Introduction

Low $V_{CE(sat)}$ Bipolar Transistors (BJTs) are an attractive alternative to planar MOSFETs for power switching in automotive management circuits. They are proving to be more ESD robust, consume less power than comparative size planar MOSFETs and often lower cost resulting in a lower system cost. This application note will address the use of Low $V_{CE(sat)}$ BJTs in automotive power management circuits.

ON Semiconductor's family of low $V_{CE(sat)}$ Bipolar Junction Transistors (BJT) are surface mount devices featuring ultra low saturation voltage $V_{CE(sat)}$ and high current gain capability in thermally efficient packages. In the automotive industry they are used as a load switch in air bag deployment, pre-drivers for high current Trench MOSFETs in fuel pumps, over voltage protection, low drop out regulation, LED backlight switching, Royer converter for LCD backlights in instrument cluster. The Linear Gain (Beta) of Low $V_{CE(sat)}$ BJT makes them ideal components in analog amplifiers and for driving directly from logic circuits.

Technology

The Low $V_{CE(sat)}$ BJT devices use a technology that was first developed over 30 years ago and was primarily used to

BOARD DESIGN

Package Thermal Design Considerations

The Low $V_{CE(sat)}$ BJT is a current driven device, compared to the MOSFET which is a voltage driven device. For this reason the designer needs to understand the limitations of the power control circuits being used, to determine the specific circuit requirements when designing with a Low $V_{CE(sat)}$ BJT. For example, if the Low $V_{CE(sat)}$ BJT is to control a current of 1 Amp and it has a worst case gain (h_{FE}) of 100 then the base current will need to be a minimum of 10 mA (I_B) to ensure the Low $V_{CE(sat)}$ BJT goes into saturation. The output of the power control circuit must be able to supply the 10 mA for the Low $V_{CE(sat)}$ BJT to be driven directly; otherwise an additional drive stage would be required.

The power rating of the package for the Low $V_{CE(sat)}$ BJT has to be consider. For Example; the ON Semiconductor Low $V_{CE(sat)}$ BJT NSS40200LT1G in a SOT−23 package is mounted on a FR4 printed circuit board 500 mm^2 1 oz copper pad. The maximum power rating (P_D) with the specified pad is 540 mW.

The input voltage to be switched is < 40 V. The ambient temperature is 25°C. The typical $V_{CE(sat)}$ for the NSS40200LT1G at 1.0 A is 80 mV. This equates to a power dissipation of 80 mW. The Minimum Gain (h_{FE}) at 1.0 A is 180. Thus the drive current (I_B) would need to be a little over 6.0 mA. The maximum limit on $V_{CE(sat)}$ at 1.0 A is 170 mV (from Data Sheet with beta 100), this equating to 170 mW, well below the 540 mW rating for the package at 25°C.

Derating the Device for Temperature

The Thermal Resistance de-rating with 500 mm^2

MOSFET Gate Driving

High Power low $R_{DS(on)}$ MOSFETs need to be switched at high frequencies to satisfy the power conversion reqirements of high efficiency. To achieve this the gate driver circuit has to deliver instantaneous currents of several amps. Low $V_{CE(sat)}$ BJTs are very suitable as they feature superior switching in linear mode, high pulse-current capability through high current density.

One of the most popular and cost-effective drive circuits is a bipolar, non-inverting totem-pole driver. As power dissipation is low, this can use a co-packaged complementary pairs in small outline surface mount packages (NSS40302PDR2G).

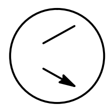

Figure 4. MOSFET Gate Driving

Over Voltage Protection

The Low $V_{CE(sat)}$ BJTs are ideal for a simple over voltage protection circuit. Zener D1 is selected for the trip voltage, Zener D2 is selected to ensure higher peaks that may get past the BJT are still clamped from reaching the load. Diode D3 acts as a Bakers Clamp improving the switching time of Q1 to under 100 ns.

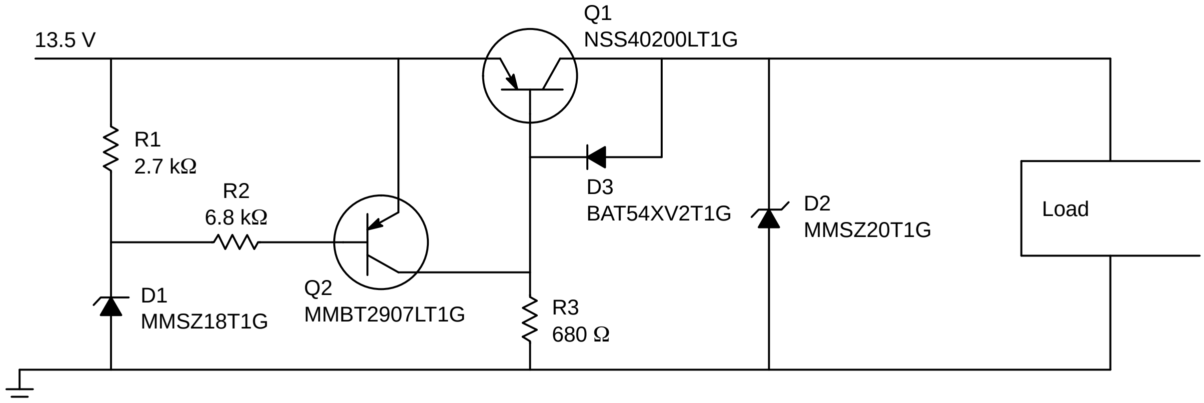

Figure 6. Over Voltage Protection

Conclusion

Low $V_{CE(sat)}$ Bipolar Transistors (BJTs) are an attractive alternative to planar MOSFETs for power switching in automotive management circuits. They are proving to be more ESD robust, consume less power and often resulting in a small Bill Of Material (BOM) and thus lower system cost.

Table 1.

Application	Feature	Benefit
Load Switch	• Low $V_{CE(sat)}$ • h_{FE} > 200 • Low R_{CE}/mm^2 • Small Size − 5.4 mm^2 • Low Profile – 1.0 mm • PNP Transistor	• High Efficiency • High Gain • Low Cost vs. MOSFET • Less Board Space • More Compact Design • High Side Control
MosFET Gate Drive	• High Pulse Current • High Frequency • h_{FE} > 200 • Low R_{CE}/mm^2 • Small Size − 5.4 mm^2 • Low Profile – 1.0 mm • PNP/NPN Transistor	• Fast Switching Time • Fast Switching Time • High Current gain • Low Cost vs. MOSFET • Less Board Space • More Compact Design • High/Low Switch
Low Drop Out (LDO) Regulator	• Low $V_{CE(sat)}$ • High Power Dissipation/mm^2 • h_{FE} > 200 • Low R_{CE}/mm^2 • Small Size − 5.4 mm^2 • Low Profile – 1.0 mm • PNP/NPN Transistor	• High Efficiency • High Current Control • High Gain • Low Cost vs. MOSFET • Less Board Space • More Compact Design • High or Low Side Control
Servo Motor Drive	•	

Table 2. PNP PORTFOLIO OF LOW $V_{CE(sat)}$ BJT

Part Number	V_{CE} (V)	I_C DC (A)	I_C Peak (A)	Package	Typical $V_{CE(sat)}$ 1 A Beta 10	Typical h_{FE} @ 5 V, 100 mA	Status
NSS12100UW3	12	1	2	WDFN3	400 mV	300	Released
NSS12100M3	12	1	2	SOT−723	280 mV	250	Released
NSS12100XV6	12	1	2	SOT−563	280 mV	250	Released
NSS12200W	12	2	3	SC−88	150 mV	250	Released
NSS12200L	12	2	4	SOT−23	65 mV	250	Released
NSS12500UW3	12	5	7	WDFN3	55 mV	250	Released
NSS20200L	20	2	4	SOT−23	65 mV	250	Released
NSS20300MR6	20	3	5	TSOP−6	80 mV	250	Released
NSS20500UW3	20	5	7	WDFN3	60 mV	250	Released
NSS30070MR6	30	0.7	2	SC−74	205 mV	310	Released
NSS30100L	30	1	2	SOT−23	200 mV	98	Released
NSS35200MR6	35	2	5	TSOP−6	78 mV	234	Released
NSS35200CF8	35	2	7	ChipFET	79 mV	253	Released
NSS40200L	40	2	4	SOT−23	80 mV	300	Released
NSS40200UW6	40	2	4	WDFN6	100 mV	250	Released
NSS40300MZ4	40	3	5	SOT−223	50 mV	250	Released
NSS40500UW3	40	5	6	WDFN3	65 mV	250	Released
NSS40600CF8	40	6	8	ChipFET	50 mV	250	Released
NSS60200L	60	2	4	SOT−23	80 mV	250	Released
NSS60600MZ4	60	6	12	SOT−223	80 mV	250	Released
NSS1C200L	100	2	4	SOT−23	100 mV	300	Released
NSS1C200MZ4	100	2	3	SOT−223	125 mV	250	Released
NSS1C300E	100	3	6	DPAK	150 mV	180	Released

Table 3. NPN PORTFOLIO OF LOW $V_{CE(sat)}$ BJT

Part Number	V_{CE} (V)	I_C DC (A)	I_C Peak (A)	Package	Typical $V_{CE(sat)}$ 1 A Beta 10	Typical h_{FE} @ 5 V, 100 mA	Status
NSS12201L	12	2	4	SOT−23	35 mV	300	Released
NSS12501UW3	12	5	7	WDFN3	31 mV	300	Released
NSS12601CF8	12	6	8	ChipFET	30 mV	300	Released
NSS20101J	20	1	2	SC−89	220 mV	500	Released
NSS20201L	20	2	4	SOT−23	37 mV	300	Released
NSS20201MR6	20	2	3				

Table 3. NPN PORTFOLIO OF LOW $V_{CE(sat)}$ BJT (continued)

Part Number	V_{CE} (V)	I_C DC (A)	I_C Peak (A)	Package	Typical $V_{CE(sat)}$ 1 A Beta 10	Typical h_{FE} @ 5 V, 100 mA	Status
NSS60601MZ4	60	6	12	SOT−223	80 mV	250	Released
NSS1C201L	100	2	4	SOT−23	100 mV	250	Released
NSS1C201MZ4	100	2	3	SOT−223	100 mV	250	Released
NSS1C301E	100	2	6	DPAK	45 mV	200	Released

Table 4. DUAL PNP/NPN/COMPLEMENTARY PORTFOLIO OF LOW $V_{CE(sat)}$ BJT

Part Number	Polarity	V_{CE} (V)	I_C DC (A)	I_C Peak (A)	Package	Typical $V_{CE(sat)}$ 1 A Beta 10	Typical h_{FE} @ 2 V, 1 A	Status
NSS40301MD	NPN	40	3	6	SOIC−8	44 mV	340	Released
NSS40300MD	PNP	40	3	6	SOIC−8	75 mV	300	Released
NSS40300DD	PNP	40	3	6	SOIC−8	75 mV	300	Released
NSS40302PD	NPN/PNP	40	3	6	SOIC−8	44/75 mV	340/300	Released