ZETEX SEMICONDUCTORS

DN80

Bipolar transistors for MOSFET gate driving applications

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Over the last few years MOSFETs have become the device of choice in power switching applications. Whilst on-resistances have significantly reduced, they often require a driver stage to obtain the best performance, particularly when driven from low-voltage, low-current sources. This is where the bipolar transistors inherent advantages excel, as explained below.

Power MOSFETs are often presented as voltage driven devices and as such may be mistakenly expected to be driven from any signal source, irrespective of current capability. This may be an acceptable assumption when driving in DC or very low frequency switching applications where fast edge speeds are not important, but increasingly power MOSFETs are used in switching circuits of hundreds of kHz to 10MHz and in these circumstances the gate charge requirements are a major consideration. The charge necessary to fully enhance a power MOSFET derives from its gate-source and gate-drain capacitances and is delivered via an external resistor. The gate voltage follows a characteristic RC time constant which (within EMI constraints) has to be short enough to traverse the linear region without incurring excessive switching losses in the power MOSFET.

The average gate current during the switching event can be calculated thus:

$$I_G = Q/t,$$

where:

I_G is the average gate current

Q is the total gate charge ($Q_{GS} + Q_{GD}$)

t is the switching transient time (t_{ON} or t_{OFF})

For example a typical 100V, 35mΩ DPAK MOSFET requires approximately 50nC. If it was required to switch in 20ns a gate current of 2.5 Amps is required.

There are many potential solutions to provide gate drive for power MOSFETs, including dedicated IC drivers, standard logic ICs, discrete MOSFETs and bipolar transistors. The selection criteria for gate driving usually include:

- Switching speed (hence current capability)
- Cost
- Current gain
- Size

Bipolar transistors are eminently suitable for this function as they exhibit fast switching in linear mode, have high pulse current capability, high current density, hence small size and cost.

One of the most popular and cost effective drive circuits is a bipolar, non-inverting totem-pole type driver as shown in Figure 1.

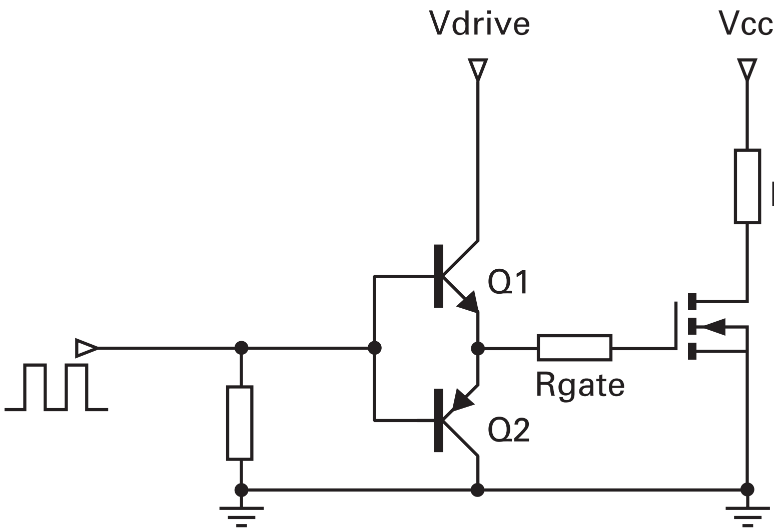

Figure 1 Totem pole driver stage for power MOSFET

If in the above example the power MOSFET was required to switch at a frequency of 1MHz and driven to 5Vgs the power dissipation in each driver transistor can be calculated, worst case (assuming Rg = 0), as approximately:

$P_D = ((V_{drive} * I_G * t * f) \div 2) + (V_{BE(ON)} * (I_C \div h_{FE}) * \text{Duty Cycle})$

$= ((5 * 2.5 * 2E^{-8} * 1E^{6}) \div 2) + (0.8 * 8.3\ E^{-3} * 2E^{-8} * 1E^{6})$

$= 125.1\text{mW}$

where:

P_D is the power dissipation

V_{drive} is the drive voltage applied to the bipolar base

I_G is the average gate current

t is the switching transient time (t_{ON} or t_{OFF})

f is the switching frequency

$V_{BE(ON)}$ is the forward base-emitter voltage

I_C is the transistor collector current

h_{FE} is the transistor forward current gain

Duty cycle is the proportion of each cycle in the on condition

Assuming the base current is supplied from V_{drive} the losses per transistor are approximately

$P_D = ((V_{drive} * I * t * f) \div 2) + (V_{drive} * (I_C \div h_{FE}) * 2E^{-8} * 1E^{6}) * \text{Duty Cycle})$

$= ((5 * 2.5 * 2E^{-8} * 1E^{6}) \div 2) + ((5 * 8.3\ E^{-3} * 2E^{-8} * 1E^{6}) * 0.02)$

$= 125.8\text{mW}$

With these power losses it is clear that bipolar transistors packaged in small surface mount packages are suitable, preferably co-packaged as complimentary dual devices. Some example transistors suitable for gate driving are shown in Table 1.

Device	Type	Package	BV_{CEO} (V)	I_C (A)	I_{CM} (A)	$h_{FE (typ)}$
Singles						
FMMTL618 FMMTL718	NPN PNP	SOT23 SOT23	20 20	1.25 -1.0	4 -2	450 450
FMMT617 FMMT717	NPN PNP	SOT23 SOT23	15 -12	3.0 -2.5	12 -10	450 450
FMMT491A FMMT591A	NPN PNP	SOT23 SOT23	40 -40	1.0 -1.0	2 -2	450 450
ZXTN2025F	PNP	SOT23	-50	-5	-10	350
ZXTN2018F	NPN	SOT23	60	5	12	200
ZXTP2027F	PNP	SOT23	-60	-4	-10	200
ZXTN2031F	NPN	SOT23	80	5	12	350
ZXTN2020F	NPN	SOT23	100	4	12	200
ZXTP2029F	PNP	SOT23	-100	-2.5	-5	200
ZXT1M322 ZXTAM322	NPN PNP	2x2mm MLP 3-L 2x2mm MLP 3-L	15 -12	4.5 -4.0	15 -12	450 450
ZXT3M322 ZXTCM322	NPN PNP	2x2mm MLP 3-L 2x2mm MLP 3-L	50 -40	4.0 -3.0	6 -4.0	450 450
Duals						
ZXTD6717	NPN/PNP dual	SOT23-6	15 -12	1.5 -1.25	5 -3	300 300
ZXTDA1M832	NPN/PNP dual	3x2mm MLP 8-L	15 -12	4.5 -4.0	15 -12	300 300
ZXTD4591E6	NPN/PNP dual	SOT23-6	60 -60	1.0 -1.0	2 -2	200 200
ZXTDE4M832	NPN/PNP dual	3x2mm MLP 8-L	80 -70	3.5 -2.5	5 -3	450 450

Table 1 Example transistors suitable for gate driving

In conclusion, whilst MOSFETs have become the default choice of power switch for many designers bipolar transistors have many useful attributes which can be used beneficially in certain applications. One such application is power MOSFET gate driving, where the bipolar transistor's fast switching in linear mode, high pulse current capability, high current density, and small size and cost make them eminently suitable for this function.

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