Battery Characterization Process

Application Note

Qualcomm Technologies, Inc.
80-VT310-24 Rev. A

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Revision History

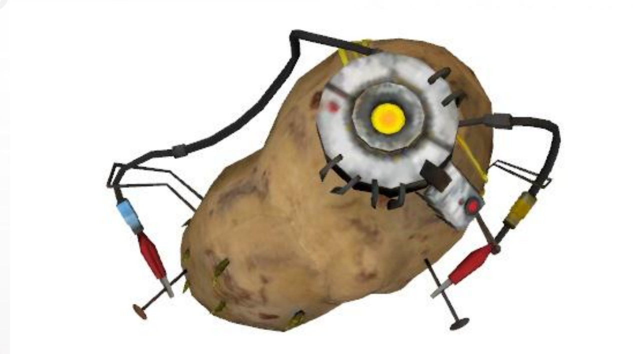
Revision	Date	Description
A	January 2013	Initial release

Contents

Introduction

Introduction

The purpose of this document is to provide a complete walkthrough on setting up a battery characterization station, and using the Qualcomm Technologies, Inc. (QTI) QSPR tool to characterize and generate a battery profile.



Supported Chambers and Analyzers

Supported Chambers and Analyzers

Temperature chambers	Battery analyzers
TEST EQUITY MODEL 107	Keithley 2306, 2308
CSZ SERIES DEMENSIONII CONTROLLER	Agilent N6705B
TENNEY 942 SERIES CONTROLLER	
SIGMA C3_C5 CONTROLLER	
TE115 F4 CONTROLLER	
ESPEC	
TPO4300	
Cincinnati Sub-Zero SERIES F4 CONTROLLER	
THERMOTRON3X00	

List of Required and Recommended Equipment

List of Required and Recommended Equipment

Equipment type	QTI's recommendation
Computer	Any PC capable of running the necessary software for characterization
Temperature chamber	Test Equity Model 107 bench top temperature chamber
GPIB interface	ICS Model 4899A GPIB interface
Battery analyzer	Keithley 2306 – dual-channel battery simulator
GPIB to USB controller	National Instruments GPIB-USB-HS GPIB controller
GPIB to serial cable	ICS
GPIB to GPIB cable	ICS
Custom power supply cable	Slide 11
Custom battery connector	Slide 12

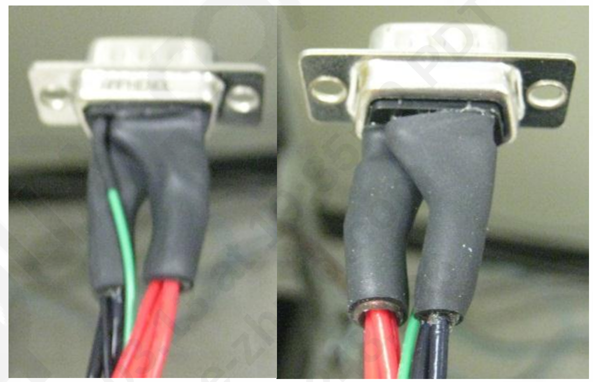
Note: QTI's recommendation column lists the equipment used by Qualcomm®, and was used to create this application note. Choosing our recommended equipment may help in getting started, and debugging any possible problems.

Custom Power Supply Cable

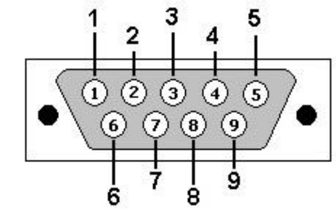
- The following cable design is QTI’s recommended way of connecting the Keithley 2306 to QTI’s custom made battery connector.

  NOTE: If you do not use QTI’s method, make sure to extend the sense lines from the power supply to the end of the cable.

- This male DB9 connector is used to connect to the female DB9 battery connector.



DB9 male pin out



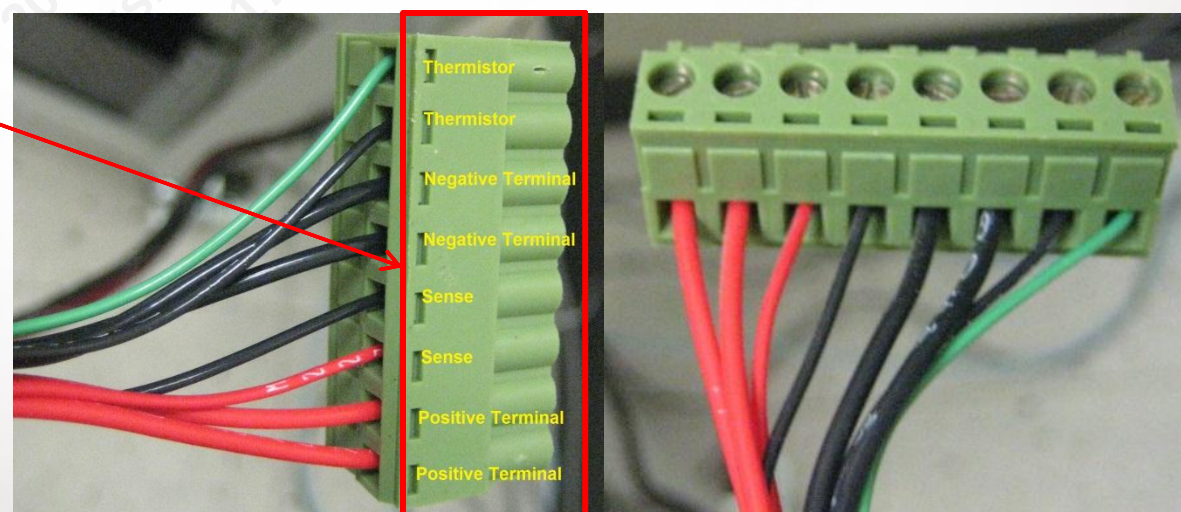
DB9: View looking into male connector

- Attach the positive voltage and sense wires to pins1-4 on the male DB9, the green wire (Thermistor) to pin 5, the additional black wire (Thermistor) to pin 6, and the negative terminals and sense wire to 7-9.

  NOTE: These pin assignments are arbitrary and are based on the connections that will be made on the battery connector.

- This is the Keithley 2306 dongle used to connect to the power supply.

  NOTE: Make sure when inserting the wires into the Keithley’s dongle that contact is made between the screw and the conductor, and not the insulation.

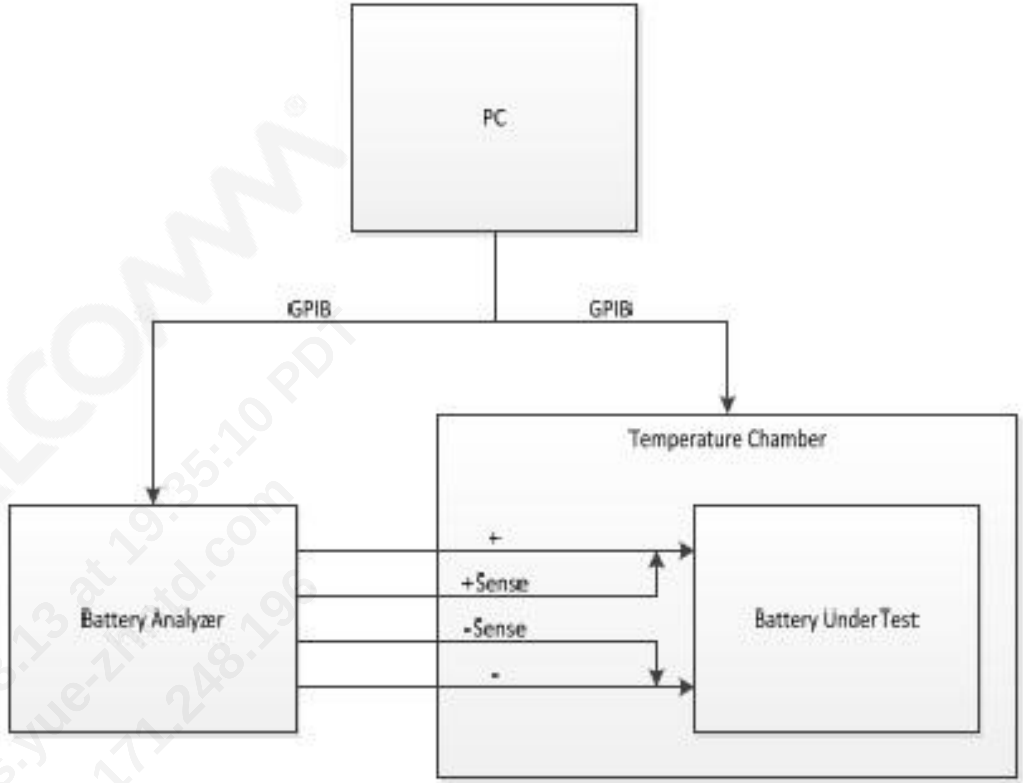


Custom Battery Cord

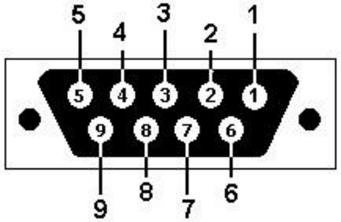
- This is QTI's recommended way of connecting the battery to the power supply cable.
- A female DB9 connector will be needed to connect to the battery's male DB9 connector on the end of the power supply cable.
- The sense wires from the power supply should be connected to the supply wires as close to the battery terminals as possible.
- On the female DB9 connect pins 1-4 to the positive terminal of the battery, and 7-9 to the negative terminal. Pin 5 and 6 should be left floating.
- For the best possible connection solder the wires from the female DB9 connector to the positive and negative terminals of the battery.

NOTE: QTI recommends using the largest diameter that will fit soldering onto the battery terminals.

- Do not connect to any other terminals on the battery such as the Thermistor, or Battery ID.



DB9 female pin out



DB9: View looking into female connector

Configuration

Software Installation

- Install all the necessary equipment drivers.
- The QDART suite is located on the Documents and Downloads webpage at downloads.cdmatech.com
- Windows XP or later is required.
- The install file is located within the Documents and Downloads\Software Tools\QDART Software Code (Tools Suite)\QDART 4805 directory.
- When installing QDART, accept the terms and conditions, select the complete installation, and fill out which equipment will be used and their GPIB addresses. Do not install the Manufacturing Toolkit.

Note: Please refer to the slide 10 for more information on equipment and GPIB port selection.

Configuring Test Equipment for QSPR

- After QDART is installed, locate and open the equipconfig.xml file within your “Qualcomm\QDART\Databases” folder. The default installation path for Windows 7 is “C:\Program Files(x86)\Qualcomm\QDART\Databases”.

- Check the <Equipment Set>. This should include your equipment and pad numbers.

- The list below is commented out. To add/change equipment copy and paste the commented out equipment into the Equipment Set.

- Do not forget to check the pad numbers on all your equipment.

equipconfig.xml - Notepad

File Edit Format View Help


```
<EquipmentSet>



<!-- Comment: Replace above equipment to match your configuration
Default WWAN call box
<Equipment identifier="Signal_Generator4" name="E5515" type="DSG" pad="1"/>
<Equipment identifier="Call_Processor1" name="HP 8960" type="CP" pad="1"/>

<Equipment identifier="Signal_Generator4" name="MT8820" type="DSG" pad="14"  />
<Equipment identifier="Call_Processor1" name="Anritsu MT8820" type="CP" pad="14"  />

<Equipment identifier="Signal_Generator4" name="CMU" type="DSG" pad="26" sad="96" />
<Equipment identifier="Call_Processor1" name="CMU" type="CP" pad="26" sad="96" />

<Equipment identifier="Signal_Generator4" name="CMW" type="DSG" pad="1"  />
<Equipment identifier="Call_Processor1" name="CMW500" type="CP" pad="1"  />

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Default power supply for UUT
<Equipment identifier="Power_Supply1" name="SCPI Power Supply" type="PS" pad="5"/>
<Equipment identifier="Power_Supply1" name="Keithley 2304" type="PS" pad="5"/>
<Equipment identifier="Power_Supply1" name="Philips 2811" type="PS" pad="5"/>

Default GPSOne equipment
<Equipment identifier="GPS_Emulator1" name="GSS4100" type="GPS" pad="2"/>
<Equipment identifier="GPS_Emulator1" name="GSS6100" type="GPS" pad="2"/>
<Equipment identifier="GPS_Emulator1" name="GSS6300" type="GPS" pad="2"/>
<Equipment identifier="Universal_Counter1" name="Agilent 53132A" type="UC" pad="3"/>


Default CW generator for GPS
<Equipment identifier="Signal_Generator1" name="IFR 20XX" type="ASG" pad="5"/>
<Equipment identifier="Signal_Generator1" name="IFR 2026A" type="ASG" pad="5"/>
<Equipment identifier="Signal_Generator1" name="IFR 2026B" type="ASG" pad="5"/>
<Equipment identifier="Signal_Generator1" name="RS SMIQ" type="ASG" pad="5"/>
<Equipment identifier="Signal_Generator1" name="Agilent PSG" type="ASG" pad="5"/>
<Equipment identifier="Signal_Generator1" name="SMA" type="ASG" pad="5"/>

Default Equipment for BMS
<Equipment identifier="Battery_Analyzer1" name="Keithley 2306" type="PS" pad="5"/>
<Equipment identifier="Battery_Analyzer1" name="Agilent N6705B" type="PS" pad="5"/>
Default Temperature Chamber for BMS
<Equipment identifier="Temperature_Chamber1" name="CSZ SERIES F4 CONTROLLER" type="TC" pad="1"/>
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<Equipment identifier="Temperature_Chamber1" name="SIGMA C3_C5 CONTROLLER" type="TC" pad="1"/>
<Equipment identifier="Temperature_Chamber1" name="TE115 F4 CONTROLLER" type="TC" pad="1"/>
<Equipment identifier="Temperature_Chamber1" name="ESPEC" type="TC" pad="1"/>
<Equipment identifier="Temperature_Chamber1" name="TP04300" type="TC" pad="1"/>
<Equipment identifier="Temperature_Chamber1" name="THERMOTRON3X00" type="TC" pad="1"/>
Default Equipment/Jammer for Femto
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<Equipment identifier="Femto_Downlink_Analyzer" name="Anritsu MS2830" type="CP" pad="1"/>
<Equipment identifier="Call_Processor1" name="Anritsu MS2830" type="CP" pad="1"/>
<Equipment identifier="Signal_Generator1" name="Agilent PSG" type="ASG" pad="5"/>
<Equipment identifier="Signal_Generator2" name="RS SMJ" type="DSG" pad="28"/>

End Comment -->
</EquipmentSet>
```
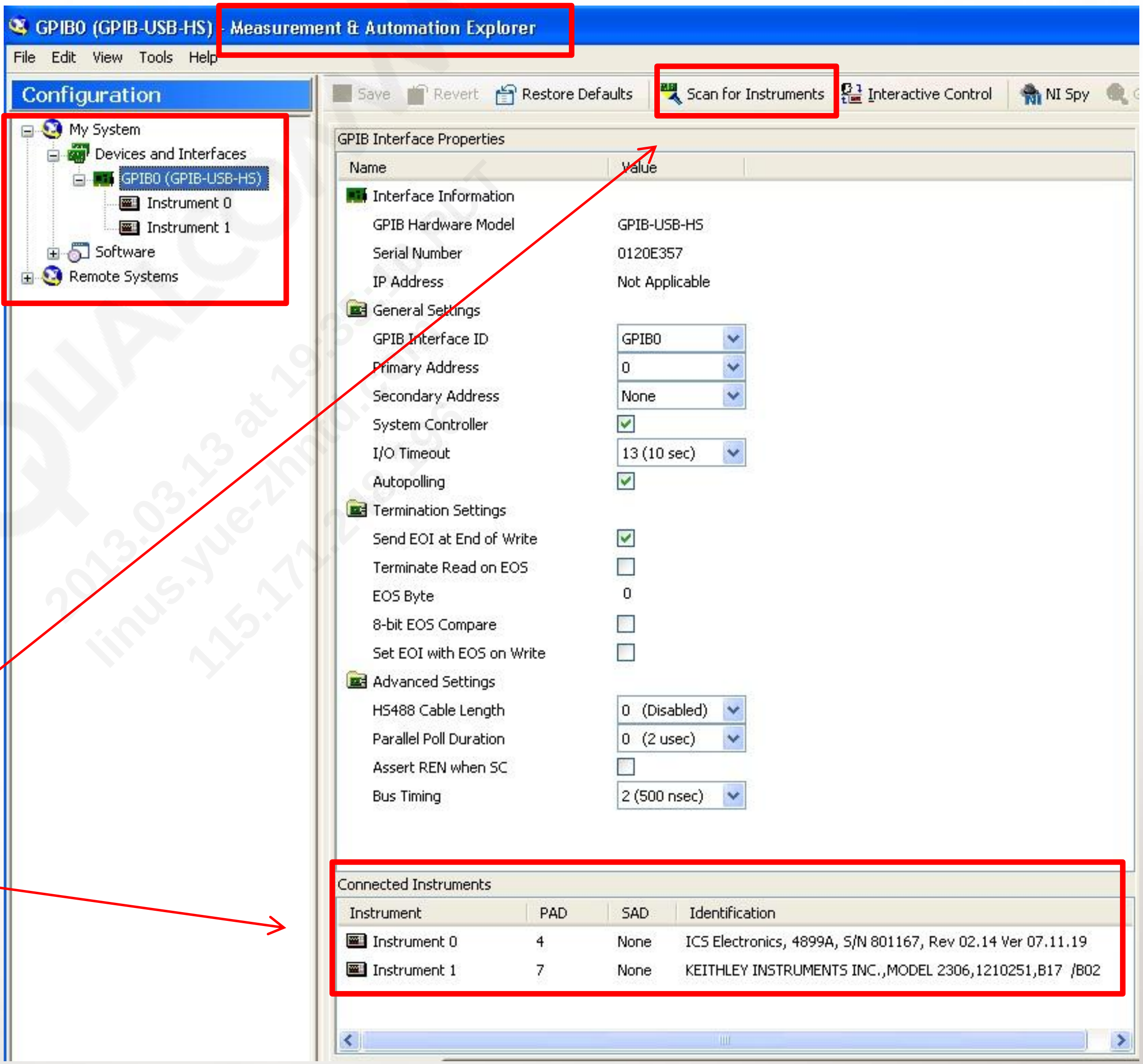

Equipment PADs

- When using the recommended National Instruments GPIB-USB-HS Controller, configuring the pads is easy.
- First, open the Measurement & Automation application. Next, navigate to My System\Devices and Interfaces\GPIB (GPIB-USB-HS).
- Once you reach this screen, use “Scan for Instruments” to find the connected equipment and the corresponding pads.

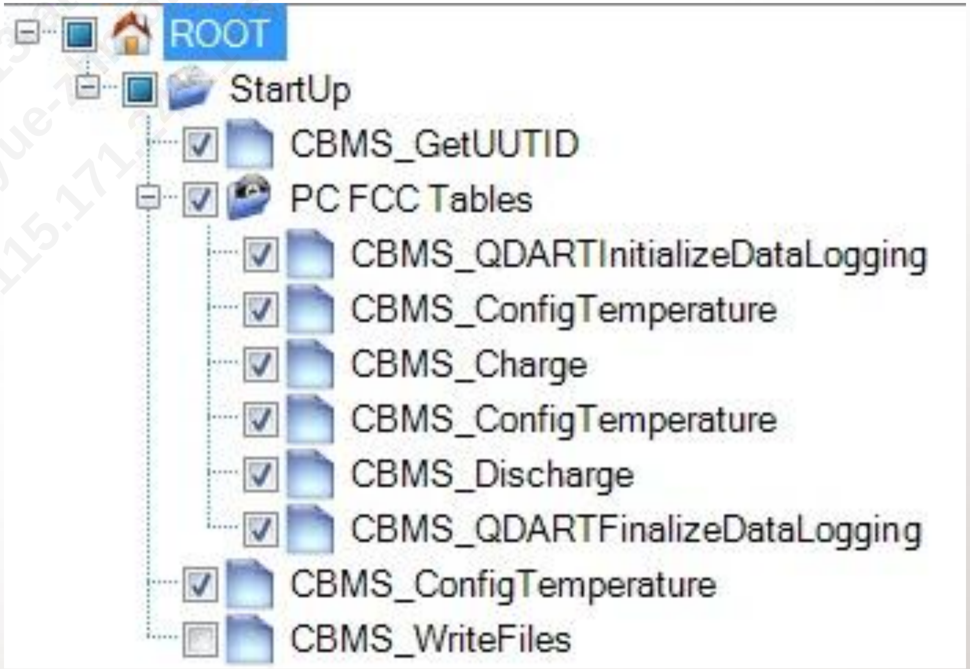


Setting up QSPR

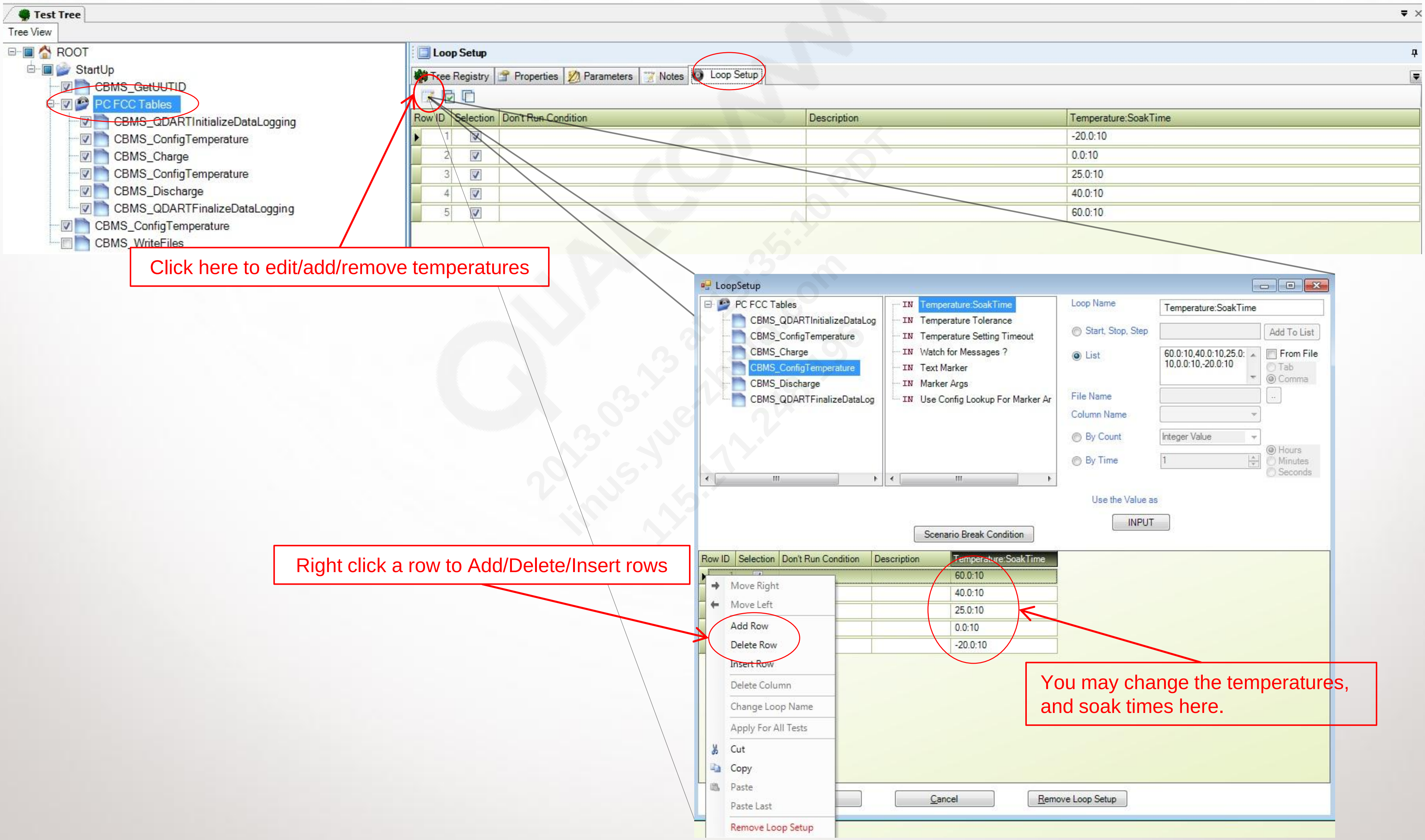
Obtain an example .XTT file for reference.

NOTE: All temperature nodes, CBMS_ConfigTemperature in this case, must be enabled in order for WriteFiles to produce your OCV results. This must be done regardless of manual testing.

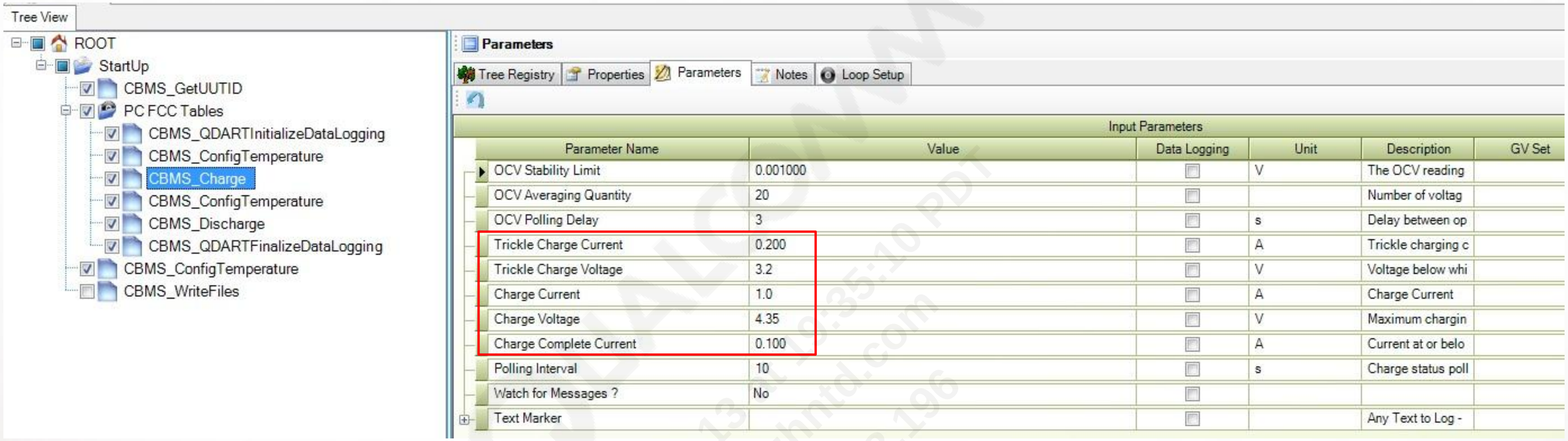
For your battery characterization, the Loop Settings, Charge, and Discharge profiles must be filled out correctly.



Setting up QSPR – Loop Setup



Setting up QSPR – Charge (1 of 3)



- Only five parameter values are required for charging: Trickle Charge Current, Trickle Charge Voltage, Charge Current, Charge Voltage, and Charge Complete Current. Refer to the next slide for definitions on these parameters.

- NOTE: Changing the other parameters on this list is not required nor recommended.

- Refer to the Troubleshooting slides for common issues with charging.

Setting up QSPR – Charge (2 of 3)

- **Trickle Charge Current**
  This parameter is the maximum amount of current in Amps that the battery will be allowed to draw at the start of the test. Only when the voltage is observed to increase above the Trickle Charge Voltage will the current be changed to the value specified by the Charge Current parameter.

  The value that this parameter is set to should be taken from the battery specification.

- **Trickle Charge Voltage**
  This parameter is the threshold below which the Trickle Charge Current will be maintained. Once a voltage measurement is taken that is equal to or exceeds this level, then the current drawn will be allowed to increase to the value specified by the Charge Current parameter.

  The value that this parameter is set to should be taken from the battery specification or should mimic the actual system value.

- **Charge Current**
  Once a battery voltage measurement is taken that exceeds the value specified by the Trickle Charge Voltage parameter, the current drawn by the battery is allowed to increase to the value specified by this parameter.

  The value of this parameter should not exceed the maximum charge current specified in the battery specification or should mimic the actual end system value.

Setting up QSPR – Charge (3 of 3)

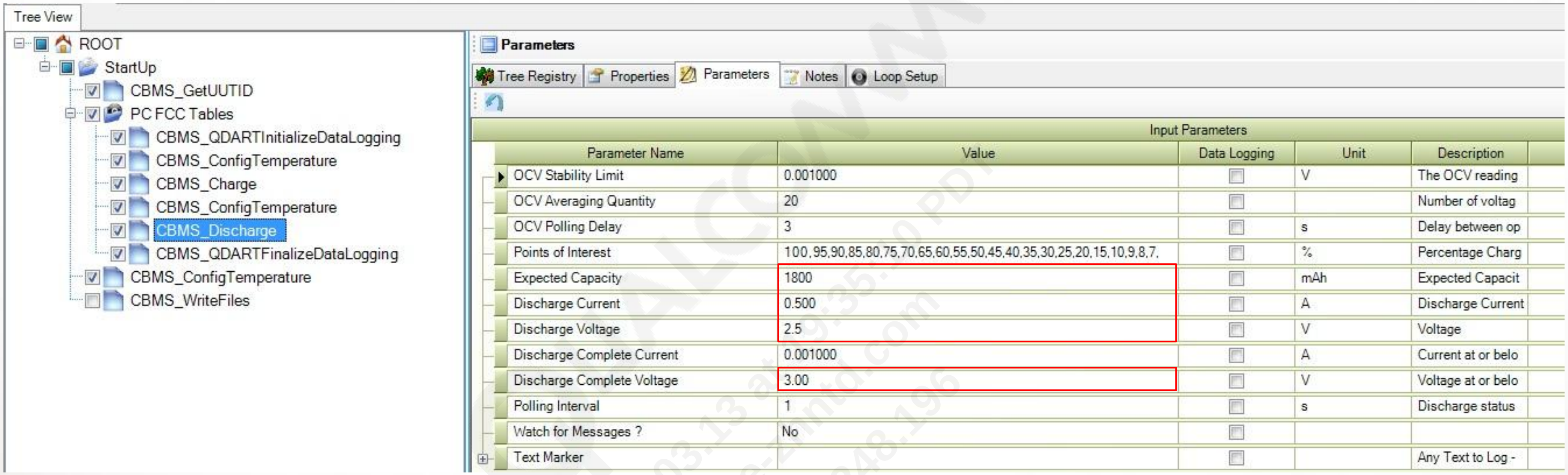
- **Charge Voltage**
  The voltage at the battery will be limited to the voltage specified by this parameter.

  The value that this parameter is set to should be taken from the battery specification and must match the value that will be used by the end system. Using one value for profiling the battery and another in the system use will cause significant errors.

- **Charge Complete Current**
  This parameter determines when the charge cycle is complete. Selection of a value depends on whether the subsequent discharge cycle is to be profiled. If the subsequent discharge cycle is to be profiled, as would always be the case during temperature profiling and would be the case during aging at selected intervals, the value should be the current in Amps at which the charge cycle is deemed complete in the final target design. Using one value for profiling the battery and another in the system use will cause significant errors. If the subsequent discharge cycle is not to be profiled, as would be the case in all but a few selected cycles during aging testing, then setting this value to around 25% of the Charge Current setting will mean that the charge test will completed before the battery is 100% charged, but this can save a considerable amount of test time. Setting this value to 0.25 A will mean that the test completes with the battery at 95% of its full charge capacity, i.e., 5% short of full charge, but the test time will reduce by around 25%. For the purposes of aging the battery ahead of the next aging profile cycle, this is acceptable.

❖ Refer to the *Application Note: Battery Characterization Test Procedure* (80-VA360-12) for more information on the other charging parameters.

Setting up QSPR – Discharge (1 of 3)



- Only four parameters values are required for discharging: Expected Capacity, Discharge Current, Discharge Voltage, and Discharge Complete Voltage. Please refer to the next slide for definitions on these parameters.

  Note: QTI strongly recommends setting the Discharge Complete Voltage to 3.0 V to collect excess data. This allows flexibility in setting the device's shutdown voltage. This does NOT determine the 0% SoC value. The shutdown voltage is set within the board file.

  Note: Changing the other Parameters on this list is not required, nor recommended.

- Refer to the Troubleshooting slides for common issues with discharging.

Setting up QSPR – Discharge (2 of 3)

- **Expected capacity**
  This parameter is the expected FCC of the battery and is used to estimate when the test routine should stop drawing current and take an OCV measurement in order to measure at the specified points of interest. The value that this parameter is set to should be taken from the battery specification. An inaccurate value for this parameter can affect test performance:

  When this parameter is significantly lower than the actual FCC, the estimated points of interest will occur much earlier in the discharge cycle. If the estimated 0% point of interest still yields an OCV above the Discharge Complete Voltage, the discharge will be extended with further OCV measurements taken at a percentage of the expected capacity equal to the difference of the final two percentages in the points of interest list (1% if the recommended points of interest values are used). With more points to analyze, this will increase the accuracy of the final percentage charge profile, particularly for low charge remaining levels, but at the expense of increased test time.

  When this parameter is significantly higher than the actual FCC, the estimated points of interest will occur much later in the discharge cycle. An OCV reading that is below the Discharge Complete Voltage will be taken before many of the estimated points of interest are reached, resulting in fewer points to analyze and thus potentially decreasing the accuracy of the final percentage charge profile, particularly for low charge remaining levels where the rate of change is typically much higher.

Setting up QSPR – Discharge (3 of 3)

- **Discharge current**
  This parameter specifies the current that will be drawn to discharge the battery. It should be set to no more than the rated maximum continuous discharge in the battery specification.

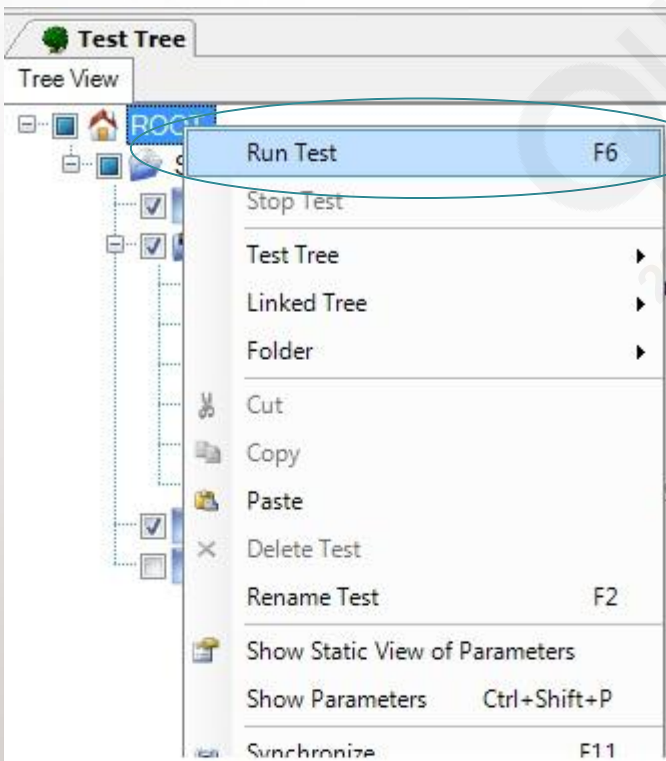
- **Discharge voltage**
  This parameter specifies the voltage that will be set during discharge. It should be set to a value above the battery collapse voltage given in the battery specification. Setting it to a value equal to or below the battery collapse voltage can result in the battery collapsing, which will distort the battery discharge profile results. Setting it too high may result in the test completing because the current drawn falls below the value specified in the Discharge Complete Current parameter but with a final OCV measurement above the Discharge Complete Voltage. In this case the test will fail, as the test will not be able to determine at least the 0% charge remaining point. A value of 100 mV above the battery collapse voltage is generally recommended.

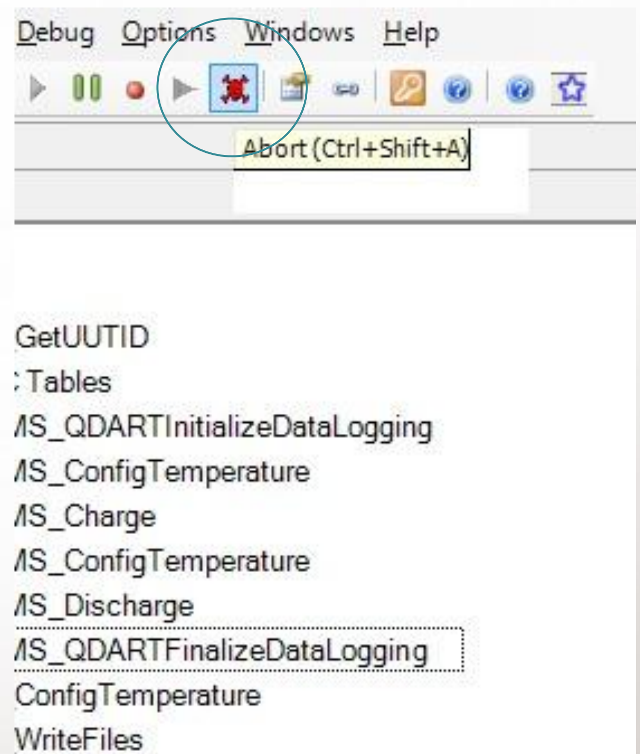
- **Discharge complete voltage**
  This parameter specifies the OCV for the 0% charge remaining point. Although it is theoretically possible to take an OCV reading that matches the value of this parameter exactly, the final OCV reading is generally below the value of this parameter, in which case the 0% charge remaining point is estimated by taking the final reading and the preceding one and interpolating accordingly. Failure to take an OCV reading that is at or below the value of this parameter will mean that the test will not be able to determine the 0% charge remaining point and the test will fail. This parameter is typically set to 3.0 V and must match the value that will be used by the end system. Using one value for profiling the battery and another in system use will cause significant errors.

❖ Refer to the *Application Note: Battery Characterization Test Procedure* (80-VA360-12) for more information on the other discharging parameters.

- To start the test, right click ROOT, select Run Test, and a chat box will appear labeled Single UUT ID, name your test here.
- To abort the test at any time, click the red skull and cross bones icon in the toolbar.

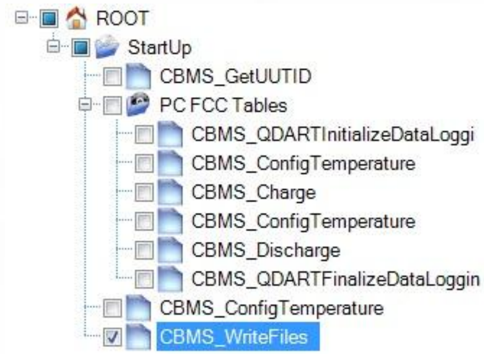
WARNING: A test aborted before finishing will not save any data.





Write Files – Generating the OCV Table

- When the characterization is completed the WriteFiles function is used to generate the battery profile.
- NOTE: The XML Log Location value must contain the exact location of the folder containing the XML files. The location in the Output Directory will be where the .c and .txt files are placed after they are generated.
- Fill out the information required in the red boxes.



Tree Registry | Properties | Parameters | Notes | Loop Setup

Input Parameters				
Parameter Name	Value	Data Logging	Unit	Description
Output Directory		☑		Path to the directory where the output files are to be written
'C' Filename		☐		The name of the 'C' file to be written
'TXT' Filename		☐		The name of the 'TXT' file to be written
XML Log location		☐		Path to the directory where the test result XML files are located
Battery Name		☐		Unique name or ID for the battery (no spaces)
Battery Full Name		☐		A descriptive name for the battery (spaces allowed)
Battery ID Voltage Max		☐	mV	Battery ID Voltage Maximum for batteries using a battery ID resistor
Battery ID Voltage Min		☐	mV	Battery ID Voltage Minimum for batteries using a battery ID resistor
Target Name		☐		Target PMIC name
Expected Capacity		☐	mAh	The default expected Full Charge Capacity of the battery
Maximum Charging Voltage		☐	mV	The maximum charging voltage
Maximum Charging Current		☐	mA	The maximum charging current
Aging Temperature		☐	C	The temperature at which the aging tests were performed
Maximum temperature profiling cycle numbe	20	☐		The maximum temperature profiling cycle number. Cycle numbers above
Watch for Messages ?	No	☐		
Text Marker		☐		Any Text to Log - Supports entries in printf(format, args) style, where its

Example .c File

```
static struct single_row_lut fcc_temp = {
		.x		= {-20, 0, 25, 40, 60},
		.y		= {1962, 1962, 1964,
1961, 1960},
		.cols		= 5
};

static struct single_row_lut fcc_sf = {
		.x		= {0},
		.y		= {100},
		.cols		= 1
};


static struct sf_lut rbatt_sf = {
	.rows		= 29,
	.cols		= 5,
	/* row_entries are temperature */
	.row_entries		= {-20, 0, 25, 40, 60},
	.percent	= {100, 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40,
35, 30, 25, 20, 15, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1},
	.sf			= {

{442,180,100,90,89},
.
(29 Rows of Data)
.
{1983,421,114,102,99},

	}
};
```

```
static struct pc_temp_ocv_lut pc_temp_ocv = {
		.rows		= 29,
		.cols		= 5,
		.temp		= {-20, 0, 25, 40, 60},
		.percent	= {100, 95, 90, 85, 80, 75, 70, 65, 60, 55,
50, 45, 40, 35, 30, 25, 20, 15, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0},
		.ocv		= {
{4180, 4179, 4176, 4173, 4167},
.
(29 Rows of Data)
.
{3200, 3200, 3200, 3200, 3200}

		}
};

struct pm8921_bms_battery_data Example = {
		.fcc
		= 1700,
		.fcc_temp_lut		= &fcc_temp,
		.fcc_sf_lut			= &fcc_sf,
		.pc_temp_ocv_lut	= &pc_temp_ocv,
		.rbatt_sf_lut		=&rbatt_sf,
		.default_rbatt_mohm		=139,

};
```

Troubleshooting Failures

Problem: Charging failure

Possible solutions:

- Check the charging parameters, specifically the units A,V, and mAh.
- Check the battery connections, only the positive and negative terminals of the battery should be connected.
- Make sure a voltage is measurable across the + and - terminal of the battery.

Problem: High temperature discharge failure

Possible solutions:

- Try re-running the battery at a lower temperature. It is possible the battery's maximum discharge temperature is rated incorrectly.
- Try re-running the test with a lower discharge current.

Troubleshooting Failures (3 of 4)

Problem: Low temperature discharge failure

Possible solutions:

- Re-run the characterization with a lower discharge current. Sometimes a very low discharge current (< 150 mA) will be required.
- Slightly increase the battery discharge voltage (+100 mV).
- Decrease the expected full charge capacity (-100 mAh).
- Check the FCC in the HTML or .c file to make sure it is close to the expected capacity of the battery. Lowering the expected capacity might be required.

NOTE: Low temperature failures are the most common, and it might be necessary try all of the techniques above.

NOTE: A combination of small diameter wire, increased battery resistance, and high current load can cause the battery's loaded voltage to dip low enough to activate the battery’s protection circuitry. This can be seen on the HTML files as -999 in the Percentage Charge table. Try the possible solutions to remedy this.

Troubleshooting Failures (4 of 4)

Problem: WriteFiles failure

Possible solutions:

- Make sure all the temperature nodes are enabled. See slide 16.
- Make sure the XML Log Location and Output Directory contain the correct paths. The XML log location must contain the path of the folder holding the XML files.

Questions?