

constant amplitude squarewave to sawtooth converter

Most electronic organs use octave dividers, which produce a symmetrical squarewave output. The harmonic content of this waveform is then altered by filtering to give the required organ voices. However, a symmetrical squarewave contains only the odd harmonics of the fundamental frequency, and those voices requiring even harmonics cannot be realistically imitated, since no amount of filtering can add harmonics which are absent. For this reason a sawtooth waveform, which contains both odd and even harmonics, is preferred as the 'raw material' for many organ voices.

A sawtooth waveform can be obtained from a squarewave as illustrated in figure 1. A capacitor is allowed to charge, either from a voltage source in series with a resistor or from a constant current source. The positive-going edge of the squarewave is used momentarily to close a (electronic) switch, which rapidly discharges the capacitor. This charging and instantaneous discharging of the capacitor produces the familiar sawtooth waveform.

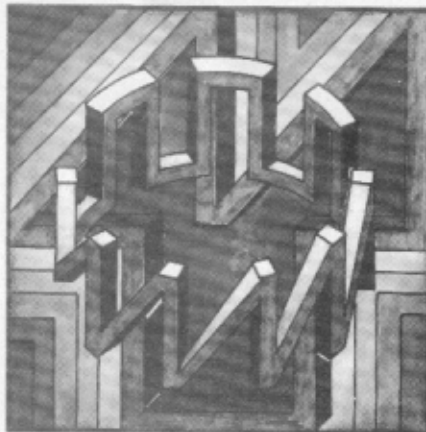
Figure 2 illustrates the differences in the spectra of the square and sawtooth waveforms. If the capacitor is charged from a voltage source then a sawtooth with an exponential curvature results, the spectrum of which is shown in figure 1b. If a constant current source is used then the sawtooth is linear, and has the spectrum shown in figure 1c.

For musical purposes an exponential sawtooth is preferred.

The disadvantage of this simple method is that the amplitude of the sawtooth waveform falls as the frequency on the input squarewave is increased, since the capacitor has less time to charge. This means that a different capacitor or charging resistor value would have to be used for each note of the organ to maintain equal amplitude over the entire compass of the instrument.

This problem can be overcome by arranging that the voltage of the source from which the capacitor is charged automatically increases as the frequency increases. This increases the charging current, which causes the capacitor to charge more rapidly and thus maintains a constant amplitude. A practical,

Most electronic organs use squarewaves as the basic signal from which all the organ voices are obtained by filtering, simply because squarewaves are easy to generate and process. However, from a musical point of view, the sawtooth is a much more useful waveform, since it contains both odd and even harmonics of the fundamental frequency, whereas the squarewave contains only the odd harmonics. The main problems involved in generating sawtooth waveforms for organ circuits have been those of cost and reproducibility. However, the circuit described here, for which a patent is pending, suffers from none of these drawbacks and could, in principle, be integrated into a microcircuit.



constant amplitude, squarewave-to-sawtooth converter is shown in figure 3. Capacitor C3 is charged via R4 from the voltage U_2 , present on C4. The leading (positive-going) edge of the input squarewave is differentiated by C2 and R2, producing a short pulse which briefly turns on T1 to discharge C3.

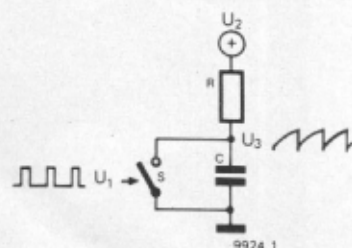
The trailing edge of the squarewave is differentiated by C1 and R1, producing a short pulse which briefly turns on T2 and charges C4 via R3. Since T2 is turned on for a fixed time, as the input frequency increases T2 will be turned on for a greater proportion of the total time, so that C4 will charge to a higher voltage. This causes the charging current into C3 to increase, thus compensating for the fact that C3 charges for a shorter time as the frequency increases.

The circuit given in figure 3 will produce a sawtooth of constant amplitude over the frequency range 60 Hz to 10 kHz.

A slight disadvantage of this circuit is that the shape of the sawtooth (and hence the harmonic content) alters as the frequency changes. This is no great drawback from a musical point of view. However, in some applications a linear sawtooth is preferred, and this can be achieved by replacing R4 with a current mirror (T3, T4) as shown in figure 4. This circuit is also equipped with a FET-source-follower, T5, which acts as buffer between C3 and the output and allows low impedance loads to be driven without degrading the sawtooth linearity.

The performance of this circuit is better

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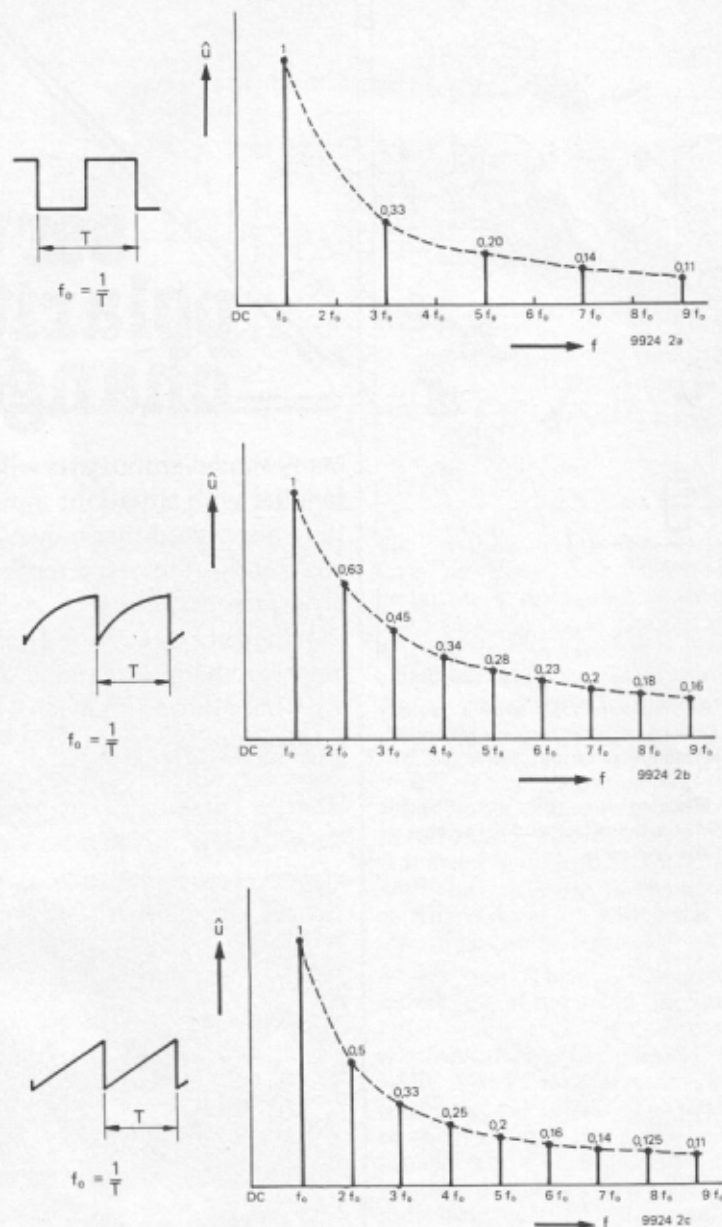


Figure 1. A sawtooth can be generated by charging a capacitor through a resistor and rapidly discharging it at regular intervals.

Figure 2. Comparison of the spectra of square, exponential sawtooth and linear sawtooth waveforms.

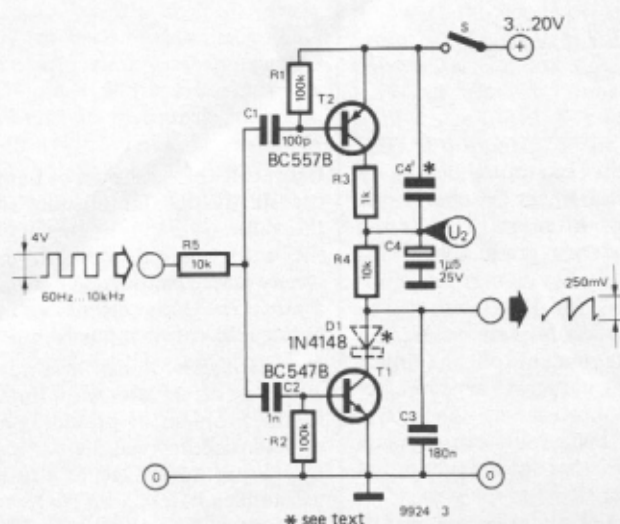
Figure 3. Circuit for converting a squarewave to a constant amplitude exponential sawtooth.

than that of the simpler circuit in that it will produce a constant amplitude sawtooth over the frequency range 10 Hz to 20 kHz.

The sawtooth output may be switched on and off by a switch at the input or output of the circuit, or by a switch in the supply line. This latter method is particularly useful if several sawtooth converters are in use, since it allows them all to be controlled by a single switch. However, if switching of the supply line is employed then D1 must be included to prevent the squarewave signal from breaking through the base-collector junction of T1 when the supply is switched off.

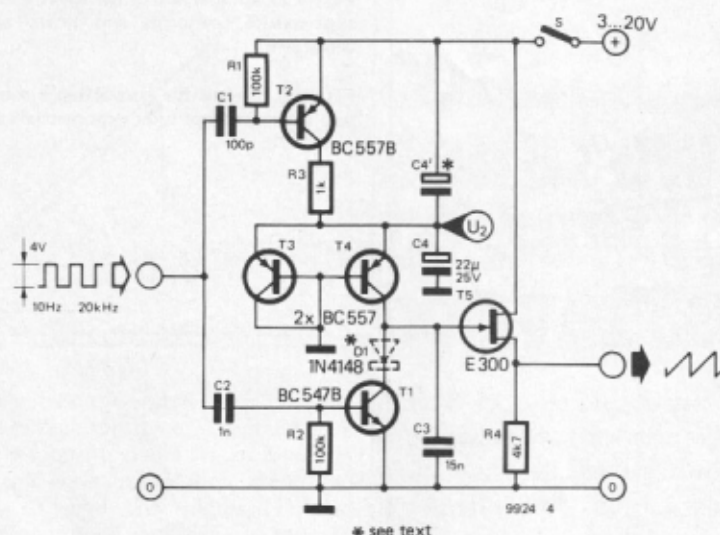
C4' can also be included to ensure that the sawtooth has a finite initial amplitude at switch-on. The amplitude depends on the value of C4', which should be no more than 4.7 μ maximum. Figure 5 shows the effect of different values of C4'. If C4' is omitted then the

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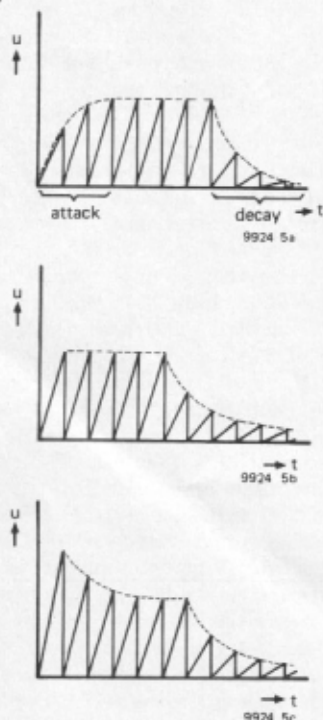


Figure 4. By replacing R4 with a current mirror a linear sawtooth may be generated. This circuit also has an output buffer, T5.

Figure 5. Showing the effect of different values of C4' on the attack and decay characteristics of the sawtooth.

amplitude of the sawtooth builds up slowly after switch-on as C4 charges via T2 (figure 5a). After switch-off the sawtooth will decay gradually as C4 discharges.

The times taken for the sawtooth to build up to its steady-state value and to decay are dependent on the input frequency, being longest at low frequencies and shortest at high frequencies. This behaviour corresponds quite closely to that of conventional musical instruments.

If C4' is included then the sawtooth signal will assume a finite amplitude immediately after switch-on. In

figure 5b this is shown as being equal to the steady-state amplitude. However, if the value of C4' is made very large then the initial amplitude will exceed the steady-state amplitude, as shown in figure 5c. This effect will be more noticeable at low input frequencies.

In conclusion, it can be said that these circuits offer an economic solution to the problem of providing a sawtooth signal in squarewave divider instruments. By taking advantage of the high input resistances offered by MOS technology it should be possible to make the capacitor values sufficiently small to allow total integration of the circuit. ■

servo polarity changer

Many model enthusiasts will be familiar with situations in which they discovered that moving a servo control in one direction prompted the model to steer in the opposite direction! The circuit described here is intended to offer a simple solution to just this problem.

