Emergency lighting

George Goh explains what to look for when you are choosing a power switching device for use in battery-powered equipment, using a fully-worked emergency lighting circuit as a design example. It turns out that the obvious choice – a power mosfet – becomes less attractive as the supply voltage falls.

Emergency lighting systems are frequently a required safety feature in business premises. Circuits for emergency lighting normally comprise a control circuit, battery pack, charger and a built-in inverter to drive a fluorescent tube.

Rechargeable battery packs are expensive. This makes the efficiency of the lamp driving circuitry crucial to the cost-effectiveness and physical size of the system.

Zetex bipolar transistors are designed using a base matrix, allowing them to offer a distinct advantage in this area. The *FZT689B* and *FZT788B* have the lowest saturation voltage in their class. This – combined with their high gain, and hence low drive requirements – means that efficient, high-current operation is achievable.

This article covers the design of all aspects of an emergency lighting unit, and includes a schematic for a typical circuit.

AC-to-DC converter

The first section of the circuit steps the mains voltage down to a low dc level, normally around 6V. This voltage is used to charge the batteries and illuminate any indicators needed.

The schematic shows a step-down transformer with a rectified output. A single 220µF capacitor is used to smooth the output. It is not imperative to have a smooth output, provided that the dc voltage is higher than that of the battery.

A 22Ω 4W resistor is employed in the circuit to drop any additional power that the battery does not absorb, and to act as a current limit. Across this is a led and resistor network to indicate when mains power is turned on.

Power switching

The second circuit block is that of the inverter power switch. This unit switches battery power into the inverter circuit when mains power is removed. Either relays or transistor switches can be used for this task. The schematic shows a transistor switch.

Conventionally two *BC327*s are used to switch in the battery to the inverter. But due to the exceptionally

Surely a mosfet's better?

The surface-mounting *FZT689B* transistor, and its through-hole counterpart the *ZTX689B*, are designed for use in high-efficiency circuits. They are especially aimed at portable, battery powered equipment where efficient power usage is of prime importance and where operation with low direct voltages is essential.

As circuits relentlessly migrate to 2.4V dc operating voltage – and below – the ability to have devices that can operate at these low voltages will become more and more important.

In some areas, mosfets have seen an increased in popularity due to their low R_{dson}. They are also easy to drive from logic devices, making interfacing with a microprocessor easier.

However, with the anticipated operating voltage heading down to 2.4V and below, it is doubtful that mosfets can operate efficiently at these lower regions. Zetex bi-polars can already operate at these low operating voltages today. With their very low saturation voltages, these devices can more than challenge the R_{dson} of present day fifth generation mosfets.

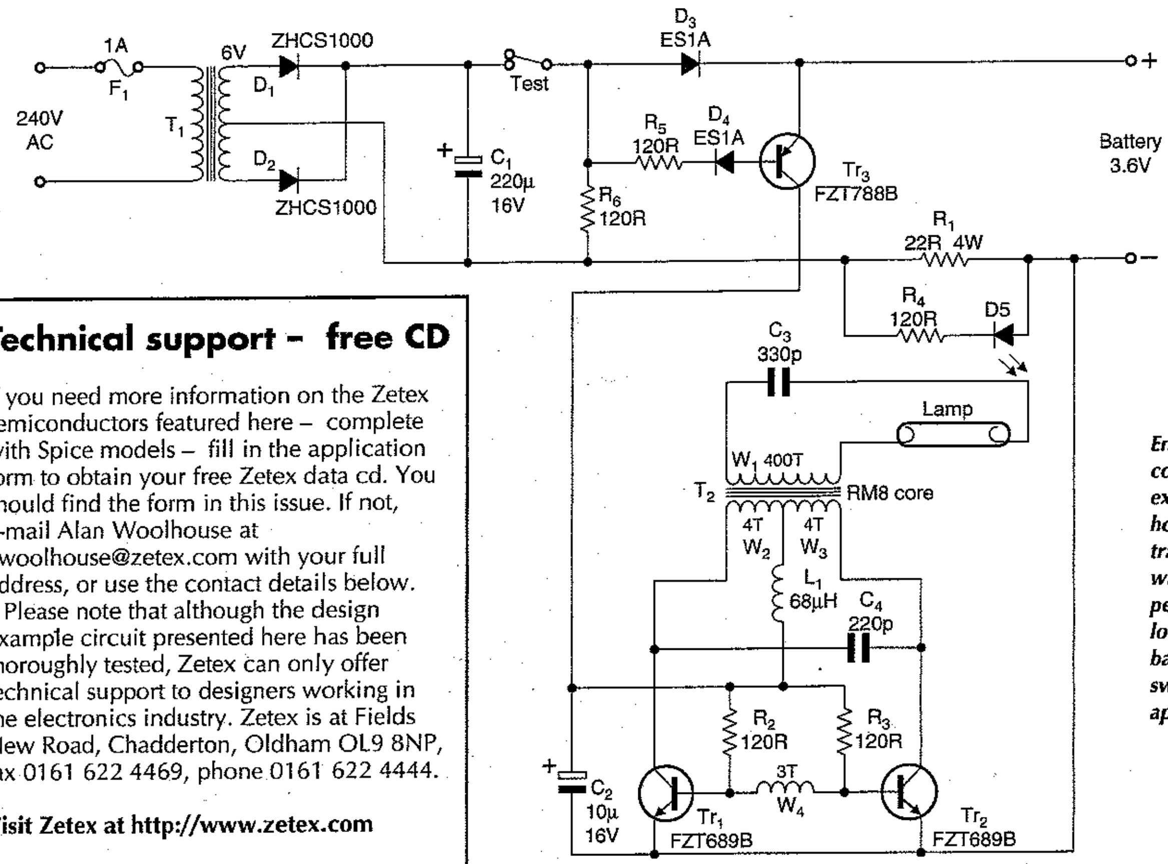
Of course bipolar devices restrict switching frequency to about 400kHz – compared with a megahertz and beyond for mosfets.

Bipolar devices also need a constant base current to keep them turned on. But don't forget that mosfets require the gate-source capacitance to be charged to turn them on. Drive circuits can often be more complex compared to those needed for bi-polar transistors.

Also, bi-polar devices exhibit secondary breakdown, which a mosfet does not. So, in general choosing a device technology for a particular design can be quite complex and needs careful consideration.

The properties we seek in a device for battery application are generally:

- Low $V_{ce(sat)}$, which translates to low conduction loss.
- High h_{fe} gain, which translates to low drive requirements.



Emergency lighting controller. This design example illustrates how well the two transistors given free with this issue perform in low-voltage battery-powered switching applications.

Technical support – free CD

If you need more information on the Zetex semiconductors featured here – complete with Spice models – fill in the application form to obtain your free Zetex data cd. You should find the form in this issue. If not, e-mail Alan Woolhouse at awoolhouse@zetex.com with your full address, or use the contact details below.

Please note that although the design example circuit presented here has been thoroughly tested, Zetex can only offer technical support to designers working in the electronics industry. Zetex is at Fields New Road, Chadderton, Oldham OL9 8NP, fax 0161 622 4469, phone 0161 622 4444.

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high gain and high continuous current rating of the *FZT788B* only one device need be used.

The low saturation voltage, i.e. on voltage, of the *FZT788B* enhances the efficiency of the circuit, thus the transistor draws very little power.

This device is turned on when the mains voltage is removed. To keep the threshold clear, a diode is incorporated in the base of the *FZT788* to ensure clean switching. In the circuit illustrated, a normally-closed switch has been included to simulate a mains failure. This switch is added for demonstration and test purposes only.

DC-to-AC conversion

Circuitry used to convert the battery voltage to ac to drive the lamp is usually based on a Royer converter. This is a classic inverter topology proposed in the middle fifties. It has been widely used ever since.

The high voltage needed to strike the tube is generated using the push-pull switching of the inverter. The inverter runs in synchronised mode, enabled to do so by the inclusion of a supply inductor.

Output voltage from the inverters is set to approximately 560V peak to provide the capability to strike the

- Good operating frequency
- Good switching speeds and low storage times.

Other properties like small physical size can be important too. We find that in practice, devices with the above properties will also allow the product to be physically small.

An often overlooked feature of bipolar switching devices for switching applications is gain hold up. As collector current rises, gain falls. If you study the curves, you will find that with a collector current of an amp, many TO220 devices have very little gain. This means that the base current required to maintain saturation is increased, becoming a significant proportion of the emitter current. That wastes energy. The *ZTX689*'s matrix chip design provides one of the best gain hold up characteristics available for devices in its power class.

Emergency lighting is a good example of where low saturation devices provide significant benefits. Such lighting is now mandatory in public buildings, offices and factories, where battery powered lighting is automatically switched on in the event of a mains power outage.

A good design will allow such emergency lamps to remain functional far in excess of the national statutory requirements – typically in excess of four hours from 2/3 'D' size rechargeable NiCd cells.

Zetex's *ZTX689B* is a device which fits the above requirements nicely. It has a very low saturation voltage, as can be seen from the graph. It also has good gain characteristics and as the switching frequency is low, in the kilohertz region, the switching properties are more than adequate.

The device is available in E-line form, i.e. in a TO-92-style package, which is small by comparison with the TO-127 or TO-220 packaged transistors normally used in emergency lighting.

No heat sink is required in the circuit presented here.

tube when the supply voltage is low. This enables the circuit to continue running even when the supply voltage has dropped to as low as 2.4V.

Frequency has been set to 50kHz via capacitor C_3. To alter the frequency, this capacitor can be changed. The effect on frequency is proportional to the inverse square of the capacitance. Decreasing the capacitor by a factor of four increases the frequency by a factor of two.

The voltage across each switching transistor when driven off by the feedback winding, is a half sinusoid with a peak value of πV_s. As the supply voltage is small, low saturation voltage is essential if good efficiency is to be achieved.

Design benefits

The design operates from just three series connected NiCd D-cells, supplying 3.6V.

Classic designs for emergency lights employ TO220 type transistors to drive the converter. The use of the Zetex SOT223 surface-mount packages reduces component cost and board size.

The *FZT689B* and *FZT788B* have the lowest saturation voltage in their class. This translates directly to improved efficiency and thus extended battery life. In addition, the low saturation voltage means there is very little power lost in the transistors, so less heat is produced. Reduced heating also has a significant effect on reliability.

Eliminating the TO220 package, with its relatively high epoxy mass and metal tab, reduces potential susceptibility to vibration. The circuit has been designed to withstand reverse battery connection and indefinite operation without a fluorescent tube in place – important in unattended applications.

Add ons

If required additional circuitry can be added to perform virtually any task the designer requires. Included in this example are an audible alarm and a high-power strobe circuit. These are in addition to the main circuit and can be added in a modular form.

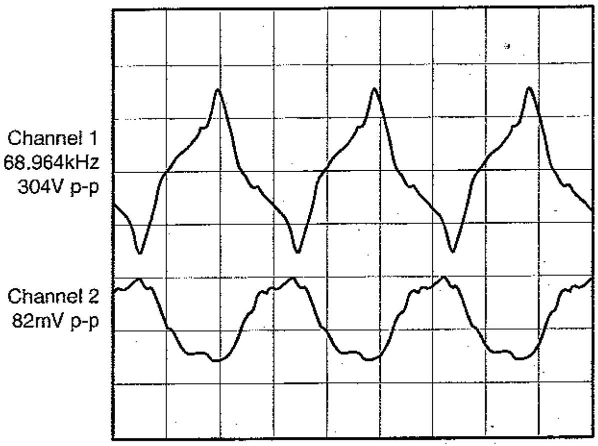
The audible circuit provides the user with a clear audible signal in the event of lamp failure or heavy smoke due to fire. The strobe provides a more powerful visual warning.

Also included in this circuit is a battery monitor led and a normally-closed momentary switch, to disconnect the mains for test purposes.

The voltage across the tube is 304V peak to peak. This is more than sufficient to maintain a strike voltage across the tube. The important trace is that of the current. It is this current that determines how long the emergency light will stay on for.

Using three D-type cells with a life of 4Ah it is possible to determine how long the battery will last. From the trace in the diagram, you can see that peak-to-peak current is 82mA. Current consumption for the circuit is 1A, measured while the circuit is powered from the battery. Thus life expectancy for the battery is 4/1=4 hours –well within specification.

This longevity figure can be lengthened or shortened by adjusting the value of C_3. Increasing C_3 increases the brightness of the tube but increases current consumption. Consequently the battery will not last as long. A balance has to be struck between brightness of tube and life expectancy of the battery. ■



Voltage and current plots for a fluorescent tube. The upper trace shows the voltage across a struck tube while the lower trace shows current flowing through the tube.

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Emergency lighting parts list

Ref	Description	Qty	Cost (£)	Farnell / RS
T_1	Mains transformer (PTH)	1	4.15	RS 201-8362
T_2	DC-DC transformer (PTH) (RM8)	1		See info.
D_1	ZHCS1000 diode (SOT23)	1		
D_2	ZHCS1000 diode (SOT23)	1		
D_3	ES1A diode	1	0.255	RS 269-984
D_4	ES1A diode	1	0.255	RS 269-984
D_5	Super-bright LED	1	0.28	RS 247-0962
C_1	220µF 16V	1		
C_2	10µF 16V	1	0.26	RS 262-4349
C_3	330pF 1kV (1812)	1	0.13	
C_4	220pF	1	0.298	RS 174-921
R_1	22R 4W (PTH)	1	0.268	RS 206-0442
R_2	120R 1/8W (1206)	1	0.026	RS 223-2136
R_3	120R 1/8W (1206)	1	0.026	RS 223-2136
R_4	120R 1/8W (1206)	1	0.026	RS 223-2136
R_5	120R 1/8W (1206)	1	0.026	RS 223-2136
R_6	120R 1/8W (1206)	1	0.026	RS 223-2136
L_1	68µH	1	0.267	RS 235-149
S_1	Test microswitch (PTH)	1	3.65	RS 228-3752
	Lens for S_1	1	0.95	RS 228-3796
Tr_1	FZT689B (SOT223)	1		
Tr_2	FZT689B (SOT223)	1		
Tr_3	FZT788B (SOT223)	1		
F_1	Fuse holder (mains) (PTH)	1	0.488	RS 417-098
F_1	Fuse (1A)	1	0.176	RS 265-1149
	Battery 3×D-type NiCd	1	16.75	RS 595-025
CFL	Tube 8W 300mm	1	1.30	RS 561-606
	Screw terminal 5A (PTH)	1	0.452	RS 425-099

Connectors

Mains, fluorescent tube holder, battery, switch.

Free with this month's issue

On the cover of this month's issue are two Zetex ZTX689B n-p-n high gain medium-power transistors (UK issues only). Their f_T is at least 150MHz and they exhibit typical turn-on and turn-off times of 30 and 800ns respectively at half an amp collector current. Here's their details:

Features
- 20 volt V_{CEO}
- Gain of 400 at 2A collector current
- Very low saturation voltage

Applications
- Darlington replacement
- Flash-gun converters
- Battery-powered circuits
- Motor drivers

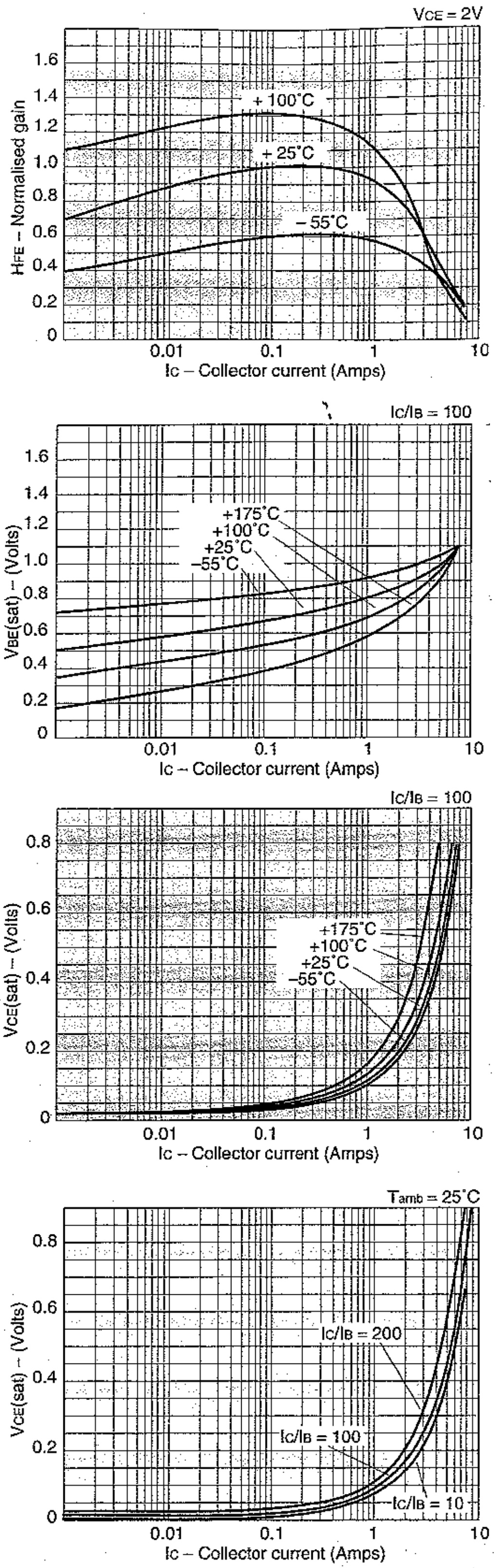
Electrical characteristics at 25°C ambient

Parameter	Symbol	Min.	Max.	Conditions
Collector-base breakdown voltage	$V_{(BR)CBO}$	20V		I_C=100mA
Collector-emitter breakdown voltage	$V_{(BR)CEO}$	20V		I_C=10mA*
Emitter-base breakdown voltage	$V_{(BR)EBO}$	5V		I_E=100mA
Collector cut-off current	I_{CBO}		0.1μA	V_{CB}=16V
Emitter cut-off current	I_{EBO}		0.1μA	V_{EB}=4V
Collector-emitter saturation voltage	$V_{CE(sat)}$		0.1V	I_C=0.1A, I_B=0.5mA*
			0.5V	I_C=2A, I_B=10mA*
Base-emitter saturation voltage	$V_{BE(sat)}$		0.9V	I_C=1A, I_B=10mA*
Base-emitter turn-on voltage	$V_{BE(on)}$		0.9V	I_C=1A, V_{CE}=2V*
Static forward current transfer ratio	h_{FE}	500		I_C=0.1A, V_{CE}=2V*
		400		I_C=2A, V_{CE}=2V*
		150		I_C=6A, V_{CE}=2V*

Absolute maximum ratings

Parameter	Symbol	Value
Collector-base voltage	V_{CBO}	20V
Collector-emitter voltage	V_{CEO}	20V
Emitter-base voltage	V_{EBO}	5V
Peak pulse current	I_{CM}	8A
Continuous collector current	I_C	3A
Practical power dissipation*	P_{totp}	1.5W
Dissipation at T_{amb} of 25°C	P_{tot}	1W
derate above 25°C		5.7mW/°C
Operating/storage temperature		–55 to 200°C

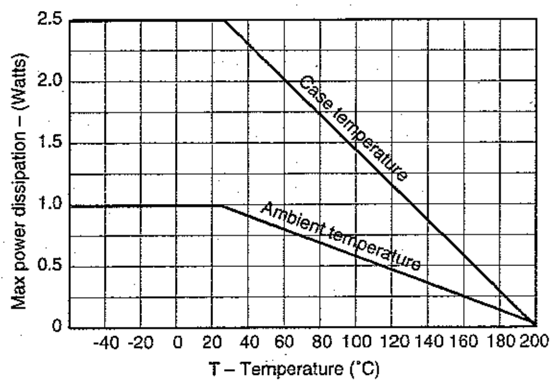
*This is power that can be dissipated assuming the device is mounted in a typical manner on a pcb with copper of at least a square inch.

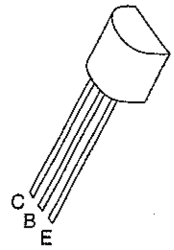


ZTX689B performance curves.

E-line package performance

The E-line package housing the ZTX689B is pin compatible with the industry standard TO92 package. While its outline is actually smaller than TO92 it is still able to dissipate 25% more power at an ambient temperature of 25°C and 42% more at 100°C.





Pin-out of the TO92-compatible ZTX689B medium-power transistor.

This table shows that at low temperature, the TO220 package performs much better than the much smaller TO92-style e-line casing, as you would expect. But by 125°C, the two are almost neck and neck in terms of their dissipation capability.

Ambient	Dissipation in milliwatts			
	TO92	TO126	E-line	TO220
25°C	800	1500	1000	2000
50°C	640	1200	870	1600
100°C	320	600	570	800
125°C	160	300	429	400
150°C	0	0	285	0
200°C	0	0	0	0