Model 401 TCP/IP-Interfaced 24-Bit Data Acquisition System Hardware Manual

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Lawson Labs, Inc.
Phone: (800) 321-5355
Phone: (610) 725-8800
Fax: (610) 725-9344
www.lawsonlabs.com
lawsnlab@lawsonlabs.com

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Introduction

The Lawson Labs, Inc. Model 401 24-Bit Data Acquisition System is a high-resolution device for translating voltages into digital form. The Model 401 communicates with a host computer using the TCP/IP protocol over a 10Base-T link. It has two multiplexed differential analog input channels and eight each digital input and digital output lines. The analog input and digital I/O sections are electrically isolated from the computer.

The Model 401 is intended for DC and low frequency applications. The data rate is programmable from 10 to 1000 samples/second. At a data rate of 10 samples/second, the RMS noise approaches one count, providing 23 bits effective resolution. (The converter is guaranteed monotonic to 23 bits.) Effective resolution decreases with increasing data rates. Even so, 20-bit effective resolution is maintained at 1000 samples/second.

The Model 401 requires a single DC supply in the range of 15 to 30 volts to power the isolated circuitry. Current draw is typically 115 milliamps in normal operation. The power and analog inputs are protected against substantial overvoltages.

Both polled and scanning modes are available. In scanning mode, the Model 401 maintains its own time base and transmits a predefined scan of one or two input channels at a preset interval. Self-calibration can remove offset and gain errors under software control.

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 simplifies the task of interfacing to the converter itself.

Section 1: Installation

The Model 401 interconnections consist of a DB25 connector for input and output, an RJ45 connector for TCP/IP, and a 2-terminal power connector. Use a crossover cable if the Model 401 connects directly to the PC or server. Use a standard cable if it connects to a hub.

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 TCP/IP cable need be connected. The power supply voltage can range from 14 to 28 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. Any regulated or unregulated power supply with high enough current ratings (within the correct voltage range) can be substituted. The board is protected against reverse voltage but will not operate without a properly connected supply. The power can be connected before or after the interface connection is made.

Note that the computer chassis ground is not connected to ground at the Model 401 because of the isolation. If your Model 401 has been mounted in the standard enclosure it will have a 47 kohm resistor placed between the computer's ground and the Model 401's chassis ground. This resistor should be removed if the two grounds are to be more than 100 volts apart. (Contact the factory for details.)

For maximum accuracy the board should be enclosed in a shielded box. Open cell foam is placed 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 collectively, they can have an effect on the least significant bits.

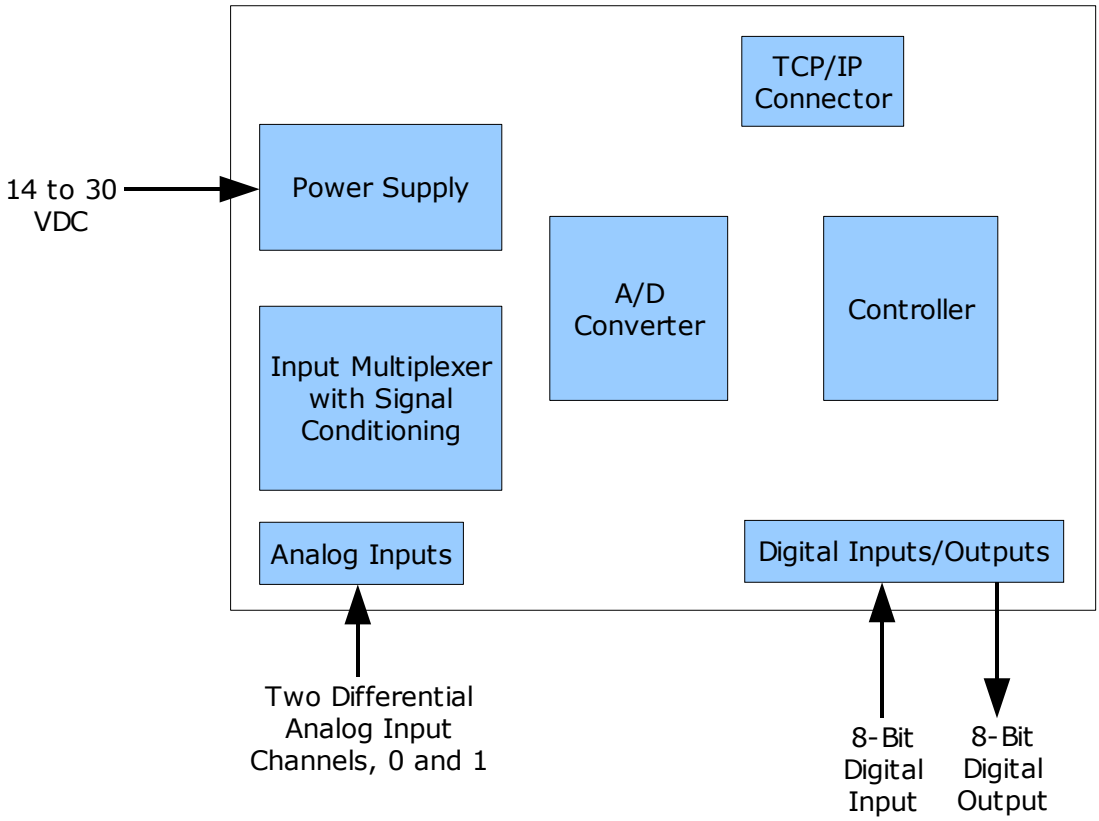

Figure 1: Model 401 block diagram

The software provided includes a DLL and sample applications, with source, in Visual C# .NET, Visual Basic .NET, Visual C++ 6.0, and Visual Basic 6.0. Win98, 2K, XP and Vista are supported. The latest version of the Model 401 SDK can be downloaded at no charge from www.lawsonlabs.com.

Section 2: Operation

Establishing Communications

Lawson Labs provides many software options for connecting to/configuring the Model 401. M40xVC, a free sample application that's a part of the Model 401 SDK will be used here to demonstrate how to establish communications. Once the Model 401 SDK is installed, run the executable version of M40xVC, which is found in the Model 401 SDK installation folder under \Samples\VC6\bin\M40xVC.exe. Before any other communications can succeed, the Model 401 needs to be initialized. Each Model 401 has a unique MAC identification number permanently programmed into the controller and printed on its label. If your server uses dynamic IP address assignment, you may need to enter the mac number in a configuration table before the server will recognize the Model 401. Follow the software start-up instructions carefully when connecting the Model 401 to your network. See the Troubleshooting section of this manual if you have difficulty connecting.

The Model 401, when first connected to the network will attempt to get an IP address assigned via BOOTP or DHCP. If that doesn't succeed before the programmable timeout expires, the last saved IP address stored in non-volatile memory will be used. Both the time-out and the default IP address can be changed from the configuration menu.

Polled Mode Overview

In polled mode, individual conversions are requested with individual commands. Other commands set the digital outputs, change input channels, recalibrate the system, or change to scanning mode. To maintain compatibility with earlier products, the offset correction channel is designated channel 7. The full scale calibration channel is designated as channel 6. The two available analog input channels are called channels 0 and 1.

System Calibration

To confirm proper operation, select channel 7 and you should see a voltage very close to zero. The offset portion of the system 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. Channel 6 should read close to +5 volts (or other full scale value) after a system calibration. The full-scale calibration removes gain and signal conditioning errors.

Connecting Analog Inputs

A battery is a convenient voltage source for checking the Model 401. 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 14 and 1, respectively for channel 0). You will also need a wire from one end (normally the negative) of the battery to ground at the Model 401 to insure that the input voltage at both input terminals is within 6.5 volts of ground. The ground at pin 3 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 401 is electrically isolated and floats in relation to the computer chassis ground. A typical D cell should read about 1.5 volts. Reverse the wires and note the polarity change. 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. The analog input channels are protected against continuous overvoltage up to 60 volts.

Because of the extreme resolution possible with the Model 401 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 temperature changes to cause thermal noise.

PIN 13:	Digital Ground		
		PIN 25:	Digital Out 7
PIN 12:	Digital In 0		
		PIN 24:	Digital Out 6
PIN 11:	Digital In 1		
		PIN 23:	Digital Out 5
PIN 10:	Digital In 2		
		PIN 22:	Digital Out 4
PIN 9:	Digital In 3		
		PIN 21:	Digital Out 3
PIN 8:	Digital In 4		
		PIN 20:	Digital Out 2
PIN 7:	Digital In 5		
		PIN 19:	Digital Out 1
PIN 6:	Digital In 6		
		PIN 18:	Digital Out 0
PIN 5:	Digital In 7		
		PIN 17:	Digital Ground
PIN 4:	Digital Ground		
		PIN 16:	Analog Ground
PIN 3:	Analog Ground		
		PIN 15:	CHANNEL 1+
PIN 2:	CHANNEL 1-		
		PIN 14:	CHANNEL 0+
PIN 1:	CHANNEL 0-		

Table 1: 25-pin connector pinout

Note: For maximum protection, any unused input terminals 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.

* Pin 13 can, optionally, serve as a trigger input.

Digital Input/Output

The digital input word, from pins 5 through 12 on the input/output connector, is updated with each conversion in polled mode and with each packet of ten conversions in normal scanning mode. For digital input scanning, the digital input byte is updated and transmitted once per conversion. The digital

inputs are active low. They can be activated by a contact closure to digital ground or by any 5 volt logic signal referenced to the same ground. The digital input word is displayed as an integer between 0 and 255. You may want to view it in binary format so that individual inputs show as ones and zeros.

The digital output command puts a latched 8-bit digital word at pins 18 through 25 on the input/output connector. Valid values are in the range of 0 to 255. The digital outputs are buffered to source or sink 20 mA. Note that when sinking current, the voltage may rise significantly above 0 volts.

Other Commands

The A/D converts constantly at the selected rate. That rate determines the frequency response of the converter. Rates from 10 to 1000 Hz are supported. There is a low-pass filter intrinsic to the conversion process. The cut-off frequency of that filter is the data rate times 0.262. For maximum effective resolution use the lowest data rate that meets your needs. For rates lower than 10 Hz, average in the application, or discard the extra data. Note that 1 / rate must be an integer multiple of the A/D's clock period. Therefore, the actual rate selected and displayed may be slightly different than the rate you enter.

The application can keep a running average of N consecutive conversions. The Model 401 is specified with the running average set to four.

Scanning Mode

The Model 401 will send data back continuously at the preset rate once a start scan command is sent. There are three different types of scan:

- Single-channel with digital input
- Multi-channel with digital input
- Multi-channel with digital input and calibration data

For single-channel scanning, the Model 401 will take data on whatever channel was selected when the scan was started. Channel change commands can be sent at any time during single-channel scanning. For multi-channel scanning, the Model 401 controls the channel selection. Do not send channel change commands during multi-channel scanning. You can send digital output commands at any time during any type of scan without altering the data acquisition timing.

Calibration scan adds a reading of channel 7, the offset channel, at the end of each scan. The software then subtracts the offset value from the other data to provide active zero-drift suppression.

Additionally, each of the above scans support two other features: 1) external triggering to start the scan and 2) scanning of externally multiplexed subchannels (up to 16 per channel: a maximum of 32 subchannels), selected with the lowest 4 bytes of the Model 401 digital output.

Section 3: Operating Suggestions

The Model 401 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 Model 401 requires a vanishingly small input current so the error caused by even very long wires is negligible. For proper operation it is necessary that the positive and negative inputs both be within 6 volts of ground. For a floating voltage source, this is generally accomplished by connecting a third wire between the Model 401 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 erratic behavior because currents will flow through different paths at different times causing unpredictable voltage drops.

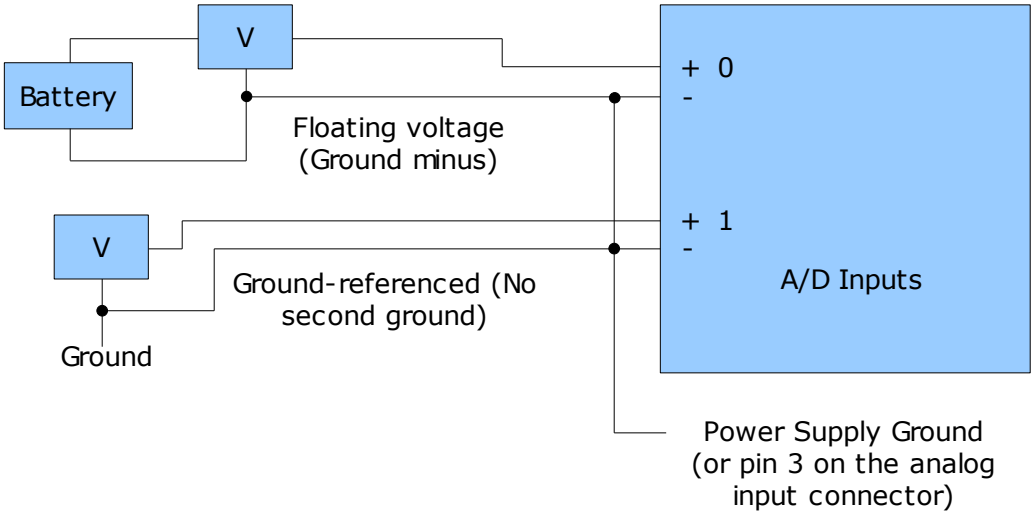

Figure 2: Typical input connections

* Remember to ground unused inputs

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

Data Rate (Hz)	Effective Resolution (bits)	Settling Time (ms)
10	23	800
50	22.5	160
100	22	80
250	21.5	32
500	20.5	16
1000	20	8

Table 2: Effect of data rate on effective resolution and settling time

Settling time is the time in milliseconds required to obtain a fully valid reading after an instantaneous full-scale step.

Effective resolution is defined as total resolution in bits minus RMS noise in bits. Numbers above use an oversampling factor of four.

See the Model 401 API documentation and the sample application source code for programmer's information. We will continue to add operating system and programming language support for the Model 401 as it becomes available.

Section 4: Troubleshooting

1. Can't connect.
   a) Make sure that power is connected properly to the 401.
   b) If a hub is being used, make sure the cable is not a crossover cable. Otherwise make sure it is.
   c) Cycle power to the Model 401. Wait 30 seconds, then try to connect again.
   d) If you are using a fixed IP address, verify it using PING.
   e) If you are using BOOTP or DHCP, verify the MAC address for your Model 401.
   f) The Model 401 can have the wrong IP address saved. To restore the default IP address, ground digital input number 3 and 4 (pins 8 and 9) and cycle the Model 401's power. The IP address will always be 10.1.1.2 after that process.
2. Model 401 won't respond to a data request.
   a) 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) Make sure another A/D input channel isn't badly over-range.
   c) Resend the rate information. If power is momentarily lost to the isolated circuitry, the A/D rate will be forgotten.
4. Data fluctuates wildly during scanning.
   a) If a data buffer overflows, your data may lose registration, that is, high, middle and low bytes of the answer may be confused. Stop and restart the scan, or reconnect to correct the problem.
5. 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.
   d) Make sure that your power supply is not being loaded to below 14 volts.

Section 5: 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 power input connector 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 calibration 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 6: Model 401 Specifications

A/D Type:	24-bit delta-sigma converter with microcontroller supervisor and optical isolation
Monotonicity:	23 bits
Linearity:	+/-0.002% of full scale
Differential Input Range:	+/-5 volts
DC Common Mode Range:	+/-6.5 volts
DC Common Mode Rejection:	-100 dB typical
Analog Inputs:	2, multiplexed true differential protected to +/-60 volts
Input Impedance:	1,000,000 megaohms typical
Programmable Data Rate:	10 to 1000 Hz, lower rates are generated through digital averaging
Effective Resolution:	Effective resolution is defined as total resolution in bits minus RMS noise in bits. The table below uses an oversampling ratio of four:

Rate (Hz)	Effective Resolution (bits)
1000	20
100	22
10	22.5

Scanning Mode:	Single, or two-channel scanning mode available. Rates are crystal-controlled for accurate timing. Divide rates above by 10 for speed and resolution in two-channel scanning mode.
Digital Inputs:	8 bits, contact closure or 5 volt logic compatible
Digital Outputs:	8 latched, ruggedized, double-buffered 5V outputs
Power Requirement:	14 to 30 VDC, regulated or unregulated, for isolated circuitry
Typical Power Consumption:	The Model 401 requires 120 mA (add drive current for active digital outputs, up to 20 mA each)
Size:	3.7 x 5.5 x 1.25 inches

An optional enclosure rugged steel enclosure for the Model 401 is available.

Limited Warranty

The Lawson Labs, Inc. Model 401 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.