SCPA043–November 2007

Programming Fun Lights With the TI TCA6507

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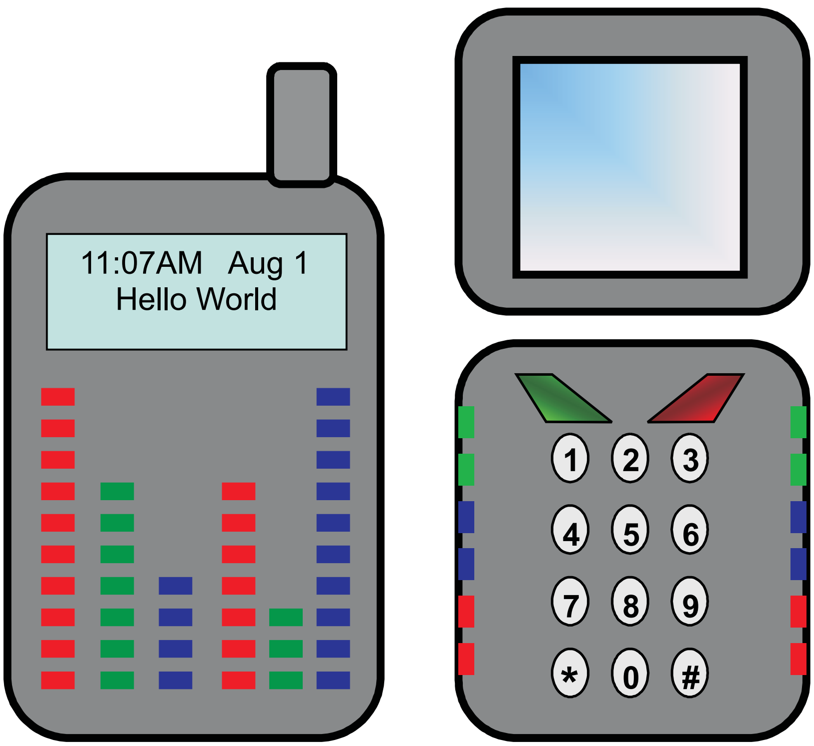
1.1 Examples of Fun Lights

Historically, end-equipment manufacturers have used lighting as a way to differentiate their product over that of their competition and to satisfy market needs. A subset of lighting, known as fun lights, has emerged and is growing in popularity in battery-powered portable applications.

Fun lights can be used to decorate the external appearance of a product and supplement its functionality. The end application may also require different colors and include a variety of blinking or dimming options. Typically, fun lights are implemented using external light emitting diodes (LEDs). See Figure 1-1 for an example of fun light applications.



Handset and MP3 Player (base)

Battery Charge Status (off during non-charging conditions)

Figure 1-1. Examples of Fun Lights

Because fun lights typically are implemented in portable applications, it is essential that the processor be minimally involved in this part of the design to conserve power, and also allow the processor to focus on the critical functions of the application. In addition, the design architect must decide on the types and colors of LEDs that are utilized, the drive levels required to support these LEDs, and voltage tolerances that the design can sustain. The sequence of the fun lights, which includes the blink modes and brightness of the LEDs, also must be determined.

1.2 I^2C LED Drivers for Fun Light Applications

I^2C LED drivers are a growing product segment that has been optimized to support fun lights. This type of device is designed to control (or dim) LEDs via the I^2C interface. Without this device, the processor or I^2C master must be actively involved in turning on and off the LEDs (per the required dimming rate), which uses valuable processor time and overloads the I^2C bus. I^2C LED drivers alleviate this issue by limiting the number of operations required by the processor in blinking LEDs creating more efficient system. An example of an I^2C LED driver for fun lights is the TCA6507 from Texas Instruments.

The TCA6507 is the first I^2C LED driver released in TI's new TCA family and is a 7-bit I^2C LED driver. This device is ideal for fun light applications for five reasons:

1. The TCA6507 is the first device of its kind in this product segment that can control both the brightness and blink modes with automatic gradual fading of the LEDs it drives.
2. The TCA6507 has a supply voltage range of 1.65 V to 3.6 V, which allows it to interface with next-generation microprocessors, where supply levels are dropping down to conserve power.
3. The TCA6507 also has superior drive capability. Each output can support up to 40 mA of sink current to drive an LED. This output drive is much higher than what a processor or CPLD can offer.
4. The TCA6507 has seven open-drain outputs and each output can support a voltage of 6.5 V (absolute maximum rating), which allows the user to drive red, green, blue, or white LEDs.
5. The TCA6507 has very low power consumption. The maximum supply current (I_{CC}) value is 25 μA in the operating mode at 400 kHz. The standby current is 10 μA. When the I^2C bus is idle, and intensity control is not used, the TCA6507 can be put into shutdown mode by setting its enable (EN) pin low. This mode provides additional power savings when the LEDs are off. A low signal on the enable pin also resets the registers and I^2C/SMBus state machine in the TCA6507 to their default state.

The TCA6507 features an oscillator that can control two pulse-width modulation (PWM) modules that provide independent, widely programmable blink/fade patterns. The TCA6507 also offers five steady levels of brightness (including on and off) for each LED. The user can program each of the seven LEDs to one of the two blink/fade patterns and/or one of the five brightness levels offered. There are 16 discrete PWM levels of brightness for all LEDs with 256 intensity steps during fading for smooth perceived transition.

Figure 1-2 shows a simplified block diagram of the TCA6507.

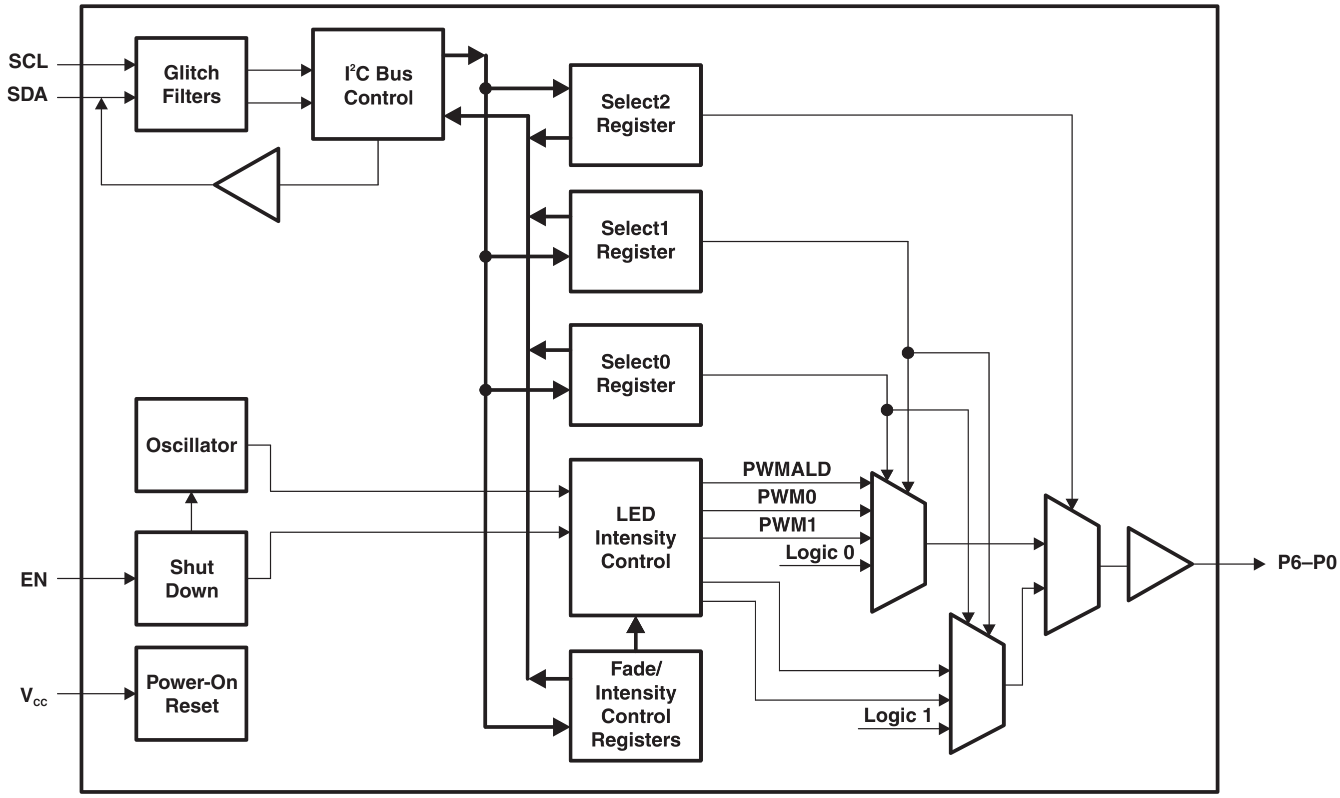


Figure 1-2. TCA6507 Block Diagram

The TCA6507 includes 11 registers that control the function and intensity of the LED. An initial setup command must be sent from the I^2C master to the TCA6507 to program the dimming rate and intensity of these registers, which in turn affect the outputs (or LEDs). From then on, only one command from the bus master is required to turn each individual output ON, OFF, or to cycle at the programmed dimming rate.

To drive LEDs, the designer must first program the state of the LED. The TCA6507 offers three options: on state, off state, or blinking mode. This is achieved through the Select2, Select1 and Select0 registers, which are 8-bit registers. These registers are designed such that bit 0 or the least significant bit (LSB) of the Select0 register, bit 0 of the Select1 register, and bit 0 of the Select2 register program the state of the LED at the output P0. Similarly, bit 1 of the Select0 register, bit 1 of the Select1 register, and bit 1 of the Select2 register control the function of the LED at the output P1. See Table 1-1 for more information.

Table 1-1. Select2, Select1, and Select0 Registers

	MSB							LSB
Select0	X[(1)]	0	0	0	0	0	0	0
Select1	X[(1)]	0	0	0	0	0	0	0
Select2	X[(1)]	0	0	0	0	0	0	0
Output or LED affected	X[(1)]	P6	P5	P4	P3	P2	P1	P0

(1) X = don't care

Depending on the values of the bits programmed in the Select2, Select1, and Select0 registers, the LEDs can be set to have one of five brightness levels and one of two blink modes. See Table 1-2 for the seven possible states of each LED.

Table 1-2. Possible States of LEDs

SELECT2	SELECT1	SELECT0	STATE
0	0	0	LED off (high impedance)
0	0	1	LED off (high impedance)
0	1	0	LED on steadily with maximum intensity value of PWM0
0	1	1	LED on steadily with maximum intensity value of PWM1
1	0	0	LED fully on (output low). Can be used as general-purpose output.
1	0	1	LED on at brightness set by One Shot/Master Intensity register
1	1	0	LED blinking with intensity characteristics of PWM0
1	1	1	LED blinking with intensity characteristics of PWM1

After the state of the LED is set, the designer must program the blink cycle and brightness of the two PWMs (PWM0 and PWM1) for the modes required in the application. This is done through writing to the Fade-On Time, Fully-On Time, Fade-Off Time, First Fully-Off Time, Second Fully-Off Time, and Maximum Intensity registers. Figure 1-3 shows how these registers affect the blink mode and intensity of the PWMs and, in turn, the LEDs. Each of these six registers has eight bits where the top four bits are dedicated to BANK1 or PWM1 and the bottom four bits are for BANK0 or PWM0. The user can program the value of these registers. The maximum time value that can be set in these registers is approximately 16 seconds. This provides a very flexible method to program fun lights and LEDs.

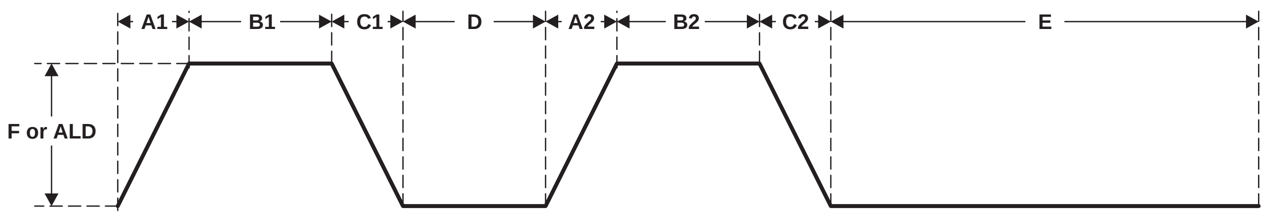


Figure 1-3. Programming for Blink Modes and Intensity

REGION	PARAMETER NAME	PARAMETER RANGE	REGISTER RANGE	REGISTER NAME	REGISTER
A1, A2	Fade-on time	0 to 16320 ms (exponential trend)	0 to 15	Fade-On Time	2
B1, B2	Fully-on time	0 to 16320 ms (exponential trend)	0 to 15	Fully-On Time	3
C1, C2	Fade-off time	0 to 16320 ms (exponential trend)	0 to 15	Fade-Off Time	4
D	First fully-off time	0 to 16320 ms (exponential trend)	0 to 15	First Fully-Off Time	5
E	Second fully-off time	0 to 16320 ms (exponential trend)	0 to 15	Second Fully-Off Time	6
F	Maximum intensity	0 to 100%	0 to 15	Maximum Intensity	7

When used to drive LEDs, the seven outputs can be configured into two banks of outputs (BANK0 and BANK1 based on the two PWMs). Each bank of outputs can be independently controlled for dimming rate and intensity through the I²C bus. The dimming and blink rates are fully programmable. The intensity of each bank of LEDs is controlled by dynamically varying the duty cycle of the signal, which has a period of approximately 8 ms and a pulse rate of 125 times per second, driving the outputs.

For example, the designer can program a blink mode as shown in Figure 1-4. Assume that this blink mode relates to PWM0 or BANK0. By comparing this cycle with that in Figure 1-3, it is noted that the LED does the following:

1. Fades on for 192 ms (value of 3 in Fade-On Time register)
2. Stays fully on for 384 ms (value of 5 in Fully-On Time register)
3. Fades off for 192 ms (value of 3 in Fade-Off Time register)
4. Stays fully off in the first half of the cycle for 512 ms (value of 6 in First Fully-Off Time register)
5. Stays fully off in the second half of the cycle for 1024 ms (value of 8 in Second Fully-Off Time register)
6. Is at 100% intensity in the fully-on state (value of 15 in the Maximum Intensity register)

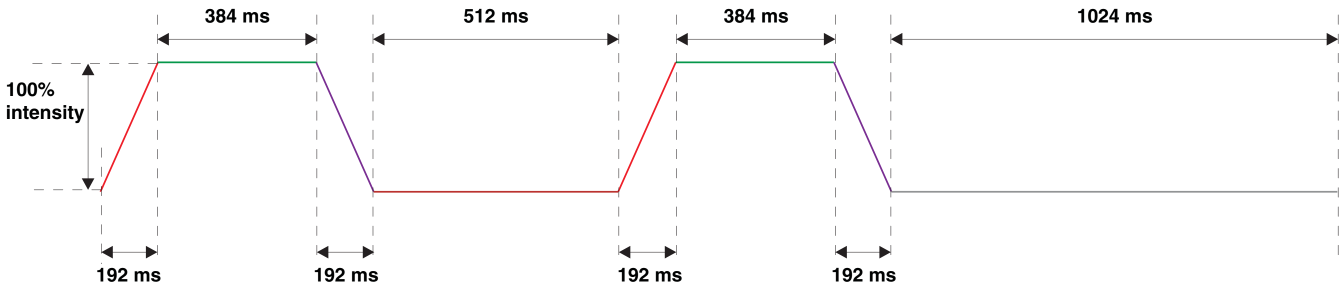


Figure 1-4. LED Blink Cycle Example

Thus, the TCA6507 is very versatile and flexible and can be used in a wide range of fun light applications.

In addition to supporting fun lights, the TCA6507 can be used for indicator lighting. Figure 1-5 shows an application where the TPS61052 boost converter and high-power LED driver and the TCA6507 can be used in combination for applications requiring flashlight functionality and/or high-brightness indicator/backlight LEDs.

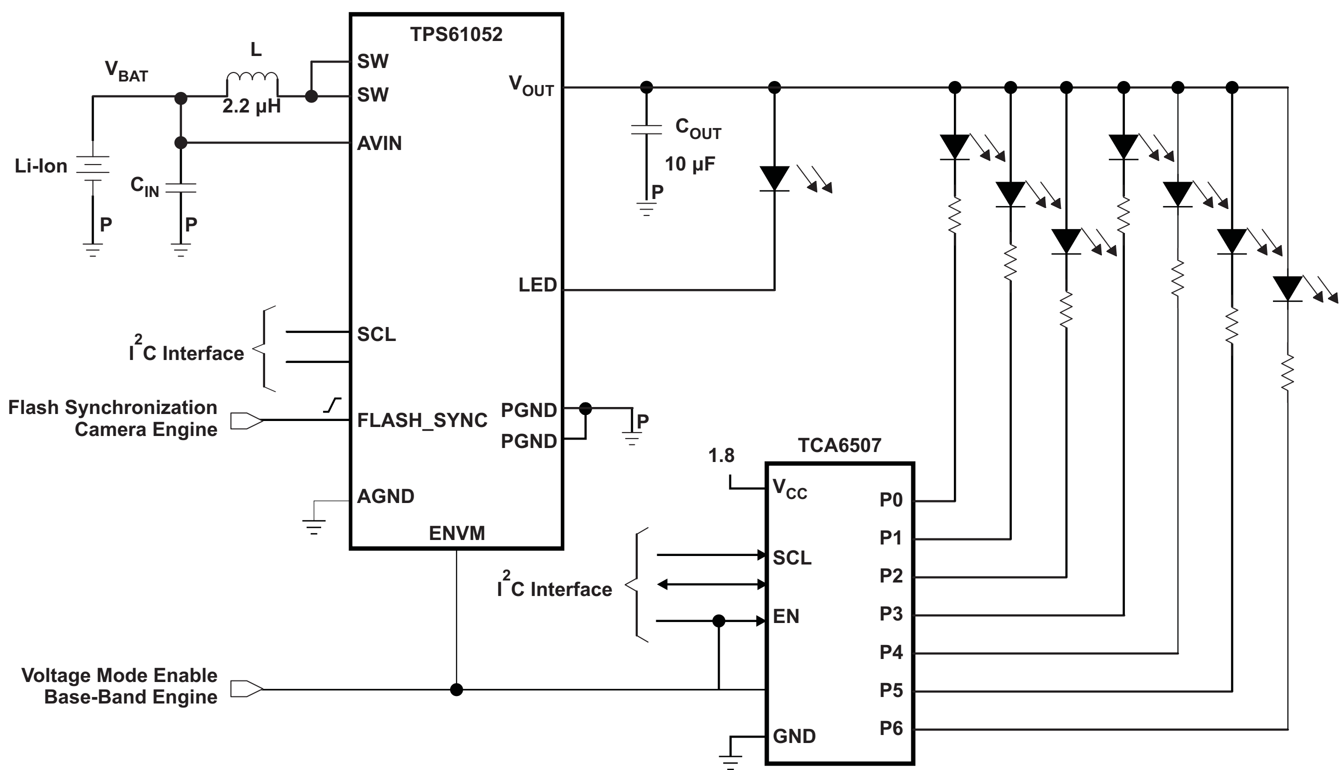


Figure 1-5. TCA6507 for Indicator Lights

The TCA6507 is a great fit for lighting applications in battery-powered portable systems. As previously mentioned, the TCA6507 is ideal for fun lights, enhancing the feature set of an application and for indicator lights. This device allows the core processor to concentrate its processing time and energy toward more critical functions such as communication, audio, or downloading wireless content. The possibilities for using the TCA6507 and I^2C LED drivers are limited only to the number of applications engineers can design.

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