Introducing
THE TRANSISTOR

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CONSIDERABLE EXCITEMENT EXISTS IN amateur radio circles over the Transistor. In some quarters the doom of the valve is already heralded, while in others the transistor is regarded as a novelty of little immediate interest. The truth, of course, is somewhere between these two points of view, and a few of the misconceptions regarding transistors may well be dealt with.

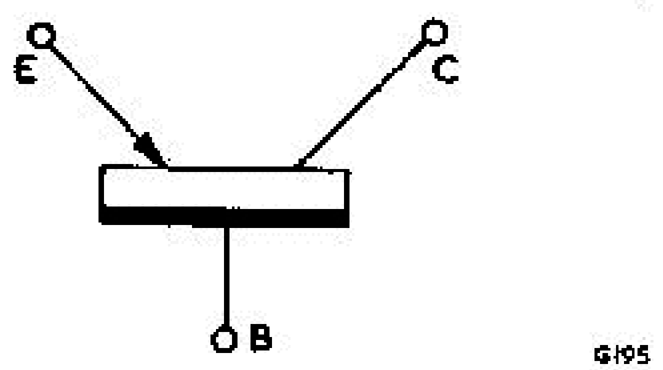

Fig. 1. *Transistor Electrodes*
E=Emitter
B=Base
C=Collector

First of all there are an almost unlimited number of *types* of transistor. This does not just mean different sizes of the same thing, but actual types of fundamentally different operating conditions. However, while there are many such variations of transistor, the only two of interest are the junction transistor and the point transistor. That is of interest to the radio constructor, for these are the only types readily available commercially. Without undue technicalities, the point transistor consists of two closely spaced points on one side of a thin slice of germanium and a flat connection on the other (Fig. 1). By appropriate treatment the device becomes the so-called crystal triode. The "emitter" roughly corresponds to the grid of a valve in its controlling action of the current flowing in the "collector" circuit, which corresponds to the anode of a conventional triode. In the junction transistor the same amplifying action is obtained by using the "junction" between two differently treated pieces of germanium. However, the action is roughly the same.

From the point of view of types available to the private radio experimenter, the point types on sale will operate up to a megacycle or so as oscillators and amplifiers, while the junction types are confined to low frequency amplifying applications. The point types are also more delicate and "ticklish" in operation and manufacture, although they are the ones capable of reasonable high frequency operation. The junction types are stable and relatively robust and an easier manufacturing proposition. The usual h.f. limit of available point types is about a megacycle, but some samples may go to 2 or more megacycles, so selection is usually necessary for h.f. work, even as a top band QRP transmitter!

It must be clearly understood that this limitation *only* applies to transistors generally on sale. Transistors of various types can be induced to do almost anything, even to oscillating and amplifying at over 100 megacycles. The snag lies in mass producing reliable standardised transistors of high performance. These snags are being overcome, and in a year or so junction transistors of good h.f. performance are expected to be generally available.

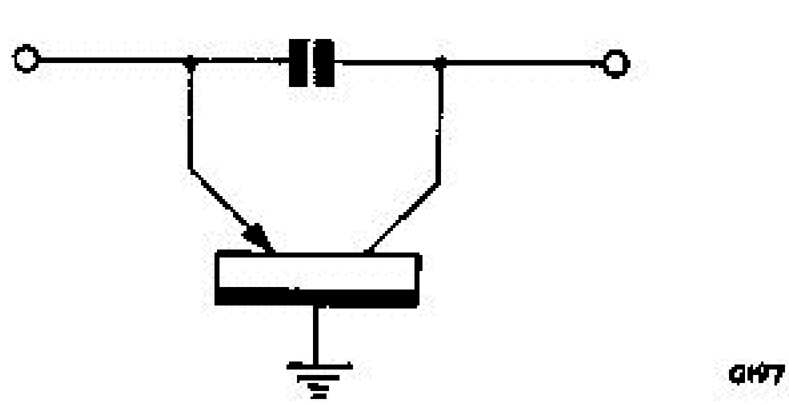

Fig. 3. *The input and output circuits are in phase, so that a single capacity can cause regenerative feedback*

The transistor is roughly analogous to a triode, and thus Fig. 2 gives the valve equivalents of possible transistor connections.

Considering the point transistor generally available, however, this analogy is a dangerous half-truth at the best. Thus there is no phase reversal between the "collector" and the "emitter," so that unlike the valve, the input and output signals are in phase. Thus no phase reversal is needed to cause oscillation, and in many cases a condenser from collector to emitter will cause positive regeneration (Fig. 3).

This lack of phase reversal also means that "cathode" bias obtained by putting resistance in the "base" return to earth causes positive regeneration and not negative feedback as with a valve. While a bias resistor in the base earth return could be bypassed with a condenser this still leaves d.c. feedback, which may still cause instability.

The above factors do not offer any insuperable barrier, however, but unfortunately there is more to come. We are so used to the very high input impedance of a valve, that we take this for granted. With a valve, the grid under conventional operating conditions takes no current. The grid is virtually a "voltage operated" device. However, the emitter circuit of a transistor has an input inpedance of around 300 ohms or so. Thus it draws appreciable current. But we are not really concerned with increasing this input impedance . . . we should be very glad if it were even smaller . . . even zero! The low impedance emitter is in fact a "current operated" device. If it were of zero impedance, a current flowing through it would lose no power, so that we could connect the

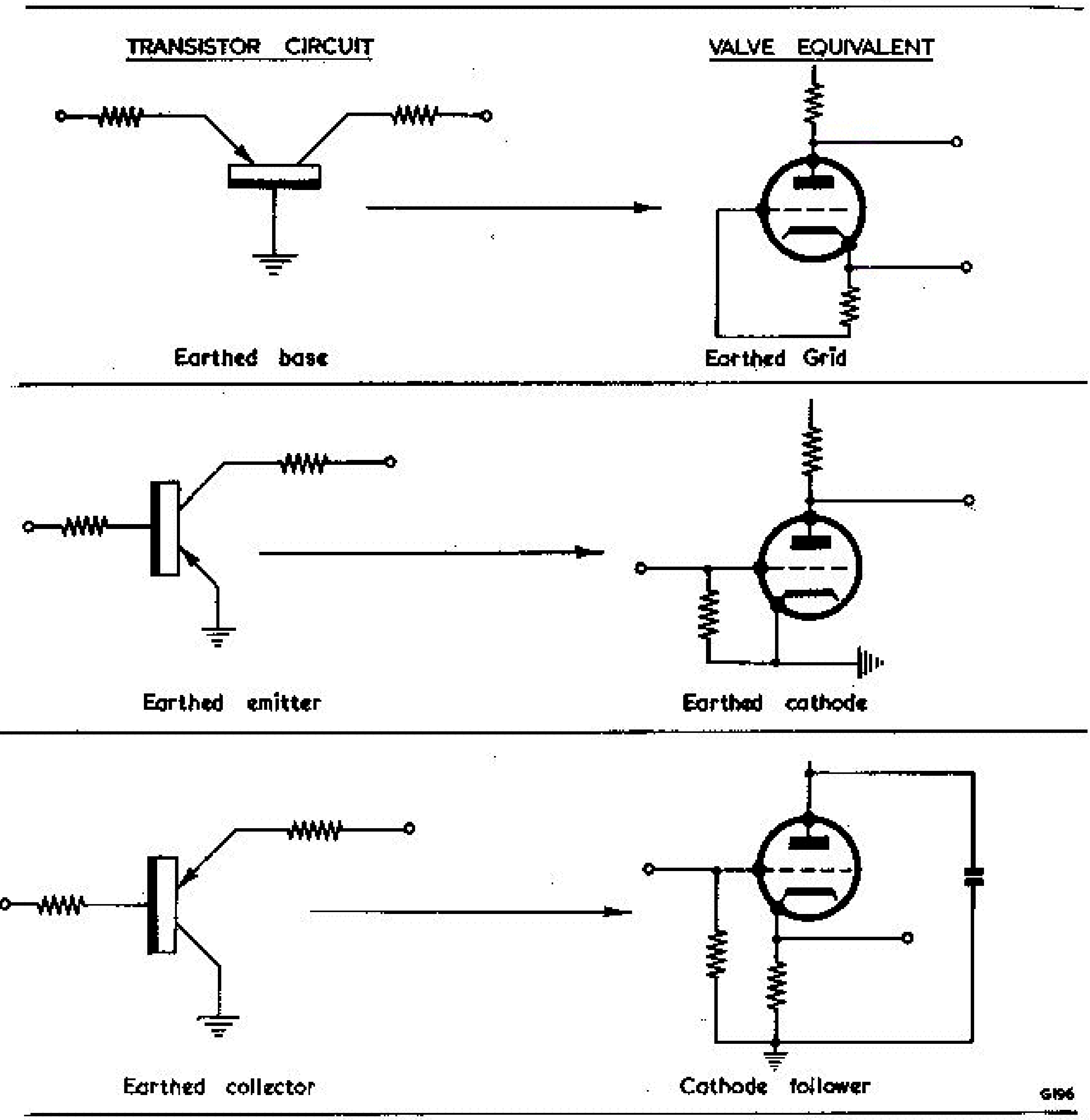

Fig. 2. Valve-Transistor Duals

transistor in series with a High-Q tuned circuit for efficient amplification (Fig. 4). This would be the exact converse of the ideal valve which consumes no grid current when a voltage is applied to the grid. The valve is so close to this ideal, that we do connect it directly in parallel with High-Q tuned circuits with no ill effect.

Unfortunately the transistor, although of low input impedance, is not quite so ideal, and is usually matched into a tuned circuit. In transistor deaf aids operating from a crystal microphone, the high impedance microphone is actually matched by a step-down transformer into the low impedance transistor "emitter" (Fig. 5). It is also to be noted that the collector has an output impedance of some 20,000 ohms, roughly equivalent to a high impedance triode anode circuit. Thus this has also to be matched into the load, which may be a pair of phones, or even a loudspeaker.

However, it will be noted that a current of, say, one milliampere flowing in the low impedance emitter input circuit represents a substantial *power* gain if it causes a change of one milliampere in the output current of the collector circuit in an impedance of 20,000 ohms. Thus if the input circuit were 200 ohms due to the emitter impedance, into the 20,000

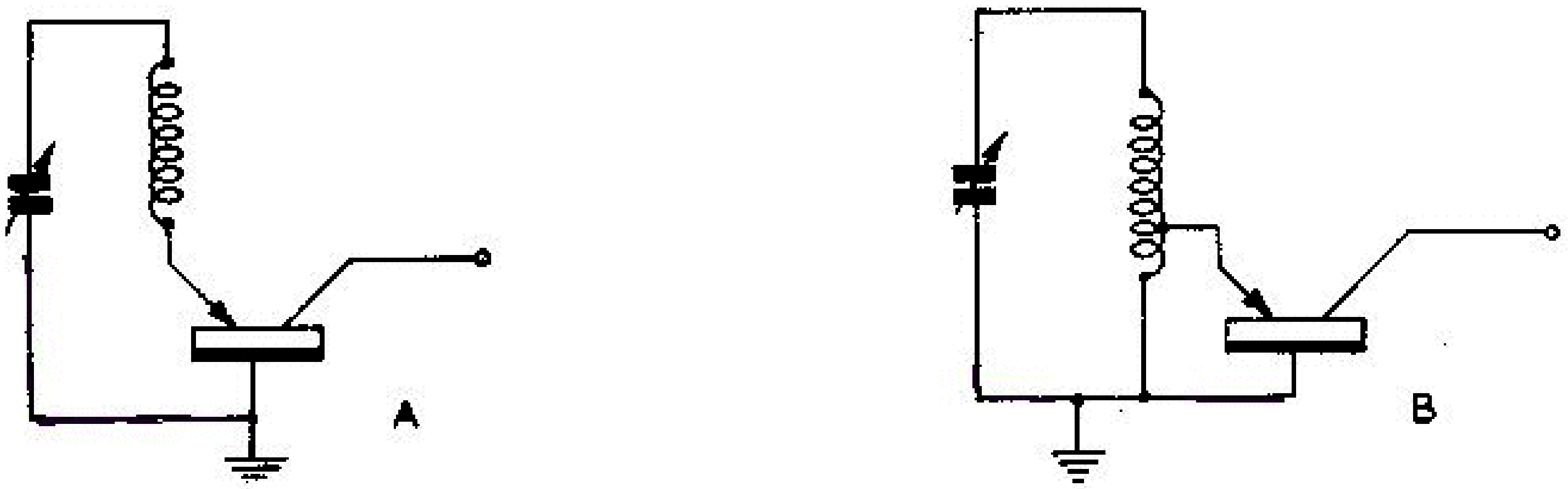

FIG.4.

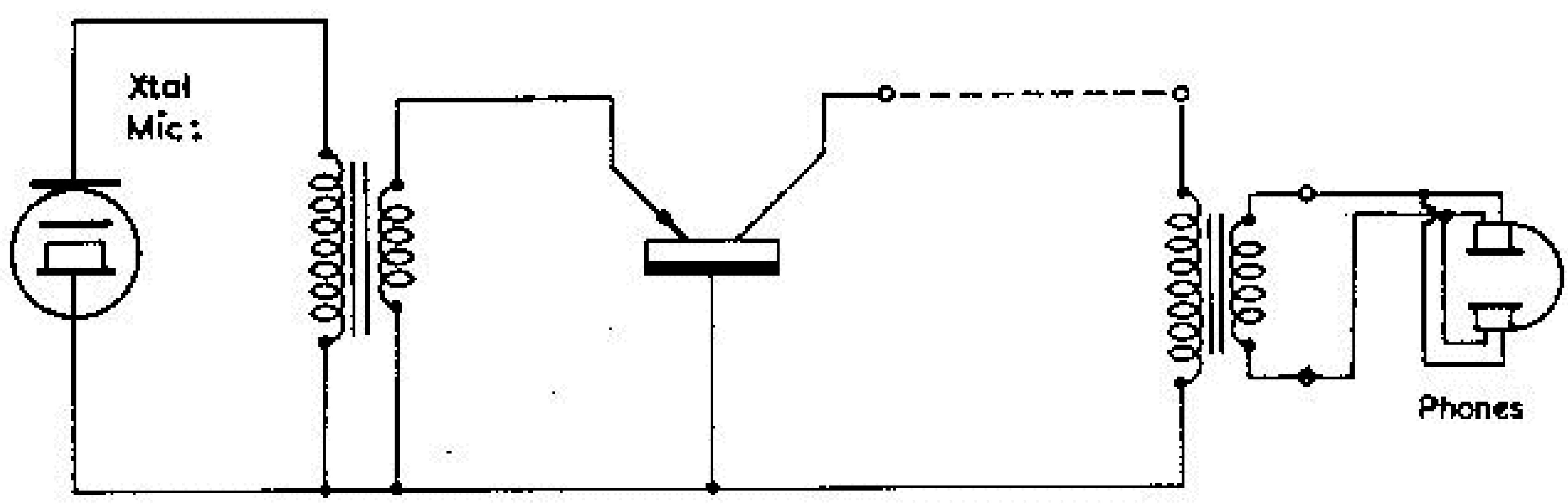

FIG.5.

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Fig. 4. A perfect "zero input impedance" transistor could be included in series with a High-Q tuned circuit for high gain amplification (A).
Actual transistors have a low but appreciable input impedance of about 300 Ω, and are tapped well down a tuned circuit for matching (B)

Fig. 5. A crystal microphone has to be matched by a step-down transformer into the low impedance input of a transistor.
Similarly, a pair of phones may be transformer matched into the high impedance collector output circuit

ohms impedance of the collector we should have a *power* gain of 100 times, or some 20 db. However, an actual *current* gain can be achieved, so much so that a three-stage junction transistor amplifier may have a gain of 90 db.

Due to the "current" operated nature of the transistor, the gain is actually expressed in terms of the "current multiplication" factor or "alpha," which plays much the same role as the mutual conductance of a normal valve. Moreover when considering transistors, it is as well to forget any analogy with valves, and consider the operation on a transistor basis. In this respect, the signal is a fluctuating *current*. The "emitter bias" is so many microamps of current and *not* voltage . . . even though we may be interested in the emitter voltage we would plot output in the collector against various fixed values of emitter current! Needless to say, also, the output current is reversed as compared with a valve and we have to be careful about not stacking up the negative h.t. voltage!

These alarming glimpses of the vagaries of transistors should not frighten one away from these interesting gadgets. There are many rewards for their peculiarities, and many simple flea powered receivers, amplifiers and even transmitters can be produced.