

April 8, 1958

J. E. RANKS

2,830,133

PHASE-INVERTING TRANSLATING CIRCUIT

Filed April 29, 1952

Fig. 1.

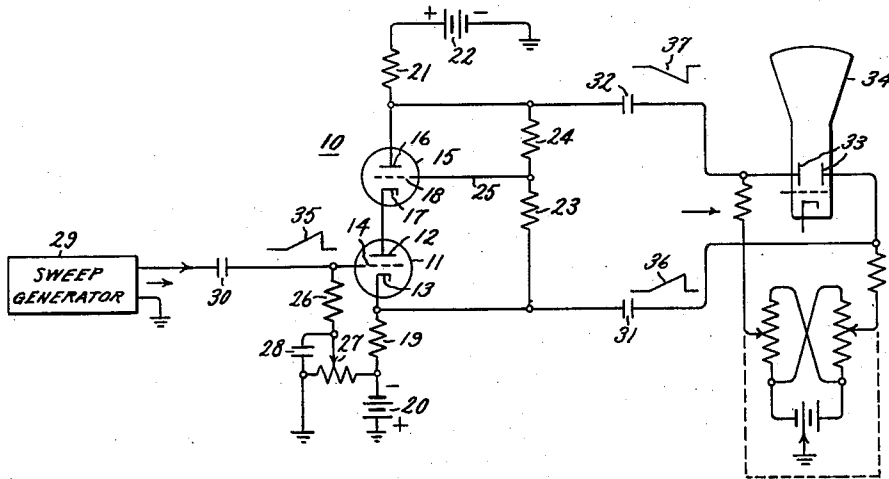
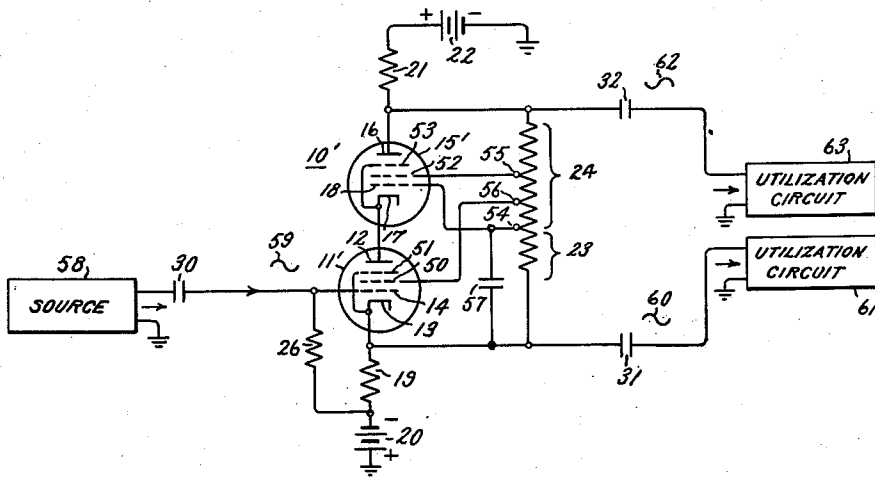


Fig. 2.



Inventor:
John E. Ranks,
by *Merton D. Morse*
His Attorney.

1

2,830,133

PHASE-INVERTING TRANSLATING CIRCUIT

John E. Ranks, Walnut Creek, Calif., assignor to General Electric Company, a corporation of New York

Application April 29, 1952, Serial No. 284,902

16 Claims. (Cl. 179—171)

My invention relates to translating apparatus and, more particularly, pertains to an improved circuit for deriving an undulating potential corresponding to an applied undulating potential, but inverted in phase. Such a circuit is especially useful in an application wherein from an unbalanced or single-ended source, i. e., one supplying an undulating potential having its alternating potential axis displaced from a plane of fixed reference potential, there is derived an undulating potential that is balanced relative to the reference potential. For convenience my invention will be described in that connection.

As used herein, the term "balanced" refers to an arrangement of the push-pull type in which a pair of undulating potentials of the same wave form are supplied to a utilization circuit with equal amplitude, but of opposite phase, at every instant of operation.

It is a general object of my invention to provide an improved phase-inverting translating circuit.

Another object of my invention is to provide a phase-inverting translating circuit which may be employed for effectively converting a single-ended source of undulating potential to a push-pull source and which affords output potential amplitudes greater than heretofore attainable.

It is a further object of my invention to provide a phase-inverting translating circuit incorporating a self-balancing feature for assuring a balanced output potential in response to an applied unbalanced input potential of variable amplitude.

Briefly stated, a phase-inverting translating circuit in accordance with my invention comprises first and second electron discharge devices each including an anode, a cathode and a control electrode. A common anode-cathode current path is provided for connecting the discharge devices in series. A cathode impedance for the first device and an anode impedance for the second device are included in this path. The circuit further includes another impedance having one terminal coupled to the cathode of the first device, another terminal coupled to the anode of the second device and a portion intermediate the terminals coupled to the control electrode of the second device. A control electrode-cathode circuit for the first discharge device is provided for applying an undulating input potential to that device, and an output circuit including the anode impedance, is provided for deriving an undulating output potential from the second device corresponding to the input potential, but inverted in phase.

The novel features, believed to be characteristic of the present invention, are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which:

Fig. 1 is a schematic circuit diagram of a phase-invert-

2

ing translating circuit constructed in accordance with my invention; and

Fig. 2 illustrates another embodiment of my invention.

With reference now to Fig. 1, there is shown, schematically, a circuit diagram of a phase-inverting translating circuit 10, constructed in accordance with the instant invention. It includes a first electron discharge device 11 having an anode 12, a cathode 13 and a control electrode or grid 14, and a second electron discharge device 15, having an anode 16, a cathode 17 and a control electrode 18. Cathode 13 is connected through a cathode impedance 19, preferably a resistor, to the negative terminal of a source of potential 20, the positive terminal of which is grounded. Anode 12 is directly connected to cathode 17, and anode 16 is connected through an anode impedance 21, also preferably a resistor, to the positive terminal of another source of potential 22, the negative terminal of which is grounded. Resistors 19 and 21 thus are included in a common anode-cathode current path for devices 11 and 15, which are thereby connected in series.

Another impedance included in the circuit is comprised of a pair of resistors 23 and 24 connected in series. The free terminal of resistor 23 is connected to cathode 13 of device 11, while the free terminal of resistor 24 is connected to anode 16 of device 15. A lead 26 extends from the junction of resistors 23 and 24 to control electrode 18 of device 15.

A control electrode-cathode circuit for discharge device 11 includes a resistor 26 extending between control electrode 14 and the variable tap of a potentiometer 27 connected in parallel with source 20. The tap of potentiometer 27 is by-passed to ground by a condenser 28. In order to apply an undulating input potential to device 11, a source 29, such as a generator of sawtooth or sweep waves, is coupled to control electrode 14 through a coupling condenser 30 and appropriate ground connections.

The output of translator circuit 10 includes cathode impedance 19 and anode impedance 21, and for deriving undulating output potentials therefrom, a pair of coupling condensers 31 and 32 extend from cathode 13 and anode 16, respectively, to a utilization circuit such as deflection plates 33 of a cathode-ray tube 34.

In constructing a translating circuit in accordance with the present invention, it has been found desirable to utilize electron tubes 11 and 15 which have essentially the same dynamic anode-cathode impedances and to have resistors 19 and 21 of substantially equal values. Also, the resistance value of resistor 24 should be slightly larger than that of resistor 23 to provide a suitable control grid-to-cathode bias potential for tube 15. However, in some applications, equal resistance values have been found to be satisfactory for resistors 23 and 24. A potentiometer 27 is provided in parallel with source 20 having a tap which is adjusted to provide a suitable grid-bias potential for tube 11.

In considering the operation of the circuit shown in Fig. 1, it is assumed that generator 29 supplies an undulating potential of sawtooth wave form, such as that represented by curve 35. As will be later seen, undulating output potentials from the translating circuit, in accordance with the invention, may be represented by sawtooth wave forms 36 and 37. It is further assumed that the undulating potentials applied to the input circuits of tubes 11 and 15 are not so large in magnitude as to effect grid current flow or anode current cut off. In other words, the tubes are operated essentially as linear devices.

From an inspection of Fig. 1 it is apparent that tube 15 is in an anode-load circuit for tube 11, and that tube 11 is in a cathode-load circuit for tube 15. Consequently, the anode-cathode current of these tubes must be the same, since there is no alternative current path,

Responsive to undulating potential 35, there is derived at load impedance 19 of tube 11, the sawtooth wave 36 which corresponds in phase to the applied wave 34. Because the anode-cathode current paths of tubes 11 and 15 are in series, the current variations which produce potential 36 also flow through resistor 21. Moreover, potential variations at anode 12, caused by the input wave, drive cathode 17 of device 15 in a direction to assist current variations in the series circuit. Hence, there is derived from anode load 21, the output voltage of wave form 37 corresponding to input wave 35, but of opposite phase.

Since the instantaneous current undulations in resistors 19 and 21 must be the same and the resistors are of equal value, the resulting instantaneous voltages applied to series resistors 23 and 24 are of equal amplitude, although of opposite phase. Consequently, from instant to instant, in each operating cycle, the potential applied to control grid 18 remains at a fixed value relative to ground.

Now it will be demonstrated that circuit 10 remains balanced at all times so that undulating potentials 36 and 37 of equal amplitude are supplied to load 33. For this analysis, let it be assumed for the moment that the impedance values presented by devices 11 and 15 are unequal, with that of device 11 the higher of the two. For such a condition to exist, the grid-cathode potential of tube 11 should be larger, in a negative sense, than the corresponding potential of tube 15. However, the anode-cathode current of these tubes must be equal and the resulting voltage drop between the anode and cathode of tube 11 should be correspondingly larger than that of tube 15. Hence, anode 12 (and cathode 17) must be more positive relative to grid 18 than originally assumed, i. e., the grid-cathode potential of tube 11 should be the larger in a negative sense, than that for tube 15 which is contradictory to the initially assumed conditions. It is evident then, that the initial assumption is invalid.

From the foregoing non-sequitur, it may be concluded that in operation, the grid biases for tubes 11 and 15 and their dynamic impedances are substantially equal at all times. With such a relationship, the output potentials 36 and 37, although of opposite polarity, have the same magnitude from instant to instant. If this latter condition does not hold true, and an unbalance does exist, for example, as a result in a shift of dynamic impedance of one tube, for example, due to large variations in input amplitude or tube aging, the resulting potential applied to cathode 17 is in a direction and of a magnitude to equalize the dynamic impedances and restore the balance condition.

It may be appropriate to point out that a change in static grid bias level in tube 11, effected by displacing tap 27, also alters the bias for tube 15. This is evident from the preceding discussion of dynamic operation, wherein it was shown that because the dynamic impedances of the tube must remain the same at all times, the grid biases must be equal.

Thus, it may be seen that in response to unbalanced saw-tooth wave 35, a push-pull undulating potential is supplied to deflection plates 33 of cathode ray tube 34. The alternating potential axis of this undulating voltage remains at a given reference value to provide a balanced wave for a variety of circumstances which, in conventional circuits, might cause an unbalance to occur.

In practice, it has been found that because tubes 11 and 15 are in series a total anode supply potential equal the sum of the maximum rated voltage for each tube may be employed and output amplitudes up to 100% greater than that available in a single tube, prior art, phase inverter circuit may be derived at each of impedances 19 and 21. Hence, it is evident that a phase-inverting translating circuit in accordance with my invention represents a material improvement over that prior art circuit.

The embodiment of my invention represented in Fig. 2,

provides a circuit amplification much nearer unity than that of the circuit illustrated in Fig. 1. Translating circuit 10', in accordance with the invention, is essentially like circuit 10 of Fig. 1 and similar elements are represented by the identical reference numerals. Instead of the triode type electrode tubes 11 and 15, pentode type tubes 11' and 15' are employed. These tubes include, in addition to the usual anode, control grid and cathode, a screen electrode or grid 50 and a suppressor electrode 51, in tube 11'; and a screen grid 52 and a suppressor grid 53 in tube 15'. Resistors 23 and 24 are represented as a single resistor having a tap 54, intermediate its end portions connected to control grid 18 of tube 15'. A tap 55 of resistor 23-24 intermediate tap 54 and the end portion thereof connected to anode 16 is connected to screen grid 52 of tube 15. Screen grid 50, of tube 11', is connected to a third tap 56 of resistor 23-24, disposed intermediate taps 54 and 55. The suppressor grids 51 and 53 of the tubes are connected to the respective cathodes thereof. A condenser 57 extends between control electrode 18 and cathode 13, and a pair of utilization circuits 58 and 59 are coupled to cathode impedance 19 and to anode impedance 21, respectively.

In constructing a signal-translating circuit 10, as shown in Fig. 2, the same considerations applied to Fig. 1 are carried out. In addition, taps 55 and 56 are adjusted to provide the required screen grid potentials for tubes 11' and 15', and the value of condenser 57 is chosen to compensate for tube and stray capacitances.

The operation of this embodiment of the invention generally follows that presented in connection with Fig. 1. A source 58 supplies an undulating potential, for example, of sine wave form 59, to the control grid circuit of tube 11'. In response to the applied wave, an in-phase undulating potential 60 is developed at impedance 19 and supplied to a utilization circuit 61. At the same time, an out-of-phase potential 62 is derived at impedance 21 and applied to another utilization circuit 63.

Condenser 57, as a result of its relationship in the circuit operates to balance out undesirable tube and stray capacitances, insofar as signal currents resulting from such capacitances are concerned. Specifically, such undesirable capacitances tend to reduce the amplitude of high frequency components in the translated undulating signal. By selecting the value of condenser 57 so that its impedance becomes low for these frequency components, potential variations are transferred from cathode 13 of tube 11' to grid 18 of tube 15'. The phase is such as to augment current variations in tubes 11' and 15' at the frequencies under consideration and thereby compensate any tendency toward a reduction in amplitude.

In addition to having the same advantages as enumerated for the circuit of Fig. 1, this embodiment of the invention is characterized by greater output single amplitudes, because of its near unity gain due to higher transconductance of the pentode-type tube. Moreover, a great degree of circuit isolation is afforded between load circuits 61 and 63 because of the added series capacitance provided by tube 15' as compared with prior single-tube circuits.

While particular embodiments of my invention have been shown and described, it is to be understood that various changes and modifications may be made without departing from this invention in its broader aspects, and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A phase-inverting translating circuit comprising first and second electron discharge devices each including an anode, a cathode and a control electrode, a common anode-cathode current path for said devices connecting said devices in series and including a cathode impedance for said first device and an anode impedance for said

5. A phase-inverting translating circuit comprising first and second electron discharge devices each including an anode, a cathode and a control electrode, a common anode-cathode current path for said devices connecting said devices in series and including a cathode impedance for said first device and an anode impedance for said second device, a first resistance having one of its

9. A phase-inverting translating circuit comprising first and second electron discharge devices each including an anode, a cathode and a control electrode, a common anode-cathode current path for said devices connecting said devices in series and including a cathode impedance

for said first device and an anode impedance for said second device, another impedance having a first terminal directly connected to said cathode of said first device and a second terminal directly connected to said anode of said second device and a portion intermediate said first and second terminals coupled to said control electrode of said second device, a control electrode-cathode circuit for said first device for applying to said first device an undulating input potential unbalanced relative to a plane of fixed reference potential, and an output circuit coupled to said cathode of said first device and to said anode of said second device for deriving an undulating output potential corresponding to said input potential, but balanced relative to said plane of fixed reference potential.

10. A phase-inverting translating circuit comprising first and second electron discharge devices each including an anode, a cathode and a control electrode, a common anode-cathode current path for said devices connecting said devices in series and including a cathode impedance for said first device and an anode impedance for said second device, another impedance having a first terminal directly connected to said cathode of said first device and a second terminal directly connected to said anode of said second device and a portion intermediate said first and second terminals coupled to said control electrode of said second device, a control electrode-cathode circuit for said first device for applying an undulating input potential to said first device, an output circuit including said anode impedance for deriving an undulating output potential from said second device corresponding to said input potential, but inverted in phase, and a capacitance having one terminal coupled to said cathode of said first device and another terminal coupled to said control electrode of said second device for compensating undesirable capacitances in said translating circuit.

11. A phase-inverting translating circuit comprising first and second electron discharge devices each including an anode, a cathode, a control electrode, and an additional electrode, a common anode-cathode current path for said devices connecting said devices in series and including a cathode impedance for said first device and an anode impedance for said second device, another impedance having a first end terminal directly connected to said cathode of said first device and a second end terminal directly connected to said anode of said second device, a first portion intermediate said first and second terminals coupled to said control electrode of said second device, a second portion intermediate said first portion and said second terminal connected to said additional electrode of said second device and a third portion intermediate said first and second portion coupled to said additional electrode of said first device, a control electrode-cathode circuit for said first device for applying an undulating input potential to said first device, and an output circuit including said anode impedance for deriving an undulating output potential from said second device corresponding to said input potential, but inverted in phase.

12. A phase-inverting translating circuit comprising first and second electron discharge devices each including an anode, a cathode, a control electrode, and a screen electrode, a common anode-cathode current path for said devices connecting said devices in series and including a cathode impedance for said first device and an anode impedance for said second device, another essentially resistive impedance having a first end terminal directly connected to said cathode of said first device, a second end terminal directly connected to said anode of said second device, a conductive connection extending from said control electrode of said second device to a first tap of said resistive impedance intermediate said first and second end terminals thereof, another conductive connection extending from said screen electrode of said second device to a second tap of said resistive impedance intermediate said second end terminal and said first tap thereof, still an-

other conductive connection extending from said screen electrode of said first device to a third tap of said resistive impedance intermediate said first and second taps thereof, a control electrode-cathode circuit for said first device for applying an undulating input potential to said first device, and an output circuit including said anode impedance for deriving an undulating output potential from said second device corresponding to said input potential, but inverted in phase.

13. In combination a first and second electron discharge device each including an anode, cathode and a control electrode, a common anode-cathode current path for said devices connecting said devices in series and including a cathode impedance for said first device and an anode impedance for said second device, another impedance having a first terminal directly connected to said cathode of said first device and a second terminal of said impedance directly connected to said anode of said second device and a portion intermediate said first and second terminals coupled to said control electrode of said second device, a control electrode-cathode circuit for said first device for applying an undulating input potential to said first device, a first output circuit including said anode impedance for deriving an undulating output potential from said second device corresponding to said input potential but inverted in phase, and a second output circuit including said cathode impedance for deriving an undulating output potential from said first device corresponding to said input potential.

14. In combination a first and second electron discharge device each including an anode, cathode and a control electrode, a common anode-cathode current path for said devices connecting said devices in series and including a cathode impedance for said first device and an anode impedance for said second device, another impedance having a first terminal directly connected to said cathode of said first device and a second terminal of said impedance directly connected to said anode of said second device and a portion intermediate said first and second terminals coupled to said control electrode of said second device, a control electrode-cathode circuit for said first device for applying an undulating input signal to said first device, means for deriving a first undulating output signal from said second device corresponding to said input signal but inverted in phase, and means for deriving a second undulating output signal from said first device corresponding to said input signal.

15. In combination a first and second electron discharge device each including an anode, cathode and a control electrode, a common anode-cathode current path for said devices connecting said devices in series and including a cathode impedance for said first device and an anode impedance for said second device, a control electrode-cathode circuit for said first device for applying an undulating input signal to said first device, another impedance having a first terminal connected to the junction of said anode impedance with said anode of said second device and a second terminal connected to the junction of said cathode impedance with said cathode of said first device, and a portion intermediate said first and second terminals coupled to said control electrode of said second device, means for deriving a first output signal from said cathode of said first device and means for deriving a second output signal from said anode of said second device.

16. In combination a first and second electron discharge device each including an anode, cathode and a control electrode, a common anode-cathode current path for said devices connecting said devices in series and including a cathode impedance for said first device and an anode impedance for said second device, a control electrode-cathode circuit for said first device for applying an undulating input signal to said first device, means for deriving signal variations from the anode of said second device, means for deriving signal variations from the

cathode of said first device, a resistance having first and second terminals and a third terminal intermediate said first and second terminals, means for applying said anode signal variations to said first terminal, means for applying said cathode signal variations to said second terminal, means coupling said third terminal to said control electrode of said second device, means for deriving a first output signal from said first terminal and means for deriving a second output signal from said second terminal.

References Cited in the file of this patent

UNITED STATES PATENTS

2,438,960 Blitz ----- Apr. 6, 1948
2,474,435 Moore ----- June 28, 1949

2,592,193
2,631,197

Saunders ----- Apr. 8, 1952
Vilkomerson et al. ----- Mar. 10, 1953

FOREIGN PATENTS

Great Britain ----- Apr. 17, 1935
Great Britain ----- July 22, 1938

OTHER REFERENCES

10 Text, Vacuum Tube Amplifiers by Valley and Wallam, Radiation Lab. Series 18, pages 440, 441, Fig. 11.23, October 1948.

Electronics, "Stable Instrument Amplifier" by Peter C. Sulzer, page 116, March 1950.