MODEL 203
20-BIT SERIALLY INTERFACED
DATA ACQUISITION SYSTEM

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        or
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Rev. 1

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INTRODUCTION

     The Lawson Labs, Inc. Model 203 20-Bit Data Acquisition
System is a high-resolution device for translating voltages
into digital form. The Model 203 communicates with a host
computer over an RS-232 serial link. It has a single
differential analog input channel, two 14-bit analog outputs,
a digital input, and 8 digital outputs.

     The Model 203 is intended for DC and low frequency
applications. The sampling rate is programmable from 0.5 to
over 120 samples/second. Effective resolution decreases with
increasing sample rates. At 1 Hz the effective resolution is
over 20 bits. 16-bit effective resolution is maintained up to
60 samples/second. The converter is guaranteed monotonic to 20
bits.

     All power and analog inputs are protected against
substantial overvoltages. The serial port is optically
isolated from the host for ground isolation and fault
protection. Error checking on the serial link assures data
integrity.

     Both polled and scanning modes are available. In polled
mode, the host computer requests each data point from the
Model 203. In scanning mode, the Model 203 maintains it's own
time base and transmits samples at a pre-defined data rate.
Line frequency rejection can be configured for 50 or 60 Hz.

     The resolution, stability, flexibility and price of the
Model 203 are achieved by using cost effective delta-sigma A/D
conversion architecture without employing an expensive delta-
sigma converter IC. A RISC microcontroller supervisor does
most of the work.

SECTION 1: INSTALLATION

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

Installation Summary

   1. Connect the serial cable between the Model 203
      SERIAL port connector and the serial port of the host
      computer. An 18 inch transition cable and a six-foot
      extension cable are provided.

   2. Connect power to the Model 203 POWER INPUT terminals.

      Without Regulator Option: Connect a regulated +12 VDC
      power supply to the POWER INPUT terminal block.

      With Regulator Option: Connect the wall-mounted power
      supply wires to the power input terminals. The white
      stripe is on the plus wire.

FIGURE 1: MODEL 203 BLOCK DIAGRAM

```
+-----------------------------------------------------------------------+
| +----------+  +-----------------------+     +-----------+ +----------+ |
| | POWER    |  | Delta-Sigma Modulator |     | RISC      | | Clock    | |
| | INPUT    |  |                       |     | Micro-    | | Generator| |
| +----------+  +-----------------------+     | Controller| +----------+ |
|                                             |           | +----------+ |
| +----------+  +-------------+ +-----------+  |           | | Digital  | |
| | Voltage  |  | Analog      | | Analog    |  |           | | Output   | |
| | Reference|  | Input Signal| | Output    |  |           | | Latch    | |
| |          |  | Conditioning| |           |  +-----------+ +----------+ |
| +----------+  +-------------+ +-----------+                             |
|                                                                        |
| +----------+  +-------------+ +-----------+  +-----------+ +----------+ |
| | Voltage  |  | Input       | | Analog    |  | Serial    | | Digital  | |
| | Inverter |  | Protection  | | Input     |  | Port      | | Output   | |
| |          |  |             | | Multiplexer| | Isolation | | Buffer   | |
| +----------+  +-------------+ +-----------+  +-----------+ +----------+ |
|     +=====================+   +==========+   +=======================+  |
|     |  ANALOG I/O         |   | SERIAL   |   |  DIGITAL OUTPUT       |  |
|     +=====================+   +==========+   +=======================+  |
+-----------------------------------------------------------------------+
```
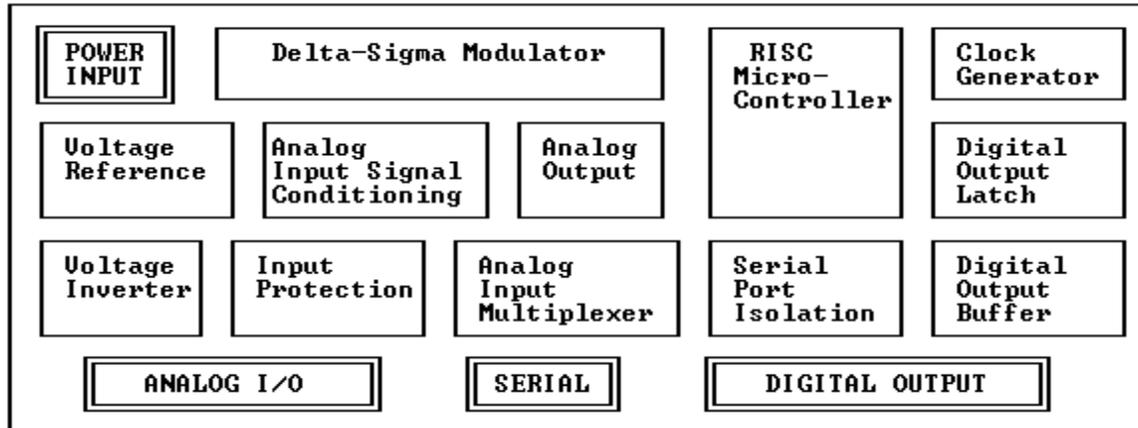
There are 4 connectors on the Model 203: Power Input,
Serial I/O, Digital Output, and Analog I/O. The single-bit
digital input is on the Analog I/O connector. Figure 1 above
shows the location of these connectors (indicated by double
lines). For operational checks, only the POWER INPUT and
SERIAL cable connections are necessary.

POWER INPUT: This 2-position terminal block located at the
upper-left corner of the board provides for connection to an
external power supply. Power connects to the "+V" and "GD"
terminals. For applications where a regulated 11 to 16 VDC
supply is not available, the regulated power supply option is
recommended. This option includes a wall-mounted unregulated
12VDC power supply module and an on-board regulator.
        The board is protected against reverse voltage but will not
operate without a properly connected power supply. The power
can be connected before or after the serial interface
connection is made.

SERIAL connector: The cables provided connect this port to
the serial port of the host computer. If only a 25-pin serial
port connector is available, you will need a 25-to-9-pin port
adapter. These are generally available or can be purchased
from Lawson Labs. The serial interface is optically isolated
from the host computer for protection in the event of
overvoltage and to isolate the grounds. If desired, the
computer chassis ground can be connected to ground at the
Model 203.

TABLE 1: COMPUTER SERIAL PORT PIN NUMBERS

| | 9 Pin | 25 Pin |
Description	Connector	Connector
TX	2	3
RX	3	2
DTR	4	20
GND	5	7
RTS	7	4

ANALOG I/O: This 8-position terminal block located at the
lower-left of the board provides connections for the digital

input, the analog outputs, and the analog input. The analog
ground terminal provides a separate path to the same point as
the "GD" ground. Use "AG" for referencing the analog outputs
or referencing analog input signals. Use "GD" ground terminals
for power or digital I/O connections.

TABLE 2: INPUT/OUTPUT TERMINAL BLOCK

```
  Terminal      Description
  ---------------------------------------------------
  "RS"          Digital input
  "GD"          Ground
  "GD"          Ground
  "AG"          Analog Ground
  "TP1"         DAC Analog Output 1 referenced to ground
  "TP2"         DAC Analog Output 2 referenced to ground
  "+IN"         Positive differential analog input
  "-IN"         Negative differential analog input
```

    DIGITAL OUTPUT: This 8-position terminal block serves the 8
digital outputs. Terminals "A" through "H" function relative
to "GD", the ground terminals, and are controlled by an 8-bit
control word. Bit 0 controls output "A"......Bit 7 controls
output "H".

SECTION 2: OPERATION

    The software drivers provided with the Model 203 work with
QBASIC or Microsoft QuickBASIC for DOS or Borland C for
Windows.

    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 has two directories,
IN_BASIC for DOS and WIN203 for Windows.

```
IN_BASIC
  DRIVR203.EXE    Executable BASIC driver software
  DRIVR203.BAS    BASIC source code for above

WIN203
  EWINM203.EXE    16-bit executable EasyWin driver software
  EWINM203.CPP    C++ EasyWin source code
  M203DLL.H       16/32-bit dynamic link library header file
  M203_16.DLL     16-bit dynamic link library
  M203_32.DLL     32-bit dynamic link library
```

    The DOS driver is discribed here. The Windows driver is
equivalent, though not identical to the DOS driver.

    Set the directory containing your DOS support files as the
current directory. Type DRIVR203 from the DOS prompt. The
first time the driver is started after installation the
"Unable to read DRIVR203.CFG file, press any key to continue"
message is displayed. Press any key you should see the Serial
Communications Menu on the screen.

Establishing Communications

    Pressing the "1" key successively, cycles the BAUD rate

from 9600 through 300. The "2" key toggles the host COM port
between COM1 and COM2. By pressing the "3" key the user can
enter a buffer size between 1 and 32767 bytes. 512 bytes is
more than adequate for polled mode. A larger buffer is
recommended for scanning mode. Selecting option "4" begins a
reliability check for the serial communication link. The host
transmits characters which are echoed back by the Model 203.
The number of characters sent and the number of errors will
appear on the screen. If an error occurs a beep will sound.
When you are satisfied that communications are intact, press
"space" to continue. If occasional serial errors are detected,
select a slower baud rate.

Polled Mode Overview

    Press enter to begin the sign-on process. After
initialization you will see the Polled Acquisition Screen.
Conversion results from the selected A/D channel will scroll
down the screen. The left hand number, "COUNT", is the raw
count from the A/D converter. It is a number between 0 and 10
million. The actual count displayed for a given voltage will
vary with the data rate. The next number, "VOLTS", is the
count translated into volts. "MIN-MAX" is the difference
between the highest and lowest voltage reading. This value is
reset to zero each time the space bar is pressed. "RESOLUTION"
is the RMS resolution in volts. "CHANNEL" is the currently
selected channel. "EF BITS OF XX" is the effective RMS
resolution in BITS, where XX is the maximum possible
resolution for the currently selected sample rate. The
effective resolution is based on the last group of 20
conversions and is equal to the total resolution minus the RMS
noise in bits.

    Commands specific to this screen are listed at the bottom.
Prompts, and responses to commands are displayed to the right
of the command line. Pressing the M key will display the
command Menu. Enter returns to the Polled Acquisition Screen.
Commands can be issued from either the command menu or the
Polled Acquisition Screen. If you are ever uncertain of the
current set-up or command keys, enter M to see the command
menu screen.

NOTE: Though the Model 203 has one analog input, the A/D
       converter system can read 3 additional on-board
       voltages; zero volts, the 5 volts reference, and the
       analog outputs. One of these four voltages can be
       selected as one of four input channels. The numbering
       of these channels, 0, 1, 6 and 7, maintains
       compatibility with other Lawson Labs products which
       have additional analog inputs.

Software Calibration

    While in the polled screen, verify the calibration by
pressing "C" and select A/D input Channel "7". Channel 7 is a
dedicated zero voltage channel provided for offset
calibration. 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 can remove errors caused by the
input circuitry as well as offsets in the A/D converter system

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 "F" to initiate a Full-scale calibration. After the full-scale calibration the converter should read very close to +5 volts.

The "S" command (System calibration) performs the above sequence automatically. It does the channel selection and both calibrations and then re-selects the original channel. Settling times are accounted for.

Connecting Analog Inputs

Now you are ready to connect an input signal to the A/D input channel. A battery is a convenient voltage source for checking the Model 203. Connect the positive and negative ends of the battery to the "+IN" and "-IN" terminals on the Analog I/O terminal block. You will also need to connect a wire from one end (normally the negative) of the battery to ground at the Model 203 to insure that the input voltage at both input terminals is within 6.5 volts of ground. There are analog ground terminals on the Analog I/O terminal block provided for this purpose. This extra ground is for common-mode requirements only, so voltage drops in the common-mode ground path will not adversely affect voltage readings. Remember that the Model 203 is optically isolated and is floating in relation to the computer chassis ground. Enter "C" and then select channel 0 to select the battery. A typical D cell should read about 1.5 volts. Reverse the wires and note the polarity change. Note that the plus sign is implicit and does not appear. Connecting the "+IN" and "-IN" terminals together and to ground will cause a potential of zero volts. An open circuit will read unpredictably. A positive overvoltage will read approximately 6.8 volts. A negative overvoltage will read approximately -6.8 volts. The analog input channel is protected against continuous overvoltage up to 60 volts. At 10 Hz the effective resolution should be 18 bits or more.

NOTE: Take care not to connect the positive and negative terminals of the battery together. A momentary short can cause the battery to be unstable and unusable for testing for several hours.

Because of the extreme resolution possible with the Model 203 it is best to shield your input signals from electrical noise. Electrical noise can be radiated through the air and picked up by wiring. It can also be introduced via the power connections.

Additionally, air currents can create sufficient thermal effects to cause degradation of effective resolution. For maximum accuracy open cell foam should be placed firmly against both sides of the board to minimize air currents. Although a copper/solder junction is not considered a good thermocouple, there are many such junctions and they will have an effect at the microvolt level.

NOTE: A strain-relief is recommended for all permanent wiring connections. Otherwise, physical stress may cause the failure of electrical connections.

You can now experiment with any of the commands. You cannot harm the Model 203 by issuing wrong 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.

Commands for Setting Up the A/D Converter

The Model 203 is designed to maintain some backward compatibility with the Model 202. Therefore the Model 203 commands often contain unused structures for compatibility.

C) Channel Selection – Selects one of four A/D channels. Channel 0 is the analog input channel and connects the analog-to-digital converter to the "+IN" and "-IN" terminals on the ANALOG I/O connector. Channel 7 is the zero voltage channel used for offset calibration. Channel 6 is the +5 volt reference channel used for full-scale calibration. Channel 1 reads back the analog outputs. This voltage is equal to the voltage of Analog Output 1 minus the voltage of Analog Output 2.

R) sample Rate – The A/D converter's sample rate and frequency response are set with this command. With 60 Hz line frequency rejection, rates from 0.5 to 120 Hz are possible.

NOTE: With BAUD rates below 4800 bps (below 2400 bps when using 50 Hz line frequency rejection), sample rates can be limited by serial communications speed.

There is a low-pass filter intrinsic to the conversion process. The cutoff frequency of this filter is dependent on the sample rate and local averaging performed by the host. For example, if the host uses local average of 2, the cutoff frequency for this filter is equal to the data rate times 0.2. As averaging increases, the filter cutoff frequency decreases.

Also, the resolution depends on the data sample rate. For maximum effective resolution, use the lowest data rate that meets your needs. Table 4 on page 14 shows the effective resolution and cutoff frequency for selected sample rates.

L) Local Average – The Model 203 driver provides a running or "moving window" average of N consecutive data samples. Press "L" and then enter the number of conversions to include in the average. The number of data samples averaged may be any number between 1 and 32,768. Press Enter to register your selection. Since this is a running average, the data rate will not be effected. However, the larger the number of data samples included in the average, the longer it takes to settle after changing A/D channels.

O) Offset calibration – This command makes the currently selected channel read 0 volts.

F) Full-scale calibration – This command makes the currently selected channel read +5 volts. If there is too little difference between the voltages used for offset and full-scale calibration, a warning message will appear.

S) System calibration – The "S" command does an automated
system calibration. A/D input channel 7 is selected and an
offset calibration is performed. Then channel 6 is selected
and a full-scale calibration is done. Finally, the original
channel is re-selected.

*) Full-scale calibration to user entered value – This
command allows a full-scale calibration to a user selected
voltage. Note: This command should be used with caution.

NOTE: The Model 203 can remove large offset or gain errors.
        Remember that input voltages beyond +/- 6.8 volts will
        be clipped. The most accurate calibration can be
        obtained using an external voltage standard.

        1. Select A/D input channel 0.
        2. Ground both analog input terminals.
        3. Do an offset calibration using the "O" command.
           Channel 0 now reads 0 volts.
        5. Apply a stable, precise +5 VDC standard to the
           analog input.
        6. Do a full-scale calibration using the "F" command.
           A/D channel 0 now reads 5 volts. Calibration is
           complete.

Care must be taken when using the offset and full-scale
calibration commands to avoid misleading readings. For
example, if you reverse the voltages for the two calibrations,
a 1.5 volt battery will read 3.5 volts.

Analog Outputs and Commands

The Model 203 has two 14-bit digital-to-analog output
channels. Each of these outputs can be individually set to a
voltage between 0 and +5 VDC. Analog Output 1 is present at
terminal "TP1", of the ANALOG I/O terminal block. Analog
Output 2 is present at terminal "TP2" of the ANALOG I/O
terminal block. Both of these voltages are referenced to the
Model 203 ground(GD). The analog output voltages can be
checked by reading the voltage at channel 1. This voltage is
equal to Analog Output 1 minus Analog Output 2.

A) Analog Output Voltage – This command sets the voltage
for either of the Analog Outputs. Enter "A" from the polled
acquisition, scanning, or menu screen, select the analog
output to update, and enter a new analog output voltage. The
analog output voltage can be 0 to 5 VDC. Both Analog outputs
are set to 0 VDC at power-up. Note: Conversion noise on the
outputs increases with decreasing baud rates.

Digital Input and Output Commands

D) Digital Input – The Digital Input command reads an
unlatched digital input signal at the "RS" terminal on the
ANALOG I/O terminal block. Pressing "D" while in the polled
acquisition, scanning, or command menu screen causes the
status at "RS" to be read and the result displayed. 5 volts =
Inactive, 0 volts = Active.

U) Digital OUtput – The digital output command places a

latched 8-bit digital word entered by the operator at
terminals "A" through "H" of the DIGITAL OUTPUT terminal
block. After pressing "U", enter the digital output word (0 -
255).

Other Commands

K) checKsum - The Model 203 keeps an 8-bit running total of
all serial data transmitted. The host computer can keep a
similar total for all received words. The host can request the
Model 203's checksum any time communications are open. The
host can then compare the two values to confirm that no serial
errors have occurred. Both checksums are set to zero after a
checksum request. Checksum OK is not a 100% guarantee that no
errors have occurred because multiple errors could cancel in
the checksum. The more frequently the checksum is requested,
the smaller the chance that a serial error will go undetected.

Scanning Mode Overview

From the polled acquisition screen, a keypress of N will
take you to the scaNning configuration menu. From this menu
you can select the channel, select the type of scanning
display, and select the desired scan interval.

Pressing C prompts you for a new channel selection. The
channel selection is the same as for the polled acquisition
mode.

Pressing I prompts you for a new scan Interval. The maximun
and minimum times are based on the baud rate and the data
rate. The scan interval will always be an integer number of
clock counts, so the interval entered will be rounded to the
nearest available rate.

Pressing D toggles the scanning Display mode; text or
graphics.

Text Scan Display

The enter key starts scanning and switches to the display
screen. This screen shows the time the scan started, the scan
time, the bytes per scan, the elapsed time, the scans
expected, and the scans completed. Pressing any key will stop
scanning at the end of the current scan and display the scan
review screen. Press space to review the scans one at a time.
Press any other key to return to the scanning configuration
menu. Then press escape to return to polled mode.

Graphics Scan Display

The Graphics Scan Display plots each point as it is
received. The positive and negative display limits can be
adjusted. Horizontal and Vertical index lines can be adjusted.

During the Graphic Scan Display Dig In, dig OUt, Channel, and
dAc commands are active.

Other available commands:

    P) Plus Display Range Limit – adjusts the positive display
       limit in mv
    M) Minus Display Range Limit – adjusts the negative display
       limit in mv
    V) Vertical Indexing – adjusts the vertical indexing in mv
    H) Horizontal Indexing – adjusts the horizontal indexing in
       secs
    E) Exit) – stops scanning

    In addition to the waveform display, there are numeric
displays at the lower-left corner of the screen. "VOLTS"
displays the voltage. "SCANs" is the number of scans
completed. "SECs/Screen" is the number of seconds required to
complete one pass of the screen with the current scan
interval. "Buffer" shows the percentage of the serial input
buffer currently filled.

                   TABLE 3: COMMAND SUMMARY
       Function   Range/Description

--
 "L" – Local Averaging   1 to 32768 running average

 "C" – Channel   0,1,6, or 7 Analog input channel selection

 "D" – Digital input   Reads the state of the unlatched digital input
                           at "RS" terminal of the Analog I/O terminal
block

 "F" – Full-scale   Makes the selected channel read 5 volts
   calibration

 "K" – checKsum   Verify the running checksum from the Model 203

 "O" – Offset   Makes the selected channel read 0 volts
   calibration

 "R" – data Rate   0.5 Hz to 120 Hz Select the sample data rate

 "S" – System   Automatically performs an offset followed by a
    calibration   full-scale calibration, then re-selects the
                           active channel

 "U" – digital oUtput   Puts a latched 8-bit digital word at terminals
                           "A" through "H" on the digital output
terminal
                           block.

 "A" – Analog Output   Sets the analog output voltage for Analog
Output
     Voltage   1 and Analog Output 2

 "*" – Full-Scale   Allows full-scale calibration to a user a
   Calibration   selected voltage

 "P" – Set Plus Limit   Sets the positive screen limit of the graphics

```
                         scan display

 "M" – Set Minus Limit    Sets the negative screen limit of the graphics
                               scan display

 "H" – Horizontal Grid    Adjusts the horizontal indexing of the graphics
      Spacing                  scan display

 "V" – Vertical Grid      Adjusts the vertical indexing of the graphics
      Spacing                  scan display

 "Esc" – Escape           Return to previous screen
```

SECTION 3: OPERATING SUGGESTIONS

Analog Input

      The Model 203 A/D card features a fully differential
input. A basic understanding of differential measurements will
help you to use your system to best advantage. The plus and
minus input terminals should be wired directly, and only, 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 card requires a vanishingly
small input current so the error caused by even very long
wires is negligible. For proper operation of the analog
interface it is necessary that the positive and negative
inputs both be within 6.5 volts of ground. For a floating
voltage source, this is generally accomplished by connecting a
third wire between the Model 203 power 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.

(a)

BATTERY — V — +IN Model 203 / −IN / AG or GD

Floating voltage with grounded minus

(b)

V — +IN Model 203 / −IN / GD

Ground-referenced (No second ground)

Ground

Ground

(c)

BATTERY — V — +IN Model 203 / −IN / GD

Voltage may or may not float.

Switch — Ground

10 K resistance — Ground
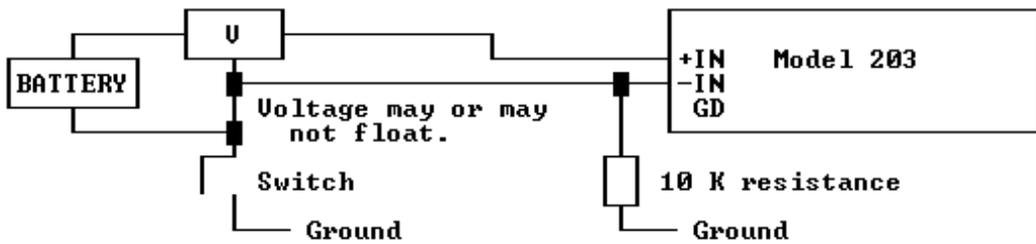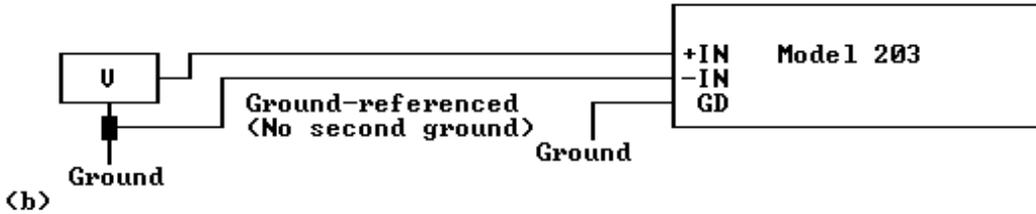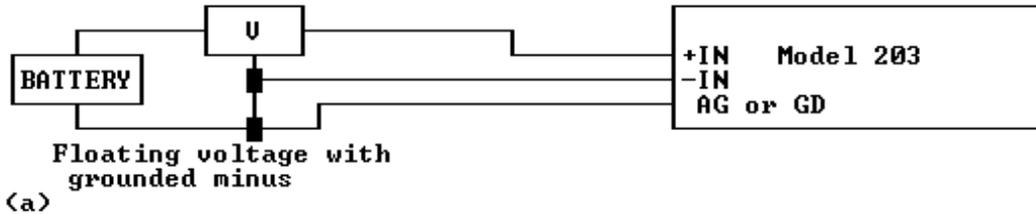
(c)   Remember that the Model 203 can float in relation to the computer's ground. This isolation provides an additional level of protection against ground loops. If the extra protection is not needed, the best noise immunity will be achieved if the Model 203 is grounded at or near the computer's chassis ground. In some cases, a 1 to 10K ohm resistor connected between the Model 203 ground and the computer ground will yield the best combination of flexibility and immunity.

Best results are obtained with filtered, buffered input 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. If shielding is not possible, next best is using twisted pair wire. 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.

The effective resolution of the A/D conversion is dependent on the data rate and the local averaging. The chart below shows the Model 203's Effective Resolution and Cut-Off Frequencies for several data rates with local averaging of 2.

TABLE 4: EFFECT OF DATA RATE ON EFFECTIVE RESOLUTION AND
         CUTOFF FREQUENCY

DATA RATE, Hz	EFFECTIVE RESOLUTION, bits	Cut-Off Frequency, Hz

120	15	24
60	16	12
30	17	6
20	17.5	4
10	18.5	2
5	19.5	1
2	20.5	0.4
1	21.5	0.2

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

Effective resolution can be increased by increasing the local
averaging. Using higher values for local averaging allows better
noise rejection without slowing the data rate. However, if
discontinuous data is to be sampled (after a channel change, for
example), the digital filter must be given time to purge itself
before the new data is valid. The settling time for the digital
filter equals local average / data rate. DRIVR203 software
conceals this settling time by pre-seeding the digital filter
after most channel changes. System calibration is slower because
it waits the full time for the digital filtration. In addition,
there is a settling time of 100 milliseconds to 16 bits required
by the hardware filtering. Several seconds are needed for the
hardware filter to settle beyond 20 bits.

Digital Input and Output

The digital input, terminal "RS" on the ANALOG I/O terminal
block, will accept a signal from TTL or 5 volt CMOS logic. It
will also work with contact closures to ground. The digital input
terminal is pulled up to 5 volts by a 22 Kohm resistor. An
inactive or disconnected digital input reads as a "1". When
grounded or driven to less than .4 volts, the digital input reads
active ("0").

The 8-bit digital output word is buffered for ruggedness.
The 8 bits of the digital output word, 0 to 7, correspond to the
digital output terminals labeled "A" through "H". When the output
code is 0, all eight outputs are low. All outputs are reset at
power-up. When sourcing up to 20 milliamps of current, the
outputs will stay close to 5 volts. When sinking any significant
current, the output voltage will rise above zero volts.

SECTION 4: USER'S TECHNICAL REFERENCE

DRIVR203 software is intended to demonstrate the features of
the Model 203. It is not a general purpose data acquisition
package. For many applications, one configuration for the Model
203 will suffice. DRIVR203 reads the DRIVR203.CFG configuration
file containing setup parameters. If this file is not present in
the current directory, a warning message is displayed and the
driver begins with standard configuration values. The following
diagram shows the basic operating structure for this driver.

FIGURE 3: DRIVER OPERATING STRUCTURE

Start ↓

```
        Serial
     Communications
        Menu
```

"Enter" ↓   ↑ "Esc"

```
Polled Mode          "M"      Command
Acquisition          ──>──    Menu
                     ──<──
                     "Esc"
```

"N" ↓   ↑ "Esc"

```
Scanning             "Enter"  Text
Configuration        ──>──    Scan
Menu                 ──<──    Acquisition
                     "Esc"

                     "Enter"  Graphic
                     ──>──    Scan
                     ──<──    Acquisition
                     "Esc
```
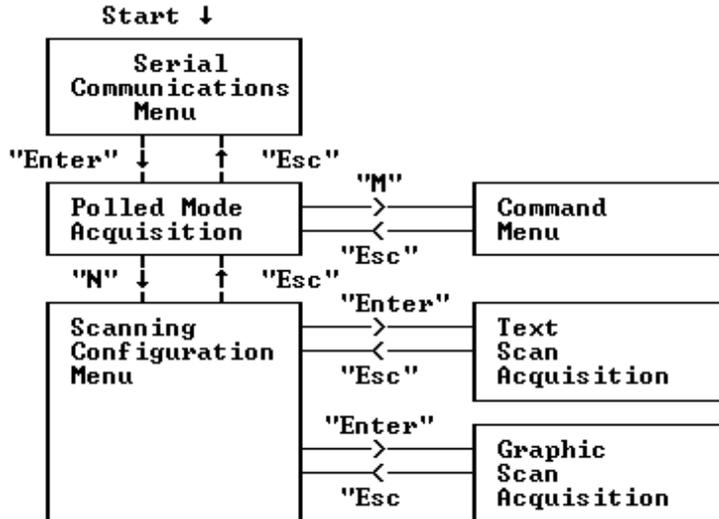
After a power-up cycle, the Model 203 waits for sign-on. To sign on, the host sends a reset command. The Model 203 identifies the host's BAUD rate from the reset command character and responds with a Hex 03. Repeated tries may be required.

After the host receives a Hex 03 it should pause and then send the sign-on command (Hex 88) with a BAUD code (0 through 5). The Model 203 will respond by sending back the BAUD code. If the host sends a different BAUD rate than the original rate, it should change to the new rate now.

The integrity of the communication link can now be tested using the Echo Test function. This feature causes any character sent to the Model 203 to be echoed back to the host. The host must wait for the echo before sending another character or the Model 203 will transmit a communications check error.

When the host is ready to proceed with sign-on it should send a Hex 0. Now the Model 203 is ready to accept the initialization values.

NOTE: The host should set its running checksum to zero at this point.

The initialization values are transmitted in four packets of three characters each. The first two characters in each packet are data, the third is a checksum (the low byte of the sum of the first 2 characters). The following are the four data initialization packets sent. A description of these values is contained in the SET A/D MODE command description below. Placeholder characters are included for compatibility with existing Lawson Labs products and their values are ignored by the Model 203.

Packet 1 – MODEREGHI%, MODEREGMID%
Packet 2 – MODEREGLO%, TIMEBASE%
Packet 3 – DIV%, placeholder
Packet 4 – placeholder, 0

The Model 203 echoes the three mode words, MODEREGHI%,

MODEREGMID%, and MODEREGLO%, from the first two packets for confirmation.

The Model 203 requires 5 additional packets. The first 2 characters are the scan interval. The remaining packets are sent for compatibility with existing Lawson Labs products and are ignored by the Model 203.

Packet 1 – SCAN%, SCAN1%
Packet 2 – placeholder, placeholder
Packet 3 – placeholder, placeholder
Packet 4 – placeholder, placeholder
Packet 5 – placeholder, placeholder

Conversion Process Overview

FIGURE 4 – Signal Path Diagram
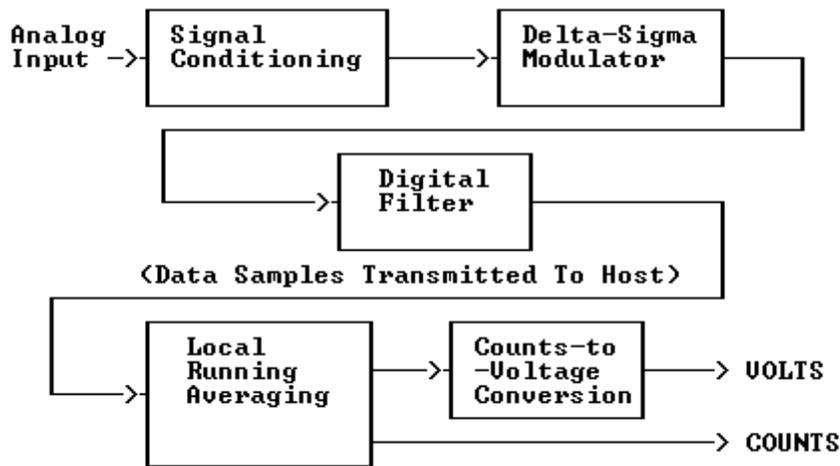
The Model 203 uses an oversampling delta-sigma modulator for A/D conversion. The data rate dictates the digital filtering which, in turn, determines the resolution and cutoff frequency. The data rate is normally set to the lowest acceptable update rate or to 5 times the highest frequency of interest. The Model 203's digital filtering can be tuned to reject 50 or 60 hz using the initialization variable SUBSAMPLE%. If your application requires a different fundamental frequency, contact the factory for details on optimizing the digital filter.

After receiving data from the Model 203, the Model 203 driver performs a running summation of N data samples before display. This summation uses RunningAve% data samples where RunningAve% is the value entered with the set Local average, "L", command.

In addition to displaying each sample as a count, the driver converts the count to VOLTS using the OFFSET# and GAIN# values obtained during the offset and gain calibrations.

VOLTS = GAIN * (COUNT – OFFSET)

Command Set

Most commands consist of three characters: a command token, an argument, and a checksum. The argument character can contain data from the host or it may be unused, depending on the command. If the packet is not received correctly, the Model 203 will transmit a single character error code and reset itself.

There are three types of commands; Output commands, Data Request commands, and Special commands. Output commands send instructions and data to the Model 203. Data request commands cause the Model 203 to transmit data back to the host.

Input and output commands can be issued at any time after sign-on unless a data request command has been issued and its response has not been received.

The only special command is RESET. It supersedes any other command. That is, it takes effect immediately. The reset command sends the Model 203 back to sign-on. Since Data requests can take many seconds to complete, it is usually necessary to empty the serial input buffer after issuing the reset command to remove partial results, if any.

Output Commands

CONTROL CODE COMMAND   Token = Hex 1

   Argument: 7-bit channel selection code, 0, 1, 6, or 7

```
 D7                                    D0
┌─────┬─────┬─────┬─────┬───┬───┬───┬───┐
│  0  │ CS2 │ CS1 │ CS0 │ 0 │ 0 │ 0 │ 0 │
└─────┴─────┴─────┴─────┴───┴───┴───┴───┘
```

       CS? <-- Channel Select Bits, 0, 1, 6, or 7
         0 <-- always 0

       Channel 0 - Analog Input
       Channel 1 - Analog Outputs
       Channel 6 - +5 VDC Reference
       Channel 7 - 0 VDC

DIGITAL OUTPUT COMMAND   Token = Hex 2

   Argument: data 0-255

   The data word will appear at the digital output terminal block. Data bit 0 is at terminal "A", through data bit 7 at terminal "H". The data is latched and remains until another digital output command is issued (or power is cycled).

Analog Output Commands

   Each of the 2 analog outputs produce an output voltage between 0 and +5 volts. The output voltage is proportional an analog output count supplied by the host for each analog output. The count is transmitted to the Model 203 in two bytes. A Set Analog Output Low Byte command is followed by a Set Analog High Byte command. The Set Analog Output High Byte command argument contains the more significant bits of the analog output count and identifies which of the analog outputs to update. The appropriate

output is updated when the high byte is sent. There is no limit
on the time between issuing the low and high bytes of the analog
output commands. Also, the analog out low byte command is
optional. Both outputs can be set (with reduced resolution) with
the high byte command alone.

    For each analog output, the analog output count, OUTCOUNT%,
can be calculated using the following formulae.

    OUTCOUNT% = MAXCNT% * (VOLTAGE / 5)

    where VOLTAGE is the analog output voltage between 0 and 5
and MAXCNT% is the maximum count for the analog output
corresponding to 5 volts. MAXCNT% can be 214, 213, 212, 211, or
210 depending on analog output resolution set by the Set Analog
Output Resolution command. Increasing resolution also slightly
increases the analog output settling time.

NOTE: You may see some non-linearity of the analog outputs
       when operating within 100 millivolts of 0 volts or 5
       volts.

SET ANALOG OUTPUT RESOLUTION   Token = Hex 5

    Argument: DACBASE%, the analog output timebase, use 64 for
            14-bit resolution, 32 for 13-bit resolution, 16 for
            12-bit resolution, 8 for 11-bit resolution, or 4
            for 10-bit resolution. Defaults to 14-bit.

        To change resolution, send this command once after
        signon.

NOTE: Since the Model 203 uses a common time base for serial
       communications and for analog output updating, the analog
       output ripple is doubled for each lower baud rate.
       Reducing the resolution will reduce the ripple.

SET ANALOG OUTPUT LOW BYTE   Token = Hex 8

    Argument: ANALOW% (0 - 255), least significant eight bits of
            the analog output count to be loaded.

    ANALOW% = INT (OUTCOUNT% - ANAHIGH% * 256)
            Defaults to 0.

SET ANALOG OUTPUT HIGH BYTE   Token = Hex 09H

    Argument: ANAHIGH% with most significant bit clear for analog
            output 1 or set for analog output 2.

    Bits 5 to 0 <- More significant bits of analog output count
    Bit 6 <- Zero
    Bit 7 <- Set for Analog Output 2, Cleared for Analog Output 1

    ANAHIGH% = INT (OUTCOUNT% / 256)

Data Request Commands:

After issuing these commands the host should wait for a
response before sending another command. When a data request
command is sent in scanning mode, the data will be sent
immediately if a scan is not in progress. Otherwise, the data
will be sent at the end of the current scan. The only data
request commands that are valid during scanning are the read
digital input command and checksum command. The data request
commands first retransmit the command token, then send the
requested data byte or bytes.

READ DIGITAL INPUT   Token = Hex 80

    Argument (Hex)
      4C   Digital Input

    The Model 203 will respond with the command token followed
by one byte of digital input data. Bit 0 of this byte indicates
the state of the digital input terminal, "RS" on the ANALOG I/O
terminal block.

CHECKSUM DIGITAL INPUT   Token = Hex 8E

    Argument (Hex)
      4C   Digital Input

    The Model 203 will respond with the command token followed by
    two bytes of data. Bit 0 of the first byte is the state of
    the digital input terminal, "RS", on the ANALOG I/O terminal
    block. The second byte is the running checksum. This command
    is useful for requesting digital inputs during scanning. See
    the driver source code for examples.

READ CONVERSION   Token = Hex 81

    Argument: Ignored

    Response: The command token is echoed immediately. Then the
    most recent analog data is sent immediately. If new data is
    not yet ready, it will be sent as soon as it is available.
    The Model 203 transmits three data bytes; LOW, MID, and HIGH.
    The least significant byte is always sent first. Use the
    following formula to obtain the conversion result in counts:
    COUNT = LOW + (MID * 256) + (HIGH * 65536)

    SET A/D MODE   Token = Hex 84

    Argument: Ignored

        This command must be followed b 2 additional packets.

        First Packet:
           MODEREGHI% – This byte is not used by the Model 203
           and is included to maintain compatibility with
           previous products

           MODEREGMID% – The most significant bit sets the
           wordlength to 24 bits. 16-bit mode is included only
           for backward compatibility.

        Second Packet:
           MODEREGLO% – TotalPeriods% = number of fundamental

periods required to equal one sampling period.
TotalPeriods% must be an even number.

TIMEBASE% = 256 - SUBSAMPLE% (SUBSAMPLE% must be an
integer between 128 and 255)

First the command token is echoed. Then the three mode
bytes are sent back to the host.

VERSION   Token = Hex 86

Argument: Ignored

The Model 203 echoes the command token followed by the
version number. Additional features and custom commands may
be available for particular version numbers.

CHECKSUM   Token = Hex 87

Argument: Ignored

The Model 203 sends back the command token followed by its
running 8-bit checksum of all data transmitted as of when the
checksum token was received. The host should zero it's
checksum after confirming that the checksums match.

Scanning Mode and Commands

There are 4 types of scanning. Scanning can be performed
with or without a checksum byte sent with each data sample
and can be started with or without being triggered by an
external signal at terminal "RS". Each of these four types
of scanning are started with a different START SCAN command
but share a common STOP SCAN command

For each scan, a three-byte conversion is sent to the
host. If checksum scanning is being used, a checksum byte is
sent after the data bytes. Before any start scan command is
sent, the host must select the desired channel.

Commands can be sent at any time during scanning unless a
data request command has been sent and a response has not
been received. If a digital input command is received by the
Model 203 between scans, it will respond immediately. If a
scan is in progress, the request will be answered after the
completion of the scan.

START SINGLE-CHANNEL SCANNING   Token = Hex 8B

Argument: Ignored

This command starts scanning. The Model 203 will echo the
command token and then begin sending data.

START CHECKSUM SCANNING   Token = Hex 8D
Argument: Ignored

This command starts checksum scanning. The Model 203 will
echo the command token and then send data. Each data point is
followed by the running checksum.

```
START TRIGGERED SCANNING                 Token = Hex 89
   Argument:      0 <-- positive edge trigger
            non zero <-- negative edge trigger

   This command starts a scan identical to the single scan
   command except that before scanning begins the Model 203
   waits for the specified edge to occur at the digital input
   terminal. A master reset command must be sent or the Model
   203 power cycled to cancel this command if the specified
   trigger does not occur.

START TRIGGERED CHECKSUM SCANNING     Token = Hex 8C
   Argument:       0 <-- positive edge trigger
            non zero <-- negative edge trigger

   This command starts a scan identical to the single-channel
   checksum scan command except that before the scan begins the
   Model 203 waits for the specified edge to occur at the
   digital input terminal. A master reset command must be sent
   or the Model 203 power cycled to cancel this command if the
   specified trigger does not occur.

END SCAN                                 Token = Hex 8A
   Argument:      Ignored

   This command will stop scanning for all four scanning types.
   If a scan is in progress, it will finish and then the Model
   203 will echo back the end scan token.

Special Command
MASTER RESET                             Token = Hex 0
   Argument:        NONE        Checksum: NONE
   The master reset is a single-byte command. Sending a master
   reset has the same effect as cycling power to the Model 203.
```

FIGURE 5: SIGN-ON SEQUENCE
(All data are in hexidecimal)

FIGURE 5: SIGN-ON SEQUENCE
(All data are in hexadecimal)

See page 25 for variable definitions

```
        ┌──────────────────────────┐
  ┌────>│ Open COM port with       │
  │     │ DTR high and RTS low     │
  │     │ with BAUD 300 to 9600    │
  │     ├──────────────────────────┤
  │     │ Wait .2 seconds          │
  │     │ Send 0                   │
  │     │ Wait .2 seconds          │
  │     └──────────────────────────┘
  │ NO        ┌──────────────────┐
  │<──────────│ Is response 3?   │
  │           └──────────────────┘
  │                   │ YES
  │           ┌──────────────────────────┐
  │           │ Wait .2 seconds          │
  │           │ Clear Checksum           │
  │           │ Send 88                  │
  │           ├──────────────────────────┤
  │           │ Wait .1 seconds          │
  │           │ Send BAUD% code          │
  │           └──────────────────────────┘
  │ NO        ┌──────────────────┐
  │<──────────│ Is Response BAUD%│
  │           └──────────────────┘
  │                   │ YES
  │           ┌──────────────────┐
  │           │ Wait .1 second   │
  │           └──────────────────┘
  │           ┌──────────────────────────────┐
  │           │ Optional Echo Test           │
  │           │ Send 0 to end echo test      │
  │           ├──────────────────────────────┤
  │           │ Send MODEREGHI%              │
  │           │ Send MODEREGMID%             │
  │           │ Send Checksum                │
  │           ├──────────────────────────────┤
  │           │ Send MODEREGLO%              │
  │           │ Send TIMEBASE%               │
  │           │ Send Checksum                │
  │           ├──────────────────────────────┤
  │           │ Send Div%                    │
  │           │ Send Placeholder             │
  │           │ Send Checksum                │
  │           ├──────────────────────────────┤
  │           │ Send Placeholder             │
  │           │ Send Mode (Polled or Scan)   │
  │           │ Send Checksum                │
  │           └──────────────────────────────┘
  │           ┌──────────────────────────┐
  │ NO        │ Receive 3 bytes, should  │
  └───────────│ match (MODEREGHI%        │
              │ MODEREGMID%, MODEREGLO%) │
              └──────────────────────────┘
                      │ YES
              ┌──────────────────┐   No
              │ Polled Mode ?    │───────┐
              └──────────────────┘       │
                   │ Yes                 │
              ┌──────────────────────────┐
              │ Sign-On complete         │
              │ Remember to calibrate    │
              │ before taking data       │
              └──────────────────────────┘
```

```
                    ┌──────────────────────────┐
                    │ Send Scan Interval Low   │
                    │ Send Scan Interval High  │
                    │ Send Checksum            │
                    ├──────────────────────────┤
                    │ Send Placeholder         │
                    │ Send Placeholder         │
                    │ Send Checksum            │
                    ├──────────────────────────┤
                    │ Send Placeholder         │
                    │ Send Placeholder         │
                    │ Send Checksum            │
                    ├──────────────────────────┤
                    │ Send Placeholder         │
                    │ Send Placeholder         │
                    │ Send Checksum            │
                    ├──────────────────────────┤
                    │ Send Placeholder         │
                    │ Send Placeholder         │
                    │ Send Checksum            │
                    └──────────────────────────┘
```

FIGURE 6: POLLED MODE SEQUENCE
(All data are in hexidecimal)

```
┌──────────────────────────┐
│ Normal Polled Mode       │
│ Operation                │
└──────────────────────────┘
              │
┌──────────────────────────┐
│ Send 1 command token     │        Select Channel
│ Send control code        │
│ Send checksum            │
└──────────────────────────┘
              │
┌──────────────────────────┐
│ Wait settling time       │
└──────────────────────────┘
              │
┌──────────────────────────┐
│ Send 81 command token    │        Request Conversion
│ Send Placeholder         │
│ Send checksum            │
└──────────────────────────┘
              │
┌──────────────────────────┐
│ Receive four-byte        │
│ response                 │
└──────────────────────────┘
              │
┌──────────────────────────┐
│ Scale in Volts           │
└──────────────────────────┘
              │
┌──────────────────────────┐
│ Store and/or display     │
│ result                   │
└──────────────────────────┘
```

SIGN-ON VARIABLES

SIGNONTOKEN	88 hex

BAUD%	BAUD%	0	1	2	3	4	5
	baud rate	9600	4800	2400	1200	600	300

MODEREGHI%   placeholder for compatibility

MODEREGMID%   80 hex sets 24-bit mode, 00 hex sets 16-bit
               mode, 16-bit mode is included for backward
               compatibility only. Use 24-bit mode for
               aquiring data.

MODEREGLO%   TotalPeriods% used to set sample period. (see
               A/D Mode command)

TIMEBASE%   60 hex for 60 Hz rejection, 40 hex for 50 Hz
               rejection

Div%   0 hex

MODE   0 hex = scanning mode, 01 hex = polled mode
               Using polled mode simplifies inital sign-on
               for code development. Otherwise scanning mode
               is recommended.

SECTION 5: TROUBLESHOOTING

1) Can't sign on.

    A. Make sure that power is connected properly to the 203.
    B. Check the communications port number and make sure you are
   connected to the proper DB connector.

C. Double-check your cable. If you are using a 9 to 25-pin
       adapter, does it match the pinout described on page 3.
    D. Try a slower baud rate.
    E. Check that the serial port has DTR high and RTS low.

2) Model 203 won't respond to a data request.

    A. Reduce averaging, you may not be waiting long enough.
    B. Remember to wait for the result from the previous request
       before issuing another.

3) Data is consistent, but wrong.

    Do a system calibration.

4) Data is noisy.

    A. Lower the data rate or increase averaging.
    B. Check shielding and grounding. Check that the DC common-
       mode range of +/-6 volts requirement is being observed.


SECTION 6: INTERNAL ADJUSTMENTS

    Hardware calibration is set at the factory and should never
need adjustment. The gain adjustment procedure should not be
attempted without an accurate voltmeter or reference standard.
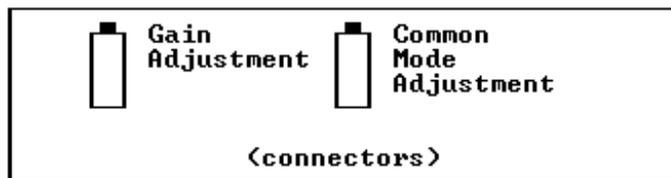
    There are 2 potentiometers on the Model 203. The
potentiometer near the middle of the board is the common-mode
rejection adjustment. The other potentiometer, near the power
input connector, adjusts the gain.

Common Mode Adjustment

    Connect both input terminals "+IN" and "-IN" to the a battery
and provide a means to alternately connect the "AG" terminal to
the "+IN" or "-IN" terminals as shown below. Note the reading at
channel zero with the negative side grounded. Move the ground to
the positive side and adjust the common-mode potentiometer so
that the reading matches. Repeat.
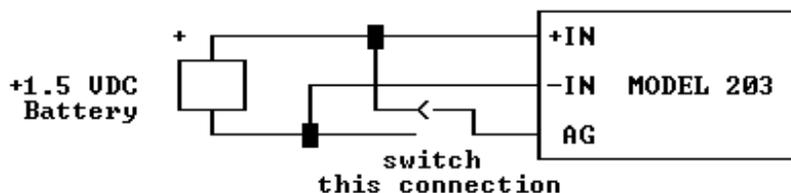
Gain Adjustment

    The A/D gain is set by connecting a known voltage to the
analog input channel. Do a system calibration then adjust the
gain potentiometer to obtain the desired reading. Repeat for best
results.

SECTION 7: MODEL 203 SPECIFICATIONS

```
TYPE:                       Serially interfaced 20-bit delta-sigma (these
                              converters have excellent noise rejection)


MONOTONICITY:               20 bits
LINEARITY:                  +/-0.006% of full scale, typical
DIFFERENTIAL INPUT RANGE:   +/- 5 volts (Note 1)
COMMON-MODE RANGE:          +/- 6.5 volts
DC COMMON-MODE REJECTION:   -96 dB minimum
ANALOG INPUT:               single, true differential, protected to 60
volts
INPUT IMPEDANCE:            100,000 megohms typical
PROGRAMMABLE LINE FREQUENCY REJECTION: 50 Hz or 60 Hz (-86 dB min)
PROGRAMMABLE SAMPLING RATE: 0.5 TO 120 Hz
```

Data Rate, Hz	Effective Resolution	Cut-Off Frequency, Hz
120	15	24
60	16	12
30	17	6
20	17.5	4
10	18.5	2
5	19.5	1
2	20.5	0.4
1	21.5	0.2

Table reflects local averaging = 2. Effective Resolution is
defined as total resolution minus RMS noise in bits.

Note 1 – Voltages from +5.0 to +6.5 and from -5.0 to - 6.5 can be
measured with slightly reduced accuracy. Other input ranges are
available as a factory option.

```
ANALOG OUTPUTS:             2, programmable 10 to 14 bit resolution,
                              settling time 1 sec to 99% for full-scale
                              step at 14-bits
DIGITAL INPUT:              single bit, contact closure or 5-volt logic
                              compatible
DIGITAL OUTPUTS:            8, latched, ruggedized, 5 volt outputs.
                              Voltage with 20 MA load: source 4.9 VDC,
                              sink 2.5 VDC
POWER REQUIREMENT:          11 TO 16 VDC, regulated (15 to 22 VDC
regulated
                              or unregulated with preregulator option)
TYPICAL POWER CONSUMPTION:  65 milliamps at 12 VDC (plus drive current
                              for digital outputs, if any)
SIZE:                       3.4 x 6.5 x 0.9 inches
SERIAL INTERFACE:           RS232, optically isolated, full duplex.
                              Automatically identifies host baud rate and
                              communicates at standard baud rate from 300
                              to 9600. Checksum transmitted on request.
OTHER FEATURES:             Signal averaging and integration are
available
                              under software control. The Model 203 can
                              operate in polled or scanning mode. In
                              scanning mode, individual readings are
                              transmitted at a predefined rate. Scanning
                              can be started by a a positive or negative
                              edge trigger. The user has complete control
```

over digital and analog outputs while
scanning.

The analog input stream is not disrupted by
other input/output.

OPTIONS: PRECISION VOLTAGE REFERENCE – For improved
accuracy and temperature stability, a
precision voltage reference option is
offered.

REGULATED POWER SUPPLY – If a regulated power
supply is not available, a power supply
option
including a wall-mounted power module and
an
on-board voltage regulator is available.

CUSTOM MODIFICATIONS: The Model 203 can be customized to perform a
variety of tasks. If you do not see a
particular feature here, call for a
quotation.

APPENDIX

TABLE 6: Command Token Summary Table

Command Token	Argument	Range / Description
00H	none	Master Reset – single byte
01H	Channel	Select Channel
02H	Digial Output Code	0 – 255 Update Digital Output
05H	DACBASE%	Set Analog Output Resolution
08H	ANALO% Lower 8 bits of Analog Output count	Set Analog Output Low Byte of OUTCOUNT%
09H	ANAHIGH% Upper bits of Analog Output Count	Set Analog Output High Byte of OUTCOUNT% and update analog output
80H	ignored	Request Digital Input
81H	ignored	Request Conversion
84H	MODEREGHI% MODEREGMID% SUBSAMPLE%. MODEREGLO% TIMEBASE%	Set A/D Mode (Warmstart), Sets Operation Mode with Data Sample TotalPeriods% and
86H	ignored	Request Version
87H	ignored	Request Checksum

| 89H | EDGE% | Start Triggered Scan – EDGE% = 0 for positive edge |

     trigger EDGE% NOT = 0 negative edge trigger

| 8AH | ignored | End scan |

| 8BH | ignored | Start Single-channel scan |

| 8CH | EDGE% | Start Triggered Checksum Scan EDGE% = 0 positive |

     edge trigger, EDGE% NOT = 0 negative edge

trigger

| 8DH | ignored | Start Single-channel scan with checksum |

| 8EH | 4CH | Request Digital input with checksum |

ERROR CODES

    The Model 203 sends a one-byte error code and resets itself if it receives an illegal instruction. There are 6 possible error codes.

01H – Incorrect CheckSum – incorrect data packet checksum has been received

02H – Command Pending Error – data request command received before a previous data request command is answered

05H – Sign-On Error – character other than 88 hex is received as the sign-on commmand

06H – BAUD Rate Error – transmitted if an invalid BAUD code is received during signon.

08H – Output Command Error – invalid output command received

09H – Data Request Command Error – invalid data request command received

LIMITED WARRANTY

    The Lawson Labs, Inc. Model 203 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 610 725-8800 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.