D5000 SERIES USERS MANUAL

REVISED: 8/1/13

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D5000 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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Chapter 1
Getting Started

Default Mode

All D5000 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.

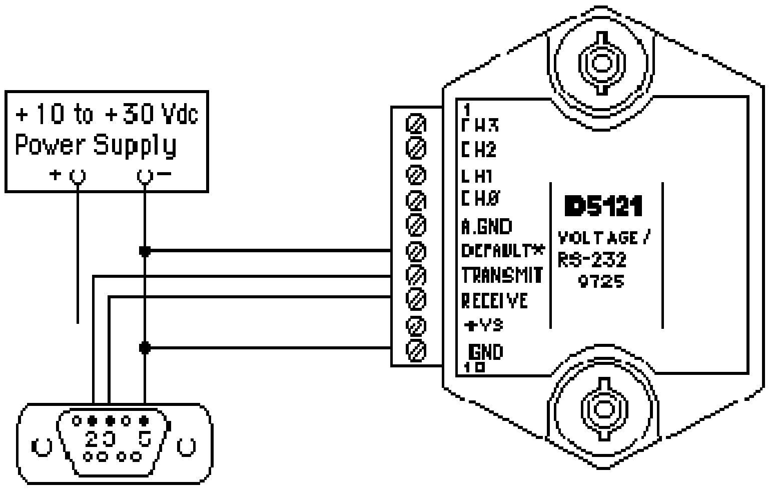
Each channel of the D5000 has its own channel address and all four channels are enabled in Default Mode. The addresses assigned to a module must be four consecutive ASCII values, such as 0, 1, 2, 3. A module in Default Mode will respond to any address except the six identified illegal values (NULL, CR, $, #, {,}). 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 address 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 D5000 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 be *+00025.00. The temperature reading will initially be in ° C which has



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.

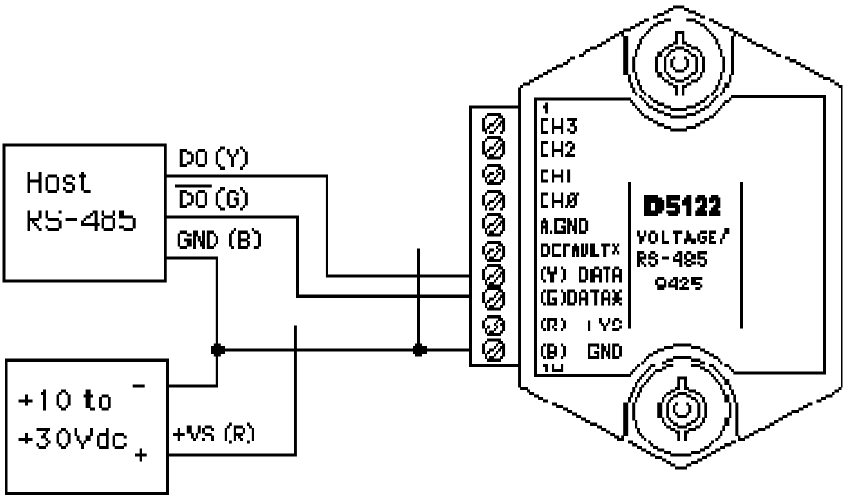


Figure 1.2 RS-485 Quick Hook-Up.

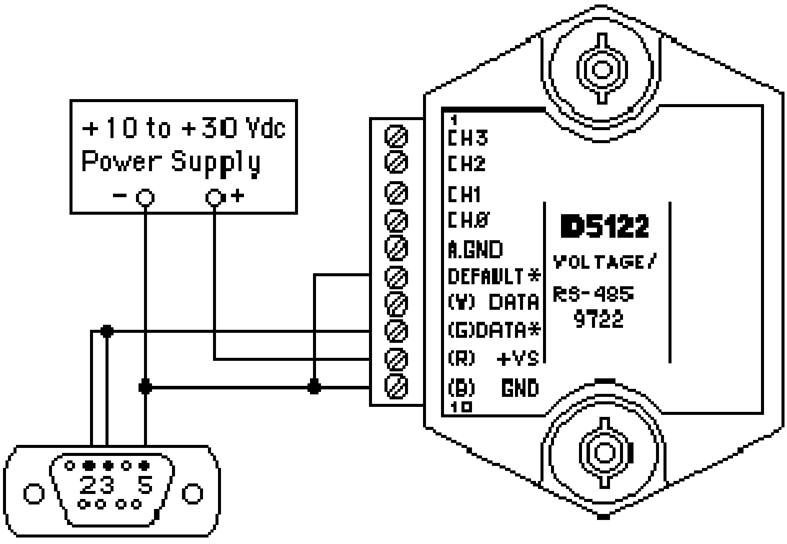
been preset at the factory. Once you have a response from the module you can turn to the Chapter 4 and get familiar with the command set.

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, no echo 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.



Note: If using a DB-25 connector ground is tied to pin 7.

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

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 modules allow user selectable output scaling in ºC or ºF on temperature data. This selection is shown in Figure 2.1 as a switch following the digital filters. The default scaling in the modules is ºC, but this may be converted to ºF by feeding the data through a conversion routine. The switch position is controlled by a bit in the setup data and may be changed with the SetUp (SU) command. The scaling selection is nonvolatile. In non-temperature applications, ºC should always be selected.

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.

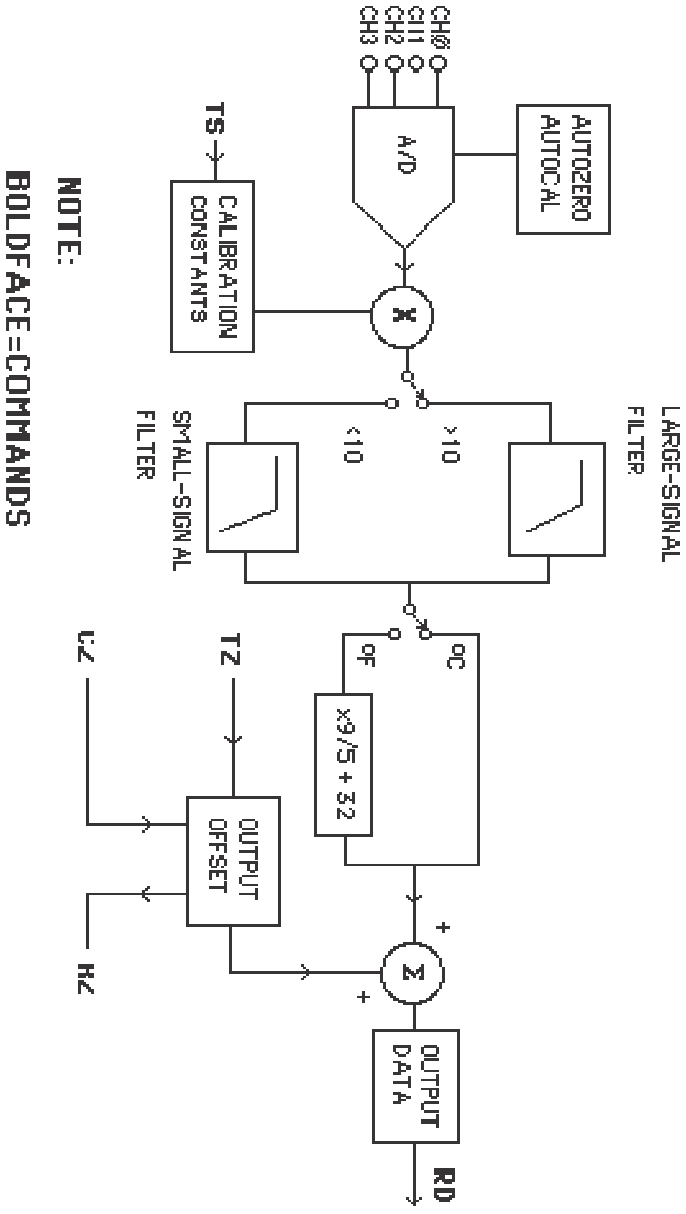


Figure 2.1 Block Diagram

Chapter 3
Communications

Introduction

The D5000 modules have 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. A practical limit for RS-232C units is about ten, although a string of 30 units is possible. Extended Addressing Mode allows many more modules to be connected into high channel count systems. Refer to Extended Addressing Mode in Chapter 9.

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 D5000 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. Although the RS-232C standard is designed to connect a single piece of equipment to a computer, the D5000 system allows for several modules to be connected in a daisy-chain network structure. 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

Single 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). The use of echo is not necessary when using a single module on the communications line.

Multi-party Connection
RS-232C is not designed to be used in a multiparty system; however the D5000 modules can be daisy-chained to allow many modules to be connected to a single communications port. The wiring necessary to create the daisy-chain is shown in Figure 3.1. Notice that starting with the host, each Transmit output is wired to the Receive input of the next module in the daisy chain. This wiring sequence must be followed until the output of the last module in the chain is wired to the Receive input of the host. All modules in the chain must be setup to the same baud rate and must echo all received data (see Setups). Each module must be setup with its own unique address to avoid communications collisions (see Setups). In this network, any characters transmitted by the host are received by each module in the chain and passed on to the next station until the information is echoed back to the Receive input of the host. In this manner all the commands given by the host are examined by every module. If a module in the chain is correctly addressed and receives a valid command, it will respond by transmitting the response on the daisy chain network. The response data will be ripple through any other modules in the chain until it reaches its final destination, the Receive input of the host.

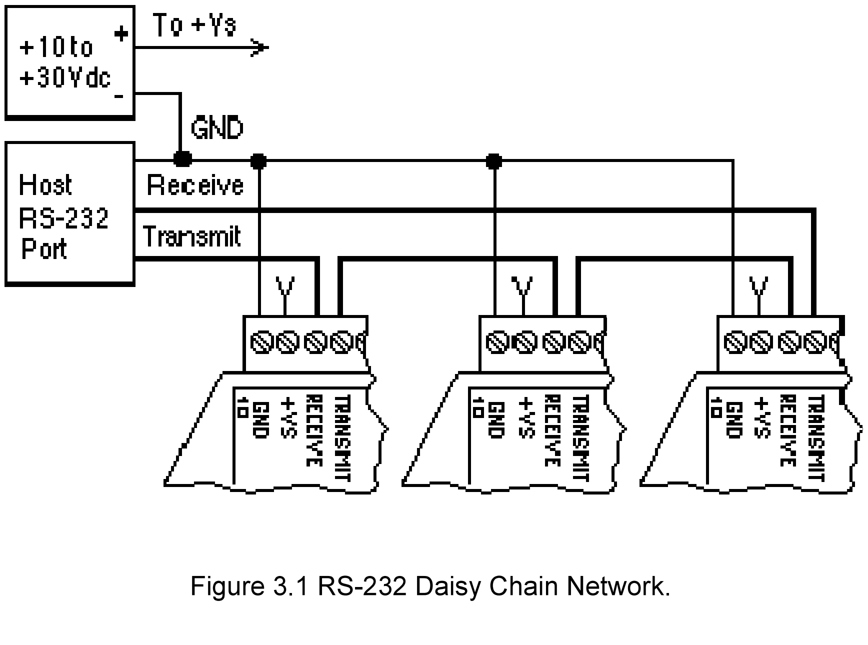


Figure 3.1 RS-232 Daisy Chain Network.

The daisy chain network must be carefully implemented to avoid the pitfalls inherent in its structure. The daisy-chain is a series-connected structure and any break in the communications link will bring down the whole system. Several rules must be observed to create a working chain:

1. All wiring connections must be secure; any break in the wiring, power, ground or communications breaks the chain.
2. All modules must be plugged into their own connectors.
3. All modules must be setup for the same baud rate.
4. All modules must be setup for echo.

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.

A properly addressed D5000 module in a daisy chain will echo all of the characters in the command including the terminating carriage return. Upon receiving the carriage return, the module will immediately calculate and transmit the response to the command. During this time, the module will not echo any characters that appear on its receive input. However, if a character is received during this computation period, it will be stored in the module’s internal receive buffer. This character will be echoed after the response string is transmitted by the module. This situation will occur if the host computer appends a linefeed character on the command carriage return. In this case the linefeed character will be echoed after the response string has been transmitted.

The daisy chain also affects the command timeout specifications. When a module in the chain receives a character it is echoed by retransmitting the character through the module’s internal UART. This method is used to provide more reliable communications since the UART eliminates any slewing errors caused by the transmission lines. However, this method creates a delay in propagating the character through the chain. The delay is equal to the time necessary to retransmit one character using the baud rate setup in the module:

Baud Rate	Delay	Baud Rate	Delay
300	33.30ms	9600	1.04ms
600	16.70ms	19200	0.52ms
1200	8.33ms	38400	0.26ms
2400	4.17ms	57600	173.6 s
4800	2.08ms	115200	86.8 s

One delay time is accumulated for each module in the chain. For example, if four modules are used in a chain operating at 1200 baud, the accumulated delay time is 4 X 8.33 mS = 33.3 mS. This time must be added to the times listed in Table 3.1 to calculate the correct communications time-out error.

For modules with RS-232C outputs, the programmed communications delay specified in the setup data (see Chapter 5) is implemented by sending a NULL character (00) followed by an idle line condition for one character time. This results in a delay of two character periods. For longer delay times specified in the setup data, this sequence is repeated. Programmed communications delay is seldom necessary in an RS-232C daisy chain since each module in the chain adds one character of communications delay.

Changing Baud Rate
It is possible to change the baud rate of an RS-232C daisy chain on-line. This process must be done carefully to avoid breaking the communications link.

1. Use the SetUp (SU) command to change the baud rate setup on each module in the chain. Be careful not to generate a reset during this process. A reset can be caused by the Remote Reset (RR) command or power interruptions.

2. Verify that all the modules in the chain contain the new baud rate setup using the Read Setup (RS) command. Every module in the chain must be setup for the same baud rate.

3. Remove power from all the modules for at least 10 seconds. Restore power to the modules. This generates a power-up reset in each module and loads in the new baud rate.

4. Change the host baud rate to the new value and check communications.

5. Be sure to compensate for a different communications delay as a result of the new baud rate.

Using A Daisy-Chain With A Dumb Terminal
A dumb terminal can be used to communicate to a daisy-chained system. The terminal is connected in the same manner as a computer used as a host. Any commands typed into the dumb terminal will be echoed by the daisy chain. To avoid double characters when typing commands, set the terminal to full duplex mode or turn off the local echo. The daisy chain will provide the input command echo.

RS-485

RS-485 is a recently developed 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 D5000 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 30 modules on one line or up to 3721 using Extended Address Mode and 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 D5000 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.

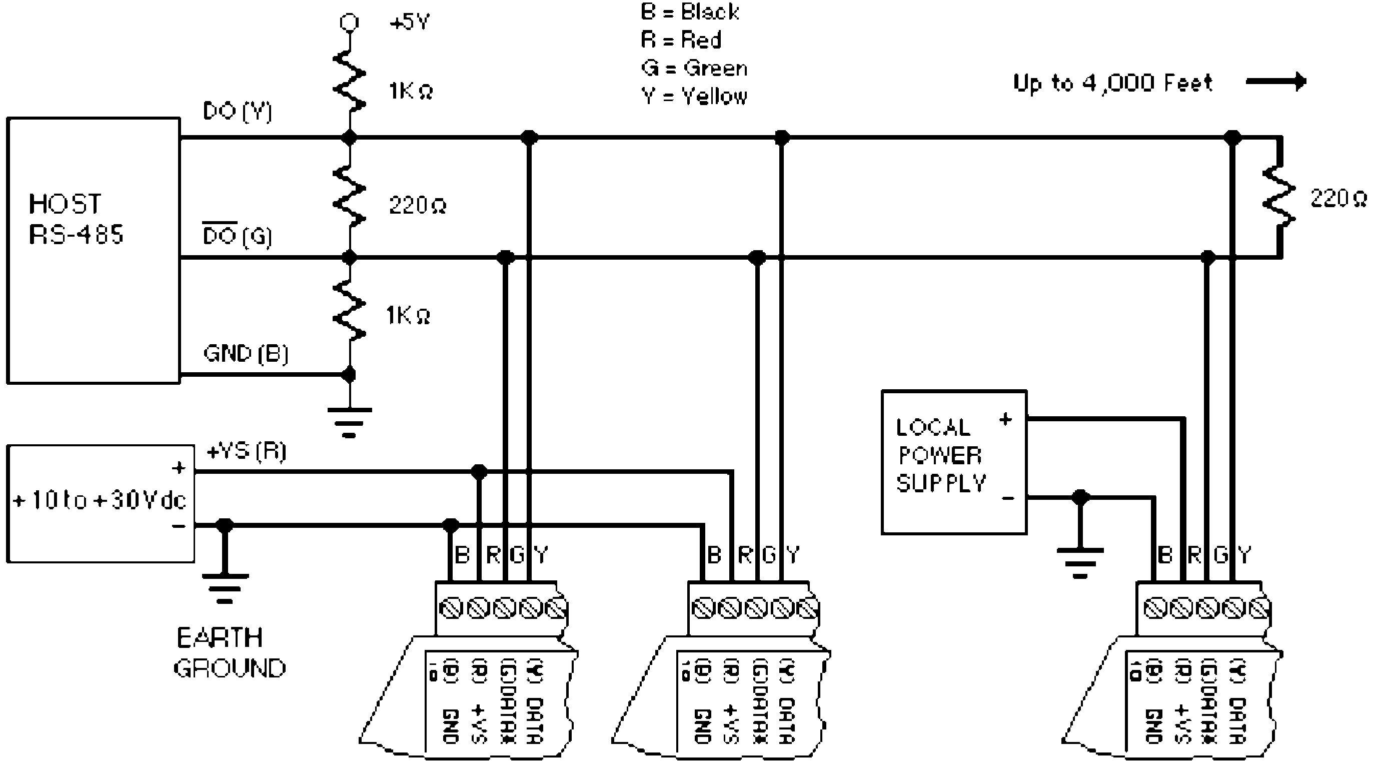


Figure 3.2 RS-485 Network.

RS-485 Multidrop System
Figure 3.2 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 labeled 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 3.2. 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 D5000 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.

Chapter 4
Command Set

The D5000 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 other two prompt characters: left curly brace ({) and right curly brace (}) are part of the Extended Addressing mode described in chapter 10.

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’.)

In addition to the command structure discussed above there is a special command format called Extended Addressing. This mode uses a different prompt, either '{' or '}' to distinguish it from the regular command syntax. The Extended Addressing mode is described in chapter 10.

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 D5000 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 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 D5000 Command Set

Command and Definition		Typical Command Message	Typical Response Message ($ prompt)
RB	Read Block of data	$1RB	*+00072.00 *+00836.00 *+01234.00 *-00932.00
RD	Read Data	$1RD	*+00072.00
REA	Read Extended Address	$1REA	*3031
RID	Read IDentification	$1RID	* BOILER
RMN	Read displayed MiNimum	$1RMN	*-00100.00
RMX	Read displayed MaXimum	$1RMX	*+00025.00
RS	Read Setup	$1RS	*31070142
RZ	Read Zero	$1RZ	*+00000.00
WE	Write Enable	$1WE	*
Write Protected Commands			
CZ	Clear Zero	$1CZ	*
ID	IDentification	$1IDBOILER ROOM	*
RR	Remote Reset	$1RR	*
SU	Setup Module	$1SU31070142	*
TS	Trim Span	$1TS+00600.00	*
TZ	Trim Zero	$1TZ+00000.00	*
WEA	Write Extended Address	$1WEA3031	*
WMN	Write displayed MiNimum	$1WMN	*
WMX	Write displayed MaXimum	$1WMX	*

D5000 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 D5000 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**

IDentification (ID)

The IDentification command allows the user to write a message into the internal nonvolatile memory which may be read back at any time using the Read IDentification (RID) command. The message may be up to 16 characters long and has no effect on the module operation. Useful information such as the module location, calibration date or model number may be stored for later retrieval.

The ID command is write protected and checksums are not supported. The module will abandon any ID command with a message length in excess of 16 characters.

```
Command:   $1IDBOILER ROOM
Response:  *

Command:   #1IDBOILER ROOM
Response:  *1IDBOILER ROOM02
```

Read Block of data

The Read Block of data command is used to read data values from all used channels in a D5000 series module. Since the read data command is the most frequently used command in normal operation the read block of data command provides a special "shorthand" way of reading data. The read block of data command decreases communications time by removing the need to send a command for every response. The data from each channel is separated by a carriage return or carriage return and line feed (if lines feed is enabled) used as a delimiter. This command can be very useful in spreadsheet applications.

In order to properly parse the data values from each channel the Read Block command returns an asterisk ("*") followed by a carriage return as response message for any disabled channel(s). The asterisk response message applies to both same the long form and short form prompts.

```
Command:   $1RB
Response:  *+00072.00
           *+00123.00
           *+78900.00
           *-00072.00

Command:   #1RB
Response:  *1RB+00072.10A2
           *2RB+00123.009F
           *3RB+78900.00B2
           *4RB-00072.00A6
```

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 Extended Address (REA)
The Read Extended Address is used to read back two character address stored by the Extended Address (EA) command. The response message is four characters representing the hex ASCII codes for the two-character address :

```
Command:   $1REA
Response:  *3031

Command:   #1REA
Response:  *1REA3031FA
```

In this example the '30' and '31' are the hex ASCII codes for the characters '0' and '1' respectively. The Extended Address is '01'.

Read IDentification (RID)
The Read Identification (RID) command is used to read data previously stored by the ID command. The RID command response message length is variable depending on the stored message length. The maximum response length can be up to 25 characters using the long form prompt and linefeeds enabled.

```
Command:   $1RID
Response:  *BOILER ROOM

Command:   #1RID
Response:  *1RIDBOILER ROOM54
```

Read MaXimum (RMX)
The Read MaXimum (RMX) command reads the displayed output value corresponding to analog input + full scale. The + full scale displayed data value may be changed by using the WMX command.

Command:	**$1RMX**
Response:	***+00020.00**
Command:	**#1RMX**
Response:	***1RMX+00020.00FD**

Read MiNimum (RMN)
The Read MiNimum (RMN) command reads the displayed output value corresponding to the analog input - full scale. The - full scale displayed data value may be changed with the WMN command.

Command:	**$1RMN**
Response:	***+00000.00**
Command:	**#1RMN**
Response:	***1RMN+00000.00F1**

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 D5000 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:

```
Command:    $1SU31070182
Response:   *

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

Trim Span (TS)

The Trim Span command is the basic means of trimming the accuracy of a D5000 module. The TS command loads a calibration factor into nonvolatile memory to trim the full-scale output of an analog input channel. The D5000 series modules contain a separate 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 D5000 series module contains four output offset registers. Specify 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 D5111 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.

Write Extended Address (WEA)
The Write Extended Address (WEA) command allows the user to set the two-byte address to be used with Extended Addressing (see Chapter 7). The argument of the command specifies the hex ASCII values of the two characters to be used as the Extended Address. For example, if the address is to be set for characters '01':

Command: **$1WEA3031**
Response: *

```
Command:   #1WEA3031
Response:  *1WEA3031FF
```

Note that '30' and '31' are the hex ASCII values for characters '0' and '1' respectively.

The EA command is write-protected and must be preceded with a WE command.

The address data may be read back with the Read Extended Address (REA) command.

Write MaXimum displayed value (WMX)
Write MiNimumdisplayed value (WMN)

The MaXimum (MX) and MiNimum (MN) commands are used to rescale the input ranges of D5000 modules to units that may be more appropriate to a particular application.

```
Command:    $1WMX+00020.00
Response:   *

Command:    #1WMX+00020.00
Response:   *1WMX+00020.00AB

Command:    $1WMN+00000.00
Response:   *

Command:    #1WMN+00000.00
Response:   *1WMN+00000.009F
```

The Write MiNimum displayed value (WMN) command assigns an output data value corresponding to the -full scale analog output value.

The Write MaXimum displayed value (MX) command assigns an output data value corresponding to the +full scale analog output value.

Let’s say that you want to scale an input to desired engineering units. For example, many sensor output signals are transmitted as 4 to 20mA signals. The following example demonstrates scaling a 4 to 20mA signal to 0 to 100% using a D5251 or D5252 module. The actual input range of these modules is 0 to 25mA to make it easier to adjust for zero and span and to allow for drift in the end points of the input.

Since the input range is 0 to 25mA and you want to use a portion of that range, you must determine the new minimum and maximum values. The two desired values: 4mA, 0% and 20mA, 100% determine the desired transfer function. Extrapolate this function to the full-scale range of the module, which is 0-25mA. This results in endpoints at 0mA, -25% and 25mA, 131.25%.

To input the new minimum and maximum values send a Write Enable command, $1WE, followed by a Write MiNmum displayed value command, $1WMN-00025.00. The response to both commands should be an *. Send a $1WE command followed by a Write MaXimum displayed value command, $1WMX+00131.25. The response to both commands should be an *.

The entire range for all four input channels of the module are rescaled and all values are read in percent.

ERROR MESSAGES

The D5000 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 D5000 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) Addressing Mode:
Extended/Normal Fahrenheit /
Celsius
Echo
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 D5000 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 microprocessor 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 Appen- dix 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 D5000 are terminated with a carriage return (ASCII $0D). Most terminals will generate an automatic linefeed when a carriage return is detected. However, for terminals that do not have this capability, the D5000 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.

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.

Bit 4
Bit 4 is used to enable or disable extended addressing mode.

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**					
NORMAL ADDRESSING				**0**				
EXTENDED ADDRESSING				**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 D5000 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 D5000 is addressed with a valid command it will not respond.

Disable CJC
This function pertains only to the D5300 series of 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 degrees Celsius. This setup is useful for calibrating the module or in cases where remote CJC is used. Normally this bit is cleared to '0'.

Celsius/Fahrenheit
The default scaling for temperature output modules is Celsius which is selected by making bit 3 = 0. To change the scaling to Fahrenheit, set bit 3 to '1'. All modules that do not have temperature output must have bit 3 cleared to zero. The scaling factors are operative only on the sensor data; HI and LO limits and setpoints must be modified by appropriate commands to reflect a scaling change (see Figure 2.1).

Echo
When bit 2 is set to '1', the D5000 module will retransmit any characters it has received on the communications line. This option is necessary to 'daisy-chain' multiple RS-232C modules. Echo is optional for systems with a single RS-232C module. Bit 2 must be cleared to '0' on RS-485 models. See Chapter 3 for a more complete description.

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				
CELSIUS					0			
FAHRENHEIT					1			
NO ECHO						0		
ECHO						1		
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 D5311 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 or ND 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 D5451 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.

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	Channels Enabled			
Filter Time Constants	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

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			
32 SECOND TIME CONSTANT			1	1	0			
64 SECOND TIME CONSTANT			1	1	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
32 SECOND TIME CONSTANT						1	1	0
64 SECOND TIME CONSTANT						1	1	1

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.

For example: Assume you have a D5111 unit and you wish to set the unit to echo so that it may be used in a daisy-chain (See Communications). Read out the current setup with the Read Setup command:

```
Command:    $1RS
Response:   *310701C2
```

By referring to Table 5.3, we find that the echo is controlled by bit 2 of byte 3. From the RS command we see that byte 3 is currently set to 01. This is the hexadecimal representation of binary 0000 0001. To set echo, bit 2 must be set to ‘1’. This results in binary 0000 0101. The new hexadecimal value of byte 3 is 05. To perform the SU command, use the data read out with the RS command, changing only byte 3:

```
Command:     $1WE   (SU is write-protected)
Response:    *

Command:     $1SU310705C2
Response:    *
```

Verify that the module is echoing characters and the setup is correct.

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
D511X, D515X, D525X	3107E1C2
D512X	3107E182
D513X, D514X	3107E142
D53XX,	3107E142
D545X	3107E1C2

Chapter 6
Power Supply

D5000 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 D5000 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. D5000 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
Error in displayed value.
Read Data (RD) values are factor of two times normal values.
Module responds with ?1 COMMAND ERROR to every command.
Characters in each response message appear as graphics characters
RS-232 Module response message preceded 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 module(s) are being used in a RS-232 daisy-chain communications configuration then ensure that the "Echo Bit" is enabled in the setup(SU) message of each module.

8. 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.

• Error in displayed value
Make sure that the °C/ F bit is set to a 0. Otherwise the values will be scaled by the °F equation.

• Read Data (RD) values are factor of two times normal values
Ensure that the Degree C/Degree F bit in the setup (SU) message is set to Degree C.

• 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 preceded by <NULL> character
Set "Delay" value to "NO DELAYS" in setup message.

Chapter 8 Calibration

The D5000 module is initially calibrated at the factory and has a recommended calibration interval of one year. Separate 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 necessary 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	F
D511X	+90mV	+00090.00	
D512X	+900mV	+00900.00	
D513X	+4.5V	+04500.00	
D514X	+9V	+09000.00	
D515X	+90V	+00090.00	
D525X	+20mA	+00020.00	
D531X	+39.13mV	+00700.00	+01292.00
D532X	+41.269mV	+01000.00	+01832.00
D533X	+17.816mV	+00350.00	+00662.00
D534X	+68.783mV	+01000.00	+01832.00
D545X	206.1	+00090.00	+00194.00

Appendix A
ASCII Table

Table of ASCII characters (A) and their equivalent values in Decimal (D), Hexadecimal (Hex), and Binary. 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
D5000 Specifications

Specifications (typical @ +25ºC 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.
• Can be used with "dumb terminal".
• Scan up to 250 channels per second.
• 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 -25ºC to +70±ºC.
Storage -25ºC to +85ºC.
Relative Humidity: 0 to 95% noncondensing.

Warranty

12 months on workmanship and material.

D5100 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.

D5200 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.

D5300 Thermocouple Inputs

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

D5450 Thermistor Inputs

- Thermistor types: 2252Ω at 25ºC
- Range: -0ºC to +100ºC.
- Resolution: 0.01ºC or º F.
- Accuracy: 0.1ºC.
- Common mode rejection: 100dB at 50/60Hz.
- Input protection to 30Vdc.
- User selectable ºC or ºF.

Appendix C
Factory Values

Listed below is a table of factory installed values for minimum and maximum displayed values for each model. This information can be used to reinstall the factory scaling values to a module using the WMN and WMX commands (see Chapter 4)

Model	Factory Minimum Value	Factory Maximum Value
511x	-00100.00	+00100.00
512x	-01000.00	+01000.00
513x	-05000.00	+05000.00
514x	-10000.00	+10000.00
515x	-00100.00	+00100.00
525x	+00000.00	+00025.00
531x	-00200.50	+00760.50
532x	-00150.50	+01250.50
533x	-00200.50	+00400.50
534x	-00100.00	+01000.00
545x	+00000.00	+00100.00