

USB4CH User Manual

Manual Revision (2010/06/01)

Board Revision E

Symmetric Research
www.symres.com

FREE WEB VERSION - PARTIAL CIRCUIT DIAGRAMS

Contents

1	Introduction	8
2	Getting started	10
2.1	Find your CDROM	10
2.2	Downloading software from the web	11
2.3	Linux revs	11
2.4	Hook up power	11
2.5	Hook up the USB cable	12
2.6	Run Diag	14
2.7	Run DVM or Scope	14
2.8	Linux USB port permissions	14
3	Application Programs	16
3.1	DVM	17
3.1.1	starting the program	18
3.1.2	ini syntax	19
3.1.3	GUI version	20
3.1.4	command line version	21
3.1.5	ASC file format	22
3.1.6	Calibrate	23
3.2	Scope	25
3.2.1	starting the program	26
3.2.2	ini syntax	27
3.2.3	GUI version	28
3.2.4	command line version	29
3.2.5	output file names	30
3.2.6	DAT file format	31
3.3	Blast	32
3.3.1	starting the program	33
3.3.2	output file names	36
3.3.3	PAK file format	37
3.3.4	typical post processing	38
3.3.5	running in the background	39

4	Utilities and Format Conversion	40
4.1	Diag	41
4.2	DevMan	43
4.3	Dat2Asc	44
4.4	Pak2Asc	46
4.5	Interpolate	48
4.6	View	49
4.7	NmeaTime	50
4.8	GpsProg	52
4.9	DigitalIo	53
4.10	SetDid	54
5	User C Library	56
5.1	Open	57
5.2	SPS rate table lookup	61
5.3	Start acquisition	62
5.4	Get Data as Packets	63
5.5	Convert Packets to Columns	65
5.6	User digital IO read	68
5.7	User digital IO write	69
5.8	Front panel red and yellow LEDs	70
5.9	Power good	71
5.10	Stop acquisition	72
5.11	Close	73
6	Sampling rates	74
6.1	Permitted rates	75
6.2	Master clock stability	76
6.3	Interpolation to other sampling rates	77
7	FIFO Depth and Overflow	78
7.1	FIFO Depth	78
7.2	FIFO Overflow	80
7.3	FIFO Creep	80
8	A/D reference voltage	81
8.1	Standard reference	82
8.2	Alternate references	82
8.3	TC correction with on board temp sensor	83
9	Analog inputs	84
9.1	Differential signals	84
9.2	DB15 pin assignments	88
9.3	Twisted pair cabling	90
9.4	Static shielding	91

9.5	Input impedance	92
9.6	Input voltage range	93
9.7	Op amp gain	93
9.8	RC antialias filtering	94
10	Analog DC calibration	95
10.1	Full Scale Voltage Span and Counts	96
10.2	Approximate counts per volt	97
10.3	Calibration slope and offset	98
11	Analog AC calibration	100
11.1	Theoretical AC transfer function	101
11.2	Measured transfer function	102
12	Digital IO	103
12.1	Digital input	103
12.2	Digital output	104
12.3	Additional digital timing and GPS signals	104
12.4	DB25 pin assignments	105
12.5	Static shielding	107
12.6	User configuration byte	107
12.7	Triggering	108
12.8	Programming the front panel red and yellow LEDs	108
12.9	Seeing the digital inputs in Scope	108
13	GPS Time Stamping	109
13.1	What is GPS ?	109
13.2	Required GPS signals	110
13.3	DB25 pin assignments	110
13.4	Using a Garmin 16x HVS with the USBxCH	112
13.5	Determining RS232 polarity	113
13.6	Determining PPS polarity	115
13.7	Front panel red LED	116
13.8	Expected NMEA strings	116
13.9	Programming the GPS antenna	117
13.10	Seeing the GPS time stamps in Scope and Blast	118
13.11	What does time stamping mean ?	119
13.12	Driving multiple USBxCH systems from one GPS	120
14	NTP Time Stamping	121
14.1	Synchronizing the PC clock to NTP	121
14.2	Setting the USBxCH to use the PC clock	122

15 Power Supply	123
15.1 Connectors	123
15.2 Voltage and current requirements	124
15.3 LED power status indicators	125
15.4 POWER GOOD signal	125
15.5 Reset and power cycling	126
15.6 Current limiting	126
16 Temp Sensor	127
16.1 Temp records	127
16.2 System level TC calibration	128
17 Specifications	129
17.1 Specifications table	130
17.2 Noise floor	131
17.3 Thermal response	134
18 Circuit Diagrams	135
19 Examples and Experiments	141
19.1 Measuring a AA battery	142
19.2 Twisted pair for 50/60Hz rejection	147
19.3 Absolute calibration	148
19.4 Using DVM with a 10 turn potentiometer	149
19.5 Ratiometric technique	154
19.6 Measuring light levels with a solar cell	155
19.7 Plotting results with GnuPlot	156
19.8 Passive geophones	159
19.9 Multiple USBxCH and network processing	160
19.10 Powering with batteries	161
20 Frequently Asked Questions	166
20.1 Software	166
20.2 Hardware	168
21 Extra supplies	172
21.1 Small Parts for cables etc	173
22 Using Adobe PDF effectively	176
23 Getting Technical Help	177

List of Figures

1.1	mini Netbook with USB4CH and geophone	9
3.1	DVM sample display	17
3.2	DVM GUI screen	20
3.3	DVM CMD text screen	21
3.4	DVM Calibrate screen	23
3.5	Scope sample display	25
3.6	Scope GUI screen	28
3.7	Scope CMD screen	29
3.8	Blast sample display	32
3.9	Blast text screen	35
6.1	SPS rate table	75
7.1	FIFO hold out time table	79
9.1	Differential vs single ended signals	85
9.2	Balanced differential inputs	86
9.3	Two terminal floating sensor connection	87
9.4	Analog DB15 pin assignment table	88
9.5	Analog DB15 pin numbers viewed from front panel	89
9.6	Analog DB15 pin signals viewed from front panel	89
9.7	Magnetic coupling of 50/60Hz noise	90
10.1	A/D counts with balanced differential input	96
10.2	A/D counts with single ended input	97
10.3	Production input offset spreads	99
11.1	AC response: theoretical sinc	101
11.2	AC response: physical measurement setup	102
12.1	Digital DB25 pin assignment table	105
12.2	Digital DB25 pin numbers viewed from front panel	106
12.3	Digital DB25 pin signals viewed from front panel	106
12.4	Digital DB25 UserCfgByte	107

13.1	GPS DB25 pin assignment table	111
13.2	GPS DB25 pin signals viewed from front panel	111
13.3	Garmin GPS 16x HVS wires	112
13.4	Garmin GPS 16x HVS wiring	113
13.5	Garmin GPS 16x HVS finished cabling	114
13.6	PPS signal polarities	115
17.1	Specifications table	130
17.2	Noise floor time domain plots	131
17.3	Noise floor histogram at 130Hz	132
17.4	Noise floor histogram at 1302Hz	132
17.5	Long term thermal response	134
19.1	AA battery test lead setup	142
19.2	AA battery DVM display screen	143
19.3	AA battery circuit floating	144
19.4	AA battery with AGND connection	144
19.5	AA battery circuit grounded	145
19.6	AA battery 6 volt circuit	146
19.7	10 turn circuit	149
19.8	10 turn photo top	150
19.9	10 turn photo bottom	151
19.10	10 turn Calibrate screen	152
19.11	10 turn DVM display screen	152
19.12	Solar cell light level measurements	155
19.13	GnuPlot graph	157
19.14	NiMH AA battery pack	161
19.15	Battery voltage divider	162
19.16	NiMH AA battery pack discharge plot	163
19.17	Lead acid 3Ah battery	164
19.18	Lead acid 3Ah battery discharge plot	165

Chapter 1

Introduction

The Symmetric Research USB4CH is a precision 24 bit analog and digital data acquisition system for use with computers having USB ports. The system has four independent analog input channels, four digital inputs, four digital outputs, and a GPS interface.

A key feature of the USB4CH is each of its four analog input channels is equipped with its own 24 bit A/D converter. This avoids channel crosstalk and skew problems that are common with systems having a single multiplexed A/D.

Some other leading features of the USB4CH are:

- Simple USB PC interface for plug and play installation
- Simultaneous synchronous analog and digital recording
- High precision 24 bit A/D converter per channel
- Analog input range of +/- 4 volts, balanced differential
- Response to true DC, sampling rates to 9.7kHz
- GPS time stamping with 800 nanosecond accuracy
- 2Mb FIFO buffer for no analog or digital data loss due to PC latencies
- On board continuously recorded temp sensor
- Finished ready to go applications, as well as User function library
- Windows XP/7 and Linux support with kernel mode drivers
- Free web software downloads

This manual covers the software and hardware aspects of the USB4CH. Also see the ReadMe.txt files in many of the software directories for further information.

We hope the USB4CH is a useful tool for your applications

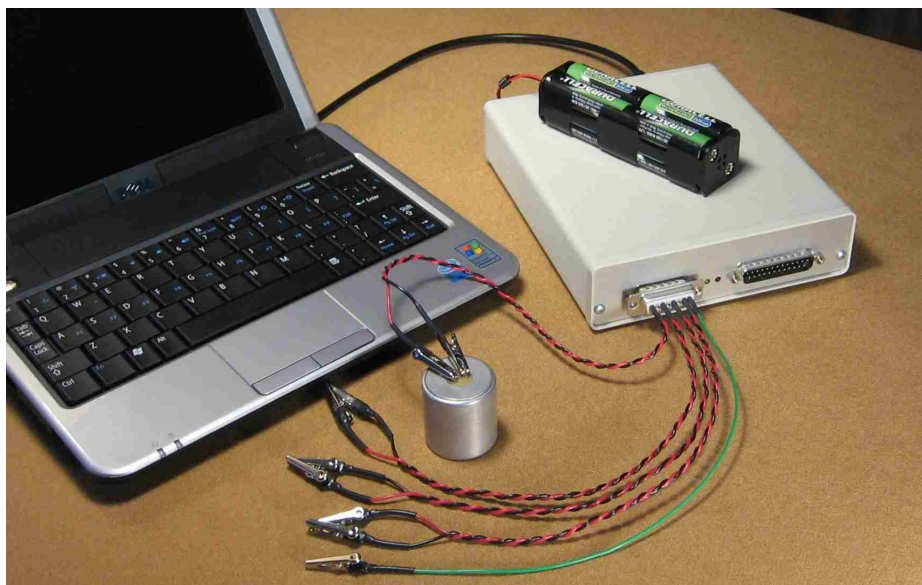


Figure 1.1: mini Netbook with USB4CH and geophone

One popular USB4CH configuration is with a mini Netbook for portable data acquisition. In the photo above, the small cylinder is a geophone, a passive sensor used for seismic surveys. A wide variety of other sensors can be used for applications from DC to 10kHz. For software support, the [Scope](#) program can be used to easily acquire, save, and display data in real time.

In this setup, the sensor is connected to one analog channel, while the other three analog channels are still available. The red/black alligator pairs are differential inputs for each of the analog inputs. The green alligator wire is AGND, which is not required for a floating passive sensor. A [GPS antenna](#) interface is provided on the DB25 for precision time stamping of acquired data.

The USB4CH is self powered. Power supplies varying from 8 to 24 volts are acceptable. A 110 vac wall transformer is supplied with the system, with 220 transformers available on request. Various types of batteries can also be used for power. As shown above, eight AA NiMH batteries will power the USB4CH for over 20 hours. See [powering with batteries](#) for a discussion. Many other configurations are possible. The USB4CH can be used with any Windows or Linux computer having a USB port.

Chapter 2

Getting started

Installation of the USBxCH is fairly easy. Here are the steps to follow:

2.1 Find your CDROM

Look for a CD in the shipping box. This CD contains the system software and a PDF User Manual with circuit diagrams. Support for both Windows and Linux is included on the same disk. To install, change to the CD directory for the operating system you are going to use, and at the command line run:

```
cmd:prompt> install.bat
```

This will create the directory `/SR/USBXCH` on your hard disk, and unzip the CD files there. This step only copies files to your hard disk. No registry entries or driver installation are made with this step. If you don't like running `install.bat` from the command line, use the shortcut icon available on the CD. Once the files are copied to your hard disk, examine the subdirectories. In particular, `/SR/USBXCH/Driver` will be needed later.

If you wish to remove the software from your system at this point, simply delete the `/SR/USBXCH` directory. Nothing else is required. Later, after the device driver has been installed, you must use the **DevMan** utility to completely remove the software.

The software must be installed in the `/SR/USBXCH` directory. Installation into other directories is not supported. Most of the executables can be run from any directory, but the shortcuts and batch files have the standard path hardwired into them. If you need to reinstall the software, rename or delete the current `/SR/USBXCH` directory and then run `install.bat` again.

2.2 Downloading software from the web

If you want to upgrade to the latest software version, or simply want to review the product, the full software package is available for free download from www.symres.com. The web postings contain all the software and User Manual, but do not include circuit diagrams. *Full circuit diagrams are included only on the CD shipped with the system.*

The [symres.com](http://www.symres.com) web site has individual postings for each operating system as a zip file. Download the appropriate file. Unzip the downloaded file into a temp directory and then run `install.bat` to further unpack the software and create `/SR/USBXCH`.

2.3 Linux revs

The Windows drivers are compatible with all versions of XP/7. Unfortunately, Linux drivers are specific to a particular version of the Linux kernel. Please compare your OS kernel version with the SR driver build version. If they are different, you will have to recompile.

Source code is provided so Linux users can rebuild for their particular kernel. SR attempts to stay current with recent kernel revs, but does not offer support for older revs.

2.4 Hook up power

For connecting power to the USBxCH do the following:

✓ Find the wall transformer

Look for the wall transformer included in the shipping box. US customers will have a 110 vac unit, while international customers may have a 220 vac unit. The output of the wall transformer should be rated at 9vdc 500ma.

Note that the USBxCH *is not powered from the USB cable*. You must use the supplied wall transformer or other equivalent power source. In USB terminology, *the USBxCH is a self powered device*.

✓ Plug the wall transformer into the wall

Do not plug a 110 volt transformer into 220 power with simple adapters that do not change the wall voltage. The wall transformer will simply output the wrong voltage and probably burn up.

✓ **Plug the 2.1mm barrel connector into the USBxCH**

Plug the 2.1mm barrel connector at the other end of the wall transformer cable into either USBxCH back panel power jack. There are two jacks on the back panel in parallel for daisy chaining power to other devices if needed. Make sure the connector is fully seated into the jack.

✓ **Is the green LED on ?**

If the wall transformer is energized at all, the green LED on the back panel near the 2.1mm power jacks should light up. If the green LED is off, then there is a basic problem with the wall transformer. Check the wall power and connections. You must fix it to continue.

✓ **Is the red LED off ?**

The red LED near the 2.1mm power jacks may momentarily light up when power is applied, but *will go off in a second or two*. If the red LED stays on, it indicates the power is not within specifications and something is wrong. Perhaps the wall transformer voltage is low, or the USBxCH is suffering a short. If the red LED is on, the problem must be fixed before the system will function correctly.

At this point, if the *green LED is on*, and the *red LED is off*, then the USBxCH is properly powered and you are ready to connect the USB cable.

2.5 Hook up the USB cable

Connecting the USB cable is the big event. The PC will detect the new USB hardware and prompt you for the location of its driver. The steps are:

✓ **Find the USB cable**

Find the USB cable included in the shipping box. One end of the cable has a flat type A USB connector for the PC. The other end has a square type B connector for the USBxCH peripheral.

✓ **Plug the flat type A end into the PC**

Plug the flat type A end into your computer. Note that the connector is polarized. Do not use excessive force and plug it in upside down.

✓ **Plug the square type B end into the USBxCH**

The next step is to plug the type B end of the USB cable into the powered up USBxCH. Doing so will start a sequence of Plug and Play events. Keep an eye on the PC when plugging it in.

✓ **Specify the driver directory to Plug and Play**

After the PC has detected the new hardware, you will have to specify where it can find the driver. For standard installations this is:

`/SR/USBXCH/Driver`

Once specified, the operating system will complete installation. Under Windows this means the Plug and Play (PnP) manager will do the following:

- Place a copy of the SrUsbXch.sys device driver file in the Windows directory: `/windows/system32/drivers`.
- Place a copy the SrUsbXch.inf driver info file in the Windows directory: `/windows/inf`.

... the info file copy will be given a system generated name like: `oem1234.inf`. The only sure way to find it is to *compare file contents* with the original in `/SR/USBXCH/Driver`. Findstr or grep may help.

Linux carries out similar steps.

✓ **Check the Device Manager**

Once PnP installation is complete, check the Device Manager to see the USBxCH listed as an available device under the SR Instrumentation group.

Suppose you unplug the USBxCH and plug it into a different PC USB port. What will happen? The PC will act as if new hardware has been detected and ask to reinstall the driver all over again. Follow the above steps and all will go fine. If plugging and replugging on the very same port, nothing will be required.

After the driver has been installed you will need to know the device name. Depending on the number of systems installed this will be `SrUsbXch0` (1,2,3 ...) etc. The device name is required for later use with programs and library functions. If this is the first USBxCH installed on the computer it will be:

`SrUsbXch0` << device name

To remove the driver, use the **DevMan** utility. It will delete the operating system copies of the driver files and corresponding registry entries.

2.6 Run Diag

After hooking up power and connecting the USB cable, run the **Diag** utility to confirm proper operation. This will check the hardware and give an error report if there are any problems. Diag can be executed from the command line, or by double clicking on the "Run Diag Install" shortcut icon. From the command line type:

```
cmd:prompt> Diag install
```

Run Diag without any command line options for a help screen. If you feel the system has a hardware problem, run **Diag debug** and **email** the report and log files to SR.

2.7 Run DVM or Scope

After running Diag, users should test acquiring data with **DVM** or **Scope**. Each comes in both GUI and command line versions. For quick starts with default parameters, double click on the shortcut icons.

When running, it is tempting to touch the analog input pins to apply small voltages. *Avoid the temptation to do this.* You will inadvertently discharge static electricity into the inputs. Even small static shocks such as those from walking on a carpet will do damage. Generally the damage is cumulative, with calibration and analog performance steadily degraded with each ESD event. If you must touch the input pins, *touch the metal enclosure immediately before doing so.* This will help discharge any static. Better yet, wear an antistatic wrist band clipped onto the front panel.

See the **Analog inputs** chapter for details on the analog input voltage ranges and differential signals. For introductory hands on usage see the **Examples and Experiments** chapter.

2.8 Linux USB port permissions

Many Linux users will have installed the USBxCH driver while logged on as "**root**" and all will run fine . . . but when they log on again as a regular user there will be trouble. The problem is under Linux, there are not only file permissions, *there are also USB hardware port permissions.* By default the *hardware port permissions* are often set to root, and if you want to run as a regular user you will have to change them.

The steps for changing the Linux USB port permissions are covered in the file:

```
/usr/local/SR/USBXCH/Driver/"000 ReadMe.txt"
```

If you are already in the `/usr/local/SR/USBXCH/Driver` directory, the basic step is to change the udev device rules. You can do so by executing:

```
cat 40-permissions.rules >> /etc/udev/rules.d/40-permissions.rules
```

and then rebooting as a regular user to reload the new rules. For Linux experts, the contents of the `40-permissions.rules` file are:

```
Contents of "40-permissions.rules" ...
```

```
# Symmetric Research USBxCH device - create with permission for all users
BUS=="usb", SYSFS(idVendor)=="15d3", SYSFS(idProduct)=="5504", MODE="0666"
```

Chapter 3

Application Programs

The USBxCH comes with three finished acquisition applications: DVM, Scope, and Blast. With these programs you can acquire data, display it on the screen, and save it to disk. Even for those planning to write their own custom software, running these applications will help you understand how the system works.

The DVM program presents its data on the screen in familiar digital voltmeter style and is suitable for low sampling rates. The Scope program presents its data as horizontal traces in oscilloscope fashion and is suitable for low and medium sampling rates. Both DVM and Scope specify their acquisition parameters with initialization files (ini files), and come in graphical (GUI) and text only (command line) versions. The Blast program is a minimal command line only program. All of its acquisition parameters are specified on the command line, and it saves its data in packet format exactly as received from the USBxCH. Blast is appropriate for all sampling rates up to the maximum the system bandwidth can support. Source code for each of these programs is included with the system, and is also available for download at www.symres.com.

The following sections give details about DVM, Scope, and Blast. The Calibrate program is for use with DVM and is also detailed here. For information about general utility and format conversion programs see Chapter 4, [Utilities and Format conversion](#).

- ▷ **DVM** enhanced multichannel digital voltmeter
- ▷ **Calibrate** DVM calibration into volts and user units
- ▷ **Scope** horizontal real time trace display
- ▷ **Blast** minimal but fast PAK file acquisition

3.1 DVM

DVM is an acquisition program for the USBxCH with a display and function much like an enhanced multichannel digital volt meter. If hand held instruments such as Fluke meters are familiar, then you will find DVM easy to use.

One feature of DVM is besides displaying values as counts or volts, it can also display values in user specified units. For example, displays reading in degrees C are possible. A calibration program is included to easily generate the coefficients for such setups.

DVM optionally saves its acquired values to ASCII disk files. This makes it easy to review experimental results, and to import data into spreadsheets etc. See the [Examples and Experiments](#) chapter for an example of importing data into GnuPlot.

DVM comes in two versions. A full GUI (graphical user interface) display, and a text only command line version. Both versions take their setup parameters from an ini initialization file. The ini syntax and keywords are the same for both. The following sections review details of using the program.

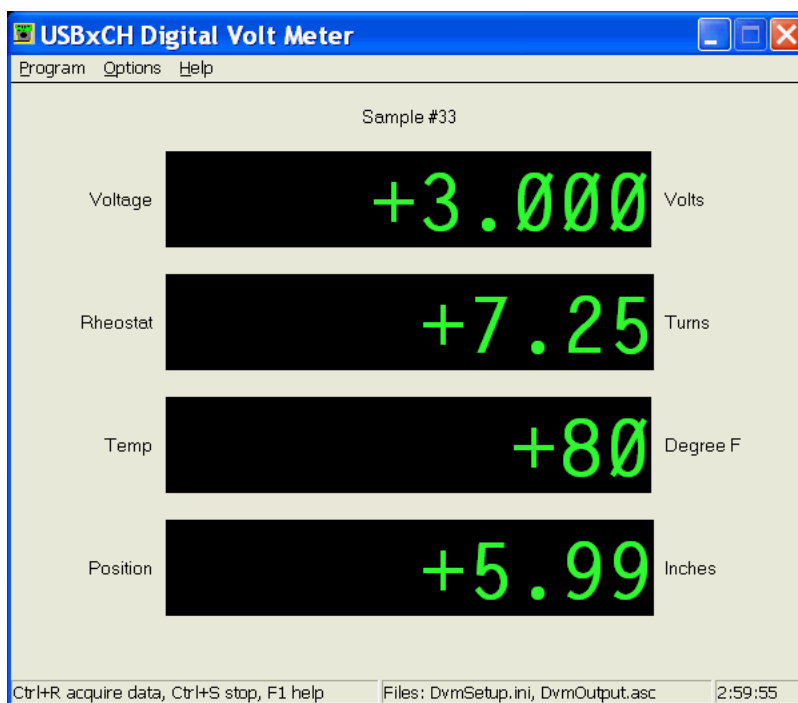


Figure 3.1: Typical DVM GUI display

3.1.1 DVM: starting the program

Starting DVM is similar for either the GUI or text only versions. From the command line type either of:

```
cmd:prompt> DvmGui parameters.ini
```

```
cmd:prompt> DvmCmd parameters.ini
```

where the first is for the GUI display and the second for the text only display. The parameters.ini file is optional. If not specified, DVM will start up with defaults. If you want to run with custom parameters, they should be specified in the ini file. There is nothing special about the ini filename, any filename may be used. In fact, having several ini files for different setups can be very handy.

Several program shortcuts are also included in the DVM directory. Double click on them to execute. Copy the shortcuts to the Windows Desktop or Start menu for easy access if needed. You can also make multiple copies of the shortcuts and edit their properties to run with different ini files.

3.1.2 DVM: ini syntax

The layout of a DVM ini file is free format ASCII with a simple syntax of the form:

`keyword = value`

Comments are denoted with a semicolon, where everything from ; to the end of line is a comment. You can create and edit ini files with text editors such as Windows Notepad or any other favorite editor. For a listing of all the DVM ini keywords, see the file:

`/SR/USBXCH/Dvm/DvmHelpIniSyntax.txt`

Keywords not specified in the ini file will be given default values. Here is an example of a short ini file:

```
; short DVM ini file:

; custom channel 0 display parameters ...

ChannelTitle 0   = "Temp"           ; any string
ChannelUnits  0   = "Degree F"       ; any string
ChannelPlaces 0   = 5                 ; total # digits shown including .
ChannelDigits 0   = 0                 ; # digits after .
ChannelSlope  0   = -0.0007109        ; calibration slope
ChannelOffset 0   = 631.757           ; calibration offset

; channel 1,2,3 are not specified and stay at default values ...
```

All DVM parameters are taken from the ini file or default program values. Changes to parameters such as the number of digits displayed must be specified in the ini file. There are no GUI dialogs for setting ini parameters such as displayed digits. To make changes, edit and reload the ini file. Besides the keywords in the fragment above, there are also keywords specifying the output filename, time format, and similar features. See the `DvmHelpIniSyntax.txt` file.

*Note the DVM sampling rate is fixed at 1Hz, and is not specified with a keyword. DVM is intended for low acquisition rate applications. Use **Scope** or **Blast** for support at user specified sampling rates.*

3.1.3 DVM: GUI version

When run in GUI mode, the DVM screen will look like:

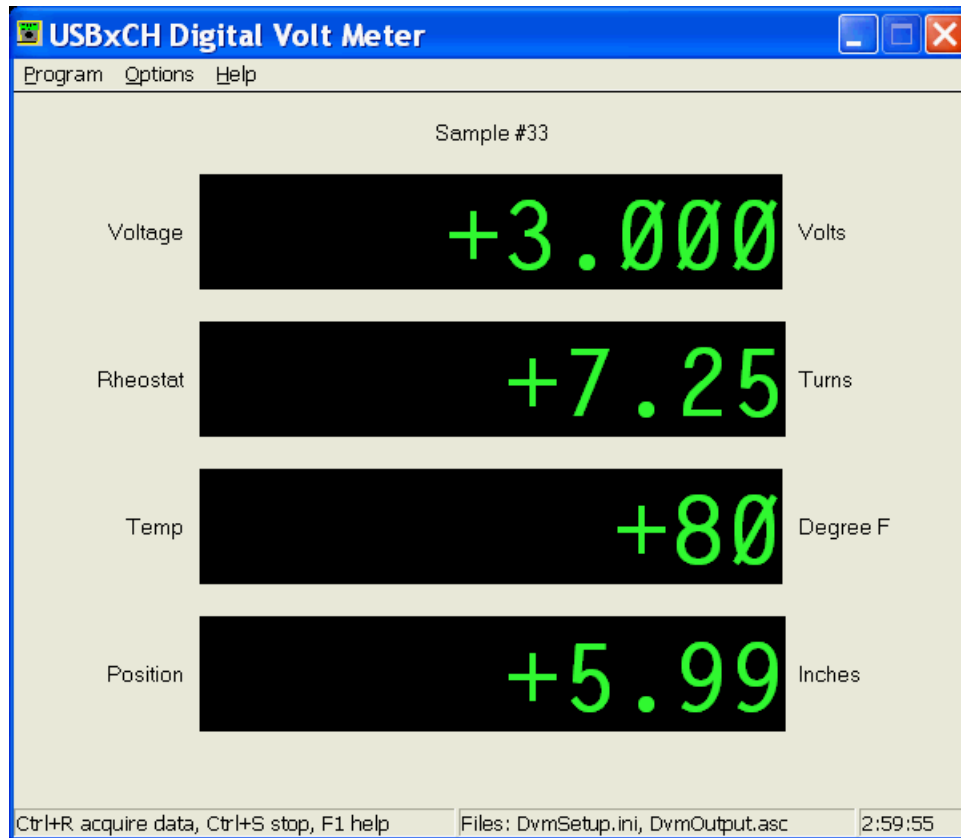


Figure 3.2: DVM GUI screen

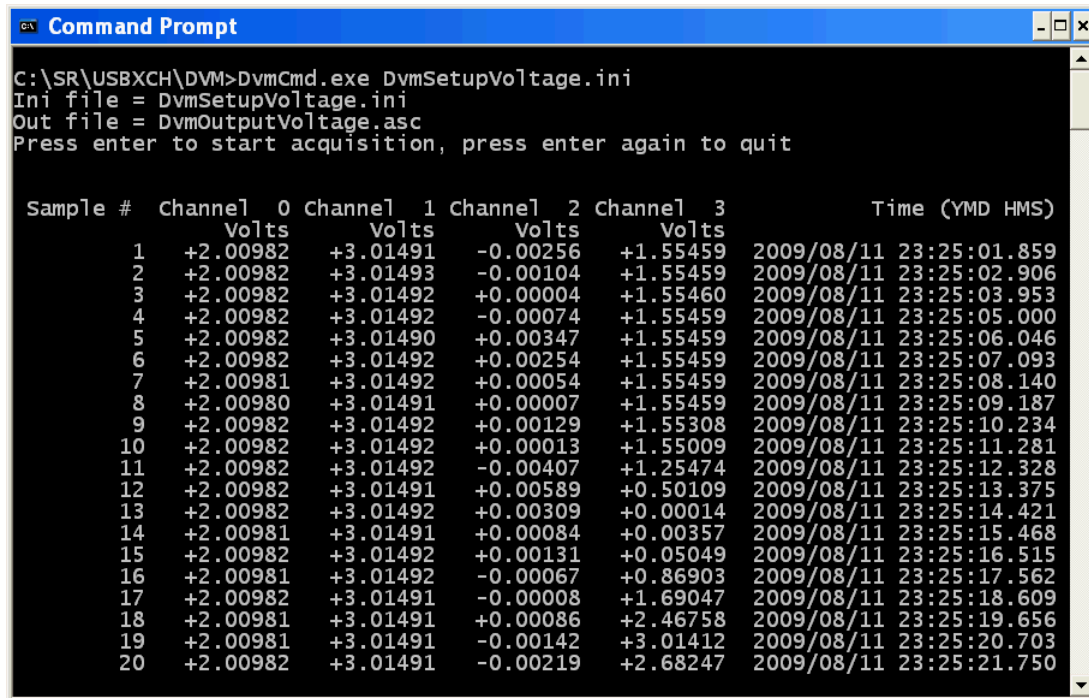
For a USB4CH, all four analog channels are displayed as green digital readouts. The channel titles are on the left and display units on the right. The titles and units can be specified independently for each channel in the DVM ini file.

Across the top of the screen is an Alt menu with various program actions. With the Alt menus you can start and stop acquisition, edit the ini file, and bring up a help screen. Each Alt menu item has a speed key for keyboard users. Note that even the ini editor can be specified in the ini file. Notepad is only the default.

Users wanting to change the display units will need calibration coefficients. The DVM **Calibrate** program can be used to compute the required slopes and offsets and automatically save them to an ini file.

3.1.4 DVM: command line version

If you like the data acquired by DvmGui, but only want to run a modest user interface without a full graphical display, then the DvmCmd text only version of the program may be useful. The DvmCmd output screen looks like this:



```
C:\SR\USBXCH\DVM>DvmCmd.exe DvmSetupVoltage.ini
Ini file = DvmSetupVoltage.ini
Out file = DvmOutputVoltage.asc
Press enter to start acquisition, press enter again to quit

Sample #  Channel 0 Volts  Channel 1 Volts  Channel 2 Volts  Channel 3 Volts  Time (YMD HMS)
1         +2.00982      +3.01491      -0.00256      +1.55459  2009/08/11 23:25:01.859
2         +2.00982      +3.01493      -0.00104      +1.55459  2009/08/11 23:25:02.906
3         +2.00982      +3.01492      +0.00004      +1.55460  2009/08/11 23:25:03.953
4         +2.00982      +3.01492      -0.00074      +1.55459  2009/08/11 23:25:05.000
5         +2.00982      +3.01490      +0.00347      +1.55459  2009/08/11 23:25:06.046
6         +2.00982      +3.01492      +0.00254      +1.55459  2009/08/11 23:25:07.093
7         +2.00981      +3.01492      +0.00054      +1.55459  2009/08/11 23:25:08.140
8         +2.00980      +3.01491      +0.00007      +1.55459  2009/08/11 23:25:09.187
9         +2.00982      +3.01492      +0.00129      +1.55308  2009/08/11 23:25:10.234
10        +2.00982      +3.01492      +0.00013      +1.55009  2009/08/11 23:25:11.281
11        +2.00982      +3.01492      -0.00407      +1.25474  2009/08/11 23:25:12.328
12        +2.00982      +3.01491      +0.00589      +0.50109  2009/08/11 23:25:13.375
13        +2.00982      +3.01492      +0.00309      +0.00014  2009/08/11 23:25:14.421
14        +2.00981      +3.01491      +0.00084      +0.00357  2009/08/11 23:25:15.468
15        +2.00982      +3.01492      +0.00131      +0.05049  2009/08/11 23:25:16.515
16        +2.00981      +3.01492      -0.00067      +0.86903  2009/08/11 23:25:17.562
17        +2.00982      +3.01491      -0.00008      +1.69047  2009/08/11 23:25:18.609
18        +2.00981      +3.01491      +0.00086      +2.46758  2009/08/11 23:25:19.656
19        +2.00981      +3.01491      -0.00142      +3.01412  2009/08/11 23:25:20.703
20        +2.00982      +3.01491      -0.00219      +2.68247  2009/08/11 23:25:21.750
```

Figure 3.3: DVM CMD text screen

If you don't even want this amount of display, there are ini keywords to turn the display off entirely. This can be useful for lower power computers only wanting to save their data to a file. The DvmCmd executable size is also smaller than DvmGui.

Note that DvmCmd uses the same ini keywords as DvmGui. You can refine keyword selections with DvmGui and then move over to DvmCmd without change.

3.1.5 DVM: ASC output file format

DVM can save its acquired results to ASCII disk files. To turn file saving on, set the ini keyword:

```
OutputFileName = "myfile.asc"
```

The output file may be given any name, but it is conventional to use the .asc extension for easy identification. You can give the empty string "" or value "NONE" for no file.

There are also ini keywords to control the output file format. Items such as header format and time display may be selected. See the file `DvmHelpIniSyntax.txt` for a complete syntax description. The general format of an ASC file is fairly simple. Data is laid out in columns, one column per channel, and one sample point per row:

DVM ASC output file layout:

```
channel 0, channel 1, channel 2, channel 3, HMS:YMD
channel 0, channel 1, channel 2, channel 3, HMS:YMD
channel 0, channel 1, channel 2, channel 3, HMS:YMD
channel 0, channel 1, channel 2, channel 3, HMS:YMD
channel 0, channel 1, channel 2, channel 3, HMS:YMD
channel 0, channel 1, channel 2, channel 3, HMS:YMD
channel 0, channel 1, channel 2, channel 3, HMS:YMD
channel 0, channel 1, channel 2, channel 3, HMS:YMD
channel 0, channel 1, channel 2, channel 3, HMS:YMD
channel 0, channel 1, channel 2, channel 3, HMS:YMD
channel 0, channel 1, channel 2, channel 3, HMS:YMD
... etc
```

For DVM, each row advances by 1 second. If the acquisition units are volts, then the voltages from channel 0 will be lined up in the first column. Channel numbering starts at 0. Files in this type of column format are easily imported into spreadsheets and analysis programs such as GnuPlot, Excel, or Matlab for plotting and processing.

See the [Examples and Experiments](#) chapter for examples of using the public domain plotting program [GnuPlot](#) and many other applications.

3.1.6 DVM: Calibrate

Sometimes users are surprised to learn A/D converters do not output their results as volts. The output from an A/D converter is actually a digital integer that is only *proportional* to the input voltage. The conversion from this digital integer to units such as volts is referred to as the calibration.

The concept of calibration for an A/D converter can be carried even further into physical sensor units. Suppose you have a sensor like a potentiometer or temperature gauge. At the minimum setting the sensor may result in a particular A/D count, and likewise at its maximum setting another count value. These two points define a line, and conversion of the count values directly into sensor units, such as potentiometer turns or °C can be done with a linear transformation having a *slope* and *offset*.

The Calibrate program makes it easy to obtain the slope and offset coefficients for such transformations. It allows you to record the transducer min and max settings, and then output an ini file for use with DVM. The Calibrate screen looks like this:

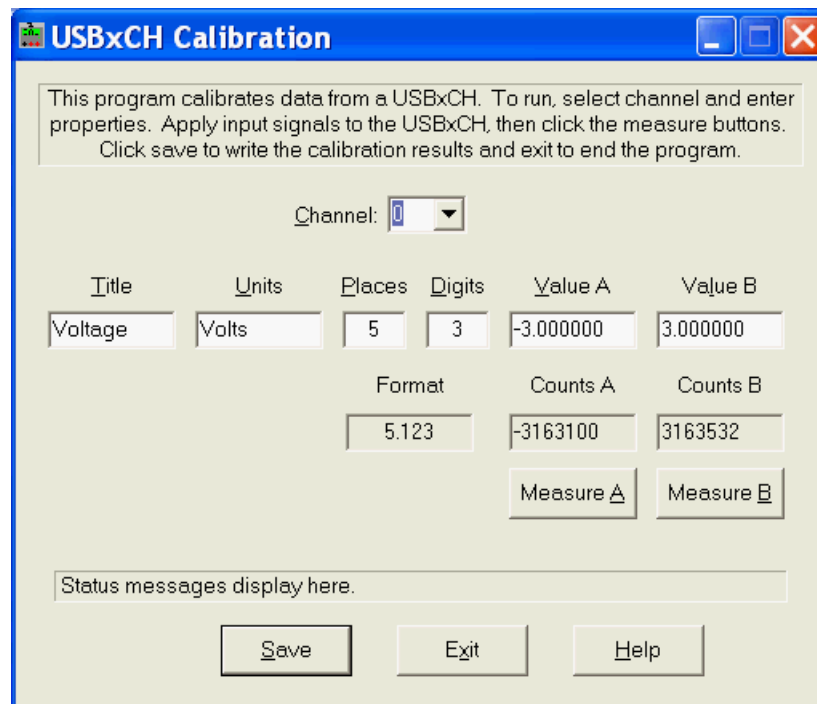


Figure 3.4: DVM Calibrate screen

To start the program, execute either CalGui.exe or CalCmd.exe from the command line, or double click on one of the provided shortcuts. *Approximate* calibration into volts is provided in the DvmSetupVolts.ini file included with the software. However, because

all A/D converters, references, and resistors have tolerances, *precision* calibration must be performed on each individual system and channel. Absolute calibration requires a lab grade reference with repeatable fixed voltages. For such applications, the SR VREF-399 heater stabilized precision reference may be useful, see www.symres.com. Applications not requiring absolute calibration may find ratiometric techniques helpful.

See the [Examples and Experiments](#) chapter for an absolute calibration demo, an example of calibration into physical sensor units, and a ratiometric experiment. For a discussion of the number of A/D counts per volt see the [Analog DC calibration](#) chapter.

3.2 Scope

Scope is a USBxCH acquisition program for acquiring and displaying data in real time as horizontal traces on the screen. The functionality is much like an oscilloscope. If viewing the AC characteristics of your data is important, then Scope is a good match.

The sampling rates for Scope are user selectable, with rates from the low Hz to several kHz supported. Analog response is to DC, which means even if sampling at kHz, DC inputs will still return the same correct DC value over and over on each sample. The Scope real time graphical display requires considerable PC CPU horsepower which may limit achieving the highest USBxCH rates. For the maximum sampling rates, use the **Blast** program.

Scope optionally saves its acquired data to **DAT** disk files. The DAT file format is binary with data organized as records that are demuxed at the bit level. DAT files contain the entire USBxCH data stream: analog, digital, GPS, and system status parameters like temperature. For easy post processing, two utility programs are provided. The **Dat2Asc** utility converts binary DAT to ASCII text files readable in any text editor. Dat2Asc files can also be imported into programs such as **GnuPlot**, Excel, and MatLab. The **View** utility displays DAT files as horizontal traces on the screen so users can scroll back and forth reviewing acquired data offline.

The Scope program comes in two versions. A full GUI graphical user interface display, and a text only command line version. Both versions take their setup parameters from an ini initialization file much like DVM, but with different keywords. The following sections review particular aspects of running Scope.

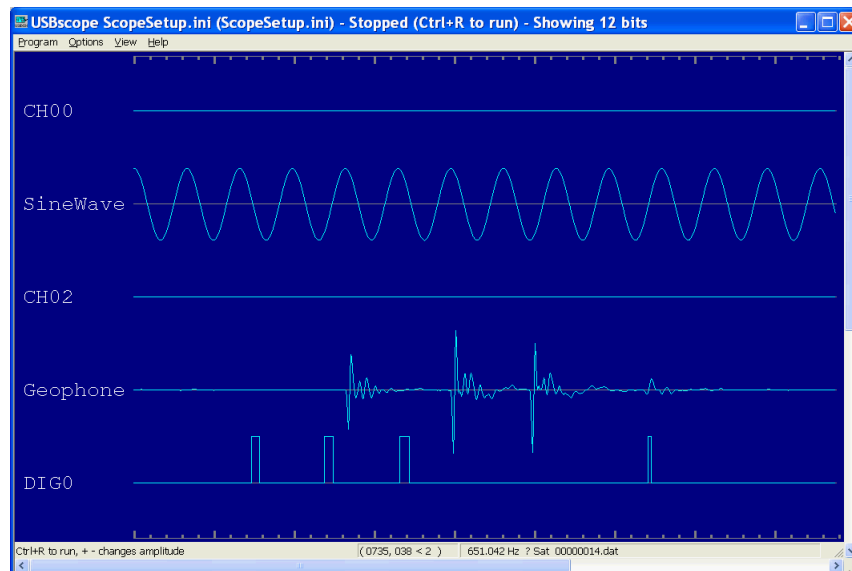


Figure 3.5: Typical Scope display

3.2.1 Scope: starting the program

Starting Scope is the same for either the GUI or the text only version, and is similar to starting DVM. From the command line type one of:

```
cmd:prompt> ScopeGui parameters.ini
```

```
cmd:prompt> ScopeCmd parameters.ini
```

where the first is for the GUI display and the second for the text only display. The parameters.ini file is optional. If not specified, Scope will start up with defaults. If you want to run with custom parameters, they should be specified in the ini file. There is nothing special about the ini filename, any filename may be used. In fact, having several ini files for different setups can be very handy. The GUI and command line versions of the program use the same ini keywords.

Several program shortcuts are also included in the Scope directory. Double click on them to execute. Copy the shortcuts to the desktop or start menu for easy access if needed. Make copies of the shortcuts and edit their properties to run with custom ini setups.

3.2.2 Scope: ini syntax

The layout of a Scope ini file is similar to that for DVM, only the keywords are different. Scope ini files are free format ASCII with a simple syntax of the form:

`keyword = value`

Comments are denoted with a semicolon, where everything from ; to the end of line is a comment. You can create and edit ini files with text editors such as Windows Notepad or any other favorite editor. For a listing of all the Scope ini keywords, see the file:

`/SR/USBXCH/Scope/ScopeHelpIniSyntax.txt`

Here is an example of a short ini file:

```
; short Scope ini file:

SamplingRate = 130.0 ; requested sampling rate
ToggleLed = ON

ChannelTitle 0 = "Channel Name 00" ; analog display names
ChannelTitle 1 = "Signal Generator 0"
ChannelTitle 2 = "Microphone"
ChannelTitle 3 = "My custom name"

DigitalTitle 0 = "DIG0" ; digital display names
DigitalTitle 1 = "DIG1"
DigitalTitle 2 = "DIG2"
DigitalTitle 3 = "DIG3"

OutputFileFormat = Dat ; Dat, None
OutputFileNaming = Sequential ; Single, Sequential, Time

; all other keywords are not specified and stay at default values ...
```

Keywords not specified in the ini file will be given default values. There are no GUI dialogs for setting ini parameters, with the exception of a few display settings that can be toggled with Alt menu commands. All other Scope parameters are taken from the ini keywords or default values. Alt menu commands are available for quick ini file editing and reloading.

3.2.3 Scope: GUI version

When run in GUI display mode, the Scope screen will look like:

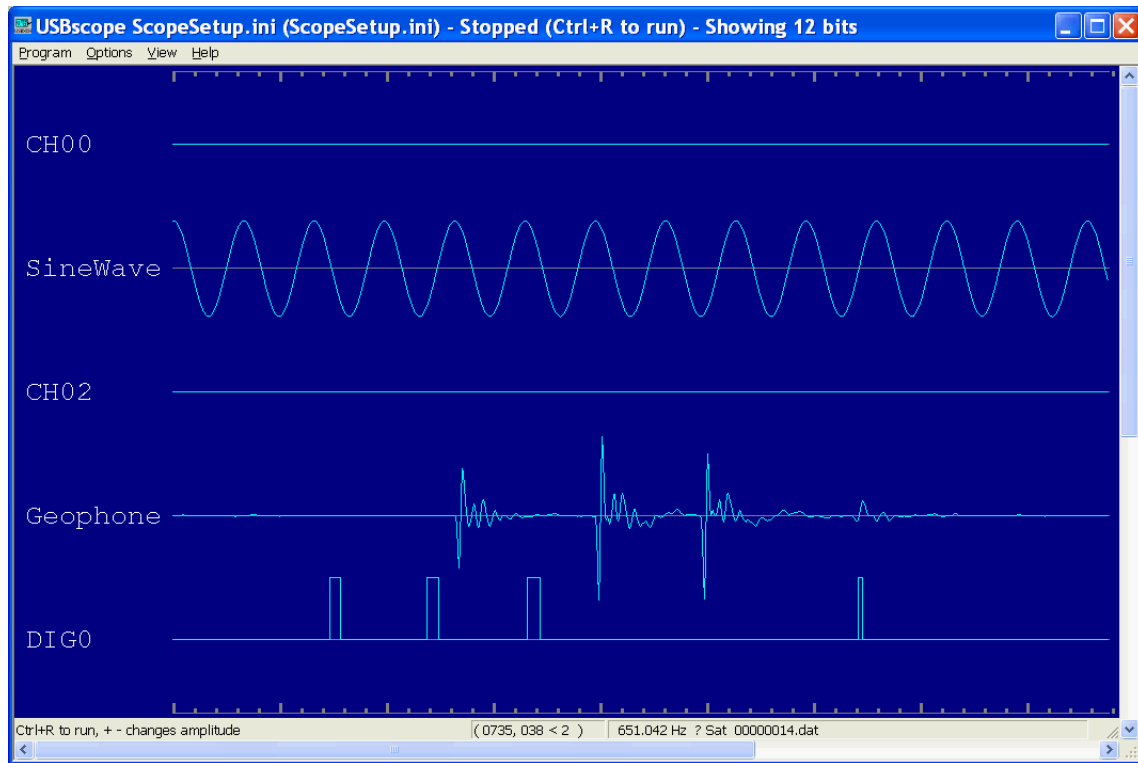


Figure 3.6: Scope GUI screen

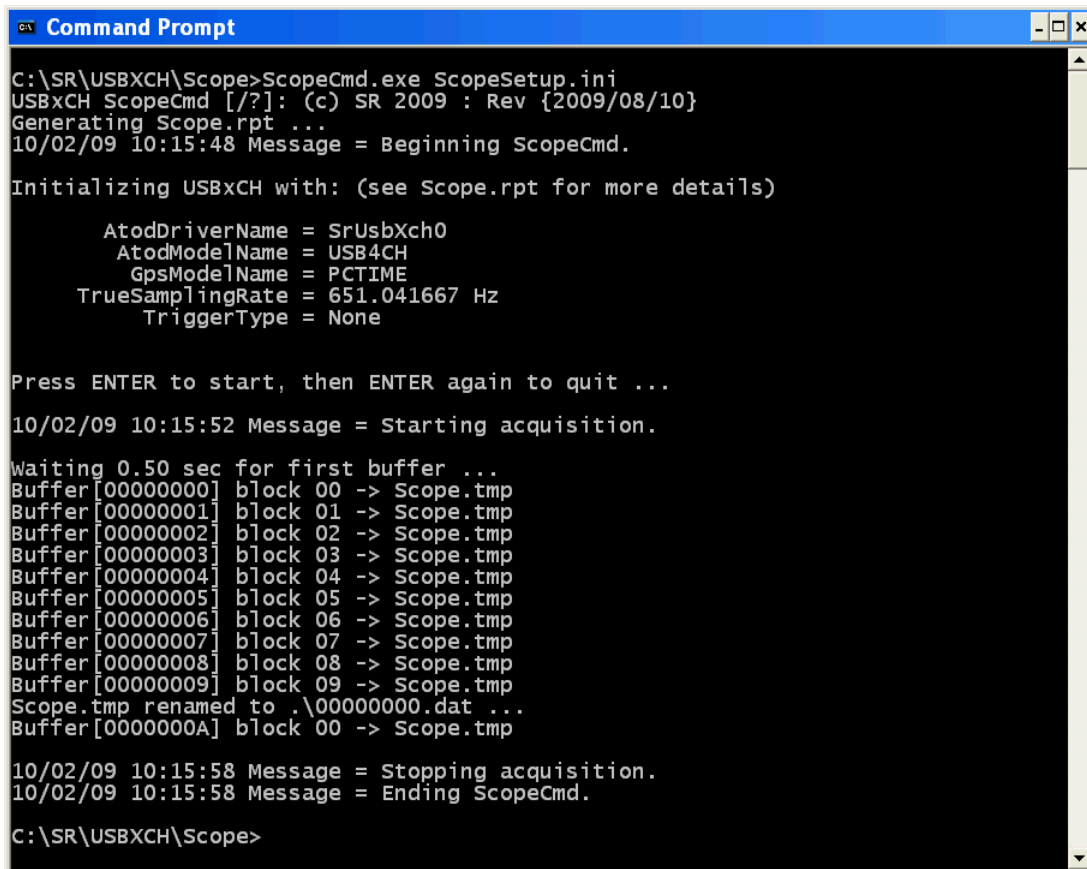
The four analog channels are displayed as horizontal traces, as well as the digital channels and GPS data too. The channel titles and enabling/disabling the display of particular channels can be specified in the ini file.

Across the top of the screen is an Alt menu with various program actions. With the Alt menus you can start and stop acquisition, edit the ini file, and bring up a help screen. Speed keys are available for keyboard users. As with DVM you can specify the text editor to use.

To change the Scope sampling rate you must edit and reload the ini file. Only rates from the [Rate Table](#) are permitted. Requested rates not on the rate table will be rounded to the nearest allowed rate. The sampling rate and other system parameters appear in the status bar at the bottom of the Scope window.

3.2.4 Scope: command line version

If you like the capabilities of ScopeGui, such as specifying sampling rates and DAT files, but want a text only display, then ScopeCmd may be a good match. The ScopeCmd screen looks like this:



```
C:\SR\USBXCH\Scope>ScopeCmd.exe ScopeSetup.ini
USBxCH ScopeCmd [/?]: (c) SR 2009 : Rev {2009/08/10}
Generating Scope.rpt ...
10/02/09 10:15:48 Message = Beginning ScopeCmd.

Initializing USBxCH with: (see Scope.rpt for more details)

    AtodDriverName = SrUsbXch0
    AtodModelName = USB4CH
    GpsModelName = PCTIME
    TrueSamplingRate = 651.041667 Hz
    TriggerType = None

Press ENTER to start, then ENTER again to quit ...
10/02/09 10:15:52 Message = Starting acquisition.

Waiting 0.50 sec for first buffer ...
Buffer[00000000] block 00 -> Scope.tmp
Buffer[00000001] block 01 -> Scope.tmp
Buffer[00000002] block 02 -> Scope.tmp
Buffer[00000003] block 03 -> Scope.tmp
Buffer[00000004] block 04 -> Scope.tmp
Buffer[00000005] block 05 -> Scope.tmp
Buffer[00000006] block 06 -> Scope.tmp
Buffer[00000007] block 07 -> Scope.tmp
Buffer[00000008] block 08 -> Scope.tmp
Buffer[00000009] block 09 -> Scope.tmp
Scope.tmp renamed to .\00000000.dat ...
Buffer[0000000A] block 00 -> Scope.tmp

10/02/09 10:15:58 Message = Stopping acquisition.
10/02/09 10:15:58 Message = Ending ScopeCmd.

C:\SR\USBXCH\Scope>
```

Figure 3.7: Scope CMD screen

If you don't want even this amount of display, there are ini keywords to turn the display off entirely. This can be useful for headless node single board computers only wanting to save their data to a file.

Note that ScopeCmd uses the same ini keywords as ScopeGui. You can refine keyword value selections with ScopeGui and then move them over to ScopeCmd without change.

3.2.5 Scope: output file names

Scope output files are saved to disk in the DAT file format. This is a binary format comprised of a header and data records, as described in the next section. This section describes the Scope output file name conventions.

Two ini keywords control the output file names and size:

```
OutputFileNaming = {NONE,YMDHMS,SINGLE}  
OutputFileNbuffers = N
```

OutputFileNaming specifies how individual output files are named. As Scope runs, it fills a temporary file `Scope.tmp`, and when full renames it according to:

NONE: turns off file output altogether. Use this option if you are setting Scope up for an experiment and don't want to save data yet.

YMDHMS: (default) creates a data subdirectory for the current Scope run with the name (year, month, day, hours, minutes, seconds) as given by the PC clock. Within the YMDHMS data directory, data is saved to `Scope.tmp` as it comes in. When filled, the temp file is renamed to `nnnnnnnn.DAT` with an 8 character sequential decimal name starting at `00000000.DAT`. A new YMDHMS data directory is created for each Scope Ctrl+R run and the sequential names will start again at 0. This filename convention is similar to the [Blast output filename convention](#).

SINGLE: renames the temporary file `Scope.tmp` to the single file named `Scope.dat`. You or downstream processing must remove `Scope.dat` before the next file is ready or an error will occur.

OutputFileNbuffers specifies the output file size. It controls how many acquisition buffers are saved to `Scope.tmp` file before it is given its permanent name and a new temp file is started. `N` can be any value between 1 and 4,294,967,295 (unsigned long).

The number of data samples per acquisition buffer varies with sampling rate and is selected so each buffer is about 1/2 second long. At a sampling rate of 130 Hz, for example, there will be 64 samples for each channel in one buffer. While at sampling rate of 2604 Hz, there will be 1302 samples for each channel in one buffer.

For more information on these and other ini keywords, refer to the file:

```
/SR/USBXCH/Scope/ScopeHelpIniSyntax.txt
```

3.2.6 Scope: DAT output file format

The binary DAT file format saves complete information about a data run, including analog, digital, GPS, and status parameters like temperature. Because binary files are smaller than ASCII, CPU and disk bandwidth requirements are reduced when saving data in real time. Most users will find it easiest to review DAT files by using the **Dat2Asc** and **View** utilities. With these utilities you don't need to know the internal binary structure of the DAT file to do offline downstream processing.

For those who are interested, the internal structure of a DAT file is detailed in the include file:

```
/SR/USBXCH/Include/SrDat.h
```

You may also wish to refer to the `Dat2Asc.c` source code for an example of how to decode the DAT data records. In general, a DAT file is comprised of a 4096 byte header, followed by data records.

The header itself is comprised of a C structure, `SrDatHdrLayout`, followed by zero padding to fill out the 4096 bytes. The fields in the header include items such as sampling rate, number of channels, etc. All of the the Scope ini keyword values are recorded in the header for a complete record of the acquisition run associated with the DAT file.

Data records follow the header and may have many different types of data. Analog, digital, GPS, and system information are all encoded in the records. Each data record starts off with a record tag giving the data type, and then the record information.

The record tag is itself a structure with an integer id indicating the type of record information following the tag structure. The following are a few of the record tag types:

```
#define SRDAT_TAGID_USBPACKET ((long)('BSUT')) // = "TUSB"
#define SRDAT_TAGID_USBANALOG ((long)('ABUT')) // = "TUBA"
#define SRDAT_TAGID_USBSERIAL ((long)('SBUT')) // = "TUBS"
#define SRDAT_TAGID_USBEQUIP ((long)('EBUT')) // = "TUBE"
#define SRDAT_TAGID_EOF ((long)('FOET')) // = "TEOF"
```

Refer to `SrDat.h` for a listing of all the record tags. Not all of the record types may appear in a specific DAT file. Within a record, data may be arranged according to the specific record type. See `Dat2Asc.c` for a decoding example.

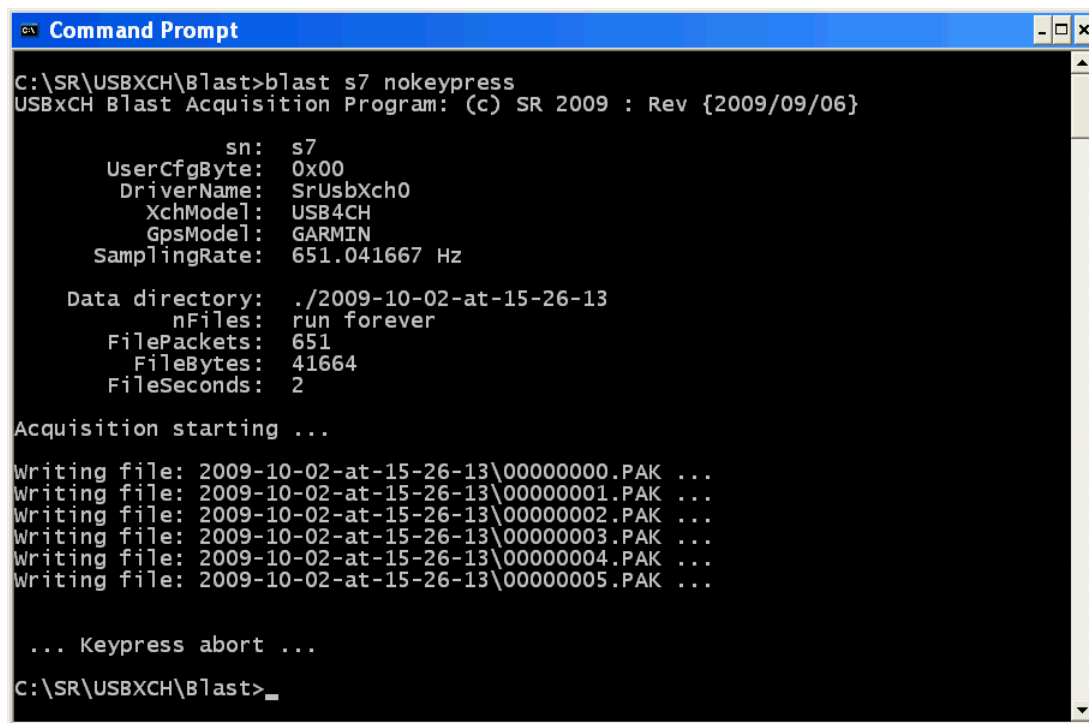
Note that because the DAT files have a header, they cannot be concatenated from the command line with the `> copy` command. Instead, use the `Dat2Asc` sequential processing feature to process multiple files.

3.3 Blast

Blast is a USBxCH acquisition program designed to use the minimum PC resources possible. It is started from the command line and saves its data to disk as **PAK** files comprised of native USB binary packets.

The sole purpose of Blast is to save data to disk quickly. It does not have a GUI display or even a real time text display of the data. If you need a text display of the data, please refer to **DvmCmd** or **ScopeCmd**. Because it uses the minimum PC resources possible, Blast is a good match if you need to make the most of the CPU and disk bandwidth available on a particular computer.

Use the **Pak2Asc** and **View** utilities for easy ways to review PAK output files. If you are writing custom software, Blast is also a good example to use as a starting point for your source code development. By comparison, DVM and Scope have much more complicated user interfaces. The following sections review particular aspects of running Blast.



```
Command Prompt
C:\SR\USBXCH\Blast>blast s7 nokeypress
USBxCH Blast Acquisition Program: (c) SR 2009 : Rev {2009/09/06}

      sn: s7
  UserCfgByte: 0x00
    DriverName: SrUsbXch0
      XchModel: USB4CH
      GpsModel: GARMIN
  SamplingRate: 651.041667 Hz

  Data directory: ./2009-10-02-at-15-26-13
        nFiles: run forever
    FilePackets: 651
     FileBytes: 41664
    FileSeconds: 2

Acquisition starting ...

Writing file: 2009-10-02-at-15-26-13\00000000.PAK ...
Writing file: 2009-10-02-at-15-26-13\00000001.PAK ...
Writing file: 2009-10-02-at-15-26-13\00000002.PAK ...
Writing file: 2009-10-02-at-15-26-13\00000003.PAK ...
Writing file: 2009-10-02-at-15-26-13\00000004.PAK ...
Writing file: 2009-10-02-at-15-26-13\00000005.PAK ...

... Keypress abort ...
C:\SR\USBXCH\Blast>
```

Figure 3.8: Typical Blast display

3.3.1 Blast: starting the program

Start Blast from the command line. There is no ini file associated with Blast as with DVM or Scope. All user options are specified on the command line. The syntax is:

```
cmd:prompt> Blast sn [gn] [nFiles] [nokeypress] [0xUC] [/?]
```

where [] indicates the parameter is optional. Running without any command line parameters or /? will give a usage message. The other command line parameters are:

"sn": specifies the USBxCH sampling rate and must be one of the following:

Blast sampling rate table:

sn	->	SPS(Hz)	PACKETS/FILE	BYTES	~ SECONDS
s1		19.531250	47	3008	5
s2		32.552083	64	4096	4
s3		39.062500	78	4992	4
s4		65.104167	97	6208	3
s5		78.125000	117	7488	3
s6		130.208333	130	8320	2
s7		651.041667	651	41664	2
s8		1302.083333	1302	83328	2
s9		2604.166667	1302	83328	1
s10		4882.812500	2441	156224	1
s11		9765.625000	4882	312448	1

Specifying the "sn" sampling rate also automatically sets the output file size. The output PAK files are measured in USB packets, with 64 bytes per packet. The approximate number of seconds of data in each output file is also listed.

"gn": specifies the time source to use and must be one of the following:

Time source table:

g0	->	NONE
g1	->	PCTIME << default
g2	->	GARMIN (NMEA = RMC, GGA)
g3	->	TRIMBLE (NMEA = ZDA, GGA)

If you have a GPS antenna, specify the proper "gn" number to generate time stamps based on its signals. For users without GPS antennas, the PCTIME option uses the PC

clock as the time source. Note that if PCTIME is the time source, then the PC clock will provide time, *even if a GPS antenna is connected to the system*. To process GPS time you must specify a GPS source. For details about using GPS with the USBxCH, see the [GPS Time Stamping](#) chapter.

nFiles: specifies how many total output files will be created. Blast will terminate once nFiles have been written. If **nFiles** is not given, the program will create output files forever, or until a keypress is made. You can also terminate the program from the operating system with Task Manager.

nokeypress: specifies Blast is to start acquiring data with no keypress required. The default behavior waits for a keypress to begin acquiring so you can have a chance to read the on screen run time summary message.

UserCfg: is passed to the Open function inside Blast. See the User C Library for information about [Open](#), and the [User configuration byte](#) for bit assignments. UserCfg should be a two digit C style hex number, like 0x14.

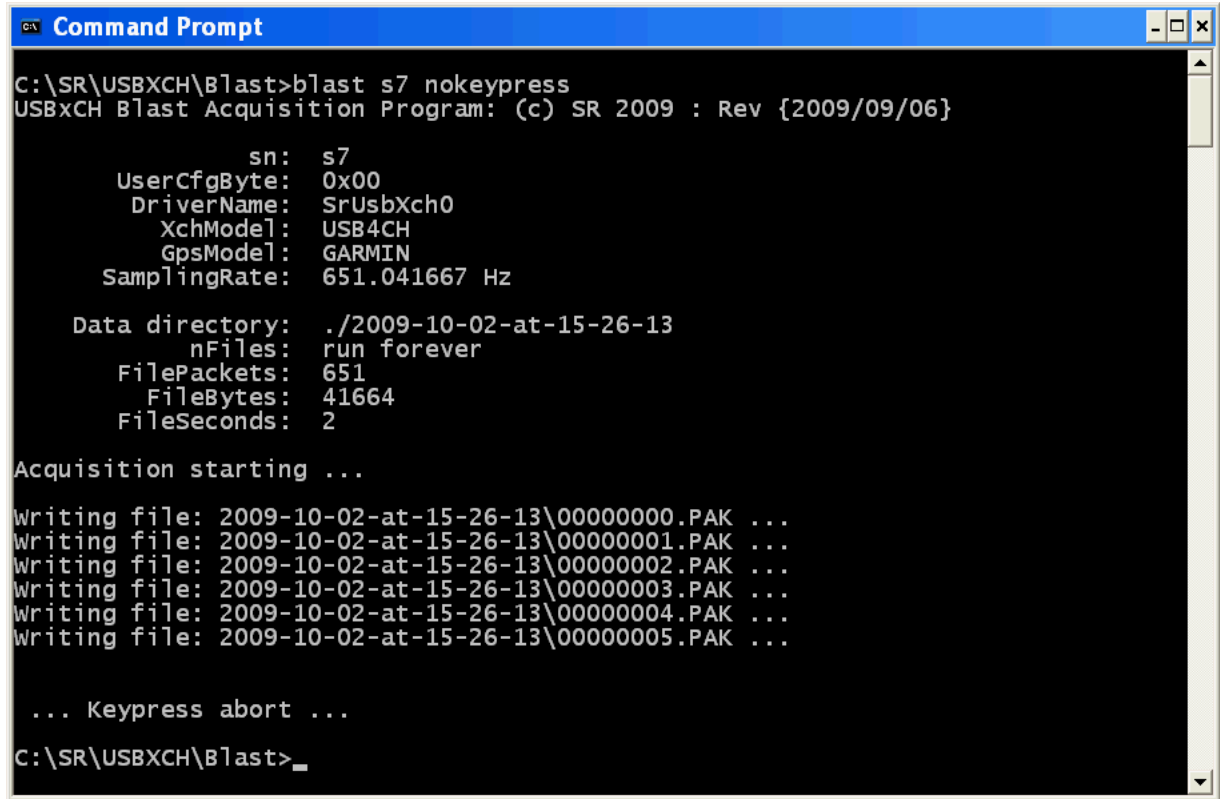
When starting up, Blast will display a summary report of the parameters it is running with on the screen. This gives you an opportunity to verify the system is actually using the parameters specified on the command line. A copy of the summary report with the filename "000 Blast Run Summary.rpt" is also placed in the YMDHMS data directory for a permanent record of the run.

After the summary display, output files will be listed on the screen as they are created. Output files are all placed in the YMDHMS data directory for the particular run. See the next section for a complete description. Each time Blast runs, a new data directory is created. When running with **nFiles** not specified, output files will be created forever. You can terminate the run by pressing 'q' on the keyboard, or killing the Blast process with the Task Manager.

A few typical Blast command lines are:

<code>blast s3</code>	< acquire at 39Hz, use PC TIME
<code>blast s3 g0</code>	< acquire at 39Hz, without any time stamps
<code>blast s3 g2</code>	< acquire at 39Hz, with a Garmin antenna
<code>blast s10 nokeypress</code>	< acquire at 4.8kHz, no keypress to start
<code>blast s11 0x04</code>	< acquire at 9.7kHz, enable Adrdy on DB25
<code>blast s8 100</code>	< acquire 100 files at 1.3kHz
<code>blast s8</code>	< acquire forever at 1.3kHz, 'q' quits

Starting Blast with: > blast s7 g2 nokeypress results in the screen:



```
Command Prompt
C:\SR\USBXCH\Blast>blast s7 nokeypress
USBxCH Blast Acquisition Program: (c) SR 2009 : Rev {2009/09/06}

      sn:      s7
  UserCfgByte: 0x00
   DriverName: SrUsbXch0
     XchModel: USB4CH
     GpsModel: GARMIN
  SamplingRate: 651.041667 Hz

  Data directory: ./2009-10-02-at-15-26-13
        nFiles: run forever
   FilePackets: 651
    FileBytes: 41664
   FileSeconds: 2

Acquisition starting ...

Writing file: 2009-10-02-at-15-26-13\00000000.PAK ...
Writing file: 2009-10-02-at-15-26-13\00000001.PAK ...
Writing file: 2009-10-02-at-15-26-13\00000002.PAK ...
Writing file: 2009-10-02-at-15-26-13\00000003.PAK ...
Writing file: 2009-10-02-at-15-26-13\00000004.PAK ...
Writing file: 2009-10-02-at-15-26-13\00000005.PAK ...

... Keypress abort ...

C:\SR\USBXCH\Blast>
```

Figure 3.9: Blast text screen

This particular run did not specify **nFiles** and thus will create output files forever. The endless run was aborted with a 'q' keypress.

For users preferring to execute by double clicking, there are several batch files in the Blast directory with preset options. From Windows Explorer, double click on these batch files to run. The command prompt screen will automatically display and look like the above. Copy, edit, and change the batch files if you wish to run with with other parameters. You may also create shortcuts to the batch files.

3.3.2 Blast: output file names

Blast output files are saved to disk in the PAK file format. This is a binary format comprised of 64 byte packets exactly as received from the USB cable. Packet format is briefly summarized in the next section. This section describes the output filename conventions.

When Blast is started, a data directory with the name YMDHMS is automatically created. YMD stands for (year, month, day) and HMS for (hours, minutes, seconds). The data directory name is formatted as:

2009-05-01-at-23-11-06

which should be read as: a Blast run was started on (2009/05/01) at (23:11:06). The YMDHMS convention keeps the data directories well ordered when sorted by name. Within a data directory for a particular run, Blast creates sequential file names like:

```
./2009-05-01-at-23-11-06/00000000.PAK
./2009-05-01-at-23-11-06/00000001.PAK
./2009-05-01-at-23-11-06/00000002.PAK
./2009-05-01-at-23-11-06/00000003.PAK
./2009-05-01-at-23-11-06/00000004.PAK
./2009-05-01-at-23-11-06/00000005.PAK

etc ...
```

The location `./` is where Blast was started. The next time Blast is run, a new data directory will be created with the new YMDHMS start time, and the sequential file names will start all over again at 00000000.PAK.

Output files are fixed in size as described in the previous section. Use the [Pak2Asc](#) utility to convert an entire series of sequential PAK files to ASCII format with one call.

If necessary, PAK files can be concatenated with the `copy` command. Because they are binary, you *must* use the `copy /b` option. End of file `ctrl+z` characters are inevitably buried in the binary PAK data and the `/b` option is required to process them correctly. PAK files *must also be concatenated in acquisition order*. If two files are concatenated in a different order than they were acquired, then the error correction codes will not track. As an example, if you have a directory with a long sequence of files then the command:

```
cmd:prompt> copy /b 0*.PAK OneSingleFile.pak
```

will concatenate all of them into a single PAK file which can be further processed. Usually concatenation is not required when using `Pak2Asc`.

3.3.3 Blast: PAK output file format

Data is transmitted from the USBxCH to the PC in 64 byte packets over the USB cable. To maximize bandwidth, Blast saves these native packets directly to its output files without any processing. The output files are all given the PAK filename extension to make them easy to identify. PAK stands for packet format.

A USBxCH packet has considerable internal structure. Within the 64 bytes, the data could be analog, digital, GPS PPS, GPS NMEA strings, system status, or error correction codes. Each packet has headers to identify its type and substructure. For most users, the easy way to deal with PAK files is to use the [Pak2Asc](#) or [View](#) conversion utilities.

For those who are interested in the binary PAK format, here is the layout:

Work underway ...

3.3.4 Blast: typical post processing

Beyond **Pak2Asc** and **View**, users may want to automate post processing data from *multiple* acquisition runs. One way is to use batch files to customize the data flow to exactly fit your needs. This section covers a few techniques.

Suppose you have data from several acquisition runs in YMDHMS directories:

```
2009-09-21-at-11-32-45/ ...
2009-09-21-at-11-33-26/ ...
2009-09-21-at-11-33-41/ ...
2009-09-21-at-11-58-15/ ...
2009-09-21-at-13-40-36/ ...
2009-09-21-at-15-03-47/ ...
2009-09-21-at-15-20-15/ ...
```

where ... indicates there are many sequential files in each directory. It is hard to know what all the directory names are, and you probably don't want to type them in with each new set of runs. To process all of these directories automatically, use a text editor to put the following line in a file:

```
@for /D %%i in (20??-*) do Pak2Asc.exe %%i/00000000.pak fw
```

Usually batch files are given a **.bat** extension. To execute a batch file, type its filename on the command line, or double click from Windows Explorer. In the **@for** line, parameter replacement will be done on the **%%i** variable, invoking the command following the **do** on every directory matching the wildcard pattern (20??-*). The batch file:

```
Pak2Asc Convert All.bat
```

in the Blast directory implements the **@for** line given above. In batch file programming, the command following "do" can even be comprised of many subcommands using **&**. For example, the following:

```
@for /D %%i in (20??-*) do cd %%i & ren *.pak *.bin & cd ..
```

would descend into each directory and rename all the pak files to have a **.bin** extension. With batch files you can process a great deal of data very quickly.

For information about batch file programming search on phrases like "command-line reference" or "batch files" in the Windows help system. Linux also has similar command line script programming.

3.3.5 Blast: running in the background

For many applications, running Blast as a background task is useful. Under Windows use the Task Scheduler to setup Blast as a background job. With Task Scheduler, you can start at a specified time, periodically, or automatically on startup. All quietly in the background while the computer can attend to other tasks. Under Linux, use the `&` command line qualifier. The USBxCH on board FIFO makes it unlikely any data will be lost even if the PC cannot serve the Blast background task immediately.

One problem that comes up with background execution is what to do with screen output. The solution is to redirect any screen display to a file with the `>` operator. The following would be typical:

```
cmd:prompt> Blast s4 nokeypress > report.txt
```

Besides saving screen output in the `report.txt` file, the Blast `nokeypress` option will start acquisition with no keyboard interaction required. Note that the above Blast command line runs continuously, saving files until the process is killed with Task Manager or the `taskkill` command. From Linux use the `kill` command.

Chapter 4

Utilities and Format Conversion

Besides the **DVM**, **Scope**, and **Blast** applications, several smaller utilities are also provided for use with the USBxCH. They cover a number of basic tasks, with most intended for processing data offline once it has been acquired. Popular utilities are **Dat2Asc** and **Pak2Asc** for converting binary DAT and PAK files to ASCII. Other utilities are:

- ▷ **Diag** general system hardware diagnostic
- ▷ **DevMan** USBxCH device driver management
- ▷ **Dat2Asc** convert Scope binary DAT data files to ASCII
- ▷ **Pak2Asc** convert Blast binary PAK data files to ASCII
- ▷ **Interpolate** change time base and sampling rate of saved DAT files
- ▷ **View** review and display DAT and PAK files
- ▷ **NmeaTime** report the NMEA strings / set PC time for systems with GPS
- ▷ **GpsProg** program a GPS antenna through the USB port
- ▷ **DigitalIo** twiddle the DB25 digital io bits
- ▷ **SetDid** set the USB DID for multiboard installations

Source code is included, and users are encouraged to use it as a starting point for developing their own custom utilities. There may be additional utilities available with the software distribution besides those listed above, see the **ReadMe.txt** files for information.

Most of the utilities are command line oriented, and have options that may be specified. Executing without any options will give a help screen. Under Windows, shortcut icons are also available that may be double clicked to run with defaults. The following sections cover each utility and their options.

4.1 Diag

Diag should be used to verify correct operation of the USBxCH after installation or if you ever have any doubts about the hardware. It is the Swiss Army knife of USBxCH hardware maintenance.

The Diag command line syntax is:

```
cmd:prompt> Diag test [gn] [driver] [/?]
```

where [] indicates the parameter is optional. Running without parameters or with /? will give a usage message. The other command line parameters are:

test: is required and specifies the particular test to run. The following are a few of the available tests. See the /? usage message for the full list:

install	= Installation test suite (dev,power,led,analog,nmea)
debug	= Debug tests for customer support
dev	= Show device descriptor
power	= Check if power is good
led	= Toggle the yellow LED
analog	= Start A/D's and display analog data
nmea	= Start A/D's and display NMEA strings
equip	= Start A/D's and display equipment info like temp
digin	= Read digital input
digout	= Send digital output
dram	= Run several DRAM FIFO tests
rev	= Get firmware revision number
reset	= Hardware reset USBxCH board with full power cycle

gn: specifies a time source. If not specified, the PC clock will be used as the time source. See [GPS Time Stamping](#) for more information.

g1	->	PCTIME	(NMEA = ZDA)	<< default
g2	->	GARMIN	(NMEA = RMC, GGA)	
g3	->	TRIMBLE	(NMEA = ZDA, GGA)	

driver: this option is required only if you are running multiple USBxCH boards on a single PC with the names (SrUsbXch0 .. SrUsbXch9). For a list of installed driver names use the [DevMan](#) utility. See [SetDid](#) for specifying the name associated with a particular board. *Single board users should not specify this parameter, accepting the factory default SrUsbXch0.*

As part of any new installation, users should run:

```
cmd:prompt> Diag install
```

This carries out a series of tests to confirm the driver is correctly installed and the basic hardware is functioning. Windows users may also double click on the "Run Diag Install" shortcut rather than executing from the command line.

If you feel the USBxCH has developed a hardware problem after running successfully for awhile, then run:

```
cmd:prompt> Diag debug
```

and email the files:

```
/SR/USBxCH/Utilities/Diag/"300 Diag History.log"  
/SR/USBxCH/Utilities/Diag/"301 Diag Last Run.rpt"
```

to Symmetric Research for technical help. *Do not delete earlier entries in the history log. They may provide clues for debugging.*

```
SR help email address:  info@symres.com
```

4.2 DevMan

DevMan is a command line utility to manage USBxCH device drivers once installed on a PC. For initial driver installation rely on the operating system Plug and Play capabilities as described in the [Getting started](#) chapter.

The DevMan command line syntax is:

```
cmd:prompt> DevMan [showall] [wakeall] [removeall] [/?]
```

where only one optional parameter may be specified at a time, and running without any options or with a `/?` will give a usage message. The parameters are as follows:

showall: scans the registry for all USBxCH references, showing both active and inactive instances. Also shows the related sys and inf files in the Windows driver directories. Plugging a USBxCH into different USB ports on the PC results in an instance of the USB driver each time. This option shows all symbolic device names, and current status for each instance.

wakeall: if the PC is put into a sleep state while USBxCH devices are plugged in and active, they will not be active on wakeup. This is an acknowledged OS level error for Windows and self powered USB devices. Running DevMan wakeall will wakeup all connected USBxCH devices after PC sleep.

removeall: deletes all USBxCH registry entries, and all driver sys and inf files in the Windows directories. If you want to clean the system of earlier driver revisions and force plug and play to load a new driver version, then use removeall.

Many of the tasks addressed by DevMan can also be carried out by hand in the Windows GUI Device Manager. Using the DevMan command line program is safer for most users, since its operations are specifically targeted at the USBxCH. It is difficult to compromise the computer with DevMan, while with Windows Device Manager you are exposed to drivers for all the hardware serving the system.

If you have forgotten the symbolic device name of a particular USBxCH, use the **showall** option to refresh yourself. For information on running multiple USBxCH systems on a single PC refer to the Examples and Experiments section [Multiple USBxCH](#).

4.3 Dat2Asc

DatAsc converts the binary DAT files generated by programs like **Scope** to ASCII format. The ASCII output is in columns that are easily readable in a text editor, as well as being suitable for importing into spreadsheet and analysis programs.

The Dat2Asc command line syntax is:

```
cmd:prompt> Dat2Asc filename format [/?]
```

where the **filename** and **format** parameters are required. Running without parameters or with a **/?** will give a usage message. The filename and format are as follows:

filename: specifies the DAT input file. A **.dat** filename extension is customary but not required. If the input file is not in DAT format, Dat2Asc will detect it and terminate with an error. A full file pathname may be given, and then both the input and output are directed to the indicated path.

If the filename has the form **nnnnnnnnn.dat**, sequential processing is initiated, and Dat2Asc will automatically look for and process the **n+1** file. For sequential mode, the starting filename *must be eight decimal digits* with a **.dat** extension. Note the filename **0.dat** has fewer than eight decimal digits and *will not* initiate sequential processing.

format: specifies the ASCII output format, where format may be:

fw	= fixed width ASCII columns
fw_hex	= fw with hex instead of decimal fields
fw_debug	= fw with low level debugging info
csv	= comma separated values
csv_hex	= csv with hex instead of decimal fields
csv_debug	= csv with low level debugging info
raw	= record format, for debugging only

The fixed width formats are easy to view by eye in text editors, while the csv formats are easiest to import into downstream processing programs like GnuPlot and Excel. A typical Dat2Asc command line for sequential processing might be:

```
cmd:prompt> Dat2Asc ./mydatadirectory/00000000.dat csv
```

this will convert all of the sequential files in `mydatadirectory`, leaving the results there in a single large ASCII file. Conversion is a multipass process with intermediate files. The names of the files created by Dat2Asc are:

```
Dat2Asc-100-TimeInfoSample.asc  
Dat2Asc-101-TimeInfoStatus.asc  
Dat2Asc-102-TimeInfoEquip.asc  
Dat2Asc-200-TimeInfoAll.asc  
Dat2Asc-300-Nmea.asc  
Dat2Asc-301-Data.asc
```

The last file, `Dat2Asc-301-Data.asc`, is the name of the final large output file with all of the combined data. For csv formats, the final data file will be given a `.csv` extension. The intermediate files may also have information you find useful.

Dat2Asc has verbose screen output. It reports the input files it processes, information about each processing step, and the files created. To run silently, simply redirect the screen output to a report file with:

```
cmd:prompt> Dat2Asc 00000000.dat fw > dat2asc.rpt
```

Techniques for automating the processing of data from multiple acquisition runs is covered in the Blast section [typical post processing](#). For a ready to go example see the batch file:

```
/SR/USBXCH/Utilities/Scope/"Dat2Asc Convert All.bat"
```

For an example of importing ASCII data into a plotting program see the Examples and Experiments section [GnuPlot](#). The techniques used with GnuPlot are similar to those that would be used with other plotting and analysis programs.

4.4 Pak2Asc

Pak2Asc converts the binary PAK files generated by programs like **Blast** to ASCII format. The ASCII output is in columns that are easily readable in a text editor, as well as being suitable for importing into spreadsheet and analysis programs.

The Pak2Asc command line syntax is:

```
cmd:prompt> Pak2Asc filename format [/?]
```

where the **filename** and **format** parameters are required. Running without parameters or with a **/?** will give a usage message. The filename and format are as follows:

filename: specifies the PAK input file. A **.pak** filename extension is customary but not required. If the input file is not in PAK format, Pak2Asc will detect it and terminate with an error. A full file pathname may be given, and then both the input and output are directed to the indicated path.

If the filename has the form **nnnnnnnnn.pak**, sequential processing is initiated, and Pak2Asc will automatically look for and process the **n+1** file. For sequential mode, the starting filename *must be eight decimal digits* with a **.pak** extension. Note the filename **0.pak** has fewer than eight decimal digits and *will not* initiate sequential processing.

format: specifies the ASCII output format, where format may be:

fw	= fixed width ASCII columns
fw_hex	= fw with hex instead of decimal fields
fw_debug	= fw with low level debugging info
csv	= comma separated values
csv_hex	= csv with hex instead of decimal fields
csv_debug	= csv with low level debugging info
raw	= packet format, for debugging only

The fixed width formats are easy to view by eye in text editors, while the csv formats are easiest to import into downstream processing programs like GnuPlot and Excel. A typical Pak2Asc command line for sequential processing might be:

```
cmd:prompt> Pak2Asc ./mydatadirectory/00000000.pak csv
```

this will convert all of the sequential files in `mydata` directory, leaving the results there in a single large ASCII file. Conversion is a multipass process with intermediate files. The names of the files created by Pak2Asc are:

```
Pak2Asc-100-SamplePackets.pak
Pak2Asc-101-StatusPackets.pak
Pak2Asc-200-TimeInfoSample.asc
Pak2Asc-300-TimeInfoStatus.asc
Pak2Asc-301-Nmea.asc
Pak2Asc-400-TimeInfoAll.asc
Pak2Asc-500-Data.asc
```

The last file, `Pak2Asc-500-Data.asc`, is the name of the final large output file with all of the combined data. For csv format, the final data file will be given a `.csv` extension. The intermediate files may also have information you find useful.

Pak2Asc has verbose screen output. It reports the input files it processes, information about each processing step, and the output files created. To run silently, simply redirect the screen output to a report file with:

```
cmd:prompt> Pak2Asc 00000000.pak fw > pak2asc.rpt
```

Techniques for automating the processing of data from multiple acquisition runs is covered in the Blast section [typical post processing](#). For a ready to go example, see the batch file:

```
/SR/USBXCH/Utilities/Blast/"Pak2Asc Convert All.bat"
```

For an example of importing ASCII data into a plotting program see the Examples and Experiments section [GnuPlot](#). The techniques used with GnuPlot are similar to those that would be used with other plotting and analysis programs.

4.5 Interpolate

Interpolate translates data acquired at one sampling rate to another time base.

Work underway ...

4.6 View

View is a GUI application displaying the data from DAT files as horizontal traces on the screen. The display looks much like Scope, except the user can scroll left and right for a detailed off line review.

Work underway ...

4.7 NmeaTime

NmeaTime reads and displays NMEA strings from the GPS system, and optionally also sets the PC clock. It is intended as stand alone utility and *is not required for time stamping analog data*. Programs like Scope and Blast will automatically time stamp data with better accuracy because they also process PPS.

The NmeaTime command line syntax is:

```
cmd:prompt> NmeaTime [gn] [forever] [set] [0xUC] [driver] [/?]
```

where [] indicates the parameter is optional. Running without parameters or with /? will give a usage message. The other command line parameters are:

"gn": specifies the type of GPS receiver attached to the system and must be one of the following:

Time source table:

g1	->	PCTIME	(NMEA = ZDA)	<< default
g2	->	GARMIN	(NMEA = RMC, GGA)	
g3	->	TRIMBLE	(NMEA = ZDA, GGA)	

For details about using GPS with the USBxCH, see the [GPS Time Stamping](#) chapter. Note that even if you have a GPS antenna attached to the system, NmeaTime will still default to the g1 PCTIME option with synthetic ZDA strings. The correct time source (g2,g3,...) *must* be specified for NmeaTime to display strings from that source.

forever: indicates NMEA strings should be acquired and displayed continuously until a 'q' keypress is made. If not specified, the NMEA string display will stop after the first string with a valid satellite count is received.

set: sets the PC time from the first valid NMEA string. Since NMEA strings are sent from the GPS antenna only once every second, the accuracy of the PC clock will be no better than 1 second. For more accurate time, use the time stamping capabilities of Scope or Blast. If you wish to use NmeaTime to periodically set the PC clock, set it up as a periodically scheduled task with the operating system.

0xUC: sets the User Configuration Byte. You may require the UC byte if you are running from an antenna with non standard signals. An example would be for an antenna with inverted RS232 polarity. See the GPS Time Stamping chapter for more details.

driver: if you are running a multiboard system, specify the name of the USBxCH board NmeaTime should use. Must be one of (`SrUsbXch0` .. `9`). If not specified will default to `SrUsbXch0`.

Note that if the GPS antenna has been programmed to emit more or different strings than are expected by one of the NmeaTime "**gn**" options, then it will not work correctly. You may get truncated versions of the strings if there are too many, or the PC time may not be set because there is not enough time information in the strings you are emitting. *Check the results of NmeaTime before assuming they are correct.*

Also be aware the NmeaTime utility *cannot be run concurrently* while Scope or Blast is running. Only one program at a time can have the USBxCH device driver open, and other programs will be excluded. The NmeaTime **set** option is not intended to time stamp analog data from Scope or Blast. It is intended for those who wish to set their PC clock to one second accuracy while booting, or at other periodic times, as an independent stand alone task. Scope and Blast will automatically time stamp data as part of their normal operation.

A few typical NmeaTime command lines might be:

```
cmd:prompt> NmeaTime forever
cmd:prompt> NmeaTime g2
cmd:prompt> NmeaTime g2 forever
cmd:prompt> NmeaTime g2 set
```

The first will display synthetic ZDA strings from the PC clock continuously until 'q' is pressed. *Even if a GPS antenna is connected to the system*, note that the **g1** default of the first command displays the synthetic PC clock ZDA strings. The second command will display strings from a Garmin antenna until satellite lock is achieved. The third command line will continue displaying strings even after satellite lock has been achieved. The fourth command will set the PC clock from the Garmin strings, quitting once satellite lock has been obtained.

4.8 GpsProg

GpsProg is a command line utility for programing a GPS antenna. With it you can set antenna features like NMEA string line up and PPS enable, *while the antenna is connected to the USBxCH*. You cannot set the NMEA RS232 baud rate with GpsProg. That is assumed to always be 4800 baud by the USBxCH. If your receiver has a different baud rate, you will have to use its manufacturer utilities to program it to 4800.

Work underway ...

Once your antenna is programmed, use the **NmeaTime** utility to check its NMEA string lineup while connected to the USBxCH. Make sure it agrees with that described in the **GPS Time stamping** chapter. Also make sure the PPS is active by watching the USBxCH front panel red led for a 1 second toggle.

4.9 DigitalIo

DigitalIo is a small command line utility for twiddling the USBxCH front panel DB25 digital IO pins. After starting up, the user is prompted for output values and they are written to the port. Besides programming the output pins, the four DB25 input pins are read and displayed on the screen as part of programming each value. For the pin number locations, see the [DB25 pin assignments](#).

The DigitalIo command line syntax is:

```
cmd:prompt> DigitalIo [driver] [/?]
```

where `driver` is optional and indicates the particular USBxCH to program. It should be one of (`SrUsbXch0` .. `9`) for multiboard USBxCH installations.

Output values are specified as single hex digits. A value of `3` would result in the bit pattern (0,0,1,1) with the least significant bit on the leftmost DB25 pin, while a value of `F` would result in (1,1,1,1). The values on the pins are latched, with the same value remaining until the next value is specified.

Note that programs like Scope and Blast *synchronously save the digital inputs along with the analog inputs* automatically. The effect is the same as a mixed signal digital oscilloscope. For most applications you do not need the DigitalIo utility to save the digital inputs.

4.10 SetDid

SetDid programs the board level EEPROM DID identifiers for multiboard installations. Use this utility to set the driver names when you wish to prepare several boards to be connected to a single PC all at once.

The SetDid command line syntax is:

```
cmd:prompt> SetDid [driver] [0-9] [showall] [/?]
```

where [] indicates the parameter is optional. Running without parameters or with /? will give a usage message. The other command line parameters are:

driver: specifies an existing USBxCH board to program with a new DID. This parameter must be one of (**SrUsbXch0** ... **9**). The board driver name will change accordingly when programmed with a new DID.

0-9: new DID value to program the board EEPROM with. The new DID must be a single digit (0 ... 9). After programming, the board will have the new driver name **SrUsbXchN** where N is the new DID number. If you want to program the board back to its original DID, you must specify the new **driver** name when calling SetDid.

showall: scans the PC for all **SrUsbXchN** that are installed. The scan is done by calling **Open()** sequentially on each of the (**SrUsbXch0** ... **9**) symbolic device names. A list of who responds and who doesn't is displayed. Use the **showall** option before and after programming to check the results are what you expected.

USB devices are identified by three numbers, their (VID/PID/DID) numbers, standing for the *vendor*, *product*, and *device* id respectively. The VID and PID are fixed for a particular vendor and product, while DID numbers are free to change as needed. Sometimes the DID is used to indicate a firmware revision, however it may also be used to distinguish between multiple devices of the same type connected to a single PC. The second meaning is used with the USBxCH, where up to 10 boards may be connected to a single PC at a time. The multiple devices are referred to as **SrUsbXch0**, **SrUsbXch1**, etc where the trailing digit is the same as the DID id number.

The USBxCH product is shipped from the factory with its on board EEPROM DID programmed to 0. This is suitable for computers with a single USBxCH attached. All of the ini files supplied with software like Scope and Blast are set up to use the device driver name **SrUsbXch0**.

If you wish to run multiple USBxCH on a single PC, *attach one at a time to the machine* and run SetDid to specify the new DID you wish each to have. Then create the corresponding

ini initialization files or command line arguments to refer to the particular board you desire. This way you can run multiple instances of Scope for example with each referring to its respective USBxCH board.

Note that you cannot have two boards with the same DID value connected to the PC at the same time. The second board will fail to install. In this situation, connect the boards one at time, programming each with a unique DID number, and try again. Also note that if you forget the DID number of a particular board, then you won't know the driver name for it. In this case run `SetDid showall` to scan for the board.

For step by step instructions on setting up a multiboard installation, see the Examples and Experiments section [Multiple USBxCH](#).

If the machine registry has become a mess and you need to clean up for a completely new start, run `DevMan removeall`. This will delete all USBxCH instances and you will have a clean start for the next plug and play event.

Chapter 5

User C Library

For those writing their own custom software, a function library is provided for controlling the USBxCH. The library is written in C and follows C calling conventions. It is supplied both as a static LIB and a dynamic DLL for either style of linking. Programs written in languages such as Basic and LabView can use the DLL library by specifying C calling conventions and including SrUsbXch.dll on their search paths.

If your primary goal is to acquire data and save it to disk, we recommend using **DVM**, **Scope**, or **Blast** for most users. These finished programs have been tested and checked for many error conditions. Once data has been saved to disk with one of them, it is relatively easy to post process and generate different displays or data formats.

If you are writing your own acquisition programs with the User Library, we recommend studying the source code for Blast. It shows the typical sequence of library function calls and can serve as a guide for development.

The following sections review each library function one per page. Note that all function names are preceded with *SrUsbXch* so they will be easy to find in source code, but that the functions are often referred to only by their base names.

5.1 Open

Include file: `SrUsbXch.h`

Prototype:

```
DEVHANDLE SrUsbXchOpen(  
  
    char *DriverName,  
  
    int XchModel,  
    int GpsModel,  
    int UserCfgByte,  
    double Sps,  
  
    double *ActualSps,  
    int *Error  
);
```

This function opens and initializes the USBxCH device driver and hardware. If successful, the system is ready to go with no other initialization required. The Open parameters set the sampling rate and other user selectable features. If you want to change the parameters, call **Close** and then Open again with the new settings.

The DEVHANDLE returned by Open should be passed to the other library functions to specify a particular USBxCH. Several systems can be installed on one computer, each with its own handle. Note that opening a particular USBxCH is exclusive, and calls to Open with the same **DriverName** by other processes will fail until a Close of the handle by the current process is done.

The function parameters are:

DEVHANDLE SrUsbXchOpen() (*function return*):

If successful, Open will return a valid device handle for subsequent use with other library functions. If Open has failed, the value `BAD_DEVHANDLE` will be returned. For a more detailed reason for the failure, check the Error return argument described below.

DriverName (*input string*):

This parameter must point to a C style character string with the USBxCH device name. Valid names are: `SrUsbXch0`, `SrUsbXch1`, ...

XchModel (*input parameter*):

Specifies the USBXCH hardware model. The four channel USBxCH is the only model currently available, and **XchModel** must equal 0x20.

GpsModel (*input parameter*):

Specifies the GPS antenna being used with the USBXCH. The following values are valid, where the constant names are defined in `SrUsbXch.h`:

0	SRDAT_GPSMODEL_NONE
1	SRDAT_GPSMODEL_TRIMBLE
2	SRDAT_GPSMODEL_ONCORE
3	SRDAT_GPSMODEL_PCTIME
4	SRDAT_GPSMODEL_GARMIN

Users that do not have a GPS receiver should use `NONE` or `PCTIME`. See the Chapter [GPS Time stamping](#) for more detail.

UserCfgByte (*input parameter*):

This byte specifies a number of digital and GPS configurations for the DB25 connector on the front panel. Among the configurable items are whether to enable or disable the DB25 Adrdy, setting the PPS idle state, and others. See Chapter 12 and the [UserCfgByte](#) table.

SPS (*input parameter*):

Specifies the sampling rate in Hz. This value should be one of the rates from the [Rate Table](#) in Chapter 6. It is not necessary to specify the rate exactly, it will be automatically rounded to one of the allowed rates. All USBxCH channels are programmed in parallel with the same sampling rate.

ActualSps (*pointer to returned value*):

This should be a pointer to a double in your program. After returning from `Open`, it will be filled in with the actual sampling rate the USBxCH was programmed with. *Do not* assume the actual sampling is the same as the rate as you requested. Only rates from the allowed [Rate Table](#) are possible.

Error (*pointer to returned value*):

This parameter will report any errors that occurred. See the include file `SrUsbXch.h` for a list of possible error code numbers and corresponding strings.

Note that although `Open` returns the handle `BAD_DEVHANDLE` on an error, this only

indicates a failure did occur. The Error return indicates the detailed reason for what went wrong.

The following page has a typical code sequence for Open. Note the use of the C & ampersand operator to pass the address of returned parameters (a pointer).

Typical code sequence for open ...

```
#include "SrUsbXch.h"          // include file ...

// allocate parameters at the top of your program ...

    DEVHANDLE handle;

    char DriverName[] = "SrUsbXch0";
    int XchModel;
    int GpsModel;
    int UserCfgByte;
    double Sps;

    double ActualSps;    // returned value
    int Error;           // returned value

// ... various code from your program would follow here, then ...

// Call the Open function

    XchModel = 0x20;           // < must be 0x20 for the USB4CH
    GpsModel = 0;              // < 0 = NONE
    UserCfgByte = 0;           // < 0 = use power up defaults
    Sps = 130.0;               // requested sampling rate in Hz

    handle = SrUsbXchOpen(
        DriverName,
        XchModel,
        GpsModel,
        UserCfgByte,
        Sps,
        &ActualSps,    // returned value
        &Error         // returned value
    );

    if ( Error ) // then print out the error code ...
        printf( "Open error ouccured, Error code = %d", Error);

    else // success, print out the actual sampling rate ...
        printf( "the ActualSps is: %f\n", ActualSps); // 130.2083 Hz

// ... continue on with other code ...
```

5.2 SPS rate table lookup

Include file: `SrUsbXch.h`

Prototype:

```
int SrUsbXchSpsRateTable( int SpsIndex, double *SpsRate);
```

The USBxCH can sample its inputs at various fixed rates. The allowed rates are listed in the [Rate Table](#) in Chapter 6. This function takes an index into that table and returns the corresponding Sps rate. This is a helper function only and does not require a device handle.

The function parameters are:

`int SrUsbXchSpsRateTable` (*function return*):

If `SpsIndex` is between 0 and 15 this function returns a 1 indicating success, 0 if not.

`SpsIndex` (*input parameter*):

The requested table index between 0 and 15.

`SpsRate` (*pointer to returned value*):

This should be a pointer to a double in your program. After returning it will be filled in with the sampling rate in Hz corresponding to the index.

A code fragment might look like:

```
double SpsRate; // < at the top of the program
SrUsbXchRateTable( 5, &SpsRate);
```

This would return the `SpsRate` 39.0625 Hz.

5.3 Start acquisition

Include file: `SrUsbXch.h`

Prototype:

```
void SrUsbXchStart( DEVHANDLE UsbXchHandle );
```

Once Open has returned a valid device handle, acquisition can be started with this function. Between the call to Open and Start, the USBxCH is in idle mode and not returning data. Starting on command is useful for a variety of situations such as controlling acquisition in response to a keypress or other signal. The matching function to Start is **Stop**.

This function takes only a device handle as a parameter, and does not have any other returns or parameters.

5.4 Get Data as Packets

Include file: `SrUsbXch.h`

Prototype:

```
unsigned int SrUsbXchGetDataAsPackets(  
  
    DEVHANDLE UsbXchHandle,  
  
    SRDAT_USBPACKET *PacketArray,  
    unsigned int nPacketsRequested,  
  
    unsigned int *nPacketsReturned,  
  
    int *Error  
);
```

After `Open` and `Start` are successful, data can then be retrieved from the USBxCH with calls to `GetDataAsPackets`. The function will attempt to read the requested number of data packets from the USBxCH. If fewer packets are ready, then those that are ready will be returned. The return value, `nPacketsReturned`, indicates how many packets were actually read. Because data is continually streaming in, this function must be called periodically at a sufficient rate to avoid the USBxCH DRAM FIFO from gradually creeping towards overflow. If `nPacketsReturned` is at least occasionally less than `nPacketsRequested`, then you know the PC is keeping up.

Packet data structures are in a dense multiplexed binary format. Analog samples, digital input values, GPS PPS ticks and NMEA strings, system temperature, power supply status, and error codes are all in the packet data stream. For easy post processing, use the helper function `PacketsToColumns` to convert packets to column arrays.

The function parameters for `GetDataAsPackets` are:

`unsigned int SrUsbXchGetDataAsPackets()` (*function return*):

The same value as `*nPacketsReturned`.

`UsbXchHandle` (*device handle*):

This should be a device handle from a successful call to `Open`.

PacketArray (*pointer to returned array*):

Pointer to an array of type SRDAT_USBPACKET for storing the requested packets. nPacketsRequested will be attempted to be read. *It is the user's responsibility to make sure the PacketArray has been allocated, and that fewer packets than the dimension of the array are requested to avoid overwriting.*

nPacketsRequested (*input parameter*):

The number of packets that will be attempted to read. Do not ask for more packets than the size of the PacketArray allocated in your program, to avoid overwriting the array.

nPacketsReturned (*pointer to returned value*):

Indicates how many packets were actually returned. The value may be less than what was requested, indicating fewer packets were available. Generally GetDataAsPackets should be called often enough so fewer packets than were requested are returned indicating the USBxCH DRAM FIFO is drained and not creeping toward overflow.

Error (*pointer to returned value*):

This parameter will report any errors that occurred. A value of 0 indicates success with no errors. See the include file SrUsbXch.h for a list of possible error codes greater than 0 and their corresponding strings.

5.5 Convert Packets to Columns

Include file: `SrUsbXch.h`

Prototype:

```
int SrUsbXchPacketsToColumns(  
  
    int FinalProcess,  
  
    SRUSBXCH_PACKET *PacketArray,  
    int nPackets,  
  
    SRUSBXCH_SAMPLEDATA *SampleArray,  
    int maxSample,  
    int *nSample,  
  
    SRUSBXCH_STATUSDATA *StatusArray,  
    int maxStatus,  
    int *nStatus,  
  
    int *Error  
);
```

The previous function, `GetDataAsPackets`, should be used to move data from the USBxCH to the PC. While very fast, many users will find its native hardware packet format difficult. This function, `PacketsToColumns`, takes the packets from `GetDataAsPackets` and converts them to easily accessed arrays of data. These arrays are essentially the same as the columns appearing in the output from the `Pak2Asc` utility.

Of course real time conversion to column arrays will use CPU horsepower and reduce the maximum sampling rate. If you need the maximum bandwidth, consider saving packets to disk and then later post processing them. This is the approach `Blast` takes. However, if you need data conveniently formatted for real time plotting, then use this function. This is approach `Scope` and its trace display takes.

This is a helper function only and does not require a device handle.

The function parameters for `PacketsToColumns` are:

`int SrUsbXchPacketsToColumns()` (*function return*):

Work underway ...

`FinalProcess` (*input parameter*):

Work underway ...

`PacketArray` (*pointer to input array*):

This should be a pointer to an array of packets as returned by `GetDataAsPackets` in the user's program. Declare the array to be of type `SRUSBXCH_PACKET`.

`nPackets` (*input parameter*):

The number of packets in the `PacketArray`. Often this would be the same as the parameter `nPacketsReturned` from `GetDataAsPackets`, although if you have been saving packets up it should reflect the total number of packets waiting to be processed.

`SampleArray` (*pointer to output array*):

Output pointer to an array of samples in the user's program. Declare the array to be of type `SRUSBXCH_SAMPLEDATA`.

`maxSample` (*input parameter*):

Maximum number of sample entries to return to prevent overwriting the `SampleArray`. *Do not pass a number larger than the number of entries in `SampleArray`.*

`nSample` (*pointer to returned value*):

Work underway ...

`StatusArray` (*pointer to output array*):

Output pointer to an array of status entries in the user's program. Declare the array to be of type `SRUSBXCH_SAMPLEDATA`.

`maxStatus` (*input parameter*):

Maximum number of status entries to return to prevent overwriting the `StatusArray`. *Do not pass a number larger than the number of entries in `StatusArray`.* For many applications the `StatusArray` should be dimensioned at 2.

nStatus (*pointer to returned value*):

Work underway ...

Error (*pointer to returned value*):

This parameter will report any errors that occurred. A value of 0 indicates success with no errors. See the include file SrUsbXch.h for a list of possible error codes greater than 0 and their corresponding strings.

5.6 User digital IO read

Include file: `SrUsbXch.h`

Prototype:

```
void SrUsbXchUserIoRd(  
    DEVHANDLE UsbXchHandle,  
    int *IoValue,  
    );
```

The DB25 connector on the USBxCH front panel has 4 digital inputs and 4 digital outputs. This function performs an *asynchronous* read of the four digital inputs.

You don't necessarily need to call this function to read the digital inputs. They are automatically saved *synchronously* at the same instant as the analog samples in the DRAM FIFO, and can be viewed in real time with programs like Scope. Apply a signal to one of the digital input pins to see the Scope digital traces respond. For information about the DB25 pin assignments and voltages, see the [Digital IO](#) chapter.

The function parameters are:

`void SrUsbXchUserIoRd` (*function return*):

None.

`DEVHANDLE UsbXchHandle` (*input parameter*):

This should be a device handle from a successful call to `Open`.

`IoValue` (*pointer to return*):

The values of the four DB25 digital input pins are returned in the low four bits of the integer pointed to by `IoValue`. For example, a value of 0x1 means digital input bit 0 is on and the others off, while 0xC means bits (3,4) are on, and (1,2) off.

A code fragment might look like:

```
int IoValue;    // < at the top of the program  
SrUsbXchUserIoRd( hUsbXch, &IoValue);
```

5.7 User digital IO write

Include file: `SrUsbXch.h`

Prototype:

```
void SrUsbXchUserIoWr(  
    DEVHANDLE UsbXchHandle,  
    int IoValue,  
    );
```

This function writes to the front panel DB25 digital outputs. The output values are latched until another call to this function is done. For information about the DB25 pin assignments and voltage levels, see the [Digital IO](#) chapter.

The function parameters are:

`void SrUsbXchUserIoRd` (*function return*):

None.

`DEVHANDLE UsbXchHandle` (*input parameter*):

This should be a device handle from a successful call to `Open`.

`IoValue` (*input parameter, value to write to DB25*):

The lower four bits of this value are written to the respective DB25 digital output pins. Use a voltmeter to measure the pins as you change them.

A code fragment might look like:

```
int IoValue;    // < at the top of the program  
IoValue = 3;    // < set the lower two bits (0,0,1,1)  
SrUsbXchUserIoWr( hUsbXch, IoValue);
```

5.8 Front panel red and yellow LEDs

Include file: `SrUsbXch.h`

Prototype:

```
void SrUsbXchUserLed(  
  
    DEVHANDLE UsbXchHandle,  
  
    int YellowLedState,  
    int RedLedState  
);
```

The USBxCH has two LEDs on its front panel, one yellow and one red. Call this function with 1 or 0 to set the states of the two LEDs to on or off.

The red LED has a power on default to toggle automatically with each GPS PPS tick from the front panel DB25 connector. *To change it to be user programmable*, set the `UserCfgByte` in the `Open` function appropriately.

The yellow LED is always available and dedicated to being user programmable.

5.9 Power good

Include file: `SrUsbXch.h`

Prototype:

```
int SrUsbXchPowerGood( DEVHANDLE UsbXchHandle);
```

This function returns the current status of the POWER GOOD signal. If a 1 is returned power is good. 0 if not.

The return of this function is the inverse of the red power status LED on the USBxCH back panel near the 2.1mm power connector. If the red LED is ON, power is not good, and this function returns a 0. Conversely, if the red LED is OFF, then power is good, and this function returns a 1.

Note that an ongoing record of the power status is automatically returned once a second in the `GetDataAsPackets` data stream. Users of `Blast` or `Scope` will already have the power status information recorded and not need to call this function.

5.10 Stop acquisition

Include file: `SrUsbXch.h`

Prototype:

```
void SrUsbXchStop( DEVHANDLE UsbXchHandle )
```

This is the matching function to Start and will stop data acquisition. It is common for a keyboard press or other signal to call this function.

The function takes only the device handle as a parameter, and does not have any other parameters or returns.

Note that stopping acquisition is not the same as calling Close. Stop *does not close the device driver*. To restart the USBxCH with a different sampling rate you must call **Close** and then **Open** again to reinitialize.

5.11 Close

Include file: `SrUsbXch.h`

Prototype:

```
int SrUsbXchClose( DEVHANDLE UsbXchHandle );
```

Close the device driver and release the USBxCH for other applications to use. Since only one process can have the USBxCH open at a time, it is important to Close the driver when you are done. Close is the matching function to Open.

This function takes only the device handle as a parameter. Its return indicates whether the Close was successful or not. Usually Close can only fail if handed a bad device handle, perhaps from a failed call to Open.

Although the USBxCH device driver will be closed by the operating system if you exit from an application, we recommend using calling Close in your programs to gracefully remove the driver from the Plug and Play system.

Chapter 6

Sampling rates

The USBxCH returns converted analog data at a variety of programmable rates. A particular sampling rate is referred to as the *SPS* (samples per second) or frequency in Hz. To set the sampling rate in programs such as **Scope** users should specify the appropriate ini keywords, or if writing their own programs, specify the sampling rate in the User C Library **Open** function.

Available rates are listed in the **Rate table** in Figure 6.1. *Arbitrary sampling rates cannot be programmed*, only rates listed on the rate table can be selected. Furthermore, you *cannot program different rates on different channels*. All the analog and digital inputs on the USBxCH are sampled at the same rate and instant, with *no channel skew*.

The USBxCH A/D chips are sigma delta converters. A simple model for their architecture is they oversample their inputs at a high rate and then signal average to produce the final result. As the amount of signal averaging increases, the final resolution improves at the cost of a lower output sampling rate. The input oversampling for the USBxCH TI ADS1255 chips is determined by the on board master clock frequency. For a master clock frequency of F_{clk} , the oversampling rate is:

$$\text{Input oversampling rate} = F_{clk} / 256$$

If F_{clk} is maximized, then oversampling is also maximized, and the noise floor at any particular final output rate is minimized because there is more signal averaging. The fastest F_{clk} the ADS1255 can work with is 10.0 MHz, and this is the master clock used on the USBxCH. Using the above formula, the oversampling rate is:

$$\text{Oversampling rate with 10 MHz master clock} = 39,062.50 \text{ Hz}$$

All final USBxCH output rates are averages from this 39 kHz oversampling rate.

6.1 Permitted rates

At the chip level, a final sampling rate is selected by programming the ADS1255 Data Rate (DR) register with the number of averages, NumAvg, to be performed on the oversampling. From the TI ADS1255 data sheet:

$$\text{SPS rate} = (\text{Fclk}_{\text{in}} / 256) * (1 / \text{NumAvg})$$

$$\text{SPS rate} = 39,062.50 / \text{NumAvg}$$

where the second equation is with a 10MHz Fclk_{in} master clock. The following table gives the possible SPS rates rounded to four decimal places:

SPS RATES FOR USB4CH 10.000 MHz (Fclk_{in}) master clock ...

DR[7:0]		NumAvg		SPS rate
11110000	=	1	->	39062.5000 Hz
11100000	=	2	->	19531.2500 Hz
11010000	=	4	->	9765.6250 Hz
11000000	=	8	->	4882.8125 Hz
10110000	=	15	->	2604.1667 Hz
10100001	=	30	->	1302.0833 Hz
10010010	=	60	->	651.0417 Hz
10000010	=	300	->	130.2083 Hz
01110010	=	500	->	78.1250 Hz
01100011	=	600	->	65.1042 Hz
01010011	=	1000	->	39.0625 Hz
01000011	=	1200	->	32.5521 Hz
00110011	=	2000	->	19.5313 Hz
00100011	=	3000	->	13.0208 Hz
00010011	=	6000	->	6.5104 Hz
00000011	=	12000	->	3.2552 Hz

Figure 6.1: USBxCH sampling rates with 10 MHz master clock

Only program the DR register with the above values. Although it might appear other NumAvg values could be specified in the DR register, only the values listed above are valid. See the TI ADS1255 spec sheet.

6.2 Master clock stability

Of course all parts have tolerances and the USBxCH master clock is no exception. The 10MHz clock used on the USBxCH is a TCXO (temperature compensated xtal oscillator) with an initial accuracy of +/- 1.5ppm, and frequency stability over the entire temperature range of +/- 2.5ppm. Thus, at a constant 25°C (room temperature), Fclkin is actually something between:

$$(10\text{MHz} - 15\text{Hz}) \leq \text{Fclkin} \leq (10\text{MHz} + 15\text{Hz})$$

while over the full temperature range Fclkin could vary by 25Hz. This is better than the average PC computer clock, which typically has 100ppm variation. And, for many applications, the TCXO is good enough to provide an absolute time base.

But what does this all mean? As an example, suppose a particular master clock initial frequency is high by 1.5ppm. The clock period would then be:

$$\text{Tclkin} = 1 / (10\text{MHz} * (1 + 1.5\text{ppm})) = (1/10\text{MHz}) * (1 - 1.5\text{ppm})$$

where the second equal sign uses the first order approximation $1/(1+x) \approx 1-x$. If this clock runs for a day the amount of time it will lose is very close to:

$$(1 \text{ day}) * 1.5\text{ppm} = 0.129,600 \text{ seconds lost}$$

This amount of error could represent many samples at high sampling rates. At 1kHz, the analog sample that would be declared to be at the next day boundary if the TCXO is used as an absolute time base would actually have come 129 samples before the true day boundary occurred.

If you know the clock is high by 1.5ppm, you could account for that fact. A good way to calibrate the master clock is to use the USBxCH GPS subsystem, see the [GPS Time Stamping](#) chapter. With GPS time stamping you can count exactly how many samples occur in a day and get an exceptionally accurate initial TCXO calibration.

Of course, calibrating for the initial TCXO accuracy does not make up for its 2.5ppm variation with temperature. If your application is exposed to significant temp variations you should track the time base with the GPS time stamps for an accurate record. If you don't have GPS, and are using the TCXO as an absolute time base, the USBxCH has an on board temp sensor. System temperatures are recorded once per second as part of the data stream. Do a thermal calibration of the time base at various temps, and then use the calibration along with the recorded temp record to make corrections.

6.3 Interpolation to other sampling rates

Some applications may require specific sampling rates such as 100Hz or 250Hz, or perhaps to be phase locked with timing marks such as GPS PPS ticks. One effective way to achieve these requirements is to interpolate. Because sigma delta converters inherently oversample and signal average there is a great deal of smoothing already making interpolation even more accurate.

The **Interpolate** utility in the Utilities chapter is one simple way to post process data to various sampling rates and phase lock conditions. Of course the interpolator requires data that is sampled at a rate greater than or equal to the final requested output rate to produce accurate results.

Work underway ...

Chapter 7

FIFO Depth and Overflow

7.1 FIFO Depth

The USBxCH is equipped with a hardware memory buffer so data can accumulate on board even if the PC is unable to read it immediately. This feature is essential if no data is to be lost during continuous acquisition runs. Even if the PC is busy with Ethernet or other activity when new data becomes ready, the USBxCH on board memory stores the data until the PC can service the task.

The buffer is organized as a FIFO (First In First Out) memory. As soon as data is acquired, it is placed in the buffer and the PC is notified so it can be read. Once read, the buffer memory is returned to the end of the FIFO. This way there are no latency or fall through times and the FIFO stands only as a guard in case the PC is busy.

The FIFO is organized as $4M \times N$ bit words, where $N = (4 \text{ or } 8)$ depending on the number of USBxCH analog channels. In the case of the USB4CH this equates to a total of 2 Mbytes in size. An important question is: how long can data accumulate before FIFO overflow occurs? Knowing this length of time affects both continuous and burst acquisition. In continuous mode it defines the amount of time the PC can be away on other tasks. At high sampling rates, where the PC bandwidth cannot stay up continuously, it defines how long a burst mode run can last.

The FIFO hold out time of course depends on the sampling rate, filling more quickly the faster the rate. To calculate the hold out time requires first knowing how many words per sample are saved. The USBxCH saves 32 words per sample. The 32 words include: the analog data from all channels, the synchronously sampled digital data, GPS time stamps, and error correction codes.

32 FIFO words per sample (includes all four channels)

Since the FIFO buffer has a total size of 4 Meg words = 4,194,304 (decimal), a total of 4,194,304 / 32 words = 131,072 samples can be stored.

$$\text{FIFO size in samples} = 4\text{M} / 32 = 131,072 \text{ total samples}$$

The hold out time is the total number of FIFO samples divided by the sampling rate:

$$\text{FIFO BUFFERING TIME in sec} = 131,072 / \text{SPS in Hz}$$

So for example, if the sampling rate is 100Hz, then the FIFO can hold out for a total of 131,072 / 100 = 1,310 seconds = 21.83 minutes. Something is wrong if the PC can't service the USBxCH in 20 minutes.

The following table summarizes the FIFO depth at the allowed sampling rates. These times are the same for any of the USBxCH products regardless of the number of channels. Note that at the slower rates data can accumulate for several hours ... !

FIFO HOLD OUT TIMES FOR USB4CH with 10.000 MHz master clock:

SAMPLING RATE	FIFO BUFFER HOLD OUT TIME			
39062.50 Hz	3.36 sec	=	0.06 min	= 0.00 hrs
19531.25 Hz	6.71 sec	=	0.11 min	= 0.00 hrs
9765.63 Hz	13.42 sec	=	0.22 min	= 0.00 hrs
4882.81 Hz	26.84 sec	=	0.45 min	= 0.01 hrs
2604.17 Hz	50.33 sec	=	0.84 min	= 0.01 hrs
1302.08 Hz	100.66 sec	=	1.68 min	= 0.03 hrs
651.04 Hz	201.33 sec	=	3.36 min	= 0.06 hrs
130.21 Hz	1006.63 sec	=	16.78 min	= 0.28 hrs
78.13 Hz	1677.72 sec	=	27.96 min	= 0.47 hrs
65.10 Hz	2013.27 sec	=	33.55 min	= 0.56 hrs
39.06 Hz	3355.44 sec	=	55.92 min	= 0.93 hrs
32.55 Hz	4026.53 sec	=	67.11 min	= 1.12 hrs
19.53 Hz	6710.89 sec	=	111.85 min	= 1.86 hrs
13.02 Hz	10066.33 sec	=	167.77 min	= 2.80 hrs
6.51 Hz	20132.65 sec	=	335.54 min	= 5.59 hrs
3.26 Hz	40265.30 sec	=	671.09 min	= 11.18 hrs

Figure 7.1: USBxCH FIFO hold out times

7.2 FIFO Overflow

The USBxCH buffer maintains an Overflow Flag. Overflow occurs if the USBxCH has been left unserved by the PC for so long that the FIFO is completely filled. If an overflow occurs then any further A/D data is discarded at the USBxCH hardware level. Data saved in the FIFO before overflow is preserved and can be read back by the PC. This way, data from a burst run is not lost.

The FIFO Overflow Flag (OV) is sticky. Once overflow has occurred, the flag stays set until a hardware FIFO reset is done. A reset can be forced by stopping and restarting acquisition in programs like **Scope**, or by calling **Close** and then **Open** in the User C Library.

7.3 FIFO Creep

For continuous data acquisition, the bandwidth of the PC, hard disk, and USB interface must all be able on average to keep up with the data acquisition rate of the USBxCH. The FIFO allows for the PC to be sporadic in its allocation of bandwidth to service the USBxCH, *but on average the PC must still be able to keep up.*

In cases where the PC can *almost but not quite* keep up with offloading data, the USBxCH FIFO *may creep very slowly toward full*, requiring hours or even days before overflow occurs. How can you know before then if the PC is not keeping up with the average bandwidth requirements?

A Partially Full (PF) flag is maintained for the FIFO. The PF flag should be clearing regularly if the PC is keeping up with the average bandwidth requirements at the particular sampling rate.

Work underway ...

Chapter 8

A/D reference voltage

All A/D converters require a reference voltage to compare their analog input against. When the analog input is equal to the reference voltage the converter outputs full counts. For other input voltages the reference sets the linear scale for the converter, see the [Analog DC calibration](#) chapter for details on the DC transfer function.

Of course, for conversions to be reliable, the reference must be the same from one power on cycle to the next and stable across temperature changes. The USBxCH uses a single precision REF02 part for its reference with the same reference voltage applied to all four converters. A DIP 8 plastic through hole package is used for maximum mechanical stability. The pinout of the REF02 is standard across several manufacturers with many grades of performance available.

A goal of the USBxCH is to achieve *absolute voltage accuracy* rather than simply ratiometric measurement, so the selection of the reference is an important consideration. However, besides the precision of the analog reference, users should be aware other factors may be equally important. Issues such as the precision and drift of the master clock as well as analog front end resistor matching are also important. For many applications, it may be more effective to use the USBxCH on board temperature sensor to perform system level corrections accounting for TC temperature changes rather than pursuing a particular precision reference.

8.1 Standard reference

The reference on the standard USBxCH is populated with a generic REF02 from Texas Instruments. The following are a few of its specifications:

```
TI part number = REF02AP
  Technology = Buried Zener
Reference voltage = 5.0 volts
Initial accuracy = 15 millivolts
  Max TC = 15 ppm/C
  Typical TC = 4 ppm/C
  Temp range = -40 to +85C
  Package = plastic DIP 8 through hole
```

The output of this reference is buffered and scaled to be suitable for use with the USBxCH ADS1255 A/D converters. A single REF02 is used to supply the converters for all channels with the same reference voltage, see the [Circuit Diagrams](#) chapter. The package is DIP 8 to reduce mechanical board stress related drift. Be aware, even though many small monolithic surface mount references advertise excellent TC ppm, they have changes with mechanical stress far exceeding their spec sheet claims.

8.2 Alternate references

High performance versions of the REF02 are available from Cirrus (formerly Thaler):

```
Cirrus part number = VRE3050
  Technology = Buried Zener
Reference voltage = 5.0 volts
Initial accuracy = 0.5 millivolts
  Max TC = 0.6 ppm/C
  Typical TC = 0.3 ppm/C
  Temp range = -40 to +85C
  Package = hybrid DIP/SMT 8
```

This is representative of the very best in the REF02 class. Besides having excellent temperature compensation, the hybrid technology has been specifically designed to relieve variations due to mechanical stress. There are also acceptable devices comparable with the standard TI part listed above from companies such as Analog Devices, Linear Technology, etc. Check their spec sheets for suitability.

8.3 TC correction with on board temp sensor

Rather than shopping for the most precise reference, an alternative is to thermally calibrate the USBxCH. Thermal calibration can be used to correct for many system level TC variations as well as the analog reference variations.

With the USBxCH on board temp sensor, the board level temperature is continuously recorded once per second. The temp record is automatically saved with the analog data stream, so it is always available. Once a calibration has been performed, it can be used as correction.

Work underway ...

Chapter 9

Analog inputs

This chapter reviews the USBxCH analog inputs. General information is given covering the nature of differential inputs, the front panel DB15 connector pin assignments, appropriate cabling techniques, and how to adjust the front end circuitry for custom input ranges and other options. See the [Analog DC calibration](#) chapter for the exact relationship of input volts to counts.

9.1 Differential signals

The USBxCH has *differential* analog inputs. Although many users are probably more familiar with *single ended inputs*, differential inputs have many benefits. Even though the system can be used in single ended fashion, differential signaling is recommended for achieving the highest precision.

The concept of a differential signal is as follows. On the USBxCH, each analog channel is equipped with three inputs: (+,-,AGND). The A/D count for the channel is given by the voltage *difference* between the (+,-) pins,

$$\text{A/D counts} = \text{slope} * (V+ - V-) + \text{offset}$$

where the slope and offset are the [Analog DC calibration](#), and (V+,V-) are measured with respect to AGND. The advantage of this is any noise which is common on both the + and - pins is subtracted away and not part of the final returned value. Common mode noise rejection with differential signals is a powerful way to reduce ground noise which is present on almost every system.

Note that the differential - pin is not ground. It is an input just like the + pin, with the only difference being its effect on the A/D counts is inverted. In fact, you can reverse the

(+, -) connections on any test setup and all that happens is the count values are inverted. Note that if you are making a single ended connection, you could just as well tie the + pin to AGND and connect the signal to the - pin. Everything would work the same as the more commonly implemented - pin grounded and signal connected to the + pin configuration, except for the inversion.

To see how differential inputs can reduce ground noise, consider the following figure:

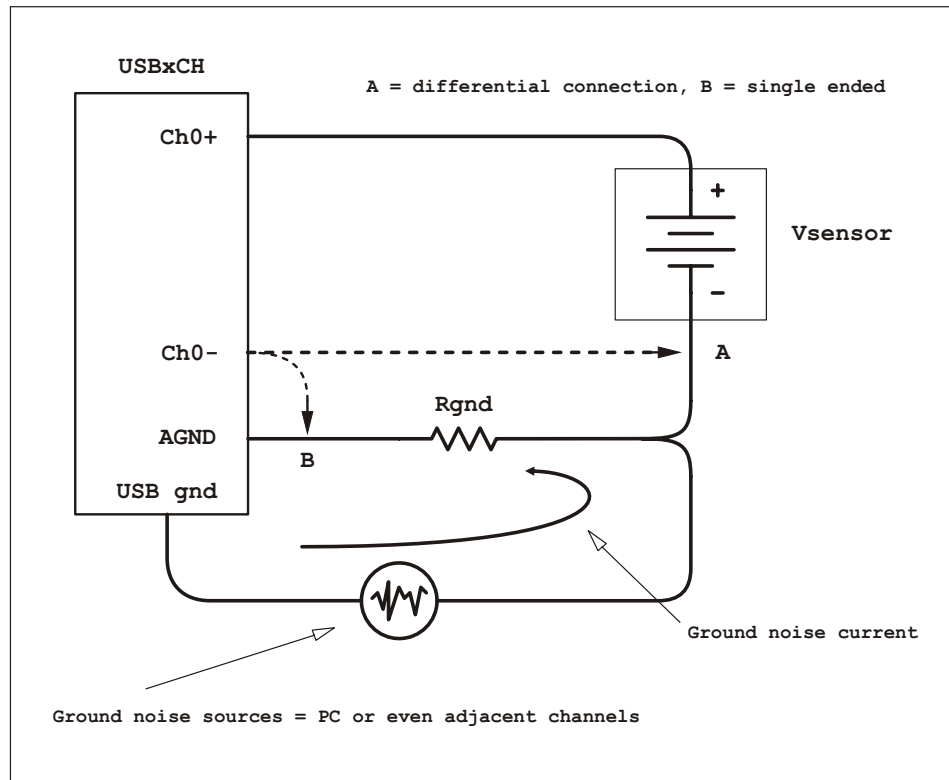


Figure 9.1: Differential vs single ended signals

The sensor or voltage which is to be connected to the USBxCH is indicated by the battery symbol inside the smaller rectangle. The sensor itself is probably not a battery, but it has an output that can be idealized as some voltage that varies with time. It will also be connected to the USBxCH with wires of unknown length depending on the installation.

It is reasonable one terminal of the sensor should be connected to the + terminal of the USBxCH as shown in the figure. But the real question is: what to do with the other terminal? It could be connected to AGND, and the system would work. In fact for a *single ended* system with multiple sensors, all of the second terminals would be connected to AGND with a single common wire, where sometimes even a chassis might be used. The resistance of that common connection is labeled Rgnd in the figure and is where the trouble starts.

Let's estimate the magnitude of R_{gnd} . 24 gauge stranded wire has a typical resistance of 0.020 ohms per foot, and a 5 foot length as might be used in many installations would have a total resistance of 0.1 ohm. Suppose a device sharing the common ground conducts 10ma. The voltage generated across R_{gnd} would be 0.001 volt, and *this would appear in series with V_{sensor}* from the viewpoint of the USBxCH. The V_{sensor} measurement is at the mercy of other devices and can suffer from crosstalk simply because of the single ended connections.

Just how big a voltage is 0.001 volts or 1 millivolt? It is huge given the 1 *microvolt* precision of the USBxCH. *The error caused by a mere 1 millivolt ground bounce would be 1000 times greater than the USBxCH sensitivity!* To cancel the contribution of the ground noise the - input should be used. Rather than leaving it unconnected, or connected to point B in the figure, connect it to point A. Since only the difference between the (+,-) inputs is converted into counts, the contribution from R_{GND} is not included in the measurement.

The improvements provided by differential measurements can be significant, and for precision results the additional - wire is well worth the cost. Many active sensors already have differential outputs, and making the connections for them is easy:

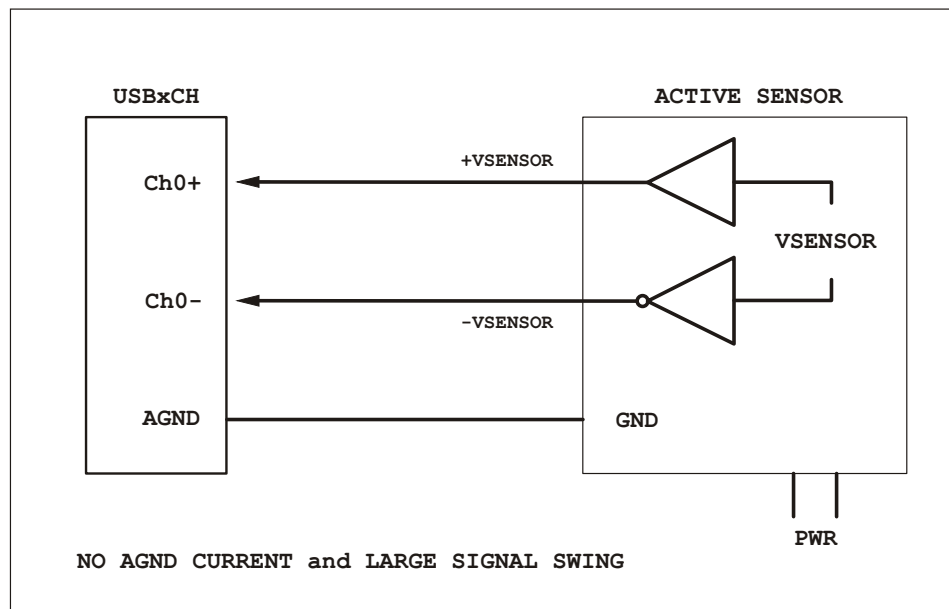


Figure 9.2: Balanced differential inputs with an active sensor

Often, active sensors go even further and have *balanced differential outputs*. That means the - output is exactly as negative as the + output is positive. The result is that all the current going out the + output is matched by that coming in the - output and there is *no current at all on AGND*. The AGND connection is still required to reference the differential signals, but with no current flowing on it common mode noise is not an issue.

To connect a floating sensor to the differential inputs simply hook the two sensor terminals to the (+, -) pins as in the next figure. Here the voltages are automatically self balancing and referenced to **AGND** because of the USBxCH input circuit. A few examples of floating sensors might be geophones, microphones, magnetic pickups, piezo cells, etc. It would still work if you incorrectly connect the - pin to **AGND**, but the inputs would no longer be balanced around **AGND** and you would be more susceptible to ground noise.

See the [Examples and Experiments](#) chapter for a demo of measuring a floating AA battery in this way.

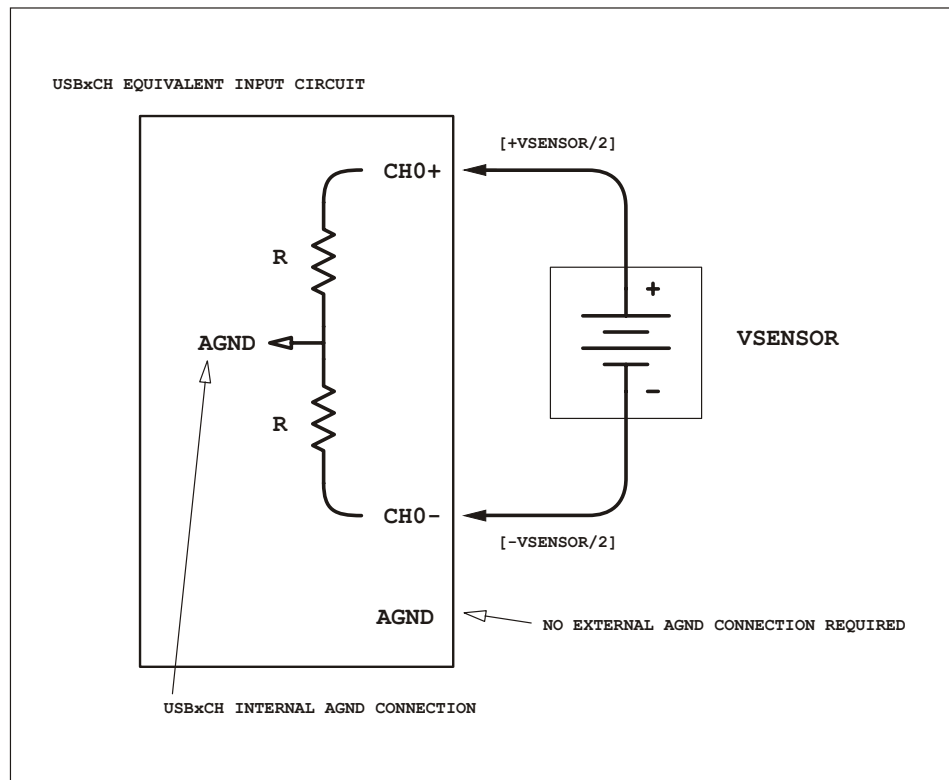


Figure 9.3: Two terminal floating sensor connection

9.2 DB15 pin assignments

The DB15 connector on the USB4CH front panel is where the analog input connections should be made. The DB15 pins have the (+, -, AGND) inputs for each of the four channels. The following table gives the pin assignments:

DB15 pin	Analog signal	Description
Diagonal pairs		
1	Channel 0 +	+ differential input
9	Channel 0 -	- differential input
2	AGND	
10	AGND	
3	Channel 1 +	+ differential input
11	Channel 1 -	- differential input
4	AGND	
12	AGND	
5	Channel 2 +	+ differential input
13	Channel 2 -	- differential input
6	AGND	
14	AGND	
7	Channel 3 +	+ differential input
15	Channel 3 -	- differential input
8	AGND	

Figure 9.4: USB4CH analog DB15 pin assignments

Note the physical connector pin numbering starts at 1, while the USB4CH channel numbering starts at 0. On the DB15, there are 8 pins across the top row, and 7 pins across the bottom. These are grouped diagonally for the various channels. For example, channel 0 (+, -) are the diagonal DB15 pair pins (1,9). This diagonal grouping keeps differential pairs next to each other when using ribbon cable connectors. All of the AGND pins are connected together and can be assigned to channels as convenient.

See the diagrams in Figures 9.5 and 9.6 for pictorial views of the front panel DB15 and the diagonal pin assignments.

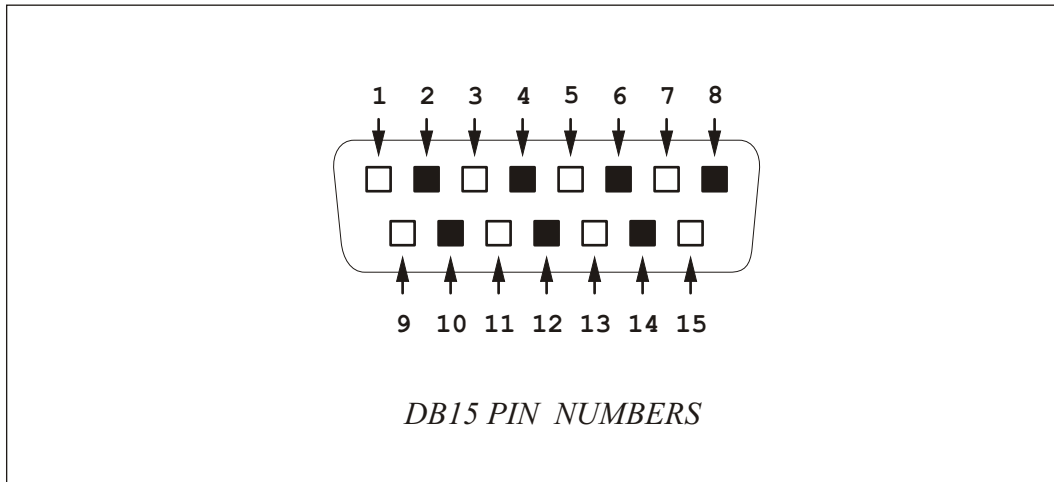


Figure 9.5: Analog DB15 pin numbers viewed from front panel

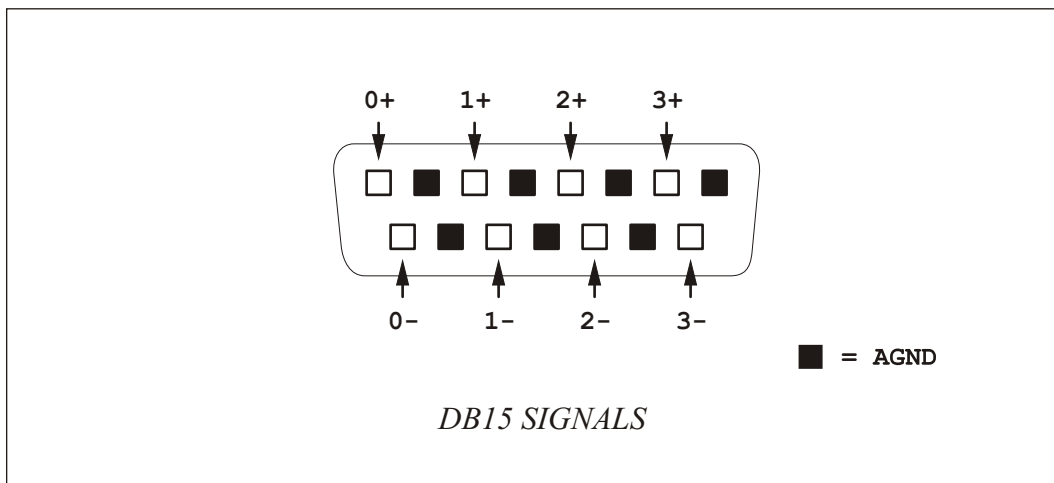


Figure 9.6: Analog DB15 signals viewed from front panel

9.3 Twisted pair cabling

Despite the benefits of differential signals, there are types of noise requiring additional measures to guard against. Two examples are magnetically coupled noise, and thermocouple effects. Both of these can degrade microvolt measurements.

By Faraday's Law, whenever time varying magnetic flux lines, $d\Phi/dt$, cross the wire loop formed by the (+,-) input cabling a noise current will be generated. While such noise can occur at any frequency, by far the most common is 50/60Hz powerline noise. At many installations, the wall power wiring is close enough and surrounds the work area sufficiently to magnetically couple to the USB4CH input cabling. The action is like a transformer with the wall wiring as primary and the USB4CH input cabling as secondary:

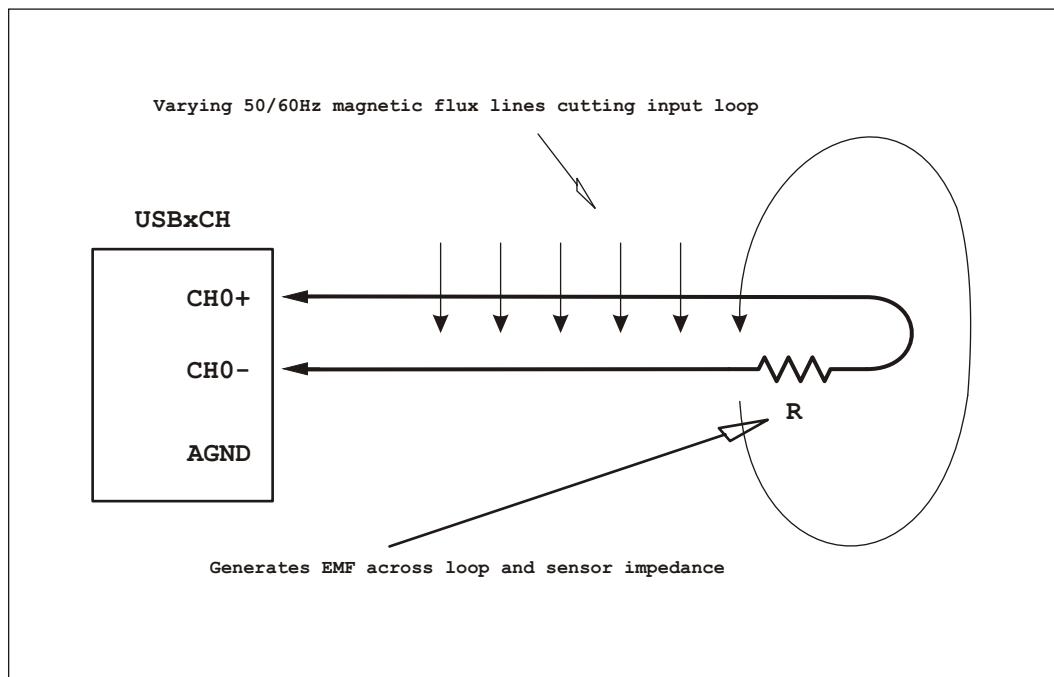


Figure 9.7: Magnetic coupling of 50/60Hz noise

Because the voltage generated by the varying flux is in series with the differential loop, it is not removed as common mode noise. The best defense against this type of noise is to prevent it from entering the system in the first place. According to Faraday's Law, reducing the area of the cable loop will reduce the EMF voltage generated. Placing or binding the leads close to each other as might be done with flat ribbon cable will help. However, even more effective is using twisted pair cable. The EMF generated by magnetic flux lines cutting each small twist has opposite polarity from one twist to the next, and cancels out. The technique is surprisingly effective, see Chapter 19, [Examples and Experiments](#). Note that

even the flat areas on twisted pair ribbon cable can cause trouble. Discrete wire twisted pairs give the best performance.

Shielded cable is not particularly effective against magnetic coupling. You will have better results with simple twisted pair in reducing 50/60Hz noise. Shielded cable is excellent for ESD protection and is discussed in the next section.

Thermocouple effects are another common problem. Whenever two dissimilar metals are connected together they generate a temperature dependent junction voltage. For a copper to tin/lead junction as might occur in a solder joint, the voltage is 3 microvolts / °C. This can be a substantial noise contribution at 24 bit sensitivity.

The way to battle against thermocouple noise is to keep both the + and - differential inputs exactly balanced with metal to metal junctions. If a junction is introduced on the + side, add one to the - side even if it is not needed. By keeping the thermocouples exactly the same on the both sides, the differential signaling will cancel the two equal sides. If the (+, -) sides are kept in the same thermal bath, the cancellation will be exact across all operating temperatures.

9.4 Static shielding

Electrostatic discharge (ESD) events directly into the DB15 analog inputs are guaranteed to damage the USB4CH. *This is not maybe, it is guaranteed.* Even though the system may appear to continue working correctly, at a minimum calibration will be changed with each ESD event.

Of course, drastic ESD events such as lightning strikes deliver irreversible damage that is visible. For such installations, ground rods, gas arrestor tubes, TVS zener diodes, and cable shielding should all be used as protection. However at the other end of the spectrum, even a mild spark generated by a finger touch from walking over a carpet will also cause damage and should be protected against.

Surprisingly the most likely components to be damaged from ESD finger touch events are the series input resistors (R402/x, R403/x), and not the integrated circuits. See the circuit diagram page [A/D signal conditioning](#). Each mild ESD event vaporizes a little bit of the resistor metalization, changing the input characteristics. The damage is interior to the resistors and will not be visible. It is cumulative, with each event vaporizing a little more metalization. Eventually, the resistor is blown open much like a fuse, and the channel will appear to have failed.

If you have a channel go dead, it is easy to see if the series input resistors are compromised. Measure their resistance with a multimeter such as a Fluke. If they measure higher than the value listed on the circuit diagram, then they have been damaged and should be replaced. One function of the input series resistors is specifically to help guard against ESD events

and their replacement in such cases is expected.

If you must touch the inputs with your fingers, *prevent static damage by touching the case immediately before*. This will bring you and the system to the same potential. This simple step will go a long way to preventing trouble. A further step is to *use shielded cable for the analog inputs*. The shield should be connected to the case of the USB4CH, which in turn is connected to the USB cable shield, which is connected onward to the PC case, and ultimately to third prong of the wall plug. The entire string of shielding forms a Faraday cage and mild ESD events are dissipated away from the sensitive electronics. *This approach is an excellent defense for installations with mild ESD risk.*

Use round shielded twisted pair multiconductor cable such as that from Belden to make such connections. The cable foil shield provides good static protection and the twisted pair is an added benefit for 50/60Hz noise rejection. See Chapter 21, [Extra supplies](#) for part numbers.

9.5 Input impedance

Input signals on the USB4CH are connected to the non-inverting pins of op amps. Because of this the system has an inherently high input impedance of 10M ohms. See the TI OPA2277 data sheet in the Docs/ChipSpecs directory.

For most applications an input impedance of 10M ohms is too high for good performance. With the tiny signal current implied by high impedance even the smallest noise sources compete, and signal to noise ratio is lost. To allow for different input impedances, the USB4CH is equipped with resistors in parallel with the inputs. See the circuit diagram, [A/D signal conditioning](#), resistors (R400/x , R401/x).

The parallel impedance setting resistors are normally populated with 51K ohm values. For applications with active sensor outputs this is a good value. It draws a reasonable amount of signal current, but does not overload the active sensor output either. Noise levels are low, and issues like the triboelectric effect of input leads are not competing with the signal.

For applications that require other input impedances, such as passive sensors, the resistors (R400/x, R401x) should be adjusted appropriately. There are SMT 0805 solder pads on the circuit board for making changes. Note that if the system is set to 10M ohm input impedance and the A/D inputs are allowed to float, conversions will be noisy and not pulled to ground reliably. To measure the USB4CH noise floor with high input impedance, short the inputs to AGND or other low impedance source.

9.6 Input voltage range

The normal full scale input range of the USB4CH is (+/-) 4 volts as described in the [Voltage Span and Counts](#) section of the Analog DC Calibration chapter. This is the input range on the (+, -) pins *as measured with respect to AGND*. The inputs are differential, but only as long as the pin voltages are within this range.

Other input ranges can be accommodated by changing resistor values on the board. For *larger* input ranges, there are solder pads on the input circuit for adding resistor dividers. For *smaller* input ranges, the gain of the front end op amp amplifier must be increased.

The location of the resistor dividers for setting larger ranges is on the circuit diagram page [A/D signal conditioning](#), resistor pairs (R402/x, R404/x) and (R403/x, R405/x). You can also populate the capacitors in this area of the circuit if RC filtering is required. Use matched components to keep the differential inputs balanced.

One popular larger input range is (+/-) 10 volts. This is fairly common with active sensors with op amp outputs. For this range leave (R402/x, R404/x) at their factory 10K values, and populate (R403/x, R405/x) with 6.67K ohms. You don't have to use exactly 6.67K resistors. Values making the input range a little larger than (+/-) 10 volts will leave a little headroom which may be helpful. Note that populating the resistor dividers also sets the input impedance. This is usually not a problem for active sensors with low impedance outputs.

9.7 Op amp gain

There are also solder pads on the board to increase the front end amplifier gain so the input voltage range is *smaller* than the factory (+/-) 4 volt default. See the circuit diagram pages [A/D input amplifiers](#), and resistors R410/x, R412/x, R413/x.

The resistor R410/x is commonly referred to as the gain setting resistor R_G , while R412/x and R413/x are the feedback resistors R_F . To keep the differential inputs balanced, make the R_F resistors are equal and closely matched. Assuming equal R_F values, the transfer function for the differential gain is:

$$(V_{out+} - V_{out-}) = (1 + 2*(R_F/R_G)) * (V_{in+} - V_{in-})$$

so with the values $R_G = 1K$ and $R_F = 10K$, the differential gain would be 21. When populating for unity gain, leave R_G empty (infinite ohms) and set $R_F = 0$ with a zero ohm resistor. This avoids offsets due to op amp input bias currents flowing through R_F .

9.8 RC antialias filtering

There are number of places on the input circuit where capacitors can be added for simple RC filtering. The capacitors are populated at the factory as follows:

(C400/x, C401/x):

These are for snubbing ESD events on the inputs. The 47pF value snubs ESD but still does not put much capacitive loading on active sensor outputs which might oscillate if overloaded.

(C406/x, C407/x, C408/x):

If your site has radio frequency contamination aliasing into the measured signal, these locations can be populated to provide some RC filtering. They are left empty at the factory.

(C412/x, C413/x):

Populate these if you wish to roll off the amplifier response. Leave these unpopulated if running the OPA2277 at unity gain.

(C414/x, C415/x):

It is critical these locations are populated with 220pF values to avoid OPA2277 oscillations. The capacitive load presented by the input circuit of the ADS1255 must be compensated for with capacitors in these locations.

The amplifier front end *is not* designed to provide antialias filtering with a sharp notch at 50/60Hz. Applications requiring powerline noise rejection should use either a custom op amp filter in front of the USB4CH, or sample at higher rates and apply numerical filtering. Twisted pair input cabling also provides an effective way to reduce 50/60Hz noise.

Chapter 10

Analog DC calibration

The physical quantity measured by the USB4CH is voltage, and its A/D converters return a count proportional to the input voltage. When the input voltage is low, a low count value is returned, and as the input increases the count value increases.

The exact relationship between a particular input voltage and the A/D counts is referred to as the *DC calibration*. It is well approximated by a straight line with a *slope and offset*. Performing a calibration requires measuring the slope and offset so application software can convert counts into volts.

As shipped, the USB4CH software is only approximately calibrated. Programs such as DVM have a typical slope and offset in their ini files. These values are reasonably good, but for highest accuracy, each USB4CH must be calibrated on site by the user. Furthermore, because the input circuitry varies slightly from channel to channel, *each of the four channels must be calibrated independently*.

The following sections cover the calculations involved with DC calibration. For an easy to use GUI program see the DVM **Calibrate** program.

10.1 Full Scale Voltage Span and Counts

The USB4CH has 24 bit A/D converters with 2^{24} counts spread out over the entire input voltage span of the system:

$$\text{TOTAL 24 BIT A/D COUNTS} = 2^{24} = 16,777,216 \text{ (decimal)}$$

Counts are returned as 32 bit *signed integers*. Theoretically, for zero input volts zero counts should be returned, and as the input goes positive or negative the count value goes positive or negative, with 2^{23} counts above zero and 2^{23} below zero.

The USB4CH has +/- 4 volt *balanced differential inputs*. Users are often surprised to learn this implies an input voltage span of 16 volts. Positive full scale counts are returned when the + analog input is + 4 volts *AND* the - input is - 4 volts, a difference of 8 volts. Negative full scale counts are returned when the voltages are reversed, resulting in the 16 volt span for the full count range. Some of the count values from positive full scale down to negative full scale are:

+ Input (volts)	- Input (volts)	Counts (hex)	Counts (decimal)
+4	-4	0x00 7FFFFFFF	8,388,607
...			
+e	-e	0x00 000002	0,000,002
0	0	0x00 000000	0,000,000
-e	+e	0xFF FFFFFFFE	-0,000,002
...			
-4	+4	0xFF 800000	-8,388,608

Figure 10.1: A/D counts with balanced differential input

Balanced differential inputs have many benefits as discussed in the [Analog inputs](#) chapter. Having a 16 volt input span also provides an excellent signal to noise ratio with low op amp power supply voltages. The voltage +e is the smallest voltage the ADS1255 A/D converter can digitize.

The USB4CH can be used as a *single ended* system by connecting the - input to ground and applying the signal to the + input only. However, with such a connection noise immunity is reduced, and the count range is cut in half effectively losing one bit of resolution. Nevertheless, for applications where single ended is appropriate the count values are listed in the table in [Figure 10.2](#).

+ Input (volts)	- Input (volts)	Counts (hex)	Counts (decimal)
+4	0	0x00 3FFFFFF	4,194,303
...			
+e	0	0x00 000001	0,000,001
0	0	0x00 000000	0,000,000
-e	0	0xFF FFFFFFF	-0,000,001
...			
-4	0	0xFF C00000	-4,194,304

Figure 10.2: A/D counts with single ended input

10.2 Approximate counts per volt

With the total counts and the 16 volt span of the previous section in hand, the theoretical counts per volt for the USB4CH is:

$$\text{Counts per Volt} = (2^{24})/16 = 1,048,576 \text{ counts / volt}$$

or equivalently,

$$\text{Counts per Millivolt} = 1,049 \text{ counts / millivolt}$$

$$\text{Counts per Microvolt} = 1.0 \text{ count / microvolt}$$

where the last two values are rounded. Of course the volts per count is just the inverse:

$$\text{Volts per Count} = 16/(2^{24}) = 1.0 \text{ microvolts / count}$$

Note that because the A/D converters have noise floors greater than 24 bits, the resolution implied by these numbers may not be fully usable. For example, at a sampling rate of 100 Hz, the system has a noise free repeatable count value of 20 bits. There are four bits, or $(2^4) * 1.0 = 16$ microvolts, of noise. You may prefer to work in 20 bit counts and 16 microvolts per count for your calculations at that sampling rate.

The input voltage span depends on the gain setting of the front end op amps. The above calculation assumes a gain of 1 on those amplifiers. By changing resistors on the board it is possible to run the amplifiers with gains of 1 to 100 with no increase in the noise floor. This is discussed in the [Analog inputs](#) chapter. The full scale input range will be smaller with added gain, but the counts per volt will be more sensitive.

We *do not recommend* using the ADS1255 PGA feature to increase the counts per volt. As

with most sigma delta A/D converters claiming to have a PGA, the ADS1255 implements this function by changing the effective oversampling. When doing this the noise floor increases in direct proportion. This is in contrast to changing the gain of the USB4CH op amps, where the gain can be increased without corresponding noise floor increases.

10.3 Calibration slope and offset

For the general differential DC transfer function in the [Analog inputs](#) chapter,

$$\text{A/D counts} = \text{slope} * (V+ - V-) + \text{offset}$$

applied to a *theoretically* perfect USB4CH, the slope is the A/D counts per volt as in the previous section and the offset is zero. So the equation becomes:

$$\text{A/D counts} = 1,048,576 * (V+ - V-)$$

For most applications the calibration equation is actually used the other way around: given the A/D counts one wants to compute the corresponding voltage. The DVM program is one example. Given the A/D counts, we have:

$$(V+ - V-) = 9.53674\text{e-}007 * \text{A/D counts}$$

$$9.53674\text{e-}007 = 1/1,048,576$$

and the slope and offset would be entered into the DVM ini file as:

```
ChannelSlope x = 9.53674e-007    ; = ( 1/1,048,576 )
ChannelOffset x = 0
```

The ini files shipped with DVM for voltage display use these theoretically perfect values. Of course, physical components are never perfect and the true slope and offset will be slightly different from this ideal. For an exact calibration of any particular USB4CH channel, you should perform a physical calibration with the DVM [Calibrate](#) program. Note that besides calibration into volts, it is possible to calibrate A/D counts into other physical quantities such as temperature. The slope and offset can include the sensor response too.

The major contribution to offset error on USB4CH boards is the V_{io} input offset voltage of the front end op amps. No op amp is ideal, and the V_{io} parameter measures what input voltage may actually be required to zero the output. For the OPA2277 amps used on the USB4CH V_{io} is +/- 50 microvolts max. See the TI spec sheet for this V_{io} specification,

as well as other details such as TC temperature variation. The following graph shows the offset spreads measured on 10 USB4CH boards for a total of 40 channels at 25 °C:

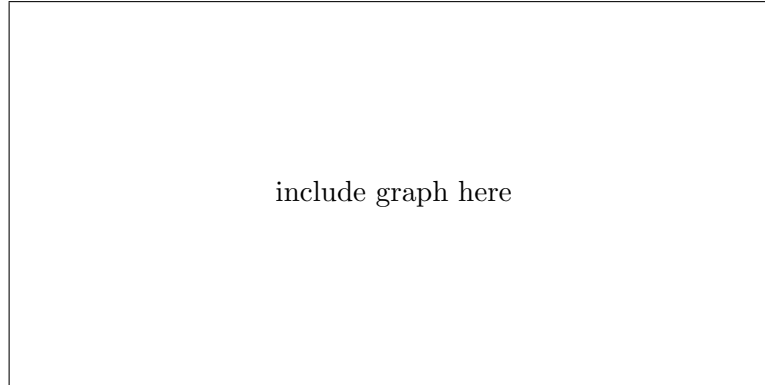


Figure 10.3: Production input offset spreads

Chapter 11

Analog AC calibration

Suppose you have a sinusoidal input. How does its amplitude and phase get modified by the USB4CH? Clearly the response will depend on frequency, and one could measure it frequency by frequency to develop a curve.

While the response can be measured one frequency at a time, the AC transfer function can be computed even more quickly and easily by measuring the response to a single square wave step input. Since a square edge contains Fourier components of all frequencies, the entire response can be computed with one test run. This is the method followed here.

In the experiment, a USB4CH DB25 digital output is used as the square wave stimulus, and the time base of the input and output will be measured with the GPS timing system. See later chapters for details on these capabilities. Using these tools the physical measurement of the AC response is easily carried out.

If you have custom electronics ahead of the USB4CH you can even use the DB25 digital output to measure the response of your front end and USB4CH combined. Simply move the DB25 square wave from the USB4CH DB15 analog input to your front end inputs and use the same techniques as reviewed here.

11.1 Theoretical AC transfer function

The dominate component of the USB4CH AC frequency response comes from its A/D converters. Because all sigma delta converters oversample their inputs and then signal average, they impose a strong low pass filter characteristic on the response. A normalized average of a sinusoid with many cycles in the averaging window tends towards zero and thus the low pass response. Nothing else in the system has a comparable effect.

In this section the theoretical amplitude response will be reviewed, and in the next section the USB4CH response will be experimentally measured for comparison. From the TI ADS1255 spec sheet the theoretical transfer function for the A/D converter is:

$$A(f) = |sinc(x)|^5 * |sinc(N)| / Normalization$$

When plotted this gives the curve:

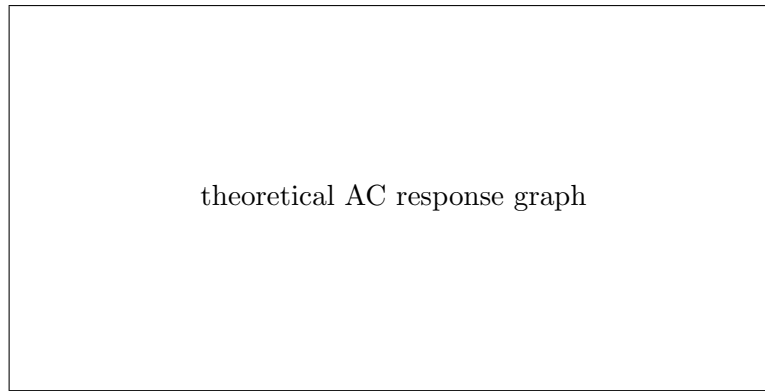


Figure 11.1: AC response: theoretical sinc

which has the familiar low pass bouncy ball response one would expect from a finite length numerical average. As the input frequency increases, when the wavelength agrees with the averaging length, the output falls to zero.

11.2 Measured AC transfer function

The experimental setup to measure the AC frequency response is:

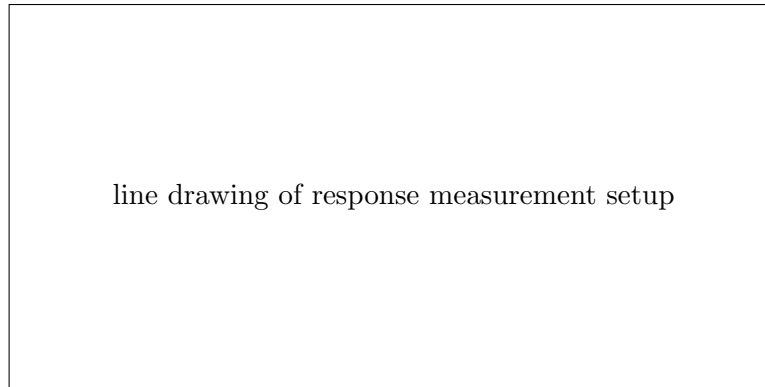


Figure 11.2: AC response: physical measurement setup

Beyond the A/D response, review the contribution of the op amp and RC signal conditioning front end ...

Chapter 12

Digital IO

The USB4CH has digital io in addition to its 24 bit analog inputs. The digital interface can be used for simple communication with external equipment and sensors. The digital io is accessed on the DB25 front panel connector, where besides general purpose inputs and outputs, there are also USB4CH timing signals and a GPS interface.

12.1 Digital input

The USB4CH has four general purpose digital inputs. The digital inputs are *synchronously* sampled and saved automatically along with the 24 bit A/D analog inputs. No special commands are required, with the effect being similar to a mixed signal oscilloscope.

You can also *asynchronously* poll the digital inputs with the User library UserIoRd() function, which will return the input values at the instant of the call. Polling has no effect on the automatic synchronous save, which continues on at the analog sampling rate regardless of whether you poll or not.

The digital inputs use standard 3.3 volt TTL/CMOS levels. Inputs near 0 volts are saved as a logical 0, while those near 3.3 volts are saved as a logical 1. All four digital inputs are buffered through HC14 Schmitt inverters for noise immunity and slow edge tolerance. The USB4CH automatically adds another inversion to the HC14 buffering so the saved digital values agree with the DB25 pins.

Besides buffering, each digital input also has RC filtering for further noise immunity and edge control. Depending on the application, you may wish to change the RC filtering to be different than the factory setting. There is also a pull down resistor on each input so they do not float when left unconnected. See the table below for the DB25 pin assignments and the [Circuit Diagrams](#) chapter for circuit details.

12.2 Digital output

In addition to digital input, the USB4CH also has four general purpose digital outputs.

The four outputs may be set at any time by calling the User Library `UserIoWr()` function. Once written, the outputs stay latched and do not change until another write is done. The power on value of the outputs is 0.

The digital outputs use standard 3.3 volt TTL/CMOS signaling. If you program an output to 0, the corresponding DB25 pin will be close to 0 volts, and likewise programming a 1 will result in the output pin being near 3.3 volts.

All the digital outputs are driven by HC14 inverters, and as with the digital inputs, the USB4CH automatically adds another inversion so the DB25 pin agrees with the programmed logic level. Each output also has a 300 ohm *series resistor* to limit the current that can be drawn from the DB25 pins. There is nothing the user can do to one of the outputs that will cause the USB4CH to crash. Even direct shorts to ground can be tolerated. The 300 ohm resistors also make it easy to connect LEDs as indicators with no additional resistors required. See the table below for the DB25 pin assignments and the [Circuit Diagrams](#) chapter for circuit details.

12.3 Additional digital timing and GPS signals

Along with general purpose digital inputs and outputs, there are also USB4CH timing signals and a GPS interface on the DB25. The signals are:

Adrdy: This output pin is a buffered version of the ADS1255 A/D converter data ready signal, indicating when an A/D conversion has been completed. Adrdy strobes at the same frequency as the analog sampling rate, with the rising edge indicating conversion completion. Applications can synchronize to the A/D sampling rate with this signal. This signal is disabled at power on and must be enabled in the [UserCfgByte](#).

*However ... be aware! Adrdy does not indicate the instant at which analog samples are taken. With *oversampling sigma delta* converters like the ADS1255, the output counts is an *average* of the analog input over the sampling period. Adrdy *only indicates* when the converters have a new sample ready to be moved onward to the PC.*

Trigger: This input pin allows the user to control when the USB4CH begins data acquisition with an external trigger. The polarity of the input can be controlled by the user. By default the trigger is assumed to idle low, with the rising edge indicating the trigger. Idleing high with a falling edge indicating the trigger can be selected by programming the UserCfgByte. See sections [12.6](#) and [12.7](#) below for more details.

GPS: By applying GPS signals from a GPS receiver to these pins you can record GPS time stamp and location information in real time along with the 24 bit analog and digital inputs. See chapter 13 for more details on using GPS with the USB4CH.

12.4 DB25 pin assignments

The digital io signals are available on the male Dsub 25 pin connector (DB25) located on the USB4CH front panel right hand side. The pin assignments are:

DB25 pin	Signal	USB4CH	Power on polarity
Top row			
1	Din bit 0	input	pull down
2	Din bit 1	input	pull down
3	Din bit 2	input	pull down
4	Din bit 3	input	pull down
5	Dout bit 0	output	low
6	Dout bit 1	output	low
7	Dout bit 2	output	low
8	Dout bit 3	output	low
9	Trigger	input	idle low, rising edge
10	Adrdy sync pulse	output	disabled
11	GPS PPS	input	idle low, rising edge
12	GPS RS232 NMEA RX	input	idle high
13	GPS RS232 NMEA TX	output	idle high
Bottom row			
14 - 25	Ground	-	-

Figure 12.1: USB4CH digital DB25 pin assignments

It is easy to count off pins on the DB25. Looking at the connector from the front, all the signal pins are on the top row. All the ground pins are on the bottom row. Counting from the left on the top row, the first four signal pins are the digital inputs, the next four signal pins are the digital outputs, etc. Note that the digital bits are counted starting from 0, while the DB25 pins are counted starting from 1.

All signals must be referenced to the ground on the DB25, where each signal should be paired with a matching ground return if possible. The following two diagrams show the pins viewed from the front panel:

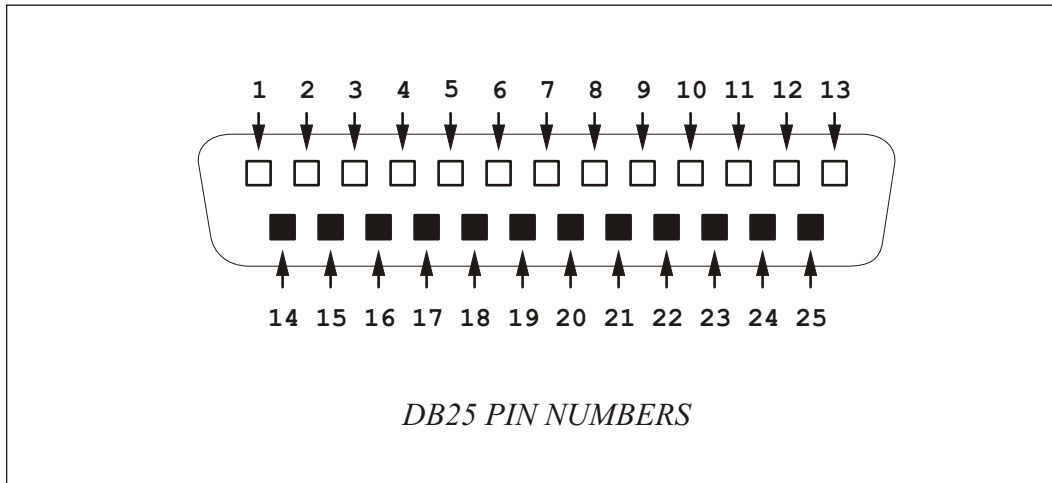


Figure 12.2: Digital DB25 pin numbers viewed from front panel

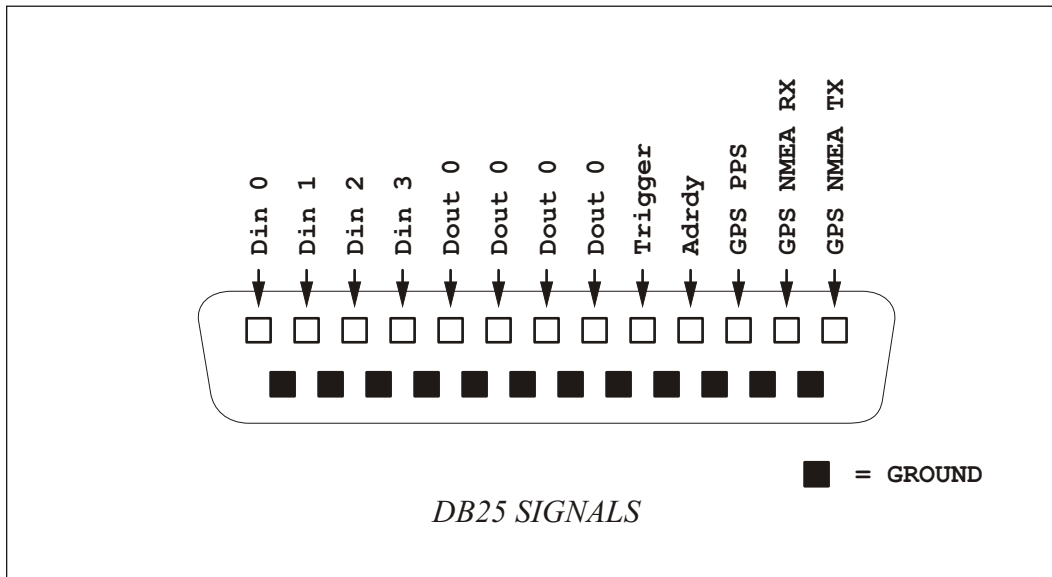


Figure 12.3: Digital DB25 signals viewed from front panel

You can test programming the digital outputs with the utility program **DigitalIo**, see Chapter 4. Measure their values with a multimeter like a Fluke. The digital inputs can be viewed in real time with **Scope**.

12.5 Static shielding

Static electricity discharge (ESD) is damaging to all solid state equipment. The DB25 connector is designed to tolerate small static shocks, *but users must take reasonable steps to avoid ESD problems*. If the ESD event is large enough, such as a lightning strike, there is no hope, but *reasonable steps against smaller events are also necessary* and can avoid failure. Even the static discharge from walking across a synthetic carpet in winter will cause severe damage.

Using *shielded* multiconductor cable for the digital connections to the DB25 is one of the best preventions possible. The foil shield should be connected to the metal DB25 housing. When a static discharge hits the cable, the jolt will be conducted down the shield, onto the USB4CH enclosure, down the USB cable shield, onto the PC enclosure, and hopefully onward to the third wire on the wall power plug. If the case of the PC is not grounded in such a fashion, it should be. Field installations should be equipped with a ground stakes to dissipate the static burst.

Foil shields connected to properly grounded conductive enclosures form a Faraday cage around the electronic equipment keeping the static discharge on the outside. If your equipment is exposed to ESD, building a Faraday cage in this fashion is an effective safeguard, and is *highly recommended*.

12.6 User configuration byte

The polarity of the timing and GPS signals on the DB25 can be programmed by the user. For example, you may want to enable or disable the Adrdy signal, or change the idle state of PPS. These selections can be made with the UserCrfByte passed to the Open function. The bit layout of UserCfByte is shown in the following table:

Bit	Function	Values	Power on default
0	TriggerPolarity	idle low or high	idle low
1	reserved	-	-
2	Adrdy	disabled or enabled	disabled
3	reserved	-	-
4	PpsPolarity	idle low or high	idle low
5	PpsLedToggle	pps toggle or programmed	pps toggle
6	NmeaRxPolarity	idle high or low	idle high
7	NmeaTxPolarity	idle high or low	idle high

Figure 12.4: USB4CH UserCfByte bit assignments

Most users will specify the values of these configuration bits by setting the values of ini keywords in programs like Scope.

12.7 Triggering

The leader length is fixed at 100 samples regardless of sampling rate ...

12.8 Programming the front panel red and yellow LEDs

Call the user library function `SrUsbXchUserLed` to program the front panel red and yellow LEDs.

Note the red LED can serve two different functions. Its power on default is to toggle on and off with every tick of the PPS signal on the DB25 connector. The function can be changed to user programmable by changing the `PpsLedToggle` bit in the `UserCfgByte`.

12.9 Seeing the digital inputs in Scope

Use the Scope application to see the digital inputs in real time. The inputs are sampled in real time and saved synchronously along with the 24 bit analog data.

Chapter 13

GPS Time Stamping

If you have a GPS receiver you can probably use it to accurately *time stamp* data acquired with the USBxCH. Using a particular receiver is often only a matter of making the appropriate cable connections. If you don't have a GPS receiver, Symmetric Research can provide ready to go antennas with the required cabling.

Besides GPS time stamping, the USBxCH also saves real time GPS *latitude* and *longitude* information. This can be useful for mobile applications, as well as for fixed networks with multiple systems that must know locations to triangulate. Both GPS *time and location* are saved continuously as part of the USBxCH data stream.

For sites where GPS reception is not possible, the USBxCH can time stamp with NTP (network time protocol). Although less accurate, NTP is useful when the open sky visibility GPS requires is not available. NTP time stamping is covered in the next chapter.

13.1 What is GPS ?

GPS is a system of orbiting satellites transmitting signals designed to determine location and time at receivers on the surface of the Earth. A GPS receiver uses multiple satellites to triangulate its location and then computes precise time by making propagation delay corrections. The final time accuracy far exceeds traditional methods like WWV.

By far the most popular use of GPS is to determine location for travel and mapping. However, for many applications *accurate time* is equally essential, allowing for the *precise correlation of analog data between widely separated installations*.

GPS receivers are surprisingly small, often no larger than a hockey puck. If your cell phone appears to receive GPS, it may not actually have a GPS receiver, but only receive GPS information from its base stations. True GPS receivers are complete stand alone units that

receive satellite signals directly. One downside to GPS is buildings, cement, and other obstacles may all interfere with reception. In those cases a long cable may be required to place the GPS receiver where reception is possible.

Some GPS receivers combine their antenna and receiver into the same enclosure, while others separate the two. If the antenna and receiver are separated, they will be connected by a RF coax cable. With either type of packaging, there is a final cable from the receiver with digital signals indicating the location and time. It is these digital signals the USBxCH requires to time stamp and locate its data.

Two major GPS manufacturers are Garmin and Trimble. Garmin receivers usually combine the antenna and receiver into the same enclosure, while Trimble often has a separate antenna. The USBxCH is compatible with both of these brands and many others. The general nature of the final GPS digital output is reasonably standard, and the USBxCH has programmable features to accommodate several of the common variations. As a specific example, this chapter will show how to connect a Garmin GPS 16x HVS.

13.2 Required GPS signals

The USBxCH requires *two* specific digital outputs from the GPS receiver:

The first GPS output is a RS232 serial signal. This signal has location and *coarse* time information. It is comprised of ASCII strings which are emitted once per second in predefined formats, with the most popular being NMEA (national marine electronics association) format. Because NMEA strings are only emitted once per second, it is difficult to determine time to better than one second with them alone, and so ...

The second GPS output is a PPS (pulse per second) TTL/CMOS signal. The leading edge of this signal is precisely aligned with the global GPS second tick. The accuracy of the PPS edge is usually within a few microseconds, where expensive receivers may even achieve nanosecond accuracy. The USBxCH is designed to use PPS in conjunction with the RS232 NMEA strings to time stamp acquired data entirely on board. The time stamping is done automatically with a dedicated FPGA. Accuracy is maintained regardless of cpu loading, interrupts, USB activity, or other system considerations.

13.3 DB25 pin assignments

The GPS receiver outputs must be connected to the USBxCH front panel *male* DB25 connector. If your GPS receiver has a cable with wire ends you should use a *female* DB25 connector to make the connections. The following table gives the USBxCH DB25 GPS pin assignments, along with a line drawing of the front panel connector in Figure 13.2. These pins are also covered in the Digital IO chapter.

DB25 pin	GPS signal	USBxCH	Power on polarity
Top row			
11	PPS	input	idle low, active high
12	RS232 NMEA RX	input	idle high
13	RS232 NMEA TX	output	idle high
Bottom row			
14 - 25	Ground	-	-

Figure 13.1: DB25 GPS pin assignment table

All signals must be reference to the USBxCH DB25 ground pins. *This is crucial.* Any noise, glitch, or grounding problems with respect to the USBxCH will result in unreliable time stamping. It is the user's responsibility to provide *clean* GPS signals *at the front panel DB25* in order to have reliable time stamping.

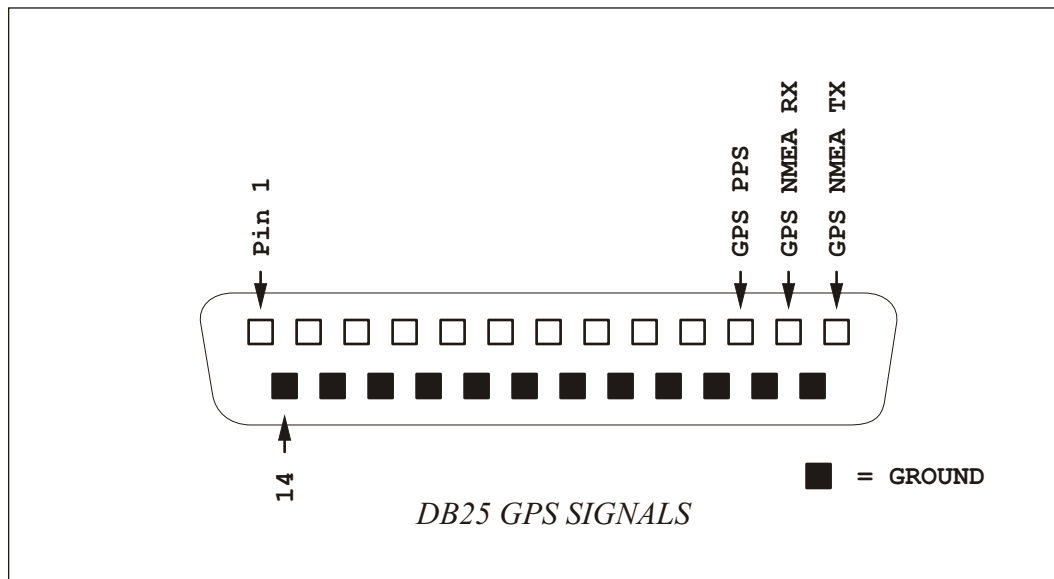


Figure 13.2: DB25 GPS signals viewed from front panel

Note that besides having a RX pin to listen to the GPS NMEA output strings, the USBxCH also has a TX pin. Most GPS receivers are configurable, and this allows the USBxCH to program receiver features. The TX programming strings are defined as part of the NMEA standard and are an output from the USBxCH point of view.

Also note that the NMEA RX pin can accept a variety of input voltage levels. There is no standard for whether GPS receivers output full +/- 12 volt RS232 or lower level

TTL/CMOS signals, so the DB25 RX pin has been designed to accept a wide range of voltage levels. All other DB25 pins expect + 3.3 volt digital levels.

The power on defaults for the signal polarities are given in the last column of the table in Figure 13.1. For an explanation of selecting different polarities with the UseCfgByte, see the sections [RS232 polarity](#) and [PPS polarity](#).

13.4 Using a Garmin 16x HVS with the USBxCH

As a specific example, this section shows how to connect a Garmin GPS 16x HVS receiver to the USBxCH. The Garmin 16x is similar to many GPS receivers, and the steps given here should be similar to those for others. If you have difficulty making cable connections, Symmetric Research offers ready to go antennas.

The Garmin 16x is a rugged unit designed for outdoor use. It can be mounted on flat wall surfaces and the ends of pipes with flanges and adapters. The unit has its antenna and receiver packaged together in a single hockey puck enclosure. For connections, there is a round multiconductor cable with outputs, inputs, and power for the puck. The following lists the Garmin multiconductor cable wire assignments:

Garmin wire	Color	Signal	Desc
1	red	power	+12 VDC power
2	black	ground	power and signal ground
3	yellow	enable on/off	power on = low
4	blue	RS232 NMEA in	NMEA config programming
5	white	RS232 NMEA out	NMEA string output +/- 12
6	gray	PPS	Pulse per second
7	green	port 2 / data in	Garmin reserved / not used
8	violet	port 2 / data out	Garmin reserved / not used

Figure 13.3: Garmin GPS 16x HVS wires

To hook up the Garmin 16x, its cable must be terminated with suitable connectors. In this example, we will use a female DB25 connector for signals, and a 2.1mm barrel connector for power. Note the Garmin cable has only one common ground wire for both power and signals. This single ground wire should be connected to a USBxCH DB25 ground pin to avoid ground bounce at the DB25. Figure 13.4 shows the wiring diagram. Note also the Garmin cable has a foil shield. Garmin recommends *not connecting the foil shield to anything* because it is part of the antenna system. We have followed that recommendation. Finally, because the 16x HVS can be powered from a wide range of supply voltages, we

have hooked it up to the USBxCH wall transformer using the daisy chain 2.1mm connector on the USBxCH back panel. If you are using an antenna that must be powered from a regulated voltage such as +5 volts, *do not connect it to the wall transformer*. The voltage will be too high. In those cases you must provide the antenna with its own +5 volts. The photo in Figure 13.5 shows the finished cabling with the 2.1mm power and DB25 connectors.

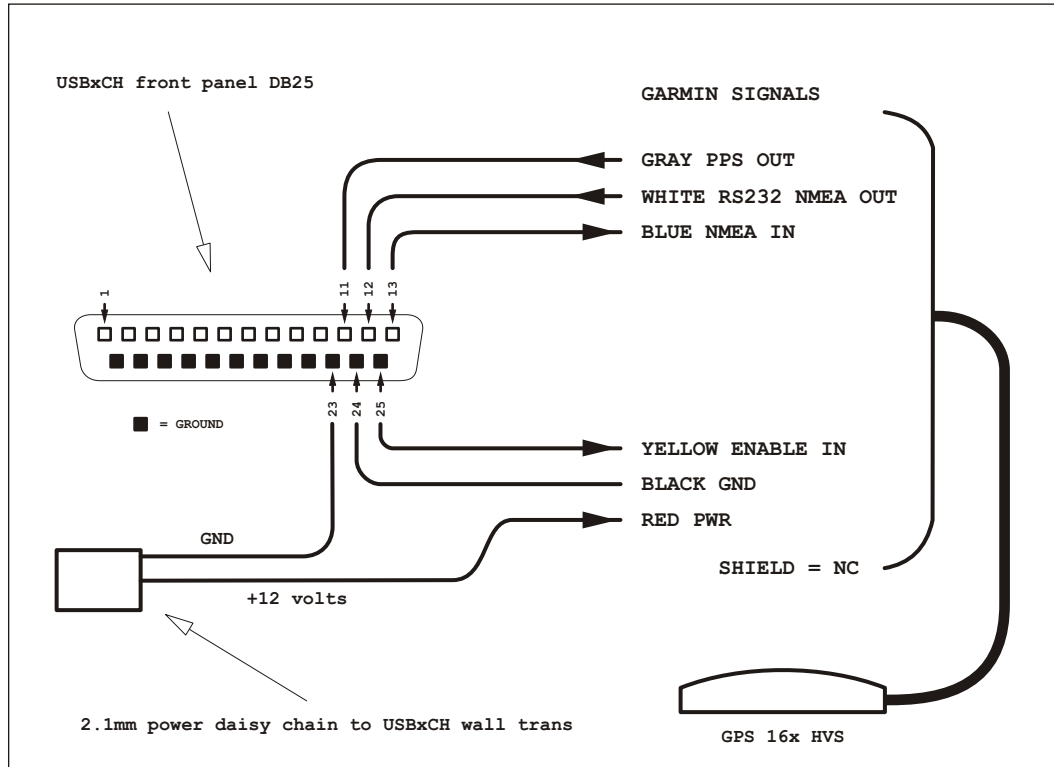


Figure 13.4: Garmin GPS 16x HVS wiring

13.5 Determining RS232 polarity

Suppose you are using a receiver other than the Garmin 16x. It may have a RS232 polarity different than the USBxCH power on default. Even within a particular GPS vendor catalog there are likely to be differences between models that must be accommodated.

To make a successful RS232 connection, there are two major considerations. The RS232 *baud rate* and *polarity*. The USBxCH expects a 4800 baud rate signal, and the GPS receiver *must be configured for that rate*. Most GPS receivers come with a utility program to set



Figure 13.5: Garmin GPS 16x HVS finished cabling

their baud rate, and you should use it to set 4800 baud. The RS232 polarity is generally less configurable, so the USBxCH has provisions to accept inverted or non inverted RS232.

RS232 polarity comes in *two* styles: Full +/- 12 volt RS232, or TTL/CMOS. Typically, 12 volt RS232 has inverted polarity, while TTL/CMOS RS232 is non inverted. Even if the signal levels are not +/- 12 volts, you may still have inverted outputs. You can determine the polarity by studying the output on a scope. If the output idles high between characters, then the signaling is 12 volt style and the USBxCH should be programmed to idle high. You can also probably do this measurement with a multimeter, watching activity between bursts of signal. Even if not a full + 12 volts, if the output reads more than a volt or two between bursts of activity you probably have 12 volt inverted idle high signaling.

If on the other hand the RS232 NMEA string output idles near 0 volts between bursts of activity, then you probably have TTL/CMOS style signaling and the USBxCH should be programmed to expect non inverted idle low.

Selecting RS232 idle high or low is programmed with the USBxCH `UserCfgByte`. For most users, the easiest way to specify a selection is with the keywords in the Scope ini file. If you are writing custom software, selections should be specified with the UserCfgByte passed to the User C Library `Open` function.

13.6 Determining PPS polarity

As with the RS232 polarity, GPS receivers also vary in their PPS polarity. It is most common for PPS to idle low and the *rising edge* to indicate the PPS tick:

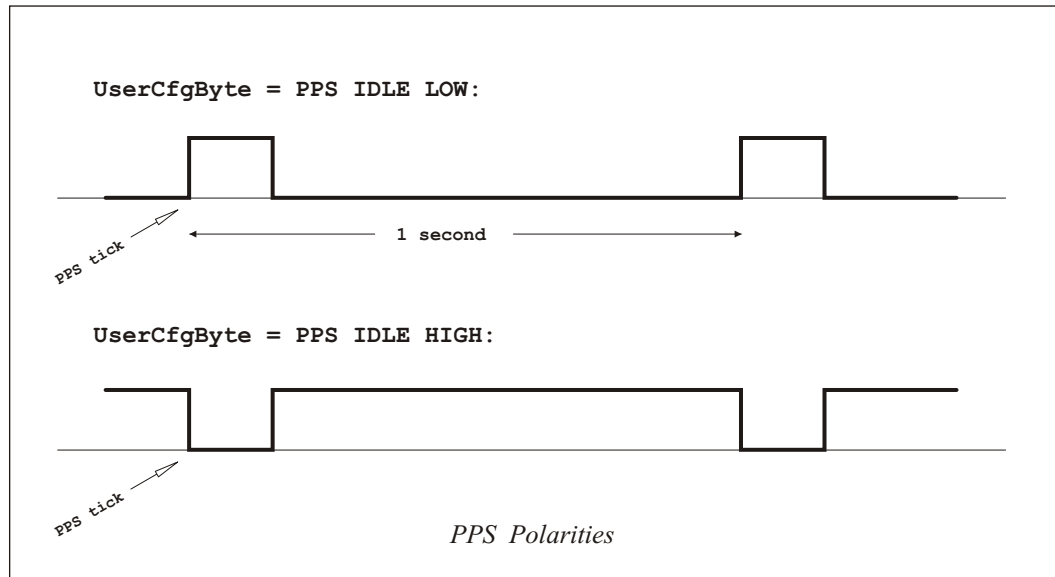


Figure 13.6: PPS signal polarities

However, there are receivers that idle high and use the *falling edge* of PPS to indicate the tick. You can accommodate the variation with the USBxCH **UserCfgByte**. The PPS convention used by a particular receiver can be determined with an oscilloscope or multimeter and observing the behavior between bursts of activity. Note that if you have the USBxCH programmed for idle low but the GPS receiver actually idles high, your system will appear to work ... but the time stamps will be off by the width of the PPS pulse!

The PPS pulse width does not matter to the USBxCH as long as it is greater than 100 *nanoseconds*. Within that constraint, it is only the leading PPS edge that signals a tick. In practice, we have never seen a PPS tick narrower than 10 microseconds, or wider than 0.5 sec. The 100 ns minimum width is easily met by most receivers. Note that if the PPS width is as wide as 0.5 sec you will have trouble determining the polarity with a multimeter. Consult the receiver's User Manual in that case.

As with RS232 polarity, for most users the easiest way to make a PPS polarity selection is with the keywords in the Scope ini file. If you are writing custom software, the UserCfgByte value should be passed to the User C Library **Open** function.

13.7 Front panel red LED

If you have a GPS antenna hooked up and successfully receiving, the front panel red led should toggle on and off once a second in response to the PPS signal. If it is not toggling, there is a problem with PPS. It may be as simple as the GPS receiver taking awhile to get full satellite lock at power on. A half hour to get lock from a cold start is not uncommon with many receivers. If the receiver has been on for awhile and successfully sending PPS, then perhaps the number of satellites has fallen too low, or the receiver needs better visibility. If you see the red led toggling, then you know PPS is being signaled by the antenna.

It is possible for the front panel red led to be set to program mode with the `UserCfgByte`, and not respond to PPS. However, the power on default is PPS toggle and GPS users should normally be able to see the red led respond.

13.8 Expected NMEA strings

Most GPS antennas can be programmed to output a wide variety of RS232 NMEA strings. In fact, it is even possible to program many antennas with obviously incorrect settings such as emitting more NMEA characters than it is possible for the RS232 baud rate to transmit in 1 second. So ... care is required.

The USBxCH hardware and software expect particular NMEA strings, and the GPS antenna should be programed accordingly. If the antenna is programmed differently the USBxCH may give incorrect results. Antennas supplied by SR will already be programmed with the correct NMEA string line up.

The first consideration for the NMEA strings is the total number of characters emitted. The USBxCH hardware buffer can only hold 255 characters per second. A NMEA string lineup less than this must be selected. The second consideration is the strings themselves. Many NMEA strings do not have sufficient coarse time and location information to provide the quantities needed to compute the time stamp. In particular we recommend the antenna be programmed to output the following two strings in this order:

<code>\$GPRMC</code>	for coarse time and date info
<code>\$GPGLA</code>	for location information

All other strings should be turned off and not emitted. For a description of the Garmin NMEA strings, please refer to section 4.2.2 in:

</SR/USBXCH/Docs/GpsSpecs/GPS16x.TechnicalSpecifications.pdf>

A copy of this Garmin document is included with the SR software distribution for convenience. In particular, the RMC and GGA string pairs expected by the USB4CH will typically read as:

```
$GPRMC,185442,A,3608.9181,N,11517.9605,W,000.0,000.0,150310,013.4,E*6F
$GPGGA,185442,3608.9181,N,11517.9605,W,2,10,1.2,880.3,M,-26.0,M,,*70
```

where the comma separated fields contain the time and location information. For example in the RMC sting, the A indicates the antenna has lock and the fields are valid, while the N indicates the latitude is in the northern hemisphere, and so forth. Note each string is terminated with a ***xx** checksum. The field values will of course vary depending on when and where you run the system. See the Garmin document for details about all the fields. When using Scope and Blast, you *do not have to decode* the time and date fields. Those programs and their conversion utilities automatically take care of the decoding. To simply verify the NMEA strings are being received, use the **NmeaTime** or **Diag** utilities.

13.9 Programming the GPS antenna

If you purchase a Garmin or Trimble GPS antenna from Symmetric Research, it will already be programmed correctly for the USBxCH. Users with other antennas will need to program the baud rate, NMEA string lineup, and PPS enable to be compatible. Note that *even the Garmin and Trimble factory defaults* are usually not compatible with the USBxCH. They tend to output too many strings and have PPS disabled.

Included with the SR supplied software is a Windows utility from Garmin for setting their basic programmable antenna features. It is included with the distribution for convenience. Besides programming the NMEA string line up to agree with the previous section, also be sure to enable the antenna to output PPS. You can find the Garmin programming utility in:

```
/SR/USBXCH/Docs/GpsSpecs/snsrxcfg_200.exe
```

To use this program you will need a computer with an RS232 port and a custom cable. See the ReadMe.txt file in the /GpsSpecs directory for more information. Garmin does not supply a programming utility under Linux.

You can also use the SR utility **GpsProg** to program a Garmin antenna *while connected to the USBxCH*, rather than a separate RS232 port. Both Windows and Linux versions of this SR command line utility are supplied.

13.10 Seeing the GPS time stamps in Scope and Blast

To see the time stamps from Scope or Blast, first acquire data to DAT or PAK files, and then run either the **Dat2Asc** or **Pak2Asc** conversion utilities respectively. The time stamps will appear as a column associated with each set of samples. The command lines:

```
cmd:prompt> Dat2Asc 00000000.dat fw
cmd:prompt> Pak2Asc 00000000.pak fw
```

would be typical, with the resulting output shown next. The analog CHx columns and digital data have been omitted to fit on the page. The time of each sample point is presented in both in decimal form as "Time as Seconds" and also "YMDHMS" formats for easy processing by downstream applications. The time in seconds is measured from (1970/01/01).

Typical Pak2Asc output:

#	Pt#	CHx	PwrH	DegC	DegF	Time in Seconds	Time as YMD HMS
0000000000	1	26.0	79	1268679282.069689	2010/03/15 18:54:42.069689	
0000000001	1	26.0	79	1268679282.070457	2010/03/15 18:54:42.070457	
0000000002	1	26.0	79	1268679282.071225	2010/03/15 18:54:42.071225	
0000000003	1	26.0	79	1268679282.071993	2010/03/15 18:54:42.071993	
0000000004	1	26.0	79	1268679282.072761	2010/03/15 18:54:42.072761	
0000000005	1	26.0	79	1268679282.073529	2010/03/15 18:54:42.073529	
0000000006	1	26.0	79	1268679282.074297	2010/03/15 18:54:42.074297	
0000000007	1	26.0	79	1268679282.075065	2010/03/15 18:54:42.075065	
0000000008	1	26.0	79	1268679282.075833	2010/03/15 18:54:42.075833	
0000000009	1	26.0	79	1268679282.076601	2010/03/15 18:54:42.076601	
0000000010	1	26.0	79	1268679282.077369	2010/03/15 18:54:42.077369	
0000000011	1	26.0	79	1268679282.078137	2010/03/15 18:54:42.078137	
0000000012	1	26.0	79	1268679282.078905	2010/03/15 18:54:42.078905	
...							

This particular data was acquired at 1302Hz. At that rate the sample period is $1/1302 = 0.0007680$ seconds, and you can confirm each time stamp is indeed incrementing by that amount. In fact the GPS controlled time stamping is so accurate you can even measure the frequency of the on board 10MHz master A/D clock controlling sampling rate with extreme precision. If you wish to also see the latitude and longitude displayed as a columns, run the conversion utilities with the **showall** command line option.

13.11 What does time stamping mean ?

Many users ask if the USBxCH A/D master clock or Adrdy signal is synchronized to the PPS tick. The answer is NO:

The USBxCH *does not* phase lock its master clock (or Adrdy) to PPS

A true statement is: The USBxCH uses GPS to *time stamp* the data it acquires. When an A/D sample *is available*, the GPS time at which it became available is recorded as part of the data stream.

This statement should be taken literally. For example, the time stamp *does not even indicate the exact instant when the sample was acquired*. Analog samples acquired with sigma delta A/D converters are averaged results over the sampling period. *The time stamp only indicates when the end of the A/D oversampling averaging period occurred*.

Given this understanding, exactly how accurate is the time stamp recorded at the end of the oversampling period? It depends on two factors. The first is obviously the accuracy of the PPS signal itself. Most receivers have accuracies in the low microseconds, while expensive receivers may be as good as nanoseconds. The length of the cable connecting the GPS receiver to the USBxCH can also be a similar issue. Two installations with different cable lengths will not deliver their PPS ticks at the same instant at the USBxCH DB25. If you need better accuracy regarding these issues, you have no choice but to improve the receiver or cabling.

The second factor is the accuracy of the USBxCH itself. This is guaranteed to be 800 nanoseconds worst case. The USBxCH time stamp is computed by a dedicated onboard FPGA controller, and is *always within 800 ns of the PPS tick*. No cpu polling, interrupt, or other activity is involved.

We are also often asked if the time stamps are the same across all the USBxCH channels. Since each channel is clocked from the same master clock and controlled in parallel by the same FPGA, there is *no skew between channels*. Each channel has identically the same timing environment. Each channel asserts Adrdy at exactly the same nanosecond, and the associated time stamp is the same across all.

Finally, users sometimes ask about using timing signals other than GPS. For example, there are systems generating PPM (pulse per minute) signals. With appropriate interpretation of the resulting data files, these systems can work with the USBxCH. With a PPM signal, timing marks will simply occur in the output files every minute rather than every second.

13.12 Driving multiple USBxCH systems from one GPS

It is possible to drive *several* USBxCH systems from *one* GPS receiver. Doing so only requires daisy chaining the GPS NMEA RS232, PPS, and ground from one USBxCH system to the next, connecting them all in parallel.

If you choose to daisy chain GPS in this fashion, *DO NOT use a full width DB25 ribbon cable* when connecting one USBxCH DB25 to the next. This will unintentionally connect the *digital outputs* on one system to the next, creating contention. The DB25 connectors have many signals and you must treat them all appropriately. Only daisy chain the NMEA, PPS, and ground with discrete wires.

Chapter 14

NTP Time Stamping

NTP (network time protocol) can be used to time stamp data acquired with the USBxCH. Although less accurate than GPS, NTP is useful for many applications where a GPS antenna is impossible because of physical location, expense, or power consumption.

Using NTP with the USBxCH is straightforward. First, use NTP to set the PC clock. This can usually be done with utilities provided by the operating system. After that, set the USBxCH to use the PC clock as its time source. Using the PC clock as a central time source in this fashion has its advantages. All hardware running in parallel on the PC will have access to the same time base.

NTP has its inherent inaccuracies. One of the primary problems are cable delays. Because USB, Web, or Ethernet delays all depend on the activity of all the attached peripherals, NTP time stamping will not have the absolute accuracy of GPS. By comparison GPS computes its time signals directly on the USBxCH board with a custom controller giving microsecond accuracy.

The next two sections cover the steps required to use the NTP time system with the USBxCH.

14.1 Synchronizing the PC clock to NTP

Each of the operating systems supported by the USBxCH has command line utilities to synchronize the PC clock with NTP. The sync is done continuously, but is not perfect. There are jumps in the PC clock as the background NTP utilities resync the PC clock.

Work underway ...

14.2 Setting the USBxCH to use the PC clock

Once the PC clock is synchronized to NTP time, all that is required is to set the USBxCH to use PC time to time stamp its data. For programs like Scope, set the ini file parameter `GPS_MODEL` to `PC_TIME` and you are done.

Work underway ...

Chapter 15

Power Supply

Reliable power is critical to the USBxCH. Many seemingly mysterious problems are actually the result of unstable power. The power supply must have sufficient voltage and current for the system to work correctly. There must be a solid ground connection between the power source, USBxCH, PC, and other peripherals without a voltage difference between one ground point and another. Failure to give adequate consideration to these aspects of the power supply will result in unreliable operation. This chapter covers some of the basics.

15.1 Power connectors

Power connectors for the USBxCH are on the back panel. Most users will already be familiar with the wall transformer 2.1mm barrel connector. Actually, there are two 2.1mm jacks on the back panel connected in parallel. This makes it easy to daisy chain several devices from the same wall transformer. It does not matter which 2.1mm jack the wall transformer is plugged into and which is used as the daisy chain.

Besides the 2.1mm power jacks, there is also a 4 pin molex power header which is available when using the USBxCH as a bare board. It is intended for field box applications where the USBxCH is part of a hardware stack. In such applications, power is often distributed on discrete wire cables with molex terminations.

It is important the power cables for the USBxCH be of sufficient gauge. 24 gauge stranded wire or larger is recommended. The inductance of skinny wires may choke the power supply off when the USBxCH hits an execution peak and demands more power. It is particularly important *the ground wire be of sufficient gauge*. If the ground wire establishes system ground and all signals are referenced to it, then any ground bounce will cause false signaling and digital errors.

15.2 Voltage and current requirements

The USBxCH requires only a single positive power supply. *The supply must be DC.* AC supplies that are directly from an AC transformer *will not work*. So for example, the power from a 9vdc 500ma unregulated wall transformer is acceptable, while that from a 9vac 500ma wall transformer is not.

The off board power is conditioned and regulated by active circuitry on the USBxCH. In fact, there are multiple linear regulators to generate the precision voltages required for 24 bit A/D converters. See the [Power supply](#) circuit diagram pages.

Off board power may vary over a wide range. The minimum is 8 volts, and the maximum 24 volts. If the power goes below 8 volts, the board will detect the error and indicate it by turning on the back panel red LED, as well as setting the power status flag to an error. If you use an unregulated DC wall transformer, it is ok to have 50/60Hz power ripples, *as long as none of the ripples go below 8 volts*. AC wall transformers do not meet this requirement and the red LED will light up.

If possible, power supplies in the range of 9 to 12 volts are recommended. Because the USBxCH uses linear regulators and consumes approximately 100ma regardless of supply voltage, the excess power at higher supply voltages is dissipated as heat and the board will run hotter. Supplies as high as 24 volts are acceptable, but cooler electronics is always better, and those in the 9 to 12 volt range are ideal. Voltages beyond 32 volts simply exceed component specifications and will cause permanent damage even before the board overheats.

The current consumption of the USBxCH depends somewhat on the sampling rate and other activities of the board. Typically it is 100ma for a USB4CH with +/- 5ma variation. At power up, while on board capacitors are charging, the board may draw as much as 350ma. The off board power supply must be capable of supplying this amount of inrush current to successfully power up. The inrush current surge may last for 2 seconds, but no longer. Active on board circuitry *always limits* the total current consumption to 350ma +/- 10% even under most short circuit conditions.

Besides wall transformers, many other supplies meeting the voltage and current requirements are acceptable. This includes lab bench supplies as well as batteries. For example, you may power the USBxCH directly from 12 volt lead acid batteries. We have even seen 9 volt transistor radio batteries used. Of course, the length of time the system will run is directly proportional to the Ah (amp-hour) rating of the battery. A 9 volt transistor radio battery will not last very long.

When running from batteries, we highly recommend including a manual switch so the battery can be connected with one clean quick action. Sparks often occur when attaching an active load to a battery with alligator clips. Not only will the sparks bounce the power and probably crash the USBxCH, it is also dangerous if there are any flammable hazards

in the area. Use a sealed snap action toggle switch to make the final battery connection.

Wall transformers, batteries, and some lab power supplies are floating and not necessarily connected to any ground system. In such cases, be aware if other devices are using the same floating supply, because the USBxCH will be sharing the ground connection with those devices. In such installations make sure a heavy ground wire is used so all the devices share the same common ground. *CPU boards are often serious offenders in this regard.* They may draw many amps when hitting execution peaks, and create inductive ground bounces for all the other devices. *If your system is behaving unreliably, review the ground system carefully.*

15.3 LED power status indicators

On the USBxCH back panel there are two LEDs, one green, one red. Both are near the 2.1mm power connectors and give a visual indication of the power status.

The green LED will light up if there is any power supply voltage at all. Even power as low as 3 volts will light it up to indicate the wall transformer or other supply is energized at some level. If the green LED is off, then check for very basic problems with the power supply itself. Things as simple as a wall plug not being turned on are common, or if you are running from batteries they may be dead. *If the green LED is not on, check the off board power and correct the problem.*

Once the green LED is on, the red LED further indicates whether the USBxCH regulators are within specifications. *If the red LED is on, the on board regulators are not functioning correctly.* The problem is most likely the off board power supply voltage is too low. For example, if the power supply is 5 volts, the green LED will be on, *but the red LED will also be on.* You must raise the power to at least 8 volts for the red LED to turn off.

The red LED may indicate other conditions besides low power supply voltage. For example, during power up the on board capacitors are charging and the regulators are momentarily out of specifications. In this case, the red LED should go off within 2 seconds and then the USBxCH will be ready to run. If the red LED stays on permanently, there is a problem that must be fixed. After verifying the off board voltage is sufficient, the red LED may be indicating there is a short on the USBxCH board itself and the current limit is activated.

Do not run for extended periods with the red LED on. Diagnose the problem.

15.4 POWER GOOD signal

The status of the back panel red LED is also available in software, and can be accessed in two ways:

First, an ongoing record of the power status is automatically saved once a second in programs like **Scope** and **Blast**. This information is continually recorded and saved in the DAT and PAK files. Besides the power status, the system temperature is also recorded as described in the next chapter.

Second, you can test the power status by calling the User C Library **PowerGood** function which returns a 1 if power is good, 0 if not. The power status is a latched value. It is cleared by calling Open and initializing the system. If power goes bad at any time during the run, the system remembers the event and IsPowerGood will return 0.

15.5 Reset and power cycling

A hardware jumper is provided on the USBxCH board to force a full power reset cycle. This is the most drastic reset possible. The power supply performs a momentary power down of the entire board. The PC plug and play system will act as if the USBxCH has been unplugged from the system, and do a complete restart.

The power cycle feature is only available if the system is being used as a bare board. The power reset header is J940 on the back edge of the board near the molex power connector. Placing a short between its two header pins will trigger the reset. The short can be made with a header jumper, a piece of wire, a screwdriver, or an open collector output from a logic device.

Power cycling is particularly useful for field box applications. If the field box can only be remotely accessed you may want to provide an internet interface to the power cycle, or perhaps periodically take the system down with a timer for a complete system reset.

15.6 Current limiting

Power consumption on the USBxCH is current limited. The current drawn from the power supply will never be more than 350ma. This includes power up inrush current. There are active power clamps enforcing a hard limit on the power. Normal power consumption after inrush current has subsided should be approximately 100ma. If more current is being consumed then something is wrong *and should be fixed*.

If the USBxCH is in current limit mode, the regulator heat dissipation will be excessive. Extended periods at the peak power supply voltage of 24 volts with the back panel red LED continuously on will push the thermal limits of what the board can withstand. The system will survive, but turn the system off and diagnose the problem.

Chapter 16

Temp Sensor

The USB4CH is equipped with an onboard temperature sensor which records the board temperature once per second. With this information you can perform system level temperature corrections that include the effects of voltage reference, op amp, and resistor TC drifts.

The physical temp sensor is a Microchip TCN75. A manufacturer spec sheet is included in the /Docs/ChipSpecs directory. The component has a max error of +/- 2°C from - 40 to + 120°C. Of course the temp sensor does not record the temperature at the exact location of the voltage reference or any other particular component. However, being a multilayer board with copper ground and power planes, the temperature is reasonably uniform from one side to the other. This is particularly true if the system is inside a field box along with other equipment.

16.1 Where is the temp data stored ?

Temperature recording is done automatically and does not require any special actions by the user. The temp reading is reported once per second as part of the GPS NMEA strings. A trailing data packet including the temperature, power supply condition, and other system indicators is tacked onto the end of the once per second NMEA strings.

If you don't have a GPS antenna you can still get the system status reports by setting the ini file parameter GPS_MODEL to PC_TIME in programs like Scope. With Blast specify the corresponding command line argument. To see the temp records, run the Pak2Asc conversion utility on the PAK data files. Plotting the system temp along with the other analog and digital data is a useful tool to determine how a site is responding to daily temp variations.

16.2 Temp calibration

For those needing the ultimate in TC correction, a system level thermal calibration can be performed. Once the response to a specific temperatures profile is known, it can be used to correct data acquired in the field. When performing a TC calibration, run several thermal cycles to account for hysteresis.

Chapter 17

Specifications

The table on the following page lists the leading USB4CH operating specifications. Many performance questions are discussed in more detail in their respective chapters. The small table here lists the primary analog components used on the board. Copies of the manufacturer specification sheets are also included in the directory `/Docs/ChipSpecs`.

A/D converter	=	ADS1255	(Texas Instruments)
A/D voltage reference	=	REF02AP	(Texas Instruments)
Front end op amp	=	OPA2277UA	(Texas Instruments)
Temp sensor	=	TCN75	(Microchip)

17.1 Specifications table

USB4CH Specs					
Parameter	Comment	Min	Typ	Max	Units
Analog input:					
Input voltage range (1)		- 4.0		+ 4.0	volts
Sampling rate (2)		3.26		9,765.625	Hz
Resolution			24		bits
Noise Floor (3)	at 130 Hz			3	bits
	at 1302 Hz			5	bits
Input Impedance (4)			51K	10M	Ω
Overvoltage tolerance (5)	10K ohm series R	- 20.0		+ 20.0	volts
Digital IO:					
Logic 1 high voltage			3.3		V
Logic 0 low voltage			0.0		V
Output current	300 ohm series R			11	ma
GPS interface:					
NMEA RX baud rate	fixed		4800		baud
NMEA TX baud rate	fixed		4800		baud
PPS pulse width		100	-	unlimited	ns
Time stamp error	worst case	-	-	800	ns
USB cable:					
USB type / bit rate	USB 1.1			12	Mbit/sec
USB cable length				6	feet
Power supply:					
Supply voltage		8	12	24	Vdc
Supply inrush current	2 s at power up		350		ma
Supply current (6)	converting		100		ma
Supply current (7)	sleeping		2		ma
General:					
Temp range		0		70	$^{\circ}\text{C}$
Board dimensions			5.28 x 6		inches

Figure 17.1: USB4CH specifications table

- (1) Min/max input on any + or - analog pin within conversion range
- (2) The USB1.1 and DRAM FIFO bandwidth limit the sampling rate to this maximum
- (3) Absolute maximum noise floor measured in peak to peak bits
- (4) Input impedance is set by onboard resistors, 51K = factory default
- (5) Absolute min/max, beyond this damage occurs, 10K series R is internal to board
- (6) Power consumption varies little with conversion rate
- (7) Sleep mode occurs when Close is executed

17.2 Noise floor

The USBxCH noise floor varies with sampling rate. This is characteristic of all systems based on sigma delta A/D converters, where the faster the final data output rate, the less time there is for signal averaging. The typical performance at various rates is:

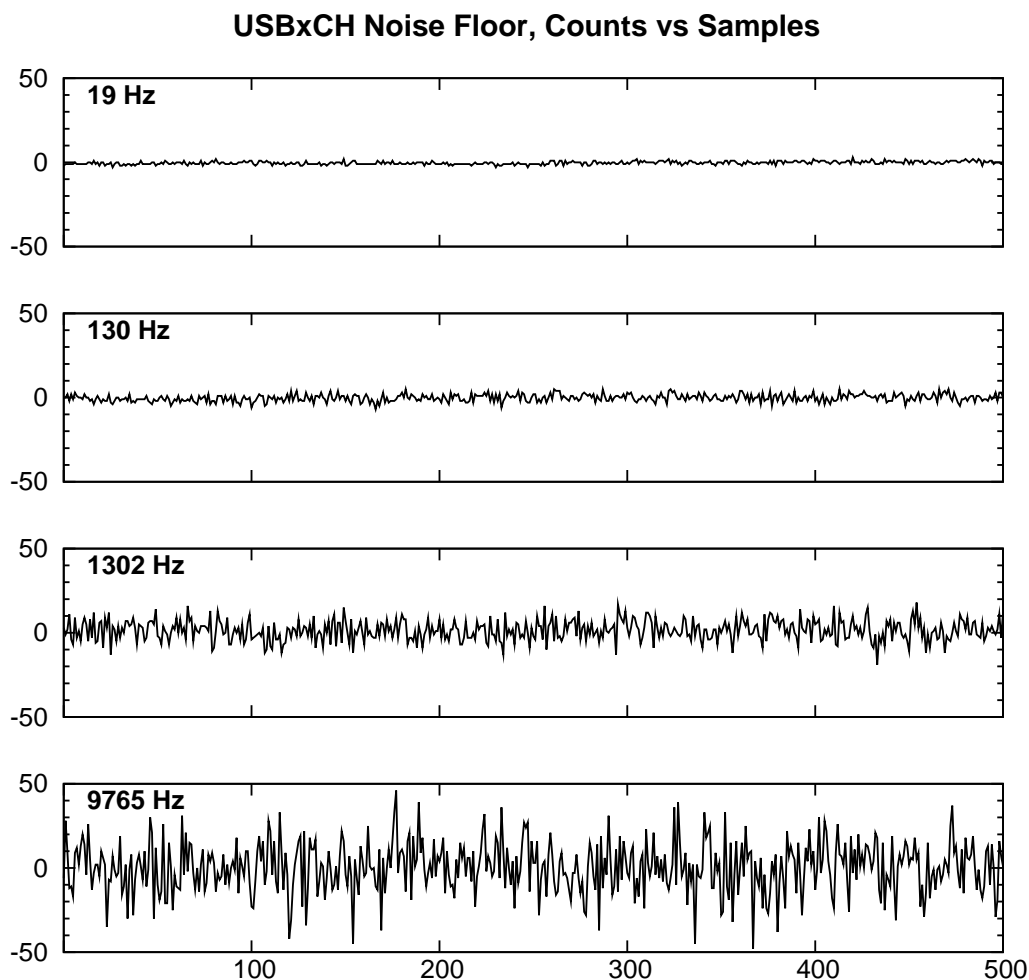


Figure 17.2: Noise floor variation with sampling rate

These graphs show the peak to peak noise versus time. The vertical axes are in counts, where 1 count is the 24th bit of the converted result. Similar results can be seen running the **Scope** program in real time. If the results from Scope are worse than the plots above, you have another noise source in the overall system besides the USBxCH.

Besides plotting the noise floor as a function of time, it is also useful to display the results as histograms:

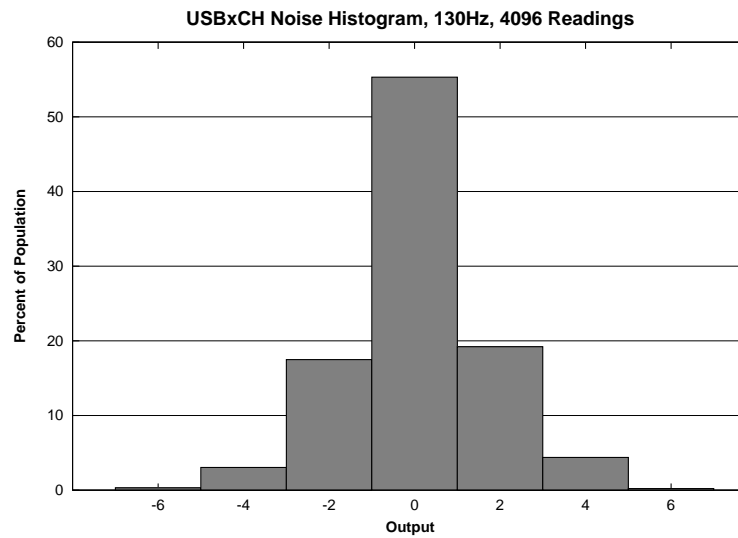


Figure 17.3: Noise floor histogram at 130Hz

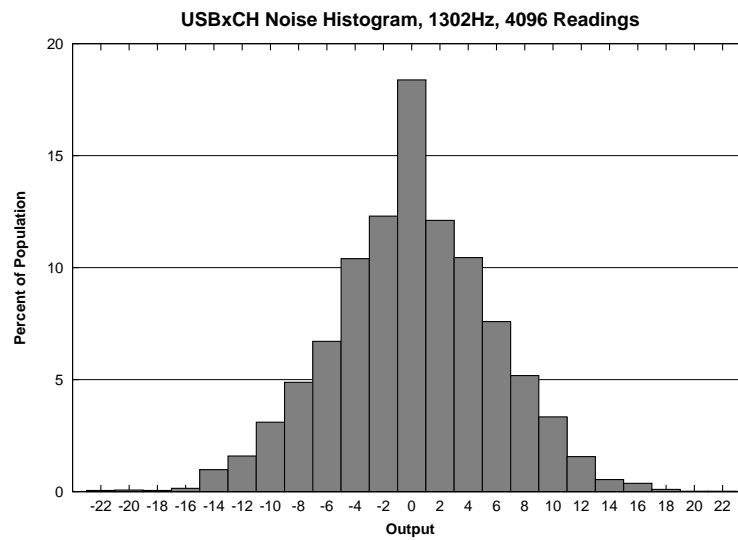


Figure 17.4: Noise floor histogram at 1302Hz

At the higher sampling rate, the width of the histogram becomes wider showing the increase

in the noise floor with sampling rate. At 130Hz, the width above the 1% level spans from -4 to +4 counts, a peak to peak total of 8 counts or 3 bits. At 1302Hz, the width spans from -16 to +16 counts, a peak to peak total of 32 counts or 5 bits. These results are in agreement with the specifications published by TI for the ADS1255 A/D converters, and include the noise performance of the USBxCH amplifier front end. To compare with the TI quoted specs, see the TI ADS1255 spec sheet, page 13 Table 6.

17.3 Thermal response

Work underway ...

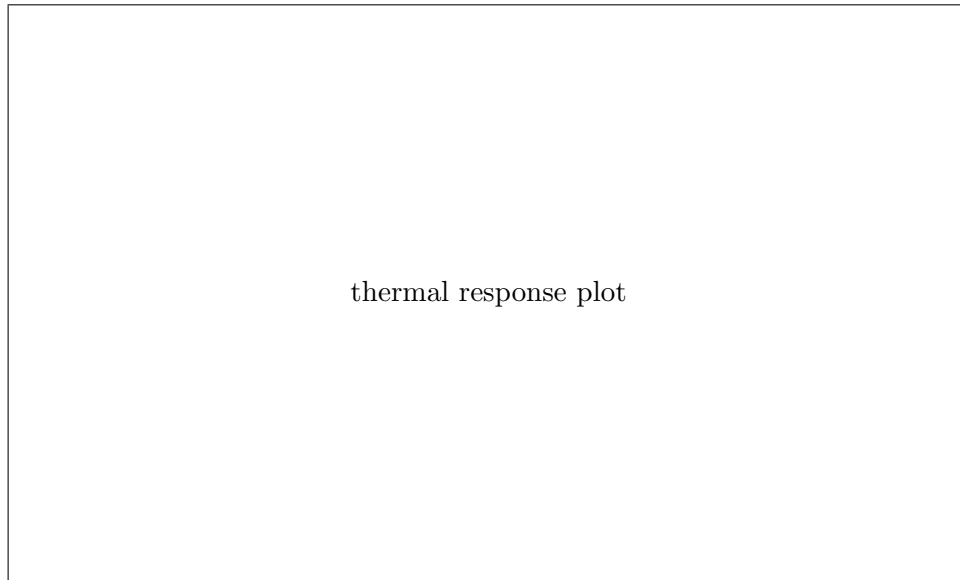


Figure 17.5: Long term thermal response

Chapter 18

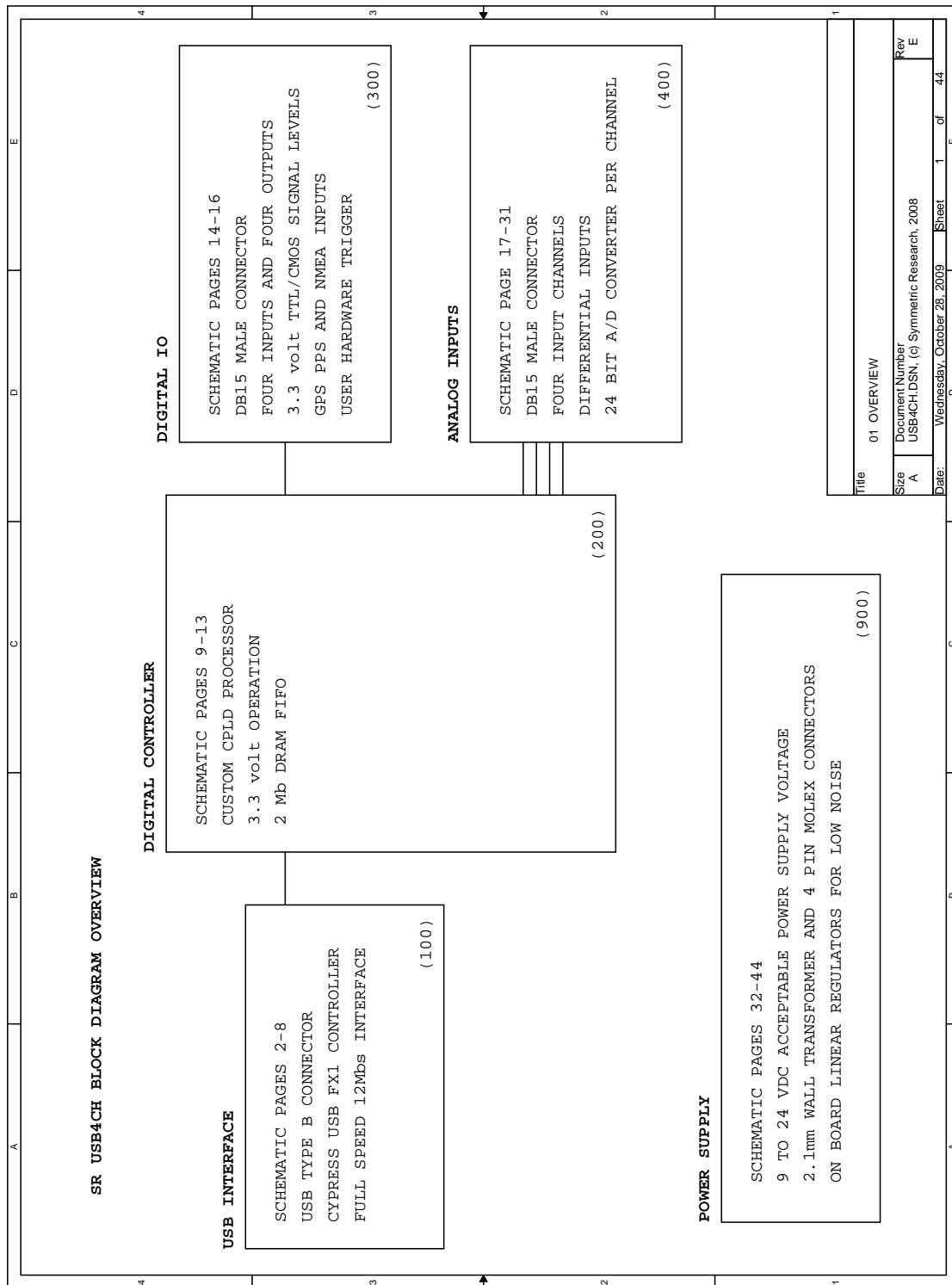
Circuit Diagrams

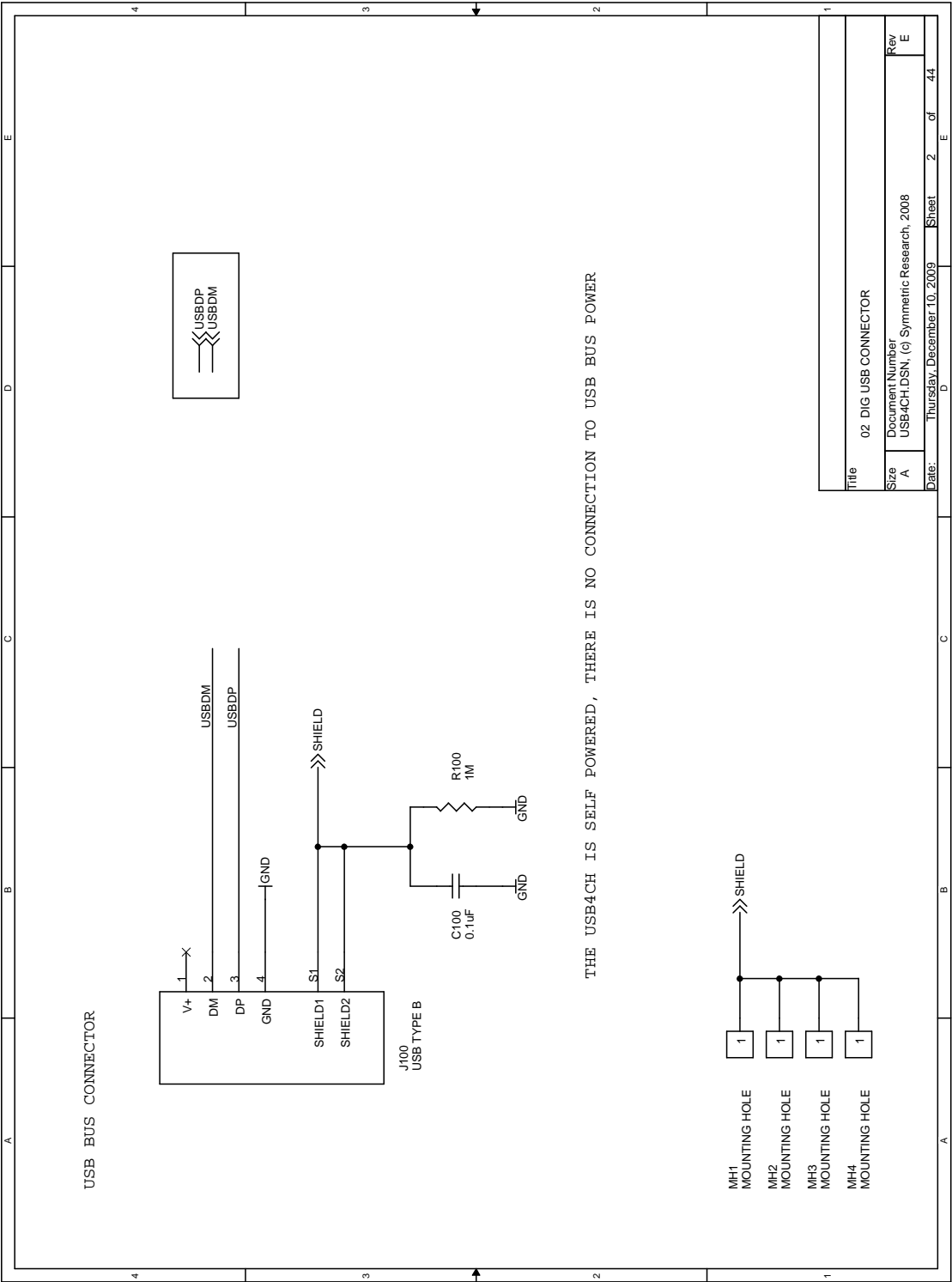
FREE WEB VERSION - PARTIAL CIRCUIT DIAGRAMS

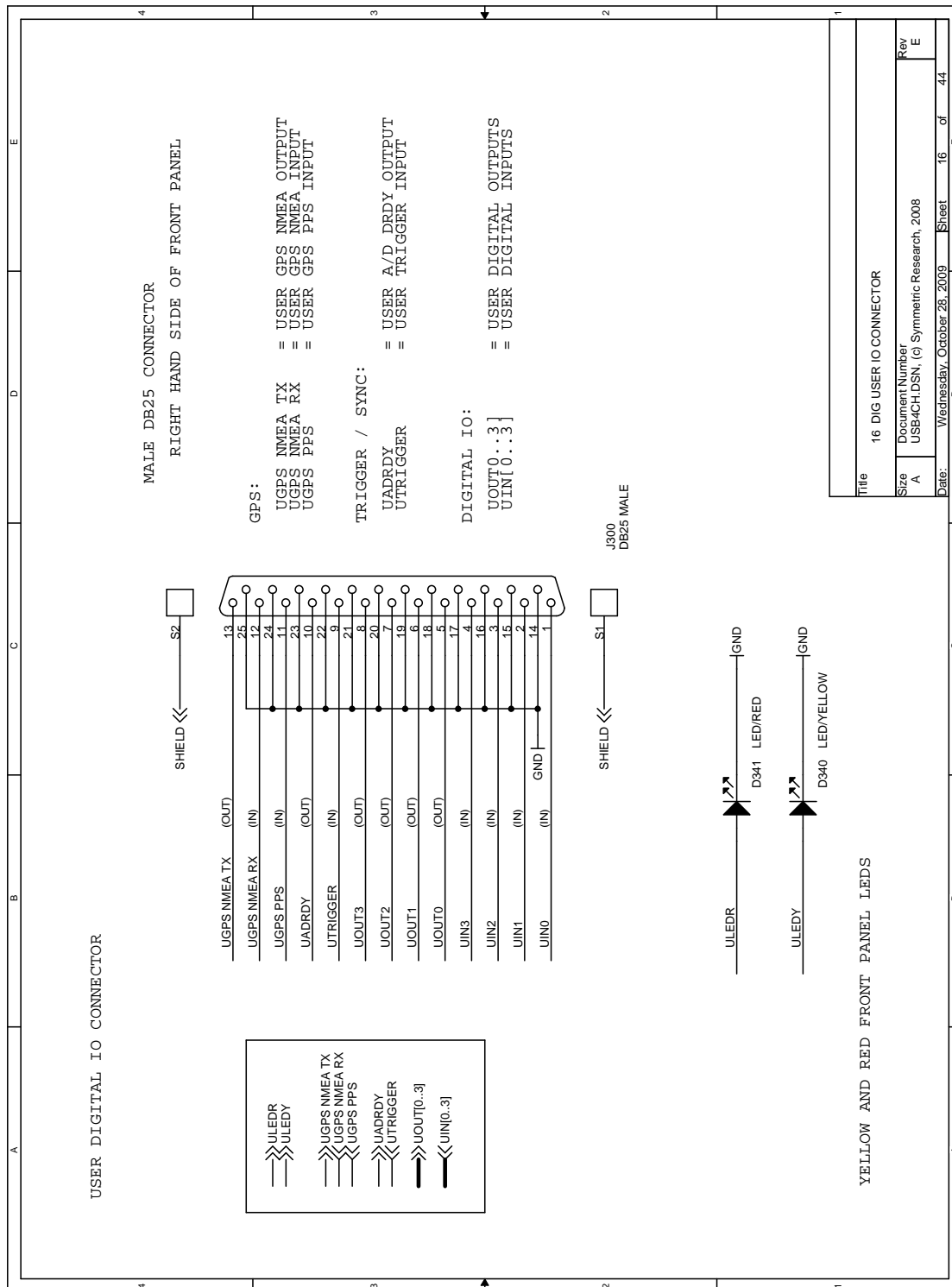
This free web copy of the User Manual includes only the Circuit Overview and connector pin assignments. Complete circuit diagrams are *provided only with purchase of the product*. Install the CDROM that came with the product shipment for the full User Manual with complete diagrams. Customers who need an update or have lost their original CDROM may obtain copies of the full User Manual by emailing SR at info@symres.com.

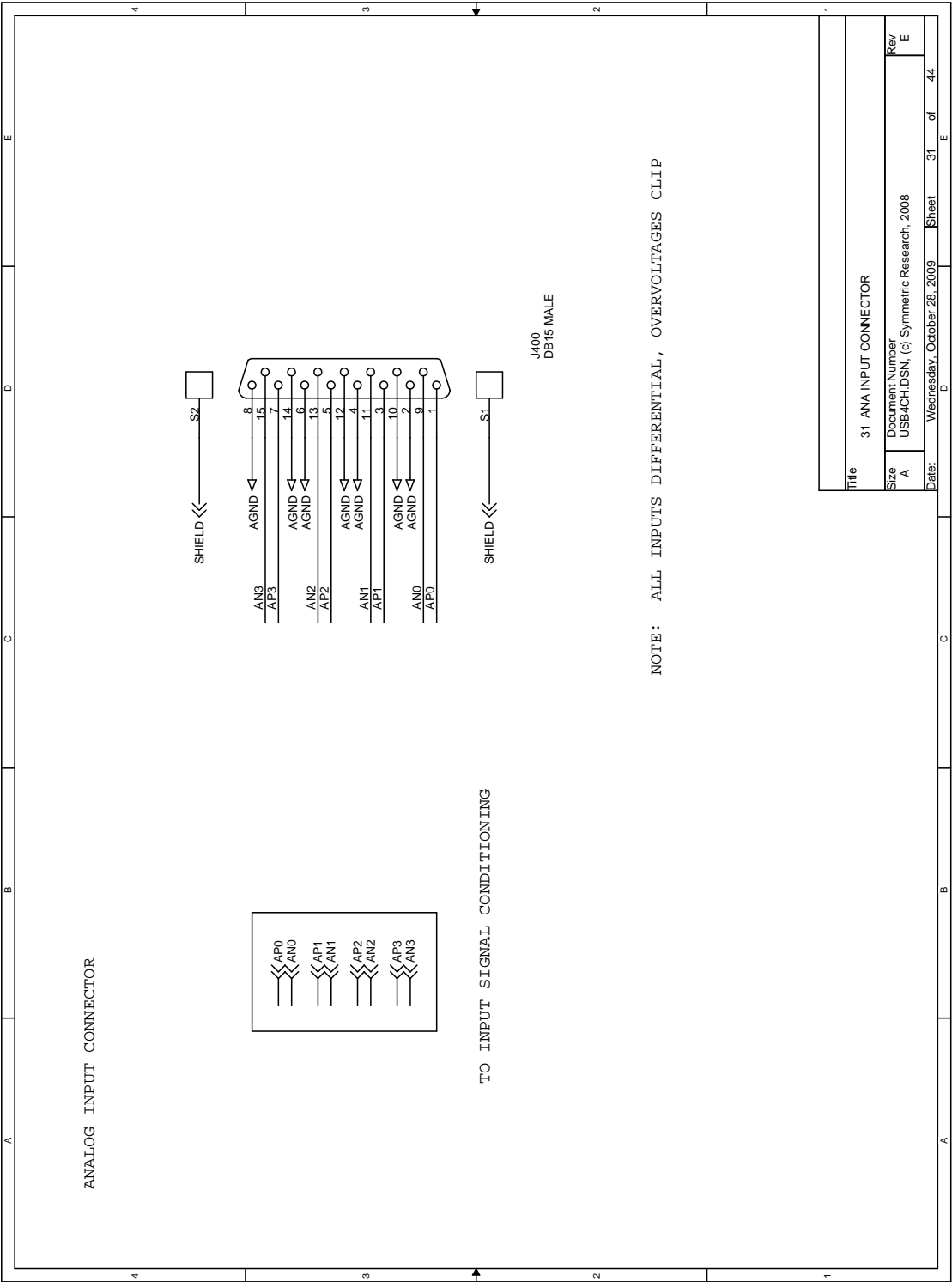
Use the Adobe Acrobat reader View/RotateView/Clockwise command to present the diagrams horizontally on the screen.

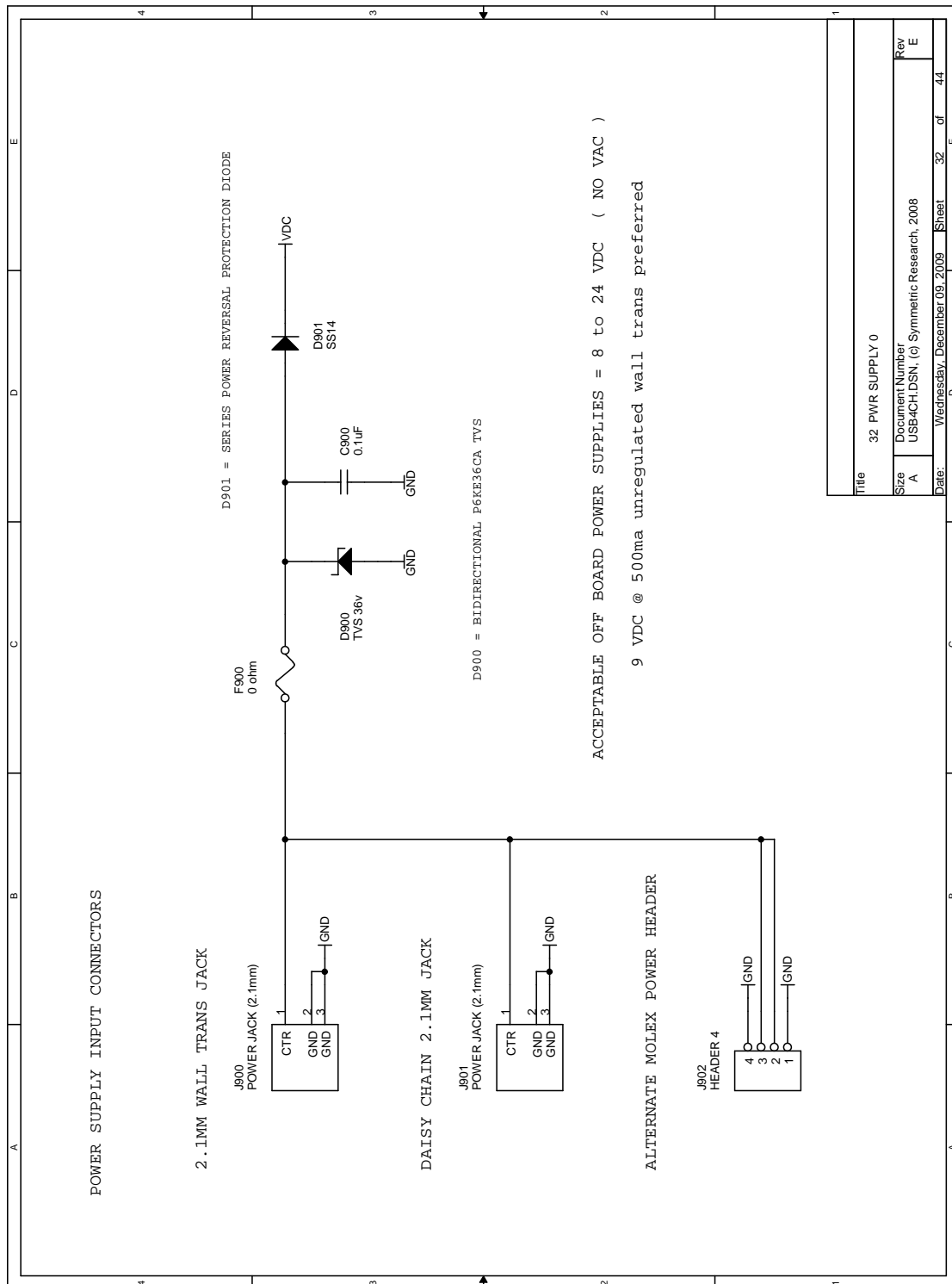
Circuit Overview	136
USB interface	137
User digital IO connector	138
Analog input connector	139
Power supply	140











Chapter 19

Examples and Experiments

This chapter reviews a few simple experiments with the USBxCH. Photos are included with many of the examples. These particular experiments were chosen to help you get started quickly with the system on your test bench:

- | | |
|---------------------------|------------------------------------------------|
| ▷ AA battery | using a battery as an analog DC test signal |
| ▷ Twisted pair | twisted pair for 50/60Hz noise rejection |
| ▷ Absolute calibration | absolute voltage calibration with the VREF-399 |
| ▷ 10 turn potentiometer | calibrating DVM in potentiometer turns |
| ▷ Ratiometric technique | ratiometric methods versus absolute |
| ▷ Solar cell light levels | measuring light levels with a solar cell |
| ▷ GnuPlot | importing USB4CH data into GnuPlot |
| ▷ Passive geophones | recording seismic signals with Scope |
| ▷ Multiple USBxCH | processing data from multiple systems |
| ▷ Powering with batteries | battery power for portable and field apps |

19.1 Measuring a AA battery

With a AA battery and the **DVM** program you can test many of the USBxCH DC analog input characteristics. In this example, besides showing basic usage, we will also review a few details regarding the three wire differential (+,-,AGND) inputs. For additional theory behind differential signals, see the **Analog inputs** chapter.

The most basic test with a AA battery is to simply connect it between the (+,-) of an analog channel, like this:

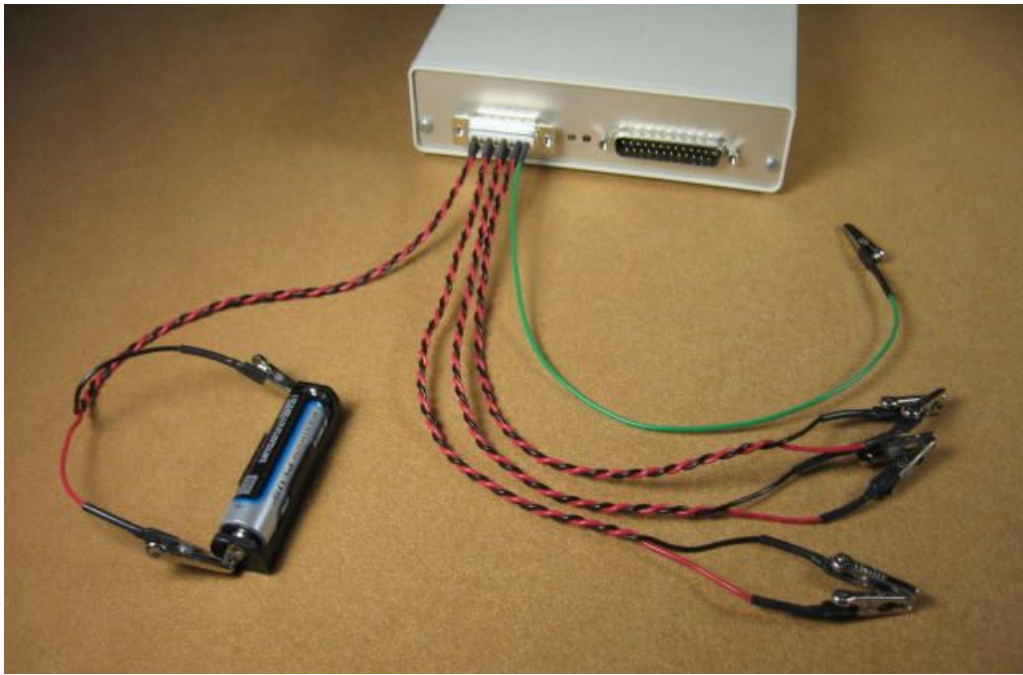


Figure 19.1: Two lead AA battery voltage measurement

In this setup, we have used a battery holder with tab lugs so the alligator clips can be easily connected, with the red and black wires of analog channel 0 connected to the (+,-) battery terminals. The USBxCH green AGND alligator clip is not connected at all, leaving the battery floating. Note the black - input *is not ground*. It is the inverted differential input.

Since a AA cell has approximately 1.5 volts, if you run the DVM program by double clicking on the "Run DvmGui Volts" shortcut you will see the following on your computer:

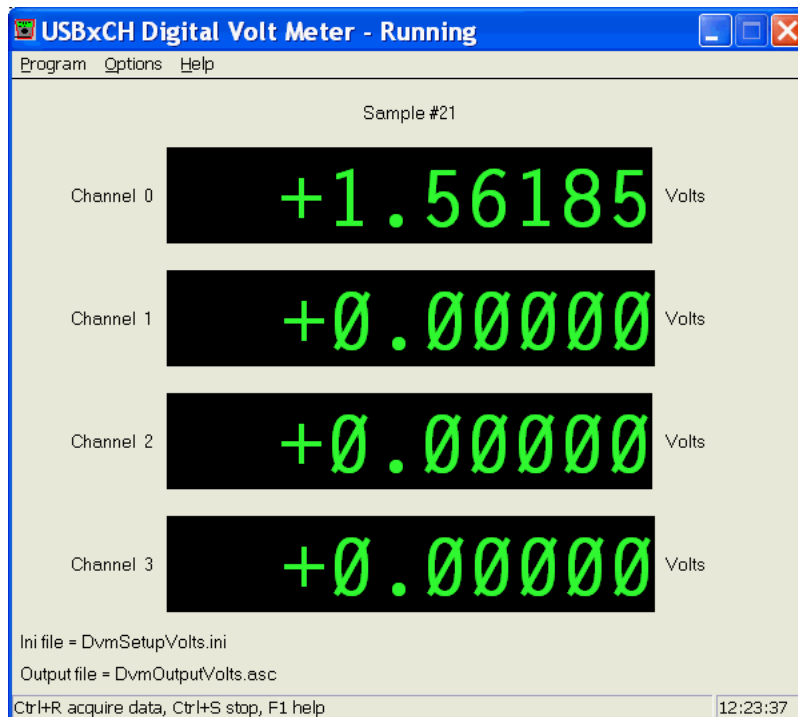


Figure 19.2: DVM with a AA battery hooked up

When making this measurement, if the differential leads are hooked up in reverse, DVM will simply read a negative voltage. Also experiment with hooking the battery up to the other channels to see the voltage appear on their respective DVM readouts. Unused (+, -) inputs should normally be left shorted together.

Performing this test, it is important to be aware that while the red and black alligators are much like the test leads of a handheld Fluke multimeter, *they also may not go more than plus or minus 4 volts with respect to AGND, or else clipping will occur.*

Given this constraint, how can we be sure the floating AA battery keeps the USBxCH (+, -) input pins within the 4 volt range of AGND? After all, there is no obvious AGND connection in Figure 19.1. The answer is a weak ground connection is maintained by the USBxCH internally as shown in the circuit fragment on the following page. In this fragment, half of the floating battery voltage is *above* AGND, while the other half is *below* AGND. If you physically measure with a handheld voltmeter you will find this is indeed true. Because of this weak ground connection, you often don't have to make an explicit AGND connection for floating voltages and sensors.

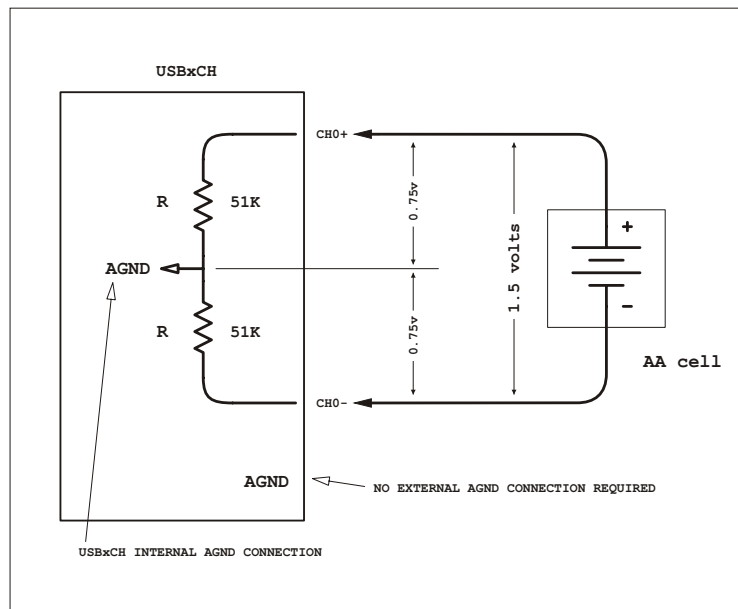


Figure 19.3: Floating AA battery circuit

What happens if instead of floating, we crowbar one terminal of the AA battery to AGND as in the following setup?

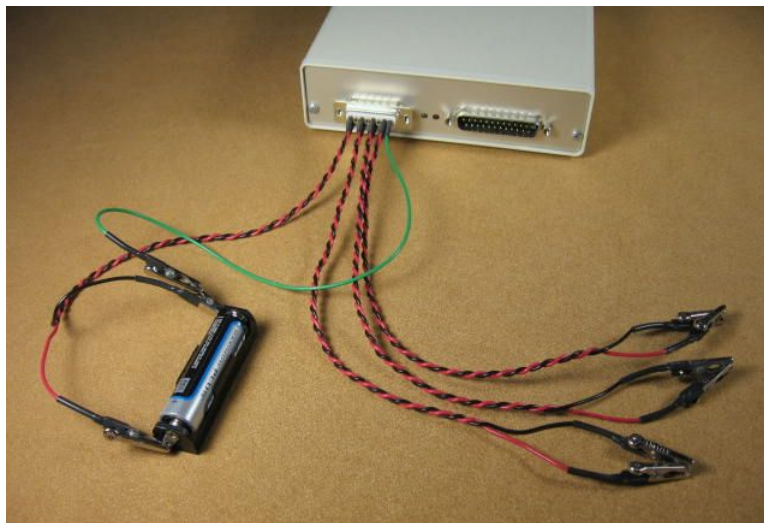


Figure 19.4: AA battery measurement with AGND connection

Here we have simply connected the green AGND alligator to the metal thumb tab of the black alligator. You will still measure 1.5 volts with DVM as before, but now the voltages

between the *inputs and AGND are different than the floating case*. Here the + input is at 1.5 volts with respect to AGND, while the - input is at AGND. The difference still remains at 1.5 volts, but the + input is pushed 0.75 volts closer to the 4 volt clipping limit. We have effectively put a short across the lower 51K ohm resistor as in the following circuit fragment:

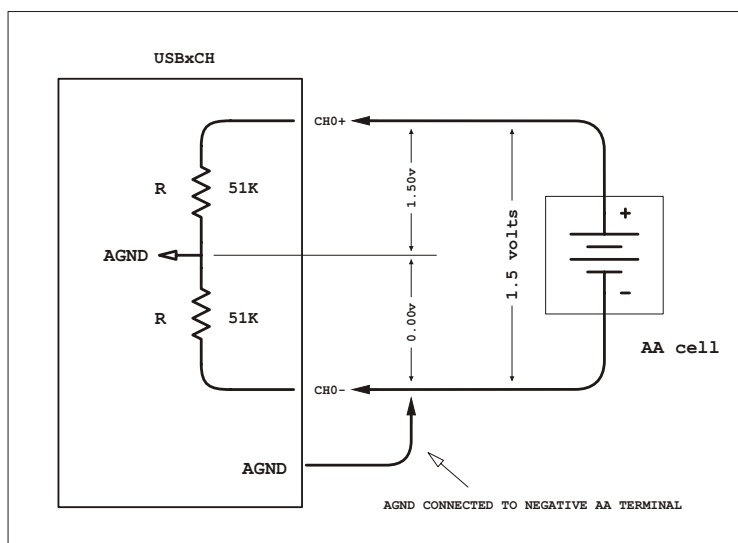


Figure 19.5: Grounded AA battery circuit

To modify the experiment further, imagine if instead of a 1.5 volt AA cell we had used a 6 volt battery. When floating, DVM would report the correct 6 volts, with 3 volts above AGND and 3 volts below, avoiding clipping. But, if we connect one of the (+, -) terminals to AGND the other terminal will be forced to 6 volts with respect to AGND, and clipping will occur. You can construct a 6 volt battery from 4 AA cells in series. The figure on the next page shows some of the results.

It is also acceptable to use adjustable floating lab supplies less than 20 volts for such experiments. Even transistor radio 9 volt batteries can be used, although their voltage is high enough so clipping will occur even in the floating case. The USBxCH inputs will not be damaged or harmed with the 9 volts of overvoltage.

■ *Do not attempt to measure high voltages such as 110/220 vac from the wall socket with the USBxCH. Not only are such voltages life threatening with the types of connectors on the system, you will also instantly destroy the front end circuitry and void the warranty. If you must measure high voltages, use resistive dividers, TVS/Zener overvoltage protection, and suitably insulated connectors in front of the USBxCH.*

Finally, note the USBxCH AGND is connected to its power supply ground as well as the PC ground when making measurements. Because of this, a ground connection is often present in ways you might not expect. For example ... if you are using a desktop machine, AGND is connected through the USB cable ground wire to the PC ground, which in turn is probably connected to the PC chassis and the third prong on the wall power. At the same time, if you use a signal generator also powered from wall power, it is probably connected to wall ground. This completes a ground loop you probably didn't expect, and provides opportunities for noise contributions. Review the entire system carefully to avoid hidden ground connections you didn't count on.

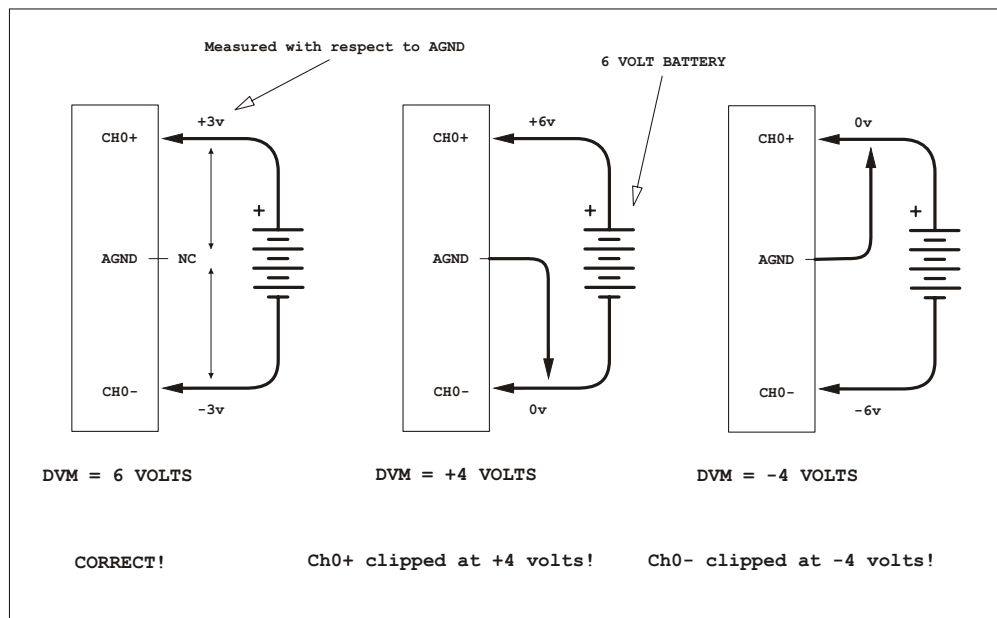


Figure 19.6: 6 volt battery circuit showing clipping depends on ground

In these experiments, all the DVM channels have been calibrated in volts. You can also calibrate for other physical units, as in the [10 turn potentiometer](#) experiment. For easy ways to plot and print results, see the [GnuPlot](#) example.

19.2 Twisted pair for 50/60Hz rejection

Work underway ...

19.3 Absolute calibration

Work underway ...

19.4 Using DVM with a 10 turn potentiometer

Besides volts, **DVM** can also display physical sensor units. This example shows how to set up a 10 turn potentiometer with DVM displaying "**turns**". Using the same techniques as this example you can easily calibrate to display other desired physical units. The circuit for the potentiometer experiment is:

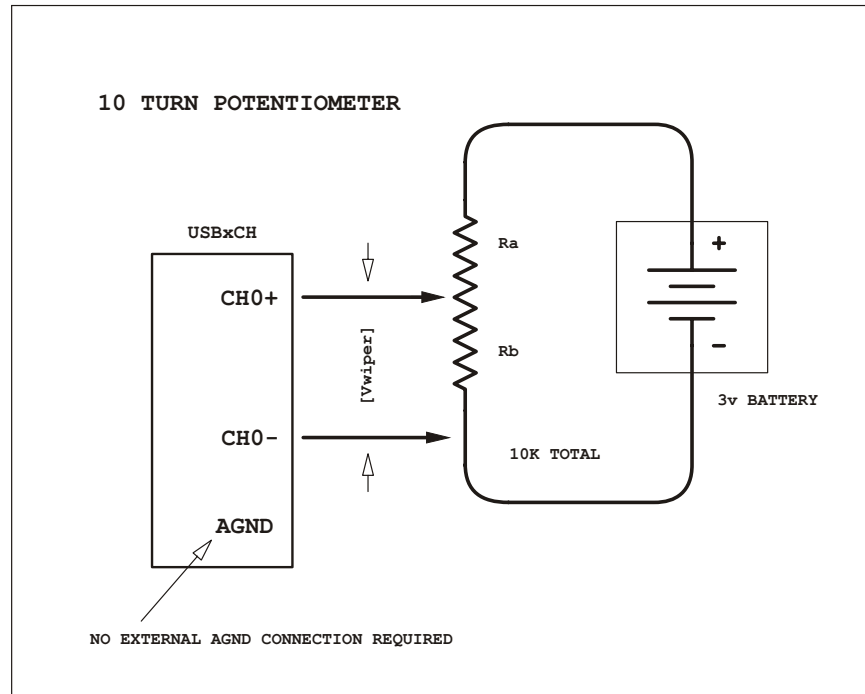


Figure 19.7: 10 turn potentiometer circuit fragment

We will assume the battery is a pair of AA cells in series providing 3 volts. It is a good idea to keep the end to end potentiometer resistance reasonably high so not too much current is drawn from the battery. With a 10K pot there would be 0.3 ma of current flowing, which is reasonable.

If R is the total end to end potentiometer resistance, R_a the resistance above the wiper, and R_b the resistance below the wiper, then we have:

$$\begin{aligned} R_a &= R \cdot (1 - T/10) \\ R_b &= R \cdot (T/10) \end{aligned}$$

where T is the physical number turns at the current setting of the 10 turn potentiometer. Of course, this assumes the wiper resistance varies linearly with turns. The linearity should

be available on the potentiometer spec sheet, or perhaps even stamped on the side of the unit. You could also check the linearity with an experiment like this. Using Ohm's law, $V = IR$, and the equation for R_b , the *voltage* across the wiper would be:

$$\begin{aligned} V_{wiper} &= (V_{bat}/R) \cdot R_b \\ &= (V_{bat}/R) \cdot (R \cdot (T/10)) \\ &= (V_{bat}/10) \cdot T \end{aligned}$$

showing V_{wiper} is directly proportional to the the number of turns T . To calibrate DVM for turns, we will use the companion program **Calibrate** to determine the slope and offset parameters. The physical setup looks like this:

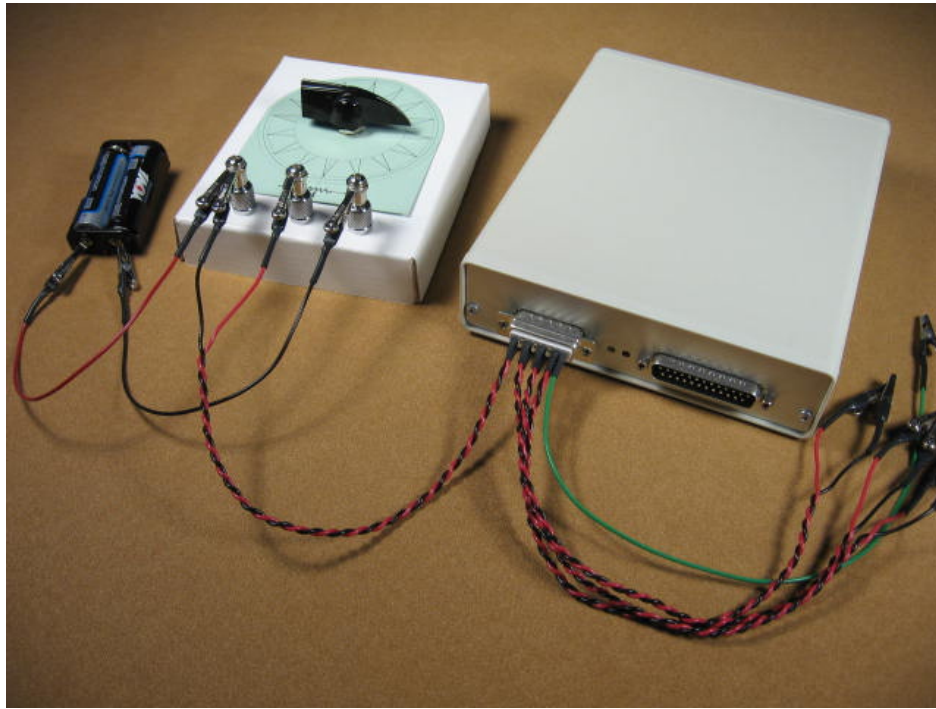


Figure 19.8: 10 turn potentiometer measurement

The potentiometer has been mounted on a simple cardboard enclosure with a green dial made from index paper. Connections to the stimulus battery, potentiometer, and USBxCH have been made with alligator clips. The USB cable and computer are not shown. Being a 10 turn potentiometer, the black knob can spin around and around and it is easy to lose track of which turn it is on, let alone measure the exact angular position.

The bottom side of the potentiometer is in the next photo, with simple wires to the three potentiometer terminals. You could easily do this experiment with the potentiometer just

lying on the table, but the cardboard enclosure and dial are simple to make for more accurate measurements.



Figure 19.9: 10 turn potentiometer photo bottom

Next, start up the DVM **Calibrate** program. To calibrate, first turn the potentiometer knob to its minimum setting, aligning the knob with the zero mark on the dial, then enter 0 for Value A and click on the Measure A button. After that, move the potentiometer thru 10 turns to its maximum setting, aligning with the zero mark again, then enter 10 for Value B and then click on the Measure B button. These two measurements define a straight line on a plot of **turns** versus A/D counts. Clicking on the Save button will automatically save the ini file "**Cal.ini**" with the corresponding slope and offset.

Loading the new "**Cal.ini**" into DVM will display the potentiometer channel in "**turns**". Note when running Calibrate you can enter the Channel Title and Units as **Potentiometer** and **Turns**, so they will also display. The Calibrate screen should look like Figure 19.10, and the resulting DVM screen like Figure 19.11.

With practice, calibration for other types of sensors should be quick. The steps are always the same. Put the sensor at its minimum setting, and take a measurement. Then put the sensor at its maximum setting, and take another measurement. Use the resulting ini file with DVM. There is nothing special about a 10 turn potentiometer, the same process can be used with any sensor that has a linear response.

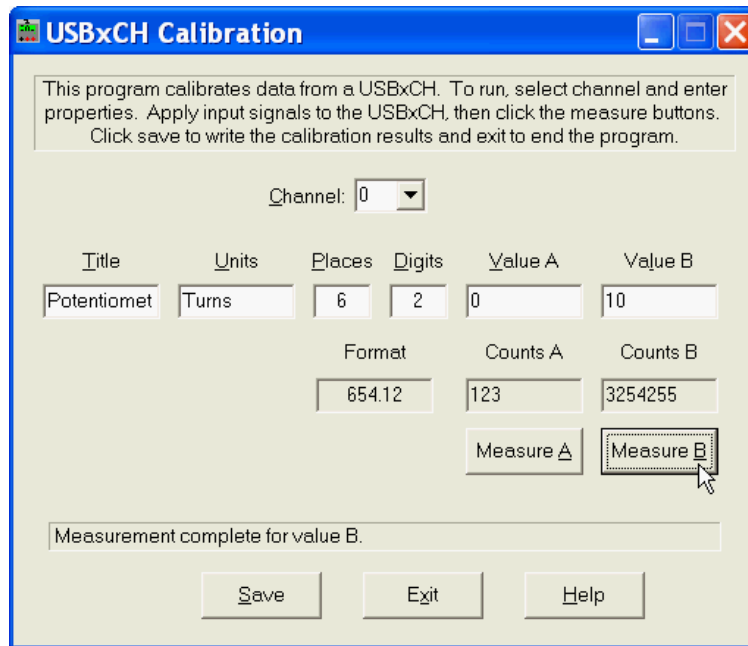


Figure 19.10: 10 turn potentiometer Calibrate screen

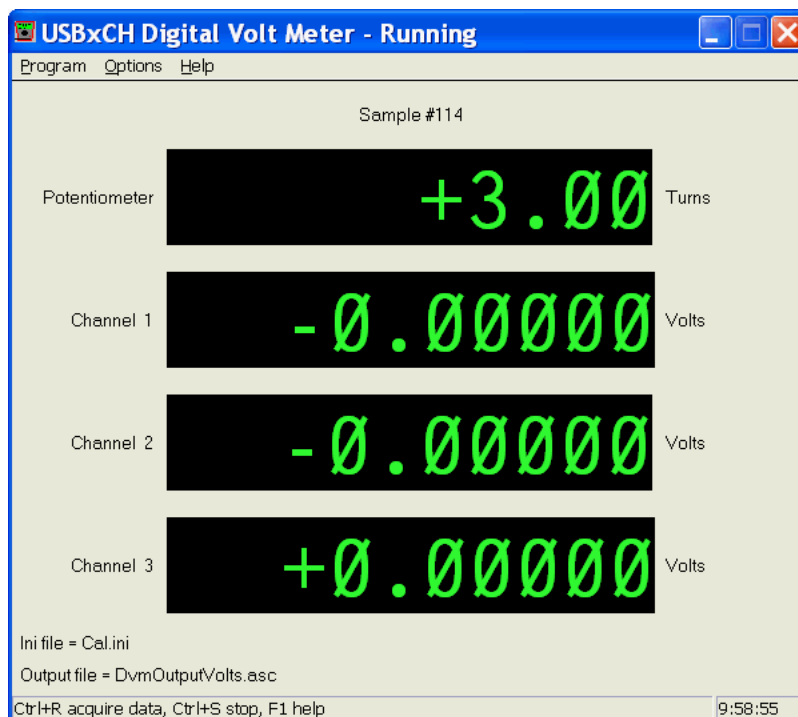


Figure 19.11: 10 turn potentiometer DVM screen

No doubt 24 bits is more resolution than is typically needed for the average potentiometer measurement. However, the idea is to apply these methods to applications that do require high precision. Even with this experiment, an 8 bit A/D would only have an angular resolution of 14 degrees, while with 24 bits you can easily achieve 0.1 degree resolution. Other types of potentiometers offer linear styles for length measurements, while many simple devices can serve as remarkably good sensors for other parameters. Silicon diodes as temperature sensors, and LEDs as light sensors are examples. There is also a huge variety of prepackaged sensors for measuring parameters of every type. See your favorite electronics catalog as in the [Extra supplies](#) chapter for possibilities. Regardless, you can use the Calibrate program to create a DVM readout in physical sensor units.

Some will observe there is a flaw with the core equation we have used in this example. It comes from the expression:

$$V_{wiper} = (V_{bat}/10) \cdot T$$

The wiper voltage is not only a function of the physical number of turns T , *but also depends on V_{bat}* . Any change in the battery voltage will result in a change in the number of turns reported on the DVM screen, regardless of whether the physical turns on the potentiometer changed or not. You won't have to work with the system very long before you notice changes in the battery voltage because of discharging or changes in temperature have an effect. At 24 bits even a small drift becomes apparent.

What can be done? One solution would be to use a battery or reference that has an extremely constant output across time, load, and temperature. The SR VREF-399 is an example of a stable potentiometer excitation source that would be suitable. However for sensors like potentiometers with outputs proportional to their stimulating voltage, there is an even better way: [ratiometric techniques](#). Ratiometric methods are simple and give excellent results.

To change this example into a ratiometric measurement the battery excitation voltage V_{bat} is simply measured on another channel at the same time as the wiper voltage. From the V_{wiper} equation above you can see dividing by the battery voltage will give the actual number of physical turns regardless of the absolute values of the voltages. Ratiometric measurements are easy to set up with a multichannel DVM. The next section shows the results that are possible.

19.5 Ratiometric technique

Work underway ...

19.6 Measuring light levels with a solar cell

Sometimes sensors can be made from unexpected devices. Any component with a voltage that varies in response to an external stimulus is a candidate.

Solar cells find their most common use as a power source. However, the voltage from a cell varies with the light level, serving as a light intensity sensor. With DVM, measurements from a cell can even be calibrated directly into light intensity units. As an example, the photo below shows a small flexible cell mounted in a cardboard holder for testing. This particular cell has a voltage ranging from 0 volts at total darkness to approximately 3 volts at full brightness. The cell is connected directly to the USBxCH channel 0 with no signal conditioning required.

Using the **Calibrate** program you can set up a DVM readout to be 1 at total darkness and 10 at total brightness. You can also have DVM save its values to an output file along with time stamps. Data runs for days or months can create a record of light intensity.

The next section shows how to use GnuPlot with values saved in `DvmOutputSolar.asc` to plot results for reports and presentations.

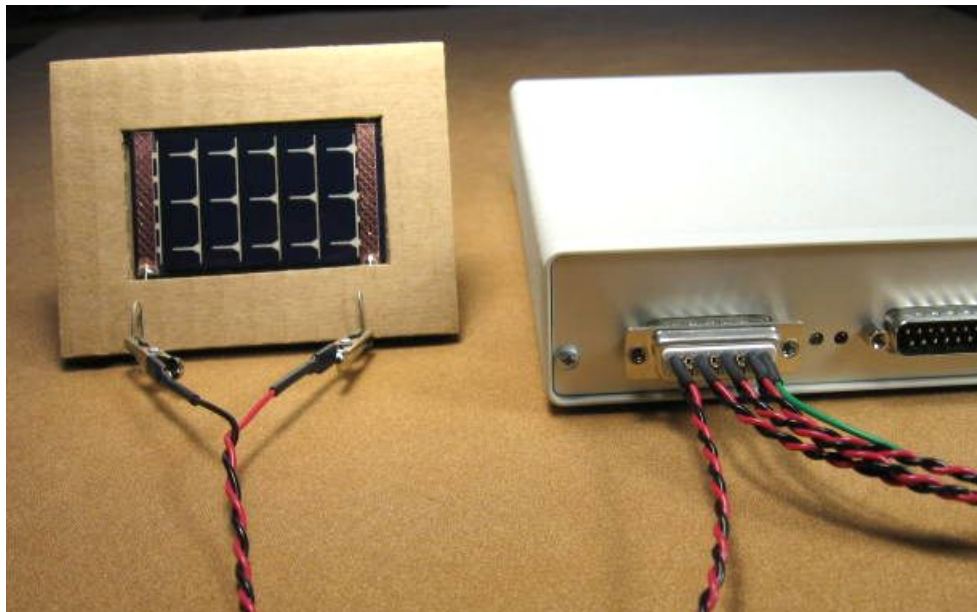


Figure 19.12: Measuring light levels with a solar cell

19.7 Plotting results with GnuPlot

After acquiring data with the USBxCH you may want to plot the values. This example shows how to use GnuPlot to generate display and report presentations. GnuPlot is a public domain program and can be downloaded for free from:

www.sourceforge.net

or found by searching the web. Documentation is included when unpacked. Excel and MatLab users may use techniques similar to the ones shown here to import data.

To use GnuPlot you first need a data file. For this example we assume you have the solar cell data collected with DVM as in the previous example. The following file fragment from `DvmOutputSolar.asc` would be typical:

Sample	Volts	OneToTen	Time (Sec)	Time (YMD HMS)
1	+0.7	+1.42	1202171952.468	2008/02/05 00:39:12.468
2	+0.7	+1.43	1202171953.629	2008/02/05 00:39:13.629
3	+0.7	+1.43	1202171954.791	2008/02/05 00:39:14.791
4	+0.7	+1.45	1202171955.953	2008/02/05 00:39:15.953
5	+0.7	+1.49	1202171957.114	2008/02/05 00:39:17.114
6	+1.0	+2.01	1202171958.276	2008/02/05 00:39:18.276

The DVM ini parameters to create this file format were:

```
; Solar cell output format and channel 1 calibration:

OutputFileName      = "DvmOutputSolar.asc"
OutputFileComment   = "Measuring solar panel response"
OutputFileShowHeader = ON
OutputFileShowIndex  = ON
OutputFileShowTimeSec = ON
OutputFileShowTimeYmd = ON
RunMode              = CONTINUOUS

DisplayTitle 1 = "Light Level"
DisplayUnits  1 = "OneToTen"
DisplayPlaces 1 = 6
DisplayDigits 1 = 2
DisplaySlope  1 = 6.02121e-007
DisplayOffset 1 = -0.00147941
```

Besides specifying the output file format, these ini parameters also calibrate the second readout to light level units of 1 to 10. Calibrate into other light intensity units as appropriate.

Once the data file has been acquired, start GnuPlot and issue the commands:

```
# SET FILE FORMAT and PLOTTING AXIS PARAMETERS:

DataFile = "DvmOutputSolar.asc"
ColSample = 1
ColVolts = 2
ColLight = 3
ColSeconds = 4
ColTime = 5

set xtics nomirror font "Helvetica Bold,14"
set ytics nomirror font "Helvetica Bold,14"
set xlabel "Sample" font "Helvetica Bold,18"
set ylabel "Volts" font "Helvetica Bold,18"
set xrange [0:120] # About 2 minutes of data
set yrange [0:5] # Solar panel outputs ~3.3v in strong sunlight

# PLOT THE SOLAR DATA:

set title "SER1CH-UA Solar Panel Data" font "Helvetica Bold,18"
plot DataFile index 1 using ColSample:ColVolts linestyle 1 title "Solar panel voltage"
```

You can also save these commands to a file and run them with the GnuPlot load command, see `Examples/Solar.gp`. The plot command does the serious work, everything else is setup. Refer to the GnuPlot PDF documentation for details. After running, the following should appear on the screen:

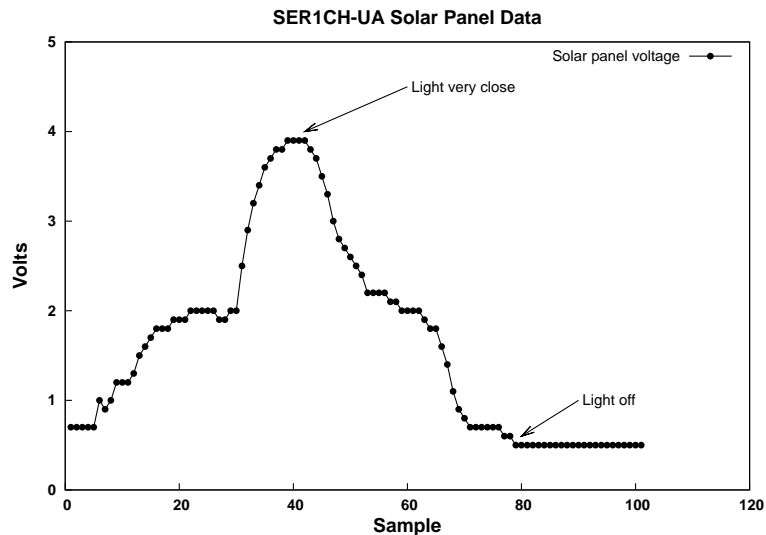


Figure 19.13: GnuPlot graph

For including the plot in a report, you'll probably want to save it as a PDF file. Other formats are possible, read about them in the GnuPlot documentation. For PDF, first run GnuPlot to output a .ps PostScript file, and then convert this file to PDF. The conversion to PDF can be done with either Adobe Acrobat Distiller or the public domain GhostScript. In the examples directory we show how to do it with GhostScript commands.

19.8 Passive geophones

Work underway ...

19.9 Multiple USBxCH and network processing

Work underway ...

19.10 Powering with batteries

For portable applications the USBxCH can be powered from batteries. The system requires 100 ma of current at 8 volts or greater, and it is entirely possible to run from AA and larger batteries for periods of days. Rechargeable batteries are particularly attractive. Two popular technologies are: NiMH (nickel metal hydride), and lead acid. This example shows how to use eight rechargeable NiMH AA cells to power the system, and also a small 3Ah (amp hour) rechargeable lead acid battery.

NiMH rechargeable batteries are readily available and used widely in digital cameras and other electronic devices. The AA size has excellent power density with 2Ah or more typical. Here we will be using Duracell AA batteries, which claim 2.6Ah. At a drain rate of 100 ma, in principle they should be able to power the USBxCH for 26 hours. In actual tests they reliably power the system for 22 hours, enough for a day of field work. The following photo shows the setup:

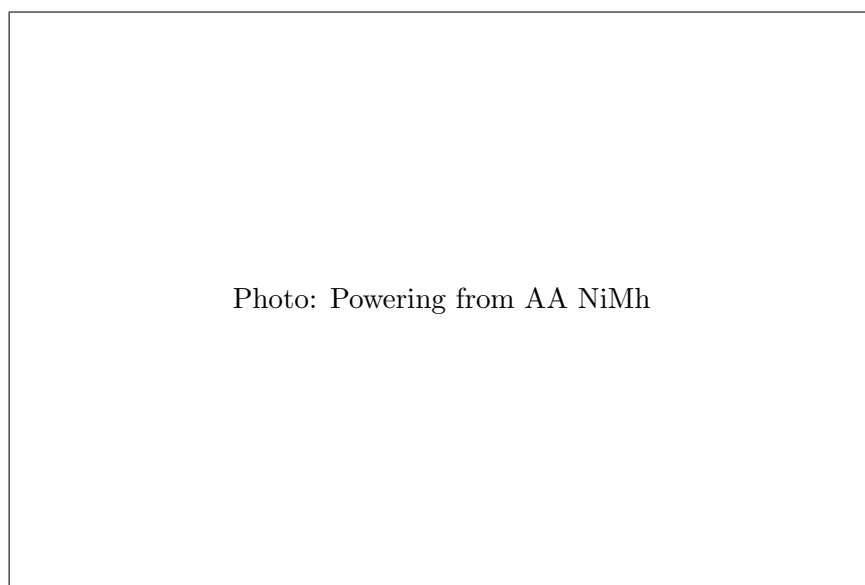


Figure 19.14: Powering from a rechargeable NiMH AA battery pack

To hold the 8 AA cells, an inexpensive battery holder organized as 4x2 cells in series has been used. Since NiMH cells have a fully charged cell voltage of at least 1.2 volts, this gives approximately 9.6 volts total. This is enough to power the USBxCH. In addition to the battery holder, there is also an on-off toggle switch. We recommend using a switch so the power can be applied at one clean instant to the USBxCH. Using alligator clips directly as a power switch is unreliable, sometimes drawing sparks and causing the system to crash on start up. Besides the battery holder and switch, there is also a 2.1mm power connector

so the battery pack can be quickly connected and disconnected for recharging.

Determining the discharge characteristics for any particular battery setup is easy: have the USBxCH measure and record its own battery voltage, giving a detailed plot of the discharge curve! One problem is the battery voltage will be greater than the +/- 4 volt USBxCH input range. To solve this, use a simple resistive divider to scale the battery voltage into range. Keep the divider resistances reasonably high so the divider doesn't drain much additional current from the battery. The following circuit is one example:

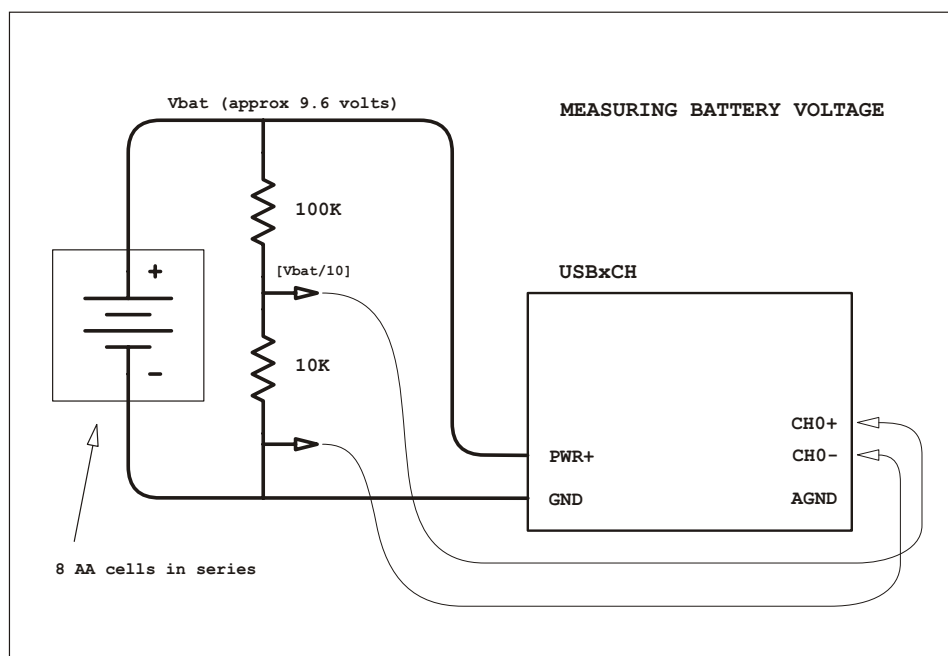


Figure 19.15: Dividing battery voltages for USBxCH measurement

To acquire the data, use the **Blast** acquisition program at a low sampling rate. There really isn't much point to sampling at high rates. The following would be typical:

```
cmd:prompt> Blast s1 g1 nokeypress
```

The **s1** option specifies sampling at 19.5Hz, while the **g1** option uses the PC clock to time stamp the data. After the run use the **Pak2Asc** utility to convert the binary PAK files to ASCII columns. As an alternative to Blast, you could also use the **DVM** program to gather data and even have a real time display of the battery voltage during the run.

While measuring the battery voltage with Blast, check the red LED on the USBxCH back panel near the 2.1mm power connectors. When the battery voltage drops low enough, the red LED will light up indicating it is too low for the on board regulators to function

correctly. At this point the run is over and it is time to stop Blast. The condition of the red power good LED is also given as a column in the Pak2Asc output file. The following **GnuPlot** graph made from the Pak2Asc data shows a typical run:

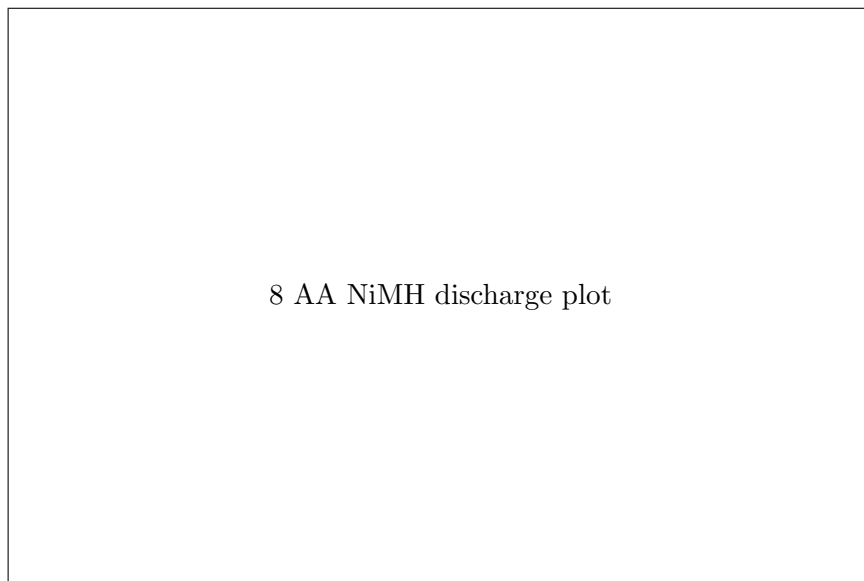


Figure 19.16: 8 AA NiMH discharge plot

Both the analog battery voltage and the power good status bit (red LED) are plotted. The power good signal (when the red LED comes on) failed at approximately 7.5 volts as it should. Note that although the USB digital portion of the system can function at battery voltages even as low as 3.5 volts, the analog subsystems such as the A/D reference will begin to fail at 7.5 volts. The USBxCH *will not meet analog specifications at voltages less than 7.5 volts*. The elapsed time for this particular run was approximately 22 hours. Given their relatively small size and good availability, NiMH AA cells are an excellent match for many applications.

Recharging NiMH batteries is fairly easy. While you could remove the 8 AA cells from the battery holder and place them in a commercial recharger, you can also recharge them all while in series still in the holder. Charging rates are quoted in fractions of a full charge C. So, for example, if the capacity is 2Ah, then a C/10 rate would use a constant current of 200ma for charging. If you have a lab bench supply, the eight AA cells in series can be recharged by applying 12 volts at a current limit of 200ma for 10 hours to the battery holder. Disconnect the battery holder from the USBxCH while recharging. Actually, you should apply the recharging voltage for 12 to 14 hours because battery charging cycles are not 100% efficient. *Do not charge at more than a C/10 rate with this method. Do not continue charging for more than 12 to 14 hours with this method either. Do not leave*

the batteries for extended periods with low rate constant trickle charging applied. Failing to observe any of these rules may cause the batteries to become hot and even explode. The problem is oxygen builds up internal to the battery once charging is complete. *We do not recommend fast rate charging at currents greater than $C/10$ for reliable battery life.* With any charging method, stop charging immediately if the batteries become hot.

For longer runs, and applications where trickle charging is required, lead acid batteries are useful. They come in a variety of sizes and Ah ratings. At one extreme are car batteries. Actually, rather than car batteries, deep discharge marine batteries are often a better match. Marine lead acids are designed for complete discharge cycles, while car batteries are designed for short bursts of extremely high current. Both types are readily available at automotive supply stores. Such batteries have an impressive amount of power, with 50Ah or more common. That represents 500 hours = 20 days of continuous operation. Of course the battery is probably powering other equipment too, so the overall run time will be correspondingly less. For more modest applications, there are smaller lead acids. The following photo shows a 12 volt 3Ah lead acid weighing in at 2.9 pounds:

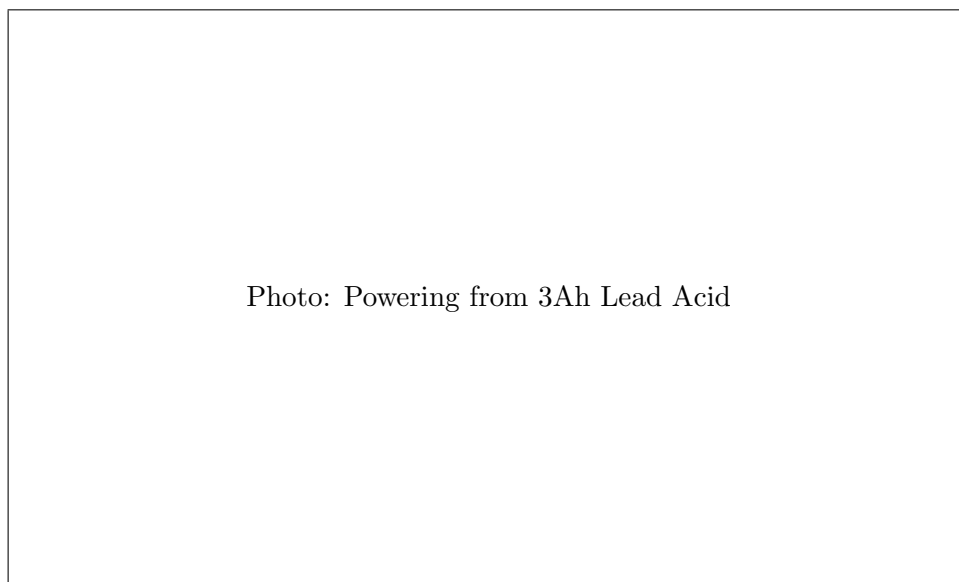


Figure 19.17: Powering from a rechargeable 3Ah lead acid battery

Lead acids are typically 12 volts, so only one battery is required. Although the photo shows alligator clips connecting to the battery itself, there is still a toggle switch so power can be cleanly applied to the USBxCH without excessive sparking. This photo also shows a voltage divider for monitoring the battery voltage with the USBxCH.

It is interesting to compare the discharge characteristics of lead acid batteries with NiMH.

Manufacturer Ah ratings are often poorly specified with regard to discharge rate, so real world tests are important. Figure 19.18 shows the results of a typical run with the 3Ah lead acid. The system actually ran for ?? hours, while one might have expected only 30 hours from the Ah rating. One explanation is the 3Ah lead acid starts at a higher voltage than the NiMH. Another is the low voltage discharge characteristics of lead acid are also better.

Recharging lead acids is not difficult. Any automotive battery charger can be used. Most have an initial fast charge cycle, followed by a trickle charge for maintenance until use.

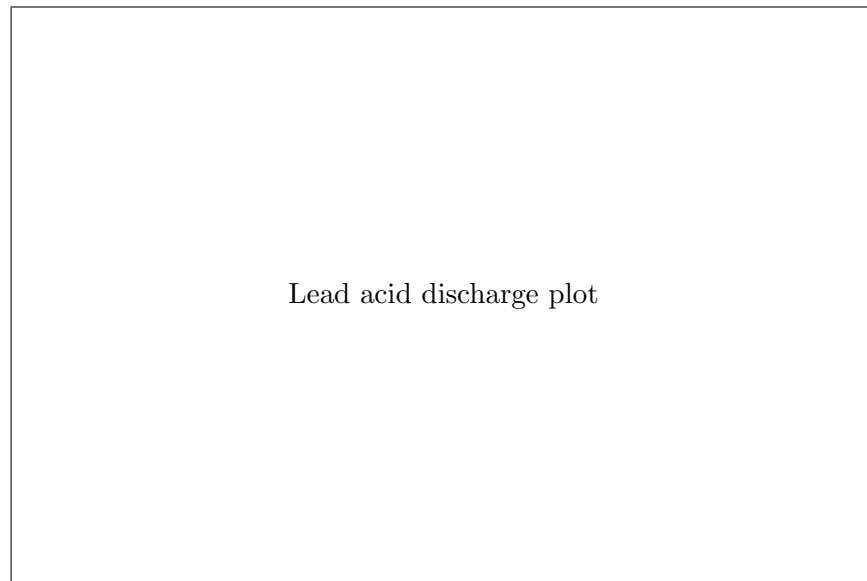


Figure 19.18: Lead acid battery discharge plot

Work underway ...

Chapter 20

Frequently Asked Questions

The following FAQ may help if you have general questions about the USBxCH.

20.1 Software

Do you include source code ?

Source code for *all* of the supplied software is included at no extra cost. This includes the driver, user libraries, and applications. Free downloads are available at our [web site](#). Customers wanting to upgrade to the latest release should download from the web. Potential customers who would like to review the software are also encouraged to download for review.

Only partial circuit diagrams are included with the free web downloads. Full circuit diagrams are included *only with the CDROM shipped with purchase*. Other than the circuit diagrams, the web releases are complete.

Does the USB4CH save its data to disk files ?

Yes. The three acquisition programs, DVM, Scope, and Blast can each save their data to disk files. DVM saves its data in ASC format, Scope in DAT, and Blast in PAK. For details, see the [Application Programs](#).

Files in the respective formats are given the filename extensions ASC, DAT, or PAK. Conversion utilities are supplied to convert from the binary DAT and PAK formats to ASC. See the [Utilities and Format Conversion](#) chapter.

What is the ASC file format ?

ASC files are ASCII text. Data is organized in columns that can be easily read in text editors and imported into other applications such as spreadsheets. In the DVM initialization file there are a number of options to control the ASC header and format to be the most convenient for your work.

The Scope and Blast programs do not output ASC files directly. Too much PC bandwidth is required at high sampling rates to keep up with ASCII formatting in real time. Use one of the offline conversion utilities to convert DAT or PAK files to more readable ASCII.

What is the DAT file format ?

DAT files are binary, with the data internally organized as records. Some records are purely data, while others have GPS time stamping information. All data is bit level demuxed and easy to process by downstream programs.

Utilities are included with the SR software to convert DAT files to ASCII which is then readable in any text editor, and can be imported into many applications.

What is the PAK file format ?

PAK files are binary, with the USB4CH 64 byte USB cable packets saved directly to the file. This format is useful when you want to save data to disk as fast as possible to maximize bandwidth with the Blast program.

Decoding a PAK file is difficult and requires detailed knowledge of how the USB4CH formats its data at the bit level. Most users should use one of the offline the conversion utilities to convert PAK files to other formats.

Can I use the USB4CH with Excel or MatLab ?

To interface with these applications, convert your DAT or PAK files into ASCII with one of the **Utilities and Format Conversion** programs and then import. ASC files from DVM can be imported directly without a conversion step.

Is it possible to call a User Library function from Visual Basic ?

The User Library is written in C and available as a DLL. The functions can be called from Visual Basic as well as other programming languages as long as you follow C calling conventions. See the **User C Library** chapter for information on the library functions.

How do I use the system with LabView ?

Set up LabView VI (virtual instrument) interfaces to the USB4CH User Library with C calling conventions, and you will have access to the library functions.

Can I run under Linux ?

Yes, drivers and applications are provided for Linux. However, before using them, confirm the Linux kernel rev on your machine agrees with the SR supplied driver. Once compiled, Linux drivers are specific to a particular Linux kernel revision. If the kernel rev on your machine does not agree with the SR driver, you will have to recompile the driver source on your particular machine.

Why doesn't the USBxCH work after waking the PC from sleep?

Some PC motherboard USB hub drivers do not wake up correctly after sleep for self powered peripherals and may even crash the system. This is a well known OS level error for several versions of Windows and Linux for which neither Microsoft or Linux provides a solution.

The USBxCH driver which is layered on top of the OS hub driver works around this problem by *automatically disabling itself* when the PC goes to sleep. This prevents any possibility of crashing on wake up. However, the price to be paid for this work around is the USBxCH driver must be *manually restarted* after waking from sleep.

A manual restart can be done either with the SR **DevMan** utility, or with the operating system Device Manager. With the DevMan utility, use the restart option. With the operating system Device Manager, go to the SrInstrumentation class and toggle the disable/enable option to remove the USBxCH yellow exclamation mark.

20.2 Hardware

Is the USB4CH powered by the USB cable ?

No. The USB4CH must be powered by a separate power source like a wall transformer. The USB4CH is referred to as a *self powered USB peripheral*. Power sources such as lab bench supplies and batteries are also acceptable.

Are wall transformers with AC outputs ok ?

No. Wall transformers with AC outputs *will not work*. The USB4CH requires a DC power supply.

The standard wall transformer for the system is an unregulated 9vdc 500ma unit with 2.1mm center positive connector. Unregulated 12vdc, as well as fully regulated supplies are also acceptable. The 50/60Hz ripples from unregulated DC wall transformers are ok if the lows of the ripples are greater than + 8 volts. See the [Specifications](#) for the allowed ranges. The ripples will not degrade analog performance.

What do the back panel green and red LEDs mean ?

The back panel green LED will light up if the USB4CH has any power at all. It indicates the wall transformer or other power source is at least energized.

The back panel red LED further indicates whether the power is sufficient for the on board regulators to run correctly. If the back panel red LED is off, then power is ok. Conversely, *if the red led is continuously on something is wrong and must be fixed before the system will run.*

Momentary flashes of the red LED during power up lasting for two seconds or less are normal. See the [Power Supply](#) chapter for more information. After a few seconds if the red LED is off and the green LED is on, the system is good.

Does the USB4CH have any digital buffering ?

Yes. It has a 2 Mbyte FIFO buffer for storing data, so results can be read back over the USB cable when the PC has available time. The FIFO prevents data loss even if the PC is heavily interrupted with other activities such as graphics or networking. See the [FIFO Depth and Overflow](#) chapter for details on exactly how long the system can hold out before requiring service from the PC.

What is the analog input voltage range ?

The analog inputs may vary from - 4 to + 4 volts for valid count values to be returned. This is the voltage range on any input pin as measured with respect to AGND. The analog inputs are differential, with (+, -, AGND) pins. See the [Analog Inputs](#) chapter for more details on the input range and differential signals.

For *larger* full scale input ranges, there are solder pads on the board for resistor dividers. For *smaller* full scale ranges, the front end amplifier gain may be increased by adjusting the RG and RF resistors. For divider and gain resistor

locations, see the [A/D signal conditioning](#) and [A/D input amplifiers](#) circuit diagrams. Note that SR *does not warrant customer modified boards*.

Is it ok to overdrive an analog input ?

Moderate overvoltages less than +/- 20 volts are ok. Each input has a 10K series resistor limiting the current that can flow. Of course, overdriving an input is hard on the system. It is better to add suitable front end circuitry to deal with the problems at a particular site rather than having the USB4CH take the brunt of the overload. Zener/TVS diodes, gas arrestor tubes, and spark gaps are all useful devices depending on the size of the problem.

Do static shocks hurt the analog inputs ?

Yes! Although the USB4CH analog inputs have resistors and capacitors to help snub static shocks, any static discharge is damaging to the system. *This includes the small sparks generated when walking over a carpet and touching the analog input pins.* Even the smallest ESD (electro static discharge) events into the analog input pins will result in degradation. System calibration will be modified even if total failure does not occur.

Before touching the USB4CH, first discharge yourself by touching a nearby metal object such as a desk or a computer case. Then touch the USB4CH metal enclosure, and finally the input connectors for any connections. Taking a moment to perform this simple routine will significantly help prevent static damage. See the [Analog inputs](#) chapter for more information.

Is the USB4CH connected to system ground ?

Yes. The AGND and GND pins on the front panel DB15 and DB25 connectors are connected to power ground and consequently also to PC ground. The outer ring of the 2.1mm power supply connector is the USB4CH power supply ground. If you use a grounded power supply, then the system will also be connected to that ground. The wall transformer supplied with the system is an unregulated floating power supply. The USB cable ground wire and shield are also connected to the PC.

Is the system opto-isolated ?

No. The USB signals are direct wire connections between the PC and USB4CH. Users requiring a floating system should use a USB opto-isolator from companies such as Sea Level.

Is there an antialias filter ?

The USB4CH amplifier circuitry has solder pads for simple RC filtering at a number of signal nodes. The factory default values for these positions are mild so no roll off occurs even for the highest A/D sampling rates. This type of antialias filtering is intended for protection against RF contamination. See the [A/D signal conditioning](#) circuit diagrams for details.

What is the 50/60Hz rejection ?

If you need powerline rejection, there are three options: numerical filters, op amp notch filters, and twisted pair. When numerically filtering use high sampling rates and then apply the numerical filter. Any op amp filters of course must be added in front of the USB4CH. Often the most effective solution for 50/60Hz rejection is to simply use twisted pair for the inputs.

Do you recommend twisted pair for 50/60Hz rejection ?

Yes! Twisted pair along with proper use of the differential inputs is often a very effective way to achieve 50/60Hz rejection. *Often more effective than any amount of numerical or op amp filtering.* Ideally the twisted pair would also have a foil shield that is connected to the USB4CH case to provide ESD shielding. See the [Analog inputs](#) chapter for more information.

How long can the USB cable be ?

The formal USB specification quotes 6 feet as the maximum. You can probably use a longer cable if needed, 12 feet being reasonable. However, you will not be successful using a 100 foot cable. That is simply beyond USB capabilities. For longer cable runs use USB hubs and repeaters for reliable operation.

Chapter 21

Extra supplies

Extra basic supplies such as cable and connectors may be required depending on the installation at a particular site. SR can often provide such supplies on request, however many customers may want to purchase such parts directly from suppliers themselves. This chapter lists a few typical parts and vendors. This list is only representative with many other suppliers providing equally good products.

DigiKey
www.digikey.com
1(800)344-4539

Mouser Electronics
www.mouser.com
1(800)346-6873

JDR Microdevices
www.jdr.com
1(800)538-5000

Abbreviations used below:

MFG = Manufacturer
DK = DigiKey
MO = Mouser
JDR = JDR Microdevices

21.1 Small Parts for cables etc

Some of the more common small parts used in USB4CH applications are as follows:

2.1mm power plug

MFG part number = CUI Inc PP3-002A
DK part number = CP3-1000A

MFG part number = Kobiconn
MO part number = 1710-2131

These are discrete wire power plugs suitable for soldering wires to. They are useful for connecting batteries and other custom power sources to the USB4CH. Use these instead of chopping the plug off of your wall transformer.

Alligator clips

MFG part number = Mueller BU-30
DK part number = 314-1010-ND

MFG part number = Silvertronic 501793
MO part number = 835-501793

The Mueller BU-30 clip has a good spring and strong teeth. The connection is wire crimp, which should also be soldered for low resistance. Making cables with these clips requires skill, but they result in inexpensive connections of good quality that are easy to use. The Silvertronic part is equivalent to the Mueller.

DB15 / DB25 solder cup Dshell connectors

MFG part number = generic
JDR part number = DB15S (female) / DB25S (female)

For making custom analog and digital USB4CH input cables, solder cup DB connectors are convenient. These are available everywhere including DK and MO. The JDR parts are generic and of good quality at a reasonable price.

Wall transformers

MFG part number = CUI Inc DPD090050-P5P-SZ

DK part number = T968-P5P-ND (9vdc 500ma 2.1mm plug, 110vac input ** US)

MFG part number = CUI Inc DPD090050E-P5P-SZ

DK part number = T973-P5P-ND (9vdc 500ma 2.1mm plug, 220vac input ** Euro)

Switching regulated wall transformers are not particularly recommended. No damage will occur, but switching regulators introduce high frequency noise into the system. Simple un-regulated DC wall transformers listed above provide a low noise supply. Linear regulated supplies are equally low noise.

Twisted pair shielded cable

MFG part number = Belden 9501

MO part number = 566-9501-100

Twisted pair provides reasonable powerline noise immunity for analog inputs. This Belden cable also has a foil shield for ESD protection and is jacketed. There are a large number of cable types available. The above is only one example.

Double twisted pair shielded cable

MFG part number = Belden 9502

MO part number = 566-9502-100

If necessary, cable with multiple twisted pair inside one shield is available. There is no particular advantage other than having more connections inside one jacket.

Potentiometers, 10 turn, 10K ohm

MFG part number = Vishay (Sfernice) 53411103

MO part number = 594-53411103

MFG part number = Bourns 3540 series

DK part number = 3540S-1-103-ND

A 10 turn pot is a simple and reasonably accurate sensor to use when testing the USB4CH or for angular measurements. DVM can be easily calibrated into turns or other units if necessary.

Potentiometers, linear slider, 10K ohm

MFG part number = Alps RSA0N11S9002

MO part number = 688-RSA0N11S9002

Linear slider pots do not have the accuracy of a 10 turn pot, but they are ideal for making linear position measurements.

Sensors, general

DK part number = Many, see their sensors listings

MO part number = Many, see their sensors listings

Both DK and MO have extensive selections of sensors that are suitable for use with the USB4CH. Temperature and pressure sensors are just a few in their listings. They can often provide an easy solution to sensor selection. PDF copies of their catalogs are available for download from their web sites.

Batteries, 12 volt lead acid

MFG part number = BB Battery BP1.2-12-T1 (12v 1.2Ah)

DK part number = 522-1007-ND

MFG part number = Power Sonic (12v 1.4Ah)

MO part number = 547-PS-1212

The batteries above are a small lead acid batteries. A good point about lead acid is they are rechargeable. A 1.2Ah battery would have enough power to run the USB4CH continuously for approximately 12 hours.

Chapter 22

Using Adobe PDF effectively

Most users will be viewing this this document in Adobe Reader. The following tips, specifically for Adobe Reader 8, may help keyboard users navigate the manual more quickly.

The red text items throughout the manual are hyperlinks. [Analog inputs](#) is an example. If you click on a hyperlink you will go to the referenced item. To get back from a hyperlink, type Alt+BackArrow. This makes it easy to come back from a hyperlink you have followed. Alt+ForwardArrow and Alt+BackArrow go forward and backward through the viewing chain you have recently traversed.

When viewing the [Circuit Diagrams](#) you may wish to rotate them by 90 degrees. This can be done quickly with the key combinations Ctrl+Shift+Plus, and Ctrl+Shift+Minus to rotate back.

You will probably also want to adjust the page display and zoom level depending on where you are looking in the manual. The following may be helpful:

Alt+V+P, S	single page display
Alt+V+P, U	two up page display
Ctrl+0	set zoom to fit page
Ctrl+1	set zoom to actual size
Ctrl+2	set zoom to fit width

If the Adobe Reader "**single key accelerators**" is turned on in the General Preferences, then you can use the Z key to drag a rectangle around a specific area you would like to view in more detail. This can be particularly helpful with the Circuit Diagrams.

Finally, using Ctrl+F will bring up the Adobe Reader text search. Use the Table of Contents at the beginning of the manual as well as the Adobe text search facility to find specific topics in the Manual.

Chapter 23

Getting Technical Help

Answers to many general questions and resources such as software downloads can be found on the SR web site. If you have specific technical questions, please email us at:

General product information: www.symres.com

Software downloads: www.symres.com

SR technical help email address: info@symres.com

If the USBxCH has a hardware problem, run **Diag debug** and email us the log and report files for a reply.



Avoid the ditch
Cathedral Gorge, Panaca, Nevada, 2006

USB4CH User Manual
Copyright ©, Symmetric Research, 2004, 2010

*This material can only be reproduced in whole or part with the written permission of
Symmetric Research*

No guarantee of suitability for any application is made with this document
All liabilities are the responsibility of the user

Email: info@symres.com Web: www.symres.com