FIG.5

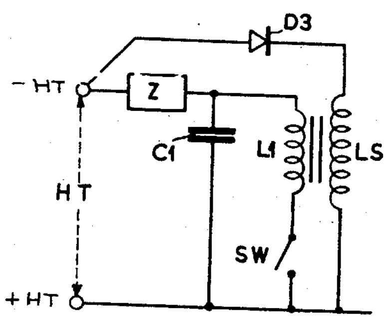

FIG.6

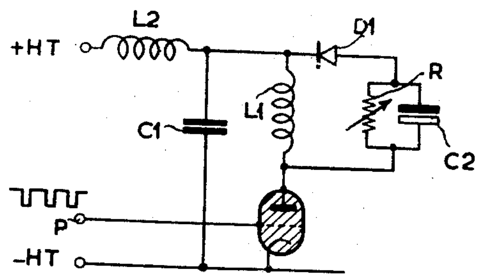

FIG.7

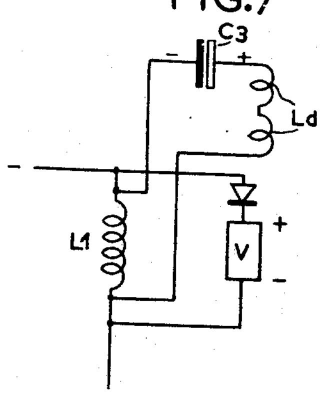

FIG.2

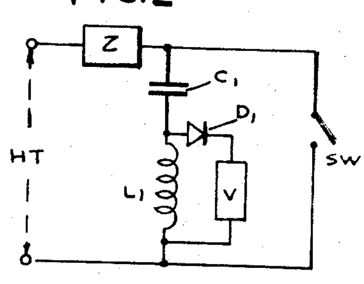

FIG.1

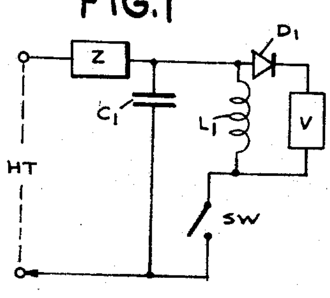

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FIG.3

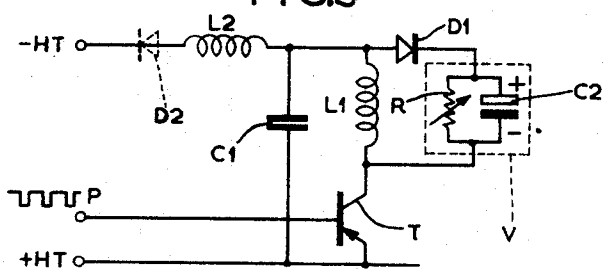
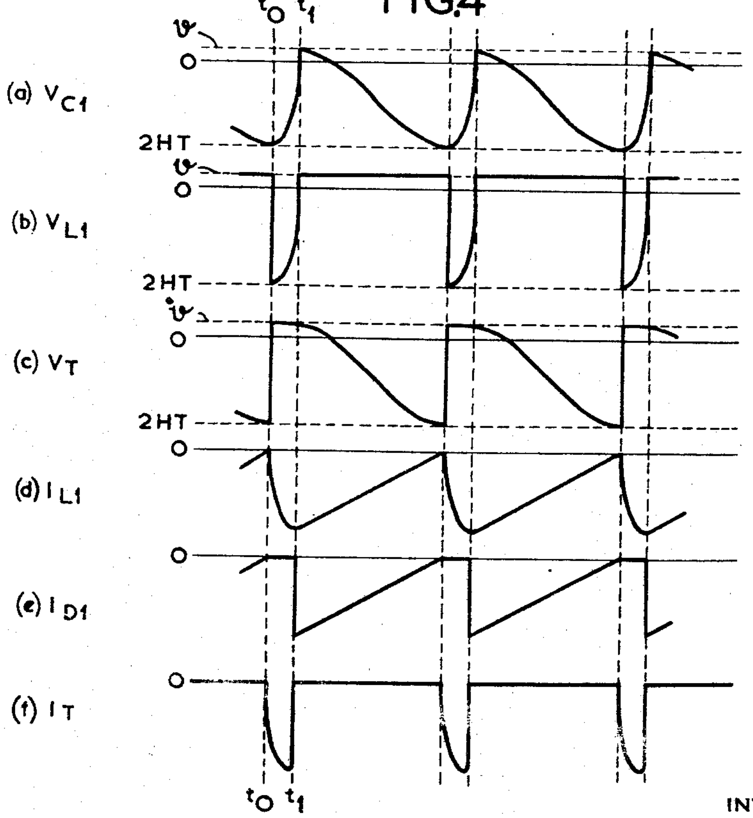


FIG.4



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2,995,679

CIRCUIT ARRANGEMENT FOR GENERATING A SAWTOOTH CURRENT IN AN INDUCTANCE

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3 Claims. (Cl. 315—29)

This invention relates to circuit arrangements for generating a sawtooth current in an inductance, i.e. to sawtooth wave generating circuits, time-base circuits and the like.

Such circuits may be used inter alia for generating sawtooth currents for magnetic deflection of the beam of a cathode ray tube e.g. in television application. Conventional circuits used for the latter purpose operate in such manner that a substantially constant voltage is applied to an inductance, which is coupled to or constituted by the deflection coils, so that a linear rise in current occurs in the inductance during the stroke period of the sawtooth cycle. During flyback, the current in the inductance is interrupted by cutting off a high-vacuum or "hard" valve which acts as a switch in series with the inductance.

Thus the current in the valve has zero value at the beginning of the stroke period and reaches a maximum value at the end of the stroke. The valve is cut off sharply while such maximum current is flowing and this initiates the flyback. The latter involves reversal of current to a maximum value of opposie sign following which the next stroke commences. Usually such current flow in the reverse direction or a corresponding transformed current, is allowed to flow through an auxiliary diode.

The switch valve must cut off sharply, and in this respect a hard valve, e.g. a pentode, is satisfactory. Alternative switching means such as transistors and thyratrons could also pass the currents required, but cannot be switched off abruptly while current is flowing unless an alternative current path is provided. However, such alternative switch means can be turned on faster than they can be turned off and are capable of passing heavy initial currents with very low voltage drop. Accordingly it is an object of the invention to provide improved circuit arrangements capable of utilizing the relatively fast turning-on characteristics of switch means that can turn on faster than they can be turned off. This may be achieved by operating the switch in such manner that it is closed or "on" during the flyback period and open or "off" during the stroke of the sawtooth, which contrasts with the conventional mode of operation wherein the switch is on during the stroke and off during the flyback. The former mode of operation has already been applied in a circuit described in U.S. Patent No. 2,507,226, issued May 9, 1950, wherein a thyratron is employed as a switch.

According to the present invention a circuit arrangement for generating a sawtooth current in an inductance comprises the means for causing the current in the inductance to have its maximum value at the beginning of the stroke period of the sawtooth, and means for causing said current to decay in a substantially linear manner to a minimum value during the stroke period, following which maximum current is restored in the inductance during the flyback period.

Preferably, a circuit arrangement according to the invention comprises the inductance and a capacitance, means for charging said capacitance during the stroke period, a switch between said inductance and capacitance whereby the capacitance may be discharged through the inductance during the flyback period in a resonant manner, means for permitting continued flow of current through said inductance in the stroke period subsequent to completion of said discharge of the capacitance, and means for applying a substantially constant voltage to said inductance during the stroke period in order to cause the continued flow of current therein to decay substantially linearly to a minimum value.

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Such a system has peak voltage and current characteristics which contrast as follows with conventional systems.

If peak voltage and peak current are required for a conventional time-base, then peak voltage is applied across the switch during current reversal and a sawtooth current increasing to peak current has to pass through the switch for part of the scan or stroke period (between half and full period according to design).

In circuits according to the present invention, peak voltages are built up across the switch during the scan or stroke period and thus cause high voltages to exist for a longer time on the switch. Also, peak current is twice as great for the same peak voltage but lasts for only a much shorter time (if the circuit is designed for the same peak current as a conventional circuit, then the peak voltage is twice as great). The power dissipation in the switch is proportional to the resistance of the switch, and in this respect a transistor is far more suitable than a thyratron since its minimum internal resistance is much smaller. Moreover, dissipation due to hole storage in a transistor may be greatly reduced in circuits according to the invention since the collector current is interrupted when it is at low value. In fact diversion of the current of the inductance to an alternative path after the flyback period allows the switch to open while carrying current at low values with only a small rise in applied volts as opposed to peak current at an instant of rapid rise in volts as conventional cases.

The switch may for example be constituted by a transistor or by a thyratron as explained more fully hereinafter.

The capacitance may be in parallel with the series combination of the inductance and the switch. Alternatively the switch may be in parallel with the series combination of capacitance and inductance (the latter being referred to hereinafter as the "main capacitance" and "main inductance" wherever confusion may arise due to the addition of auxiliary or optional reactances).

Where convenient, the expressions "charge" and "discharge" will be applied to the inductance as well as to the capacitance in the sense of transfer of energy to or from either of said reactances.

The means for applying a substantially constant voltage to the inductance during its discharge so as to linearise the latter may comprise a battery in series with a rectifier effective to prevent discharge of the capacitance through the battery. Alternatively, said means may comprise a rectifier in series with a resistance connected in parallel with a storage capacitance which is large enough to be held charged at a substantially constant level corresponding to the voltage appearing across the inductance during scan. As a further alternative, said means may comprise a transformer coupling arranged between the inductance and the H.T. supply points of the charging circuit so that the linearly decreasing current fed back to the supply permits a constant D.C. voltage across the inductance. In the latter arrangement there is the advantage that energy is recovered during the stroke period by way of current fed back to the supply, but a rectifier is required to prevent pulses of current being taken from the H.T. supply in the flyback periods when the current in the inductance rises rapidly.

The capacitance-charging circuit may operate in any suitable manner, but preferably the charging of the capacitance is effected resonantly through a charging choke with which said capacitance is resonant to a frequency such that a half cycle corresponds approximately to the stroke period.

Where the circuit arrangement is employed for magnetic deflection of the beam of a cathode-ray tube, e.g. for television line deflection, the main inductance may, if desired, be actually constituted by the deflection coil or coils.

Moreover, since the sawtooth current in the inductance always has the same sign, centralisation of the scan on the tube screen requires e.g. transformer or capacitance coupling from the inductance to the deflection coil.

The switch may be actuated by synchronisation pulses in the case of television or like applications, or it may be actuated by a relaxation oscillator circuit when the invention is applied to a D.C. transformer or voltage changer.

Embodiments of the invention will now be described by way of example with reference to the accompanying diagrammatic drawings.

Referring to FIGURE 1, a simple and generalised form of the circuit arrangement comprises a capacitor C1 which is charged from an H.T. supply through a charging impedance Z during the stroke of the sawtooth, and an inductance L1 through which capacitor C1 is discharged resonantly when a switch SW is closed for the flyback period. During the stroke period, the inductance L1 discharges through means V which provide a discharge path for the continued flow of the current in the inductance. In addition means V applies to the inductance L1 a substantially constant voltage. A rectifier D1 is provided in series with means V to prevent direct discharge of C1 through means V instead of through L1.

If charging of capacitance C1 is to be affected resonantly, the impedance Z is contituted by a charging choke with which capacitor C1 resonates to a frequency such that a half cycle corresponds approximately to the stroke period.

FIGURE 2 shows a circuit in which the switch SW is in parallel with the series combination of the capacitance C1 and inductance L1 instead of being in series with the said inductance.

In either of the circuits of FIGURES 1 and 2 the means V may be constituted by a battery or by a resistance shunted by a capacitance of very large value. The latter solution is employed in FIGURE 3 which shows a circuit arrangement similar to that of FIGURE 1, in which the switch SW is constituted by a P-N-P junction transistor T. An electrolytic capacitor C2 is shunted by a resistance R providing a path without which the dischange of current from inductance L1 would be prevented due to the capacitor C2 charging up to the peak voltage appearing across L1. In addition to preventing direct discharge of C1 through R, rectifier D1 also prevents discharge of capacitor C2 due to "ringing" with choke L2.

Half cycle resonant charging of capacitor C1 is effected through a charging choke L2 and an optional rectifier D2. D2 is only necessary if the resonant frequency of L2—C1 is such that one half cycle is smaller than the stroke period in which case C1 would otherwise discharge back into L2.

Operation of the circuit of FIGURE 3 will now be described more fully with reference to the graphs of FIGURE 4.

At the end of a stroke, at time t_0, it will be assumed that there is no energy left in L1, while C1 is already resonantly charged by L2 to a voltage V1 equal to twice the HT voltage (curve *a*). When transistor T is turned on at instant t_0, this capacitor voltage V_{C1} starts from a peak negative value equal to 2HT and decreases sinusoidally in the flyback period t_0—t_1 as capacitance C1 discharges through inductance L1 (L2 is actually in parallel but is large compared with L1 and its effect will hence be neglected).

The voltage continues to follow a sinusoidal law until it goes just positive to an extent v (FIGURE 4, curve *a*), but then D1 conducts and allows the current in inductance L1 (I_{L1}, curve *d*) to take an alternative return path through resistance R and capacitance C2 (means V) in place of the path through the switch T. Following the instant t_1, the current in inductance L1 flows through means V and decreases linearly due to a substantially constant voltage v being applied across it by means V. The linearity of such decrease permits the current in the inductance L1 to provide scanning action through the stroke period from instant t_1 to the subsequent instant t_0.

Due to the provision of the alternative path through R—C2, the transistor T can be opened without rupturing the inductive current thus minimising power dissipation due to hole-storage in the transistor. The transistor T must be on for the whole of the flyback period and can stay on for an initial portion of the stroke period; however, in the latter condition it will tend to interfere with the re-charging of capacitor C1 and therefore it is desirable that the transistor T should be turned off as soon as possible after the end of the flyback period.

While inductance L1 delivers its energy to the means V, capacitance C1 will once again be charged to a value 2HT (as shown in curve *a*) resonantly in a time determined by L2 and C1.

In addition to the curve *a* and *d* mentioned above, curve *b* represents the changes in the voltage V_{L1} across the inductance L1, curve *c* represents the voltage V_T across the switch T and curve *e* represents the current I_{D1} through rectifier D1. In addition, curve *f* represents the emitter-collector current I_T of the transistor, such current being approximately the difference between the currents I_{L1} and I_{D1} of curves *d*, *e*.

When the current through inductance L approaches zero at an instant t_0 (curve *d*) the switch T is again closed and the cycle repeated.

The transistor T is switched on by the leading edges of negative-going pulses applied to a pulse input point P and switched off by the trailing edges thereof. In 405-line television line-deflection applications of the circuit of FIGURE 3, such pulses are of 12–14 μs duration with a stroke duration of about 85 μs.

Preferably, the voltage difference applied between the collector and emitter electrodes of the transistor at the instant when it is switched on has a value sufficient to cause avalanche multiplication of the charge carriers through collision in the depletion layer of the collector, at least at the start of the flyback period. The switching on process is thus speeded up, the current through the transistor building up more rapidly and the voltage there across collapsing more suddenly, so that a power transistor can be made to work much faster than it would without making use of the avalanche effect.

Furthermore, the voltage between the collector- and emitter-electrodes of the transistor can be made to collapse to practically zero value by connecting a capacitor of, say some thousands of pF between said electrodes. Such a capacitor serves to store sufficient charge-carriers to sustain the discharge through the transistor until the voltage there across has collapsed to the desired low value.

FIGURE 5 shows a circuit in which the means V include a transformer coupling arranged between the inductance and the H.T. supply points of the charging circuit so that the linearly decreasing current fed back to the supply induces a constant D.C. voltage across the inductance L1. In such an arrangement, as aforementioned, energy is recovered during the stroke period by way of current fed back to the supply but a rectifier D3 is required to prevent pulses of current being taken from the voltage supply in the flyback periods when the current in the inductance L1 rises rapidly. For this purpose the rectifier D3 must be polarized in the reverse direction with respect to the supply voltage.

FIGURE 6 shows a circuit similar to that of FIGURE 3 in which the P-N-P junction transistor is replaced by a thyratron, the polarity of the H.T. voltage being appropriately reversed. The grid of the thyratron is driven by positive pulses applied at point P in place of the megative pulses required for base control in FIGURE 3.

Where the circuit is used for displaying a scan on a cathode ray tube, centralisation of the scan on the screen may be effected e.g. by transformer coupling between the inductance L1 and the deflection coils, or by A.C. coucase of a junction transistor such as transistor T of FIGURE 7 where the coils are indicated at *Ld*.

Hitherto the operating conditions of transistor T have not been examined closely, and preferred conditions for television applications will now be considered for the case a junction transistor such as transistor T of FIGURE 3.

When the base of a junction transistor is held slightly positive, a voltage many times greater than the normal "turn-over" voltage (e.g. about 10 times the normal operating voltage in the case of a 2-watt power transistor) can be applied across the collector-emitter path without much current flowing. If the base is now made to pass even a small current the collector current and collector power dissipation would become excessive if the collector voltage were not allowed to fall to a value which is far lower than the initial voltage applied. In the present case the voltage across transistor T falls owing to the voltage drop developing across the inductance L1 which is in series with the transistor. This has the effect of increasing the gain of transistor T to a very high value over this limited range of base currents and voltages. This characteristic allows very high speed of voltage reduction across T, which in turn is favourable for application of the circuit to television time-base circuit arrangements for magnetic line deflection. For maximum efficiency, the base is not merely made to pass a small current—instead, it is driven hard negative to ensure that the transistor is operating in the "Knee" or "hard-on" condition, and this may be effected with the aid of regenerative feedback or an external generator.

What is claimed is:

1. A circuit for producing a sawtooth current through an inductance, comprising a transformer having a primary winding which constitutes said inductance and having a secondary winding, a charging circuit comprising a voltage source, an impedance, and a capacitor continuously connected to be charged from said source through said impedance, a switch connected to selectively connect said primary winding across said capacitor thereby to discharge said capacitor, and a secondary circuit connected across said secondary winding and comprising a source of voltage and a rectifier connected in series, said rectifier being polarized in the reverse direction with respect to the last-named voltage, thereby to supply a substantially constant voltage across said primary winding during the charging periods of said capacitor.

2. A circuit as claimed in claim 1, in which a single source of voltage is connected in both said charging circuit and said secondary circuit thereby to serve as the sources of voltage in these circuits.

3. A circuit for producing a current having a sawtooth shaped waveform in an inductance comprising a capacitor, an inductive impedance, means serially continually connecting said impedance and capacitor to a source of voltage, means periodically connecting said inductance in parallel with said capacitor, a winding inductively coupled to said inductance, a rectifier, and means serially connecting said rectifier and winding to a source of voltage, said rectifier being polarized in the reverse direction with respect to said last-named source of voltage.

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