June 14, 1927. 1,632,389

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OSCILLATION GENERATING AND SUPPLY SYSTEM

Filed Dec. 8, 1923

Fig. 1

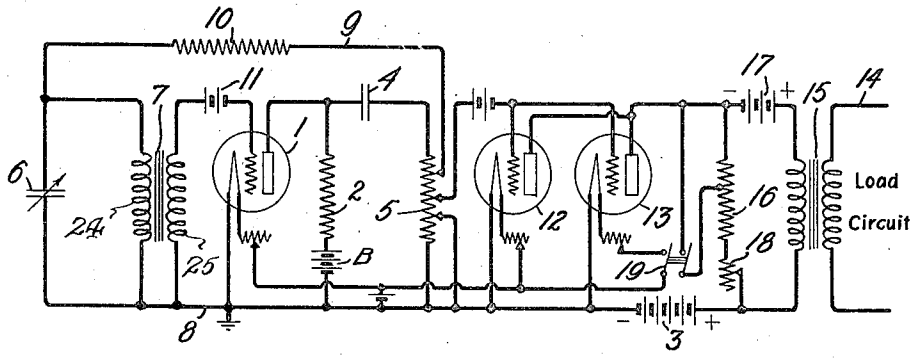
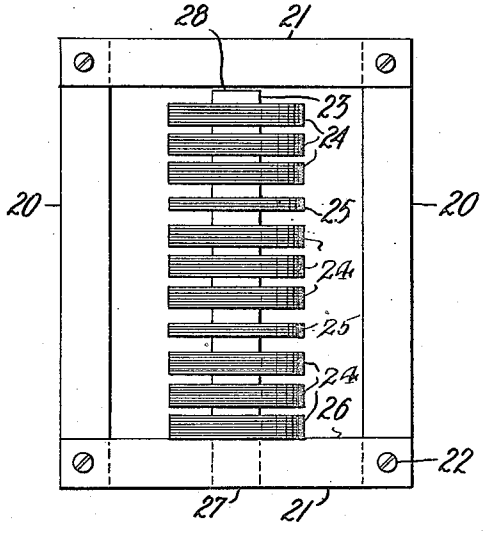


Fig. 2



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Patented June 14, 1927. 1,632,389

UNITED STATES PATENT OFFICE.

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OSCILLATION GENERATING AND SUPPLY SYSTEM.

Application filed December 8, 1923. Serial No. 679,316.

This invention relates to oscillation generating and supply systems, and particularly to apparatus adapted to produce low frequency oscillations of very pure wave form.

Vacuum tube or other electric discharge oscillators as hitherto constructed have been unable to produce oscillations within the low frequency range extending from zero to a few hundred cycles per second without accompanying harmonics of relatively large magnitude. In certain fields as, for example, in testing telegraph conductors, cables, etc., it is highly desirable to be able to produce oscillations of the order of 4 to 60 cycles per second without accompanying harmonics, the magnitude of which is greater than a few per cent of that of the fundamental. Filters at such frequencies are impracticable because of their excessive size and cost.

In vacuum tube oscillators of the usual type, there is a feedback of alternating current from the output to the input circuit of the tube. The oscillations thus supplied to the input circuit operate by virtue of the amplifying property of the tube to set up amplified oscillations in the output circuit thus augmenting the alternating current in the output circuit and consequently augmenting also the oscillations fed back to the input circuit. This process continues until the oscillations build up to a limiting magnitude determined by the amplification afforded by the tube and the losses in the system. Beyond this limiting magnitude, an additional increment to the oscillations in the input circuit would not set up in the output circuit an alternating current increment sufficient to compensate for the consequent increments in alternating current energy dissipation occurring in the entire system.

The process just described involves large variations in the electromotive force impressed on the grid circuit and large variations in space current in the plate circuit. As soon as the grid becomes positive with respect to the cathode, a space current is drawn to it from the cathode thus rendering unsymmetrical the resulting grid potential wave, since the positive potential peaks or half cycles are diminished. Accordingly, the non-symmetrical grid potential, which, in effect, comprises both a wave of the fundamental frequency and a series of waves of even harmonics thereof, will give rise in the input circuit to an amplified wave which is by no means sinusoidal but contains the same harmonics as the wave in the input circuit. Obviously, the larger the input current the greater will be this distorting effect.

The large variations in space current involve operating the vacuum tube from a point at or below the lower knee of its well-known grid potential plate current characteristic to a point at or above the upper knee of this characteristic. It follows that faithful repetition of the input wave form in the amplified output wave is no longer secured and additional distortion is produced.

Particularly at low frequencies are the effects of distortion most difficult to avoid. The frequency determining circuit, at such frequencies, includes a relatively large inductance. An air core inductance, of the magnitude required, is not only excessive in size but involves distributed capacities which defeat its purpose. Cores of ordinary magnetic materials have been used and have caused additional distortion for the reason that, as previously explained, alternations of the oscillator build up to a large limiting magnitude determined by losses in the tube itself. These cores are, therefore, subjected to such wide ranges of magneto-motive force that the resulting flux also varies greatly and on account of the non-linear magnetic characteristic of the core introduces a further distortion.

According to the present invention, the alternating grid potential impressed on the oscillator tube is maintained so low that, with the grid polarization employed, the space current flowing in the grid circuit is of zero or negligibly small magnitude. This is accomplished primarily by a special transformer coupling the frequency determining circuit and the grid circuit. This transformer has a magnetic core which at very low magnitude of current in the frequency determining circuit experiences a low flux density. The core therefore produces a certain core loss which makes its presence felt as an effective resistance in the frequency determining circuit. With increasing magnitudes of current and flux density,

this core loss resistance rises much more rapidly than the voltage across the coil and shortly reaches a point where the loss is so great that the amplifying action of the tube is barely able to compensate for it. Accordingly, as the oscillating current of the oscillator circuits builds up, it shortly reaches its limiting value imposed by the transformer and stabilizes at that magnitude. This limit is so determined by the design of the oscillator circuit and its elements including the transformer and the amplifier, that the maximum alternating voltage applied to the grid circuit does not cause appreciable space current to flow in the grid circuit. This is in marked contrast to prior oscillator design in which the oscillators stabilize at a point determined by the rapid increase in energy dissipation in the amplifier itself and in its electrode circuits.

In order to minimize the distortion occasioned by the curved I_B—E_C characteristic, a large resistance is connected in series in the space current circuit and this tends to straighten the characteristic and make approximately linear that portion of the characteristic to which the operation of the tube is restricted.

The supply of very low frequency oscillations from an oscillator to a load circuit involves an additional difficulty. For a transformer which will effectively transfer these very low frequency oscillations, a magnetic core is highly desirable to enable the necessary inductance to be obtained without coils of immoderate size. This transformer cannot be directly connected in the space current circuit since that would involve polarization of the magnetic core which would consequently entail distortion and production of harmonics. It might be supposed that the load connection could be made to the oscillator through a series blocking condenser but this would involve an inordinately large capacity and the inherent tendency of the capacity element to discriminate against the lower frequencies rather than against the higher harmonic frequencies. A feature of this invention consists in neutralizing the polarizing effect of space current in a magnetic core transformer in such manner that the transformer may be connected directly to the oscillating system without the interposition of a blocking capacity element.

The novel features which are considered characteristic of the invention are pointed out with particularity in the appended claims. The invention itself, however, both as to the details of its organization and its mode of operation will be best understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 illustrates schematically an oscillator supply circuit embodying the invention, and Fig. 2 shows the transformer which couples the frequency determining circuit to the grid circuit.

Referring to Fig. 1, a vacuum tube oscillator comprising one or more vacuum tubes 1 of well-known type is shown with a space current source B connected through a series resistance 2. Connected across the plate and cathode is an alternating current path including a capacity element 4 and a high resistance 5 from which is tapped a feedback conductor 9. A variable capacity 6 and a primary winding of a transformer 7 constitute a frequency determining circuit upon which oscillations are impressed through the common ground conductor 8 and the feedback path 9 which includes high resistance 10.

Transformer 7 is specially designed to transmit low frequency currents effectively and to be very efficient when operated at low core flux density. For this purpose a permalloy core is especially suitable with a magnetic circuit closed except for a small stabilizing air gap. For a description of the characteristics of permalloy, reference is made to an article by Arnold and Elmen, published in the Journal of the Franklin Institute, May, 1923. It is sufficient to state that the core may comprise an iron-nickel alloy as described in the Arnold-Elmen article having at least 30% nickel and the balance iron, or in which the nickel is within a few per cent of 78.5% of the nickel-iron content, which is heat treated to develop therein a permeability greater than iron at magnetizing forces in the entire range below 2/10 gauss. While the flux density is below the magnitude where the core losses are not too great, a potential variation in the frequency determining circuit will cause similar variations to be passed on to the grid circuit in the amplifier with sufficient strength so that the resulting portion of the amplified wave returned over feedback path 9 to the frequency determining circuit will maintain the potential variations at their original value. With higher flux densities occasioned by larger currents, the core losses soon rise to a point beyond which they can no longer be made up by the amplifier. This extraordinarily rapid increase in core loss with increasing flux density is peculiarly characteristic of certain magnetic materials such as permalloy. It, moreover, occurs at a flux density which is comparatively low thus enabling the oscillator to stabilize at a correspondingly low current amplitude.

Resistance 10 of the feedback path restricts oscillations fed back to small magnitudes. Its variable connection to resistance 5 permits the electromotive force impressed on the grid circuit to be regulated as desired. A source 11 is preferably used to negatively polarize the grid and the alter-

nating electromotive force induced in the secondary winding of transformer 7 is preferably maintained so small in magnitude that the grid does not become positive and hence does not tend to draw space current from the cathode. Consequently, the oscillations in the grid-cathode circuit are symmetrical and substantially free from harmonics. The plate circuit of tube 1 includes in its space current path, a resistance 2 of the order of magnitude of the internal plate circuit alternating current impedance of the tube itself. The alternating current paths through resistances 5 and 10 are of several times the tube internal plate circuit impedance. It follows that the combined tube and external circuit characteristic is fairly linear over a considerable range of grid potential variations. The effect of this is to permit the amplifier to amplify impressed alternating input waves without substantial distortion.

The oscillations in resistance 5 set up a potential difference in the input circuit of an amplifying system comprising one or more amplifiers 12 permanently connected in circuit and one or more additional amplifiers 13 adapted to be connected in parallel as circumstances dictate. The output circuit of these amplifiers is associated with a load circuit 14 by means of a magnetic core transformer 15 designed to efficiently transmit alternating current at low frequencies. As has been previously pointed out, it is desirable to prevent direct current polarization of the core by the primary winding and to do this without interposition of a blocking capacity. For this purpose, space current of the amplifier 12 is caused to traverse a resistance 16. The primary winding of transformer 15 is in a shunt path to resistance 16, the path also including a neutralizing source of voltage 17. Any tendency for space current to flow through the primary winding is overcome by oppositely-poled voltage source 17, variable resistance 18 enabling an exact balance to be had. This circuit permits low frequency currents to be transmitted very effectively and by reason of leakage inductance of the transformer, causes some discrimination in favor of low frequency currents as against those of higher frequencies.

A double-pole switch 19 enables the additional tubes 13 to be cut in as desired, its left-hand contact closing their cathode-heating circuit. At the same time, the right-hand contact of the switch short-circuits a portion of resistance 16 to permit the neutralizing balance to be maintained with the increased space current.

Fig. 2 illustrates diagrammatically certain details of one form which transformer 7 may take. Flat side strips 20 of permalloy are stacked up alternately with end strips 21 of similar material. This rectangular frame core may be held in assembled position by bolts 22, or preferably clamps. Strips 23 of the same material extend down between the lower end strips 21 to the margin 27, as indicated in dotted lines. As so far described, there is a space factor of 50% in the core structure except for the overlapping corner portions which have substantially no unoccupied space. However, the central leg of the core is filled by inserting between the alternate long strips, shorter strips 23 which extend only to the margin 26, there abutting corresponding strips 21. On the central leg of the core are wound primary winding coils 24 and secondary coils 25.

In an actual oscillator designed for a working range of approximately 4 to 600 cycles, the following circuit constants and characteristics were involved: Amplifier 1, two Western Electric V type tubes in parallel, resistance 10, 700,000 ohms; total resistance element 5, 360,000 ohms; resistance 2, 24,000 ohms; capacity 4, 8 M. F.; capacity 6, variable up to 2 M. F.; voltage of source B, 250 volts.

The details of transformer 7 are approximately as follows: width of strips 20, 21 and 23, 7/8"; thickness of these strips 6 mils; overall length of strip 21, 4¾"; of strip 20, 6"; air gap 28 at end of central core leg approximately 10 mils. The core structure was piled up until it attained a thickness or depth perpendicular to the plane of the paper of about 2". Under these circumstances, the flux density of the permalloy core ranges from about 200 gauss at the loweset frequency to about 4 gauss at 500 cycles. With such a circuit, the magnitude of harmonics at no time exceeded 2½% to 3% of the magnitude of the fundamental, whereas with the best previously designed oscillators working in this frequency range, the harmonics rose to about 80% of the fundamental at the lower frequency setting.

Frequency variation of the circuit illustrated is obtained by varying condenser 6. This does not, however, give a very large frequency range. In order to increase the range resort may be had to the expedient of dividing the windings of transformer 7 into a plurality of primary sections 24 and secondary sections 25, as illustrated in Fig. 2. The sections of each winding may be connected in parallel or in parallel series combinations all in well-known manner to vary the effective inductance accordingly. Illustration of this well-known feature is omitted in the interest of simplicity of disclosure.

In the transformer, certain constants of which have previously been given, the nine primary winding sections each comprise

1,800 turns of No. 31 single silk covered copper wire, the two secondary sections are each wound with 3,300 turns of No. 39 double silk covered copper wire.

Throughout this disclosure, the term "vacuum tube" has been used in a generic sense to denote electron relays or electric discharge devices of any character whatever, regardless of their evacuation or gaseous pressure or of the manner of energizing their cathodes or controlling their respective impedances. It may be noted that the amplifiers 12 and 13 actually used with the circuit described were Western Electric O type tubes.

It will, of course, be appreciated that the magnitudes given are merely illustrative of one very useful circuit, and that not only these magnitudes, but the circuit structure itself and the apparatus, may be widely varied without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. An oscillator for producing frequencies of the order encountered in Morse telegraph practice comprising an electron relay having input and output circuits coupled by a transformer, said transformer having a core comprising a magnetic material having permeability higher than that of iron at magnetizing forces of 2/10 gauss or less and comprising at least 30% nickel and the balance iron, said core operating to limit the amplitude of the energy supplied by said output circuit to said input circuit.

2. An oscillator comprising an amplifier having output and input circuits coupled in feedback relation by a transformer, said transformer having a core of magnetic material comprising nickel and iron having developed therein by heat treatment permeability greater than iron at magnetizing forces in the entire range below 2/10 gauss and of such dimensions that at the definite frequency for which the oscillator is tuned, the total copper and core loss for low magnetizing forces on the core is less than the gain in the remainder of the system, but that at larger magnetizing forces the core loss rises so rapidly as to overcome the gain whereby the magnetizing force is limited to low values at which substantially sinusoidal oscillations are produced.

3. An oscillator comprising a three-element electron relay, an input circuit therefor, an output circuit therefor, means coupling said circuits comprising a transformer having a core of magnetic material having higher permeability than that of iron at magnetic forces of 2/10 of a gauss or less and including nickel and iron, the nickel being within a few per cent of 78.5% of the nickel-iron content, and a resistance limiting the current supplied to said primary winding to a value corresponding to a core flux density not exceeding 200 gauss.

4. Means for producing low frequency oscillations of high purity of wave form, a load circuit, means for augmenting said oscillations and transferring them to said load circuit without introducing distortion, comprising a vacuum tube amplifier directly connected to said oscillation producing means, a magnetic core transformer having a primary winding directly connected to the output circuit of said amplifier whereby voltages of all frequencies are impressed on said winding without substantial discrimination, and means to neutralize the tendency of the vacuum tube direct current to polarize said core, said transformer having a secondary winding connected to said load circuit.

In witness whereof, I hereunto subscribe my name this 1st day of December, A. D. 1923.

AUSTEN M. CURTIS.