May 9, 1944. A. M. CRAVATH 2,348,525

APPARATUS FOR GENERATING CODED ALTERNATING CURRENT

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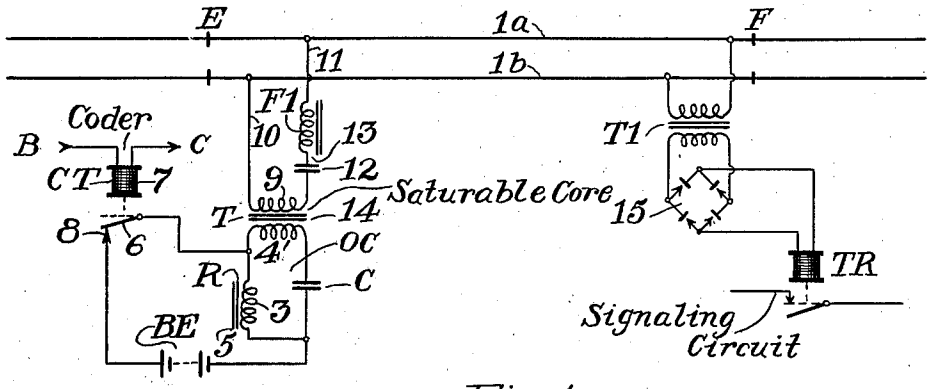


Fig. 1

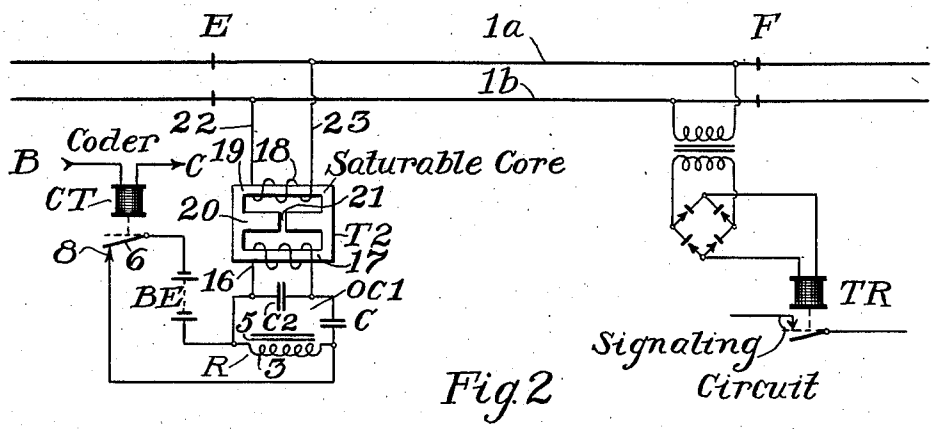


Fig. 2

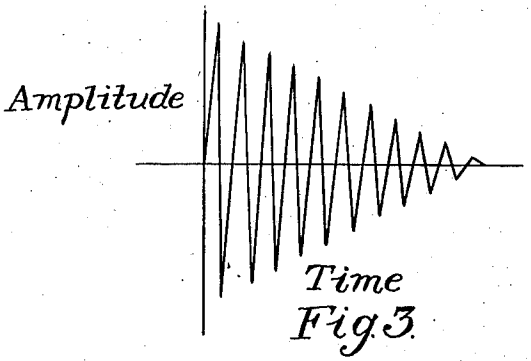


Fig. 3

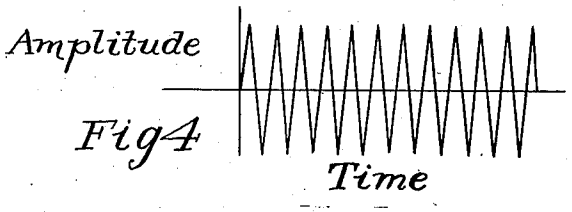


Fig 4

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APPARATUS FOR GENERATING CODED ALTERNATING CURRENT

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5 Claims. (Cl. 177—380)

My invention relates to apparatus for generating coded alternating current, and more particularly to apparatus for deriving coded alternating current from a source of unidirectional current.

Coded alternating current is used quite extensively in signal systems, for example, in signal systems for railways. When such current is used for signal systems for railways a stretch of railway track is divided into successive insulated track sections, each of which is provided with a track circuit to which coded alternating current is supplied for control of cab signals or wayside signals or both. The alternating current supplied to each such track circuit is coded at one or another of different code rates according to different traffic conditions. Alternating current of 100 cycles per second is that commonly used in present day signal systems for railways, and the coding is effected by coders which periodically interrupt the circuit at one or another of different rates, the code rates of 180, 120 and 75 interruptions per minute being those preferred. Each such code consists of alternate on and off periods, current flowing each on period and no current flowing each off period. Preferably, the on and off periods of a code are of substantially equal duration. Generally speaking the alternating current is supplied to the different track circuits from a transmission line extending along the railway from a central power plant at which the generator is located. The coding however is usually effected by a coder individual to each track circuit.

It has been proposed to generate alternating current for railway signal systems by generators located along the railway, one for each control track circuit. By such an arrangement the signal system is not subject to failure due to storms and other weather conditions that may destroy a transmission line. Also such arrangement avoids the relatively high cost of a transmission line. When generators, one for each track circuit, are used the driving energy is derived from a local battery. Such local generators must therefore be reliable in operation, relatively low in cost and of relatively high efficiency in order to save on the output required from the battery.

In view of the circumstances recited above, a feature of my invention is the provision of novel and improved apparatus for generating coded alternating current from power derived from a source of unidirectional current.

Another feature of my invention is the provision in apparatus of the type here involved of novel, reliable and inexpensive means for supplying alternating current of a preselected frequency and code rate from power derived from a source of unidirectional current.

Also a feature of my invention is the provision in apparatus for a railway signal system of novel and improved means for supplying a track circuit with coded alternating current from power derived from a local battery.

Again, a feature of my invention is the provision of novel and improved means for apparatus of the type here involved for effecting substantially constant amplitude oscillations in response to a wave of damped oscillations.

Again, a feature of my invention is the provision of novel means for deriving a wave or code impulse of alternating current of a preselected duration and of substantially uniform amplitude from a wave of damped oscillation.

Other features, advantages and objects of my invention will appear as the specification progresses.

The above features, advantages and objects of my invention are attained by providing an oscillating circuit, a magnetically saturable coupling device, coding means and a suitable source of unidirectional current. The oscillating circuit includes a reactor having a winding mounted on a magnetizable core and across which reactor winding a source of unidirectional current is connected over a contact of a coder having a cyclic operation each cycle of which consists of an on and an off period. The source of current is connected to the reactor winding each on code period and is disconnected therefrom each off code period. Consequently, magnetic energy is stored in the reactor core when unidirectional current flows in the reactor winding each on code period and such stored energy decays while the unidirectional current is interrupted each off code period. The electromotive force created in the reactor winding due to the decay of the stored energy creates oscillations in the oscillating circuit. Such oscillations are of a frequency preselected by the proportion of the parts of the oscillation circuit and are of a damped wave, the initial amplitude of such oscillations being also predetermined by proper proportioning of the parts. The coupling device for coupling this oscillating circuit to the control circuit may be a transformer characterized by a saturable magnetic core, a primary winding of the transformer being included in the oscillating circuit and a secondary winding of the transformer being connected to the control circuit. The core of

the transformer saturates when the oscillations flowing in the primary winding are of a preselected amplitude which is something less than the amplitude of the first few cycles of the oscillations created in the oscillating circuit due to the decay of the magnetic energy stored in the reactor core. Hence there is induced in the secondary winding of the transformer oscillations during each off code period of the coder, such oscillations being of a preselected frequency which is the same as the natural frequency of the oscillating circuit. Since the transformer is provided with a saturable core, the power drawn from the oscillating circuit is reduced during the early part of the damped oscillations created therein and the rate at which the oscillations die out is reduced. Also the transformer can be made to feed the required energy for a short time after the damped oscillations have become too small to supply the required power. The electromotive force induced in the secondary winding of the transformer in response to each wave of oscillations created in the oscillating circuit has, therefore, an amplitude less than the amplitude of the damped oscillations during the early part of the wave and is maintained at its initial amplitude for a period after the oscillations of the oscillating circuit become relatively small. It follows, therefore, that during each off period of the coder, there is supplied from the secondary winding of the transformer to the control circuit, a wave or code impulse of alternating current of a frequency preselected by the proportion of the oscillating circuit and of substantially uniform amplitude due to the saturable magnetic characteristic of the coupling transformer. Furthermore, this code impulse of alternating current thus supplied to the control circuit in response to each damped wave of oscillations created in the oscillating circuit can be made to persist for a duration substantially equal to the off code period of the coder. Hence if the on and off code periods of the coder are substantially equal, the on and off periods of the coded alternating current supplied to the control circuit are likewise substantially equal.

A very sudden dying out of each code impulse of the alternating current is obtained by having the direct current circuit closed by the coder at just the instant the code impulse of alternating current is to be stopped, because such closing of the direct current circuit short circuits the oscillating circuit as far as the flow of the oscillations is concerned.

A filter tuned sharply at the frequency of the alternating current derived from the oscillating circuit may be interposed between the transformer secondary winding and the control circuit to suppress harmonics.

Again, a three-legged transformer and a condenser may be used as the coupling device. The primary and secondary windings are placed on the two outside legs of such core structure and the center leg, with an air gap, serves as a magnetic shunt. The outside leg on which the secondary winding is mounted is proportioned for magnetic saturation, while the center leg is of larger cross section and does not saturate at the amplitude of the oscillations flowing in the primary winding. The first advantage of this latter transformer is that when the secondary winding leg is saturated and an increase of the current flowing in the primary winding causes an increase in the flux, most of this increment of flux flows through the unsaturated center leg and hence the electromotive force induced in the secondary winding is retained more constant in amplitude. The second advantage of this three-legged transformer is that the leakage reactance due to the magnetic shunt, which is roughly equivalent to an inductance in series with the secondary winding, tends to filter the output and reduce harmonics. The condenser associated with such transformer is connected across the primary winding and serves the purpose of tuning out the higher inductance of the primary winding at low current, and thus prevents frequency variations in the oscillating circuit. Such condenser also maintains the required value of primary winding current after the energy in the reactor has died down to a low value and hence aids in maintaining the code impulses of alternating current supplied to the control circuit at the constant amplitude. This condenser also serves the purpose of suppressing harmonics.

I shall describe two forms of apparatus embodying my invention, and shall then point out the novel features thereof in claims.

In the accompanying drawing, Figs. 1 and 2 are diagrammatic views showing two different forms of apparatus embodying my invention when used to supply coded alternating current to a track circuit for a railway signal system. Figs. 3 and 4 are diagrams illustrating operating characteristics of the apparatuses of Figs. 1 and 2. In each of the different views like reference characters are used to designate similar parts.

It is to be understood, of course, that my invention is not limited to apparatus for supplying coded alternating current to a track circuit of a railway signal system but that this one use will serve to illustrate the many places where apparatus embodying my invention will be useful.

Referring to Fig. 1, the reference characters *1a* and *1b* designate the track rails of a stretch of railway which are formed by the usual insulated rail joints with a track section E—F, and which section may be one section of a series of successive sections of a signal system. The track section E—F is provided with a track circuit which includes a source of coded alternating current connected across the rails at one end of the section and a code responsive track relay connected across the rails at the other end of the section. According to my invention, the source of coded alternating current for the track circuit of the section E—F includes an oscillating circuit OC, a coupling transformer T, a coder CT and a suitable source of unidirectional current, such as a battery BE.

The oscillating circuit OC includes a winding 3 of a reactor R and a condenser C connected in series across primary winding 4 of transformer T. The winding 3 of reactor R is mounted on a magnetizable core 5 and the oscillating circuit is proportioned for resonance at a preselected frequency, such as, for example, 100 cycles per second.

The coder CT may be any one of the several types well known to the art, and it is sufficient for this application to point out that coder CT is provided with a contact member 6 which is cyclically operated between a first position indicated by a solid line in the drawing and a second position indicated by a dotted line as long as an operating winding 7 is effectively energized from any convenient source of current, such as a battery whose terminals are indicated at B and C. This cyclic operation of coder CT may be of any suitable code rate such as, for example,

180 cycles per minute. The arrangement is preferably such that contact member 6 when at its first position engages a back contact 8 and when raised to its second position disengages this contact 8, contact member 6 being at its two positions for substantially one-half of each cycle. As an aid to the understanding of my invention, I shall refer to the period in which contact member 6 engages contact 8 as the on period of the code cycle, and the period in which contact member 6 is raised out of engagement with contact 8 as the off code period of the cycle.

Battery BE is connected across winding 3 of reactor R over contact 6—8 of coder CT. It follows that during each on code period contact 6—8 is closed and direct current flows from battery BE through reactor winding 3 and magnetic energy is stored in core 5 of the reactor, but that when contact 6—8 is opened each off code period the direct current in winding 3 is interrupted and the magnetic energy stored in core 5 decays to create an electromotive force in winding 3. Such electromotive force in turn sets up oscillations in the oscillating circuit OC, the frequency of the oscillations being the natural frequency of the circuit and which I have stated hereinbefore may be of the order of 100 cycles per second. These oscillations are damped, the oscillations having an initial amplitude predetermined by the proper proportioning of the parts and dying away to zero in a period also predetermined by the proportion of the parts. Preferably, the damped wave of oscillation would die out or at least fall to a relatively low value during the off code period of coder CT so that the above described operation of creating a wave of oscillations in the oscillating circuit is repeated each cyclic operation of coder CT.

A secondary winding 9 of transformer T is connected across the rails 1*a* and 1*b* of section E—F over wires 10 and 11, a filter F1 comprising a condenser 12 and an inductor 13 being preferably interposed in wire 11. This filter F1 is tuned to pass alternating current of the frequency corresponding to that of the oscillations created in the oscillating circuit OC, and in the case here assumed for illustration, it is tuned to pass alternating current of 100 cycles per second. It is clear that the oscillations flowing in primary winding 4 induce an electromotive force of a corresponding frequency in secondary winding 9 and alternating current of the same frequency is supplied to the track circuit through the filter F1. Transformer T is characterized by a saturable core 14. That is, the parts are so proportioned that core 14 is saturated by current flowing in the primary winding 4 when such current is of an amplitude somewhat less than the initial amplitude of the oscillations created in the oscillating circuit OC by the action of coder CT. Consequently, during the first part of the damped wave of the oscillations, the core 14 of transformer T is saturated and an electromotive force of substantially constant amplitude is induced in secondary winding 9 of the transformer during such first part of the damped wave. After the oscillations have become too weak to supply the required power the increase in the coupling when the transformer becomes unsaturated maintains the requisite power by increasing the rate of withdrawal of the remaining oscillatory energy. Furthermore, by thus reducing the power drawn from the oscillating circuit during the early part of each wave of the oscillations, the rate at which the oscillations die out is reduced. When contact 6—8 of coder CT is next closed, the oscillating circuit OC is short circuited as far as the flow of the oscillations is concerned and the oscillations are quickly reduced to zero causing the electromotive force induced in secondary winding 9 to be reduced to zero.

From the foregoing description, it is to be seen that by proper proportioning of parts the code impulses of alternating current supplied to the track circuit from secondary winding 9 can be made to have a substantially uniform amplitude of a predetermined value and to have a duration which is substantially equal to the off code period of coder CT. Since a code impulse of alternating current is supplied to the track circuit each off period of coder CT, the track circuit current is of the same code rate as the operation cycle of coder CT. Furthermore, such coded alternating current will be substantially free from harmonics due to filter F1.

In Fig. 3 there is illustrated the damped wave of the oscillations created in the oscillating circuit OC due to the decaying of the magnetic energy in the core of reactor R, and in Fig. 4 there is illustrated the substantially constant amplitude electromotive force induced in secondary winding 9 in response to the damped wave of the oscillating circuit.

In practicing the invention, the coding of the direct current supplied to reactor R would be governed by traffic conditions but such control is not shown in the drawing since it forms no part of my invention and would be in accordance with standard practice.

A code responsive relay TR is connected across the rails of section E—F adjacent the end F of the section by means of the usual transformer-rectifier combination comprising a transformer T1 and a full wave rectifier 15. Hence track relay TR is supplied with an energizing impulse of current during each code impulse of alternating current supplied to the track circuit and the relay is operated at a rate corresponding to the rate of operation of coder CT. Relay TR would be used to govern a signaling circuit for controlling any suitable signaling device associated with section E—F. When a train occupies section E—F, track relay TR would be shunted in the usual manner to effect a corresponding control of the associated signaling circuit. Also the coded alternating current supplied to the track circuit of section E—F would be effective to control cab signals by means of any one of the several well-known forms of cab signal apparatus responsive to coded alternating current.

Referring to Fig. 2, the track rails 1*a* and 1*b* of a stretch of railway are formed with a track section E—F provided with a track circuit the same as in Fig. 1. In Fig. 2, the means for supplying coded alternating current to the track circuit consists of an oscillating circuit OC1, a coupling transformer T2, a condenser C2, coder CT and battery BE. The oscillating circuit OC1 of Fig. 2 includes winding 3 of reactor R, condenser C and a primary winding 16 of transformer T2, and is proportioned for a preselected natural frequency the same as the oscillating circuit of Fig. 1. That is, oscillating circuit OC1 is resonant at a preselected frequency such as 100 cycles per second. Consequently, a wave of oscillations is created in oscillating circuit OC1 during each off code period of coder CT due to the decay of the magnetic energy stored in core 5 of reactor R during the on code period of the coder, the

operation being substantially the same as described in detail in connection with the oscillating circuit of Fig. 1.

Transformer T2 is provided with a three-legged core structure, primary winding 16 being mounted on one outside leg 17, and a secondary winding 18 being mounted on the other outside leg 19. The center leg 20 of the transformer is of greater cross section than either outside leg 17 or 19 and is preferably provided with an air gap 21. This core structure of transformer T2 is proportioned for saturation of the outside leg 19 on which the secondary winding 18 is mounted when oscillations of an amplitude somewhat less than the initial amplitude of the oscillations created in the oscillating circuit OC1 due to the action of coder CT flow through primary winding 16, but that the center leg 20 is not saturated under such conditions. The other outside leg 17 on which primary winding 16 is mounted would also be saturated under such conditions. It is clear that the center leg 20 forms a magnetic shunt for the outside legs 17 and 19.

Secondary winding 18 of transformer T2 is connected to the track circuit of section E—F over wires 22 and 23. It follows that the oscillations caused to flow in primary winding 16 induce an electromotive force of a corresponding frequency in secondary winding 18 and alternating current of the same frequency is supplied to the associated track circuit. Due to the saturable characteristics of the core structure of transformer T2, the amplitude of the electromotive force and in turn of the alternating current supplied to the track circuit will be substantially constant notwithstanding the oscillations flowing in the primary winding are of a damped wave. Also each such code impulse of alternating current supplied to the track circuit may be made to persist for substantially the full off code period of coder CT. An advantage of transformer T2 is that when the outside legs of the core structure are saturated and an increase in primary winding current causes an increase in the magnetic flux, most of the increment of the flux flows through the unsaturated leg 20 and hence the electromotive force induced in the secondary winding 18 is more constant in amplitude. Another advantage of transformer T2 is that the leakage reactance due to the magnetic shunt, which is roughly equivalent to an inductance in series with the secondary winding, tends to filter the output and reduce the harmonics of the current supplied to the track circuit.

Condenser C2 is connected across the primary winding 16 of transformer T2 and serves the purpose of tuning out the high inductance of primary winding 16 at low amplitude of the oscillations and thus prevents frequency variations of the oscillations due to variations of the oscillating circuit. Also, condenser C2 serves the purpose of maintaining the critical required primary winding current after the oscillations in the oscillating circuit have died down to a low value. Furthermore, condenser C2 serves the purpose of smoothing out harmonics.

A track relay TR is connected across the rails of section E—F of Fig. 2 in the same manner as in Fig. 1, and hence it is operated by the coded alternating current supplied to the track circuit when the section is unoccupied and is shunted to control the associated signaling circuit when the section is occupied. Also the coded alternating current of the track circuit of Fig. 2 is effective to control cab signal apparatus in the same manner as pointed out in connection with the apparatus of Fig. 1.

It is to be seen, therefore, that I have provided novel and improved means for supplying coded alternating current of a preselected frequency and of substantially uniform amplitude to a control circuit from power derived from a source of unidirectional current. Also the duration of each such code impulse of alternating current is maintained at substantially its constant amplitude for the full on code period of the current.

Although I have herein shown and described only two forms of apparatus for generating coded alternating current embodying my invention, it is understood that various changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of my invention.

Having thus described my invention, what I claim is:

1. In combination, a control circuit, a transformer having a saturable magnetic core, a reactor having a winding mounted on a magnetizable core, a capacitance; an oscillating circuit including in series said reactor winding, said capacitance and a primary winding of said transformer and proportioned for resonance at a preselected frequency; a source of undirectional current, a coder having a cyclic operation consisting of an on and an off period, means controlled by said coder to connect said current source across said reactor winding each said on code period to store magnetic energy in the reactor core and to disconnect the current source from the reactor winding each said off code period to cause a damped wave of oscillations of said preselected frequency to flow in said oscillating circuit each said off code period due to the decay of the stored magnetic energy, and a secondary winding of said transformer connected to said control circuit to supply that circuit with a code impulse of alternating current in response to each such wave of oscillations and which current is of substantially constant amplitude due to the saturable characteristic of said transformer core.

2. In combination, a control circuit, a transformer provided with a magnetic core saturable when oscillations of a preselected frequency and of a given amplitude flow in a primary winding of the transformer, a reactor having a winding mounted on a magnetizable core, a capacitance; an oscillating circuit including in series said primary winding, said reactor winding and said capacitance and proportioned for resonance at said preselected frequency, a source of unidirectional current, a coder having a cyclic operation consisting of an on and an off period, means including a contact of said coder to connect said current source across said reactor winding each said on period to store magnetic energy in the reactor core and to disconnect the current source from the reactor winding each said off period to cause oscillations of a damped wave form to flow in said oscillating circuit unimpeded by any energy stored in said capacitance each said off code period and the first cycle of which wave is greater than said given amplitude, and a secondary winding of said transformer connected to said control circuit to supply to that circuit alternating current each coder off period in response to said oscillations and which alternating current is of substantially uniform ampli-

tude because of the saturable characteristic of said transformer core.

3. In combination, a control circuit, a transformer provided with a saturable magnetic core and having a secondary winding connected across said control circuit, a reactor provided with a winding mounted on a magnetic core, a condenser, said reactor winding and said condenser connected in series to a primary winding of said transformer to form an oscillating circuit proportioned for resonance at a preselected frequency, a source of unidirectional current, a coder having a contact member alternately operated to a first and a second position at a predetermined code rate, and said source of unidirectional current connected across said reactor winding over the first position of said contact member to cause magnetic energy to alternately build up and decay in the reactor core and the decay of which energy is effective each time to cause damped oscillations to flow in the oscillating circuit and alternating current of said preselected frequency and of substantially constant amplitude to be supplied to said control circuit due to said oscillating circuit and the saturable magnetic characteristic of said transformer.

4. In combination, a control circuit, a transformer having a three-legged magnetic core structure with a primary winding mounted on a first one of said legs and a secondary winding mounted on a second one of said legs, said secondary winding connected to said control circuit, a reactor having a winding mounted on a magnetizable core, a condenser; said reactor winding, said condenser and said primary winding connected in series to form an oscillating circuit tuned to resonance at a preselected frequency; a source of unidirectional current, a coder having a contact member which is operated at a predetermined code rate, said source of unidirectional current connected across said reactor winding over said contact member to periodically create a wave of damped oscillations in said oscillating circuit due to the periodic storing of magnetic flux in the core of said reactor and the periodic decay of such flux, said first and second transformer core legs proportioned for saturation by such wave of oscillations to cause a code impulse of alternating current of said preselected frequency and of substantially uniform amplitude to be supplied to the control circuit, and the third transformer core leg proportioned for non-saturation by such wave of oscillations and provided with an air gap to form a magnetic shunt which serves to filter the alternating current output and reduce the harmonics.

5. In combination, a control circuit, a transformer having a three-legged magnetic core structure with a primary winding mounted on one outside leg and a secondary winding mounted on the other outside leg, said secondary winding connected to said control circuit, a reactor having a winding mounted on a magnetizable core, a condenser; said reactor winding, said condenser and said primary winding connected in series to form an oscillating circuit tuned to resonance at a preselected frequency; a source or unidirectional current, a coder having a cyclic code operation which consists of on and off periods, means controlled by said coder to connect said source of unidirectional current across said reactor winding each such on code period to create a wave of damped oscillations in the oscillating circuit each off code period due to the periodic storing of magnetic flux in the core of said reactor and the periodic decay of such flux, said one outside transformer core leg proportioned for saturation by such wave of oscillations flowing in the primary winding to cause a code impulse of alternating current of said preselected frequency and of substantially constant amplitude to be supplied to the control circuit, the center transformer core leg proportioned for non-saturation by such wave of oscillations and provided with an air gap to form a magnetic shunt; and another condenser connected across said primary winding to prevent frequency variations in the oscillating circuit, to aid in maintaining the duration of the code impulse of alternating current and to suppress harmonics.

AUSTIN M. CRAVATH.