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.

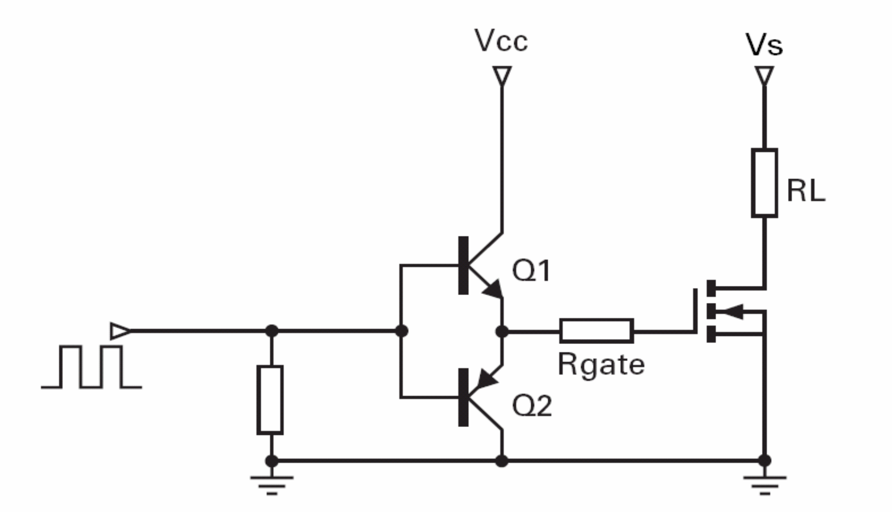

Figure 1 Totem pole driver stage for power MOSFET

If in the above example the power MOSFET was required to switch at a frequency of 1MHz and driven to $8V_{GS}$ the power dissipation in each driver transistor can be calculated, worst case (assuming Rg = 0), as approximately:

$$P_{D(npn)} = ((V_{CC} - V_G/2) \bullet Q \bullet f) + (V_{BE} \bullet I_B \bullet t \bullet f)$$
$$= ((12 - 4) \bullet 50E^{-9} \times 1E^{6}) + (0.8 \bullet 0.8E^{-3} \bullet 2E^{-8} \bullet 1E^{6})$$
$$= 0.4W$$

$$P_{D(pnp)} = ((V_G/2) \bullet Q \bullet f) + (V_{BE} \bullet I_B \bullet t \bullet f)$$
$$= ((4 \bullet 50E^{-9} \bullet 1E^{6}) + (0.8 \bullet 0.8E^{-3} \bullet 2E^{-8} \bullet 1E^{6})$$
$$= 0.2W$$

where:

P_D is the power dissipation

V_{CC} is the driver stage supply voltage (assumed in this case to be 12V)

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_B is the transistor base current (I_c/h_{FE})

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. Table 1 presents some of the transistors and gate drivers available from Zetex, which are suitable for the gate drive application. Full details of Zetex high speed non-inverting, single MOSFET gate drivers available at www.zetex.com.

Gate drivers							
Device	**Package**	**V_{cc} (V)**	**$I_{SINK(PK)}$ (A)**	**I_{SOURCE} (A)**	**I_{SINK} (A)**	**Prop. delay times (ns)**	**Switching time (ns)**
				@ I_{IN} = 10mA			
ZXGD3001E6	SOT23-6	12	9	4.2	2.2	<3	<11
ZXGD3002E6	SOT23-6	20	9	2.2	2.0	<1.6	<10.8
ZXGD3003E6	SOT23-6	40	5	1.6	1.4	<1.8	<8.9
ZXGD3004E6	SOT23-6	40	8	1.9	1.9	<1.1	<13.4

Single transistors					
Device	**Type**	**Package**	**BV_{CEO} (V)**	**I_{CM} (A)**	**$h_{FE\ (min)}$**
ZXTN07012EFF	NPN	SOT23F	12	10	500
ZXTP07012EFF	PNP	SOT23F	12	8	500
ZXTP23015CFH	PNP	SOT23	15	10	250
ZXTN19020DFF	NPN	SOT23F	20	20	300
ZXTP19020CFF	PNP	SOT23F	20	10	250
ZXTN25020DFL	NPN	SOT23	20	8	300
ZXTP25020DFL	PNP	SOT23	20	6	300
ZXTN07045EFF	NPN	SOT23F	45	6	500
ZXTP07040DFF	PNP	SOT23F	40	6	300
ZXTN25040DFL	NPN	SOT23	40	6	300
ZXTP25040DFL	PNP	SOT23	40	5	300
ZXTN2040F	NPN	SOT23	40	2	300
ZXTP2041F	PNP	SOT23	40	2	300
ZXTN19060CFF	NPN	SOT23F	60	12	250
ZXTN2038F	NPN	SOT23	60	2	100

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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