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Emergency lighting systems and battery powered fluorescent lighting

Zetex Semiconductors

Introduction

Battery powered fluorescent lighting is an important application area that significantly benefits from the low saturation voltage exhibited by Zetex Super- β transistors. These transistors replace the TO126 and TO220 types commonly used in this application, giving savings in cost and size whilst providing improvements in efficiency too. Since most of the circuit losses now occur in the magnetic components and base drive, this translates to excellent circuit efficiency and extended battery life. Furthermore, the low power losses in transistors minimise temperature rises in them - important in reliability terms. This application note has been updated to include additional choices of transistors to provide 90% DC-AC conversion efficiency.

Description

Emergency lighting systems are frequently employed as a required safety feature within business premises. These systems essentially comprise a control circuit, a battery pack, a trickle charging circuit, and either an in-built incandescent lamp, or an inverter that will allow the battery supply to drive the existing fluorescent tubes. It is the latter version, and the requisite DC-AC inverter that are addressed within this application note.

Figure 1 presents a block diagram of a typical emergency lighting system. The control circuit monitors the mains supply, and if all is well, allows the charger to trickle charge the battery pack. In the event of the mains voltage failing, the controller then enables the inverter which provides sufficient power to a fluorescent tube to provide illumination.

It should be noted that this tube is quite often a standard ceiling tube that would otherwise be powered by the mains supply. Fluorescent tubes are employed in these applications because they are many times more efficient at converting electrical energy into light than conventional incandescent bulbs. This efficiency translates directly into extended battery life.

The number of series connected cells used in an emergency lighting system is kept to a minimum to optimize storage efficiency, reliability and cost. The resultant low output voltage of the battery pack does however make it more difficult to design high efficiency converters.

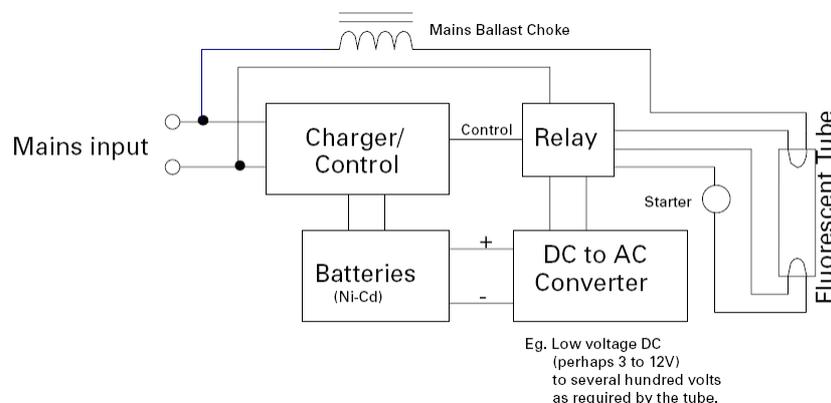


Figure 1 Typical emergency lighting system schematic

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Fluorescent tube characteristics

Figure 2 shows the V-I characteristics of an 8W fluorescent lamp after striking. Prior to ignition, the tube requires a peak voltage of approximately 200-300V to initiate conduction, yet once struck the tube voltage drops to around 56V after warm-up period.

In 50Hz main lamps, fluorescent lamps' are driven by magnetic core ballasts at low frequency; typically 50Hz. However, magnetic ballasts allow sufficient time for the ionized mercury gas in the discharge to recombine between each half cycle of the 50/60Hz supply, thereby necessitating a re-strike of the lamp. The effects of this viz: lamp lifetime, audible hum and a noticeable lamp light flicker are significantly reduced if the fluorescent lamps are excited at higher frequencies, for example, above 25kHz. The higher frequency excitation also provides a higher lumens/watt output, yielding higher overall efficiency, as there is no longer sufficient time for significant re-combination to occur.

The striking voltage of the lamp increases both with age and decreasing temperature - so the open circuit output voltage of the converter needs to be set to, typically between 400V and 1000V (or higher, dependent on tube dimensions and characteristics) for reliable operation. The ballast capacitor value must be set to source about 145mA to supply the full tube power. In many emergency lighting systems, the output power of the inverter (and therefore the light output of the tube) is limited so to provide a longer operating time from the available energy source.

The circuits presented in this note however have been designed to operate at an output power of 8W. This serves to demonstrate the capability of the transistors and the basic topology, and can be used as a starting point for development of lighting inverters for a customer's specific application.

High Efficiency DC-AC Converters

The high voltage AC supply required by the fluorescent lamp is generated using a push pull switching converter forced to run in synchronized mode by the inclusion of a supply inductor. This converter topology is also known as a resonant version of the popular push-pull power inverter developed by George Royer, and so is often termed a "Royer" Converter.

The following describes two fluorescent lamp circuits, both for 8W output, but designed for different input voltage ranges. Both circuits enable very high conversion efficiency. Each is designed to operate from just two series connected cells, either lead acid type providing 4V nominal or Ni-Cd/Ni-MH types at 2.4V. The same basic circuit is used for both voltage variants, but the component and transformer details are adjusted accordingly. The circuit shown in Figure 3 can be used for the 2.4V or 4V supplies by selecting the appropriate component values from Table 1, or modified for any other supply voltage by consideration of the required transformer turns ratio.

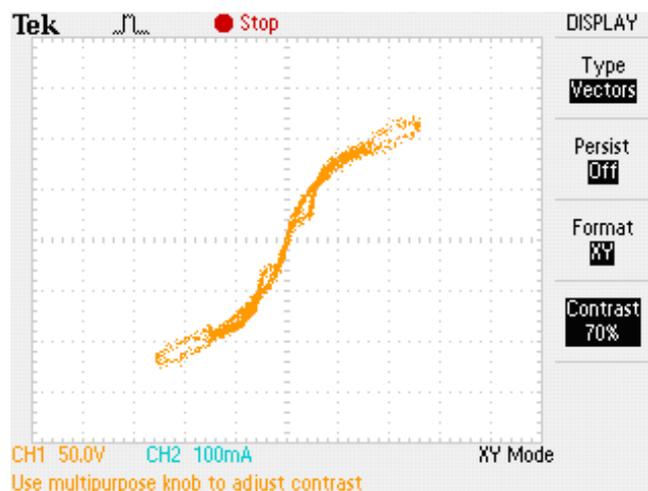


Figure 2 Current-voltage characteristics for 8W linear fluorescent tube

+V	2.4 Volt	4 Volts
R1	120Ω 0.5W	120Ω 0.5W
R2	120Ω 0.5W	120Ω 0.5W
Q1	ZXTN19020CFF	ZXTN19020CFF or ZXTN25020CFH or ZTX869
Q2	ZXTN19020CFF	ZXTN19020CFF or ZXTN25020CFH or ZTX869
C1	ARCOTRONICS 2.2nF R76 1000Vdc/ 400Vac Polypropylene	ARCOTRONICS 2.2nF R76 1000Vdc/ 400Vac Polypropylene
C2	ARCOTRONICS 0.47μF R66 63Vdc/ 40Vac Polyester	ARCOTRONICS 0.15μF R66 63Vdc/40Vac Polyester
C3	100μF 6.3V Electrolytic	100μF 6.3V Electrolytic
L1	COILCRAFT MSS1278-223MLB 22μH±20% SMD inductor	COILCRAFT MSS1038-223MLB 22μH±20% SMD inductor
T1	FERROXCUBE RM8/I 3C90 cores with 0.73mm spacer. CPV-RM8/I-1S-12PD or CPV-RM8-1S-8-PG coil former	FERROXCUBE RM8/I 3C90 cores with 0.53mm spacer. CPV-RM8/I-1S-12PD or CPV-RM8-1S-8-PG coil former
W1	500T 0.18mm neatly wound (first winding)	400T 0.18mm neatly wound (first winding)
W2 & W3	3T each, 0.5mm (second and third windings)	4T each, 0.5mm (second and third windings)
W4	3T 0.31mm (fourth winding)	3T 0.31mm (fourth winding)

NOTE: Use insulating tape between W1 and other windings. Core spacer must be made from a non-conducting material

Table 1 Component values for 2.4V and 4V nominal supply fluorescent lamp inverters

The following describes two fluorescent lamp circuits, both for 8W output, but designed for different input voltage ranges. Both circuits enable very high conversion efficiency. Each is designed to operate from just two series connected cells, either lead acid type providing 4V nominal or Ni-Cd/Ni-MH types at 2.4V. The same basic circuit is used for both voltage variants, but the component and transformer details are adjusted accordingly. The circuit shown in Figure 3 can be used for the 2.4V or 4V supplies by selecting the appropriate component values from Table 1, or modified for any other supply voltage by consideration of the required transformer turns ratio..

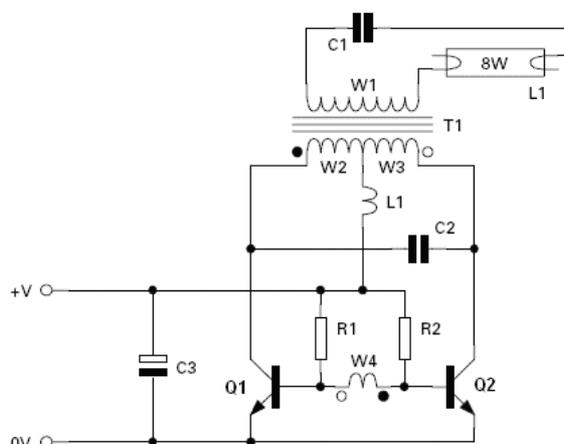


Figure 3 Resonant push-pull inverter for low DC to high AC voltage conversion

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The spacer used with the core is not too critical for this design. If the unloaded (no tube) oscillation frequency of the converter is more than 10% away from 130kHz, a thinner spacer could be used instead to reduce the frequency. The primary winding of the transformer must be bifilar-wound so that the leakage inductance of each half of the winding is approximately equal. If the leakage inductances are unequal, a higher voltage stress could be imposed on the collector terminal of the transistor during turn-off transition, compromising the circuit efficiency. In normal run mode, the ac voltage across ballast capacitor C1 relies on the oscillating frequency and value of C1. A higher voltage rating capacitor might have to be used for C1 if the actual oscillating frequency is lower than 28kHz or when a smaller capacitance value is desired.

The 'no-load' output voltage of the inverters has been set to approximately 600V peak, to facilitate lamp ignition from low input voltage supplies. The 4V design for instance, could strike tubes down to a 2.2V input, and once struck the lamp will continue to work for supplies down to 1.5V. During normal running, the operating frequency of 28kHz is set by the C1 and C2, together with the magnetizing inductance of the transformer secondary winding W1.

Before striking, or in the event of a damaged or removed lamp, resonant capacitor C2 and the transformer primary windings W2 & W3 inductance set the oscillation frequency to a safe 130kHz where the circuit can run indefinitely without harm. The voltage across each switching transistor when driven off (by the feedback winding) is a half wave sinusoid with a peak value of approximately three times the supply voltage. Therefore the VCEO of Q1 and Q2 should be around 20 volts. The collector current when the device is on is fairly square with a ripple at twice the frequency of oscillation, where the ripple current level reduces if a higher value L1 is used.

Figures 4 and 5 show these waveforms. As the supply voltage is so small, low saturation voltage is critical in achieving good efficiency from the converter.

The designs have been optimised to meet the following key factors:

1. Cost The designs operate from just two series connected Ni-Cd/Ni-MH or lead-acid cells - the fewer cells that are used in a battery pack, the cheaper and more volume efficient it will be. Also, replacing the TO-220 type transistors normally used with ZXTN19020CFF or ZXTN25020CFH transistors reduces component and board size.

2. Battery Life The ZXTN19020CFF and ZXTN25020CFH transistors give by far the lowest saturation voltage of devices in their class. This translates directly to improved circuit efficiency and extended battery life. With most of the remaining losses occurring in the magnetic components and base drive, the efficiency of the 4V design is around 90% and the 2.4V design a very creditable 85%.

3. Operating Range The 4V design will work for battery voltages in the range of 1.5V up to 8V. The 2.4V design from 0.95V to 6V. These wide operating ranges means that the circuits will withstand the high supply voltage that can occur with rapid charging, yet are capable of wringing the last ounce of charge from failing battery packs.

4. Reliability The designs give enhanced reliability in several areas. The low power losses of ZXTN19020CFF & ZXTN25020CFH minimise temperature rises in the transistors; important in reliability terms. Eliminating the bulk of E-line or TO220 type transistors removes potential susceptibility to vibration. Also the circuits will withstand reverse battery connection and indefinite operation without a fluorescent tube - important in un-attended applications.

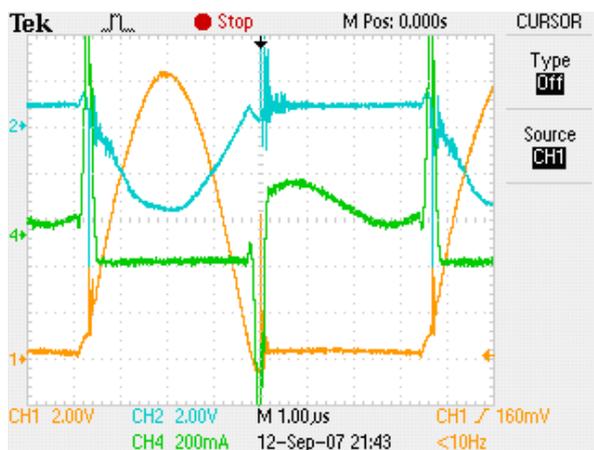


Figure 4 Inverter operating waveforms for No Load 1. V_{CE} , 2. V_{BE} , and 3. I_E , 2V/div, 2V/div and 0.2A/div respectively. $F_{op} \approx 130\text{kHz}$.

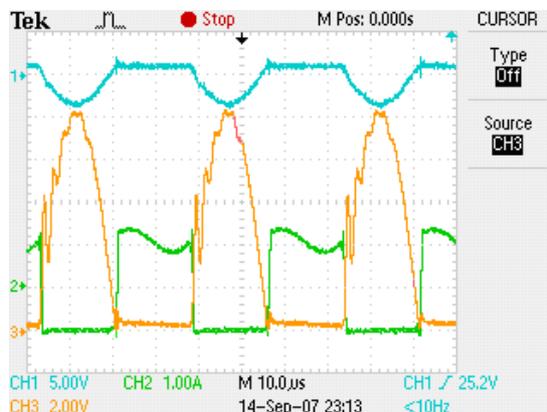


Figure 5 Inverter operating waveforms for 8W fluorescent tube load 1. V_{BE} , 2. I_E , and 3. V_{CE} , 5V/div, 1V/div and 2A/div respectively. $F_{op} \approx 28\text{z}$.

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Appendix

Partial characterisation of ZXTN19020CFF. Full details available at

www.zetex.com/3.0/3-3-2b.asp?rid=1

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
Collector-base breakdown voltage	BV_{CBO}	65	85		V	$I_C=100\mu A$
Collector-emitter breakdown voltage	BV_{CEO}	20	25		V	$I_C=10mA$
Emitter-base breakdown voltage	BV_{EBO}	7	8.3		V	$I_E=100\mu A$
Collector-base cut-off current	I_{CBO}		<1	50 20	nA μA	$V_{CB}=10V$ $V_{CB}=50V, T_{amb}=100^\circ C$
Emitter-base cut-off current	I_{CEX}		<1	100	nA	$V_{EB}=5.6V$
Collector-emitter saturation voltage	$V_{CE(sat)}$		23 45 55 135	30 65 70 175	mV	$I_C=1A, I_B=100mA(*)$ $I_C=1A, I_B=10mA(*)$ $I_C=2A, I_B=40mA(*)$ $I_C=7A, I_B=280mA(*)$
Base-emitter saturation voltage	$V_{BE(sat)}$		960	1050	mV	$I_C=7A, I_B=280mA(*)$
Base-emitter turn-on voltage	$V_{BE(on)}$		840	950	mV	$I_C=7A, V_{CE}=2V(*)$
Static forward current transfer ratio	h_{FE}	200 180 100 45	350 340 220 95	500		$I_C=0.1A, V_{CE}=2V(*)$ $I_C=2A, V_{CE}=2V(*)$ $I_C=7A, V_{CE}=2V(*)$ $I_C=15A, V_{CE}=2V(*)$
Transition frequency	f_T		150		MHz	$I_C=50mA, V_{CE}=10V, f=50MHz$
Input capacitance	C_{ibo}		315		pF	$V_{EB}=0.5V, f=1MHz(*)$
Output capacitance	C_{obo}		40	50	pF	$V_{CB}=10V, f=1MHz(*)$

(*) Measured under pulsed conditions. Pulse width $\leq 300\mu s$; duty cycle $\leq 2\%$.

Conclusion

The application note has described practical implementation of a 'Royer' converter using Zetex low $V_{CE(sat)}$ transistors for driving a T5 8W fluorescent lamp used in an emergency lighting system. The high efficiency Royer driver operates at a frequency of around 130kHz during striking, falling to 28kHz once struck. The circuit gives an instant start characteristic as no heater warm up time is required.

If necessary, the circuit can be adapted to operate from a single 2V cell. Other possible variants will drive higher wattage tubes at reduced power levels giving emergency back-up of, normally, mains powered tubes.

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