Super E-Line Applications in Automotive Electronics

Replacement of Large Packaged Transistors with an Enhanced TO92 Product

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Car buyers are now demanding greater and greater sophistication in their purchases, which along with extra safety features, pollution controls, security systems and manufacturing cost-cutting measures, are leading to an ever-increasing use of electronics in automobiles. Automobile electronics have extended from the occasional radio, to cover every major area within a vehicle. Engine management, fuel injection system controls, transmission controls, anti-lock braking systems, electronic displays, warning systems, etc., are just a few examples of the wide range of electronic systems that can be presently found in modern cars.

Many of these systems involve high current loads such as relays, solenoids, lamps, displays, motors and audible warning systems. These require one or more power transistors to interface between the controlling logic and the load. This brief note explains some of the major problem areas in selecting devices and circuits for automobile use, and demonstrates the use of the Zetex Super E-Line range of transistors in some practical examples.

Problem Areas

The hazards for power devices in automotive electronic systems are both mechanical and electrical. The mechanical hazards centre on the extreme operating temperature range endured by the devices.

To help designers evaluate the performance of Super E-Line transistors as temperatures vary, Zetex can supply a wide range of temperature-related data on both standard and special characteristics. Figure 1 shows the standard data sheet $V_{CE(sat)}$ against I_C graph for a ZTX602 Super E-Line Darlington transistor. Note how the characteristics are shown for a range of temperatures. Even when this data is not given on the data sheet, Zetex can supply this quickly for customers who require such information.

Mechanical Requirements

Passenger compartment temperatures can vary from - 40°C to + 85°C with the engine compartment ambient reaching as high as 120°C. High ambient temperatures place serious constraints on the performance and reliability of any power semiconductors used. As a result, Metal Can encapsulated devices or plastic types that are grossly overrated are normally required. However, Zetex manufacture a range of inexpensive medium power transistors that are ideally suited to these severe operating conditions.

Zetex Super E-Line and E-Line bipolar transistors are encapsulated in a special Silicone plastic that allows operation at junction temperatures up to 200°C. This gives them the temperature performance of Metal Can devices with the robustness and low cost of a plastic encapsulation. Figure 2 illustrates some of the advantages given by the E-Line package. It compares the power rating against ambient temperature of the Super E-Line 1W package, with standard TO92, TO237 and TO220 style packages.

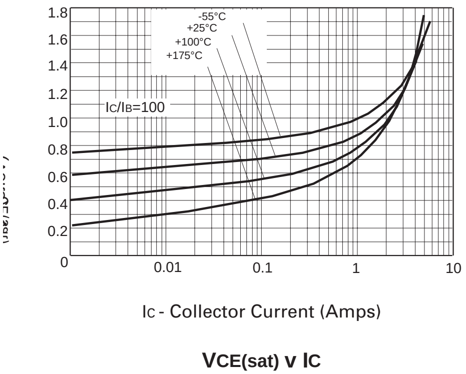

Figure 1
Typical Collector Emitter Saturation Voltages vs Collector Current, with Temperature as a Parameter.

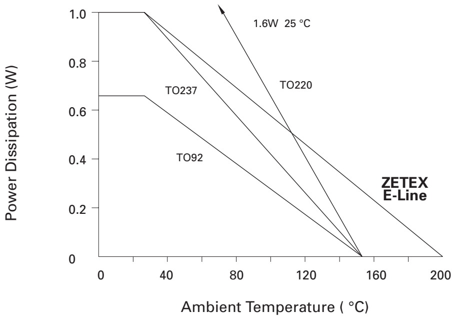

Figure 2
Power Derating Curves Showing Power Dissipation Advantage of the E-Line encapsulation.

Note how standard TO92 and TO237 types give inferior performance to that of the E-Line range, with even the TO220 style devices requiring a heatsink to match E-Line types in ambient temperatures above 110°C. Also, even higher levels of power dissipation are permissible if the E-Line devices are mounted on circuit boards with a low thermal resistance. For instance, devices from the Super E-Line range can dissipate 1.5W when mounted on a circuit board providing 1 square inch copper area to the collector termination. Furthermore, pulse applications allow higher powers still. Figure 3 shows the actual power dissipation permissible for a ZTX650 mounted on a 1 inch square board for a range of pulse widths. This chart can be used for design analysis when using any of the ZTX649-658 and ZTX749-758 transistor ranges.

Extensive reliability testing has been done on the packaging and chips that make up the Zetex E-Line range, confirming both power ratings and quality. Temperature cycling, climatic and electrical life evaluation tests are routinely carried out on all of the Zetex discrete products to guarantee continuing quality.

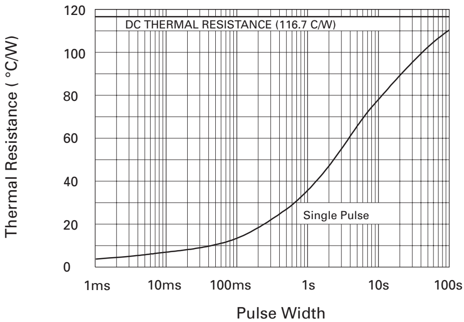

Figure 3
Transient Thermal Resistance for a ZTX650 Series Transistor Mounted on a 1" square FR4 PCB.

Electrical Requirements

Before moving on to some application examples, it is worth highlighting some of the electrical hazards that affect their design. Apart from normal 10-15V operation, automotive electronic systems have to withstand a wide range of transients. These include reverse battery connection, double voltage supplies, a 240V/0.5J positive line transient, an 80V/50J load dump transient, a -100V/0.5J supply disconnect transient and many other lower energy but higher voltage transients. Figures 4 and 5 show the voltage waveforms of the first two of these transients. A further requirement is that the system can withstand a reasonable amount of mistreatment during maintenance. Accidents do happen and efforts should be made to limit their seriousness.

Application Examples

The design of load driver circuits which operate uslng a vehicle's normal battery voltage range, comes from a fairly straightforward consideration of drive levels, output current and power dissipation.

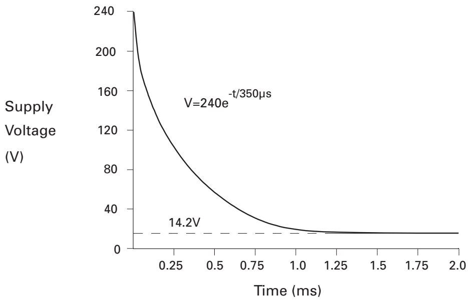

Figure 4
Common Automotive Transients - 240V Line Transient.

Reverse battery protection and transient protection, however, can be achieved in number of ways, with occasionally some conflict of effect. In the following application examples, consideration is given to the problems of designing load driver circuits for automobile use.

Figure 6 shows a simple unprotected lamp driver circuit. In this circuit, a reverse connected battery would force current through the collector-base junction of the output transistors and into the control IC, with possibly disastrous consequences. One good solution to this problem is to insert a

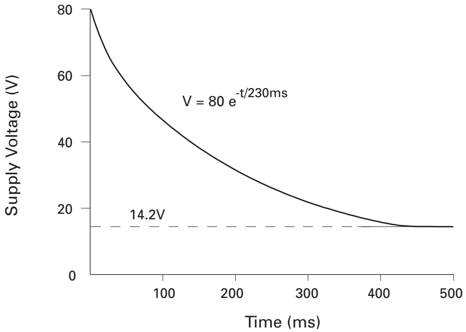

Figure 5
Common Automotive transients - "Load Dump".

diode in series with the supply (shown dotted). This provides excellent protection, but at the expense of a 0.7V voltage drop, which in some applications may be unacceptable. A second solution is to add a diode across the collector-emitter terminals of the output device. This diode shorts the fault current to ground, thus protecting the transistor and drive IC without causing any voltage drop in normal operation. However, which reverse battery protection technique used may well depend on the type of transient protection employed.

The wide range of transients that occur within an automobile often require a number of different protection techniques to be employed. Two strategies are common when dealing with the 80V load dump transient that can be caused if the battery becomes disconnected whilst the alternator is charging. These are to clamp the transient with a low-voltage zener or VDR, or to use an output transistor whose breakdown voltage is greater than the transient. Figure 7 illustrates the clamp method. Using a voltage clamp allows a high performance, low voltage transistor such as the Zetex ZTX449 to be used as the output device. The clamp component has to withstand a current that is several times greater than the normal current taken by the load. This can cause very high power dissipation in the clamp for heavy loads, so the technique is normally restricted to lower current load drivers.

Using a high voltage transistor (i.e. greater than 80V) makes a clamp

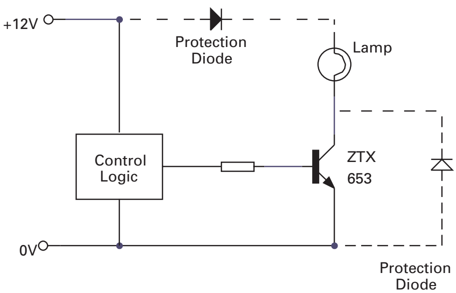

Figure 6
Reverse Battery Protection.

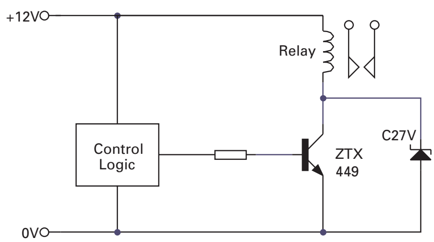

Figure 7
Transient Clamp using a Low Voltage Driver and High Current Zener Diode.

unnecessary for the load dump transient. The current handling capability of high voltage transistors of a given chip size are generally not as good as their low voltage counterparts, but Zetex can offer suitable Super E-Line transistors with a 2A continuous rating (The 100V ZTX653 for instance). Using a high voltage transistor does not completely eliminate the need for some form of clamp circuit. Transients as high as 500V can occur in an automobile, and measures must be taken to limit these. However, these high voltage transients are low energy types which can be easily controlled using a low power clamp

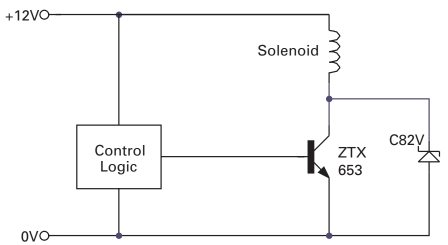

Figure 8
High Voltage Driver with Low Current Rated Transient Clamp.

circuit. Thus, the circuit when using a high voltage output transistor (shown in Figure 8) looks identical to the low voltage clamp circuit of Figure 7, however the power rating of the clamp component (and it's cost) will be much lower.

Any load that can be removed from the circuit, such as a lamp bulb that can be unscrewed or a relay that can be unplugged, may be a potential reliability hazard during maintenance. Accidental shorts can all too easily happen (cleaning connectors with a screwdriver, for instance) and so it can be very worthwhile to protect the driver circuit against this possibility. Figure 9 shows an output circuit which includes a short-term current limit function to protect the output transistor.

The characteristics of the circuit block labelled CONTROL LOGIC in the previous diagrams can be important when selecting output devices. Often this element is constructed using low output current MOS or CMOS circuits. Since many loads such as lamps and relays can under some circumstances take surge currents in excess of 1 A, the output devices used must either employ interface circuits or have very high current gain. This high gain can be achieved by using MOSFET or Darlington transistors. For instance, the Zetex ZVN4206 MOSFET transistor could be substituted for the ZTX449 in Figure 7, allowing a low output current logic circuit to be used. Zetex also supply NPN and PNP Darlingtons that are

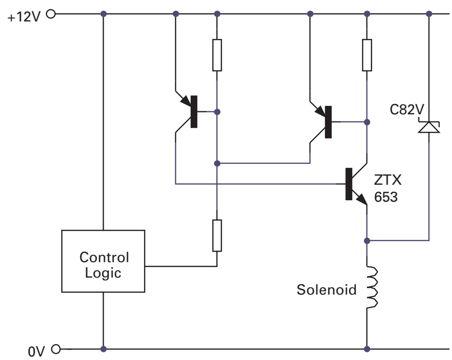

Figure 9
Load driver with current limit.

equally suitable for these applications. Figure 10 shows a four-phase stepping motor driver using ZTX600 Darlington transistors, directly driven from a CMOS microprocessor.

ZETEX Super E-Line Product Range

Tables 1 and 2 within Appendix A show some of the wide range of Zetex Super E-Line devices that can be useful in automotive applications. The tables can be used to choose the best device to suit the particular circuit requirements of voltage, current and gain. The gain and current specifications of a load driver are normally easy to calculate, but as mentioned previously, the breakdown voltage required is dependent on the transient protection method used.

Most medium power E-Line and Super E-Line devices can now also be supplied in the centre collector lead configuration. This allows the superior performance of the Zetex Super E-Line and E-Line range to be utilised in replacing TO202, TO220, TO237, SOT89, TO126, TO225 and many other packages without the expense of re-tooling circuit boards.

Additionally, many of the devices listed are available in the surface mount SOT223 package.

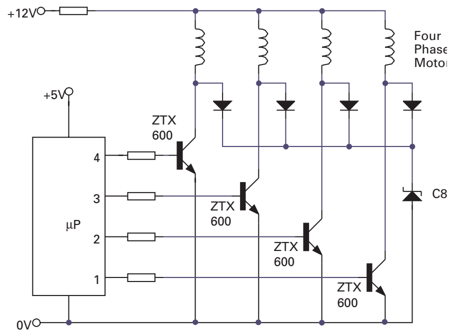

Figure 10
Four Phase Stepper Motor Drive Circuit using ZTX600 Darlington Transistors.

Appendix A

A selection of some of the Zetex range of products particularly suited to Automotive applications. For full characterisation refer to Data Book.

NPN PNP	ZTX649 ZTX749	ZTX650 ZTX750	ZTX651 ZTX751	ZTX652 ZTX752	ZTX653 ZTX753	UNITS
V_{CBO}	35	60	80	100	120	V
V_{CEO}	25	45	60	80	100	V
V_{EBO}	5					V
I_{CM}	6					A
I_C	2					A
P_{TOT}	1					W
h_{FE} min	75 @ I_C=2A, V_{CE}=2V	80 @ I_C=1A, V_{CE}=2V		55 @ I_C=1A,V_{CE}=2V		
h_{FE} min	15 @ IC=6A, V_{CE}=2V	40 @ I_C=2A, V_{CE}=2V		25 @ I_C=2A, V_{CE}=2V		
$V_{CE(sat)}$ max	0.5V @ I_C=2A, I_B=0.2A					V

Table 1
ZTX649-653 & ZTX749-753 Series Main Parameters.

NPN PNP	ZTX602	ZTX603	ZTX604 ZTX704	ZTX605 ZTX705	UNITS
V_{CBO}	80	100	120	140	V
V_{CEO}	60	80	100	120	V
V_{EBO}	10				V
I_{CM}	4				A
I_C	1				A
P_{TOT}	1				W
h_{FE} min	500 @ I_C=2A, V_{CE}=5V		2000 @ I_C=1A, V_{CE}=5V		
h_{FE} min	2000 @ I_C=1A, V_{CE}=5V				
$V_{CE(sat)}$ max	1.0V @ I_C=1A, I_B=1mA		1.5V @ I_C=1A, I_B=1mA		V

Table 2
ZTX602-605 & ZTX704-705 Series Main Parameters.