11.3 Power Transistors

The amplifying devices can be either MOSFETs or BJTs. The MOSFETs offer superior performances over the BJTs [3–5]. They require virtually zero input current, and they have faster switching times, no secondary breakdown, and stable gain and response time over a wide temperature range. The BJT current gain β_F can vary widely with temperature, and the variation of the MOSFET transconductance g_m with temperature is less than the variation of the BJT current gain β_F. As a result, power MOSFETs are replacing power BJTs in most applications.

There are no significant differences in the internal construction of small-signal and power BJTs. Although the mechanism of operation of power MOSFETs is same as that of small-signal MOSFETs, the power MOSFETs differ in their internal construction from the small-signal transistors in order to have more channel width for obtaining more current-carrying capability. To achieve a large channel width with good characteristics, power MOSFETs are fabricated with a repetitive pattern of small cells operating in parallel. The voltage ratings of power MOSFETs range from 50 V to 100 V, with current ratings from 10 A to 30 A.

There are two basic power MOSFET structures. The first is called a *DMOS* device, which uses a double-diffusion process; its cross section is shown in Fig. 11.2(a). It has two parallel current paths from the drain to the source. The *p*-substrate region is diffused deeper than the *n*+-source. The *n*-drift region must be moderately doped so that the drain breakdown voltage is sufficiently large and the thickness of the *n*-drift region is made as thin as possible to minimize drain resistance. The second structure, as shown in Fig. 11.2(b), uses a vertical channel known as a VMOS structure. In this case, the *p*-substrate diffusion is performed over the entire surface, and a V-shaped groove is then formed, extending through the *n*-drift region. For a high efficiency, on-resistance R_{on}, which should be low, can be found from

$$R_{DS(on)} = R_{SC} + R_{CH} + R_{DC} \tag{11.1}$$

where R_{SC} = source terminal contact resistance
R_{CH} = channel resistance
R_{DC} = drain terminal contact resistance

The values of the contact resistances R_{SC} and R_{DC} are proportional to the semiconductor resistivity. From Eq. (7.3), we can find the channel resistance R_{CH} in the linear region of operation as given by

$$R_{CH} = \frac{v_{DS}}{i_D} = \frac{L}{W\mu_n C_{ox}(v_{GS} - V_t)} \tag{11.2}$$

This explains why the channel length should be low and the width should be high to reduce on-resistance. An increase in the drain current increases the power loss and the junction temperature, which in turn increases the threshold voltage V_t and R_{CH}, thereby limiting the drain current.

For the sake of illustration of power amplifiers, we will show and analyze circuits using BJTs. The BJT analysis can be applied to MOSFET circuits by substituting $\beta_F = 0$ for the BJT current gain. Table 11.2 lists the circuit parameters for replacing a BJT by a MOSFET in a circuit.

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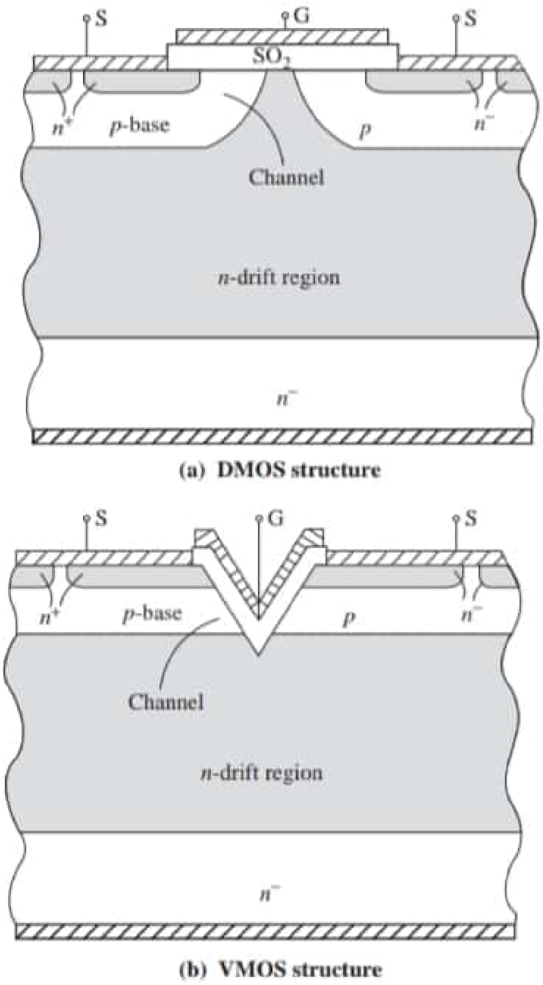
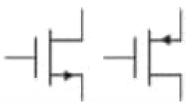
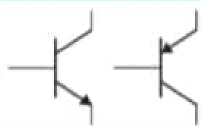
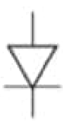
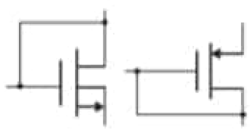
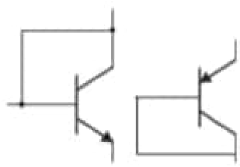


FIGURE 11.2 Cross section of a power MOSFET

TABLE 11.2 Circuit parameters of MOSFETs and BJTs

Circuit Parameters	MOSFETs	BJTs
		
Supply voltage	Power supply $\pm V_{DD}$	$\pm V_{CC}$
Output current	Drain current i_D	Collector current i_C
Driving voltage	Gate–source voltage v_{GS}	Base–emitter voltage v_{BE}
Input voltage	Gate voltage v_G	Base voltage v_B
Transistor input current	$i_G \simeq 0$	Base current i_B
Current ratio	$\frac{i_D}{i_G} \simeq \infty$	$\frac{i_C}{i_B} = \beta_F$
Diode-connected transistor 		

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