Dec. 23, 1941. W. J. ALBERSHEIM 2,267,690

PHOTOELECTRIC CELL CIRCUIT

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FIG. 1

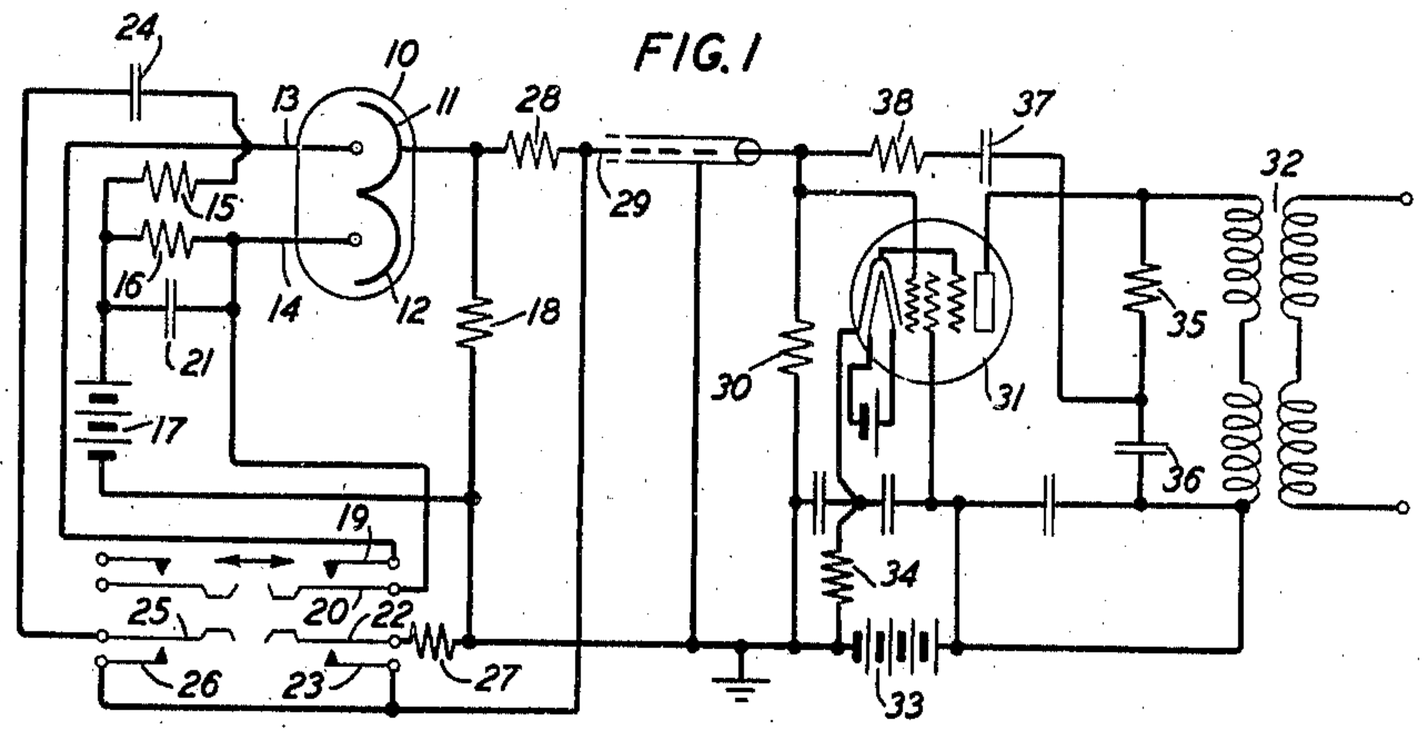
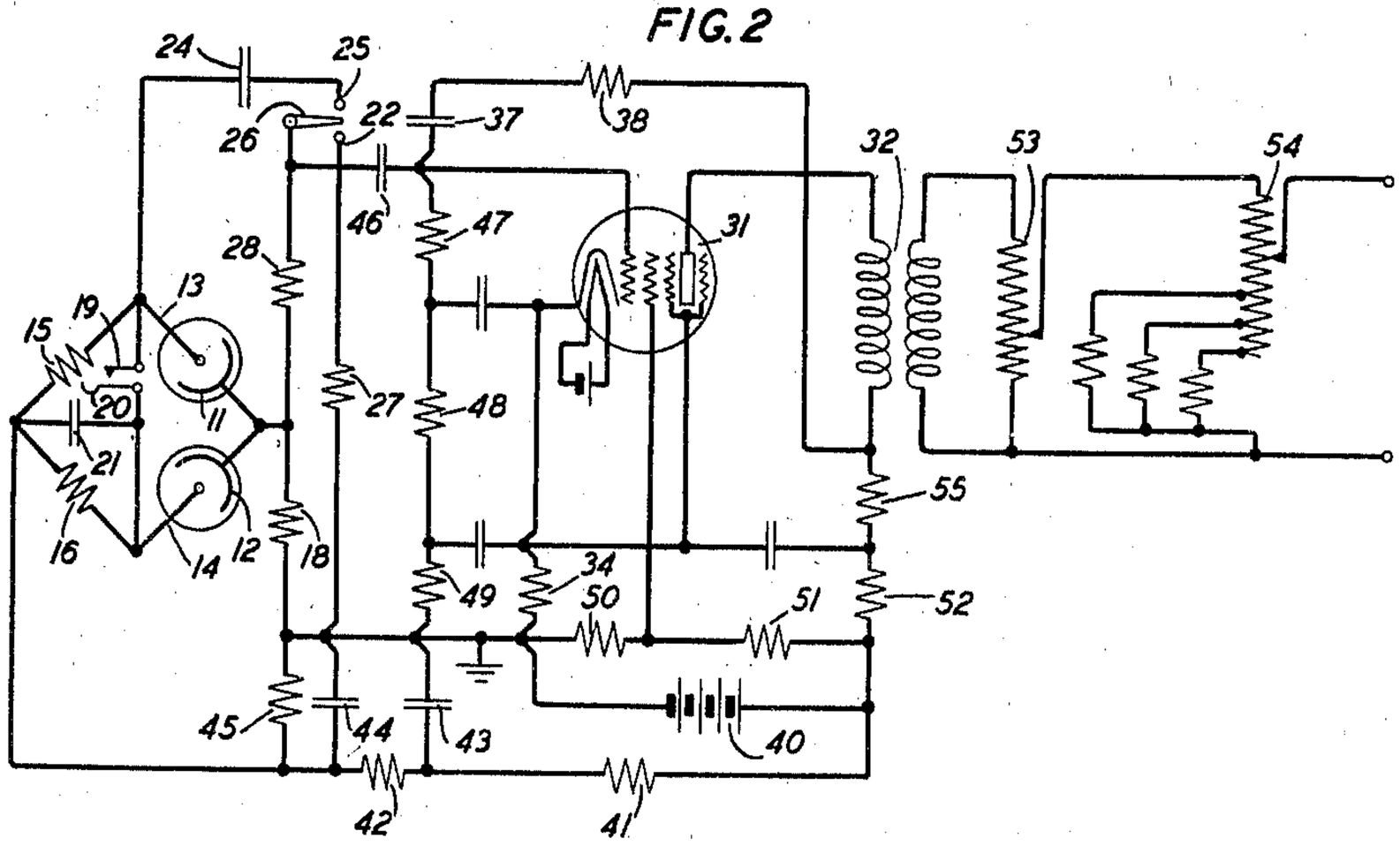


FIG. 2



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PHOTOELECTRIC CELL CIRCUIT

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This invention relates to photoelectric cell and amplifier circuits, and especially to apparatus employing such circuits for producing electric currents varying in accordance with sound recorded photographically upon a film.

When the sound is recorded in the form of two complementary records in opposed phase relation in a single track to form a push-pull sound record, two photoelectric cells, or photoelectric cell elements, must be employed, one for each complementary record. When the sound is recorded in the form of a single sound record, a single photoelectric cell may be employed, or two photoelectric cell elements in parallel.

The object of the present invention is an apparatus which will efficiently reproduce a push-pull film sound record and may be easily switched to efficiently reproduce a single sound record.

A feature of the invention is a resistance-capacitance coupling network for two independent photoelectric cells, or a double photoelectric cell in which either the anodes or the cathodes of the double cell are internally connected, which will accurately reproduce two complementary records so as to produce a true push-pull effect.

Another feature of the invention is a switching arrangement to change the network from push-pull operation to parallel operation without material change in the gain or frequency characteristic of the network.

A further feature of the invention is a network for coupling a high impedance device, such as a photoelectric cell, to another device, such as the input of a thermionic amplifier, through a transmission line of high capacitance, such as a shielded cable without material loss of the higher frequencies.

A further feature of the invention is a thermionic amplifier in which a portion of the output of the amplifier is fed back negatively in parallel relationship with the transmission line to reduce the apparent impedance of the input circuit of the amplifier attached to the line.

In the drawing:

Fig. 1 diagrammatically shows a photoelectric cell network and amplifier circuit according to the invention; and

Fig. 2 diagrammatically shows an alternative arrangement of the circuit.

In Fig. 1, the photoelectric cell 10 may have a double cathode 11, 12 and two anodes 13, 14 contained within a single envelope, or, as shown in Fig. 2, two separate cells may be used. The anode 13 is connected through resistor 15 to the positive pole of a source of polarizing potential 17, the anode 14 being similarly connected through the resistor 16 to the same source 17. The negative pole of the source 17 is connected through resistor 18 to the cathodes 11, 12. The resistors 15, 16 form with the photoelectric cell elements a bridge circuit.

The anode 13 is connected to a switch contact 19, and the anode 14 is connected to the other contact 20 of the switch. In reproducing a standard single record, the contacts 19, 20 are closed, connecting the anodes 13 and 14 together and the capacitor 21 across the resistors 15, 16. The switch contacts 22, 23 are also closed connecting the resistor 27 from the grounded side of the transmission line, through the switch contacts 22, 23 to the ungrounded side of the transmission line, thus reducing the apparent impedance of the photoelectric cells and network, as viewed from the transmission line, and making the transmission efficiency substantially the same as in the push-pull position.

The pulsations in the currents of the photoelectric cells 11, 13 and 12, 14 due to the variations in the light from the record are in phase, and produce like variations of potential across the resistors 15, 16 which are transmitted through capacitor 21 and source 17 to appear as a pulsating difference of potential across the resistor 18. The differences of potential developed across the resistor 18 are transmitted through resistor 28 to the terminals of resistor 27 which is in parallel relationship with the transmission line.

To convert the network for the reproduction of push-pull records, the contacts 19, 20 and 22, 23 are opened and the contacts 25, 26 closed, connecting the capacitor 24 from the anode 13 to the ungrounded side of the transmission line. The anode 13 is thus connected through capacitor 24 and resistor 28 to cathode 11, and anode 14 is connected through capacitor 21 and resistor 18 to cathode 12. If the light impressed upon the photoelectric cell 11, 13 increases, a current will flow from cathode 11 through resistor 28 and capacitor 24 to anode 13. If, at the same time, the light impressed upon the photoelectric cell 12, 14 decreases a similar amount, the current in the resistor 18 will decrease, which is equivalent to a current flowing from the anode 14 through capacitor 21 and resistor 18 to cathode 12. The voltage drops produced in the resistors 18 and 28 are thus in the proper direction to add together and produce a combined voltage across the transmission line. The voltages produced in the photoelectric cells, which, like the push-pull sound records, are opposed in phase are thus combined

to produce voltages across the transmission line which are in phase and a true push-pull action is produced.

The voltages developed across the resistor 27, or those developed across the resistors 18 and 28 are supplied through the transmission line 29, which may have the form of a shielded cable as shown, to the resistor 30 in the input of the amplifying device 31. The amplifying device 31 may be of any desired type, such as the suppressor grid pentode diagrammatically illustrated. The output of the device 31 is supplied through the output transformer 32, to any utilization circuit, such as a sound reproducer or rerecording device, further amplification being used if desired.

The source 33 supplies current through the transformer 32 to the anode of the device 31 and to the screen grid. The resistor 34 may be a conventional grid biasing resistor.

The resistor 35 and capacitor 36, in parallel relationship with the primary winding of the transformer 32 form a frequency discriminative voltage divider. A portion of the output voltage of the device 31 is thus fed back through the capacitor 37 and resistor 38 to the input circuit of the device 31, effectively in parallel relationship with the resistor 30. The effect of this feedback is to reduce the apparent impedance of the input circuit of the device 31 as viewed from the transmission line and thus reduce the loss at high frequencies. As the voltage fed back from the drop across the capacitor 36 decreases with increasing frequency the device 31 may be given a gain frequency characteristic which rises at the higher frequencies to further compensate for any losses. Thus, the complete circuit may have a gain-frequency characteristic which is substantially flat, or which rises at the higher frequencies as desired.

The coupling network in Fig. 2 is similar to the network in Fig. 1, and elements having similar functions in the figures have been similarly designated. In Fig. 2 separate photoelectric cells have been shown in place of the combined photoelectric cell shown in Fig. 1 and a simpler form of key is shown. It will be obvious that either type of cell or key may be used in either figure. The operation of the network in Fig. 2 is similar to the operation of the network in Fig. 1 as described hereinabove.

The source of power 40 may be a battery or a rectifier energized by an alternating current power supply. The series impedances 41, 42 and shunt capacitors 43, 44 filter out any noise or pulsations from the source of power. The bleeder resistor 45 stabilizes the voltage delivered from the source of power. Due to the capacitor 44, the resistor 45 has little effect upon the action of the photoelectric cell network, which is the same as described hereinabove in connection with Fig. 1.

The output from the network is applied through the transmission line and the series capacitor 46 to the resistors 47, 48 and 49 in series. The voltages developed across the resistor 47 are amplified by the amplifying device 31. A grid biasing potential is supplied by the resistor 34 and is filtered by the resistors 48, 49 and the associated capacitors. The resistors 50, 51 form a voltage dividing network for the screen grid of the device 31. The resistor 52 reduces the voltage supplied to the anode of device 31 and, with its associated capacitor, decouples the anode circuit and reduces undesired coupling effects.

The output of the device 31 is supplied through an output transformer 32, or other coupling device, to a transmission line, which may include an unbalanced attenuator 53, 54. The changes in the impedance of the attenuator 53, 54 will be reflected through the transformer 32 and will cause the voltage drop across the primary of the transformer 32 to change with changes in the setting of the attenuator. If the feedback voltage were derived from the voltage drop across the primary winding of the transformer 32, this effect would cause the feedback voltage to change materially with the changes in the attenuator 53, 54 or other similar device in the transmission line. The feedback voltage is therefore derived from the voltage drop in a resistor 55 intercalated in the anode circuit, and is supplied through resistor 38 and capacitor 37 to the input circuit of the device 31. The change in feedback voltage with change in the impedance of the output circuit is thus materially reduced.

In a practical embodiment of the invention as shown in Fig. 2 the various elements had the following values: A Western Electric 9A photoelectric cell was used with a Western Electric 479G key, resistors 15, 16 and 27 were 4 megohms, resistors 18 and 28 were 2 megohms, capacitors 21 and 24 were 0.01 microfarad, capacitor 46 was 0.02 microfarad, resistor 47 was 3 megohms, resistors 48 and 49 were 100,000 ohms, resistor 34 was 1,000 ohms, the amplifier 31 was a Western Electric 310A vacuum tube, resistors 41 and 42 were 50,000 ohms, resistor 45 was 100,000 ohms, capacitors 43, 44 were 8 microfarads, resistor 50 was 40,000 ohms, resistor 51 was 75,000 ohms, the source 40 was about 200 volts, resistor 52 was 45,000 ohms, resistor 55 was 20,000 ohms, resistor 38 was 1.5 megohms, capacitor 37, .001 or .02 microfarad, transformer 32 similar to the Western Electric 132C output transformer, attenuator 53 was a Daven FP–39 attenuator, and 54 was a Western Electric TA–4190 potentiometer, while the undesignated by-pass capacitors were about 0.5 microfarad. While specific details are given of one practical embodiment of the invention, the invention is not in any way limited to the values cited, but many other combinations of elements may be used and still be within the scope of the claims.

What is claimed is:

1. In a film sound reproducing system, a pair of resistors and a pair of photoelectric cell elements connected to form a bridge circuit, one set of similar electrodes of said cells being joined to a terminal of said bridge, a second pair of resistors connected in serial relationship, the junction of said resistors being connected to said set of similar electrodes, a source of polarizing potential connected from the free end of one of said second pair of resistors to the junction of said first pair of resistors, a capacitor connected from the said free end of said resistor to the junction of one of said first resistors and one pair of said elements, switching means for connecting the said junction of said first resistor and said element to the similar junction of the other of said first resistors and the other element or, at will, breaking said connections and connecting a second capacitor from the junction of the other of said first resistors and the other pair of said elements to the free end of the other of said second resistors, and a work circuit connected to the free ends of said second resistors.

2. In a film sound reproducing system, a bridge circuit having as adjacent arms the current paths of a pair of photoelectric elements,

and as opposite arms a pair of resistors in serial relationship, a second pair of resistors in serial relationship, the junction of said resistors being connected to the junction of said elements, a source of polarizing potential connected from the junction of said first pair of resistors to the free end of one of said second pair of resistors, a pair of capacitors connected respectively from the ends of a conjugate arm of said bridge to the free ends of said second pair of resistors and a transmission line connected to the free ends of said second pair of resistors, whereby excitations of said photoelectric elements in opposed phase produces voltages across said transmission line in the same phase.

3. Light sensitive apparatus comprising a pair of photoelectric elements in parallel relationship, a pair of resistors in parallel relationship connected in serial relationship with said elements, a second pair of resistors in serial relationship, the junction of said resistors being connected to similar electrodes of said elements, a capacitor connected from the other electrodes of said elements to the free end of one of said second pair of resistors, a source of polarizing potential connected from said free end to said first pair of resistors, a transmission line of relatively high capacitance connected to the free ends of second pair of resistors, a thermionic amplifying device connected to said line, means for feeding back a portion of the output of said device in reversed phase to said transmission line whereby the input impedance of said device is effectively decreased.

4. In combination, a source of signal currents having inherently a relatively high impedance, a transmission line having a relatively large shunt capacitance, a network for connecting said source to one end of said line, a thermionic amplifier having an input and an output circuit, means for connecting said line to the input circuit of said amplifier, and means for feeding back energy from the output circuit of said amplifier in shunt to the input circuit and transmission line, in such phase as to reduce the apparent impedance of the input circuit whereby the relative loss of high frequencies in said transmission line is materially reduced.

5. In a film sound reproducing system a bridge circuit having as adjacent arms the current paths of a pair of light sensitive elements and as opposite arms a pair of resistors in serial relationship, a second pair of resistors in serial relationship, the junction of said second pair of resistors being connected to the junction of said elements, a source of polarizing potential connected from the junction of said first pair of resistors to the free end of one of said second pair of resistors, a capacitor connected from one end of the conjugate arm of said bridge to said free end of said resistor, a transmission line connected to the free ends of said second pair of resistors, an amplifier connected to the other end of said line, switching means for connecting a second capacitor from the other end of said conjugate arm to the free end of the other of said second resistors, and, at will, breaking said connection and connecting both ends of said conjugate arm, and connecting a resistor across said transmission line, whereby the output of said network for equal illumination is substantially equal for both positions of said switching means.

6. A system for photoelectrically scanning balanced two track sound records, including in a circuit two light sensitive elements, one for each of said two sound tracks, means for connecting said two light sensitive elements as to direct current parallel to each other, with like polarities connected with each other, while connecting said light sensitive elements as to alternating current in opposition to each other and in series, said means including two serially arranged resistances, one for each said two light sensitive elements and arranged to combine the output of the same, a single amplifier tube, and means for directly connecting the outer ends of said two serially arranged resistances with said amplifier tube.

7. A system for photoelectrically scanning balanced two track sound records, including in a circuit two light sensitive means, one for each of said two sound tracks, means for connecting said two light sensitive means as to direct current parallel to each other, with like polarities connected with each other, while also connecting said light sensitive means as to alternating current in opposition to each other and in series, said means including two serially arranged resistances, one for each said two light sensitive means and arranged to combine the output of the same, a single amplifier tube, and means for directly connecting the outer ends of said two serially arranged resistances with said amplifier tube, said light sensitive means consisting of a photoelectric tube including within a vessel two separate anodes and a single cathode common to both said anodes.

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