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PATENT SPECIFICATION

DRAWINGS ATTACHED

846,131



Date of Application and filing Complete Specification May 6, 1957.

No. 14362/57.

Application made in United States of America on May 15, 1956.

Complete Specification Published Aug. 24, 1960.

Index at acceptance:—Class 40(6), T(1A2:1A3:1A5:1R:2P:2T2:2T3J:2T4:4A1).

International Classification:—H03f.

COMPLETE SPECIFICATION

Automatic Gain Controls for Radios

9 We, TEXAS INSTRUMENTS INCORPORATED, of 6000 Lemmon Avenue, Dallas, Texas, United States of America, a corporation organized and existing under the Laws of the State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

10 This invention relates to electrical amplifier circuits and more particularly to electrical amplifying circuits using semiconductor devices and suitable for use in radio receivers.

15 While semiconductor devices can be made to function to a certain extent like vacuum tubes, the analogy between the two is in no sense complete, and many difficulties are encountered in adapting vacuum tube circuits to operate with transistors. In most cases, in fact, complete redesign of the circuit becomes inevitable.

20 One particular difficulty, that has been encountered in the use of semiconductor devices to perform functions previously performed by vacuum tubes, has occurred in the previous attempts to design amplifier circuits using transistors and capable of amplifying incoming signals having a wide range of amplitudes.

25 In an n-p-n transistor, for example, it is common to introduce the signal to be amplified to the emitter of the transistor and to bias this emitter for normal amplification to a potential of 0.1 to 0.2 volts negative with respect to the potential of the base. When the amplitude of the incoming signals begins to reach this order of magnitude, serious distortion results both in the input stage of the amplifier and in the stages that follow. Automatic volume control may be applied to the input stage to reduce the bias between the emitter and the base, and thus reduce the amplification of the input stage and avoid over-loading the following stages, but this

causes clipping and more serious distortion in the input stage.

50 An object of this invention, therefore, is to provide a means for preventing overloading and distortion, not only in the subsequent stages of an amplifier, but also in the initial stage, and at the same time to minimize distortion as a result of so doing.

55 The invention may be utilized to prevent the overloading of either the first or any subsequent stage of an amplifier, but the particular value and importance of this invention lies in protecting the first stage of a semiconductor high frequency amplifier from overloading without at the same time introducing serious distortion. In this connection, it should be pointed out that the second or subsequent stages of the amplifier may be either transistor stages or vacuum tube stages, and in either case the invention will be useful. However, again, because of the particular nature of semiconductor amplifiers, the invention is especially useful where the subsequent stages of amplification are of the semiconductor type.

60 According to the invention a radio receiving system is characterised by a signal circuit which includes a tuned circuit comprising a parallel-connected inductor and capacitor, at least one plural electrode semiconductor device having its input connected to said signal circuit to provide the first high frequency amplifier stage of a semiconductor amplifier, and a semiconductor diode connected across at least a portion of said tuned circuit to attenuate high amplitude signals by increasing the damping of said tuned circuit.

65 It has been found possible to attenuate the excess amplitude of high level input signals without appreciably affecting low level operation and without causing serious distortion. Either point contact or junction diodes may be utilized for this purpose, and they may be of germanium or silicon or other semiconductor material. Some special advantages are

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obtained by the use of silicon diodes, since they have less curvature of the resistance characteristic near the origin, but ultimately exercise greater control by changing resistance faster for a given change in voltage at higher levels.

The portion of the high level signals passing through the semiconductor diode may by appropriate circuit arrangements be utilized to change the emitter-base bias on the first transistor, and thus further control the volume of the signal as it is amplified.

In addition to providing means for preventing the overloading of an amplifier stage, this invention provides an automatic gain control circuit which may be used in a complete radio receiving circuit and employing only semiconductor devices and no vacuum tubes.

Examples of circuit arrangements are given in the accompanying drawings, in which:—

Figure 1 is a schematic illustration of one desirable circuit arrangement for the application of the principles of this invention to the first amplifier stage of a radio receiver;

Figure 2 is a schematic illustration of a second circuit arrangement for applying the principles of this invention to the first stage of a radio receiver;

Figure 3 is a schematic illustration of still another circuit applying the principles of this invention to the first stage of a radio receiver; and

Figure 4 is a schematic illustration of still another circuit applying the principles of this invention to the first stage of a radio receiver.

As illustrated in Figure 1, an incoming radio signal arrives at an antenna 10 and the several ground connections shown and is applied to a fixed condenser 12 shunted by a radio frequency choke 11 having high impedance at the signal frequency but providing a DC path to ground. The condenser 12 forms a part of a resonant circuit, which consists of an inductance 13 and a variable condenser 14, and this circuit is tunable, by operation of the variable condenser, to resonance with any particular radio carrier wave that it is desired to receive. A secondary coil 15 is coupled to the inductance coil 13 and serves to take from the resonant circuit 13, 14 a signal of reduced voltage and increased current, for application to an n-p-n transistor 16. The secondary coil is connected to the emitter 16a of the transistor and also through a resistor 17 to ground.

The resistor 17 is shunted by a radio frequency bypass condenser 18 in the usual manner and serves to control the bias between the emitter 16a and the base 16b of the transistor 16. It should be noted in this connection that the normal bias of the emitter with respect to the base of a typical transistor will be about 0.1 to 0.2 volt, with the emitter being negative with respect to the base. This

bias is supplied from a source which is not shown. Any increase of this bias would increase the current flow through the transistor, and hence the resistor 17 is so arranged in the circuit that an increase in the flow of current through the resistor tends to reduce the bias.

In accordance with the present invention, it has been found that a semiconductor diode may be connected into such circuit as has just been described, in such a way as to act as a load on the resonant circuit 13, 14, and since the resistance of the diode is non-linear, being quite high for small potentials across it and relatively much lower for higher potentials across it, the diode will serve to load the resonant circuit 13, 14 and attenuate high level signals attempting to pass through it, while having very little effect on low level signals passing through the resonant circuit 13, 14.

As illustrated in Figure 1, the diode 19 is connected in series with a variable resistance 20 from a point at the ungrounded end of the resonant circuit 13, 14 to a point at the ungrounded end of the bias resistor 17 and bypass condenser 18. As a result of this connection, the current that passes through the diode 19 also passes through the bias resistor 17, as well as the variable resistor 20, all of which are connected in series. This provides a shunt path across the resonant circuit 13, 14, thus loading this circuit to an extent dependent upon the effective resistance of this shunt circuit. Since the resistance of the diode 19 varies non-linearly, the effect of the shunt circuit will be much greater at higher signal amplitudes. Germanium diodes begin to be effective at resonant circuit voltages of around 0.1 to 0.2 volt and silicon diodes at somewhat higher voltages of around 0.3 to 0.4 volt. The effectiveness of this circuit in controlling the input to the transistor 16 can be varied by varying the resistance of the variable resistor 20, since as this resistance is increased the shunting effect of the diode circuit will obviously decrease at all input signal levels. The variable resistance 20, therefore, should be set at a point that will give sufficient maximum signal handling capability for the circuit, but at the same time will reduce incidental distortion to a minimum.

The circuit of Figure 1 performs an additional function by the passage of the diode circuit current through the bias resistor 17. Since the diode 19 is a rectifier, a direct current component results in the diode circuit, and by properly orienting the diode in the circuit, the direct current component may be caused to act upon the bias resistor 17 so as to decrease the bias between the emitter and the base when large signals are received, thus lowering the amplification of the transistor 16 and protecting subsequent stages of the amplifier from overloading. Since the

emitter in an n-p-n transistor is normally negative with respect to the base and it is necessary to reduce this bias in order to reduce the current flow through the transistor it is necessary that the current flow through the resistor 17 be such as to make the ungrounded end of the resistor more positive with respect to ground as the current flow in the diode circuit increases. Therefore, the diode 19 should be connected into the circuit in such a manner that electron flow is from ground through the diode circuit to the resonant circuit 13, 14.

A small amount of differential distortion of the modulation occurs when the amplitude of the signals is near the point at which the diode begins to conduct. This may be reduced by increasing the resistance of the variable resistor 20, but this increase in resistance also results in the decrease of the maximum signal-handling capability of the circuit. Therefore, depending upon the intensity of the signals that are likely to be encountered, the variable resistor 20 may be adjusted so that the maximum signals to be encountered can be properly handled, and yet the distortion held to a minimum.

The same circuit may be used with a p-n-p type transistor, but in this case the diode should be connected into the circuit in the opposite direction, since the bias between the emitter and the base is opposite for a p-n-p transistor and should be oppositely affected by the diode circuit.

In Figure 2, a modification of the circuit of Figure 1 is illustrated. Here the signal is received by an antenna 25 and impressed across a fixed condenser 26 connected between the antenna and ground. The fixed condenser 26, together with an inductance 27 and a variable condenser 28, forms the tuned resonant circuit, and a secondary coil 29 inductively coupled to the coil 27 receives a low voltage, increased current signal and impresses it on the emitter of an n-p-n transistor 30. A bias resistor 31 and a bypass condenser 32 connected in parallel between the other end of the pickup coil 29 and ground serve to control the bias between the emitter and the base.

The overload control in Figure 2 consists of a semiconductor diode 33 connected in series with a variable resistance 34 directly across the resonant circuit 27, 28, 29. The operation of this circuit is the same as the operation of the circuit of Figure 1, except that the current which the semiconductor diode takes from the circuit does not pass through the bias resistor 31, and hence no automatic bias control is accomplished.

The same circuit is shown in Figure 3 as is shown in Figure 2, with the exception of the fact that the semiconductor diode 33 and the variable resistance 34 are connected in series between the ungrounded side of the

variable condenser 28 and ground, instead of being connected across the inductance coil 27. This results in a circuit in which there is no direct current return for the current flowing through the diode 33. As a consequence of this difference, the results of using this circuit with a point contact diode have not been satisfactory. However, if a junction type diode is used in this type of circuit, it is found that the circuit works quite satisfactorily.

The circuits of Figures 1, 2 and 3 have all been shown as applied to n-p-n transistors, but they can, of course, be applied to p-n-p transistors as well. The use of the circuits of Figures 1, 2 and 3 and other similar circuits makes possible an increase of 20 to 40 decibels in the input signal range that can be handled without overloading the first and subsequent stages of a transistorized radio receiver. This is particularly important in mobile receivers. By proper adjustment of automatic volume control circuit values, it is possible to greatly reduce distortion while enormously extending the operating range. Signals of an amplitude of 500,000 microvolts with 80 per cent modulation can be handled with very little distortion.

In the embodiment shown in Figure 4, an incoming radio signal from an antenna 50 passes through a shielded lead-in to a DC isolating condenser 51 and then through another shielded lead-in to a resonant circuit, where it is impressed across a fixed condenser 52 connected between the lead-in and ground. The resonant circuit consists of the fixed condenser 52, a variable condenser 53 and a radio frequency inductance 54, connected in series. A semiconductor diode 55 is connected across the inductance coil 54 of the resonant circuit 52, 53, 54 to act as a high amplitude signal attenuator, as previously described. The inductance 54 is coupled to a secondary 56, which has fewer turns, and thus the two coils act as a radio frequency step-down transformer. One end of the secondary 56 is connected to the emitter of a double-base tetrode grown junction n-p-n transistor 57, and the other end of the secondary 56 is connected to ground through a bias control resistor 58, shunted by a radio frequency bypass condenser 59. An automatic volume control or bias lead 60 supplies one of the base connections of the transistor 57 with the proper bias potential from a source not shown, and this lead is grounded through a radio frequency bypass condenser 61. Another similar lead 62 supplies the other base connection of the transistor 57 with bias potential, and this lead is similarly grounded through a radio frequency bypass condenser 63.

WHAT WE CLAIM IS:—

1. A radio receiving system characterised by a signal circuit which includes a tuned



emitter in an n-p-n transistor is normally negative with respect to the base and it is necessary to reduce this bias in order to reduce the current flow through the transistor it is necessary that the current flow through the resistor 17 be such as to make the ungrounded end of the resistor more positive with respect to ground as the current flow in the diode circuit increases. Therefore, the diode 19 should be connected into the circuit in such a manner that electron flow is from ground through the diode circuit to the resonant circuit 13, 14.

A small amount of differential distortion of the modulation occurs when the amplitude of the signals is near the point at which the diode begins to conduct. This may be reduced by increasing the resistance of the variable resistor 20, but this increase in resistance also results in the decrease of the maximum signal-handling capability of the circuit. Therefore, depending upon the intensity of the signals that are likely to be encountered, the variable resistor 20 may be adjusted so that the maximum signals to be encountered can be properly handled, and yet the distortion held to a minimum.

The same circuit may be used with a p-n-p type transistor, but in this case the diode should be connected into the circuit in the opposite direction, since the bias between the emitter and the base is opposite for a p-n-p transistor and should be oppositely affected by the diode circuit.

In Figure 2, a modification of the circuit of Figure 1 is illustrated. Here the signal is received by an antenna 25 and impressed across a fixed condenser 26 connected between the antenna and ground. The fixed condenser 26, together with an inductance 27 and a variable condenser 28, forms the tuned resonant circuit, and a secondary coil 29 inductively coupled to the coil 27 receives a low voltage, increased current signal and impresses it on the emitter of an n-p-n transistor 30. A bias resistor 31 and a bypass condenser 32 connected in parallel between the other end of the pickup coil 29 and ground serve to control the bias between the emitter and the base.

The overload control in Figure 2 consists of a semiconductor diode 33 connected in series with a variable resistance 34 directly across the resonant circuit 27, 28, 29. The operation of this circuit is the same as the operation of the circuit of Figure 1, except that the current which the semiconductor diode takes from the circuit does not pass through the bias resistor 31, and hence no automatic bias control is accomplished.

The same circuit is shown in Figure 3 as is shown in Figure 2, with the exception of the fact that the semiconductor diode 33 and the variable resistance 34 are connected in series between the ungrounded side of the

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The circuits of Figures 1, 2 and 3 have all been shown as applied to n-p-n transistors, but they can, of course, be applied to p-n-p transistors as well. The use of the circuits of Figures 1, 2 and 3 and other similar circuits makes possible an increase of 20 to 40 decibels in the input signal range that can be handled without overloading the first and subsequent stages of a transistorized radio receiver. This is particularly important in mobile receivers. By proper adjustment of automatic volume control circuit values, it is possible to greatly reduce distortion while enormously extending the operating range. Signals of an amplitude of 500,000 microvolts with 80 per cent modulation can be handled with very little distortion.

In the embodiment shown in Figure 4, an incoming radio signal from an antenna 50 passes through a shielded lead-in to a DC isolating condenser 51 and then through another shielded lead-in to a resonant circuit, where it is impressed across a fixed condenser 52 connected between the lead-in and ground. The resonant circuit consists of the fixed condenser 52, a variable condenser 53 and a radio frequency inductance 54, connected in series. A semiconductor diode 55 is connected across the inductance coil 54 of the resonant circuit 52, 53, 54 to act as a high amplitude signal attenuator, as previously described. The inductance 54 is coupled to a secondary 56, which has fewer turns, and thus the two coils act as a radio frequency step-down transformer. One end of the secondary 56 is connected to the emitter of a double-base tetrode grown junction n-p-n transistor 57, and the other end of the secondary 56 is connected to ground through a bias control resistor 58, shunted by a radio frequency bypass condenser 59. An automatic volume control or bias lead 60 supplies one of the base connections of the transistor 57 with the proper bias potential from a source not shown, and this lead is grounded through a radio frequency bypass condenser 61. Another similar lead 62 supplies the other base connection of the transistor 57 with bias potential, and this lead is similarly grounded through a radio frequency bypass condenser 63.

WHAT WE CLAIM IS:—

1. A radio receiving system characterised by a signal circuit which includes a tuned



846,131

5 circuit comprising a parallel-connected inductor and capacitor, at least one plural electrode semiconductor device having its input connected to said signal circuit to provide the first high frequency amplifier stage of a semiconductor amplifier, and a semiconductor diode connected across at least a portion of said tuned circuit to attenuate high amplitude signals by increasing the damping of said tuned circuit.

10 2. A radio receiving system according to Claim 1, wherein a resistance is connected in series with said semiconductor diode for controlling the degree of damping of said tuned circuit.

15 3. A radio receiving system according to Claim 2, wherein said resistance is variable.

20 4. A radio receiving system according to any one of the foregoing claims, wherein the plural electrode semiconductor device is connected to a secondary circuit which is inductively coupled to the signal circuit.

5. A radio receiving system according to any one of the foregoing claims, wherein said

signal circuit includes an antenna circuit 25 having a radio frequency choke.

6. A radio receiving system according to any one of the foregoing claims, wherein a second capacitor is connected in series with said inductor. 30

7. A radio receiving system according to Claim 1, wherein a resistance is connected in series with said semiconductor diode and wherein connections are provided for applying the voltage developed across said resistance as a bias for said semiconductor device. 35

8. A radio receiving system according to any one of the foregoing claims, wherein said plural electrode semiconductor device is a triode transistor. 40

9. An improved radio receiving system substantially as described with reference to the accompanying drawings.

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Leamington Spa: Printed for Her Majesty's Stationery Office, by the Courier Press.—1960.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained

PATENTS ACT, 1949

SPECIFICATION NO. 846,131

Reference has been directed, in pursuance of Section 8, of the Patents Act, 1949, to Specification No. 840,550.

THE PATENT OFFICE,
25th November, 1961

DS 98570/1(13)/R.153 200 11/61 PL