Aug. 4, 1931. P. H. CRAIG 1,817,612

SOUND REPRODUCING SYSTEM

Filed July 11, 1928

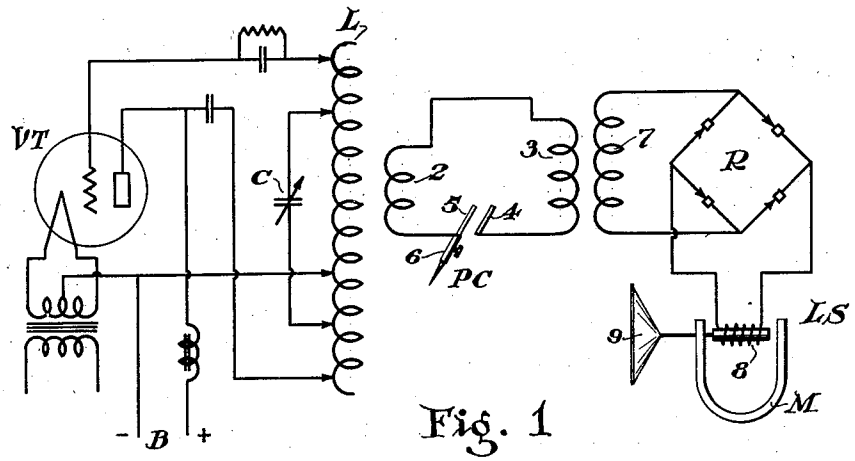


Fig. 1

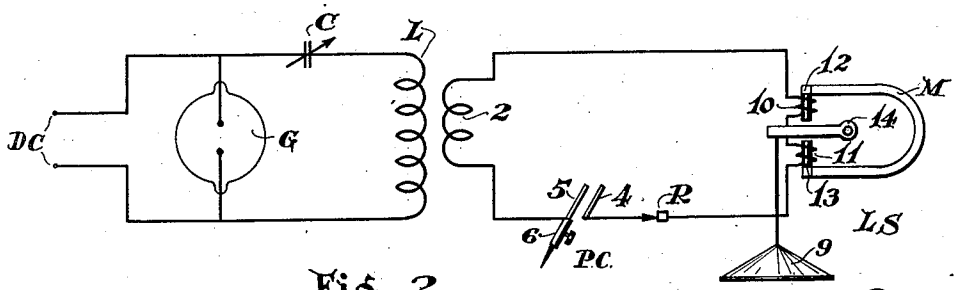


Fig. 2

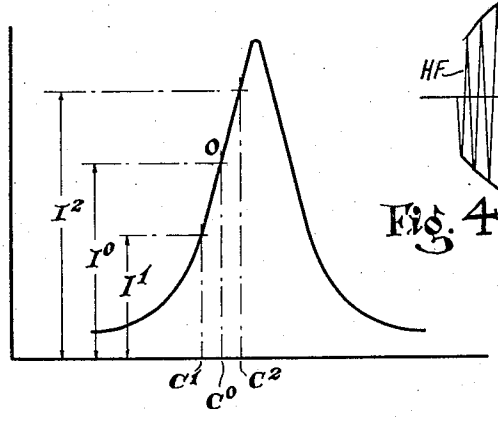


Fig. 3

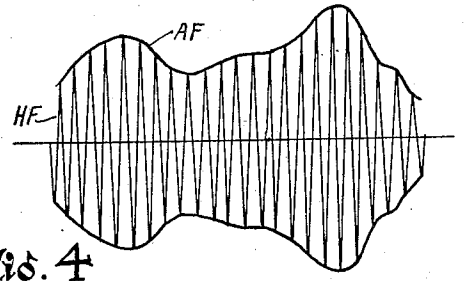


Fig. 4

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UNITED STATES PATENT OFFICE

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SOUND REPRODUCING SYSTEM

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My invention relates to a system for the electrical reproduction of sound from a phonograph record or other sound record.

My invention also involves a novel method for the electrical reproduction of sound from a sound record.

In most known systems for the electric reproduction of sound from a record, the current variations produced by the pickup device are very weak, and audio-frequency current amplifiers are employed to amplify these weak currents to a strength sufficient to operate a loud-speaker. Such amplifiers are objectionable on account of distortion introduced and the magnification of noises inherent in the amplifiers themselves, this disadvantage becoming more objectionable in systems employing several amplifiers connected in cascade.

An object of my invention is to devise an electrical system for the reproduction of sound in which the extraneous noises inherent in the system itself are reduced to a minimum.

A further object of my invention, is to device an electrical sound reproducing system in which the sound record serves to modulate a source of current and the modulated current is applied directly to the loud speaker or sound reproducing element without amplification.

A further object of my invention is to devise a system for the electric reproduction of sound in which super-audible currents are employed througout the system, and without the use of amplifiers.

My invention is illustrated in the accompanying drawings in which:

Fig. 1 is a circuit diagram of one form of my invention;

Fig. 2 is a circuit diagram of another form of my invention; and

Figs. 3 and 4 are curves for illustrating the operation of the systems shown in Figures 1 and 2.

Referring to Fig. 1, I have shown a conventional form of vacuum tube oscillator comprising an inductance coil L and a variable condenser C forming a frequency determining circuit associated with a three-element vacuum tube VT to form an oscillator of the type commonly known as a Hartley circuit. Inductively coupled to inductance L is a coil 2 of a small number of turns or tapped directly off, and in circuit therewith is a second coil 3 and a pick-up condenser PC. The pick-up condenser PC comprises a stationary condenser plate, or plates, symbolized by the element 4 in the drawings, and a movable plate, or series of plates, symbolized by the element 5, mounted upon and operated by the stylus arm which carries the phonograph needle. The phonograph stylus arm is symbolized in the drawings by the element 6. Coil 3 is inductively coupled to a coil 7 which is in circuit with a bridge rectifier R and a loud-speaker or sound reproducing element LS. The coupling may also be capacitative and the coupling system 3—7 may be done away with entirely. Rectifier R may be half-wave also.

The operation of Fig. 1 is as follows:

The frequency determining circuit of the oscillator is adjusted to produce an alternating current of super-audible frequency. The oscillator has sufficient capacity to supply enough energy for the operation of the loud-speaker LS without employing intermediate stages of amplification, either high or low frequency. Coils 2 and 3 are preferably made of relatively large wire having low resistance and with only a few turns, even as low as a single turn each. The pick-up condenser PC has sufficient normal capactiy to form with the inductance of coils 2 and 3 a tuned circuit slightly out of tune with the current generated by the vacuum tube oscillator. The natural frequency of this circuit may be either slightly higher or slightly lower than the frequency of the oscillator current. Variation of the capacity of the pick-up condenser PC by operation of the stylus arm 6 will produce corresponding variations in current flowing in the tuned circuit. In Fig. 3 I have illustrated the manner in which the current flowing in the tuned circuit varies with variation of the capacity of the pick-up condenser. For example, the ordinates of the curve represent effective values of the current flowing in the tuned circuit, and the

abscissas represent corresponding values of the capacity of the pick-up condenser PC. It will be noted that the curve shown in Fig. 3 is a typical resonance curve showing the variation of current in a tuned circuit when the capacity of the circuit is varied in a manner such that the natural frequency of the circuit is varied from a point below the frequency of the applied current to a point above this frequency. The normal capacity of the pick-up condenser PC, that is, the capacity of the condenser with the stylus in its neutral or normal position, should be such that the tuned circuit operates upon a straight-line portion of one of the sides of the resonance curve. For example, a suitable operating point is indicated at O on the curve shown in Fig. 3, and the value of the normal capacity of pick-up condenser corresponding to this point is indicated at the point C^o. The point of operation may be fixed by suitably adjusting the value of the inductance of either or both of coils 2 and 3, or by adjusting the capacity of the pick-up condenser. The effective value of the normal current is indicated by the ordinate I^o. Assume that in operation the capacity of the pick-up condenser varies from C^o to C^1 as a minimum and from C^1 to C^2 as a maximum, then the current flowing in the tuned circuit will vary from the effective value I^o to I^1 as a minimum and from I^o to I^2 as a maximum. The current induced into coil 7 by coil 3 will vary in amplitude the same as the current flowing in the tuned circuit. Due to the action of the rectifier R, the varying high frequency current is rectified and a low frequency current corresponding in frequency and shape to the amplitude variations of the stylus arm 6 will flow in the loud speaker circuit and will operate the loud speaker accordingly.

From a consideration of Fig. 3, it will be seen that the effectiveness of the pick-up device in modulating or varying the amount of high frequency current transferred from the oscillator to the loud speaker depends upon the steepness of the resonance curve, and the sharper the resonance, the greater is the effectiveness of the pick-up device. Accordingly, it is important that the resistance of the tuned circuit be made as small as possible. To this end, all coils included in the tuned circuit are made of relatively large wire having low resistance and with only a few turns.

Fig. 4 illustrates how the pick-up varies the amplitude of the high frequency current HF. The rectifier serves to suppress the lower half of the modulated wave, and the loud-speaker responds to the audio-frequency envelope AF.

The loud speaker LS is preferably of the electro-dynamic type wherein the movable element comprises a coil 8 arranged between the poles of a magnet M in such manner that varying currents flowing through the coil produce oscillations of the coil corresponding to the current supplied, and oscillations of the coil are transmitted to a cone-diaphragm 9. The drawing is merely diagrammatic and serves to indicate only the type of apparatus employed. The coil 8 preferably has very low resistance and offers very little impedance to the flow of the high frequency current.

The rectifier R is shown as a "bridge" rectifier comprising four rectifier units connected in a bridge to permit current to flow in the directions indicated by the arrows, thus giving full-wave rectification. If desired, the loud-speaker may be connected in series with coil 7 with only one rectifier unit inserted in the circuit for half-wave rectification. The rectifier units may be any form suitable for the purpose, such as thermionic valves, gaseous ionization rectifiers, copper oxide or other types of rectifiers.

In Fig. 2, I have shown another form of my invention in which the source of high frequency current comprises a gaseous arc G connected across a source of direct current DC, and having a frequency determining circuit including a coil L and a condenser C connected in shunt therewith. The coil 2 is inductively coupled to the coil L or tapped off therefrom the same as in Fig. 1, but coils 3 and 7 shown in Fig. 1 are omitted, and rectifier R and the loud-speaker LS are connected directly in circuit with the coil 2 and the pick-up condenser PC.

Operation of Fig. 2 is as follows:

The gaseous arc G has a negative-resistance characteristic, and sets up continuous oscillations in the frequency determining circuit including the condenser C and the inductance coil L. The frequency of these oscillations is adjusted to be super-audible by adjusting the valves of either or both of the elements L and C. Oscillations are induced in the coil 2 from coil L the same as in Fig. 1, and the rectifier element R serves to rectify these oscillations to produce a low frequency current corresponding in frequency and wave shape to the variations of the stylus arm 6. The armature 14 of the loud-speaker is vibrated in accordance with the low frequency current, and these vibrations are transmitted from the armature to the cone diaphragm 9.

Since the rectifier R in Fig. 2 is connected directly in series with the tuned circuit, this element should preferably be of a type which has low internal impedance. I have found that a commercial type of rectifier known as Raytheon "A cartridge" gives satisfactory results. While I have shown only a single rectifier element connected directly in series with the tuned circuit, it is to be understood that a "bridge" arrangement of four elements giving full-wave rectification may be employed after the manner shown in Fig. 1. It

is to be noted that the coils 10 and 11 of the loud speaker are included directly in the tuned circuit, and their inductive reactances must be considered in fixing the point of operation on the resonance curve.

The loud-speaker employed in Fig. 2 is somewhat different from that employed in Fig. 1. Magnet M is provided with two pole-pieces 12 and 13 around which coils 10 and 11 are wound. These pole-pieces are preferably formed of powdered compressed iron, or other powdered compressed magnetic material, such as an alloy of nickel and iron giving high values of permeability. The operating coils 10 and 11 are formed of a few turns of heavy wire, thereby resulting in coils having low resistance and low inductance. Thus the high frequency currents are not choked out by the operating windings of the loud-speaker. This type of loud speaker may be used in the circuit of Fig. 1 also.

It will be appreciated that loud-speakers of ordinary construction are not suitable for operation in my system of sound reproduction due to the high inductance of the windings, but special constructions as indicated above must be employed in order to permit the passage of the high frequency current through the operating winding of the loud-speaker itself.

A suitable pick-up condenser for operation in my system may be made by employing aluminum plates separated by tissue paper which has been saturated with a solution of borax. The condenser is preferably "formed" by inserting the tissue paper between the aluminum plates while still wet with the borax solution, and applying a voltage between the plates for about 24 hours, or until the paper becomes dry. The condenser will then be found to have greatly increased capacity and therefore, high current carrying capacity. For example, I have been able to pass 100 milli-amperes through a pick-up condenser of this construction. This current value is sufficient to actuate the loud-speaker without any amplification whatever. Care should be exercised to keep the high frequency conductors separated from each other to prevent by-passing of the high frequency current. The ratio of turns between coil 3 and coil 7 may be either step-up or step-down to accommodate the needs of the particular rectifier and loud speaker employed.

It is to be understood that other types of oscillators may be employed with my pick-up device, the only essential requirement being that the oscillator should deliver an alternating current of a constant and inaudible frequency.

It is apparent that the pick-up condenser may assume other forms than that here shown and described, and that it may be operated from other types of sound records.

From the foregoing it will be observed that I have devised a system for the electrical reproduction of sound in which I generate a high frequency current of sufficient energy to operate a loud-speaker without amplification. This current is then controlled or modulated by the pick-up device in accordance with the sound waves recorded on a sound record. The modulated wave is then rectified and employed to operate the loud-speaker without amplification.

I have devised a system in which no amplifying tubes are employed for amplification of either high frequency or low frequency currents. I accomplish this by employing a source of high frequency current of sufficient power to operate the loud-speaker without amplification. The principal advantage in the use of high frequency currents is that sufficient current can be passed through the condenser pick-up to operate the loud-speaker directly, and the amplifying tubes can, therefore, be eliminated.

What I claim is:

1. A sound reproducing system comprising a source of current constant super-audible frequency and of sufficient energy to operate a loud-speaker, a sound record, means for modulating said current in accordance with the record, and means for rectifying said modulated current and operating said loud-speaker solely by the energy of said modulated current.

2. A sound reproducing system comprising a source of current of constant and super-audible frequency, a translating circuit connected to said source of current, means for controlling the amount of current supplied to said translating circuit in accordance with a sound record, means for rectifying said supplied current, and a sound translating device operated solely by the energy of said supplied current.

3. A sound reproducing system comprising a source of current of constant and super-audible frequency, a tuned circuit coupled to said source of current and having a natural frequency different from the frequency of the source, a sound record, means for varying a tuning element of said tuned circuit whereby the current in said circuit is varied in accordance with the sound record, means for rectifying said current, and a sound translating device operated solely by said modulated current.

4. A sound reproducing system comprising a source of current of constant and super-audible frequency, a tuned circuit coupled to said source of current and having a natural frequency different from the frequency of the source, said tuned circuit including a variable condenser, a sound record, means for varying the capacity of said condenser in accordance with the sound record whereby the current in

said tuned circuit is varied according to the sound record, means for rectifying the varying current, and a loud-speaker operated solely by the energy of the rectified current.

5. A method of reproducing sound from a sound record which consists in generating an electric current of constant super-audible frequency and of sufficient energy to operate the ultimate sound translating device, modulating the current in accordance with the sound record, rectifying the modulated current, and operating the ultimate sound translating device solely by the energy of said modulated current.

6. A method of reproducing sound from a sound record which consists in, generating an electric current of constant super-audible frequency and of sufficient power to operate a loud-speaker, supplying the high-frequency current directly to a translating circuit, and controlling the energy so supplied in accordance with the sound record, rectifying the supplied current, and operating the loud-speaker solely by said rectified current.

7. A sound reproducing system comprising a source of current of constant super-audible frequency, a translating circuit connected to said source and including a pick-up condenser of relatively large capacity, means for varying the capacity of the condenser in accordance with a sound record, means for rectifying the current in the translating circuit, and a sound translating device operated solely by the energy of the rectified current, said translating device comprising a loud-speaker having an operating winding of low inductance and resistance with a core of finely divided magnetic material.

8. A sound reproducing system comprising a source of current of constant and super-audible frequency, a translating circuit connected to said source of current, means for controlling the amount of current supplied to said translating circuit in accordance with a sound record, and a sound translating device operated solely by the energy of said supplied current.

9. A method of reproducing sound from a sound record which consists in generating an electric current of constant super-audible frequency and of sufficient energy to operate the ultimate sound translating device, modulating the current in accordance with the sound record, and operating the ultimate sound translating device solely by the energy of said modulated current.

In witness whereof I affix my signature.

PALMER HUNT CRAIG.