Application Report

SLUA975–October 2019

# BQ79606A-Q1 Daisy Chain Communication Timing


## ABSTRACT

This application report discusses vertical interface timing of the BQ79606A-Q1 in detail and explains why the device has the fastest communication time in the industry. First, it provides an overview on how the BQ79606A-Q1 can be connected in a daisy chain configuration. Then, it defines all the command and response types that the device can support. The bit and the byte structures are described and the timing of each is provided. Finally, the application report dives into the response time of the following:

- Broadcast read
- Broadcast write
- Single read
- Single write commands

This report also explains how to find the time calculation for each command. The calculations are supported with examples and lab results.


## Contents



## List of Figures



## List of Tables




Copyright © 2019, Texas Instruments Incorporated

## Trademarks

All trademarks are the property of their respective owners.

## 1 Introduction

The BQ79606A-Q1 is a voltage monitoring device for large battery stack systems. The device has the ability to measure single cell voltages as well as the voltage across any connector used to create larger battery stacks in a module. The BQ79606A-Q1 is designed with low voltage differential daisy chain communication, allowing for the connection of up to 64 devices (one base and 63 stacks). The vertical interface allows for fast communication between devices in the stack and the host.

## 2 BQ79606A-Q1 in Daisy Chain

The BQ79606A-Q1 can be used in multi drop or daisy chain configuration. The focus of this application report is on the daisy chain configuration. By definition, the device located near the host in daisy chain configuration is called either a base or a bridge. The address of this base or bridge is usually zero. The bridge is not monitoring any cells. The only purpose of the bridge is to communicate to the host and translate to send data to the stack. The base is used to monitor cells as well as communicate with the host and translate to send data to the stack. The devices following the base or the bridge are stack devices. The last device in the stack is called Top of Stack (TOS), which can be configured using the CONFIG register.

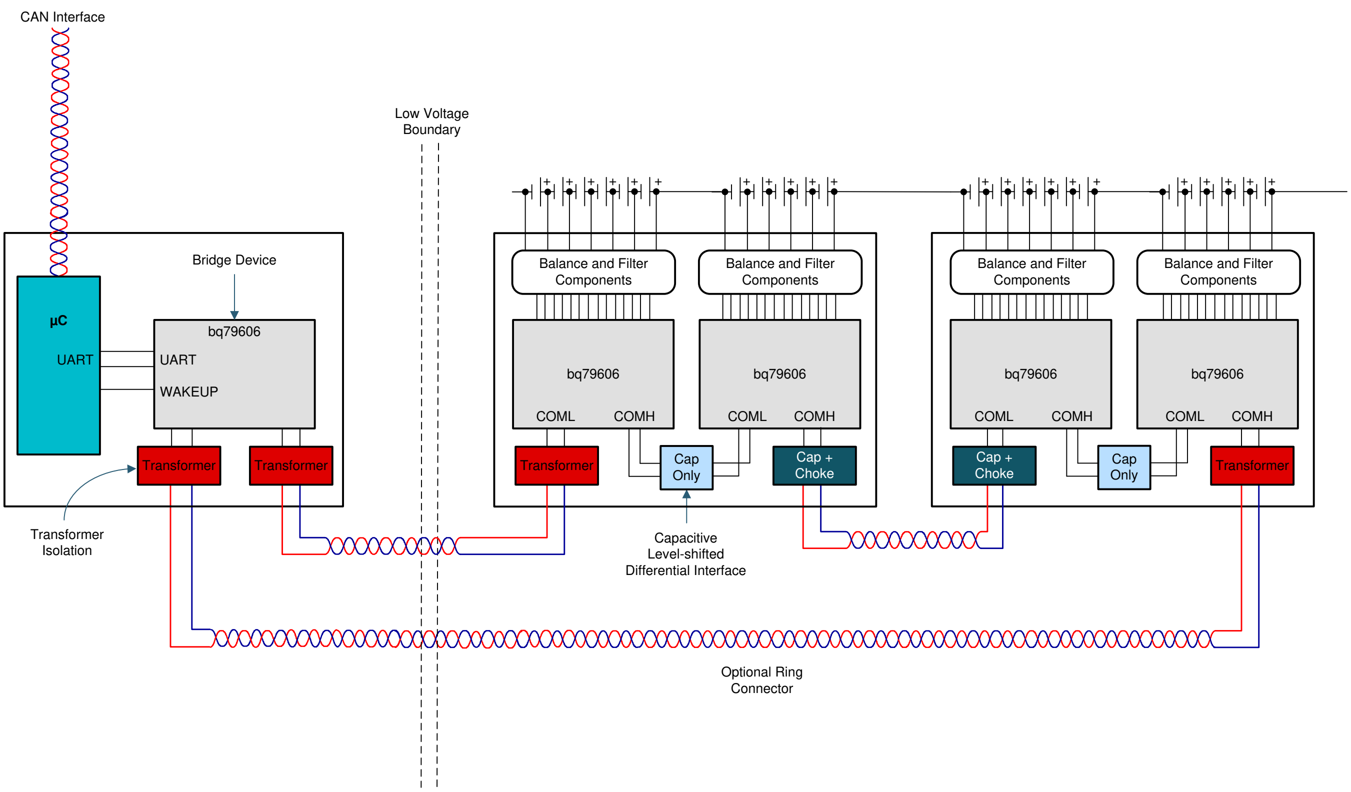


**Figure 1. Daisy Chain Configuration**

In bridge daisy chain configuration, the bridge device is needed to connect the stack devices to the host through UART. The bridge device is usually placed on a low voltage boundary and isolation components (such as a transformer) are used to connect it with stack devices setting on the high voltage as shown in Figure 1. The BQ79606A-Q1 can be stacked up to 64 devices. The base daisy chain configuration can also be used. The base device is integrated into the stack. It monitors the bottom cells in the stack and handles the communication bus with the host through UART. In this configuration, digital isolation is needed to isolate the base device located in the high voltage boundary with the host located in the low voltage boundary.



Copyright © 2019, Texas Instruments Incorporated

# 3 Vertical Communication Interface

## 3.1 Command and Response Definitions

The BQ79606A-Q1 has six command and responses as listed below:

- **Single Device Read:** This command is used to read a register or registers from a single device in the stack.
- **Single Device Write:** This command is used to write a register or registers to a single device in the stack.
- **Stack Read:** This command is used to read a register or registers from the stack devices only (does not include the base or bridge).
- **Stack Write:** This command is used to write a register or registers for the stack devices only (does not include the base or bridge).
- **Broadcast Read:** This command is used to read a register or registers for all of the devices in the stack including the base or bridge.
- **Broadcast Write:** This command is used to write a register or registers for all of the devices in the stack including the base or bridge.

## 3.2 Bit Definition and Timing

The BQ79606A-Q1 transmits bits using two communication pins (COM*P and COM*N). The two pins are driven in opposite directions using a TX driver. A zero is transmitted as a half bit period low followed by a half bit period high on the COM*P pin and a half bit period high followed by a half bit period low on the COM*N pin. The COM pins are driven to +5 V when high and to 0 V when low and settles to 2.5 V in idle state. The differential signal (COM*P – COM*N) settles at 0 V and switches between +5 V and -5 V.

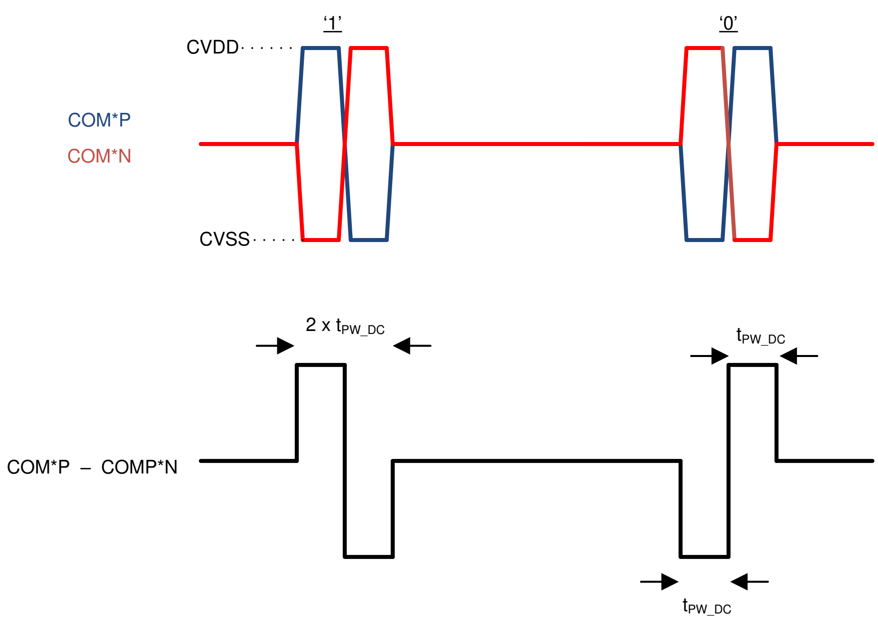


**Figure 2. Differential Signal**

A byte contains 13 bits:

- Half bit for Preamble
- Two bits for SYNC
- One bit for start of frame
- Eight bits for DATA
- One bit for byte error
- Half bit for Postamble



Copyright © 2019, Texas Instruments Incorporated

A bit period lasts for 500 ns. Nominal time to transmit 13 bits is 6.5 µs plus 0.5 µs for bus short and 1.375 µs for bus idle periods. This adds up to 8.375 µs to transmit a full byte. The BQ79606A-Q1 supports four baud rates:

- 125 Kbps
- 250 Kbps
- 500 kbps
- 1 Mbps

Nominal response byte-to-byte delay is fixed by UART baud rate. Estimated delay is around 1.925 µs for 1 Mbps. With this baud rate, it takes 10.3 µs for a full byte to be transmitted. The response byte-to-byte delay increases as the baud rate decreases. For 500 Kbps, the byte time with the delay is 20.3 µs and that increases to 81.2 µs for 125 Kbps.

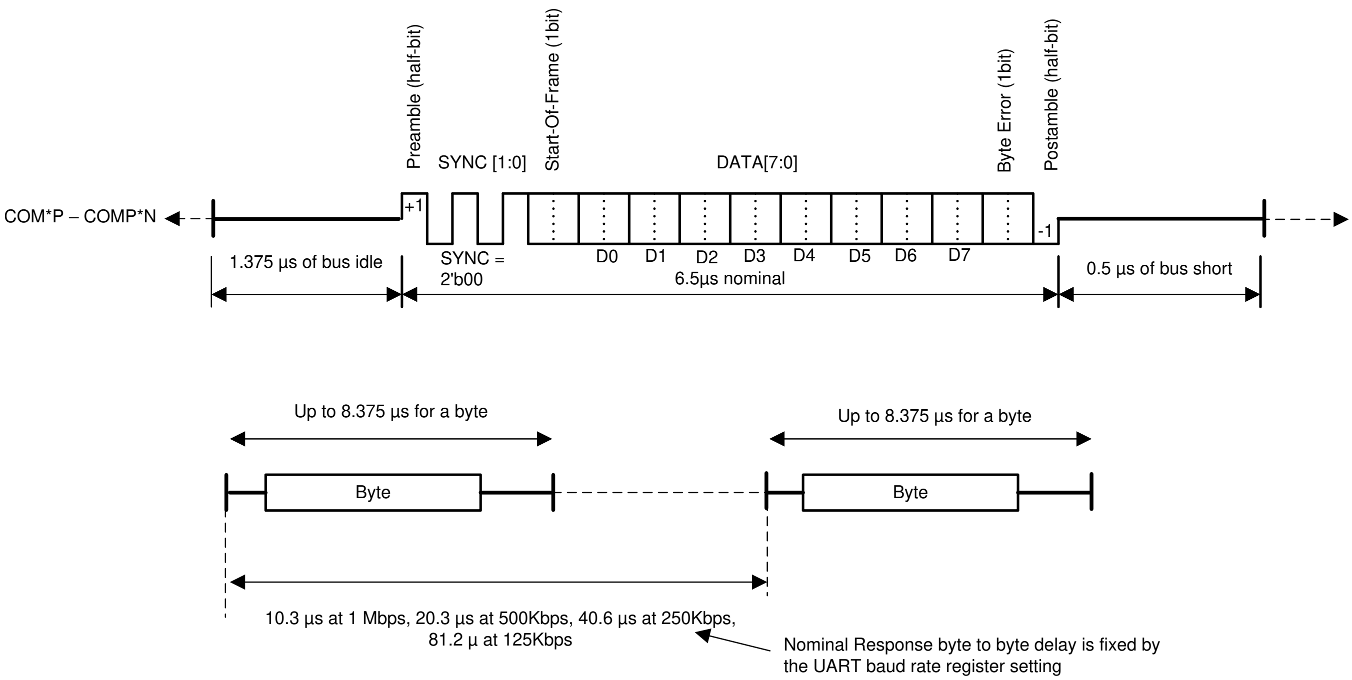


**Figure 3. Bite and Byte Structure**

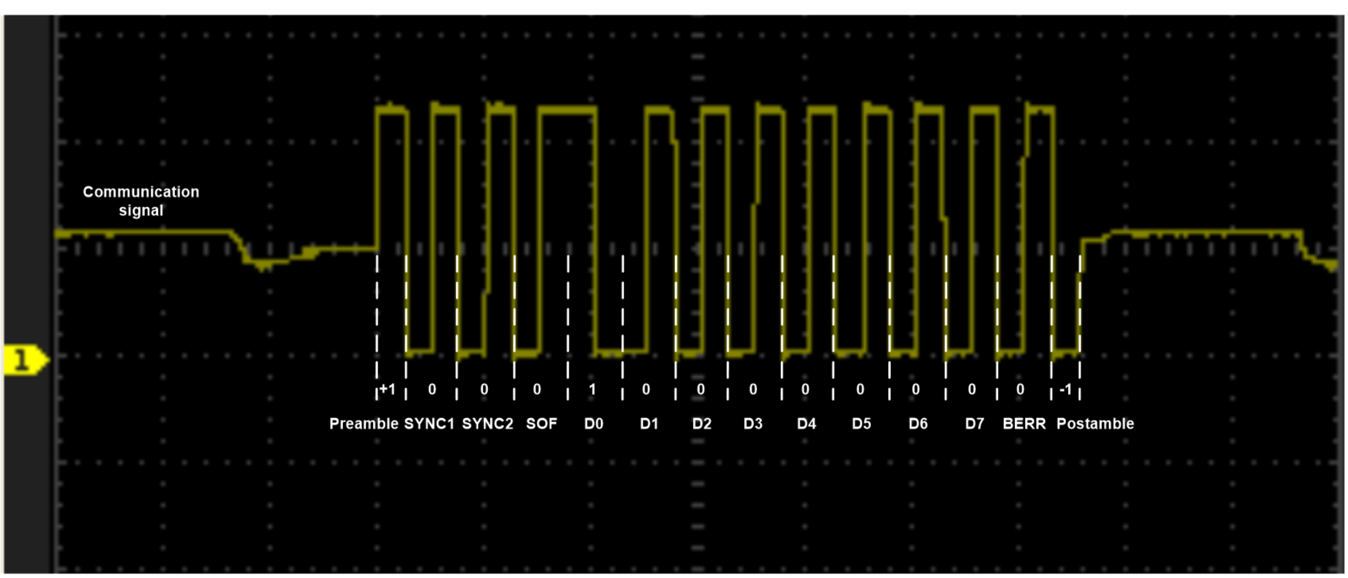


**Figure 4. Example Scope Plot of a Byte Structure**



Copyright © 2019, Texas Instruments Incorporated

# 4 Daisy Chain Response Time

The response time of the BQ79606A-Q1 to a command depends on the type of the command itself. This section discusses the time required for single and broadcast reads and single and broadcast writes. The stack read and write is similar to broadcast with the exception that the base or bridge does not respond to read or write. The focus of this application report is the fastest baud rate of 1 Mbps. Once the concept is understood, similar steps can be used to calculate other baud rates using the timing provided above.

## *4.1 Single Command Read*

### 4.1.1 Command Frame

A single command as defined earlier is used to read up to 128 bytes from any specified device in the stack including the base or bridge. The single device read command consists of seven bytes:

1. Command initialization byte
2. Device address byte
3. Two bytes of register address to start reading from
4. Data bytes to specify the number of registers to read
5. Two bytes of CRC

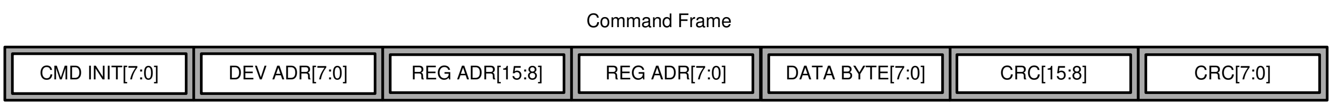


**Figure 5. Single Read Command Frame**

As discussed earlier, the length of each byte for 1 Mbps is 10.3 µs including the response byte to byte delay. The UART re-clock time for the bridge or base device is 12 µs typical. The re-clock time between each stack device is 3 µs typical. Based on that, it takes the single command 10.3 µs × 7 (for seven bytes) + 12 µs of re-clocking (UART re-clock) to read to reach the base or bridge device. That totals to 84.1 µs. As the command travels north through the stack devices, it adds the 3 µs re-clocking time for each device in the stack. An example is a stack of 16 devices + one bridge (total of 17 devices). The command takes 10.3 µs × 7 (7 byte of the command) + 12 µs (UART re-clocking) + 3 × 16 devices = 132.1 µs typical.

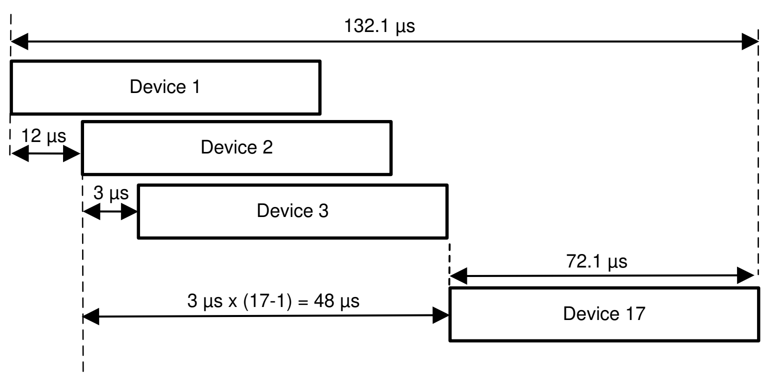


**Figure 6. Single Read Command Frame Time**

### 4.1.2 Response Frame

Once the single command read is received, the device that matches the address of the command has to respond to it. All other devices do not respond to the single read command. The response time depends on the location of the device in the stack as well as how many registers are requested for read. The baud rate matters too. In this example, only 1 Mbps is considered. The response frame of a single device read consists of six bytes plus the data bytes. The response starts with the following:

- One byte of response initialization


Copyright © 2019, Texas Instruments Incorporated

- One byte of device address
- Two bytes of register address
- Data (can be as long as one byte to 128 bytes, depending on the command request)
- Two CRC bytes

Response Frame

| RESP INIT[7:0] | DEV ADD[7:0] | STRT REG ADD[15:8] | STRT REG ADD[7:0] | DATA MSB[7:0] | . . . | DATA LSB[7:0] | CRC[15:8] | CRC[7:0] |
|---|---|---|---|---|---|---|---|---|

**Figure 7. Single Read Response Frame**

The response time can be calculated as follows:

1. Calculate the time of the response bytes 6 × 10.3 µs (six bytes) + 10.3 × Data bytes (can be from one to 128 bytes).
2. Calculate the time it takes for the byte to propagate all the way down to the host.

Again, it takes 3 µs re-clocking from device to device and 12 µs to the host. Following the example above, for 16 devices plus the bridge and to read two registers from the last device, the byte response is 6 × 10.3 + 10.3 × 2 = 82.4 µs. It will take 16 × 3 µs for stack re-clocking plus the 12 µs for the UART re-clocking. This totals to 142.4 µs.

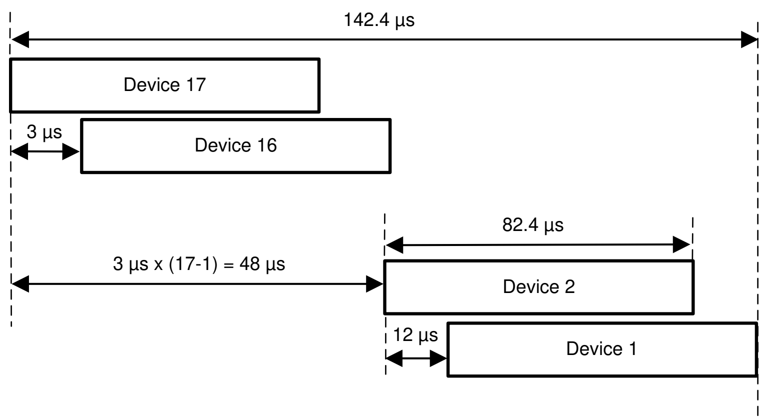


**Figure 8. Single Read Response Frame Time**

## 4.2 *Broadcast Command Read*

### 4.2.1 Command Frame

Broadcast command read as defined earlier is used to read up to 128 bytes from all devices in the stack including the base or bridge. The command consists of six bytes starting with the command initialization byte followed with two bytes of register address to start reading from, data bytes that specify how many registers to read, and two bytes of CRC.

Command Frame

| CMD INIT[7:0] | REG ADR[15:8] | REG ADR[7:0] | DATA BYTE[7:0] | CRC[15:8] | CRC[7:0] |
|---|---|---|---|---|---|

**Figure 9. Broadcast Read Command Frame**



Copyright © 2019, Texas Instruments Incorporated

Similar to the single device read case, the length of each byte for 1 Mbps is 10.3 µs (that includes the response byte to byte delay). The UART re-clock time for the bridge or base device is 12 µs typical. The re-clock time between each stack device is 3 µs typical. For the broadcast command read to reach the base or bridge device takes 10.3 µs × 6 + 12 µs of re-clocking (UART re-clock). As the command travels north through the stack devices, it adds the 3 µs re-clocking time for each device in the stack. For example, a stack of 16 devices + one bridge (total of 17 devices). The command takes 10.3 µs × 6 (six byte of the command) + 12 µs (UART re-clocking) + 3 × 16 devices = 121.8 µs typical.

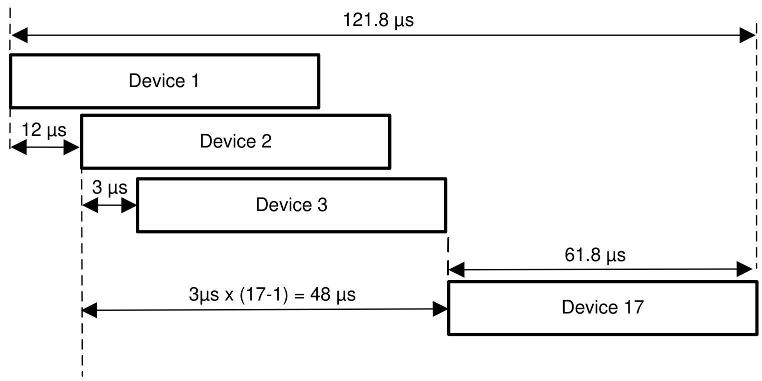


**Figure 10. Broadcast Read Command Frame Time**

### 4.2.2 Response Frame

Once the broadcast command read is sent, every device in the stack waits for the device above it to respond first before it can forward the received data and its own response. The top of stack device responds first to the command. The bottom device forwards all the data of all the devices in the stack before forwarding its data. The response time depends on how many devices in the stack as well as how many bytes are requested for read. In this example, only 1 Mbps is considered. The response frame of a broadcast device read consists of six bytes plus the data bytes itself for each device. The response starts with the following:

- One byte of response initialization
- One byte of device address
- Two bytes of register address
- Data (can be as from one byte to 128 bytes depending on the command request)
- Two CRC bytes

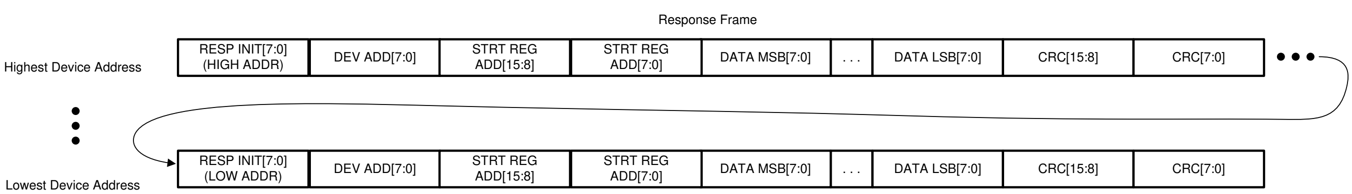


**Figure 11. Broadcast Read Response Frame**

The response time can be calculated as follows:

1. Calculate the time of the response bytes for each device 6 × 10.3 µs (six bytes) + 10.3 × Data bytes (can be from 1 to 128 bytes).
2. Multiply that time with the number of response that the device has to forward downstream.
3. Calculate the time it takes for the byte to propagate all the way down to the host.

Again, it takes 3 µs re-clocking from device to device and 12 µs to the host. Following the previous example, for 16 devices plus bridge and to read two registers from all device, the byte response is 6 × 10.3 + 10.3 × 2 = 82.4 µs. There is total of 17 devices, so it takes 17 × 82.4 µs or 1400.8 µs. It takes 16 × 3 µs for stack re-clocking plus the 12 µs for the UART re-clocking. This totals to 1460.8 µs.


Copyright © 2019, Texas Instruments Incorporated

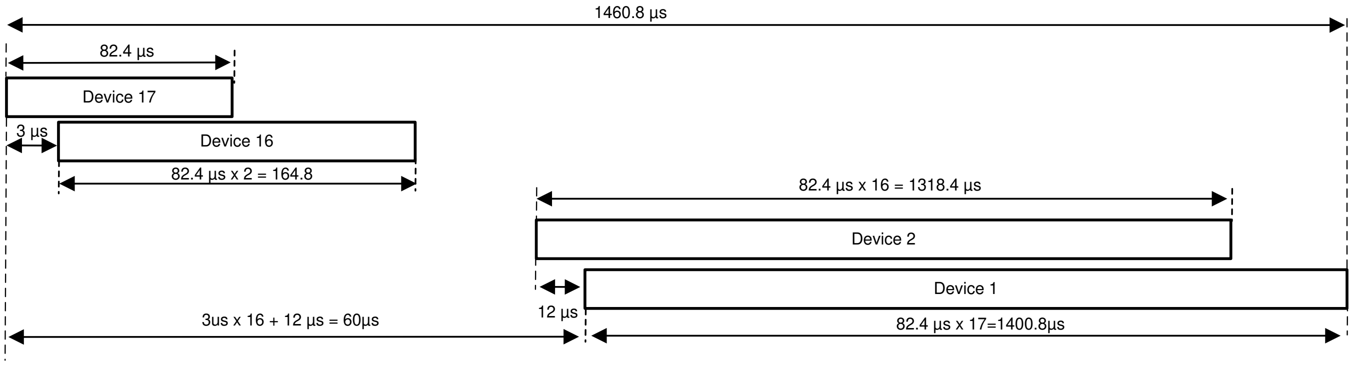


**Figure 12. Broadcast Read Response Frame Time**

## *4.3 Single Command Write*

Single command write, as defined earlier, is used to write up to eight bytes to any specified device in the stack including the base or bridge. The single device write command consists of six bytes plus up to eight bytes of data to write. It starts with command initialization byte followed by the following:

- Device address byte
- Two bytes of register address to start writing to
- Data bytes (up to eight bytes)
- Two bytes of CRC

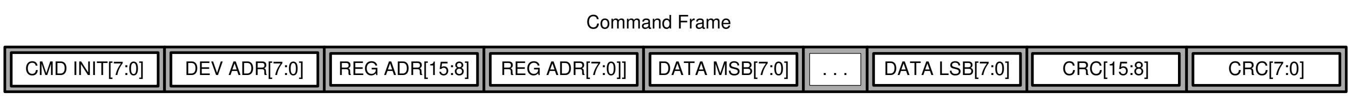


**Figure 13. Single Write Command Frame**

The length of each byte for 1 Mbps is 10.3 µs (that includes the response byte to byte delay). The re-clock time for the bridge or base device is 12 µs typical. The re-clock time between each stack device is 3 µs typical. For example, when you write eight bytes to 17 devices, the single write command to reach all 17 devices (a stack of 16 devices plus one bridge) must take 10.3 µs × 6 (six bytes of the command) + 12 µs (UART re-clocking) + 3 × 16 devices + 10.3 × 8 bytes to write. This totals to = 204.2 µs.

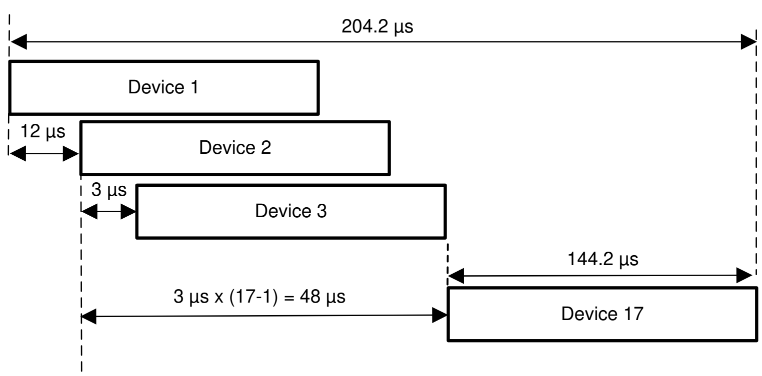


**Figure 14. Single Write Command Frame Time**



Copyright © 2019, Texas Instruments Incorporated

## 4.4 Broadcast Command Write

Broadcast command write is used to write up to eight bytes to all devices in the stack including the base or bridge. The command consists offive bytes plus up to eight bytes of data to write. It starts with the command initialization byte followed two bytes of register address to start writing to and data bytes (up to eight bytes).

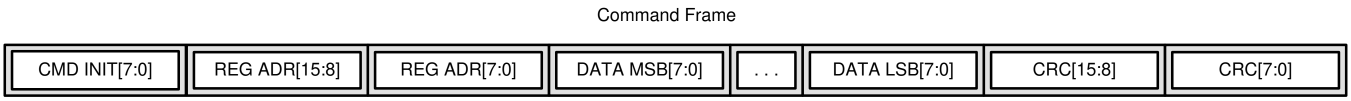


**Figure 15. Broadcast Write Command Frame**

The length of each byte for 1 Mbps is 10.3 µs (that includes the response byte to byte delay). The re-clock time for the bridge or base device is 12 µs typical. The re-clock time between each stack device is 3 µs typical. For example, when you write eight bytes to 17 devices, the broadcast write command to reach all 17 devices (a stack of 16 devices plus one bridge) must take 10.3 µs × 5 (five byte of the command) + 12 µs (UART re-clocking) + 3 × 16 devices + 10.3 × 8 bytes to write. This totals to 193.9 µs.

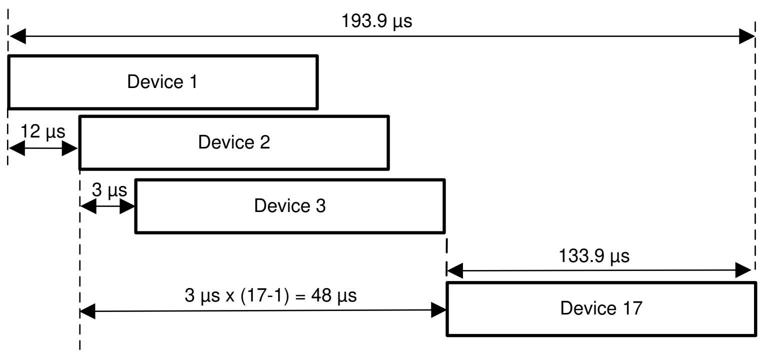


**Figure 16. Broadcast Write Command Frame Time**

## 4.5 Example

In this example, three devices are stacked up in daisy chain as shown in Figure 17. A broadcast read command to read all the ADC voltages measurements for all three devices is sent (12 registers for each device). Every device must respond to the command and send 12 bytes of ADC measurements to the host.

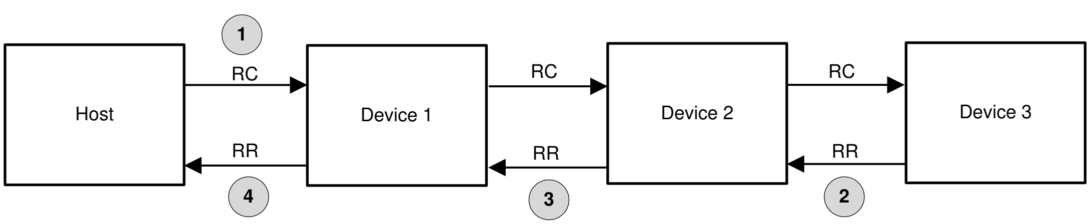


**Figure 17. Lab Set Up**

Figure 18 shows the lab results for this command. Initially, the host sent the command that is captured in location 1. After 79.8 µs, device three received the command. None of the devices responded until device three starts responding to the command by sending 12 bytes of voltage readings. Device two received all the bytes from device three and forwarded them downstream to device one, including its response (as shown in location two). Finally, device one forwarded upstream devices data plus 12 bytes of its reading to the host (as shown in location three). Device-to-device re-clock time is only 3 µs typical. By the end, the host received all the responses from all three devices. This command takes 79.8 µs to reach all devices and 574.2 µs for the response to reach the host, so only 654 µs is needed to read all ADC voltages.


Copyright © 2019, Texas Instruments Incorporated

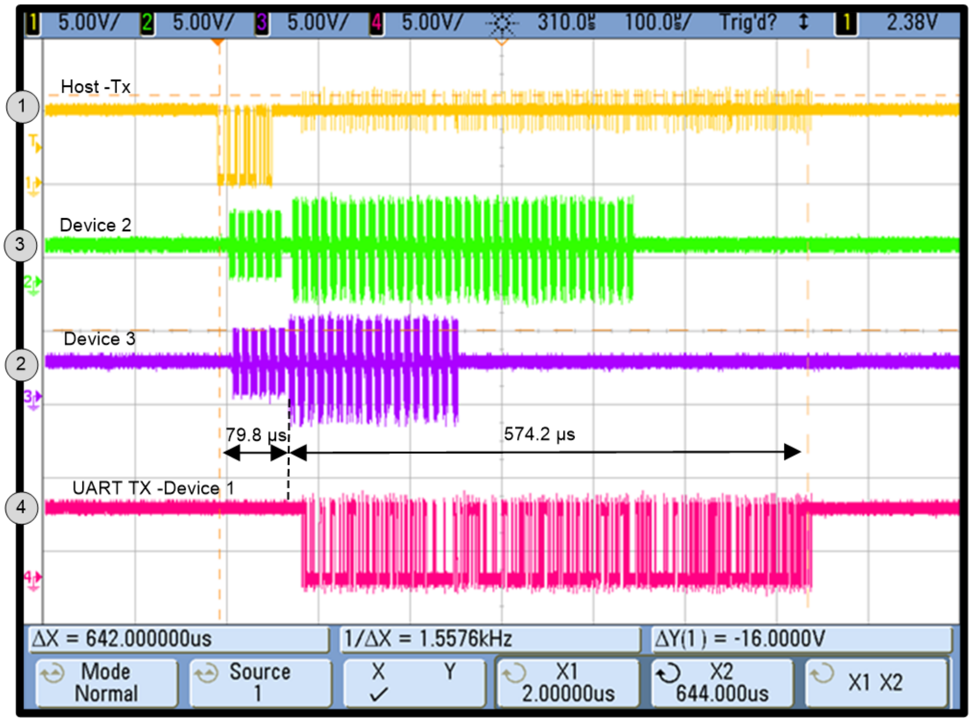


**Figure 18. Test Results for Broadcast Reading Command**

## 5 Summary

The BQ79606A1-Q1 has the fastest communication time in the industry. It can read 96 cell voltages in less than 3 ms. This is only possible due to the vertical interface scheme used in this device. Each cell consists of two bytes of data, which is 192 bytes transferred to the host in record time. The devices are stacked in daisy chain configuration. A bridge or base is used to communicate to the host using UART. The daisy chain is bi-directional and half duplex, and therefore, has a transmitter (TX) and receiver (RX) on both interfaces (COMH and COML). For each direction, it uses two pins that are driven in opposite direction to generate a differential signal of 500 ns for each bit. Each byte consists of 13 bits and with delays a byte 10.3 µs. The device uses six commands structure to communicate and provides information back to the host: single device read and write, broadcast read and write, and stack read and writes.

The communication speed of the BQ79606A-Q1 is important to report information to the host, such as voltage and temperature measurements, in timely manner. This is useful for synchronization with other measurements in the system such as current. Time is as important as accuracy when it comes to SOC and SOH estimations. Fault Tolerate Time Interval (FTTI) is also dependent on how fast the commands are transmitted and how fast the faults and responses are reported back to the host. With this communication speed, the BQ79606A-Q1 can achieve 100 ms FTTI time.



Copyright © 2019, Texas Instruments Incorporated

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2022, Texas Instruments Incorporated