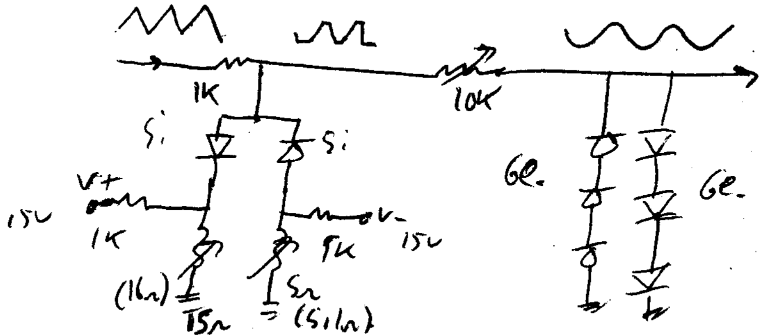
Triangle to sine wave shaper



From H.P 3311A Function

Gen

Canceling cusps on the peaks of shaped sine waves

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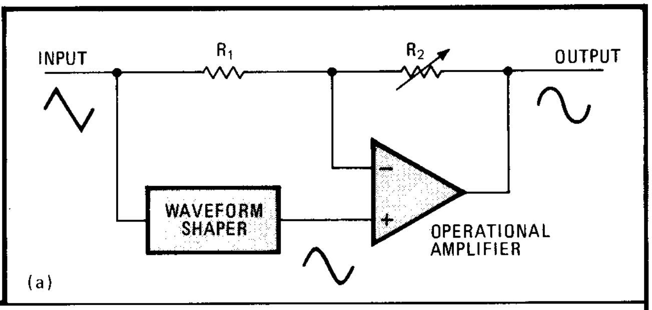
Most triangle-to-sine-wave converters employed in a function generator are incapable of reducing cusps on the output peaks, so that discontinuities occur in the derivative. This design (Fig. 1a) subtracts a portion of the triangular wave from a shaped sine wave. As a result, the slope at the wave's peak can be reduced to zero with negligible harmonic distortion. In addition, the design is insensitive to the occurrence of small changes in triangular-wave amplitude.

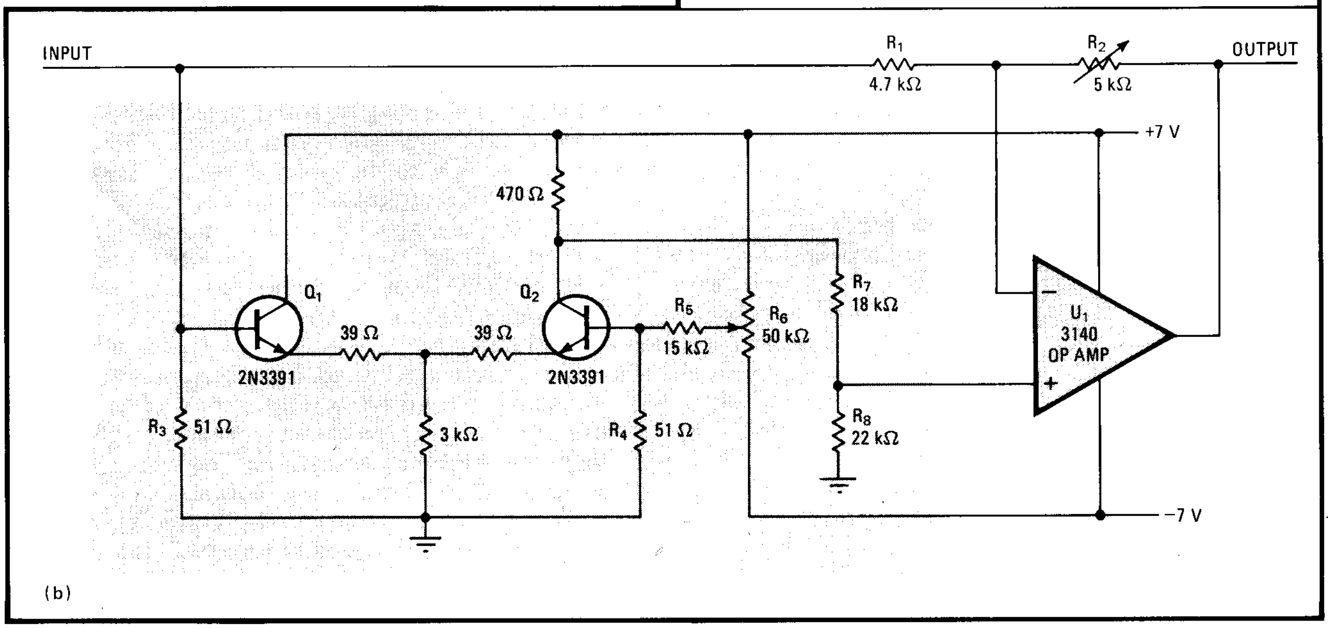
Results for three different wave shapers are shown in the table. Because the differential amplifier has the lowest distortion and highest bandwidth, it is presented as an example (Fig. 1b).

Operational amplifier U_1 subtracts the triangular-wave input from the shaped sine wave, and resistors R_1 and R_2 control the amount of negative feedforward. The differential amplifier, functioning as the shaper, consists of transistors Q_1 and Q_2. Any differences in transistor characteristics, which develop even-order harmonic distortion at the output, is adjusted with resistors R_4, R_5, and R_6. Finally, R_7 and R_8 feed the shaped signal to the noninverting input of U_1.

The circuit's performance has been measured with a spectrum analyzer. It suppresses odd harmonics by more than 52 decibels. □



Shaper. This negative feedforward scheme (a) subtracts traingular components from sine waves and cancels cusps of their peaks. The scheme is implemented with a differential amplifier (b). Op amp U_1 subtracts the triangular wave from the sine-wave output, thereby suppressing odd harmonics by more than 52 dB.



OPERATING CHARACTERISTICS OF THREE WAVEFORM SHAPERS				
Shaper	Triangular-wave input (V p-p)	Sine-wave output (V p-p)	Total harmonic distortion (%)	Frequency (kHz) at 2% THD
Four-diode type	3.45	2.400	0.7	150
Field-effect transistor	2.48	0.072	0.6	40
Differential amplifier	0.38	0.560	0.4	200

Resistor trimming optimizes generator's sine wave

Intersil's 8038 function generator produces a sine wave by shaping a triangle wave with a ladder network, two rungs of which are accessible. The potentials imposed on these pins (1 and 12) by external sources determine both waveform symmetry and distortion. But independent adjustment of those potentials to optimize the waveform, as proposed in the application notes, may be **very difficult in practice because both parameters are functions of both potentials,** says Pete Pomeroy of United Electronics Corp., South Africa. Instead of using potentials, Pomeroy proposes placing one potentiometer that varies from 60 to 100 kΩ between pin 12 and ground of the device to control symmetry and another that varies from 10 to 20 kΩ between pins 1 and 12 and ground to control distortion. Because of the low resistance values used in the ladder, the pots have little effect on the voltage distribution within, so that adjustments can be made more easily. Once the sine wave's symmetry is optimized with the first pot, it is a simple matter to reduce distortion by a factor of two or three with the second pot. No retrimming is necessary.

Synthesizing sine waves from triangles

The next time you must synthesize a sine wave, remember that a clipped triangular waveform can approximate a sine wave with fairly low total harmonic distortion, says Mike Callahan, who's with Mostek Corp., Carrollton, Texas. Sometimes it's easier to go the triangular route, he points out, rather than fuss with tuned LC or RC circuits, especially if you do not really require less than 1% distortion. A pure triangle wave has 11% total harmonic distortion, which can be cut to about 6% by hard-clipping the waveform so that its peaks are truncated. However, soft-clipping it (merely rounding the peaks a bit) **produces an even better approximation, with distortion down to around 3.5%**—which is good enough for many general-purpose testing requirements.

basic organ tone generator. In this circuit, *R1*, *R2*, and *C1* form a low-pass filter, while *C2*, *C3*, and *R3* are a high-pass filter. Since the phase shifts of these two networks are opposite, the only frequency at which the device can oscillate is where the total phase shift across the two networks is 180°. It is at this frequency that oscillation takes place. The best results occur when *C1* is about twice the capacitance of *C2* and *C3* (which have the same value) and *R3* is about one tenth the value of *R1* and *R2* (which also have the same value). The circuit is trimmed by *R3*, and the output is taken from across *C1*, where the harmonic distortion is lowest. The output of this circuit must be coupled through a high-impedance buffer to prevent loading. The transistor must have a high beta.

Synthetic Sine Waves. The synthetic sine-wave approach is used in some expensive laboratory types of generators. The theory is to create a number of small straight-line segments joined together so that the result looks like a sine wave—but with a number of tiny steps in it. The wave is thus like the top of a picket fence whose tips have been cut to resemble a sine wave. Obviously, the more segments, the better the approximation to the desired waveform.

The circuit in Fig. 2 illustrates the use of 12 diodes and associated resistors to synthesize a sine wave from a triangle wave to within 0.25% rms error. Why a triangle wave? Because this is an easy waveform to produce with op amps—which are now being used extensively in test equipment.

The 12 diodes are arranged in pairs and connected to a bias network as shown. The input triangle waveform is applied to the common junction of each pair. The network consisting of *R1A* through *R7A* biases the upper row of diodes (with respect to the reference output) in a voltage progression that represents the *positive* peaks of each

Fig. 2. This diode circuit synthesizes a sine wave from a triangle wave. The bias arrangement determines at which point in the triangle each of the diodes comes in.