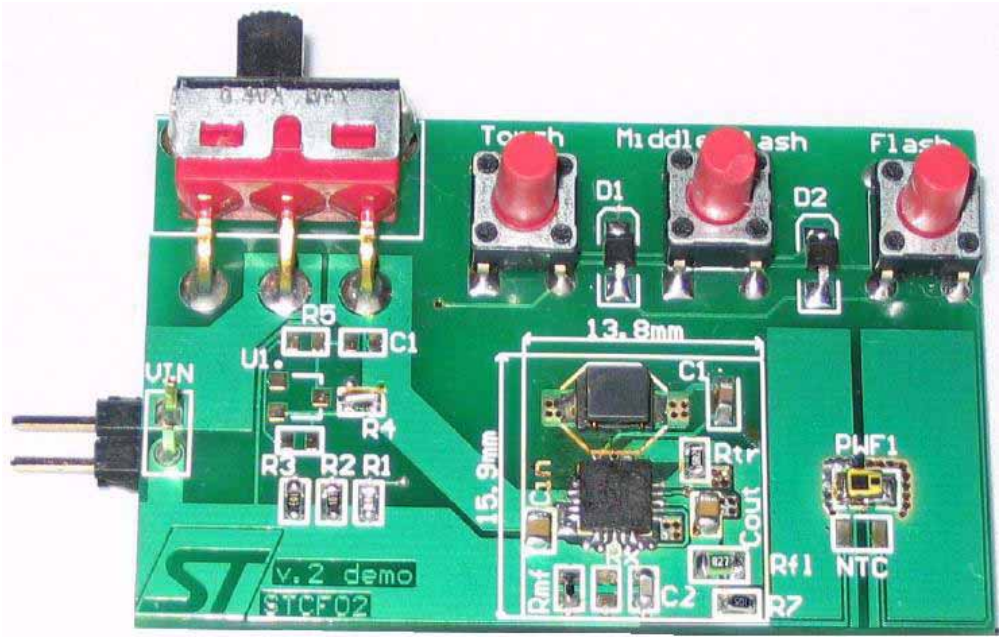
AN2304
Application note

LED driver for single flash

Introduction

This application note is dedicated to the design of a flash LED driver using STCF02, which is a step-up/down current mode converter. Schematic and functional description, recommendations for PCB Layout and external components selection are also evaluated. This device is dedicated for driving a single LED with forward voltage range 2.7 to 5 V.

Photo of reference design board



Contents

1 Schematic description

The Flash LED driver is based on STCF02 device with all necessary external components. High operational frequency (1.8MHz) small size external component usage, resulting a very compact design of the Flash LED device. The device can operate in five modes:

- Shutdown mode
- Shutdown mode with activated NTC LED temperature sensing
- Torch mode
- Middle flash mode
- Flash mode

These modes can be selected by a combination of logic signals connected to enable pins.

Table 1. Truth table selection mode

EN1	EN2	EN3	ILED	ILED_MAX (mA)	MODE
0	0	x	0	0	Shutdown
1	0	1	0	0	Shutdown+NTC
0 1	1 1	x 1	I_{TORCH}= 160mV/(R_{TORCH}+R_{FLASH})	250	Torch+NTC
1	0	0	I_{MFLASH} = f(I_{FLASH}, R_{MFLASH})	500	Medium Flash+NTC
1	1	0	I_{FLASH} = 160mV/R_{FLASH}	600	Flash+NTC

1.1 Application schematic

Figure 1. Typical application schematic

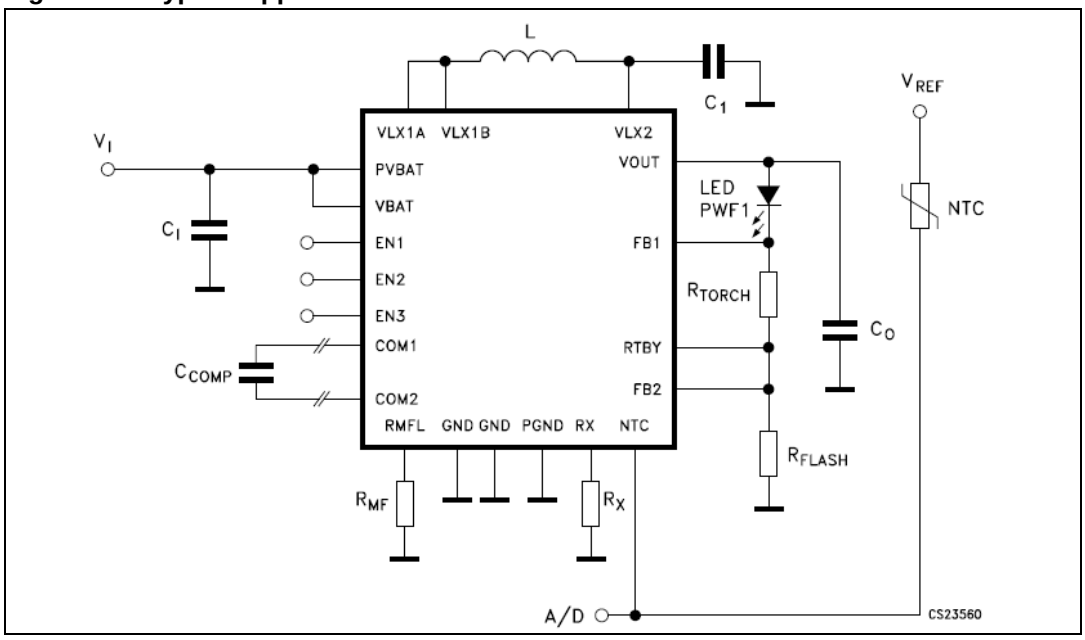


Figure 2. STCF02 Demo board electric schematic

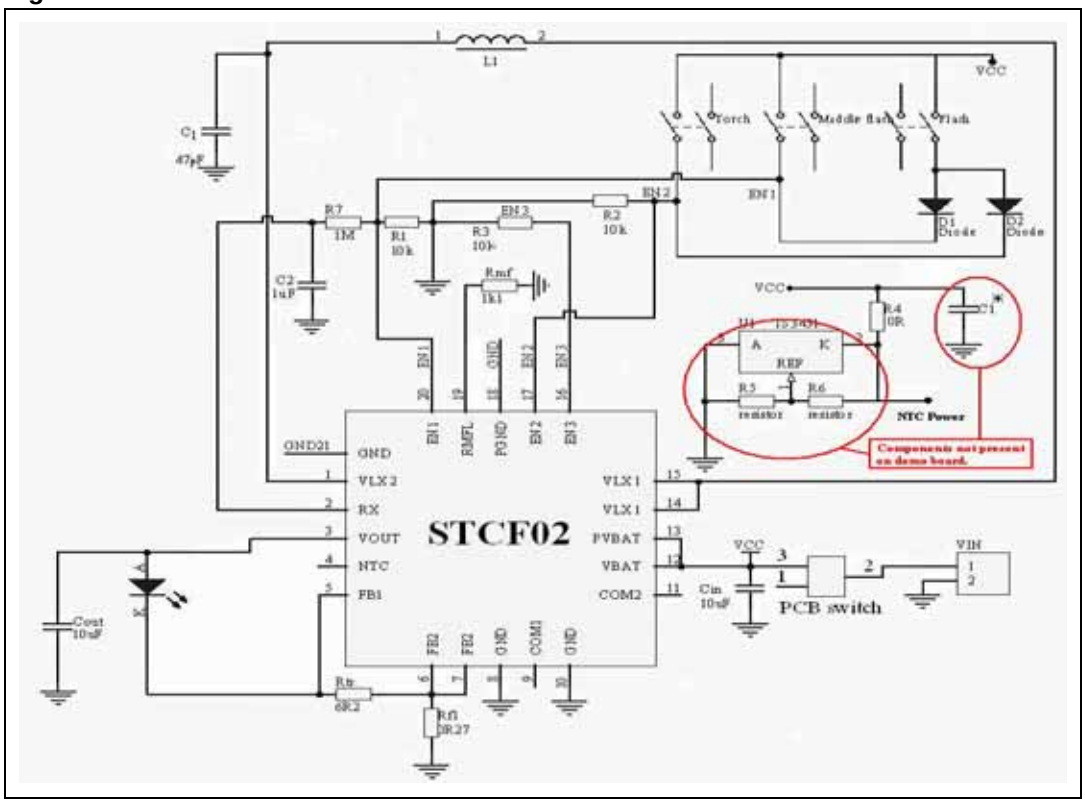


Table 2. STCF02 Demo board BOM List

Symbol	Parameter	Type	Supplier & part number	Typ. value			Unit
				Min	Typ	Max	
R_{FLASH}	Sensing flash current resistor	Thick film type (0805)	ROHM MCR10EZHFLOR27		0.27		Ohm
R_{TORCH}	Sensing torch current resistor	Thick film type (0603)	ROHM MCR03EZPJ6R20		6.2		Ohm
R_{MF}	Setting Resistor for middle flash mode	Thick film type (0402)	ROHM MCR01MZSF1K10		1100		Ohm
C_{IN}	Input filtering capacitor	Ceramic type (0603) 6.3 V	TDK C1608X5ROJ106MT		10	2x10	µF
C_{OUT}	Output capacitor	Ceramic type (0603) 6.3 V	TDK C1608X5ROJ106MT		10		µF

Table 2. STCF02 Demo board BOM List (continued)

Symbol	Parameter	Type	Supplier & part number	Typ. value			Unit
				Min	Typ	Max	
L	4.5(L) x 4.7 (W) x 1.4 (L)	Low profile inductor shielded	TDK VFL5014A-4R7		4.7		µF
		DCR			0.12		Ohm
		Isat			1.7		A
R1	Anti bump resistor	Thick film type (0402)	ROHM MCR03EZPJ10KR00		10		KOhm
R2	Anti bump resistor	Thick film type (0402)	ROHM MCR03EZPJ10KR00		10		KOhm
R3	Anti bump resistor	Thick film type (0402)	ROHM MCR03EZPJ10KR00		10		KOhm
R4	Resistor	Thick film type (0402)	ROHM MCR03EZPJ1R00		0		Ohm
R7	Safety shutdown resistor	Thick film type (0402)	ROHM MCR03EZPJ1MR00		1		MOhm
C1	Filtering Capacitor	Ceramic (0603)	TDK C1608C0J1H470J		47		pF
C2	Safety shutdown capacitor	Ceramic type (0603) 6.3 V	TDK C1608X5ROJ105MT		1		µF
D1	Schottky diode		STPS1L40M				
D2	Schottky diode		STPS1L40M				
LED	Luxeon LED	PWF1	LXCL-PW1				

2 Selection of external components

2.1 Input and output capacitor selection

For input and output capacitors it is recommended to use a ceramic capacitor with low ESR. For a good stability of the device supplied by a low input voltage of 2.7 V at maximum ratings, it is recommended to use 10 uF/6.3 V as a minimum value of input capacitor and 10 uF/6.3 V as a minimum value of output capacitor.

Note: See recommended components in *Table 2.*

2.2 Inductor selection

Shielded thick inductor with low DC series resistance of wiring is recommended for this application. For good efficiency it is recommended to use an inductor with series DC resistance R_{DCL}<R_D/10, [Ω, Ω1] where RD is dynamic resistance of LED.

For nominal operation, the peak inductor current can be calculated by this formula:

Equation 1

$$I_{PEAK} = \left(\frac{I_{OUT}}{n} + \frac{(V_{OUT} - V_{in}) \bullet V_{IN}^{2}}{2 \bullet L \bullet F \bullet V_{OUT^2}} \right) \bullet \frac{V_{OUT}}{V_{IN}}$$

Where:

- I_{PEAK} Peak inductor current
- I_{OUT} Current sourced at the VOUT pin
- n Efficiency of the STCF02
- V_{OUT} Output voltage at the pin Vout
- V_{IN} Input voltage at the pin Vin
- L Inductance value of the inductor
- F Switching frequency

Note: See recommended components in Table 2.

2.3 LED selection

Any LED with forward voltage from 2.7 V to 5 V is feasible for use with device STCF02. LED forward voltage must include the voltage spread of this value. It is possible to set the LED current in the three different operating modes (torch, medium flash, high flash) through three external sensing resistors.

Note: See recommended components in Table 2.

2.4 R_{FLASH} selection

R_{FLASH} resistor can be selected by equations R_{FLASH}=160mV/I_{FLASH} and P_{RFLASH}=R_{FLASH}*I_{FLASH}^2, where PRFLASH is the dissipated power on R_{FLASH} resistor. It is recommended to use thick metal film resistor 0603 package size with 1% tolerance. Maximum flash LED current for STCF02 device is 600mA in battery voltage range from 2.7 V to 5.5 V.

2.5 R_{TORCH} selection

R_{TORCH} resistor can be selected by equations:

Equation 2

$$R_{TORCH} = \frac{160mV - (I_{TORCH} \bullet R_{FLASH})}{I_{TORCH}}$$

Equation 3

$$P_{RTORCH} = R_{TORCH} \bullet I^{2}_{TORCH}$$

where P_{RTORCH} is the dissipated power on R_{TORCH} resistor. It is recommended to use thick metal film resistor with 1% or 5% tolerance. Maximum torch LED current for STCF02 device is 250 mA in voltage range from 2.7 V to 5.5 V.

2.6 R_{MF} selection

With this resistor it is possible to set the LED current value in middle flash mode. The value of R_{MF} resistor is defined by equation:

Equation 4

$$I_{MF} = \frac{10^{-5}}{R_{FL}}\left(3000 + \frac{13000 \bullet R_{MF}}{13000 + R_{MF}}\right)$$

where I_{MF} is middle flash LED current. It is recommended to use thick film resistor in 0402 package size.

2.7 C_{COMP} selection

This component could optionally be used if the error amplifier bandwidth, which is set to 2kHz default, has to be decreased in case of unstable function of driver, which could cause the use of different inductor and output capacitor values. It is recommended to use a ceramic capacitor in 0402 package size.

2.8 NTC and Rx resistor selection

The NTC resistor for sensing LED temperature and the Rx resistor create the voltage divider. Output of this divider is compared to the internal voltage reference 1.192 V. When the voltage of the voltage divider output is increased over the reference, the logic will switch off the power circuit.

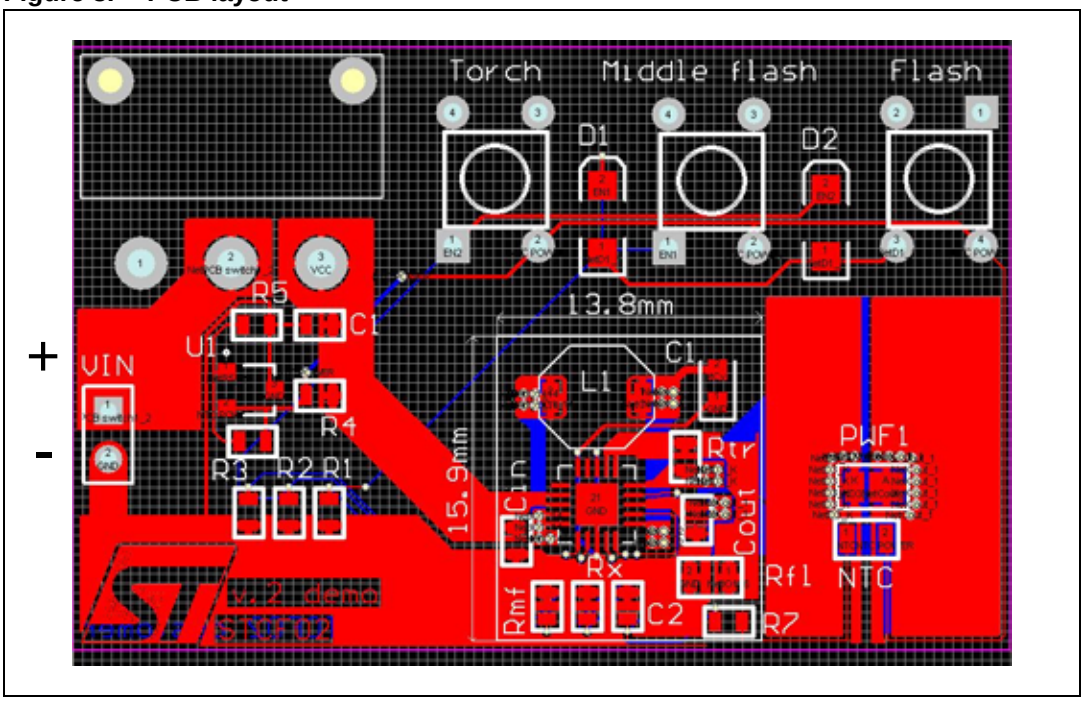
The maximum current, which could flow through the NTC pin is 1mA. Voltage divider must be supplied from an external voltage source.

3 PCB design

3.1 PCB design rules

STCF02 is a powerful switched device, the PCB must be designed in line with rules for designing switched supplies. It is recommended to use at least four layers PCB to save the area on application PCB. The power wirings must be as short as possible and wide, because of large current. Place all external components close to the STCF02. High-energy switched loops should be as small as possible to reduce EMI. Most of LEDs need cooling, which could be done by defined area of copper on the PCB. Use the reference guide of each LED to design the heatsink. Place the RFLASH resistor as close as possible to pin 8. When the change of PCB layer is needed, use enough vias. Place the NTC resistor as close as possible to LED for good temperature sensing. Direct connection of GND and PGND is needed to achieve correct value of output current. The Led current should not flow through this track! Sensing of the voltage on the Rflash resistor has to be done with a wire from pin 7 directly connected to Rflash resistor, no current flows through this track. Pin 6 and pin 7 have to be connected on the pin of Rflash resistor. Expose pad has to be connected to the PGND with a track as wide as possible.

Figure 3. PCB layout



Input supply range = 2.7 V to 5.5 V

- Torch mode selection: pushing the Torch button, we will have 25 mA current flowing through the WLed, no time limit is present. Is possible to reach up to 250 mA of torch current calculating the R_{torch} resistor using this formula:

Equation 5

$$I_{TORCH} = \frac{16mV}{R_{TORCH} + R_{FLASH}}$$

- Medium Flash mode selection: pushing the Medium Flash button, we will have 150 mA current flowing through the WLed, safety shutdown is active and after maximum 0.5 sec. the WLed will be turned off. Is possible to reach up to 500 mA of medium Flash current calculating the Rmflash resistor using this formula:

Equation 6

$$I_{MF} = \frac{10^{-5}}{R_{FL} \bullet \left[3000 + \left(\frac{13000 \bullet R_{MF}}{13000 + R_{MF}}\right)\right]}$$

- Full Flash mode selection: pushing the Full Flash button, we will have 600 mA current flowing through the WLed, safety shutdown is active and after maximum 0.5 sec. the WLed will be turned off. Is possible to reach up to 600 mA of full Flash current calculating the Rflash resistor using this formula:

Equation 7

$$I_{FLASH} = \frac{160mV}{R_{FLASH}}$$

4 Safety shutdown in flash mode

Alternatively to NTC temperature sensing and protection, it is possible to properly drive all the STCF02 features with only the EN1 and EN2 pins and include the safety shutdown mode. This feature has to be active only for Mid Flash and Full Flash operating mode because in Torch mode there is no risk of burning the LED because of the low current flowing through it.

The purpose of this specific application is to avoid LED burning if the microcontroller does not work properly (this means EN1 and/or EN2 are pins stuck in a high logic level). If EN2 is stuck at high level while EN1 still in low level, the selected mode is Torch, and the safety shutdown in not needed.

If EN1 is stuck at high level, the STCF02 is in Mid/Full Flash mode and the LED should be protected from long time operation at high peak current. In this condition, after an RC defined time, the LED automatically goes off and stays off waiting for EN1/EN2 pin resuming at low level.

After the microcontroller reset, both EN pins will go at low level (device enters "All off" mode) and the capacitor is discharged. At this point, the STCF02 is ready to resume the normal operating mode.

In typical operating conditions safety shutdown time is about 500msec. This is possible by applying an RC filter with R=1 MOhm and C=0.47 uF.

Figure 4. Safety shutdown RC circuit

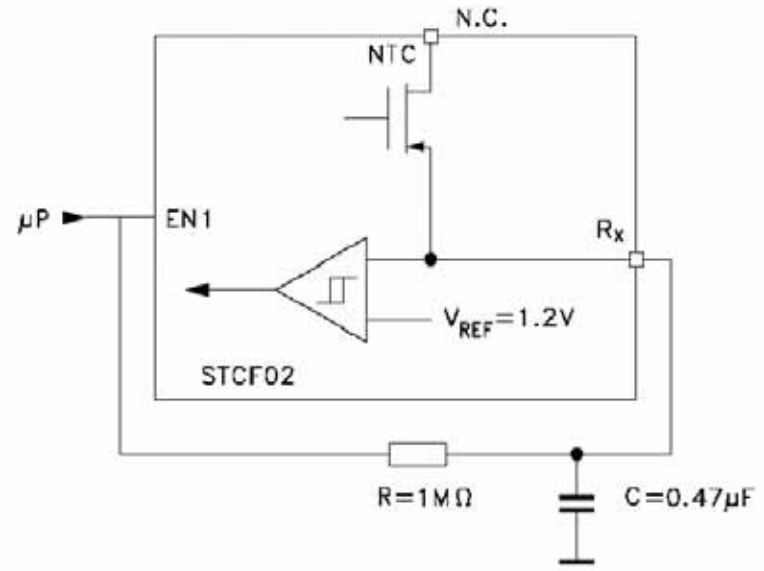
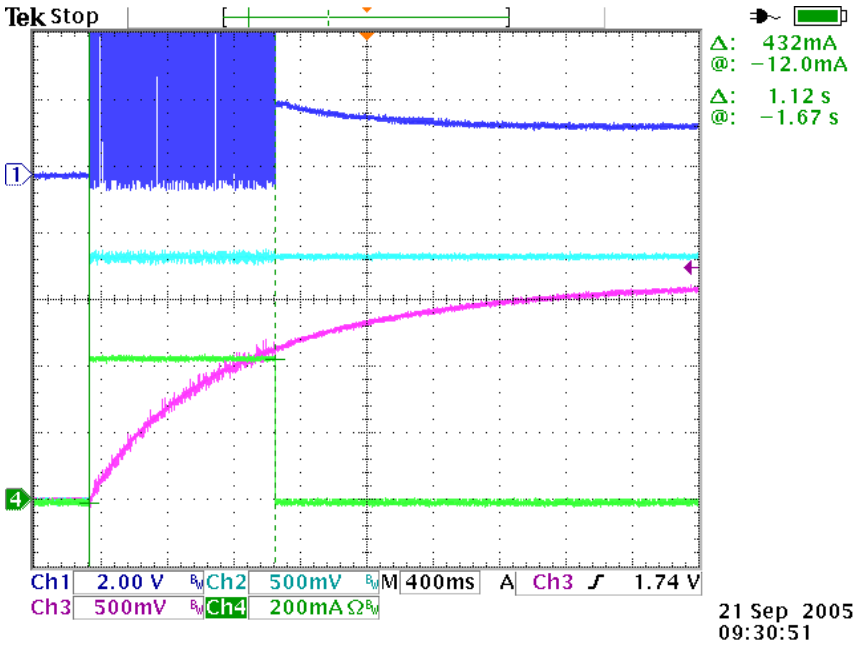


Figure 5. Safety shut down graphics



Operation for RC filter R=1M Ohm, C=1.0 uF; VLX1 switching voltage (dark blue), during flash mode with EN1 voltage in high level (light blue). The RX pin voltage (violet) increases and the output current (light green) goes down after one second (1.192 V threshold reached).

5 Revision history

Table 3. Revision history

Date	Revision	Changes
26-Jan-2006	1	First issue
04-Apr-2006	2	- Pictures changed - New values added in table “Bill of Material“
25-May-2006	3	- Pictures changed
06-Feb-2007	4	- Pictures changed - BOM changed - Minor text changes

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