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Soft limiter for oscillator circuits uses emitter-degenerated differential pair

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Most oscillator circuits include a nonlinear amplitude control that sustains oscillations at a desired amplitude with minimum output distortion. One approach uses the output sinusoid's amplitude to control a circuit element's resistance, such as that of a JFET operating in its triode-characteristics region. Another control method uses a limiter circuit that allows oscillations to grow until their amplitude reaches the limiter's threshold level. When the limiter operates, the output's amplitude remains constant. To minimize nonlinear distortion and output clipping, the limiter should exhibit a "soft" characteristic.

Based on a waveform shaper that imposes a soft limitation or saturation characteristic, the circuit in **Figure 1** comprises a simple RC (resistor-capacitor)-ladder phase-shift oscillator and an amplitude-control limiter circuit. R_1, R_2, and R_3 have values of 10 kΩ each, and C_1, C_2, and C_3 have values of 1 nF each. The following **equation** defines output voltage V_{OUT}'s frequency, f_O.

$$f_O = \frac{\sqrt{6}}{2\pi RC} = \frac{\sqrt{6}}{2\times\pi\times 10\ k\Omega\times 1\ nF} \approx 39\ kHz.$$

The inverting-amplifier block in **Figure 1** comprises transistors Q_1 and Q_2, a differential pair that presents a nonlinear-transfer characteristic, plus an IVC (current-to-voltage converter) based on operational amplifier IC_1. For oscillation to occur, the inverting amplifier's gain magnitude must exceed 29. Selection of appropriate values of bias current, I_{EE}; the transistor pair's emitter-degeneration resistances, R_{E1} and R_{E2}; and R_{E3} produces the amplifier's nonlinear-transfer characteristic, V_{OUT} versus V_{IN} (**Figure 2**).

A small input voltage produces a nearly linear-amplifier-transfer characteristic. However, large values of input voltage drive Q_1 and Q_2 into their nonlinear region, reducing the amplifier's gain and introducing a gradual bend in the transfer characteristic. A current mirror comprising Q_3 and Q_4 converts the shaping circuit's output

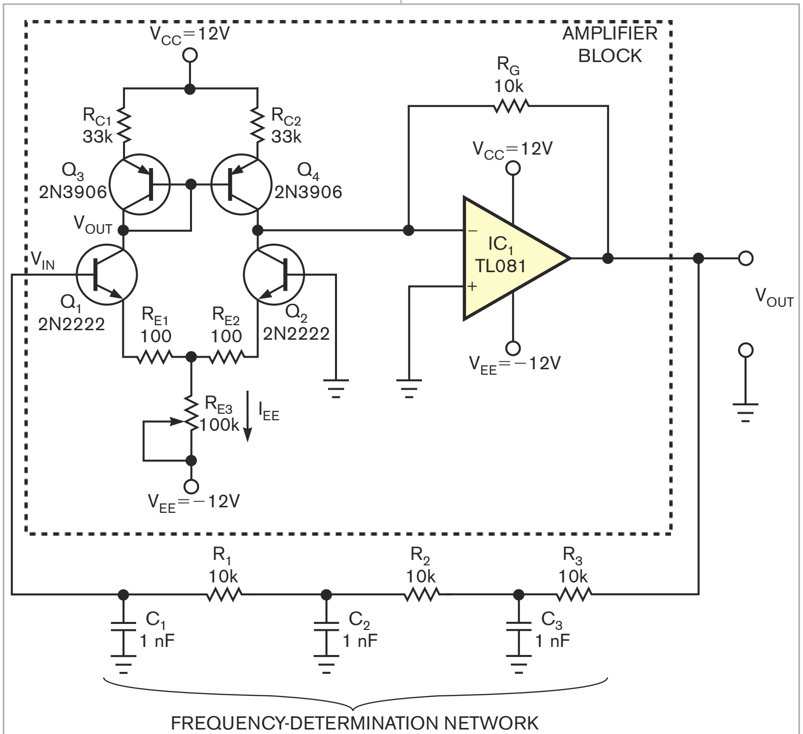

Figure 1 A phase-shift RC-oscillator circuit uses an emitter-coupled amplitude limiter.

to a single-ended current, which operational amplifier IC_1 converts to an output voltage. In the prototype circuit, calibration trimmer R_{E3} has a value of approximately 33 kΩ. **Figure 3** shows the oscillator's output voltage for the component values in **Figure 1**, and **Figure 4** shows the sinusoidal output's spectral purity.

The nonlinear amplifier's wave-shaping action occurs independently of frequency, and this circuit offers convenience for use with variable-frequency oscillators. Note that IC_1's gain-bandwidth product limits the circuit's performance. To use the limiter portion of the circuit with a noninverting amplifier, such as a Wien-bridge oscillator, apply the signal input voltage to Q_2's base, and ground Q_1's base. **EDN**

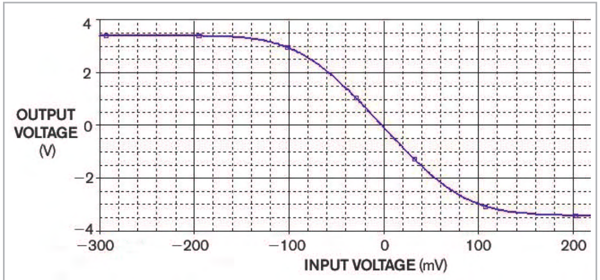

Figure 2 The transfer-characteristic output voltage versus input voltage for the nonlinear amplifier shows a gradual onset of limiting at approximately 100-mV input.

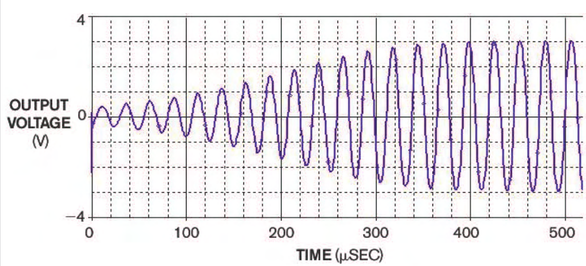

Figure 3 For the component values in Figure 1, the oscillator's output voltage reaches full amplitude in approximately 400 µsec, or 15 cycles after start-up.

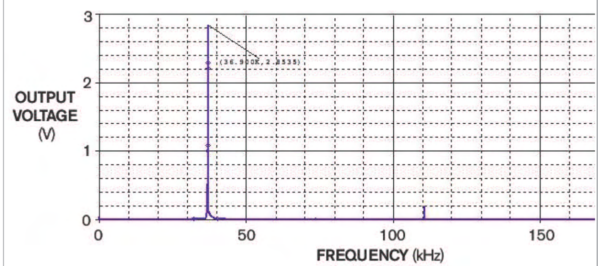

Figure 4 The oscillator's output spectrum shows only a slight amount of third-harmonic output.