

**MODEL 250
23-BIT DATA ACQUISITION SYSTEM**

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Rev. 4

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INTRODUCTION

The Lawson Labs, Inc. Model 250 23-Bit Data Acquisition System is a high-resolution, medium speed, device for translating voltages into digital form. The Model 250 communicates with a host computer via the parallel port. It

has 6 multiplexed differential analog input channels with provision for expansion to a total of 96 channels. Twenty digital input/output lines are available for general purpose use.

The Model 250 accepts +/- 5 volt signals. It can digitize waveforms of up to several kHz while maintaining excellent DC accuracy. The data rate is programmable from under 10 to over 5000 samples/second. The Model 250 can be set to operate either as a sampling converter (Track/hold mode) for AC signals, or as a tracking only converter for DC signals. At full speed, effective resolution is over 19.5 bits. Digital averaging increases the effective resolution. In Track/hold mode, averaging can reduce only residual converter noise, allowing 20-bit effective resolution at reduced speed. In DC mode, all noise sources can be reduced through averaging, including noise on the input signal itself. At a data rate of 80 samples/second in DC mode, the RMS noise approaches one count, providing 23 bits effective resolution. (The converter is monotonic to 22 bits.)

The Model 250 requires a triple output DC supply at +5 and +/- 15 volts. A well regulated linear supply is provided. Both the power inputs and analog inputs are protected against substantial overvoltages.

Polled and scanning modes are available. In polled mode, the host computer requests individual conversions. In scanning mode, the host sends the scanning sequence and timing information to the Model 250 then sends a "start" command. The Model 250 paces itself precisely while acquiring and transmitting the data. With external multiplexers, up to 96 input channels can be scanned. Scanning rates from under 1 per hour to over 5000 per second are supported. Other features under software control include triggering, self-calibration, eight general purpose digital inputs and eight digital outputs.

The exceptional resolution, linearity, speed, and flexibility are achieved by combining a multi-pass, self-correcting, successive approximation converter with a RISC microcontroller supervisor. The microcontroller allows the sophisticated A/D to communicate via a standard parallel interface. A bi-directional or high-speed parallel port is not required.

SECTION 1: INSTALLATION

The Model 250 interconnections consist of three cable connectors and a 5-pin circular power connector. Locate the cable connectors at the bottom of the card. From left to right, they are analog input, parallel port, and digital input/output.

NOTE: Always handle circuit cards by the edges. Static electricity can damage computer circuitry so care should be taken to control static discharge.

For operational checks, only the power supply and parallel cable need be connected. The board is protected against incorrect power supply voltages but will not operate without a proper supply. The power can be connected before or after the interface connection is made to the host computer.

Figure 1 shows the input and output connectors. The 4-bit

optically isolated output allows use of Model 17B, 20B, and 35B multiplexers and multiplexed amplifiers.

The parallel interface uses a high-density 15-pin connector. The Model 250 shares a common ground with the host computer. Under some circumstances, best noise performance will be obtained by making an additional connection between a ground pin on the Digital I/O connector and chassis ground at the host computer. The parallel pinout is defined in Table 1. The cable provided can be used with standard 25-pin D-sub type extender cables. Parallel Port cable lengths over 25 feet may reduce speed or decrease effective resolution.

For maximum accuracy and stability the board should be enclosed in a shielded box. Even if the Model 250 is placed inside another enclosure, we recommend leaving the board in its standard case.

FIGURE 1: MODEL 250 BLOCK DIAGRAM

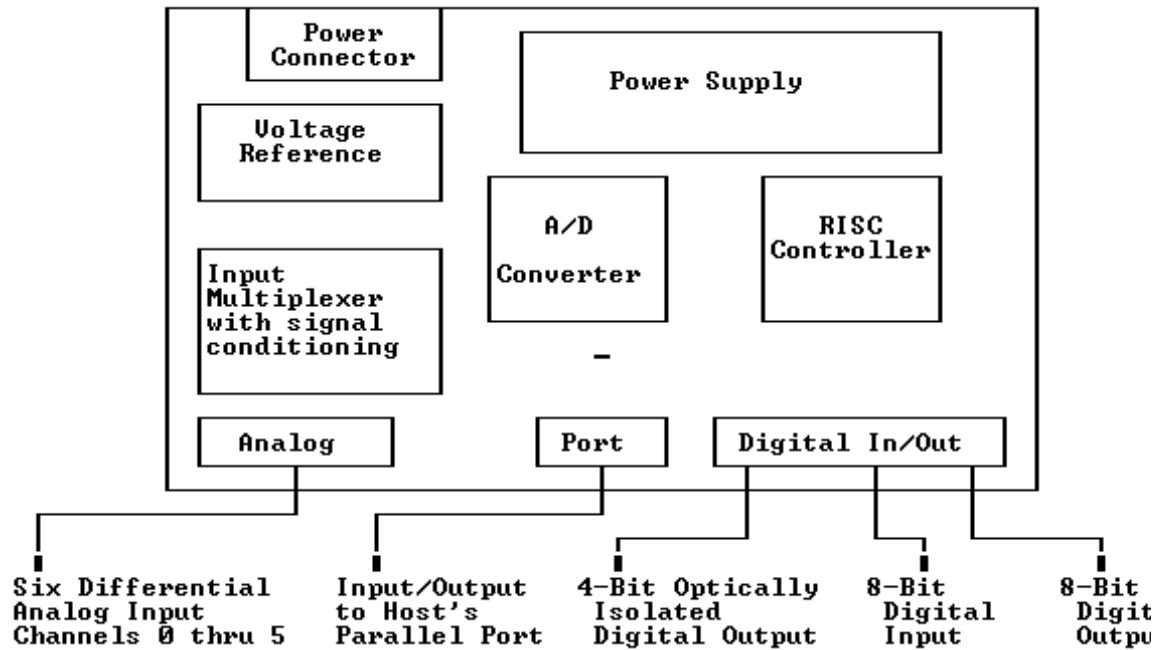


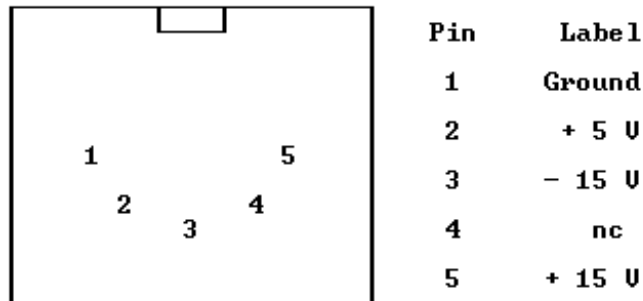
FIGURE 2: PARALLEL CONNECTOR PINOUT

Model 250 Parallel Port Connector Pin Number	Host LPT Port Pin Number
1	11
2	7
3	8
4	9
5	2
6	10
7	12
8	24

9	23
10	6
11	13
12	23
13	3
14	4
15	5

The black pigtail (if present) connects to the shield only.

FIGURE 3. POWER INPUT CONNECTOR PINOUT



SECTION 2: OPERATION

The software driver provided includes an executable file and a source file for Microsoft QuickBASIC.

First make a backup copy of the support disk. You may want to make a directory on your hard drive and copy the support files into the directory. Your disk contains the following files:

```
DRIVR250.EXE  Executable driver software
DRIVR250.BAS  BASIC source code for above
DRIVR250.CFG  Configuration file
DRIVR250.QLB  Library for QuickBASIC (reg trdmrk) environment
DRIVR250.LIB  Stand-alone library
250Axxxx.CAL  Self-calibration file
FACTxxxx.CAL  Factory calibration file
FACTxxxx.CA~ Backup for factory calibration file
```

NOTE: Substitute the last four digits of your Model 250's serial number for xxxx in the above calibration file names.

The calibration files are specific to your particular Model 250. Be sure to make a back-up copy of your support disk. Set the directory containing your support files as the current directory. Type DRIVR250 from the DOS prompt. You should see the Main Menu on the screen.

Establishing Communications

Option 1) Parallel Port - Pressing the "1" key successively cycles the parallel port address through three choices. Parallel/monochrome cards usually use the 3BC port address. LPT1 or LPT2 cards normally use either 378 or 278 (all addresses are given in hexadecimal). If you are unsure of your port address, many computers display the addresses of installed ports when the computer is started. Otherwise, you may need to check your documentation to determine the correct parallel port address. Select option 2, Check Port, to verify the integrity of the parallel link. The check should take less than a minute to finish. When the Port Check finishes, you are given the opportunity to manually set the port settling delay. That delay is normally left at zero. For parallel cables longer than 25 feet, or for extremely electrically noisy environments, you may choose to increase the settling delay. A settling delay of 1 should provide generous timing margins for all but the most extreme circumstances. It may be practical to run hundreds of feet of cable with longer settling delays. If communications errors are detected by the port check itself, the settling delay will be incremented and the test will be repeated. If the communications check fails completely, first recheck the port address. Then, double check the cable and power connections.

Long-Term Calibration

Each Model 250 has two associated calibration files. The FACTxxxx.CAL is a factory calibration file that must be loaded each time DRIVR250 is run. 250Axxxx.CAL is a self-calibration file that should be re-created every month for maximum accuracy. You should not need to concern yourself with the long-term calibration files at this time because your Model 250 has been pre-calibrated. The last active calibration file is always loaded when starting DRIVR250. If you select option 3 you will see the name of the currently loaded calibration file at the bottom of the screen. Press Esc 3 to return to the Main Menu. See Page 12 for details on recalibration.

Polled Mode Overview

After the communications have been established, select Option 4, Polled Operation, from the Main Menu. You will see the polled acquisition screen. Conversion results from the selected A/D channel will scroll in the lower left corner of the screen. The left hand number is the raw count from the A/D converter. The count can vary from approximately -4 million to +4 million. Next to the count is the equivalent voltage. Each count represents just over one microvolt.

In the lower right are calculated figures for evaluating DC performance. Maximum, minimum and average values are given. The difference between the maximum and minimum is also displayed, labeled "delta". Pressing space resets the maximum, minimum, and delta readings. The average is calculated for successive blocks of 40 readings each. The standard deviation, in millivolts, is calculated from the same sample. The effective resolution (in bits) is 23 bits minus the RMS noise expressed in bits.

The top half of the screen shows the current operating

configuration. The following menu choices are available:

C) Analog Input Channel - Channels 0 through 7 are available. Channels 0 through 5 are signal inputs from the Analog input connector. Channel 6 is always connected to a full-scale reference voltage and channel 7 is always connected to zero volts. Channels 6 and 7 are used for self-calibration.

E) External Sub-channel - The A/D sub-channel code appears at the pins labeled A, B, C, & D on the digital I/O connector. If an external multiplexer or multiplexed amplifier is connected, the sub-channel code will select the appropriate channel on the multiplexer. The sub-channel code can be set from 0 to 15. If no external device is connected to the analog input channel, the external sub-channel selection will have no effect on the voltage reading. The external sub-channel is set to zero at power-up.

A) Remote Averaging - The Model 250 can perform digital averaging of 2, 4, 8, 16, 32, 64, or 128 samples. Remote averaging is performed before the data is sent to the host computer. In DC mode, the result will be the average of the input voltage during the entire averaging period. Therefore, all noise sources, including noise present in the signal itself can be attenuated. In Track/hold mode, the input voltage is sampled only once, even if many conversions are averaged. Some noise reduction can still be achieved, but effective resolution beyond 21 bits is unlikely. Under most circumstances in Track/hold mode, there is no benefit in averaging more than eight conversions.

L) Local averaging - Local averaging is performed in the host computer, after data has been received but before it is displayed. Best DC performance is usually obtained with a mixture of remote and local averaging.

T) Track/hold - Select either Track/hold or DC sampling. Track/hold is needed for AC signals, DC mode offers better noise performance, particularly with remote averaging.

D) Digital input - The digital input command reads an unlatched 8-bit digital input word from pins 18 through 25 on the digital input/output connector. The most recent result is shown next to the "D" command on the polled operation screen.

U) Control OUtputs - The digital output command puts a latched 8-bit digital word at pins 6 through 13 on the digital input/output connector. After pressing "U", enter the word to output. These outputs are reset to zero at power-up.

K) ChecKsum - The Model 250 keeps a running total of all serial data transmitted. The total is kept in modulo 256 form, ie., any carry out of an 8-bit binary word is discarded. Therefore, the checksum is always a number from 0 to 255. The host computer keeps a similar total for all received words. The host can request the Model 250's checksum any time communications are open. The host then compares the two values to confirm that no communications errors have occurred. The "Checksum OK" is not a 100% guarantee that no errors have occurred since multiple errors could cancel in the checksum. The more frequently the checksum is requested, the smaller the

chance that an error will go undetected.

S) System calibration. The System calibration command first selects channel 7 and obtains an offset voltage correction. Then channel 6 is selected and a full-scale gain correction factor is established. Finally, the original channel is reselected. For maximum accuracy, the system calibration should be performed regularly. Calibrations should be more frequent during warm-up or during periods of rapid ambient temperature change. You should generally recalibrate after changing the mode or averaging settings.

O) Offset calibration. The average current channel reading is forced to zero volts. Normally channel 7 would be selected before using this command. Note that if an offset calibration is done on channel 6, subsequent readings would fall between zero and -10 volts.

To verify function, press "C" and select analog input channel 7. Because channel 7 is a dedicated zero channel, you should see a voltage in the general vicinity of zero. Enter "O" to initiate an Offset calibration. After the offset calibration the voltage should read very close to zero. This offset calibration removes errors caused by the input signal conditioning circuitry as well as offset errors in the A/D converter itself. Confirm that the reading is close to zero volts. Press "C" and select A/D Channel "6". This channel is a dedicated full-scale channel. Enter "S" to initiate a System calibration. After the system calibration channel 6 should read within 25 microvolts of +5 volts.

Now you are ready to connect an input signal to one of the A/D input channels. A battery is a convenient voltage source for checking the Model 250. Connect the positive and negative ends of the battery to a pair of positive and negative analog input pins on the analog input connector. (Pins 1 and 9, respectively for channel 0). You will also need a wire from one end (normally the negative) of the battery to ground at the Model 250 to insure that the input voltage at both input terminals is within 11 volts of ground. The ground at pin 15 is provided for the purpose. This third connection for common-mode purposes allows more flexibility in connections, and guarantees that ground loops can always be avoided. However, it is easily overlooked, and its absence will cause erratic readings. Enter "C" and select the input channel which you have connected to the battery. A typical D cell will read between 1.2 and 1.56 volts. Reverse the wires and note the polarity change. Note that the plus sign is implicit and does not appear. Connecting the input wires directly together will cause a potential of zero volts. An open circuit will read unpredictably. A positive overvoltage will read over 5 volts. A negative overvoltage will read under -5 volts. Note that the Model 250 can measure accurately to several millivolts above +5 volts as well as to several millivolts below -5 volts.

The analog input channels are protected against continuous overvoltage up to 35 volts. With the initial settings from the provided configuration file (DC mode, no averaging) the effective resolution should be 19.5 to 20.5 bits.

Because of extreme resolution possible with the Model 250 it is important to carefully shield your input signals from electrical noise for best performance. If shielding is not

possible, equal length twisted pair signal wires are recommended. Electrical noise can be radiated through the air and picked up by wiring and/or circuitry. It can also be introduced via the power connections. Also, moving air can create sufficient thermal effects to cause degradation of effective resolution.

You can experiment now with any of the commands. You cannot harm the Model 250 by issuing random commands. As long as you do not answer Yes to the "DO YOU WANT TO SAVE YOUR CONFIGURATION" prompt when you exit the program, you can always restart from the last saved set-up. If no configuration file is present, you will begin from the standard configuration.

Connecting Analog Inputs

FIGURE 4: ANALOG INPUT CONNECTOR PINOUT

PIN 8...+5V REF. OUTPUT	PIN 15...GROUND
PIN 7...REF. GROUND	PIN 14...CHANNEL 5-
PIN 6...CHANNEL 5+	PIN 13...CHANNEL 4-
PIN 5...CHANNEL 4+	PIN 12...CHANNEL 3-
PIN 4...CHANNEL 3+	PIN 11...CHANNEL 2-
PIN 3...CHANNEL 2+	PIN 10...CHANNEL 1-
PIN 2...CHANNEL 1+	PIN 9....CHANNEL 0-
PIN 1...CHANNEL 0+	

Note: For maximum protection, and lowest noise, any unused inputs should be connected to ground. This is done to protect the circuitry from static discharges which can be of extremely high voltage. Open inputs can also pick up noise. Strain-relief is recommended for all permanent wiring on the connector. Otherwise, physical stress may cause the failure of an electrical connection. The connector hood provided includes a strain-relief clamp.

Reference ground and 5 volts are brought out to the analog connector to be used for cases where the system calibration command is not sufficient, or for referencing external signal conditioning circuitry. The 5 volt reference output is independently buffered and can source or sink over 10 milliamps. Large capacitive loads may cause instabilities. Dynamic loading on the +5 volt reference output may decrease effective resolution.

Digital Input/Output Commands

The pin assignment for the digital inputs and outputs are shown in Figure 4. The four optically isolated digital outputs can be used to control Lawson Labs Model 17B, 20B, and 35B multiplexers and multiplexed amplifiers. The optically

isolated lines work in reference to "Guard" (pin 5).

FIGURE 5: DIGITAL INPUT/OUTPUT CONNECTOR PINOUT

PIN 13...DIGITAL OUTPUT 7	PIN 25...DIGITAL INPUT 7
PIN 12...DIGITAL OUTPUT 6	PIN 24...DIGITAL INPUT 6
PIN 11...DIGITAL OUTPUT 5	PIN 23...DIGITAL INPUT 5
PIN 10...DIGITAL OUTPUT 4	PIN 22...DIGITAL INPUT 4
PIN 9...DIGITAL OUTPUT 3	PIN 21...DIGITAL INPUT 3
PIN 8...DIGITAL OUTPUT 2	PIN 20...DIGITAL INPUT 2
PIN 7...DIGITAL OUTPUT 1	PIN 19...DIGITAL INPUT 1
PIN 6...DIGITAL OUTPUT 0	PIN 18...DIGITAL INPUT 0
PIN 5...GUARD	PIN 17...GROUND
PIN 4...OUTPUT D	PIN 16...GROUND
PIN 3...OUTPUT C	PIN 15...GROUND
PIN 2...OUTPUT B	PIN 14...GROUND
PIN 1...OUTPUT A	

Note: Pins 1 through 4 are optically isolated digital outputs. They function relative to pin 5 only.

Press Esc to return to the main menu from the polled mode screen.

Scanning Mode

Selecting option 5 from the main menu yields the scan mode menus. There are three types of scanning available: single-channel fast scanning, normal multi-channel scanning and independent, time-stamped scanning. Fast scanning allows the maximum data rate to be achieved. Most computers can keep up with fast scanning rates in excess of 5 kHz. Normal and time-stamped scanning are limited to a little over 2 kHz because alternate zero and signal measurements are taken, allowing for automatic zero drift suppression. Time-stamped scanning is similar to normal scanning except it proceeds independently, whether or not the host reads the data as it is taken. A means is provided for the host to re-synchronize with the Model 250 without disturbing the acquisition process. Time-stamped scanning mode is useful for situations where the host computer cannot monitor the parallel port continuously. It is needed because the Model 250's output buffer will fill quickly at high data rates.

All scan types allow for Track/hold or DC operation. Remote averaging is not available in Fast Single-channel mode.

Press T to toggle through the various scanning setup screens. The four screens are described below.

Fast Single-Channel Scan Mode

Options 0 through 5 correspond to the six analog input channels. After entering 0 - 5, you will be asked for the external sub-channel code. This code is only significant if an external multiplexer or other device is connected to the optically isolated output port.

Option 6) Inter-channel Delay- This delay does not apply to single-channel scanning and is omitted for fast scanning. See below.

Option 7) Scanning Rate - Select Option 7 and enter the desired rate. The high and low limits are shown. If you enter a value outside the valid range, the nearest attainable rate will be selected. Fast scanning rates can be from over 5 kHz to under 250 Hertz.

Option 8) Number of scans - Scanning will stop after a keypress or after a pre-set number of scans have completed. For simplicity, DRIVR250 limits the maximum number of samples per iteration to 32766.

Option 9) Triggering - Three triggering modes are available: Positive edge, negative edge, and none. If "none" is selected, scanning will begin immediately upon issuing the start scan command. Positive edge triggered scanning will not begin until the Digital Input 7 (Digital I/O Connector pin 25) switches from zero to 5 volts. Negative edge triggering waits for the same input to pass from a high to a low state. Multiple Model 250s can be synchronized if a single trigger signal is used.

Enter) - After pressing Enter, a brief calibration is done at the current settings. Then you are asked to press a key to begin. In triggered scanning, the keypress will enable the trigger, but not actually begin the data collection. The Model 250 will wait indefinitely for the trigger signal. A keypress while waiting period will cancel the scanning iteration.

Esc) - Press Esc to return to the Main Menu.

Normal Scan Mode

Normal Scanning is basically the same as Fast single-channel scanning with the differences described below.

Selections 0 through 5 correspond to the six A/D input channels. With an external multiplexer connected, 1 to 96 channels can be selected for scanning. The A/D input channels are displayed with the external control codes that are active for that channel. From 1 to 16 sub-channels can be active for each A/D channel. Any active subchannels must be contiguous. After pressing the channel number, the user will be prompted for the starting and ending sub-channels. If the ending sub-channel code is lower than the starting sub-channel code, that A/D channel will be skipped during scanning.

Option 6) Inter-channel Delay - This delay allows extra settling time after each channel selection. It can be set from 0 to 4351 in multiples of 17 microseconds. In general, with low impedance signal sources, specified accuracy can be obtained with a delay of 17 or higher. A noticeable improvement may be realized with delays two or three times that long. For very high impedance sources, much longer delays may be necessary. Increasing the interchannel delay will reduce the maximum achievable scanning rate.

Option 7) Scanning Rate - The valid range of Normal Scanning rates is from 1 to over 2000 scans per second. The maximum allowed rate will depend on the number of channels per scan and the inter-channel delay.

Time-stamped Scan Mode

Time-stamped scanning gives the host computer flexibility to perform other tasks without losing the continuity of the acquisition process. The time stamp is the number of scans begun since the start scan command was issued. It is transmitted at the start of each scan. After 67,108,863 scans, the time stamp rolls over to 0. Until that point, the elapsed time is the product of the time stamp and the scan interval. Longer intervals can be tracked by counting rollovers.

After starting time-stamped scanning, the host computer can stop servicing the parallel port for long intervals. Data that is not read from the port is lost, but the time-base is maintained. Digital output commands can be issued without disturbing scanning. During time-stamped scanning, the checksum is used to verify each scan, so the Checksum request should not be issued.

A variation on time-stamped scanning is time-stamped calibration scanning. It adds the full-scale calibration channel as the first data point in each scan. This feature allows the host to keep the gain calibration current over extended scanning periods.

Acquiring and Viewing Scanned Data

After scanning is started, the scan status is displayed. Any scanning sequence can be stopped at the end of the current scan by pressing a key. Fast and normal scanning will stop, regardless, after the designated number of scans. Time-stamped scanning will continue indefinitely, overwriting older data after the available memory has been filled. In time-stamped mode, Pressing Esc cancels scanning immediately. The Model 250 will be reinitialized if a time-stamped scan is stopped with Esc instead of another key.

After scanning, you can page through the data on the screen. For multi-channel scanning, the external sub-channel codes (CC) are listed vertically under headings for each of the six analog input channels. Press space for subsequent scans. Press Escape to return to the scanning menu.

Press Esc again to return to the Main Menu.

Self-Calibration

Your Model 250 is factory calibrated and that calibration has been verified against a very stable 24-bit system. It is possible that over time, aging effects will degrade the monotonicity of the system. The self-calibration routine has been provided to allow you to restore full accuracy at any time. We recommend that you save your original calibration file so that you will always have a baseline to return to.

Calibration should be performed after a 30 minute warm-up period. Substantial care has gone into reducing the temperature sensitivity of the calibration. However, best results will be obtained if the calibration is done at the approximate temperature expected during use. If extreme ambient temperature fluctuations are expected (and maximum accuracy is required), you may want to have a family of current calibration files. Then, you can load the calibration that corresponds to the current ambient temperature.

The self-calibration process generates a 4095-point correction table. Under normal operating conditions, a monthly recalibration should be sufficient. Any reasonably fast computer should be able to complete a self-calibration in under an hour.

The last 4 digits of the Model 250's serial number are used in the calibration file names so that multiple Model 250s can be used on the same computer. The fourth character in the self-calibration file name can be changed if you wish to keep a family of calibration files accessible at the same time. From the Main Menu, select Option 3) Long-term Calibration. You should see the name of the current calibration file at the bottom of the screen. If desired, Select 1) to load a new calibration file. As shipped, the ID code is the letter "A" plus the last four digits of the serial number (found on the bottom of the Model 250 itself). Remember that those four digits are also used to locate the correct factory calibration file. When DRIVR250 starts, it loads the current long-term calibration file as well as the factory calibration file. The current calibration file name is preserved when you save your configuration.

Option 2) performs the actual self-calibration and saves it using the current active filename. If a file already exists with that name, the original file will be renamed with a "~" in place of the last character. The self-calibration process may take almost an hour. The "test data" is displayed in the lower right portion of the screen. It increments to hex FFF by the end of the calibration. Press 3 to return to the Main Menu.

FIGURE 6: EFFECT OF OPERATING MODE AND REMOTE AVERAGING ON EFFECTIVE RESOLUTION

AVERAGING	TRACK/HOLD MODE	DC MODE
1	19.5	19.5
2	19.5	20
4	20	20.5
8	20	21
16	-	21.5
32	-	22
64	-	22.5
128	-	23

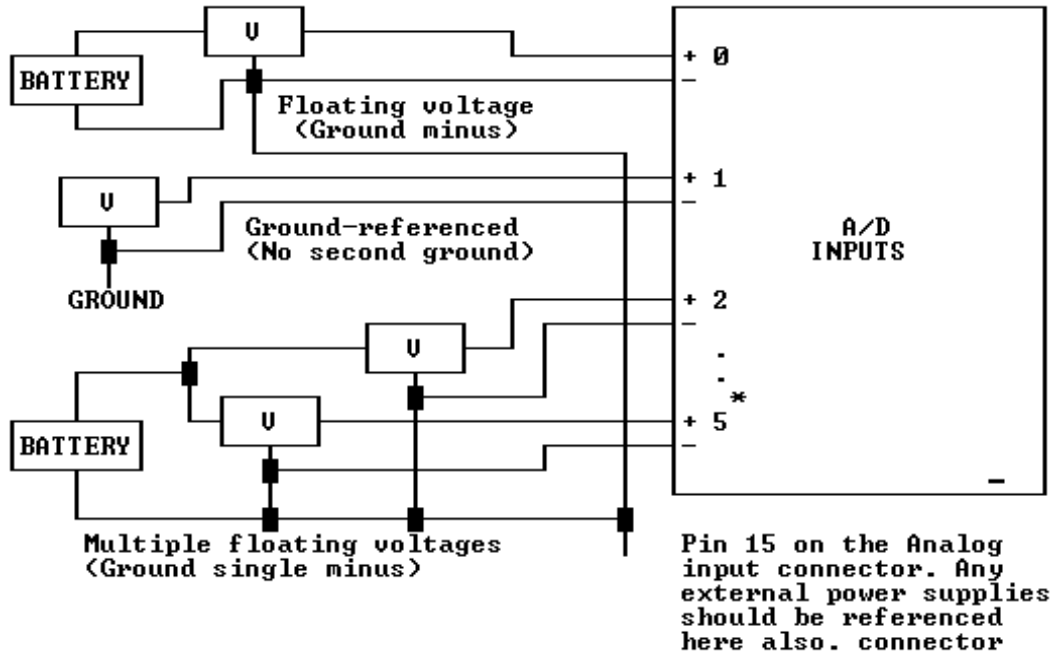
* Effective resolution is defined as total resolution minus RMS noise in bits.

SECTION 3: OPERATING SUGGESTIONS

The Model 250 A/D card features fully differential inputs. A basic understanding of differential measurements will help you to use your card to best advantage. The plus and minus input pins should be wired directly to the voltage being measured. In this way, it is assured that the only current flowing in the wires will be the input current of the A/D converter. Because the wires have finite resistance, any current flowing will cause a voltage drop and a corresponding error. The A/D converter requires a vanishingly small input current so the error caused by even very long wires is negligible. For proper operation it is necessary that the positive and negative inputs both be within 11 volts of ground. For a floating voltage source, this is generally accomplished by connecting a third wire between the Model 250 ground and a ground terminal at the source of the measured voltage. Ground currents may flow in this wire, but the resulting voltage drop will not cause a measurement error. Redundant grounding can cause ground loops. Ground loops can cause unpredictable behavior.

High frequency common mode noise can reduce effective resolution. A capacitor from the negative analog input terminal to the pin 15 ground may help. A similar capacitor on the positive input may be needed to balance the inputs.

FIGURE 7: TYPICAL INPUT CONNECTIONS



* Remember to ground unused inputs

Best results are obtained with filtered, buffered voltages. Electrical noise travels through the air and can be picked up by interconnecting wires. The first defense against noise is shielding. Use shielded wire with the shield connected at one or both ends to ground. (See above). The lower the impedance of the voltage source, the less susceptible the wiring will be to electrical noise. If noise problems persist, try to locate the source of the interference and shield it. Electric motors, electric heaters and flickering fluorescent lights are potential sources of interference.

Digital Input and Output

The digital input lines will accept signals from TTL or 5 volt CMOS logic. They will also work with contact closures to ground. Inactive input pins are pulled up to 5 volts by 100K resistors. The input voltage should not go above 5 volts or below ground.

The 8-bit digital output word is also 5 volt CMOS logic. Each output can source or sink several milliamps.

CAUTION: The digital circuitry can be damaged if these lines are pulled above 5 volts or below ground.

The optically isolated output port is primarily intended for controlling external input multiplexers and multiplexed amplifiers.

FIGURE 8: OPTICALLY ISOLATED DIGITAL OUTPUT CODE

CODE	OUTPUT	D	C	B	A
------	--------	---	---	---	---

0	0 0 0 0
1	0 0 0 1
2	0 0 1 0
3	0 0 1 1
4	0 1 0 0
5	0 1 0 1
6	0 1 1 0
7	0 1 1 1
8	1 0 0 0
9	1 0 0 1
10	1 0 1 0
11	1 0 1 1
12	1 1 0 0
13	1 1 0 1
14	1 1 1 0
15	1 1 1 1

Electrically, each output line is the collector of an optically coupled NPN transistor whose emitter is connected to guard. Note that guard is not connected to ground on the Model 250. The guard is usually connected to the external device's ground. Each output line can drive two low-power TTL loads or many CMOS loads. An external pull-up resistor (from the collector to the external positive supply) must be used. Typically, 20 K ohms is appropriate (the external supply can be as high as 24 VDC). When the output code is 0, all four phototransistors are off and no current is drawn through the transistors. If the input to an inverting buffer is connected to output line A (with the appropriate pull-up resistor), the input level is forced high by the resistor so the buffer output would be 0. If the output code is 1, the A transistor will turn on and pull the buffer input to a logic level 0. The buffer output will then be a logic level 1.

SECTION 4: USER'S TECHNICAL REFERENCE

DRIVR250 software is intended to demonstrate the features of the Model 250. It is not a general purpose data acquisition package. The Model 250 software interface resides primarily in the M250.QLB library. CALLS to the library are used to configure and operate the Model 250. A summary is given below. For more detail, please refer to the source listing, DRIVR250.BAS.

The M250.QLB library processes a 16-bit command word. Also passed (by long reference) are a long integer and an integer variable. When a response is expected, the library returns a long integer, RESPONSE%. The integer variable is used to report any error conditions back to BASIC. Many commands that pass data to the Model 250 include the data being sent in the least significant 8 bits of the COMMAND word. After any COMMAND is issued, the host should check that ERRORCODE% is equal to zero. A non-zero value is an error code which will help to establish the nature of the problem.

The following commands require 8-bit data to be added to the command word:

ChannelCodeCMD% = &H100 select input channel (control code)

valid data: 0 to 127

The channel selected is defined by the data as follows:

CHANNEL% * 16 + SUBCHAN%

CHANNEL% is the A/D input channel number: 0 to 7

SUBCHAN% is the external expansion code: 0 to 15

external multiplexers or multiplexed amplifiers are required in order to use the external control code

Example: COMMAND% = ChannelCodeCMD% + CHANNEL% * 16 + SUBCHAN%
CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP

DigitalOutCMD% = &H200 set digital output

valid data: 0 to 255

The data word appears at the 25-pin connector pins 6-13

Example: COMMAND% = DigitalOutCMD% + DIGOUTWORD%
CALL M250 (COMMAND%, RESPONSE&, ERRORCODE%)
IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP

TrackHoldCMD% = &H300 set sampling mode

valid data: 0 or 1

1 is track then hold, 0 is track only

track only is usually referred to as "DC mode"

Example: COMMAND% = TrackHoldCMD% + HOLD%
CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP

RemoteAvgCMD% = &H500 set number of samples to average

valid data: 1, 2, 4, 8, 16, 32, 64, or 128

Example: COMMAND% = RemoteAvgCMD% + AVERAGE%
CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP

ConvertCMD% = &H600 get conversion command

valid data: 0 to 127

Data is the channel to select for the conversion in the same form as for the ChannelCode command.

The conversion result is passed back as RESPONSE&

Example: COMMAND% = ConvertCMD% + CHANNEL% * 16 + SUBCHAN%
CALL M250 (COMMAND%, RESPONSE&, ERRORCODE%)
IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
COUNT& = RESPONSE&

CalOffsetCMD% = &H7000 offset calibration

valid data: 0 to 127

Data is the channel to select for the conversion in the same form as for the ChannelCode command.

On entry, RESPONSE& is set based on the power of 2 of the number of samples to average. The valid range for POWER2% is 0 - 9 (1 to 512 samples). After this command is issued, the selected input channel will read 0 volts.

Example: COMMAND% = CalOffsetCMD% + CHANNEL% * 16 + SUBCHAN%


```
RESPONSE& = 2 ^ POWER2% + (POWER2% * 65536)
CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
```

CalFullScaleCMD% = &H6000 full scale calibration command

The CalFullScale command is identical to the CalOffset above except that the average count is passed back in RESPONSE&. The actual scaling is done by the CALLing routine.

```
Example: COMMAND% = CalFullScaleCMD% + CHANNEL% * 16 + SUBCHAN%
RESPONSE& = 2 ^ POWER2% + (POWER2% * 65536)
CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
A$ = INKEY$                    'absorb keystroke, if any
IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
```

The following commands request data from the Model 250, but do not require data to be added to the command word. After the CALL, RESPONSE& will contain the result.

VersionCMD% = 3 request version number from Model 250
The version number is passed back as RESPONSE&

```
Example: COMMAND% = VersionCMD%
CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
VERSION% = RESPONSE&
```

DigitalInCMD% = 5 request digital input word
The digital input status from the Digital I/O connector pins 18-25 is passed back as RESPONSE&

```
Example: COMMAND% = DigitalInCMD%
CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
LASTDIGINP% = RESPONSE&
```

ChecksumCMD% = 4 'verify checksum
The Checksum command has no effect except on ERRORCODE%. If ERRORCODE% = 0 then the data received since the last Checksum command are in all probability correct. Note that if checksum commands are not issued frequently, there is a small chance that multiple errors will cancel and no checksum error will be detected.

```
Example: COMMAND% = ChecksumCMD%
CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
```

There are four DoScan commands. Each one initiates a particular type of scanning sequence. The sequence must have been previously defined using Set commands. Once the scan is fully defined, a SendScan command should be issued. All scanning modes write data into an array beginning at DSTARTSEG%.

The scanning commands pass an address into the library in RESPONSE&. On entry, RESPONSE& is the starting segment for the

data array. On exit, RESPONSE& is the number of scans completed. Pressing the space bar during scanning will stop the process. For time-stamped scanning, the Esc key will cancel scanning in mid-scan. You may need to reset the Model 250 in that event.

```
DoStampCalScanCMD% = 2    start time-stamped scan w/calibration
DoNormalScanCMD% = 6      start normal scan
DoStampScanCMD% = 7       start time-stamped scan
DoFastScanCMD% = 8       start fast scan
```

All DoScan commands are issued in the same way. The only difference is the Command word itself.

```
Example:  COMMAND% = DoNormalScanCMD%
          RESPONSE& = DSTARTSEG%
          CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
          COMPLETESEANS = RESPONSE&
          A$ = INKEY$      'absorb keystroke, if any
          IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
```

```
ScanCalCMD% = 11          pre-scan calibration command
On entry, RESPONSE& is set based on the power of 2 of the
number of samples to average. The valid range for POWER2% is
0 - 9 (1 to 512 samples). More averaging means better
reproducibility, but longer calibration time.
```

```
Example:  COMMAND% = ScanCalCMD%
          RESPONSE& = 2 ^ POWER2% + (POWER2% * 65536)
          CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
          A$ = INKEY$      'absorb keystroke if any
          IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
```

```
PortTestCMD% = 10        'parallel port test
```

The PortTest command resets the Model 250 and checks the function of the parallel port. It sends back the read/write delay in RESPONSE&. The delay will be zero unless errors were encountered. You can manually increase the delay for extra timing margins. The read/write delay is initialized in the SetPort command.

```
Example:  COMMAND% = PortTestCMD%
          CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
          IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
          RWDELAY% = RESPONSE&
```

The Set commands pass scanning parameters to the M250 in DATA1&. In some cases, additional data is sent in the low byte of COMMAND%.

```
SetRateCMD% = &HC000
```

The SetRate command establishes the scanning rate for fast and normal scanning. See the SetStampRate command for time-stamped scanning. DATA1& is set to reflect the scan interval. the interchannel delay is added to the command word.

```
Example:  COMMAND% = SetRateCMD% + INTERCHAN%
          CALL M250(COMMAND%, DATA1&, ERRORCODE%)
          IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
```

SetScanChannelsCMD% = &HD000

This command specifies the active channels for multi-channel scanning. A single 8-bit byte is written to each of 8 locations. The 8 locations are addressed by adding an index to the command word. The valid index range is 0 through 7. The first position is reserved for expansion. It must be set to zero. The next 6 positions define the channel selection sequence during the scan. DATA1& is derived from the channel code sequence and is put at the location for that channel. The 8th position is the total number of active data points. The valid range for the total is 1 to 97. The 8 positions must all be set before the scan configuration is sent to the Model 250.

```
Example:  FOR INDEX% = 0 to 5
          COMMAND% = SetScanChannelsCMD% + INDEX% + 1
          DATA1& = CHAN%(INDEX%)
          CALL M250(COMMAND%, DATA1&, ERRORCODE%)
          IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
        NEXT INDEX%
```

SetCalCMD% = &HC00 setup long-term calibration process
StartCalCMD% = &HD00 start long term self-calibration

These commands are not normally needed in application code because long-term calibration need be done only monthly (or even annually). We recommend using DRIVER250 itself for calibration or using the DRIVER250 self-calibration subroutines essentially intact.

SendSetupCMD% = &HE000

The scanning information previously defined with Set commands is sent in a block to the Model 250. Two other parameters are also passed when the SendSetup command is issued. The SendSetup command must be issued before a DoScan command is sent. DATA1& = number of scans to complete (1 to 32766). For Time-stamped scanning DATA1& is the buffer size (1 to 32766). The trigger type (TRIGGERTYPE%) is added to the command word. Valid types are:

0	= no trigger
1	= positive edge
2	= negative edge

```
Example:  COMMAND% = SendSetupCMD% + TRIGGERTYPE%
          DATA1& = NUMNORMALSCANS
          CALL M250(COMMAND%, DATA1&, ERRORCODE%)
          IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
```

SetPortCMD% = &HF000 set parallel port address

This command initializes the Read/write delay and the port address and resets the Model 250. The read/write delay is passed to the library in RESPONSE&. The port base address (PORTADDR%) is added to the command word.

```
Example:  COMMAND% = SetPortCMD% + PORTADDR%
          RESPONSE& = RWDELAY%
          CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
          IF ERRORCODE% <> 0 THEN
            PRINT "Parallel Port not found "
            PRINT "Press any key to continue "
            A$ = INPUT$(1)
          END IF
```

SetStampRateCMD% = &HE00 set time-stamp scan rate
The rate is determined by the interval between scans. That interval is held in three bytes STAMPLO%, STAMP MID%, & STAMP HI%. The low byte is added to the command word. The other bytes are passed in DATA1&.

Example: COMMAND% = SetStampRateCMD% + STAMPLO%
 DATA1& = STAMP MID% + STAMP HI% * &H100
 CALL M250(COMMAND%, DATA1&, ERRORCODE%)
 IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP

GetCalFilesCMD% = &HA000 get long-term calibration and
 factory calibration arrays
The library needs to load the correct .CAL files before the Model 250 can perform as specified. Letter% is an ascii code available for housekeeping purposes. The original calibration provided uses the letter "A". SERIALCODE% is derived from the last 4 digits of the M250's serial number.

Example: COMMAND% = GetCalFilesCMD% + Letter%
 RESPONSE& = SERIALCODE%
 CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
 IF ERRORCODE% <> 0 THEN GOSUB FileError

GetStampScanCMD% = &H9000 get one scan during time-stamped
 scanning
After a DoStampScanCMD% or DoStampCalScanCMD% has been issued, data is retrieved with the GetStampScan command. On exit, RESPONSE& is a pointer used to locate data in the scan buffer.

Example: COMMAND% = GetStampScanCMD%
 CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
 IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP

EndStampScanCMD% = &H8000 end time stamp scanning
This command stops time-stamped scanning. RESPONSE& returns a pointer into the scan buffer to locate the most recent data.

Example: COMMAND% = EndStampScanCMD%
 CALL M250(COMMAND%, RESPONSE&, ERRORCODE%)
 IF ERRORCODE% <> 0 THEN GOTO ERRORTRAP
 RESPONSE& is the current scan buffer location

SECTION 5: TROUBLESHOOTING

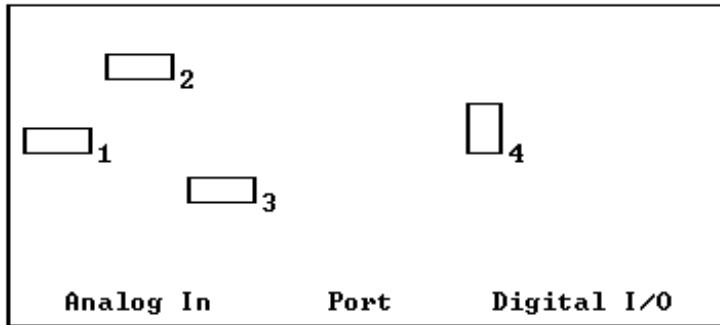
- 1) Can't reset the Model 250.
 - A. Check parallel port address.
 - B. Make sure that power is connected properly to the 250.
 - C. Double-check your cable. If you are using an extender cable, are all lines extended?.
- 2) Data appears random.
 - A. Check channel selection and input cable pinout.
 - B. Issue a checksum command to verify communications.

- C. Select channel 7 to verify conversion at zero volts.
- 3) Data is consistent, but wrong.
 - A. Do a system calibration.
 - B. Check channel selection.
 - C. Make sure another A/D input channel isn't badly over-range.
 - D. Make sure the correct .CAL file is loaded.
- 4) Data is noisy.
 - A. Increase filtering or digital averaging.
 - B. Use DC mode if appropriate.
 - C. Check shielding and grounding. Check that the DC common-mode range of +/-11 volts is being observed.
 - D. Make sure another A/D input channel isn't badly over-range.
 - E. An incorrect or missing long-term calibration file can cause excessive noise at certain voltages.
 - F. Refer to OPERATING SUGGESTIONS a more complete discussion of noise issues.
- 5) Optically isolated outputs are not working.
 - Check connection to guard.
- 6) Scanning fails, reporting a buffer overflow error.
 - A. Slow down the scanning rate.
 - B. Remove TSRs or interrupt driven options.
 - C. Use time-stamped scanning mode.
- 7) QuickBASIC won't run DRIVR250.BAS
 - A. Missing command line switch /AH
 - B. Missing library switch /L DRIVR250.QLB
 - C. Library file is not in current directory.

SECTION 6: INTERNAL ADJUSTMENTS

Hardware calibration is set at the factory and should never need adjustment. The software should always be able to calibrate to yield peak accuracy. If you change any of the adjustments, particularly numbers 3 or 4, you may not be able to restore specified performance.

FIGURE 9. Location of Internal Adjustments



There are four potentiometers on the board. Their functions are as follows:

- 1) DC Common-mode rejection adjustment - To reset the common-mode adjustment first, connect the + and - input pins of a channel to the +5 volt reference pin on the analog input connector. Select that channel in polled mode. Adjust the common-mode potentiometer for a reading of zero. Perform a system calibration and then repeat for best results.
- 2) Gain adjustment - The gain is set by connecting a known voltage to an analog channel. Do a system calibration then adjust the gain potentiometer to obtain the desired reading. Repeat for best results. Note that the +5 volt reference on the analog input connector will be affected by this adjustment.
- 3) Residual Amplifier gain adjustment - This adjustment is factory set and should not be changed. Aging effects may slightly change the gain of the residual amplifier, but that is corrected for by the 4095-point software calibration. If this potentiometer is too far out of adjustment, the software calibration will run out of range.
- 4) DAC Buffer offset adjustment - This adjustment is also factory set for zero volts offset. Offset errors at this amplifier are corrected for in the 4095-point calibration.

SECTION 7: MODEL 250 SPECIFICATIONS

TYPE:	23-bit successive approximation A/D converter with parallel interface
MONOTONICITY:	22 bits
LINEARITY:	0.0005% of full scale
DIFFERENTIAL INPUT RANGE:	+/- 5 volts At least 150 millivolts of over-voltage can be accommodated without overranging. No phase reversal occurs, even for extreme over-voltages.
COMMON-MODE VOLTAGE RANGE:	+/- 11 volts

DC COMMON-MODE REJECTION: 96 dB minimum

INPUT IMPEDANCE: 100,000 megohms typical

ANALOG INPUTS: 6, fully differential, protected to 32 volts, expandable to 96 channels using optional multiplexers

DIGITAL INPUTS: 8-bits, contact closure or 5-volt CMOS or TTL logic compatible

DIGITAL OUTPUTS: 4 optically isolated lines plus 8 latched logic outputs

POWER REQUIREMENT: +15 VDC at 30 mA
-15 VDC at 20 mA
+ 5 VDC at 10 mA (with all digital outputs OFF. Add 88 mA for all ON)
Standard supply requires for input 120 VAC +/- 10% at 60 Hertz

SIZE: 5 x 6.5 x 1 inches board only
5.6 x 6.9 x 1.8 inches in enclosure
3 x 4.8 x 2.6 inches power supply

WEIGHT: 3 Lbs. Model 250 in enclosure
3 Lbs. external power supply

DATA RATE: Programmable, 3 points per hour to over 5400 samples per second

EFFECTIVE RESOLUTION: Effective resolution is defined as total resolution minus RMS noise in bits. At 5 kHz, it is 19.5 bits. Digital averaging will yield a maximum of 20 bits in Track/hold mode. Effective resolution approaches 23 bits in DC mode at 80 Hertz.

PARALLEL INTERFACE: 4-bit buffered interface with error checking. A bi-directional or high-speed port is not required. A 6-foot cable is provided for use with an LPT port.

OPERATING MODES: The Model 250 can operate in polled or scanning mode. In polled mode, individual readings are transmitted on request. In scanning mode, a pre-defined block of data is transmitted at a preset interval. Time-stamped scanning mode allows the Model 250 to proceed with data collection independent of the host computer. Both polled and scanning modes offer Track/hold or DC operation.

SELF-CALIBRATION: The Model 250 has extensive built-

in self-calibration capabilities.
Under software control, a 4095-
point calibration will restore full
accuracy.

LIMITED WARRANTY

The Lawson Labs, Inc. Model 250 is guaranteed against defects in materials and workmanship for a period of one year from the date of delivery. Products must be returned to Lawson Labs for warranty service. Contact Lawson Labs at 800 321-5355 for return authorization before returning anything for service.

The above warranty is in lieu of all warranties express or implied. Lawson Labs will not be liable for indirect or consequential damages caused by any defect in this product. Some states do not allow the limitation of consequential damages, so the above exclusion may not apply to you.