TABLE 14.8
Common-Base/Common-Gate Amplifier Summary

	C-B AMPLIFIER	C-G AMPLIFIER
Terminal voltage gain $A_{vt} = \frac{\mathbf{v_o}}{\mathbf{v_1}}$	$+g_m R_L$	$+g_m R_L$
Signal-source voltage gain $A_v = \frac{\mathbf{v_o}}{\mathbf{v_i}}$ $R_{th} = (R_I \| R_6)$	$\frac{g_m R_L}{1+g_m R_{th}}\left(\frac{R_6}{R_I+R_6}\right)$	$\frac{g_m R_L}{1+g_m R_{th}}\left(\frac{R_6}{R_I+R_6}\right)$
Input terminal resistance	$\frac{1}{g_m}$	$\frac{1}{g_m}$
Output terminal resistance	$r_o(1+g_m R_{th}) = r_o + \mu_f R_{th}$	$r_o(1+g_m R_{th}) = r_o + \mu_f R_{th}$
Input signal range	$0.005(1+g_m R_{th})$	$0.2(V_{GS}-V_{TN})(1+g_m R_{th})$
Terminal current gain	$\alpha_o \cong +1$	$+1$

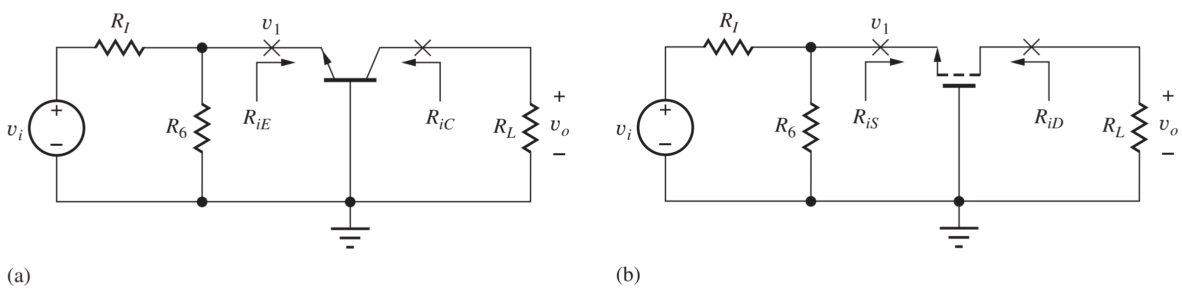

Figure 14.26 Circuits for use with summary Table 14.8; (a) common-base amplifier, (b) common-gate amplifier.

Both amplifiers can provide significant voltage gain, low input resistance, and high output resistance. The higher amplification factor of the BJT gives it an advantage in achieving high output resistance; the C-B amplifier can more easily reach very low levels of input resistance because of the BJT's higher transconductance for a given operating current. The FET amplifier can inherently handle larger signal levels.

14.5 AMPLIFIER PROTOTYPE REVIEW AND COMPARISON

Sections 14.1 to 14.4 compared the three individual classes of BJT and FET circuits: the C-E/C-S, C-C/C-D, and C-B/C-G amplifiers. In this section, we review these results and compare the three BJT and FET amplifier configurations.

14.5.1 THE BJT AMPLIFIERS

Table 14.9 collects the results of analysis of the three BJT amplifiers in Fig. 14.27; Table 14.10 gives approximate results.

A very interesting and important observation can be made from review of Table 14.9. If we assume the voltage loss across the source resistance is small, the signal-source gains of the three amplifiers have exactly the same form:

$$|A_v| \cong \frac{g_m R_L}{1+g_m R} \cong \frac{R_L}{\frac{1}{g_m}+R} \tag{14.91}$$

in which R is the external resistance in the emitter of the transistor (R_E, R_L, or $R_I \| R_6$, respectively). We really only need to commit one formula to memory to get a good estimate of amplifier gain!

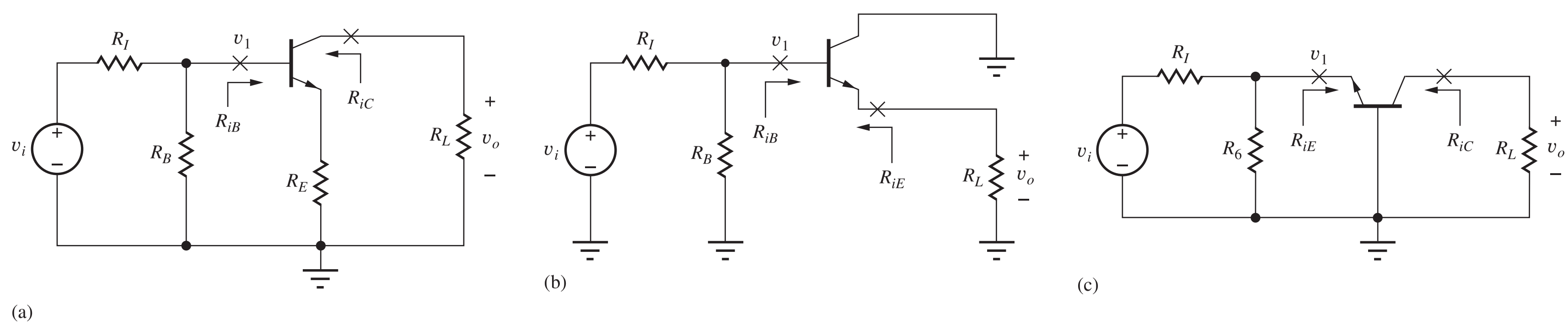

Figure 14.27 The three BJT amplifier configurations: (a) common-emitter amplifier, (b) common-collector amplifier, and (c) common-base amplifier.

TABLE 14.9
Single-Transistor Bipolar Amplifiers

	COMMON-EMITTER AMPLIFIER	COMMON-COLLECTOR AMPLIFIER	COMMON-BASE AMPLIFIER
Terminal voltage gain $A_{vt} = \dfrac{\mathbf{v_o}}{\mathbf{v_1}}$	$\cong -\dfrac{g_m R_L}{1 + g_m R_E}$	$\cong +\dfrac{g_m R_L}{1 + g_m R_L} \cong +1$	$+g_m R_L$
Signal-source voltage gain $A_v = \dfrac{\mathbf{v_o}}{\mathbf{v_i}}$	$-\dfrac{g_m R_L}{1 + g_m R_E}\left[\dfrac{R_B \| R_{iB}}{R_I + (R_B \| R_{iB})}\right]$	$+\dfrac{g_m R_L}{1 + g_m R_L}\left[\dfrac{R_B \| R_{iB}}{R_I + (R_B \| R_{iB})}\right] \cong +1$	$+\dfrac{g_m R_L}{1 + g_m (R_I \| R_6)}\left(\dfrac{R_6}{R_I + R_6}\right)$
Input terminal resistance	$r_\pi + (\beta_o + 1) R_E$ $\cong r_\pi (1 + g_m R_E)$	$r_\pi + (\beta_o + 1) R_L$ $\cong r_\pi (1 + g_m R_L)$	$\dfrac{\alpha_o}{g_m} \cong \dfrac{1}{g_m}$
Output terminal resistance	$r_o (1 + g_m R_E)$	$\dfrac{\alpha_o}{g_m} + \dfrac{R_{th}}{\beta_o + 1}$	$r_o[1 + g_m (R_I \| R_6)]$
Input signal range	$\cong 0.005(1 + g_m R_E)$	$\cong 0.005(1 + g_m R_L)$	$\cong 0.005[1 + g_m (R_I \| R_6)]$
Terminal current gain	$-\beta_o$	$\beta_o + 1$	$\alpha_o \cong +1$

TABLE 14.10
Simplified Characteristics of Single BJT Amplifiers

	COMMON-EMITTER ($R_E = 0$)	COMMON-EMITTER WITH EMITTER RESISTOR R_E	COMMON-COLLECTOR	COMMON-BASE
Terminal voltage gain $A_{vt} = \dfrac{\mathbf{v_o}}{\mathbf{v_1}}$	$-g_m R_L \cong -10V_{CC}$ (high)	$-\dfrac{R_L}{R_E}$ (moderate)	1 (low)	$+g_m R_L \cong +10V_{CC}$ (high)
Input terminal resistance	r_π (moderate)	$\beta_o R_E$ (high)	$\beta_o R_L$ (high)	$1/g_m$ (low)
Output terminal resistance	r_o (moderate)	$\mu_f R_E$ (high)	$1/g_m$ (low)	$\mu_f (R_I \| R_4)$ (high)
Current gain	$-\beta_o$ (moderate)	$-\beta_o$ (moderate)	$\beta_o + 1$ (moderate)	1 (low)

In addition, the same symmetry exists in the expressions for input signal range:

$$|v_{be}| \leq 0.005(1 + g_m R) \text{ V} \tag{14.92}$$

Note as well the similarity in the expressions for the input resistances of the C-E and C-C amplifiers, the input resistance of the C-B amplifier and the output resistance of the C-C amplifier, and the output resistances of the C-E and C-B amplifiers. Carefully review the three amplifier topologies in Fig. 14.27 to fully understand why these symmetries occur.

The second form of Eq. (14.91) deserves further discussion. The magnitude of the terminal gain of all three BJT stages can be expressed as the ratio of total resistance R_L at the collector to the total resistance R_{EQ} in the emitter loop! R_{EQ} is the sum of the external resistance R [i.e., R_E, R_L, or $(R_I \| R_6)$, as appropriate] plus the resistance $(1/g_m)$ found looking back into the emitter of the transistor itself. This is an extremely important conceptual result.

Table 14.10 is a simplified comparison. The common-emitter amplifier provides moderate-to-high levels of voltage gain, and moderate values of input resistance, output resistance, and current gain. The addition of emitter resistor R_E to the common-emitter circuit gives added design flexibility and allows a designer to trade reduced voltage gain for increased input resistance, output resistance, and input signal range. The common-collector amplifier provides low voltage gain, high input resistance, low output resistance, and moderate current gain. Finally, the common-base amplifier provides moderate to high voltage gain, low input resistance, high output resistance, and low current gain.

14.5.2 THE FET AMPLIFIERS

Tables 14.11 and 14.12 are similar summaries for the three FET amplifiers shown in Fig. 14.28. The signal source voltage gain and signal range of all three amplifiers can again be expressed approximately as

$$|A_v| \cong \frac{g_m R_L}{1 + g_m R} = \frac{R_L}{\dfrac{1}{g_m} + R} \tag{14.93}$$

and

$$|v_{gs}| \leq 0.2(V_{GS} - V_{TN})(1 + g_m R) \text{ V} \tag{14.94}$$

in which R is the resistance in the source of the transistor (R_S, R_L, or $(R_I \| R_6)$, respectively). Note the symmetry between the output resistances of the C-S and C-G amplifiers. Also, the input resistance of the C-G amplifier and output resistance of the C-D amplifier are identical. Review the three amplifier topologies in Fig. 14.28 carefully to fully understand why these symmetries occur. The addition of resistor R_S to the common-source circuit allows the designer to trade reduced voltage gain for increased output resistance and input signal range.

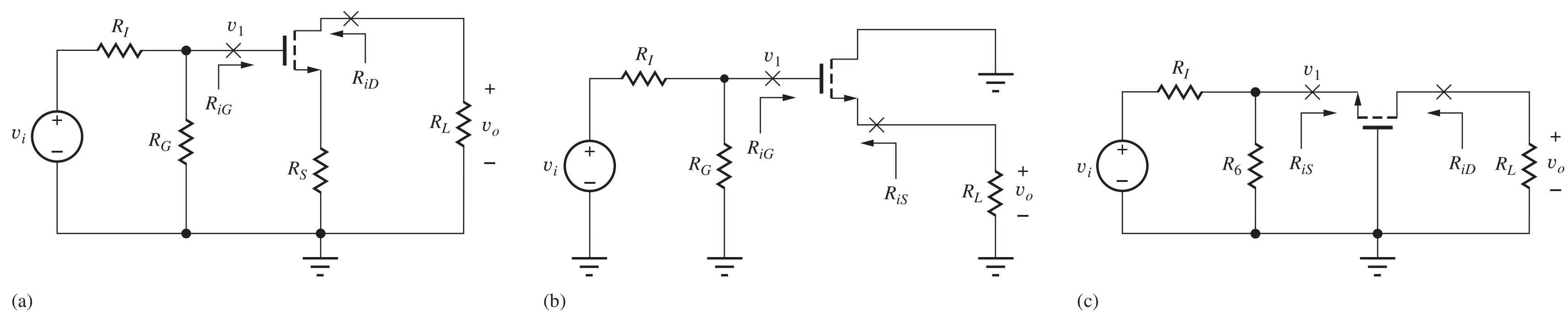

Figure 14.28 The three FET amplifier configurations: (a) common-source, (b) common-drain, and (c) common-gate.

TABLE 14.11
Single-Transistor FET Amplifiers

	COMMON-SOURCE AMPLIFIER	COMMON-DRAIN AMPLIFIER	COMMON-GATE AMPLIFIER
Terminal voltage gain $A_{vt} = \frac{\mathbf{v_o}}{\mathbf{v_1}}$	$-\frac{g_m R_L}{1 + g_m R_S}$	$+\frac{g_m R_L}{1 + g_m R_L} \cong +1$	$+g_m R_L$
Signal-source voltage gain $A_v = \frac{\mathbf{v_o}}{\mathbf{v_i}}$	$-\frac{g_m R_L}{1 + g_m R_S}\left(\frac{R_G}{R_I + R_G}\right)$	$+\frac{g_m R_L}{1 + g_m R_L}\left(\frac{R_G}{R_I + R_G}\right) \cong +1$	$+\frac{g_m R_L}{1 + g_m (R_I \| R_6)}\left(\frac{R_6}{R_I + R_6}\right)$
Input terminal resistance	∞	∞	$1/g_m$
Output terminal resistance	$r_o(1 + g_m R_S)$	$1/g_m$	$r_o[1 + g_m(R_I \| R_6)]$
Input signal range	$0.2(V_{GS} - V_{TN})(1 + g_m R_S)$	$0.2(V_{GS} - V_{TN})(1 + g_m R_L)$	$0.2(V_{GS} - V_{TN})[1 + g_m(R_I \| R_6)]$
Terminal current gain	∞	∞	$+1$