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IGNITION SYSTEM FOR INTERNAL COMBUSTING ENGINES

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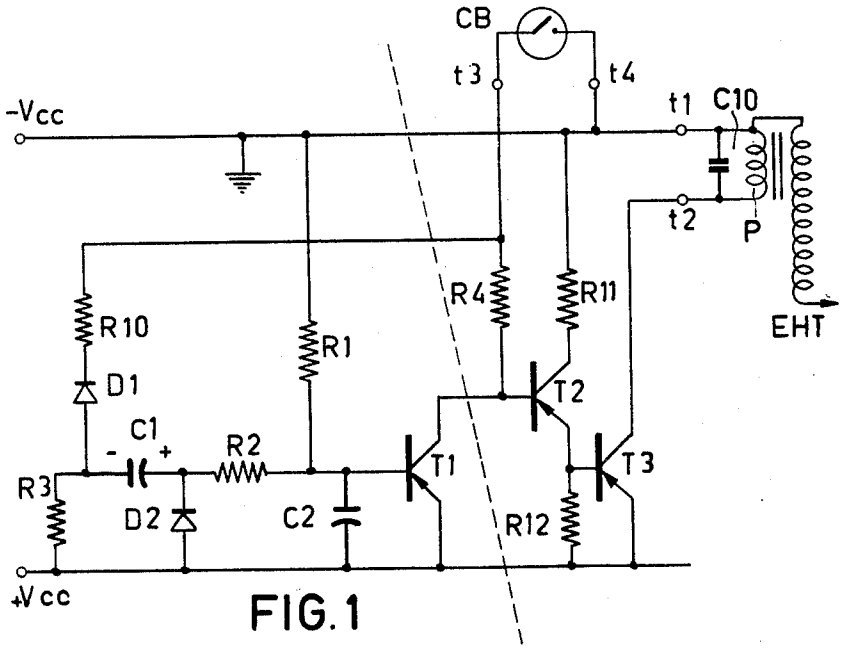


FIG.1

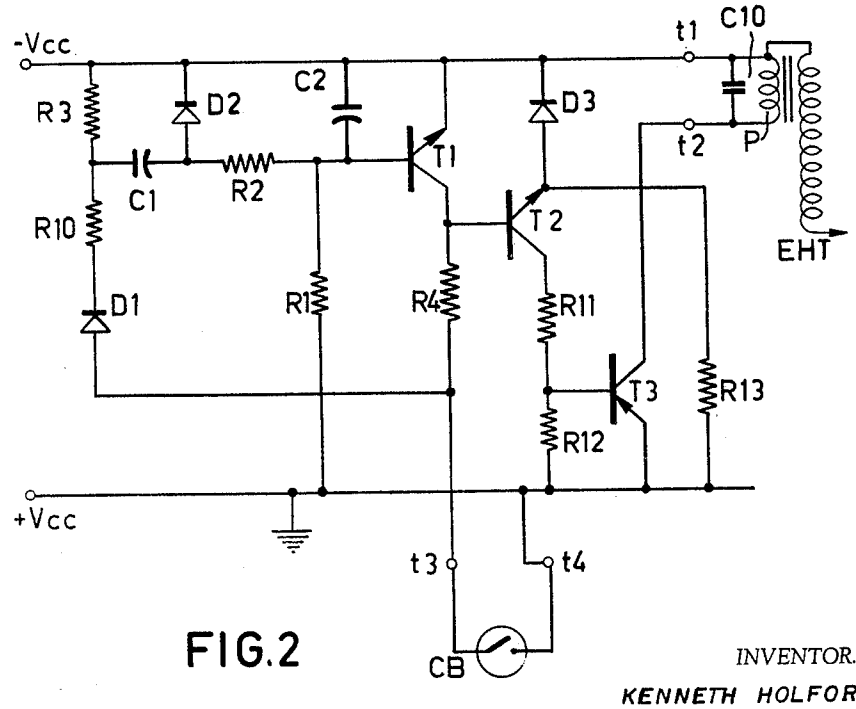


FIG.2

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IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINES

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This invention relates to ignition circuits for internal combustion engines, and it is an object of the invention to provide improved circuits of this type employing transistors.

The invention provides an improved ignition circuit for an internal combustion engine having an ignition coil and a contact-breaker. The circuit comprises a transistor, means for connecting the emitter-collector path of said transistor effectively in series with the primary winding of said coil across a supply battery, means for deriving from said battery forward bias current for the transistor whenever the contact-breaker is in the closed condition, and means for inhibiting the occurrence or the effect of said forward bias when the engine is stationary.

Such a circuit is adapted to automatically stopping the flow of primary D.C. current when the engine is left stationary with the ignition circuit switched on. With battery-driven circuits such as are used in motor vehicles, this is desirable both for obvious current economy reasons and because there is difficulty in providing the transistor voltage rating needed for the retention of the present low-current type of coil. In the case of an ignition circuit employing transistors, it is better to raise the peak coil current by a factor of three or so (to e.g. 10 amps) since the voltage rating can then be reduced from 300–600 volts to 100–200 volts. The exact value will depend upon future advances in transistor design. In the past, such high currents have required the provision of a resistance external to the coil in order to dissipate the heat generated when the engine stops since a current equal to the peak value then flows continuously. Such a current (e.g. 10 amps) also constitutes a considerable battery drain.

In a circuit according to the invention, the inhibiting means will always work at zero engine speed. In addition, the bias inhibiting means will work at very low engine cranking speeds dependent on the circuit constants, but this must obviously not extend into the starting speed range since the engine then would be prevented from starting.

The means for inhibiting the forward bias may achieve this effect by providing substantially the effect of a short circuit between the base and emitter of the transistor which is connected in series with the ignition coil.

This may, for example, be done by a switch controlled by a centrifugal device. Preferably, the means for substantially providing the effect of a short circuit comprises the emitter-collector path of an auxiliary control transistor and means for causing saturation thereof.

The latter circuit may be arranged so that the control transistor is controlled at its base and the control circuit thereof includes means for applying standing forward bias to the control transistor such as to cause saturation thereof, and means for neutralizing said forward bias when the engine speed is greater than a predetermined minimum speed. The said neutralizing means may comprise means for causing intermittent charging of a first capacitor from the battery in response to engine crank rotation and means for discharging said capacitor into a

storage capacitor connected between the emitter and base of the control transistor. The means for providing intermittent charging may employ the existing contact breaker of the engine (although a separate engine-driven device could be used if desired).

Two embodiments of the invention employing an auxiliary control transistor will now be described with reference to the accompanying drawing, wherein:

FIG. 1 is a circuit diagram of a first embodiment employing transistors of the same conductivity type; and

FIG. 2 is a circuit diagram of a second embodiment employing transistors of opposite conductivity type.

Referring to FIGURE 1, of the drawing, the system shown therein is suitable for a negative ground motor vehicle.

The circuit has terminals *t1–t2* which constitute means for connecting a main transistor T3 in series with a primary winding P of the ignition coil. The circuit also has terminals *t3–t4* for connecting to an engine-driven contact-breaker CB. The circuit has the advantage that the contact breaker and the coil may, if desired, be conventional components already present on a vehicle before the invention is applied. In this case there is no need to alter the timing of the contact-breaker. A transistor T2 generates forward bias current for transistor T3 whenever CB is closed. Resultant periodic collector conduction occurs in T3 and in primary coil P when the engine rotates and thereby produces ignition pulses for the spark plugs. A steady current flow would occur therein when the engine is stationary if it were not for the means for inhibiting said forward bias when the engine is stationary or nearly stationary. In this embodiment, the means for supplying forward bias to T3 include a limiting resistance R4 in addition to T2. The means for inhibiting the forward bias of T3 are shown to the left of the dashed dividing line in the figure and are adapted to provide substantially the effect of a short circuit between the base and the emitter of T3. This is accomplished by applying a short circuit between the base of T2 and the emitter of T3, which has the same effect as a short-circuit between the base and emitter of T3 since T2 is connected as an emitter-follower driver stage. Transistor T2 is desirable at present because of the relatively low amplification factor of available transistors and may not be required in the future. T2 allows a smaller contact breaker control current than transistor T3 would if used alone.

The means for providing the effect of a short-circuit comprise the emitter-collector path of an auxiliary control transistor T1. The control transistor T1 is controlled at its base by a control circuit which includes a resistor R1 for applying a standing forward bias to the control transistor T1 such as to cause saturation thereof, and means or neutralizing said forward bias when the engine speed is greater than a predetermined minimum speed. The neutralization of the forward bias is obtained by intermittent charging of a first capacitor C1 from the D.C. supply battery *Vcc* and means for discharging said capacitor into a storage capacitor C2 connected between the emitter and base of the control transistor T1. The transfer of charge from C1 and C2 involves a reversal of polarity which is permitted by the use of a diode D2 for charging capacitor C1.

The means for providing intermittent charging employs the same engine-driven contact breaker CB which also supplies the forward bias current to the main transistor T3.

In operation, with the engine stationary, the 1 ma. or so base current flowing to T1 through R1 causes saturation of T1 and thus reduces the voltage between collector and emitter of T1 to a value low enough to prevent significant conduction in T2 and T3. The rest of the circuit is used to provide (when the engine rotates) a positive

voltage between the base and emitter of T1 (across C2) to turn off T1 and allow the circuit to perform normally.

With the engine stationary and with CB either closed or opened, diode D2 is forward biased via R1 and R2 and capacitor C2 is charged by the voltage drop across R2 and D2 in parallel therewith so that its upper electrode is negative with respect to its lower electrode. Capacitor C2 is connected in parallel with the base-emitter path of PNP transistor T1 so that T1 is driven into heavy conduction. Saturation of T1 prevents the flow of base current in transistors T2 and T3. When the engine is cranked, contact breaker CB alternately opens and closes. When CB closes, C1 is charged through D1 and D2 with the polarity indicated in FIG. 1. When CB opens, D1 and D2 are reverse biased and C1 discharges through R2 and R3 into C2 transferring a part of its charge to capacitor C2 thereby establishing a positive bias across C2. Capacitor C2 then begins to discharge through R1 and tends to become charged to the opposite polarity through this resistor, while C1 further discharges through R1, R2 and R3. After one or two such charge transfers following each other at relatively close time intervals, capacitor C2 is charged with its upper electrode positive with respect to its lower electrode thereby reverse biasing transistor T1 into cut-off. As long as the engine continues to rotate, capacitor C2 retains the positive charge on its upper electrode for a period of time depending on its capacitance value and on the resistance value of R1. If the successive contact interruptions of the contact breaker CB occur at a sufficiently high frequency, i.e. if the revolving speed of the engine is higher than a given minimum value determined to a first approximation by the RC time constant formed by capacitor C2 and resistor R1, C2 will remain charged in the reverse biasing direction and transistor T1 will be held in the non-conductive state. The response of the circuit, i.e. the rate of charge of C2, is such that not more than the first one, or possibly the first two ignition sparks will be suppressed upon starting the engine provided that the engine rotates above said minimum speed which is determined by the R and C values of the elements R1, R2, R3, R10, and C1 and C2, respectively, and of the voltage Vcc.

When the engine stops the positive voltage across C2 decays. Capacitor C2 then becomes negatively charged via resistor R1 so as to forward bias transistor T1 into the saturation condition. The current in T2 and T3 is cut off about two seconds after the engine stops.

One possible set of practical values and components is given below by way of illustration for the circuit of FIGURE 1:

Table

Vcc	12 volts.
T1	Mullard type OC42.
T2	Mullard type OC22.
T3	Bendix type B1181 selected for $\alpha' > 20$ at 10 amps collector current.
D1 and D2	Mullard type OA10.
R1	12K.
R2	1.2K.
R3	1K.
R4	470Ω.
R10	12Ω.
R11	10Ω.
R12	3Ω.
C1	120 μf. (25 v. working).
C2	500 μf. (6 v. working).
C10	0.5 μf.

Diode D1 is not always essential but it is advantageous in that, when CB opens, it prevents current from flowing from C1 through R4. Such a current could cause current flow in T3.

The lowest engine speed for satisfactory operation occurs when C2 discharges during the cycle to a voltage which is insufficient to bias off T1 at the base. This speed is determined by the following consideration: The contact breaker has just opened and current is flowing from C1 to C2 establishing a voltage across C2. The contacts then close and C1 is very rapidly recharged. With the contacts still closed, C2 is discharging through R1, and to some extent through R2 returning some of its charge to C1. At the same time current is building up in the ignition coil by flowing through T3. If the contacts remain closed sufficiently long T1 will again conduct, turning off T3 and thereby producing a spark. As the contacts have not yet opened the spark is too early. However, with the values given in the table the circuit is designed to work down to 60 r.p.m. and therefore premature ignition will only occur below 60 r.p.m. In the case where engine cranking is done by an electric starter motor, such speeds are usually exceeded.

R10 is added to prevent the circuit from exceeding the peak current ratings of the diodes D1–D2 when CB closes and C1 is recharged.

With the circuit of FIGURE 1 there may be some difficulty in getting the voltage across T1 to a sufficiently low value when it is saturated. In such a case, there could be objectionable current flow in T3 (it is assumed for simplicity that T2 is omitted). This current can be reduced by providing a reverse biasing voltage in series with the emitter of T3. This would normally be achieved by using a diode or a resistor in the emitter of T3 and passing a current through them. This bleed current may be obtained from the common supply by means of a second resistor. However, since these are in the emitter of the output stage the normal current levels there are high. The bleed current would therefore also have to be fairly large to establish said voltage. If a driver T2 is included, the diode or resistor still has to be in the output emitter. If, however, a combination of n-p-n- and p-n-p-transistors is used, the diode or resistor can be placed in a part of the circuit carrying a smaller current. This then permits operation with a smaller current bleed. In the case of the resistor this is easily explained in another way. As the normal current is much smaller a larger resistor value can be used for the same voltage loss. A larger resistor then needs less current for the same voltage when it comes to providing the turn-off bias voltage for the second half of the cycle. The diode case is illustrated by D3 in the circuit of FIGURE 2, which also introduces a combination of n-p-n and p-n-p transistors (in the case of three transistors T2 should be of the same conductivity type as T1 and opposite to T3). The circuit of FIGURE 2 is also slightly rearranged (with respect to FIGURE 1) so that it can operate with the positive-ground system more frequently used in vehicles. Corresponding components have the same reference numerals and the component values can be the same except where stated below.

The value of R4 is changed from <70Ω to 220Ω. Transistor T3 is the same as before, and the n-p-n transistors T1–T2 are Mullard type OC140 and RCA type 2N1070 (selected for $\alpha' > 25$ at 1 amp) respectively. Transistor T2 now drives T3 from its collector instead of its emitter and for this reason the T2 stage is different. The diode D3 (e.g. Mullard OA210) is placed in its emitter lead, and resistor R13 (24 ohms) is added to provide the bleed current.

Diode D3 can be replaced by a resistor as aforesaid, but a diode is preferable.

With these values, the current in T2–T3 is cut off after about two seconds or less as in the case of FIGURE 1.

What is claimed is:

1. An engine ignition circuit comprising an ignition coil having a primary winding, a source of D.C. supply voltage, a transistor having an emitter-collector path and an input circuit for controlling current flow in said path, means for connecting said emitter-collector path effectively in series with said primary winding and said source of supply voltage, an engine driven contact-breaker, means controlled by said engine for applying a forward bias cur-

rent to said transistor input circuit in the closed condition of said contact-breaker, and means providing a low resistance current path across said transistor input circuit when said engine is stationary thereby to inhibit the effect of said forward bias on said transistor.

2. Apparatus as described in claim 1 wherein said low resistance path comprises a second transistor having its emitter-collector path connected across said input circuit and having a control electrode for controlling the current flow in said path, and means coupled to said control electrode and responsive to engine rotation for driving said second transistor into heavy conduction below a given engine speed.

3. Apparatus as described in claim 2 wherein said control electrode is the base electrode and wherein said means for driving the second transistor into heavy conduction comprises a control circuit coupled to said base electrode, said control circuit comprising means for applying a standing forward bias to said base electrode and means for effectively neutralizing said forward bias for an engine speed greater than said given engine speed.

4. Apparatus as described in claim 3 wherein said neutralizing means comprise a first capacitor, a second capacitor connected between the base and emitter electrodes of said second transistor, means responsive to engine crank rotation for causing intermittent charging of said first capacitor from said supply source and means for discharging said first capacitor into said second capacitor.

5. Apparatus as described in claim 4 wherein said means for causing intermittent charging of said first capacitor comprises said engine contact breaker and means connecting said contact breaker in series with said first capacitor across said supply source.

6. Apparatus as described in claim 4 further comprising a diode serially connected with said first capacitor and said supply source and poled so as to permit a polarity reversal of the charge on said second capacitor with respect to the polarity of the charge on said first capacitor.

7. An engine ignition circuit comprising an ignition coil, a source of D.C. supply voltage, a transistor having an emitter and collector for establishing a current path and a base electrode for controlling the current flow in said path, means for connecting said emitter-collector path effectively in series with a portion of said coil across said supply voltage source, means coupled to said base electrode for interrupting current flow in the emitter-collector path in timed relation with engine rotation, and means controlled by said engine rotation for establishing a substantially short-circuit connection between the base and emitter of said transistor below a given engine speed thereby to inhibit current flow in said emitter-collector path.

8. An engine ignition circuit comprising an ignition coil, a source of D.C. supply voltage, a first transistor having an emitter and collector for establishing a current path and a base electrode for controlling the current flow in said path, means for connecting said emitter-collector path effectively in series with a portion of said coil and said supply voltage source, means coupled to said base electrode for interrupting current flow in the emitter-collector path in timed relation with engine rotation, a second transistor having an emitter and collector for establishing a current path and a base electrode, means connecting the emitter-collector path of said second transistor between the base and emitter of said first transistor, and means controlled by said engine rotation and coupled to said second transistor base electrode for causing saturation of said second transistor below a given engine speed thereby to establish a substantially short-circuit connection between the base and emitter of said first transistor to inhibit current flow in its emitter-collector path.

9. Apparatus as described in claim 8 wherein said means for causing saturation comprises a control circuit directly coupled to said second transistor base electrode, said control circuit including means for establishing a standing D.C. forward bias across the base and emitter of said second transistor of a value to produce saturation therein, and means controlled by said engine rotation for effectively neutralizing said forward bias for an engine speed greater than said given speed.

10. Apparatus as described in claim 8 wherein said first and second transistors are of opposite conductivity types.

11. Apparatus as described in claim 8 further comprising a third driver transistor directly interconnected between said first and second transistors and wherein said first and third transistors are of opposite conductivity types.

12. An engine ignition cicuit comprising an ignition coil having a primary winding, a source of D.C. supply voltage, a transistor having an emitter-collector path and an input circuit for controlling current flow in said path, means for connecting said emitter-collector path effectively in series with said primary winding and said source of supply voltage, an engine driven contact-breaker, means including said contact-breaker for applying a forward bias voltage to said transistor input circuit, and means responsive to engine speed coupled to said input circuit and independent of the condition of said contact breaker for neutralizing said forward bias below a given engine speed thereby to inhibit current flow in said emitter-collector path.

13. Apparatus as described in claim 12 further comprising means directly connected to said input circuit for applying a relatively small D.C. reverse bias voltage thereto.

14. Apparatus as described in claim 12 wherein said neutralizing means comprises means responsive to engine speed for establishing a low resistance conection across said transistor input circuit for an engine speed lower than said given engine speed.

15. An engine ignition circuit comprising an ignition coil havng a primary winding, a source of D.C. supply voltage, a transistor having an emitter-collector path and an input circuit for controlling current flow in said path, means for connecting said emitter-collector path effectively in series with said primary winding and said source of supply voltage, an engine driven contact-breaker, means including said contact breaker for periodically applying a forward bias voltage to said transistor input circuit, and means coupled to said input circuit and responsive to engine speed for substantially neutralizing said forward bias voltage whenever said engine is stationary and said contact breaker is closed thereby to inhibit current flow in said emitter-collector path.

16. An engine ignition circuit comprising an ignition coil having a primary winding, a source of D.C. supply voltage, a transistor having an emitter-collector path and an input circuit for controlling current flow in said path, means for connecting said emitter-collector path effectively in series with said primary winding and said source of supply voltage, means coupled to said input circuit and responsive to engine rotation for causing periodic interruption of current flow in the emitter-collector path in synchronism with engine rotation, a second transistor having an emitter and collector for establishing a current path and an input circuit for controlling current flow therein, means connecting the emitter-collector path of said second transistor across the input circuit of said first transistor, a control circuit coupled to said second transistor input circuit, said control circuit comprising a D.C. current path for applying a forward bias voltage to said second transistor input circuit and means responsive to engine rotation for effectively neutralizing said forward bias above a given engine speed.

17. Apparatus as described in claim 16 wherein said neutralizing means comprises, a first capacitor, a second capacitor connected across said second transistor input circuit, means responsive to engine rotation for causing intermittent charging of said first capacitor from said supply source and means for intermittently discharging said first capacitor into said second capacitor so as to charge

said second capacitor with a polarity opposing said forward bias voltage.

18. Apparatus as described in claim **16** wherein said neutralizing means comprise a first capacitor, a diode, an engine contact breaker, means serially connecting said first capacitor, said diode, and said contact breaker across said supply source, a second capacitor connected across said second transistor input circuit, means providing a D.C. connection from one plate of said first capacitor to one plate of said second capacitor and to a point on said D.C. current path whereby a charge stored on said first capacitor is periodically transferred to said second capacitor in synchronism with engine rotation.

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