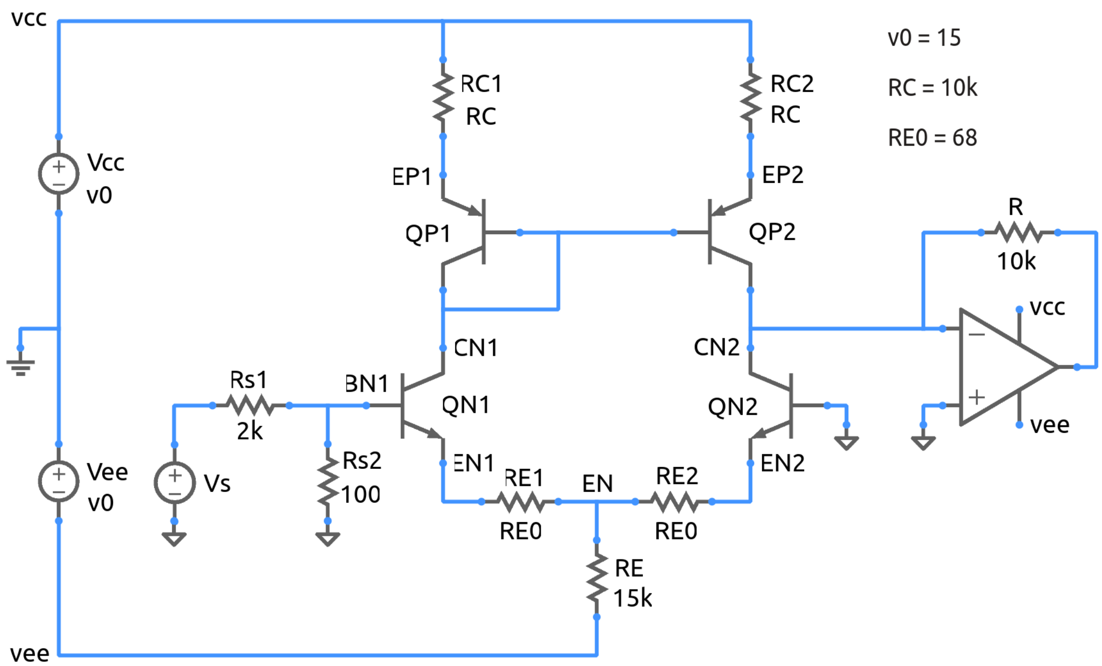
bjt_tri_to_sin.sqproj



(S. Franco, Design with Op Amps and Analog ICs)

Figure 1: BJT circuit to convert triangular wave to sine wave.

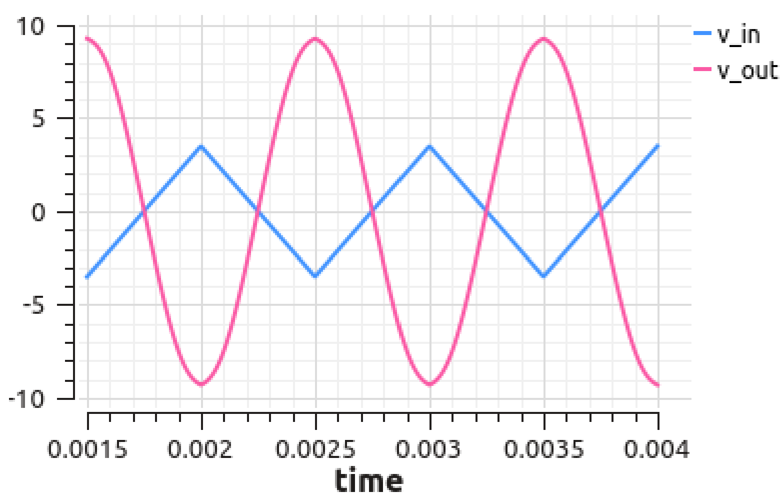


Figure 2: V_i and V_o versus time for the circuit of Fig. 1.

Shown in Fig. 1 is a wave shaper circuit which converts a triangular wave to a sine wave. In this circuit, the nonlinear nature of a BJT I_C-V_{BE} curve is used. If the input voltage is small

in magnitude, the circuit works as an amplifier. If the input is large, the output tends to saturate gradually, and this feature helps in converting a triangular wave to a sine wave.
Note that the BJT part of the circuit is a voltage-to-current (transconductance) amplifier, the output of the amplifier being the current entering the Op Amp circuit at node $CN2$. One of the input voltages V_{in}^2 (the base of Q_{N2}) of the transconductance amplifier is held constant at 0 V. When the other input V_{in}^1 (i.e., the base of Q_{N1}) is also 0 V, Q_{N1} and Q_{N2} carry the same current (say, I_0). The current through Q_{P1} is also I_0 since it is in series with Q_{N1}. Because of the mirror action of the Q_{P1}-Q_{P2} pair, the current through Q_{P2} is I_0 as well. No current flows through the Op Amp circuit, and the output voltage is 0 V.
Consider now the case that $V_{\text{in}}^1 = v_1$, where v_1 is a positive voltage. The current through Q_{N1} (and therefore the current through Q_{P1}) increases to $I_0 + i_1$, and that through Q_{N2} decreases to $I_0 - i_1$. Because of the mirror action of the Q_{P1}-Q_{P2} pair, the current through Q_{P2} also increases to $I_0 + i_1$. Applying KCL at node $CN2$, we find that the current going into the Op Amp circuit is $(I_0 + i_1) - (I_0 - i_1) = 2\,i_1$, producing an output voltage $V_{\text{out}} = -2\,i_1 R$. The key feature of this circuit is that i_1 is a nonlinear function of v_1, and that makes it possible to "distort" a triangular input voltage to a sinusoidal output voltage.

Exercise Set

1. Simulate the circuit. Plot V_{in} and V_{out} versus time, and verify that the circuit functions as a triangular-to-sine converter.

2. Plot the Fourier spectrum of V_{in} and V_{out} (using the second solve block).

3. Reduce the input voltage by a factor of 10 (or equivalently, reduce R_{S2} by a factor of 10), and simulate the circuit. Plot V_{in} and V_{out} versus time. Note that the circuit is now working as an amplifer.

4. Plot the currents I_{QN1} and I_{RC1} (together) versus time. Repeat for I_{QN2} and I_{RC2}. Explain your observations.

5. Plot V_{out} versus V_{in}, and observe the nonlinear nature of the transfer curve.

6. How will you change the output voltage magnitude without changing the spectrum?

References

1. S. Franco, *Design with Operation Amplifiers and Analog Integrated Circuits,* McGraw-Hill, 1998.