

## **Introduction**

The ISL6295 is a cost effective, highly accurate IC that measures, stores, and reports all of the critical parameters required for Li-ion battery monitoring with a minimum of external components.

The ISL6295 internal time base and reference voltages are factory trimmed. Applications that only utilize the ISL6295's coulomb counting and current measurement functions may not require calibration at time of PCA manufacture, especially if precision resistors are used at the SR (current sense) and ROSC (oscillator reference) connections.

For best accuracy of current, voltage, and temperature measurements, additional calibration should be performed. This document provides the necessary calibration procedures for the ISL6295 fuel gauge IC.

The parameters requiring calibration include: charge and discharge current measurement, pack voltage measurement, GPAD voltage measurement, and internal and external temperature measurements.

The calibration procedures are based on an evaluation platform hardware and software, provided by Intersil. The calibration procedures can be combined with the manufacturer's final test procedure to minimize the manufacturing time. The required measurement instruments for the calibration are specified in this document.

## **Calibration Overview**

### **Charge/Discharge Current Calibration**

The SR pin input voltage measurement has been calibrated by Intersil at the time the ISL6295 is manufactured. However due to the tolerance of the battery pack's sensor resistor, a calibration for the charge/discharge current measurement is recommended.

PCB-level calibration of the ISL6295 current measurement function allows the use of low-cost current sense resistors with lower tolerance, without sacrificing measurement accuracy.

A two-point calibration procedure is used to determine the gain and offset error of current measurement. These gain and offset constants are saved to ISL6295 EEPROM, for later retrieval by the application host processor. The host processor applies this gain and offset corrections to the raw ADC results.

### **VP and GPAD Voltage Calibration**

The VP pin and GPAD pin voltage measurements are not calibrated by Intersil at the time the ISL6295 is manufactured. For accurate voltage measurement, calibration of these ADC channels is recommended.

A two-point calibration procedure is used to determine the gain and offset error for both VP and GPAD voltage measurements. These gain and offset constants are saved to EEPROM for later retrieval by the host processor. The host processor applies these gain and offset corrections to the raw ADC results.

### **Internal Temperature Sensor Calibration**

The ISL6295 features an on-chip silicon diode for internal temperature sensing. A Delta-Sigma A/D with a user selectable resolution up to 16-bits is provided for an accurate temperature measurement.

Due to the discrepancy between the actual device temperature measurement and the ideal model, Intersil uses a linear curve fitting method to determine the coefficients of the linear equation as shown on the ISL6295 datasheet. Using this equation, the die temperature can be calculated. The accuracy of the temperature measurement, however, is still not optimized due to the fact that each device may have unique values that may affect the offset term in the model. Therefore, a 1-point offset calibration, usually at expected nominal battery pack temperature, is described. This offset constant is saved to EEPROM for later retrieval by the host processor.

After the 1-point calibration, the on-chip temperature measurement accuracy is within  $\pm 3^{\circ}\text{C}$  over an operating range of  $-20^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

### **External Temperature Sensor Calibration**

The ISL6295 includes an external temperature sensor interface function, which is a temperature independent, 12.5 $\mu\text{A}$  nominal current source. Due to the variations of this NTC source current, and tolerance of the external NTC, a 1-point calibration at room temperature is required to determine the gain error of the external temperature measurement circuit. This gain correction constant is saved to EEPROM for later retrieval by the host processor.

If an external NTC is not used, calibration of this function need not be performed.

### Requirements

The calibration software is provided on CDROM, and can be installed on any PC meeting the following minimum requirements:

- Intel Pentium class processor, 133MHz or higher
- Minimum of 128MB of RAM
- Minimum of 20MB of free hard disk space
- Video Display 1024 x 768, 256 colors, or better
- Windows 98SE, NT, 2000, or XP operating system

The ISL6295 calibration software requires the following test & measurement equipment and software:

- Keithley 2400 Source Meter
- Agilent 6632B or 66332B DC Power Supply
- Agilent 34970A Data Acquisition Switch Unit, with 34901A 20 Channel Multiplexer module
- Type J Thermocouple
- DeVaSys USBI2CIO interface (provided with the ISL6295EVAL1 kit)
- GPIB interface
- NI-VISA Software

IMPORTANT: Due to licensing restrictions, the NI-VISA software is not provided by Intersil. If you have previously purchased National Instruments software (e.g. Measurement Studio or Labview) or hardware (e.g. NI GPIB interface), the NI-VISA software may have been included. Otherwise, the NI-VISA software can be purchased directly from National Instruments. For further information about NI-VISA licensing, please visit the following web page:

<http://ni.com/visa/license.htm>

### Software Installation

#### Software Setup – BatteryBench

1. Insert the BatteryBench CD into the host PC CDROM or DVD drive
2. If you have disabled the CD Autoplay feature, you can run the setup program manually by selecting the Start menu, choosing Run, and typing D:\setup.exe (replace D with whatever is appropriate for your CD-ROM configuration)
3. Follow the on-screen instructions to complete the installation

#### Software Setup – DeVaSys USB-I2C/IO Drivers

1. Plug the USB-I2C/IO board into your computer, using the (provided) USB cable.
2. Your computer should detect the new hardware and prompt you for the location of the device driver.
3. Direct the installation dialogs to look in the CDROM for the device driver.
4. The new hardware wizard should complete without errors and as a result both the RED and GREEN LEDs on the USB-I2C/IO board should light.

## Hardware Setup

The diagram below shows test & measurement equipment connections required for module calibration. In a production environment, the connections to battery module would normally be made using a “bed-of-nails” type test fixture.

With equipment connected as shown, the safety circuit is effectively bypassed. This is often necessary because many safety circuits will power-up in a discharge-disabled mode, which will interfere with the calibration process.

If the GPAD input is not used, there is no need to connect test equipment to this circuit node.

The Agilent 34901A 20-Channel Mux module must be inserted into topmost slot (marked “100”) of the Agilent 34970A Data Acq Unit. This will map the 20 physical mux channels to logical channel numbers 101 through 120.

Voltage at VP and GPAD is measured by logical channel 101 of the Agilent 34970A, so connect these leads to the 34901A terminal block marked “CH01”. For best accuracy, the leads between the 34907A and battery module should be separate from the leads that connect the battery module to the DC power supply.

Temperature is measured by a J-Type thermocouple at logical channel 120 of the 34970A, so connect the thermocouple to the 34901A terminal block marked “CH20”. The ANSI standard color code for a J-Type thermocouple is +RED, -WHITE.

The thermocouple should be positioned close to the ISL6295 device and/or thermistor for best calibration accuracy.

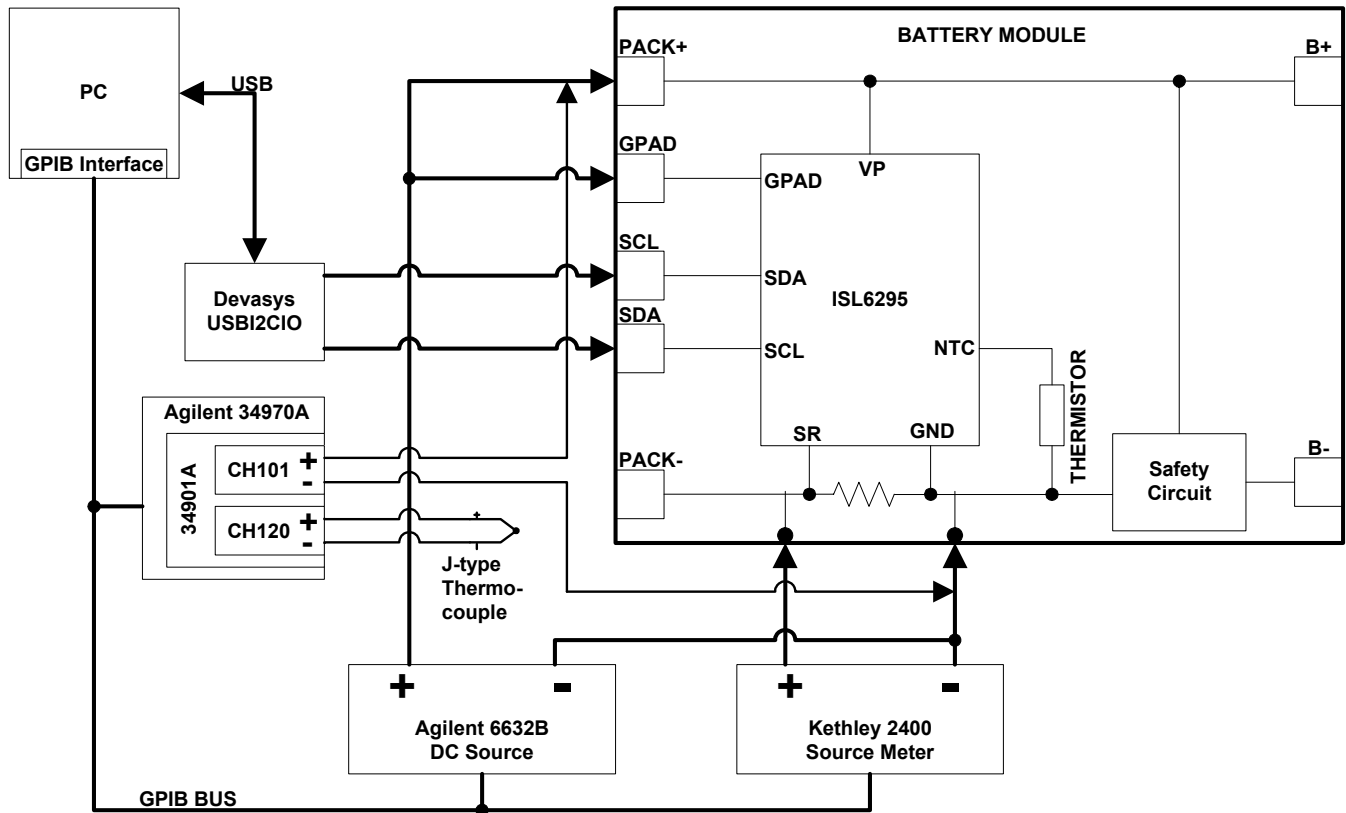


FIGURE 1. ISL6295 CALIBRATION SETUP

## Calibration Procedure: Internal Temperature Sensor

The block diagram in Figure 1 shows the equipment connections for internal temperature sensor calibration. To minimize the heating effect of the IC and the surrounding circuit to the temperature measurement, the internal and/or external temperature sensor calibration should be performed first.

The automated calibration software will first apply operating power to the module by commanding the Agilent 6632B to output 4V with a 100mA current limit.

A brief pause (~0.5s) is then provided to allow the ISL6295 to complete the POR sequence that will occur if device was previously un-powered. Then the A/D Config Register, and the eight A/D Control Registers are configured.

The value 0x80 is written to the A/D Config Register (RAM bank 1, address 0x43). This enables A/D conversions, and selects Run Mode (continuous conversions).

The value 0xD9 is written to the ITctrl Register (RAM bank 1, address 0x46). This enables the internal temperature measurement A/D channel, selects the single-ended (340mV) reference, and selects 13-bit A/D resolution. This resolution setting provides a good balance of calibration accuracy versus calibration time. If a different A/D resolution setting is desired, this can easily be changed. Each additional bit of A/D resolution will double the A/D conversion time, and increase time required for module calibration.

All other analog measurement channels are then disabled by clearing the Enable bit in the corresponding A/D Control Registers.

After a brief pause (~3s) to allow for A/D conversion time, the ITres register is read. This value is converted to °C, using the following formula:

$$\text{InternalTemp} = \frac{\text{ITres} - 22761}{76.3} (^{\circ}\text{C})$$

Note that the ITres value is left-justified. With 13-bit resolution selected, the least significant 2 bits in ITres register are undefined. The automated calibration software will zero these bits before applying the above formula.

Also note that the ISL6295 ADres values are stored in SIGN + MAGNITUDE format. Before using the results from an A/D conversion, the raw ADres value is converted to two's compliment form. Please see Appendix B in this document for more information about this topic.

Actual temperature is then determined by commanding the Agilent 34970A to measure the J-Type thermocouple connected to logical channel 120.

Internal Temperature Offset can now be calculated:

$$\text{IntTempOffset} = \text{ActualTemp} - \text{InternalTemp}$$

The result of this calculation is formatted as a signed byte, and then written to EEPROM bank 0 address 0x9B.

## Calibration Procedure: External Temperature Sensor

The block diagram in Figure 1 shows the equipment connections for external temperature sensor calibration. To minimize the heating effect of the IC and the surrounding circuit to the temperature measurement, the internal and/or external temperature sensor calibration should be performed first.

The primary source of External Temperature measurement error is the variations in the NTC source current. The calibration technique employed here determines the actual NTC source current, then calculates and stores a value that can later be used to convert NTC pin voltage into units of resistance. When thermistor resistance is known, the temperature can be determined using a simple table-lookup-with-linear-interpolation algorithm.

Accurate measurement of temperature using a thermistor connected to the NTC pin requires a pre-defined temperature versus resistance lookup table. At startup, the BatteryBench software reads the NTCLUT.DEF file to populate this lookup table. Please refer to Appendix A in this document for a description of the NTCLUT.DEF file format.

The automated calibration software will first apply operating power to the module by commanding the Agilent 6632B to output 4V with a 100mA current limit.

A brief pause (~0.5s) is then provided to allow the ISL6295 to complete the POR sequence that will occur if device was previously un-powered. Then the A/D Config Register, and the eight A/D Control Registers are configured.

The value 0x80 is written to the A/D Config Register (RAM bank 1, address 0x43). This enables A/D conversions, and selects Run Mode (continuous conversions).

The value 0xDA is written to the ETctrl Register (RAM bank 1, address 0x4A). This enables the external temperature measurement A/D channel, selects the single-ended (340mV) reference, and selects 13-bit A/D resolution. This resolution setting provides a good balance of calibration accuracy versus calibration time. If a different A/D resolution setting is desired, this can easily be changed. Each additional bit of A/D resolution will double the A/D conversion time, and increase time required for module calibration.

All other analog measurement channels are then disabled by clearing the Enable bit in the corresponding A/D Control Registers.

After a brief pause (~3s) to allow for settling, the ETres register is read. This value can be converted into a voltage using the following formula:

$$V_{\text{NTC}} = 0.34\text{V} \times \left(1 - \frac{\text{ETres}}{32768}\right)$$

Note that the ETres value is left-justified. With 13-bit resolution selected, the least significant 2 bits of the ETres register are undefined. The automated calibration software will zero these bits before applying the above formula.

Also note that the ISL6295 ADres values are stored in SIGN + MAGNITUDE format. Before using the results from an A/D conversion, the raw ADres value is converted to two's complement form. Please see Appendix B in this document for more information about this topic.

Actual temperature is then determined by commanding the Agilent 34970A to measure the J-Type thermocouple connected to logical channel 120.

Since actual temperature is now known, and the NTC thermistor temperature versus resistance curve is known, a table lookup with linear interpolation can be used to approximate the NTC resistance (which we will call:  $R_{NTC}$ ).

Using Ohm's Law, the NTC source current can now be easily calculated:

$$I_{NTC} = \frac{V_{NTC}}{R_{NTC}}$$

Finally, the NTC measurement gain correction constant can be calculated. A value of 10,000 represents unity gain.

$$\text{ExtTempGain} = \frac{12.5\mu\text{A}}{I_{NTC}} \times 10000$$

The result of this calculation is formatted as an unsigned 16-bit word. This value is written to the two bytes in EEPROM bank 0 memory starting at address 0x9D, least significant byte first.

### **Calibration Procedure: Current Measurement**

The block diagram in Figure 1 shows the equipment connections for current measurement calibration.

The primary sources of current measurement error are current sense resistor tolerance, and gain/offset error of the internal sense amplifier. These errors can be quantified using a 2-point calibration procedure.

The automated calibration software will first apply operating power to the module by commanding the Agilent 6632B to output 4V with a 100mA current limit.

A brief pause (~0.5s) is then provided to allow the ISL6295 to complete the POR sequence that will occur if device was previously un-powered. Then the A/D Config Register, and the eight A/D Control Registers are configured.

The value 0x80 is written to the A/D Config Register (RAM bank 1, address 0x43). This enables A/D conversions, and selects Run Mode (continuous conversions).

The value 0xD0 is written to the Ictrl Register (RAM bank 1, address 0x42). This enables the current measurement A/D

channel, selects the differential (170mV) reference, and selects 13-bit A/D resolution. This resolution setting provides a good balance of calibration accuracy versus calibration time. If a different A/D resolution setting is desired, this can easily be changed. Each additional bit of A/D resolution will double the A/D conversion time, and increase time required for module calibration.

All other analog measurement channels are then disabled by clearing the Enable bit in the corresponding A/D Control Registers.

A command is then issued to the Keithley 2400 source meter, instructing it to turn its output off. There will be no current flowing through the current sense resistor.

After a brief pause (~3s) to allow for settling, the Ires register is read multiple times, pausing long enough for an A/D conversion to occur between samples (at 13-bit resolution, one A/D conversion occurs every 1/2 second). The average of these Ires values is then calculated and saved for later use.

The raw Ires value can be converted into ampere units using the following formula:

$$I_{\text{reported}}(\text{A}) = \frac{0.17(\text{V}) \times I_{\text{res}}}{0.020(\Omega) \times 32768}$$

Note that the Ires value is left-justified. With 13-bit resolution selected, the least significant 2 bits of the Ires register are undefined. The automated calibration software will zero these bits before applying the above formula.

Also note that the ISL6295 ADres values are stored in SIGN + MAGNITUDE format. Before using the results from an A/D conversion, the raw ADres value is converted to two's complement form. Please see Appendix B in this document for more information about this topic.

A command is then issued to the Keithley 2400 source meter, instructing it to source exactly 1A current.

After a brief pause (~3s) to allow for settling, the Ires register is again read multiple times, pausing long enough for an A/D conversion to occur between samples. The average of these Ires values is then calculated.

The Keithley 2400 is then queried, to determine the actual current.

Now that the two data points are known (actual & reported current, at 0A and 1A), it is easy to calculate the gain and offset error.

$$\text{CurrentGain} = \frac{I_{\text{actual @ 1A}} - I_{\text{actual @ 0A}}}{I_{\text{reported @ 1A}} - I_{\text{reported @ 0A}}} \times 10000$$

$$\text{CurrentOffset} = I_{\text{actual @ 0A}} - \frac{\text{CurrentGain} \times I_{\text{reported @ 0A}}}{10000}$$

CurrentGain is formatted as an unsigned 16-bit word. This value is written to the two bytes in EEPROM bank 0 memory



starting at address 0x8D, least significant byte first. A value of 10,000 represents unity gain.

CurrentOffset is formatted as a signed byte, and then written to EEPROM bank 0 address 0x8F.

### Calibration Procedure: VP Voltage Measurement

The block diagram in Figure 1 shows the equipment connections for voltage measurement calibration.

The primary source of VP voltage measurement error is due to the tolerance of the internal voltage divider, and the input offset error of the internal buffers. These errors can be determined, and correction constants can be derived using a 2-point calibration procedure.

The automated calibration software will first apply operating power to the module by commanding the Agilent 6632B to output 3V with a 100mA current limit.

A brief pause (~0.5s) is then provided to allow the ISL6295 to complete the POR sequence that will occur if device was previously un-powered. Then the A/D Config Register, and the eight A/D Control Registers are configured.

The value 0x80 is written to the A/D Config Register (RAM bank 1, address 0x43). This enables A/D conversions, and selects Run Mode (continuous conversions).

The value 0xDB is written to the VPctrl Register (RAM bank 1, address 0x4E). This enables the VP voltage measurement A/D channel, selects the single-ended (340mV) reference, and selects 13-bit A/D resolution. This resolution setting provides a good balance of calibration accuracy versus calibration time. If a different A/D resolution setting is desired, this can easily be changed. Each additional bit of A/D resolution will double the A/D conversion time, and increase time required for module calibration.

All other analog measurement channels are then disabled by clearing the Enable bit in the corresponding A/D Control Registers.

After a brief pause (~3s) to allow for settling, the VPres register is read multiple times, pausing long enough for an A/D conversion to occur between samples (at 13-bit resolution, one A/D conversion occurs every 1/2 second). The average of these VPres values is then calculated and saved for later use.

The raw VPres value can be converted into voltage units using the following formula:

$$V_{\text{reported}}(V) = \frac{10.2(V) \times V_{\text{Pres}}}{32768}$$

Note that the VPres value is left-justified. With 13-bit resolution selected, the least significant 2 bits of the VPres

register are undefined. The automated calibration software will zero these bits before applying the above formula.

Also note that the ISL6295 ADres values are stored in SIGN + MAGNITUDE format. Before using the results from an A/D conversion, the raw ADres value is converted to two's complement form. Please see Appendix B in this document for more information about this topic.

A command is then issued to the Agilent 6632B DC Power Supply, instructing it to increase output voltage to 4V with 100mA current limit.

After a brief pause (~3s) to allow for settling, the VPres register is again read multiple times, pausing long enough for an A/D conversion to occur between samples. The average of these VPres values is then calculated.

Actual VP voltage is again measured by commanding the Agilent 34970A to measure the voltage at logical channel 101. This value is saved for later use.

Now that the two data points are known (actual & reported VP voltage, at 3V and 4V), it is easy to calculate the gain and offset error.

$$VPGain = \frac{V_{\text{actual @ 4V}} - V_{\text{actual @ 3V}}}{V_{\text{reported @ 4V}} - V_{\text{reported @ 3V}}} \times 10000$$

$$VPOffset = V_{\text{actual @ 3V}} - \frac{VPGain \times V_{\text{reported @ 3V}}}{10000}$$

VPGain is formatted as an unsigned 16-bit word. This value is written to the two bytes in EEPROM bank 0 memory starting at address 0x90, least significant byte first. A value of 10,000 represents unity gain.

VPOffset is formatted as a signed byte, and then written to EEPROM bank 0 address 0x96.

### Calibration Procedure: GPAD Voltage Measurement

The block diagram in Figure 1 shows the equipment connections for voltage measurement calibration.

The primary source of GPAD voltage measurement error is due to the tolerance of the internal voltage divider, and the input offset error of the internal buffers. These errors can be determined, and correction constants can be derived using a 2-point calibration procedure.

The automated calibration software will first apply operating power to the module by commanding the Agilent 6632B to output 3V with a 100mA current limit.

A brief pause (~0.5s) is then provided to allow the ISL6295 to complete the POR sequence that will occur if device was previously un-powered. Then the A/D Config Register, and the eight A/D Control Registers are configured.

The value 0x80 is written to the A/D Config Register (RAM bank 1, address 0x43). This enables A/D conversions, and selects Run Mode (continuous conversions).

The value 0xDD is written to the GPADctrl Register (RAM bank 1, address 0x56). This enables the GPAD voltage measurement A/D channel, selects the single-ended (340mV) reference, and selects 13-bit A/D resolution. This resolution setting provides a good balance of calibration accuracy versus calibration time. If a different A/D resolution setting is desired, this can easily be changed. Each additional bit of A/D resolution will double the A/D conversion time, and increase the time required for module calibration.

All other analog measurement channels are then disabled by clearing the Enable bit in the corresponding A/D Control Registers.

After a brief pause (~3s) to allow for settling, the GPADres register is read multiple times, pausing long enough for an A/D conversion to occur between samples (at 13-bit resolution, one A/D conversion occurs every ½ second). The average of these GPADres values is then calculated and saved for later use.

The raw GPADres value can be converted into voltage units using the following formula:

$$V_{\text{reported}}(V) = \frac{6.2(V) \times \text{GPADres}}{32768}$$

Note that the GPADres value is left-justified. With 13-bit resolution selected, the least significant 2 bits of the GPADres register are undefined. The automated calibration software will zero these bits before applying the above formula.

Also note that the ISL6295 ADres values are stored in SIGN + MAGNITUDE format. Before using the results from an A/D conversion, the raw ADres value is converted to two's complement form. Please see Appendix B in this document for more information about this topic.

Actual GPAD voltage is then determined by commanding the Agilent 34970A to measure the voltage at logical channel 101. This value is saved for later use.

A command is then issued to the Agilent 6632B DC Power Supply, instructing it to increase output voltage to 4V with a 100mA current limit.

After a brief pause (~3s) to allow for settling, the GPADres register is again read multiple times, pausing long enough for an A/D conversion to occur between samples. The average of these GPADres values is then calculated.

Actual GPAD voltage is again measured by commanding the Agilent 34970A to measure the voltage at logical channel 101. This value is saved for later use.

Now that the two data points are known (actual & reported GPAD voltage, at 3V and 4V), it is easy to calculate the gain and offset error.

$$\text{GPADGain} = \frac{V_{\text{actual @ 4V}} - V_{\text{actual @ 3V}}}{V_{\text{reported @ 4V}} - V_{\text{reported @ 3V}}} \times 10000$$

$$\text{GPADOffset} = V_{\text{actual @ 3V}} - \frac{\text{GPADGain} \times V_{\text{reported @ 3V}}}{10000}$$

GPADGain is formatted as an unsigned 16-bit word. This value is written to the two bytes in EEPROM bank 0 memory starting at address 0x94, least significant byte first. A value of 10,000 represents unity gain.

GPADOffset is formatted as a signed byte, and then written to EEPROM bank 0 address 0x98.

### Time Count Test

Figure 2 shows the BatteryBench Calibration window. On the right-hand side of this window is a section called "Time Count Test".

The Time Count Test function is provided as a means to easily verify accuracy of the time base calibration that was performed at time of IC manufacture.

Due to the length of time required by this test, which is typically 5 minutes or more, it will not be included in the normal battery module production test.

Performing this Time Count Test is very easy. Enter the desired test duration in seconds, and then click the associated "GO" button. Please wait until such time that this test has completed before using the other functions of the BatteryBench software.

#### The Time Count Test Works as Follows:

First, the value 0x80 is written to the A/D Config Register (RAM bank 1, address 0x43). This enables A/D conversions, and selects Run Mode (continuous conversions).

Then the value 0x80 is written to the ACCclr register (RAM bank 1, address 0x62). This will clear the GPADT accumulator.

Next, the value 0x90 is written to the ACCctrl register (RAM bank 1, address 0x63). This enables GPAD voltage & time accumulation.

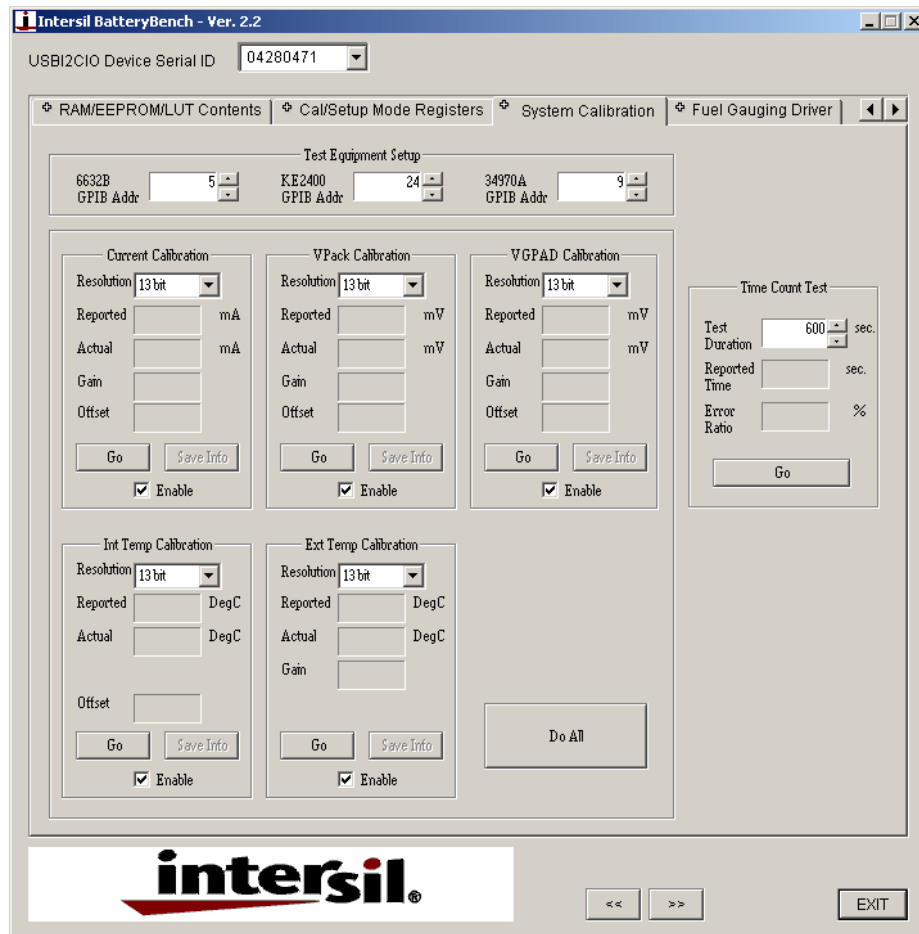


FIGURE 2. BATTERYBENCH CALIBRATION SCREEN

After pausing an amount of time specified in the on-screen “Test Duration” edit box, the GPADT register is read (RAM bank 0, address 0x3C). Since the GPADT register increments once every 500ms when GPAD voltage & time accumulation is enabled, we can easily determine the internal time base error.

$$\text{ReportedTime} = \text{GPADT} \times 0.5(\text{s})$$

$$\text{ErrorRatio} = 100\% \times \left(1 - \frac{\text{ReportedTime}}{\text{TestDuration}}\right)$$

Since the GPADT resolution is 0.5s per bit, and it is not possible to synchronize the start of this test with the ISL6295 internal time base, there can be up to 0.5s of error in the reported time. It is suggested that test duration is sufficiently long to minimize this source of error. The default test duration setting is 600s, which will reduce this error to less than 0.08%.

The Time Count Test results are for verification purposes only. No data is saved to ISL6295 EEPROM upon completion of this test.

### Test Equipment Setup

The default GPIB addressed for the three devices (Agilent 6632B, Agilent 34970A, and Keithley 2400) are automatically set to the default factory settings when BatteryBench is launched.

If actual GPIB address setting does not match these defaults, the user should make changes as necessary, before attempting module calibration. The program will display a message when communication with the test equipment is unsuccessful.

### “Ala-Carte” Calibration

If desired, the user can calibrate one A/D channel at a time, by clicking on the “GO” button associated with that A/D channel.

When calibration is performed in this manner, the gain and/or offset values are not automatically saved to ISL6295 EEPROM. The user should click the “Save Info” button once calibration has completed to save these values to ISL6295 EEPROM.

*Intersil Corporation reserves the right to make changes in circuit design, software and/or specifications at any time without notice. Accordingly, the reader is cautioned to verify that the Application Note or Technical Brief is current before proceeding.*



## Automated Calibration

Clicking the “Do All” button will start the automated calibration sequence. The following A/D channels are calibrated, in the order specified below:

1. Internal Temperature
2. External Temperature
3. Current
4. VP
5. GPAD

To exclude any of these A/D channels from the automated calibration sequence, the associated “Enable” checkbox should be un-checked.

During the automated calibration sequence, the gain & offset values are automatically saved to ISL6295 EEPROM. This will overwrite the previous contents of the EEPROM locations.

The automated calibration sequence cannot be stopped once started. The user should refrain from using other BatteryBench features during this time.

## Appendix A NTC Look-up Table

The NTC look-up table is stored in text format, in file named NTCLUT.DEF, which must be located in the same directory as the ISL6295.EXE program file.

Each line of text in the NTCLUT.DEF file corresponds to the resistance in kΩ of the thermistor at a specific temperature.

Ten NTC resistances must be specified, each on a separate line of text, and each line specifying resistance in kohm units. The first entry specifies NTC resistance at -20°C. The second line specifies NTC resistance at -10°C. This pattern continues, each line specifying a thermistor resistance in kΩ at a temperature 10°C greater than the previous line. The tenth and final line specifies NTC resistance at 70°C.

An example NTCLUT.DEF file is installed with the BatteryBench software. The values in this file correspond to the temperature-versus-resistance curve of a Semitec 103AT thermistor, and are as follows:

67.77
42.47
27.28
17.96
12.09
8.313
5.827
4.160
3.020
2.228

If a different style of thermistor is used, or if a paralleled resistor is used to extend the low-temperature measurement range, then the NTCLUT.DEF file should be modified with

appropriate resistance values to provide accurate External Temperature measurement results.

For instance, with a 24.9k resistor in parallel with a Semitec 103AT thermistor, the NTCLUT.DEF file would contain the following lines of text:

18.20
15.69
13.01
10.43
8.138
6.232
4.722
3.564
2.693
2.045

## Appendix B SIGN-MAGNITUDE Format

The ISL6295 stores the A/D results using sign-magnitude format.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Sign	Absolute Value of Number (Magnitude)														

The maximum positive value that can be represented in sign-magnitude format is 0x7FFF, which is equal to decimal 32767.

The value zero can be represented in two ways using sign-magnitude format: 0x0000 and 0x8000.

The maximum negative value that can be represented in sign-magnitude format is 0xFFFF, which is equal to decimal -32767.

Most computers and programming languages do not understand sign-magnitude representation of signed numbers, and will provide erroneous results when attempting mathematical operations on negative numbers stored in this format.

Therefore, it is necessary to convert the A/D results to the standard two’s complement representation before any mathematical operation is performed. The following C function provides this conversion:

```
short signMagToShort (unsigned short val) {
    if (val & 0x8000)
        return (-1 * (short)(val & 0x7FFF));
    else
        return (short)val;
}
```

For further reading about signed number representations in binary computers:

[http://en.wikipedia.org/wiki/Signed\\_number\\_representations](http://en.wikipedia.org/wiki/Signed_number_representations)