

Using I²C™ Communication with the bq275xx Series of Fuel Gauges

Jeff Mueller and Ming Yu

HVAL - Battery Management Solutions

ABSTRACT

This application report provides two examples that illustrate the bit-transaction details of I²C™ commands used with the Texas Instruments bq275xx series of battery fuel gauges. The first example shows how to implement a simple fuel gauge command that interrogates the gauge for reading cell voltage. The second example shows the added bit transitions required to access a gauge subcommand, specifically requesting firmware version information. Other I²C commands can be executed in the same manner, using the methodology of these two examples.

Example 1: Reading Cell Voltage

I²C commands are always initiated by the host with a START (S) bit sequence, immediately followed by a 7-bit I²C address with the most-significant bit (MSB) sent first. An eighth bit of 0 is sent by the host, indicating that the next byte to be sent will be a write to the gauge. For the bq275xx series of parts, these 8 bits form the byte 0xAA. Once the start bit and address byte have been successfully received by the gauge, the gauge responds with an ACKNOWLEDGE (A) bit sequence. The gauge is now ready for the subsequent command directive from the host. Further descriptions of the control bit sequences are presented in the Glossary of this document.

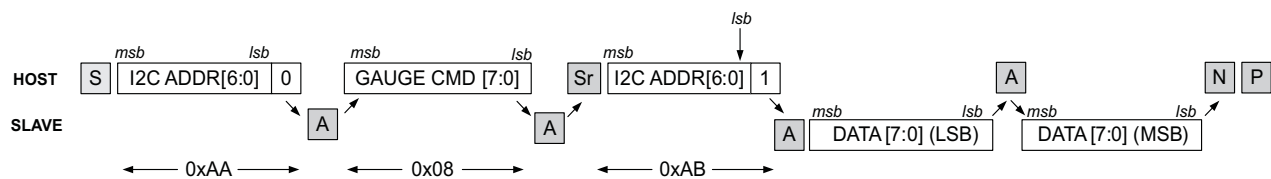


Figure 1. Simple I²C Command Transaction Sequence

After the successful transmission of the I²C address and read/write bit, the gauge command code can be sent by the host, in this case 0x08 for the *Voltage()* command. The command code is actually a base address location within the gauge and must not be confused with the I²C address for the gauge. Once this location is sent by the host, the gauge responds by sending an ACKNOWLEDGE bit sequence and then executing the corresponding command subroutine.

Even though two-byte locations are used for many gauge commands, writing to only the single byte is required to start gauge command processing. In this case, only 0x08 was written to the gauge, even though the command consists of the two consecutive command bytes 0x08 and 0x09. Most commands consist of two bytes, because the data is returned to these command locations and are also two bytes – the least-significant byte (LSB) is stored in the lower address (0x08), whereas the most-significant byte (MSB) is stored in the higher address (0x09). Like the I²C address data, the gauge command is sent MSB-first.

I²C is a trademark of Philips Corporation.

The host initiates the reading of the command data by sending a REPEAT START (Sr) bit sequence. This is immediately followed by the gauge's 7-bit I²C address plus the read-bit directive (1), which together create the byte 0xAB. The gauge responds with an ACKNOWLEDGE bit sequence, then takes control of the data bus. The first data byte (LSB) is stored at the gauge's 0x08 location and is strobed out by the gauge MSB-first. If the host responds with an ACKNOWLEDGE bit sequence, the gauge automatically increments the command location to 0x09, then strobes out the MSB stored there. If the host responds with a NO ACKNOWLEDGE (P or NACK) bit transmission, no further data is spooled to the host. The host terminates the present command packet by sending a STOP bit.

Example 2: Reading the Firmware Version

Reading the firmware version is an example of using the bq275xx's subcommands. Subcommands are unique, as they represent another level of depth into the gauge command structure. All subcommands are accessed through the gauge's paired command locations at 0x00 and 0x01. The subcommands are written LSB-first. Hence, to send the FW_VERSION subcommand (0x0002), the host writes 0x02 to command location 0x00 and 0x00 to 0x01. Again, I²C always writes the MSB first.

The format for address/command/data exchange between host and gauge is similar to the previous example and is shown in Figure 2. As in Example 1, the host initiates transmission with a START bit, followed by the gauge's I²C address and a WRITE bit of 0 (0xAA). The gauge responds with an ACKNOWLEDGE, then the host specifies the command address of 0x00. Again, the gauge responds with an ACKNOWLEDGE.

At this stage, the host must make additional writes to the gauge to set the subcommand code of 0x0002. Hence, the host sends the low byte of the subcommand (0x02). The gauge acknowledges. Then the host sends the high byte of the subcommand (0x00). The gauge issues a NO ACKNOWLEDGE. The host completes the writing process by issuing the STOP bit sequence. Now the gauge is prepared to return firmware information to the host.

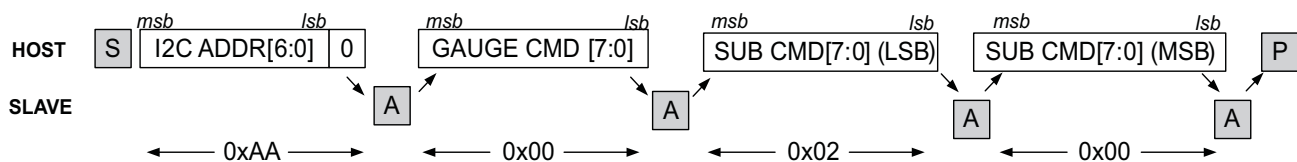


Figure 2. I²C Subcommand Initiation Sequence

To start the reading process, the host proceeds in a manner similar to Example 1, by issuing a START (S) bit sequence, immediately followed by the gauge's 7-bit I²C address and the eighth bit of 0 (altogether, 0xAA for the bq275xx series of parts). The gauge responds with an ACKNOWLEDGE bit sequence. The host sends the Control() command of 0x00, and the gauge acknowledges. The gauge address location has now been set.

To retrieve the data at 0x00 and 0x01, the host proceeds as before. It initiates the reading of the command data by sending a REPEATED START bit sequence. This is immediately followed by the gauge's 7-bit I²C address plus the read-bit directive (1), which together create the byte 0xAB. The gauge responds with an ACKNOWLEDGE bit sequence, then takes control of the data bus. The first data byte (LSB) is stored at the gauge's 0x00 location and is strobed out by the gauge MSB-first. If the host responds with an ACKNOWLEDGE bit sequence, the gauge automatically increments the command location to 0x01, then strobes out the MSB stored there. The host terminates the entire command process by sending a STOP bit.

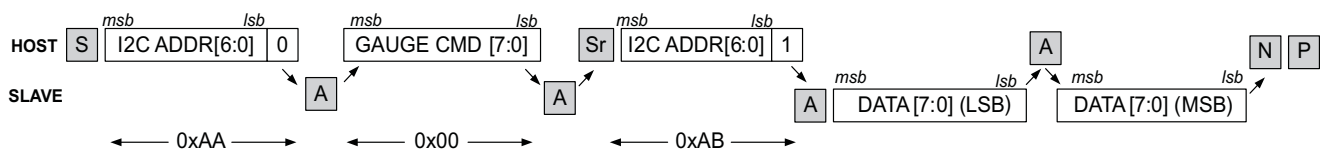


Figure 3. I²C Read Subcommand Sequence

Summary

In summary, remember the following critical aspects when implementing I²C communication between host and bq275xx gauges:

1. Handshaking between the host and gauge is performed by five bit sequences: START, REPEAT START, ACKNOWLEDGE, NO ACKNOWLEDGE, and STOP.
2. The I²C address and read/write bit is the first data item sent at the beginning of an I²C packet transmission. The I²C address must not be mistaken for the gauge's command address, the latter being the second data field to be transmitted by the host.
3. The host initiates all communication to the gauge and uses the WRITE directive at the end of the I²C address (total byte is 0xAA). When followed by the gauge command, this sets the command address from which the host writes or reads gauge data.
4. When reading or writing multiple bytes, the host should use the gauge's base-address auto-increment feature, rather than specifying the gauge address location each time a byte is transferred.
5. Whether command address or gauge data, all I²C data is transferred between host and gauge with the least-significant byte first.
6. All bytes transferred between host and gauge is transferred most-significant bit first.

Glossary: Control-Bit-Sequence Definitions

START: The START-bit sequence is a host-generated bit that begins the transmission of every packet. It is defined by a high-to-low transition on the SDA line, while the SCL line is high.

REPEAT START: The REPEAT-START-bit sequence is also a host-generated bit. It has the same characteristics as the START bit, but appears in the middle of a packet transmission. It tells the slave that the gauge command (address) has been specified and data is ready for transfer to/from that command address.

STOP: The STOP-bit sequence indicates the end of a transmission packet. It consists of a low-to-high transition of the SDA line, while the SCL line is high.

ACKNOWLEDGE: The ACKNOWLEDGE-bit sequence follows every (successful) data field sent between the host and gauge. The device receiving the data field is responsible for sending the bit sequence. The sequence consists of the SDA line being maintained in a low-status, while the SCL line is pulsed high.

NO ACKNOWLEDGE: The NO-ACKNOWLEDGE-bit sequence is frequently used by the host or gauge to indicate the last data byte has been transmitted/received, and that the host should terminate the packet with a STOP-bit sequence. It can also be used to indicate that an I²C device is not listening or capable of responding to the host at a given time. The sequence consists of the SDA line floating in a high state, while the SCL line is pulsed high.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
RF/IF and ZigBee® Solutions	www.ti.com/lprf

Applications

Audio	www.ti.com/audio
Automotive	www.ti.com/automotive
Broadband	www.ti.com/broadband
Digital Control	www.ti.com/digitalcontrol
Medical	www.ti.com/medical
Military	www.ti.com/military
Optical Networking	www.ti.com/opticalnetwork
Security	www.ti.com/security
Telephony	www.ti.com/telephony
Video & Imaging	www.ti.com/video
Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2009, Texas Instruments Incorporated