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. R₁, R₂, and R₃ have values of 10 kΩ each, and C₁, C₂, and C₃ have values of 1 nF each. The following equation defines output voltage $V_{OUT}$'s frequency, $f_0$.

$$f_0 = \frac{\sqrt{E}}{2\pi RC} = \frac{\sqrt{E}}{2 \times \pi \times 10 \, \text{kΩ} \times 1 \, \text{nF}} \approx 39 \, \text{kHz}.$$

The inverting-amplifier block in Figure 1 comprises transistors Q₁ and Q₂, a differential pair that presents a nonlinear-transfer characteristic, plus an IVC (current-to-voltage converter) based on operational amplifier IC₁. 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 Q₁ and Q₂ into their nonlinear region, reducing the amplifier's gain and introducing a gradual bend in the transfer characteristic. A current mirror comprising Q₃ and Q₄ converts the shaping circuit's output to a single-ended current, which operational amplifier IC₁ 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 IC₁'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 Q₂'s base, and ground Q₁'s base.