

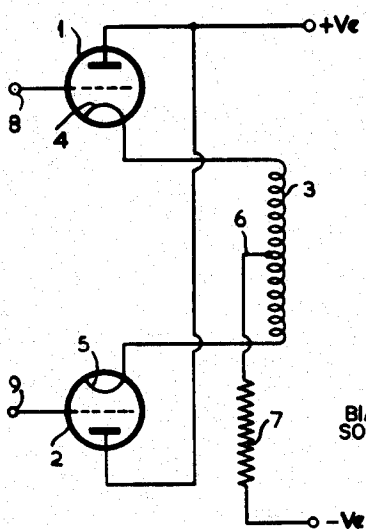
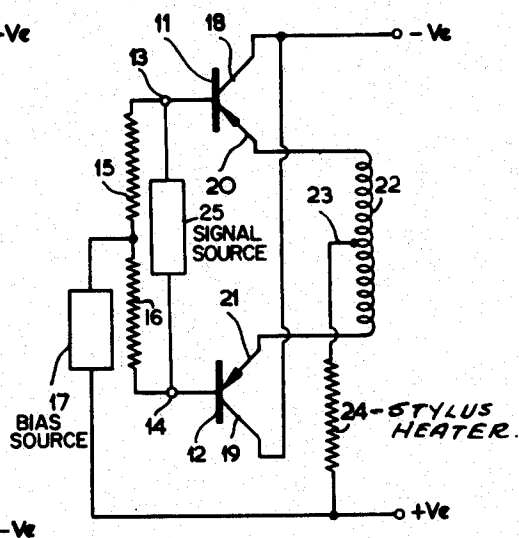
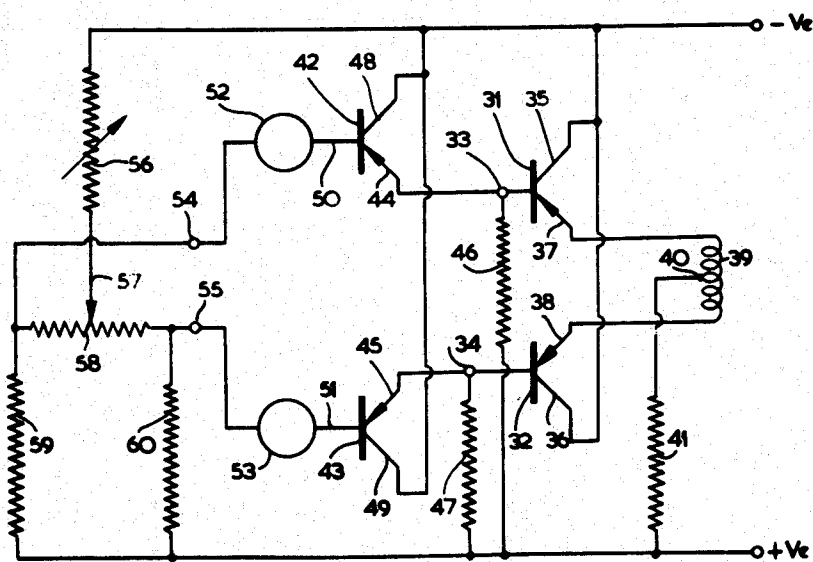
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J. E. RICH

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AMPLIFIER FOR ELECTRICALLY HEATED STYLUS

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INVENTOR
JOHN EDSALL RICH

BY

Frank R. Injari
AGENT

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AMPLIFIER FOR ELECTRICALLY HEATED STYLUS

John Edsall Rich, West Wickham, England, assignor to
North American Phillips Company, Inc., New York,
N.Y., a corporation of Delaware

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The invention relates to electric circuit arrangements, for example, electric amplifiers, and is particularly but not exclusively concerned with such amplifiers when used in conjunction with an indicating instrument, for example, electro-cardiographs and like electro-biological equipments wherein small voltages available at the surfaces of, or at points in, living bodies are caused to be amplified and thereby to affect an indicator in response to said voltages.

Hitherto, commercially available equipment of this type has used thermionic valve amplifiers, usually adapted to operate from A.C. mains. In such an equipment there is an output stage which operates an indicating device having a recording stylus adapted to produce a trace on a paper or like chart. It is desirable that the indicating device should have a frequency response extending from D.C. to an upper frequency limit, which for electrocardiography would be of the order of 50 cycles per second. The natural resonance frequency of the indicating device will be within its frequency response range and in order that this resonance shall be satisfactorily damped, we have been accustomed to operate the output stage in so-called class "A," the internal resistance of the output stage providing at least part of the damping. Class "A" operation is necessary to enable the damping to be substantially constant. This will occur provided the signal variations are not so high as to cause overload of the output stage.

Referring to FIGURE 1 we have found that with a valve operated amplifier it was convenient to use a pair of similar valves 1, 2 in a push pull class A cathode follower circuit with the operating coil 3 of the indicating instrument connected between the two cathodes 4, 5 and the centre tap 6 of this coil being connected in series with a bias resistance 7 through which the combined cathode currents flowed. Signal voltages are applied differentially between control grids 8, 9; grid connections are not shown. It has been found that when transistors are substituted for valves a similar circuit is of advantage. When transistors of the type currently available are used the voltage supply source may have a voltage of the order of twelve volts and since the overall power requirements of transistors are less than with valves it becomes possible to have a battery operated, yet quite portable, electrocardiograph or like amplifier.

We have found however that a transistor circuit will operate in an improved manner if the resistance corresponding to 7 in FIGURE 1 has a proportionally higher value than that used with a valve circuit. Thus whereas with a valve circuit the D.C. voltage across this resistance would be only a small fraction of the D.C. voltage between anode and cathode of the output valves, with the corresponding transistor circuit we have found the D.C. voltage across the resistance may with advantage be made equal to or even slightly greater than the D.C. voltage across the collector and emitter of the transistors. The improvements which occur with a transistorized output stage and a high resistance (which will now be referred to as an equalizing resistance) are as follows.

Firstly this resistance effects a more accurate equalization of the power amplification provided by each of the output transistors.

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Secondly, overload of the transistors due to excessive signal input to the base electrodes is prevented because under these conditions one transistor will be cut off while the other is conducting, and the equalizing resistance will then no longer act in an equalizing capacity but will introduce a high degree of negative feedback in the base-emitter circuit of the conducting transistor. This feedback limits the effective signal input to the conducting transistor at the level existing when the other transistor becomes cut off. This arrangement is also a safeguard against excessive movement and possibly damage to the pointers and stylus of the indicating instrument.

Thirdly, the average standing current of the two output transistors is maintained substantially constant for all signal levels in the recording range i.e. before overload occurs. As a consequence the above-mentioned damping provided for the resonant elements of the indicating instrument is also maintained substantially constant.

Fourthly, the high value of equalizing resistance prevents "thermal runaway" of the transistors occurring when their temperature is appreciably disturbed. This is because the said resistance produces an automatic bias voltage of high value which tends to suppress increase of current in both the transistors. Generally the equalizing resistance exerts a stabilizing action in the circuit.

The price to be paid for these improvements resulting from the high value of equalizing resistance is a high power loss in this resistance, which power loss is significant with a battery operated equipment. It will be appreciated that furthermore this power loss which is due to the product of a substantially constant current and voltage serves no useful purpose, requires a high wattage resistance to accommodate the heat generated and may require special measures to dissipate this heat, the power dissipation being of the order of four watts.

One type of indicating device uses a heated stylus carried by the pointer, together with a heat sensitive chart. The heating power for such a stylus may be of the order of four watts. In order that such heating power may be adjustable to vary the intensity of the marked trace a variable resistance is customarily used in series with the stylus heater and the supply source. This variable resistance also consumes power which can be comparable with that consumed by the stylus and has therefore to be of substantial power rating.

A further power loss occurs when the amplifier preceding the transistorized output stage incorporates thermionic valves. The heating power for the cathodes of such valves becomes appreciable if conventional indirectly heated cathode valves are used, and in the case of two such valves the power required may be of the order of four watts.

Thus in an equipment of the type described having an output stage incorporating transistors, there are high power losses involved in the heated stylus and its control resistance, and in certain thermionic valve heaters (if thermionic valves are used) and an equalizing resistance is required to be present which can accommodate relatively high powers.

According to the present invention an electric circuit arrangement includes a device dependent for its operation on electric heating and in co-operative relationship with a transistor or transistors, the electric heater of said device being adapted to be heated by at least part of the emitter-collector current of said transistor or transistors.

According to an embodiment of the invention a pair of transistors are connected in a push-pull output stage, the electric heater of the device being adapted to be heated by at least part of the combined emitter-collector currents of the pair of transistors.

According to a preferred embodiment the equalizing

resistance of a transistorized push-pull emitter follower output stage is constituted by the heater resistance of a stylus and/or a thermionic valve. When only the stylus heater is so arranged means may be provided for varying the heating power in said resistance by varying the base-emitter bias voltage of the transistors in said output stage.

In order that the invention may be more clearly understood reference will be made to the accompanying drawing in which FIGURE 1 shows a push pull class A cathode follower output circuit using valves, FIGURE 2 shows a basic transistorized output stage and FIGURE 3 shows a preferred development. FIGURE 1 has already been referred to above.

In FIGURE 2, 11 and 12 are transistors arranged as push-pull D.C. amplifiers having signal derived voltages applied differentially between the base terminals 13, 14 from a differential signal source 25. D.C. bias currents are applied to base terminals 13, 14 through resistances 15, 16 from source 17. Collectors 18 and 19 are commoned and returned to a negative direct voltage, for example of 12 volts. Each of the emitters 20, 21, is taken to the operating coil of a moving coil indicating device 22 which is centre tapped at 23 and connected through equalizing resistance 24 to the positive pole of the battery. The resistance 24 is constituted by the heater resistance of the stylus carried by the pointer actuated by coil 22. The mechanical details of the pointer and stylus are not shown.

The average D.C. emitter-collector current in the transistors is adjusted to allow during recording of signals and without distortion thereof, a peak deviation of the pointer of the indicating instrument across the full width of the recording chart. The combined average D.C. current for both transistors flows through stylus heater resistance 24 which is arranged so that the combined currents provide a suitable amount of heat for the stylus so as to effect a suitably defined trace on the recording chart during said full width deviation.

When the maximum deviation of the pointer is not across the full width of the chart it is possible that the heater power supplied to the stylus may be excessive and produce too intense a trace, and in order that the heating power may be reduced the base bias of transistors 11 and 12 is suitably modified, by adjustment of bias source 17 so that the current in resistance 24 is then at a lower value.

Assuming that the amount of heat required by the stylus is proportional to the pointer deviation, then the lower operating currents of the transistors 11 and 12 can of course still accommodate the lower value deviation without amplitude distortion occurring while still providing adequate heat to the stylus. This is because the heat produced by the stylus is proportional to and falls as the square of the operating current whereas the limit of permissible deviation without distortion falls with the first power of the current. Thus if the heating power of the stylus is adequate when the current is adequate for distortion-free deviation across the full width, there cannot be distortion when the heating power is reduced to correspond with smaller deviations.

A further advantage of the connection of stylus heater resistance 24 as shown in circuit of FIGURE 2 is that the two transistors give a degree of stabilization of the power supplied to the heater, provided the base bias voltage of the two transistors is maintained substantially constant. This stabilization is valuable as it can prevent the effects of variations in transistor characteristics, for example those due to temperature.

FIGURE 3 shows a preferred push-pull circuit including an output stage together with a push-pull driver stage and is intended to show a method of controlling the current through the equalizing resistance and also a method of varying the currents in the two output transistors to effect "shift" of the pointer of the indicator.

In FIGURE 3, 31 and 32 are transistors arranged as push-pull D.C. amplifiers having signal drive voltages applied differentially between base terminals 33, 34. Collectors 35, 36 are connected to the negative pole of a battery. Emitters 37, 38 are each taken to an end of the operating coil of a moving coil indicating device 39 the centre tap 40 of which is connected through equalizing resistance 41 to the positive pole of the battery. Resistance 41 is constituted by the heater resistance of a heated stylus.

The signal drive voltage for the base-electrodes of each of transistors 31, 32 is derived from respective driver transistors 42, 43 arranged as emitter-follower stages. Thus corresponding emitters 44, 45 are connected to base electrodes 33, 34. There are also emitter load resistances 46, 47 returned to the positive battery terminal. Collectors 48, 49 are connected directly to the negative battery terminal. Base electrodes 50, 51 have voltages applied from two sources (a) from signal sources 52, 53 which act differentially with respect to the base electrodes and (b) from a bias voltage circuit now to be described. This circuit produces two distinct bias voltages negative with respect to positive battery terminal, at points 54 and 55.

These bias voltages are derived from a potentiometer network across the battery terminals, which consists of a variable resistance 56 connected between the negative battery terminal and the slider 57 of a potentiometer 58 the ends of which are connected to points 54, 55; resistances 59, 60 respectively are connected from the potentiometer ends to the positive battery terminal. Variation of resistance 56 effects a variation of the bias voltage at points 54, 55 each in the same sense. In consequence the potentials at base electrodes 33, 34 follow this variation due to emitter follower action of transistors 42, 43.

The potentials at emitters 37, 38 also follow the potentials at their corresponding base electrodes 33, 34. Since these potential changes are in the same sense and of the same amount for each transistor, the sum of the emitter currents of each changes, but the difference between the emitter currents remains the same. Accordingly, the indicator coil 39 does not produce a pointer movement during these changes. However, the combined emitter currents flow through resistance 41.

Thus resistance 56 serves to determine the current in resistance 41 and since this is the heater of a stylus the heat developed therein is under the control of resistance 56; resistance 56 only requires small power dissipation in itself, as it only has to influence the current in base electrodes 50, 51 (which may be of the order of micro-amperes).

Potentiometer 58 when its slider 57 is moved, serves in similar manner to control the static deflection or shift of the pointer of the indicating instrument. This is achieved by differentially changing the emitter currents of the transistors 31, 32 through the emitter follower action of transistors 42, 43. The combined emitter currents of emitters 37, 38 remain constant during such control and accordingly the heating of resistance 41 is unaffected by movement of slider 57. Here again potentiometer 58 may be a low power dissipation device.

Resistance 56 and potentiometer 58 therefore have, independently of one another, control over stylus heating and pointer shift respectively. It will be appreciated that the heating current and shift currents are to a large extent established at the values determined by the setting of resistance 56 and potentiometer 58, provided that the battery voltage does not change, even though the transistors 42, 43 and 31, 32 may undergo variations due to temperature or other effects: this is because of the emitter follower action of these transistors.

What is claimed is:

1. An electric circuit arrangement including a device dependent for its operation on electric heating, said device comprising a coil and an electrically heated stylus,

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an amplifier comprising two transistors each having base, emitter and collector electrodes, said transistors being connected in push-pull arrangement, means for applying an input signal to the transistor bases, supply voltage means connected to the collectors, a load circuit connected between the emitters, said load circuit comprising said coil and being provided with a center-tap, and a resistor connected between said center-tap and the ground point of said input, said resistor being constituted by said electrically heated stylus, whereby said stylus performs the dual function of providing a high equalizing resistance for the push-pull connected transistors and heat for the operation of the device.

2. An electric circuit arrangement including a device dependent for its operation on electric heating, said device comprising a coil and an electrically heated stylus, an amplifier comprising two transistors each having base, emitter and collector electrodes, said transistors being connected in push-pull arrangement, means for applying an input signal to the transistor bases, means for supplying bias current to said bases, supply voltage means connected to the collectors, a load circuit connected between the emitters, said load circuit comprising said coil and being provided with a center-tap, a resistor connected between said center-tap and the ground point of said input, said resistor being constituted by said electrically heated stylus, whereby said stylus performs the dual function of providing a high equalizing resistance for the push-pull connected transistors and heat for the operation of the device, and means for simultaneously adjusting the

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bias current of each transistor in the same sense, thereby effecting variation of the stylus heater current, said means comprising a push-pull transistor driven stage for said amplifier, the collectors of the driven stage transistors being connected to said supply voltage means, the emitters of the driven stage transistors being connected to the bases of the amplifier respectively, and a potentiometer network connected across the supply voltage terminals, said network comprising a potentiometer having two fixed ends and a sliding contact, the two fixed ends being coupled respectively to the two bases of the driven stage transistors, the sliding contact being coupled to one end of said source through a variable resistor, each of the two fixed ends of the potentiometer being connected to the other end of said source through a resistor.

3. An electric circuit arrangement as claimed in claim 2, further comprising additional bias current adjusting means for adjusting the bias current of the two transistors in opposite senses.

References Cited in the file of this patent

UNITED STATES PATENTS

2,644,738	Gardner	July 7, 1953
2,691,075	Schwartz	Oct. 5, 1954
2,761,917	Aronson	Sept. 4, 1956
2,812,393	Patrick	Nov. 5, 1957
2,846,526	Moore et al.	Aug. 5, 1958
2,859,402	Schaeve	Nov. 4, 1958
2,874,233	Guyton et al.	Feb. 17, 1959
2,932,714	Merrill	Apr. 12, 1960