Application Note 21
Issue 2 January 1996

Bipolar Transistor Considerations for Battery Powered Equipment

Leading to Efficiency and Competitive Advantages in Portable Systems

Neil Chadderton

Introduction

The last few years has witnessed an increasing trend towards portability, this no doubt being due to a waiting market, and the advances in the enabling technology within the digital domain. This in turn has produced impetus to the advancement of the analogue technologies, as the customer requirements dictate a move to integrated, lower cost, energy efficient products. These new technologies include higher capacity battery systems and a re-assessment of power management techniques. The new philosophy includes careful charge control to ensure maximum battery capacity and lifetime, and consideration of voltage and current ratings - leading to the design and characterisation of components specific to the application.

It is easy to assume that within say, a laptop computer or a mobile phone, that the circuit boards will be wholly populated with digital ICs, with little or no analogue circuitry. This is in fact far from the truth; as the control systems tend to incorporate more features, and microprocessors and microcontrollers move to higher speeds and lower operating voltages, the demands placed on the system power supplies, battery charge schemes, and circuit block power switches become more exacting. Portability implies smaller and lighter components, which is usually considered to be in opposition with higher power requirements. The analogue sections and consequently the switching devices used for these systems, must then be considered and chosen carefully to meet product objectives.

Zetex Semiconductors has developed a bipolar transistor technology that enables a range of devices ideally suited to many of the high current, efficiency conscious circuit concerns of todays battery powered and portable products. This technology, the Matrix Geometry, was initially introduced to effect small DC motor drivers for cameras, and has been greatly enhanced to provide a range of transistors un-matched by any other manufacturer. This range includes a 5A continuous device in the TO-92 style E-Line package; SOT223 rated up to 7A; the SuperSOT SOT23 series which includes a 3A continuous part; and the capability of producing Super-β transistors, thereby allowing cost-effective replacement of larger Darlington and MOSFET transistors.

This application note aims to provide a general overview of this Zetex bipolar transistor technology with particular respect to selection criteria, comparison against competing MOSFET solutions, and performance advantages for low voltage applications.

Bipolar Vs MOSFET

Bipolar technology has perhaps been somewhat overshadowed in recent years, particularly since the birth of the MOSFET. This is to be expected due to two main reasons. Firstly; each major new technological advancement brings a wealth of publicity, promotion and a vast exposure of new design methods and circuitry. Unfortunately, this same PR drive comes at some cost: it is by its nature very selective, and has led to a commonly held view that bipolar can always be replaced with a MOS based product, particularly when speed, cost effectiveness and on-state efficiency are of concern. This view is true **only some of the time**. If adopted in too general a fashion, this approach can lead to non-optimised products, with the usual market disadvantages in performance and cost. There is no single device, or single technology solution to every application. The second factor is a general stagnation of bipolar device research as semiconductor manufacturers move to the latest technologies. Zetex recognises that optimised bipolar products offer the best fit design option in many cases, and has pushed the technology to higher performance standards than any of it's competitors. This section shows that modern bipolar technology, can provide a credible alternative to MOS based designs, and in many cases is the preferred choice. This is not to decry the use of MOSFETs, but rather to demonstrate that each device technology has it's advantages **and** disadvantages, and that each new application should be judged individually, not on a wholesale basis.

The information shown in Table 1 provides a basic technology overview of important Bipolar and MOSFET characteristics. To do this, a comparison has been effected between a Zetex 3rd generation bipolar product such as the geometry/process used for the SuperSOT series, and a typical latest generation MOSFET device.

1. Bipolar still claims the highest **silicon utilisation** of any transistor technology. This is due to the pattern of current flow within the geometry. Optimised bipolar geometries force the majority of the current flow vertically through the structure. MOSFETs however, still need to channel the current initially in a lateral manner before conducting through the bulk of the device. This fact allows an optimised bipolar device to use a smaller area to exhibit a given level of on-state loss, or, put another way, a bipolar device can conduct higher levels of current for the same area of silicon. This smaller silicon area leads to smaller packaging options required to encapsulate that silicon (which is a main contributer to the final product cost) and of course smaller products. Figure 1 illustrates the Zetex pioneered Matrix geometry on which many of the leading edge products are based.

Another point worth considering is how the on-state loss varies with temperature. While the components of

Table 1
Bipolar and MOSFET Technology Overview.

Performance Feature	Zetex 3rd Generation Bipolar Transistor	Typical Latest Generation MOSFET
1. Silicon utilisation	Excellent	Moderate
2. Drive voltage	<1V (V_{BE})	<2.7V (V_{th}) to 5V
3. Drive power	Moderate (high β)	Very low
4. Speed	Fast	Very fast
5. ESD sensitivity	Rugged	Sensitive
6. Price	Moderate	Expensive

pure resistance will increase with increasing temperature, this may be compensated for (within a given drive condition) by decreasing threshold voltage (for the MOSFET) or increasing h_{FE} (for the bipolar). MOSFET datasheets typically show $R_{DS(on)}$ increasing by a factor of x1.7 to x2 over the operating temperature range. Bipolar devices, particularly low voltage variants as designed for battery powered applications, show a high degree of $V_{CE(sat)}$ temperature compensation, (please refer to Figure 2).

2. The amount of **drive voltage** required to activate, turn-on, enhance etc is an important characteristic of any semiconductor device. Different technologies either address the issue directly in terms of transconductance, (Gm, gFS), or by secondary effects, Eg. current gain.

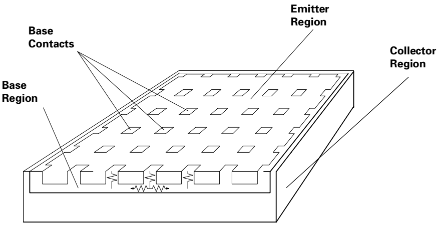


Figure 3
The Matrix Geometry
Distributed base resistance is minimised using a large matrix of base contact holes. By keeping the size of these holes small, little emitter area is lost and so active chip area is maximised.

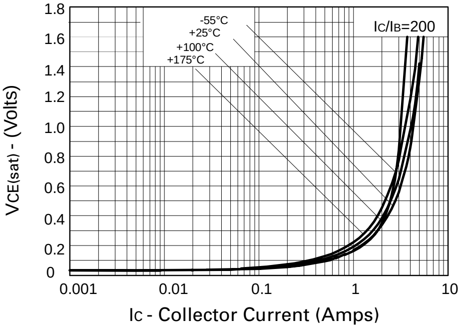


Figure 2
$V_{CE(sat)}$ vs Ic for ZTX788B, Illustrating Degree of Temperature Dependence.

Due to reducing system operating voltages, MOSFET vendors have reduced the threshold voltage, and therefore the gate-source voltage required for enhancement of the MOSFET channel. Even so, for full enhancement, to achieve datasheet and quoted resistance values, many standard MOSFETs can still require 10V or more, while low threshold devices need 4.5 to 5V. Many systems may not have this level of voltage drive available, so it is very important to fully assess the true level of on-resistance presented to the circuit, in order to understand the loss mechanisms.

For the bipolar device, the usual enabling parameter of concern is current gain, h_{FE} or β. However to assist this comparison exercise - in terms of drive voltage the bipolar transistor of course only requires a V_{BE} to promote collector-emitter conduction. For low currents this V_{BE} can be less than 400mV, perhaps rising to 1V or so at moderate to high currents, (please refer to Figure 3), thus allowing true logic level operation from 5V, 3.3V and lower operating voltage logic families.

3. The **drive power** required by a switching device is an important concern, and must be considered to appreciate the full system's power loss. At DC and low frequencies, the MOSFET's drive power requirement is essentially zero, while the bipolar transistor requires base current, leading to losses in the base ($V_{BE(sat)}$ x I_B) and (if required) the base drive resistor ($(V_{logic} - V_{BE})^2 / R_B$). These losses can be minimised however, by employing devices with very high current gain.

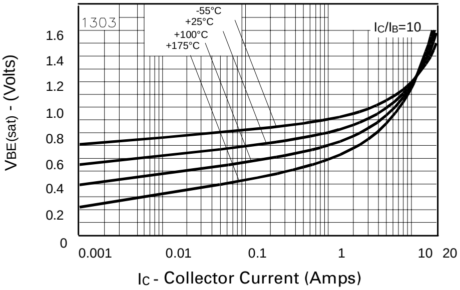


Figure 3
$V_{BE(sat)}$ or "Required Turn-on Voltage" for ZTX948.

These Super-β transistors possess typical mid-band h_{FE} values around 450 to 800 (dependent on device), which allows direct logic mA rated outputs to control single transistors which switch many amperes.

4. The **switching speed** capability is perhaps more straightforward - MOSFETs are operated routinely from 10s to 100s of kHz, and even to several MHz, although care must be taken with appropriate gate drive circuitry to ensure a high current charge/discharge buffer for the gate+Miller capacitance. Optimised bipolar devices however can still compete easily up to 100kHz (around x2 the benchmark figure adopted for standard bipolar), and with careful attention to base charge control much higher.

5. ESD is still an issue with some assembly contractors, though the compliance to safe handling standards, and investment in static safe environments will reduce this concern.

6. Price. As MOSFETs require more silicon area than bipolar parts for a given current capability, and MOSFET production processes demand state of the art alignment and etching, as well as more mask stages than bipolar, the difference in cost of manufacture and therefore the selling price, can be very significant.

7. The **reverse blocking** capability of a bipolar transistor depends on the state of the base terminal. If this is left open circuit/high impedance, as could be the case with a PNP in high side switch, then the B_{VEBO} parameter determines the reverse blocking voltage. MOSFETs cannot reverse block due to the inherent drain-source body diode. For some applications where reverse blocking is essential, MOSFETs can be configured as back to back pairs, such that each MOSFET blocks the body diode of it's partner. This does however double the on-resistance seen by the circuit. Figure 4 shows the typical B_{VECO} characteristic of a representative Super-β transistor.

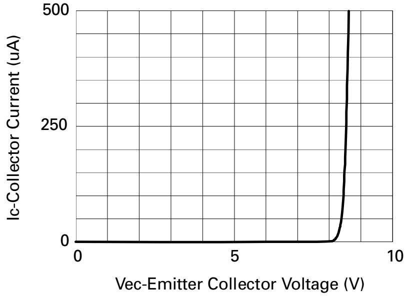


Figure 4
Reverse Blocking Capability of Bipolar Transistors.

8. Bipolar transistors can sometimes offer the useful feature of **inverse gain** or h_{FC}. This is particularly the case for the lower voltage variants, where the inverse gain can peak at between 33 to 50% of the peak forward gain. This is because the relatively highly doped collector region can also function well as an "emitter". For the Super-β parts this presents a peak inverse gain in the region of 100 to 300 typically. This feature can be useful for instance in positive line switching networks, where the selection of supply lines may effectively reverse the collector-emitter bias seen by the pass transistor. Another application benefit of importance is the possibility of conducting negative transients, as caused by external influences on the supply rail or inductive loads. This feature can be used to advantage in some circuits by allowing the omission of the collector-emitter diode that would otherwise be required, to prevent damage to the transistors emitter-base junction. Figure 5 shows the inverse gain characteristic for low collector currents, in the saturation region for the FMMT717 PNP SOT23 transistor.

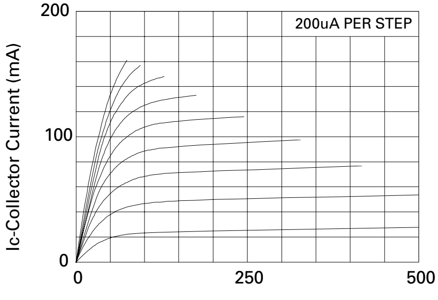


Figure 5
Inverse Gain Characteristic of FMMT717.

9 and 10. These last two factors are somewhat of an invention, but serve to demonstrate that when considered in terms of equivalent on-resistance (whether that is $R_{DS(on)}$ for a MOSFET, or $R_{CE(sat)}$ for a bipolar transistor) and most importantly **cost**, the bipolar option can be very attractive.

Figures 6 and 7 help to illustrate some of the points raised in 1 and 3 above, namely the silicon efficiency, on-state loss, and drive losses. These charts show the amount of power loss exhibited by a range of SOT23 and one SOT89 surface mount transistors as a function of load current. Figure 6 shows curves for NPN and N-Channel parts, and Figure 7 shows curves for PNP and P-Channel parts. These curves do **NOT** represent the minimum loss irrespective of package - they refer to industry standard and best-in-class SOT23 and SOT89 products only. It is noteworthy that the BCX69 part referenced is actually a SOT89 packaged transistor.

Key Parameters

The previous section has touched on some of the circuit parameters useful in comparing the two technology classes, when considering products for battery powered systems. Perhaps the most useful of these parameters is $R_{CE(sat)}$, this being the collector-emitter resistance, and is equivalent (in a datasheet sense) to $R_{DS(on)}$; the common MOSFET benchmark parameter. Table 2 shows a selection of the low voltage variant Zetex transistors specifically developed for battery system operation, and includes $R_{CE(sat)}$ figures for illustration purposes. As with any datasheet figure, point measurement values must be used as guidelines only. For application specifics, knowledge of the circuit operating conditions, datasheet test points and characterisation curves can usually lead to a credible interpolation.

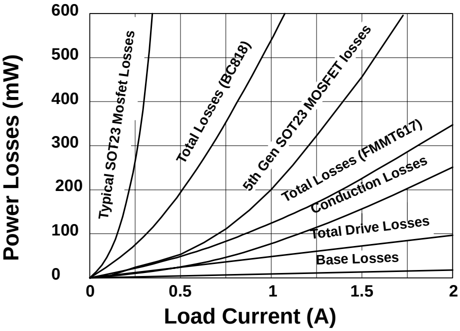


Figure 6
NPN/N-Channel Power Loss vs Load Current comparison.

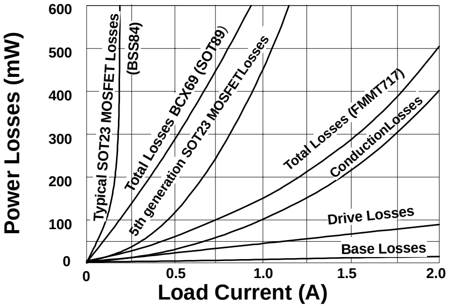


Figure 7
PNP/P-Channel Power Loss vs Load Current comparison.

Device (Note 1)	Polarity	I_C (DC)	I_{CM}	$V_{CE(sat)}$ (Note 2)	$R_{CE(sat)}$	h_{FE} (Note 3)
FMMT617	NPN	3	12	50mV @ 1A 150mV @ 3A	50mΩ	450 typ
FMMT618	NPN	2.5	6	50mV @ 1A 100mV @ 2A	50mΩ	450 typ
FMMT717	PNP	2.5	10	80mV @ 1A 140mV @ 2A	80mΩ	450 typ
FMMT718	PNP	1.5	6	110mV @ 1A 150mV @ 2A	55mΩ	450 typ
ZTX688B	NPN	3	10	50mV @ 1A 250mV @ 3A	50mΩ	750 typ
ZTX788B	PNP	3	8	50mV @ 0.5A 300mV @ 3A	100mΩ	650 typ
ZTX1048A	NPN	4	20	24mV @ 0.5A	48mΩ	450 typ
ZTX869	NPN	5	20	25mV @ 0.5A 180mV @ 5A	50mΩ	450 typ
ZTX949	PNP	4.5	20	40mV @ 0.5A 240mV @ 5A	80mΩ	200 typ

Table 2
Low Voltage transistors for Battery and Portable Systems.

Notes:

1. These represent a selection from some of the transistor families available from Zetex. Eg. the ZTX688B is a 12V 3A part from the ZTX688B-696B series, similarly the ZTX788B is part of the ZTX788B-795A series. Please note that surface mount equivalents are available for any ZTX (through-hole) pre-fixed part.

2. These $V_{CE(sat)}$ values are point measurements only, and depend on collector current, base drive level, and temperature. Please consult the appropriate datasheet for full DC characterisation. The corresponding values of $R_{CE(sat)}$ are shown for this point measurement, for application specific values consult the datasheet.

3. These values are guidance only, and are typical mid-band figures. Please refer to the appropriate datasheet. (Appendix A contains FMMT717 data).

The voltage rating parameters also require some examination. For bipolar parts the voltage rating most often quoted is the B_{VCEO} parameter, which is the collector-emitter breakdown voltage with the base terminal open-circuit. The primary breakdown of the epitaxial layer however is more closely represented by the B_{VCBO} or B_{VCES} parameters, and for many circuit topologies it is this rating that is of most relevance as the base is never open circuit; being driven actively, or tied to the appropriate rail by a resistor. For realistic comparisons with MOSFET devices, the primary value given by B_{VCBO} , B_{VCES}, or even B_{VCEV} should be considered if allowed by the circuit. This will probably lead to the selection of a lower voltage rated part than would otherwise be the case, leading to a lower $V_{CE(sat)}$ specification, and hence higher circuit performance. Please refer to Figure 8.

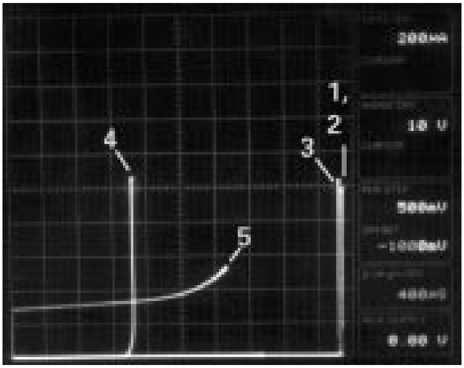


Figure 8
Voltage Breakdown Modes of ZTX849.

1 - BV_{CBO}, 2 - BV_{CES}, 3 - BV_{CEV}, 4 - BV_{CEO}, 5 - BV_{CE} with V_{BE} = 0.5V
Scaling: 10V/div horiz.; 200µA/div vert.

Table 3 provides a guide to common bipolar/MOS terminology.

Bipolar	MOSFET
I_C (DC)	I_D (DC)
I_{CM}	I_{DM}
BV_{CES}	BV_{DSS}
$V_{BE(sat)}$	V_{GS}
I_{EBO}	I_{GSS}
I_{CES}	I_{DSS}
$R_{CE(sat)} = V_{CE(sat)}/IC$	$R_{DS(on)} = V_{DS(on)}/ID$
h_{FE}	g_{FS}
C_{ibo}	C_{iss}
C_{obo}	C_{oss}

Table 3
Bipolar/MOSFET Terminology.

Zetex datasheets for the very low $V_{CE(sat)}$, high current transistors include curves showing how $V_{CE(sat)}$ varies with both forced gain and temperature, as well as the more usual h_{FE} profile, $V_{BE(on)}$, $V_{BE(sat)}$ and safe operating area (SOA) charts. Appendix A presents an example of the characterisation available for many of the battery product targeted bipolar transistors: in this case the datasheet for the FMMT717 SOT23 PNP device. This is a 12V, 2.5A continuous high gain transistor that has been developed specifically for use as an high efficiency positive line switch for DC rail control, and high current DC-DC converters.

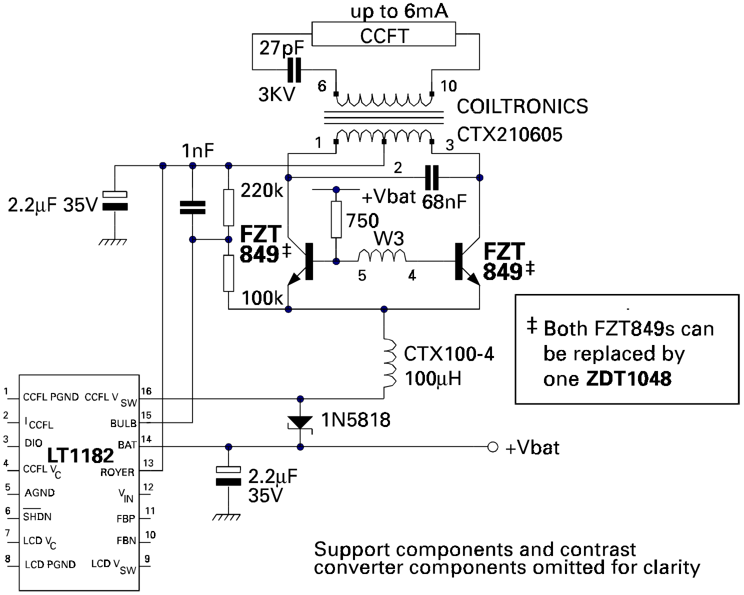
Applications

LCD Backlighting

Perhaps the most difficult power supply to effect within a laptop, and which has attracted much interest from many vendors, is the high voltage DC-AC inverter required by the fluorescent tube used to provide back/edge lighting for the LCD display. The tube expects a very high voltage to initiate conduction, perhaps 1kV, and several hundred volts during operation. This supply compliance must be effected with a very high degree of efficiency from the available energy source; - typically a ten cell NiCd or NiMH battery pack. The ZTX1048A series of transistors permit conversion efficiencies of over 90% providing significant increases in battery life, and therefore less re-charge cycles. The ZTX1048A and ZTX1049A devices have been developed specifically for the resonant push-pull (or Royer) inverter used almost exclusively for this purpose, and Zetex has already achieved many design-ins in this application. The ’1048 and ’1049 transistors are also available as an uncommitted dual device in the space saving SM-8 package as the ZDT1048 and ZDT1049.

[**Note**: The SM-8 package is an eight lead version of the popular SOT223 package and can thus yield a 50% space saving].

Figure 9 shows a floating lamp CCFL circuit developed by Linear Technology, using the LT1182 CCFL/LCD contrast dual switching regulator, and either a



‡ Both FZT849s can be replaced by one **ZDT1048**

Support components and contrast converter components omitted for clarity

Figure 9
Floating Tube CCFL Backlight Inverter (Linear Technology) using 2 x FZT849 or the ZDT1048 SM8 Dual transistor.

pair of FZT849s or a ZDT1048 SM-8 dual transistor to produce a 90% efficient inverter. Please refer to Linear Technology application note AN65 Oct 95, “A Fourth Generation of LCD Backlight Technology” by Jim Williams.

Power Supply Switching

Power supply switching for load management (such as peripheral control, transmit circuit blocks in handphones, and RAM back-up) should be considered carefully in terms of the DC and peak currents required; the allowable voltage drop across the switch element (the PCMCIA power switching specification for example, states a 5% maximum drop at a 1A output, from the nominal 5V or 3.3V rail); ease of drive and cost constraints. The FMMT717 is a SOT23 PNP transistor that exhibits a best in class $V_{CE(sat)}$ of 100mV at a pass current of 1A, equating to a switch resistance of 100mΩ. This on-state performance also allows a 2.5A DC capability, providing a power switch for PCMCIA (peripherals may demand up to 1.5A peak for say hard disc spin-up), mobile phone battery chargers, and battery management systems, that is reliable and offers the most space and cost efficient solution. To perform the same function with a P-Channel MOSFET would require a much larger die (and therefore package) and therefore an increase in price and weight for the user.

Analogue IC vendors manufacture microprocessor power supply supervisory devices, that monitor the state of memory supply rails and switch over the supplies as required. These devices often require a low loss PNP or P-Channel part as the pass element, and this function can usually be effected with much less cost by a suitable PNP transistor.

Voltage Regulation

Low drop out regulator controller ICs are now available that provide the user with the advantages of a monolithic voltage reference, and the freedom to specify the output device relevant to the application. These devices usually require a PNP device to function as the linear drop element. To allow the system to operate down to the minimum input voltage as the battery pack reaches the end of a discharge cycle, implies that the transistor must exhibit very low $V_{CE(sat)}$, preferably with a minimal amount of base drive drawn from the controller IC.

Device	Package	I_C (DC)	PD	$V_{CE(sat)}$	@I_c /I_b
FMMT717	SOT23	2.5A	625mW	100mV	1A /10mA
ZTX788B	E-Line	3A	1W	190mV	1A /5mA
ZTX949	E-Line	4.5A	1.2W	190mV	3A /60mA
ZBD949	TO126	5A	2W/25W	480mV	5A /50mA

Table 4
PNP Transistors for Low Dropout regulator Designs.

There are a number of Zetex parts ideally suited for this application, and Table 4 provides an overview of suitable parts. Figure 10 shows two typical LDO regulator circuits published by Linear Technology and MAXIM.

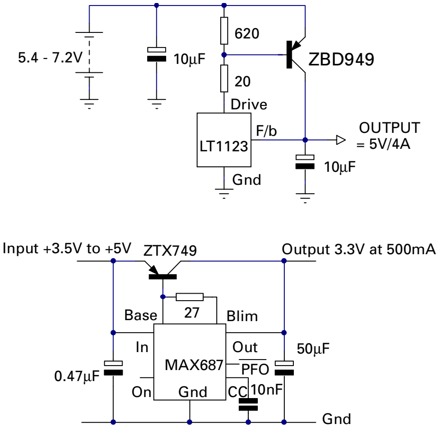


Figure 10
Low Drop Out Regulators - IC + Discrete Implementation.

DC-DC Converters and Fast Chargers

Battery charge management and fast charge circuit topologies using intelligent charge, voltage inflection, current, and cell temperature monitoring, frequently employ a DC-DC converter to effect an efficient charge transfer between the available source and the battery pack. This is usually a step down or Buck converter which dictates a fairly high operating frequency (to meet inductor size constraints), and is also subject to very tight cost control. To meet these requirements, Zetex have a range of high current, high gain transistors available in E-Line, SOT223 and TO126 that allow converter designs to 100kHz, and fast charge currents of up to 5A. Figure 11 shows a circuit designed by Benchmarq Microelectronics Inc., that uses the 3A rated ZTX788B for a low cost fast charger running at typically 80kHz and supplying a charging current of 2.3A. (This particular circuit being configured to charge two cells, and will accept an input voltage up to 15V). The circuit uses a turn-off circuit devised by Benchmarq to remove switching losses associated with bipolar transistor storage time and turn-off fall time, to allow the transistors to exhibit similar switching efficiences to large MOSFETs. This switch-off circuit is also shown in Figure 12. Q2 is driven by the PWM switching controller, and with the emitter resistor sets the base current for the high current PNP. These components are selected to ensure that on-state losses are acceptable for a given load condition without incurring excessive drive loss. When Q2 switches off, the inductor L1 rings, turning Q1 on hard. Q2 then performs active pull-up on the base of Q3 -the switching transistor. This method, and similar circuit techniques to remove base charge can be used to allow cost effective bipolar DC-DC converters.

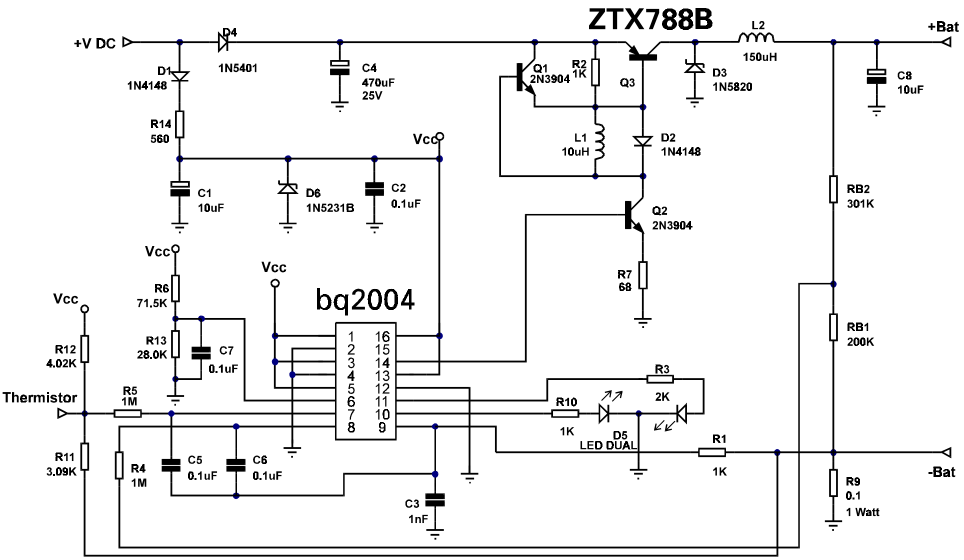


Figure 11
Fast Charge Circuit (Benchmarq Microelectronics) using the ZTX788B.

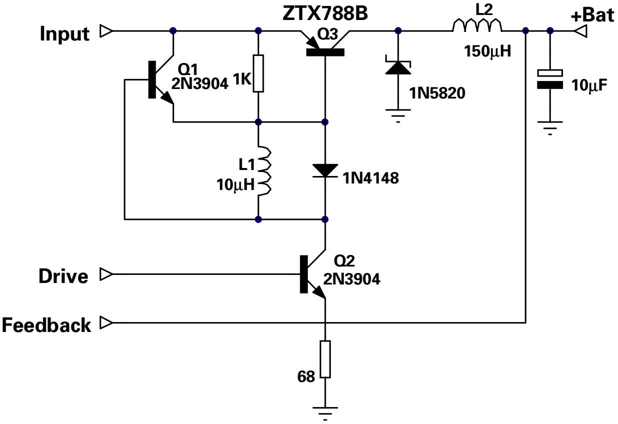


Figure 12
Turn-off circuit for Bipolar Transistors, allowing High Efficiency DC-DC Conversion at High Frequency.

APPENDIX A

FMMT717 datasheet including absolute maximum ratings, detail sheet and full DC characterisation.

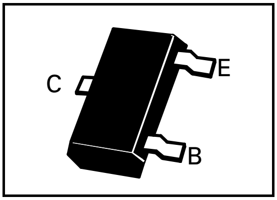
“SuperSOT”
SOT23 PNP SILICON POWER (SWITCHING) TRANSISTOR

FMMT717

FEATURES

- * **625mW POWER DISSIPATION**
- * **I_C CONT 2.5A**
- * 10A PEAK PULSE CURRENT
- * EXCELLENT H_{FE} CHARACTERISTICS UP TO 10A (PULSED)
- * LOW SATURATION VOLTAGE

COMPLEMENTARY TYPE – FMMT617
PARTMARKING DETAIL – 717



SOT23

ABSOLUTE MAXIMUM RATINGS.

PARAMETER	SYMBOL	VALUE	UNIT
Collector-Base Voltage	V_{CBO}	-12	V
Collector-Emitter Voltage	V_{CEO}	-12	V
Emitter-Base Voltage	V_{EBO}	-5	V
Peak Pulse Current **	I_{CM}	-10	A
Continuous Collector Current	**I_C**	**-2.5**	**A**
Base Current	I_B	-500	mA
Power Dissipation at T_{amb}=25°C*	**P_{tot}**	**-625**	**mW**
Operating and Storage Temperature Range	T_j:T_{stg}	-55 to +150	°C

*Maximum power dissipation is calculated assuming that the device is mounted on a ceramic substrate measuring 15x15x0.6mm

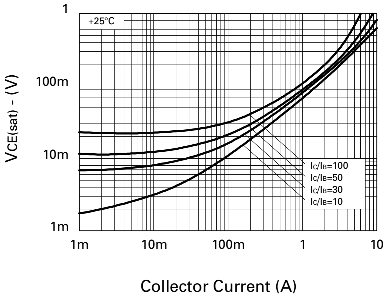
**Measured under pulsed conditions. Pulse width=300µs. Duty cycle ≤ 2%

ELECTRICAL CHARACTERISTICS (at T_{amb} = 25°C unless otherwise stated).

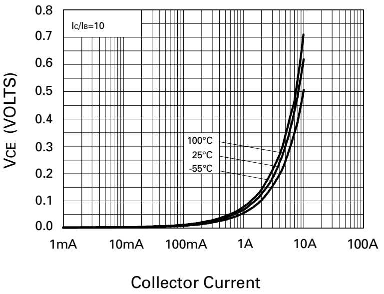
PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT	CONDITIONS.
Collector-Base Breakdown Voltage	$V_{(BR)CBO}$	-12	-35		V	I_C=-100μA
Collector-Emitter Breakdown Voltage	$V_{(BR)CEO}$	-12	-25		V	I_C=-10mA*
Emitter-Base Breakdown Voltage	$V_{(BR)EBO}$	-5	-8.5		V	I_E=-100μA
Collector Cut-Off Current	I_{CBO}			-100	nA	V_{CB}=-10V
Emitter Cut-Off Current	I_{EBO}			-100	nA	V_{EB}=-4V
Collector Emitter Cut-Off Current	I_{CES}			-100	nA	V_{CES}=-10V
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$		-10 -100 -110 -180	-17 -140 -170 -220	mV mV mV mV	I_C=-0.1A, I_B=-10mA* I_C=-1A, I_B=-10mA* I_C=-1.5A, I_B=-50mA* I_C=-2.5A, I_B=-50mA*
Base-Emitter Saturation Voltage	$V_{BE(sat)}$		-0.9	-1.0	V	I_C=-2.5A, I_B=-50mA*
Base-Emitter Turn-On Voltage	$V_{BE(on)}$		-0.8	-1.0	V	I_C=-2.5A, V_{CE}=-2V*
Static Forward Current Transfer Ratio	h_{FE}	300 300 180 60 45	475 450 275 100 70			I_C=-10mA, V_{CE}=-2V* I_C=-100mA, V_{CE}=-2V* I_C=-2.5A, V_{CE}=-2V* I_C=-8A, V_{CE}=-2V* I_C=-10A, V_{CE}=-2V*
Transition Frequency	f_T	80	110		MHz	I_C=-50mA, V_{CE}=-10V f=100MHz
Output Capacitance	C_{obo}		21	30	pF	V_{CB}=-10V, f=1MHz
Turn-On Time	$t_{(on)}$		70			V_{CC}=-6V, I_C=-2A I_{B1}=I_{B2}=50mA
Turn-Off Time	$t_{(off)}$		130			

*Measured under pulsed conditions. Pulse width=300μs. Duty cycle ≤ 2%

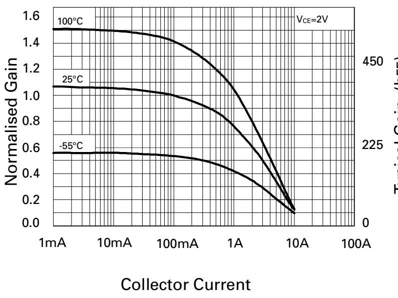
TYPICAL CHARACTERISTICS



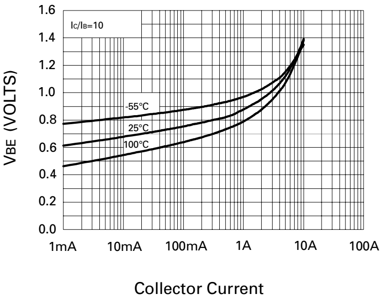
$V_{CE(SAT)}$ vs I_C



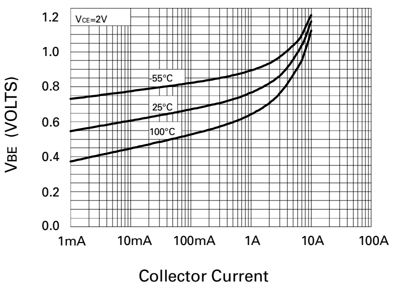
$V_{CE(SAT)}$ vs I_C



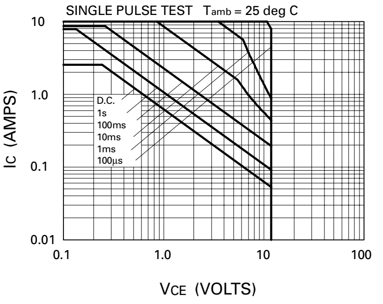
h_{FE} vs I_C



$V_{BE(SAT)}$ vs I_C

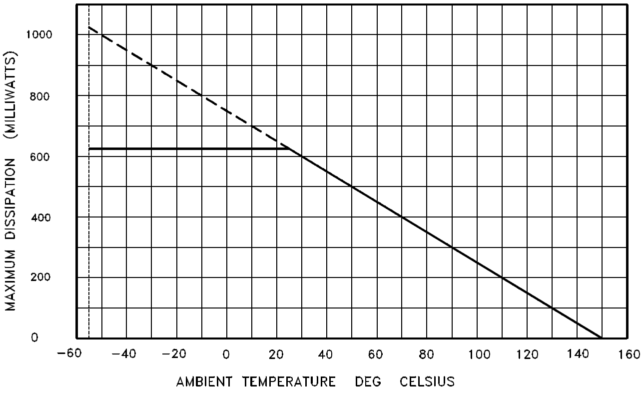


$V_{BE(ON)}$ vs I_C

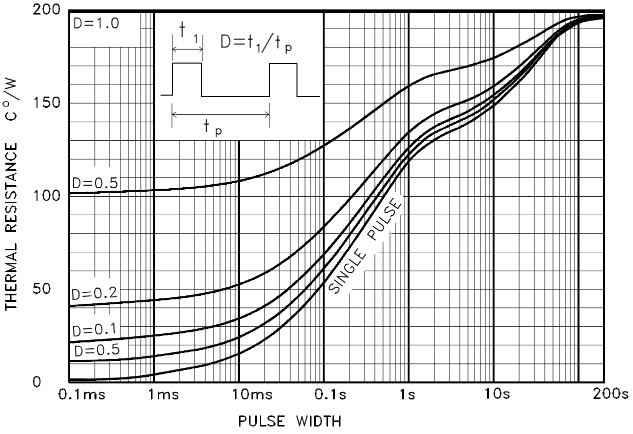


Safe Operating Area

THERMAL CHARACTERISTICS



DERATING CURVE



MAXIMUM TRANSIENT THERMAL RESISTANCE

* Reference above figures, Devices were mounted on a 15mmx15mm ceramic

NOTE: Spice parameter data for FMMT717 can be provided upon request.