CIRCUIT CONVENTIONS

The Valve "Equivalent Generator"

By "CATHODE RAY"

SOME time ago[1] I mentioned a number of the things that give rise to confusion in talking about circuits—questions of in which direction current flows, whether a condenser is being charged or discharged, which is series and which parallel, and so on. Among them I mentioned the controversy that had been raging about the valve "equivalent generator," but on this particular ground I refused to come out into the open. Now that the big guns have been silent for some time it may be safe to do so. I have a feeling that many readers must have decided that any matter disputed by such eminent authorities must be too involved and uncertain for them even to attempt to understand. And yet it is constantly coming up in technical books and articles, so it is perhaps worth another attempt to get it clear. In case this sounds rather presumptuous on my part, I would say right away that I have nothing new to contribute beyond an attempt to show why I think the viewpoint of D. A. Bell in this country and F. E. Terman in U.S.A. is the most helpful for students to take.

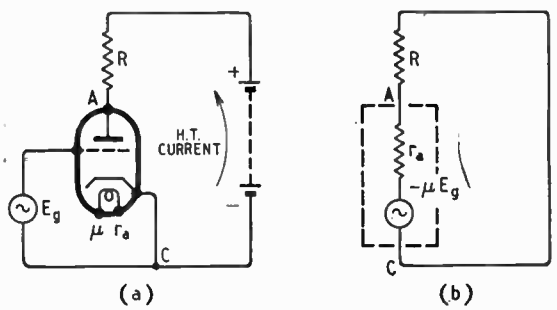

Fig. 1. (*a*) shows the essentials of a triode amplifier circuit, and (*b*) the equivalent generator circuit. A and C mark anode and cathode points respectively.

The valve "equivalent generator" or "equivalent circuit" principle, of course, is an idea for simplifying the theory of valve amplifiers by replacing (on paper) the driven valve (Fig. 1*a*) by an imaginary generator (Fig. 1*b*), giving a voltage μE_g and having an internal resistance r_a. The arguing starts when one draws arrows or + and − signs to show the directions of the voltages and currents.

These questions are not really matters of absolute right or wrong, any more than the question of driving to right or left of a road. The authorities can decide on either. But once it has been decided failure to conform is likely to lead to collisions and disputes. Seeing that the valve equivalent is a device intended to help the mind, it is a great advantage if the convention adopted fits the facts and also fits other, already accepted, conventions. That is why there were protests when one authority showed two equal signal currents flowing in opposite directions, and another reversed the usual convention by reckoning the cathode voltage relative to the anode, so that (contrary to what is generally understood) anode and grid signal voltages were in phase.

But why should there be any difficulty or dispute? The answer is quite simple; it is the H.T. supply. Conscious that this is really the ultimate source from which any power obtained from the valve comes, people feel they have to acknowledge the debt by using the H.T. as the standard of current and voltage direction. And to do so they may have to stand on their heads or perform other unnatural mental gymnastics. All this is quite unnecessary, and the whole thing is easy, clear, and altogether in line with the rest of simple circuit theory if we don't try to mix Fig. 1*b* with Fig. 1*a*.

You will see I have left out the H.T.B. from Fig. 1*b*. I have done so because it has nothing to do with the imaginary generator. Its purpose is to feed the valve shown in Fig. 1*a*. To decide directions of voltages and currents in Fig. 1*b* according to the direction of the H.T. voltage and current in Fig. 1*a* is like a bricklayer wanting to start at the top of a building and work downwards because that is the way his breakfast went.

A much more relevant and fundamental convention than that is to reckon voltages with respect to the earthy side. In a valve circuit of the general type under discussion, anode and grid voltages are by general acceptance reckoned with respect to their common point, the cathode, which is usually earthed. Anybody who, for the sake of appeasing the H.T. supply, throws over this convention, is more likely to confuse than help. It is an undisputed fact that when the grid of a resistance-coupled or resonant amplifier is made relatively posi-

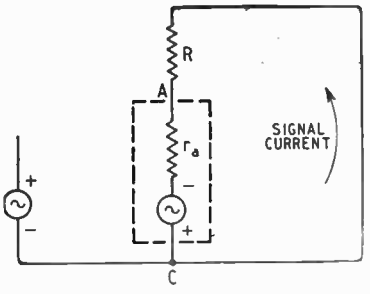

Fig. 2. When the grid signal voltage is positive (relative to C) the result in the anode circuit can be attributed to a positive (in-phase) generator voltage relative to A or a negative (180° out-of-phase) voltage relative to C. The latter way of putting it is preferable because the accepted custom is to specify both anode and grid voltages relative to C, and to reverse this custom with one of them is to invite confusion.

[1] *Wireless World*, Sept., 1946, p. 299.

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tive the anode goes relatively negative. That fixes the phase or direction of the output voltage. At such a moment the generator polarity must be as shown in Fig. 2, and the direction of the current (using the classical convention, which is opposite to the electron flow) must be as shown by the arrow, all of which agrees with experimental fact.

So what is all the argument about? Well, it seems to worry

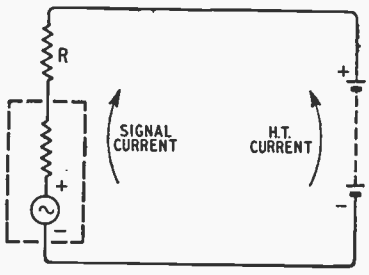

Fig. 3. When the imaginary generator is on its positive half-cycle, it opposes the H.T. source and reduces the steady current.

some people to have a *negative* voltage ($-\mu E_g$), causing a current which from the point of view of the H.T. source is *positive*. But why drag in the H.T. source? It is merely a device for keeping the valve in working condition, and when (for purposes of theoretical calculation) we have replaced the valve, and its H.T. supply unit, and its socket, and the maker's name on the glass, and everything else appertaining to the valve, by a generator inside a dotted line, which (within assumed limits) produces the same external effects, why display this irrational concern for the views of the H.T.?

When considering the signal voltages in an amplifier, it would be very tiresome if we had to be always thinking of the steady H.T. and G.B. voltages that happen to be necessary for the happy domestic life of the valve. The sort and quantity of food one eats admittedly has a lot to do with the efficiency of one's work, but it would be a distraction and waste of time to keep on about it throughout the working day. Similarly, in a signal voltage diagram or discussion it clarifies matters to leave steady voltages out of it. This is so generally accepted that when a statement is made that the effect of a certain signal is to drive the anode of a valve negative it is not considered necessary to explain that the anode is not really absolutely negative, but only relative to its potential in the absence of the signal.

In this valve equivalent affair the mixing of domestic and business matters is bound to cause confusion. In Fig. 1*a* the source of power is a battery, and the direction of the power flow from it is right to left, and positive is anti-clockwise. In Fig. 1*b* the source of power is a generator, the direction of power left to right, and positive is clockwise. So, if the equivalent generator and H.T. battery are shown in the same diagram, as in Fig. 3, a positive generator voltage is seen to be in opposition to the battery. It is therefore perfectly natural for a *negative* generator voltage (corresponding to a positive half-cycle on the grid) to *assist* the battery and increase the anode current—as we know in fact it does.

The only room for question I can see is why the voltage of the fictitious generator should be assumed to be $-\mu E_g$—apart, that is, from a not unnatural desire to make it fit the observed facts. D. A. Bell has given[2] a logical derivation on a basis of accepted conventions, although even he—quite unnecessarily, as it turns out—includes the steady current among his *Wireless Engineer* basic conditions.

He points out that the valve (unlike the imaginary generator) is a passive device; it has no voltage source inside it, and any changes of anode current are caused by varying the voltages applied, from outside it, to grid and anode. In the circuit in question the only variation in anode voltage is due to the drop in the anode load, and this voltage opposes the grid voltage changes, which is how the minus sign comes in.

Any real valve is non-linear; that is to say, the changes of anode current are not exactly proportional to the changes in applied voltage. But if the changes are small compared with the steady anode current, there is not a very serious difference between the real valve and an ideal valve in which the anode current changes are proportional to the voltage changes. It is this ideal valve that is imitated by the fictitious generator. So one mustn't expect too much of the generator idea if the signal voltage is so large that there is appreciable distortion. But until it is necessary to take account of distortion in the valve, the simple equivalent generator does help a lot—so long as one is quite clear about it.

Just one more point. For simplicity these arguments are concentrated on a circuit with a purely resistive anode load. But the generator substitute gives the right answer with any sort of load, and, in fact, it is with reactive loads that its help is most valuable.

[2] *Wireless Engineer*, Nov., 1945, p. 532, and *Electronic Engineering*, Feb., 1946, p. 56.

ROBOT PHONE RECORDER

A SOUND recording device of considerable novelty has recently been invented and is being mass-produced in Switzerland. Known as the Ipsophone, this instrument, which employs a magnetic steel wire, is designed for use as an automatic message recorder on telephone circuits. On a number being called, in the subscriber's absence, this device answers the telephone in the following manner: "Here is Mr. Brown's Ipsophone. Your message is being automatically recorded. Go ahead."

This application is, of course, not new but the ingenious feature of the equipment is the safety code number. The subscriber, before leaving his home, sets one of 1,023 possible combinations of numbers. If when absent he rings his own number to hear any messages recorded, the machine counts from zero to nine three times, and the subscriber has to repeat with it the figures forming his code number. This actuates a circuit and starts the play-back mechanism.

If he desires to record his answer to the message for the advice of his secretary he has to say two words, e.g., "Hello, hello," and then dictate his remarks. If, however, he wishes to eliminate the recorded message, he merely speaks another code word and the wire is demagnetized.