TI Designs

Optimizing Efficiency by Handshaking Adjustable Adapters and Battery Chargers Reference Design

Description

This TI Design is a software implementation that uses an integrated programmable digital-to-analog driver to interface with an adjustable, high-voltage dedicated charging port (HVDCP). This solution allows for charging efficiency optimization (critical for fast charging applications) by modifying the output voltage of the adapter according to the charge current requirements.

Resources

TIDA-03029	Design Folder
BQ25890H	Product Folder
MSP430F5529	Product Folder

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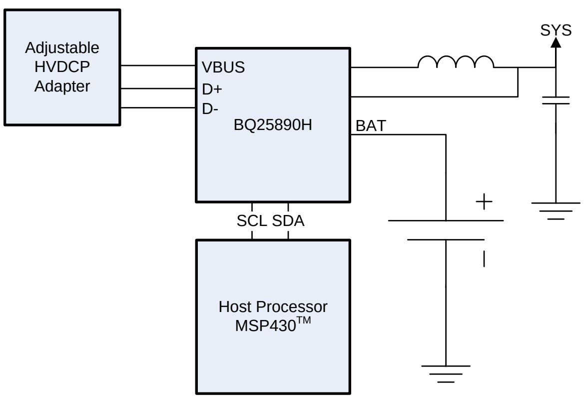
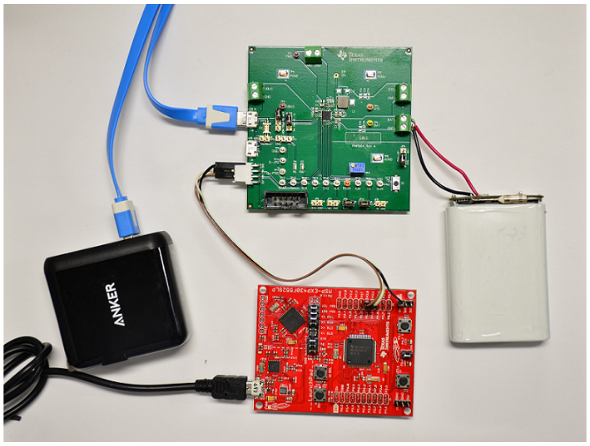
Features

- Integrated Programmable DAC Driver (HIZ, 0 V, 0.6 V, 1.2 V, 2 V, 2.7 V, and 3.3 V) to Emulate USB Nonstandard Adapters
- Charge Efficiency of 93% at 2 A and 91% at 3 A
- High Input Voltage Operation Range From 3.9 V to 14 V to Enable High Power and Fast Charging Application
- Input Current Limit From 100 mA to 3.25 A, With 50 mA Resolution to Support High-Voltage Adapters

Applications

- Smart Phone
- Tablet PC
- Portable Internet Devices





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1 System Overview

1.1 System Description

This TI Design showcases an implementation for handshaking between an adjustable HVDCP adapter and the BQ25890H device running software on a MSP430F5529. This single-cell fast charger incorporates a programmable D+ and D– output driver in addition to its input current detection scheme that provides the user with the flexibility required to control adjustable adapters. By fine tuning the output of the adapter, users can achieve efficiency optimization that translates to better overall thermal performance in fast charging applications.

1.2 Key System Specifications

The operating input range of the BQ25890Hs is 3.9 V to 14 V, enabling the use of HVDCP adapters for fast charging applications. This software allows the system to charge a Li-ion battery at optimal efficiency, based on a constant, fast charging setting. Fast-charge current settings of 2 A and 3 A were used for this design, providing a charge efficiency of approximately 93% and 91%, respectively.

1.3 Block Diagram

Figure 1 shows the block diagram of the TIDA-03029.

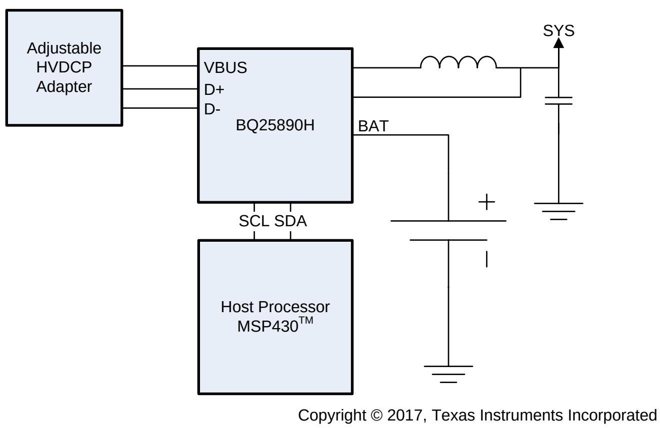

Figure 1. Block Diagram of TIDA-03029

1.4 Highlighted Products

1.4.1 BQ25890H

The BQ25890H device has the following key features.

- High efficiency, 5-A, 1.5-MHz switch mode buck charge
  - 93% charge efficiency at 2 A and 91% charge efficiency at 3 A charge current
  - Optimized for high-voltage input (9 V and 12 V)
- Single input to support USB input and adjustable high-voltage adapters
  - Support 3.9-V to 14-V input voltage range
  - Input current limit (100 mA to 3.25 A with 50-mA resolution) to support USB2.0, USB3.0 standard, and high-voltage adapters
  - Maximum power tracking by input voltage limit up-to 14 V for a wide range of adapters
  - Autodetect USB SDP, CDP, DCP, and nonstandard adapters
- Narrow VDC (NVDC) power-path management
  - Instant-on works with no battery or deeply discharged battery
  - Ideal diode operation in battery supplement mode

- BATFET control to support ship mode, wakeup, and full-system reset
- High regulation accuracy
  - ±0.5% charge voltage regulation
  - ±5% charge current regulation
  - ±7.5% input current regulation

1.4.2 MSP430F5529

The MSP430F5529 device has the following key features.

- Low supply voltage range
  - 3.6 V down to 1.8 V
- Ultra-low power consumption
  - Active mode (AM):
    - All system clocks active:
      - 290 µA and MHz at 8 MHz, 3.0 V, flash program execution (typical)
      - 150 µA and MHz at 8 MHz, 3.0 V, RAM program execution (typical)
- Unified clock system
  - FLL control loop for frequency stabilization
  - Low-power low-frequency internal clock source (VLO)
  - Low-frequency trimmed internal reference source (REFO)
  - 32-kHz watch crystals (XT1)
  - High-frequency crystals up to 32 MHz (XT2)
- Two universal serial communication interfaces

2 Software Theory

The BQ25890H allows each of the D+ and D– lines to be controlled independently to output one of the preset voltage levels (0 V, 0.6 V, 1.2 V, 2.0 V, 2.7 V, 3.3 V, and HIZ). Each line can be set to one of these presets through I^2C; this allows the user to implement a handshaking protocol between the charger and an adapter with an interface that allows adjusting the voltage, such as the CHY100 and CHY103 interfaces.

With the ability of controlling the adapter voltage, the user can fine tune the operating point of the charger to ensure high efficiency during charging. In addition, higher voltages allow efficient high charge currents. As a byproduct charge time is decreased, making it even more appealing for high capacity cells.

Register 01 of the BQ25890H device includes the bits required to control the D+ and D– output driver. The host processor can communicate through I^2C to the charger, and modify this register to emulate the relevant adapter interface. This register also includes the bits to enable detection of HVDCP adapters during the input current detection.

2.1 *Software Control Loop*

The BQ25890H device provides operating information based on its integrated control loops. The MSP430™ uses this information to control the D+ and D– lines through the charger to let the adapter know what voltage to provide. If an HVDCP adapter is detected (during charging) the host monitors the status of the INDPM loop. For a fixed charge current setting, the host will instruct the adapter by means of the D+ and D– output driver of the charger to decrease the voltage just before the device enters INDPM; this way, the adapter provides the necessary power to the charger while operating with higher efficiency that a fixed output adapter. Figure 2 and Figure 3 show the main control loop and handshaking flowchart, respectively..

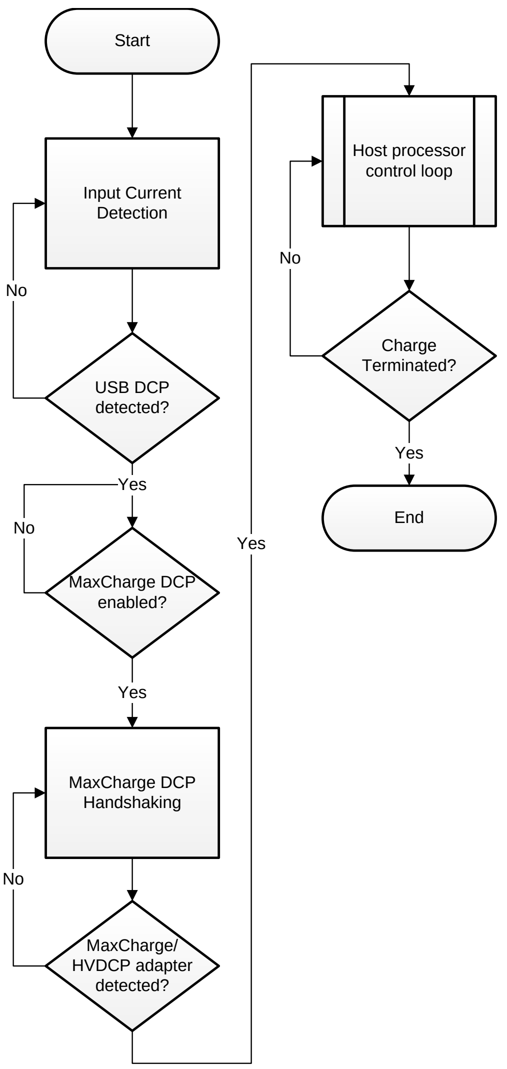

Figure 2. Main Control Loop

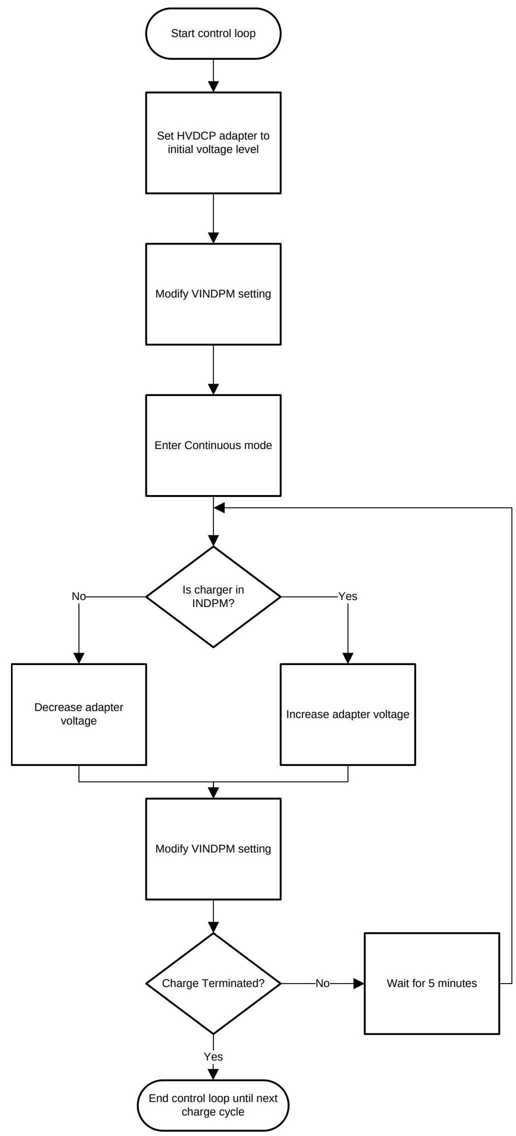

Figure 3. Handshaking Flowchart

2.2 Example of Controlling a High Voltage Adjustable Adapter using the D+ and D– Driver

For this exercise, assume the adapter we want to interface with has the following specifications:

- Voltage range: 5 V to 8 V
- Current rating: 1.5 A
- Adjustable voltage with 500 mV steps
- Interfaces through D+ and D– lines

Table 1. Example HVDCP Adapter D+ and D– Thresholds

D+ (V)	D– (V)	Mode Selected
0.6	1.2	Set output to 5 V
0.6	2.7	Set output to 8 V
0.6	0.6	Adjustable mode

In adjustable mode, increasing the voltage a step on the D+ from 0.6 V to 3.3 V with a duration of at least 2 ms forces the output to increase by 500 mV (ΔV). To decrease the voltage the same principle applies, but on the D– line.

Several functions can be implemented to modify register 01 to control the D+ and D– lines. These functions can be tailored to work with multiple adjustable adapters.

- **setDPlus()** – sets the D+ line voltage to one of the presets (see Figure 4).
- **setDMinus()** – sets the D– line voltage to one of the presets (see Figure 5).
- **setAdapterVoltage()** – instructs the adapter to set the output voltage (see Figure 6).
- **increaseVoltage()** – instructs the adapter to increase the voltage by one step (see Figure 7).
- **decreaseVoltage()** – instructs the adapter to decrease the voltage by one step.

```
void setDPlus(voltageLevel){
        parse voltageLevel;
        set/clear REG01[7:5];
}
```

Figure 4. setDPlus()

```
void setDMinus(voltageLevel){
        parse voltageLevel;
        set/clear REG01[4:2];
}
```

Figure 5. setDMinus()

For example, if users want to set the example adapter to 8 V, users could implement setAdapterVoltage() using a function similar to Figure 6.

```
void setAdapterVoltage(DP,DM)
{
        setDPlus(DP);
        setDMinus(DM);
}

Function call:
```

Figure 6. setAdapterVoltage()

To use the voltage steps to increase the voltage to 6 V, an example implementation could be similar to Figure 7.

```
void increaseVoltage(){
        setAdapterVoltage(0.6, 0.6); // Enter
adjustable mode

        setDPlus(3.3); //Modify D+
        wait_ms(2);   // Duration of step
        setDPlus(0.6); //Revert to original level
}

//Increase to 6V

setAdapterVoltage(0.6, 1.2); // Set adapter to 5V

int i = 0;

for(; i <= 1; i++){
        increaseVoltage(); //2 steps, 500mV each
}
```

Figure 7. increaseVoltage()

Figure 8 represents an example of how this behavior would look after implementing the increase or decrease functions, where Dx_y represents the specific D+ and D– thresholds based on the protocol used and ΔV, where ΔV is the resolution of the output voltage steps.

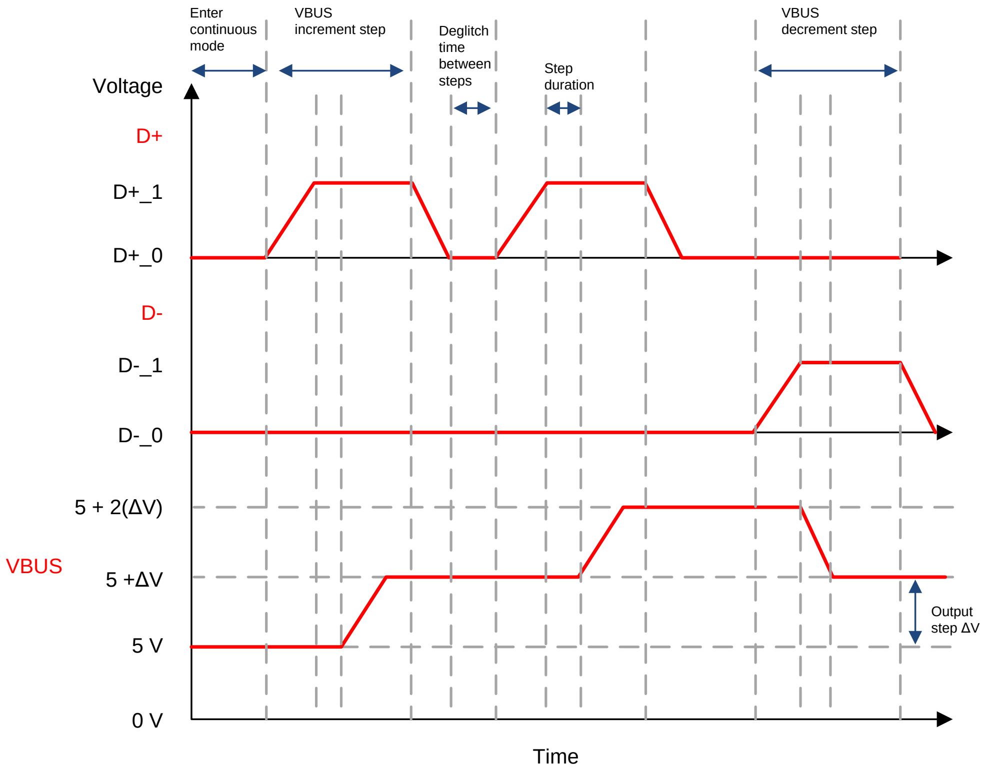

Figure 8. Adjustable Adapter-Output Steps

3 Getting Started Hardware and Software

3.1 Hardware

For software evaluation purposes, a BQ25890EVM-664 and MSP430FF2259 Launchpad™ will be used. Use the following instructions to set up the devices.

1. Replace the IC on the BQ25890EVM-664 with a BQ25890H device.
2. Connect the SDA, SCL, and GND lines of the charger board on connector J7 to the following pins on the Launchpad:
   - SDA – P3.0
   - SCL – P3.1
   - GND – any GND on the Launchpad
3. Connect a Li-ion cell or a bipolar power supply on port J4.
4. Move the jumper on header JP2 between D– and D–/PG.
5. Remove the jumper on JP1.
6. Move the switches on S2 towards JP5.
7. Connect the HVDCP adapter to J5.

3.2 Software

Use the following instructions for software setup.

1. Install the latest version of Code Composer Studio™ (CCS) from ti.com.
2. Download the .zip file containing the sample software and use the import wizard of CCS to import the files.
3. Connect the Launchpad to the computer using the included USB cable.
4. Follow the instructions at *Printf support for MSP430 CCSTUDIO compiler* to set up the CCS environment to support printf() to see the debug messages of the software.
5. Build and run the code on the Launchpad.

4 Testing and Results

Figure 9 presents efficiency values for common charge current thresholds using an adjustable HVDCP adapter and the BQ25890H device. Figure 9 showcases how the software control loop fine-tuned the charging efficiency using an adjustable voltage through the D+ and D– interface. In this example, users can see that the efficiency peaked around VBUS = 6.4 V. Additional robustness can be added to the software of the application to account for varying charger currents and as the battery voltage changes during operation.

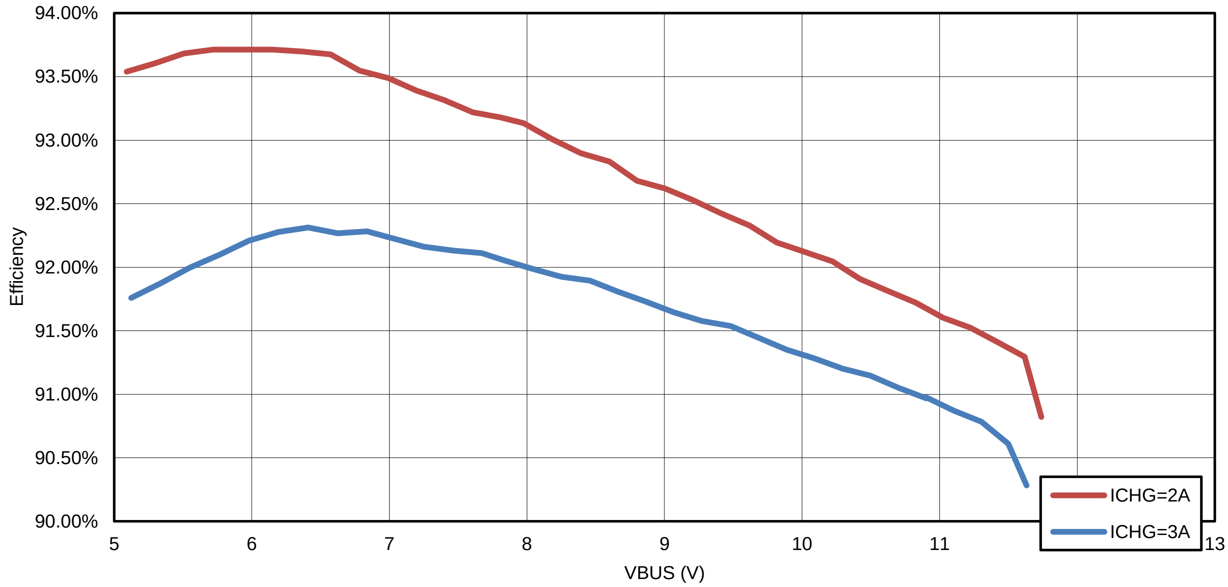

Figure 9. BQ25890H Charge Efficiency Using Anker QC3.0 Adapter

5 Design Files

5.1 Schematics

To download the schematics, see the design files at TIDA-03029.

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-03029.

6 Software Files

To download the software files, see the design files at TIDA-03029.

7 Related Documentation

1. Texas Instruments, *Handshaking Between Adjustable HVDCP Adapters and Battery Chargers*, SLUA786

7.1 Trademarks

8 About the Author

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