
Using the MCP1643 Constant Current LED Driver for Low Start-Up Voltage Applications

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INTRODUCTION

This document aims to help engineers design different constant current DC-DC boost converters for multiple LEDs or a high-power LED using the MCP1643 constant current step-up regulator.

MCP1643 DEVICE SHORT OVERVIEW

The MCP1643 is a compact, high-efficiency, fixed frequency, step-up DC-DC converter optimized as an LED constant current generator. This product provides an easy-to-use power supply solution, with a minimum number of external components for applications powered by one-cell and two-cell alkaline, NiCd, and NiMH batteries.

The MCP1643 is a pulse-width modulation-only device that operates at a fixed 1 MHz switching frequency. The device has an operating input voltage range from 0.5V to 5V ($V_{IN} < V_{LED}$) with 0.65V start-up voltage.

The internal feedback voltage is set to 120 mV for low-power dissipation when sensing and regulating LED current. A single resistor sets the constant current output that drives the LED load. The device features an output overvoltage protection that limits the output voltage to 5.0V (typical) in case the LED fails or the output load is disconnected.

The LED will either be turned OFF or ON using the Enable input. A True Output Load Disconnect mode provides input-to-output isolation while in shutdown ($EN = GND$) by removing the normal boost regulator diode path from input to output. Shutdown state consumes 1.2 μA from input at room temperature. The LED can be turned ON and OFF with a variable duty cycle pulse-width modulation (PWM) signal applied to the EN pin for dimming applications. The device also features a thermal shutdown at +150°C with 25°C hysteresis.

MCP1643 is available in 8-lead MSOP and 8-lead 2 x 3 mm TDFN packages.

Device Key Features

- 1.8A Typical Peak Input Current Limit
- Up to 550 mA LED Load Current ($V_{IN} > 2.2V$)
- Low Start-up Voltage: 0.65V
- Low Operating Input Voltage: Down to 0.5V
- Maximum Input Voltage: $V_{LED} < 5.0V$
- Maximum Output Voltage:
 - 5.0V
 - Overvoltage Protection
- Low Reference Voltage:
 - $V_{FB} = 120$ mV
 - Minimal Power Loss on Sense Resistor
- Pulse-Width Modulation Mode Operation (fixed 1 MHz)
- Internal Synchronous Rectifier
- Internal Compensation
- Inrush Current Limiting
- Internal Soft-start 240 μs (typical)
- Shutdown ($EN = GND$):
 - True Load Disconnect
 - Dimming Control by Variable Duty Cycle
 - Shutdown Current: 1.2 μA (typical)
- Overtemperature Protection

TYPICAL APPLICATIONS

The MCP1643 can be integrated in a variety of applications starting from the basic one-LED driver, powered from one-cell alkaline or NiMH/NiCd, to multiple infrared LEDs, white LEDs and RGB LEDs.

Figure 1 describes the use of the MCP1643 as a simple DC-DC current source step-up (boost) converter that uses a resistor (R_{SET}) to set the desired current.

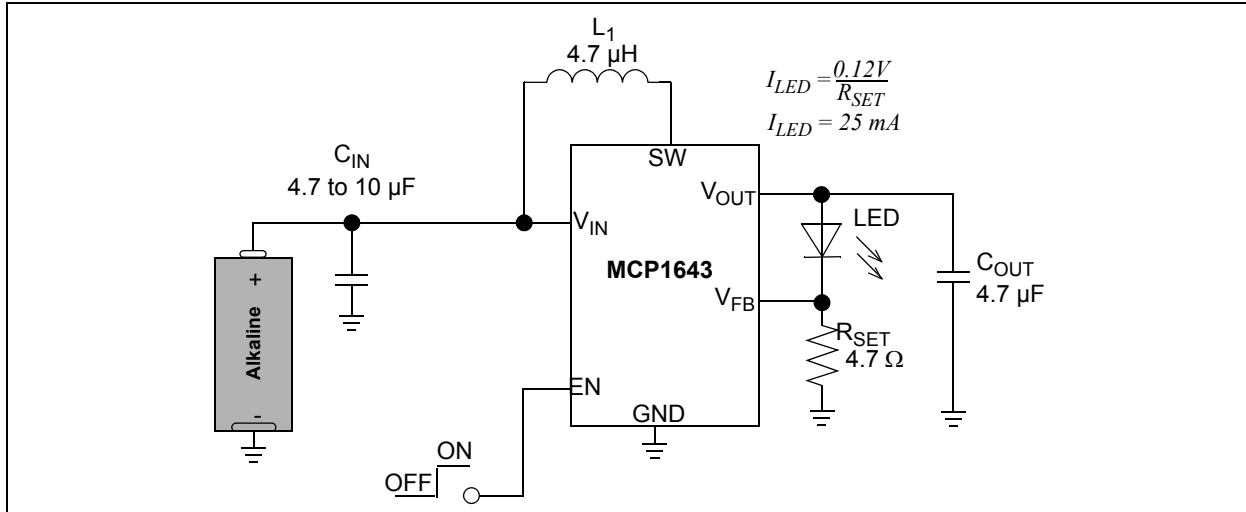


FIGURE 1: MCP1643 Typical Application.

The maximum LED current on the MCP1643 is determined by the input voltage.

For a fully charged battery, the maximum regulated LED current is 450 mA. Note that in comparison with alkaline, the NiMH/NiCd batteries have lower nominal voltage, so the maximum LED current delivered by the MCP1643 will also be lower (around 350 mA). The MCP1643 will continue to deliver up to 150 mA even when the batteries are almost depleted (0.65V). Figure 2 shows the minimum input voltage necessary for the MCP1643 to regulate the set output current.

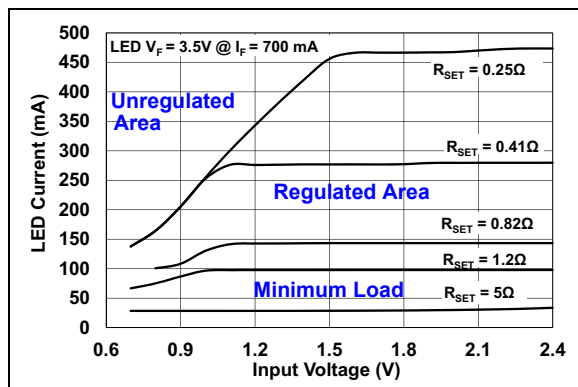


FIGURE 2: Output Current vs. Input Voltage.

Maximum and Minimum LED Current Limits

Like all LED current drivers, MCP1643 has some limitations regarding the maximum and minimum load current limits as shown in Figure 3.

The output LED current stays in regulation while $V_{IN} < V_{OUT}$ with 300–400 mV headroom (because of the boost topology).

The maximum load current is determined by the Input Current Limit, which is 1.8A. If the selected LED current forces an input current bigger than the MCP1643's maximum peak current, the LED current will not be able to regulate and will fluctuate with input voltage. The battery must also be able to sustain the amount of current needed by the MCP1643 converter.

The minimum output LED current that the MCP1643 can regulate is 20 mA.

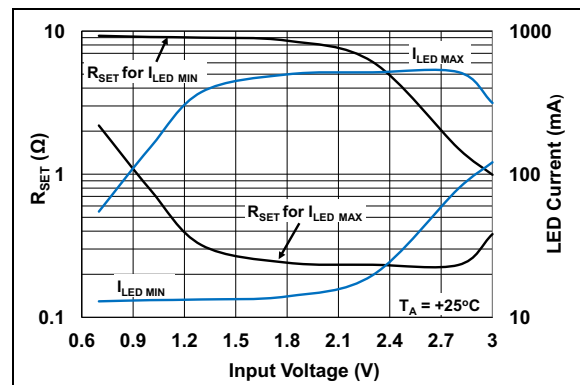


FIGURE 3: Minimum and Maximum Limits for LED Current in Regulation.

RECOMMENDED APPLICATIONS

MCP1643 as a One-Cell LED Driver

One of the simplest applications uses the MCP1643 as a constant current LED driver with a selectable current set by modifying the sense resistor's value. For 2.4Ω, the set current is 50 mA and can be increased to 100 mA and 150 mA by connecting sense resistors in parallel. Refer to [Figure 4](#).

The MCP1643 allows PWM dimming by turning the LED ON or OFF with a variable duty cycle PWM signal applied to the EN pin. The maximum frequency for dimming is limited by the internal soft-start of 240 μs (typical). By varying the duty cycle of the PWM signal applied to EN input, the LED's average current is changing linearly and the light intensity changes as well.

For a more detailed description and functionality, as well as PCB layout, see MCP1643 Synchronous Boost LED Constant Current Regulator Evaluation Board (ADM00435) User's Guide[1].

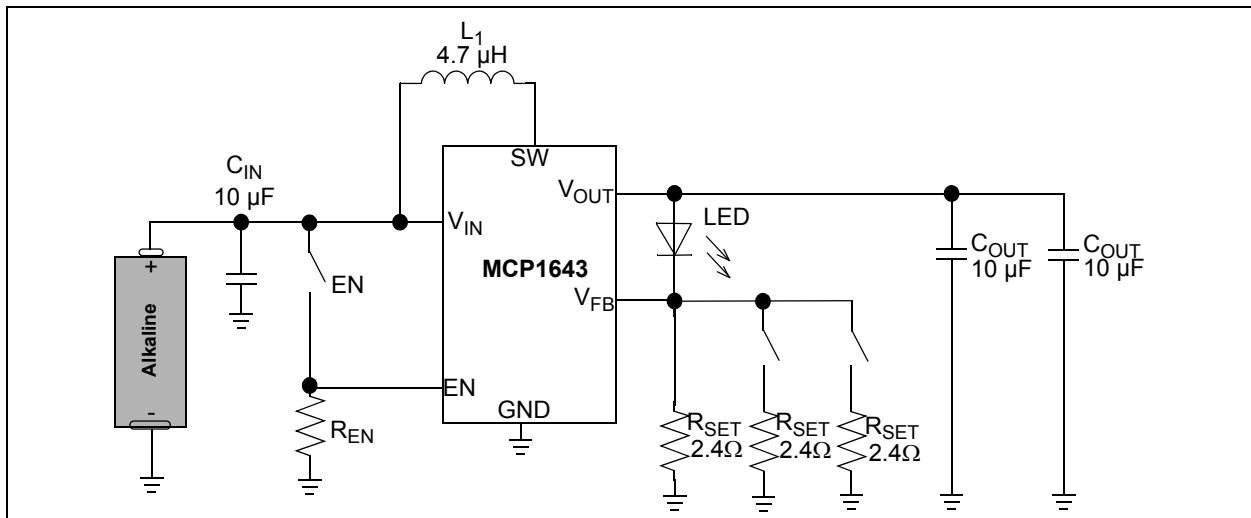


FIGURE 4: One-cell, One White LED with Three Steps-Selectable Current Application.

MCP1643 as Two Series LEDs Driver

The MCP1643 can also be used to drive two LEDs in series. (See [Figure 5](#).) However, the maximum voltage is limited by the overvoltage protection that restricts the output voltage to 5.0V. Because of this protection, the

MCP1643 can handle two low-voltage LEDs, such as infrared (for remote control) and red, but cannot handle high-voltage LEDs, such as white and blue.

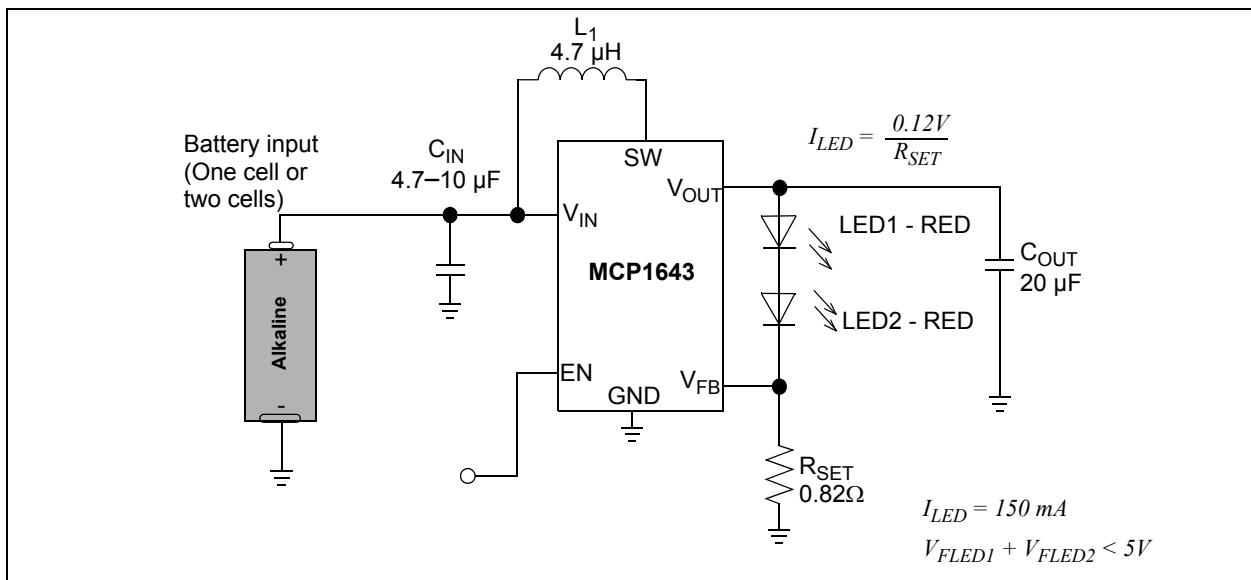


FIGURE 5: Two Series LEDs with 150 mA Set Current Application.

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MCP1643 as a Parallel LED Driver

The MCP1643 device features a maximum output current of 550 mA. To take advantage of this amount of current, low-current LEDs can be paralleled as demonstrated in Figure 6. The maximum number of LEDs is determined by the maximum output current of the converter (550 mA) divided by the LED current rating. For example, if the LED rated current is 50 mA, a maximum number of 11 LEDs can be used. The same number of resistors is also required, with identical value.

One pair of LED and resistor is used to set the current measured by the MCP1643. The other pairs will follow, controlled by the first pair's current.

This application is most suited for portable backlight devices where low-power SMD resistors are arranged in a line for LCD illumination. This low-cost, low-component count solution replaces the need for a high-voltage constant current boost converter that may require a big inductor and occupy a lot of PCB space.

As an option, the brightness of the LEDs can be set with PWM dimming.

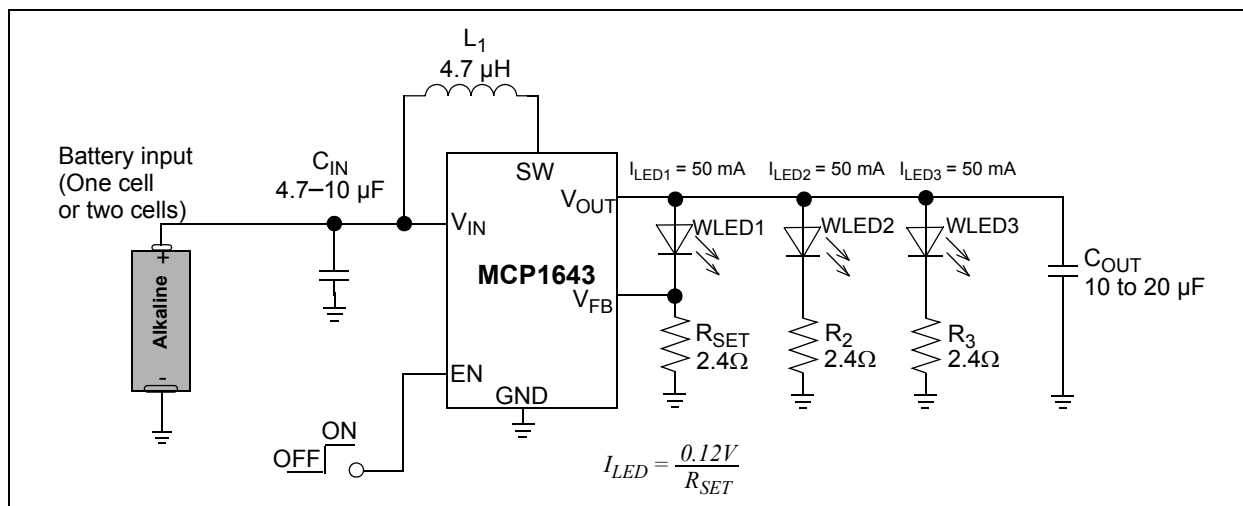


FIGURE 6: Multiple Paralleled LEDs Application.

MCP1643 IN EMBEDDED SYSTEMS

Driving an RGB LED

An RGB LED is made of three LEDs (red, green and blue) with a common cathode or anode that can be driven simultaneously or one at a time to form any color of the visible spectrum. Each color of the LED has a different forward voltage, so a current source is needed to drive each LED independently.

The block diagram of the MCP1643 RGB LED Driver Demonstration Board (ADM00612) in [Figure 7](#) shows the use of MCP1643 as an RGB LED driver. The MCP1643 is used both as a current source for the high-power RGB LED and as a voltage source for the PIC16F1455 microcontroller. The power is being supplied by a one-cell AA battery.^[2] [Figure 8](#) displays the MCP1643 RGB LED Driver Demonstration Board.

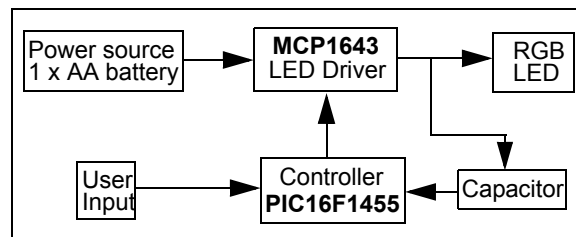


FIGURE 7: MCP1643 RGB LED Demo Board Block Diagram.

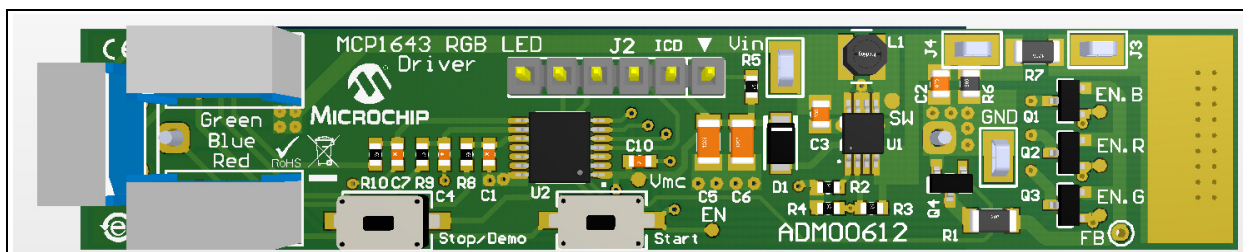


FIGURE 8: MCP1643 RGB LED Driver Demonstration Board (ADM00612).

Board Principle of Operation

The MCP1643 features a maximum output current of 550 mA, but it only has one output. To drive three LEDs independently, the MCP1643 must be controlled by a PIC[®] microcontroller (MCU). Using a soft-start time of 240 μ s, the MCP1643 output can be multiplexed for each color without any current overshoot, for a LED frequency of 70 Hz.

The MCP1643's LED current path has to be changed via external transistors in order to power each LED individually.

The MCP1643 device is also used (for a brief period of time) as a voltage source by disconnecting the LEDs and the feedback resistor and controlling the feedback voltage (with a resistor divider) to raise the output voltage to a fixed value of 4V.

Considering that the MCP1643 is also used to drive three LEDs and power the control system, the chip will be enabled at a frequency of around 300 Hz (4 x 70 Hz).

MCP1643 as an RGB LED Driver

To use the MCP1643 as a single-LED driver, the typical schematic can be used, but in order to use it as a multiple independent LED controller, some conditions must be met:

- The MCP1643 output must be moved from one LED to another with the same feedback resistor.
- The MCP1643 must be disabled and re-enabled each time the control system changes the current path.
- The MCP1643 output voltage must be dropped in order to prevent any current overshoot when changing to a different LED color.

A PIC MCU is required to accomplish this functionality. [Figure 9](#) shows the timing of the control signals. Green, blue and red signals are the transistors' gate voltages. These transistors are used to change the current path of each color. After they receive a command signal (gate voltage), the transistors will conduct and the corresponding color will form a closed current loop with the LED driver. The MCP1643's Enable signal is synchronized with these gate signals and has an additional enable period when no LED is controlled. During this period, the output voltage rises to a fixed voltage and the MCP1643 acts like a voltage source.

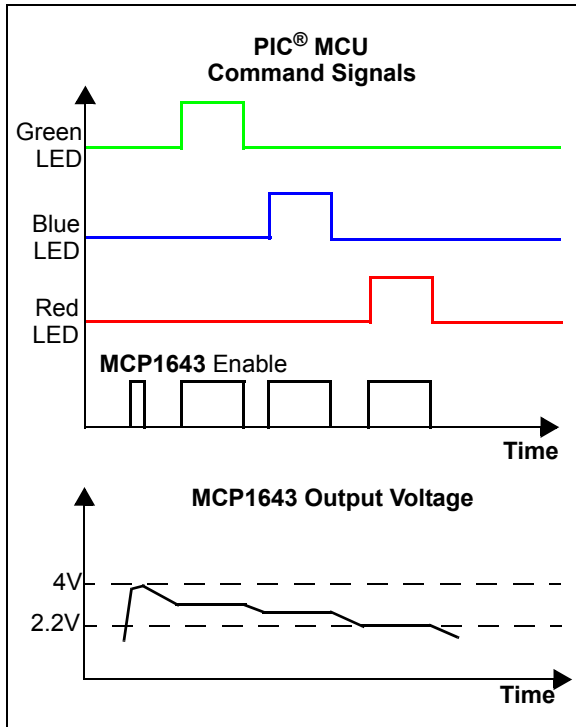


FIGURE 9: MCP1643 Theory of Operation.

Importance must be given to the order of the Enable signals. (Refer to Figure 10.) Starting the MCP1643 without connecting the LED to its output will cause the device to increase the output voltage to a maximum of 5V. If the LED is then connected into the circuit, the output capacitor will uncontrollably discharge into the LED, damaging the LED.

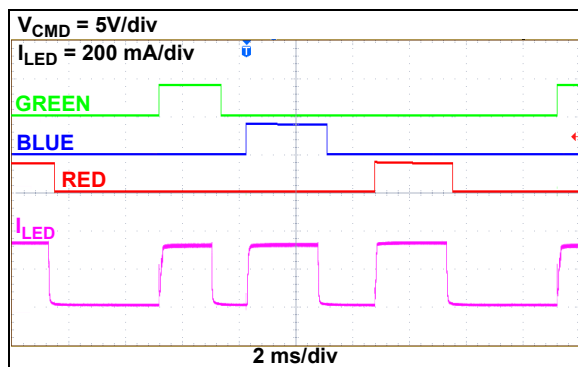


FIGURE 10: LED Current and Enable Signals.

The dead time between the Enable signals is different because of the forward LED voltage difference. For positive voltage transitions (from low voltage to high voltage), the dead time can be eliminated, but doing so is not recommended.

Using MCP1643 as a DC-DC Voltage Source

In order to use the MCP1643 as a voltage source, a few external components must be used. A transistor is added to disconnect the feedback resistor from the feedback loop of the MCP1643 current driver, and a resistor divider is left in the feedback loop to raise the voltage to an appropriate level used by the control system. Figure 11 exemplifies this usage. When the LEDs are not connected but the MCP1643 is enabled, the output voltage (red signal) increases to around 4V in a short period of time.

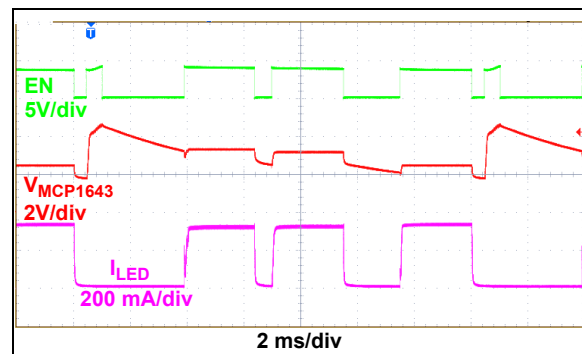


FIGURE 11: MCP1643 Enable, Output Voltage and LED Current.

Because of the multiplexing, the PIC MCU voltage is not regulated and will drop with time (depending on the multiplexing frequency), the amount of stored energy and the power consumption of the control system. If a more regulated voltage is needed, the MCP1643 can be followed by an LDO. For example, if a 3.3V supply is necessary, a low quiescent current LDO (such as MCP1702) can be used, and the output voltage of the MCP1643 should be set to more than 3.6V. Note that the voltage drop will not influence the functionality of the PIC MCU with a supply voltage of 2.3V to 5V.

Additional components such as the following are also needed to avoid interfering with the LED's control voltages:

- A Schottky diode to prevent any voltage from going back into the LED.
- A capacitor to store the energy when the MCP1643 is driving the LEDs.

Apart from not needing another DC-DC converter for the control system, this approach has another advantage. When the converter is turned OFF, the PIC MCU will also be turned OFF. The entire system will only use the 1.2 μ A (typical) shutdown current of the MCP1643 device.

The system can be restarted either manually by enabling the MCP1643 (which will automatically power the microcontroller as well), or by an external voltage source applied to the microcontroller for at least 100 ms.

Figure 12 shows the electrical schematic of the MCP1643 RGB LED Driver Demonstration Board (ADM00612). The schematic is divided into blocks that point out to the functionality of each part of the system.

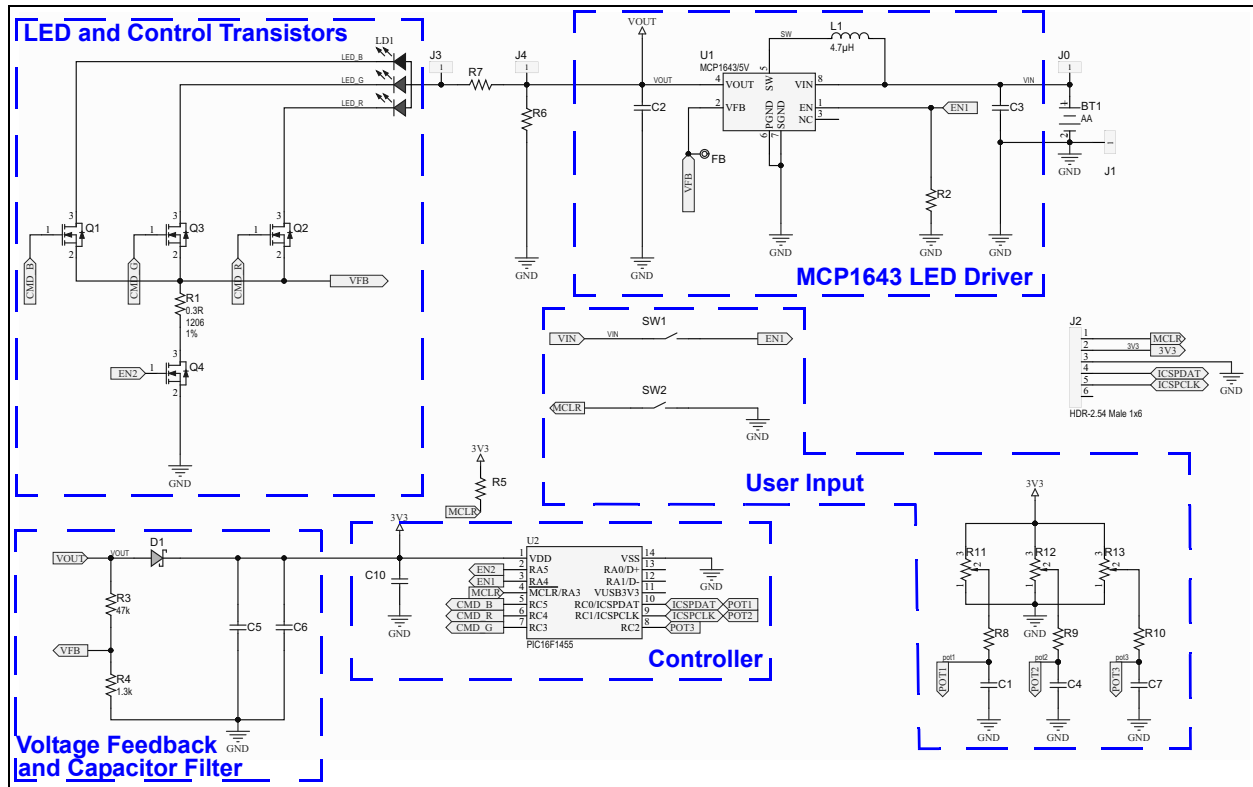


FIGURE 12: MCP1643 RGB LED Driver Demonstration Board Electrical Schematic.

Printed Circuit Board and Recommended Layout

The layout should be done with respect to the general DC-DC converter's rules: the power traces that carry the most amount of current should be as short as possible and should not pass under or close to any sense or high-impedance signal traces. The switching node must also be as short as possible to decrease interference. See Figure 13 and Figure 14.

The input and output capacitors should be as close to the converter as possible and the use of a ground plane is recommended.

For devices that tend to heat up, a lot of vias to a copper plane should be added to help with heat dissipation.

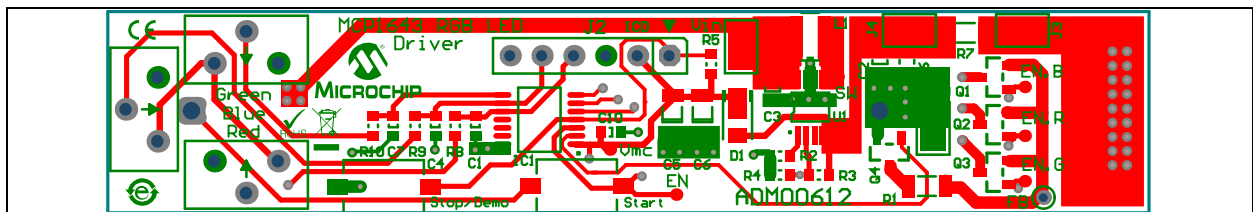


FIGURE 13: MCP1643 RGB LED Driver Demonstration Board – Top Copper and Silk.

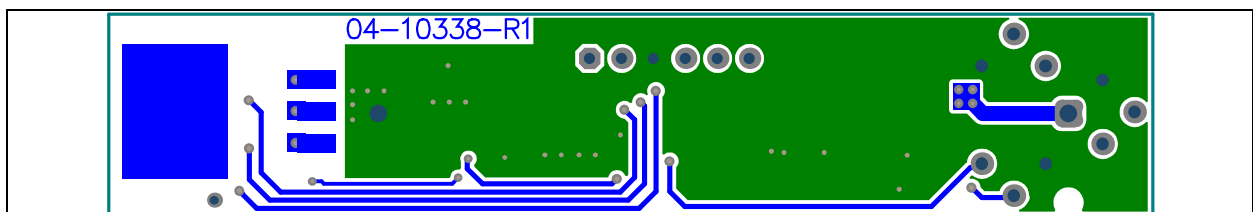


FIGURE 14: MCP1643 RGB LED Driver Demonstration Board – Bottom Copper.

CONCLUSION

The MCP1643 is a versatile Synchronous Boost DC-DC LED Driver Converter designed especially for one-cell alkaline battery-powered applications with low start-up voltage and high current capabilities. The low standby (shutdown) current of 1.2 μA increases battery life when not in use, while the low component count and low PCB area occupied allow for more portable applications. Designing new DC-DC converters with MCP1643 is simple, and by attaching a microcontroller, the designs become more versatile and user-friendly.

REFERENCES

- [1] *MCP1643 Synchronous Boost LED Constant Current Regulator Evaluation Board User's Guide* (DS20005196), Microchip Technology Inc., @2014.
- [2]. *MCP1643 RGB LED Driver Demonstration Board User's Guide* (DS50002437), Microchip Technology inc. @2015.

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