

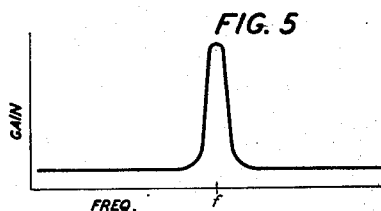
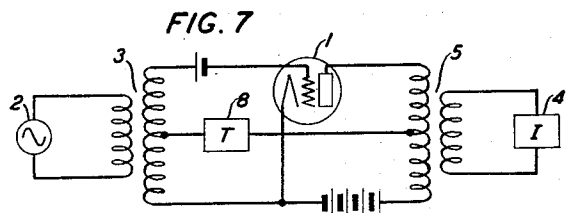
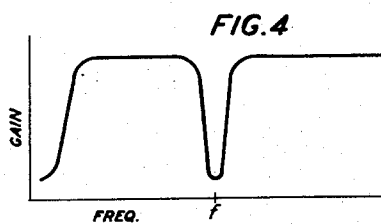
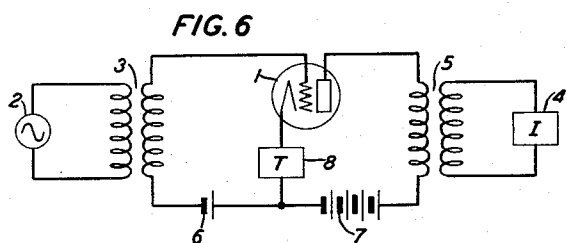
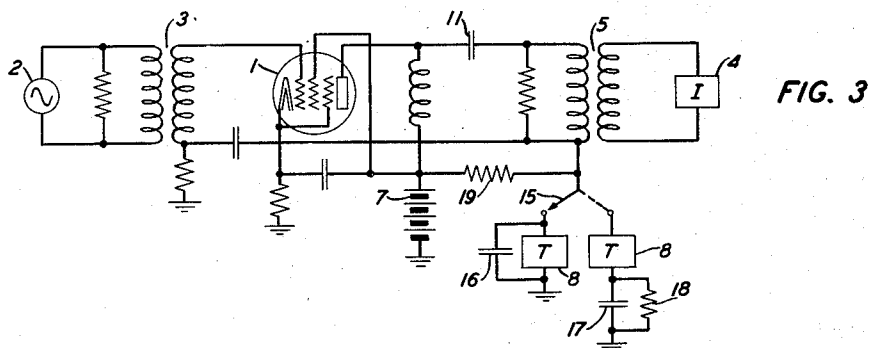
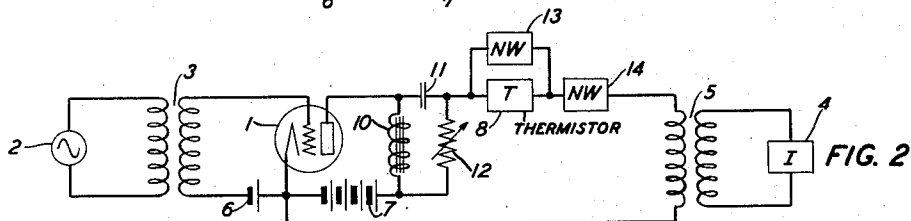
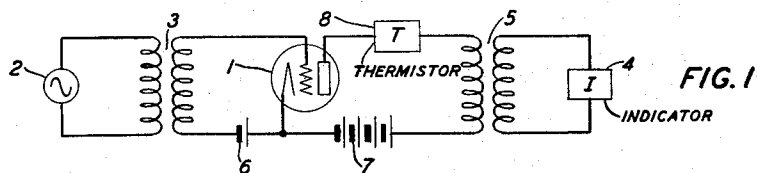
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2,369,030

AMPLIFIER CIRCUIT

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2,369,030

AMPLIFIER CIRCUIT

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The present invention relates to the amplification of electrical waves for signaling or like purposes, and particularly to the use of a negative resistance device, such as a thermistor, in wave amplification.

An object of the invention is an amplifier of simplified and economical construction capable of increased utility and effectiveness.

It is known that certain substances, such as semi-conductors including certain crystals or compounds of certain uranium oxides, of boron and of other elements can be made to exhibit negative resistance effects by use of a direct current bias to bring the device to the proper region of its volt-ampere characteristic where the slope is in the negative direction. More recently improvements in the construction of thermistor elements have greatly increased the range of frequencies over which they are responsive so that it is practical to use them for amplifying waves covering the speech band or an even wider band. Examples of such construction are given in United States patent to G. L. Pearson 2,276,864, March 17, 1942.

I have found that negative resistance elements including thermistors, such as those disclosed by Pearson, are well adapted for use in the plate circuit of a vacuum tube amplifier and can be used in this way to modify in some desirable manner the operation of the vacuum tube circuit. The vacuum tube has to be supplied with space current from a battery or similar source, and the impedance of a thermistor, for example, can readily be made of such value that, when placed in series relation between the load, the plate battery and the cathode-anode terminals of the vacuum tube, the current passing through the thermistor brings it into its negative resistance region. The amplification factor of the circuit may thus be increased in a very simple and economical way, or the operation of the circuit can be modified or controlled in other respects. In other circuit arrangements the thermistor is placed in parallel relation with the cathode-anode terminals of the tube as regards the direct current circuit, and in series with the alternating current output circuit.

The nature and objects of the invention will appear more fully from the following detailed description of certain illustrative embodiments as given in the attached drawing.

Fig. 1 is a simple schematic circuit diagram showing one manner of associating a thermistor with an amplifier in accordance with this invention;

Figs. 2, 3, 6, and 7 show other circuit arrangements according to the invention; and

Figs. 4 and 5 show frequency characteristics obtainable with the circuit of Fig. 3.

In Fig. 1, the vacuum tube 1 has its input or grid circuit coupled to a source of waves 2 to be amplified, through input coupling coil 3. The output for the amplified waves leads to any suitable utilization circuit shown as indicator 4 through output coupling coil 5. The grid is provided with the usual bias battery 6, and the plate is supplied with space current from plate battery 7. Included in series between the battery 7 and the plate is the thermistor 8, which may be of any suitable construction, such as the type shown in the Pearson patent.

In this circuit the source 2 may be a telephone transmitter or line in which case the tube 1 operates as a voice current amplifier. The indicator 4 would then be a telephone receiver or loud-speaker. This example is cited to make it clear that the invention contemplates the amplification of a band of frequencies of which the voice band is illustrative. The band may be narrower or wider than the speech band within the capabilities of the apparatus, especially the thermistor. Taking the speech band as illustrative, the thermistor 8 is to have a sufficiently high speed of response to give a negative resistance effect at the highest frequency of the band to give the greatest effect, although, if desired, the thermistor could operate over a chosen part only of the total band. Assuming the thermistor to have an amplifying characteristic covering the band represented by the waves from source 2, this amplification is added to that of the tube 1 above to give increased amplification of the band. The tube 1, being a unilateral transducer, prevents the thermistor from amplifying toward the source 2. The tube 1 need not, of course, be a triode but could be a pentode or other type tube. The gain frequency characteristic of the circuit as a whole is determined in part by the tube 1 and in part by the thermistor 8. By controlling the design of the thermistor, a control is had over the gain frequency characteristic of the circuit. It is common in the art to use shaping networks which are attenuators. The thermistor can be used to provide a gain up to a certain frequency after which it becomes a loss, at higher frequencies, depending upon its design. It offers a possibility, therefore, of use as a shaping network operating with an intrinsic gain over part or all of the utilized frequency range. For this purpose it can

have shaping networks associated with it if desired.

In the circuit of Fig. 1, the thermistor resistance lowers the effective plate voltage since it is directly in series with battery 7 and the plate. A parallel supply is shown in Fig. 2, the plate being supplied through impedance 10, and the signal or alternating path continuing through blocking condenser 11 to the thermistor 8 and output coupling. Bias current for the thermistor is supplied through resistor 12 which may be adjustable. Shaping networks 13 and 14 are shown associated with thermistor 8. Either or both may be omitted but if used they give a more complete control over the gain frequency characteristic.

In Fig. 3, the inductive effect of a thermistor 8 is made use of in either of two ways depending upon the position of switch 15. It is known that the thermal lag of a thermistor gives the device a reactive effect equivalent to an inductance. When the thermistor is associated with a parallel capacity 16, a low loss antiresonant circuit is provided, resulting in a narrow band of loss.

When a capacity is connected in series with the thermistor, a sharply resonant effect results. By throwing the switch 15 to the right the thermistor is connected in circuit with series condenser 17. By-pass resistance 18 is provided for the direct current. In either position of the switch 15, the thermistor is provided with energizing current from plate battery 7 through series resistance 19 to bias the thermistor to its negative resistance region.

With switch 15 in the position shown, a gain frequency characteristic like that of Fig. 4 is obtained. At the frequency f of resonance, a dip is produced in the characteristic because of the high series attenuation in the signal output branch at this frequency. The impedance of the thermistor and attenuation of the transformers at very low frequencies near zero account for the falling off of the gain characteristic at low frequencies.

With the switch 15 thrown to the right, a gain frequency characteristic of the Fig. 5 type is obtained. Here the series attenuation in the output signal branch is high except at the frequency f of resonance, where it falls to a very low value giving a gain peak.

Figs. 6 and 7 show the thermistor 8 connected in the negative feedback connection of an amplifier. In Fig. 6 the thermistor is placed in the cathode lead and is common to the grid and plate circuits. In Fig. 7, a hybrid coil type of feedback is used. In both cases the energizing current for the thermistor is obtained from the plate supply. The feedback action is controlled by the characteristic of the thermistor. If the thermistor has associated with it elements to give it a marked frequency characteristic as in Fig. 3, a band elimination effect can be obtained with the circuits of Figs. 6 and 7.

With the foregoing as illustrative examples, still other circuit modifications will occur to those skilled in the art within the spirit and scope of the invention.

What is claimed is:

1. A vacuum tube amplifier circuit comprising an input circuit including a source of input waves of given frequencies and an output circuit including a load for using the amplified waves, a thermistor having a frequency of response including at least some of the input wave frequencies, and means coupling said thermistor to said

vacuum tube amplifier circuit in series relation to said load to modify the amplifying action of the circuit for said waves such that the modified amplifying action for waves of a frequency corresponding to the thermistor frequency response is in opposite relation to the modified amplifying action for waves of other frequencies.

2. An amplifier circuit having an input circuit and an output circuit, a source of input waves connected to the input circuit for amplification by said amplifier circuit, a load and a thermistor connected in series with each other in said output circuit, said thermistor having a response frequency the same as certain of the input wave frequencies for selectively modifying the frequency amplitude characteristic of said amplifier circuit such that the amplitudes of input waves of frequencies equivalent to the thermistor response frequency and the amplitudes of input waves of other frequencies are modified in opposite sense.

3. A circuit according to claim 2 including a source of anode current for said amplifier circuit which embodies an anode-cathode discharge path, and means connecting said thermistor in series between said source of anode current and the anode-cathode discharge path.

4. An amplifier having a space discharge path, an input circuit and an output circuit, a source of input waves connected to said input circuit for amplification by said amplifier, a source of anode current for said amplifier, a response device for said waves connected to said output circuit, a thermistor connected in said output circuit in series relation to said device for further amplifying said input waves and connections for energizing said thermistor from said source of anode current.

5. A two-stage amplifying circuit of which the first stage comprises a space discharge vacuum tube amplifier having the usual space current supply source and the second stage comprises a negative resistance of the series type serially included in the output circuit of said vacuum tube amplifier between said supply source and the space discharge path of said vacuum tube and receiving its energy of amplification from said source, and a utilization circuit for the amplified output in series with said negative resistance.

6. An amplifying circuit for currents of a certain range of frequencies comprising a vacuum tube amplifier having a cathode-anode space path and current source therefor, said amplifier amplifying the currents of said frequency range, and a semiconductor negative resistance device exhibiting series negative resistance properties throughout said frequency range connected in the output circuit of said vacuum tube amplifier and energized from said source for further amplifying said currents of said frequency range, and a utilization circuit for the amplified waves serially related to said device.

7. An amplifying circuit comprising a space discharge device amplifier having a source of space current and means for continuously increasing the amplifying action of said circuit comprising a solid element series negative resistance in circuit with said space discharge device and energized by current from said source, and a utilization circuit for the amplified currents serially related to said negative resistance element.

8. In an amplifying circuit for a band of frequencies, a space discharge tube amplifier having a source of space current, a thermistor having a

thermal lag whereby said thermistor has an inductive component of impedance, means to connect said thermistor in circuit with said tube and to energize said thermistor from said source, and a capacitive reactance in circuit with said thermistor and resonating therewith to modify the gain frequency characteristic of said amplifying circuit.

9. A circuit according to claim 8 in which said space discharge tube amplifier has an alternating current output circuit for the amplified waves, said thermistor being connected in series in said output circuit.

10. A vacuum tube amplifier having an input circuit and an output circuit for amplifying waves of a band of frequencies, a source of space current therefor, a feedback path from said output circuit to said input circuit for said waves, and a thermistor in said feedback path introducing a negative resistance into said path at frequencies within said band, and means to energize said thermistor from said source.

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