The FMMT718 Range, Features and Applications

Replacing SOT89, SOT223 and D-Pak Products with High Current SOT23 Bipolar Transistors.

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Designers of surface mount products wishing to drive loads with currents above a few hundred milli-amps were previously forced to resort to using either large through-hole products or expensive SOT89, SOT223 and D-Pak surface mount transistors.

Now with the introduction of the Zetex FMMT718 and FMMT618 series of PNP and NPN bipolar transistors, loads of up to 6A peak, 2.5A continuous can be driven by SOT23 packaged devices.

These SuperSOT devices provide many advantages including vastly improved circuit efficiency, component and board space savings, and improved reliability. It is true to say that these state of the art devices give performance unmatched by any other SOT23 transistor and many larger SOT89 and SOT223 devices.

This note outlines the features, benefits and applications of the Zetex PNP SuperSOT series, plus some additional NPN applications, and follows on from application note AN11 which covered the low voltage variant NPN types FMMT618 and FMMT619.

Since AN11 detailed how Zetex achieved the exceptional current and saturation voltage performance given by the SuperSOT range, package characteristics and chip design will not be repeated in this note.

Features and Benefits of the FMMT618/718 Series

The key parameters of the FMMT618 and FMMT718 series are listed in Table 1 (overleaf).

The first feature to note is that these SOT23 transistors are capable of dissipating 625mW - around twice the industry standard for SOT23 packaged products. Achieved using a custom lead frame, this means that for a given power dissipation a Zetex SuperSOT chip will run cooler than any competitors' SOT23 devices. This gives improved reliability and the option to reduce PCB area if desired.

Secondly, the saturation voltages are the lowest of any SOT23 of comparable BV_{CEO} in the market place today and lower than many competitors SOT89 and SOT223 types. This translates to lower power dissipation in switching applications, again giving improved reliability and smaller PCB areas.

The SuperSOT Series								
POLARITY	NPN				PNP			
	FMMT618	FMMT619	FMMT624	FMMT625	FMMT718	FMMT720	FMMT722	FMMT723
BV_{CEO}	20V	50V	125V	150V	20V	40V	70V	100V
I_C CONT	2.5A	2A	1A	1A	1.5A	1.5A	1.5A	1A
I_C MAX	6A	6A	3A	3A	6A	4A	3A	2.5A
Midband h_{FE}	450	450	450	450	450	450	450	450
Typical h_{FE} at I_C	360 2A	225 2A	140 1A	45 1A	230 2A	290 1A	275 1A	250 1A
Typical $V_{CE(sat)}$ at I_C	130mV 2.5A	150mV 2A	165mV 1A	180mV A	145mV 1.5A	245mV 1.5A	140mV 1A	210mV 1A
P_{tot}	625mW	625mW	625mW	625mW	625mW	625mW	625mW	625mW

*Measured with device mounted on a 15 x 15 x 0.6 mm ceramic substrate.

Table 1
NPN and PNP SuperSOT Series Parametric Overview.

These features combined with high mid-band h_{FE} and fast switching speeds make the series ideal for switching applications such as DC-DC converters, motor drivers, lamp and solenoid drivers, display drivers, power supply line switching, buffers etc. These transistors will also suit linear applications, e.g. the low series base resistance inherent in the SuperSOT design approach gives excellent low noise performance.

A few example applications are suggested below, that exploit many of the key features of the FMMT718/618 series.

'H'-Bridge Motor Drivers

'H'-bridge motor drivers are used in a wide range of products such as disc drives, coin control mechanisms, automotive applications, servo systems, toys etc. These drivers provide bi-directional outputs from single polarity supplies, usually under the control of a logic IC or microcontroller. They are usually constructed using two NPN and two PNP transistors, all operating in grounded emitter mode (see Figure 1). By turning on one NPN device and the diagonally opposite PNP device, (say NPN1 and PNP1) virtually all the supply voltage can be applied across the motor load. Switching the second pair of transistors instead reverses the supply to the load. 'H'-bridge transistors often require additional collector-emitter diodes to protect the drivers from regenerative currents and transients that can be generated by the load motor.

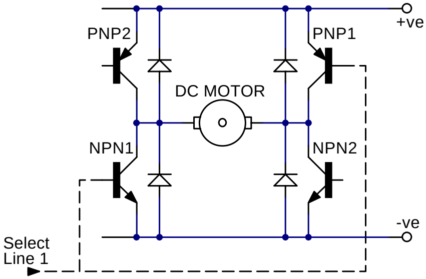

Figure 1
Conceptual 'H'-Bridge Motor Driver.

In battery powered applications it is vital that as much of the supply as possible is applied across the load, maximising battery life through greater efficiency and lower end of life battery voltage. Using the FMMT618 and FMMT718, the bridge circuit shown in Figure 2 will handle load/stall currents up to 1.5A. The circuit can easily be adapted for lower current motors by increasing the value of the base drive resistors. (Set I_B for the PNPs to 1/50 of the maximum load current and I_B for the NPNs to 1/100). The saturation voltage losses at 1.5A are a total of only 0.3V for both NPN & PNP transistors combined, and at lower load currents less than half this level can be expected.

The combination of low saturation losses and low base drive requirements of the FMMT618/718 gives improved motor performance and endurance. Parallel diodes are often not necessary for this circuit as the reverse h_{FE} of the driver transistor is sufficiently high to conduct regenerative currents and transients safely away. The small size of the SOT23 package and reduced component count allowed means this bridge circuit can be constructed using much less PCB area than previous designs, giving product size and cost improvements.

For higher voltage motors, the controlling logic is rarely capable of driving the PNP transistors directly. In Figure 3, this problem is overcome by the use of a pair of general purpose NPN transistors to act as buffers/level translators. The h_{FE} of the bridge transistors becomes more important as the supply voltage to the motor is increased as base drive losses are supply dependant. The high h_{FE} of the FMMT618/718 means that these losses can be minimised, saving PCB area and cost.

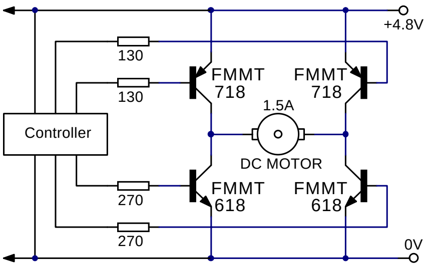

Figure 2
'H'-Bridge Motor Driver using SuperSOT Bipolar Transistors.

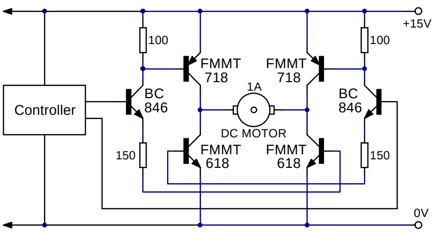

Figure 3
'H'-Bridge Motor Driver with Small Signal Buffer Transistors.

Both of these 'H'-bridge circuits are intended for direct logic drive though the circuit given in Figure 2 requires logic with high current outputs (up to 30mA) if 1.5A loads are to be driven. If this logic drive level is not available, the buffer circuit of Figure 3 provides a solution which is not only inexpensive, but outperforms most SOT89 solutions and many SOT223 based circuits too.

Power MOSFET Gate Drivers

The input capacitance of power MOSFETs and IGBTs range from a few hundred picofarads to tens of nanofarads. When Miller effects are taken into account (the amplification of feedback capacitances) by using the more valid method of evaluating gate charge rather than Ciss to calculate effective input capacitance, values around three times higher are obtained. To minimise switching losses in these power devices, particularly in high frequency converters, it is vital that the gate capacitances are charged and discharged as rapidly as possible. Consequently, driver circuits must act as low impedance voltage sources, capable of supplying large transient charge currents. Since standard switching power supply control ICs are rarely able to drive larger capacitance MOSFETs adequately, a high speed buffer is often used.

Complimentary emitter followers as shown in Figure 4 can provide an ideal buffer function if transistors of high current capability combined with high f_T are utilised. The FMMT618 and FMMT718 provide this combination of characteristics so that the 10nF effective capacitance of two IRF840 MOSFETs in parallel can be charged to 12V in under 30ns - a feat requiring a peak current of around 4A. The circuit includes a resistor which can be used to introduce a turn-on delay without effecting turn-off performance - sometimes required to avoid cross conduction problems in push-pull output stages.

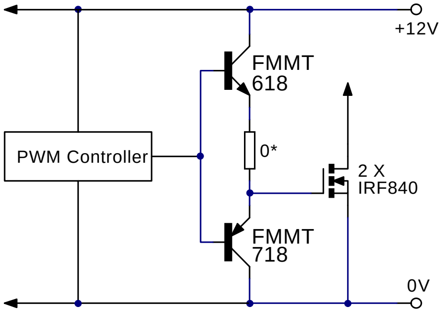

Figure 4
MOSFET/IGBT Complimentary Emitter Follower Gate Driver.

Where 5V logic provides a custom pulse width modulated controller, a buffer can be required to level translate, giving 10V or greater gate drive for the power switches. By using an FMMT2369 switching transistor, the circuit shown in Figure 5 converts 5V logic drive to a 12V gate drive signal. Driving the emitter of the FMMT2369 from the logic output avoids signal inversion.

The FMMT2369 gold doped switching transistor has a very short storage time which, combined with the high gain FMMT618 gives the circuit a turn-on time of only 20ns when driving a MOSFET with an effective input capacitance of 2nF. The FMMT718 helps make turn-off times even shorter, leading to reduced cross-conduction problems in bridge or push-pull converters.

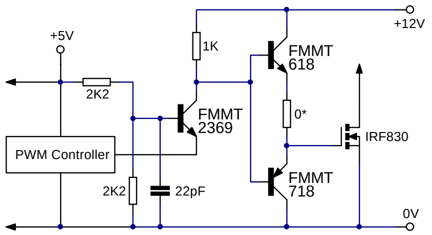

Figure 5
MOSFET/IGBT Gate Driver using Emitter Driven FMMT2369 for Buffering.

By giving excellent high current performance in a SOT23 package, the FMMT618 and FMMT718 replace SOT223 and SOT89 transistors in these gate drive circuits leading to cost and PCB area savings - particularly in very high frequency converters.

'H'-Bridge Siren Driver

Many modern burglar and automotive alarm sirens employ an 8Ω moving coil loudspeaker driven by a bipolar 'H'-bridge. Handling peak output currents of 2A, the TO126 or TO220 packaged output transistors normally used require parallel collector emitter diodes to divert destructive reverse transients generated by the inductive load. In the circuit shown in Figure 6, FMMT619 and FMMT720 SOT23 transistors replace these bulky and expensive leaded transistors, giving other savings too. High reverse h_{FE}, inherent in the matrix technology used to manufacture the Zetex transistors eliminates the need for parallel collector emitter protection diodes. The FMMT619 and FMMT720 conduct reverse collector current sufficiently well to clamp any inductive transients generated by the load.

A specially designed Zetex Siren Driver IC, the ZSD100, provides a variable frequency drive to the SOT23 'H'-bridge ensuring a very loud (and irritating!) noise is generated. The combination of the ZSD100 and a SOT23 'H'-bridge produces an extremely compact and inexpensive module.

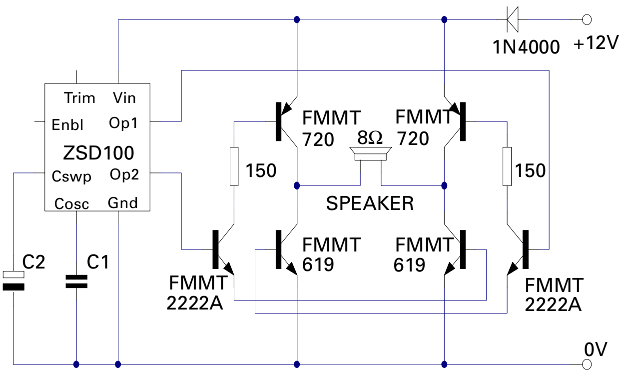

Figure 6
'H'-Bridge for Driving Moving Coil Loudspeakers within Alarm/Siren Systems.

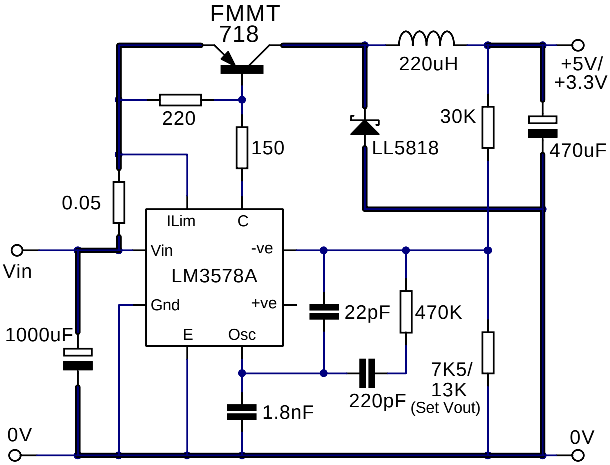

Figure 7
DC-DC Step-down Converter Effected with PNP SuperSOT. High Current Paths Shown in Bold.

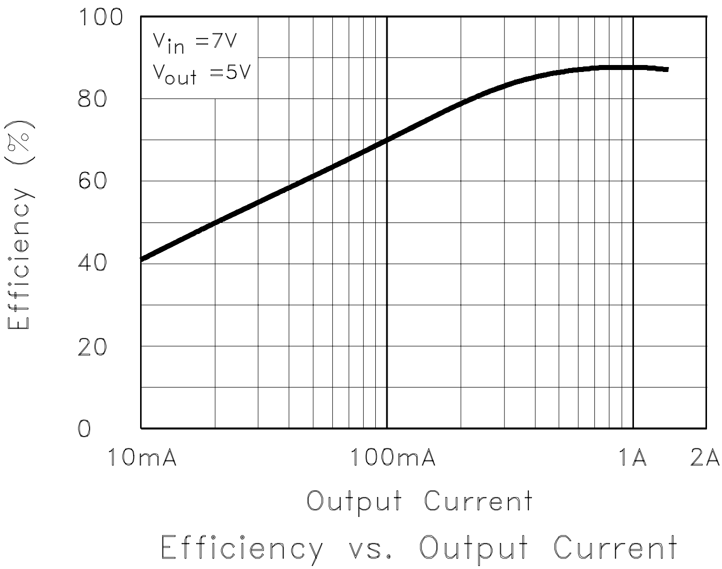

Figure 8
Efficiency Vs Output Current Profile for FMMT718 DC-DC Converter of Figure 7.

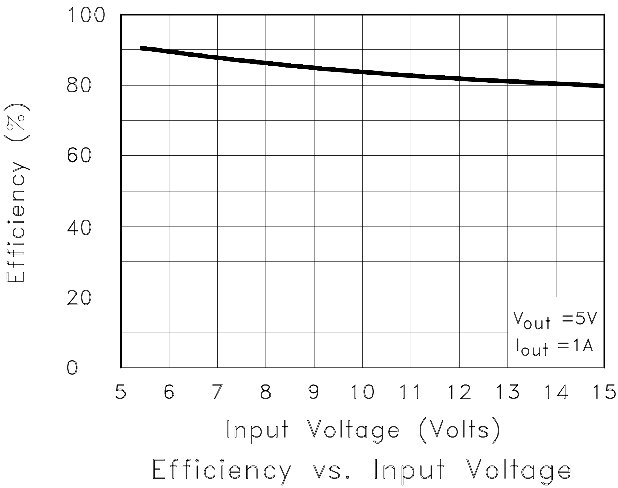

Figure 9
Efficiency Vs Input Voltage Profile for FMMT718 DC-DC Converter of Figure 7.

DC-DC Converter

Using standard PWM controllers it is easy to construct Buck step down converters with low component counts. Harder to achieve are designs that are both simple and efficient as required for today's battery operated equipment. The key to maximising efficiency is eliminating voltage drops in all high current areas.

In the Buck converter shown in Figure 7, the high current paths are via the 50mΩ sense resistor, the series switching transistor, output inductor L1 and the Schottky diode. Once the resistance of the output inductor has been minimised, the most critical component (particularly when V_{IN} approaches V_{OUT}) is the saturation voltage drop of the switching transistor. By using an FMMT718, which drops only 200mV @ 1.5A, this converter can operate at an efficiency of over 90% at minimum input voltage and an I_{OUT} of 1.5A. As the input voltage is increased, the operating gain of the switching transistor becomes more important. The high gain of this transistor allows base drive losses to be minimised leading to high efficiencies over a wide supply range. (Please refer to Figures 8 and 9).

The fast rise and fall times of the FMMT718 allows the converter to operate at 50kHz with minimal switching losses. At this frequency it is essential to use low ESR input and output capacitors, and keep any wires carrying switched high currents very short so as to minimise RFI and output ripple. (These wires are shown as bold in Figure 7).

The converter will operate from a supply of (V_{OUT} +0.5V) up to 16V. The converter's output voltage can be set to 5V or 3.3V by selection of R1. The circuit will supply loads from 0 to 1.5A, current limiting to around 2A with a shorted output.

LCD Backlighting Converter

Cold cathode fluorescent lamps as used for portable computer LCD backlighting and similar applications, require a converter generating between 1 and 2kV to strike and run. Standard circuits provide control of tube brightness against input supply variations, and other factors such as temperature, tube ageing etc. These circuits commonly use SOT223 transistors in the high voltage converter, since high currents must be passed with minimal saturation losses if good efficiency is to be achieved. In Figure 10, FMMT619 SOT23 transistors have been used to replace SOT223 BCP56 types. The FMMT619s, exhibiting a saturation voltage of only 125mV at 1A - less than half that of the BCP56s, not only reduces cost and PCB area, but also raises converter efficiency over the original SOT223 transistors.

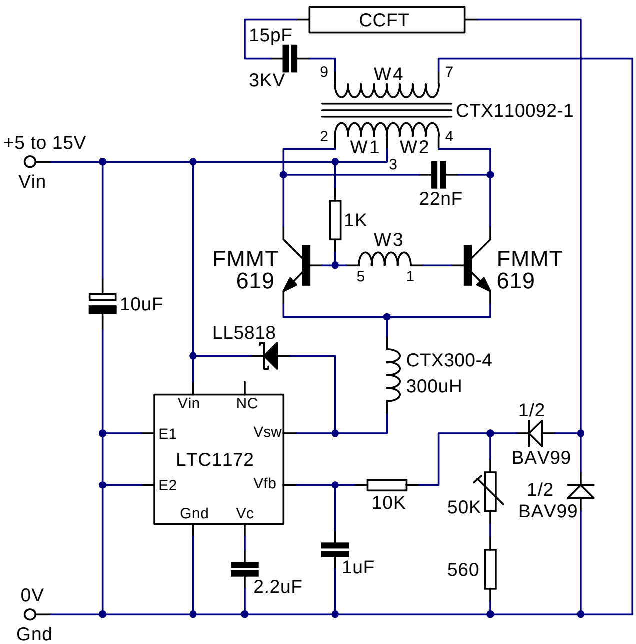

Figure 10
LCD Backlighting Inverter.

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