![TEXAS INSTRUMENTS]

Configuring External EEPROMs Used in bq2060 and bq2060A Applications

Battery Management

ABSTRACT

Charging, discharging, and the entire battery system can be a complex and difficult application to understand. Accurately measuring the energy in and out of this battery system is just as complex, if not more so. The bq2060/A was developed with very extensive sophisticated functions and algorithms to measure energy transfer throughout a wide range of applications with high accuracy. Thus, configuring the bq2060 for the exact battery specification and application can be a complicated task. To support this extensive configuration, an external EEPROM device is used in conjunction with the bq2060/A. With 128 8-bit EEPROM configuration bytes and the many required formulas to compress them, the EEPROM can appear intimidating. However, if you exclude the string data and take them one at a time (most in 2 byte words), the task does not appear so daunting.

In the *Definitions and Nomenclature* Section there are some tips and solutions to frequently asked questions. There are 2 sample snapshots of the EV2200-60 software denoting a Li-Ion example and a NiMH example. They are not intended as a complete solution for your specific application, only as a reference. A review of each EEPROM location, one by one, in the same order as the EV2200-60 software is provided. Taken one at a time, this application note makes these more understandable.

Introduction

Definitions and Nomenclature

Formulas in the Data Sheet: All names in italics in the data sheet formulas correspond to the exact EEPROM registers. The names in CAPS in the formulas are in real units. For example:

$$Light\ Discharge\ Current = \frac{ILEAK * 1024}{45}$$

ILEAK is the real world units (milliamps) and the *Light Discharge Current* is the raw value that is stored into the EEPROM after the calculation.

Valid Discharge: The best way to be sure that the part is going to learn a new <u>Full Charge Capacity</u> value during a discharge is to watch the VDQ bit in the <u>Pack Status</u> register. If it is cleared at any time during the discharge prior to EDV2 bit being set in the <u>Pack Status</u> register then the part does not learn. The main reason the VDQ bit would be cleared is charge activity during the discharge.

Learning: During a valid discharge cycle, the part does not write the new <u>Full Charge Capacity</u> value until about 10 milliamp hours (mAh) of charge are applied to the pack anytime after reaching EDV2. In other words, when the part discharges to *EDV2* with the VDQ bit set in the <u>Pack Status</u> register, the <u>Full Charge Capacity</u> register does not update until 10 mAh of charge are applied.

How to Use This Document

When this document says *See XXXX in the Data Sheet*, do a search for the exact *XXXX* phrase to find information on that topic in the data sheet. Registers found in the field descriptions that are underlined are SMBus registers. They are described in detail in the SMBus specification (see *Other Sources* below) and are polled in the *Data* and *Extended* screens of the EV2200-60 software. Registers names in italics are EEPROM locations.

Below are examples of a Li-Ion 3 cell configuration and a NiMH 10 cell configuration that were created using this document as a guideline. They are examples only and not intended to meet all requirements.

This document does not describe calibration values in the EEPROM because the EV2200-60 software performs the calibration. It does not describe EDV's because they are described in detail in the data sheet. Compensated EDV's are also described in explicit detail in the *Compensated EDV(CEDV) Theory and Operation* application note.

EEPROM addresses are shown for each EEPROM field in the EEPROM *Fields Descriptions* section. Even EEPROM addresses in a 2 byte (word) value are the LSByte (least significant byte) of the data word. Odd EEPROM addresses are the MSByte (most significant byte) of the data word. Example: Remaining Time Alarm [0x02, 0x03] → 0x02 is the LSByte and 0x03 is the MSByte

Other Sources**:**
1. SMBus specification on the SBS Forums web site at:
   http://www.sbs-forum.org/specs/index.html
2. Compensate EDV (CEDV) Theory and Operation Application Note
3. Using Advance Features of the bq2060 Gas-Gauge IC (SLVA151)
4. bq2060A data sheet (SLUS500)
5. bq2060A EVM User's Guide (SLUU063)

Sample EEPROM Configurations

Below are 2 Examples of EEPROM Configurations. They are intended as a reference. The values in each are true, valid examples but are in no way applicable to all user specific applications.

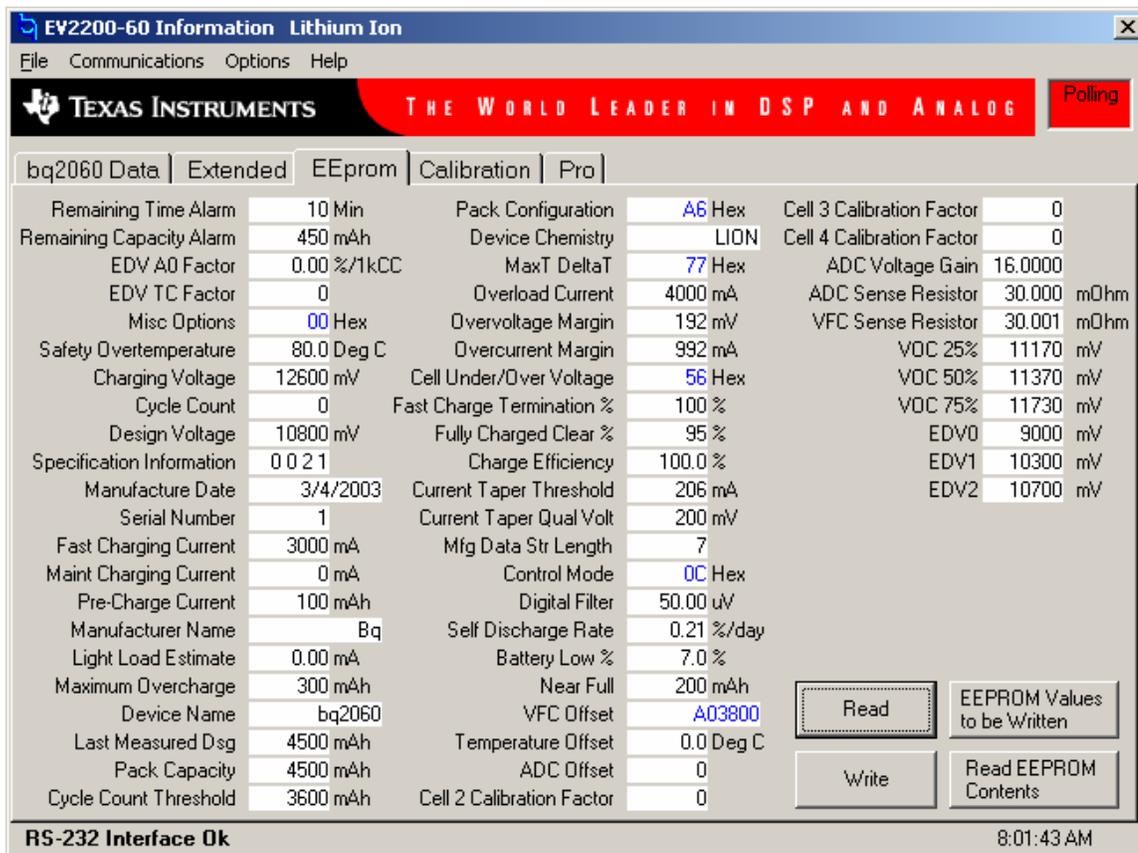Example: 10-cell NiMH configuration from the bq2060A EVM User's Guide

Example Li-Ion 3-cell configuration from the bq2060A EVM User's Guide

EEPROM Field Descriptions

Remaining Time Alarm [0x02, 0x03]: When the average time to empty falls below this value, then the Remaining Time Alarm bit is set in <u>Battery Status</u>.
Normal Setting: About 10 minutes.

Remaining Capacity Alarm [0x04, 0x05]: When the <u>Remaining Capacity</u> (RM) falls below this value, then the Remaining Capacity Alarm bit is set in <u>Battery Status</u>.
Normal Setting: About 10% of the <u>Full Charge Capacity</u>.

EDV A0 Impedance Age Factor [0x06]: When EDVs are set to compensated (*Pack Configuration* bit 4 = 1), this value adjusts EDVs for aging. This is a specialized function that is not used in most cases.
Normal Setting: Typically this is disabled by setting it to 0.

EDV TC Factor [0x07]: (bq2060A only) Used for compensated EDVs.

Misc Options [0x08]: (bq2060A only)

NE1	SOT	HIT	-	-	-	-	-
No EDV1	Safety overtemp	Max temp range	0	0	0	0	0

- □ NE1: Setting this bit to a 1 completely disables the EDV1 threshold. <u>Remaining Capacity</u> is not adjusted at the EDV1 threshold with this bit set.
  Normal Setting: This bit should usually be set to 0.

- □ SOT: Setting this bit to 1 causes the bq2060A to only use *Safety Overtemperature* to control the CFC pin. Setting this bit to a 0 causes the bq2060A to use the normal control methods (including *Safety Overtemperature*) for the CFC pin.
  Normal Setting: This bit should usually be set to 0.

- □ HIT: This bit increases the values in *MAXT* and *Safety Overtemperature* by 16 °C if set to a 1. If this bit is set to 0, then the values in *MAXT* and *Safety Overtemperature* function as a standard bq2060 with no 16 °C increase.
  Normal Setting: Usually the 16 °C increase that this bit can adjust for is not needed. Therefore, it is most common to set it to 0.

Safety Overtemperature [0x09]:   (bq2060A only) If required, this field can be used as secondary FET control or to blow a fuse if the cells get to hot. It is linked with the CFC pin (See SOT bit in *Misc Options*).
  Normal Setting: Be sure it is set above *MAXT*. This value should be derived from cell manufacturer specifications to prevent a catastrophic event.

Charging Voltage [0x0a, 0x0b]: With Li-Ion, it is used in qualifying when charging should be complete (see *Current Taper Qual Voltage*). With NiMH and Li-Ion it is part of the calculation for determining over voltage conditions (see *Overvoltage Margin*). As long as broadcasts are enabled it is also sent as a broadcast.
  Normal Setting: This should be set to the value of the pack charging voltage applied. Charger tolerances should be taken into account with this setting.

Cycle Count [0x0e, 0x0f]: This is the number of times that the bq2060 has accumulated a total of *Cycle Count Threshold* mAh of DISCHARGE (see *Cycle Count Threshold*). It accumulates discharge even if interrupted by charging. Its purpose is to give the manufacturer an indication of the battery usage in the event of a pack returned from the field.
  Normal Setting: This should be set to 0.

Design Voltage [0x12, 0x13]: This is the theoretical nominal voltage of the battery pack. This value is used in <u>ATRATE</u> calculations and milliwatt mode (SMBus battery mode MSByte bit 7).

Normal Setting: This varies by cell manufacturer, but Li-Ion is typically about 3.6-V per cell and NiMH is typically 1.2 V to 1.3 V. Please refer to cell manufacturer data sheet for exact numbers.

Specification Information [0x14, 0x15]: This performs 2 purposes. The high byte has the current and voltage multipliers. The bq2060 does not require any multiplier so use 0x00. The low byte is the SBS specification revision. See the SBS Implementers Forum web page for more information (http://www.sbs-forum.org/specs/index.html). **Normal Setting**: 0x0031 for SBS specification v1.1 with PEC error checking, or 0x0021 for SBS specification V1.1 without PEC error checking.

Manufacturers Date [0x16, 0x17]: This is the date of manufacture. It is stored in the EEPROM in packed format. The EV2200-60 software or our Smart Battery Test System (SBTS) accepts the date in standard date format so the packed format does not need to be used. This data does not affect the operation, nor is it used by the part in any way.

Serial Number [0x18, 0x19]: This is a 16 bit serial number that does not affect the operation nor is it used by the part in any way. It is usually used for battery identification.

Fast Charging Current [0x1a, 0x1b], Maintenance Charging Current [0x1c, 0x1d], and Pre-Charge Current [0x1e, 0x1f]: These values are used to fill the Charging Current register. The Charging Current is set to one of these 3 values or 0 mA (Suspend Current) depending on the operating conditions. (See Charge Control section in the data sheet) The Charging Current register plus the *Overcurrent Margin* is used to check for the Terminate Charge Alarm in Battery Status.
Normal Settings:

☐ Fast Charging Current: Set this to the current that the charger produces during fast charge mode. For Li-Ion make sure that there is enough clearance for the *Current Taper Threshold* to insure proper charge termination (see *Current Taper Threshold*)

☐ Maintenance Charging Current: For Li-Ion this is usually set to 0. For NiMH this is set to a *trickle charge* value. This keeps the battery full after a charge termination. The Charging Current is set to 0 mA on charge termination, and when the termination condition ceases it is set to *Maintenance Charging Current*.

☐ Pre-Charge Current: This can be used for Li-Ion or NiMH. The Charging Current is set to this value when the battery voltage is below EDV0 or when the temperature is between 0 and 5°C.

Manufacturer Name [0x20-0x2a]: String data that can be a maximum of 10 characters. This field does not affect the operation nor is it used by the part in any way.

Light Load Estimate (Light Discharge Current) [0x2b]: This value gives the bq2060 a way to decrement Remaining Capacity for Discharge currents that are present but below the *Digital Filter*. This is only operational when no Discharge current above the *Digital Filter* is detected and Clock and Data are both High. This is most commonly used for a Host system that goes into a suspend condition with the clock and data lines high. *The Light Load Estimate* is a fixed value. It decrements the Remaining Capacity by the value in the *Light Load Estimate* register at a periodic rate, not by actual currents, so it is just an estimate. (See *Light Discharge* or *Suspend Current Compensation* in the data sheet).
Normal Setting: This value is usually set to 0. Always set to 0 if the actual light load current is above the *Digital Filter* because the bq2060 counts this current when it is above the *Digital Filter*.

Maximum Overcharge [0x2e, 0x2f]: When the battery is charged above the Full Charge Capacity by the amount stored in *Maximum Overcharge* then the Terminate Charge Alarm is set along with related alarms in Battery Status.
Normal Setting: This is application dependant. An example would be 200-300 mAh.

Device Name [0x30-0x37]: String data that can be a maximum of seven characters. This field does not affect the operation, nor is it used by the part in any way.

Last Measured Discharge (LMD) [0x38, 0x39]: This is the stored backup of the Full Charge Capacity register. This register is updated when the bq2060 completes a learning cycle. When the part learns a new Full Charge Capacity value during a valid discharge it then writes that new value to *Last Measured Discharge* a couple of seconds after the update. Full Charge Capacity is commonly known as FCC. (See FullChargeCapacity in the data sheet).
Normal Setting: This value is dependant on the cell configuration and chemistry. The initial value for this register should be set to the full capacity of the pack at pack assembly.

Pack Capacity [0x3a, 0x3b]: This value is used for the Absolute State of Charge (ASOC) calculation by the part. It is also used for the Design Capacity register. If the bq2060 is set for milliwatt mode then the part converts *Pack Capacity* to milliwatt hours and stores it in Design Capacity. If the part is not set for milliwatt mode then *Pack Capacity* is moved directly to Design Capacity. (See DesignCapacity in the data sheet).
Normal Setting: This value should be set to initial *Last Measured Discharge (LMD)* value.

Cycle Count Threshold [0x3c, 0x3d]: This value is used to increment the EEPROM and SMBus *Cycle Count* register (See Cycle Count). When the bq2060 accumulates enough discharged capacity equal to the *Cycle Count Threshold*, it increments the Cycle Count by 1. This discharged capacity does not have to be consecutive. In other words the internal register that accumulates the discharge is not cleared at any time except when the internal accumulating register equals the *Cycle Count Threshold* and increments the Cycle Count.
Normal Setting: This is usually set to about 80% of the initial *LMD* value.

Pack Configuration (PKConfig) [0x3f]:

DMODE	SEAL	CSYNC	CEDV	VCOR	CHEM	LCC1	LCC0
Display Mode	Seal	Charger Sync	Compensated EDVs	Voltage Correction	Chemistry	Number Cells 1	Number Cells 0

(See *Pack Configuration* in the data sheet)

☐ DMODE: Display mode refers to LED configuration. If the display mode bit is 1 then the display is in relative mode. If it is 0 then it is in absolute mode. In relative mode the LED display is based on a percentage of the Full Charge Capacity, which is stored in the Relative State of Charge (RSOC) register. If it is in absolute mode then the LED display is based on a percentage of *Pack Capacity*, which is stored in the Absolute State of Charge (ASOC) register. Absolute State of Charge is commonly known as *ASOC* and Relative State of Charge is commonly known as RSOC.
Normal Setting: This is most commonly set to relative mode or 1

☐ SEAL: If this bit is set to a 1 then the bq2060 is sealed. If it is a 0 then it is unsealed. When the bq2060 is in sealed mode, the bq2060 conforms to the SBS data specification and it does not allow writes to the EEPROM. This means that all communications to addresses that are not in the SBS data specification (all addresses not on the bq2060 Data or Extended screens in the EV2200-60 software) are not accessible. Also the SBS data is read only accessible except for SMBus addresses 0-5. When the bit is 0 or unsealed, the EEPROM can be written. All addresses up to 0x7f are read/write accessible except internal hardware registers.
Normal Setting: This bit can be 0 while in development but should always be set to a 1 when the part is in the field.

☐ Charger Sync: If this bit is set then when the bq2060 detects a charge termination it writes the Remaining Capacity register to the percentage of the Full Charge Capacity programmed in *Fast Charge Termination Percent*. If this bit is 0, the Remaining Capacity register is not altered with a charge termination. Also, if this bit is 0, there can be situations where the bq2060 may not learn. The part must charge to a Remaining Capacity above (Full Charge Capacity – *Near Full)* to set the VDQ Bit (valid discharge bit in Pack Status*)*. If this bit is 0, and the charger does not charge enough to set VDQ on the next discharge, then the part does not learn. **Normal Setting**: This bit is almost always set to 1. If an externally controlled charger is used (if it sends the charger synchronization command in manufacturer access when it thinks the battery is full) this may not be desired, however, this is not common.

☐ CEDV: Set this bit to a 1 when the Compensated EDV algorithm is desired. Set it to a 0 when the Fixed EDV algorithm is acceptable. **Normal Setting**: This document does not describe the 2 types of EDV algorithms. However, this bit is usually a 0. Compensated EDVs are for advanced users and require complex data taking for cell characteristics. For most users fixed EDVs are acceptable (See *End-of-Discharge Thresholds* and *Capacity Correction* in the data sheet).

☐ VCOR: Set this bit to a 1 to enable midrange voltage correction. Set it to a 0 to disable this function. If set to 0, the bq2060 does not attempt midrange corrections so the *VOCXX* values stored in EEPROM are ignored (see *VOC25%, VOC50%,* and *VOC75%*).

☐ CHEM: Set this bit to a 0 for NiMH chemistry and set it to a 1 for Li-Ion chemistry. If set for NiMH, then no individual cell monitoring can be used. Both the *LCC1* and *LCC0* bits must be 0. If set for Li-Ion, then individual cell monitoring can be used but it is not required. **Normal Setting**: Depends on cell chemistry.

☐ LCC1,0: Use these bits to determine the number of cells if individual cell monitoring is required. If it is not required then set both bits to 0. **Normal Setting**: Depends on Configuration.

Device Chemistry [0x40-0x44]: String data that can be a maximum of 4 characters. This field does not affect the operation nor is it used by the part in any way.

MAXT [0x45 Most Significant Nibble]: This value is set to the temperature that charging must be stopped at. The bq2060 sets the Charging Current to 0 and sets the Terminate Charge Alarm bit in the Battery Status register. **Normal Setting:** This is chemistry and cell manufacturer dependant. Common values are between 50 and 60°C.

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DeltaT [0x45 Least Significant Nibble]: This is for NiMH chemistry only. For Li-Ion Chemistry set this to the maximum value. This is the ΔT value in the $\Delta T/\Delta t$ termination algorithm for NiMH cells. The bq2060 checks for a ΔT rise in temperature over given Δt time sample. In other words, for the bq2060 to detect a charge termination in NiMH, the temperature must rise more than *DeltaT* in *DeltaT Time* (Δt) seconds (See *DeltaT Time* and Rate Programming in the data sheet). These settings are critical to insure maximum and accurate reported usable capacity from the battery. **Normal Setting**: Depends on cell characteristics.

Overload Current [0x46, 0x47]: This value is used in the EDV algorithms. It is only used with discharge current. When the discharge current detected by the bq2060 is greater than this value, the bq2060 disables EDV detection. This prevents the voltage drop caused by excessive discharge currents from causing a false EDV detection. **Normal Settings**: A high enough setting above the maximum system discharge current that prevents false detections.

Overvoltage Margin [0x48]: This value is used in detecting an overvoltage condition. When the battery voltage is above the (Charging Voltage + *Overvoltage Margin*), the Charging Current is set to zero (suspend) and the Terminate Charge Alarm bit is set in Battery Status.
Normal Setting: This value should be high enough that ripple on the charger voltage does not cause a false overvoltage condition, but low enough that the Charging Current goes to suspend before the battery exceeds its maximum specifications.

Overcurrent Margin [0x49]: This value is used in detecting an overcurrent condition. When the charging current is above the (Charging Current + *Overcurrent Margin*), the Charging Current is set to zero (suspend), and the terminate charge Alarm bit is set in Battery Status.
Normal Setting: This value should be high enough that charger current tolerances do not give a false overcurrent condition but low enough that the Charging Current goes to suspend before the battery exceeds its maximum specifications.

Cell Under/Over Voltage [0x4a]: These values are only used for Li-Ion chemistry with individual cell monitoring on. They are used for terminating discharge (cell under) or charge (Cell Over) currents when the battery voltage exceeds these ranges.
Normal Setting: Be sure to set these values inside the tolerances of the pack protector IC being used.

Fast Charge Termination Percent [0x4b]: With the CSYNC bit set in *Pack Configuration* this is the percentage of Full Charge Capacity that the Remaining Capacity is set to when the bq2060 detects a charge termination.
Normal Setting: For Li-Ion this is usually set to 100%. For NiMH this value varies depending on where maintenance charging current starts. A good example number for NiMH is 95%

Fully Charged Clear Percent [0x4c]: After the battery is full, when the Remaining Capacity reaches this percentage of Full Charge Capacity (or when Relative State of Charge reaches the *Fully Charged Clear Percent*), the fully charged bit in Battery Status is cleared. In other words, when the battery is full, the bq2060 does not clear all the charge termination flags until the battery capacity falls below this value.
Normal Setting: This value is user dependant. A good number is usually between 90-95%

Charge Efficiency [0x4d]: This value is used by the bq2060 as a means to compensate charging for loss of energy getting to the battery. In other words, if a battery loses some of the energy that is being applied to it, then the user can set this value to help compensate for that loss. When charging, the bq2060 reduces the amount of charge it increments Remaining Capacity by the percentage stored in *Charge Efficiency*. This value is used for Li-Ion and NiMH (See *Efficiency Temperature Compensation*).
Normal Setting: For most modern cells (especially Li-Ion), this value can be set to 100%.   Some NiMH cells may require a slight reduction, but should not be less than 95%.

Current Taper Threshold [0x4e]: For Li-Ion only. While charging, when the voltage reaches the (Charging Voltage – *Current Taper Qual Voltage*), the bq2060 starts trying to detect a charge termination. When the current falls below the value stored in *Current Taper Threshold*, the bq2060 sets all the conditions for requesting a charge termination and writes Remaining Capacity to the *Fast Charge Termination Percent* if the CSYNC bit is set in *Pack Configuration*. The bq2060 does not use the ADC for detecting this. It uses the VFC, which integrates the charge into the battery. The reason for this is to help reduce the possibility of a false termination with chargers that use the pulse charge method or have substantial ripple on the charging current.
Normal Setting: This value depends on cell characteristics and charger specifications.

DeltaT Time [0x4e]: For NiMH only (See *DeltaT).*

Holdoff Time [0x4f]: For NiMH only. This is the amount of time after charging starts before the bq2060 starts looking for a $\Delta T/\Delta t$ termination. When NiMH cells are depleted and charging is started, temperature changes can cause a false termination. The *Holdoff Time* value helps prevent this from happening.
Normal Setting: This depends on cell characteristics and operating conditions.

Current Taper Qual Voltage [0x4f]: For Li-Ion only. The bq2060 uses this value as a qualification voltage that the battery voltage must meet prior to looking for a current taper termination (See *Current Taper Threshold*). The bq2060 starts trying to detect current taper termination only when the battery voltage is above (Charging Voltage – *Current Taper Qual Voltage*).
Normal Setting: This value is dependant on charger characteristics. It needs to be set so that ripple voltage, noise, and charger tolerances are taken into account. A value selected too low can cause early termination. If the value selected is too high then it can cause no or late termination detection. A good example value is 200mV.

Manufacturers Data Length [0x50]: This value should always be set to 7.

Control Mode [0x51]:

NDF	-	HPE	CPE	LED	SC	-	SM
No Digital Filter		Host PEC	Charger PEC	4-5 LEDs	Smart Charger		Disable Smart Messages

☐ NDF: This bit disables the digital filter during discharge if the SMBus lines are high. This is a method of detecting discharge currents when the discharge current is below the *Digital Filter* threshold (see Light Discharge or Suspend Current Compensation in the data sheet)
Normal Setting: This bit should usually be set to 0

☐ HPE, CPE: These bits enable PEC error checking on charger (CPE) or host (HPE) broadcasts.
Normal Setting: Set to a 1 when the charger or host accepts PEC error checking.

☐ LED: Set this bit to a 1 for 5 LED applications and set to a 0 for 4 LED applications. If the circuit has only 4 LEDs, the bq2060 sets each LED to 25% increments in capacity. If the circuit has 5 LEDs, the bq2060 sets each LED to 20% increments in capacity.
Normal Setting: Depends on the application.

☐ Smart Charger: This bit is used to help the bq2060 learn if the charger has limited functionality and may sometimes prevent a learning cycle. If this bit is a 0 then the bq2060 reduces the Full Charge Capacity by 0.78% when EDV2 is reached. It also writes the new Full Charge Capacity to the EEPROM *Last Measured Discharge* value. Refer to *Using Advance Features of the bq2060 Gas-Gauge IC* application note for detailed description.
Normal Setting: This bit is typically set to 1.

☐ SM: If this bit is set, the bq2060 does not broadcast any smart messages.
Normal Setting: If the charger or host does not accept broadcast messages, it is a recommended to set this bit to a 1 to prevent any communication problems.

Digital Filter [0x52]: This value is stored in microvolts (µV) and its setting is influenced by the sense resistor value. It is used to prevent noise or part offset from affecting the Charge/Discharge counting. In other words, any voltage sensed by the part on the sense resistor outside of the range of ± *Digital Filter* is counted towards the Remaining Capacity. Any voltage inside ± *Digital Filter* is not counted and is discarded as noise.
Normal Setting: Set this value above the noise threshold. It depends on the quality of the board layout and the VFC offset of the bq2060. Usually 50 µV is a good number for the bq2060 but can be lowered if required. Only lower it if the VFC offset is calibrated and active.

Self Discharge Rate [0x53]: This value is an estimate of capacity reduction caused by battery inactivity. It is stored in percent per day but it does not decrement just once per day (See Self Discharge in the data sheet).
Normal Setting: This number is only an estimate to help compensate for inactive capacity reduction. This feature offers limited accuracy and is dependant on the Cell chemistry and structure. NiMH's *Self Discharge Rate* is usually substantially higher than Li-Ion. A good example for NiMH is 1% per day. A good example for Li-Ion is 0.21% per day.

Battery Low Percent [0x54]: This value is used in conjunction with *EDV2*. It is a common mistake to get the definition of *Battery Low Percent* and *EDV2* confused. *Battery Low Percent* is the percent of capacity expected when the battery reaches *EDV2* voltage. When the battery is discharging, if the voltage drops to the *EDV2* threshold then the Remaining Capacity is written down to the *Battery Low Percent* of Full Charge Capacity. When discharging, if the Remaining Capacity gets to the *Battery Low Percent* of Full Charge Capacity, the bq2060 holds the Remaining Capacity at this value until the battery voltage drops to the EDV2 threshold. This is a major factor in how the bq2060 learns a new Full Charge Capacity.
Normal Setting: the normal setting for this value is 7%

Near Full [0x55]: Remaining Capacity must be above (Full Charge Capacity - *Near Full*) for the bq2060 to set the VDQ bit in Pack Status. In other words, the Remaining Capacity must be above (Full Charge Capacity – *Near Full*) when discharging starts for a learning cycle to be initiated (VDQ being set).
Normal Setting: This is user dependant. A good example is 200 mAh.

Efficiency Temperature Compensation [0x63], Efficiency Drop Off Percentage [0x64], and Efficiency Reduction Rate [0x65]: All these values are for NiMH only, and have no effect for Li-Ion battery.
Normal Settings: These values are all user and application dependant.

☐ Efficiency Temperature Compensation: The bq2060 adds this value to the Charge Efficiency value (described above) above the *Efficiency Drop Off Percentage* for every degree over 25°C (See Formula Below).

☐ Efficiency Drop Off Percentage: When <u>Remaining Capacity</u> is below this percentage of <u>Full Charge Capacity</u>, the only charge rate reduction is *Charge Efficiency*. Above this value, all the compensation values described here including *Charge Efficiency* are used (See Formula Below).

☐ Efficiency Reduction Rate: This is an increase in reduction rate in addition to the *Charge Efficiency* that is applied above the *Efficiency Drop Off Percentage* for every percentage above the *Efficiency Drop Off Percentage* (See Formula Below).

FULLEFF%= ERR%(RSOC – EDOP%) + TEFF%(Temperature - 25℃) + CHGEFF%

This formula applies only above the Efficiency Drop Off Percentage
Efficiency Reduction Rate = ERR%
Charge Efficiency = CHGEFF%
Efficiency Temperature Compensation = TEFF%
Efficiency Drop Off Percentage = EDOP%
RSOC = SMBus Relative State of Charge register
Temperature = SMBus Temperature in converted to degrees C
The total reduction rate (all reductions combined) = FULLEFF%

VOC25% [0x6c, 0x6d], VOC50% [0x6e, 0x6f], and VOC75% [0x70, 0x71]: These values are an alternative (midrange voltage correction) method for the bq2060 to update <u>Remaining Capacity</u> using voltage correction if it is grossly inaccurate (> than 25% error). For batteries that have been inactive for a long time, the *Self Discharge Rate* may not be accurate since it is only an estimate. However, the *VOCXX* values can be much more accurate.   When the battery voltage of an inactive battery (virtually no charge or discharge) gets below these values, the <u>Remaining Capacity</u> is written to the corresponding percentage of the <u>Full Charge Capacity</u>. When the battery voltage of an inactive battery (virtually no charge or discharge) is above this value, <u>Remaining Capacity</u> is written to the corresponding percentage of <u>Full Charge Capacity</u>. Writing <u>Remaining Capacity</u> up is useful for a battery that has just had a full reset or is powered for the first time. Writing <u>Remaining Capacity</u> down is useful for a battery that has excessive inactivity. The bq2060 takes 2 voltage measurements separated by 20 seconds when the current is between 0 and –64 mA to qualify a midrange correction. There is a chance with a sudden heavy load drop off, that a false correction could be made before the battery voltage reaches steady state.
Normal Setting: These values are usually not used because there is a chance that there could be a false correction. However, if required, these values can be found by taking data on the battery cells and finding what the steady state voltage is for the cells at each of the percentage values. (See *Midrange Capacity Corrections* in the data sheet)

EDV0, EDV1, and EDV2 [0x72-0x7d]: See data sheet for description.

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