregulated +10 to +30Vdc. Power-supply ripple must be limited to 5V peak-to-peak, and the instantaneous ripple voltage must be maintained between the 10 and 30 volt limits at all times. The modules contain a low voltage detection circuit that shuts down all circuits in the module at approximately 9.5 Vdc. All power supply specifications are referred to the module connector; the effects of line voltage drops must be considered when the module is powered remotely.

All D5000M modules employ an on-board switching regulator to maintain good efficiency over the 10 to 30 volt input range; therefore the actual current draw is inversely proportional to the line voltage. D5000M modules without sensor excitation consume a maximum of .75 watts and this figure should be used in determining the power supply current requirement. For example, assume a 24 volt power supply will be used to power four modules. The total power requirement is 4 X .75 = 3 watts. The power supply must be able to provide 3 / 24 = 0.125 amps.

The low voltage detection circuit shuts down the module at approximately 9.5Vdc. If the module is interrogated while in a low power supply condition, the module will not respond. Random NOT READY error messages could indicate that the power supply voltage is periodically drooping below the 10V minimum.

Small systems may be powered by using wall-mounted calculator-type modular power supplies. These units are inexpensive and may be obtained from many retail electronics outlets.

For best reliability, modules operated on long communications lines (>500 feet) should be powered locally using small calculator-type power units. This eliminates the voltage drops on the Ground lead which may interfere with communications signals. In this case the V+ terminal is connected only to the local power supply. The Ground terminal must be connected back to the host

Chapter 7
Troubleshooting

Symptom:
RS-232 Module is not responding to commands
RS-485 Module is not responding to commands
Module responds with ?1 COMMAND ERROR to every command.
Characters in each response message appear as graphics characters
RS-232 Module response message preceeded by <NULL> character.

• RS-232 Module is not responding to commands

1. Using a voltmeter, measure the power supply voltage at the +Vs and GND terminals to verify the power supply voltage is constantly between +10 and +30Vdc.

2. Verify using an ohmmeter that there are no breaks in the communications data lines.

3. Connect the module to the host computer and power-up each device (module and computer) then using a voltmeter measure the voltage between RECEIVE and GND. This voltage should be approximately - 10Vdc. Repeat the measurement between TRANSMIT and GND terminals and confirm the voltage value to be approximately -10Vdc. If either of the two readings is approximately 0.0Vdc then the communications data lines are wired backwards. Proper communications levels on both TRANSMIT and RECEIVE terminals should idle at -10Vdc.

4. If you are using a serial communications converter (A1000) ensure that the communications Baud Rate switch is set to the proper Baud Rate value.

5. Confirm software communications settings in Host computer match those values being used by the connected module(s).

6. If the Baud Rate value being used in the application is greater than 300 Baud and the module will only communicate 300 Baud then make sure that the DEFAULT* terminal is not connected to Ground (GND).

7. If the problem is not corrected after completing the steps above then connect the module by itself to a Host computer as outlined in Chapter 1.0 under "Quick Hook-up". Start the supplied Utility software and please call the factory for further assistance.

• RS-485 Module is not responding to commands

1. Perform steps 1, 2, 4, 5 and 6 listed above.

2. Ensure that module RS-485 "Data" line (module terminal pin #7) is connected to the Host RS-485 "Data+" line.

3. Ensure that module RS-485 "Data*" line (module terminal pin #8) is connected to the Host RS-485 "Data-" line.

4. If the problem is not corrected after completing the steps above then connect the module by itself to a Host computer as outlined in Chapter 1.0 under "Quick Hook-up". Start the supplied Utility software and please call the factory for further assistance.

• Module responds with ?1 COMMAND ERROR to every command

Ensure that characters in the command message are uppercase characters. All commands consist of uppercase characters only.

• Characters in each response message appear as graphics characters

1. Set the communications software parity setting to "M" for 'MARK' parity type and 7 data bits. Or, utilize any parity type in both the module and software other than "NO" parity.

2. In custom written software routines, mask off the most significant bit of each received character to logic "0". Thus forcing the received character to 7-bit ASCII value.

• RS-232 Module response message preceeded by <NULL> character

Set "Delay" value to "NO DELAYS" in setup message.

Chapter 8
Calibration

The D5000M module is initially calibrated at the factory and has a recommended calibration interval of one year. Seperate calibration constants for each channel are stored in the EEPROM and may be trimmed using the Trim Span (TS) and Trim Zero (TZ) commands. There are no pots to adjust. Calibration procedure is as follows.

Voltage and current inputs: clear the output offset register using the Clear Zero (CZ) command. Zero trims are not neccessary due to the built-in auto-zero function. Apply a known calibrated voltage or current to the input of the module. The calibrated stimulus should be adjusted to be near 90% of the full scale output of the modules for best results. Obviously, the accuracy of the calibrated voltage or current must be better than the rated accuracy of the module, which in most cases is 0.02% of full scale. Use the Read Data (RD) command to obtain an output reading. If the output corresponds to the applied input, no calibration is necessary. If the output is in overload, check the circuit connections or use a different input value to obtain an output within the operating range of the module.

To trim the output, use the Trim Span (TS) command. The argument of the TS command should correspond to the desired module output. After performing the TS command, verify the trim with the RD command. For example to trim a channel in a D5121 module:

1. Clear the output offset register.

Command: **$1WE**
Response: * **(CZ is write protected)**

Command: **$1CZ**
Response: *

2. Apply an input voltage near 90% of rated full scale. In this case we will use a +900mV input voltage that is accurate to at least 0.02%. Obtain an output reading.

Command: **$1RD**
Response: ***+00900.30**

In this case, the output of the module is off by 300µV. To trim:

Command: **$1WE**
Response: * **(TS is write protected)**

Command: **$1TS+00900.00**
Response: *

This sequence will trim the output to +00900.00. Verify:

Command: **$1RD**
Response: ***+00900.00**

This same procedure should be repeated for all four channels in the module. The calibration procedure is complete when all four channels have been calibrated.

Table 9.1 Calibration Values

Model	Input Stimulus	Output Data
D511XM	+90mV	+00090.00
D512XM	+900mV	+00900.00
D513XM	+4.5V	+04500.00
D514XM	+9V	+09000.00
D515XM	+90V	+00090.00
D525XM	+20mA	+00020.00
D531XM	+39.13mV	+00700.00
D532XM	+41.269mV	+01000.00
D533XM	+17.816mV	+00350.00
D534XM	+68.783mV	+01000.00
D545XM	206.1Ω	+00090.00

Appendix A
ASCII Table

Table of ASCII characters (A) and their equivalent values in Decimal (D), Hexadecimal (Hex), andBinary.Claret (^) represents Control function.

A	D	Hex	Binary	D	Hex	Binary
^@	0	00	00000000	128	80	10000000
^A	1	01	00000001	129	81	10000001
^B	2	02	00000010	130	82	10000010
^C	3	03	00000011	131	83	10000011
^D	4	04	00000100	132	84	10000100
^E	5	05	00000101	133	85	10000101
^F	6	06	00000110	134	86	10000110
^G	7	07	00000111	135	87	10000111
^H	8	08	00001000	136	88	10001000
^I	9	09	00001001	137	89	10001001
^J	10	0A	00001010	138	8A	10001010
^K	11	0B	00001011	139	8B	10001011
^L	12	0C	00001100	140	8C	10001100
^M	13	0D	00001101	141	8D	10001101
^N	14	0E	00001110	142	8E	10001110
^O	15	0F	00001111	143	8F	10001111
^P	16	10	00010000	144	90	10010000
^Q	17	11	00010001	145	91	10010001
^R	18	12	00010010	146	92	10010010
^S	19	13	00010011	147	93	10010011
^T	20	14	00010100	148	94	10010100
^U	21	15	00010101	149	95	10010101
^V	22	16	00010110	150	96	10010110
^W	23	17	00010111	151	97	10010111
^X	24	18	00011000	152	98	10011000
^Y	25	19	00011001	153	99	10011001
^Z	26	1A	00011010	154	9A	10011010
^[	27	1B	00011011	155	9B	10011011
^\	28	1C	00011100	156	9C	10011100
^]	29	1D	00011101	157	9D	10011101
^^	30	1E	00011110	158	9E	10011110
^_	31	1F	00011111	159	9F	10011111
	32	20	00100000	160	A0	10100000
!	33	21	00100001	161	A1	10100001
“	34	22	00100010	162	A2	10100010

A	D	Hex	Binary	D	Hex	Binary
#	35	23	00100011	163	A3	10100011
$	36	24	00100100	164	A4	10100100
%	37	25	00100101	165	A5	10100101
&	38	26	00100110	166	A6	10100110
‘	39	27	00100111	167	A7	10100111
(	40	28	00101000	168	A8	10101000
)	41	29	00101001	169	A9	10101001
*	42	2A	00101010	170	AA	10101010
+	43	2B	00101011	171	AB	10101011
,	44	2C	00101100	172	AC	10101100
-	45	2D	00101101	173	AD	10101101
.	46	2E	00101110	174	AE	10101110
/	47	2F	00101111	175	AF	10101111
0	48	30	00110000	176	B0	10110000
1	49	31	00110001	177	B1	10110001
2	50	32	00110010	178	B2	10110010
3	51	33	00110011	179	B3	10110011
4	52	34	00110100	180	B4	10110100
5	53	35	00110101	181	B5	10110101
6	54	36	00110110	182	B6	10110110
7	55	37	00110111	183	B7	10110111
8	56	38	00111000	184	B8	10111000
9	57	39	00111001	185	B9	10111001
:	58	3A	00111010	186	BA	10111010
;	59	3B	00111011	187	BB	10111011
<	60	3C	00111100	188	BC	10111100
=	61	3D	00111101	189	BD	10111101
>	62	3E	00111110	190	BE	10111110
?	63	3F	00111111	191	BF	10111111
@	64	40	01000000	192	C0	11000000
A	65	41	01000001	193	C1	11000001
B	66	42	01000010	194	C2	11000010
C	67	43	01000011	195	C3	11000011
D	68	44	01000100	196	C4	11000100
E	69	45	01000101	197	C5	11000101
F	70	46	01000110	198	C6	11000110
G	71	47	01000111	199	C7	11000111
H	72	48	01001000	200	C8	11001000
I	73	49	01001001	201	C9	11001001
J	74	4A	01001010	202	CA	11001010
K	75	4B	01001011	203	CB	11001011

A	D	Hex	Binary	D	Hex	Binary
L	76	4C	01001100	204	CC	11001100
M	77	4D	01001101	205	CD	11001101
N	78	4E	01001110	206	CE	11001110
O	79	4F	01001111	207	CF	11001111
P	80	50	01010000	208	D0	11010000
Q	81	51	01010001	209	D1	11010001
R	82	52	01010010	210	D2	11010010
S	83	53	01010011	211	D3	11010011
T	84	54	01010100	212	D4	11010100
U	85	55	01010101	213	D5	11010101
V	86	56	01010110	214	D6	11010110
W	87	57	01010111	215	D7	11010111
X	88	58	01011000	216	D8	11011000
Y	89	59	01011001	217	D9	11011001
Z	90	5A	01011010	218	DA	11011010
[	91	5B	01011011	219	DB	11011011
\	92	5C	01011100	220	DC	11011100
]	93	5D	01011101	221	DD	11011101
^	94	5E	01011110	222	DE	11011110
_	95	5F	01011111	223	DF	11011111
‘	96	60	01100000	224	E0	11100000
a	97	61	01100001	225	E1	11100001
b	98	62	01100010	226	E2	11100010
c	99	63	01100011	227	E3	11100011
d	100	64	01100100	228	E4	11100100
e	101	65	01100101	229	E5	11100101
f	102	66	01100110	230	E6	11100110
g	103	67	01100111	231	E7	11100111
h	104	68	01101000	232	E8	11101000
i	105	69	01101001	233	E9	11101001
j	106	6A	01101010	234	EA	11101010
k	107	6B	01101011	235	EB	11101011
l	108	6C	01101100	236	EC	11101100
m	109	6D	01101101	237	ED	11101101
n	110	6E	01101110	238	EE	11101110
o	111	6F	01101111	239	EF	11101111
p	112	70	01110000	240	F0	11110000
q	113	71	01110001	241	F1	11110001
r	114	72	01110010	242	F2	11110010
s	115	73	01110011	243	F3	11110011
t	116	74	01110100	244	F4	11110100

A	D	Hex	Binary	D	Hex	Binary
u	117	75	01110101	245	F5	11110101
v	118	76	01110110	246	F6	11110110
w	119	77	01110111	247	F7	11110111
x	120	78	01111000	248	F8	11111000
y	121	79	01111001	249	F9	11111001
z	122	7A	01111010	250	FA	11111010
{	123	7B	01111011	251	FB	11111011
|	124	7C	01111100	252	FC	11111100
}	125	7D	01111101	253	FD	11111101
~	126	7E	01111110	254	FE	11111110
	127	7F	01111111	255	FF	11111111

Appendix B
D5000M Specifications

Specifications (typical @ +25° C and nominal power supply unless otherwise noted.)

Analog
- Four analog input channels.
- Maximum CMV, input to output at 60Hz: 500V rms.
- Leakage current, input to output at 115Vrms, 60Hz: <2μA rms.
- 15 bit measurement resolution.
- 8 conversions per second.
- Autozero & autocalibration—no adjustment pots.

Digital
- 8-bit CMOS microcomputer.
- Digital scaling, linearization and calibration.
- Nonvolatile memory eliminates pots and switches.

Digital filtering
- Small and large signal with user selectable time constants from 0 to 64 seconds.

Communications
- Communications in ASCII via RS-232C, RS-485 ports.
- Selectable baud rates: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200.
- NRZ asynchronous data format; 1 start bit, 7 data bits, 1 parity bit and 1 stop bit.
- Parity: odd, even, none.
- User selectable channel address.
- ASCII format command/response protocol.
- Communications distance up to 4,000 feet (RS-485).
- Transient suppression on RS-485 communications lines.
- Communications error checking via checksum.
- All communications setups stored in EEPROM.

Power
Requirements: Unregulated +10V to +30Vdc, 0.75W max
Internal switching regulator.
Protected against power supply reversals.

Environmental
Temperature Range: Operating -25°C to +70°C.
Storage -25°C to +85°C.
Relative Humidity: 0 to 95% noncondensing.

Warranty
12 months on workmanship and material.

D5100M Voltage Inputs
• Voltage ranges: ±100mV, ±1V, ±5V, ±10V, ±100Vdc.
• Resolution: 0.01% of FS (4 digits).
• Accuracy: ±0.02% of FS max.
• Common mode rejection: 100dB at 50/60Hz.
• Zero drift: ±1 count max (autozero).
• Span tempco: ±50ppm/°C max.
• Input burnout protection to 250Vac .
• Input impedance: ≤ ±1V input = 100MΩ min.
≥ ±5V input = 1MΩ min.

D5200M Current Inputs
• Current ranges: 4-20mAdc.
• Resolution: 0.04% of FS.
• Accuracy: 0.04% of FS.
• Common mode rejection: 100dB at 50/60Hz.
• Zero drift: ±1 count max (autozero).
• Span tempco: ±50ppm/°C max.
• Voltage drop: 1.0V max.

D5300M Thermocouple Inputs
• Thermocouple types: J, K, T, E (factory set).
• Ranges: J = -200°C to +760°C
K = -150°C to +1250°C
T = -200°C to +400°C
E = -100°C to +1000°C
• Resolution: ±1°C.
• Overall Accuracy (error from all sources) from 0 to +40°C ambient: ±1.0 °C.
• Common mode rejection: 100dB at 50/60Hz.
• Input impedance: 100MΩ min.
• Lead resistance effect: <20μV per 350Ω.
• Open thermocouple indication.
• Input burnout protection to 250Vac.
• Overrange indication.
• Automatic cold junction compensation and linearization.

D5450 Thermistor Inputs
• Thermistor types: 2252Ω at 25°C
• Range: -0°C to +100°C.
• Resolution: 0.01°C .
• Accuracy: ±0.1°C.
• Common mode rejection: 100dB at 50/60Hz.
• Input protection to 30Vdc .

Appendix C
Modbus Scaling Table

Modbus Register Data

The D5000M contains four analog inputs for measuring four separate analog signals. The four inputs are defined on the D5000M product label as CH0, CH1, CH2 and CH3. The common signal ground for each of the channels is designated as A. GND for Analog Ground.

Each of the four analog inputs are converted into Modbus data values. These data values are then mapped and stored into registers that can be read using the Modbus Function 04. The valid Modbus register locations for each data value are: 30001 for CH0, 30002 for CH1, 30003 for CH2 and 30004 for CH3.

Modbus Data Values

The D5000M modules return Modbus data values that conform to the Modbus RTU protocol standard. The data values are returned as binary 16-bit data values between 0 and 65535 or hexadecimal 0x0000 to 0xffff. Each data value represents the present analog input data and may be interpreted as a percentage of the analog input full scale range. A table has been provided to indicate the Positive and Negative input full scale data values and the analog values that they represent.

Modbus Scaling Example

The D5000M modules return their analog values as 16-bit binary percentage of full scale data. These values can be viewed using the DGH Utility Software. They are also easily interpreted by most commercial process control software programs. In order to understand how the calculation works we have provided an example below.

This example utilizes data values from a D5251M module.

-Full Scale Displayed Value: +00000.00mA
+Full Scale Displayed Value: +00025.00mA

-Full Scale Modbus Binary Value: 0x0000
+Full Scale Modbus Binary Value: 0xFFFF

Assume that 4.0mA is applied to one analog input channel. The expected data values is computed as:

% of Full Scale = (data value - -Full Scale) / (+Full Scale - -Full Scale)
% of Full Scale = (4.0 - 0.0)/(25.0 - 0.00)
= 16% (0.16)
Binary value = (% of Full Scale) * (0xffff - 0x0000)
= (0.16 * (65535 - 0))
= 0x28F5
Reference

More information about the Modbus RTU protocol can be found on the Internet at "http://www.modbus.org" .

Model	-FS Displayed	+FS Displayed	-FS Modbus	+FS Modbus
D5111M	-100.00mV	+100.00mV	0000	ffff
D5112M	-100.00mV	+100.00mV	0000	ffff
D5121M	-1000.00mV	+1000.00mV	0000	ffff
D5122M	-1000.00mV	+1000.00mV	0000	ffff
D5131M	-5000.00mV	+5000.00mV	0000	ffff
D5132M	-5000.00mV	+5000.00mV	0000	ffff
D5141M	-10000.00mV	+10000.00mV	0000	ffff
D5142M	-10000.00mV	+10000.00mV	0000	ffff
D5151M	-100.00V	+100.00V	0000	ffff
D5152M	-100.00V	+100.00V	0000	ffff
D5251M	+0.00mA	+25.00mA	0000	ffff
D5252M	+0.00mA	+25.00mA	0000	ffff
D5311M	-200.00 °C	+760.00 °C	0000	ffff
D5312M	-200.00 °C	+760.00 °C	0000	ffff
D5321M	-150.00 °C	+1250.00 °C	0000	ffff
D5322M	-150.00 °C	+1250.00 °C	0000	ffff
D5331M	-200.00 °C	+400.00 °C	0000	ffff
D5332M	-200.00 °C	+400.00 °C	0000	ffff
D5341M	-100.00 °C	+1000.00 °C	0000	ffff
D5342M	-100.00 °C	+1000.00 °C	0000	ffff
D5451M	+0.00 °C	+100.00 °C	0000	ffff
D5452M	+0.00 °C	+100.00 °C	0000	ffff