MODEL 201
24-BIT DATA ACQUISITION SYSTEM

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INTRODUCTION

The Lawson Labs, Inc. Model 201 24-Bit Data Acquisition

System is a high-resolution device for translating voltages into digital form. The Model 201 communicates with a host computer over an optically isolated RS-232 serial link. It has 6 multiplexed differential analog input channels with provision for expansion to a total of 96 channels. There are eight programmable gain ranges. Twenty digital input/output lines are available for general purpose use. Future expandability is provided through stacking option cards.

The Model 201 is intended for DC and low frequency applications. The data rate is programmable from under 1 to over 300 samples/second. At a data rate of one sample/second, the RMS noise approaches two counts, providing 23 bits effective resolution. (The converter is guaranteed monotonic to 24 bits.) Effective resolution decreases with increasing data rates. Even so, 16-bit effective resolution is maintained to over 250 samples/second.

The Model 201 requires a single DC supply in the range of 11.5 to 50 volts. Current draw is typically 18 milliamps in normal operation and only 2 milliamps in "sleep" mode. The power and analog inputs are protected against substantial overvoltages. These features, (plus error checking on the serial link), make the Model 201 well suited for battery powered remote operation.

Both polled and scanning modes are available. In scanning mode, the Model 201 maintains it's own time base and transmits a pre-defined scan of up to 96 input channels at a preset interval. Scanning rates from under 1 per day to over 300 per second are supported. Other features under software control include self-calibration, variable input filtration, and bipolar or unipolar input ranges.

The exceptional resolution, stability, flexibility and price are achieved by combining an accurate, but complex, delta-sigma type A/D converter with a microcontroller supervisor. The microcontroller makes it simple for the user to enjoy the power of the delta-sigma converter by issuing straight-forward commands over a standard serial interface.

SECTION 1: INSTALLATION

The Model 201 interconnections consist of three cable connectors, a 32-pin expansion connector, and a 2-terminal power connector. Locate the cable connectors at the bottom of the card. They are for, from left to right, analog input, serial input/output, 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 serial cable need be connected. The power supply voltage can range from 11.5 to 50 VDC and does not need to be regulated. Power is connected to the terminals on the orange terminal block. The power terminals are labeled "+" and "-". The wall-mounted transformer supplied has a white stripe on the positive wire. A battery, or other DC supply (in the 11.5 to 50 VDC range) can be substituted. The board is protected against reverse voltage but will not operate without a properly connected supply. The Model 201 is well suited for battery power. In the sleep mode only 2 mA is required.

A supply voltage of greater than 24 VDC will increase current consumption by as much as 3 milliamps. (The power can be connected before or after the serial interface connection is made.)

Figure 1 shows the input and output connectors. The 4-bit optically isolated output allows use of Model 17, 20, and 35 multiplexers and multiplexed amplifiers. The pinout for the expansion connector is given in Appendix 1.

The serial interface uses a 9-pin connector and is optically isolated from the host computer. The isolation protects the host computer in the event of extreme overvoltage. Note that the computer chassis ground is not connected to ground at the Model 201. The serial pinout is defined in Table 1.

You will need to make the necessary connections for either a 9- or 25-pin serial port (9-pin to 25-pin adapters may be useful). Note that pins 2 and 3 are swapped in the cable for 25-pin serial ports. Some portable computers have 5 volt RS232 serial ports instead of 12 volt ports. If your computer has a 5 volt serial port you will want to move the jumper by the serial connector (see Figure 2) to the 5 volt position.

For maximum accuracy the board should be enclosed in a shielded box. 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 nanovolt level. (With a gain of 64, each count represents 9 nanovolts).

FIGURE 1: MODEL 201 BLOCK DIAGRAM

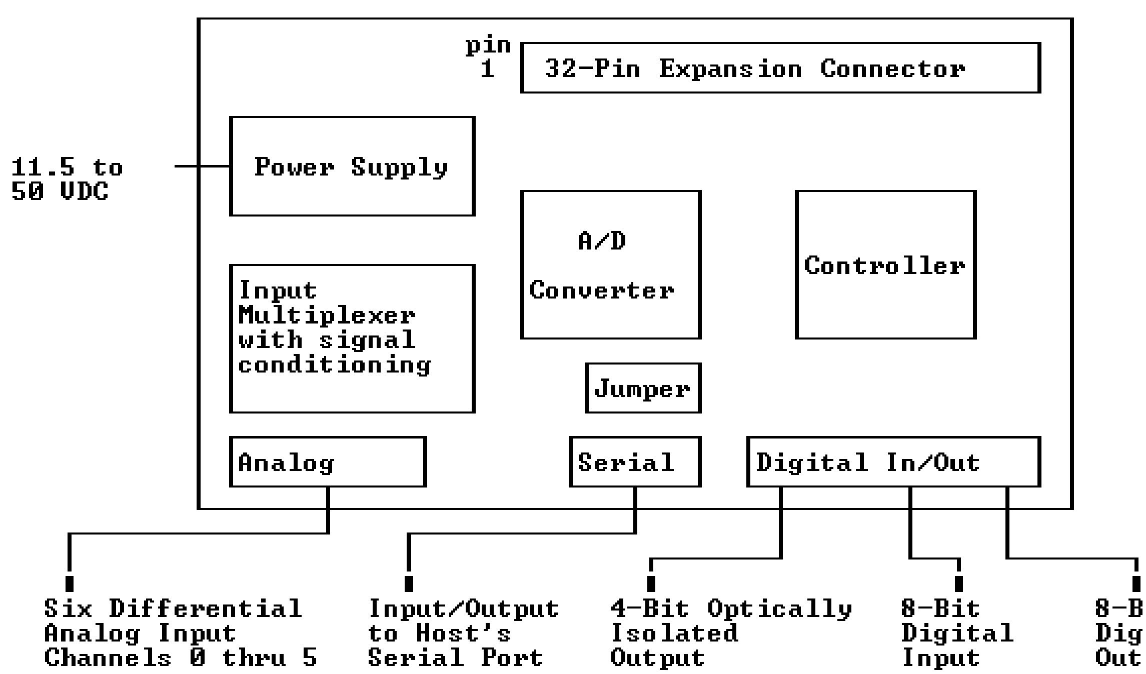

TABLE 1: SERIAL CONNECTOR PINOUT

Description	Model 201 Pin Number	Computer Serial Port Pin Number 9 Pin	25 Pin
TX	2	2	3
RX	3	3	2
DTR	4	4	20
GND	5	5	7
RTS	7	7	4

FIGURE 2: SERIAL PORT VOLTAGE JUMPER POSITION

12 Volt Position   5 Volt Position

SECTION 2: OPERATION

The software driver provided with the unit includes an executable file and a source file for QBASIC or 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:

IN_BASIC directory

DRIVR201.EXE	Executable driver software
DRIVR201.BAS	BASIC source code for above
DRIVR201.CFG	Configuration file
DEMO201.BAS	BASIC source code for polled mode demonstration
SCAN201.BAS	BASIC source code for scanning demonstration
SCRIPT.EXE	Executable file to generate sign-on scripts
README.SCR	Instructions for SCRIPT.EXE

WIN201 directory

See the readme file in WIN201 for a description of the Windows drivers and DLL.

Set the directory containing your support files as the current directory. Type DRIVR201 from the DOS prompt. You should see the 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 may be needed 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 201. 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. If you get a "can't wake" message, double check the power connections and serial cable pinout.

Polled Mode Overview

Once communications have been set up, the user can sign on to the 201 by pressing the Enter key. After establishing communications you will see the Polled Acquisition Screen. Conversion results from the selected A/D channel will scroll down the screen. The left hand number is the raw count from the A/D converter. It will be a number between 0 and 16,777,215. The next number is the count translated into volts. Next is the difference between the highest and lowest reading. The next number is effective RMS resolution in bits. The effective resolution is based on the last 20 conversions. The last two numbers are the A/D channel selected and the isolated external code selected. Commands specific to this screen are listed at the bottom. Prompts, and responses to commands are displayed to the right of the command line. Bipolar or unipolar mode is indicated by a "+/-" or "+" with the current gain setting in the upper right hand corner. Pressing space resets the maximum and minimum readings. Pressing the M key will display the command Menu, a summary of commands. Enter brings back 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, enter M to see the command menu screen.

Software Calibration

At installation the standard values will have been retrieved from the configuration file provided. To verify function, press "C" and select A/D input Channel "7". 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 "F" to initiate a Full-scale calibration. After the full-scale calibration the converter should read very close to +5 volts. The full-scale calibration also removes signal conditioning errors.

The "S" command (System calibration) performs the same sequence automatically. It does the channel selection and both calibrations and then reselects the original channel. Settling times are accounted for. The "FILTER DELAY" message indicates a settling time delay.

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 201. 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 201 to insure that the input voltage at both input terminals is within 6 volts of ground. The ground at pin 15 is provided for the purpose. This extra ground is for common-mode requirements only, and while necessary, it is non-critical. Remember that the Model 201 is optically isolated and is floating compared to the computer chassis ground. Enter "C" and select the input channel to which you have connected the battery. Note that the reading does not stabilize until the settling time has elapsed. 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 input wires directly together will cause a potential of zero volts. An open circuit will read unpredictably. A positive overvoltage will read 5 volts. A negative overvoltage will read -5 volts. Severe negative overvoltages may appear to be positive overvoltages. The analog input channels are protected against continuous overvoltage up to 60 volts. With the initial settings from the provided configuration file (10 Hz data rate) the effective resolution should be 22 bits.

Because of extreme resolution possible with the Model 201 it is necessary to carefully shield your input signals from electrical noise. 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, air currents 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 201 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.

It is possible to set up the Model 201 in a meaningless way, i.e. if you do an offset and a full-scale calibration on zero volts, then any voltage will read zero. If in doubt, press "S" for system calibration. Also, with large filters and/or averaging, you may have to wait for the response to a command.

Connecting Analog Inputs

FIGURE 3: 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-
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PIN 4...CHANNEL 3+

PIN 3...CHANNEL 2+

PIN 2...CHANNEL 1+

PIN 1...CHANNEL 0+

PIN 11...CHANNEL 2-

PIN 10...CHANNEL 1-

PIN 9....CHANNEL 0-

Note: For maximum protection, 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 has a strain-relief clamp.

Digital Input/Output Commands

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

The "E" command sends a 4-bit word to the optically isolated External control code port at pins 1 through 4 of the digital input/output connector. The current 4-bit word is shown on the polled acquisition screen as the external control code (EXT). These isolated outputs can only pull down in relation to guard (pin 5). Pin assignments 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 17, 20, and 35 multiplexers and multiplexed amplifiers.

The "U" (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.

FIGURE 4: DIGITAL INPUT/OUTPUT CONNECTOR PINOUT

PIN 13...DIGITAL OUTPUT 7

PIN 12...DIGITAL OUTPUT 6

PIN 11...DIGITAL OUTPUT 5

PIN 10...DIGITAL OUTPUT 4

PIN 9...DIGITAL OUTPUT 3

PIN 8...DIGITAL OUTPUT 2

PIN 7...DIGITAL OUTPUT 1

PIN 6...DIGITAL OUTPUT 0

PIN 5...GUARD

PIN 4...OUTPUT D

PIN 25...DIGITAL INPUT 7

PIN 24...DIGITAL INPUT 6

PIN 23...DIGITAL INPUT 5

PIN 22...DIGITAL INPUT 4

PIN 21...DIGITAL INPUT 3

PIN 20...DIGITAL INPUT 2

PIN 19...DIGITAL INPUT 1

PIN 18...DIGITAL INPUT 0

PIN 17...GROUND

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.

Commands for Setting Up the A/D Converter

G) Gain - Gains of 1,2 ... 128 can be selected. Effective resolution is reduced at gains above x4 or x8. The voltages shown are after the gain stage. To get voltage at the input, divide the displayed reading by the gain.

Note: The 5 volt reference output cannot be used for full-scale calibration at gains other than 1.

W) Word length - The word length can be reduced from 24- to 16-bits using the W command. For higher data rates, maximum throughput can only be obtained in the 16-bit mode. No information is lost because the effective resolution is 16 bits or less at those high data rates. Note that not all of the decimal places on the voltage display are significant in 16-bit mode.

R) sample Rate - The A/D converter's data rate and frequency response are set with this command. Rates from 10 to 1027 Hz are possible. There is a low-pass filter intrinsic to the conversion process. The cut-off frequency of that filter is the data rate times .262. For maximum effective resolution use the lowest data rate that meets your needs.

P) biPolar/uniPolar mode - the input range can be selected as +/- 5 volts (bipolar) or 0-5 volts (uniPolar). Nominal resolution improves in the unipolar mode for positive signals, but some of that improvement is lost to fixed amplitude noise sources.

A) Average - The Model 201 will average consecutive conversions. Press "A" and then "+" or "-" to cycle through the choices. The number of conversions averaged must be a power of 2, ie., 1, 2, 4, 8, 16, etc. The maximum number of conversions to average is 32,768. Press Enter to register your selection. The A/D data rate divided by the averaging factor gives the number of samples transmitted per second. Note that with high averaging values, data arrives slowly. At 10 Hz with 32768 averaging, each data point takes 54.6 minutes.

T) filTering - The Model 201 has a programmable single-pole filter in the signal path before the A/D converter. Press "T" to cycle through the 3 choices for the filter cutoff frequency: 400, 40, or 4 Hz. The lower filter cutoff frequencies remove lower frequency noise, but require longer settling times after channel changes.

B) standBy - The standby command puts the A/D converter into low-power mode. A/D conversions cannot be requested in standby mode but all mode and calibration information is retained. Issuing a "B" command a second time restores normal operation.

S) System calibration - The "S" command does an automated system calibration when the gain is set to one. 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.

For gains other than one, no system calibration will be performed. A message indicating this fact will be displayed in the lower right-hand corner of the screen. See below for a description of how to calibrate your Model 201 for gains other than one.

Note that the Model 201 can remove offset or gain errors from external circuitry up to 5% of full scale. Larger offsets can be zeroed out but a reduced input range will result. Input voltages over 5.1 volts will be clipped to protect the A/D.

The most accurate calibration can be obtained using the following method. Assume an amplifier is connected to A/D input channel 0.

1. Select A/D input channel 0.
2. Apply zero volts to amplifier input. Assume the amplifier output is +10 millivolts.
3. Do an offset calibration. Channel 0 now reads 0 volts.
4. Apply full-scale input signal to amplifier input. Assume the amplifier output is now 4.9 volts.
5. Do a full-scale calibration. A/D channel 0 now reads 5 volts. Calibration is complete.
6. Note that now A/D input channel 7 will now read -10 millivolts and that channel 6 now will read +5 volts overrange.

Ground and 5 volts are brought out to the analog connector to be used for cases where the system calibration command is not sufficient. If the gain is greater than one, the 5 volt reference signal cannot be used for full-scale calibration. The best full-scale calibration results will be obtained if the actual full-scale voltage is applied to an analog input channel before issuing a full-scale calibration command for that channel. The 5 volt reference and reference ground on the analog input connector facilitate the derivation of a full-scale calibration voltage for gains other than one. For example, a 1.25 volt reference would be required for a gain of four. Two series resistors with a ratio of 3 to 1 will provide one-quarter of the 5 volt reference. The total impedance of the divider network should be in the 5K to 200K range.

Other Commands

Z) asleep (Z)/ awake (Z) - In sleep mode the A/D and input section is shut completely off to minimize power consumption. The control section checks periodically for serial activity from the host. When activity is detected, the Model 201 turns itself on and waits for start-up information. Note that for lowest power consumption that the analog input voltages should be disabled.

K) checKsum - The Model 201 keeps a running total of all serial data transmitted. The total is kept in modulo 256 form, ie., any carry out of 8-bit binary is discarded. Therefore, the checksum is always a number from 0 to 255. The host computer can keep a similar total for all received words. The host can request the Model 201'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.

C) Channel - Selects one of eight A/D input channels. The inputs are differential and should always be maintained within 6 volts of the ground of the board for proper operation. Two of the channels are dedicated to calibration.

Scanning Mode

From the polled acquisition screen, a keypress of N will take you to the scaNning menu. The scanning menu will allow the operator to change the channel(s) to scan, scan interval, and the type of scan. There are three types of scans available, normal, self-calibration, and single-channel.

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. For normal and self-calibrating scans, the A/D input channels are displayed with the external control codes that are active for that channel. In the single-channel mode only the selected channel will be displayed with it's corresponding external control code. After pressing the channel number the user will be prompted for the external code for that channel. For multi-channel scans, both the starting and ending external channels are entered. If the ending channel code is below the starting code, that A/D channel will be skipped during scanning. The single-channel scan takes data from any one input channel.

Pressing 6 will prompt you for a new scan interval. The minimum time is based on the baud rate, the number of readings per scan, and the A/D speed. The A/D speed is determined by the settings entered (press Esc then "M" to check your A/D settings). The maximum time is determined solely by the baud rate. The scan interval will always be an integer number of clock counts, so the time resolution will increase with the baud rate.

The scan type is changed by the 7 key. In normal mode, all of the selected A/D channels are scanned during each scan interval. The calibration scan behaves in the same way with the exception that a system calibration is done prior to each scan. Because no settling time is needed, the highest sampling rates are for single-channel scans. In normal and single-channel scans, a system calibration is performed prior to the first scan only.
Note: The self-calibration scan is only valid for a gain of one.

The enter key starts the scan and displays the status. The screen will show the time the scan started, the interval time, bytes per scan, elapsed time, scans expected, and scans completed. Pressing the space bar will stop scanning at the end of the current scan. Pressing Escape will cancel the current scan. In either case, if any scans were completed, they will be displayed next. Press space for subsequent scans. Press Escape to return to the scanning menu.

Escape from the scan menu takes you back to polled mode.

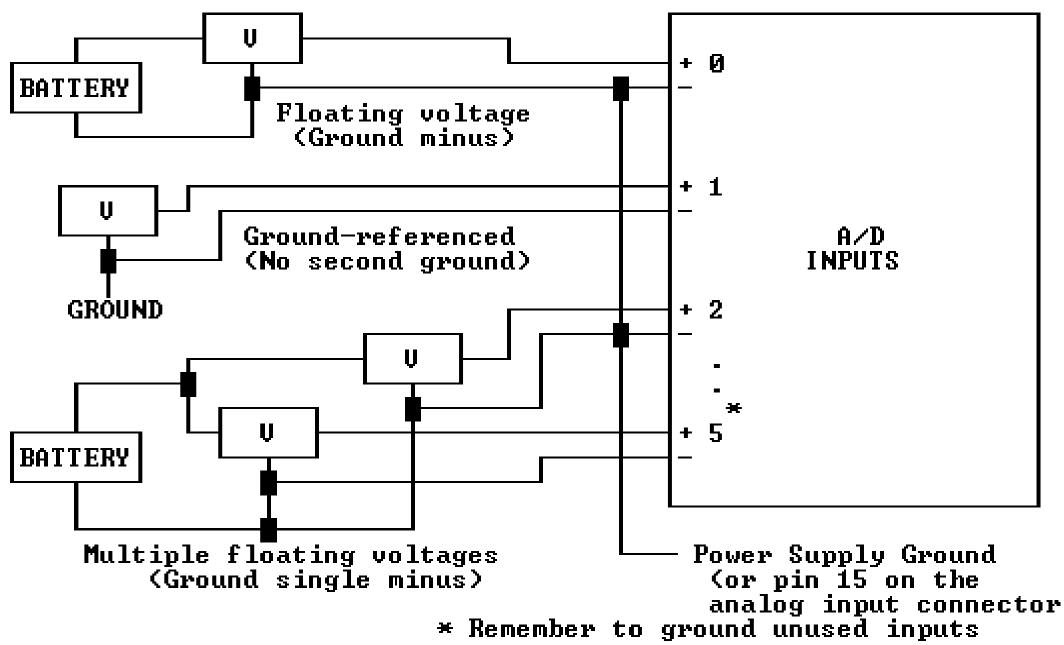
TABLE 2: COMMAND SUMMARY

Function	Range/Description
"A" - Averaging	1 to 32768, incremented in powers of 2, ie., 1, 2, 4, . . .
"B" - standBy	toggles between standby mode and normal mode
"C" - Channel	analog input channels 0 to 5; channel 6 is +5 volts reference for full scale calibration, channel 7 is 0 volts for offset calibration
"D" - Digital input	reads an unlatched 8-bit digital word at pins 18 through 25 on the digital input/output connector.
"E" - External control code	sends a 4-bit word to the optically isolated external control code port
"F" - Full-scale	makes the selected channel read 5 volts
"G" - Gain	1, 2, 4, 8, 16, 32, 64, 128
"K" - checKsum	requests a checksum from the Model 201
"O" - Offset calibration	makes the selected channel read 0 volts
"P" - biPolar/ uniPolar mode	the input range can be selected as +/- 5 volts (bipolar) or 0-5 volts (unipolar).
"R" - data Rate	10 Hz to 1 KHz
"S" - System	calibration automatically performs an offset and full scale calibration
"T" - filTer	400, 40, or 4 Hz cutoff frequency
"U" - digital oUtput	puts a latched 8-bit digital word at pins 6 through 13 on the digital input/output connector.
"W" - Word length	16- or 24-bit conversion result
"Z" - asleep (Z)/ awake (Z)	In sleep mode the A/D and input section is shut completely off to minimize power consumption.

SECTION 3: OPERATING SUGGESTIONS

The Model 201 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 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 volts of ground. For a floating voltage source, this is generally accomplished by connecting a third wire between the Model 201 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.

FIGURE 5: TYPICAL INPUT CONNECTIONS



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.

TABLE 3: EFFECT OF GAIN AND DATA RATE ON EFFECTIVE RESOLUTION

DATA

RATE:	EFFECTIVE RESOLUTION, bits							
	Gain of 1	Gain of 2	Gain of 4	Gain of 8	Gain of 16	Gain of 32	Gain of 64	Gain of 128
10 Hz	22	22	22	21	20	19	18	17
25 Hz	20	20	20	20	19.5	18.5	17.5	16.5
50 Hz	19.5	19.5	19.5	19.5	19	18.5	17.5	16.5
100 Hz	19	19	19	18.5	18	17.5	17	16
250 Hz	15	15	15.5	15.5	15.5	15.5	15	14.5

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

TABLE 4: APPROXIMATE SETTLING TIMES

EFFECTIVE RESOLUTION (bits)	SETTLING TIME: sec Filter Cutoff Setting of 400 Hz	Filter Cutoff Setting of 40 Hz	Filter Cutoff Setting of 4 Hz
16	.030	.30	3.0
20	.035	.35	3.5
24	.043	.43	4.3

Note: For maximum accuracy, wait twice the theoretic settling times.

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.

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

FIGURE 6: 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 201. 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 for low-power TTL or 47 K ohms for CMOS 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

DRIVR201 software is intended to demonstrate the features of the Model 201. It is not a general purpose data acquisition package.

For many applications, one configuration for the Model 201 will suffice. To simplify the task of including Model 201 support in existing software you will find a program called DEMO201.BAS on your disk. This program will load a DRIVR201.CFG configuration file and allow data collection in polled mode only. You may find it desirable to use DEMO201 once you have settled on a configuration for your Model 201. SCAN201.BAS performs the same task as DEMO201.BAS except that it supports scanning mode only.

After power-up (or a reset) the Model 201 waits for sign-on for approximately 8 seconds. If there is no serial input activity, the Model 201 puts itself to sleep. To sign on, the host sends a reset command at 300 baud. If the Model 201 is in sleep mode or at a different baud rate it will not necessarily respond correctly on the first attempt, so repeated tries may be required. The response should be Hex 80 if the Model 201 was asleep or Hex 3 if it was awake.

After the host receives a Hex 3 it should pause and then send the sign-on command (Hex 88) with a baud code. The Model 201 will respond by sending back the baud code at 300 baud. The host and the Model 201 now switch to the chosen baud.

The integrity of the communication link can now be tested. Any character sent to the Model 201 will be echoed back. The host must wait for the echo before sending another character. Echoing will continue unless the host sends nothing for approximately 8 seconds. Then the Model 201 will transmit a communications check error and put itself back to sleep.

When the host is ready to proceed with sign-on it should send a "null" (Hex 0). Now the Model 201 is ready to accept the initialization values.

Note: The host should set its running checksum for all received data to zero at this point.

Those initialization values are transmitted in four packets of three characters each. The first two bytes in a packet are data. The third is a checksum byte (the sum of the first 2 bytes modulo 256). The first two initialization packets contain the following information: A/D data rate, gain, word length, standby status, and bi/unipolar range. The next two packets set averaging, pre-filtering, and polled/scanning status.

The Model 201 will retransmit three mode words from the first two packets for confirmation (these mode words are actually written into the A/D converter and read back before retransmission.

Polled Mode:

You will normally sign on in polled mode. (See Page 20 for scanning mode). After sign-on, the Model 201 will wait indefinitely for instructions.

The instruction packets 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 201 will transmit a single character error code and wait for sign-on.

There are three types of commands. Output commands send data to the Model 201. Data request commands cause the Model 201 to transmit characters back to the host.

Output commands can be issued at any time after sign-on. The host should wait for the response to a data request command before sending another command.

The third type of command is the single-byte command. There are two single-byte commands: cancel and reset. Both supersede any pending commands. That is, they take effect immediately. The cancel command stops a data request command. The reset command sends the Model 201 back to sign-on. If the host doesn't sign on within approximately 8 seconds, the Model 201 goes to sleep.

Data requests with extensive averaging can take minutes to complete. The cancel command will stop the pending data request even if the Model 201 has begun to transmit the result. Therefore, it is usually necessary to empty the serial input buffer after issuing the cancel command.

The reset command may also leave partially completed transmissions in the buffer and should be handled similarly.

Output Commands:

There are eight output commands. They can be sent at any time after sign-on except when a data request command has been issued but not answered.

FILTER COMMAND Token = Hex 3

Argument: 0 = 4 Hz cutoff
1 = 40 Hz cutoff
2 = 400 Hz cutoff

Sets the single-pole pre-filtering cutoff frequency to the value specified by the argument.

CONTROL CODE COMMAND Token = Hex 1

Argument: 7-bit channel selection code, 0-127

The lowest 4 bits control optically coupled output bits A, B, C, & D on the 25-pin DB connector. The next 3 bits select the A/D analog input channel (0 through 7). The most significant bit is ignored.

AUXILIARY OUTPUT COMMAND   Token = Hex 2

Argument: data 0-255

The data word will appear at the digital input/output 25-pin connector. Data bit 0 is at pin 6, data bits 1-7 are at pins 7-13. The data is latched and will remain until another command is issued (or power is cycled).

AVERAGE COMMAND   Token = Hex 4

Argument: 0,1,2,3,4,...15

The argument is the power of 2 of the number of points to average for each transmitted reading.

Note that at the 10 Hz data rate if averaging is set to 15 (215 = 32768) each reading will take over 54 minutes.

EXPANSION OUTPUTS   Tokens = Hex 6,7,8, & 9

Argument: 8-bit data 0-255

Writes data to an expansion card (if present). An expansion card is needed to take advantage of these commands.

Data Request Commands:

After issuing these commands the host should wait for a response before sending another data request. 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)

OC	Expansion 0
2C	Expansion 1
4C	Digital Input
8C	Expansion 3
CC	Expansion 4

The Model 201 will respond with the command token followed by one byte of digital input data. If the argument byte is 4C, then the data will come from the 8-bit digital input port. An expansion card is needed to use the other digital inputs.

READ CONVERSION   Token = Hex 81

Argument: Ignored

Response: The command token is echoed immediately. Then the A/D is read and the 201 transmits two or three data bytes. The least significant byte is always sent first. To obtain the conversion result in counts:

```
16-Bit mode   COUNT# = LOW + (MID * 256)
24-Bit mode   COUNT# = LOW + (MID * 256) + (HIGH * 65536)
```

To convert the count to millivolts use one of the following formulae.

```
16-Bit unipolar mode MVOLTS =  COUNT# * .076294#
16-Bit bipolar mode  MVOLTS = (COUNT# * .152588) - 5000
24-Bit unipolar mode MVOLTS =  COUNT# * .0002980232#
24-Bit bipolar mode  MVOLTS = (COUNT# * .0005960464) - 5000
```

If the host changes the A/D mode or averaging during a read conversion, the result should be discarded.

OFFSET CALIBRATION   Token = Hex 82

Argument: 7-bit channel selection code 0-127

First, the Model 201 will echo the command token. Then, it will select the channel specified by the argument, wait the settling time and force that channel to read 0 volts. The Model 201 can zero offsets up to 1/2 of full scale. When the calibration is complete, a two- or three-byte calibration result is transmitted. The least significant byte is always sent first. Note that the offset channel remains selected after this command is issued.

FULL-SCALE CALIBRATION   Token = Hex 83

Argument: 7-bit channel selection code 0-127

First, the Model 201 will echo the command token. Then, it will select the channel specified by the argument, wait the settling time and force that channel to read 5 volts. The Model 201 can increase the gain by 15% or decrease the gain by 5% from the nominal value. Remember that the actual input voltage should not exceed +/- 5 volts. Also, if your offset calibration voltage was not zero volts, you will shift the available calibration range. The offset calibration should be done before the full-scale calibration. When the calibration is complete, a two- or three-byte calibration result is transmitted. The least significant byte is always sent first. Note that the full-scale channel remains selected after this command is issued.

Note: If the gain is not 1, the desired full scale voltage should be applied to the input channel specified in the argument. The nominal full-scale voltages are x1 = 5; x2 = 2.5; x4 = 1.25; x8 = .0625; x16 = .03125; x32 = .015625; x64 = .0078125; x128 = .00390625.

For gains above x1, if a full-scale reference is not available, use this sequence:

Set gain = 1

Do offset calibration (at channel 7)
Do full-scale calibration (at channel 6)
Reset desired gain
Do offset calibration (at desired channel)

SET A/D MODE Token = Hex 84

Argument: This command uses 3 argument bytes sent in sequence; MODEREGHI%; MODEREGMID%; and MODEREGLO%. A delay of several milliseconds is required before sending the arguments.

Most of the A/D converter set-up information is compressed into these three bytes.

MS-Bit

MODEREGHI%	M 2	M 1	M 0	G 2	G 1	G 0	X	S
MODEREGMID%	W L	X	X	P	X	F 1 0	F 9	F 8
MODEREGLO%	F 7	F 6	F 5	F 4	F 3	F 2	F 1	F 0

LS-Bit

X always 0
M mode bits (normally zero)
G power of 2 for gain (zero for gain of 1)
S 1 = standby, 0 = normal operation
WL 1 = 24-bit word length, 0 = 16-bit word length
P 1= unipolar, 0 = bipolar
F data rate = 19531.25/(F in decimal form)
valid range for F in decimal is 19 to 2000

See the DRIVR201.BAS source file for a complete description of the mode registers.

First the command token is echoed. Then the three mode bytes are sent back to the host. The bytes are actually read back from the A/D converter before being re-transmitted.

VERSION Token = Hex 86

Argument: Ignored

The Model 201 echos 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 201 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

When the host signs on in scanning mode, the Model 201 requires 5 packets of additional information. The first 3 data bytes in the packets are the scanning interval. The units for that interval are dependent on baud rate. At 9600 baud each scanning interval count is worth 256 microseconds. At 300 baud each count is worth 8192 microseconds. The next 6 data words are the starting and ending external control code for each A/D channel. The most significant nibble is the starting code. The least significant nibble is the ending code. If no external multiplexer is present at that A/D channel, both the starting and ending code should be zero. If a channel is to be skipped, set the starting code greater than the ending code (normally 1,0). The seventh data word is unused. The Model 201 will take care of all channel selection and filter delays for multi-channel scanning.

For single-channel scanning, the host must select the desired channel before sending the start single-channel scanning command.

Any of the three start scanning commands can be sent now. For each, the number of conversion data bytes will depend on whether 16- or 24-bit mode is selected for the A/D. In either case the low byte is sent first and the high byte last. The A/D channels are scanned in ascending order. If external multiplexing is used, all the external channels for an A/D channel are transmitted before the next A/D channel is selected.

Output commands can be sent at any time during scanning. Data request commands can be used sparingly. If a checksum or read digital input is received by the Model 201 between scans, it will respond immediately. If a scan is in progress, the request will be handled after the completion of the scan.

NORMAL SCAN Token = Hex 89

Argument: Ignored

When the Model 201 receives a normal scan token it echos the token back and sends a start of scan token (Hex F0) to the host. Next, the conversion results for all of the channels are sent followed by an end of scan token (Hex 0F). The 201 will now wait the remainder of the scanning interval before sending another start of scan token.

END SCAN Token = Hex 8A

Argument: Ignored

This command will stop any type of scanning. If a scan is in progress, it will finish and then the Model 201 will echo back the end scan token.

SINGLE-CHANNEL SCAN Token = Hex 8B

Argument: Ignored

The Model 201 will echo the command token and then send data only. The host must pre-select the desired channel. There are no start or end scan tokens in single-channel mode.

SELF-CALIBRATE SCAN Token = Hex 8C

Argument: Ignored

Model 201 will echo the self-calibrate scan token. Then the Model 201 sends a start of scan token (Hex F0) followed by the results of a offset and full-scale calibration. The conversion results for all of the A/D channels are sent followed by an end of scan token (Hex 0F).

Special Commands:

SLEEP Token = Hex 88

Argument: Ignored

The Model 201 echoes the sleep token then powers down the A/D converter and input conditioning circuitry. The digital outputs and optically isolated output port are not changed. To minimize power consumption in sleep mode, the host should zero these outputs before issuing sleep. A/D calibration and mode information is lost.

Note: The sleep token is also used in the sign-on sequence.

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 201. The host must revert to 300 baud to re-establish communications.

CANCEL Token = Hex 85

Argument: NONE
Checksum: NONE

The cancel command is a single-byte command. It cancels any pending data request command. The Model 201 will echo the cancel token after receiving the cancel command.

FIGURE 7: SIGN-ON SEQUENCE
(All data are in hexadecimal)

** Short sign-on for version 4 and later

See page 23 for variable definitions

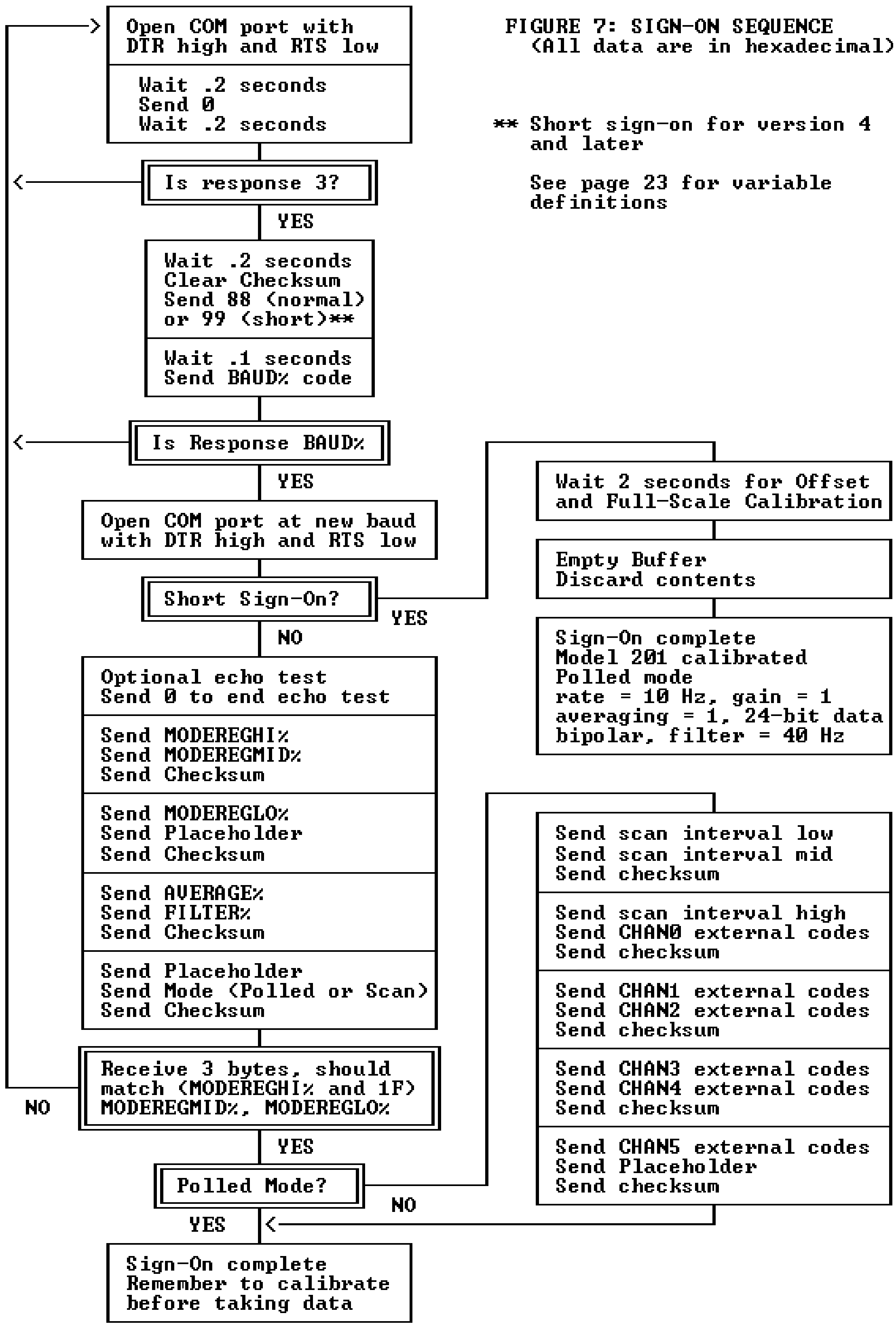
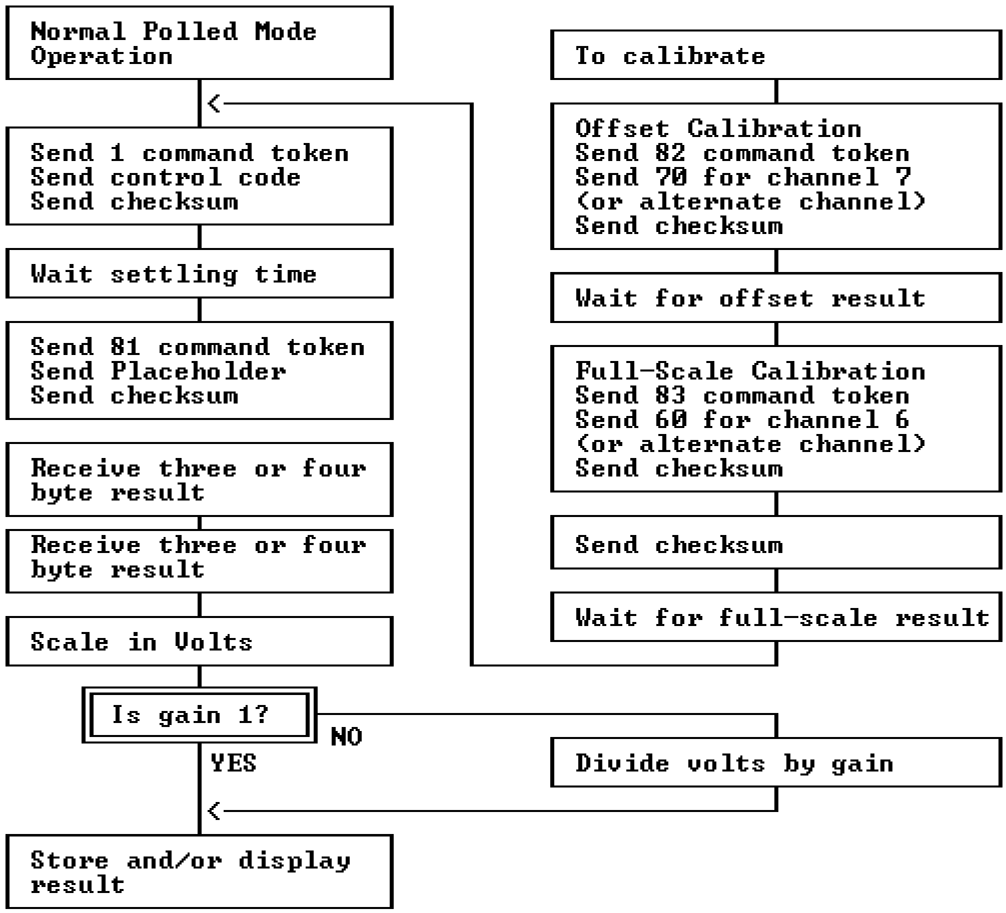


FIGURE 8: POLLED MODE SEQUENCE
(All data are in hexadecimal)



SIGN-ON VARIABLES

SIGNONTOKEN	88 hex	normal sign-on						
	99 hex	short sign-on (polled mode only)						
BAUD%	BAUD%	0	1	2	3	4	5	
	baud rate	9600	4800	2400	1200	600	300	
MODE REGISTERS	see SET A/D MODE command on page 19							
AVERAGE%	AVERAGE%	0	1	2	3	. . .	15	
	points to avg.	1	2	4	8	. . .	32768	
FILTER%	FILTER%			0	1	2		

	cutoff frequency (Hz)	4	40	400

MODE	0 scanning mode 1 polled mode
SCAN INTERVAL	SCANINT = (3906.25/2^BAUD%)*(seconds-.99995) where seconds is desired scan interval. SCANINT is a triple precision unsigned integer with bytes of low, mid and high.
CHAN0 to CHAN5	External codes (for scanning only) High nibble is 4-bit external control code for first point on CHAN Low nibble is 4-bit external control code for last point on CHAN

SECTION 5: TROUBLESHOOTING

1) Can't sign on.

   A. Try a slower baud rate.
   B. Make sure that power is connected properly to the 201.
   C. Check the communications port number and make sure you are connected to the proper DB connector.
   D. Double-check your cable. If you are using a 9 to 25-pin adapter, does it match the pinout described on page 3.
   E. Check that the serial port has DTR high and RTS low.

2) Model 201 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.

   A. Do a system calibration.
   B. Check the gain setting.
   C. Check uni/bipolar setting.
   D. Make sure another A/D input channel isn't badly over-range.

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 is being observed.
   C. Make sure another A/D input channel isn't badly over-range.

5) Optically isolated outputs are not working.

   Check connection to guard.

6) Didn't receive expected data, and instead receive alternating 5 hex and 80 hex from Model 201.

   Model 201 has put itself to sleep. You must sign-on to re-establish communications. Likely reasons for going to sleep include power cycle, checksum error, or invalid command.

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 performance.

There are two potentiometers on the board. The potentiometer closest to the connectors is the common-mode rejection adjustment. The other adjusts the reference voltage. Changing the reference voltage has the effect of changing the gain.

If you wish to reset the common-mode adjustment first, connect the + and - input pins of a channel to a ground on the analog input connector. Zero the channel by using the offset command. Now remove the connection to ground and connect both input pins to the 5 volt reference on pin 8 of the analog input connector. Adjust the common-mode potentiometer for a reading of zero. Repeat for best results.

The A/D 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.

SECTION 7: MODEL 201 SPECIFICATIONS

TYPE:	24-bit sigma delta (these converters have excellent noise rejection). Serially interfaced.
MONOTONICITY:	24 bits (up to 50 Hz data rate)
LINEARITY:	0.002% of full scale typical up to 50 Hz data rate
DIFFERENTIAL INPUT RANGE:	+/- 5 volts or 0 to 5 volts
COMMON-MODE RANGE:	+/- 6 volts
DC COMMON-MODE REJECTION:	96 dB minimum
RESOLUTION:	16 or 24 bits, software selectable
INPUT IMPEDANCE:	100,000 megohms typical
PROGRAMMABLE GAIN:	1, 2, 4, 8, 16, 32, 64, or 128
ANALOG INPUTS:	6, fully differential, protected to 60 volts, expandable to 96 channels using optional multiplexers
DIGITAL INPUT:	8-bits, contact closure or 5-volt logic compatible
DIGITAL OUTPUT:	4 optically isolated lines plus 8 latched logic outputs

POWER REQUIREMENT: +11.5 to +50 VDC regulated or unregulated

TYPICAL POWER CONSUMPTION: up to +24 VDC power supply voltage
- operation . . . . 18 milliamps
- standby . . . . . 14 milliamps
- sleep . . . . . . 2 milliamps
- add 3 milliamps to each at +50 VDC

SIZE: 5 x 6.5 x 1.2 inches

SPEED: The Model 201 has a programmable conversion rate which also determines the cut-off frequency of the low-pass filter. Representative values are given below. Effective resolution is 24 bits minus RMS noise in bits. Effective resolution may be reduced at gains above x4.

DATA RATE:	10 Hz	30 Hz	100 Hz	300 Hz
CUT-OFF FREQUENCY:	2.6 Hz	7.9 Hz	26 Hz	79 Hz
EFFECTIVE RESOLUTION (RMS BITS):	22	20	19	15
SETTLING TIME (SECONDS):	.4	.13	.04	.013

SERIAL INTERFACE: RS232, optically isolated, full duplex. Programmable from 300 to 9600 Baud. Checksum transmitted on request.

OTHER FEATURES: Also under software control are signal averaging and variable input filtration. The Model 201 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. Sleep mode drastically reduces power.

OPTIONAL EXPANSION CAPABILITY: A stacking expansion board can hold memory, additional A/D or D/A converters, or additional digital input and output.

CUSTOM MODIFICATIONS: The Model 201 can be custom programmed to perform a wide variety of tasks. If you do not see a particular feature here, it may still be available. Special versions of the microcode have been done to add a variety of features. Call for information. the

Model 201 can be optimized for process control, remote data-logging, chromatography, or other applications.

APPENDIX

EXPANSION CONNECTOR PINOUT

PIN 1	+12 VDC
PIN 2	-12 VDC
PIN 3	+7 VDC
PIN 4	-7 VDC
PIN 5	+5 VDC
PIN 6	-5 VDC
PIN 7	Analog Ground
PIN 8	RFS IN
PIN 9	RFS OUT
PIN 10	TFS IN
PIN 11	TFS OUT
PIN 12	+2.5 V REF
PIN 13	-2.5 V REF
PIN 14	+5 V REF
PIN 15	A Filter
PIN 16	B Filter
PIN 17	Digital Ground
PIN 18	Digital +5 VDC
PIN 19	Spare Select 4
PIN 20	Spare Select 6
PIN 21	Expansion Write
PIN 22	Expansion Read
PIN 23	D0 Expansion Bus
PIN 24	D1 Expansion Bus
PIN 25	D2 Expansion Bus
PIN 26	D3 Expansion Bus
PIN 27	D4 Expansion Bus
PIN 28	D5 Expansion Bus
PIN 29	D6 Expansion Bus
PIN 30	D7 Expansion Bus
PIN 31	E Analog In Channel Select
PIN 32	F Analog In Channel Select

LIMITED WARRANTY

The Lawson Labs, Inc. Model 201 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.