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ART OF MODULATING AN ELECTRONIC CIRCUIT

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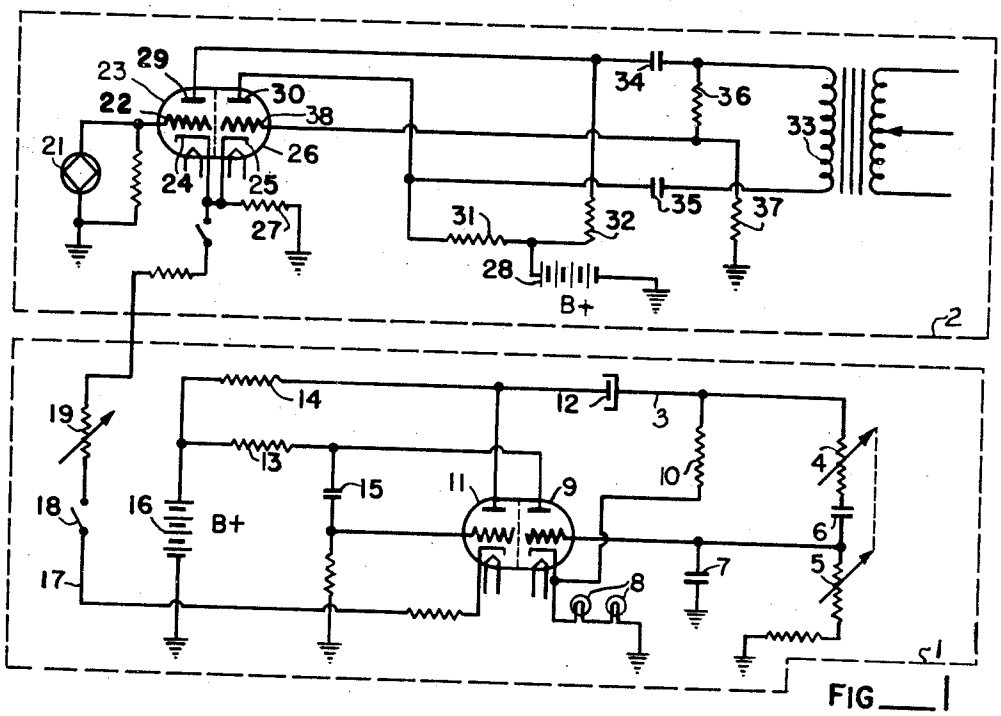


FIG. 1

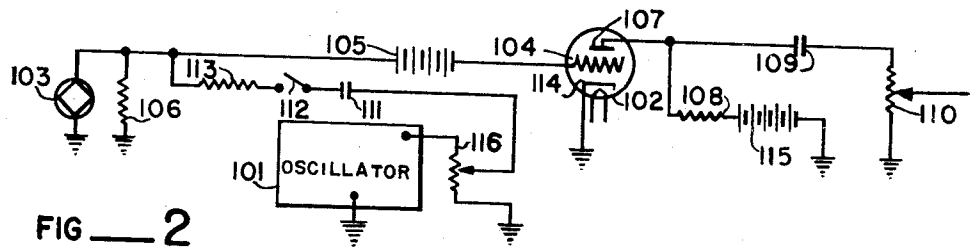


FIG. 2

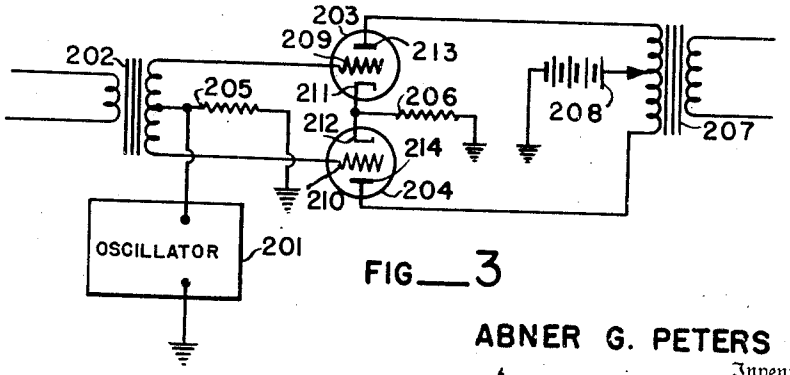


FIG. 3

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ART OF MODULATING AN ELECTRONIC CIRCUIT

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The present invention relates to the art of modulating an electronic circuit, and in more particular to the art of modulating a vacuum tube to obtain a variation in gain at the modulation frequency. Such modulation is very desirable in an amplification circuit transmitting music, where it is desired to obtain a tremolo effect in the output. By tremolo is meant the audible effect of periodic amplitude modulation of audible frequencies.

In actual practice the device of the present invention has been used in musical instrument amplifier circuits to produce a very desirable and pleasing tremolo effect in the output of the amplifier circuit.

In the prior art there have been devices for producing the tremolo effect in amplifier circuits, but such devices have been of a mechanical nature, bulky, expensive, and unreliable. Also, in many such prior art devices, it has been impossible to turn the tremolo effect on and off without a long period of onset and decay of the effect. This has been due to the inertia of the mechanical means and the time required for such means to come up to speed or to die down from speed.

Having in mind these defects of the prior art, it is an object of the present invention to produce a tremolo device which is entirely electronic.

A further object of the present invention is the production of a tremolo device in which the tremolo frequency may be easily varied.

Another object of the present invention is the provision of means for easily varying the amplitude of the tremolo modulation.

Another object is the elimination of appreciable onset and decay periods.

Another object is the production of the tremolo effect without the transmission to the output of the tremolo voltage.

The above objects are accomplished by developing electronically, as by a Wien bridge oscillator, a tremolo voltage and applying such voltage to a tube of an amplifier to vary the gain of such tube, and, hence, the amplitude of the audio-frequency output of the tube, and then removing the amplified tremolo voltage by attenuation or cancellation.

A further object is to vary the gain of an electronic audio amplifier by electronic means at a cyclic rate to produce a tremolo in said amplifier's output.

Several circuits embodying the fundamental construction outlined above are shown in the accompanying drawings, in which:

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Fig. 1 is a schematic diagram of an electrical circuit embodying the present invention, in which the tremolo voltage is removed in the output by cancellation.

Fig. 2 is a diagram of a modification in which the tremolo voltage is removed in the output by attenuation.

Fig. 3 is a diagram of a modification in which the tremolo voltage is removed in the output by cancellation.

FIGURE 1

In Figure 1 there is shown a schematic diagram of an electrical circuit embodying the present invention. In this circuit the tremolo voltage is furnished by a Wien bridge oscillator. This tremolo voltage is impressed on a phase inversion circuit to modulate a voice frequency. The tremolo voltage in the output circuit of the phase inverter is removed by cancellation. In Figure 1 the circuit may be divided into two parts, the Wien bridge oscillator circuit 1, and the phase inversion circuit 2.

The Wien bridge oscillator circuit of Figure 1 is simply a regenerative audio amplifier, in which the feed-back path 3 is tuned by means of the frequency selective resistance-capacity network comprising variable resistances 4, 5, and the condensers 6, 7. Usually these resistors are equal, and the condensers are of equal value. To avoid overload of the regenerative amplifier, one or more incandescent lamps are placed between cathode and ground of the first stage tube 9 and connected to the degenerative feed-back resistor 10. Rapid increase in resistance of these lamps 8 with respect to increases in feed-back voltage from a second stage tube 11 is used to limit operation to linear portions of the tube characteristics of the first stage tube 9. Resistance tuned oscillators of the Wien bridge type have a high degree of frequency stability and require a very short warm-up time to attain stable operation. The first and second stage tubes 9, 11 may be separate tubes or they may be in one envelope, as indicated in the drawing. Further, these tubes may each have a plurality of grids instead of the single grid shown in the drawing, as such is desirable in some modifications of this Wien bridge circuit. The feed-back from the second stage tube 11 passes through a high capacity electrolytic condenser 12 to prevent loss of feed-back voltage. Plate load resistors 13, 14 are shown. The condensers 15 and 12 act as coupling capacities between the two stages. Power is supplied to the circuit from the B-battery 16. The output

circuit 17 of the second stage is grounded through the phase inversion circuit 2. Power is taken from the oscillator by connecting to the second stage cathode an output circuit 17. In the output circuit 17 is a tremolo control switch 18, and a variable amplitude control resistor 19.

While applicant has found that a Wien bridge oscillator is the most desirable source of tremolo voltage because of its frequency stability, simplicity, and cost of construction, there are other frequency generators that may be used.

The phase inversion circuit 2 has a microphone 21 that applies audio voltage frequencies to the input circuit and the grid 22 of the phase inverter tube 23. The cathode 24 of this inverter tube 23 is connected to the output 17 of the oscillator 1, to the cathode 25 of an amplifier tube 26, and to ground through a resistor 27. The B-plus power supply 28 is connected to the plates 29, 30 of the tubes 23, 26 through individual plate load resistors 31, 32. The plates are connected to opposite ends of a transformer 33 through condensers 34, 35. Two resistors, 36, 37 are connected in series, from output coupling capacitor 34 of first stage tube 23 to ground to form a voltage divider to which grid 38 of the amplifier tube 26 is connected.

Operation of Figure 1

In the operation of the device shown in Fig. 1, sound frequencies are impressed on the microphone 21, which translates the sound frequencies into equivalent electrical frequencies which are applied to the grid 22 of the inverter tube 23. Power is supplied to the inverter tube and to the amplifier tube 26 from the B-plus power source 28. The grid 38 of the amplifier tube 26 is supplied with audio frequency voltage from the plate 29 of the inverter tube 23 by the voltage divider network 36, 37 and this causes the audio voltage output of the amplifier tube 26 to be reversed in phase from the audio voltage output of the inverter tube. The output of the two tubes 23, 26 is coupled to a transformer 33 through a condenser 34, 35 in series with each tube. The output of each tube is connected to one end of the primary of the transformer so that the out-of-phase audio voltage will be additive across the transformer.

The oscillator 1 furnishes the tremolo voltage to the phase inversion circuit 2. Power for the oscillator is furnished by the B-plus power source 16 and is applied to the plates of both tubes 9, 11 through plate resistors 13, 14. The output of the second stage tube 11 is coupled to the grid of the first stage tube 9 by electrolytic condenser 12 and the frequency selective resistance capacity network 4, 5, 6, 7 The output of the first stage is fed to the grid of the second stage by coupling capacitor 15. The values of the elements of the network 4, 5, 6, 7, determine the oscillation frequency of the oscillator. The construction of such oscillators is well known in the art. The cathode circuit of the second stage tube is completed to ground through the output circuit 17, switch 18, amplitude control 19 and the common cathode resistor 27 of the tubes 23, 26 of the phase inversion circuit. Adjustment of the resistor 19 controls the amplitude of the tremolo voltage applied to the inversion circuit and hence the amplitude of the tremolo in the output of the inversion circuit. Opening of the switch 18 in the oscillator output circuit 17 removes the tremolo voltage from the phase inversion circuit.

When the tremolo voltage is applied to the common cathode bias resistor 27 of the tubes of the inversion circuit 2, it is also applied to the cathodes 24, 25 of these tubes. This tremolo voltage causes the gain of the tubes to vary, and to vary in phase, thus simultaneously modulating the amplitude of the audio-frequency output of both tubes at the tremolo frequency. The in-phase tremolo voltage appears in the output of both tubes and is transmitted through the network to the audio output transformer 33 along with the audio voltages. At the transformer the tremolo voltages of the two tubes 23, 26 will be in phase across the transformer, thus producing no tremolo voltage drop across it, it thereby being cancelled. This leaves to be transmitted by the transformer only the effect of the tremolo voltage on the audio signal, and not the tremolo voltage itself.

It is readily apparent that part of the tremolo voltage output of the inverter tube 23 is transmitted by coupling capacitor 34 and the voltage divider network resistors 36, 37 to grid 38 of the amplifier tube 26, and that this voltage is out-of-phase with the tremolo voltage applied to tube 26. However, due to the reactance of capacitor 34 to the very low tremolo frequency, the amount of unbalance is negligible.

FIGURE 2

In Fig. 2 is shown a schematic diagram of an electronic circuit embodying a modification of the present invention. In this circuit the tremolo voltage is furnished by a vacuum tube oscillator 101, similar to the oscillator 1 of Fig. 1. This tremolo voltage is impressed on a conventional audio amplifier tube 102 to modulate in amplitude the audio frequency output of said tube. The tremolo voltage in the output circuit of the amplifier is removed by attenuation. It is well known in the art that the gain or amplification factor of an amplifier tube may be varied by varying the voltage of any one, or more, of the elements of a multi-element tube. For the purpose of simplification, this description will be confined to the modulation of the grid bias voltage of a simple triode audio amplifier at tremolo frequencies.

The audio amplifier circuit has a microphone 103 that applies audio frequency voltages to the input circuit and the grid 104 of the amplifier tube 102. The input circuit consists of a grid bias cell 105 to provide static bias voltage on grid 104, and a grid leak resistor 106. The output circuit consists of plate 107, plate load-resistor 108, output coupling capacitor 109, and potentiometer volume control 110. The tremolo voltage is fed to grid 104 of the amplifier tube 102 from the oscillator 101 via a network comprising a D. C. blocking capacitor 111, a tremolo "off-on" switch 112, and an audio isolating resistor 113. The cathode 114 of the amplifier tube 102 is tied directly to ground. Power for the tube 102 is supplied by the B-battery 115. Provision is made in the oscillator for varying the frequency. The amplitude of the output of the modulator is governed by the voltage divider 116.

Operation of Figure 2

In the operation of the device shown in Fig. 2, sound frequencies are impressed on microphone 105, which translates the sound frequencies into equivalent electrical frequencies, which are applied to the input circuit and the grid 104 of the amplifier tube 102. Power is supplied to the amplifier tube 102 via the plate load resistor 108

from B-plus power source 115. The tremolo voltage from the oscillator 101 is fed to the grid 104 of the amplifier tube 102 via a D. C. blocking condenser 111, a tremolo "off-on" switch 112, and an audio isolating resistor 113. The D. C. blocking capacitor 22 prevents any D. C. voltage present in the output circuit of the oscillator from being applied to the grid 104 of amplifier tube 102. The audio isolating resistor 113 is of such a value that it prevents the audio voltage applied to the grid of said tube from being shorted to ground through the oscillator output circuit. When the tremolo "off-on" switch 112 is closed, the applied alternating tremolo voltage adds to, and subtracts from, the static bias voltage applied, in this case, by bias cell 105, thus varying the gain or amplification factor of the amplifier tube 102 at the tremolo frequency. There appears then at plate 107 and its associated output circuit, the amplitude modulated audio frequencies and the amplified modulating tremolo voltage. The values of the output coupling capacitor 109 and the volume control potentiometer 110 are so chosen as to readily pass the audio frequencies and to highly attenuate the very low tremolo frequency.

The coupling capacitor 109 and volume control potentiometer 110 are in series across the output of amplifier tube 102. According to the formula for capacitive reactance, it can be seen that the reactance varies inversely as the frequency and as the capacity. By representing the coupling capacitor 109 as a variable resistance in series with potentiometer 110, its discrimination against the very low frequency voltage of 6 C. P. S. can be appreciated.

If we choose a tremolo voltage of 6 C. P. S., a coupling capacitor 18 of 0.005 mfd., a volume potentiometer 19 of 50,000 ohms, and the lowest audio frequency to be amplified at 70 C. P. S., the results are as follows. The reactance of the coupling capacitor 18 to the tremolo voltage of 6 C. P. S. is 5,310,000 ohms. This reactance is in series with the volume potentiometer of 50,000 ohms. The ratio of these two resistances is 1:106. Thus the amount of tremolo voltage in the output is negligible. However, the low audio frequencies are not objectionably attenuated. The attenuation at 70 C. P. S. is the ratio of 1:9. If better passage of low audio frequencies is desired, an M-derived type or a pi-section filter may be used in the output circuit, whereby the attenuation of the audible frequencies is negligible and the attenuation of the tremolo frequency is practically complete. The construction of such filters is well known in the art.

FIGURE 3

In Figure 3, there is shown a diagram of a modification of the circuit of Figure 1, as in this modified circuit the tremolo voltage is also removed by cancellation. However, in Figure 3, the audio signal is placed in opposite phase by an input transformer.

Figure 3 shows an electronic oscillator 201 which furnished the tremolo voltage, an audio input transformer 202, vacuum tubes 203, 204, grid leak resistor 205, cathode resistor 206, output transformer 207 and B-plus power source 208.

The center tap of the secondary of the audio input transformer 202 is grounded through the grid leak resistor 205 and its output is fed to two grids 209, 210 of vacuum tubes 203, 204 which are operating in what is commonly known as a push-pull circuit. The cathodes 211, 212 of tubes 203, 204 are grounded through the common

cathode bias resistor 206. To the plates 213, 214 of said tubes is connected the primary of the audio output transformer 207. To the center tap of the primary of said audio output transformer is connected the B-plus power source 208, which furnishes B-plus power for the tubes 203, 204. The secondary or output of audio output transformer 207 may be connected to a speaker or to following stages not shown.

The tremolo voltage from the oscillator 201 is introduced at the junction of the grid leak resistor 205 and the center tap of the secondary of the audio input transformer 202.

Operation of Figure 3

An audio signal voltage is fed to the primary of audio input transformer 202. By transformer action the audio signal voltage is applied in opposite phase to the grids 209, 210 of the tubes 203, 204. The signal voltage is amplified by action of the tubes 203, 204 and this amplified output of said tubes is applied, reversed in phase, to the primary of the audio output transformer 207. Since the audio signal voltage is of opposite phase across the primary of the audio output transformer 207, the audio frequency voltage is additive across said transformer and the combined output of both tubes is available at the secondary of said audio output transformer. The tremolo voltage from the frequency electronic oscillator 201 is applied in phase to the two grids 209, 210 of the tubes 203, 204 by virtue of being introduced at the center tap of the secondary of the audio input transformer 202; or it may be applied to the cathodes 211, 212 at their junction with the common cathode resistor 206 and so be in phase for both tubes. The load impedance desired for the oscillator 201 is the deciding factor in choosing the point for introducing the tremolo voltages. In either case, the tremolo voltage modulates the bias voltage of both tubes in phase, thus varying their gain or amplification factor at the tremolo voltage frequency. The amplified tremolo frequency voltage appears in the output of both tubes and is applied across the primary of audio output transformer 207. Since this voltage is in phase, it produces no voltage drop across the primary of said transformer and thereby does not appear in the output or secondary of said output transformer.

Thus we have in the output only the amplitude modulated audio frequency voltage, the modulating voltage being cancelled at the primary of audio output transformer 207.

Having thus described my invention, I claim:

1. A tremolo frequency modulator, comprising: an oscillator for producing voltage oscillations at tremolo frequencies; a variable gain audio circuit having an input circuit and an output circuit; means for impressing the tremolo voltage oscillations of said oscillator on said variable gain audio circuit to vary at tremolo frequencies the gain thereof and the amplitude of the audio frequencies in said output circuit; and said output circuit having means for removing said tremolo voltage oscillations.

2. A tremolo frequency modulator, comprising: an oscillator for producing voltage oscillations at tremolo frequencies; a variable gain audio circuit having an input circuit and an output circuit; means for impressing the tremolo voltage oscillations of said oscillator on said variable gain audio circuit to vary at tremolo frequencies the gain thereof and the amplitude of the audio frequencies in said output circuit; and said out-

put circuit having means for eliminating said tremolo voltage oscillations by obtaining phase cancellation.

3. A tremolo frequency modulator, comprising: an oscillator for producing voltage oscillations at tremolo frequencies; a variable gain audio circuit having an input circuit and an output circuit; means for impressing the tremolo voltage oscillations of said oscillator on said variable gain audio circuit to vary at tremolo frequencies the gain thereof and the amplitude of the audio frequencies in said output circuit; and said output circuit having connected therein a transformer and said phase inverter circuit having means for supplying the audio voltages out-of-phase to said transformer and the tremolo voltages in-phase to said transformer whereby the audio voltages are additive and the tremolo voltages are cancelled.

4. A tremolo frequency modulator, comprising: an oscillator for producing voltage oscillations at tremolo frequencies; a variable gain audio circuit having an input circuit and an output circuit; means for impressing the tremolo voltage oscillations of said oscillator on said variable gain audio circuit to vary at tremolo frequencies the gain thereof and the amplitude of the audio frequencies in said output circuit; and said audio circuit having means for removing said tremolo voltage oscillations.

5. A tremolo frequency modulator, comprising: a Wien bridge oscillator for producing voltage oscillations at tremolo frequencies; a phase inverter circuit for audio frequencies having an electronic tube, an input circuit for audio frequencies, and an output circuit; means for impressing the tremolo voltage oscillations of said oscillator on said tube to vary at tremolo frequencies the gain of said tube and the amplitude of the audio frequencies in said output circuit, and said output circuit having means for removing said tremolo voltage oscillations.

6. A tremolo frequency modulator, comprising: an oscillator for producing voltage oscillations at tremolo frequencies; a circuit for audio frequencies having an electronic tube, an input circuit for audio frequencies, and an output circuit; means for impressing the tremolo voltage oscillations of said oscillator on said tube to vary at tremolo frequencies the gain of said tube and the amplitude of the audio frequencies in said output circuit, and said output circuit having means for removing said tremolo voltage oscillations.

7. A tremolo frequency modulator, comprising: means for producing voltage oscillations at tremolo frequencies; an audio circuit having connected therein an input, an output, and two tubes; said audio circuit being so arranged that audio frequencies passing therethrough will be in phase opposition; means for impressing the tremolo voltage oscillations of said oscillator on said tubes in phase to vary at tremolo frequencies the gain thereof and the amplitude of the audio frequencies in said output; and said output having means for eliminating said tremolo voltage oscillations by obtaining phase cancellation.

8. A tremolo frequency modulator, comprising: means for producing voltage oscillations at tremolo frequencies, a phase inverter having an electronic tube and an output circuit, means for impressing said tremolo voltage oscillations on said tube to vary at tremolo frequencies the gain of said tube and the amplitude of the audio frequencies output thereof, and said output circuit having means for removing said tremolo voltage oscillations.

9. A tremolo frequency modulator, comprising: means for producing voltage oscillations at tremolo frequencies, a variable gain phase inverter circuit having an input and an output circuit for audio frequencies, means for impressing said tremolo voltage oscillations on said phase inverter circuit to vary at tremolo frequencies the gain of said inverter circuit and the amplitude of the audio frequencies in said output circuit, and said output circuit having means for removing said tremolo voltage oscillations.

10. A tremolo frequency modulator, comprising: an oscillator for producing voltage oscillations at tremolo frequencies; an audio circuit having connected therein an input, and an output having an output load; said audio circuit being so arranged that audio frequencies passing therethrough to said output will be in phase opposition; means for impressing the tremolo voltage oscillations of said oscillator on said circuit to vary at tremolo frequencies the gain thereof and the amplitude of the audio frequencies in said output; said audio circuit being so arranged that said subsonic oscillations will pass to said output in-phase; and said output load being so connected in said audio circuit that out-of-phase audio voltages are additive across the output load, and in-phase tremolo voltages are cancelled.

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