Adding Intelligence to Lighting Applications

LED Lighting

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LED Lighting

LEDs are no longer used just for providing the pretty red and green indicator lights on electronic equipment. Advances in technology have allowed LEDs to be used as practical sources of illumination. The primary benefits of LEDs are long life, durability and efficiency. When driven properly, a power LED can last tens of thousands of hours without a degradation of light output. The typical efficacy of a power LED, measured in lumens per watt, is 20-30. This is much greater than incandescent light sources and is only exceeded by fluorescent light sources. Since the LED is a solid-state device, it can withstand shock and vibration that would damage a filament bulb.

LED Applications

The benefits of LED lighting are helpful in many types of lighting applications:

- Automotive and aircraft cabin lighting
- Automotive and aircraft instrument panel lighting
- Architectural emergency exit lighting
- Architectural color effect lighting
- Industrial and outdoor lighting
- Traffic and railway signals
- Automotive Brake Lights
- Dot matrix signs and video displays
- LCD display backlighting
- Personal flashlights
- Medical instrument and tool lighting
- Digital camera flash and video light

Efficient LED Control

LEDs must be driven with a source of constant current. Most LEDs have a specified current level that will achieve the maximum brightness for that LED without premature failures. An LED could be driven with a linear voltage regulator configured as a constant current source. However, this approach is not practical for higher power LEDs due to power dissipation in the regulator circuit. A switch-mode power supply (SMPS) provides a much more efficient solution to drive the LED.

An LED will have a forward voltage drop across its terminals for a given current drive level. The power supply voltage and the LED forward voltage characteristics determine the SMPS topology that is required. Multiple LEDs can be connected in series to increase the forward voltage drop at the chosen drive current level.

The SMPS circuit topologies adopted to regulate current in LED lighting applications are the same used to control voltage in a power supply application. Each type of SMPS topology has its advantages and disadvantages as presented in the table below.

This design guide presents two types of LED driver solutions. First, an analog driver IC can be used independently or together with a MCU for added intelligence. Second, the LED drive function can be integrated into the MCU application.

Common SMPS Topologies Useful for LED Lighting

<table>
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<tr>
<th>Regulator Topology</th>
<th>Vin to Vout Relationship</th>
<th>Complexity</th>
<th>Component Count</th>
<th>Comments</th>
</tr>
</thead>
</table>
| Charge Pump        | Vout < Vin < Vout        | Low        | Medium          | - Limited Iout range  
|                    |                          |            |                 | - No inductors       |
| Buck               | Vin > Vout              | Medium     | Medium          | - Chopped Iin  
|                    |                          |            |                 | - High side drive    |
| Boost              | Vin < Vout              | Medium     | Medium          | - Extra parts needed to isolate output from input |
| SEPIC              | Vout < Vin < Vout       | Medium     | High            | - Smooth Iin  
|                    |                          |            |                 | - Multiple outputs  
|                    |                          |            |                 | - Two inductors      |
| Buck-Boost         | Vout < Vin < Vout       | High       | High            | - Single Inductor  
|                    |                          |            |                 | - Up to four switches|
Driving LEDs With a Charge Pump

A charge pump power supply does not have inductors that are required in other SMPS topologies. This provides a more compact and less expensive circuit. The downside is that charge pumps cannot supply large amounts of current compared to the other topologies. Charge pump circuits are most useful for backlighting applications. Common applications include PCs, LCD displays and automotive instrumentation.

Literature on the Web

- MCP1252/3 Data Sheet, DS21572
- MCP1252 Charge Pump Backlight Demo Board User’s Guide, DS51551
- MCP1252/3 Evaluation Kit User’s Guide, DS51313
- Power Solutions Design Guide, DS21913

MCP1252 Charge Pump Backlight Demonstration Board

Part Number: MCP1252DM-BKLT

Demonstrates the use of a charge pump device in an LED application and acts as a platform to evaluate the MCP1252 device in general. Light intensity is controlled uniformly through the use of ballast resistors. A PIC10F206 MCU provides an enable signal to the MCP1252 and accepts a push-button input that allows the white LEDs to be adjusted to five different light intensities.

Charge Pump LED Driver Using the MCP1252
Driving LEDs With a Buck Regulator

A buck regulator topology is used when the input supply voltage is always greater than the LED forward voltage. The buck regulator circuit requires an inductor. A high switching frequency is beneficial because it reduces the size of the inductor.

The MCP1612 is a buck regulator device that is ideal for driving power LEDs. The MCP1612 can supply up to 1A without using an external power transistor. Typical power LED drive current levels include 350 mA and 700 mA. The MCP1612 switches at 1.4 MHz to minimize the size of the inductor.

Literature on the Web

- MCP1612 Data Sheet, DS21921
- MCP1612 Evaluation Board User’s Guide, DS51529
- Power Solutions Design Guide, DS21913

Buck Voltage Regulator Example Using the MCP1612

MCP1612 Synchronous Buck Regulator Evaluation Board

Part Number: MCP1612EV
Features a 1A 1.4 MHz synchronous buck regulator in two buck converter applications. The applications use the 8-lead MSOP and 8-lead DFN packages respectively. Selectable output voltages and a shutdown terminal are available on each converter.
Driving LEDs With a Boost Regulator

A boost regulator topology is used when the output voltage of the converter must be equal to or greater than the input voltage. A boost regulator is useful for driving a chain of LEDs connected in series. It is beneficial to drive multiple LEDs in series. This ensures that all LEDs receive the same amount of current and have the same brightness level.

Literature on the Web

- MCP1650/51/52/53 Data Sheet, DS21876
- MCP1650 Multiple White LED Demo Board User’s Guide, DS51586
- AN948 – Efficiently Powering Nine White LEDs Using the MCP1650, DS00948
- Power Solutions Design Guide, DS21913

MCP1650 Multiple White LED Demonstration Board

Part Number: MCP1650DM-LED2

The MCP1650 Multiple White LED Demo Board uses the MCP1650 IC to power the nine white LEDs which are connected in series. A PIC10F202 microcontroller in a SOT-23 6-pin package is used to provide the PWM signal to the MCP1650. It also accepts a push button input that allows the user to adjust the white LEDs to three different intensities of 100%, 50% and 25%.
Lighting Solutions

Driving LEDs With a SEPIC Regulator
The Single-Ended Primary Inductance Converter (SEPIC) regulator topology uses an additional inductor, but provides the following advantages for battery powered applications:

- The converter can buck or boost as the input voltage changes.
- The circuit topology provides inherent short-circuit protection due to the use of a coupling capacitor.

Literature on the Web
- MCP1650/51/52/53 Data Sheet, DS21876
- MCP1650 3W White LED Demo Board User’s Guide, DS51513
- Power Solutions Design Guide, DS21913

Li-Ion Input to 3.6V 3W LED Driver (SEPIC Converter)

MCP1650 3W White LED Demonstration Board
Part Number: MCP1650DM-LED1
Demonstrates the MCP165X Boost Controller product family in a battery-powered white LED application with an input voltage range of 2.0V to 4.5V.
LED lighting applications can benefit from the intelligence of a MCU. The MCU can be used for a variety of tasks, including the user interface, communication, battery status monitoring and temperature measurement.

One application for a MCU in LED lighting is brightness control. A power LED can be dimmed by reducing the drive current. However, this is not the most efficient way to control the brightness of a LED. A power LED provides the best efficiency at the maximum rated drive current. Better efficiency can be obtained by turning the LED on and off using a low frequency PWM signal. The PWM signal is connected to the enable input of the SMPS control IC. The LED is always driven at the maximum current level when it is on.

The MCP1650 Multiple White LED Demo Board and the MCP1650 3W White LED Demo Board both take advantage of the 6-pin PIC10F206 MCU. The PIC10F206 device provides the user button interface and generates the PWM control signal for the SMPS IC. The PIC10F206 has an internal oscillator and reset circuit, so no external circuitry is required. The PIC10F206 device could also be used to linearize the brightness control or monitor battery status.

**Integrate Multiple Tasks**

The LED current drive function can be integrated with other tasks on the same MCU. Members of the PIC12FXXX and PIC16FXXX device families facilitate this integration with on-board comparators, voltage references, PWM modules and A/D converters. A PIC MCU with an on-chip comparator, such as the PIC12F675, can be used to implement a switch-mode LED driver. Furthermore, 8, 14 and 20-pin devices in these families have compatible pin-outs for upward and downward migration.

The PIC16F785 is a 20-pin device that integrates analog peripherals for SMPS applications and an 8-bit MCU. The PIC16F785 has two on-chip op amps, two on-chip comparators, two analog PWM modules and an adjustable voltage reference. These peripherals can be digitally configured to implement a wide variety of SMPS circuit topologies. Once configured, the analog control circuitry can run independently of the MCU. This frees the MCU for other tasks such as communications and status monitoring. The PIC16HV785 device adds a shunt voltage regulator to reduce external component count.

**Literature on the Web**

- AN874 – Buck Configuration High-Power LED Driver, DS00874
- AN1035 – Designing with HV Microcontrollers, DS01035
- PIC16F785/HV785 Device Data Sheet, DS41249

**Compatible Pinouts Provide Migration Options**

<table>
<thead>
<tr>
<th>Migration Options</th>
<th>8-Pin</th>
<th>14-Pin</th>
<th>20-Pin</th>
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<tr>
<td>8-Pin</td>
<td>PIC12F615</td>
<td>PIC16F616</td>
<td>PIC16F631</td>
</tr>
<tr>
<td></td>
<td>PIC12F675</td>
<td>PIC16F630</td>
<td>PIC16F677</td>
</tr>
<tr>
<td></td>
<td>PIC12F629</td>
<td>PIC16F684</td>
<td>PIC16F685</td>
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<tr>
<td></td>
<td>PIC12F683</td>
<td>PIC16F688</td>
<td>PIC16F687</td>
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<tr>
<td>14-Pin</td>
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<tr>
<td>20-Pin</td>
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</tbody>
</table>
Buck LED Driver Using an On-chip Comparator

PIC16HV785 Boost LED Driver Application
**Full Digital Control**

LEDs can be driven with a fully digital control loop. Instead of measuring the LED current with an op-amp or comparator circuit, the LED current is sampled using an ADC. A proportional-integral-derivative (PID) algorithm or digital compensation filter replaces the analog control loop. Similar to the analog solution, a digital PWM is used to drive the LED. The PID algorithm or digital filter calculates the duty cycle for the PWM peripheral.

Devices in the PIC18F and dsPIC30F families offer 8-bit and 16-bit solutions respectively for fast calculation of digital control loops. In addition, these families have fast ADC peripherals and specialized PWM modules for power control applications.

**Comparison of Analog vs. Digital Control Functions**

![Comparison Diagram](image)

**RGB LED Driver Application with PFC**

The 28-pin dsPIC30F2010 device can provide a highly integrated solution for LED lighting applications. The PWM peripheral can drive 3 strings of LEDs for a RGB color application, replacing 3 separate analog control ICs. Furthermore, there are resources left over for active power factor correction (PFC) and digital communications.

**Literature on the Web**

PIC18F1230/1330 Device Data Sheet, DS39758

dsPIC30F2010 Device Data Sheet, DS70118
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