Relaxation Oscillators

What they are and how they work

Basic Electronics

by GERALD COHN

A great many pieces of electronic equipment employ an oscillator of one type or another. The different types include crystal oscillators, LC (or tuned) oscillators such as the Hartley and Colpitts, Schmitt trigger oscillators, as well as the type discussed here, the relaxation oscillator.

The relaxation oscillator is one of the simplest types comprising only three components. Perhaps the first relaxation oscillator to be developed used the neon lamp as the active device.

A neon lamp or discharge tube has a glass envelope with two leads which is filled with the rare inert gas, neon. When a high voltage is applied to the tube, the gas ionises and gives a characteristic red glow as the "discharge" current flows. While neon lamps are now only used as indicators on equipment, they once had more important applications such as the relaxation oscillator used in an oscilloscope timebase.

Special neon discharge tubes were also used as voltage regulators, at typically 150V.

The circuit of Fig. 1 shows the relaxation oscillator based on the neon lamp. Here the capacitor C, is charged via resistor R. The neon lamp is connected across the capacitor.

When the voltage across the capacitor reaches the firing voltage of the neon lamp, the lamp will light and the capacitor will discharge to a value where the lamp extinguishes. Now the capacitor will once again start to charge repeating the whole cycle again. This cycle will continue for as long as power is applied to the circuit. So the circuit oscillates and so the neon blinks on and off.

The frequency of oscillation of the circuit is dependent on three factors — the values of the charging resistor, the capacitor and the supply voltage. Increasing the value of the charging resistor or increasing the value of the capacitor will reduce the frequency of oscillation, while increasing the value of the supply voltage will tend to increase the frequency of oscillation.

If the supply voltage is too high we find that the current through the resistor is enough to maintain conduction in the neon lamp thereby preventing the circuit from operating as an oscillator.

The voltage waveform shown in Fig. 3a shows the charging and discharging of the capacitor. In the case shown, the neon fires at about 95V and extinguishes below 70V.

Fig. 2 shows why the neon lamp can function as an oscillator device. Below the firing voltage, a neon lamp can be regarded as a very high resistance, which is represented by the section of the curve below the firing point. Then, at the firing point, the neon suddenly breaks down to what can be regarded as a "negative resistance" which is indicated by a region of the curve where increasing current across the lamp results in reduced voltage across it.

This negative resistance region of the neon characteristic has a negative slope while a normal resistor (shown by the straight line on Fig. 2) has a positive slope.

Readers with access to a variable high voltage power supply can demonstrate this negative resistance characteristic of the neon, if they so wish. Just connect the neon in series with the high voltage (say 100 to 200V, variable) via a 1M resistor. Now raise the voltage until the neon just fires and measure the voltage across the neon. Now increase the voltage marginally, say by 10V, to increase the neon current. A new measurement across the neon will show that the voltage across it has reduced slightly, rather than increased. Eventually, a point will be reached where increasing the neon current will again cause an increase in voltage, which would mean that the neon had moved out of the negative resistance region.

So the criterion for oscillation, which is met by the neon, is a negative

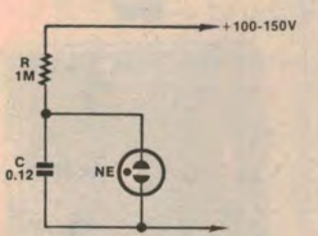


FIG. 1

Fig. 2 shows the negative resistance characteristic of the neon lamp while Fig. 3a shows the voltage waveform across the capacitor in the neon circuit of Fig. 1. Fig. 3b shows the voltage across the capacitor in the diac circuit of Fig. 4.

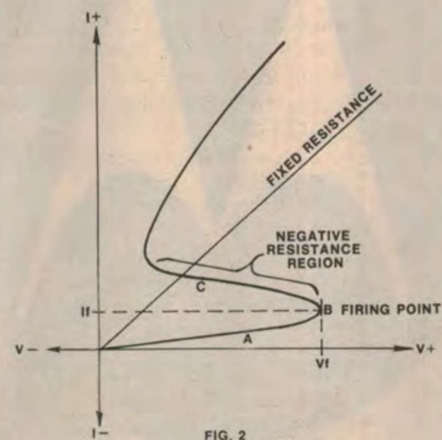


FIG. 2

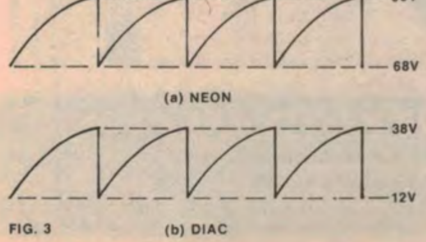


FIG. 3

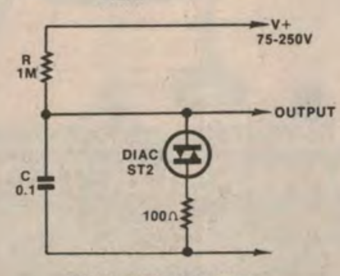


FIG. 4 : DIAC OSCILLATOR

resistance characteristic beyond its breakdown or firing point. The negative resistance allows the neon to discharge the capacitor and then extinguish, allowing the capacitor to charge up again, and so on. Relating this to the Fig. 2, the capacitor first charges along the curve from A to B, where the neon fires and discharges the capacitor along the curve from B to C. At C, the neon extinguishes and reverts to its high resistance state at A, allowing the cycle to begin again.

We should point out that Fig. 2 only represents the positive region of the neon characteristic. As the neon is a bipolar device, it will work just as well in the same circuit with a negative voltage applied.

Another device which has a negative resistance characteristic and which can be used in a relaxation oscillator is the Diac. This is a three-layer solid state device which is normally used to trigger SCRs and Triacs. Like the neon, the Diac has a high resistance state up to its "breakover" or firing voltage which may be anywhere from 27 to 40V, positive or negative.

When the Diac fires, it breaks down to a negative resistance. The Diac can be used with the same components as the neon and will operate over a wider input voltage range. Just to be on the safe side we have added a 100 ohm resistor in series with the Diac, for protection. Fig. 4 shows the Diac circuit, while Fig. 3(b) shows the oscillator waveform.

Yet another device which has a negative resistance characteristic and which can be used in a relaxation oscillator is the unijunction transistor or UJT, for short. This is a three terminal device which, unlike the normal bipolar transistor, has only one junction. In some ways, it is rather like a diode with two cathode connections, marked B1 and B2. The other connection is known as the emitter.

The UJT is commonly used in timing circuits and as a trigger current generator for SCRs and Triacs. A typical circuit using a UJT is shown in Fig. 6. When power is applied, the capacitor is charged towards the positive rail via the 10k resistor.

When the capacitor voltage reaches the so-called "peak point" voltage of the UJT, Vp, the emitter-base-1 path of the UJT becomes a negative resistance and discharges the capacitor to deliver a voltage pulse at base-1. When the capacitor has discharged the emitter-base-1 path reverts to its high resistance path and the capacitor is able to recharge again, continuing the cycle.

The resulting waveforms at the emitter and base-1 of the UJT are shown in Fig. 6. We should also mention that, coincident with the positive voltage pulse at base-1, the UJT also delivers a weak negative going pulse at base-2 which can be useful in some circuit applications.

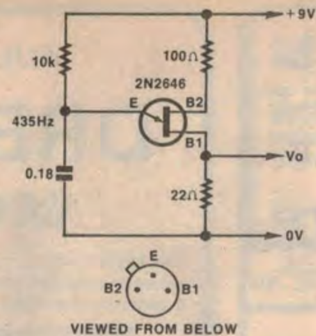


FIG. 5 : UJT OSCILLATOR

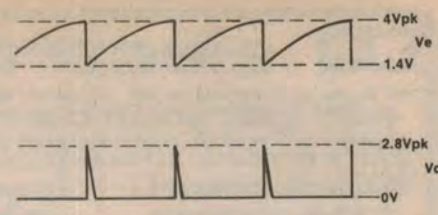


FIG. 6

The upper waveform of Fig. 6 shows the voltage across the capacitor in the UJT circuit while the lower shows the output obtained from B1 of the UJT.

The UJT parameter of particular interest is the "intrinsic standoff ratio". This parameter is the ratio of the "peak point" voltage of the UJT minus 0.6V, to the voltage applied between base-2 and base-1. Typical unijunctions have an intrinsic standoff ratio of from 0.47 to 0.8. To explain this further, if a UJT has an intrinsic standoff ratio of 0.5 and an interbase voltage of 10V, then the "peak point" voltage is 5.6V.

The problem with the UJT intrinsic standoff ratio is that the circuit designer has to accept the tolerance spread and relatively poor temperature stability of this parameter. Recognising this, the General Electric Company of the USA developed a new device which is called a "programmable unijunction transistor" or PUT, for short. This device has the advantage of being able to substitute for the UJT but the "intrinsic standoff ratio" or Vp, can be programmed by selecting two resistors. In addition, the PUT has generally improved parameters over the UJT.

Actually, the PUT is a silicon controlled-rectifier, SCR, with an anode gate rather than the cathode gate of conventional SCRs. An SCR remains in the non-conducting state until triggered into conduction by a signal of low voltage and current into the gate. In the case of the PUT (or anode-gate SCR) the gate voltage must be 0.6V below the anode for the device to break into conduction.

To put it another way, the anode of the PUT must rise 0.6V above the gate voltage, for the device to conduct. When the PUT is used as a UJT, the gate voltage is fixed by selection of a pair of resistors (hence the reference to "programming") and the anode must rise above the gate voltage for conduction to begin. The PUT version of the UJT oscillator is shown in Fig. 7. This is simplified in normal practice, to the circuit of Fig. 8.

All of the components used in the circuits described here should be available from your local parts supplier.

For those readers wishing to learn more about UJTs, PUTs, Diacs, SCRs and their application, we refer you to the General Electric SCR Manual, (see review in the December 1979 issue) which is available from technical bookshops and some parts suppliers.

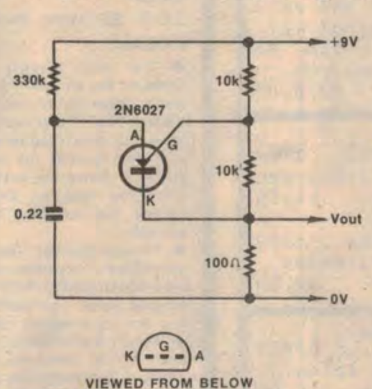


FIG. 7 : PUT OSCILLATOR

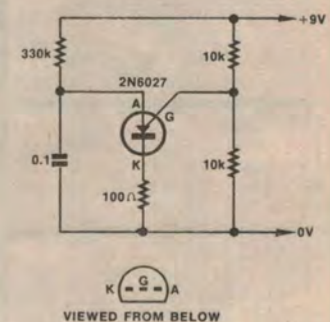
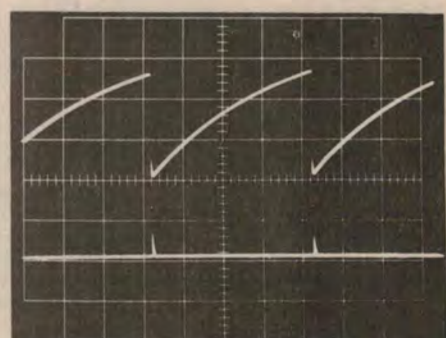


FIG. 8



The photograph shows the waveforms obtained from the UJT circuit of Fig. 5. Note that these are similar to those of Fig. 6. The CRO settings for these waveforms were: 0.5ms/cm and 2V/cm.