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FREQUENCY DISCRIMINATORY AMPLIFIER

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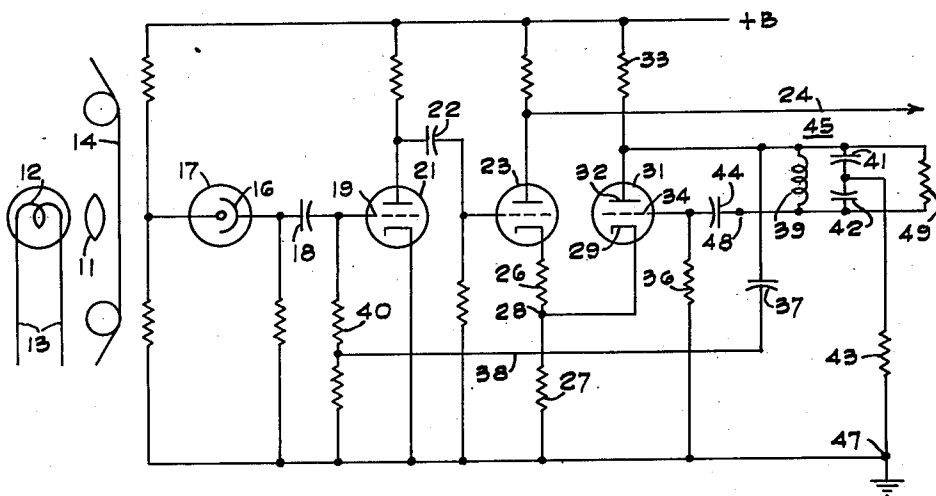


Fig. 1

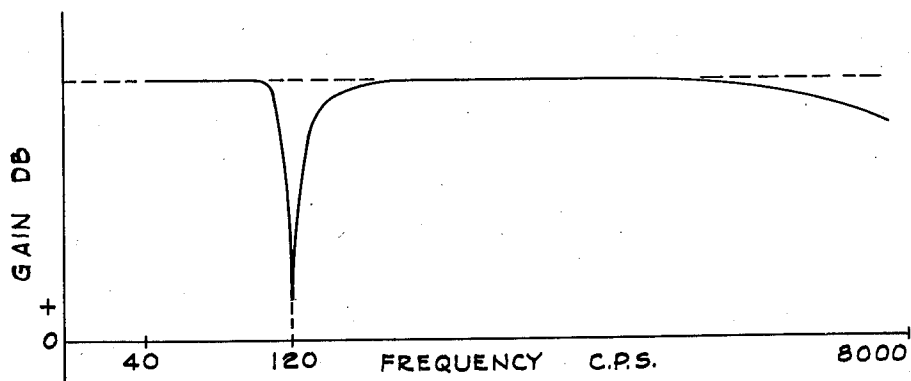


Fig. 2

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FREQUENCY DISCRIMINATORY AMPLIFIER

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This invention pertains to a frequency discriminatory amplifier and more specifically to improvements in circuits for rejecting one or more specific electrical frequencies within a band of frequencies.

A filter which rejects a single frequency most strongly, passing frequencies both above and below a rejected frequency band, has an important characteristic, the "sharpness" of rejection. That is to say, the graph of attenuation versus frequency has a peak at the rejection frequency and the width of the peak near its maximum attenuation value represents the width of the rejection frequency band, while the width at lower attenuations determines the sharpness of the graph and represents the "sharpness" of the rejection. It sometimes is desired to make the width of the rejected frequency band narrow, and in addition to make the rejection "sharp."

It is easily possible to design very sharp rejection circuits for radio frequencies, but for low audio frequencies the design is difficult, and in the past sharp low-frequency rejection circuits have required the use of expensive high Q reactances.

The instant invention provides a more economical apparatus for low frequency rejection that has a sharper rejection curve than that of any previously existing method. Its use is not confined to low frequencies, however, but it is also applicable at all other frequencies, the control of which may be accomplished by electronic tubes and ordinary inductances and capacitances.

One purpose, then, of this invention is to provide an apparatus for sharply attenuating a particular electrical frequency or frequencies while passing neighboring frequencies with comparatively little attenuation.

In the use of hot cathode electronic tubes and of incandescent filament lamps in electronic circuits it is often desirable to operate the heaters and filaments thereof on alternating electrical current having a frequency within the audible range. There may then be induced in these electronic circuits an alternating component having twice the supply frequency. If as is usually the case the supply is from commercial 60-cycle circuits, the introduced frequency will be 120 cycles per second. This frequency is within the easily audible range, and in the case of sensitive circuits the presence of this frequency can be very evident. In some cases it is essential to eliminate or greatly to reduce this unwanted frequency.

Another purpose of this invention then is to

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eliminate from electronic circuits unwanted frequencies introduced by filaments operating from alternating current power supplies.

An example of a case in which ripple introduced by filaments has been particularly obnoxious and difficult to deal with is in the reproduction of sound from a motion picture film sound track. In such equipment, as commonly constructed, an exciter lamp provides light which is viewed through a moving film sound track by a phototube or photoelectric cell. Any alternations of the filament supply to the exciter lamp will affect the photoelectric means so that a frequency double that of the filament supply will be introduced to the circuit of the photoelectric means. To evade this difficulty the exciter lamp is often operated on direct current or on super-audible alternating current but such arrangements require complicated and expensive filter systems or the use of a high frequency oscillator and power driver stage.

The apparatus of this invention, however, permits filament operation on 60-cycle supply while eliminating the 120-cycle component from the output, the attenuation peak having a sharpness that is unobtainable by the use of any other type of circuit employing components of comparable quality and size, thus providing a simplified system in which neither expensive filter systems nor high frequency oscillators are required.

Still another purpose of this invention then is to eliminate filament hum from motion picture sound systems in which the exciter lamp is directly energized by a 60-cycle supply source.

In an example of the instant invention the removal of 120-cycle filament hum from such a motion picture sound system begins with the withdrawal of a small amount of audio energy at some intermediate point of the sound amplifier. This energy is selectively amplified at the 120-cycle frequency by a sharply selective circuit including a negative feedback amplifier and a rejection circuit and the amplified energy thereof, having a band width that may be made narrow is fed back to the input of the sound amplifier in a negative sense. This effectively suppresses a narrow band width, removing signal frequencies at 120-cycles but does not affect the transmission of signals of other frequencies so that with the exception of a narrow band of signal centered at 120-cycles all signal frequencies are faithfully transmitted to the output of the sound amplifier and since the band of signal frequencies suppressed is made very narrow

there is no perceivable deterioration of output sound quality.

One type of passive linear rejection circuit which may be employed, and which is described in the detailed description hereinafter, is a three-terminal single-section resonant T network employing inductance, capacitance, and resistance. This particular network has a single sharply-peaked attenuation characteristic. The choice of circuit, however, is not confined to this particular design of rejection network, but any other design of network including resistance-inductance and resistance-capacitance types for single or multiple band rejection, or for high rejection or low rejection, may be employed instead.

The advantages of this system of hum elimination include a much greater sharpness and selectivity for a given quality of components than has been achieved by any other method. In addition, the rejection circuit being of low impedance at off-resonance frequencies and being maintained near ground potential has a negligible electrostatic noise pickup, and the residue of negative feedback through the rejection circuit at all frequencies tends to reduce hum and microphonics. The effectiveness of the rejection circuit which is responsible for many of these advantages is explained by the fact that the rejection circuit employed is characterized by a very high Q, or figure of merit, even though the inductance coil employed therein has a low Q. The effectiveness of the entire circuit may be explained by the fact that it employs a first negative feedback loop around an amplifier, a second negative feedback loop around a second amplifier embraced within the first loop, and a passive rejection circuit embraced within the second loop. It is a unique feature of such a circuit that although the sharpness of the characteristic of the second feedback loop is little or no greater than that of the passive rejection circuit characteristic, the sharpness of the first feedback loop characteristic is considerably greater than that of the second loop, while the stability of the entire circuit is excellent. This stability distinguishes this circuit from positive feedback circuits for accomplishing the same purpose, the stability of which is far inferior.

Other purposes, objects and advantages of the invention will be apparent from the following description in which:

Figure 1 is a schematic diagram of an embodiment of the invention.

Figure 2 depicts the characteristic curve of the filter employed in the described embodiment of the invention.

In Fig. 1 a motion picture sound film exciter has an optical system represented by the lens 11 and has a light source indicated by the lamp filament 12, which is supplied with 60-cycle alternating current through the conductors 13. A motion picture film 14 carrying a sound track is continuously moved through the beam of light produced by the lamp 11 so that the cathode 16 of a phototube 17 is illuminated by the modulated beam of light. This light also contains a 120-cycle component because the filament 12 of the exciter lamp 11 has two periods of maximum brightness during each cycle of the supply current corresponding to the positive and negative current maxima.

This 120-cycle frequency signal would be heard as hum in the speaker were it not removed by the apparatus of this invention wherein a narrow band of frequencies centered at 120 cycles per

second is suppressed, so that the output of the amplifier contains neither hum nor audio response within this band. The suppressed band is made so narrow that the absence of this audio response is not noticeable to the ear; that is, the tone quality of the output is not degraded.

The cathode 16 of the phototube 17 is connected through a coupling condenser 18 to the control grid 19 of a triode amplifier tube 21. This tube is coupled through a condenser 22 to a second stage tube 23, from the anode of which a conductor 24 is connected through to subsequent amplifier stages to a speaker (not shown).

The cathode resistance of the amplifier tube 23 consists of two resistors 26 and 27 connected in series. The junction 28 thereof is connected to the cathode 29 of a triode 31 having its anode 32 connected through a resistor 33 to a source of positive potential and its control grid 34 grounded through a resistor 36. This triode therefore behaves as a linear amplifier of its cathode potential variations without change of phase at the anode 32. The anode 32 is connected through a coupling condenser 37, conductor 38, and resistor 40 to the input control grid 19 of the first amplifier tube 21. A resonant circuit 45 composed of a reactance 39, two capacitances 41 and 42 and a resistor 43 is connected between the anode 32 and control grid 34 of the tube 31 through a coupling condenser 44. This resonant circuit has the form of a three-terminal filter section of the bridge T type having input terminals 46 and 47 and output terminals 48 and 47. A resistor 49 is also part of the circuit but its function is merely to reduce the sharpness of its tuning to the degree found most desirable in the particular application for which the device is intended change of the resistance of this resistor from an optimum value broadening the resonance peak of the resonant circuit. When the optimum value of the resistor is employed a still sharper resonance curve may be attained by employing a reactor having a higher Q, by using a different type of filter, or by employing additional filter stages.

For frequencies other than 120 cycles per second, the resonant circuit acts as a low-impedance connection between the anode 32 and grid 34; it therefore may be regarded as a highly effective negative feedback loop from anode to grid around the tube 31, greatly reducing its amplification. As a result, only a relatively small amount of energy at these frequencies is transmitted through the conductor 38 to the amplifier input at grid 19. This energy being in phase opposition to that derived from the phototube 16, therefore constitutes a negative feedback but since the amount thereof is very small the amplifier output derived from the conductor 24 is reduced only slightly at these frequencies.

The circuit 45, however, is designed to resonate at signal frequencies of 120 cycles per second, so that its impedance becomes high at these frequencies and little if any energy at these frequencies is negatively fed back from the anode 32 to the grid 34. Consequently tube 31 amplifies the 120-cycle energy impressed on its cathode 29 and presents to the input grid 19 of the tube 21 through the conductor 38 a greatly augmented negative feedback of signal having a frequency of 120 cycles per second. As a result, the gain of the amplifier composed of the tubes 21 and 23 is depressed by a large amount for 120-cycle and adjacent frequencies only.

When the amplifier by itself has a frequency

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characteristic that is perfectly flat between 40 and 2000 cycles the addition of the anti-hum circuit results in the frequency characteristic curve of Fig. 2. Inspection of this curve indicates that a fairly uniform output is obtained between 40 and 8000 cycles, the frequency band removed by the hum elimination circuit being so narrow as to affect the quality only in an inappreciable degree.

The sharpness of the attenuation trough may be made optimum for the conditions presented because of the very high equivalent Q or figure of merit which may be attained from the resonant circuit 45 when employed in the manner described and hence although hum is successfully eliminated the loss of frequency response is not otherwise apparent to the ear.

What is claimed is:

1. A frequency discriminatory amplifier comprising, a first thermionic discharge tube, means for impressing signals on the input thereof having a range of frequencies including signals at undesired frequencies, a second thermionic discharge tube having at least an anode, cathode and control electrode having its input electrodes coupled to the output of said first thermionic discharge tube, a resistor connected in the anode-cathode circuit of said second thermionic discharge tube, a third thermionic discharge tube having an input electrode connected to said resistor, a network resonant at said undesired frequencies connected between the input and output circuits of said third thermionic discharge tube and a signal circuit interconnecting the output of said third thermionic discharge tube and the input of said first thermionic discharge tube.

2. A frequency discriminatory amplifier comprising, a first thermionic discharge tube, means for impressing signals on the input thereof having a range of frequencies including signals at undesired frequencies, a second thermionic discharge tube having at least an anode, cathode and control electrode, a circuit coupling the output of said first thermionic tube and the input of said second thermionic tube, a resistor connected between the cathode of said second thermionic tube and a terminal of a direct-current potential source, a third thermionic discharge tube having at least an anode, cathode and control electrode, the cathode of said third thermionic tube being connected to the cathode end of said resistor, a network connected between the anode and control electrode of said third thermionic discharge tube, said network being resonant at said undesired

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signal frequencies, a circuit connecting the output of said third thermionic discharge tube and the input of said first thermionic discharge tube and an output circuit connected to the output of said second thermionic tube.

3. A frequency discriminatory amplifier comprising, a first thermionic discharge tube, means for impressing signals on the input thereof having a range of frequencies including signals at undesired frequencies, a second thermionic discharge tube having at least an anode, cathode and control electrode, circuit means coupling the output of said first thermionic discharge tube and the input of said second thermionic tube, a source of direct-current potential for said second thermionic discharge tube, a resistor connected between the anode of said second thermionic discharge tube and a positive terminal of said direct-current potential source, a second resistor connected between the cathode of said second thermionic discharge tube and a lower potential terminal of said direct-current potential source, an output circuit connected to the anode of said second thermionic discharge tube, a third thermionic discharge tube having at least an anode, cathode and control electrode, the cathode of said third thermionic discharge tube being connected to said second resistor and the control electrode thereof being connected to said direct-current potential source, an inductive-capacitive network interconnecting the input and output circuits of said third thermionic discharge tube, said network being tuned to resonate at said undesired signal frequencies and a signal circuit interconnecting the output circuit of said third thermionic discharge tube and the input of said first thermionic discharge tube forming a negative feedback circuit in which signals of said undesired frequencies preponderate over signals of other frequencies.

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