# MASTER OSCILLATOR

When a capacitor and an inductor are connected in parallel, the circuit is called a "tank circuit". Tank circuits exhibit certain electrical properties which make them useful in many oscillator circuits. Since the oscillator in the EC/130 uses a tank circuit, it seems worthwhile to investigate some of the properties of tank circuits briefly.

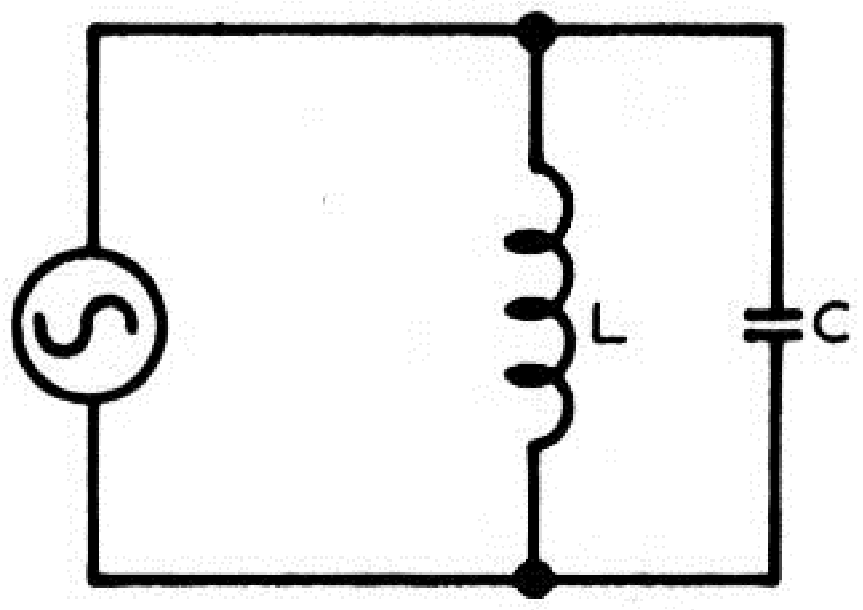

Figure 1

Consider the tank circuit in Figure 1. If an A.C. voltage is applied across the tank circuit as shown, some current (IC) will flow through the capacitor (C) and some current (IL) will flow through the inductor (L). How much current will flow through each depends upon the reactance of each. The reactance is dependent upon the applied frequency. Figure 2 shows the interdependence of frequency and reactance. Reactance is plotted on the Y axis and frequency on the X axis. Note that capacitive reactance goes down as frequency goes up, and inductive reactance goes up as frequency goes up.

Every tank circuit will produce oscillations at some particular frequency. For example, consider the circuit in Figure 3.

When the transistor is turned on, 12 volts* will be dropped across the tank circuit. The capacitor will charge to 12 volts, and current will flow through the coil, storing energy in it's core. If the transistor is now turned off, the capacitor will begin to discharge through the coil, keeping energy stored in the core. But, as the capacitor discharges, the discharge current decreases exponentially. The properties of inductors are such that they oppose changes in current, so the magnetic field collapses, continuing current flow down through the coil and actually charging the capacitor to 12 volts IN THE OTHER DIRECTION, that is, with -12 volts on the top, and -24 volts** on the bottom. At this point, all the energy is stored

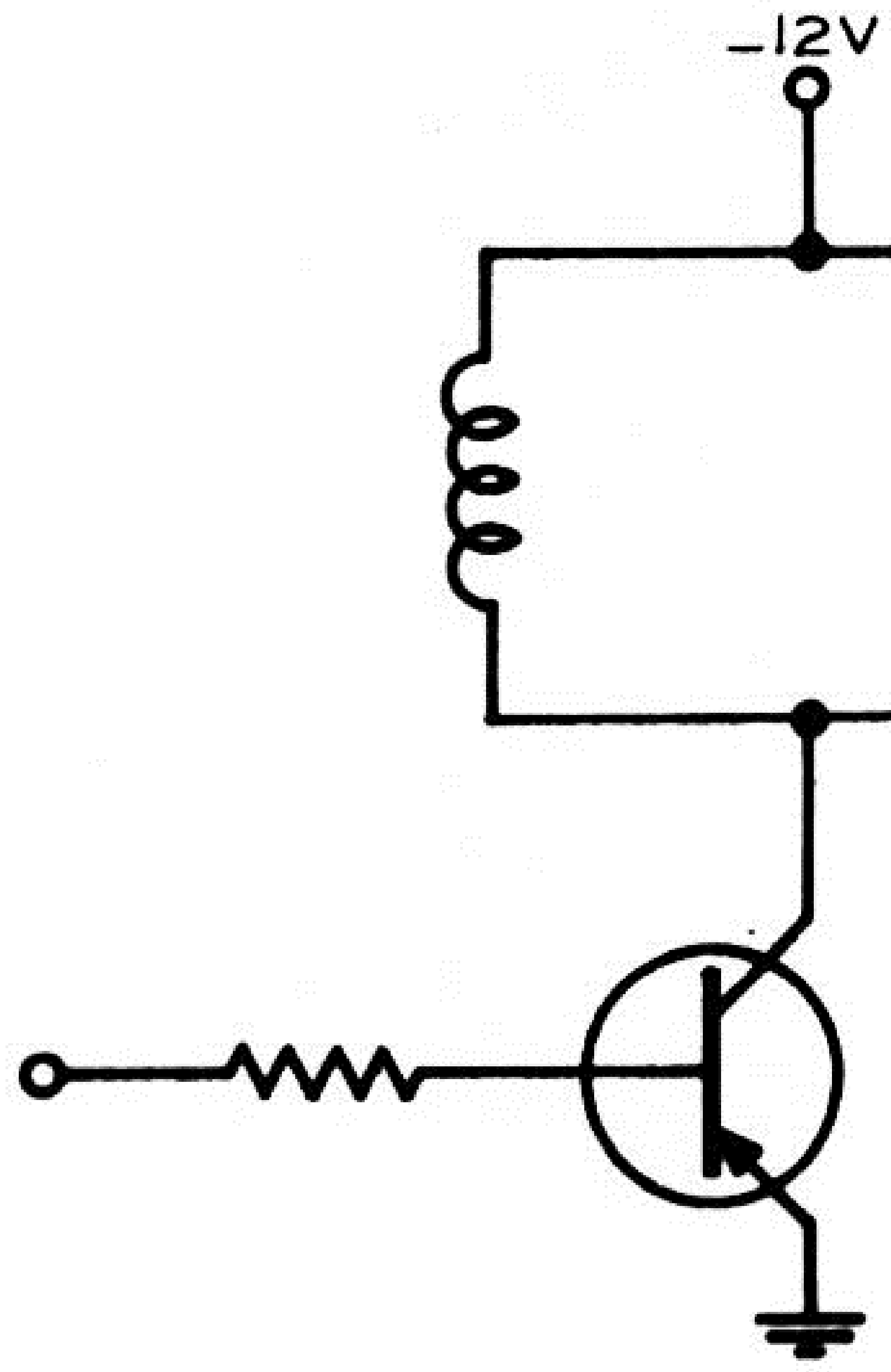

Figure 3

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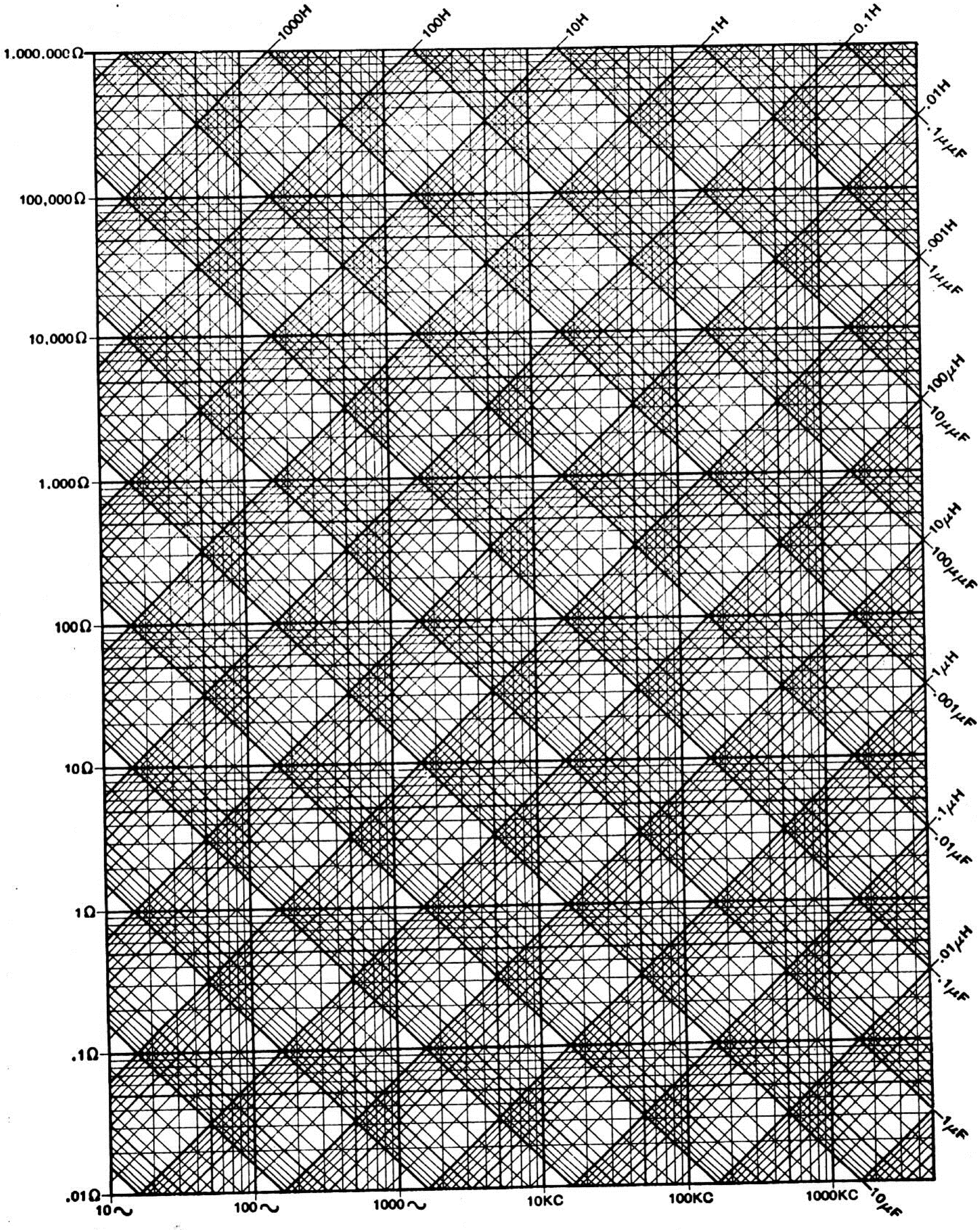
* At resonance, the tank circuit presents a very high impedance to the collector circuit. Hence almost all the voltage will be dropped across the tank circuit.

** Don't hit the panic button! It is characteristic of inductive loads to cause the collector voltage to swing an equal amount each side of the supply voltage with this type of circuit connection.


1000H
100H
10H
1H
0.1H
.01H
.1μF
.001H
1μF
100μH
10μF
10μH
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1μH
.001μF
.1μH
.01μF
.01μH
.1μF
1μF
10μF
1.000.000Ω
100,000Ω
10,000Ω
1,000Ω
100Ω
10Ω
1Ω
.1Ω
.01Ω
10~
100~
1000~
10KC
100KC
1000KC

Figure 2

in the capacitor. Now the capacitor begins to discharge again up through the coil, storing energy into the core again by building up the magnetic field again. As before, the collapsing magnetic field restores the energy to the capacitor by inducing a current in the coil that will charge the capacitor in the opposite direction, that is, with the collector side of the capacitor more positive than the other side. Again the capacitor begins to discharge, etc. ad inf. This charge, discharge, recharge cycle would continue forever, except for energy dissipated as heat into the resistance of the circuit. The copper wire in the coil accounts for most of the circuit resistance. Because energy is lost each cycle, the oscillations of the tank circuit are "damped" and will eventually die out altogether. A damped oscillation of a tank circuit is shown in Figure 4a. Note the decrease in voltage amplitude as energy is used up in the resistance of the circuit. If there were less resistance in the circuit, the tank circuit would ring or oscillate much longer, as shown in Figure 4b. Clearly, as the resistance of a tank circuit goes down, efficiency at resonance goes up. Since most of the resistance is in the coil, the merit of the coil determines, to a large extent, the effeciency of the tank circuit. The Merit (Q) of a coil is defined as the ratio of its inductive reactance to its resistance, or algebraically, $Q = \frac{XL}{R}$. Therefore, the higher the Q of the coil, the longer the tank circuit will ring before being damped out by the resistance of the circuit.

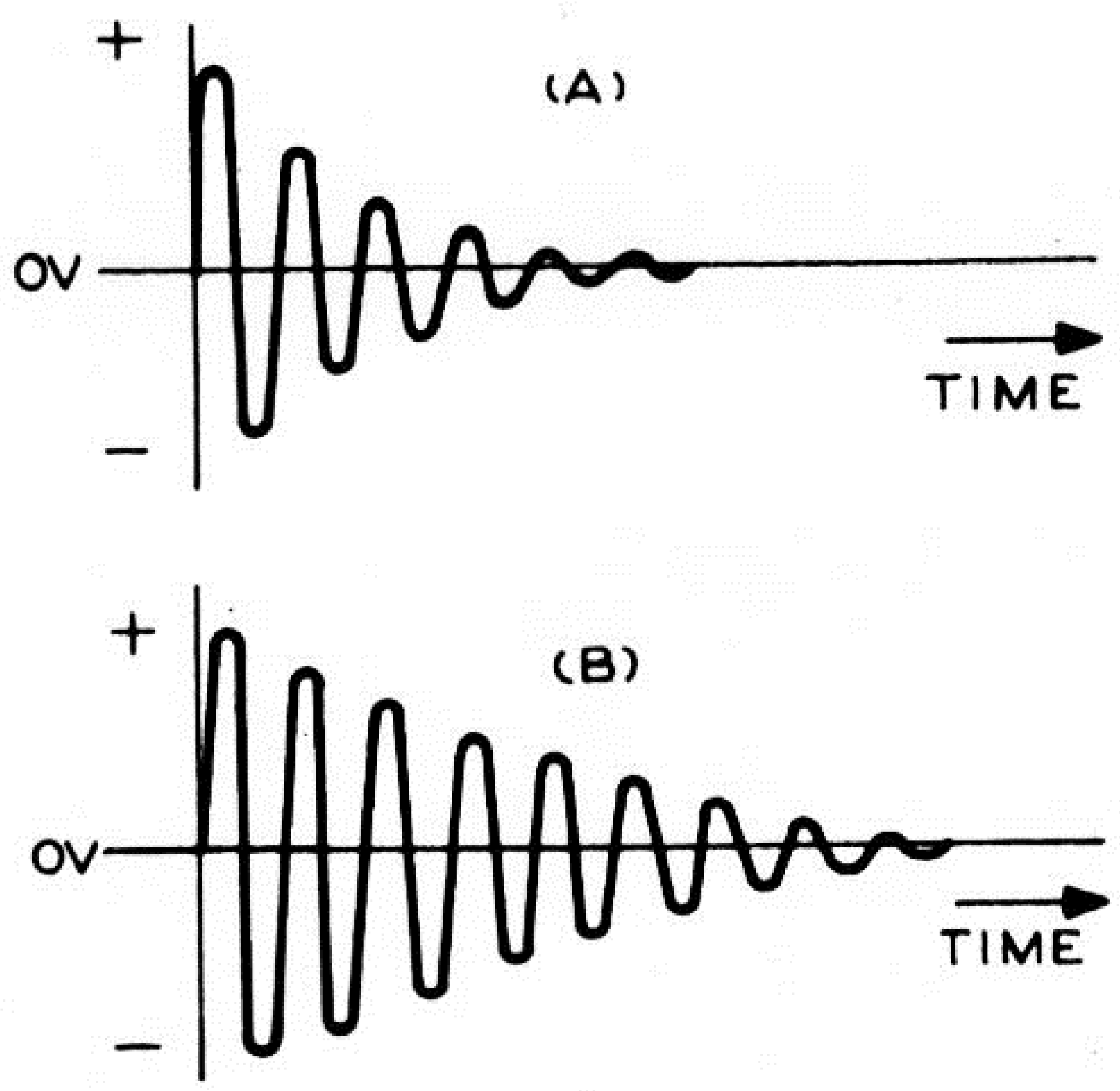

Figure 4ab

The frequency at which a tank circuit will oscillate (called the resonant frequency) is the frequency at which the inductive reactance equals the capacitive reactance. Stated algebraically, resonance occurs when XL = XC.

$$X_L = 2\pi FL$$

$$X_C = \frac{1}{2\pi FC}$$

$$2\pi FL = \frac{1}{2\pi FC}$$

$$(2\pi FL)\quad(2\pi FC) = 1$$

$$(2\pi F)^2 = \frac{1}{LC}$$

$$2\pi F = \sqrt{\frac{1}{LC}}$$

$$F = \frac{1}{2\pi\sqrt{LC}} \quad *$$

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* Development of this formula presupposes the use of a high Q coil in the tank circuit. If Q is low, other parameters become significant.

This, then, is the formula for finding the resonant frequency of a tank circuit.

Thus far, only the damped oscillations of a tank circuit have been considered. Fortunately, means have been devised to replenish the energy lost in a tank circuit due to internal resistance and external loading. Figure 5 shows one method of sustaining oscillations. Compare Figure 5 with Figure 3 and note the similiarity. In Figure 5 the total capacity must be used to determine the resonant frequency. (Remember that the total capacitance of series capacitors is found by the double reciprocal method, not by simple addition!) Since the signal is developed across both capacitors, some portion of the total signal developed will be felt at the junction of the two capacitors. What percentage of the total signal will be felt at this point depends upon the ratio of the capacitances. (For example, if the ratio C1:C2 is 1:2, then 1/3 the total signal will be felt across C2.) If this signal is fed back into the transistor with sufficient amplitude to control the transistor, then regeneration is effected. The feedback signal pulses the transistor on at the appropriate time each cycle, and this replenishes the energy lost due to heat and loading. This type of oscillator is called the Colpitts oscillator, or circuit, named after the inventor of the circuit.

For purposes of analysis, consider a sinusoidal input to the base of Q1 in Figure 5 with the input frequency exactly equal to the resonant frequency of the tank circuit. If the bias is such that the input signal will turn the transistor on during

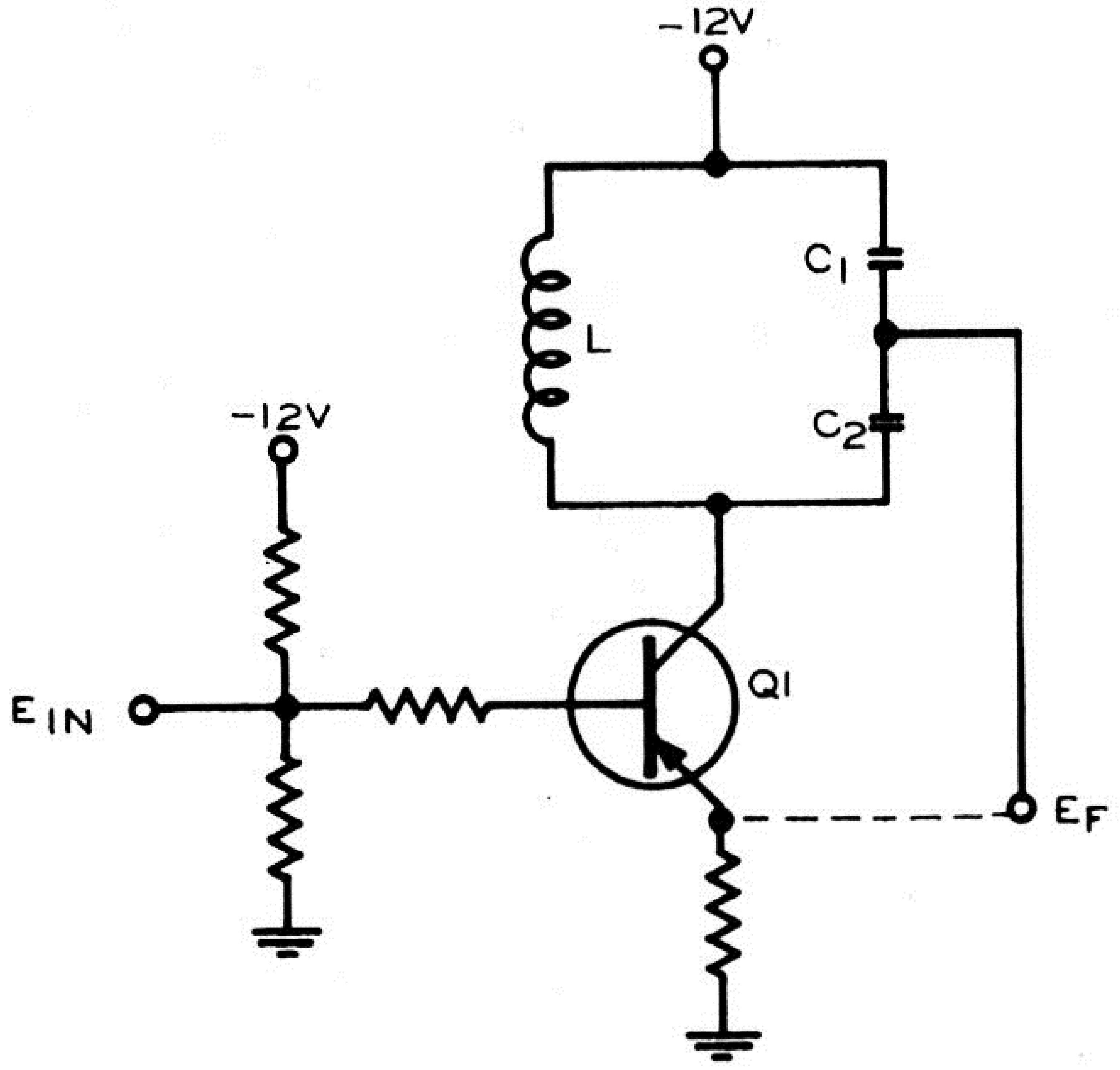

Figure 5

the negative half-cycle, and off during the positive half-cycle, the transistor will turn on to "charge" up the tank circuit, then turn off to allow the tank to oscillate. But the next negative half-cycle of the input, the transistor will again turn on, thus effectively replenishing the energy lost by the tank circuit. If a signal ($E_F$) is taken from the junction of the capacitors, and compared to the input signal (Ein), it will be discovered that $E_F$ is out of phase with Ein. If $E_F$ were applied to the base of Q1, it would oppose the input signal and negate the very purpose of the feedback signal. If, however, $E_F$ is applied to the emitter of Q1, quite a different situation exists. For example, as the input goes negative to turn Q1 on, $E_F$ goes positive, and a positive potential on the emitter of Q1 will also turn Q1 on. By the same token, as the input signal goes positive to turn Q1 off, $E_F$ goes negative to turn Q1 off. (If there is any doubt or confusion at this point draw out the waveforms for Ein and Eo as related in time.) The logical question that arises is, why the necessity of two signals to control Q1? Why indeed? If the input signal is removed and the appropriate bias level is applied to the base, and a bypass capacitor put on the base to prevent degeneration, the circuit will work just as well as before. In Figure 6, this very thing has been done. The 8.2K and 4.7K resistors in the base circuit establish about -4.37 volts base bias, and the .1 capacitor is the base bypass capacitor that puts the base at signal ground. The 3.3K resistor in the emitter circuit is the resistor across which the output signal is taken. Remember the formula for finding the resonant frequency of a tank circuit?

$$F = \frac{1}{2\pi \sqrt{LC}}$$

$$F = \frac{1}{6.28 \sqrt{100 \text{ X } 10^{-6} \text{ X } 530 \text{ X } 10^{-12}}}$$

$$F = \frac{1}{6.28 \text{ X } 23 \text{ X } 10^{-8}}$$

$$F = 692\text{KC}$$

So the tank circuit is resonant at 692KC.

Two things should be noted about the capacitors in the tank circuit. First, the value of capacity needed to give the desired frequency was VERY CAREFULLY determined. Second, the RATIO of the capacitors was carefully calculated to provide an abundance of regenerative feedback to assure oscillations under any condition. These points are emphasized to point out the necessity of exact value replacements. Substitutions for different value capacitors are unacceptable. These values of capacitors yield an output that is not a pure sine wave. The output is a distorted sinusoid with unsymmetrical half-wave periods. This is unimportant, and is mentioned so that it will come as no great shock to see a waveform on a scope that is other than the classical sine wave. The output of the oscillator is taken through an emitter follower with two 1.5K resistors from the emitter to +6 volts. The effect of the voltage divider is to limit the base current of the inverter which it drives. The 56pf capacitor assures **minimum** rise time.

This oscillator circuit is an old standby that has been used over and over again. There is essentially nothing new in this circuit; if it looks any different, it's because the oscillator has been adapted to the particular demands of the machine.

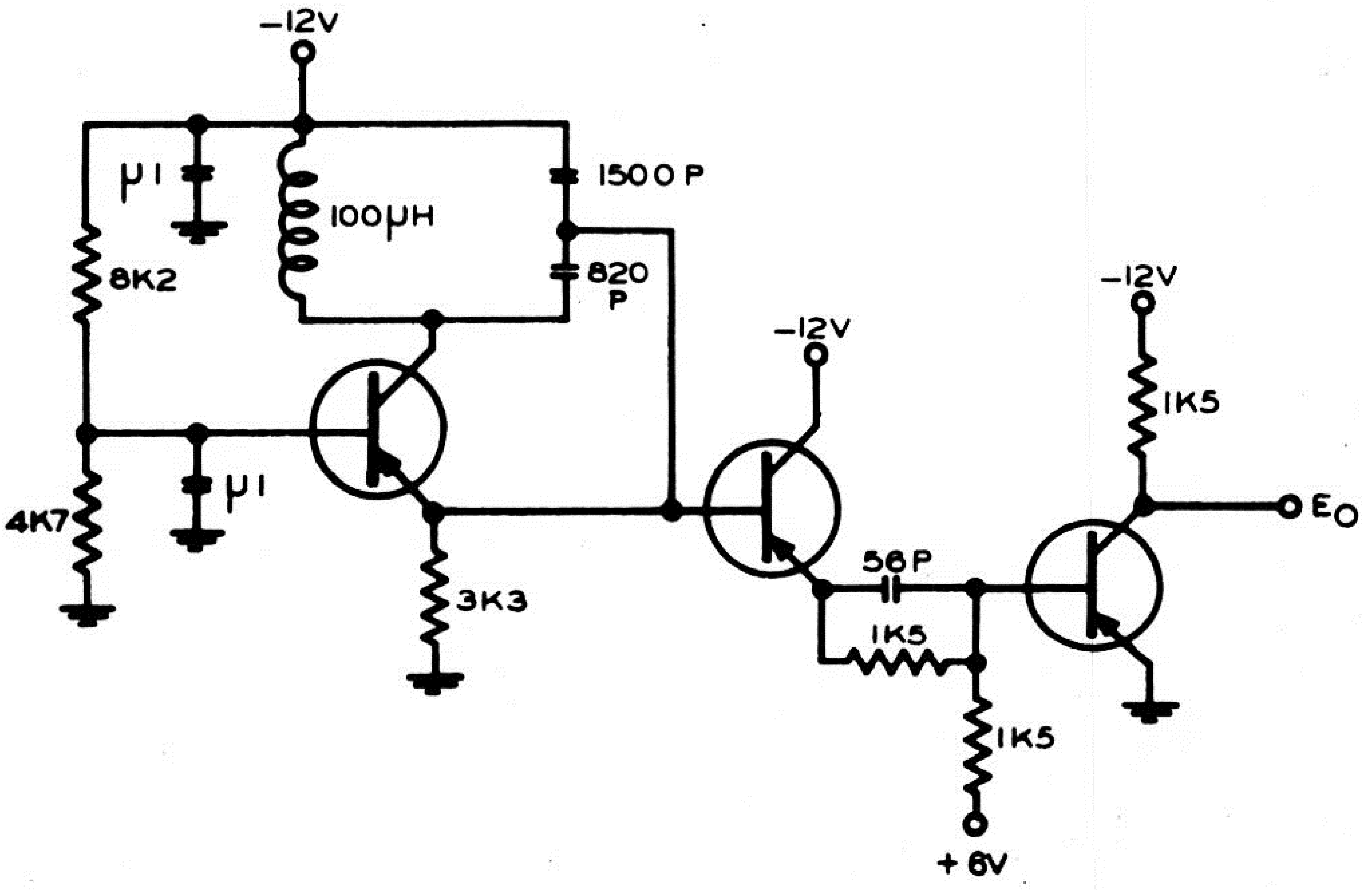

**Figure 6**