SOLUTION The input impedance of the base is:

$$z_{in(base)} = \beta r_e = (200)(180\ \Omega) = 36\ k\Omega$$

The input impedance of the stage is:

$$z_{in(stage)} = 10\ k\Omega \parallel 2.2\ k\Omega \parallel 36\ k\Omega = 1.71\ k\Omega$$

The ac input voltage to the base is:

$$v_{in} = \frac{1.71\ k\Omega}{600\ \Omega + 1.71\ k\Omega}\ 50\ mV = 37\ mV$$

The voltage gain is:

$$A_V = \frac{r_c}{r_e} = \frac{2.65\ k\Omega}{180\ \Omega} = 14.7$$

The output voltage is:

$$v_{out} = (14.7)(37\ mV) = 544\ mV$$

PRACTICE PROBLEM 10-6 Using Fig. 10-8, change the β value to 300 and solve for the output voltage across the 10 kΩ load.

Example 10-7

Repeat the preceding example, but this time include r'_e in the calculations.

SOLUTION The input impedance of the base is:

$$z_{in(base)} = \beta(r_e + r'_e) = (200)(180\ \Omega + 22.7\ \Omega) = 40.5\ k\Omega$$

The input impedance of the stage is:

$$z_{in(stage)} = 10\ k\Omega \parallel 2.2\ k\Omega \parallel 40.5\ k\Omega = 1.72\ k\Omega$$

The ac input voltage to the base is:

$$v_{in} = \frac{1.72\ k\Omega}{600\ \Omega + 1.72\ k\Omega}\ 50\ mV = 37\ mV$$

The voltage gain is:

$$A_V = \frac{r_c}{r_e + r'_e} = \frac{2.65\ k\Omega}{180\ \Omega + 22.7\ \Omega} = 13.1$$

The output voltage is:

$$v_{out} = (13.1)(37\ mV) = 485\ mV$$

Comparing the results with and without r'_e in the calculations, we can see that it has little effect on the final answer. This is to be expected in a swamped amplifier. When you are troubleshooting, you can assume that the amplifier is swamped when a feedback resistor is used in the emitter. If you need more accuracy, you can include r'_e.

PRACTICE PROBLEM 10-7 Compare the calculated v_{out} value to the measured value using MultiSim.

Example 10-8

What is the output voltage in Fig. 10-9 if $\beta = 200$? Ignore r'_e in the calculations.

SOLUTION In Example 10-6, we calculated $z_{in(base)} = 36\ k\Omega$ and $z_{in(stage)} = 1.71\ k\Omega$. The first stage has these values because its circuit values are the same as those of Example 10-6. The ac input voltage to the first base is:

$$v_{in} = \frac{1.71\ k\Omega}{600\ \Omega + 1.71\ k\Omega}\ 1\ mV = 0.74\ mV$$

The input impedance of the second stage is the same as the first stage: $z_{in(stage)} = 1.71\ k\Omega$. Therefore, the ac collector resistance of the first stage is:

$$r_c = 3.6\ k\Omega \parallel 1.71\ k\Omega = 1.16\ k\Omega$$

and the voltage gain of the first stage is:

$$A_{V_1} = \frac{1.16\ k\Omega}{180\ \Omega} = 6.44$$

The amplified and inverted ac voltage at the first collector and the second base is:

$$v_c = (6.44)(0.74\ mV) = 4.77\ mV$$

The second stage has an ac collector resistance of 2.65 kΩ, calculated in Example 10-6. Therefore, it has a voltage gain of:

$$A_{V_2} = \frac{2.65\ k\Omega}{180\ \Omega} = 14.7$$

The final output voltage equals:

$$v_{out} = (14.7)(4.77\ mV) = 70\ mV$$

Another way to calculate the output voltage is to use the overall voltage gain:

$$A_V = (A_{V_1})(A_{V_2}) = (6.44)(14.7) = 95$$

Then:

$$v_{out} = A_V v_{in} = (95)(0.74\ mV) = 70\ mV$$

Figure 10-9 Two-stage amplifier example.