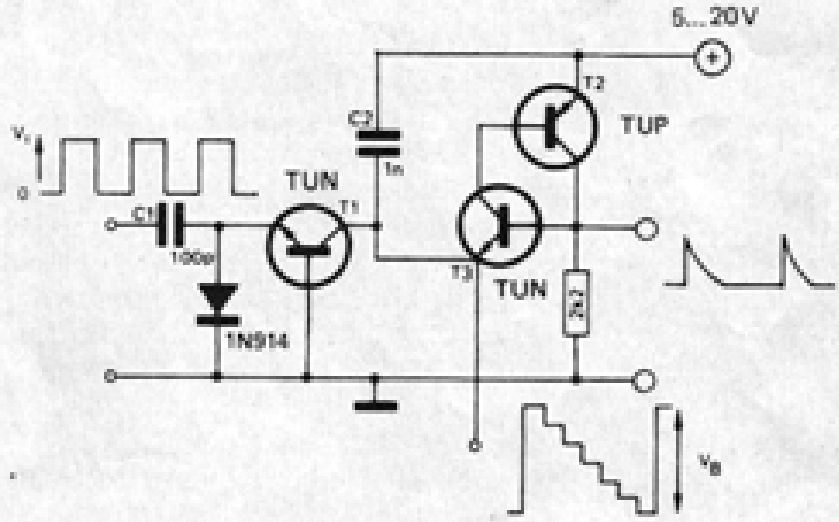
staircase generator

F. Hebinck



A convenient way of generating a good 'staircase waveform' is to use a diode-transistor pump driven by a square wave as shown in figure 1.

Before the square wave is applied to the input, capacitor C2 is uncharged. Consequently, there is no voltage across it and transistor T3 is cut off because its emitter is at +10 V.

During the first positive going pulse, the diode conducts and capacitor C1 is charged to just under the peak value of the waveform (peak value minus the voltage across the diode). Because the diode prevents the emitter of T1 rising much above ground potential, the negative-going pulse drives the emitter negative by an amount equal to the peak value of the waveform less the voltage across the diode. Therefore T1 conducts and the voltage on its collector falls sharply. In other words, C1 is discharged and C2 is charged by an almost equal amount. (The difference is caused by the base current of T1.)

If C1 and C2 are equal, the voltage change across C1 will equal the change across C2 plus twice the drop across the diode. However, if C2 is much larger than C1, the change across it will be much smaller.

Capacitor C1 is charged again during the next positive-going pulse. As T1 and T3 are not conducting, the charge on C2 cannot leak away and the voltage at T3 emitter remains constant. During the next positive-going pulse, more charge flows from C2 to C1 and the voltage on T3 emitter falls sharply again.

This process is repeated with the voltage on T3 emitter falling in a staircase pattern until it is negative. Transistor T3 then conducts, and positive feedback from T2 to T3 produces an avalanche effect that rapidly discharges C2. When C2 is discharged, the whole cycle starts again from the top of the staircase.

An approximate formula for the number of steps (n) is

$$n = \frac{C_2}{C_1} \times \frac{V_s}{V_w - 2\,V_d}$$

where V_s = supply voltage
V_w = peak value of the square wave
V_d = voltage across the diode

Therefore, if C1 is 100 pF and C2 390 pF and the diode voltage 550 mV, the number of steps produced by the circuit in figure 1 is

$$n = \frac{390 \times 10}{100(5 - 1.1)} = 10.$$

The staircase waveform generator can be used in many applications, such as a D/A convertor, frequency divider, driver for a transistor curve tracer, as well as to produce special sound effects and so on.