15.10 COMPUTER ANALYSIS

Program 15.1—Series-Fed Class A Amplifier

Using Design Center, the circuit of a series-fed class A amplifier is drawn as shown in Fig. 15.28. Figure 15.29 shows some of the analysis output. Edit the transistor model for values of only **BF** = 90 and **IS** = 2E-15. This keeps the transistor model more ideal so that PSpice calculations better match those below.
The dc bias of the collector voltage is shown to be

$$V_c(\text{dc}) = 12.47 \text{ V}$$

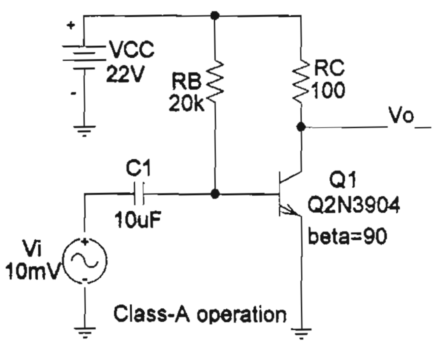

Figure 15.28 Series-fed class A amplifier.

```
Series-fed Class-A Amplifier

****   CIRCUIT DESCRIPTION
**************************************************

 ****   BJT MODEL PARAMETERS
         Q2N3904-X1
          NPN
       IS  2.000000E-15
       BF  90

****   SMALL SIGNAL BIAS SOLUTION
**************************************************
NODE  VOLTAGE                NODE  VOLTAGE             NODE  VOLTAGE
( VL)              12.4670   ($N_0001) 22.0000         ($N_0002)  0.0000
($N_0003)          .8146

   VOLTAGE SOURCE CURRENTS
   NAME          CURRENT
   V_Vi          0.000E+00
   V_VCC         -9.639E-02
   TOTAL POWER DISSIPATION  2.12E+00  WATTS

**** BIPOLAR JUNCTION TRANSISTORS
NAME           Q_Q1
MODEL          Q2N3904-X1
IB             1.06E-03
IC             9.53E-02
VBE            8.15E-01
VBC            -1.17E+01
VCE            1.25E+01
BETADC         9.00E+01
GM             3.69E+00
RPI            2.44E+01
RO             1.00E+12
BETAAC         9.00E+01
FT             5.87E+19
```

Figure 15.29 Analysis output for the circuit of Fig. 15.28.

With transistor beta set to 90, the ac gain is calculated as follows:

$$I_E = I_c = 95 \text{ mA (from analysis output of PSpice)}$$

$$r_e = 26 \text{ mV}/95 \text{ mA} = 0.27 \ \Omega$$

For a gain of

$$A_v = -R_c/r_e = -100/0.27 = -370$$

The output voltage is then

$$V_o = A_v V_i = (-370) \cdot 10 \text{ mV} = -3.7 \text{ V(peak)}$$

The output waveform obtained using **probe** is shown in Fig. 15.30.
For a peak-to-peak output of

$$V_o(\text{p-p}) = 15.6 \text{ V} - 8.75 \text{ V} = 6.85 \text{ V}$$

the peak output is

$$V_o(\text{p}) = 6.85 \text{ V}/2 = 3.4 \text{ V}$$

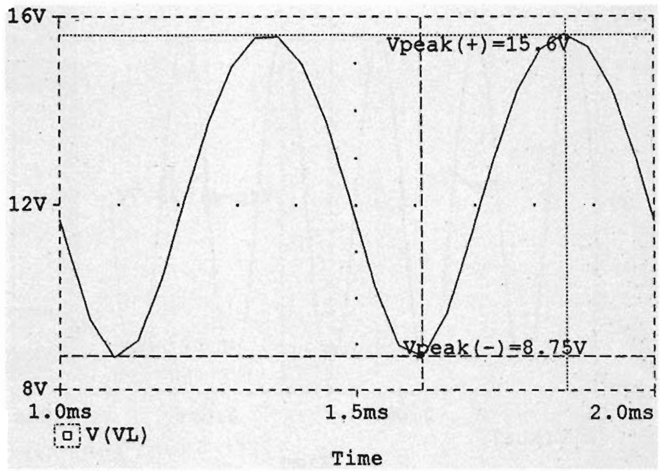

Figure 15.30 Probe output for the circuit of Fig. 15.28.

which compares well with that calculated above.

From the circuit output analysis, the input power is

$$P_i = V_{CC}I_C = (22\text{ V}) \cdot (95\text{ mA}) = 2.09\text{ W}$$

From the probe ac data, the output power is

$$P_o(\text{ac}) = V_o(\text{p-p})^2/[8 \cdot R_L] = (6.85)^2/[8 \cdot 100] = 58\text{ mW}$$

The efficiency is then

$$\%\eta = P_o/P_i \cdot 100\% = (58\text{ mW}/2.09\text{ W}) \cdot 100\% = 2.8\%$$

A larger input signal would increase the ac power delivered to the load and increase the efficiency (the maximum being 25%).

Program 15.2—Quasi-Complementary Push-Pull Amplifier

Figure 15.31 shows a quasi-complementary push-pull class B power amplifier. For the input of $V_i = 20\text{ V(p)}$, the output waveform obtained using **probe** is shown in Fig. 15.32.

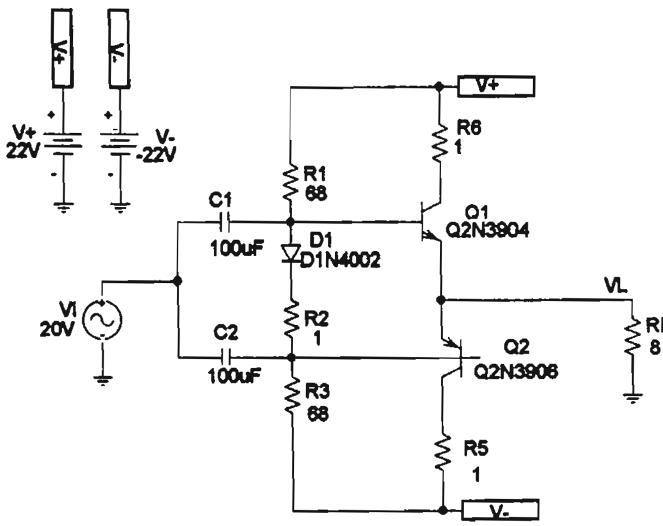

Figure 15.31 Quasi-complementary class B power amplifier.

P_L

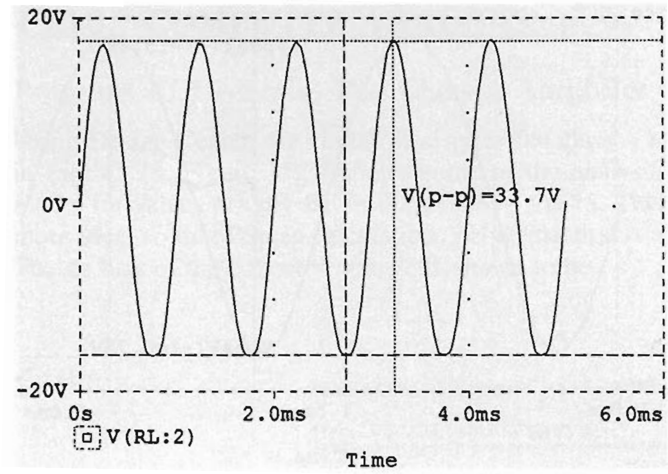

Figure 15.32 Probe output of the circuit in Fig. 15.31.

The resulting ac output voltage is seen to be

$$V_o(\text{p-p}) = 33.7 \text{ V}$$

so that

$$P_o = V_o^2(\text{p-p})/(8 \cdot R_L) = (33.7 \text{ V})^2/(8 \cdot 8 \,\Omega) = 17.7 \text{ W}$$

The input power for that amplitude signal is

$$P_i = V_{CC}I_{\text{dc}} = V_{CC}[(2/\pi)(V_o(\text{p-p})/2)/R_L]$$
$$= (22 \text{ V}) \cdot [(2/\pi)(33.7 \text{ V}/2)/8] = 29.5 \text{ W}$$

The circuit efficiency is then

$$\%\eta = P_o/P_i \cdot 100\% = (17.7 \text{ W}/29.5 \text{ W}) \cdot 100\% = 60\%$$

Program 15.3—Op-Amp Push-Pull Amplifier

Figure 15.33 shows an op-amp push-pull amplifier providing ac output to an 8-Ω load. As shown, the op-amp provides a gain of

$$A_v = -R_F/R_1 = -47 \text{ k}\Omega/18 \text{ k}\Omega = -2.6$$

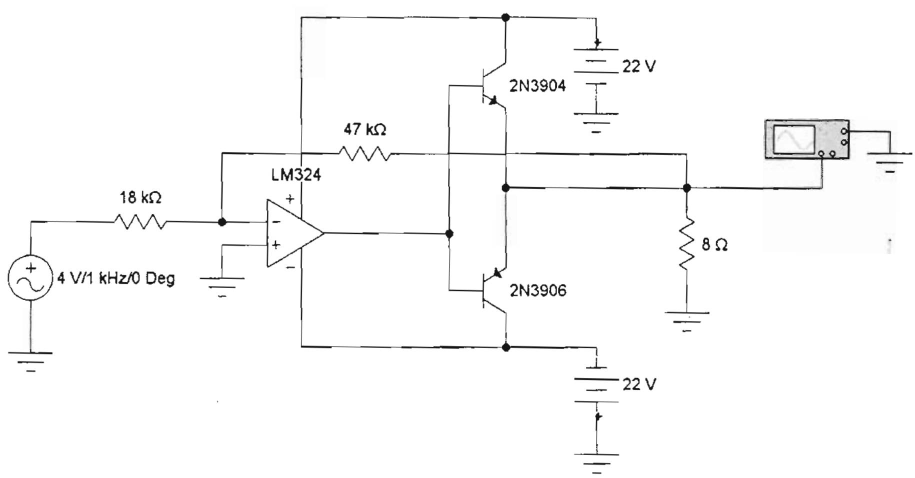

Figure 15.33 Op-amp class B amplifier.

P_L

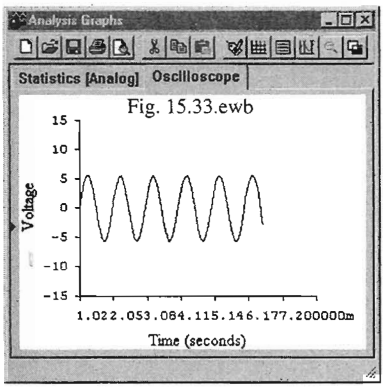

Figure 15.34 Probe output for the circuit of Fig. 15.33.

For the input, $V_i = 1$ V, the output is

$$V_o(\text{p}) = A_v V_i = -2.6 \cdot (1\ \text{V}) = -2.6\ \text{V}$$

Figure 15.34 shows the oscilloscope display of the output voltage.
The output power, input power, and circuit efficiency are then calculated to be

$$P_o = V_o^2(\text{p-p})/(8 \cdot R_L) = (20.4\ \text{V})^2/(8 \cdot 8\ \Omega) = 6.5\ \text{W}$$

The input power for that amplitude signal is

$$P_i = V_{CC} I_{\text{dc}} = V_{CC}[(2/\pi)(V_o(\text{p-p})/2)/R_L]$$
$$= (12\ \text{V}) \cdot [(2/\pi) \cdot (20.4\ \text{V}/2)/8] = 9.7\ \text{W}$$

The circuit efficiency is then

$$\%\eta = P_o/P_i \cdot 100\% = (6.5\ \text{W}/9.7\ \text{W}) \cdot 100\% = 67\%$$

MATHCAD

The calculations for the class B power amplifier of Example 15.7 and for the class B power amplifier of Example 15.12 are shown below. Using Mathcad, one can enter any desired value of **VCC, RL,** and **VL peak,** with all the calculations immediately providing the new results.

Class-B Power Amplifier (Example 15.7)

VCC := 30 RL := 16 VLpeak := 20

$ILpeak := \frac{VLpeak}{RL}$ ILpeak = 1.25

$Idc := 2 \cdot \frac{ILpeak}{3.14159}$ Idc = 0.796

$Pidc := VCC \cdot Idc$ Pidc = 23.873

$Poac := \frac{VLpeak^2}{(2 \cdot RL)}$ Poac = 12.5

$n := \left(\frac{Poac}{Pidc}\right) \cdot 100$ n = 52.36

Class-B Power Amplifier (Example 15.12)

VCC := 25 RL := 4

$maxPidc := \frac{\left(2 \cdot VCC^2\right)}{(3.14159) \cdot RL}$ maxPidc = 99.472

$maxPoac := \frac{\left(VCC^2\right)}{(2 \cdot RL)}$ maxPoac = 78.125

$n := \left(\frac{maxPoac}{maxPidc}\right) \cdot 100$ n = 78.54

$P2Q := maxPidc - maxPoac$ P2Q = 21.347

The harmonic distortion calculations of Examples 15.13 and 15.14 are shown for a select set of values for **A1** through **A4.**