Features and Applications of the FMMT617 and FMMT717 “SuperSOT” SOT23 Transistors

3A NPN and 2.5A PNP SOT23 Bipolar Devices

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Introduction

The following note describes some of the features, benefits and applications of the FMMT617 NPN and FMMT717 PNP SOT23 transistors developed by Zetex. These devices extend the FMMT620 and FMMT720 high performance surface mount bipolar ranges. Specially optimised for the stringent requirements of battery powered systems, these tiny SOT23 packaged devices will replace much larger bipolar and MOSFET transistors, leading to significant savings in component costs and PCB sizes. Indeed the FMMT617 and FMMT717 transistors outperform many SOT223 and SOT89 types plus all SOT23 transistors presently available world-wide in terms of current handling and low losses.

Features

As can be seen in Table 1, the FMMT617 is a 15V NPN transistor capable of switching loads of up to 3A continuous, 12A peak. Designed to give a high mid-band gain of 450, the matrix chip geometry ensures this level of

Parameter	FMMT617	FMMT717	Units
Polarity	NPN	PNP	
BV_{CEO}	15	12	V
$I_{C\ continuous}$	3	2.5	A
$I_{C\ maximum}$	12	10	A
Mid-band h_{FE}	450	450	
Typical h_{FE}	320	275	
@I_C	3	2.5	A
Typical $V_{ce(sat)}$	150	160	mV
@I_C	3	2.5	A
Ptot	625	625	mW

Table 1
Parametric Overview.

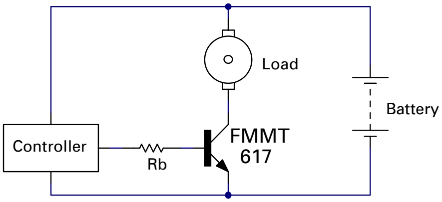

Figure 1
Generic Load Driver For Text Discussion.

performance is maintained well above the 3A rating. For example, it's typical h_{FE} at 5A is still around 240 and even at 12A the h_{FE} is a creditable 80, thus allowing the devices to handle very high current pulses, and tolerate switching transients. Giving a saturation voltage of only 150mV at 3A for a forced gain of 60, the FMMT617 is a highly efficient switch.

The FMMT717, though not quite as good as it's NPN counterpart, still gives excellent performance. It is a 12V PNP device rated at a collector current of 2.5A continuous, 10A peak. Also designed to give a mid-band gain of 450, the h_{FE} is still around 275 at 2.5A I_c. The saturation voltage of this part is a low 160mV at 2.5A.

The key features vital in battery powered equipment are low $V_{CE(sat)}$ and high h_{FE}. Both these parameters are important determinants of losses and hence battery life. Consider the simple motor driver circuit using the FMMT617 shown in Figure 1.

Conduction losses and the much lower base current losses occurring in the FMMT617 are charted in Figure 2. Conduction losses are given by $V_{CE(sat)}$ x I_c and base current losses by I_b x V_{be}.

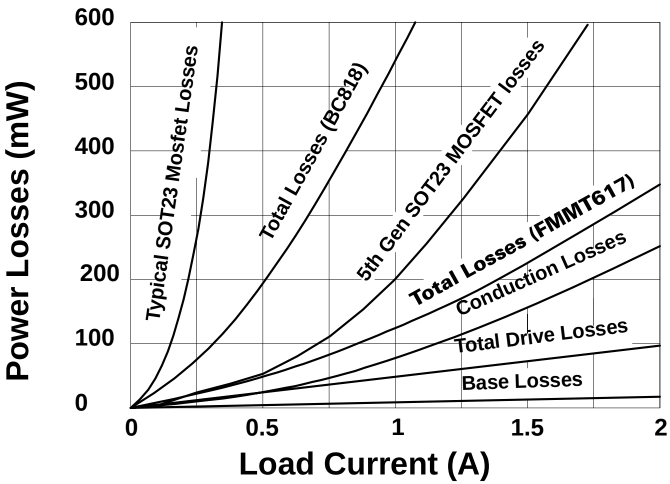

Figure 2
Graph of Power Losses (mW) vs Load Current (A).

However, the necessary base current must be taken from the 4.8V supply, incurring additional base drive losses in the driver circuit, raising the driver losses to a level comparable with conduction losses. To even approach such low conduction losses, competitive bipolar types would require far more base drive than the FMMT617 and hence cause base drive losses many times higher. To demonstrate this, the total losses of a FMMT617 and a competitive driver transistor (BC818) are also charted in Figure 2.

Using MOSFETs would eliminate the drive power losses, but as can be seen by reviewing the performance of the best MOSFET presently available in SOT23 (see Figure 2), the on-resistance makes conduction losses very much higher than the total losses obtained using the FMMT617. Furthermore, battery supplies rarely provide sufficient gate-drive voltage for the MOSFETs to obtain their minimum on-resistance values, a factor that rapidly gets worse as the batteries reach their end of life voltage.

The low losses obtained using the FMMT617 in this motor driver circuit can only be matched by competitive bipolar or MOSFET devices in much larger packages, e.g. TO220, D-PAK, the best performance examples of SOT223 or SO8 etc.

These alternatives are considerably more expensive, eat up far more PCB area, are more difficult to mount and often unable to match the reliability of SOT23 packaged devices. The motor driver circuit demonstrated is an example of the kind of high current, efficiency sensitive applications for which the FMMT617 and FMMT717 are particularly advantageous. Following are further application examples where these devices are ideally suited.

Motor Drivers

Providing bi-directional motor drivers for battery powered equipment requires either half-bridge controllers with centre-tapped battery packs or a full 'H'-bridge circuits with untapped batteries. Half-bridge controllers are simple and can be very cost-effective, but for a given motor power their drivers must pass twice the current of equivalent 'H'-bridge circuits. Also, as the operating voltage of the motor is only half of the total supply, the saturation voltage of the driver transistors must be kept to a minimum to maintain efficiency and battery life. The high current capability and low saturation voltage of the FMMT617 and FMMT717 make these transistors ideal for half-bridge controllers.

The circuit shown in Figure 3 is suitable for motors with peak currents up to 2.5A, giving saturation losses of only 90mV at 1A and 250mV at 2.5A. Using only 25mA base drive for the PNP and 15mA for the NPN, (current levels easily supplied by servo controllers and many logic ICs without the need for buffer stages), base drive losses are even smaller than conduction losses. Total conduction and driver losses are only a fraction of those obtained using industry standard transistors such as the BC818 and BC808, ensuring most of the energy taken from the battery is supplied to the load. High reverse gain eliminates the need for catch diodes in this circuit to protect the drivers from their inductive load, thus further reducing component counts. This half-bridge motor driver utilising the FMMT617 and FMMT717 gives useful savings in component count and costs without compromising efficiency or battery life. Typical applications are in positional systems, linear motor drives, servo and actuator drivers and toys.

In applications where the motor is driven predominately in one direction, it is possible for half-bridge circuits to discharge it's two battery sections unequally, wasting capacity and money when only partly discharged batteries are discarded. For these situations, a full bridge circuit is preferable. Although full bridge circuits halve the motor current required for a given power, two driver transistors are in the motor current path so low saturation voltage is still very important. Consequently, the FMMT617 and FMMT717 are equally applicable to this circuit topology too. Figure 4 shows a full bridge circuit using the FMMT617 and FMMT717 that will drive a 2.5A peak motor bi-directionally with exceptionally low losses. Note again that the buffers and catch diodes required by some competitive solutions are not required with this driver circuit, enhancing it's cost-effectiveness.

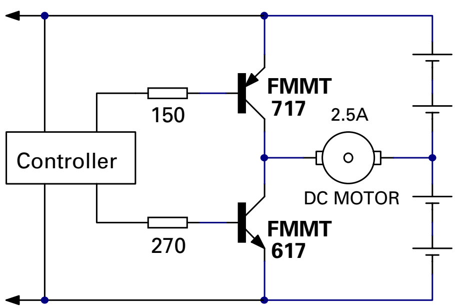

Figure 3
Half-bridge Motor Driver.

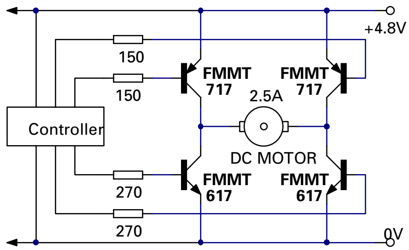

Figure 4
'H' bridge Motor Driver.

Active Power Switches (Including Mobile Communications and PCMCIA)

To maximise the endurance of complex battery powered products such as Mobile telecoms, Pagers, Laptop and Notebook computers etc., it is frequently necessary to switch the power supply of intermittently used circuit sections. To achieve low losses and ensure compliance with standard IC power supply specifications it is vital that these switches give very low voltage drops. For instance, 5% tolerance on a 3.3V supply equates to only 165mV. However, load currents can be high, for example the supply current demands of mobile phone RF output stages can peak at 2A, PCMCIA memory cards and hard disk drive modules can demand 300mA to 1A. To make the designer's life even harder, circuit constraints usually dictate that the +ve supply rail must be switched, making it difficult to use NPN bipolar transistors or N-channel MOSFETs which perform better than their P type counterparts. Meeting these stringent requirements usually necessitates the use of large and expensive P-channel MOSFETs or switch ICs.

The PCMCIA interface standard in particular adds to the cost and complexity as not only are it's supplies switched, they can also be set to several voltage levels, causing isolation problems that double the number of active switches needed.

Considerable savings in cost and component count can be made by substituting FMMT717 bipolar transistors for the alternative solutions currently used as supply switches. The low saturation voltage of the FMMT717 makes it an excellent low loss switch. Figures 5 and 6 show two PCMCIA interface supply switches. The PCMCIA interface standard provides two switched outputs, V_{cc} and V_{dd}. The supply V_{cc} must be switchable between 3.3V and 5V, and V_{dd} between 0V, 5V and 12V. The V_{cc} switch in Figure 5 is capable of sourcing 1A continuous and will supply peaks of over 3A. Controlled simply via logic drive signals, the typical voltage drop of either the 3.3V or 5V switch at 1A is around only 80mV. To achieve comparable performance using P-channel MOSFETs switch would require chips so large they would only fit in SO8, D-PAK, TO220 etc. and cost many times more than the SOT23 FMMT717 bipolar transistors. Also, when MOSFETs are used as the active switch element, two devices, one reversed and wired in series, must be used for the 3.3V switch to isolate the 3.3V input supply from the circuit's output when 5V out is selected. This is because the MOSFET's body diode conducts if the device becomes reverse biased, so a second device, (reverse wired) is required to block this effect. Not only does the use of MOSFETs for the 3.3V switch double its cost, it also doubles on-resistance and hence on-voltage drop. The FMMT717 can safely block a reverse voltage of 1.7V (5V-3.3V) hence no special measures are necessary.

The V_{dd} switch has been designed to

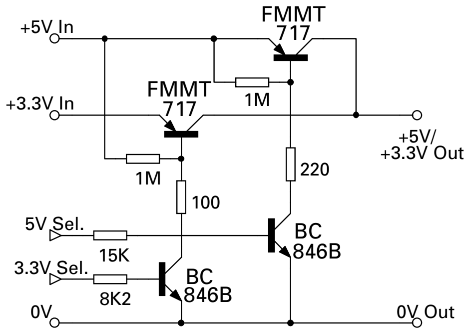

Figure 5
Typical Positive Line Switch - 1.

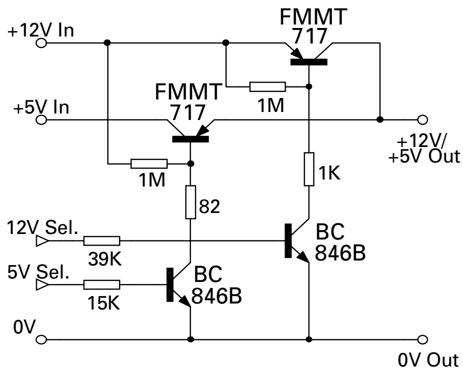

Figure 6
Typical positive line switch - 2.

source 1A from either the 5V or 12V outputs as with the Vcc switch but accepting slightly higher voltage drops. Although the Vdd circuit looks very similar to the Vcc switch, note that the collector-emitter leads of the 5V V_{dd} switch have been reversed. This transistor is operated in reverse mode. Since the reverse h_{FE} of the FMMT717 is very high, peaking at around 200, the transistor operates very efficiently, giving a saturation voltage drop of only 85mV in reverse mode for the component values shown. The transistor is used in this way so that it can isolate the 5V input line from the switches output when the 12V select line is activated. This requires the 5V switch to block a reverse voltage of 7V (12V-5V) and the FMMT717 must be connected as shown to guarantee that it can do this. P-channel MOSFETs could be used in this application but the cost and performance penalties cited against their use for the Vcc switch are equally applicable here. By exploiting the high reverse h_{FE} of the FMMT717, this PCMCIA V_{dd} switch gives a simple low cost circuit with excellent performance that is very hard to beat.

Appendix A

To further demonstrate the extremely low loss exhibited by the SuperSOT series, Figure 7 and 8 have been included which reproduce the $V_{CE(sat)}$ curves for the FMMT617 and FMMT717.

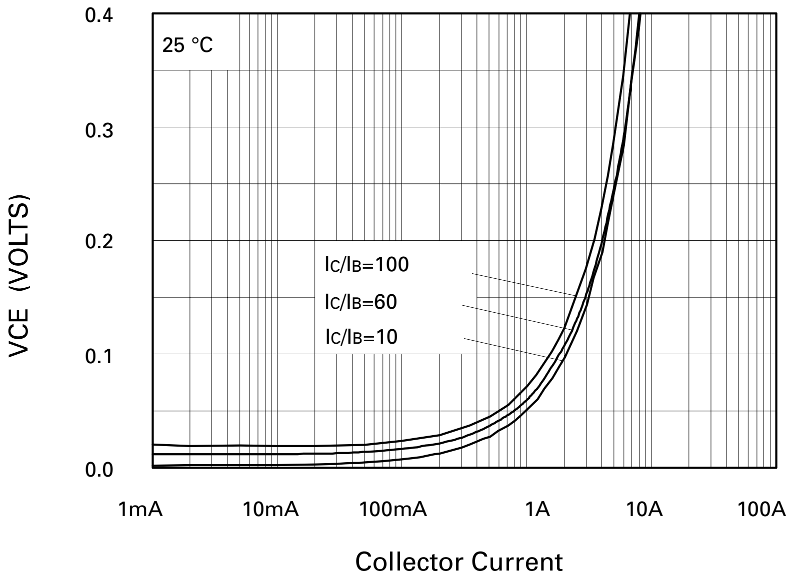

Figure 7
FMMT617 $V_{CE(sat)}$ v I_C.

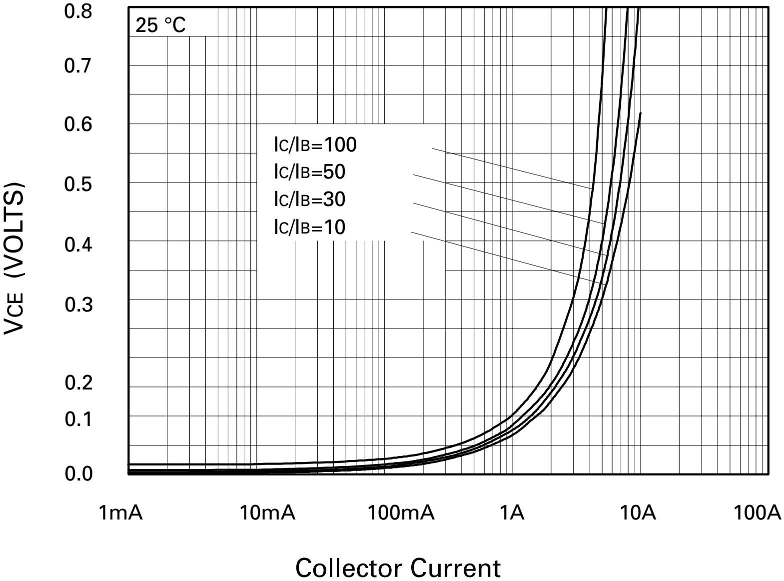

Figure 8
FMMT717 $V_{CE(sat)}$ v I_C