Bq2060 ADC Offset, Voltage, Temperature, Current and VFC Gain Calibration: Updated 5/28/01

These calibrations can be done simultaneously. Basically the procedure will be to take some initial readings of prior calibration factors, take several readings to obtain average reported values, and then solve equations to determine the new calibration factors to write into RAM and EEPROM. Voltage calibration equations change with the programming of the bq2060. The programming of LCC1 and LCC0 in PackConfig LSBs will determine whether individual cell measurements are made and what equations are needed.

Each reference voltage for calibration should be the node voltage from the bottom of the cell stack to the appropriate tap on the battery. The calibration routine should determine the appropriate measured node voltage for comparison by adding the appropriate cell voltages together. The ADC offset voltage calibration requires that no current is present in sense resistor.

	Ext Measurement	bq2060 Reported
Node 1	DVMn1	Cell1V
Node 2	DVMn2	Node2=Cell1V+Cell2V
Node 3	DVMn3	Node3=Cell1V+Cell2V+Cell3V
Battery Voltage	DVMtot	Bvolt=Voltage
Temperature	Text	Temp=Temperature

Bq2060 readings are as follows:

Cell1V	Command 0x3f
Cell2V	Command 0x3e
Cell3V	Command 0x3d
Voltage	Command 0x09
Temperature	Command 0x08

Case 00: If LCC1=LCC0=0, Node1, Node2, and Node3 will not be used and those rows may be grayed out. This selection designates that no individual cell measurements will be made.

Case 01: If LCC1=0, LCC0=1, selection indicates that battery is 2-cell battery and only Cell1V and Voltage will be used. Node2 and Node3 rows may be grayed out.

Case 10: If LCC1=1, LCC0=0, selection indicates that battery is 3-cell battery. Thus Node3 row may be grayed out.

Case 11: If LCC1=LCC0-1, selection indicates that battery is 4-cell battery and all rows will be used.

Equation for FSV factor computation for Case 00 is slightly different than for other cases. All other voltage calibrations factors, C2PCAL, C3PCAL, and C4PCAL, have the same equations for each case, though they may not all need to be computed.

1. Read Light Load Estimate at Cmd 0x25. If MSB (high byte) is non-zero, then save value to restore when calibration is complete. Temporarily change Light Load Estimate to zero by writing Cmd 0x25 with only high byte changed to zero (leave LSB same value).

2. Read initial calibration factors from RAM:

Parameter	Name	Command	Type
Temp Offset	TOFFo	0x40 MSB	signed 8bit
ADC Offset	OFFo	0x41 LSB	signed 8bit
FullScaleGain	FSVo	0x43	unsigned 16bit
Cell2 Gain	C2PCALo	0x41 MSB	signed 8bit
Cell3 Gain	C3PCALo	0x42 LSB	signed 8bit
Cell4 Gain	C4PCALo	0x42 MSB	signed 8bit

3. Make one initial reading immediately, wait 2.25s between sample times and take two more samples of each of the following parameters for 3 readings total. All of the voltage parameters may be read if desired, but not all will be used depending on the LCC1/0 programming. Cell#4 voltage will never be needed and is not included in the list. More readings than 3 each may be made for more accuracy. Then take the average value of each parameter value before using in calibration equations.

Parameter	Name	Command	Type
Temperature	Temp	0x08	unsigned 16bit (Temperature in degrees K x 10)
Voltage	Bvolt	0x09	unsigned 16bit
Cell#1 Voltage	Cell1V	0x3f	unsigned 16bit
Cell#2 Voltage	Cell2V	0x3e	unsigned 16bit
Cell#3 Voltage	Cell3V	0x3d	unsigned 16bit
Inverse Offset	INVOFF	0x5f MSB	signed 8bit

4. Plug initial calibration factors and averaged readings into the following formulas and solve for the new calibration factors.

Temperature:
TOFF = 10*(Text-Temp)+TOFFo

Ex: TOFFo = 10d (+1.0K offset), Text=298.0, Temp=297.0;
TOFF = 10*(298-297)+10=20d or 0x14 (2.0 deg offset)

ADC Offset:
OFF = OFFo-INVOFF

Ex: OFFo=0, INVOFF=3;
OFF=0-3=-3d or 0xfd

Voltage:
Note that all equations have the expression (OFF-OFFo). This of course could be replaced by -(INVOFF) if desired.

Case 00 (LCC1=LCC0=0):

FSV = DVMtot/[(Bvolt/FSVo) + 2(OFF-OFFo)/65536]

Case 01 (LCC1=0, LCC0=1):

FSV = DVMn1/[(Node1/FSVo) + (OFF-OFFo)/65536]

C2PCAL = DVMtot/[8x[(Bvolt/(FSVo+8xC2PCALo)) + (OFF-OFFo)/65536]] – FSV/8 (Need result of FSV calc first)

Case 10 (LCC1=1, LCC0=0):

FSV = DVMn1/[(Node1/FSVo) + (OFF-OFFo)/65536] (same as Case 01)

C2PCAL = DVMn2/[8x[(Node2/(FSVo+8xC2PCALo)) + (OFF-OFFo)/65536]] – FSV/8 (same as Case 01)

C3PCAL = DVMtot/[8x[(Bvolt/(FSVo+8xC3PCALo)) + 2(OFF-OFFo)/65536]] – FSV/8

Case 11 (LCC1=LCC0=1):

FSV = DVMn1/[(Node1/FSVo) + (OFF-OFFo)/65536] (same as Case 01)

C2PCAL = DVMn2/[8x[(Node2/(FSVo+8xC2PCALo)) + (OFF-OFFo)/65536]] – FSV/8 (same as Case 01)

C3PCAL = DVMn3/[8x[(Node3/(FSVo+8xC3PCALo)) + 2(OFF-OFFo)/65536]] – FSV/8 (same as Case 10)

C4PCAL = DVMtot/[8x[(Bvolt/(FSVo+8xC4PCALo)) + 2(OFF-OFFo)/65536]] – FSV/8

5. Take new ADC offset, Temperature offset, and Voltage calibration factor values and write them to RAM and to EEPROM.

6. If value for Light Load Estimate was non-zero, then restore saved value to Cmd 0x25. (If full reset will be done afterwards, this step is not necessary.)

Current Gain:

This calibration requires that the ADC offset is calibrated first. Do not perform this calibration until the previous calibration which includes ADC offset has been completed.

1. Read initial ADC Sense Resistor Gain from RAM, ADCSRGo, at Cmd 0x44.

2. Apply known value discharge load, DVMcur.

3. Calibration should wait 2.25s before collecting the first Current sample from Cmd 0x0a. Wait two more 2.25s periods, taking an additional Current sample after each delay interval. More samples may be taken for higher accuracy. The average of the Current samples should be made. Average reading is ADCcur

4. Compute new ADC Sense Resistor Gain factor.

ADCSRG = ADCSRGo * DVMcur / ADCcur

5. Write Current Gain factor to both RAM and EEPROM.

VFC Calibration:

Quick way (+/-3% result)

The quickest way is to use value from current gain and compute VFC Sense Resistor Gain (VFCSRG) without any measurement. This will achieve +/-3% accuracy. Measurement will take much longer than Current Gain compuation.

VFCSRG = 0.65536*ADCSRG

Long way (improved accuracy)

The transfer function of the VFC is determined by measuring how long the converter takes to output a given number of pulses with a given input voltage. The described method will measure its output frequency with a known constant input voltage by counting the time required to output a given number of pulses.

1. Voltages measured by bq2060 must be above EDV levels. RM value must be greater than zero (if discharging current used for calibration). RM value may be set to desired value by writing value to Cmd 0x26.

2. Write VFC Sense Resistor Gain value of 0x0001 to RAM at Cmd 0x45.

3. Apply external charge or discharge current of known value, DVMcurr

4. Monitor Cmd 0x5d. This value will increment if charging or descrement if discharging. This calibration requires a very accurate Tn time measurement for Nn increments or decrements of Cmd 0x5d. Accuracy of result depends on accuracy of time measurement. If Cmd 0x5d is only read every 10ms and it timer granularity is only 55msec, then time accuracy cannot be better than 65msec because exact time when Cmd 0x5d changed cannot be determined. The error from time measurement plus error in external current DVM reference will determine total error for this calibration. Counting a larger number of Nn increments (longer Tn) will be required to improve accuracy.

5. Computation for VFC Sense Resistor Gain (VFCSRG) follows:

VFCSRG = DVMcurr(mA) * Tn * 18.204444 / Nn

Example: If DVMcurr = 2000mA discharge and Cmd 0x5d is read until it decrements by Nn = 50 (decimal), assume Tn measurement made is 18.75s.

VFCSRG = 2000 * 18.75 * 18.204444 / 50 = 13653 (This is typical value for 30mohm sense resistor.)

If polling of 0x5d is done every 10msec and timer granularity is 55msec, then error is 100*0.065s/18.75s=0.35% in addition to reference current error. Calibration should not use Nn less than 25 or Tn less than 10s.

6. Write new VFCSRG value to RAM at Cmd 0x45 and to appropriate EEPROM location.

Bill Jackson