Golden GG Maker and Resistance Temperature Compensation Optimizer

This user's guide is provided as a simple guide for the GPC Golden GG Maker tool. This document includes a summary of the tool, requirements, how to submit data, and examples of each. This guide also describes how to obtain the required log files and GG file.

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1   Tool Summary

Gauging Parameter Calculator (GPC) Resistance Temperature Compensation and Golden GG maker tool is a math calculation tool that helps the battery designer to refine the Impedance Track battery gauge parameters for a given battery, specifically to improve low-temperature discharge accuracy.

The need to optimize resistance temperature compensation arises due to differences in temperature distribution in the cells during steady-state, constant temperature lab test, where the default compensation parameters are obtained, and during cell heating caused by discharge in an actual system where heating and cooling of the cells are inhomogeneous. This results in somewhat different relationship between cell impedance and temperature readings of the temperature sensor, which can be taken into account using the present tool.

Resistance temperature compensation parameters can be optimized only in newer gauges that use two exponent temperature compensation (Rb). This includes bq30z5x,bq40zXX and above in multi-cell gauges, and bq27541 and above in single-cell gauges. If you are not sure if your gauge supports two exponent Rbs, you can submit a GG file exported from you firmware with this package to the tool, and the tool will give an error message if two exponent Rbs are not supported.

While Ra and Qmax parameters can be learned by the gauge automatically through performing a traditional optimization cycle, this tool also allows to obtain thermal model parameters that do not update in single cell (handheld) gauges, which help with high rate tests accuracy. It also provides Ra0_charge value (helps to reach 100% SOC during charge more accurately), which does not self update and is not yet available in older chem IDs. In addition, this tool can utilize the log file from the optimization cycle if some problems with learning Qmax and Ra have been observed, or to obtain all golden GG parameters by using Arbin or Maccor testers on a bare cell without using an actual EVM.

The tool requires two log files of a charge / relaxation / discharge /relaxation test performed under load and heat exchange conditions similar to an actual device, or ideally inside the actual device. Log files are recorded at room temperature and low temperature starting conditions.

They can be created with various test equipment such as Maccor or Arbin battery testers or by using logging capabilities of TI's EV Software (EVSW) or Battery Management Studio (bqStudio) software with an evaluation board connected through USB.

This tool also requires a gauge parameter file exported from your gauge EVM or device PCB using EVSW or bqStudio after chosen chemical ID data has been programmed. This file will be used to detect present firmware properties that affect the parameters, and will be returned after Ra tables, Qmax, and thermal parameters have been populated with new values.

This guide describes how to obtain the required log files and GG file.

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2 Required Data

The GPC tool requires a single .zip file containing one configuration file, two data files at room and low temperatures and one configuration parameters file (gg file) as input. The name of the .zip file is not important. The .zip file should contain following files:

- config.txt
- roomtemp.csv
- lowtemp.csv
- gg.csv

2.1 Configuration File (1 Each)

The configuration file is a text file named config.txt and is an ASCII text dictionary containing the following information:

- ProcessingType = 4 <Determines the type of tool used. Value should be 4 for Resistance Temperature Compensation Optimizer and Golden GG Maker tool>
- ChemID = <Chemical ID selected or released for your cell. Selection can be performed using GPC: Chemical ID selection tool>
- NumCellSeries = <Number series cells for which voltage data in the log are reported. Note that if your battery pack has 3 series cells, but your log file is for a single-cell voltage as is recommended, this value should be 1>
- VoltageColumn = <Zero-based column number for the voltage data in your data logs>
- CurrentColumn = <Zero-based column number for the current data in your data logs>
- TemperatureColumn = <Zero-based column number for the temperature data in your data logs>
- ElapsedTimeColumn = <Zero-based column number for the elapsed time data in your data logs>

Typical settings are:

    ProcessingType=4
    ChemID=3514
    NumCellSeries=1
    ElapsedTimeColumn=0
    VoltageColumn=6
    CurrentColumn=4
    TemperatureColumn=1

2.2 Data Log File

2.2.1 Test Setup

Best results are achieved if the actual device is available. In this case, logging can be performed by soldering wires to the I2C or HDQ outputs of your gauge PCB inside the device and to EV2400 inputs, while bqStudio is recording the logged data. The device should be discharged at typical high load (not extreme high load).

If the device is not yet available, as it is often the case, testing can be performed with a bare battery. It is recommended to place the battery into a "thermal box" which emulates the heat exchange behavior of the actual device by slowing down heat transport from the battery to the air. The thermal box can simply be a plastic box with openings for wires but otherwise isolating PCB and the cells from the environment, slowing down heat exchange to a level similar to the actual system.

To perform the low temperature test, it is necessary to place either the device or the thermal box with the EVM and the cell into the thermal chamber, and set its temperature to 0°C or other low temperature you would like to optimize for. It is not recommended to use a bare cell or open EVM-cell combination, because the thermal chamber fan is blowing directly at it and will cause a very different thermal environment from the actual device. The cell will have much less self-heating, resulting in shorter run-time (impedance increases with lower temperature) and less accurate gauging parameters.

If the device is not available, discharge and charge can be performed using external battery test equipment such as Arbin or Maccor, or even current/voltage regulated power supply and electronic load commonly found in electronics labs. If battery test equipment is used, logging will be provided by the equipment. If power supply/electronic load are used, logging needs to be done using your gauge EVM connected to EV2400 and performed by bqStudio.

Placement of the thermistor is very important both for calculating battery resistance temperature compensation parameters, Ra tables, and for thermal parameters. If you are using EVM for logging, you can unsolder the thermistor connected to the EVM and solder it to longer wires, so the thermistor can be placed directly at the cell surface and taped tightly to it. It is also recommended that the thermistor would be "underneath" the cell and not directly exposed to the air and possibly blowing fan, because it would measure more of air temperature than the cell temperature. If you are using a thermocouple from Maccor and Arbin, it should also be attached directly to the cell surface. Placing the cell in a thermal box (with the thermistor inside the box) also helps to read actual cell temperature.

2.2.2 Test Procedure

The required test consists of the following steps:

1. The charging is performed at room temperature. Optional: If the cell was at a different temperature before, let it relax for 2 hr at room temperature prior to the test.

2. Charge using CC/CV charging to full using taper current as in your actual charger, for example C/20. Use nominal CC charge rate and CV voltage. If another charging method is specified by the cell maker, this other method can be used. If you are charging in a device, using the device charger is the best.

3. Let the battery relax for 2 hrs to reach full equilibrium open circuit voltage (OCV). If in a device, shut down the device during this period to avoid low current discharge.

4. Set discharge test temperature (first 25°C, than 0°C or other low temperature of your choice).

5. Wait for 1 hr until pack reaches thermal equilibrium and cell temperature will stop changing. If temperature did not stabilize (can happen for larger systems) use more time.

6. Discharge the battery at system typical high rate until the minimal voltage, as specified by the cell manufacturer, is reached. If you are discharging in a device, discharging to device minimum voltage is acceptable.

7. Let the battery relax for 5 hrs to reach full equilibrium OCV. If in a device, shut down the device during this period to avoid low current discharge. Go to step 1, and repeat all steps with temperature set to 0°C in step 4).

The resulting room temperature log is exemplified in Figure 1. Low temperature log should have similar shape of the curves, but discharge would start at a lower temperature. :
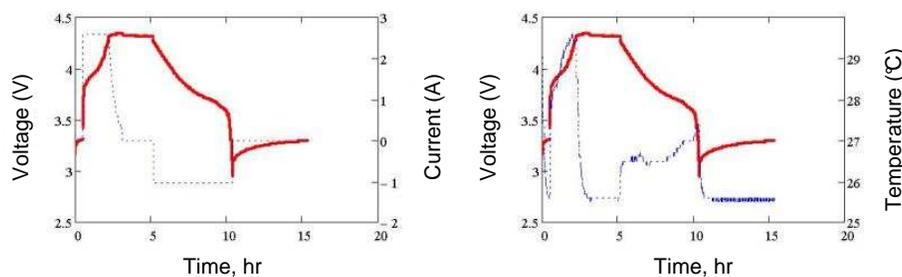

Figure 1. Voltage Current and Temperature Profiles of the Room Temperature Test Required for Golden GG Creation

Data logging should store data into a file containing the following columns, in a coma-separated (CSV), tab separated, or space separated format:

- Time (in seconds elapsed)
- Voltage (in millivolts)
- Current (in milliamps where discharge current is negative)
- Cell temperature (measured by a thermistor attached to the surface of the cell, in degrees Celsius). One decimal place is acceptable.

If the original data format is not one of the supported formats (for example Microsoft® Excel®), the data file must be saved as .csv. Any text that is not part of data-columns, such as the log file header generated by bqStudio or EV Software, as well as empty lines should be removed from the file prior to submission. One row of column names can remain, (the tool will skip it), as long as it has just one name per column. An easy recording method utilizes TI's bqStudio software utility called GPC Packager that reads data directly from a TI fuel-gauge.

Values of current in ampere and voltage in volts are acceptable, the tool will auto detect it and use the correct scale factor.

The columns can be in any order since the column positions are defined in the config.txt file.

However, both room temperature and low temperature logs should have the same column positions for t,V,I,T values. The log file can have some other data columns that are not used in this tool (no need to remove them), as long as the size of the zip file prepared for submission does not exceed 2MB. Note that since it is a compressed file, you can sometime squeeze it some more by utilizing different compression settings in your archiver program.

The sampling interval can be from 5 to 100 seconds.

The initial charging portion needed for Ra0_charge calculation. Relaxation data is required both before and after the discharge.

Precision of the measurements is important. In particular, current measurement should be better than 0.1% of range accuracy, and for voltage measurement 1 mV at room temperature. 16-bit ADC is recommended.

The room data log should be renamed as: **roomtemp.csv**, and low temperature log as **lowtemp.csv** prior to submission of the package, regardless of actual text format.

2.3 Gauge Configuration (GG) File

GG files are commonly exported by the EV Software (*.gg) or by bqStudio (*.gg.cvs). You can use either format, depending if the gauging IC you are using is an older one supported by EV Software or a newer one supported by bqStudio.

To create the GG file for the tool, please follow these steps:

1. Program chosen chem ID
2. Export <name>.gg file or <name>.gg.csv file
3. Rename the file regardless of format to gg.csv

When the processing is complete, the tool will create gg_out.csv which will be the same file, except Ra, Qmax, Ra0_ch, and thermal parameters will be replaced with newly calculated values, and Ra flags and update status will be set to indicate a completed optimization cycle.

2.4 Examples

2.4.1 Config.txt File

ProcessingType=4
ChemID=3514
NumCellSeries=1
ElapsedTimeColumn=0
VoltageColumn=6
CurrentColumn=4
TemperatureColumn=1

2.4.2 Excerpted Example Data Log

In the following excerpt, the columns are:

```
elapsed time (sec), voltage (mV), current (mA), temperature (C)
```

```
20.02833  2975.308      0       28.95893
30.04369  2974.984      0       28.88429
40.05915  2975.308      0       28.91459
50.09006  2974.984      0       28.73499
60.13664  2975.308      0       28.74904
70.20198  3008.069    99.9098   28.89834
80.20158  3023.314    99.9098   28.77718
90.23994  3300.643  1300.396    28.79125
100.2554  3360.975  1300.396    28.79125
110.2708  3404.115  1300.221    28.58133
120.2859  3439.146  1300.572    28.59754
```

3 Data Submission

The zip file created as previously described needs to be submitted to the GPC tool through the web-interface here:

https://www.ti.com/powercalculator/docs/gpc/gpcUpload.tsp

After processing, an E-mail with a report is sent to the E-mail address you will provide when logging in.

Report contains optimized values of Qmax, Ra table, Ra0_charge, and thermal parameters.

If any format or other errors are present, they will be reflected in the report.

The file containing optimized resistance temperature compensation parameters will be attached. It will be called chemdat12_<chem ID>, if you used Battery Management Studio to generate your GG file, or <chem ID>.chem, if you used EV Software. You should use the same tool you used to export the GG file to program the parameters into the gauge by clicking on the "Chemistry" icon and choosing "Update chemistry from external file". It will assure correct chemical ID as well as optimized temperature correction coefficients.

In addition, the original GG file populated with the new values of the parameters generated by the tool will be attached to the report with the name gg_out.csv.

Prior to programming of this GG file into the gauge, please make sure that chemdat12 or *.chem file is programmed as previously described. The actual format of the GG file will be the same as your original file, not necessarily csv. Please rename it using the original naming convention as <name>.gg or <name>.gg.csv prior to using EV Software or Battery Management Studio to program it into your gauge. After programming, the gauge is ready for exporting of the golden image, that can be programmed into other ICs as part of production.

3.1 Example Report

```
Resistance temperature compensation optimizer, rev=1.5

Optimized Impedance Track parameters:

Qmax,mAh : 3897

Ra table normalized to 25C, uncompressed, unscaled

DOD,% Ra,mOhm

  0         92
 11.11      92
 22.22      95
 33.33     112
 44.44     113
 55.56     105
 66.67     133
 77.78     153
 80.95     160
 84.13     171
 87.3      187
 90.48     197
 93.65     205
 96.83     247
100        345


Ra0_ch, mOhm : 170     This firmware is not explicitly supporting Ra0_ch, FCC drop could occur at
low temperatures if used

Thermal parameters:

T Time Constant     560
T Rise     31

Optimized resistance temperature compensation parameters saved in chemdat12


All GG values updated and saved in gg_out.csv


Info: current in A detected, divider changed to 1
Info: voltage in V detected, divider changed to 1
```

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