

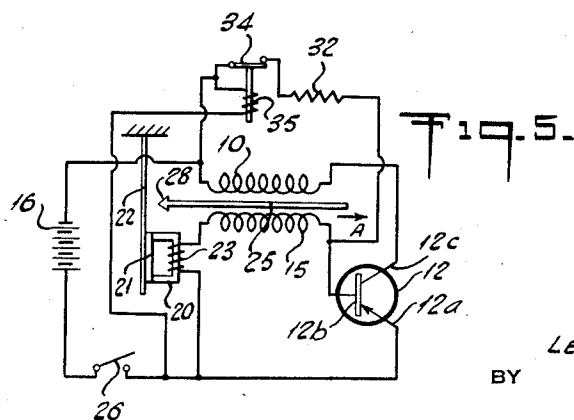
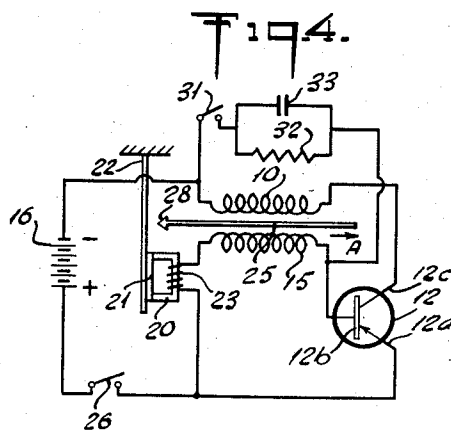
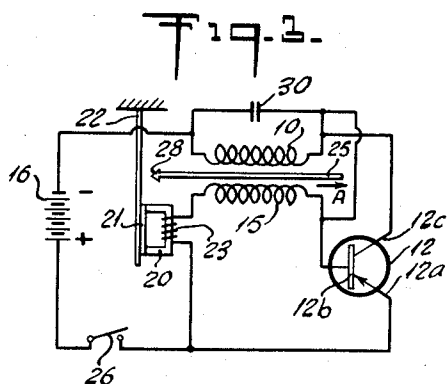
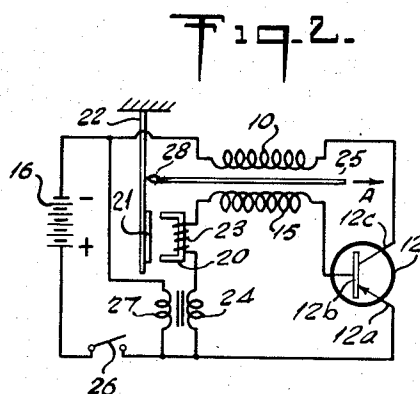
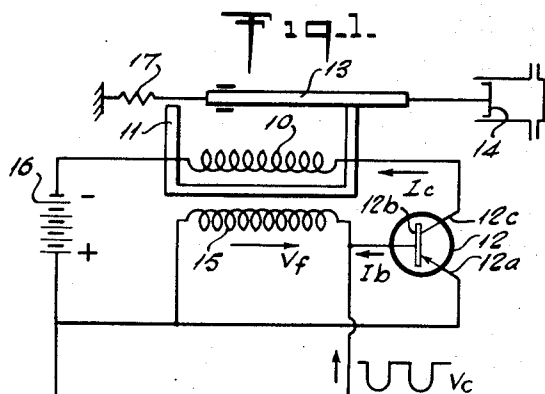
July 12, 1960

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2,945,168

VIBRATORY ELECTROMAGNETIC DEVICE

Filed March 25, 1958



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VIBRATORY ELECTROMAGNETIC DEVICE

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Filed Mar. 25, 1958, Ser. No. 723,760

Claims priority, application Germany Apr. 12, 1957

14 Claims. (Cl. 318—128)

The present invention relates to vibratory electromagnetic devices, more particularly to an electromagnetic vibrator comprising a magnetic winding or solenoid energized by an interrupted or pulsating direct current and a cooperating magnetic plunger or armature connected to or arranged in driving relation with the vibrating or reciprocating part of a pump or equivalent driven member.

While the invention will be described in the following with specific reference to the operation of a fuel pump for internal combustion engines, such as for use on automotive vehicles, it is to be understood that the improved system of converting direct current into pulsating current or the vibratory electromagnetic drive according to the invention will have other uses and applications, both for the operation of vibratory or reciprocating devices, as well as in the general utilization of the pulsating direct current being produced.

It has already become known to produce a pulsating direct current for the operation of a pump or the like electromagnetically driven member from a direct current storage battery by the utilization of an automatic or self-running periodic electromagnetic interrupter or vibratory converter, having an armature or vibratory magnetic member in driving connection with the reciprocating piston of the pump or equivalent driven member. Such devices are subject to serious defects and drawbacks, due mainly to the relatively high exciting currents required for their operation, giving rise to heavy sparking or arcing between the interrupting contacts as a result of the high inductance of the magnetic winding. Accordingly, such a vibratory drive has a low efficiency and a limited life due to rapid wear of the contacts and to other causes, not to mention the necessity of continuous supervision and attendance in order to insure satisfactory service and operation.

Accordingly, an important object of the present invention is the provision of an improved electromagnetic vibratory device of the type referred to, whereby the foregoing and related difficulties and drawbacks inherent in the previously known devices are minimized or substantially eliminated.

Another object of the invention is the provision of an electromagnetic vibratory converter, to change direct current into pulsating current, which is substantially devoid of any current-carrying interrupting or vibrating contacts, whereby to substantially eliminate arcing or sparking, as well as other defects well known and characteristic of interrupting devices according to the prior art.

Yet another object of the invention is the provision of an improved electromagnetic vibratory device of high efficiency in converting direct current into pulsatory current of substantially square or rectangular wave shape.

Still another object of the invention is the provision of a self-running square wave pulse generator or relaxation oscillator, comprising a saturable amplifier, preferably a semi-conductive or transistor amplifier, wherein the amplitude and width of the output current pulses is deter-

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mined by the saturation current of the amplifier substantially independently of the amplitude and width of the input or control current pulses.

A further object of the invention is the provision of a self-running electromagnetic vibratory current interrupter or drive operating a reciprocating driven member, having auxiliary means for starting the same by an initial starting control pulse or voltage.

The invention, as to its ancillary and related objects as well as novel aspects, will be better understood from the following detailed description of a few practical embodiments, taken in reference to the accompanying drawing forming part of this specification and wherein:

Fig. 1 is a schematic representation and wiring diagram of a separately-controlled transistor-operated electromagnetic vibrator embodying the principles of the invention and suitable for operating a pump or an equivalent reciprocating or vibratory driven member; and

Figs. 2 to 5 are diagrams similar to Fig. 1 and showing modifications of a self-running vibratory drive or relaxation oscillator according to the invention and including means for initially starting the operation of the device.

Like reference numerals denote like parts in the different views of the drawing.

With the foregoing objects in view, the invention involves generally the provision of a vibratory magnetic member or armature of either the open or iron-clad type having an exciting winding and means to intermittently control said member, comprising a saturable amplifier, preferably a semiconductive or transistor amplifier having an emitter, a collector and a base electrode, the latter being normally biased to collector current cut-off, and an output circuit including a source of direct current in series with said winding and connected to said emitter and collector, in accordance with the well-known grounded or common emitter configuration of a standard transistor circuit. There is further provided a source of control voltage, such as in the form of periodic voltage pulses, connected to said base electrode having a relatively low amplitude or value normally to produce a collector or output current substantially below the saturation current of the transistor or equivalent amplifier. The weak or insufficient input pulses are regenerated by the provision of positive reactive feedback means between the collector circuit and the base electrode of the transistor, in such a manner as to result in a consecutive practically instantaneous rise or build-up and fall or decay, respectively, of the collector current pulses between zero and full saturation output current of the transistor, substantially independently of the amplitude and duration of said controlling pulses. In other words, there is produced by the invention a rectangular or square-wave shaped pulsed output current controlled by an extremely weak input voltage and suitable for the operation of a pump or an equivalent reciprocating driven member.

The control pulses applied to the base of the transistor or equivalent amplifier may be supplied by a separate source, such as an auxiliary electromagnetic vibrator of low power and being practically free from sparking or arcing, by a multivibrator or any other periodic pulse or peak voltage generator. Due to the cumulative regeneration of the weak control pulses by the positive feedback action according to the invention, the amplitude of the control pulses need only be sufficient normally to result in a collector current just above cut-off, to safely and positively initiate the rapid build-up of the current to full saturation and to result in an equally rapid fall or decay of the pulses, as will be further understood from the following.

Alternatively, the device may be of the self-running type, in the manner of a relaxation oscillator, by the provision of a suitable control or pulse voltage generator

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synchronized with the operation of the vibratory magnetic member. In a preferred embodiment, this generator may be in the form of a simple magneto or permanent magnet device having a winding connected to the base of the transistor and arranged to be actuated by the spring-biased vibratory magnetic member upon return to its zero position at the instants of cessation of the collector current pulses. In a device of the latter type, auxiliary means must be provided to produce an initial starting pulse, to set the oscillator or drive into operation, as will be described in greater detail hereafter.

Referring more particularly to Fig. 1 of the drawing, there is shown an electromagnetic drive comprising an iron core 11 having wound thereon a magnetic exciting winding 10. The core 11 is fitted with an armature or magnetic member 13 displaceable in its longitudinal direction, as shown in the example illustrated, and arranged to actuate the piston 14 or equivalent reciprocating or vibrating member of a fuel pump or the like driven member. One end of the winding 10 is connected to the minus pole of a source of direct current 16, such as the storage battery of a motor vehicle, while the opposite end of said winding is connected to the collector electrode 12c of a PNP power transistor 12 having its emitter electrode 12a connected to the plus pole of the source 16. The core 11 is further provided with a feedback winding 15, in addition to the main winding 10, whose one end is connected to the plus pole of the source 16 and whose opposite end is connected to the base 12b of the transistor 12, acting as the control electrode in accordance with the common or grounded emitter configuration or operating circuit of the standard transistor amplifier.

Further applied to the base or control electrode 12b of the transistor is a negative pulse voltage V_c supplied by a suitable source, such as a multivibrator, blocking oscillator etc., whereby the transistor, being normally substantially non-conductive or biased to collector current cut-off, is rendered periodically conductive in the rhythm of the control pulses V_c . More particularly, as soon as the control voltage V_c assumes a value sufficiently negative in respect to the normal or zero bias, a base current I_b is caused to flow between the emitter 12a and the base 12b, resulting in a corresponding amplified collector current I_c exciting the winding 10 of the electromagnet. As a result, the iron core is magnetized and a positive feedback voltage V_f induced in the winding 15 during the rate of increase of the collector current of such a polarity as to increase the control voltage V_c and to cause a still greater rise of the collector current I_c . The latter thus increases rapidly to its saturation value due to the accumulative feedback action, as determined by the capacity or size of the transistor. Upon reaching the full saturation collector current of the transistor, the feedback voltage V_f ceases, whereby to cause the collector current to return to its original value or non-conductive condition of the transistor. Again, the direction of the feedback voltage is such as to assist the fall or decay of the current, whereby to result in a practically rectangular or square-wave shaped current pulse, substantially independently of the amplitude and duration of the control pulses V_c . Each collector current pulsation energizes the magnet core 11 to, in turn, result in a periodic actuation of the magnetic member 13 and piston 14 or equivalent driven member in cooperation with a balance or return spring or the like 17.

In an arrangement afore-described, relatively low control voltages of very short duration are sufficient to temporarily render the transistor conductive and to set up a fully saturated collector current pulse, as a result of the accumulative feedback action. The same operation is then repeated by the succeeding control voltage pulses V_c .

The embodiment shown by Fig. 2 differs essentially from Fig. 1 by the fact that no separate control voltage pulses are required and that the system is self-excited in

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the manner of a relaxation oscillator by periodically changing between practically zero and fully saturated collector current of the transistor 12, in the manner further understood from the following. There is provided, in the example illustrated, for the maintenance of the relaxation oscillations a magneto or permanent magnetic impulse generator consisting of a U-shaped iron core 20 fitted with a permanent magnet armature 21 which is mounted upon the end of leaf spring 22 secured cantilever-fashion at the opposite end thereof. The iron core 20 carries an auxiliary winding 23 connected in the base-emitter circuit of the transistor 12 in series with the feedback winding 15 and the secondary winding 24 of an auxiliary starting transformer having a primary 27 connectible to the source 16 through a control switch 26.

In an arrangement of this type, closing of the switch 26 results in the current through the primary 27 increasing from zero to maximum and causing a starting voltage pulse to be induced in the secondary 24 and applied between the base and emitter of the transistor 12. As a result, the transistor is rendered initially conductive, causing an exciting current I_c through the magnet winding 10. As long as this current actuating the armature 13 and associated driven member increases, a voltage is fed back from the auxiliary winding 15 upon the input circuit of the transistor of such polarity as to result in a further increase of the exciting current I_c until reaching full saturation, in the manner described hereinbefore.

Under the effect of the exciting current I_c of the winding 10, the iron core or plunger 25 is displaced in the direction towards the right, as indicated by the arrow A in the drawing, actuating at the same time the piston of a fuel pump or other reciprocating or vibratory member. As soon as the exciting current I_c has assumed its full saturation, as determined by the capacity or size of a transistor, the feedback voltage in the winding 15 disappears, whereby to result in a rapid fall or decay of the current and causing the armature or iron core 25 to return to its original position, that is, in a direction opposite to the arrow A and under the influence of a suitable return spring or equivalent balancing means (not shown). Shortly before reaching its zero or rest position, the end 28 of the armature 25 strikes the spring 22 of the magnetic pulse generator, whereby to suddenly pull away the permanent magnet 21 from the core 20, as shown in the drawing, such as to result in a voltage peak being induced in the winding 23 and applied between the base and emitter of the transistor, to initiate a renewed operating cycle. The system is accordingly maintained in a continuous state of relaxation oscillations determined by the combined electrical parameters of the circuit as well as the mechanical characteristics of the vibratory member or members.

The arrangement according to Fig. 3 comprises a vibratory armature 25, an exciting winding 10 and a feedback winding 15, the former being connected in the collector circuit and the latter being connected to the base of the transistor 12, in substantially the same manner as in Fig. 2. Similarly, the pulse voltage generator comprises a U-shaped iron core 20 carrying a winding 23 and a permanent magnet armature 21 mounted upon a leaf spring or the like 22, to provide a closed magnetic flux path in the rest position of the magnet 21, as shown in the drawing. Again, the magnet 21 is briefly pulled away from the core 20 just prior to the return of the armature 25 to its rest position, in such a manner as to induce a peak voltage in the winding 23 applied to the base 12b of the transistor, to maintain sustained relaxation oscillations or vibration of the armature, in the manner described hereinabove.

In order to produce an initial starting pulse, there is provided according to this modification a capacitor 30 connected between the minus pole of the source 16 and the base 12b of the transistor 12. As a result, closing of the switch 26 causes a charging of the capacitor by

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the source 16, thus, in turn, creating a starting voltage pulse, to initiate the first collector current pulse or relaxation oscillation. The system then continues to oscillate by the action of the control voltage generator 20—22, in the manner described hereinbefore.

Instead of starting the operation by means of the main control switch 26, an auxiliary push button or starting switch 31 may be used having one contact connected to the minus pole of the source 16 and having its cooperating contact connected to the base electrode 12b of the transistor through a limiting resistor 32 shunted by a capacitor 33, in the manner as shown by Fig. 4. In order to start the operation, after initial closing of the switch 26, switch 31 is closed temporarily, whereby to apply a negative potential from the source 16 to the base 12b relative to the emitter 12a within the brief interval during which the capacitor 33 forms practically a short-circuit to the minus pole of the source 16 for the incipient base current. This, in turn, causes a collector current I_c through the exciting winding 10, whereby to start the relaxation oscillations, in a manner similar to the preceding embodiments.

Alternatively, the operation of the starting switch 31 may be effected automatically by means of a relay or electromagnetic switch, in the manner shown by Fig. 5. To this end, the relay has a contact 34 operated by a control winding 35 which is connected to the source 16 upon closing of the switch 26. The normally closed relay contact 34 connects the positive pole of the source 16 with the base 12b of the transistor through a limiting resistor 32. As a result, upon closing of the switch 26, current is allowed to flow through the base-emitter junction of the transistor until the instant when the magnetic field of the winding 35 has attained its full strength, to thereby open the contact 34. The short delay from the closing of switch 26 required for the building up of the magnetic field in the winding 35 and opening of the contact 34 is sufficient to render the transistor conductive to start or initiate the operation of the system. If desired, a resistor may be connected in series with the winding 31, to control the delay or build-up time of the magnetic field.

One of the major advantages of a device of the type described is the fact that it is substantially devoid of any current-carrying vibrating contacts, whereby to enable its use within or in the vicinity of an explosive atmosphere. As an example, an electrically-operated fuel pump according to the invention may be safely mounted close or adjacent to the fuel tank of a motor vehicle.

While a PNP type transistor has been shown in the drawing for illustration, it is understood that the transistor 12 may be of the NPN type, in which case the polarity of the source as well as that of the feedback voltage V_f must be reversed by providing a proper winding sense of the winding 15.

The system may also be maintained in an oscillating condition by passing a small continuous biasing current through the base-emitter junction of the transistor, in which case the collector current is caused to fluctuate periodically between a relatively low value and full saturation at a repetition frequency determined by the electrical and mechanical constants and parameters of the system.

In the foregoing the invention has been described with reference to a specific illustrative device. It will be evident, however, that variation and modifications, as well as the substitution of equivalent elements for those shown herein for illustration, may be made without departing from the broader scope and spirit of the invention as set forth in the appended claims. The specification and drawing are accordingly to be regarded in an illustrative rather than in a restrictive sense.

I claim:

1. In an electromagnetic vibrator including a vibratory member and an exciting winding to control said mem-

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ber; operating means comprising a saturable amplifier having output electrodes and a control electrode, an output circuit including a source of direct current in series with said winding and connected to said output electrodes, regenerative coupling means between said output circuit and said control electrode, to cause a rapid build-up and decay of the output current between zero and full saturation of said amplifier, upon initial application of a relatively small control potential pulse to said control electrode, and means separate from and synchronized with said member, to produce and apply a periodic pulse potential to said control electrode, to maintain said member in sustained vibrating condition by consecutive output current build-ups of said amplifier.

2. In an electromagnetic vibrator including a vibratory magnetic member and an exciting winding to control said member; operating means comprising a semiconductive amplifier having an emitter, a collector and a base, a source of direct current connected to said emitter and collector in series with said winding, regenerative coupling means between said collector and base, to cause a rapid build-up and decay of the collector current between zero and full saturation of said amplifier, upon initial application of a relatively small pulse potential to said base, and means separate from and synchronized with said member to produce and apply a periodic pulse potential to said base, to maintain said member in sustained vibrating condition by consecutive collector current build-ups of said amplifier.

3. An electromagnetic vibratory device as claimed in claim 2, said member being provided with of resilient biasing means to cause said member to return to zero position upon cessation of an output current pulse through said winding, and said last means being comprised of a magnetic peak voltage generator connected to said base electrode and arranged for actuation by said member upon returning to said zero position.

4. In an electromagnetic device as claimed in claim 2, including auxiliary means to apply an initial starting voltage pulse to said base.

5. In an electromagnetic vibrator including a vibratory magnetic member and an electromagnet to control said member having an exciting winding; operating means comprising a semiconductive amplifier having an emitter, a collector and a base, a source of direct current connected to said emitter and collector in series with said winding, an auxiliary winding in inductive relation with said first winding and regeneratively connected to said base, to cause a rapid build-up and decay of the collector current between zero and full saturation of said amplifier, upon initial application of a relatively small control pulse potential to said base, and means separate from and synchronized with said member, to produce and apply a periodic pulse potential to said base, to maintain said member in sustained vibration by consecutive collector current build-ups of said amplifier.

6. In an electromagnetic vibrator including a magnetic member resiliently biased to a zero position, an electromagnet to control said member having an exciting winding and a reciprocating driven member connected to said magnetic member; operating means comprising a saturable amplifier having output electrodes and a control electrode, an output circuit including a source of direct current in series with said winding and connected to said output electrodes, a feedback winding upon said electromagnet regeneratively connected to said control electrode, to cause a rapid build-up and decay of the output current between zero and full saturation of said amplifier, upon initial application of a relatively small control pulse potential to said control electrode, and means separate from and synchronized with said member, to produce and apply a periodic pulse potential to said control electrode, to periodically excite said winding and to operate said member by consecutive output current buildups of said amplifier.

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7. A vibratory drive as claimed in claim 6, said last means being comprised of a magnetic peak voltage generator arranged for actuation by said magnetic member upon return thereof to said zero position.

8. A vibratory drive as claimed in claim 7, including auxiliary means to apply an initial starting voltage pulse to said control.

9. A vibratory drive as claimed in claim 7, including a starting switch, a transformer having a primary connectible to said source upon closing of said switch and a secondary connected to said control electrode, to apply an initial starting voltage pulse to said control electrode upon closing of said switch.

10. A vibratory drive as claimed in claim 7, including a starting switch and a capacitor arranged to be charged by said source and connectible to said control electrode during temporary closing of said switch, to apply an initial starting voltage pulse to said control electrode.

11. A vibratory drive as claimed in claim 7, including a starting switch, a relay having an inductive winding connectible to said source upon closing of said switch, to produce an exciting current exponentially increasing from zero to a maximum, and a normally closed relay contact and circuit connections thereto to apply a temporary starting potential to said control electrode between the instants of closing of said switch and opening of said contact by said maximum exciting current.

12. In an electromagnetic vibrator including a magnetic member resiliently biased to a zero position, an electromagnet to control said member having an exciting

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winding and a reciprocating driven member connected to said magnetic member; operating means comprising a semiconductive amplifier having an emitter, a collector and a base, an output circuit including a source of direct current connected to said emitter and collector in series with said winding, a feedback winding upon said electromagnet regeneratively connected to said base, to cause a rapid build-up and decay of the output current between zero and full saturation of said amplifier, upon initial application of a relatively small control pulse potential to said base, and means separate from and synchronized with said member, to produce and apply a periodic pulse potential to said base, to periodically excite said winding and to operate said member by consecutive collector current build-ups of said amplifier.

13. A vibratory drive as claimed in claim 12, said last means being comprised of a magnetic peak voltage generator having a magnet and a winding connected to said base, and actuating means for said generator controlled by said magnetic member, to induce a starting voltage pulse in said last-mentioned winding upon return of said member to its zero position.

14. A vibratory drive as claimed in claim 13, including auxiliary means to apply an initial starting voltage pulse to said base electrode.

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