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Utilizing a White LED Driver to Cost-Effectively Drive Power-Limited Xenon Flashes in Digital Cameras and Camera Phones

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APPLICATION NOTE

Over the last several years, the digital cameras and camera-equipped cell phones has migrated from exotic specialty items to a mainstream offerings. The digital image sensors within these products can be either CCD or CMOS technology based. To support the image sensor in low light conditions a flash circuit is mainstream for a digital camera and becoming more common for camera phones. The primary light source to address the flash requirement are xenon bulbs (commonly used in film and digital cameras today) and the now emerging high brightness White LEDs.

The primary advantage of xenon is the high light output power generated during the flash pulse. The LED approach, however, has the advantage of being relatively small and thin and can be turned on for extended periods of time for video capture albeit with a modest light output compared to xenon. Specifically, xenon lamps provide very short flash bursts, capable of freezing the picture captured by the camera. They do require a special driver to generate a high voltage as well as a large reservoir capacitor to store the energy.

We have found that a White LED Driver provides a cost-effective option for driving a power-limited Xenon flash light to illuminate a photographic scene. This paper depicts the basics of the xenon concept and details a typical low power/low cost flash application.

XENON LAMP CONCEPT

The xenon lamp is built with a glass envelope, with one electrode on each ends, filled by a low pressure of a rare gas mixture. In steady state, the voltage across the electrodes is set to a value well below the trigger voltage as depicted Figure 1. At this point, no current flows and the system is stable until a trigger voltage is applied to the third electrode. This high voltage pulse, in the 1 kV range for the considered low power lamp, comes from a transformer built with a small magnetic core triggered by an abrupt discharge of the capacitor C2 (see Figure 2).

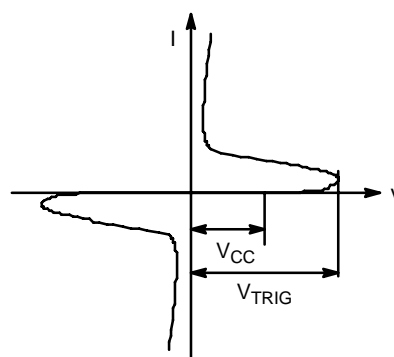


Figure 1. Xenon Flash Breakdown Voltage

The gas mixture is ignited and the plasma generates a bright flash, the typical duration being 2ms for consumer applications. Depending upon the type of flash involved, the amount of energy stored into capacitor C1 can be as low as 1 Joule (small camera) up to thousands of Joules for professional applications. The energy dissipated into the flash lamp is given by equation 1 below:

$$E_J = \frac{1}{2} * C * V^2 \quad (\text{eq. 1})$$

Basically, the capacitor is charged up to 160V to 600V, depending upon the type of xenon lamp used. A low power hand held camera will not need more than few Joules and the output voltage will be in the range of 160 to 250V. Higher voltages are normally found in equipment one would use in professional studios.

Beside the DC voltage, a high voltage pulse must be provided to ignite the plasma in the lamp, creating the high intensity arc between the two end electrodes. The pulse amplitude depends upon the type of lamp used in the system, ranging from a low of 1.6 kV up to 10 kV or more. The miniature size xenon lamp are triggered with a 1.6 kV/5μs pulse applied to the third external electrode of the tube. Such a pulse is generated by means of a dedicated pulse

transformer associated with a high voltage capacitor as depicted Figure 2. The capacitor is charged up to the flash DC voltage (200 V in the application) and abruptly discharge into the primary side of the pulse transformer when the push button S1 is activated. The high voltage coming from the secondary side is applied to the lamp (on the external surface) and the flash is activated.

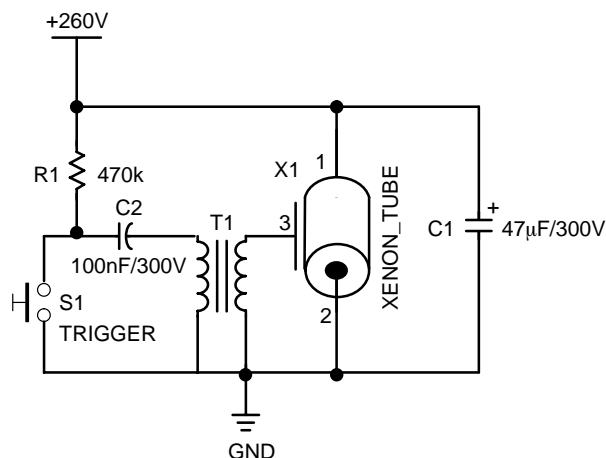


Figure 2. Basic Xenon Flash

The primary advantage of such a concept is high light output and very short pulse duration, allowing the snap shot photos to freeze mobile subjects. The drawbacks are the large physical size of the reservoir capacitor, the need for high voltage on board and the recycle time needed to recharge the capacitor between shots (in the 5 to 10 sec range for consumer applications).

Depending on the sensitivity of the imager and the aperture of the lens, a relative small capacitor is sufficient to get bright pictures under consumer normal environment. Consequently, a simple converter can be used to boost the battery voltage up to the 200 V required by the low voltage xenon tube.

LOW POWER FLASH CONVERTER

The converter is based on the NCP5007 chip from ON Semiconductor, originally developed to drive a string of white LED in series. At this point, the main consideration is the voltage limitation associated with the maximum 28 V silicon breakdown. To overcome this challenge, one can

either use an external transistor, capable to sustain 250 V minimum, or use a transformer with a 1:10 primary to secondary ratio. The second alternative has been made possible by the tiny transformer, developed by TDK, the primary voltage being well below the maximum rating specified by the NCP5007 data sheet.

Assuming a 50 µF reservoir capacitor and a low size xenon tube with a 200 V operating voltage, the amount of energy handled by the flash will be:

$$E_J = \frac{1}{2} * 50e^{-6} * 200^2 = 1 \text{ Joule} \quad (\text{eq. 2})$$

Such energy will be dumped from the battery to the reservoir capacitor by means of the boost converter built with the DC/DC. Although the NCP5007 structure is based on the flyback, it cannot be used directly since the chip operates in a Pulse Frequency Mode (PFM) with a variable T_{on} combined with a constant 300 ns T_{off} maximum. Consequently, if the traditional flyback topology was used the secondary inductor cannot be fully discharged during the T_{off} and the magnetic core will rapidly saturate, yielding a very low inductance on the primary side and low energy transfer.

To overcome that limitation, an hybrid method is to combine the fly back with a forward mode, thus increasing the output voltage capability. Such a combination is achieved by means of four diodes assembled in a bridge structure as depicted in the schematic diagram given in Figure 3. The dual diodes, assembled in a SOT-23 package, carry the output current during the switching cycles.

During the T_{on} time, pin 8 of transformer T1 is Low, thus the battery voltage appears on the secondary side, pin 1: this is the forward mode of operation. The reservoir capacitor is charged by the current flowing through diode D2. When the T_{off} cycle takes place, the primary voltage reverts and the reservoir capacitor is charged by the current flowing through diode D1: this is the fly back mode of operation.

The concept is supported by the demo board depicted Figure 3, powered by two standard alkaline AA type dry cell battery. The system is powered by switch S1, and the converter is controlled by switch S2 connected to the Enable pin. The third switch S3 is a push button to manually trigger the flash.

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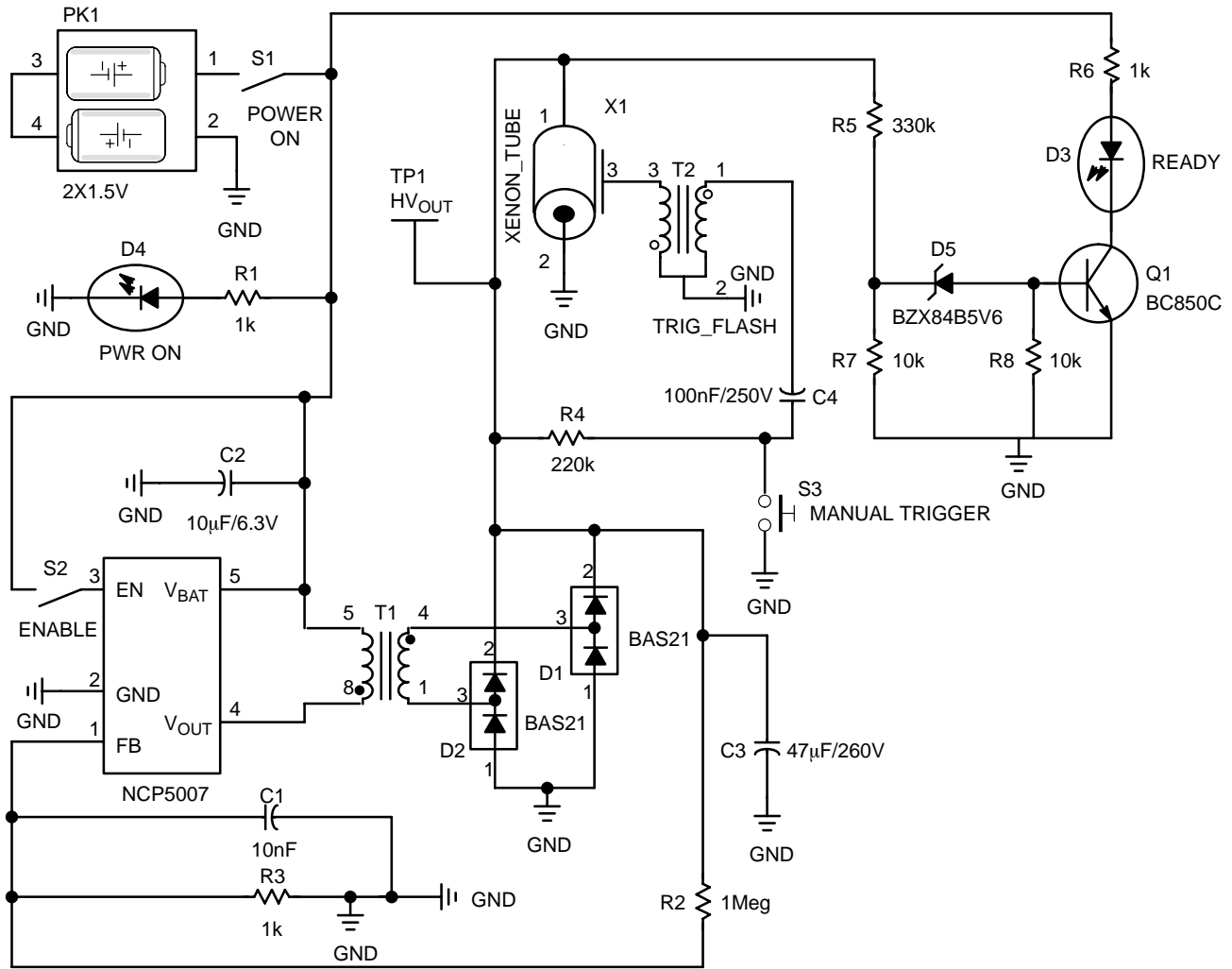


Figure 3. Demo Board Schematic Diagram

The waveforms captured in Figure 4 illustrate the voltages during the re-charge of the reservoir capacitor. The signals correspond to U1/pin 4 (top trace), D1/pin 3 (middle trace) and D2/pin 3 (bottom trace). As expected, the Forward mode takes place when the U1/switch is ON, the Fly back cycle being generated when the switch turns OFF.

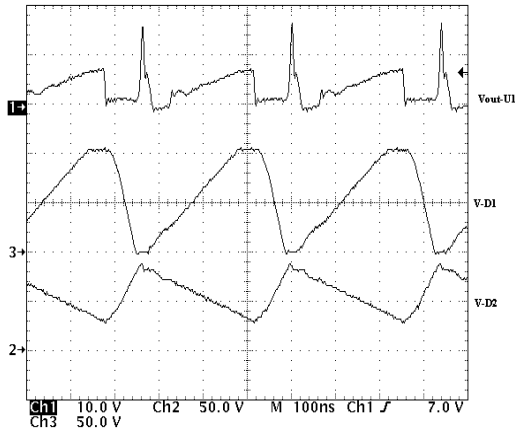


Figure 4. Primary Side & Secondary side Output Voltages

Figure 5 illustrate the high voltage pulse triggered by the push button. The main reservoir capacitor is discharged as soon as the xenon lamp is ignited: see the current flowing into the tube Figure 6.

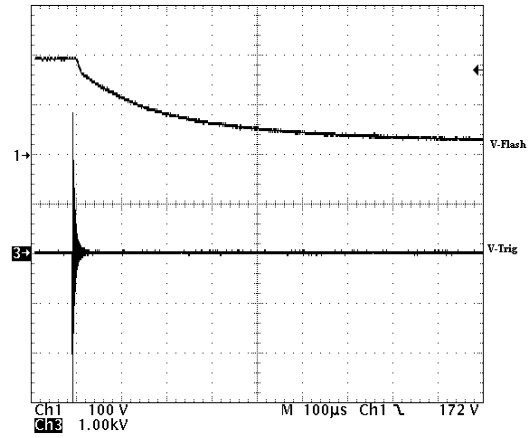


Figure 5. Flash Pulsed Trigger Voltage & Output Voltage Discharge

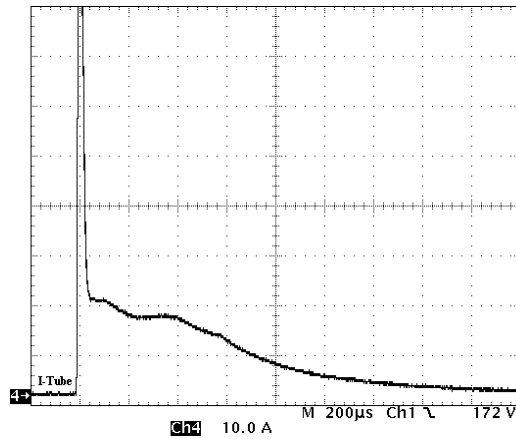



Figure 6. Xenon Tube Discharge Current

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Table 1. XENON FLASH DEMO BOARD PART LIST

Used	Part	Designator	Footprint	Description
3	1 k Ω	R1, R3, R6	0805	Resistor
2	10 k Ω	R7, R8	0805	Resistor
1	220 k Ω	R4	1218	Resistor
1	1 M Ω	R2	0805	Resistor
1	330 k Ω	R5	0805	Resistor
1	10 nF	C1	0805	Ceramic Capacitor
1	10 μ F/10 V	C2	0805	Ceramic Capacitor, TDK
1	100 nF/250 V	C4	1210	Ceramic Capacitor, TDK
1	47 μ F/260 V	C3	RB-.2/.4	Electrolytic Capacitor, Nichon
1	BC850C	Q1	SOT-23	ON Semiconductor, NPN transistor
1	LHN971	D4	1210	OSRAM LED, green
1	LHN974	D3	1210	OSRAM LED, red
1	BZX84B5V6	D5	1210	ON Semiconductor, Zener
2	BAS21	D1,D2	SOT-23	Rectifier diode, ON Semiconductor
1	2X1.5V			Battery Holder
1	NCP5007	U1	TSOP5	White LED driver, ON Semiconductor
1	POWER ON/OFF	S1	APEM_CMS	Manual Switch
1	ENABLE	S2	SIP3	Manual Switch
1	TRIG	S3	PUSH_BUT_CMS	Push Button
1	XENON_TUBE	X1	XENON	Xenon flash tube
1	LDT565630T	T1	QFN16_4X4	Converter Transformer, TDK
1	TRIG FLASH	T2	Murata	Pulse Transformer

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