June 15, 1937. G. T. FORD 2,084,135

AMPLIFIER CIRCUITS

Filed Nov. 21, 1935

FIG. 1

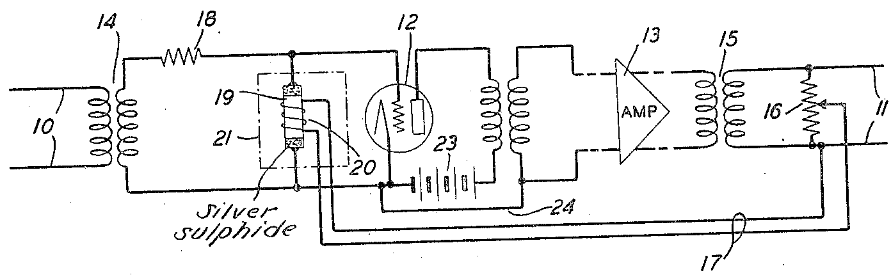
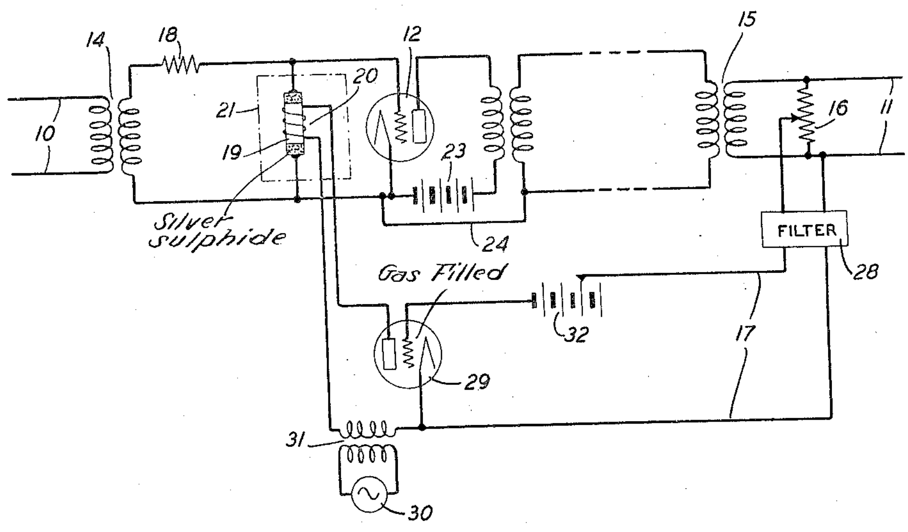


FIG. 2



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AMPLIFIER CIRCUITS

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3 Claims. (Cl. 179—171)

The present invention relates to the variable control of transmission through a circuit for signaling, indicating, and like purposes, and particularly to the use of thermosensitive material in such a circuit.

While not limited in its broader aspects thereto, the invention is especially concerned with the use of silver sulphide for current control purposes, this material having such a large temperature coefficient of resistance that resistance changes of the order of ten or one hundred or even more are readily obtained by variations in temperature within ranges that can be conveniently produced and controlled.

An object of the invention is to control the volume or amplitude of waves transmitted through an amplifier circuit under control of the output current by means of a thermosensitive element such as silver sulphide.

A related object is to control the gain of an amplifier circuit in a simple manner independently of any control of amplifier tube characteristics.

Other objects and the various features of the invention will appear as the description proceeds.

Silver sulphide is noteworthy for its large negative temperature coefficient of resistance, the resistance-temperature relation for this material being given by the equation

$$R = R_0 e^{-.05t}$$

where

R_0 is the resistance at $t=0$ and

t is the temperature on the centigrade scale.

This relation holds for temperatures up to about 179° C. at which point the resistance suddenly falls by a factor of about 40 with further increase of temperature of about one degree. A practical notion of the size of the coefficient for this material may be had from considering that the resistance of a sample of silver sulphide is substantially divided by 2 by a temperature rise of about 14° C. within the temperature range indicated above. The characteristics of the material are such that large factors of resistance change can be obtained in the vicinity of room temperature and higher temperatures without having to go to excessive temperature levels. Resistances composed of this material may be obtained by compressing chemically pure silver sulphide powder at a sufficiently high pressure to form a compact body, for example, 16,000 pounds per square inch or by immersing a silver wire in saturated vapor of boiling sulphur for a sufficiently long time to convert the silver entirely to silver sulphide. Terminals can be secured to the block or wires so formed by brightening the ends of the material and soldering or tinning leads to the sample. Silver sulphide is unstable when subjected for considerable periods to direct current but has stable and reproducible characteristics when used with alternating current.

The nature of the invention will be more fully comprehended from the following detailed description of specific embodiments as illustrated in the attached drawing forming a part of the specification.

In the drawing:

Fig. 1 is a schematic circuit diagram of a volume or amplitude control circuit embodying the invention; and

Fig. 2 shows a modified circuit of the same general nature.

Referring to Fig. 1 the line **10** may be a telephone line or a circuit used for the transmission of any other desired type of signal that is to be amplified by the amplifier comprising stages **12** and **13**, and the output circuit or line **11** may also be a telephone line or may lead to any suitable type of receiver or reproducer. The signals incoming over line **10** are transferred through input transformer **14** to the grid or input circuit of first stage tube **12** from which the output waves are transferred to subsequent stage or stages **13**, if more than a single stage of amplification is used, and the final output waves are transferred through output transformer **15** to circuit **11**. The cathodes of the different stages are preferably interconnected by wire **24**. Space current source **23** is provided for stage **12**.

The input or grid circuit of stage **12** comprises high resistance **18** and potentiometer resistance **19** comprised of silver sulphide or other material of suitably high temperature coefficient of resistance. The waves received from line **10** through input transformer **14** set up a current flow in the circuit including the secondary of input transformer **14** and resistances **18** and **19** in series. The drop of potential appearing across resistance **19** is applied to the grid circuit of the amplifier **12**.

The silver sulphide resistance **19** is preferably included in a heat chamber **21** in which there is also placed a heating coil **20**, the terminals of which are connected by circuit **17** to suitable points on resistance **16** connected across the output circuit **11**. The arrangement of the elements **19**, **20** and **21** may be very simple and compact and, if desired, the inclosure **21** may be omitted entirely. For example, in one case used by applicant the heater element **20** consisted of a coil of No. 46 insulated nichrome wire wound directly on a sample of silver sulphide with no inclosing chamber 21. If it is desired, however, to control the rate of heat dissipation a heat insulating inclosure 21 may be provided.

In operation, a portion of the output current in resistance 16 is led through circuit 17 to the heater 20, which raises the temperature of the silver sulphide resistor 19, reducing its resistance and hence tending to decrease the signal voltage applied to the grid circuit of the amplifier 12. With a fairly constant amount of applied wave from the circuit 10 a state of equilibrium is reached in which the rate at which heat is lost to the surroundings of resistance 19 equals the rate at which heat is supplied to resistance 19 from heater 20. If for any reason the amplitude of the output current tends to increase, more current is fed back through the circuit 17 to the heater 20 thus raising the temperature of resistor 19 and lowering its resistance so that a smaller proportion of the input wave is applied to the grid circuit of the tube 12 thus tending to lower the output wave amplitude. If, on the other hand, there is a tendency for the amplitude of the output wave to fall, less heating current is supplied to the resistor 19 so that its temperature falls, its resistance rises, and a larger proportion of the input waves are applied to the grid circuit of tube 12.

In this way the circuit as a whole tends automatically to maintain a constant output level or with a different adjustment of the circuit the total range of output amplitude is reduced below the range that would be obtained without the control circuits 17, 19 and 20.

It will be noted that the gain control action that has been described takes place without changing the grid bias or any of the other fixed potentials of the amplifier 12. Any suitable type of grid bias (not shown) may be used for the tube 12 and any suitable type of tube may be used. Electrically, the control is similar to that obtained by a potentiometer with a sliding contact in the grid circuit of the amplifier 12 but the circuit of Fig. 1 avoids the use of a sliding contact or any other mechanically movable part.

By controlling the physical size of the elements 19 and 20 and the heat characteristic of the heat chamber 21 (if a heat chamber is used), the rapidity of operation of the volume control circuit may be varied within wide limits. For example, it may be rendered insensitive to any except slow changes in the transmitted wave or it may be made responsive to changes approximating instantaneous amplitude changes of the transmitted waves. In the latter case, the circuit reduces portions of the wave of excessive amplitudes or peaks.

The circuit of Fig. 2 is, in general similar to that of Fig. 1 except that the circuit 17 includes a valve 29 of any suitable type illustrated as a three-electrode gas-filled or "trigger" tube. This tube is supplied with alternating current voltage from any suitable alternating current source 30 preferably through a transformer 31. The grid or input circuit of valve 29 includes a biasing battery 32 preferably adjustable.

In the operation of the circuit of Fig. 2 the bias voltage in the tube 29 may be set so that the amplitude control circuit does not come into operation until the amplitude of the waves in the output circuit 11 exceeds a predetermined minimum value as determined by the adjustment of the bias voltage 32 or the adjustment of the slider on resistance 16, or both. When the amplitude of the waves in the circuit 11 exceeds the minimum value referred to, the voltage of the grid of tube 29 is driven sufficiently positive to cause the tube to discharge during positive half waves of the plate potential and send current through the heater 20 thus lowering the resistance of the silver sulphide potentiometer 19 and reducing the amplitude of waves applied to the grid of the tube 12. This action continues so long as the amplitude of the output wave in circuit 11 is sufficient to drive the grid of the valve 29 positive, or in the positive direction, far enough to permit discharge of the tube. A filter 28 may be provided in circuit 17 to permit waves of only certain frequencies to control the discharge of the valve 29. For example, in the case of a radio receiver, filter 28 may be designed to pass the carrier frequency but not the side-bands so that the gain control is exercised by the carrier wave of the broadcasting station and a change in the strength of the carrier wave is compensated by an appropriate change in the resistances 19 such that the output signal waves and circuit 11 remain constant.

Various modifications within the spirit and scope of the claims will occur to those skilled in the art in view of the two illustrative forms that have been given.

What is claimed is:

1. A voltage limiting circuit comprising an amplifier having input and output circuits, a silver sulphide resistor in the input circuit, a heater winding associated in heat transfer relation with said resistor, said heater winding being connected to the output circuit of said amplifier whereby output current flows through the heater winding and varies the temperature of said resistor and a valve included in the circuit of the heater winding, biased to permit output current only in excess of a predetermined amplitude to cause current to flow in the heater winding.

2. In a speech transmission system, an amplifier for amplifying speech waves, having an input circuit and an output circuit, a temperature sensitive resistor connected in the input circuit having a heating element, a circuit for passing a portion of the amplified speech waves in the output circuit through said heater element to control the resistance of said temperature sensitive resistor, the physical dimensions of said resistor and heating element being so small and the heat dissipating factor being so large that the resistance changes of said resistor follow the envelope of speech waves, whereby portions of the speech wave of greatest amplitude are effectively reduced.

3. In combination, an amplifier for signal waves comprising an input circuit and an output circuit, a resistor having a temperature coefficient of resistance included in the input circuit, a heater element for varying the temperature of said resistor to control the amplitude of signal waves impressed on the amplifier input, a gas-filled space discharge device having a grid or control element, a source of alternating current connected to the discharge terminals of said device in series with said heater element, a circuit coupling the grid of said device to the output circuit of said amplifier, and a source of bias voltage in the grid circuit of said device.

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