TRANSISTOR OSCILLATORS with CRYSTAL CONTROL

By NATHANIEL RHITA

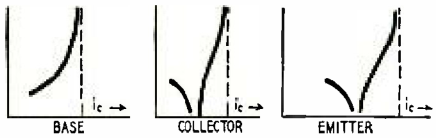

Fig. 1—Impedance variations of transistor elements as functions of the collector current.

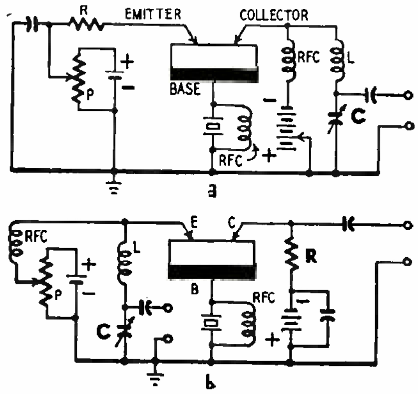

Fig. 2—Two forms of the transistor oscillator, with the crystal connected in the base circuit.

MANY laboratories are engaged in the present race to develop new circuits for transistors and to discover new applications for them. Transistors are similar to tubes in certain respects but their circuits are usually much different. Within the past few months, transistor amplifiers and multivibrators have been described here. Recently several new and basic crystal-controlled oscillators have been disclosed. These circuits have relatively large output, good sinusoidal waveform, and excellent frequency stability.

The new transistor circuits are quite flexible. The crystal may be connected to the emitter, base, or collector, whichever is most convenient or desirable. (The terms emitter, base and collector correspond to cathode, grid and plate.) Also, a tuned circuit is needed in one of the circuits of the transistor. In any case, two requirements must be met: First, a high impedance is required in the base circuit. This provides the necessary feedback to maintain the oscillations. In addition, the high impedance of the quartz crystal must be matched to the transistor. A potentiometer accomplishes the matching.

Fig. 1 shows how the impedance of a transistor element varies with collector current, I_c. For each element there is some critical current which corresponds to high impedance. For example, if the crystal is used in the emitter circuit, the impedance of this transistor element must be raised so that it matches the crystal. Collector current is adjusted for operation close to the dotted line (Fig. 1). In the new oscillators, this current is controlled by the emitter bias.

Figs. 2-a and 2-b show the crystal in the base circuit. A choke bypasses the crystal to give the base a d.c. return to ground. A series circuit LC (in either the collector or emitter circuit) is tuned to the crystal frequency. R is used to prevent shorting out the transistor to ground through a bypass capacitor.

In both circuits P controls the collector current. It is adjusted for optimum output with stability. The usual precautions, chokes and bypass capacitors, keep r.f. out of the batteries. Sinusoidal output is available from the terminals shown in the diagrams.

The crystal is connected in the collector circuit in Figs. 3-a and 3-b. A parallel-resonant network tunes the base to the crystal frequency and provides the high impedance for feedback. As in the previous figures, the emitter bias is adjustable. This time the *collector* must match the crystal impedance.

Figs. 4-a and 4-b are suitable when the crystal is connected in the emitter circuit. The first figure shows a parallel resonant network in the base circuit. This is tuned to the crystal frequency. Note that it supplies the high impedance needed in this circuit. In Fig. 4-b a series-tuned network LC is used in the collector circuit. Note that the emitter battery is *reversed*. This is necessary because of the high bias developed across the base resistor. This bias makes the emitter *positive* with respect to the base. The negative battery voltage overcomes part of this bias and leaves a small positive potential on the emitter.

In each of these diagrams the collector battery may be 22.5 volts or less. The emitter bias may be supplied by a single 1.5-volt cell. However, Fig. 4-b may require a larger emitter battery to overcome the drop in the base resistor.

These circuits were invented by two scientists, Everett Eberhard and Richard O. Endres. Their patent (No. 2,570,436) is assigned to RCA.

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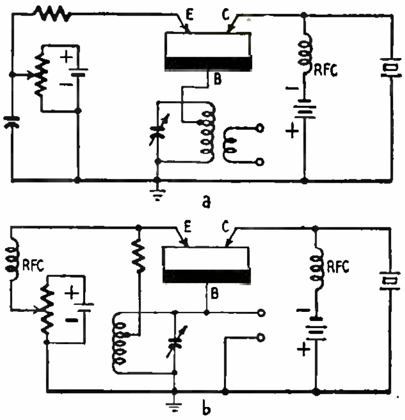

Fig. 3—Two methods of operating the transistor oscillator with the crystal in the collector arm.

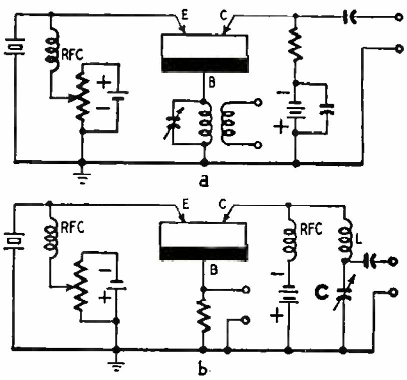

Fig. 4—The crystal is connected in the emitter branch in these modifications of the oscillator.