PCUHCU Calibration Techniques

for the

AARTS System

AN #20130712-01

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Accel-RF Corporation specializes in the design, development, manufacture, and sales of accelerated life-test/burn-in test systems for RF and Microwave semiconductor devices. This white paper describes technical information related to the AARTS Hardware. For more information contact:

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1 Overview

The AARTS station utilizes several custom boxes manufactured by Accel-RF Corporation, including the Power/Heater Control Unit (PCUHCU). This box employs circuitry that must be calibrated. Digital-to-Analog Converters (DACs) drive the voltage- and current-control loops. Analog-to-Digital Converters (ADCs) are used to measure pre-switch voltage, DUT voltage, and DUT current. These devices employ calibration factors to optimize accuracy. This application note describes the technique used to calibrate both sets of devices.

2 ADC/DAC Calibrations

This document describes how to perform a full calibration of a PCUHCU brick. The brick should come from the factory already calibrated, but on occasion re-calibration may be desired. The calibration factors are stored on-board the PCUHCU motherboard in non-volatile memory. Hence, bricks may be moved between channels, or even completely replaced without the need to transfer calibration files like legacy PCU units required.

This process assumes the operator has access to either an Agilent 34401 or 34410 digital multimeter (DMM). Note, all AARTS systems have built-in DMMs, and that may be used for calibration purposes if a lab-version is not available. The USBControl software program must be used to calibrate the bricks.

2.1 Accessing the Calibration Form

The USBControl program is used to determine all DAC and ADC calibration factors. There are two communication avenues available to access the PCUHCU motherboard processor: USB and/or GPIB. There is a USB port on the brick itself, and a unique one for each brick located on the back of the PCUHCU mainframe. The PCUHCU brick requires a 48-V power supply for powering its internal circuitry. The PCUHCU mainframe contains such a source and it is recommended that any customer-based calibration be performed in situ using such a mainframe.

The easiest way to access the PCUHCU motherboard is via the GPIB interface since it is already connected to the main AARTS computer for life-testing purposes. The main concern in this case is to correctly identify the proper GPIB address for the box (channel) being calibrated. Note: some systems have more than one PCUHCU mainframe. The rest of this app note presumes the GPIB interface is being utilized, and not the USB interface.

First, the LifeTest program must NOT be running to use the USBControl program as they may try to access the GPIB and./or USB buses simultaneously. Hence, stop the LifeTest program if it is running, then launch the USBControl program. A Form similar to that of Figure 2-1 should appear. Since the USB interface is not being employed, no PCUHCU devices are displayed in the main windows. Note, the HPS_Pulser devices (i.e. fixtures) may be displayed, but they are different device types. There will be no PCUHCU item in the menu list at the top. Click CTRL-F2 to force all device types to become available. A Form similar to Figure 2-2 should appear. Click on the PCUHCU menu item to launch the PCUHCU interface.

A Form similar to Figure 2-3 is presented. Note that there are no entries in the device information box at the top. That is because the USB interface mode is selected as default. To establish a communication link to the PCUHCU brick, the operator must enter the proper GPIB card number, GPIB address, and slave address in the right hand “Interface” control box. Except for some DC systems with large numbers of channels, the GPIB card number will always be “0”. The GPIB addresses will generally start with “1”. Right Click in the Top menu of the LifeTest program and select “Display GPIB Card and Address Info” option to see which channels correspond to which addresses.

Figure 2-1: USBControl Program

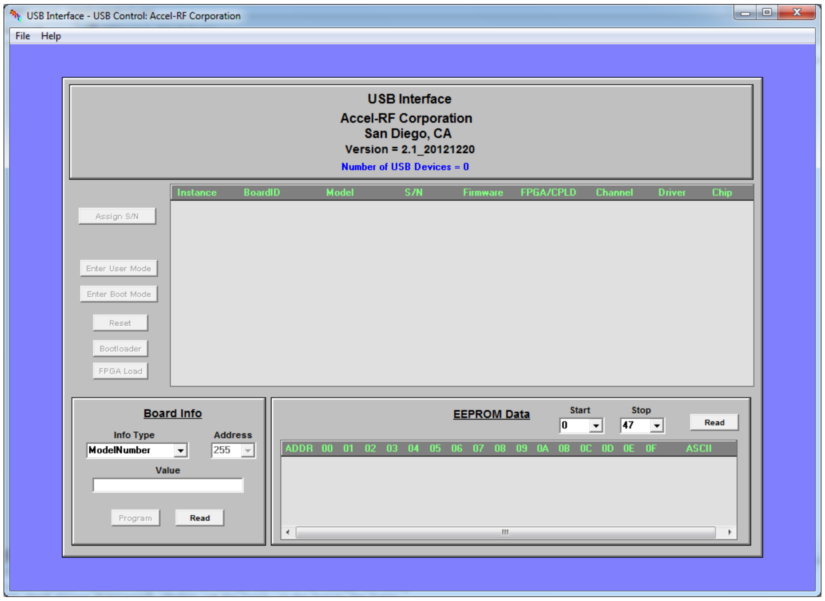


Figure 2-2: PCUHCU Menu Item Displayed (CTRL-F2)

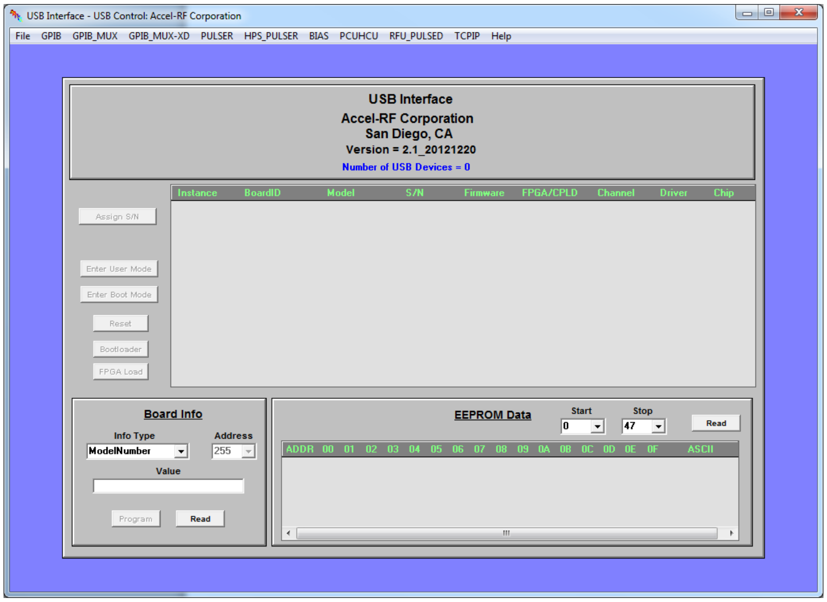


Figure 2-3: PCUHCU Form (USB Interface)

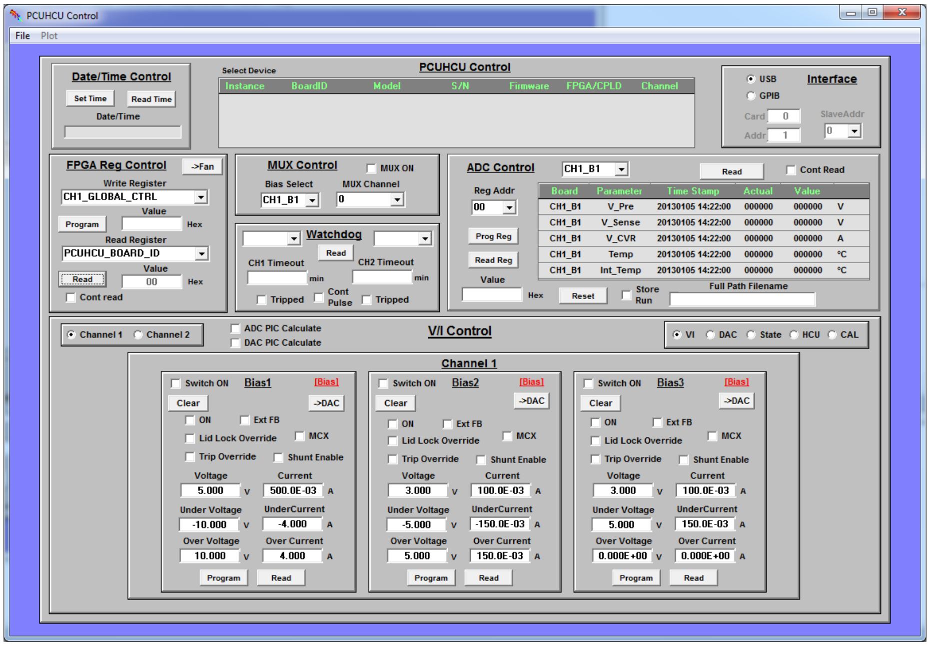
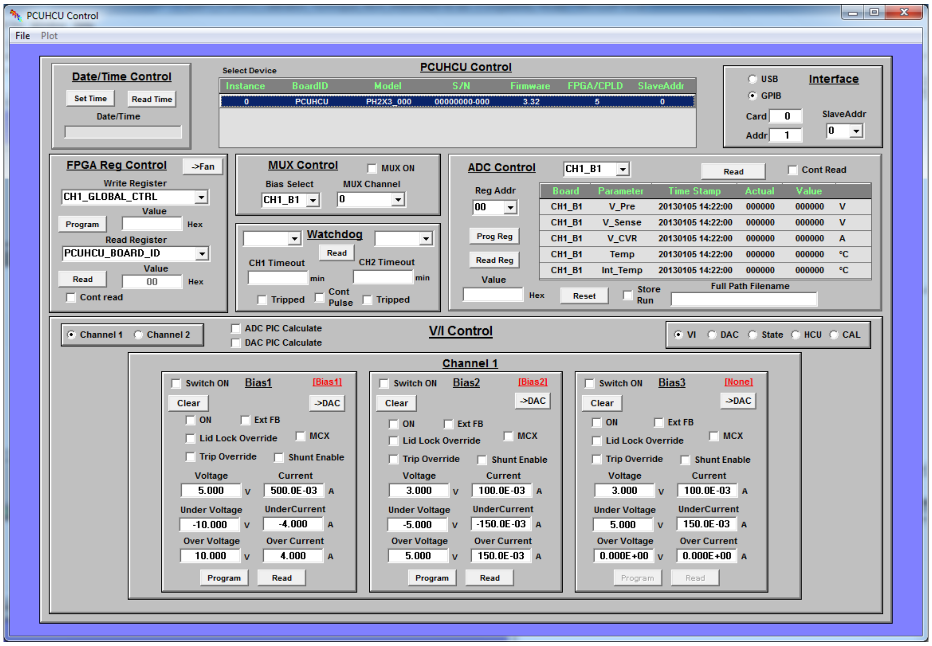


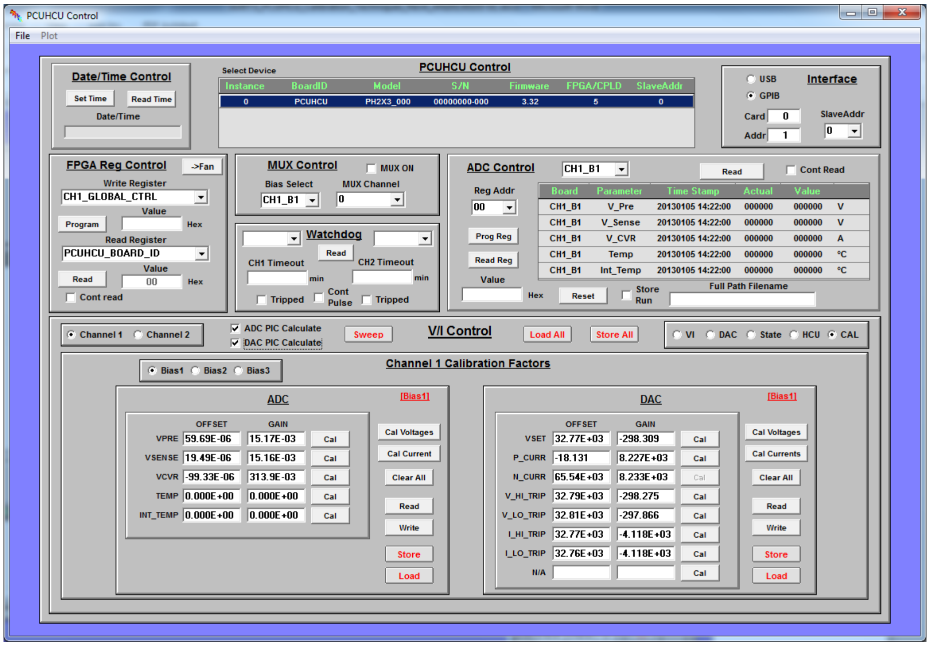
Figure 2-4: PCUHCU Form (GPIB Interface)



The SlaveAddr represents which slot in the PCUHCU mainframe the PCUHCU brick is plugged into. Slot 0 is the farthest left, and slot 5 is the farthest right. Each brick contains two channels. Slot 0 contains channels 1 and 2, slot 1 contains channels 3 and 4, and so on. Choose the proper SlaveAddr in the box that contains the channel of interest. Note that the PCUHCU Form only refers to channels "1" and "2" - these refer to the appropriate channels associated with the channel of interest based on the SlaveAddr.

The lower boxes contain several radio button options. Click on the "Cal" button and then "Load All" to load the existing calibration factors in the brick into memory. A form similar to Figure 2-5 should appear. Select the channel of interest and the Bias of Interest. Check the "ADC_PIC_Calculate" and "DAC_PIC_Calculate" check boxes to force the processor of the motherboard to apply calibration factors to all readings and settings. The following sections discuss calibration of ADC and DAC values.

Figure 2-5: PCUHCU Cal Interface



The connection configuration for all ADC and DAC voltage measurements is shown in Figure 2-6. If the AARTS system internal DMM is used, the FRONT/BACK switch should be set to "Front" and long cables connected between the fixture of interest and the DMM. Do not forget to set the switch to "Back" for normal LifeTest operation later.

The connection configuration for all ADC and DAC current measurements is shown in Figure 2-7. Note that the PCUHCU stimulus will be limited to ~2.5A as the limit of the Agilent meter is 3A. The internal DMM current monitoring mode will effectively short the output. Hence, the current calibrations will occur in current-limit mode of the respective supplies.

If only one DMM is available, the operator will need to switch between voltage and current mode as required for the parameter of interest. If two meters are available, the operator may set the GPIB addresses to unique values (ones that do not conflict with any instruments used by the system of course), and then define one for voltage and one for current.

It should be noted that this current calibration is different from that of the legacy PCU boxes and does not require external load resistors.

Figure 2-6: Voltage Measurement Configuration

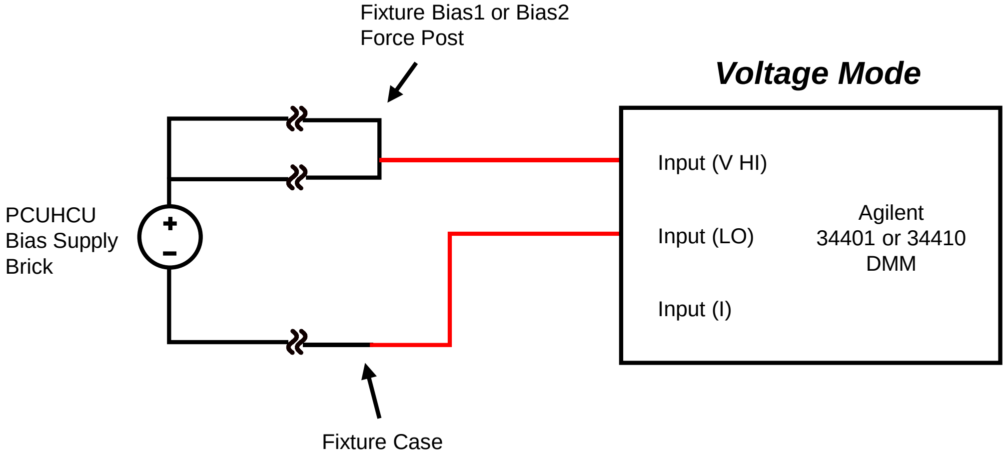
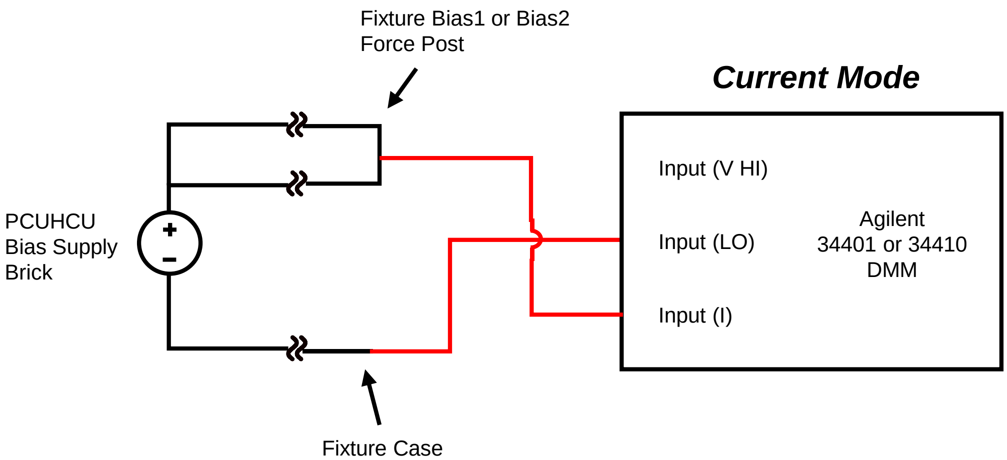


Figure 2-7: Current Measurement Configuration



2.2 Calibrating DAC Factors

DACs are used in a variety of ARF instruments to control stimulus. Within the PCUHCU DACs are employed to set the voltage and current values. They are also used in the trip comparator circuits for fast shutdown of the supplies upon over/under voltage and current conditions. This section describes the technique used to calibrate these factors.

First, note (as shown in Figure 2-5) that the bias Type is displayed in Red in the ADC and DAC control boxes. This should match the expected type in the brick.

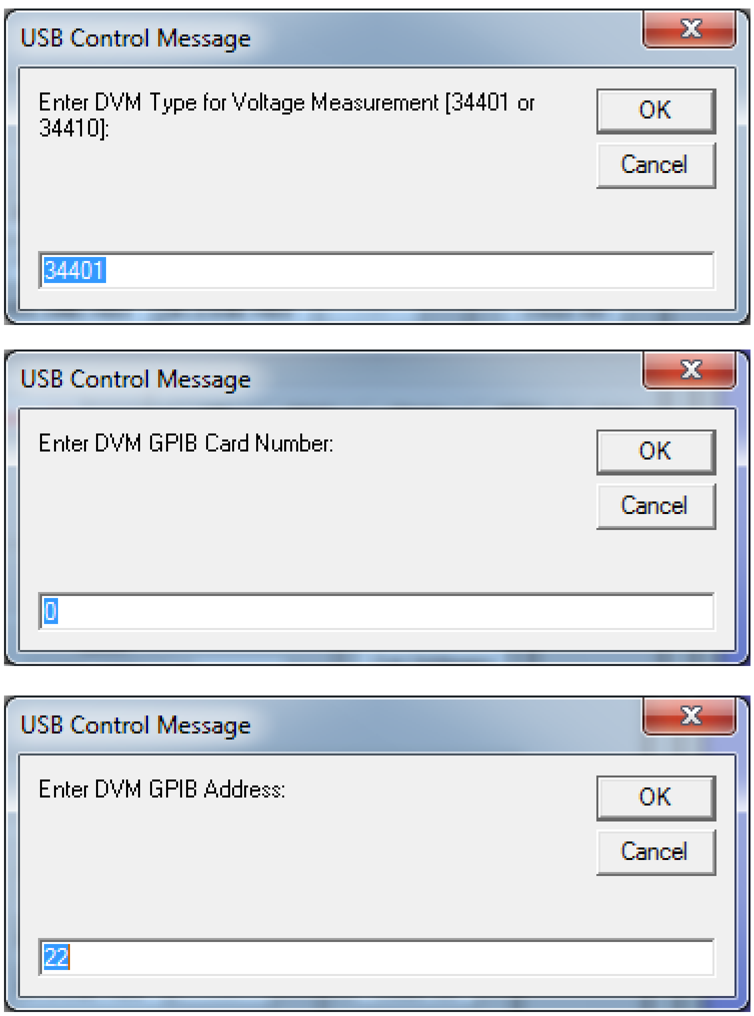
The parameters of interest for DAC values are:

VSET (target Voltage)
P_CURR (target Positive Current)
N_CURR (target Negative Current)
V_HI_TRIP (high trip value of Voltage)
V_LO_TRIP (low trip value of Voltage)
I_HI_TRIP (high trip value of Current)
I_LO_TRIP (low trip value of Current)

Note that Negative Current for standard Bias1-type sources is not valid and is disabled when that type supply is selected. It is active for Bias2-type sources.

Set the measurement system to Voltage Mode (Figure 2-6) and click on “Cal Voltages” in the DAC section. The first time a “Voltage” type measurement is performed, message boxes similar to Figure 2-8 are presented to configure the voltage meter. Enter the appropriate values for DMM type, GPIB Card, and GPIB Address of the measurement device (Note: the default address for external DMMs is typically 22, but the internal AARTS DMM is typically set to 28).

Figure 2-8: Voltage Setup Inputs



A message box similar to that shown in Figure 2-9 indicates what stimulus will be applied to the channel. Click OK to continue the process. A Form similar to Figure 2-10 will show progress. When complete the values will be populated in the appropriate text boxes. The program will continue automatically through all voltage measurements. When complete, click on the "Store" button in the DAC control box area to write and store the values in the PCUHCU non-volatile memory.

Figure 2-9: DAC Voltage Measurement Information Box

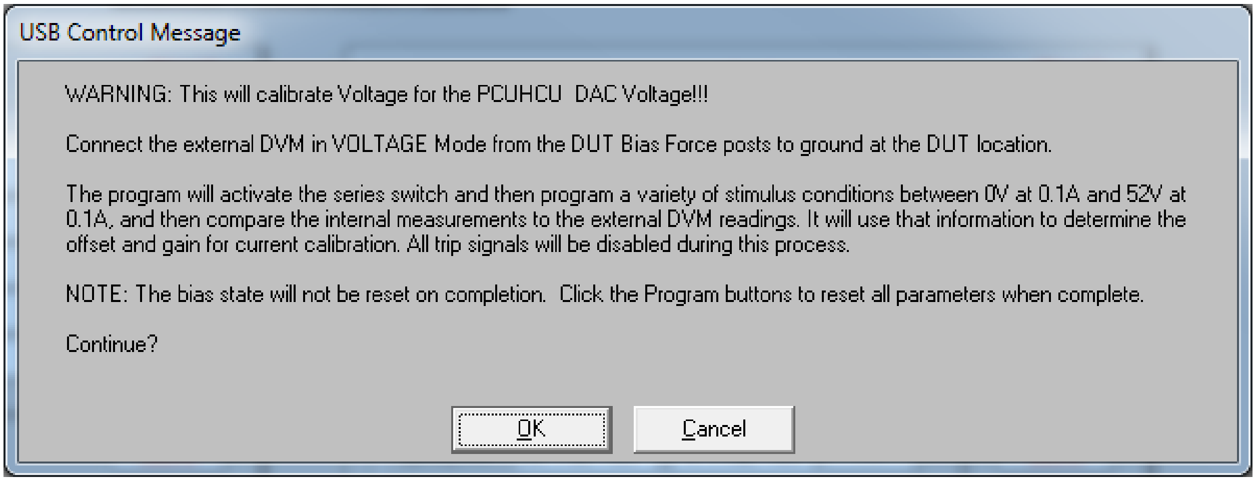
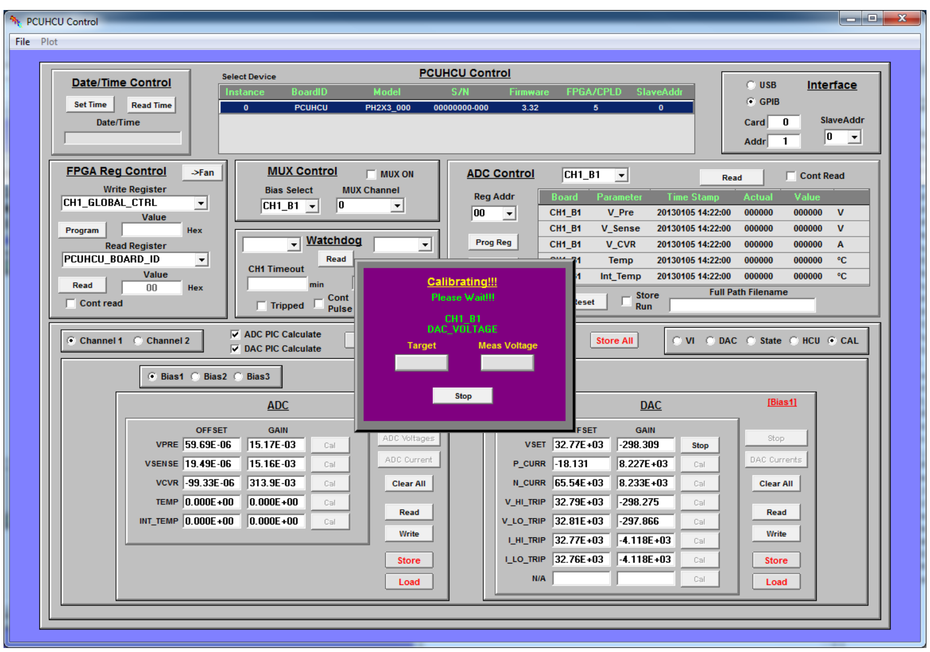


Figure 2-10: DAC Voltage Calibration Informational Box



To calibrate DAC currents, setup the measurement system for Current Mode (Figure 2-7) and click on “Cal Currents” in the DAC section. The first time a “Current” type measurement is performed, message boxes similar to Figure 2-8 are presented to configure the current meter. Enter the appropriate values for DMM type, GPIB Card, and GPIB Address of the measurement device (Note: the default address for external DMMs is typically 23, but the internal AARTS DMM is typically set to 28).

A message box similar to that shown in Figure 2-11 indicates what stimulus will be applied to the channel. Click OK to continue the process. A Form similar to Figure 2-12 will show progress. When complete the values will be populated in the appropriate text boxes. The program will continue automatically through all current measurements. When complete, click on the “Store” button in the DAC control box area to write and store the values in the PCUHCU non-volatile memory.

Figure 2-11: DAC Current Measurement Information Box

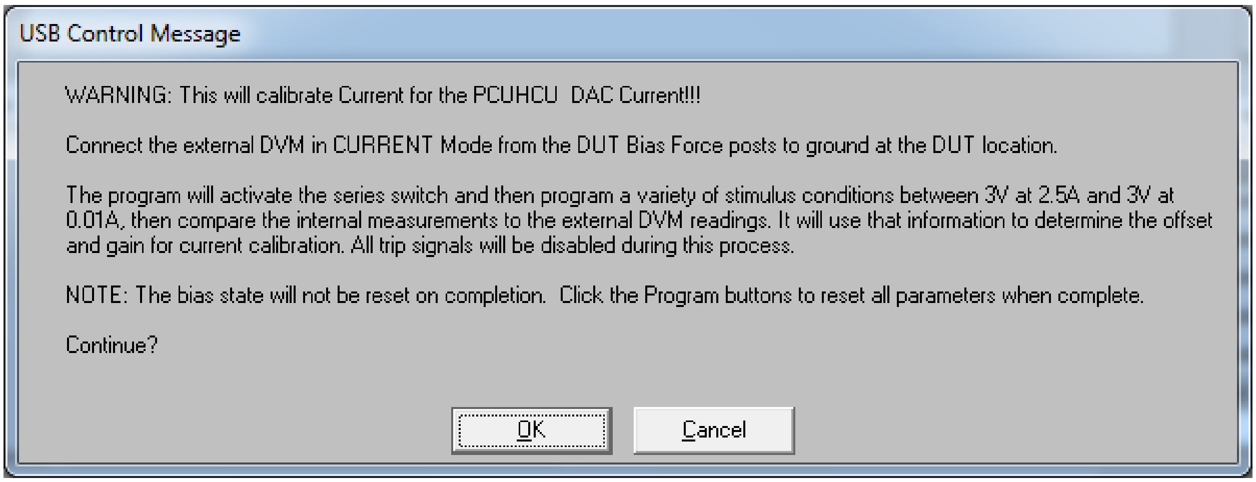
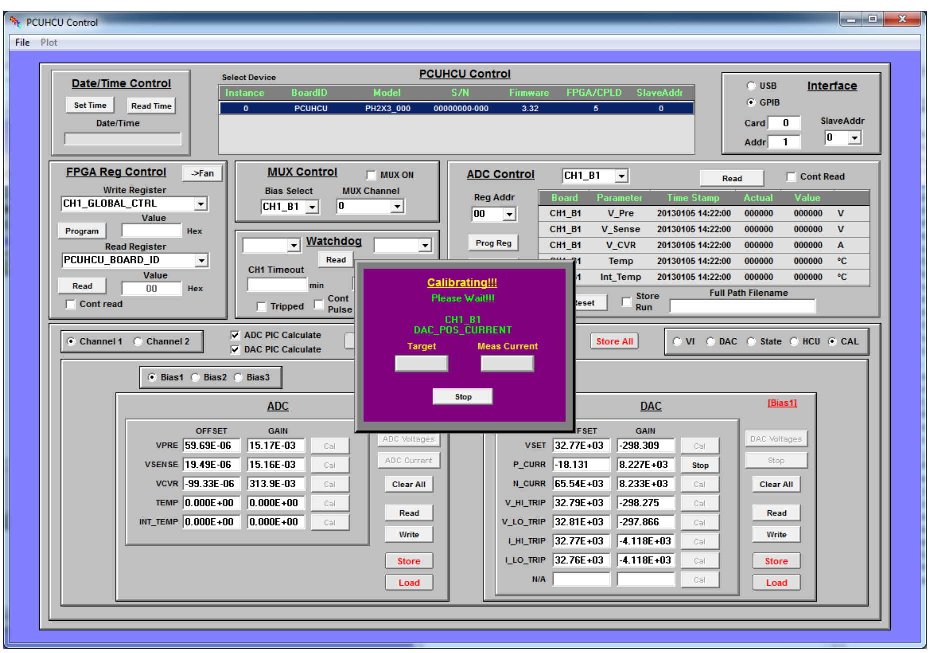


Figure 2-12: DAC Current Calibration Informational Box



2.3 Calibrating ADC Factors

ADCs are used for voltage and current measurements. This section describes the technique used to calibrate these factors.

First, note (as shown in Figure 2-5) that the bias Type is displayed in Red in the ADC and DAC control boxes. This should match the expected type in the brick.

The parameters of interest for ADC values are:

VPRE (Pre-Switch Voltage)
VSENSE (DUT Voltage)
VCVR (DUT Current)

Set the measurement system to Voltage Mode (Figure 2-6) and click on “Cal Voltages” in the ADC section. The first time a “Voltage” type measurement is performed, message boxes similar to Figure 2-8 are presented to configure the voltage meter. Enter the appropriate values for DMM type, GPIB Card, and GPIB Address of the measurement device (Note: the default address for external DMMs is typically 22, but the internal AARTS DMM is typically set to 28).

A message box similar to that shown in Figure 2-13 indicates what stimulus will be applied to the channel. Click OK to continue the process. A Form similar to Figure 2-14 will show progress. When complete the values will be populated in the appropriate text boxes. The program will continue automatically through all voltage measurements. When complete, click on the “Store” button in the ADC control box area to write and store the values in the PCUHCU non-volatile memory.

Figure 2-13: ADC Voltage Measurement Information Box

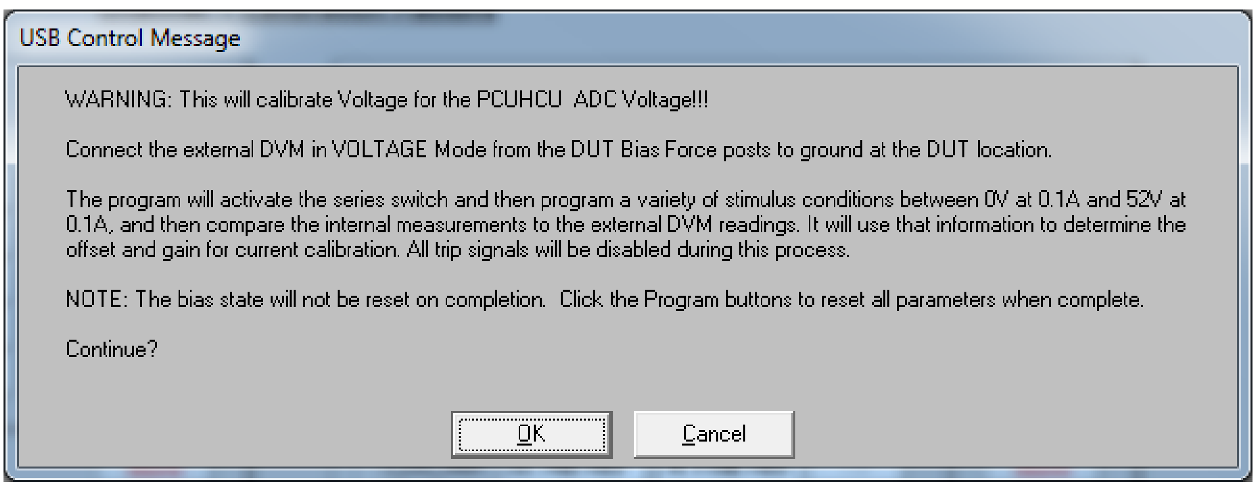
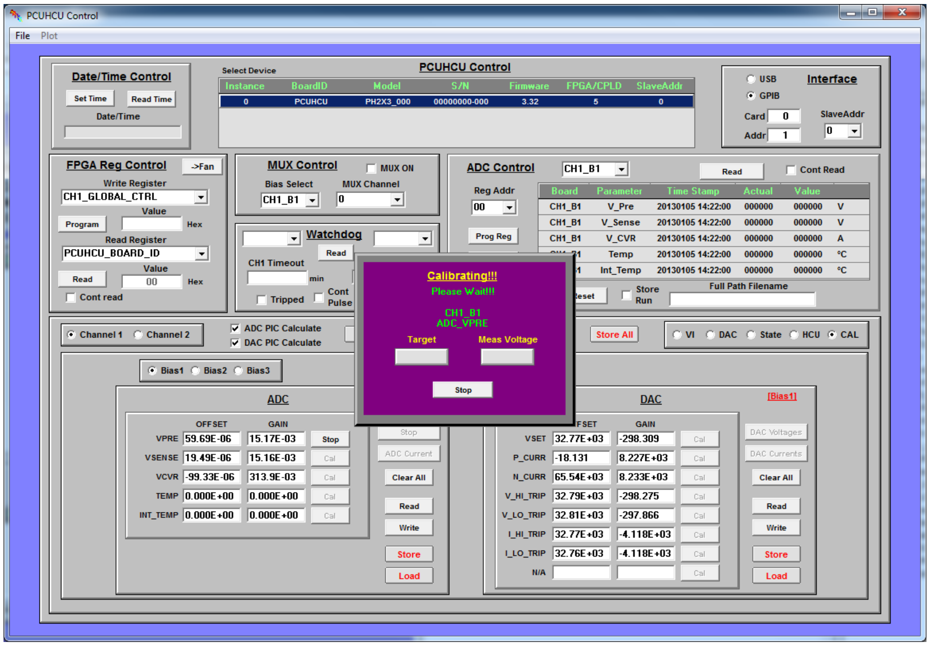


Figure 2-14: ADC Voltage Calibration Informational Box



To calibrate ADC current, setup the measurement system for Current Mode (Figure 2-7) and click on "Cal Currents" in the ADC section. The first time a "Current" type measurement is performed, message boxes similar to Figure 2-8 are presented to configure the current meter. Enter the appropriate values for DMM type, GPIB Card, and GPIB Address of the measurement device (Note: the default address for external DMMs is typically 23, but the internal AARTS DMM is typically set to 28).

A message box similar to that shown in Figure 2-15 indicates what stimulus will be applied to the channel. Click OK to continue the process. A Form similar to Figure 2-16 will show progress. When complete the values will be populated in the appropriate text boxes. Click on the "Store" button in the ADC control box area to write and store the values in the PCUHCU non-volatile memory.

Figure 2-15: ADC Current Measurement Information Box

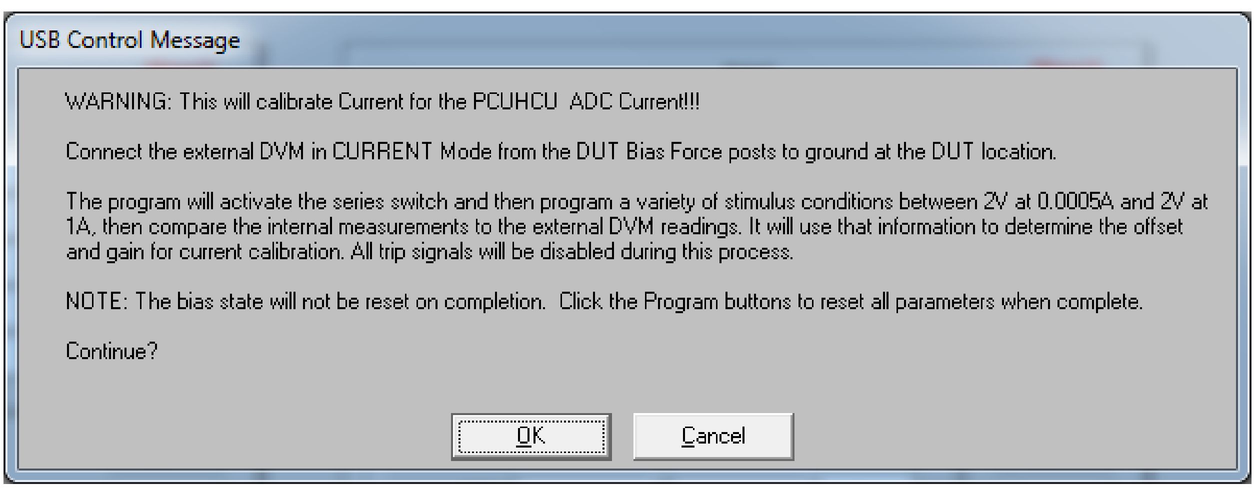
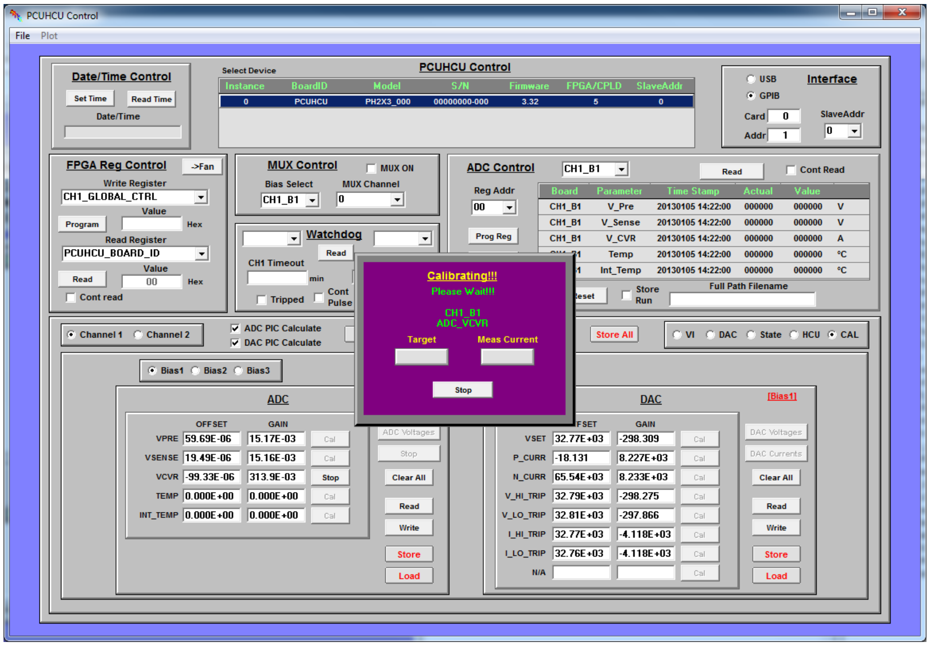


Figure 2-16: ADC Current Calibration Informational Box



3 Verifying the Calibrations

There are several ways to check calibration values. One way would be to set up an appropriate stimulus (with or without a load), program it into the supply using the VI Interface (see Figure 2-4), select the ADC of interest using the pull-down box in the “ADC Control” area, and clicking the Read button. The values displayed should properly read what an external meter should read. This is fine for a few points, but is time consuming for verifying performance over a large range.

An interface exists in the USBControl program to assist automated characterize the calibration over a wide operating range. Click the “Sweep” command button in the “Cal” Section to launch the Form shown in Figure 3-1. Select the Channel/Bias and Parameter of interest and then click on “Create Defaults”. This sets up a set of stimulus values to cover a wide range of operating points. Then click on “Run Sweep” to take measurements.

3.1 Verify Voltage Settings and Measurements

Set the measurement system to Voltage Mode (Figure 2-6) and click the “Run Sweep” command button. The first time a “Voltage” type measurement is performed, message boxes similar to Figure 2-8 are presented to configure the voltage meter. Enter the appropriate values for DMM type, GPIB Card, and GPIB Address of the measurement device (Note: the default address for external DMMs is typically 22, but the internal AARTS DMM is typically set to 28).

An informational box similar to Figure 3-2 reminds the operator what mode to set up. Click OK to Continue.

Figure 3-1: PCUHCU ADC/DAC Characterization Form

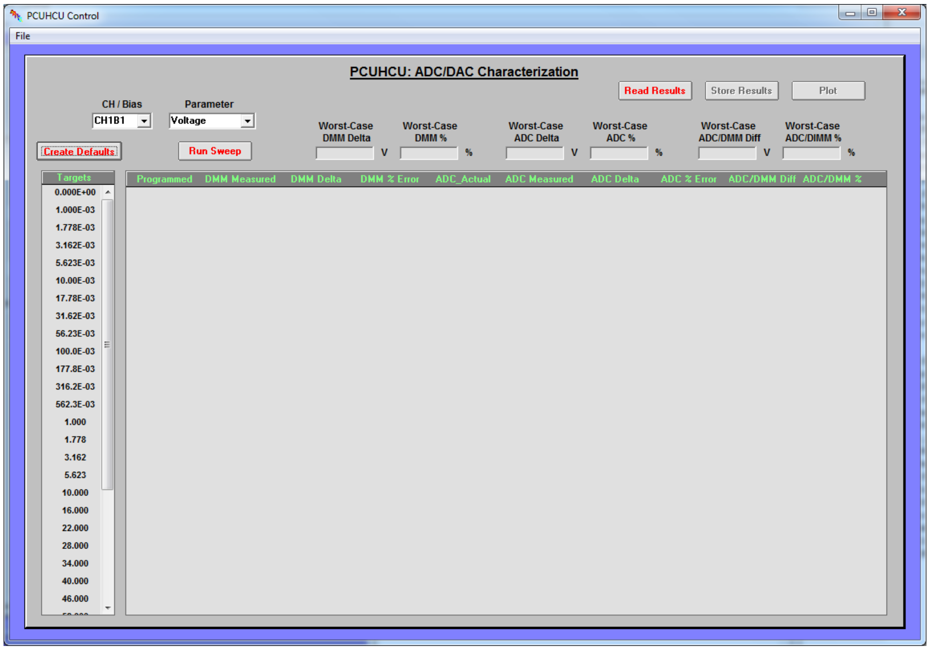
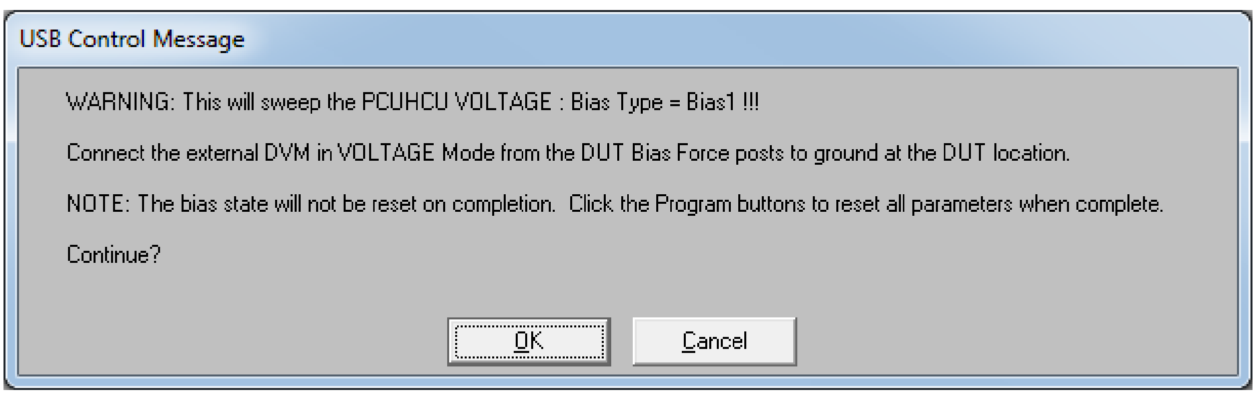
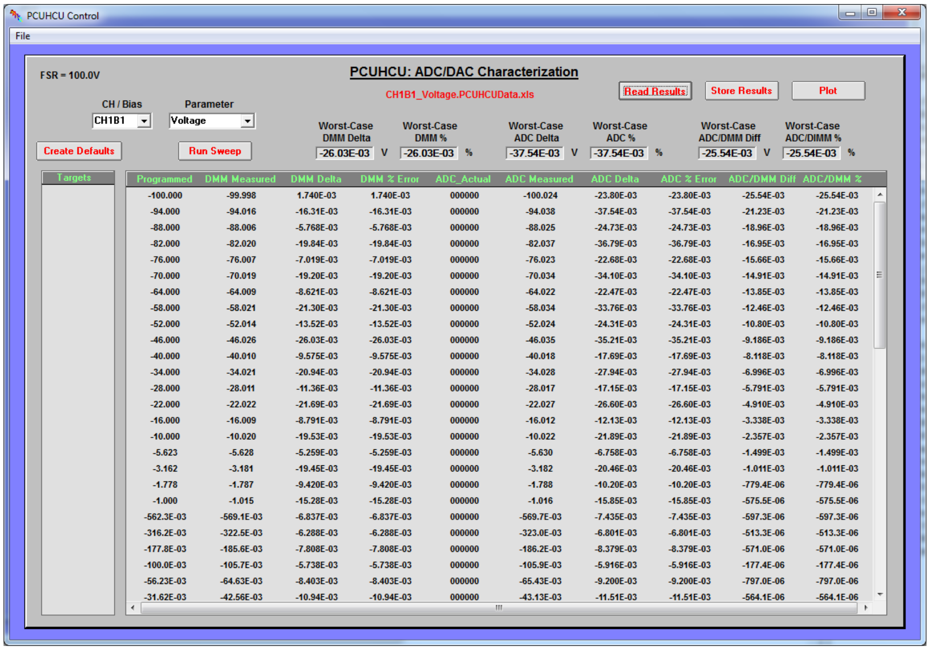


Figure 3-2: Voltage Characterization Informational Box



The results are populated in the center list box as the measurements are being made. The target programmed value, the DMM measured value, and the ADC measured values are displayed; along with the deviation from ideal values. The worst case deviation values are also presented. Further, the deviation as percentage of Full Scale Range (FSR) is calculated (note: this is the value against which most power supplies are specified). Figure 3-3 illustrates typical results for a Bias1 voltage sweep. Click on the “Plot” command button to plot the results (similar to that shown in Figure 3-4).

Figure 3-3: Voltage Measurement Results



Programmed	DMM Measured	DMM Delta	DMM % Error	ADC_Actual	ADC Measured	ADC Delta	ADC % Error	ADC/DMM Diff	ADC/DMM %
-100.000	-99.998	1.740E-03	1.740E-03	000000	-100.024	-23.80E-03	-23.80E-03	-25.54E-03	-25.54E-03
-94.000	-94.016	-16.31E-03	-16.31E-03	000000	-94.038	-37.54E-03	-37.54E-03	-21.23E-03	-21.23E-03
-88.000	-88.006	-5.768E-03	-5.768E-03	000000	-88.025	-24.73E-03	-24.73E-03	-18.96E-03	-18.96E-03
-82.000	-82.020	-19.84E-03	-19.84E-03	000000	-82.037	-36.79E-03	-36.79E-03	-16.95E-03	-16.95E-03
-76.000	-76.007	-7.019E-03	-7.019E-03	000000	-76.023	-22.68E-03	-22.68E-03	-15.66E-03	-15.66E-03
-70.000	-70.019	-19.20E-03	-19.20E-03	000000	-70.034	-34.10E-03	-34.10E-03	-14.91E-03	-14.91E-03
-64.000	-64.009	-8.621E-03	-8.621E-03	000000	-64.022	-22.47E-03	-22.47E-03	-13.85E-03	-13.85E-03
-58.000	-58.021	-21.30E-03	-21.30E-03	000000	-58.034	-33.76E-03	-33.76E-03	-12.46E-03	-12.46E-03
-52.000	-52.014	-13.52E-03	-13.52E-03	000000	-52.024	-24.31E-03	-24.31E-03	-10.80E-03	-10.80E-03
-46.000	-46.026	-26.03E-03	-26.03E-03	000000	-46.035	-35.21E-03	-35.21E-03	-9.186E-03	-9.186E-03
-40.000	-40.010	-9.575E-03	-9.575E-03	000000	-40.018	-17.69E-03	-17.69E-03	-8.118E-03	-8.118E-03
-34.000	-34.021	-20.94E-03	-20.94E-03	000000	-34.028	-27.94E-03	-27.94E-03	-6.996E-03	-6.996E-03
-28.000	-28.011	-11.36E-03	-11.36E-03	000000	-28.017	-17.15E-03	-17.15E-03	-5.791E-03	-5.791E-03
-22.000	-22.022	-21.69E-03	-21.69E-03	000000	-22.027	-26.60E-03	-26.60E-03	-4.910E-03	-4.910E-03
-16.000	-16.009	-8.791E-03	-8.791E-03	000000	-16.012	-12.13E-03	-12.13E-03	-3.338E-03	-3.338E-03
-10.000	-10.020	-19.53E-03	-19.53E-03	000000	-10.022	-21.89E-03	-21.89E-03	-2.357E-03	-2.357E-03
-5.623	-5.628	-5.259E-03	-5.259E-03	000000	-5.630	-6.758E-03	-6.758E-03	-1.499E-03	-1.499E-03
-3.162	-3.181	-19.45E-03	-19.45E-03	000000	-3.182	-20.46E-03	-20.46E-03	-1.011E-03	-1.011E-03
-1.778	-1.787	-9.420E-03	-9.420E-03	000000	-1.788	-10.20E-03	-10.20E-03	-779.4E-06	-779.4E-06
-1.000	-1.015	-15.28E-03	-15.28E-03	000000	-1.016	-15.85E-03	-15.85E-03	-575.5E-06	-575.5E-06
-562.3E-03	-569.1E-03	-6.837E-03	-6.837E-03	000000	-569.7E-03	-7.435E-03	-7.435E-03	-597.3E-06	-597.3E-06
-316.2E-03	-322.5E-03	-6.288E-03	-6.288E-03	000000	-323.0E-03	-6.801E-03	-6.801E-03	-513.3E-06	-513.3E-06
-177.8E-03	-185.6E-03	-7.808E-03	-7.808E-03	000000	-186.2E-03	-8.379E-03	-8.379E-03	-571.0E-06	-571.0E-06
-100.0E-03	-105.7E-03	-5.738E-03	-5.738E-03	000000	-105.9E-03	-5.916E-03	-5.916E-03	-177.4E-06	-177.4E-06
-56.23E-03	-64.63E-03	-8.403E-03	-8.403E-03	000000	-65.43E-03	-9.200E-03	-9.200E-03	-797.0E-06	-797.0E-06
-31.62E-03	-42.56E-03	-10.94E-03	-10.94E-03	000000	-43.13E-03	-11.51E-03	-11.51E-03	-564.1E-06	-564.1E-06

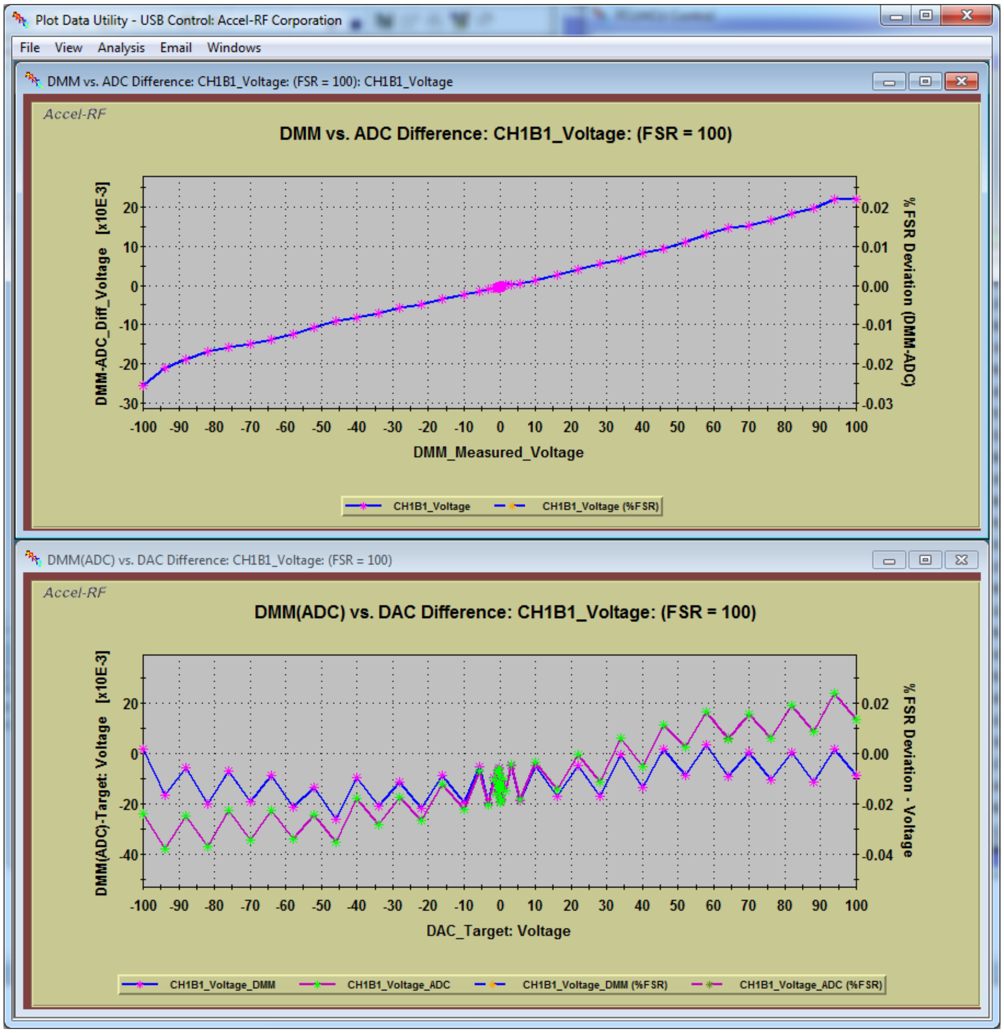
The top plot contains the ADC Measurement Accuracy (as compared to the external reference DMM). The horizontal axis is the external DMM values. The primary vertical axis is the difference between internal and external measurements in real magnitude. The secondary axis presents the deviation in percentage of FSR.

The bottom plot presents the DAC Settability Accuracy. The horizontal axis contains the programmed target. There are two primary plots, one for ADC measurements and one for external DMM measurements. The two secondary plots provide the value as a percentage of FSR.

It should be noted that, while it is nice to have close settability values, the LifeTest program will use its internal iteration controls to drive the supply to that required to yield the use-defined targets. For instance, if there is a large current in the device (e.g. Bias1 drain current = 1A), there will be an I*R voltage drop between the supply and the load. The LifeTest program will iterate the supply up by whatever value is required to overcome that drop. Hence, it is the measurement accuracy that is more important.

Where the settability accuracy comes into play is the value of compliance defined. There is no iteration process in the LifeTest program that accommodates compliance levels – they are whatever the calibration accuracy determines. In practice, the operator should be giving some headroom such that the supply does not hit compliance under normal device degradation operation. Hence, this accuracy is less critical.

Figure 3-4: Voltage Measurement Results (Plotted)



3.2 Verify Current Settings and Measurements

Set the measurement system to Current Mode (Figure 2-7) and click on “Run Sweep”. The first time a “Current” type measurement is performed message boxes similar to Figure 2-8 are presented to configure the current meter. Enter the appropriate values for DMM type, GPIB Card, and GPIB Address of the measurement device (Note: the default address for external DMMs is typically 23, but the internal AARTS DMM is typically set to 28).

An informational box similar to Figure 3-5 reminds the operator what mode to set up. Click OK to Continue.

Figure 3-5: Current Characterization Informational Box

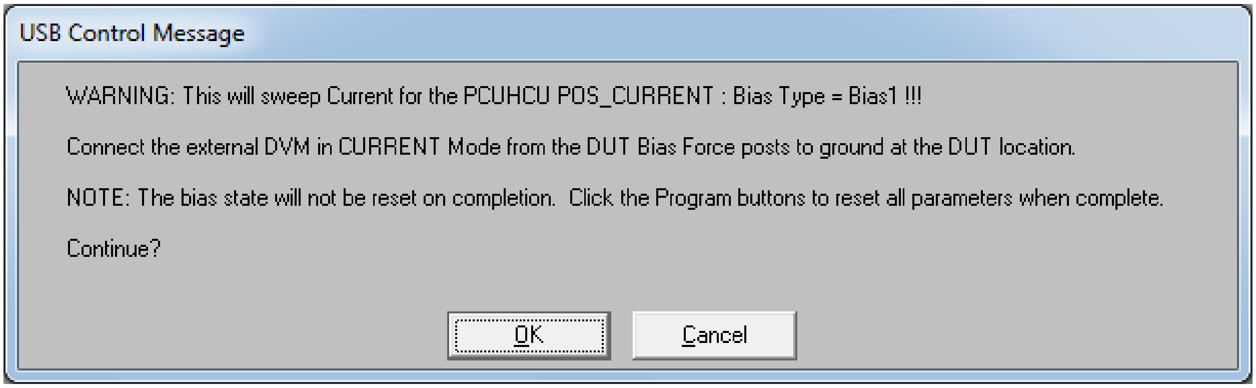
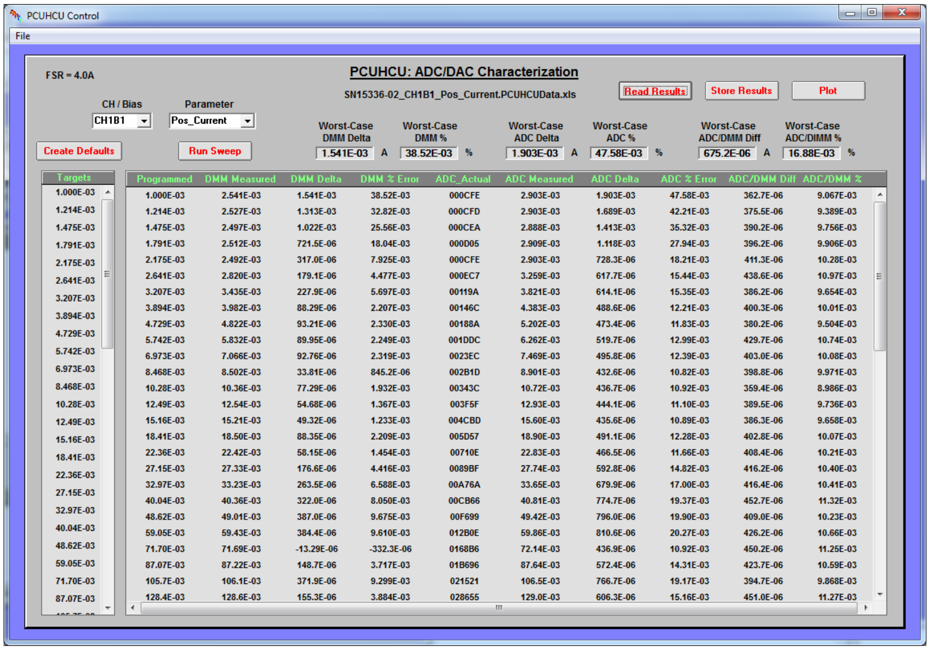
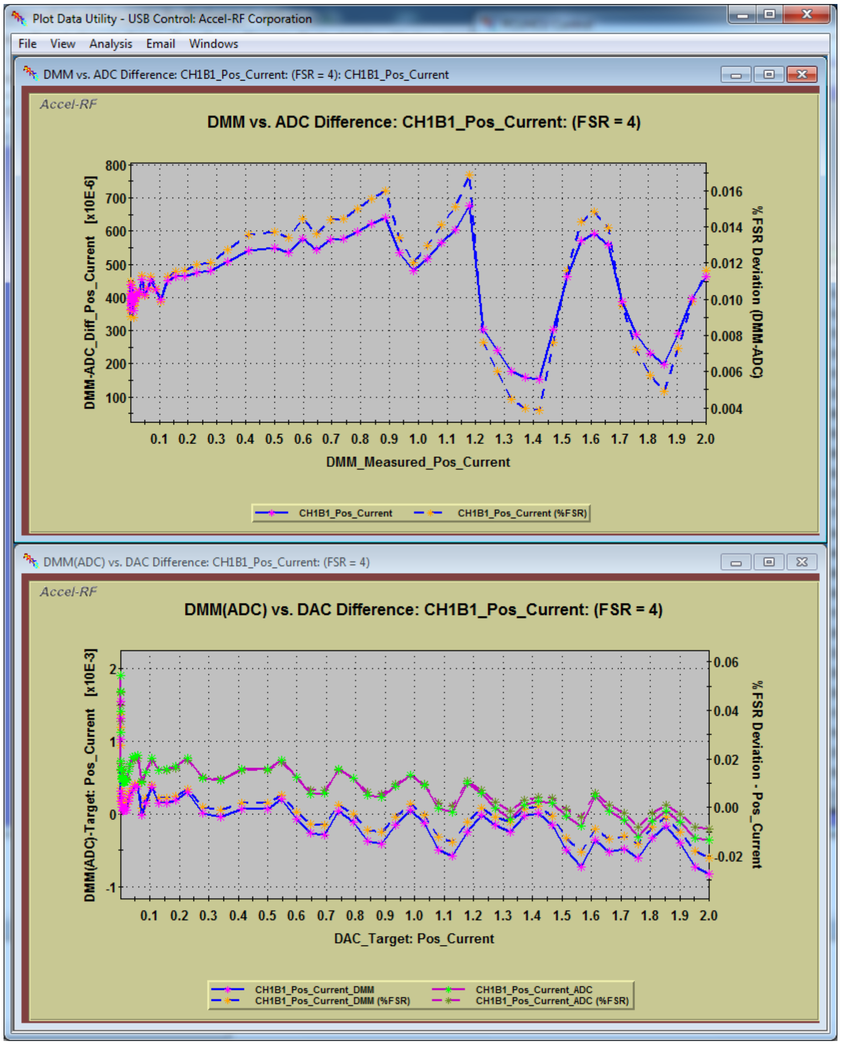


Figure 3-6: Current Measurement Results



The results are populated in the center list box as the measurements are being made. As with voltage measurements, the results may be plotted by clicking on the Plot command button. Figure 3-7 presents a typical set of measured values.

Figure 3-7: Current Measurement Results (Plotted)



3.3 Storing Results

The measurement results can be stored using the "Store Results" command button. They may also be retrieved by clicking the "Read Results" command. This is useful for future reference.