AND8320/D

Xenon Flash Application Design Based on NCP5080 Integrated with IGBT Driver and Photo Sense Function

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Introduction

Nowadays Cameras are more and more popular in PDAs, GPS devices, and cell phones. As camera pixel increases to 5 mega pixels, higher quality imaging together with photo flash function is required to be integrated in portable devices. There are two traditional ways for flash application, the first is WLED (White Light Emitting Diode) based flash, which has advantage in space, but require longer flash duration to tens or hundreds milliseconds, so it's more suitable for still picture shooting. Unlike WLED has very narrow spectrum, Xenon flash has wider spectrum with excellent color balance (light spectrum closer to sunlight) in the visible region. Spectrum is also stable with tube aging. Currently Xenon flash tube from factory is very small, allowing integration without sacrificing portable devices' size. Because of its good performance, Xenon tubes are widely used as camera strobes in DSC (Digital Still Camera) and more and more popular in cell phones.

This paper presents how to design Xenon flash application based on NCP5080 which is a high voltage boost driver integrated with IGBT driver, photo sense function, thermal shutdown, transformer primary side current limit and flash control input. The reference circuit can be used in many different applications. Part numbers of important components are also provided. External component selection and layout recommendation for such application are also presented bellow.

REFERENCE CIRCUIT

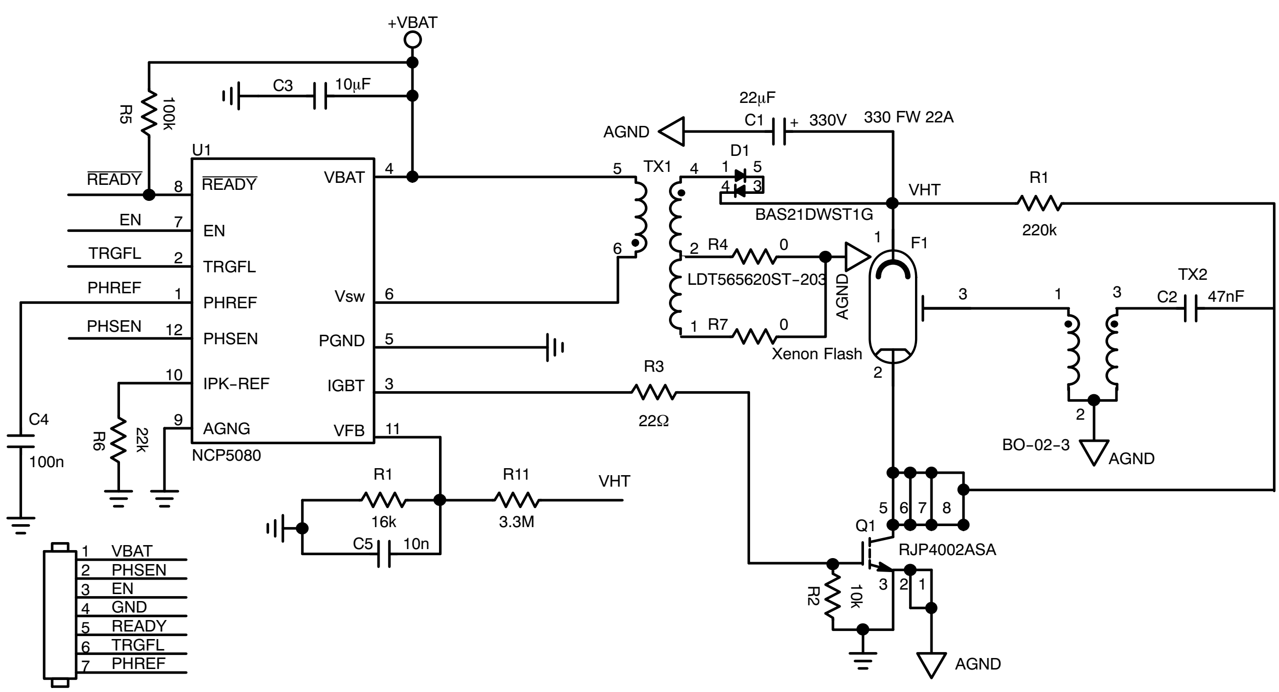


Figure 1. Reference Circuit of NCP5080 for Xenon Flash Application

NCP5080 INTRODUCTION

Internal Block Diagram of NCP5080

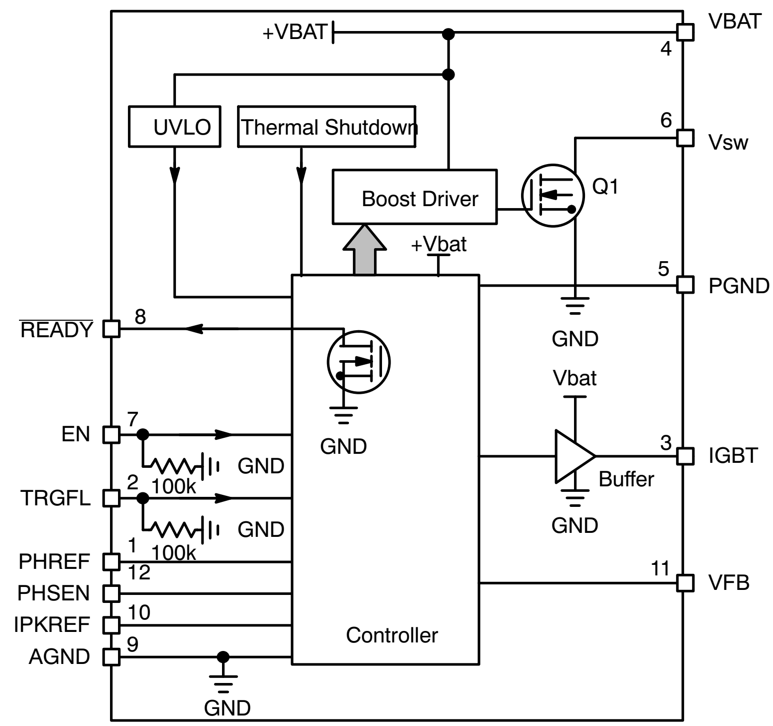


Figure 2. Internal Block Diagram of NCP5080

Transformer Primary Side Peak Current Setting

To avoid large sink current from battery in portable applications, which may result in large voltage drop of battery voltage in different points of system, transformer TX1 primary side peak current could be easily set by an external resistor, which is R6 in reference circuit. Designers can adjust this peak current according to different application requirements, and maximum value of this peak current should not be over 1.5 A for NCP5080. The peak current can be obtained from following equation:

$$I_p = \frac{14000 \times 1.14}{R6} (A) \qquad \text{(eq. 1)}$$

Output Voltage Control

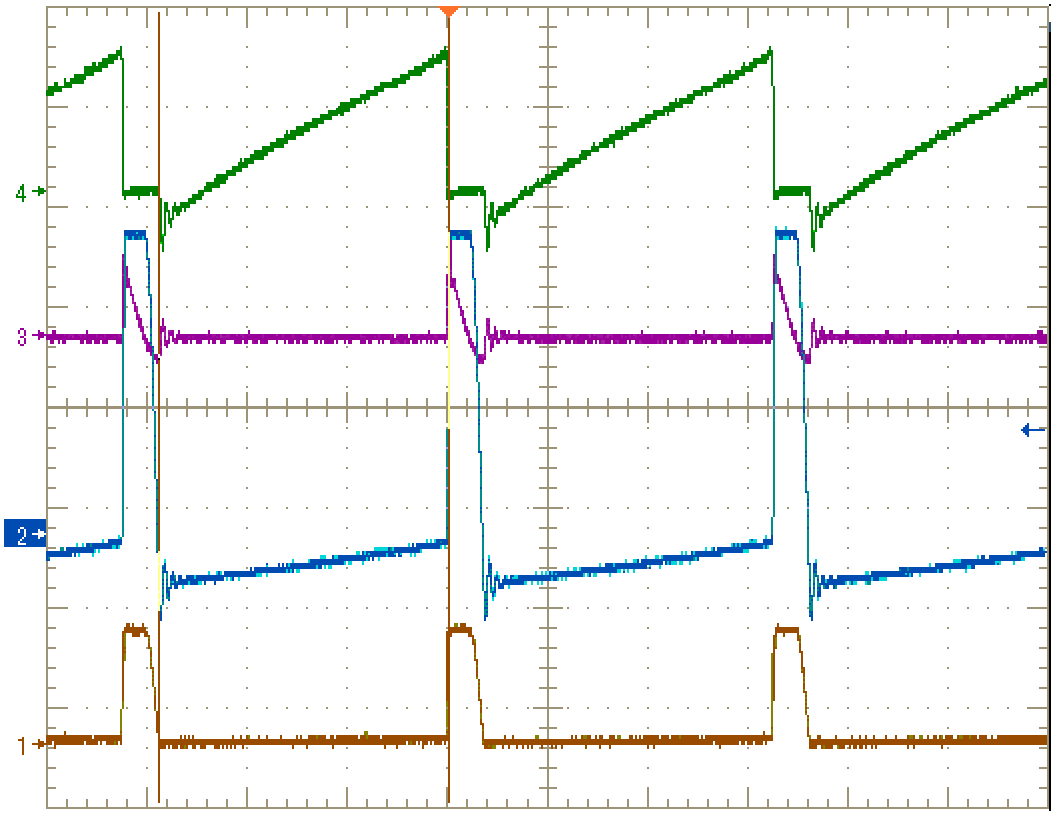
By simple external resistor network, NCP5080 can control output voltage by detecting feedback voltage on FB Pin and adjusting the charge/discharge of transformer and conversion of energy from V_{BAT} to reservoir capacitor. Output voltage V_{out} can be set by:

$$V_{out} = \left(\frac{R11}{R10} + 1\right) \times V_{REF} \qquad \text{(eq. 2)}$$

Where R11 and R10 are feedback resistors and V_{REF} is internal reference voltage (1.15 V typically).

Charging of Reservoir Capacitor

After being powered with 2.7 V through 5.5 V input voltage and enabled (EN = High), NCP5080 starts the conversion of energy from power supply to reservoir capacitor. NCP5080 integrates transformer primary side current limit and its operating frequency is from 15 kHz to 600 kHz with internal time out of t_{on} and t_{off}. These characteristics provide wide adaptability to different transformers and application conditions.



Ch1: SW; Ch2: TX1 secondary side voltage; Ch3: TX1 secondary side current; Ch4: TX1 primary side current

Figure 3. Working of NCP5080 When Secondary Current Can Decrease to Zero

During t_{on} time Q1 is turned on and primary side of transformer TX1 is charging. Its current rises until it reaches to peak current set by R6. t_{on} is determined by start current of primary side and inductance of primary side. If primary current starts from zero and we ignore voltage drop on Q1, t_{on} could be estimated by following equation:

$$t_{on} = \frac{I_p \times L_p}{V_{BAT}} \qquad \text{(eq. 3)}$$

During t_{off} time Q1 is switched off and energy has to be released to reservoir capacitor, the t_{off} time is determined by V_{out} and maximum current of secondary, this time could be approximately estimated by following equation when primary current starts from zero at each switching cycle and ignore negative current of secondary side:

$$t_{off} = \frac{L_p \times I_p \times \frac{N_s}{N_p}}{V_{out}} \qquad \text{(eq. 4)}$$

Where L_p is primary inductance, I_p is peak current of primary side, (N_s/N_p) is secondary/primary ratio. So the operating frequency of NCP5080 could be estimated by $((1)/(t_{on} + t_{off}))$ and should be from 15 kHz to 600 kHz;

1. It's strongly recommended to not let NCP5080 work without reservoir capacitor, which may cause overheat of transformer and damage of transformer and NCP5080.
2. When NCP5080 is disabled or powered off, there is no special leakage path for reservoir capacitor; high voltage will not disappear immediately but exist for certain time, which depends on capacitance of the reservoir capacitor and leakage current. BE CAREFUL!

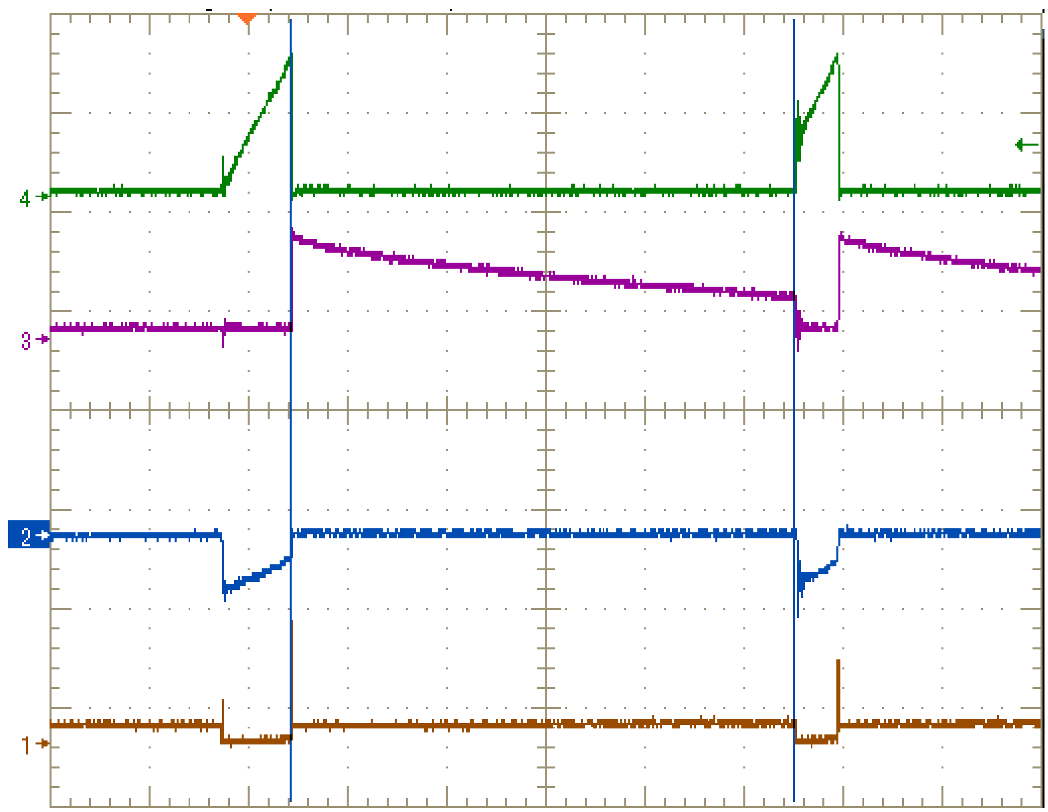


Figure 4. Working of NCP5080 when Secondary Side Current Cannot Decrease to Zero

At the startup stage, secondary side current will not decrease to zero because V_{out} is too low and current decrease slope of secondary side is limited. So at the next t_{on} time, primary side current starts not from zero, this will decrease t_{on} time. At this stage internal time out of NCP5080 will control end of t_{off}.

Two charge times with different transformer primary side peak current I_p and reservoir capacitor are provided below for reference:

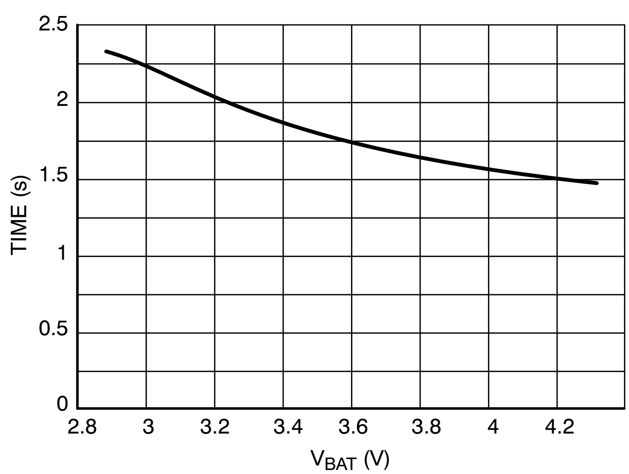


Figure 5. Charge Time of Reservoir Capacitor versus V_{BAT} with I_p = 0.75 A, 240 V_{out} and 33 μF Reservoir Capacitor

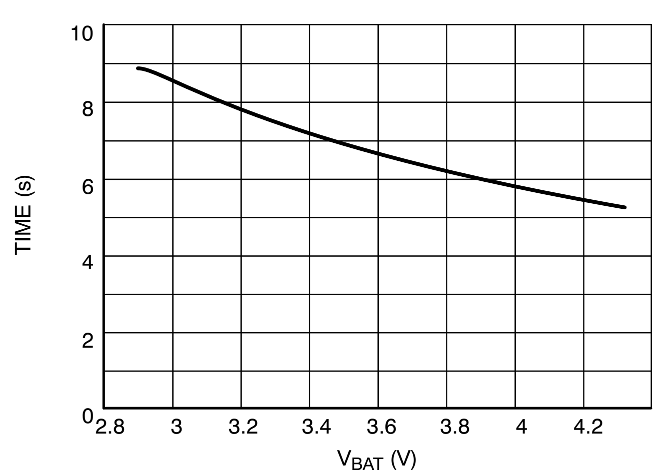


Figure 6. Charge Time of Reservoir Capacitor versus V_{BAT} with Ip = 1.5 A, 300 V_{out} and 120 μF Reservoir Capacitor

Photo Sense Function

The photo sense function provides a simple way to control the light energy generated from Xenon tube to scenery to avoid over exposure. The PHREF pin should be biased according to real application, because of the brightness detected by photo sensor is determined by distance between senor and scenery, path attenuation of light from scenery to sensor. It is easy to adjust the resistor between PHSEN and ground to adapt real application.

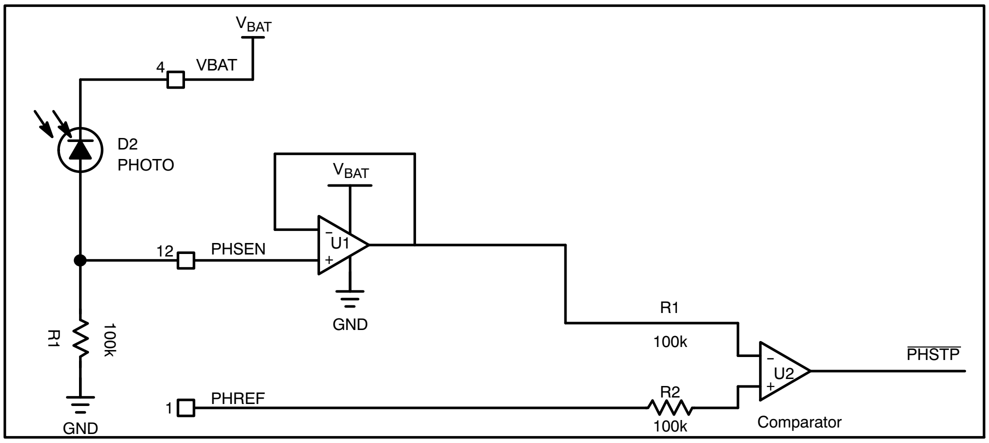


Figure 7. NCP5080 Photo Sense Function Diagram

To make sure photo sense function works correctly, PHREF should be set according to real application and between 0.5 V and 1.5 V; Designers can select photo sensor D2 and R1 to make sure PHSEN voltage (equals to Iv * R1, Iv is photo current of photo sensor) be higher than PHREF voltage level when brightness detected by D2 reaches corresponding value. Designers should take into account the attenuation of brightness from scenery under shoot to photo sensor. Once PHSEN voltage level is higher than PHREF, NCP5080 will pull IGBT to low and terminate current flash immediately, whatever the status of TRGFL is.

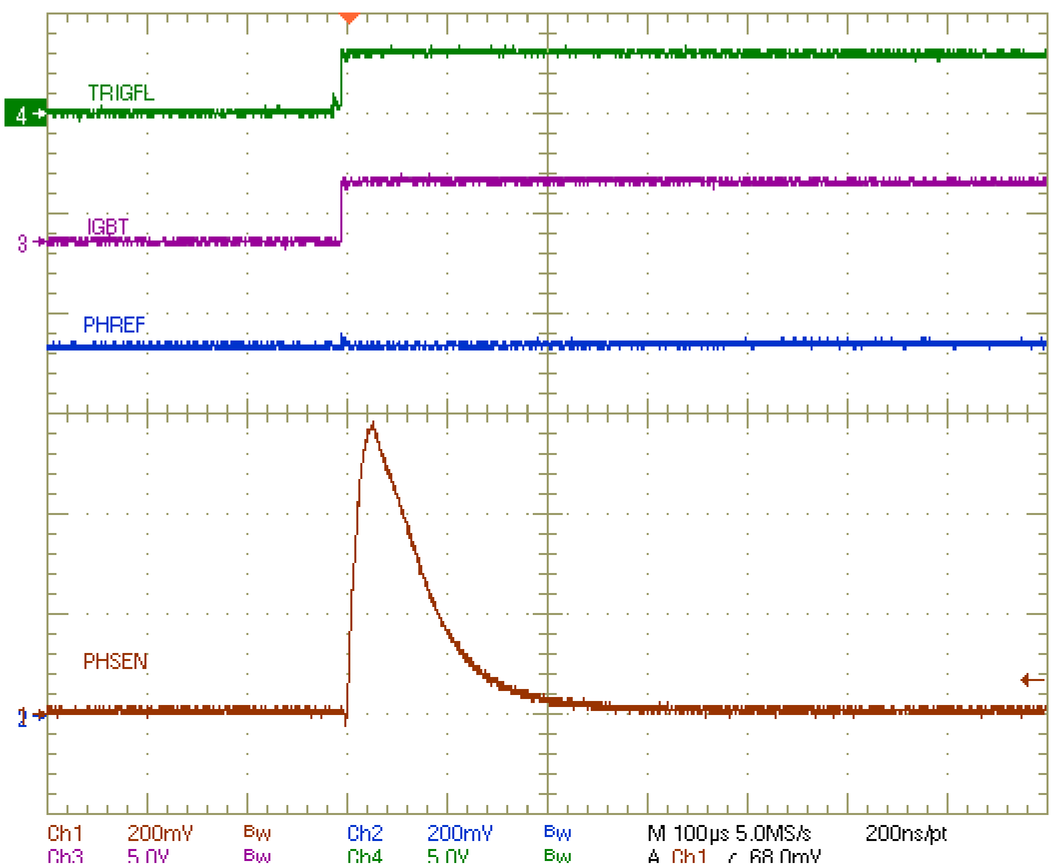


Figure 8. Flash Duration Not Terminated by Photo Sense Function (PHSEN Lower than PHREF)

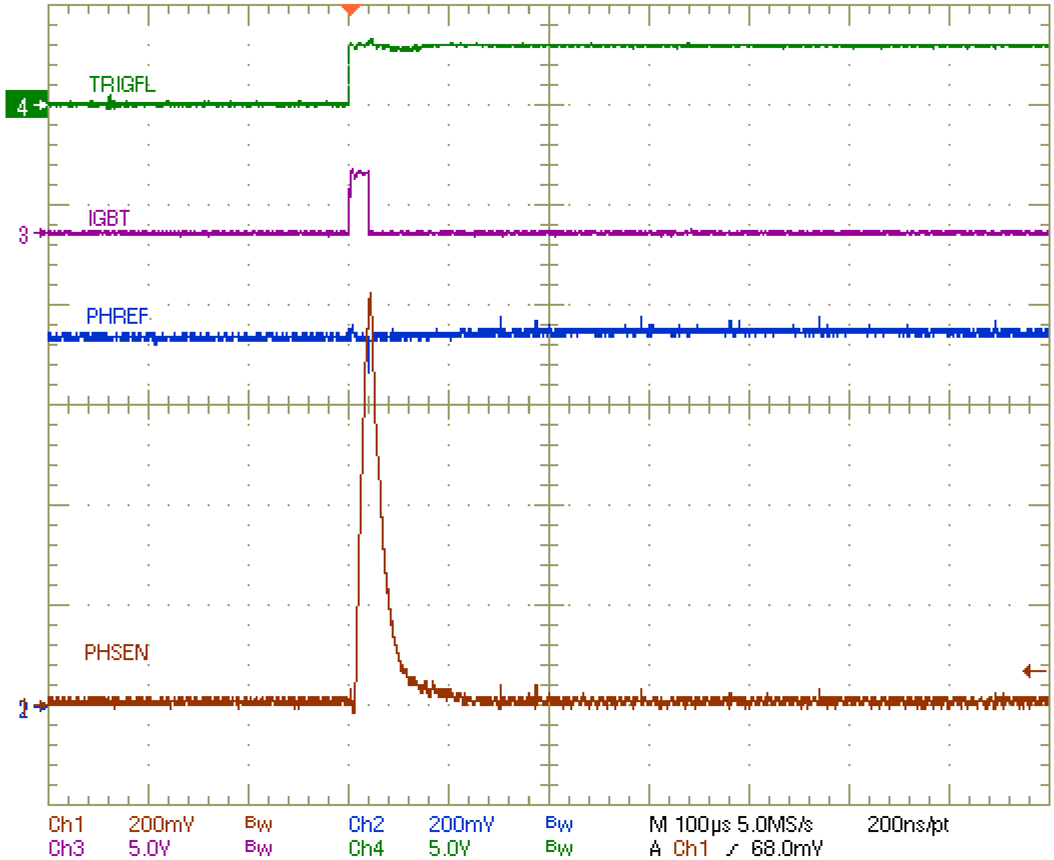


Figure 9. Flash Duration Terminated by Photo Sense Function (PHSEN Higher than PHREF)

If photo sense function is not required, PHREF can be biased by voltage between 0.5 V and 1.5 V, and connect PHSEN to ground directly, floating of PHSEN may cause misjudgment of photo sense function because of noise.

Table 1. PHOTO SENSE FUNCTION TRUTH TABLE

Condition	Operation	Comment
$0.5\ V \le PHREF \le 1.5\ V$ PHSEN = GND	Photo Sense Function Deactivated	Flash is controlled by TRGFL
PHREF Fixed(0.5 V ~ 1.5 V) PHSEN = Iv * R1	Photo Sense Function Activated	Flash is controlled by TRGFL and PHREF/PHSEN relations, flash will be terminated once PHSEN > PHREF

The photo sense function can also be used by application software to detect ambient light condition and disable NCP5080 if flash is not required. Figure 10 gives implementation idea for this function.

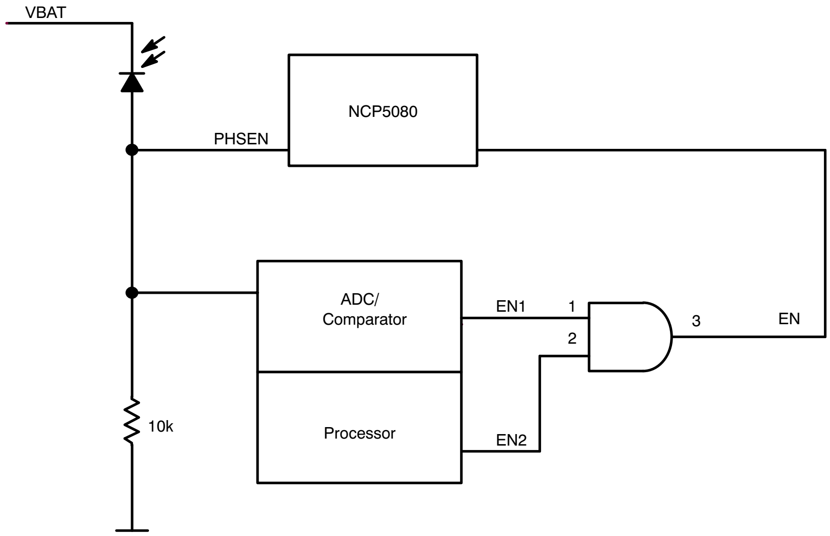


Figure 10. Diagram for Brightness Detect and NCP5080 Enable Control

PHSEN signal from photo sensor is provided to NCP5080 and ADC/Comparator module. If environment light brightness is low ADC/Comparator will output high, and AND gate will output high if auto flash function is enabled. NCP5080 controls charging of reservoir capacitor and flash then. If environment light brightness is high enough, ADC/Comparator will output low, AND gate will output low also and disable NCP5080 to avoid charging of reservoir capacitor, to avoid waste of energy converted from V_{BAT} since the Xenon tube need not be triggered. The AND gate can be removed if processor can detect light condition (from ADC or comparator) and complete the function of AND gate by software.

IGBT Driver

NCP5080 integrates IGBT driver, which has powerful drive capability. It powers from V_{BAT}, so IGBT gate drive voltage should be compliant with V_{BAT}. Another serial resistor R3 is added for different IGBT drive requirements, such as special turn−on and turn−off dv/dt requirements of IGBT.

Flash Control

By a positive edge and lasts for certain time, NCP5080 IGBT pin will output high voltage to turn on IGBT and start a flash. Flash will continue until reservoir capacitor is fully discharged, or flash duration is terminated by photo sense function or TRGFL is pulled low.

Ready for Flash Indication

NCP5080 will pull READY pin to low when it detects V_{out} reaches setting value, READY pin is an open drain structure, so an external pull up resistor is required. This is indication of flash ready; a flash can be started after READY is low.

External Component Selection

Selection of D1

The most important parameter of D1 is reverse voltage VR, which should be much higher than working voltage of Xenon flash tube plus N * V_{BAT} reversed voltage potential at anode of diode during t_{on} time, what’s more, output voltage ripple because of V_{out} detect and control should also be considered.

Reverse recovery time also is an important parameter of diode, from Figure 3 we can see there is reverse current flows from reservoir capacitor through diode to secondary side of TX1, which will cause energy loss and recharge to battery. Maximum reverse recovery time of BAS21DW5T1G is 50 ns.

Selection of Xenon Tube

Tube is dominant for light energy emitting; it determines reservoir capacitor working voltage and trigger pulse requirement for trigger circuit. Based on light energy and working voltage requirements, there are many choices in the market. Among wide offer in the market, NamKwong (http://www.namkwong.com.hk/) as well as Perkin Helmer (http://www.perkinelmer.com/) can supply very small form factor tubes that will make the resulting module small enough to fit in a mobile camera phone handset. The tube mounted on the board associated with this application note is NamKwong one.

Selection of Transformer TX1

According to fly back converter principle, primary switching current is related to primary inductance, since peak current of primary is limited by NCP5080, so the larger I_p is, the longer t_{on} is and the lower switching frequency of NCP5080 is.

Ratio of transformer should be larger than 10:1 because of V_{ds} of Q1 is 40 V maximum. If V_{out} is set to 300 V, peak voltage of V_{ds} will be the sum of 30 V (10:1 ratio) and voltage spike caused by leakage inductance. So leakage inductance should be as small as possible, voltage spike at SW pin caused by leakage inductance may damage NCP5080 and cause energy loss also. When use low ratio transformer like 10:1, 200 nH leakage inductance or lower is recommended.

Rated TX1 primary side current will affect the charge time of reservoir capacitor and operating frequency of NCP5080, remember that maximum of primary peak current should be lower than 1.5 A.

Another parameter of transformer is DC resistance of primary and secondary side, which will cause energy loss. Recommended transformer and supplier: CJ5143−AL − Coilcraft (http://www.coilcraft.com/), and LDT565620ST−203: TDK (http://www.component.tdk.com/index.php)

Photo Sensor Selection

There are different kinds of photo sensor in market, such as photo diode and photo transistor, its principle is similar but different in output and sensitivity. Following parameters should be taken into account when select the photo sensor.

1. Spectrum Sensitivity: It's better if sensor's peak sensitivity is around 570 nm, closer to CIE standard human visibility is better;
2. Temperature characterization of photo sensor: Some sensor is sensitive to temperature, working temperature should be taken into account if end product will work under wide temperature conditions;
3. Linearity of sensor's sensitivity, slope rate of sensor output versus brightness is not constant typically: The more linear the better;
4. Output variation between sensors of the same batch and different batches;

IGBT Selection

1. Safe Operating Area (SOA): IGBT should work under the SOA area specified in its datasheet. Its collector−emitter maximum voltage is higher than Xenon tube working voltage and it can satisfy maximum current requirement of Xenon tube; Typical GPIO has no enough current drive capability to turn on/off IGBT fast enough, NCP5080 integrates this IGBT driver, saving external one to lower total cost and solution size.

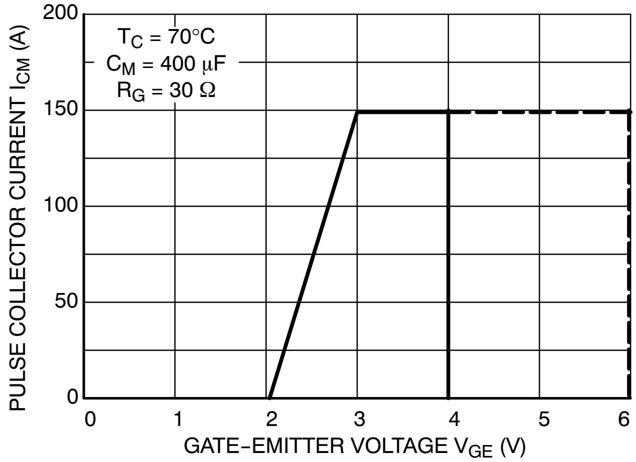


Figure 11. Performance Curve of RJP4002ANS

2. Gate Drive Voltage ($V_{GE(th)}$) should be compliant with V_{BAT} of NCP5080, that's to say $V_{GE(th)}$ should be lower than V_{BAT}. NCP5080 can work well when V_{BAT} is from 2.7 V to 5.5 V, which includes most IGBT gate drive voltage range for portable Xenon flash application.
3. Gate drive capacitance cooperates with turn−on/turn−off characterization, this will affect turn−on/turn−off speed and trigger signal. An external resistor R3 is provided in reference circuit to adapt to different turn−on/turn−off requirements.

Reservoir Capacitor Selection

Reservoir capacitance should be selected according to Xenon tube flash energy requirement:

$$C \le \frac{2 \times E}{{V_{out}}^2} \qquad \text{(eq. 5)}$$

Here E is flash energy of tube, please use nominal value for calculation in case tube differences cause reliability issue of end product. Too high energy will decrease tube life time or even damage the tube. Take the tube in reference circuit as an example, its flash energy E is 1.57 Ws typically and nominal working voltage is 300 V, reservoir capacitor should be less than (2 x 1.48)/(300^2) = 49 μF, so 47 μF or 33 uF is acceptable theoretically, considering capacitance tolerance, temperature coefficient, its recommended value is 33 μF.

Rated voltage of this capacitor should be higher than V_{out} of course, such as 330V or higher rated voltage capacitor for

300 V application. And low leakage current, low DF is strongly preferred.

Leakage current will cause power loss, decrease output voltage and effect READY output stability of NCP5080;

Recommended supplier of reservoir capacitor: www.rubycon.com

Trigger Coil

Selection of trigger coil depends on trigger requirements of Xenon tube, which determines peak voltage of trigger signal, positive or negative pulse and so on. And reference trigger capacitor can be found in trigger coils' datasheet.

Recommended supplier of trigger coil: http://www.tokyo-coil.co.jp/index.html.

Table 2. BOM OF REFERENCE CIRCUIT

Item	Qty	Reference	Part Description	Package	Supplier	Ref Part #
1	1	U1	Flash Reservoir Capacitor Charger	LLGA12	ON Semiconductor	NCP5080MUTXG
2	1	F1	Xenon Flash Tube		NamKwong Perkin Helmer	
3	1	TX1	Transformer		TDK	LTD565620ST-203
4	1	Q1	IGBT	VSON-8	RENESAS	RJP4002ANS
5	1	C1	22/33 μF/330 V		Rubycon	33 FW 22A
6	1	D1	Diode	SC-88A	ON Semiconductor	BAS21DW5T1G
7	1	C2	47 nF/400 V, 10%	1210	TDK	C3225X7R2J473K
8	1	C3	10 μF/6.3 V, 20%	0603	TDK	C2012X5R0J106M
9	1	C4	100 nF/25 V, 20%	0402	TDK	C2012X5R1E104M
10	1	C5	10 nF/25 V, 20%	0402	TDK	C2012X5R1E103M
11	1	R1	220 kΩ, 5%	0805	Standard	
12	1	R3	22 Ω, 5%	0603	Standard	
13	1	R2	10 kΩ, 5%	0402	Standard	
14	2	R4, R7	0 Ω	0603	Standard	
15	1	R5	100 kΩ, 5%	0402	Standard	
16	1	R6	22 kΩ, 1%	0402	Standard	
17	1	R10	16 kΩ, 1%	0402	Standard	
18	1	R11	3.3 MΩ, 5%	0805	Standard	
19	1	J1	6-Pin 1.27 mm Pitch Connector			
20	1	TX2	Trigger Coil		Tokyo coil	BO-02-3

Reference Design Module

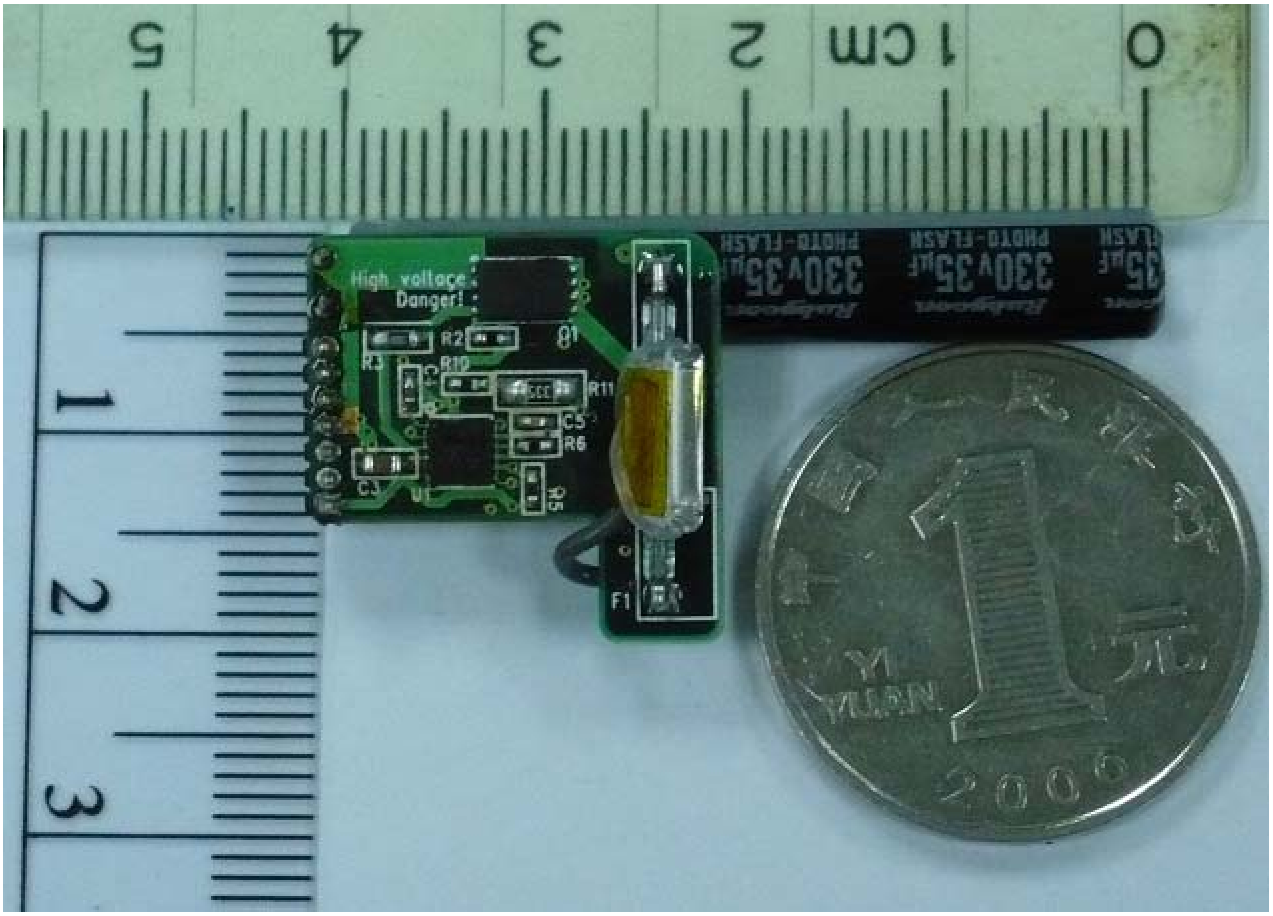


Figure 12. Reference Design Module Picture

A tiny module is built based on reference circuit; from Figure 12 we can see the size of module is only about 42 mm by 20 mm.

PCB Layout Recommendation

Better performance and lower risk will be resulted if following layout items are paid attention to:

1. Decrease area of large current or high voltage loops during t_{on}/t_{off} and flash period, avoid direct angle traces, which can decrease parasitic inductance and decrease noise and EMI level;
2. One point ground connection is recommended, which will avoid noise and EMI cross by ground connection;
3. Try to avoid trace under transformer, ground copper is recommended under transformer, which will avoid interference noise to sensitive signals, such as PHSREF and PHSEN.
4. Distance between high voltage nets and low voltage nets should be kept away to a safe level to avoid electrical discharge. Try to keep high voltage net away from board edge if possible to avoid possible human body contact during board debugging/operating.

Summary/Conclusion

This paper has presented how to design Xenon flash application based on NCP5080. Introduction of NCP5080 and its integrated functions such as IGBT driver and photo sense function. External component selection and recommended layouts for this application has been presented also.

Although certain BOM list is provided in this paper, customer could develop different circuits and BOMs to satisfy different requirements, such as to get more light energy output capability by using more powerful Xenon tube with larger reservoir capacitor, to change charge time by modifying peak current limit of transformer, to use different trigger methods and different trigger coils.

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