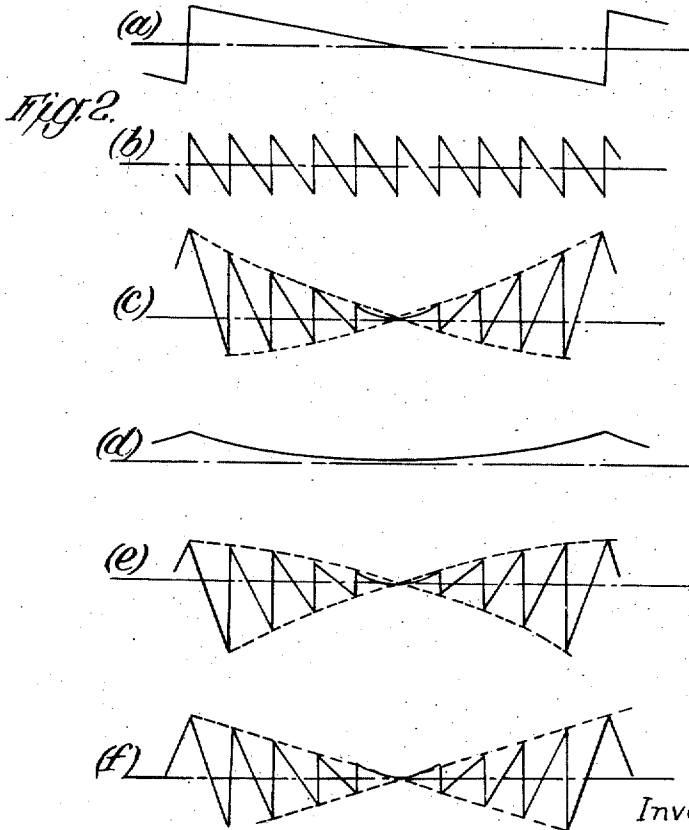
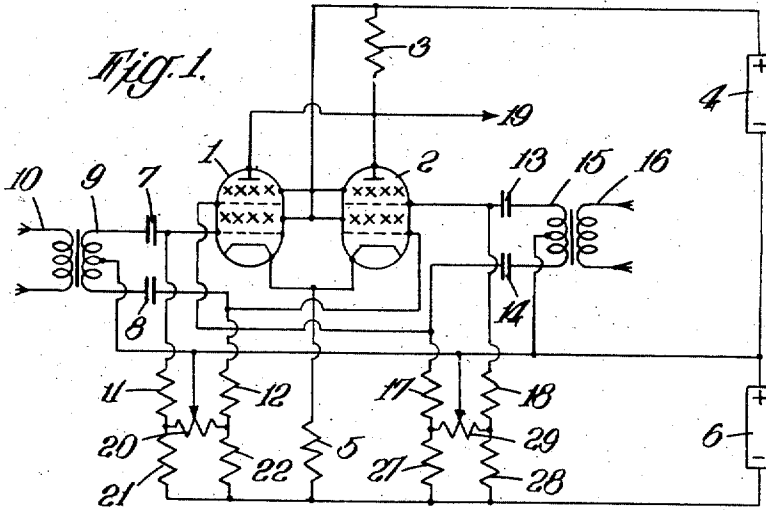


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MODULATOR CIRCUIT
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MODULATOR CIRCUIT

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This invention relates to modulator circuit arrangements.

A form of modulator circuit arrangement which is commonly employed in practice comprises an electron discharge valve having two control electrodes, whereby signals applied to said control electrodes can be modulated one with the other. It is desirable that in such arrangements the characteristics of the control electrodes should be linear over the range of potentials at which they will be required to operate.

However, in practical valves the characteristics of the control electrodes are not linear over any appreciable range, especially in the case of the inner control electrode (that is the control electrode nearer the cathode) whose characteristics follow the usual approximate $3/2$ power law. If the outer control electrode (that is the control electrode more remote from the cathode), is maintained at a fixed potential relative to the cathode, the undesired variations which result due to the non-linear characteristic of the inner control electrode alone can be greatly reduced, by connecting said cathode to a cathode resistance having a value much larger than the reciprocal of the mutual conductance of the valve, so that the total cathode current is then substantially constant. However, this expedient is not applicable, when, as is envisaged above, the other signal is applied to the outer control electrode, since it is usually desired to apply the other signal to the latter electrode with reference, not to cathode potential, but earth potential or some other relatively fixed potential.

The main object of the present invention is to provide an improved modulator circuit arrangement employing a valve having two control electrodes to which the signals to be modulated are applied, with a view to reducing the aforesaid undesired variations.

According to the present invention there is provided a modulator circuit arrangement comprising an electron discharge valve having an inner control electrode and an outer control electrode whereby signals applied to said control electrodes can be modulated one with the other, and wherein means is provided for applying feedback potentials to both said control electrodes, said potentials being such as substantially to annul undesired variations in the output of said arrangement which would otherwise occur due to non-linearity of the characteristic of said inner control electrode.

The present invention is especially applicable to modulator circuit arrangements wherein it is

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desired to form the product of two signals which have positive and negative portions, since it can be shown theoretically that if variations due to non-linearity of the control electrodes are eliminated it is possible by employing two similar valves in a balanced arrangement to obtain a resultant which is dependent only upon the product of the two signals.

Therefore the object of the present invention in one of its aspects is to provide an improved modulator circuit arrangement for forming the product of two signals having positive and negative portions and according to this aspect of the invention there is provided a modulator circuit arrangement comprising means for modulating said signals one with the other in positive polarity, means for simultaneously modulating said signals one with the other in negative polarity, and means for adding said modulated signals whereby variations which are dependent only on one or the other of said signals are substantially balanced out.

In order that the said invention may be clearly understood and readily carried into effect, the same will now be more fully described with reference to the accompanying drawings in which

Figure 1 illustrates a modulator circuit arrangement according to one example of the invention, and

Figure 2 comprises waveforms explanatory of the operation of the circuit of Figure 1.

Referring to the drawing, it is assumed that the circuit arrangement of Figure 1 is employed to form the product of a first signal having a periodic sawtooth waveform such as shown at *a* in Figure 2 and a second signal having a periodic sawtooth waveform of widely different period such as shown at *b* in Figure 2. The circuit of Figure 1 comprises two hexode valves 1 and 2 which have their anodes inter-connected, and connected through an anode load resistance 3 to a source of positive potential indicated conventionally at 4. The cathodes of the valves 1 and 2 are connected by means of a common cathode resistance 5 to the negative terminal of a source of bias potential indicated at 6. The inner control electrodes of the valves are respectively connected by means of condensers 7 and 8 to opposite ends of the centre-tapped secondary winding 9 of a transformer to whose primary winding 10 the waveform *a* is applied. The waveform *a* is therefore applied in opposite phase in the inner control electrodes respectively. The centre tap of the winding 9 is connected to the

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positive terminal of the source of potential 6, while the inner control electrodes of the valves 1 and 2 are respectively connected via leak resistances 11 and 12 to the higher potential ends of bias resistances 21 and 22. These ends of the resistances 21 and 22 are inter-connected by a bias control resistance 20, an adjustable contact on which is connected to the positive terminal of the potential source 6, the other ends of the resistances 21 and 22 being connected to the negative terminal of the potential source 6. This arrangement of resistances allows differential variation of the bias applied to the respective inner control electrodes, thereby allowing correction for small differences in the characteristics of these electrodes. The outer control electrodes of the valves 1 and 2 are, similarly, connected via condensers 14 and 13 to opposite ends of the centre-tapped secondary winding 15 of a further transformer, whose primary winding 16 has applied to it the second waveform *b* so that the waveform *b* is applied in opposite phase to the outer control electrodes respectively. The centre tap of the winding 15 is connected to the positive terminal of the potential source 6 while the outer control electrodes are connected via leak resistances 17 and 18 to bias resistances 27 and 28 which are connected to the potential source 6 by means of a bias-control resistance 29 in the same way as the resistances 21 and 22. The bias applied to the control electrodes of the valves 1 and 2 is such that the valves remain conducting throughout the range of values which the waveforms *a* and *b* may take. The screen electrodes of the valves 1 and 2 are coupled as shown directly to the positive terminal of the potential source 4.

Let the waveforms *a* and *b* be denoted respectively by V_{g1} and V_{g3} and let i_0 be the unmodulated current in each of the valves 1 and 2. Then if the inner and outer control electrodes of the valves 1 and 2 have linear characteristics the modulated anode current i in the valve 1 would be

$i = i_0(1 + k_1 V_{g1})$ for variations of V_{g1} only, and $i = i_0 + k_3 V_{g3}$ for variations of V_{g3} only, in each case V_{g1} and V_{g3} being measured from the mean bias potential applied to the respective electrodes, and k_1 and k_3 being constants. Thus for variations at both control electrodes.

$$i = i_0(1 + k_1 V_{g1})(1 + k_3 V_{g3})$$

Similarly since the waveforms *a* and *b* are applied in reversed phase to the control electrodes of the valve 2, the modulated anode current i in the valve 2 would be

$$i = i_0(1 - k_1 V_{g1})(1 - k_3 V_{g3})$$

If the two modulated anode currents are then added as in Figure 1 the resultant output is

$$i_0(1 + k_1 V_{g1})(1 + k_3 V_{g3}) + i_0(1 - k_1 V_{g1})(1 - k_3 V_{g3}) = 2i_0(1 + k_1 k_3 V_{g1} V_{g3})$$

Therefore variations in the modulated anode currents which are dependent only upon V_{g1} and V_{g3} are balanced out irrespective of whether V_{g1} or V_{g3} are positive or negative in sign with respect to said mean bias value.

However, due to the curvature of the characteristics of the inner control electrodes of the valves 1 and 2 the added outputs would, in the absence of the cathode resistance 5, be distorted as shown at *c* in Figure 2. If, on the other hand, the cath-

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ode resistance 5 has a value which is much greater than

$$\frac{1}{g}$$

the total cathode current of the valves 1 and 2 would be maintained substantially constant, and assuming the outer control electrodes are maintained at a fixed potential relative to the cathode potential, variations in the outputs due to the curvature of the characteristics largely balance out. However, the waveform *b* is applied to the outer control electrodes with reference to a point of relatively fixed potential determined by the potential source 6, and consequently potential fed back to the cathodes of the valves 1 and 2 due to the resistance 5, has the same effect as a similar variation of opposite phase applied in push-push to the outer control electrodes. The variation in cathode potential during a period of the waveform *a* would be as indicated at *d* in Figure 2 and the final result, if the cathode resistance has a value much greater than

$$\frac{1}{g}$$

would be an anode current having a curvature component such as indicated at *e* in Figure 2, the curvature being of opposite phase to that which would be encountered in the circuit of Figure 1 in the absence of the cathode resistance 5. The cathode resistance 5 is therefore chosen such that the curvature in the combined outputs due to the non-linear characteristics of the inner control electrodes is only partly reduced and a curvature of opposite phase substantially equal to said reduced curvature is produced due to the effect of the potentials fed back by the resistance 5 on the waveform applied to the outer control electrodes. The combined outputs therefore approximate to the idealised waveform illustrated at *f* in Figure 2, which is the undistorted product of the waveform *a* and the waveform *b*, and can be obtained at the output terminal 19 and may be applied, for example, as described in United States patent applications Ser. No. 788,799, filed November 29, 1947 and Ser. No. 6053, filed February 3, 1948.

The value of the cathode resistance 5 will in general be of the order of

$$\frac{1}{g}$$

for example, between

$$\frac{1}{3g} \text{ and } \frac{3}{g}$$

In the example illustrated the waveforms are applied to the control electrodes of the valves 1 and 2 by way of centre-tapped transformers, but it will be understood that any other suitable means of applying push-pull inputs can be employed, such as valves with equal anode and cathode loads.

While the invention has been described as applied to forming the product of two periodic sawtooth waveforms, it may of course be applied to any waveforms of which it is desired to form a product.

I claim:

1. A modulator circuit arrangement for forming the product of two waveforms, said circuit comprising a pair of cathode coupled thermionic valves each having an inner control electrode and an outer control electrode, means for applying one waveform in push-pull between the inner con-

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5 trol electrodes of said valves and a point of substantially fixed potential, means for applying another waveform in push-pull between the outer control electrodes of said valves and said point, means for adding the anode currents in said valves and for generating an output signal proportional to the added currents, and an impedance connected effectively between the cathodes of said valves and said point and common to the inner control electrode circuits, the outer control electrode circuits and the anode circuits of said valves to compensate for curvature of the characteristics of said inner control electrodes, said impedance being proportioned to cause negative feedback to the inner control electrode circuits of said valves for partial compensation of said curvature and to cause negative feedback to the outer control electrode circuits of said valves for variation of the anode currents of said valves substantially compensating for the remainder of said curvature. 10 15 20

2. In a modulator circuit arrangement according to claim 1, said impedance comprising a resistance having a magnitude of the order of the reciprocal of the mutual conductance of said valves.

3. In a modulator circuit arrangement according to claim 1, said impedance comprising a resistance having a magnitude between one third and three times the reciprocal of the mutual conductance of said valves.

4. A modulator circuit arrangement for forming the product of a sawtooth waveform of one frequency and a sawtooth waveform of a substantially lower frequency, said circuit comprising a pair of cathode coupled thermionic valves each 35

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having an inner control electrode and an outer control electrode, a source of said first waveform, means for applying said first waveform in push-pull between the inner control electrodes of said valves and a point of substantially fixed potential, a source of said second waveform, means for applying said second waveform in push-pull between the outer control electrodes of said valves and said point, means for adding the anode currents in said valves and for generating an output signal proportional to the added currents, and an impedance connected effectively between the cathodes of said valves and said point and common to the inner control electrode circuits, the outer control electrode circuits and the anode circuits of said valves to compensate for curvature of the characteristics of said inner control electrodes, said impedance being proportioned to cause negative feedback to the inner control electrode circuits of said valves for partial compensation of said curvature and to cause negative feedback to the outer control electrode circuits of said valves for variation of the anode currents of said valves substantially compensating for the remainder of said curvature. 5 10 15 20 25

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