CMOS function generator

Using only one inexpensive CMOS IC and a handful of discrete components, it is possible to build a versatile function generator that will provide a choice of three waveforms over the entire audio spectrum and beyond.

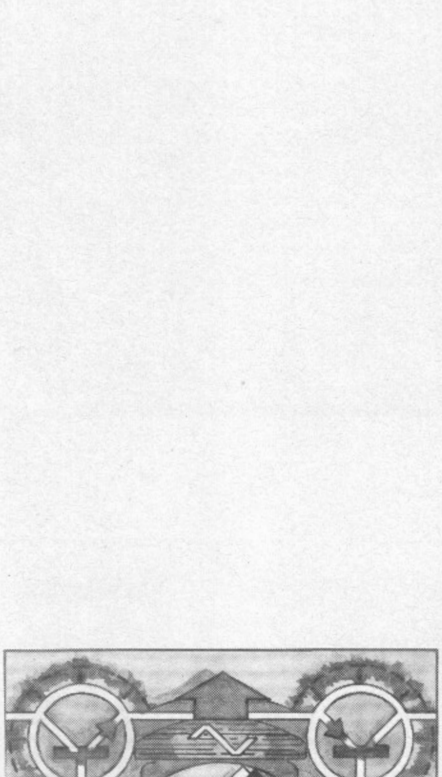
The aim of this project was to produce a simple, cost-effective, general purpose audio generator, which was easy to build and use. This aim has certainly been achieved, since the circuit offers a choice of sine, square and triangle waveforms and a frequency range from about 12 Hz to 70 kHz, yet uses only one CMOS hex inverter IC and a few discrete components. Of course, the design does not offer the performance of more sophisticated circuits, particularly as regards waveform quality at higher frequencies, but it is nonetheless an extremely useful instrument for audio work.

Block diagram

Figure 1 illustrates the operating principles of the circuit. The heart of the generator is a triangle/squarewave generator consisting of an integrator and a Schmitt trigger. When the output of the Schmitt trigger is high, the voltage fed back from the Schmitt output to the input of the integrator causes the integrator output to ramp negative until it reaches the lower trigger threshold of the Schmitt trigger. At this point the output of the Schmitt trigger goes low, and the low voltage fed back to the integrator input causes it to ramp positive until the upper trigger threshold of the Schmitt trigger is reached. The output of the Schmitt trigger again goes high, and the integrator output ramps negative again, and so on. The positive- and negative-going sweeps of the integrator output make up a triangular waveform, whose amplitude is determined by the hysteresis of the Schmitt trigger (i.e. the difference between the upper and lower trigger thresholds). The output of the Schmitt trigger is, of course a square wave consisting of alternate high and low output states.

The triangle output is fed through a buffer amplifier to a diode shaper, which 'rounds off' the peaks and troughs of the triangle to produce an approximation to a sinewave signal.

Any one of the three waveforms may then be selected by a three-position switch and fed to an output buffer amplifier. The frequency of all three signals is varied by altering the integrator time constant, which changes the rate at which the integrator ramps, and hence the signal frequency.



Complete circuit

The practical circuit of the CMOS function generator is given in figure 2. The integrator is based on a CMOS inverter, N1, whilst the Schmitt trigger uses two inverters with positive feedback, N2 and N3.

The circuit functions as follows; assuming, for the moment, that the wiper of P2 is at its lowest position, when the output of N3 is high a current

$$\frac{U_b - U_t}{P_1 + R_1}$$

flows through R1 and P1, where U_b is the supply voltage and U_t is the threshold voltage of N1. Since this current cannot flow into the high impedance input of the inverter, it all flows into C1 or C2 (depending on which is selected by S1).

The voltage drop across C1 thus increases linearly, so the output voltage of N1 falls linearly until the lower threshold voltage of the Schmitt trigger is reached, when the output of the Schmitt trigger goes low. A current

$$\frac{-U_t}{P_1 + R_1}$$

now flows through R1 and P1. This current also flows into C1, so the output voltage of N1 rises linearly until the upper threshold voltage of the Schmitt trigger is reached, when the output of the Schmitt trigger goes high and the whole cycle repeats.

To ensure symmetry of the triangle waveform (i.e. the same slope on both positive-going and negative-going portions of the waveform) the charge and discharge currents of the capacitor must be equal, which means that $U_b - U_t$ must equal U_t. Unfortunately U_t is determined by the characteristics of the CMOS inverter and is typically 55% of supply voltage, so $U_b - U_t$ is about 2.7 V with a 6 V supply and U_t is about 3.3 V.

This difficulty is overcome by means of P2, which allows symmetry adjustment. Assume for the moment that R4 is con-

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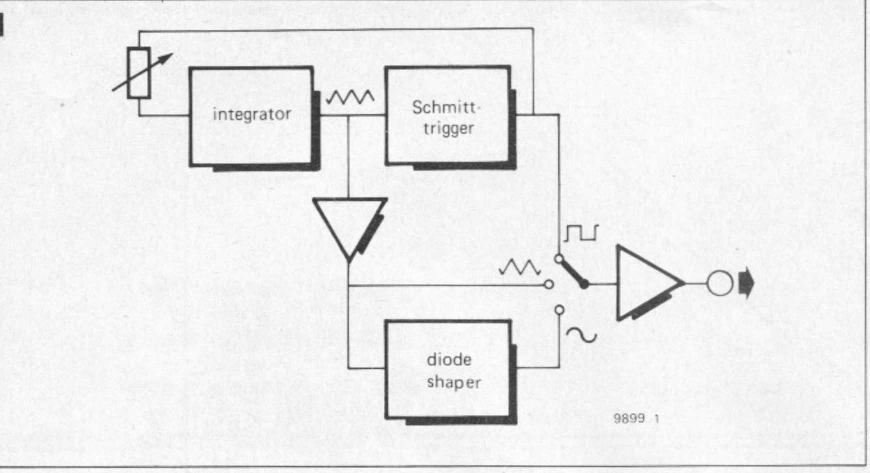

Figure 1. Block diagram of the CMOS function generator.

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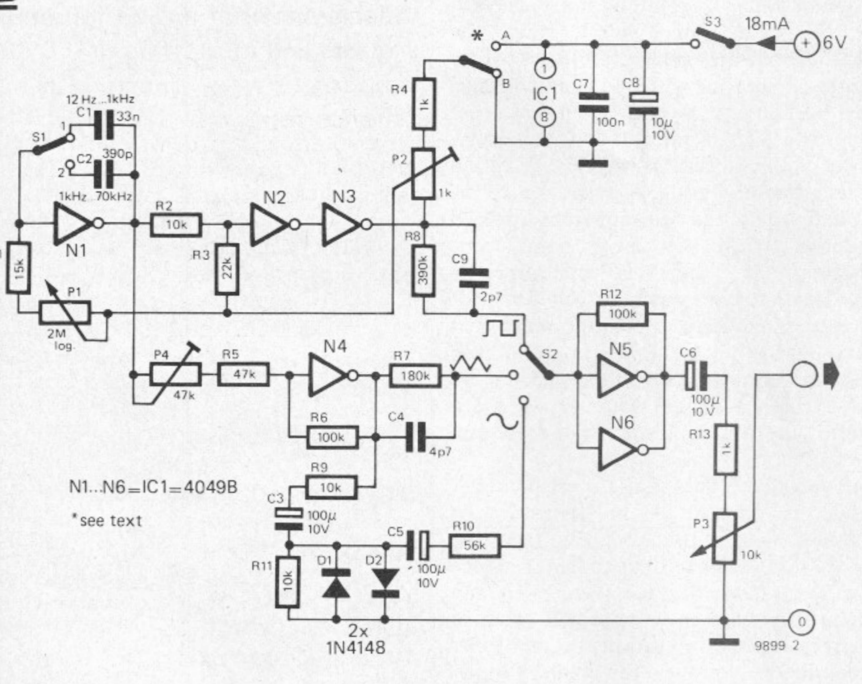

Figure 2. Complete circuit of the function generator.

Photos. The three output waveforms produced by the function generator.

nected to the positive supply rail (position A). Whatever the setting of P2, the high output voltage of the Schmitt trigger is always U_b. However, when the output of N3 is low, R4 and P2 form a potential divider so that a voltage from 0 V to 3 V can be fed back to P1, depending on the wiper setting of P2. This means that the voltage across R1 and P1 is no longer $-U_t$ but $U_{P_2} - U_t$. If the slider voltage of P2 is about 0.6 V then $U_{P_2} - U_t$ will be around −2.7 V, so the charge and discharge currents will be the same. Of course, the adjustment of P2 must be carried out to suit each individual function generator, owing to the tolerance in the value of U_t. In cases where U_t is less than 50% of the supply voltage, it will be necessary to connect the top of R4 to ground (position B).

Two frequency ranges are provided, which are selected by means of S1; 12 Hz-1 kHz and 1 kHz to about 70 kHz. Fine frequency control is provided by P1 which varies the charge and discharge current of C1 or C2 and hence the rate at which the integrator ramps up and down.

The squarewave output from N3 is

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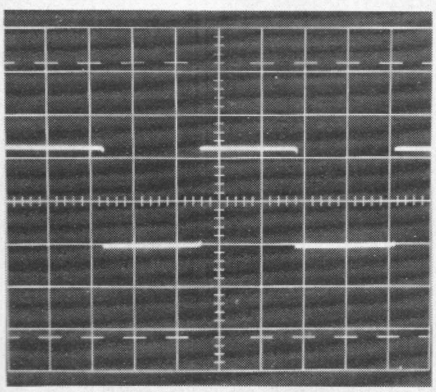
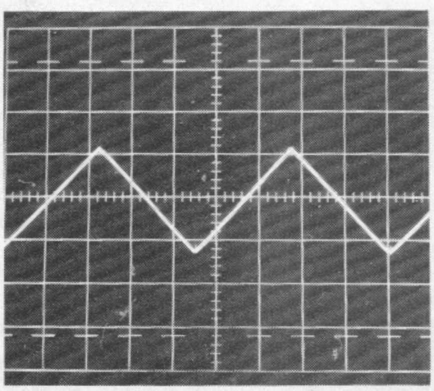


3b



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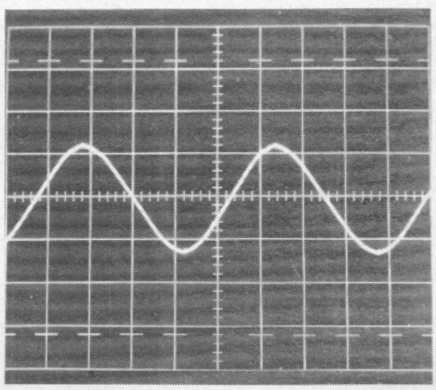

taken via a waveform selector switch, S2, to a buffer amplifier, which consists of two inverters (connected in parallel to boost their output current capability) biased as a linear amplifier. The triangle output is taken through a buffer amplifier N4, and thence through the selector switch to the output buffer amplifier.

The triangle output from N4 is also taken to the sine shaper, which consists of R9, R11, C3, D1 and D2. Up to about plus or minus 0.5 volts D1 and D2 draw little current, but above this voltage their dynamic resistance falls and they limit the peaks and troughs of the triangle signal logarithmically to produce an approximation to a sine wave. The sine output is fed via C5 and R10 to the output amplifier.

Sine purity is adjusted by P4, which varies the gain of N4 and thus the amplitude of the triangle signal fed to the sine shaper. Too low a signal level, and the triangle amplitude will be below the diode threshold voltage, so that it will pass without alteration; too high a signal level, and the peaks and troughs will be clipped severely, thus not giving a good sine wave.

The input resistors to the output buffer amplifier are chosen so that all three waveforms have a peak to peak output voltage of about 1.2 V maximum. The output level can be adjusted by P3.

Adjustment procedure

The adjustment procedure consists simply of adjusting the triangle symmetry and sine purity. Triangle symmetry is actually best adjusted by observing the squarewave signal, since a symmetrical triangle is obtained when the squarewave duty-cycle is 50% (1-1 mark-space ratio). P2 is adjusted to achieve this. In cases where the symmetry improves as the wiper of P2 is turned down towards the output of N3 but exact symmetry cannot be obtained, the top of R4 should be connected in the alternative position.

Sine purity is adjusted by varying P4 until the waveform 'looks right' or by adjusting for minimum distortion if a distortion meter is available. Since the supply voltage alters the output voltage of the various waveforms, and hence the sine purity, the circuit should be operated from a stable 6 V supply. If batteries are used they should never be allowed to run down too far.

CMOS ICs used as linear circuits draw more current than when used in the normal switching mode, and the supply voltage should not be greater than 6 V, otherwise the IC may overheat due to excessive power dissipation.

Performance

The quality of the waveforms can be judged from the oscilloscope photographs. In all three cases the vertical sensitivity is 500 mV/div and the timebase speed 200 μs/div. ◄

zener tester

This simple tester provides a reliable means of measuring zener voltages and of plotting the variation of zener voltage with zener current.

In many cases the breakdown voltage of a zener diode is printed, fairly clearly, on the case. For example, the type number of the zener family is often printed, together with the zener voltage, so a BZY88 6V8 would be a 6.8 V zener from the BZY88 family. Unfortunately, some manufacturers merely print an indecipherable code, which has to be looked up in the relevant data book in order to find the zener parameters. Furthermore, there is sometimes a requirement for testing 'job lots' of unmarked devices, or components that have been lying in the junkbox and have had their markings rubbed off. In all these cases a zener tester can prove a useful addition to the 'lab' test equipment.

The reverse characteristic of a zener diode is illustrated in figure 1. At voltages below the zener voltage the device draws very little current. Once the breakdown voltage is reached any further increase in voltage will produce a large increase in current, i.e. above its breakdown voltage the zener diode behaves as a more or less constant voltage device. However, since the zener diode possesses a finite internal resistance (known as the dynamic resistance), the zener voltage will vary slightly with current, due to the voltage dropped across this internal resistance. Because of this, manufacturers always quote zener voltage at a certain current (usually between 5 and 10 mA).

It is, of course, possible to test a zener diode using a battery, series resistor and a multimeter to measure the zener voltage. However, the current flowing through the zener will be determined by the value of the resistor and the difference between the battery voltage and the zener voltage, and will obviously be less for high-voltage zeners than for low-voltage zeners. This can lead to errors in the measurement.

The zener tester described in this article feeds a known, constant current through the zener. Furthermore, a choice of seven different zener currents is provided, which allows the zener voltage to be plotted against current.

The circuit of the zener tester, which contains only nine components, is given in figure 2. T1 and T2 function