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(54) **Ignition circuit.**

(57) The described invention relates to an automotive ignition circuit for use in an ignition system in which a distributor is provided with a magnetic sensor.

A periodic signal provided by the magnetic sensor is compared with two reference potentials by means of two comparators. An output signal provided by one comparator is used to enable the supply of current to an ignition coil whilst an output signal provided by the second comparator is used to disable current in the ignition coil. In this way the switching on and off of the flow of current through the ignition coil are made independent of one another enabling more accurate ignition timing to be obtained at all engine speeds.

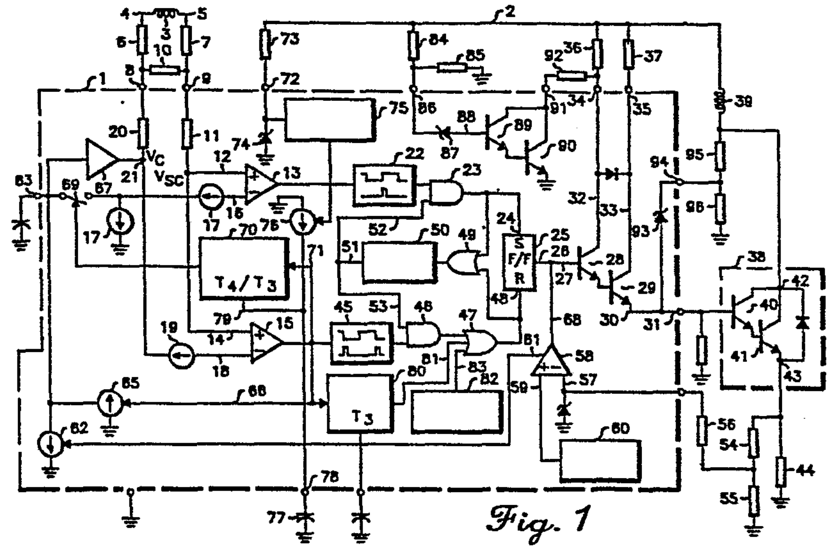

Fig. 1

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IGNITION CIRCUIT

TECHNICAL FIELD

This invention relates to an ignition circuit suitable for use in an automotive ignition system having a distributor which is provided with a magnetic sensor.

BACKGROUND ART

Automotive ignition circuits utilising magnetic sensors are known. The magnetic sensor replaces the contact breaker set within the distributor and provides a periodic waveform output.

The periodic waveform is compared with a reference level and the result of this comparison is used to control both the dwell period i.e. the time during which current flows in the ignition coil and the spark, when the coil current is switched off.

The dwell time and the spark are defined by the single reference level and this results in this known circuit having disadvantages. Timing errors arise and result in sparks coming too early at low engine speed. Also since the dwell time cannot be regulated over the full speed range the known circuit uses more power than is desirable.

This invention seeks to provide an automatic ignition circuit suitable for use with a magnetic sensor and in which the above mentioned disadvantages are mitigated.

BRIEF SUMMARY OF THE INVENTION

According to the present invention there is provided an automotive ignition circuit for controlling the supply of current to an ignition coil and suitable for use in an ignition system in which a distributor is provided with a magnetic sensor, the circuit comprising a first comparator for comparing the amplitude of a periodic signal fed from the magnetic sensor with a first reference potential level and for providing a first output signal indicative of the amplitude of the periodic signal crossing the first reference potential level, a second comparator for comparing the amplitude of the periodic signal with a second reference potential level and for providing a second output signal indicative of the amplitude of the periodic signal crossing the second reference potential level and means for enabling and disabling the supply of current to the ignition coil in response to the first and second output signals respectively.

In an embodiment of the invention the means for enabling and disabling the supply of current to the ignition coil includes a set-reset flip-flop arranged to be set in response to the said first output signal and reset in response to the said second output signal.

Differentiating means may be provided between the set-reset flip-flop and the first and second comparators for differentiating the first and second output signals.

Means may be provided for preventing a change of state of the flip-flop for a predetermined period following the setting and resetting in response to the first and second output signals respectively.

The means for preventing the change of state of the set-reset flip-flip may comprise gating means positioned between the differentiating means and the set-reset flip-flop, the gating means being blocked for the said predetermined period following the setting and resetting of the flip-flop.

The gating means may be blocked by an output signal fed from a monostable, triggered in response to the setting and resetting of the flip-flop.

Means may be provided for maintaining the flip-flop in a reset condition during periods when no periodic signal is provided by the magnetic sensor.

Means may be provided for adjusting the effective value of the first reference potential level in order to control the point in time during a cycle of the periodic signal at which the supply of current to the ignition coil is enabled.

The means for adjusting the effective value of the first reference potential may conveniently comprise means for adding a control potential to the periodic signal.

The control potential may be derived from charge storage means arranged to be charged during a first portion of each cycle of the periodic signal and discharged during a second portion.

The charge storage means may be charged in response to the periodic signal crossing the second reference potential level in a first predetermined direction and may be discharged in response to the current in the ignition coil attaining a predetermined value, preferably a limiting value.

Means responsive to distributor speed and/or ignition circuit supply potential may be provided for periodically charging the charge storage means to a reference potential during periods when the distributor speed and/or the supply potential fall below predetermined values.

The means for enabling and disabling the supply of current to the ignition coil may include one or more output transistors and means may be provided for protecting the said one or more output transistors against potentials greater than a predetermined value.

An exemplary embodiment of the invention will now be described with reference to the drawings in which:

Figure 1 is a schematic block diagram of an automotive ignition circuit in accordance with the present invention; and

Figures 2 - 5 are explanatory waveform diagrams illustrating the operation of the ignition circuit of Figure 1.

Referring now to Figure 1 the ignition circuit shown therein is particularly suitable for production on an integrated circuit chip illustrated by a dashed line box 1, those elements lying within the box 1 being located on the chip. The circuit operates from a supply potential line 2 which is coupled to an automotive battery via an ignition switch (not shown).

A magnetic sensor 3 which replaces the contact breaker set in the automotive distributor has output terminals 4 and 5 which are respectively connected via resistors 6 and 7 to input pins 8 and 9 of the chip 1. A further resistor 10 is coupled between the pins 8 and 9, the resistors 6, 7 and 10 being provided in order to adapt the amplitude of the signal provided by the magnetic sensor 3 to the integrated circuit chip 1.

The pin 9 is coupled via a resistor 11 to a positive input 12 of a first comparator 13 and also to a positive input 14 of a second comparator 15.

A second and negative input terminal 16 of the comparator 13 receives a reference potential from voltage sources 17 of values V_1 and V_4 coupled between the terminal 16 and ground. A second and negative input terminal 18 of the comparator 15 also receives a reference potential of value V_2 from one terminal of a voltage source 19, a second terminal of which is coupled through a resistor 20 to the pin 8.

Referring also now to Figure 2, when the cam of the distributor is rotating a cyclic waveform as shown in line A of Figure 2 will be developed between the terminals 4 and 5 of the magnetic sensor 3. In order to control the dwell time, that is the time during which current flows through the ignition coil, a feedback voltage V_c derived in a manner to be described is applied to a terminal 21 and is added to the cyclic waveform derived from the magnetic sensor 3 so that a new cyclic signal V_{SC} is applied to the terminal 12 of the comparator 13 and is compared with the reference potential provided by the sources 17 at the negative input 16 of the comparator 13.

The comparator 13 provides a rectangular output waveform having a transition each time the cyclic waveform applied to the positive terminal 12 of the comparator crosses the reference potential applied to the negative terminal 16. This output waveform of the comparator 13 is differentiated by a differentiator 22 which provides an output pulse on each rising edge of the waveform output of the comparator 13 indicative of the cyclic waveform crossing the reference potential in a first predetermined direction. The differentiated output pulse provided by the differentiator 22 is fed to one input of an AND gate 23 whose ouput is connected to a set input 24 of a set-reset flip-flop 25.

The flip-flop 25 has an output 26 connected to a base 27 of one transistor 28 of a pair of Darlington connected output transistors 28 and 29, the transistor 29 having an emitter 30 which is connected to an output pin 31 of the ignition circuit. The transistors 28 and 29 have collectors 32 and 33 respectively, the collector 32 of the transistor 28 being connected to a pin 34 of the integrated circuit whilst the collector 33 of the transistor 29 is connected to a pin 35. The pins 34 and 35 are in operation coupled to the supply potential 2 via load resistors 36 and 37 respectively. The output pin 31 is coupled to a switch 38 for switching current flow through the ignition coil 39. The current switch 38 also consists of two Darlington connected transistors 40 and 41, the transistor 41 having its collector electrode 42 connected to one terminal of the ignition coil 39 a second terminal which is coupled to the supply potential 2, while emitter electrode 43 of the transistor 41 is connected to one terminal of a resistor 44 whose other terminal is connected to ground reference potential.

Current through the ignition coil 39 is turned off by means of the comparator 15 which compares the cyclic signal provided by the magnetic sensor 3 and appearing between the pins 8 and 9 differentially with the reference potential provided by the source 19. The comparator 15 also provides a rectangular output waveform having a transition edge each time the cyclic waveform crosses the value of the reference potential.

The output waveform of the comparator 15 is differentiated in a differentiator 45 which provides an output pulse for each negative going edge of the rectangular waveform indicative of the cyclic waveform falling below the value of the reference potential. Each output pulse provided by the differentiator 45 is connected to one input of an AND gate 46 whose output is fed via an OR gate 47 to the reset input 48 of the flip-flop 25. Each pulse at the reset input 48 of the flip-flop 25 is operative to reset the flip-flop and to turn off the transistors 28 and 29 and hence the transistors 40 and 41 and to cut off the current through the ignition coil 39 thereby producing an ignition spark.

In order to protect the ignition circuit against noise the set and reset inputs 24 and 48 respectively of the flip-flop 25 are connected to respective inputs of an OR gate 49 whose output triggers a monostable multivibrator 50 which in turn has an output 51 connected to a second input 52 of the AND gate 23 and to a second input 53 of the AND gate 46. Each time the flip-flop 25 changes state the monostable 50 is triggered and provides an output pulse which blocks each of the AND gates 23 and 46 during the period of the output pulse of the monostable 50 which is typically 250 microseconds. This prevents any further changes of state of the flip-flop 25 during this 250 microsecond period and provides the flip-flop 25 with some noise immunity.

The ignition circuit of the invention as shown in Figure 1 provides accurate ignition timing at different speeds with relatively low power consumption by regulation of the dwell time in accordance with the engine speed. The dwell time is sought to be controlled in such a manner that the time period T_r during which current through the ignition coil 39 has reached a limiting value is kept at a constant proportion, typically 8% of the period T of the cyclic waveform provided by the magnetic sensor 3.

The potential V_c applied to the terminal 21 and added to the signal provided by the sensor 3 is dependent upon engine speed and the effect of this added engine speed dependent potential is effectively to vary the reference potential level for the comparator 13 in dependence upon engine speed. In waveform A as shown in Figure 2 the line V_2 represents the fixed value of the reference potential for the comparator 15 provided by the source 19, the line V_{sc1} represents the effective value of the reference potential of the comparator 13 for high engine speed, whilst the line V_{sc2} represents the effective value of the reference potential for the comparator 13 at low engine speed.

As can be seen the effective value of the reference potential for the comparator 13 moves up and down the waveform provided by the magnetic sensor 3 as the engine speed decreases and increases. The range of on-timing, that is the range of variation in time at which current through the ignition coil 39 is switched on by the output from the comparator 13, is defined by the lines of R_1 and R_2.

At low engine speed the sensor waveform crosses the low speed reference level V_{sc2} at one range extremity R_2 whilst at high speed the waveform crosses the high speed reference level V_{sc1} at the range extremity R_1. Coil current is turned off at each downward crossing D by the sensor waveform of the reference potential V_2.

Line B of Figure 2 illustrates current through the ignition coil at low speed whilst the waveform at line C illustrates current through the coil at high speed. At time t_1 current begins to flow through the ignition coil, at time t_2 current reaches its limiting value and at time t_3 current ceases to flow. The timescales of the waveforms B, and C are of course different but the figures clearly illustrate that the current limiting time T_r remains a substantially constant proportion of the period T of the sensor waveform.

Referring once again to Figure 1 a potential divider formed by series connected resistors 54 and 55 is connected between the emitter electrode 43 of the transistor 41 and ground. The junction between the resistors 54 and 55 is coupled through a resistor 56 to a negative input 57 of an operational amplifier 58 a positive input 59 of which receives a reference potential of value V_3 from a band gap reference circuit 60. The operational amplifier 58 has a first output 61 which is operative to turn on a current generator 62. The current source 62 is connected to a pin 63 of the integrated circuit 1 and is operative to discharge a capacitor 64 which is connected externally of the integrated circuit 1 between the pin 63 and ground. A second current source 65 is connected in parallel with the current source 62 between the pin 63 and ground and is operative to charge the capacitor 64. The current source 65 is turned on by a leading edge of the rectangular waveform fed via a connection 66 from the output of the comparator 15.

The instantaneous potential appearing on the capacitor 64 is applied via a voltage follower 67 to the terminal 21 where it is added to the waveform provided by the magnetic sensor 3 and is operative to change effectively the reference level of the comparator 13 and hence to control the dwell time. Typically the current source 62 which discharges the capacitor 64 generates a current which is approximately six times that generated by the current source 65 which charges the capacitor 64.

In operation the current source 65 is firstly turned on by means of the output waveform fed from the comparator 15 and this current source 65 charges the capacitor 64. A current flowing through the ignition coil 39 builds up and consequently the potential applied to the input terminal 57 of the operational amplifier 58, which is representative of the value amplitude of the current flowing through the ignition coil also increases. The reference potential applied to the input terminal 59 of the operational amplifier 58 is set at a value representative of the coil reaching its maximum, i.e. limiting, value and when this limiting value is reached the operational amplifer 61 will provide an output signal at its output 61 which switches on the current source 62 which commences to discharge the capacitor 64.

The operational amplifier 58 is also utilized to regulate the coil current by providing a second output 68 connected to the base electrode 27 of the transistor 28. In this way current through the output transistors 28 and 29, and hence the coil current flowing through the ignition coil 39, are regulated.

A problem can arise at low speed and low supply voltage. Under these conditions it is possible that the current flowing through the ignition coil 39 may never reach its limiting value. Consequently in each cycle of the waveform provided by the magnetic sensor 3, the output fed from the comparator 15 will turn on the current source 65 to charge the capacitor 64 but because the coil current never limits, the current source 62 will never be turned on. The effect of this is illustrated in Figure 3 to which reference will now be made.

In Figure 3 and considering firstly Figure 3A the level of the potential V_4 is indicated, together with the level $V_4 + V_1$ representing the actual potential applied to the input 16 of the comparator 13 and derived from the voltage sources 17. The waveform V_m is the sensor waveform applied between the input terminals 14 and 18 of the comparator 15 whilst the waveform V_{sc} is the waveform applied to the positive input terminal 12 of the comparator 13. Figure 3B shows the waveform output provided by the comparator 15 whilst the waveform shown in Figure 3C illustrates the increasing potential on the capacitor 64. Ignition coil current is illustrated in Figure 3D and the line I_L indicates the limiting value of the coil current. As can be seen in Figure 3A the effect of the steadily increasing charge on the capacitor 64 is to cause the overall level of the waveform V_{sc} to rise until it no longer crosses the level V_{on} applied to the negative input terminal 16 of the comparator 13. The points P1, P2 and P3 at which the waveform V_{SC} crosses the level V_{on} represent the turning on of the coil current caused by an output of the comparator 13 and as can be seen the point P3 will be the last turn on of this coil current. Thereafter the coil current will not be turned on and the ignition circuit will cease to function properly.

This problem is overcome by connecting the pin 63 to the potential source 17 through a switch 69 which is normally open. The switch is closed in response to an output pulse provided by a speed detector 70 which provides output pulses in response to being triggered at a triggering input 71 by means of the output waveform fed from the comparator 15. The speed detector 70 provides output pulses following triggering after either a delay time T_1 or T_2. The delay time T_1 or T_2 is chosen in dependence upon supply voltage as follows. An input pin 72 of the circuit 1 is coupled to the supply potential 2 through a resistor 73. A Zener diode 74 is connected between the pin 72 and ground potential. A voltage detector 75 is also connected to the pin 72 and detects whether or not the Zener diode 74 is limiting, which limiting takes place at normal supply voltage.

The voltage detector 75 controls current supplied by a current source 76 connected to a control input 79 of the speed detector 70. The control input 79 is also connected to a pin 78 of the integrated circuit chip 1. An external capacitor 77 is coupled between the pin 78 and ground.

The current source 76 and the capacitor 77 are the time determining elements of the speed detector 70. At low supply voltages the voltage detector 75 controls the current supplied by the source 76 to a first relatively high value so that the speed detector operates on delay time T_1 which is dimensioned such that output pulses provided by the speed detector 70 disappear at a frequency at which the output waveform provided by the magnetic sensor 3 is sufficiently large that the critical situation illustrated in Figure 3 does not occur. At speeds higher than this critical frequency the speed detector 70 will be retriggered before an ouput pulse is provided so that no output pulses will occur.

Where speed falls below this critical value so that periodically an output pulse is provided by the speed detector 70 this pulse operates to close the switch 69 thereby connecting the capacitor 64 to the potential source 17. This results in the capacitor 64 being charged to the reference level of the potential source 17 each time that an ouput pulse is provided by the speed detector 70. The effect of periodically charging the capacitor 64 to the reference potential of the source 17 will now be described with reference to Figure 4.

In Figure 4, Figure 4A illustrates the magnetic sensor waveform V_m, Figure 4C illustrates the output of the comparator 15 Figure 4D shows the output pulses provided by the speed detector 70, the period T_c representing the period of the output pulses of the speed detector during which the switch 69 is closed. Figure 4E shows the potential on the capacitor 64 whilst Figure 4F illustrates the current through the ignition coil 39. This current through the coil as shown in Figure 4F once again can be seen not to rise to the limiting value I_L. During the period T_c, during which the switch 69 is closed due to the speed detector 70 not having been reset for a period T_1, the potential on the capacitor 64 is held at the potential V_{on} of the source 17. The effect of this on the waveform applied to the positive input terminal 12 of the comparator 13 is illustrated in Figure 4B. The waveform V_{sc} can be seen to be stepped down in level at points P_c which correspond to the closing of the switch 69 so that the waveform does not continue to rise above the levels of the reference potentials V_4 + V_4 and V_1 but continues to cycle about those levels. The ignition circuit keeps its high sensitivity and normal operation at low supply voltage and speed.

At normal supply voltage the speed detector 70 is switched to a much longer time constant T_2 and as will now be seen this longer time constant enables the speed detector to detect very low speeds e.g. cranking speeds to ensure that the ignition circuit can follow acceleration and deceleration at such low speed. When the voltage detector 75 detects limiting of the Zener diode 74 the current supplied by the current source 76 is switched to a much lower value so that the delay time of the speed detector 70 adopts the much longer time constant T_2. Typically the speed detector 70 will provide outputs at delay T_1 at distributor speeds of 430 revolutions per minute whilst the delay time T_2 becomes operative at distributor speeds of 60 r.p.m.

Operation of the ignition circuit with the speed detector 70 at very low speed is illustrated in Figure 5 to which reference will now be made.

In Figure 5, Figure 5A illustrates the sensor waveform V_m together with the waveform V_{SC} applied to the positive input 12 of the comparator 13. The levels L_1, L_2 and L_3 represent the spark level set by the potential V_2, the ON level for the current source 65 and the on level for the current source 62 respectively. Waveform 5B shows the output of the comparator 15, Figure 5D shows the potential on the capacitor 64, whilst the waveform 5E illustrates the current through the ignition coil 39.

A problem at very low speed such as cranking speed is that the amplitude of the sensor waveform V_m becomes so small that the comparator 15 switches the current source 65 on for such a short period during each cycle that the capacitor 64 remains substantially totally discharged. As can be seen in Figure 5A it is possible that the sensor waveform may not cross the reference level $V_4 + V_1$. In Figure 5C the speed detector 70 can be seen to provide an output pulse which commences at a delay time T_2 after triggering and continues until retriggered by another output from the comparator 15. In Figure 5D the capacitor 64 can be seen to be charging for a short period following the end of the period T_C. In this way the voltage level V_{SC} can rise until it becomes equal to $V_4 + V_1$ so that comparator 13 can switch the coil current on. As soon as the current is at its limiting value, capacitor 64 is discharged again by current source 62. The capacitor 64 can be seen to be prevented from remaining permanently discharged as during each period T_C during which output pulses provded by the speed detector 70 the switch 69 closes and the capacitor 64 is restored to the reference level V_4. The ignition circuit can in this way follow any acceleration or deceleration at very low speed.

The ignition circuit has several protection devices. A circuit 80 is also triggered by the output signal fed from the comparator 15. In the absence of an output waveform from the comparator 15, i.e. when the distributor is not rotating, an output 81 is fed from the circuit 80 through a second input of the OR gate 47 to the reset input of the flip-flop 25 to maintain that flip-flop in a reset condition and thereby prevent current flowing through the ignition coil 39. The ignition coil is therefore prevented from being burnt out whilst the distributor is not rotating. A power-on reset circuit 82 is also provided and this circuit has an output 83 also coupled to a third input of the OR gate 47. The power-on reset circuit 82 senses the initial application of the supply potential 2 and provides an output pulse to re-set the flip-flop 25 until such time as a sensor waveform is provided by the magnetic sensor 3 during the starting of the engine.

An over voltage protection circuit is provided for the Darlington connected transistors 28 and 29. A pair of resistors 84 and 85 are connected in series between the supply potential 2 and ground. The junction of these resistors is coupled to pin 86 of the chip 1. A Zener diode 87 is coupled between the pin 86 and a base electrode 88 of a pair of Darlington connected transistors 89 and 90. The transistor 90 of the Darlington connected pair is coupled to a further pin 91 of the chip, which pin is connected through a resistor 92 to the pin 35 to which the collector electrode 33 of the transistor 29 is connected. When the potential at the pin 86 exceeds the breakdown voltage of the Zener diode 87 the pin 91 which is coupled to the collector electrode of the transistor 90 is pulled down the clamps the potential at the pin 35 to a safe voltage at which the output transistor 28 and 29 can still operate. The voltage at which this protection commences is dimensioned by the values of the resistors 84 and 85. The transistors 40 and 41 of the switch 38 are protected by means of a further Zener diode 93 mounted on the integrated circuit chip and connected between a pin 94 and the output pin 31 of the chip. Two series connected resistors 95 and 96 are connected between the collector electrode 42 of the transistor 41 and ground potential and the pin 94 of the chip is coupled to the junction of the resistors 95 and 96.

The invention has been described by way of example only and modifications may be made without departing from the scope of the invention.

CLAIMS

1. An automotive ignition circuit for controlling the supply of current to an ignition coil and suitable for use in an ignition system in which a distributor is provided with a magnetic sensor, the circuit comprising a first comparator for comparing the amplitude of a periodic signal fed from the magnetic sensor with a first reference potential level and for providing a first output signal indicative of the amplitude of the periodic signal crossing the first reference potential level, a second comparator for comparing the amplitude of the periodic signal with a second reference potential level and for providing a second output signal indicative of the amplitude of the periodic signal crossing the second reference potential level and means for enabling and disabling the supply of current to the ignition coil in response to the first and second output signals respectively.

2. An ignition circuit as claimed in claim 1 wherein the means for enabling and disabling the supply of current to the ignition coil includes a set re-set flip-flop arranged to be set in response to the said first output signal and reset in response to the second output signal.

3. An ignition circuit as claimed in claim 1 or 2 wherein differentiating means is provided between the set re-set flip-flop and the first and second comparators for differentiating the first and second output signals.

4. An ignition circuit as claimed in any preceding claim wherein means is provided for preventing a change of state of the flip-flop for a predetermined period following the setting and resetting in response to the first and second output signals respectively.

5. An ignition circuit as claimed in claim 4 wherein the means for preventing the change of state of the set re-set flip-flop comprises gating means positioned between the differentiating means and the set re-set flip-flop the gating means being blocked for the said predetermined period following the setting and resetting of the flip-flop.

6. An ignition circuit as claimed in claim 5 wherein the gating means is blocked by an output signal fed from a monostable circuit triggered in response to the setting and re-setting of the flip-flop.

7. An ignition circuit as claimed in any preceding claim wherein means is provided for maintaining the flip-flop in a reset condition during periods when no periodic signal is provided by the magnetic sensor.

8. An ignition circuit as claimed in any preceding claim wherein means is provided for adjusting the effective value of the first reference level in order to control the point in time during a cycle of the periodic signal at which the supply of current to the ignition coil is enabled.

9. An ignition circuit as claimed in claim 8 wherein the means for adjusting the effective value of the first reference potential comprises means for adding a control potential to the periodic signal.

10. An ignition circuit as claimed in claim 9 wherein the control potential is derived from charge storage means arranged to be charged during a first portion of each cycle of the periodic cycle and discharged during a second portion.

11. An ignition circuit as claimed in claim 10 wherein the charge storage means is a capacitor.

12. An automotive ignition circuit as claimed in claim 10 or 11 wherein the charge storage means is charged in response to the periodic signal crossing the second reference potential level in a first predetermined direction and discharged in response to the current in the ignition coil attaining a predetermined value.

13. An ignition circuit as claimed in claim 12 wherein the capacitor is discharged in response to the current in the ignition coil attaining a limiting value.

14. An ignition circuit as claimed in any one of claims 10-13 wherein means responsive to distributor speed and/or ignition circuit supply potential is provided for periodically charging the charge storage means to a reference potential during periods when the distributor speed and/or the supply potential fall below predetermined values.

15. An ignition circuit as claimed in any preceding claim wherein the means for enabling and disabling the supply of current to the ignition coil includes one or more output transistors means being provided for protecting the transistors against potentials greater than a predetermined value.

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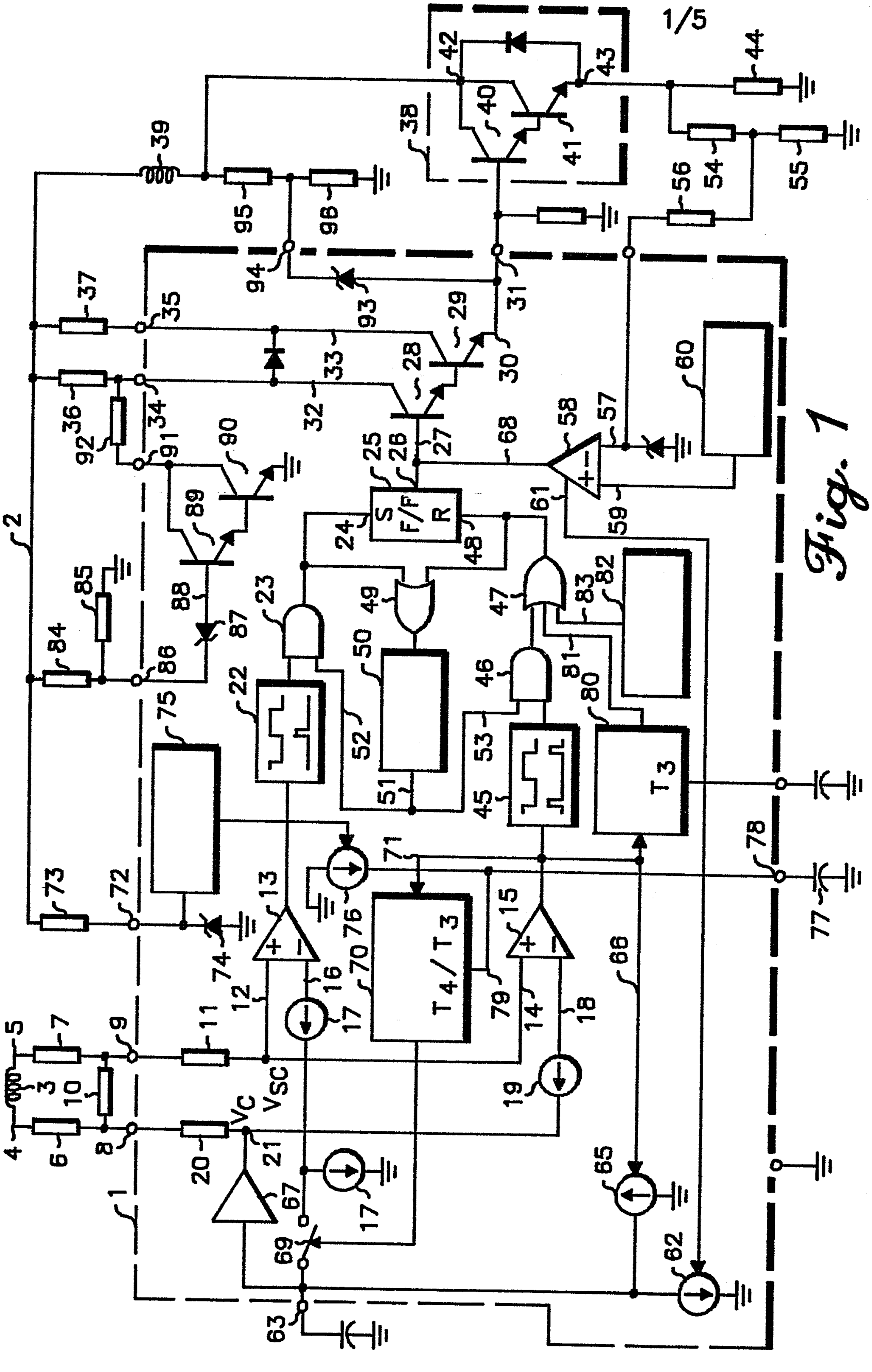

Fig. 1

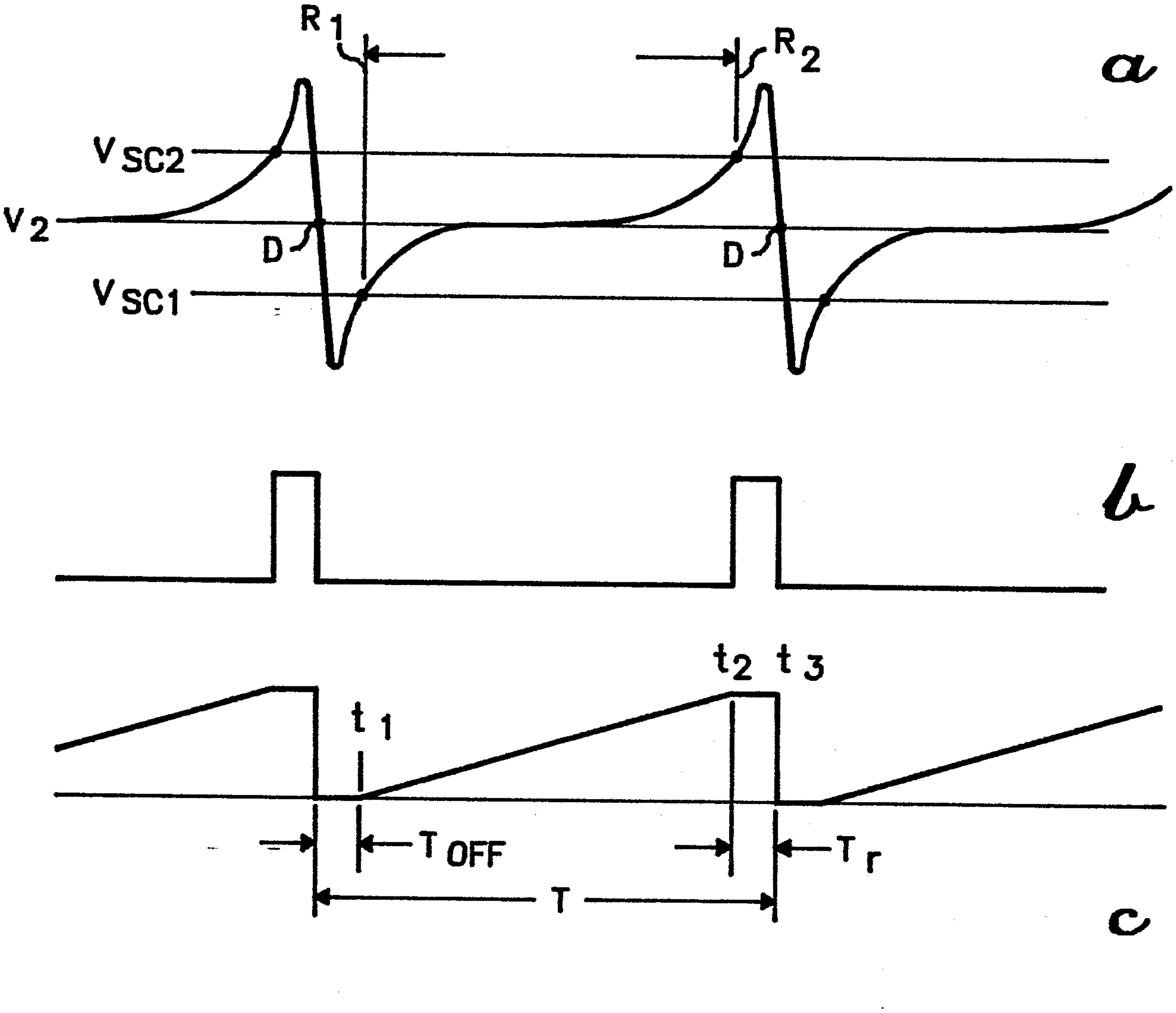

Fig. 2

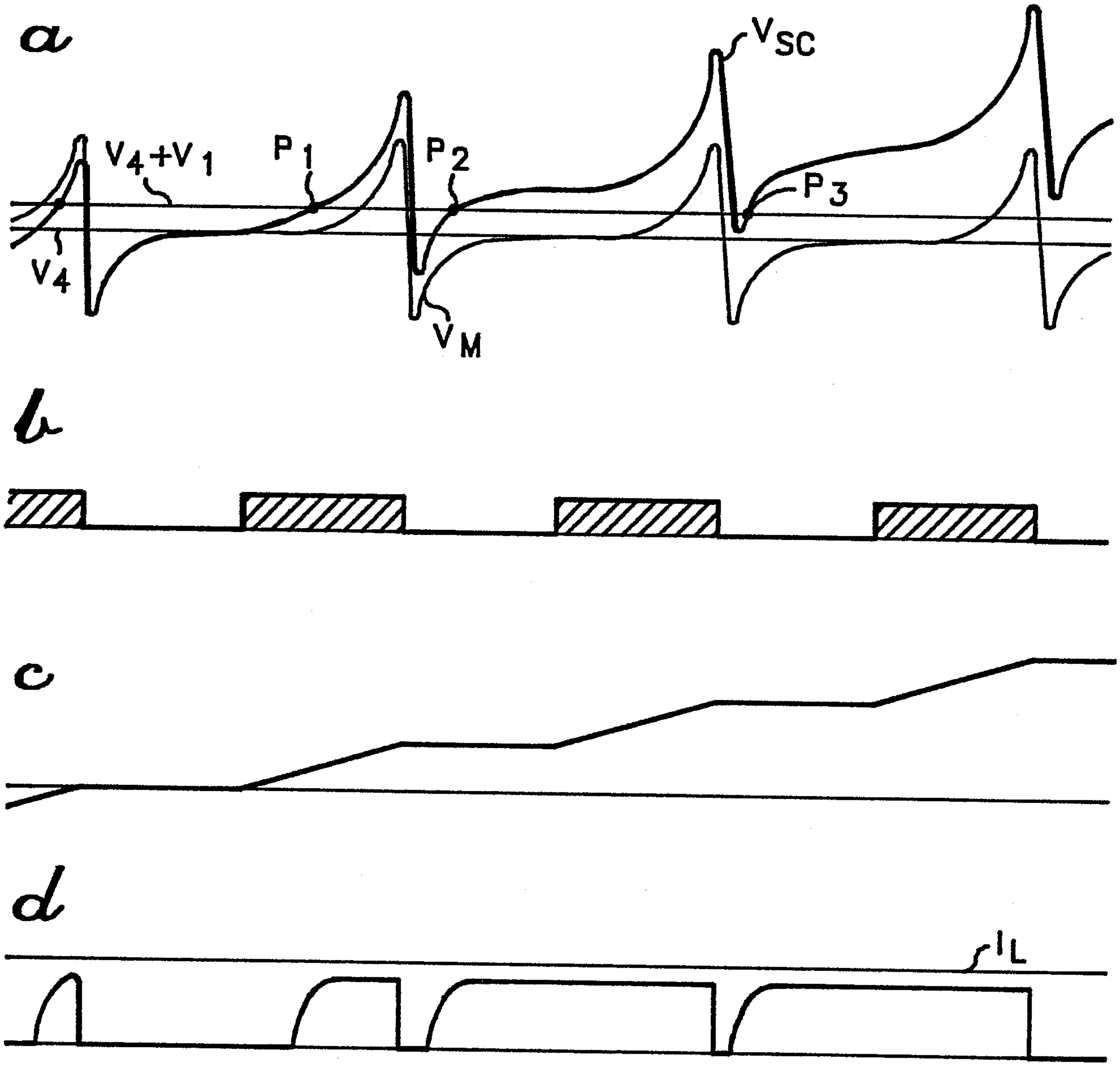

Fig. 3

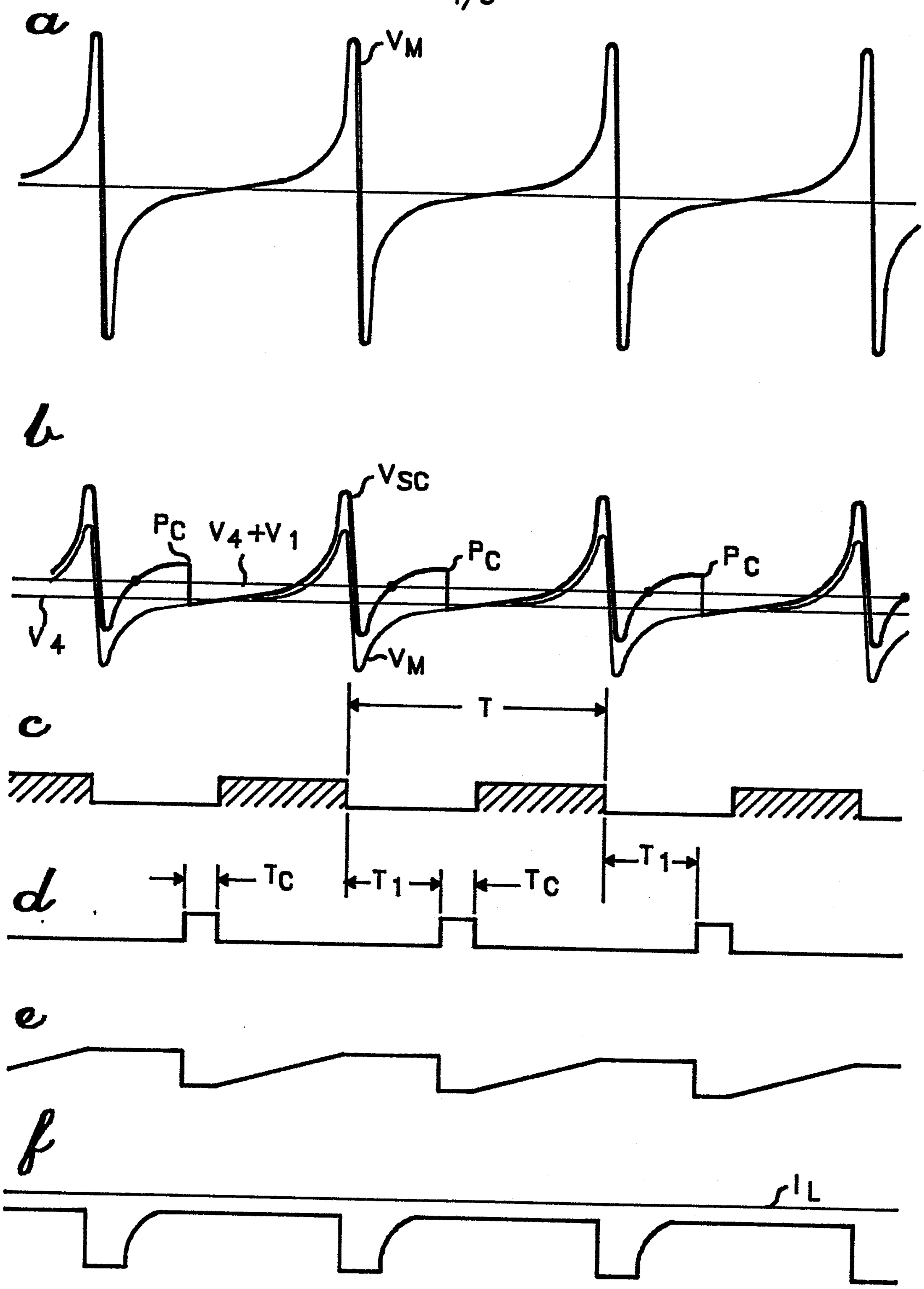

Fig. 4

Fig. 5