Driving Lumileds® LEDs with Microchip Microcontrollers
Agenda

- Review of LED drive requirements
- Driver Topologies
- System Software
- Flash Sequence Control Codes
- Development Tools
- Tour of the programming GUI
- Step-by-Step Programming sequence
- Trouble shoot Guide
Hi-Power LED Drive Requirements

- 1 Watt LED
  - Full intensity 350mA, Maximum current 500mA
  - 2.8VDC, typical forward voltage at 350mA
- 3 Watt LED
  - Full intensity 700mA, Maximum current 1A
  - 4.3VDC, typical forward voltage at 700mA
- 5 Watt LED
  - Full intensity 700mA, Maximum current 1A
  - 7.1VDC, typical forward voltage at 700mA
LED Driver Topologies
Design Requirements

- Simple and inexpensive
- One button control interface
- Efficient drive of 1, 3 & 5 Watt LEDs
- Battery operation with Intensity compensation
- Intensity control
- Programmable Flash Sequences
- Use small inexpensive microcontroller
- Ease of programming
## Competing Driver Topologies

### Linear Current Driver

**Upside**
- DC current drive
- Easy to control intensity

**Downside**
- Inefficient power transfer to LED
- Heat dissipation in the MOSFET
- No advanced features
Competing Driver Topologies
Single Chip Switchers

- **Upside**
  - Efficient power drive

- **Downside**
  - Two chip solution due to reference voltage
  - Difficult to control Intensity
  - No Advanced features
Microcontroller + Comparator Based Driver Circuits

- **Upside**
  - Switching topologies can be used for efficiency
  - Battery measurement for battery life, intensity stability, and temperature control are possible
  - Intelligent flash and intensity modes are possible
  - Comparable cost with added features

- **Downside**
  - Non-traditional approach
  - More complex to design
- At startup, Q1 is on
- The inductor/LED current climbs
- Just above the Drive Level, Q1 is off
- The inductor/LED current falls
- Just below the Drive Level, Q1 is back on
Single Comparator
Boost Topology Driver

- The inductor charges in the first phase
- And discharged into C2 in the second phase
- The capacitor voltage climbs until the LED conducts
- The LED acts as a shunt regulator on C1’s voltage
Drive Level Output and Battery Monitor

- GP5 drives the PWM low pass filter for the Drive Level signal
- GP5 also drives the diode reference for battery measurement
- Battery voltage is used to compensate the PWM output
Microcontroller-based LED System Software
Two Versions of Demo Software

- Full Version of Software
  - Virtual button commands for intensity set
  - Virtual buttons to select flash sequences
  - Virtual button for power on and off

- Demo Version of Software
  - First Button press turns board on in continuous mode
  - Next Button presses select flash sequences
  - After the last flash sequence, the board turns off
Virtual Button User Interface

- **VPRESS:** press the push button < 1.5 sec.
  - Increments or decrements intensity.
- **VPUSH:** press the push button > 1.5 sec. But < 3.0 sec.
  - Toggles increment / decrement function
  - A double VPUSH causes a Power down
- **VHOLD:** press and hold the push button for > 3.0 sec. (function auto repeat function)
  - Cycles through flash light and flash sequence modes.
### Control Software

- Software design used 5 tasks in a multi-tasking design
  - PWM: Generates Drive Level output and controls system timing
  - KEY: Monitors the push button and decodes virtual buttons
  - ADC: Monitor the battery and calculates compensation constants
  - CONTROL: Decodes virtual button commands
  - AUTOSEQ: Accesses and executes programmed flash sequences.
Preprogrammed Flash Sequences

- Preprogrammed flash sequences automatically execute 1 of 4 possible flash light sequences.
- Control Codes available for Set Intensity, Delay Time, Goto step, Shutdown and Repeat/Return
  - Repeat Return can be nested up to 4 levels deep
- Provisions for 4 sequences are available
- Each sequence must be less than 64 opcodes
  - Total number of opcodes must be < 120
Time Delay and Intensity Set Control Codes

- Time delay can be set between 0 and 6.3 Seconds
  
<table>
<thead>
<tr>
<th>Time Delay Control Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bits: 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>0 1 X X X X X X</td>
</tr>
<tr>
<td>Time Delay: 0 - 6.3 seconds</td>
</tr>
</tbody>
</table>

- Intensity can be set between 0 and 63.
  
<table>
<thead>
<tr>
<th>Intensity Control Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bits: 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>0 0 X X X X X X</td>
</tr>
<tr>
<td>Intensity: 0-63</td>
</tr>
</tbody>
</table>

- 0 turns off the LED.

- 63 results in the maximum brightness.
GOTO and Shutdown Control Codes

- A GOTO jumps to the destination control code specified
- GOTOs must jump to valid instructions in the same sequence
- Sequences start with control code #1
- The Shutdown control code is a GOTO to location 0

GOTO Control Code

<table>
<thead>
<tr>
<th>Bits</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 6 5 4 3 2 1 0</td>
<td></td>
</tr>
<tr>
<td>1 1 X X X X X X</td>
<td></td>
</tr>
</tbody>
</table>

Shutdown Control Code

<table>
<thead>
<tr>
<th>Bits</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 6 5 4 3 2 1 0</td>
<td></td>
</tr>
<tr>
<td>1 1 0 0 0 0 0 0</td>
<td></td>
</tr>
</tbody>
</table>
Repeat and Return OpCodes

- A Repeat loops the codes between the Repeat and Return the specified number of times
- The number of cycles must be between 1 and 63
- Repeats can be nested 4 deep.

- A return code will cause a loop back to the most recent Repeat code.

<table>
<thead>
<tr>
<th>Repeat Control Code</th>
<th>Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td></td>
<td>1 0 X X X X X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Return Control Code</th>
<th>Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td></td>
<td>1 0 0 0 0 0 0 0</td>
</tr>
</tbody>
</table>

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Examples

- Set intensity to maximum
  - Bright = 63
  - Goto 2

- Set maximum intensity for 3 seconds then stop
  - Bright = 63
  - Time = 3.0
  - Bright = 0
  - Goto 4

- Flash LED at 1 Hz rate
- Flash 5 times
- Then delay 5 seconds and start over
  - Repeat = 5
  - Bright = 63
  - Time = 0.5
  - Bright = 0
  - Time = 0.5
  - Return
  - Time = 5.0
  - Goto = 1
# More Examples

- **Delay 30 seconds**
  - Repeat = 6
  - Time = 5.0
  - Return

- **Flash at 1Hz**
- **Flash 5 Times**
- **Then shutdown**
  - Repeat = 5
  - Intensity = 63
  - Time = 0.5
  - Intensity = 0
  - Time = 0.5
  - Return
  - Shutdown
Development Tools
The PIckit™ 1 Development Kit

- The PIckit™ 1 is designed to be a low cost programmer/development board for Microchip’s low pin count flash parts
- The LED demo board is designed to plug into the 14-pin expansion header
- The PIckit™ GUI is replaced with the LED demo board programming GUI to program the demo board
- Graphical control code builder
- Drag and Drop editor modes
- Default settings
- Sequence size status display
- Read, Write, and Verify
- File Load, Save, and Update
Create the Control Codes

- Click to select the required control
- Or, enter data in the associated box
- Click “Compile” to create the control code
Insert/Delete/Replace the control code into the sequence

- Select the appropriate edit mode
- And click to place the control code in the sequence
- Remember only 64 codes per sequence and 120 total
Default Settings

- Determines the starting intensity.
  - Changes to the intensity are retained through power down

- Determines the starting mode.
  - New mode selections are retained through power down
  - Only enabled modes can be selected

- Mode1 is the continuous intensity mode (no flash)
Program/Verify/Read the program in the demo board

- “Read” copies the current code from the demo board into the GUI
- “Write” programs the current GUI configuration and code into the board
- “Verify” compares the code in the demo against the GUI configuration
- “Quit” ends the GUI program
The file pull down menu contains all file commands:

- All configuration files have the extension *.FLT
- “Load” imports both programming and configuration information
- “Update” imports only programming, leaving configuration unchanged
- “Save” exports both programming and configuration information
- “Exit” ends the GUI program
Programming Sequence

- Remove one battery and J1.
- Insert the Demo board into the PICkit™ programmer with the LED facing the USB cable.
- Load and Start the GUI.
- Load the desired base software (full or demo).
- Create the desired configuration.
- Click PROGRAM.
- When complete remove the Demo board.
- Press and hold the push button for 5 seconds.
- Replace J1 and then replace the battery.
Trouble Shooting Problems

- Board programs but does not run
  - Remove a battery, press the button, replace the battery
- Flash sequence starts, then hangs
  - Check sequence for a REPEAT without a corresponding RETURN
- LED flashes momentarily then unit turns off
  - Replace batteries
- Board fails to program
  - Remember to remove jumper J1
Trouble Shooting Problems continued

- With Demo Software, After power up Unit turns off immediately
  - If the last enabled flash sequence starts with a shutdown command, reprogram the board with the last sequence disabled
  - If the last enabled flash sequence does not use the shutdown command, replace the batteries

- NOTE: at full intensity, the maximum battery life is between 2 and 6.5 hours depending on battery chemistry
Summary

- Driving High Power LEDs present a number of design challenges.
- Microcontroller based drivers are efficient, simple, and add value to the final product.
- The example software provides a wealth of features using only a single button for control.
- The pre-programmed flash sequence capability provides user customizable features to the light.
- The GUI programming interface simplifies the design and loading of the flash sequences.
Resources

- Small Pin-Count Flash Microcontroller Data Books
  - PIC12F629/675 DS41190C
  - PIC16F630/676 DS40093C

- Application notes
  - AN874 Buck Configuration Hi-Power LED Driver (DS00874)
  - Thermal Design Using Luxeon™ Power Light Sources AB05 (available from the Lumileds Web page)
  - 8-Pin Tips-n-Tricks Booklet (DS40040)
  - Comparator Tips-n-Tricks Booklet (DS41215)

- Development tools
  - MPLAB® Integrated Design Environment
  - PICkit™ 1 Flash Starter Kit

- Web Pages
  - Microchip Technology Inc. www.Microchip.com
  - Lumileds Lighting, LLC www.Lumileds.com
Thank you