```
          MODEL 302 USB-INTERFACED
          24-BIT DATA ACQUISITION SYSTEM

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## INTRODUCTION

The Lawson Labs, Inc. Model 302 24-Bit Data Acquisition System is a high-resolution device for translating voltages into digital form. The Model 302 communicates with a host computer using USB (Universal Serial Bus). It has six multiplexed differential analog input channels, three analog outputs, four digital inputs and eight digital output lines. All the input/output circuitry is optically isolated from the computer.

The Model 302 is intended for DC and low frequency applications. The data rate is programmable from 50 to 1000 samples/second. At a data rate of 50 samples/second, the RMS noise approaches one count, providing nearly 23 bits effective resolution. The converter is guaranteed monotonic to 23 bits. Effective resolution decreases with increasing data rates. Even so, over 20 bits of effective resolution are maintained at 500 samples/second.

The Model 302 requires a single DC supply in the range of 15 to 30 volts to power the isolated circuitry. With the preregulator removed (a factory option), the range is 9 to 15 VDC. Current draw is typically 30 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 302 maintains its own time base and transmits a pre-defined scan of one to eight input channels at a preset interval. The last two channels are for gain and offset correction. Self-calibration can remove drift 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 302 interconnections consist of a 14-position analog input screw terminal block, a 16-position screw terminal block for other Input/Output, a 2-terminal power connector, and a USB connector. An extension cable is available, as an option, to connect between a 4-terminal polarized header on the Model 302 board and a bulkhead-mounting USB connector. The bulkhead fitting is made to mount in a DB9 serial connector openning to aid in retrofitting existing hardware.
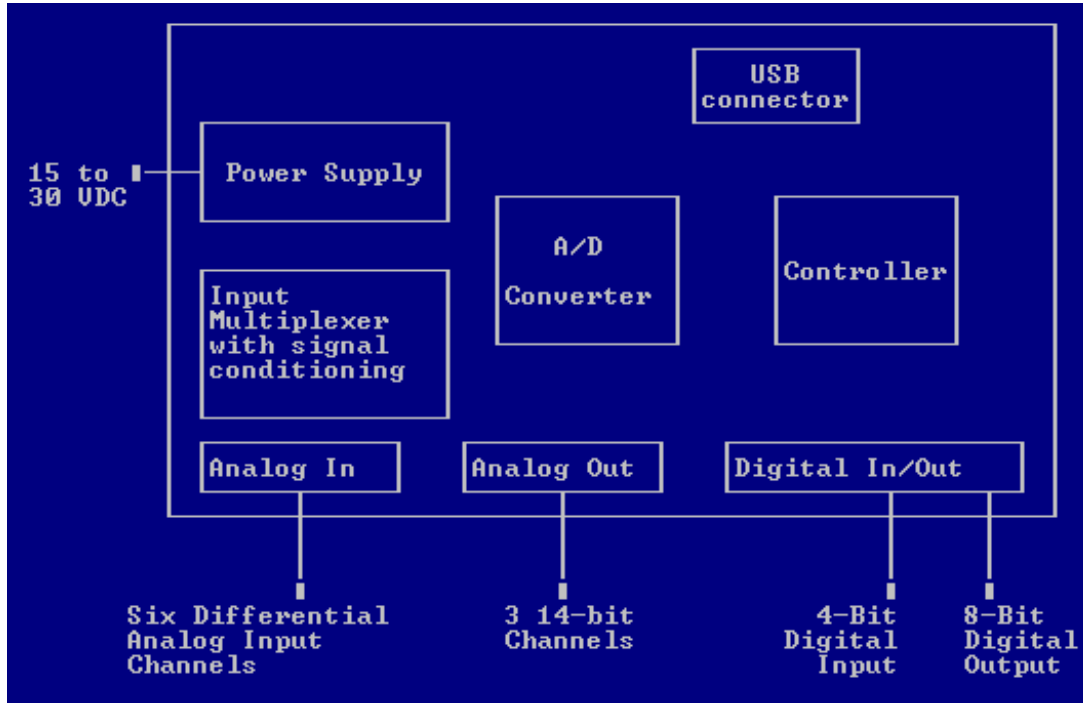
NOTE:  Always handle circuit cards by the edges. Static electricity can damage computer circuitry, so care should be taken to control static discharge.

For operational checks, only the power supply and serial cable need be connected. The power supply voltage can range from 15 to 30 VDC and does not need to be regulated. Power is connected to the 2-terminal block. The power terminals are labeled "+V" and "GD". The wall-mounted transformer supplied has a white stripe on the positive wire. A battery, or other DC supply (in 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 serial interface connection is made.

Note that the computer chassis ground is not connected to ground at the Model 302 because of the optical isolation. We normally recommend placing a 5K to 100K ohm resistor between the two grounds near the Model 302 if there is no other common ground point.

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

**FIGURE 1**:  MODEL 302 BLOCK DIAGRAM



```
                                    USB
                                 connector

15 to ■——  Power Supply
30 VDC                          A/D           Controller
                             Converter
          Input
          Multiplexer
          with signal
          conditioning

          Analog In      Analog Out      Digital In/Out


          Six Differential   3 14-bit       4-Bit    8-Bit
          Analog Input       Channels       Digital  Digital
          Channels                          Input    Output
```

The software drivers provided include a system-level USB driver, a DLL and sample application code, with source, in VC or VB. Win98 and Win2000 are supported. Refer to the read_1st.txt file on the disk before installing the drivers. Do not forget to follow the steps described there for adding your Model 302's ID number to the device list.


## SECTION 2: OPERATION
## Establishing Communications

Once the driver is installed, run the executable version of the VC or VB sample application. (The VB code has a more-developed user interface.) Before any other communications can succeed, the Model 302 needs to be initialized. Each Model 302 has a unique identification number permanently programmed into the controller and printed on its label. You will need to enter that number. The driver will then locate the requested device and assign it to the application for as long as the application is loaded. If you ever cannot regain access to a Model 302, unplug the USB cable, wait for the hourglass to disappear (if you see it), then re-plug in the USB cable. This process will re-enumerate the device.

# Polled Mode Overview

In polled mode, individual conversions are requested with individual commands. Other commands set the analog outputs or digital outputs, change input channels, recalibrate the system, or change to scanning mode. The offset correction channel is designated channel 7. The full scale calibration channel is designated as channel 6. The six available analog input channels are called channels 0 through 5. Note that labels on the board itself are 1 through 6, etc. The assumption is that from a developer or programmer's perspective, zero-based references are more appropriate, but that the user would prefer counting to start from 1.

## System Calibration

To confirm proper operation, select channel 7 and look for a voltage in the general vicinity of 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 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 302. Connect the positive and negative ends of the battery to a pair of positive and negative analog input terminals on the analog input connector. You will also need a wire from one end (normally the negative) of the battery to ground at the Model 302 to insure that the input voltage at both input terminals is within 6.5 volts of ground. Several ground terminals are provided for the purpose. This third wire ground is for common-mode requirements only, and, while necessary, it is non-critical. Remember that the Model 302 is optically isolated and floats in comparison 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 302 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.

## FIGURE 2:  CONNECTOR PINOUT

**Analog Input Connector (14 terminals)**

+1  −1  +2  −2  +3  −3  +4  −4  +5  −5  +6  −6  GD  GD(ground)

**Other Input/Output Connector (16 terminals)**

| **Analog Out** | | | **Digital In** | | | | | **Digital Output** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 1 | 2 | 3 | 4 | | GD | A | B | C | D | E | F | G | H |

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 that may be subject
flexing. Otherwise, fatigue may cause the failure of an electrical
connection.

# Digital Input/Output

The digital input word is updated with each conversion in polled mode, with each
packet of ten conversions in normal scanning mode, or with each conversion in
digital input scanning modes. 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 terminals A through H 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 50 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 .262. For maximum effective resolution use the lowest data rate that meets your needs. For rates lower than 50 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 302 is specified with the running average set to four.
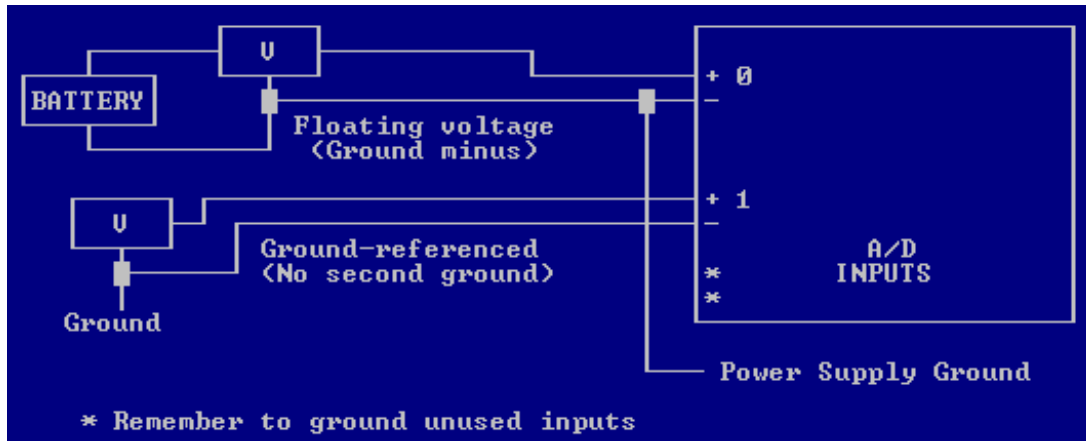
## Scanning Mode

The Model 302 will send data back continuously at the preset rate if a start scan command is sent. There are six different types of scan, single-channel, single-channel with digital input, multi-channel, multi-channel with digital input, multi-channel with calibration data, and multi-channel with digital input and calibration data.

For single-channel scanning, the Model 302 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 302 controls the channel selection. It sequentially selects the input channels and converts the data. Do not send channel change commands during multi-channel scanning. You can send analog or digital output commands at any time during either type of scan without altering the data acquisition timing.

## SECTION 4: OPERATING SUGGESTIONS

The Model 302 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 302 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 302 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 3**: 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.

**FIGURE 4:** EFFECT OF DATA RATE ON EFFECTIVE RESOLUTION
AND SETTLING TIME

| DATA RATE | EFFECTIVE RESOLUTION | SETTLING TIME |
|-----------|----------------------|---------------|
| 50 Hz | 22.5 | 160 MS |
| 100 Hz | 22 | 80 MS |
| 250 Hz | 21.5 | 32 MS |
| 500 Hz | 20.5 | 16 MS |
| 1000 Hz | 20 | 8 MS |

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 minus RMS noise. Numbers above use an oversampling factor of four.

See the FuncDesc.doc file and the sample application source code for programmer's information. We will continue to add operating system and language support for the Model 301 as appropriate.

## SECTION 4: TROUBLESHOOTING

1) Can't Initialize.
   A. Make sure that power is connected properly to the 302.
   B. If hubs are being used, make sure they are powered.
   C. Double-check your cabling.
   D. Try unplugging the USB cable from the Model 302. If you
      see the hourglass, wait for it to disappear, then plug the cable back in. Close and
      reopen the application. You may also need to cycle power to the Model 302 itself.
   E. It may be possible under some circumstances for your Model 302 to be marked as
      belonging to an application that is not responding. It may be necessary to
      explicitly free the device. Select "utilities" in our sample application and free
      the device in question. Then unplug and replug the USB cable to re-enumerate the
      device.
   F. Make sure the ID number of the device you want to initialize is listed in the
      configuration file. See the read_1st.txt file for details.

2) Model 302 won't respond to a data request.
   A. Remember to wait for the result from the previous request before issuing another.
   B. Occasional USB traffic does not go through. You can request again if the initial
      request fails.
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 forgotton.

4) Data fluctuates wildly during scanning
   A. If either the DLL's 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 reset the data buffer pointers to correct the problem.
   B. If "A" persists, slow the scanning rate, or locate and suspend the other application
      or system driver that is causing the USB driver to not be serviced frequently enough.

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.

## 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 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 301 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:              6, multiplexed true differential protected to +/-60 volts

INPUT IMPEDANCE:            1,000,000 megohms typical

PROGRAMMABLE DATA RATE:     50 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. Figures below use an
                            oversampling ratio of four.

                           Rate    Effective Resolution in Bits
                           ----------------------------------
                           1000                   20
                            100                   22
                             50                   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.

 ANALOG OUTPUTS:     3 at 14-bit resolution. Outputs will settle to within 1%
                     of full scale in 1 second.

DIGITAL INPUTS:     4 bits, contact closure or 5 volt logic compatible

DIGITAL OUTPUTS:    8 latched, ruggedized, double-buffered 5V outputs

POWER REQUIREMENT: 11 to 15 VDC, regulated or unregulated, for isolated circuitry

TYPICAL POWER       The microcontroller operates as a low-power
CONSUMPTION:        USB bus-powered device. The analog input and digital I/O requires
                    25 MA (add drive current for active digital outputs, up to 20 MA
                    each)

SIZE:               6.5 x 4.8 x 0.8 inches
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We have written our own system drivers for maximum reliability. Drivers are provided for
Win98, with VC and VB sample application code. Up to 32 Model 302s can be connected to one
PC using hubs. The A/Ds can be split between applications, or all used by the same
application. An optional enclosure will be offered soon.

## LIMITED WARRANTY

The Lawson Labs, Inc. Model 302 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.