DC Voltmeter Lab 0:

ALICE 1.3 Desktop is a multi-purpose and useful set of tools for measuring electronic circuits in lab projects and experiments. But with all its capabilities it can be a little intimidating at first to get comfortable using all of the tools. In this Tutorial we are going to go over one of those features (The DC Voltmeter) so that you can get the most out of the software.

1.0 Background:

The ALM1000 contains two 16 bit 100KSPS analog to digital converters (ADC). These voltage inputs are often used to measure time varying waveforms as in the ALICE oscilloscope interface. However, there are often times when simple, accurate, DC measurements are all that is required. The following simple user interface is provided for that purpose. It provides the means to accurately calibrate the measurements of voltages outside the built in 0 to 5 Volt range of the ADALM1000 through the use of resistor voltage dividers.

1.1 Required files:

The DC Voltmeter Tool Windows executable program is included with the ALICE 1.3 desktop installer package. Instructions for installing the software on Windows can be found at the following link:

https://wiki.analog.com/_media/university/tools/m1k/alice/alice-install-procedure.pdf

The Python source code is also available from the Analog Devices GitHub repository and is generally compatible with version 2.7 of Python. Other than the pysmu library bindings the program only imports modules generally included with standard Python installation packages.

1.2 Connections:

It is assumed that the reader is somewhat familiar with the functionality and capabilities of the ADALM1000 hardware. For more on the ADALM1000 hardware please refer to the documents listed in the main ALICE User Guide:

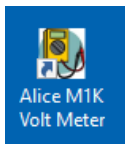First a few notes on nomenclature used in this document:

CH A refers to the Channel A SMU input / output pin on the 8 pin connector
CH B refers to the Channel B SMU input / output pin on the 8 pin connector
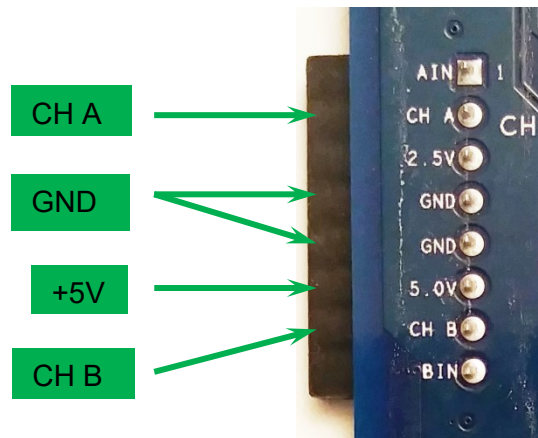
ADALM1000 8 Pin Connector

1.3 Screen Setup:

Once the program is run by double clicking on the desktop icon:

The main screen, as shown in figure 1, should appear. Be sure that the ALM1000 is plugged into the USB port before starting the program.
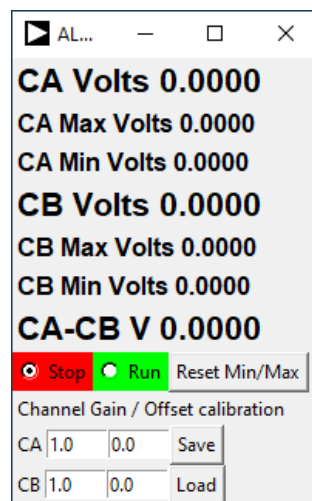

Figure 1, Voltmeter Window

At the top of the screen the measured DC voltages for channel A and channel B are displayed. Below the channel A voltage display are displays showing the Maximum and Minimum values (since the last time it was reset). Similarly below the channel B voltage display are displays showing the Maximum and Minimum values (since the last time it was reset) And below that is the display of the calculated voltage difference (CA-CB) between the two voltages. Below that are two buttons to run and stop (pause) the program looping and stop taking new measurements continuously. At the bottom there are entry slots for gain and offset calibration factors for both channels which can be used in conjunction with external voltage divider resistors to extend the range of voltages that can be measured.

1.4 Use Example:

To demonstrate how to use the Voltmeter Tool consider the resistor network, shown in figure E1, as a voltage divider and we wish to measure the voltages at the 4 nodes and the voltages across the 6 resistors. Resistor values other than those shown can of course be substituted which will give different node voltage results.

In the figure the nodes are numbered from N0 to N4 with N0 being the ground or common node that all the voltage measurements will be made with respect to. With the Voltmeter Tool we can measure two node voltages at a time and the voltage difference between those two nodes.
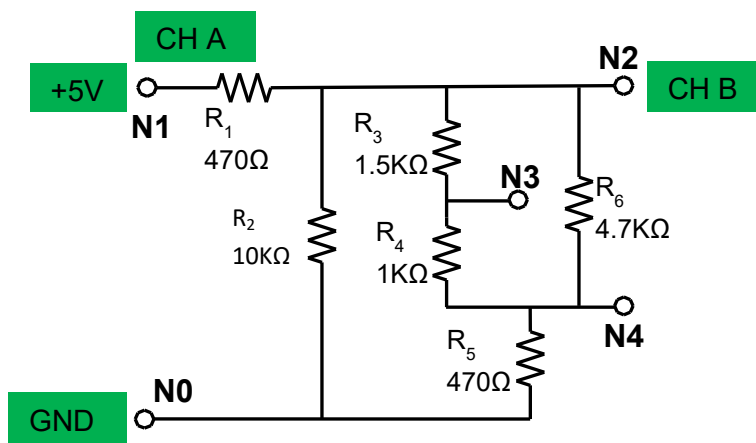

Figure E1, Test resistor network, measuring nodes N1 and N2

The solderless breadboard layout for the network in E1 is shown in figure B1.
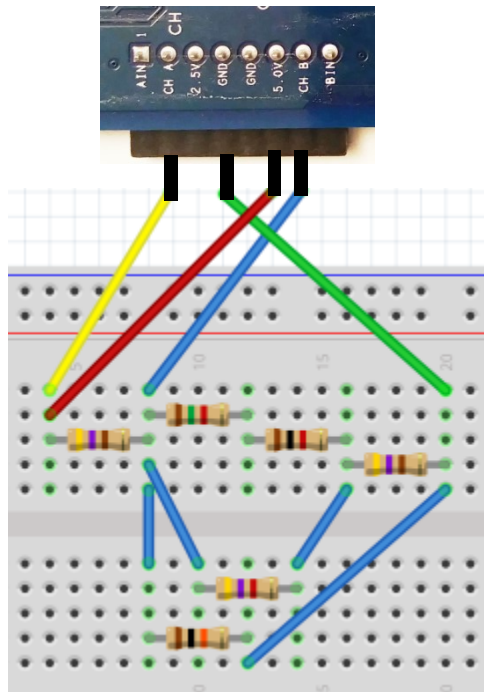

Figure B1, Test resistor network breadboard connections measuring nodes N1 and N2.

We start with the network powered from the fixed +5 volt power supply at node N1 and the channel A input also connected to N1. The channel B input is connected to node N2. Figure E2 shows the results.
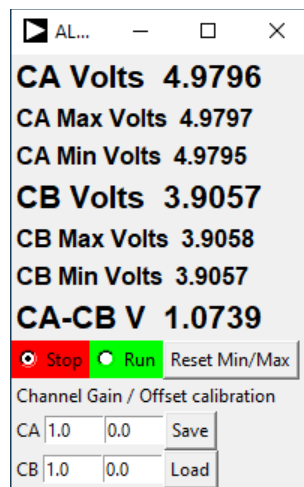

Figure E2, Measuring nodes N1 and N2

We can now proceed around the network measuring pairs of nodes until we can fill out the table below. Figure E3 shows the voltmeter inputs connected to nodes N3 and N4. Any combination of two nodes can be measured and the voltage difference between the two nodes will be displayed.
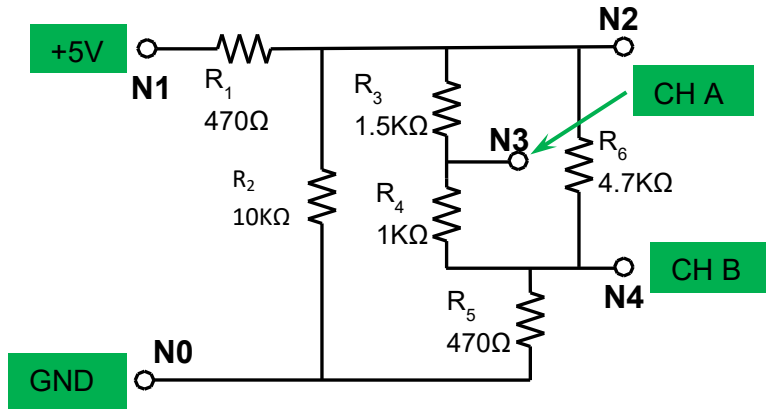

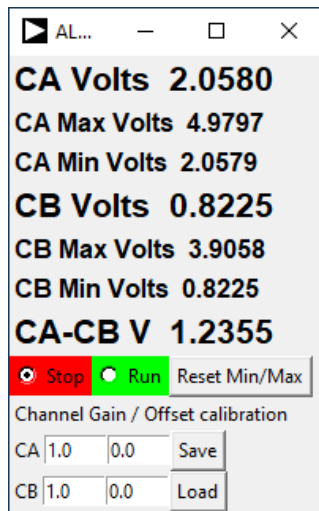Figure E3, Test resistor network, measuring nodes N3 and N4

Figure E4, Measuring nodes N3 and N4

Node	Voltage
N0	0.00
N1	4.9796
N2	3.9057
N3	2.058
N4	0.8225

Table 1 Node voltages

From the measured node voltages (and the difference voltages) we can get the voltages across the 6 resistors.

Resistor	Voltage
R1	N1 – N2 =1.0739
R2	N2 – N0 =3.9057
R3	N2 – N3 =1.8477
R4	N3 – N4 =1.2355
R5	N4 – N0 =0.8225
R6	N2 – N4 =3.0832

Table 2 Resistor voltages

From these voltages and the values of the resistors the currents through the resistors can be calculated using Ohms Law.

If the lab experiments you will be doing are limited to using only the +5 V supplied by the ALM1000 then you can stop the tutorial at this point and defer reading the rest of the tutorial till a future point when the labs involve voltages other than 0 to 5 V.

2.0 Calibrating the Voltmeter for an external voltage divider

To keep production costs of the board low, certain tradeoffs were made. One was to forego programmable input gain ranges that use resistor dividers. This limited the usable DC input voltage range to 0 to +5V. Many users need a way around this restriction when measuring circuits powered by supply voltages other than (read larger) the built in supplies. This limitation on the allowable DC voltages that can be measured can of course be expanded through the use of an external voltage divider.

The contents of the blue box in figure 2 represent the input of the M1k in Hi-Z mode. Resistor R_1 in combination with the internal 1 MΩ resistor and optional resistors R_2 and R_3 form a voltage divider network to reduce the voltage seen at the input to the M1k at the CH A pin. To introduce an optional DC offset for measuring negative voltages resistor R_2 is included and could be connected to either the fixed +2.5V or +5V supplies on the M1k.
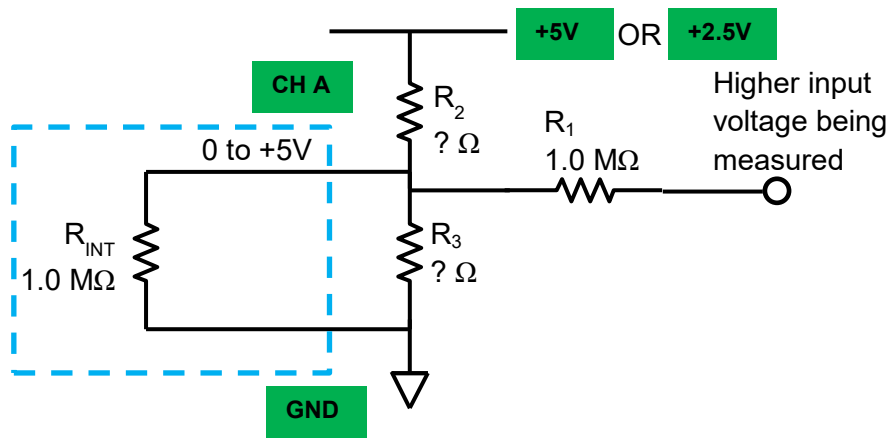
Figure 2, External voltage divider options.

As a simple first example we can just use a 1 MΩ resistor for R_1 and not include the other resistors, R_2, R_3 from figure 2. This gives us a total input resistance of 2 MΩ. Since R_1 and R_2 will be approximately equal the voltage that appears at the CH A input pin will be approximately ½ the voltage that is applied to the divider input at R_1.

To allow for the reduction in the voltage the Voltmeter program include the ability to multiply the voltage it measures (in the range from 0 to 5) by a gain factor before the measurement is displayed. An external voltage divider like this can also introduce a constant offset as well. The program starts with the gain calibration factors for both channels set to 1.0. The program also includes the ability to subtract an offset from the measurement. The offset calibration factors for both channels are set to 0.0 to start. Places to enter these calibration values are at the bottom of the Voltmeter window.

The first step in the calibration procedure is to connect the resistor divider input (the end of R_1) to ground. We just calculated that the voltage at the CH A pin will need to be multiplied by approximately 2 to equal the actual input voltage. So as a preliminary guess enter 2.0 as the value in the CA gain value. Press the Run button. The screen should look something like figure 3 with some small non-zero values for CA Volts and CB Volts. There is a small DC offset due to the leakage current from the overvoltage ESD protection diodes on the M1k inputs and the parallel combination of R_{INT} and R_1.

We will only be working on Channel A in this example so you can disregard channel B for now. You can just repeat the steps for a divider connected to B later.
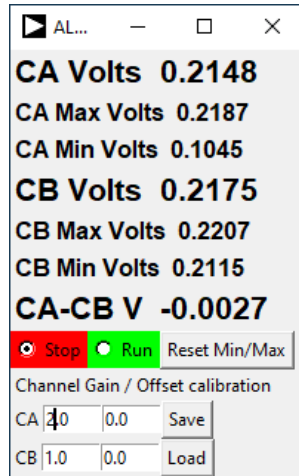

Figure 3, Divider step one R_1 input grounded.

In addition to just typing in the entry values, while the program is running, you can hover the mouse cursor in the CA entry and use the mouse wheel to increment or decrement the digit next to the cursor. Left Click in the CA Offset entry and adjust the value until the displayed CA Volts is as close to 0.0 as you can get it. See figure 4.
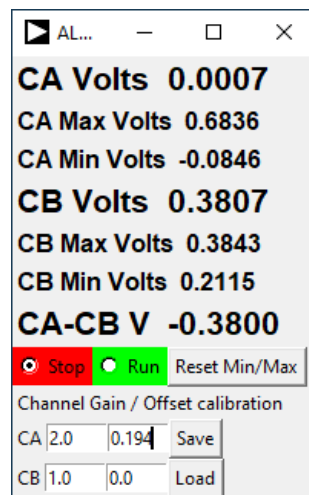

Figure 4, First pass for Offset value.

Your results will vary depending on your exact board and external resistor value but for this example the offset value entered was 0.194.

Earlier we had just guessed a gain value of 2 based on nominal resistor values. Now we need to determine the actual gain factor. We know the value for the internal +5 volt supply because we measured it in the earlier example, figure E2 (with no external voltage divider in series with the input). Connect the divider resistor R_1 to the fixed +5 V pin on the M1k. Adjust the CA gain value until the CA reading displayed is as close to the previous value for the 5 volt supply (4.979 in this example). See figure 5.
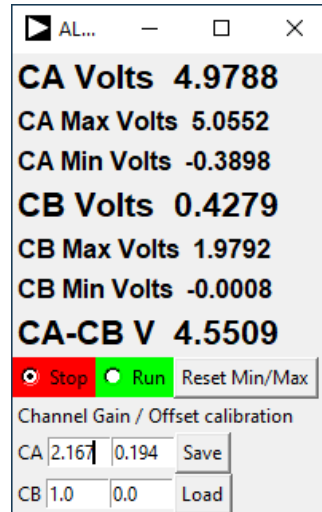

Figure 5, First pass adjustment of Gain.

As we can see the DC gain setting is slightly more than 2 (2.167 to be exact) which is to be expected based on the internal 1 MΩ resistor and external 1 MΩ R_1 resistor forming a 2:1 voltage divider.

There is a small interaction between the gain and offset values so it is always a good idea to go back and check the offset setting with this new gain value. Connect R_1 back to ground.
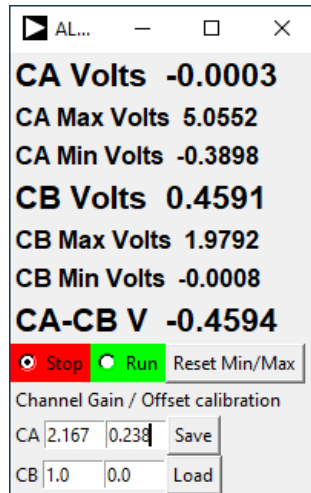
Figure 6, Second pass adjusted Offset value.

In figure 6 we see that the offset value is now 0.238. Now we can go back and double check the gain value with this new offset value. Connect R_1 back to the +5 V pin. See figure 7.
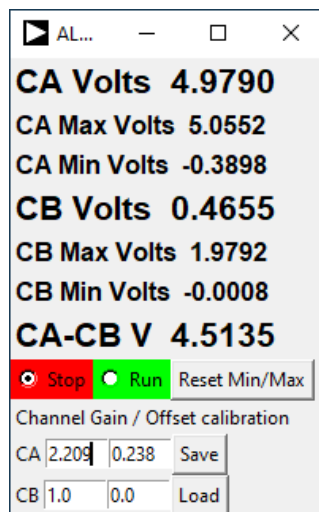

Figure 7, Second pass adjusted Gain value.

The gain value increased slightly to 2.209. For really accurate calibration is might be necessary to iterate back and forth adjusting the offset and gain several times. But for most cases a second pass is enough.

The input gain factor of 2 (2.2 to be exact) increases the allowable measurement range from 0 to +5 V to more than 0 to +10 V. Enough to work with circuits powered from a 9 V battery. If you have a 9 V battery connect the negative battery terminal to ground and the positive battery terminal to voltage divider

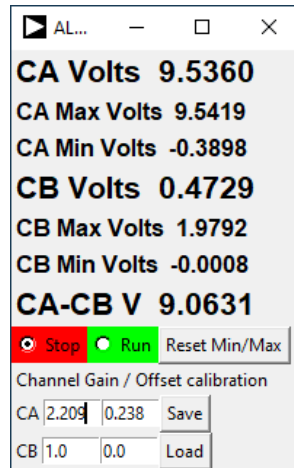resistor R_1. You should now read around 9.5 volts for a fresh battery as in figure 8.

Figure 8, Measuring a 9 V battery.

3.0 Next Steps – Time to Tinker!:

There are more things you can do with the interface but these are the basics to get you started. You can explore the rest by exploring or tinkering on your own. The best way to become familiar with your M1k and the ALICE tools is to start tinkering with electronics. Using some parts from your parts kit put together some other simple circuits that you might have seen or been interested in learning more about (measuring the M1k fixed power supply rails, a resistor voltage divider, powering LEDs or a DC motor, etc.) or explore new electrical components or circuits. Eventually you will be building and analyzing more and more complex circuits.

Appendix:

Using a more accurate known voltage to calibrate against is always a good idea. The AD584 voltage reference from the ADALP2000 Analog Parts Kit is a good choice. Plug it into your solderless breadboard and connect as shown in figure A1. The AD584 is configured as a 2.5V reference by connecting pins 1 and 3 together. Connect both voltmeter input channels to the 2.5V output of the AD584. Note: the internal 2.5V and 5V sources of the ALM1000 are not accurate enough for the best calibration of the Voltmeter tool (unless you can accurately measure them with a good bench DMM).
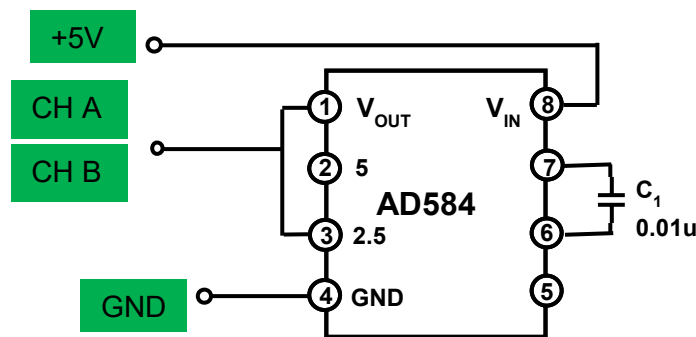

Figure 4 AD584 2.5 V reference connections

After double checking your connections press the Run button. The meter should values for CA Volts and CB Volts close to 2.5 Volts.

If the AD584 is powered from a 9 V battery rather than the +5 Volt supply in the M1k, it can produce an accurate +5 V output as well. This is done by connecting the 5 V pin (Pin 2) to the output pin (Pin 1).

Customizing the program

There may be times when the user wishes to customize the program to add additional functions such as controlling the digital I/O pins on the ALM1000. This should be relatively easy to do in the Python program file. There are a number of Python tutorial examples available.