

## Experiment # 10

### UJT and SCR RELAXATION and SINUSOIDAL OSCILLATORS

#### INTRODUCTION:

Though the unijunction transistor (UJT) and the silicon-controlled rectifier (SCR) are commonly used in power control circuits, they can also be advantageously employed in designing simple relaxation (nonsinusoidal) and sinusoidal oscillators using a minimum parts count for a discrete oscillator circuit. Such designs are particularly useful in telephone tone-generator applications, where multiple-sine-wave audio signals are needed for simulating touch-tone frequencies.

#### Proposed Circuits:

Consider the circuit shown in Fig. 1. Initially the UJT is off and  $V_{BB}$  begins charging C through R. When  $V_o$  exceeds  $V_p$  as determined by equation (1), the UJT fires very quickly discharging C down to its “on” or saturated value,  $V_{EB(sat)}$ , where it stays until the emitter current  $I_E$  drops below the holding, or “valley” current  $I_V$ . Provided the current then flowing through resistor R is less than the valley current  $I_V$  for the UJT, it then switches back to its high impedance state and the process repeats.

$$V_p \cong 0.6V + hV_{BB} \quad (1)$$

The requirement that after C has discharged, the emitter current must be less than  $I_V$  if the UJT is to switch back to its high impedance state, places a lower limit on the allowable value of R. Assuming that C is discharged down to  $V_E = V_{EB(sat)}$ , then

$$V_{BB} - I_V R = V_{EB(sat)} \quad (2)$$

or

$$R_{\min} = \frac{V_{BB} - V_{EB(sat)}}{I_V} \quad (3)$$

Since the discharge time is usually negligible, the period of the above oscillation is given by

$$T = -RC * \ln \left( \frac{V_{BB} - V_p}{V_{BB} - V_{EB(sat)}} \right) \quad (4)$$

As an example, consider the design of a saw-tooth generator using the 2N4948 UJT with the parameters:

$$R_{BB} = 12k\Omega \text{ max, } h = 0.82 \text{ max, } V_{EB(sat)} = 3.0V \text{ max, } I_v = 4.0mA \text{ min}$$

The minimum voltage to which the capacitor will charge is given by

$$V_p \approx -0.6 + hV_{BB}$$

With  $V_{BB}=15V$ , then  $V_P=12.9V$

The minimum value to which the capacitor should discharge is given by  $V_{EB1(sat)} = 3.0V$ . Thus the amplitude of the output waveform should be

$$V_o = V_P - V_{EB1(sat)} = 12.9 - 3 = 9.9V$$

The period of the waveform is given by

$$T = -RC * \ln \frac{V_{BB} - V_P}{V_{BB} - V_{EB1(sat)}}$$

or

$$T = -10k\Omega * 0.1mF * \ln \frac{15V - 12V}{15V - 3V} = 1.64 msec$$

It is obvious from this last equation that the smaller R is, the smaller T will be, or the higher the frequency will be. Its minimum value is determined by

$$R_{min} = (V_{BB} - V_{EB1(sat)}) / I_v$$

or

$$R_{min} = \frac{15V - V}{4mA} = 3k\Omega$$

A slight modification in the circuit of Fig. 1 results in the circuit of fig. 2 with  $R_1$  and  $R_2$  added to provide a take-off for the output voltages. Usually, these resistances are of the order of few tens of Ohms and are much smaller than  $R_{BB}$ . This will not affect the analysis performed above. Typical output waveforms of the circuit of Fig. 2 are shown in Fig. 3.

By utilizing the current pulses flowing between  $B_2$  and  $B_1$  and modifying the circuit as shown in Fig. 4 a sinusoidal output can be obtained. In fact the current pulse contains a large amount of harmonics. If the tuned circuit is tuned at one of them, then sinusoidal output will be obtained. With adjustments to resistor R (shown as  $X\Omega$  for this example), the current pulses can be controlled so that relatively undistorted sine wave is available at  $B_2$ .

Alternatively, a sinusoidal oscillation can be obtained from a UJT by exploiting its negative resistance to advantage. As you know oscillations can not build up in physical LC circuits unless an external source continuously supply energy to compensate for the losses in the internal resistances of physical elements. To help maintain oscillation we have to cancel-out the effect of these internal resistances. Obviously, this requires a negative resistance. Negative resistances are not physically available. However, we can obtain them using devices exhibiting negative-resistance performance in part of their characteristics; for example the UJT. Fig. 5 shows such a circuit in which the UJT negative resistance is used to cancel-out the physical resistances of the coil. The potentiometer sets the peak point of the emitter and should be adjusted for maximum output consistent with a good sine wave. The output is output 200 mV and the circuit operates from 1 kHz to 500 kHz by using suitable values for L and C.

SCRs also can be used for generating oscillations. Consider the circuit shown in Fig. 6. The voltage across the SCR rises until there is sufficient gate current to switch it on. Note that the capacitor will charge from the 15 V supply via the resistor 47 K. The anode resistor is selected so that when the SCR conducts, the current through the SCR will drop below the minimum hold current and thus the SCR will switch off. Note that when the SCR conducts the capacitor will start discharging via the low resistance of the conducting SCR. Eventually the voltage across the SCR will drop to the minimum hold voltage. When this happens the 47 K resistor will ensure that the current through the SCR is less than the hold current. That is

$$\frac{15 - V_{holdmin}}{47 K} < I_{holdmin}$$

Once the SCR switched off, a new cycle will start.

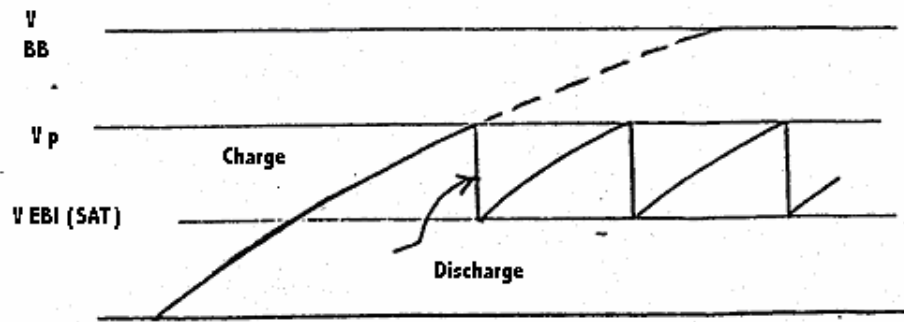
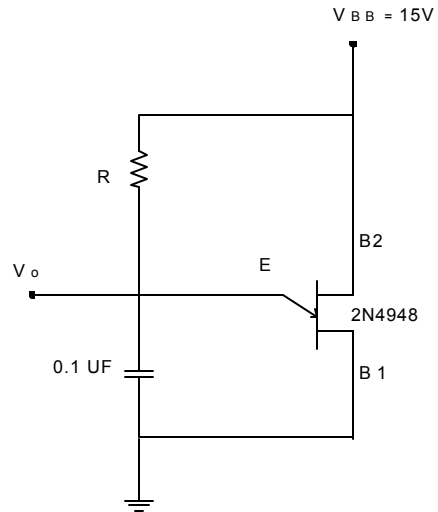
**Supply voltage and temperature are critical and not every SCR will oscillate.**

Alternatively, an improved performance can be obtained by including an inductor, such as a speaker coil, as shown in Fig. 1. The improvement here is achieved because the back e.m.f. of the inductor helps to switch off the SCR. The components in this circuit are not critical and the circuit can work satisfactorily over a wide range of DC supply voltages. Frequencies of oscillation from 100Hz to 10 kHz can be easily obtained.

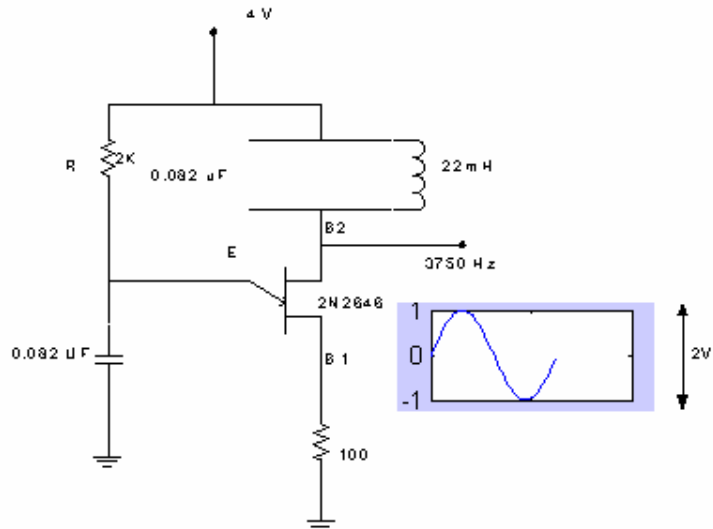
### **EXPERIMENTAL WORK:**

In the laboratory you will construct the circuits of Figs. 1-7, check their proper operation by checking the waveforms at different points in the circuit. Also check the controllability of the frequency of oscillation and the waveshapes obtainable.

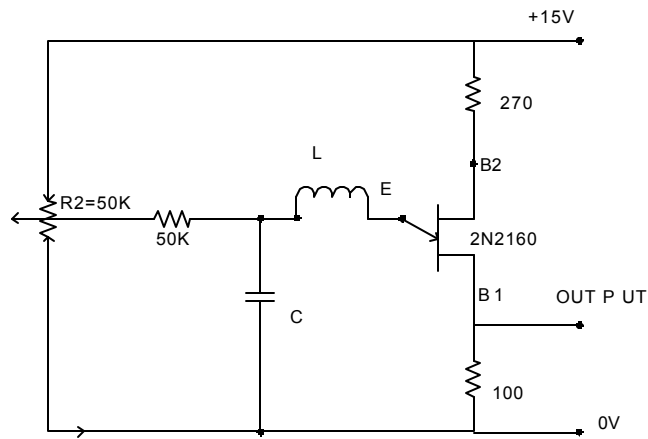
You may like to design your own oscillator. We encourage this. Please do check your own designs during the laboratory hours.



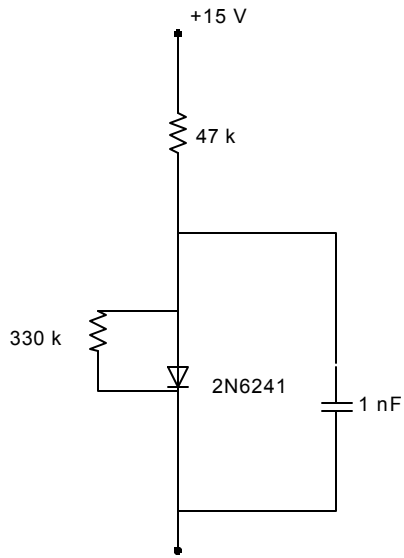
**Fig.1: Capacitor Charging Using UJT**



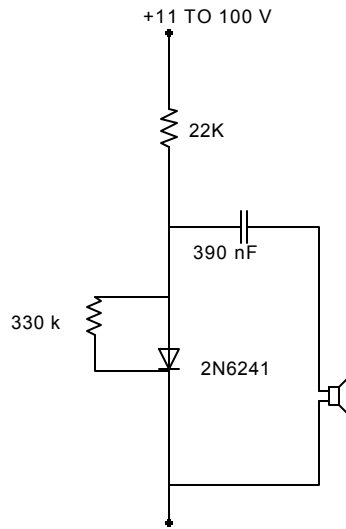
**Fig.4: Modified Circuit of Fig.2**



**Fig.5: UJT Negative Resistance Used to Cancel-Out the Physical Resistance of the Coil**



**Fig.6: SCR Used for Oscillations Generation**



**Fig.7: Improved Circuit for Oscillations Generation**