United States Patent [19]
Callies et al.
[11] 3,926,557
[45] Dec. 16, 1975

[54] IGNITION DEVICE FOR INTERNAL COMBUSTION ENGINES

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[22] Filed: Aug. 20, 1973

[21] Appl. No.: 389,516

[30] Foreign Application Priority Data

Aug. 21, 1972 Austria 7180/72
Mar. 6, 1973 Austria 1982/73

[52] U.S. Cl. .... 123/148 E; 123/148 OC
[51] Int. Cl.^{2} F02P 1/00
[58] Field of Search .... 123/148 E, 148 OC

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Primary Examiner—Charles J. Myhre
Assistant Examiner—Ronald B. Cox
Attorney, Agent, or Firm—Stevens, Davis, Miller & Mosher

[57] ABSTRACT

An ignition device for an internal combustion engine comprising a timing member for providing an output which is a function of the angular position of the crank shaft or of the position of a piston in a cylinder of the engine, a pulse generator for turning the timing member on and off and a switching transistor connected to the pulse generator for coupling the ignition transformer of the engine to a source of d.c. voltage. The switching frequency of the transistor is determined by the pulse generator to control the start, end and duration of the period in which ignition energy is produced.

24 Claims, 27 Drawing Figures

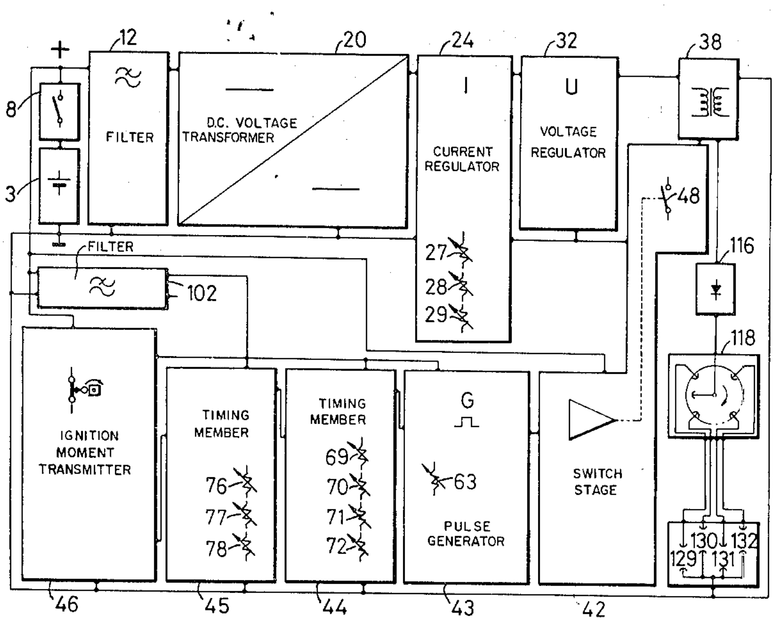
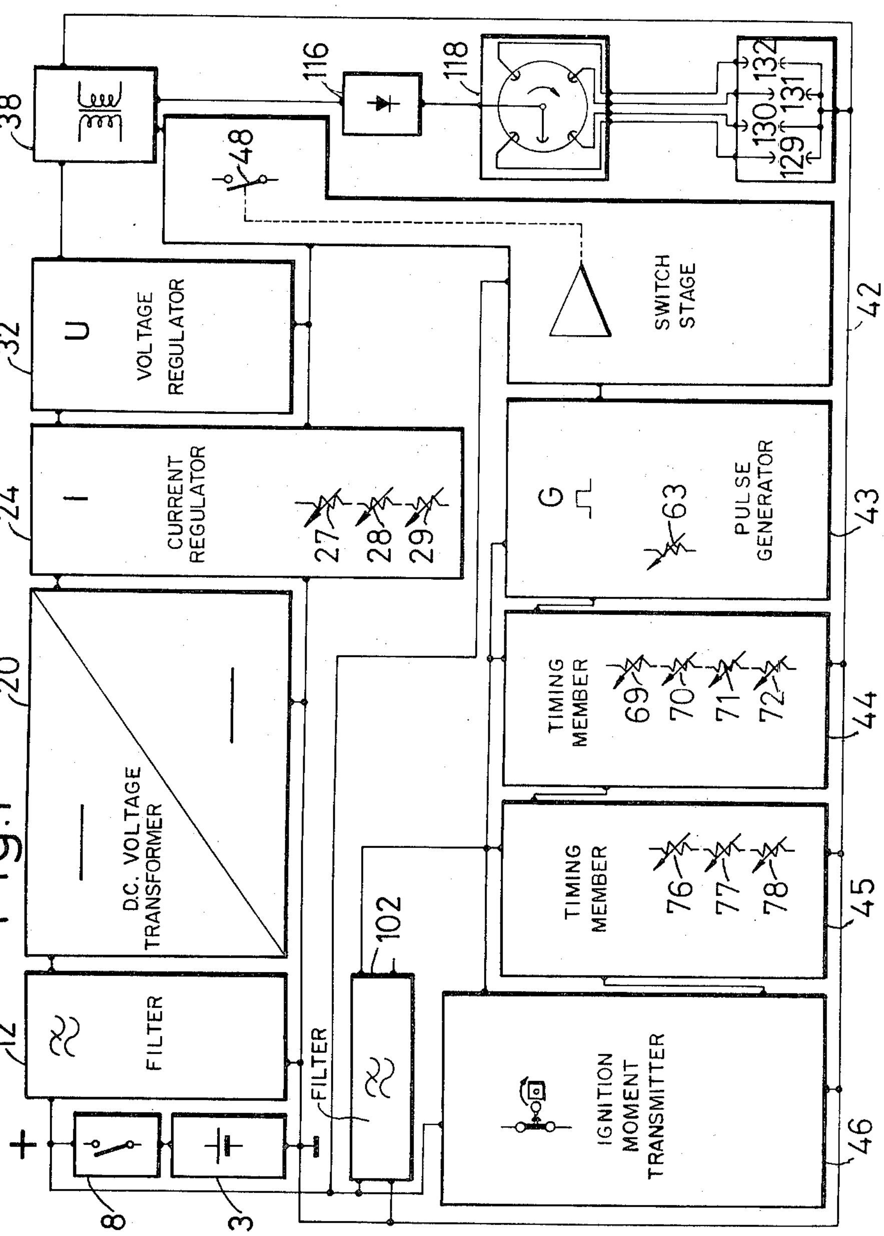


Fig.1



+
8
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FILTER
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D.C. VOLTAGE TRANSFORMER
24
I
CURRENT REGULATOR
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U
VOLTAGE REGULATOR
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SWITCH STAGE
42
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63
PULSE GENERATOR
43
TIMING MEMBER
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TIMING MEMBER
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FILTER
IGNITION MOMENT TRANSMITTER
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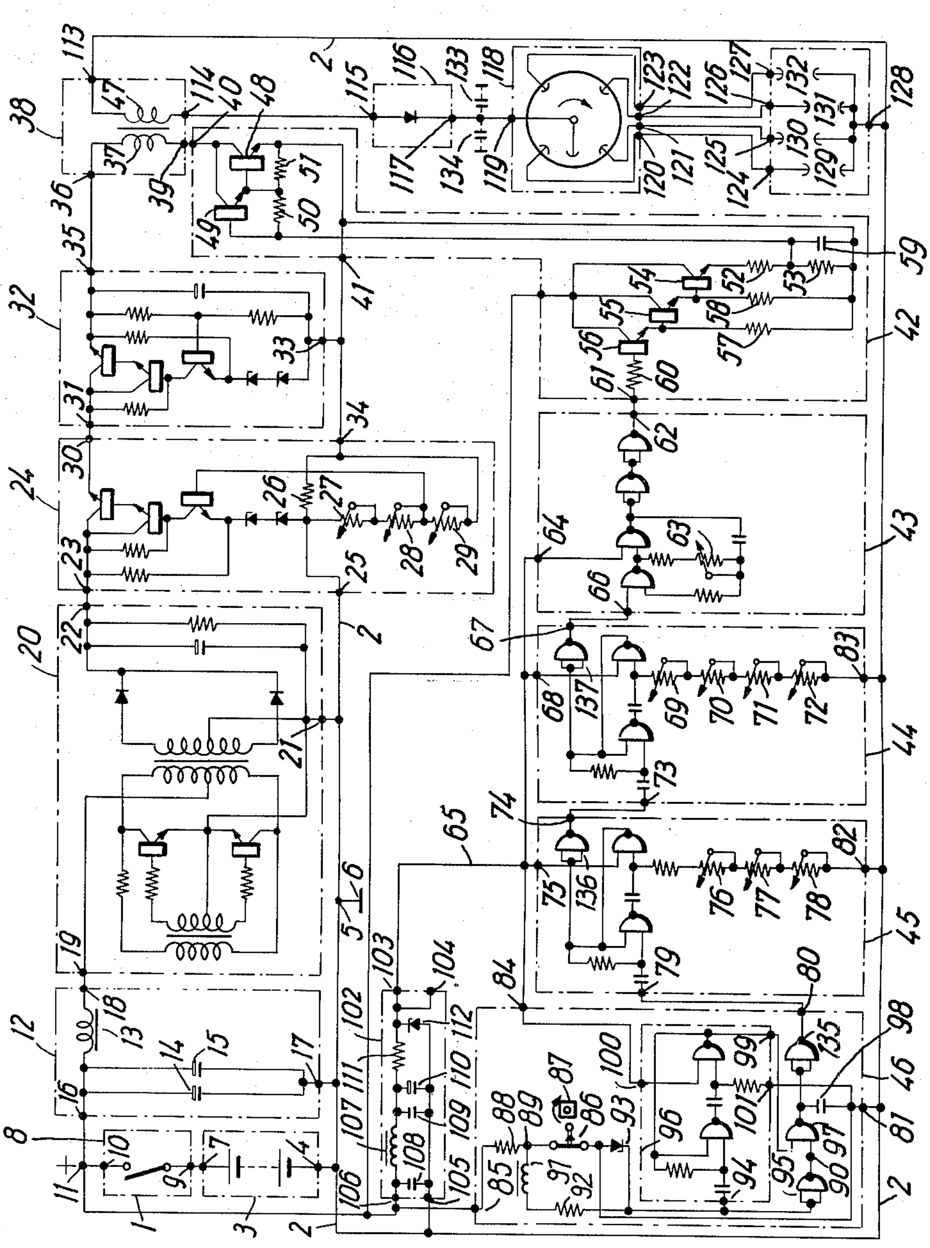


Fig. 2

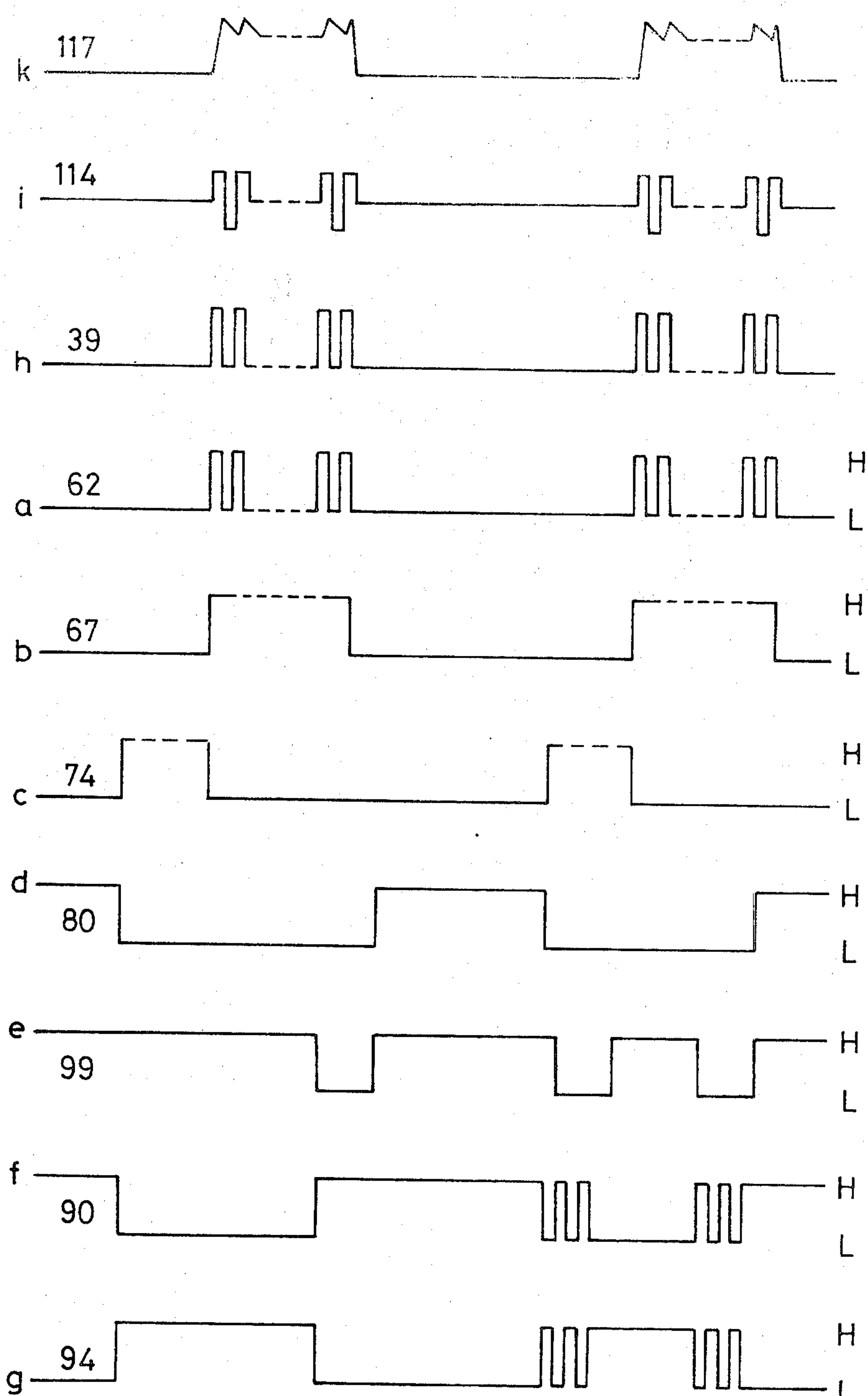
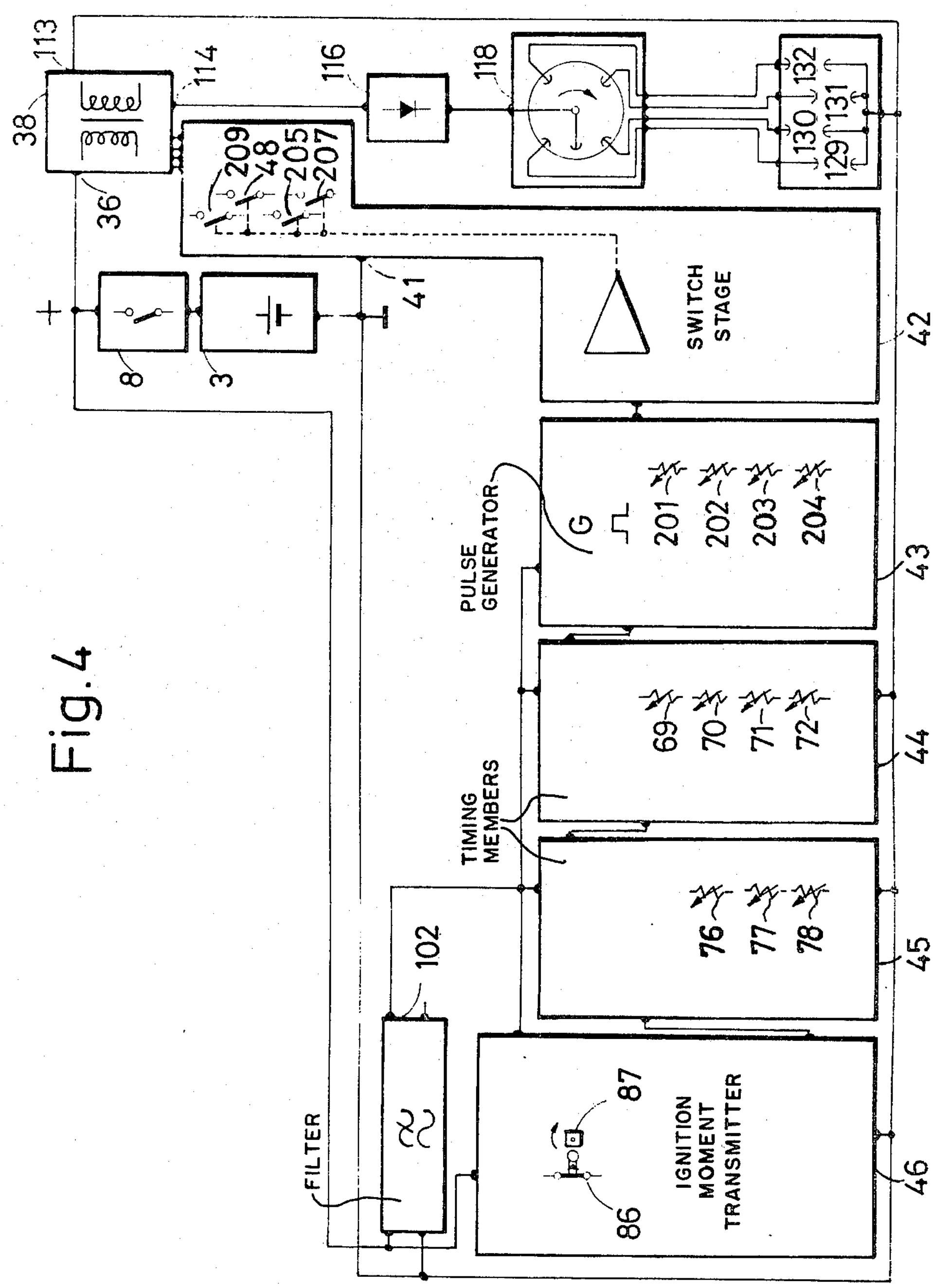


Fig. 3

Fig.4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PULSE GENERATOR
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TIMING MEMBERS
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FILTER
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IGNITION MOMENT TRANSMITTER
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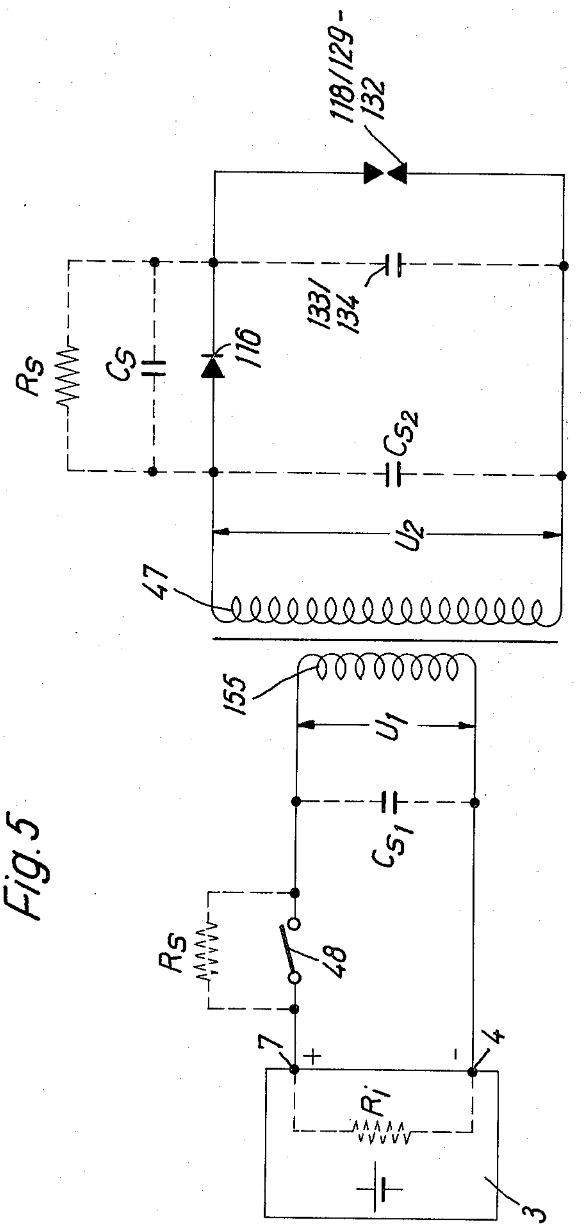


Fig.5

Fig.6

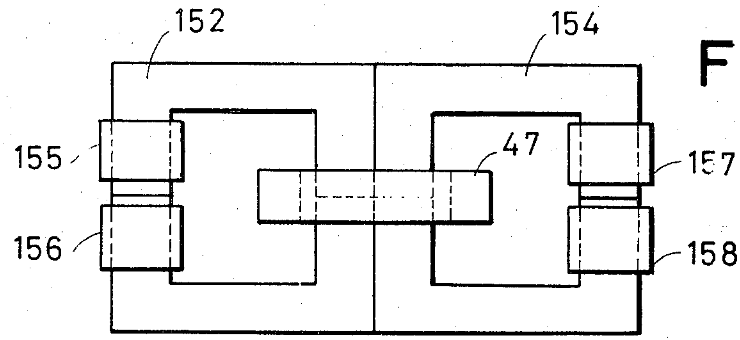


Fig.7

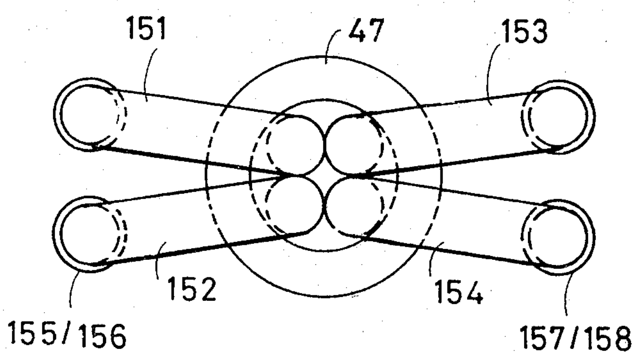


Fig.8

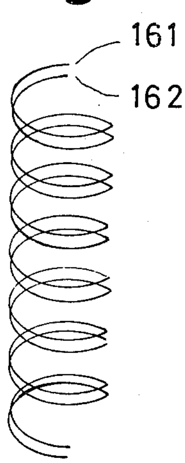


Fig.9

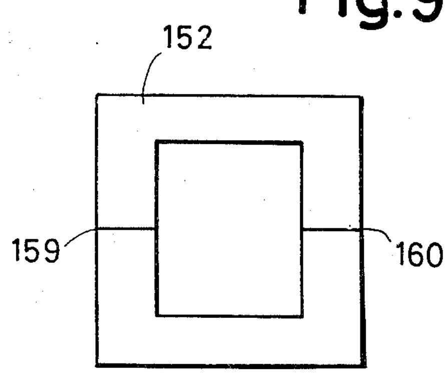
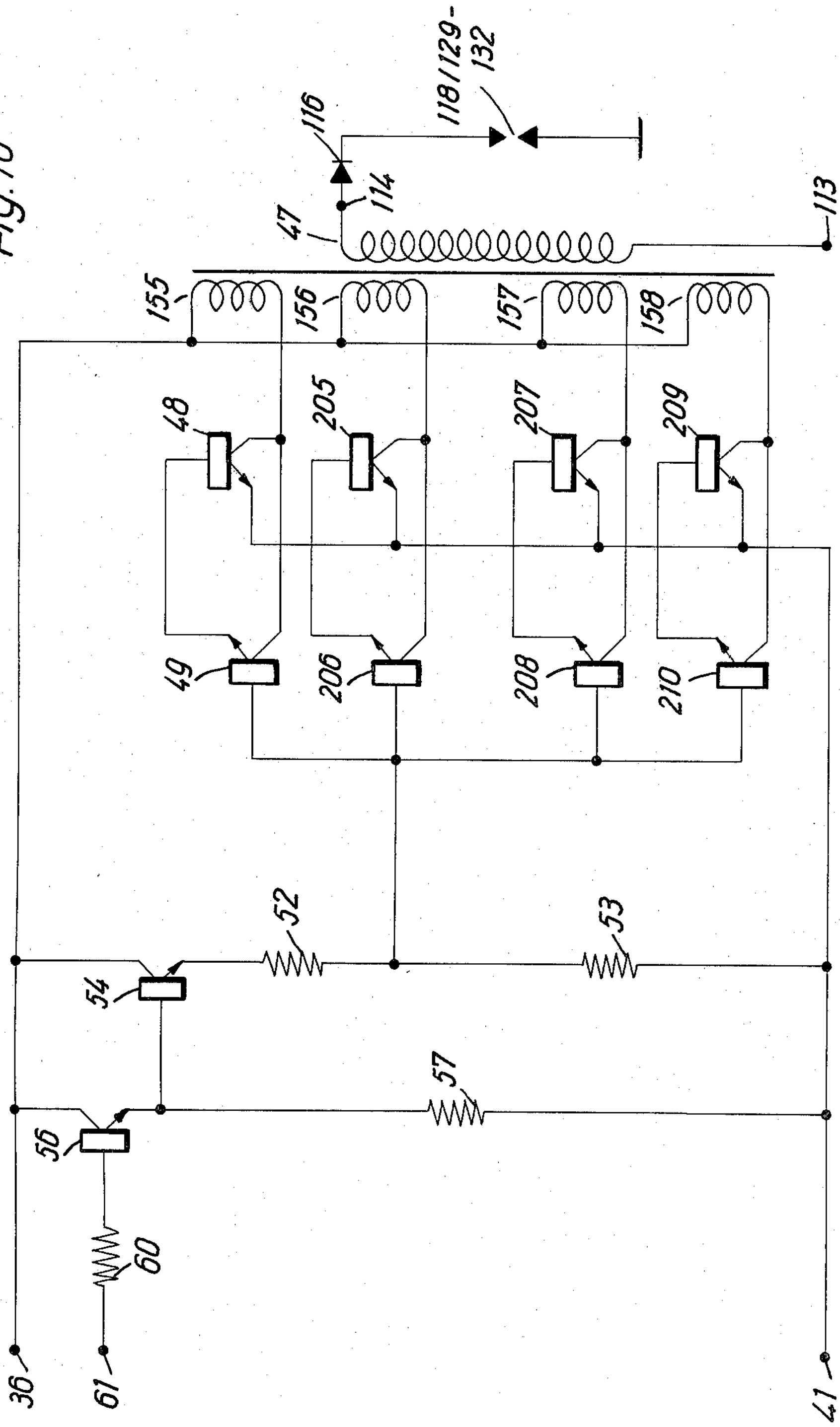


Fig. 10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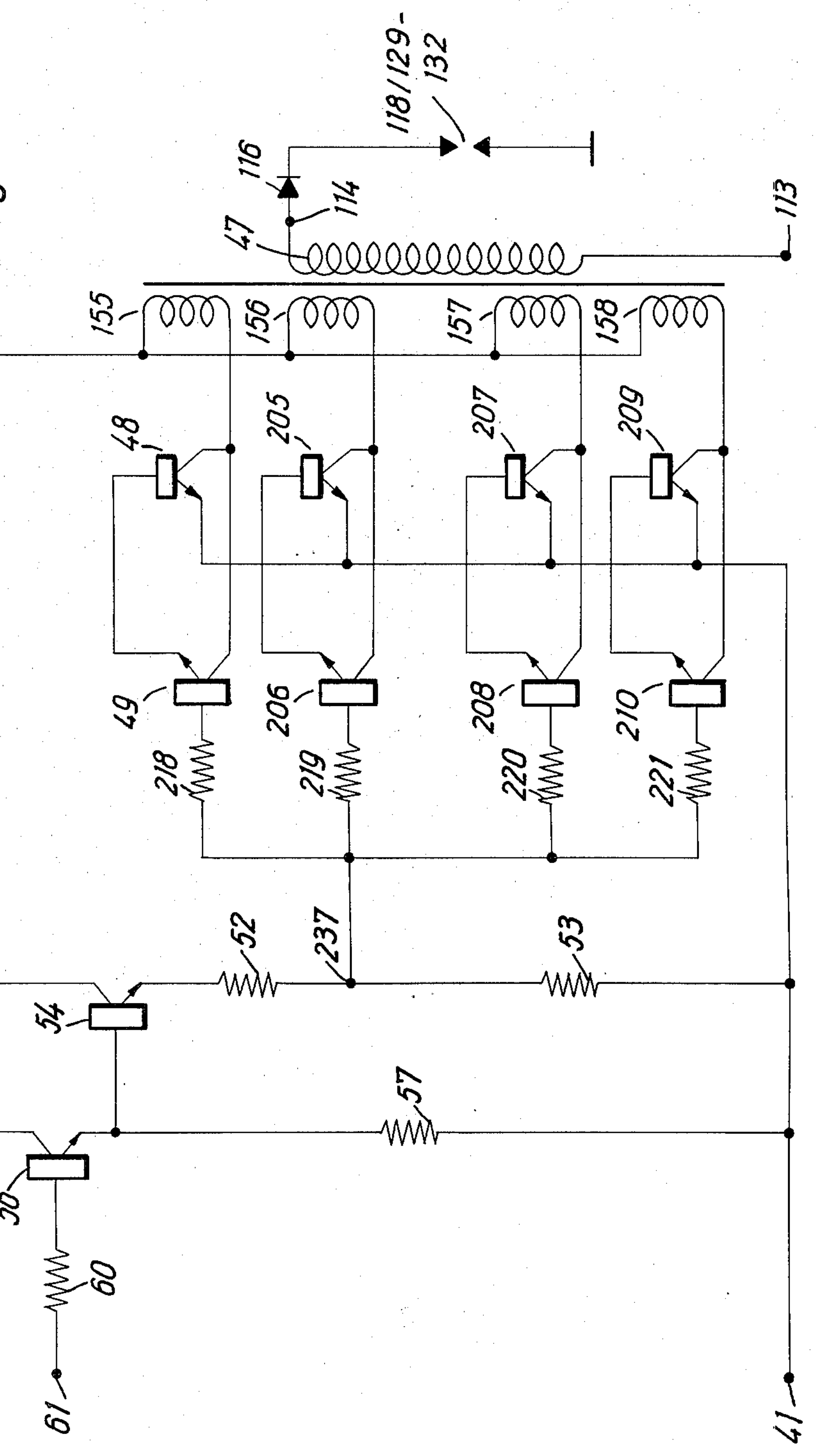
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Fig. 11

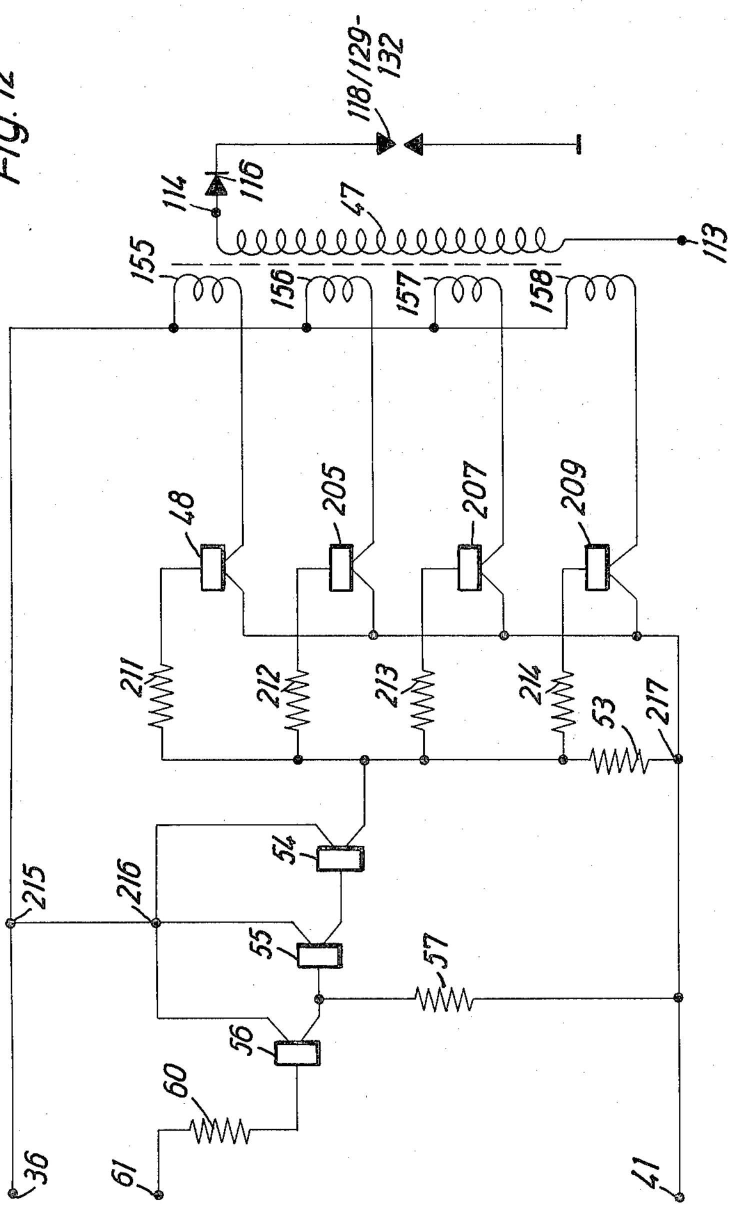
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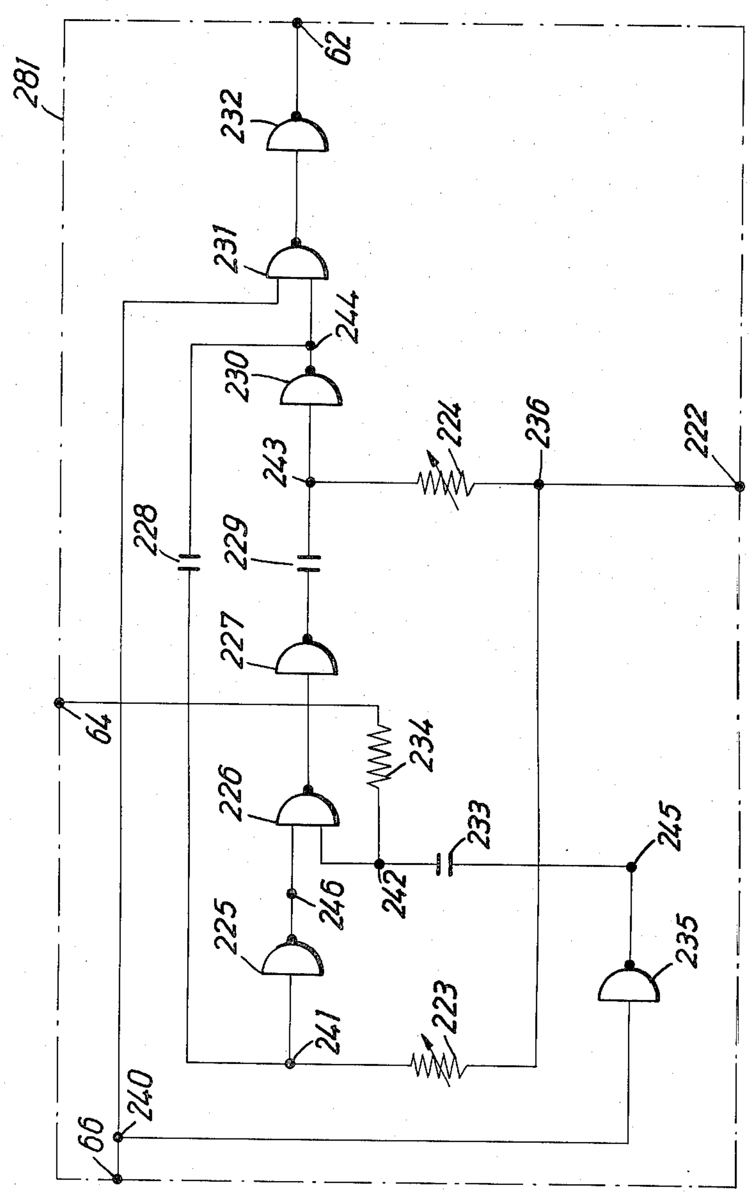
Fig. 12

Fig. 13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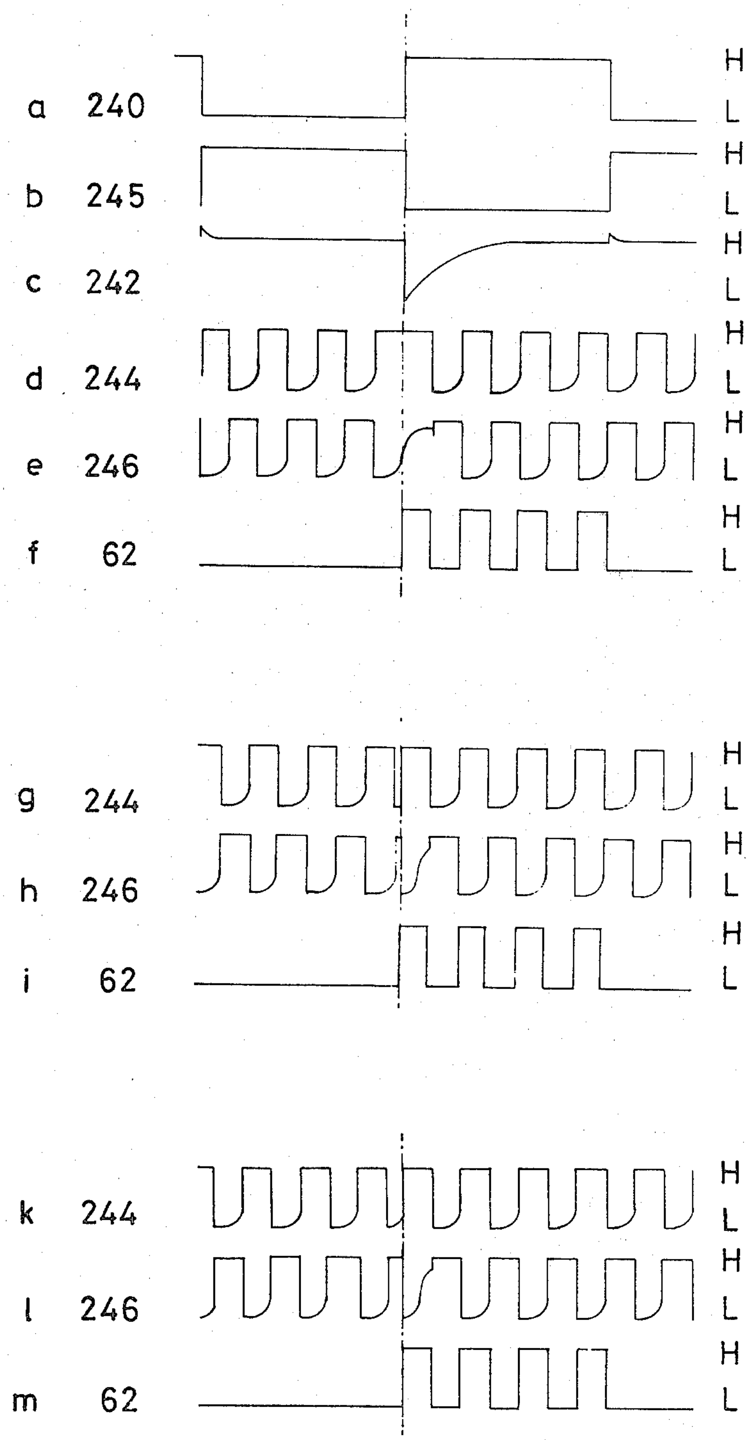

Fig. 14

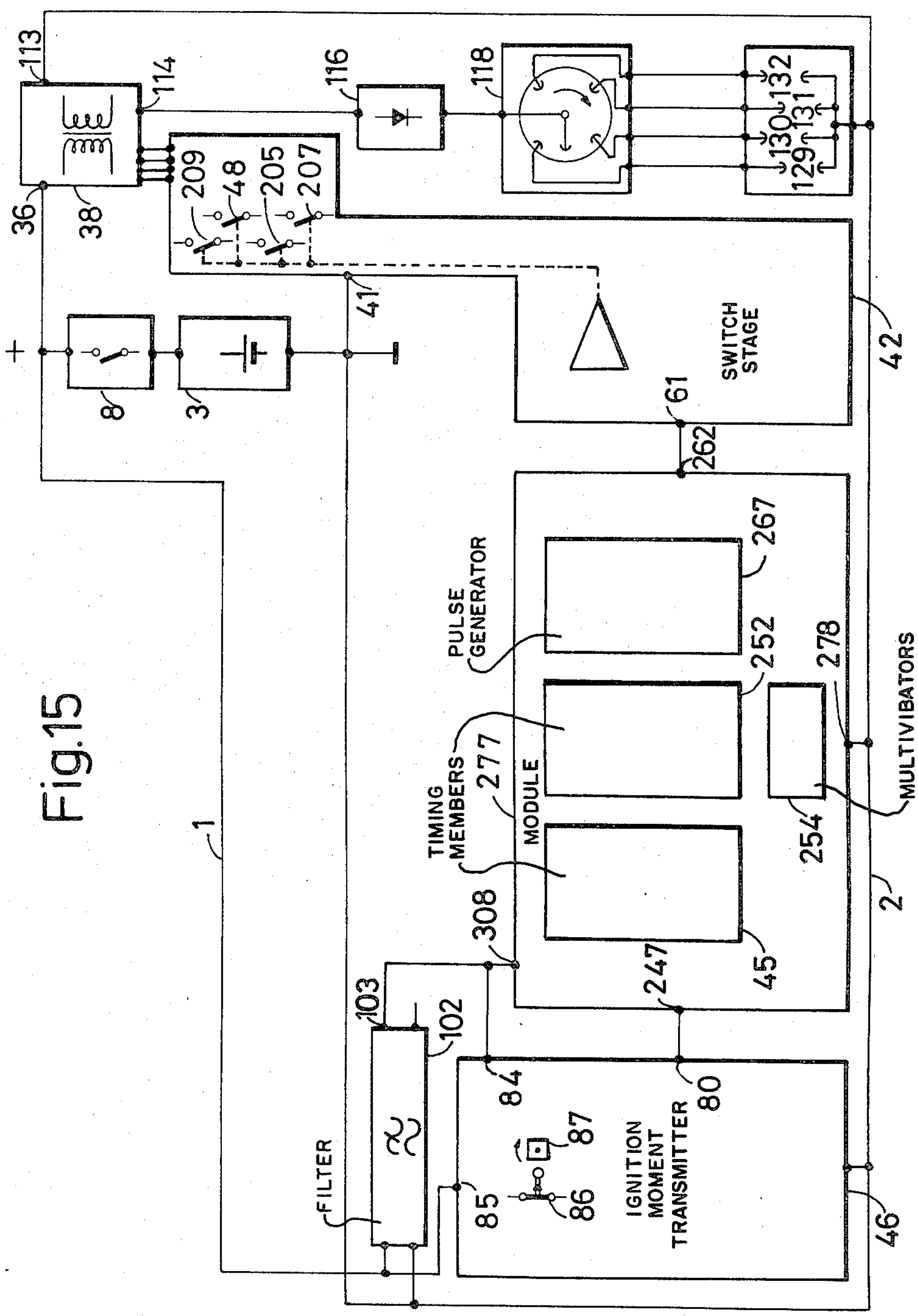
SWITCH STAGE
PULSE GENERATOR
TIMING MEMBERS
MODULE
MULTIVIBATORS
FILTER
IGNITION MOMENT TRANSMITTER
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Fig.15

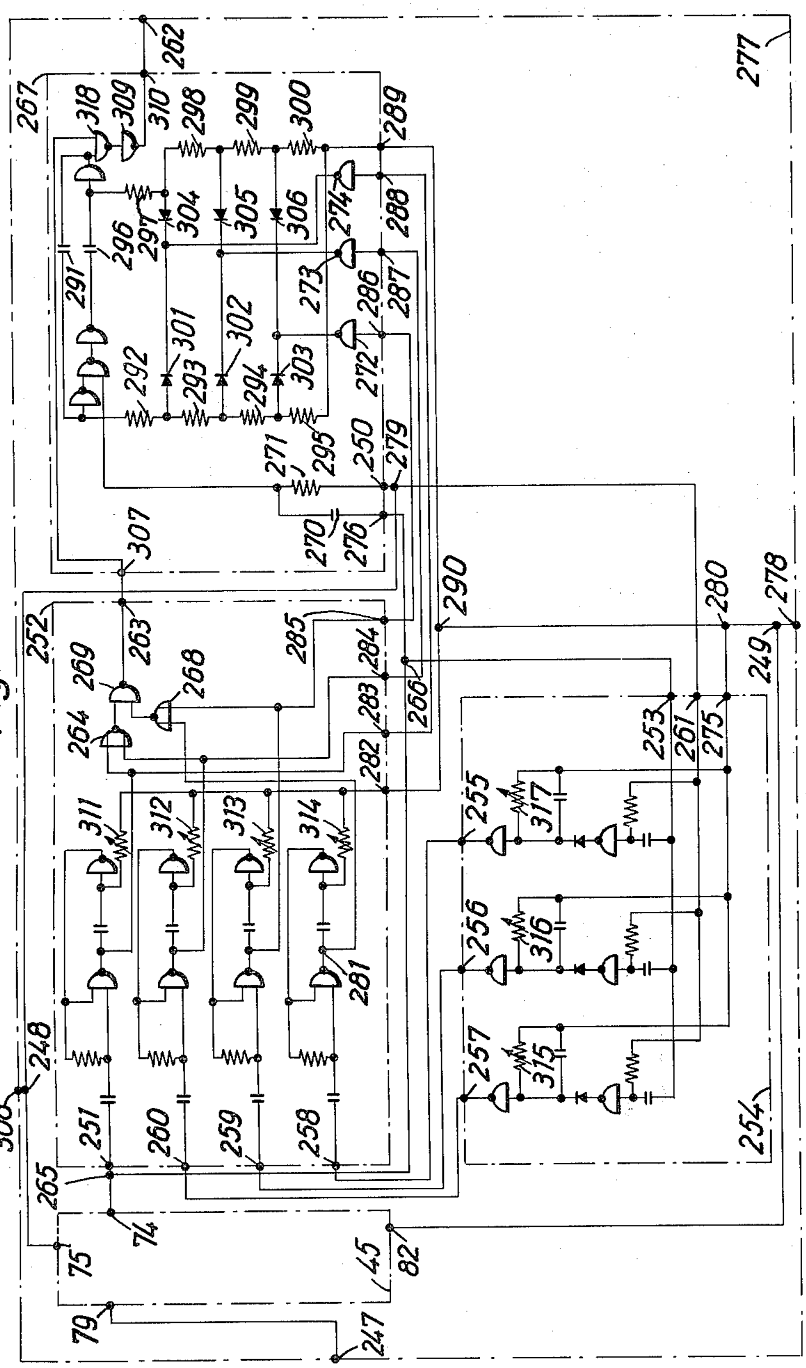
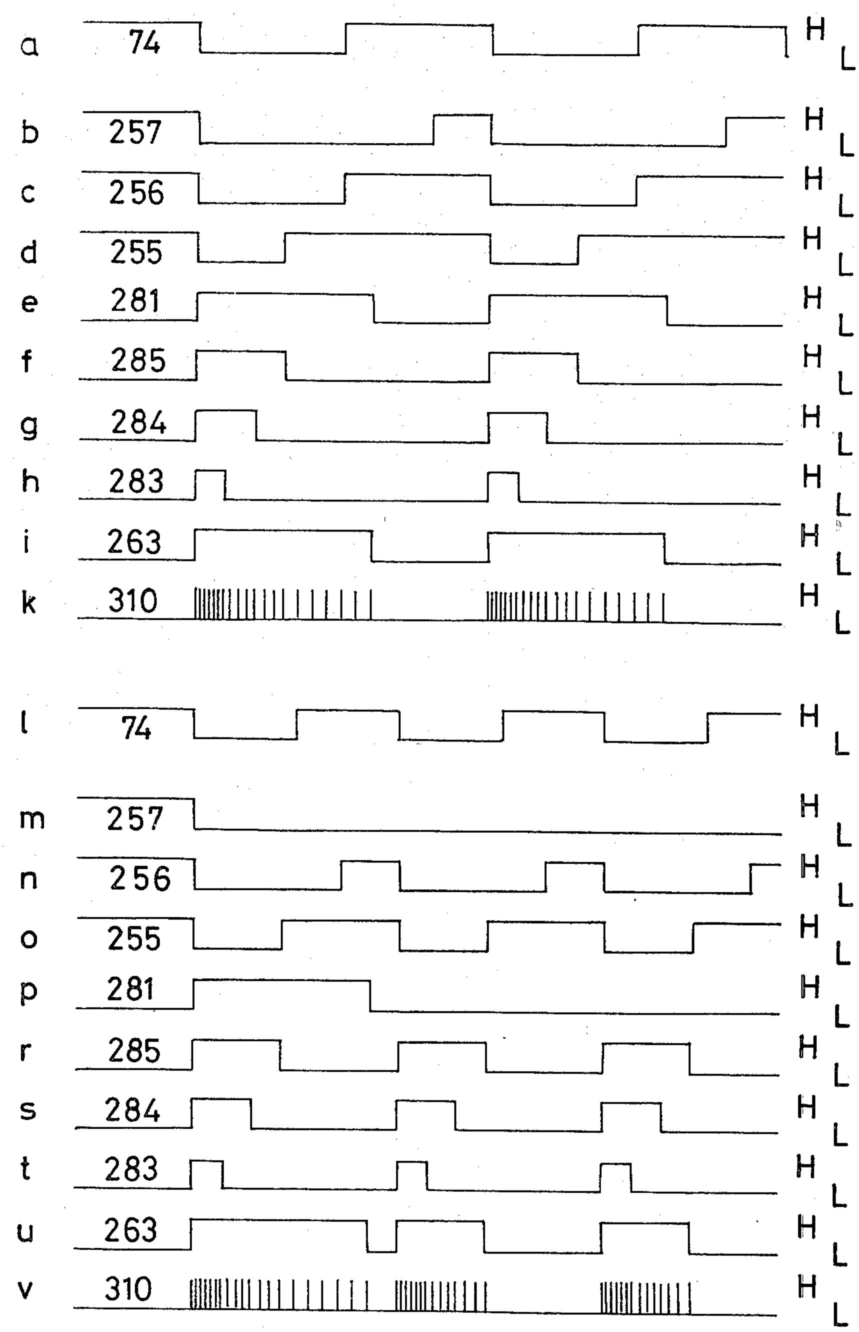


Fig. 16

Fig. 17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l 74 H L
m 257 H L
n 256 H L
o 255 H L
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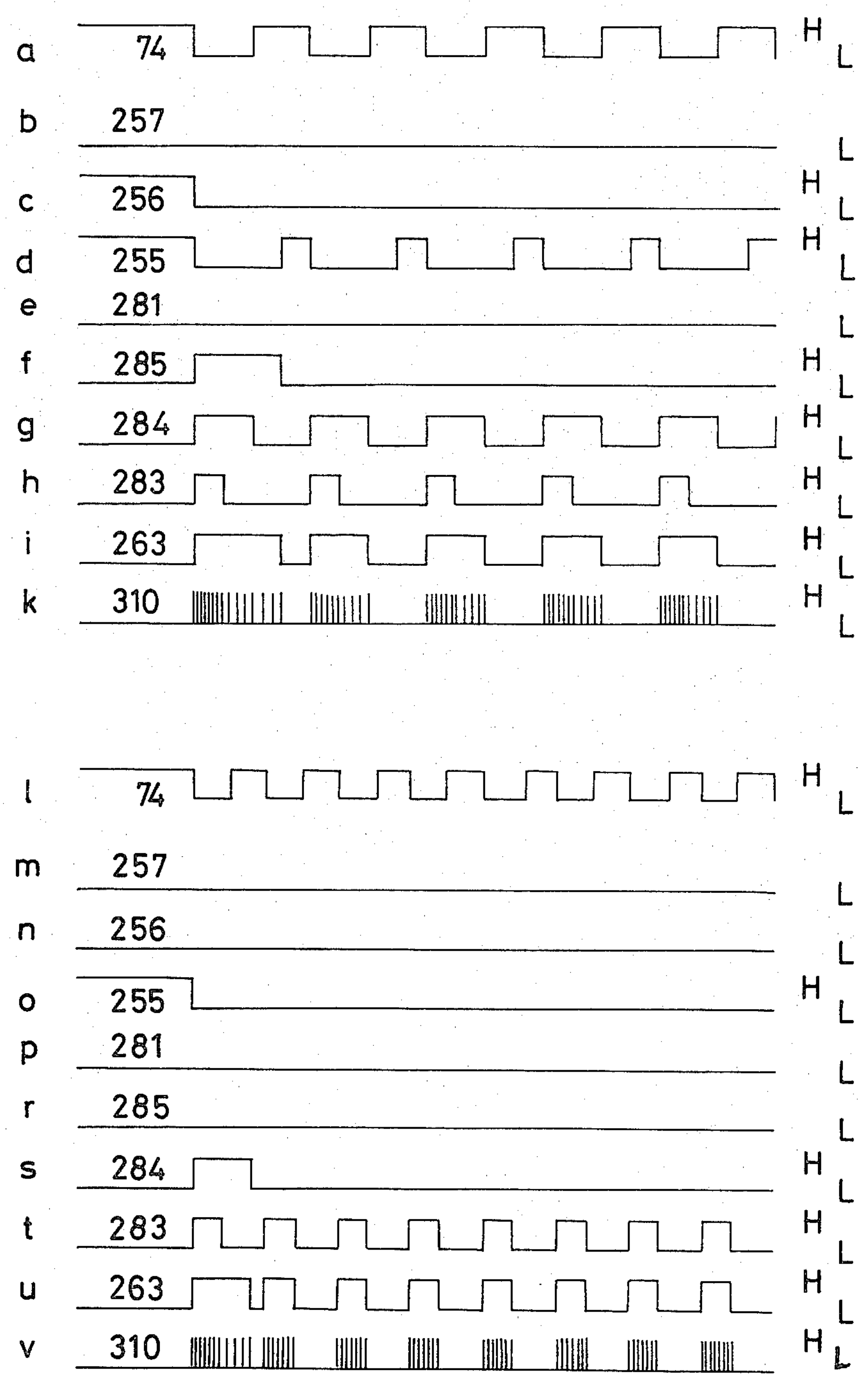
r 285 H L
s 284 H L
t 283 H L
u 263 H L
v 310 H L

Fig. 18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283
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v
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H
L

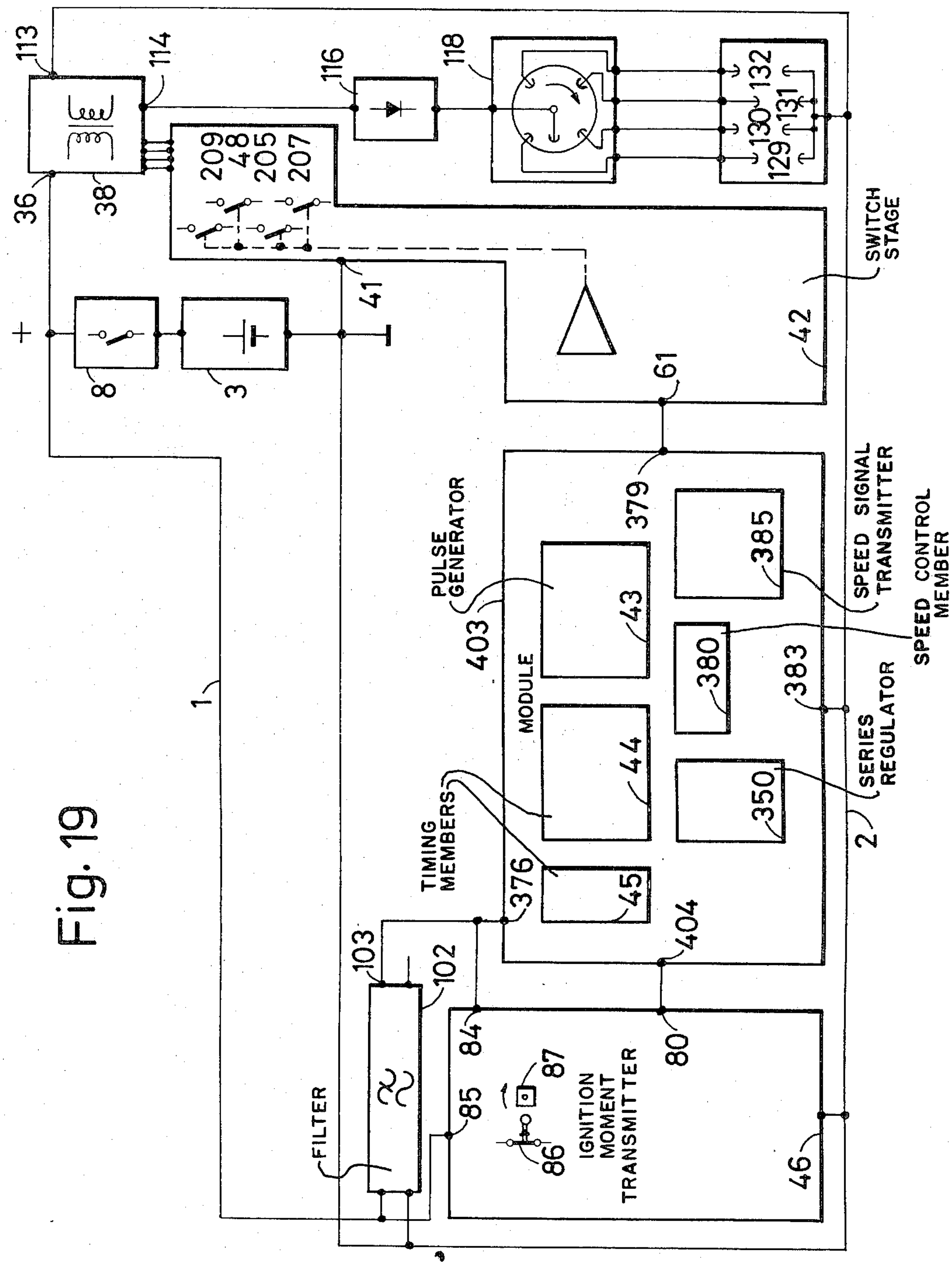
SWITCH STAGE
PULSE GENERATOR
MODULE
TIMING MEMBERS
SPEED SIGNAL TRANSMITTER
SPEED CONTROL MEMBER
SERIES REGULATOR
FILTER
IGNITION MOMENT TRANSMITTER
113
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Fig. 19

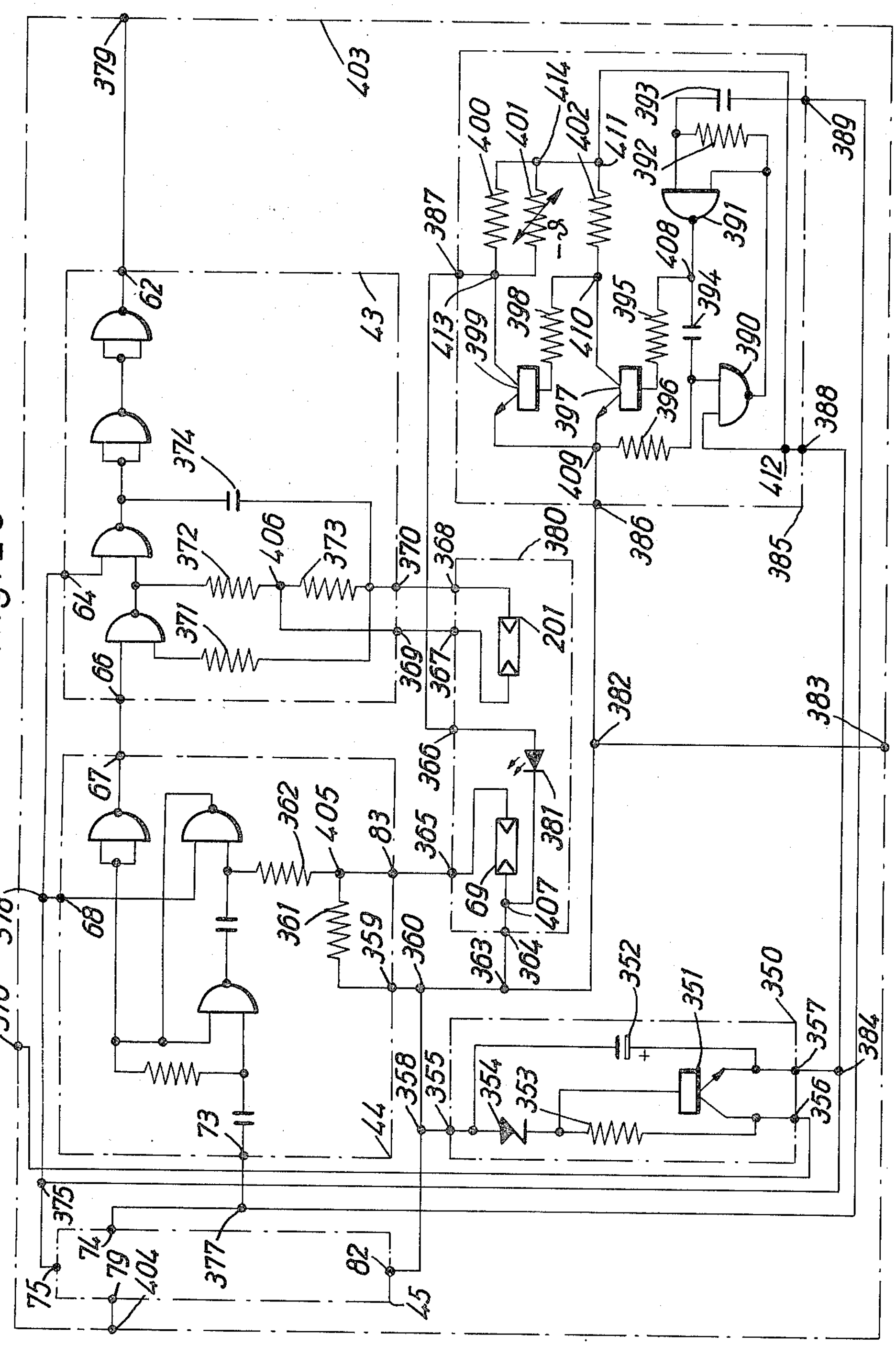


Fig. 20

Fig. 21

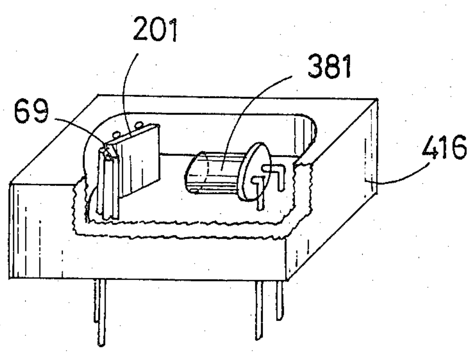
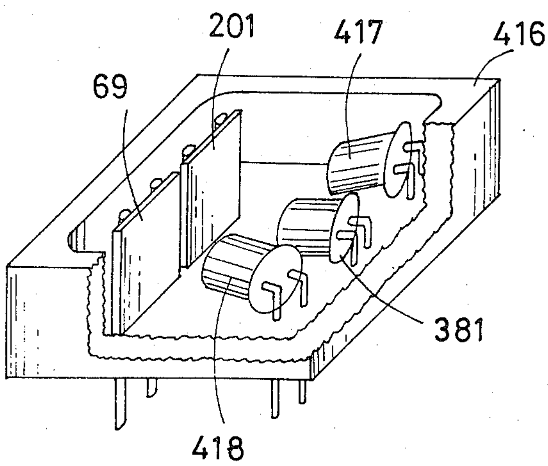


Fig. 22



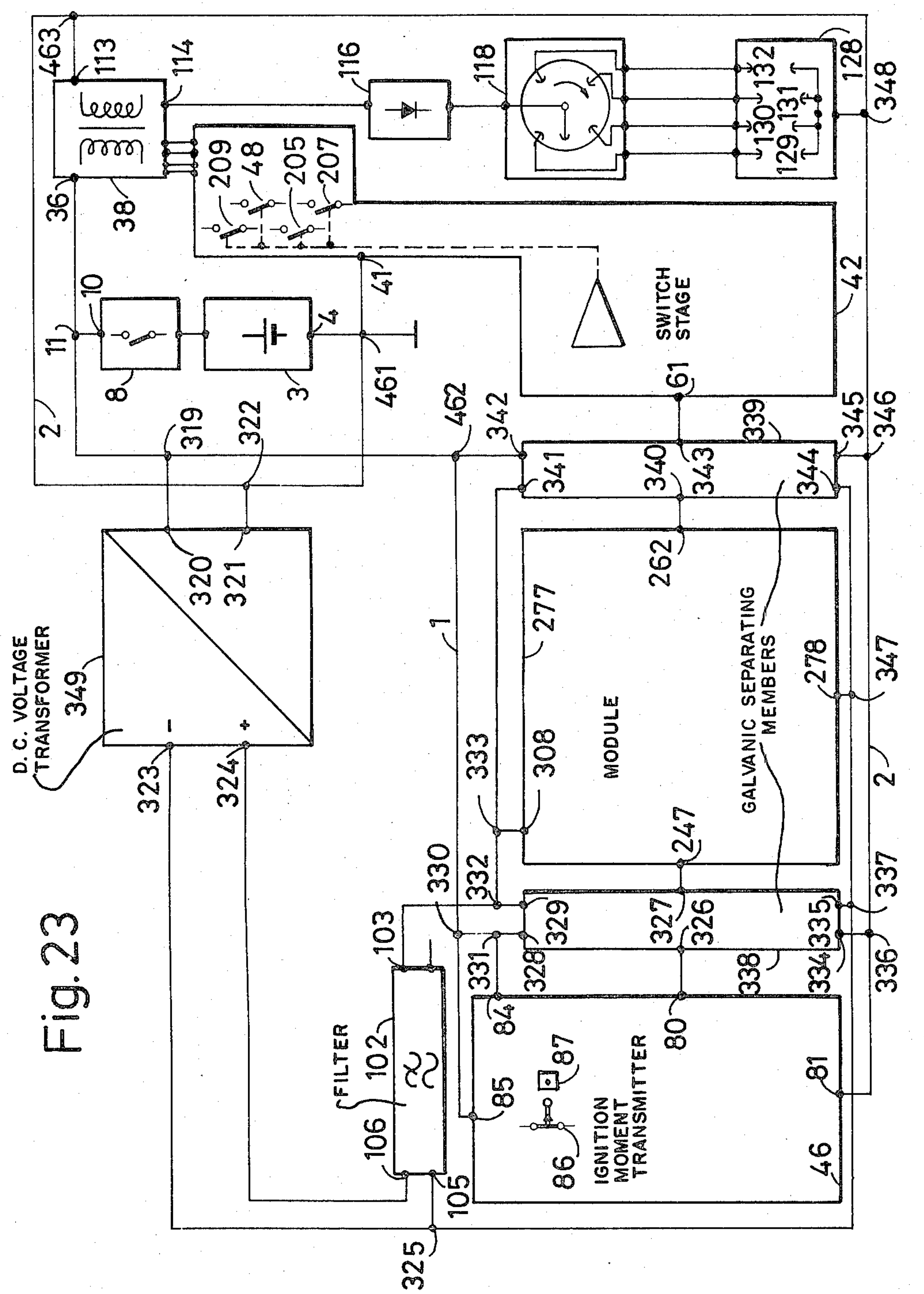
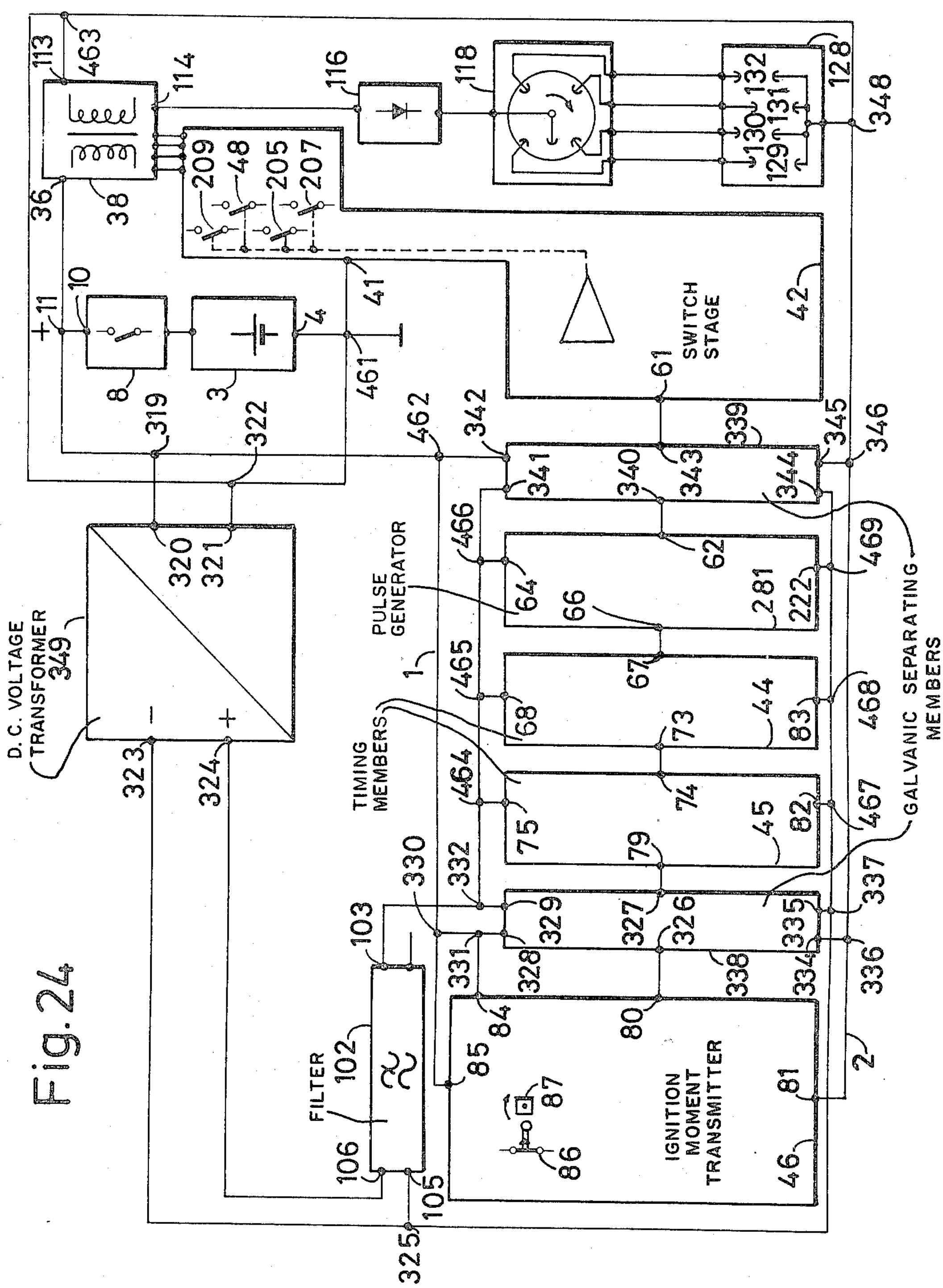

D.C. VOLTAGE TRANSFORMER
SWITCH STAGE
MODULE
GALVANIC SEPARATING MEMBERS
FILTER
IGNITION MOMENT TRANSMITTER

Fig. 23


D.C. VOLTAGE TRANSFORMER
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FILTER
IGNITION MOMENT TRANSMITTER
PULSE GENERATOR
TIMING MEMBERS
GALVANIC SEPARATING MEMBERS
SWITCH STAGE

Fig. 24

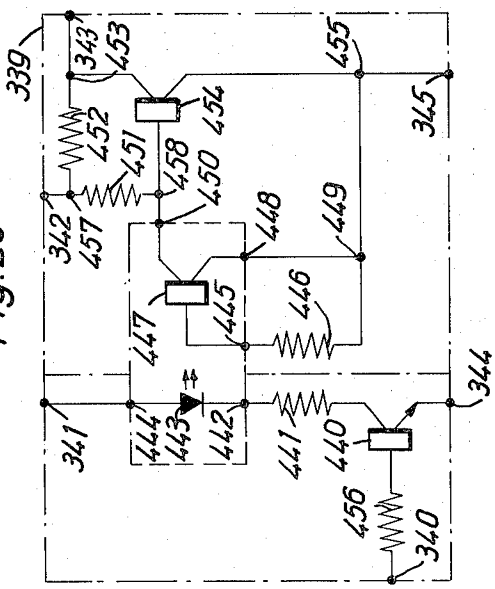

Fig. 26

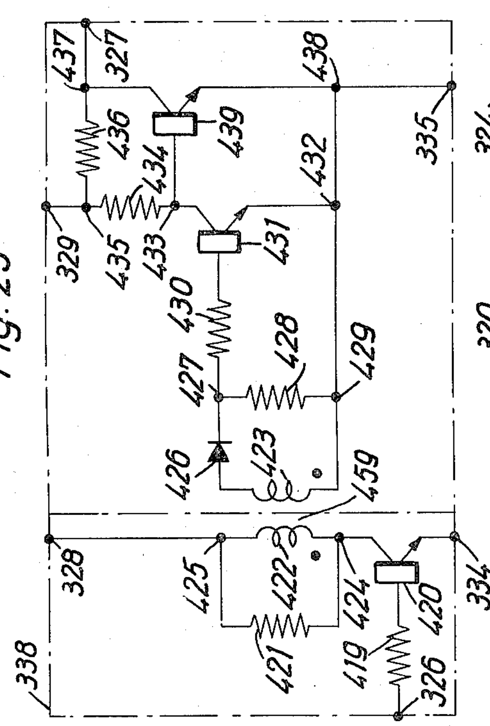

Fig. 25

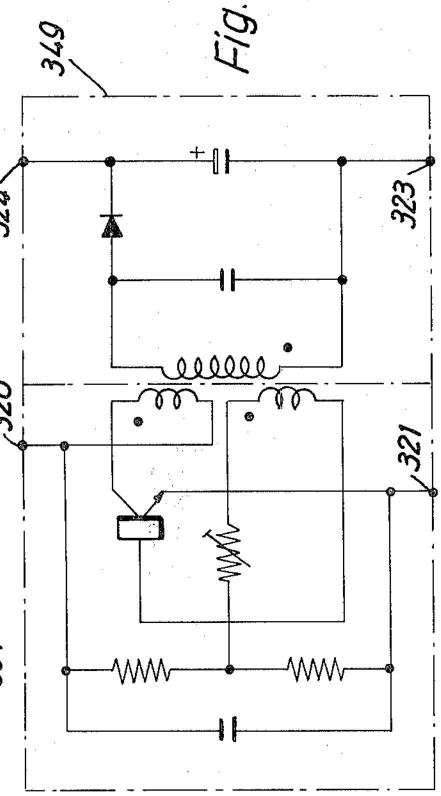

Fig. 27

IGNITION DEVICE FOR INTERNAL COMBUSTION ENGINES

The present invention relates to an ignition device for internal combustion engines. In the known ignition devices the ignition or power is produced by opening the breaker in the circuit of the primary side of the ignition transformer. The ignition energy made available by the ignition transformer for each ignition is, however, limited, among other things by the time available in each case for the building up of the magnetic field in the ignition transformer.

The object of the present invention is to create an ignition device by which a relatively large ignition energy (i.e. the energy of the are which can be varied as desired is made available for each ignition, the ignition voltage and ignition current, as well as their duration and their start being variable as desired within wide limits independently of each other. By this measure or these features, the combustion process which takes place in the internal combustion engine and the nature of composition of the combustion gases are to be controlled in the manner desired.

In order to attain this object, an ignition device for an internal combustion engine, in connection with which a source of d.c. voltage can be connected to the ignition transformer via a transistor which serves as a switch, is so developed in accordance with the invention that the switch frequency of the transistor serving as a switch can be determined by a pulse generator which can be connected and disconnected by a time member acting as a function of the angular position of the crank shaft or of the position of the piston in the engine cylinder in such a manner that the start, end and length of the production of the ignition energy of the arc can be freely varied.

It is advantageous to use a pulse generator whose output pulses are of rectangular or substantially rectangular form. An astable multivibrator can serve as such a pulse generator. While retaining the rectangular form, the delivery of a relatively large amount of energy per ignition is assured.

It is advantageous to use as the pulse generator a special embodiment of an astable multivibrator in connection with which a starting device sees to it that the rectangular oscillation is conducted at the time of ignition with full pulse length to the output logic for delivery to the switch stage. The pulse generator continues to operate after starting of the engine. It is furthermore advantageous for the pulse generator to operate with frequency-determining resistances connected to ground potential, whereby an easy introduction of process variables is made possible to vary the start, end and length of the production of ignition energy.

In some cases it is advantageous to provide a d.c. voltage transformer by which the voltage of the battery for the supplying of the transistor which serves as a switch can be increased from, for instance, 12 V to about 50 to 100 V, and preferably 70 V.

A half-wave rectification on the secondary side of the ignition transformer can be provided. The advantage obtained is that the reaction of the load capacitance on the primary side is substantially reduced and this capacitance can at the same time be used as a charging capacitor. Furthermore, there is obtained a polarization which has the advantage that with corresponding switching, the burning-off takes place on the outer electrode of the spark plug, a stronger development of which is easier to obtain structurally than in the case of the central electrode. Furthermore, there is the advantage that the d.c. arc is stiffer.

With varying voltage of the d.c. voltage source it is advisable to provide a current and voltage regulator so that a load which is sensitive to the supply voltage, for instance digital circuits, is provided with a constant supply and on the other hand that a freely variable set-point determination for the parameters of the ignition energy is possible.

Since the ignition energy for each ignition can be produced with a relatively long duration with the new ignition device reference is no longer had in the following to "moment of ignition," as in the case of conventional ignition devices, but rather, for purposes of clear definition, reference is had to the start and the end of the production of the ignition energy.

The start of the production of the ignition energy can be determined in a customary manner as with a mechanically actuated breaker or breaker switch. However, the start of the production of the ignition of energy can also be controlled without the use of contacts. By the provision of a time-increasing member may be combined either with the breaker or with a release member which acts without contacts, such as a semiconductor device or inductive transmitter, one has available a large range of variation for establishing the start of the production of the ignition energy as one desires and for providing variable starting points.

In order to achieve a good transfer of energy in the ignition transformer, it is advantageous to provide said ignition transformer with a core which is closed for the magnetic flux and therefore keeps the mounting-air gap as small as possible. Furthermore, the ignition transformer is preferably developed as a wide-band transformer in order to improve the energy transfer and have a relatively large frequency range available. It is advisable to provide for an ignition transformer developed as wide-band transformer, a ferrite core which has one or more disk windings on the secondary side. Since the plastic sealing compositions customary for transformer and ignition transformers have a tendency to shrink, an air gap is produced between the shielding housing and the surface of the sealing composition, thus resulting in an ionizing path. In order to exclude this ionizing path, the plastic sealing composition is provided on the outside with a "Faraday's cage" which, however, is not closed in order to avoid a short-circuit winding on the secondary side. This Faraday's cage can be represented, for instance, by a layer of graphite which is sprayed onto the high-voltage insulation. This layer can also be developed in the form of a grid.

It is advantageous to change the ignition output as a function of operating and surrounding data which are determined or measured directly or indirectly and which can be introduced as correcting variables via controlling elements into the current controller. Furthermore, properties of the exhaust gases can also be measured and act as correcting variables on the current controller.

It is advantageous to develop the ignition transformer in such a manner that it has two or more annularly or similarly developed ferrite cores and that each ferrite core has two or more primary windings, and for one leg of all the ferrite cores to lie within a single secondary winding which is traversed uniformly and in the same direction by the magnetic fluxes. In a preferred embodiment, the ferrite cores consists of two ushaped halves, whereby air gaps are present which should be kept as small as possible upon the mounting. As a result of this embodiment of the ignition transformer, in which, as a result of the use of a plurality of magnetic circuits, the total induction obtainable is substantially increased over that obtainable with a single magnetic circuit, the number of turns required per volt of output high voltage decreases. As a result, the transformation behavior is substantially improved and an increase in the switching frequency is possible, since the inherent capacitance of the secondary winding decreases. Furthermore, by the use of a plurality of magnetic circuits, due to the decreasing number of secondary turns, the transmission ratio is reduced, as a result of which the ignition power is substantially increased. As a result of this, it is furthermore possible to omit the d.c. transformer provided for the supplying of the transistor serving as a switch, with its high heat losses which occur particularly at high ignition power, since the more favorable transmission ratio no longer makes an increase in battery voltage necessary.

By providing a plurality of primary windings on each closed magnetic circuit, it is possible in advantageous fashion to obtain the necessary primary power for the ignition transformer in several power stages in which each primary winding has associated with it a transistor which operates as a switch and has the corresponding power control, so that instead of one large transistor which serves as a switch, a plurality of smaller power transistors are used. In this way price advantages are obtained as well as a better distribution of power heat loss with respect to the cooling surface. Furthermore, there is obtained an advantageous effect on the height of the switch peaks which occur in the switching operation with a magnetic circuit. By this structural development of the power part, the reliability of the overall arrangement is also increased, dispite the use of a plurality of transistors serving as a switch and the control thereof.

It is advantageous to modify the control for the transistors serving as a switch so as to adapt same to the specific ignition power required by an internal combustion engine by associating another transistor in a Darlington circuit with each switch transistor, in which case resistors can be present in the base of the Darlington transistor alternatively with the use of particularly high-grade, insulating sealing compositions for the ignition transformer, the magnetic circuits can be so dimensioned that the transistors in the Darlington circuit and their base resistors can be dispensed with, in which case then base resistors are inserted in advantageous fashion in each base lead of the switch transistors, the necessary control power for the switch transistors being provided by a common power control stage. The controlling power stage is advantageously developed in such a manner that the transistor which provides the main power has another transistor associated with it in a Darlington circuit. The ferrite cores of the ignition transformer are advantageous formed, for reasons of mounting, of two U-shaped core halves, whereby inavoidable air gaps are formed which are kept small as smallas possible.

The switch frequency is advantageously variable within a range of from 1 to 20 kilocycles, as a result of which it is possible to influence the ignition power via the effect, related to the change in the switch frequency, on the transmission properties of the ignition transformer, as a result of which, through the controllable ignition power, special operating conditions of the internal combustion engine are taken into account. Furthermore, by means of the variable switch frequency and the ionizing action connected with it, the environmental variables and composition of the exhaust gas can be taken into account, depending on the ratio of the gasoline-air mixture.

In order to avoid the known opening and closing chatter which occurs upon the actuation of the contact-breaker switch, a circuit which suppresses the chattering is provided which may consist, for instance, of digital switch elements and a capacitor.

The desired change in the start of the production of the ignition energy, its duration or its end, and the desired change in the switch frequency is advantageously brought about via controlling elements which may, for instance, be potentiometers or magnetic, optical or similar devices. The correcting variables are primarily the operating data which are determined or measured directly or indirectly. Furthermore, environmental data can also be taken into consideration as correcting variables. Furthermore, properties of the exhaust gases can also be measured and be fed as correcting variables via controlling elements either to the pulse generator which determines the switching frequency or to the timing members which determine the duration or start and end of the production of ignition energy. In connection with the possibility of producing ignition currents of relatively long duration which are provided by the new ignition device, it is advantageous to make the ignition distributor contacts wider than was heretofore customary.

The new ignition device which gives off a high ignition arc energy permits the production of an arc which is resistant to forces of deflection; this provides the advantageous possibility of, if desired, so deflecting the arc by the bringing about of certain flow conditions in the combustion chamber that the focal lines of the arc lie in a curved surface. This deflection can occur because the energy can be controlled therefore, the focal-line surface can be varied as desired.

One advantageous development of the controlling elements for the subassemblies determining the start, the duration and the end of the production of the ignition energy, as well as the switching frequency, consists in developing the controlling elements as photoresistors which are coupled optically with a photodiode which changes its intensity of illumination as a function of a process variable, for instance as a function of speed of rotation, whereby a change in resistance is effected in the photoresistors. An input of a plurality of process variables on the same photoresistors can be obtained by the provision of a plurality of optically coupled photodiodes, one photodiode being associated with each process variable.

One particularly advantageous development of the subassemblies determining the start, the duration and the end of the ignition energy, as well as those determining the switch frequency consists in introducing the process variable into the controlling elements in freely selectable stages. The process variables can be formed as a function of operating and possibly environmental data determined or measured directly or indirectly, as well as a function of the composition of the exhaust gas. In the case of the process variable of speed of rotation, one to several stages are provided in the manner that, for instance, for the initial speed of rotation, there is set an ignition duration of 40 ms, an ignition energy of up to 14 Ws and a high voltage of up to 40 kv; for the idle speed an ignition duration of 5 ms, an ignition energy of up to 4 Ws and a high voltage up to 40 kv; for an average speed an ignition duration of 3 ms, an ignition energy of up to 0.5 Ws and a high voltage of up to 40 kv; for the maximum speed an ignition duration of 1.5 ms, an ignition energy of up to 0.2 Ws and a high voltage of up to 40 kv. In this way, during the starting process, the effect of the shunting of the spark plugs is substantially reduced, during the idle speed there is taken into account in addition consideration of the shunt on non-homogeneities of the preparation of the mixture, while at the medium speed substantially non-homogeneities of the preparation of the mixture are acted on, and at the maximum speed value is placed on dependable ignition with strong flow in the combustion chamber. Value must be placed on the increased ignition power parameters due to the increased demand on the dependability of operation of internal combustion engines, for instance dependable operation for **50,000** miles, and the requirements resulting from the exhaust gas laws, since electrode spacings of up to 2 mm are to be taken into consideration, inter alia, at the spark plugs.

With the particularly high ignition power, it is advantageous to effect the supplying from the battery of the logical circuits in galvanically separated subassemblies described via a d.c. voltage transformer. For this purpose galvanic separating members are provided which galvanically separate the subassemblies in question which are supplied by the d.c. voltage transformer from the rest of the ignition device. The galvanic separating members may be provided with transformers or optical coupling elements.

The supplying from the battery of the structural groups galvanically separated affords the possibility of using logical circuits which require a constant supply voltage and are more unfavorable in their signal-noise ratio than logical circuits in COS MOS design.

One embodiment of the ignition device in accordance with the invention is indicated in the drawings which show diagrammatically:

FIG. **1**, a block diagram of the ignition device;

FIG. **2**, a wiring diagram;

FIGS. 3*a* to 3*i* and 3*k*, pulse diagrams;

FIG. **4**, a block diagram of the ignition device;

FIG. **5**, an equivalent circuit diagram of the ignition transformer provided with a plurality of ferrite cores in accordance with the invention, shown only for one magnetic circuit;

FIG. **6**, the new ignition transformer in side view;

FIG. **7**, a top view of the transformer of FIG. **6**;

FIG. **8**, a portion of a double winding;

FIG. **9**, a ferrite core consisting of U-shaped parts, with air gaps;

FIG. **10**, several primary windings with their transistors serving as a switch and their control;

FIG. **11**, several primary windings with their transistors serving as a switch for them and their control, in expanded form;

FIG. **12**, several primary windings with their transistors serving as a switch for them and their control, in a different form;

FIG. **13**, a wiring diagram of a pulse generator;

FIGS. **14***a* to **14***i* and **14***k* to **14***m*, pulse diagrams;

FIG. **15**, a block diagram of the ignition device;

FIG. **16**, a wiring diagram for the speed-dependent adjustment of the duration of the ignition time and switch frequency;

FIGS. **17***a* to **17***i*, **17***k* to **17***p* and **17***r* to **17***v*, pulse diagrams;

FIGS. **18***a* to **18***i*, **18***k* to **18***p* and **18***r* to **18***v*, pulse diagrams;

FIG. **19**, a block diagram of the ignition device;

FIG. **20**, a wiring diagram for the speed-dependent adjustment of the duration of the ignition time and switch frequency;

FIG. **21**, a perspective view of the assembly consisting of a photodiode and **2** photoresistors;

FIG. **22**, a perspective view of the assembly consisting of **3** photodiodes and **2** photoresistors;

FIG. **23**, a block diagram of the ignition device;

FIG. **24**, a block diagram of the ignition device;

FIG. **25**, a galvanic separating member in an embodiment with a transformer;

FIG. **26**, a galvanic separating member in an embodiment with optical coupling, and

FIG. **27** shows a d.c. voltage transformer in an embodiment as a single-ended transformer.

FIGS. **1** to **3** show an ignition device in which a d.c. voltage transformer supplies the power stage, while the other subassemblies are fed by the battery. The ignition power is varied as a function of the process via a current controller.

FIGS. **4** to **12** show an ignition device in which the d.c. voltage transformer with voltage and current controller is eliminated. The entire ignition device is fed by the battery. The change in the ignition power as a function of the process is obtained via the variable pulse generator frequency in combination with the transmission behavior of the ignition transformer which consists of a plurality of magnetic circuits. The power stages are divided up so as to obtain an economical and dependable solution.

FIGS. **13** and **14** show a pulse generator for the production of the switch frequency which can operate with reference to ground and has particular advantages in combination with the rest of the system.

FIGS. **15** to **18** show the control as a function of the process of the new ignition device, using as an example the speed in four freely selectable stages. All parts of the system are supplied by the battery.

FIGS. **19** to **22** show the control as a function of the process of the new ignition device, using the speed as an example in freely selectable continuous dependence. The introduction of the correcting variables takes place via optical coupling elements. All parts of the system are supplied by the battery.

FIGS. **23** to **27** show the new ignition device with the introduction of a supply separated galvanically from the battery for assemblies which are sensitive to noise voltage in combination with galvanic separating members by a d.c. voltage transformer. All other parts of the system are supplied by the battery.

The figures are described in further detail on the following pages.

The ignition device of FIGS. **1** and **2** is connected via the positive line **1** and negative line **2** to a d.c. voltage source **3** whose negative terminal **4** is connected via the terminal **5** with the negative line **2** and ground **6** and whose positive terminal **7** is connected via its terminals **9** and **10** of the ignition switch **8** with the positive line **1** via the terminal **11**. The source of d.c. voltage **3** can have a voltage of, for instance, **12** V.

The supplying of the d.c. voltage transformer **20** takes place via a filtering device **12** which is connected at the terminal **16** with the positive line **1** and at the terminal **17** with the negative line **2.** It is a lowpass filter consisting of the choke **13** with the capacitors **14** and **15,** which has the object of keeping away the switching frequency of the d.c. voltage transformer **20** as a superimposed disturbance of the d.c. voltage supply at the terminal **19** from the d.c. voltage source **3.** The cutoff frequency of the filtering device **12** is determined by the choke **13** and the capacitor **14,** while the capacitor **15** prevents the entrance of high frequencies. The output terminal **18** of the filter device **12** is connected with the input terminal **19** of the d.c. voltage transformer **20** to the positive supply.

The d.c. voltage transformer **20** is connected via the terminal **21** with the negative line **2.** In the case shown as the example, the d.c. voltage transformer **20** is a push-pull transformer of known type. A single-ended transformer can also be used. The d.c. voltage transformer **20** has the object of converting the voltage of the d.c. voltage source **3** to a d.c. voltage of, for instance, 50 to 100 V, and preferably 70 V. The output terminal **22** of the d.c. voltage transformer **20** is connected with the input terminal **23** of a known current regulator **24.**

The negative reference point of the current regulator **24** is produced via the connection of the terminal **25** with the negative line **2.** The actual value of the load current to be regulated is tapped off as a voltage value from the resistor **26.** The establishing of the set point is effected via controlling elements **27, 28, 29** which are potentiometers in the embodiment shown by way of example, the controlling element **27** being actuated as a function of the position of the throttle, the controlling element **28** as a function of the ignition moment and the controlling element **29** as a function of the nature of the gasoline-air ratio. The output terminal **30** of the current regulator **24** is connected with the input terminal **31** of a known voltage regulator **32.**

The negative reference point is produced by the connection of the terminal **33** of the voltage regulator **32** with the terminal **34** of the current regulator **24.** The voltage regulator **32** has the purpose of providing a constant output voltage. The output terminal **35** of the voltage regulator **32** is connected with the input terminal **36** of the primary winding **37** of the ignition transformer **38.**

The terminal **39** of the primary winding **37** of the ignition transformer **38** is connected via the terminals **40, 41** of the switch stage **42** to the negative reference point **34** of the current regulator **24** and the negative reference point **33** of the voltage regulator **32.** The switch frequency of the ON or OFF condition of the switch stage **42** is determined by the pulse generator **43** in combination with the timing members **44, 45** and the ignition moment transmitter **46.** By the switching of the switch stage **42,** a voltage is induced in the primary winding **37,** this voltage being transformed to a high voltage in the secondary winding **47** of the ignition transformer **38.**

The transformer **38** consists of two U-shaped cores which are combined together to form a closed core without air gap. The core material of the transformer **38** is preferably ferrite material. The secondary winding **47** of the transformer **38** is preferably developed as a disk winding.

The switch stage **42** consists of the switch transistor **48** and of the transistor **49** which is connected with the switch transistor **48** in the known Darlington circuit. The resistors **50, 51** serve to adjust the operating point of the transistor **48** acting as a switch. In order to obtain the necessary control power for the transistor **49,** the emitter resistors **57, 58, 52, 53** are associated with the transistors **54, 55, 56** which operate in a known collector circuit, the resistors **52, 53** determining the operating point of the transistor **49.** The capacitor **59** prevents self-oscillations. The base of the transistor **56** is connected via the decoupling resistor **60** and the terminal **61** with the output terminal **62** of the pulse generator **43.** The pulse generator **43** operates in the known embodiment as an astable multivibrator. The potentiometer **63** permits a variation of frequency of the pulse generator **43** to optimize the switch frequency to the transfer behavior of the ignition transformer **38.** The pulse generator **43** is built up of logical circuits in an integrated technique. The logical reference point is brought up with the line **65** via the terminal **64** of the pulse generator **43.** The pulse generator **43** is connected and disconnected via the timing member **44** for preselectable intervals of time. The switch command arrives via the connection of the terminal **66** of the pulse generator **43** with the terminal **67** of the timing member **44.** FIG. **3a** shows the pulse diagram for the terminal **62,** and FIG. **3b** the pulse diagram of the terminal **67.**

The timing member **44** is developed as a monostable multivibrator of known type. The monostable multivibrator is constructed of logical circuits in an integrated technique. The logical reference point is brought up with the line **65** via the terminal **68** of the timing member **44.** The "on" time of the timing member **44** can be freely varied. The provision of the desired value is effected via the controlling elements **69, 70, 71, 72** which are potentiometers in the embodiment shown by way of example, the controlling element **69** being actuated as a function of the speed of rotation, the controlling member **70** as a function of the position of the throttle, the controlling element **71** as a function of the moment of ignition and the controlling member **72** as a function of the nature of the gasoline-air ratio. The timing member **44** is turned on via the connection of the terminal **73** of the timing member **44** with the terminal **74** of the timing member **45.**

The timing member **45** is developed as a monostable multivibrator of known type. The monostable vibrator is constructed of logical circuits in an integrated technique. The logical reference point is connected with the line **65** via the terminal **75** of the timing member **45.** FIG. **3c** shows the pulse diagram of the terminal **74** of the timing member **45.** The time delay which is introduced by the timing member **45** for the commencement of the production of the ignition energy can be freely varied. The provision of the desired value is effected via the controlling elements **76, 77, 78** which are potentiometers in the embodiment shown by way of example, the controlling element **76** being actuated as a function of the speed, the controlling element **77** as a function of the position of the throttle, and the controlling element **78** as a function of the nature of the gasoline-air mixture.

The timing member **45** is turned on via the connection of its terminal **79** with the terminal **80** of the ignition moment transmitter **46.** The pulse diagram of the terminal **80** is shown in FIG. **3d.** The logical reference point is connected to the line **65** via the terminal **84.** At the terminal **85** the ignitionmoment transmitter **46** is connected with the positive line **1.** The negative reference point of the ignition-moment transmitter **46** is produced by the connecting of the terminal **81** with the negative line **2.** For the timing members **44, 45,** the negative reference point is prepared via the connections of the terminals **82, 83** with the negative line **2.** The ignition-moment transmitter serves to introduce the ignition process. In the embodiment shown in FIG. 2 there is shown a traditional breaker switch **86** which is actuated as a function of the crank angle by a cam **87** driven by the internal combustion engine. The ignition process is introduced in traditional manner by the opening of the breaker switch **86.** Since the opening and closing of the breaker switch **86** is accompanied by contact chattering, the first instant of opening can be noted for maintaining the clear open condition. This is achieved by a control logic which consists of the known monostable multivibrator **96** with the logical circuits **95, 97** and **135** in combination with the capacitor **98.** The resistor **88** provides a shunt current over the breaker switch **86** as long as it is closed so as to avoid oxidation of the contact. The shunt current has a value of 20 to 100 ma, and preferably 50 ma. The choke **91** in combination with the resistor **92** and the Zener diode **93** prevents the feeding of noise frequencies. If the breaker switch **86** opens, then there takes place at terminal **89** a transfer of voltage from the potential of the negative line **2** to the potential of the positive line **1,** less the voltage drop at the resistor **88.** The transfer of voltage from negative to positive arrives at the logical circuit, namely on the NAND gate **95** connected as an inverter and, via the terminal **94,** into the monostable multivibrator **96.** The output of the NAND gate **95** is connected with the first input, and the output of the monostable multivibrator **96** is connected at the terminal **99** with the second input of the logical circuit, namely the NAND gate **97.** The output of the NAND gate **97** is connected via the NAND gate **135,** connected as an inverter, with the terminal **80** of the ignitionmoment transmitter **46** for the turning on of the timing member **45** at the terminal **79.** The pulse diagram of the terminal **94** is shown in FIG. **3g,** that of the terminal **90** is FIG. **3f,** and that of the terminal **99** in FIG. 3*e*, while that of the terminal **80** is shown in FIG. **3d.**

From the pulse diagrams of FIGS. 3*a* to 3*i* and 3*k*, there can be noted the course of the function as associated with the parts of the ignition device shown on blocks in FIG. **1.**

In each of FIGS. **3e** to **3g** there is shown in the first half of the pulse diagram a chatter-free operation of the breaker switch **86** and in the second half the preventing of the opening and closing chatter. Voltage intrusions at the logical outputs are counteracted by the capacitor **98** which lies between the terminal **81** of the ignition-moment transmitter **46** and the output of the logical circuit **97** and the input of the logical circuit **135.** The logical reference point of the monostable multivibrator **96** in the ignition-moment transmitter **46** is supplied via the connection of the terminals **84, 100** of the ignition-moment transmitter **46.** The negative reference point of the monostable multivibrator **96** in the ignition-moment transmitter **46** is formed via the terminals **101** and **81** in the ignition-moment transmitter **46.**

The filter member **102** is connected with the positive line **1** by the terminal **106** and with the negative line **2** by the terminal **105.**

The filtering device **102** consists of the choke **107,** the capacitors **108, 109, 110** and the series connection of resistor **11** and Zener diode **112.** The choke **107** with the capacitors **108, 109** is developed as a lowpass filter in the known pi network. The low-pass filter is intended to keep superimposed noises of the d.c. voltage supply away from the supply line of the timing members **44, 45** for the pulse generator **43** and of the ignition-moment transmitter **46,** which are supplied from the terminal **104** in a connecting line (not shown in the drawing). The capacitor **110** prevents the entrance of high frequencies. The Zener diode **112** with the series connected resistor **111** prevents overvoltages at the terminals **103, 104** of the filter device **102.** The logical reference point, namely the line **65,** is connected with the terminal **103** of the filter device **102.** The negative reference point of the logical circuits in the pulse generator **43,** in the timing members **44, 45** and in the ignition-moment transmitter **46** is not shown in the connecting points.

The high-voltage alternating voltge which is tapped off from the secondary winding **47** of the ignition transformer **38** at the terminals **114** and **113** in good connection to the negative line **2,** and thee frequency of which is determined by the pulse generator **43** and its effective duration by the timing member **44,** the release taking place by the ignition-moment transmitter **46** in combination with the timing member **45,** is fed via the rectifier path **116** with the terminals **115, 117,** and the ignition distributor **118** with the terminals **119** and **120** to **123,** to the spark plugs, namely **4** spark plugs in the example shown in the drawing. Via the terminal **128,** the spark plugs **129** to **132** are connected at their reference points with the negative line **2.** The positive connections of the distributor with the spark plugs are effected via **120** with **124,** via **121** with **125,** via **122** with **126** and via **123** with **127.** The high-voltage alternating voltage at the output of the ignition transformer **38** at the terminals **114, 113** is rectified in the rectifier path **116** in a half-wave rectifier circuit. The stray capacitance **133** and line capacitance **134** of the screened lines which extend to and from the ignition distributor **118** act as a charging capacitor. The capacitances are indicated in dotted line. Due to the small inherent capacitance of the rectifier **116,** the reaction of the capacitors **133, 134** with the square of the transformation ratio on the primary side of the ignition transformer **38** is extensively prevented, since the capacitance of the rectifier **116** acts as a series capacitance to the capacitances **133, 134.** By this compensation, the highest possible switching frequency of the switch stage **42** is obtained with the ignition transformer **38.**

The timing members **45, 44** are monostable multivibrators which enter into operation in the voltage transfer from, for instance, 12 V to 0 V. In order to fulfill the function described, shown in FIG. 3, inverting gates are provided behind their output, namely gate **136** in the timing member **45** and gate **137** in timing member **44.**

The transistors which are shown as npn transistors can, with suitable change in the circuit, also be developed as pnp transistors, for instaance as silicon transistors.

The logic shown refers to integrated circuits, series COS MOS of RCA. It is characterized by particularly high suppression of noise voltages. Since its supply voltage can also vary within wide limits, the d.c. voltage supply can be effected from a source of d.c. voltage **3** with varying output voltage, for instance a battery. Other logic series of other manufacturers can also be supplied with high suppression of noise voltage, but do not permit such a large variation of their d.c. voltage supply. When they are used, control units must be employed, possibly in combination with a d.c. voltage transformer **20.**

From the secondary side of the ignition transformer **38,** the stepped-up alternating voltage is fed to a rectifier path **116** and, via the mechanical ignition distributor **118,** to the spark plugs **129** to **132.** Instead of the mechanical ignition distributor **118,** an electronic ignition distributor can also be provided.

This ignition device which produces and gives off a very high ignition are energy and in connection with which the duration, start and end of the arc produced at the electrodes of the spark plugs is variable within very large limits which have not previously been achieved, is particularly well suited for the introduction of, i.e. the influencing by, correcting variables which are characteristics of the operation of the internal combustion engines and their environment. These correcting variables are fed to controlling elements which are indicated or combined as follows in the block diagram of FIG. **4:** switch stage **42** contains the transistors **48, 205, 207, 209** serving as a switch with corresponding power amplification. The pulse generator **43,** preferably an astable multivibrator, contains controlling members - in the embodiment shown by way of example potentiometers **201** to **204** - with which there are associated correcting variables which are dependent, for instance, on the throttle, the ignition moment, the speed and the nature of the gasoline-air ratios used. The timing member **44,** preferably a monostable multivibrator, contains controlling elements - in the embodiment shown by way of example potentiometers **69** to **72** - with which there are associated correcting variables which are dependent, for instance, on the throttle, the ignition moment, the speed and the nature of the gasoline-air ratio used.

The timing member **45,** which is also preferably a monostable multivibrator, contains controlling elements - in the embodiment shown by way of example potentiometers **76** to **78** - with which there are associated correcting variables which are dependent, for instance, on the throttle, the speed of rotation and the nature of the gasoline-air ratio used.

46 is the ignition-moment transmitter in combination with a breaker switch **86** and cam **87. 102** is a filter device consisting of choke, capacitors, a series connection of a resistor and Zener diode; it is intended to keep superimposed noieses of the d.c. voltage supply away from the supply line of the timing members **44, 45,** of the pulse generator **43** and of the ignition-moment transmitter **46.**

FIG. **5** shows the equivalent circuit diagram of the ignition transformer, shown as consisting of a primary winding, for instance **155,** in combination with the secondary winding **47.** The source of alternating voltage U **1** has the internal resistance $R_{primary}$ which is composed of the series circuit of the internal resistance of the storage battery **3,** the residual saturation resistance of the transistor **48** serving as a switch and the ohmic resistance of the primary winding **155.**

$$R_{primary} = R_i + R_s + R_{winding}$$

This resistance is stepped up by the square of the transformation of the turns ratio between primary and secondary windings on the secondary side to the resistance $R_{secondary}$. $R_{secondary}$ together with the internal resistance R_s of the rectifier **116** forms the internal resistance of the source of high voltage. The winding and stray capacitances on the secondary side are stepped up with the square of the transformation ratio to the primary side and thus limit the switching frequency obtainable with the transistor **48** serving as a switch.

$$C_{st} = ü^2 \times C_{s2}$$

The ignition and the spark plugs are represented as arc paths **118, 129** to **132.** The stray capacitances **133, 134** of the feedline are substantially reduced by the series capacitance of the rectifier **116** with respect to their effect on the transformation properties of the ignition transformer **38** and act at the same time as a charging capacitor for the half-wave rectifier **116.**

The transformer **38** developed in accordance with the invention which is shown in FIGS. **6** and **7** has four rectangular ferrite cores **151, 152, 153** and **154** of closed construction. The secondary coil **47** surrounds in each case one leg of all ferrite cores which, on their other, opposite legs, each bear two primary windings, for instance **155, 156** and **157, 158** respectively.

FIG. **9** shows a ferrite core **152** which is composed of two pieces and has air gaps **159, 160** which are to be kept as small as possible. The split construction makes it possible to place the completely wound coils with their supports over the legs.

Instead of two primary windings, for instance **157, 158,** arranged apart in space and one over the other on a leg, a double or multiple winding can be provided whereby the stray losses are reduced, particularly when in the case of a large numbers of turns, several layers are required. A part of a double winding, pulled open, is shown in FIG. **8.** The windings which travel in the same direction are designated **161** and **162.**

FIG. **10** shows the multiple control of the primary windings in circuit diagram.

The primary windings **155** to **158** have switch transistors **48, 205, 207, 209** and transistors **49, 206, 208, 210** in Darlington circuit associated with them. The secondary winding **47** is connected at its one end via the output terminal **114** and the rectifier **116** with the ignition distributor **118** and the spark plugs **129** to **132** (see FIG. **4**). The other end is connected by the output terminal **113** to the grounding point of the vehicle. The transistors **56, 54** are connected behind the pulse generator **43** to amplify the output and impart a sufficient control power to the Darlington circuit. The resistors **52** and **53** are emitter resistors for the transistor **54** which operates in collector circuit; their resistance ratio is determined in accordance with the need for bias voltage of the Darlington circuit. Resistor **57** is the emitter resistor for the transistor **56** which operates in a collector circuit. The resistance matching to the pulse generator **43** is effected by the resistor **60** via the terminal **61.** The positive supplying of the circuit takes place via the terminal **36** and the negative supplying via the terminal **41.**

In FIG. **11** there is shown the mutual uncoupling of the base currents by the resistors **218** to **221** for the transistors **49, 206, 208, 210** operating in Darlington circuit. By introduction of the base resistors **218** to

221, contrary to the circuit shown in FIG. 10, the result is obtained that the residual saturation voltage of the transistors 48, 205, 207, 209 serving as switches become less and the individual dispersions become less. In this way the scope of use of transistor types is increased.

In detail, the resistor 218 is connected at its one end with the base of the transistor 49, the resistor 219 with the base of the transistor 206, the resistor 220 with the base of the transistor 208, and the resistor 221 with the base of the transistor 210. The other ends of the resistors 218 to 221 are connected to each other and connected to the junction of the resistors 52 and 53 at point 237.

In FIG. 12 there is shown a particularly economical multiple power control of the primary side in a circuit diagram. This circuit has become possible, since sealing compositions of higher electrical insulating power which have recently come on the market have made possible a reduction in the insulation paths on the one hand between the secondary winding and the grounded ferrite-core leg and on the other hand between the primary winding and the second winding (see FIGS. 6 to 9). By the reduced structural size, the length of the iron path of a magnetic circuit of the ignition transformer consisting of two or more magnetic circuits can be reduced. In this way there results a reduced need for current in the primary winding in order to obtain the same magnetic flux. As a result, the transistors 48, 205, 207, 209 which serve as switches can be selected from a smaller power class, together with the advantage of relatively smaller loss power.

In detail, the transformer consisting, for instance, of four primary windings 155 to 158 and one secondary winding 47 is connected at one end of the primary winding 155 with the collector of the switch transistor 48, at the primary winding 156 with the collector of the switch transistor 205, at the primary winding 157 with the collector of the switch transistor 207, at the primary winding 158 with the collector of the switch transistor 209, while the other ends of the primary windings 155 to 158 are connected via the terminals 215, 36 with the positive potential of the supply (see FIG. 4). The emitters of the transistors 48, 205, 207, 209 which serve as switches are connected with each other and connected via the terminals 217, 41 to the negative potential of the supply. The base of the switch transistor 48 is connected via the resistor 211, the base of the switch transistor 205 via the resistor 212, the base of the switch transistor 207 via the resistor 213, the base of the switch transistor 209 via the resistor 214, with the emitter of the transistor 54 which operates in collector circuit. The base resistors 211 to 214 serve for the mutual uncoupling of current. The emitter of the transistor 54 which operates in collector circuit is connected via the resistor 53 and the terminals 217, 41 with the negative potential of the supply. The transistor 55 operates with the transistor 54 in a Darlington circuit in order to increase the current amplification. Its emitter is connected with the base of the transistor 54. The base of the transistor 55 leads to the emitter of the transistor 56 which operates in a collector circuit and the base of which is connected via the resistor 60 for impedance matching to the pulse generator 43 via the terminal 61 with the output terminal 62 of the pulse generator 43. The emitter of the transistor 56 is connected via the resistor 57 and the terminal 41 with the negative potential of the supply. The collectors of the transistors 54, 55, 56 are connected with positive potential of the supply via the terminals 216, 215, 36.

The circuit shown with the transistors 54, 55, 56 produces the necessary control power for the switch transistors 48, 205, 207, 209. The secondary winding 47 of the transformer has its one end connected via the terminal 114 with the rectifier 116, the ignition distributor 118 and the spark plugs 129 to 132. The other end is connected via the terminal 113 with the grounding point of the vehicle.

The circuit on the primary side of the ignition transformer, in the manner in which it has been selected in accordance with the invention, in particular also has the following advantage. The division of power present on the primary side makes possible the use of transistors of small switching power so that the expense, even though several transistors are used, is less when employing a single transistor of very high switching power. Furthermore, this has inherent in it the advantage that the heat losses are better distributed and, upon failure of one or several switch transistors, the operation is not greatly impaired and can still be maintained to the necessary extent for a relative long period of time.

FIG. 13 shows another embodiment of the pulse generator 43 (see FIG. 2).

FIG. 14 shows the course of the functions in pulse diagrams at the points indicated.

The pulse generator 281 consists of a known astable multivibrator, consisting of the logical inverter circuits 225 and 230, as well as the capacitors 228 and 229 and the resistors 223 and 224. In order to obtain a very rapid starting of oscillation so as to operate with the full pulse length of an "on" pulse already upon the first rectangular oscillation, so as to avoid a falsifying of the moment of ignition, the logical inverter circuit 235 has been supplemented by the differentiation member consisting of the capacitor 233, resistor 234, and logical inverter circuit 226, 227 in the known astable multivibrator circuit. Furthermore, the pulse generator 281 consists of the logical AND circuit 231, 232 so as to free the generator frequency or switch frequency at the switch stage 42 for the duration of the function of the timing member 44 (see FIG. 2).

The input terminal 66 is connected with the output terminal 67 of the timing member 44. The terminal 66 leads on the one hand via the junction point 240 to an input of the NAND gate 231 and on the other hand to the input of the logical inverter circuit 235. The output of the logical inverter circuit 235 is connected, via the capacitor 233, junction 242, with an input of the NAND gate 226 and which is connected via junction 242, resistor 234, and terminal 64 with positive potential of the supply. The other input of the NAND gate 226 is connected with the output of the logical inverter circuit 225 whose input extends on the one hand via the junction 241 to the capacitor 228 and is connected on the other hand via the junction 241, resistor 223, junction 236, and terminal 222 with negative potential of the supply. The other end of the capacitor 228 is connected via the point 244 with the output of the logical inverter circuit 230 and the input of the NAND gate 231 whose output is connected with the input of the logical inverter circuit 232 whose output is connected via the output terminal 62 with the input terminal 61 of the switch stage 42. The output of the logical inverter circuit 227 is connected via the capacitor 229 and junction 243 with the input of the logical inverter circuit 230 and is connected on the other hand via point 243, resistor **224**, junction **236** and terminal **222** to the negative potential of the supply.

The logic shown refers to integrated circuits, Series COS MOS, for instance of RCA. The positive and negative logical reference points of these integrated circuits are not shown.

Instead of the individual resistors **224** and **223** shown in the case given by way of example, any other combinations of resistors can be used, for instance in series or parallel connection. For this fixed resistors, variable resistors and strain gauges can, for instance, be used as linear resistors, while as nonlinear resistors there may be used, for instance, photoresistors, thermistors and low-temperature conductors, field plates and transistors, as well as combinations of linear and nonlinear resistors.

The frequency and the pulse duty factor of the pulse generator **281** are determined on the one hand by the capacitor **228** with the resistor **223** and the capacitor **229** with the resistor **224** and can be varied by a corresponding dimensioning of the parts.

FIG. **15** shows the system relationships of the circuit **277** with the other elements of the ignition system.

FIGS. **16** to **18** serve to explain the switching details further.

The circuit **277** is a combination module of the timing members **45** and **252**, the pulse generator **267** and the circuit **254**, a displacement of the ignition time and of the switch frequency which is dependent on the speed being obtained by the modules **252** and **267**. The circuit **277** shows the time-delay member **45** in the circuit of FIG. **2**. The module **252** is - for the displacement as a function of speed of the ignition time in connection with circuit **254** - a different embodiment of the timing member **44** (see FIG. 2), while the module **267** is a different embodiment of the pulse generator **43** (see FIG. 2) for the displacement of the switch frequency as a function of the speed of rotation. The circuit **277** is connected via the input terminal **247** with the output terminal **80** of the ignition-moment transmitter **46**, while the output terminal **262** leads to the input terminal **61** of the switch stage **42**. The terminal **308** of the circuit **277** is connected with positive potential of the supply and the terminal **278** is connected with negative potential of the supply.

For a further explanation of FIG. **16**, four pulse diagrams have furthermore been shown in FIGS. **17** and **18**. The **4** pulse diagrams show the corresponding pulses at the indicated points of the timing member **252** with the circuit 254 and of the pulse generator **267** during the starting process and at three other speed points. FIGS. **17***a* to **17***k* apply for the lowest engine speed range during the starting process prior to the first switch point. FIGS. **17***l* to **17***v* show the first switch point at higher engine speed. FIGS. **18***a* to **18***k* show the second switch point at again higher engine speed. FIGS. **18***l* to **18***v* show the third switch point at still higher engine speed.

The circuit **254** consists of a plurality - in the specific case three - of known re-triggerable monostable multivibrators. The monostable multivibrators of circuit **254** are controlled by the output pulse of the timing member **45** which represents the time-delayed pulse of the ignition-moment transmitter **46**, by the connection of the terminal **74** via the junctions **265**, **266** with the terminal **253**. The duration of the output pulses of the monostable multivibrators of circuit **254** is of different length. When the distance in time between two input pulses at the terminal **253** of circuit **254** is smaller than the duration of the output pulse of one or more monostable multivibrators of the switch **254**, their outputs **255**, **256**, **257** remain in quasi-stable condition. However, if the difference in time between two input pulses at the terminal **253** of the circuit **254** is greater than the duration of the pulse of one or more monostable multivibrators of the circuit **254**, then each of these monostable multivibrators gives off an output pulse to the multiple timing member **252**. The multiple timing member **252** consists of a plurality - in the specific case four - of known non-retriggerable monostable multivibrators and of the logical OR circuit **264**, **268**, **269**. With a different number of none-retriggerable monostable multivibrators, the logical OR circuit **264**, **268**, **269** is correspondingly broadened or reduced.

Several - in the specific case three - of these monostable multivibrators receive their input pulses from the circuit **254** via the input terminals **258**, **259**, **260**. One of the monostable multivibrators of the multiple timing member **252** receives its input pulse directly from the timing member **45** via the terminals **74**, **265**, **251**. The duration of the output pulses of the monostable multivibrators of the multiple timing member **252** is of different length. The output pulses of the monostable multivibrators of the multiple timing members **252** are connected with each other via a logical OR circuit **264**, **268**, **269**. The longest pulses present at the inputs of the logical OR circuit **264**, **268**, **269** act on the output of the logical OR circuit **264**, **268**, **269** via the output terminal **263**. The dimensioning of the monostable multivibrators of circuit **254** has been effected in such a manner that with an increase in the speed of rotation of the engine - and therefore with an increasingly small difference in time between two pulses of the ignition-moment transmitter **46** via the terminal **74** of the timing member **45** - one monostable multivibrator after the other of the multiple timing member **252** no longer receives an input pulse, since the controlling monostable multivibrators of circuit **254** pass one after the other into the quasi-stable condition. Starting at one engine speed, the duration of the pulse at the output terminal **263** of the logical OR circuit **264**, **268**, **269** is determined solely by the monostable multivibrator of the multiple timing member **252** which receives its input pulse not via the circuit **254**, but directly from the terminal **74** of the timing member **45**.

The pulse generator **267** can be switched electronically in its frequency in any desired number of stages. In the embodiment shown by way of example, three switchings with four frequency stages are shown. The pulse generator **267** consists of a known astable multivibrator, a logical AND circuit **318**, **309**, a capacitor **270** with the resistor **271** as differentiating member, the logical inverter circuits **272**, **273**, **274** and the resistors **292**, **293**, **294**, **295** with the diodes **301**, **302**, **303** and the capacitor **291**, as well as the resistors **297**, **298**, **299**, **300** with the diodes **304**, **305**, **306** and the capacitor **296**.

From the first pulse at the terminal **74** of the timing member **45**, which for all practical purposes represents a time-delayed pulse of the ignition-moment transmitter **46**, the pulse generator **267** is stimulated to oscillate via the connecting of the terminal **74** of the timing member **45** via the connecting points **265**, **266** to the terminal **276** and thereupon resynchronized by each additional pulse at the terminal **74** of the timing member **45**. By the synchronization the result is obtained that the pulse generator 267 commences with the full length of pulse at each ignition moment. The very short synchronization pulse is formed from the time-delayed pulse of the ignition-moment transmitter 46 by the differentiator member 270, 271. The outputs of the monostable multivibrators of the multiple timing member 252 are connected via the output terminals 283, 284, 285 with the logical inverter circuits 274, 273, 272 of the pulse generator 267 via the input terminals 288, 287, 286. In this way, due to the output pulses at the output terminals 283, 284, 285 of the multiple timing member 252, depending on the number of monostable multivibrators of the multiple timing member 252 which are in operation, a given sequence of frequency switchings of the pulse generator is brought about. As long as an output pulse is present at the terminal 263 of the multiple timing member 252, a number of groups of pulses with frequencies associated with them, depending on the number of monostable multivibrators of the multiple timing member 252 which is in operation, will enter into action. In the example shown, one possibility of frequency association of the pulse generator 267 with the duration of the ignition power present is shown. By interchanging the connection between the output terminals 283, 284, 285 of the multiple timing member 252 and the input terminals 286, 287, 288 of the pulse generator 267, other associations of the frequency of the pulse generator 267 with the duration of the ignition power are also possible. The frequency and the pulse duty factor of the pulse generator 267 are determined on the one hand by the capacitor 291 with the resistors 292, 293, 294, 295 and on the other hand by the capacitor 296 with the resistors 297, 298, 299, 300.

A change in frequency which is dependent on speed of rotation is obtained in the manner that the resistors 292, 293, 294, 295 and 297, 298, 299, 300 respectively are connected in groups by the logical inverter circuits 272, 273, 274 over the diodes 301, 302, 303 and 304, 305, 306 respectively against negative potential of the supply. For example, one group is formed of the logical inverter circuit 272, the diodes 303, 306 and the resistors 295, 300. A change in frequency is brought about by the application of an input pulse to the logical inverter circuits 272, 273, 274 and remains in existence for the duration of the input pulse. If not input pulse is present at the logical inverter circuits 272, 273, 274, then the pulse generator 267 oscillates at its natural frequency. The output terminal 263 of the multiple timing member 252 is connected with the input terminal 307 of the pulse generator 267 so as to release the switch frequency of the pulse generator 267 at the switch stage 42 for the duration of the output signals at the terminal 263 of the multiple timing member 252 in combination with the logical AND circuit 318, 309 of the pulse generator 267, so that the pulses of the astable multivibrator of the pulse generator 267 are present at the terminal 310 for the duration of the output pulses of the logical OR circuit 264, 268, 269 of the multiple timing member 252.

The resistors 311 to 314 of the multiple timing member 252 and the resistors 315 to 317 of the circuit 254 are made variable and dependent on directly or indirectly measured or determined operational and possibly environmental data.

The input terminal 247 of the circuit 277 leads to the input terminal 79 of the timing member 45 which is connected via the terminal 75, point 248 with the output terminal 308 to positive potential, and via the terminal 82, point 249, output terminal 278 to negative potential. The output terminal 74 of the timing member 45 leads to the input terminal 251 of the multiple timing member 252 and via points 265, 266 to the terminal 253 of the circuit 254 and to point 276, pulse generator 267. The output terminals 255, 256, 275 of the circuit 253 are connected with the input terminals 258, 259, 260 of the multiple timing member 252. The circuit 254 is connected with the output terminal 261 via the points 279, 248 and via the output terminal 308 of the circuit 277 with positive potential of the supply. The output terminal 275 of the circuit 254 is connected via the points 280, 249 via the output terminal 278 of the circuit 277 with negative potential. The output terminal 263 of the multiple timing member 252 is connected with the input terminal 307 of the pulse generator 267 whose output terminal 310 leads to terminal 262 of the circuit 277. The output terminals 283, 284, 285 of the multiple timing member 252 are connected with the input terminals 288, 287, 286 of the pulse generator 267. The input terminal 250 of the pulse generator 267 is connected via the points 279, 248, terminal 308 of circuit 277, with positive potential of the supply. The input terminal 289 of the pulse generator 267 is connected via the points 290, 280, 249, terminal 478, with negative potential. The input terminal 282 of the multiple timing member 252 is connected via the points 290, 280, 249, terminal 278, with the negative potential.

The logic shown refers to integrated circuits, Series COS MOS, for instance of the RCA company. The positive and negative logical reference points of these integrated circuits is not shown.

Instead of the individual resistors 311 to 317 shown in the example, any desired other combination of resistors, for instance in series or parallel connection, can be used. In this connection, fixed resistors, variable resistors and strain gauges can, for instance, be used as linear resistors and photoresistors, thermistors and cold conductors, field plates and transistors, for instance, can be used as nonlinear resistors, it being also possible to use combinations of linear and nonlinear resistors.

FIG. 19 shows the circuit 403 which represents another embodiment of the circuit 277 shown in FIG. 15. The control of the timing member 44 and of the pulse generator 43 as a function of the speed is effected by an analogous process.

The circuit 403 consists of the timing members 45, 44, the pulse generator 43 (see FIG. 2), the series regulator 350, the speed signal transmitter 385 and the speed control member 380. The circuit 403 is connected via the input terminal 404 with the output terminal 80 of the ignition-moment transmitter 46. The output terminal 379 is connected with the input terminal 61 of the switch stage 42. The circuit 403 is connected via the terminal 376 with positive potential and via the terminal 383 with negative potential of the supply.

FIG. 20 shows the more detailed development of the circuit 403.

The circuit 403 contains the timing members 44, 45 with the known monostable multivibrator circuit and the pulse generator 43 in the known astable multivibrator circuit. The process-dependent resistor 69 for the timing member 44 and the process-dependent resistor 201 for the pulse generator 43 are developed as photoresistors. They are photoconductively connected with the photodiode 381 which in the present case operates in dependence on the speed of rotation. Further process variables can be coupled to the timing member **44** and the pulse generator **43** with in each case another photodiode which is photoconductively connected with the photoresistors **69, 201.** The photodiode **381,** controlled in the present case by the speed signal transmitter **385,** gives off for each ignition moment a light pulse of constant intensity over the entire speed range to the photoresistors **69** and **201.** Since the photoresistors **69** and **201** can relese a pulse train frequency of a few cycles, while the photosignal train of the photodiode **381** can amount, however, depending on the speed, to **10** to **500** cycles, the change in resistances of the photoresistors **69, 201** is deteermined by the photopulse train of the photodiode **381,** since, as a result of the high integration time of the photoresistors **69, 201,** the dead time between **2** light pulses is not recognized. At high speed of rotation and high ignition-moment sequence there results a high photopulse density of the photodiode **381** and thus a small resistance of the photoresistors **69** and **201.** This results in the case of the timing member **44** and the photoresistor **69** in a short duration pulse and in the case of the pulse generator **43** and the photoresistor **201** in a high switch frequency. The standardized light signal of the photodiode **381** is, in the case of the example, obtained from the speed signal transmitter **385** by a known monostable multivibrator consisting of the logical circuits **390, 391,** the capacitors **393** and **394** and the resistors **392, 395, 396,** in combination with the transistors **397** and **399** serving for the amplification of the power in the emitter circuit, in the manner that for each ignition moment, independently of the speed of rotation, a constant, rectangular current pulse of constant voltage is imparted to the photodiode **381.** The constancy of voltage is assured by the series regulator **350,** while the temperature compensation of the circuit is obtained via the resistors **400** and **401.**

The input terminal **404** of circuit **403** leads to the input terminal **79** of the time-delay member **45** whose positive potential is brought to the supply via the terminal **75,** points **375, 384** of the terminal **357** of the series regulator **350.** The negative potential of the supply for the time-delay member **45** comes from the terminal **383** of the circuit **403** via the points **382, 363, 360, 358** to the terminal **82.** The output terminal **74** of the time-delay member **45** leads on the one hand over the points **377** to the input terminal **73** of the timing member **44** and on the other hand via terminal **389** to the speed signal transmitter **385.** The positive potential of the timing member **44** is connected to the terminal **68** and is brought via the points **378, 375, 384** from the terminal **357** of the series regulator **350.** The negative potential of the timing member **44** for terminal **359** is brought via points **360, 363, 382** from the terminal **383** of the circuit **403.** The output terminal **67** of the timing member **44** leads to the input terminal **66** of the pulse generator **43** whose terminal **64** is brought for positive potential from the points **378, 375, 384** from the terminal **357** of the series regulator **350.** The output terminal **62** of the pulse generator **43** is connected to the output terminal **379** of the circuit **403.** The resistors **361, 362** with the photoresistor **69** in the speed control member **380** is controlling for the time of the timing member **44.** One end of the resistor **362** extends via point **405,** terminal **83** of the timing member **44,** and terminal **365** of the speed control member **380** to the photoresistor **69.** The other end of the resistor **362** is connected with the known monostable multivibrator. The resistor **361** has its one end connected to the point **405** and its other end connected to terminal **359** of the timing member **44.** The other end of the photoresistor **69** extends over point **407,** and terminal **364** of the speed control member **380,** and further over the points **363, 382,** via the terminal **383** of the circuit **403** to the supply with negative potential. The resistors **372** and **373** with the photoresistor **201** of the speed control member **380** are determinative of the frequency for the pulse generator **43.** The one end of the resistor **372** is connected with the known astable multivibrator of the pulse generator **43.** The other end of the resistor **372** extends over point **406,** resistor **373,** terminal **370** of the pulse generator **43,** terminal **368** of the speed control member **380** to the one end of the photoresistor **201** of the speed control member **380** whose other end is connected over the terminal **367** of the speed control member **380,** and terminal **369** of the pulse generator **43** to the point **406.** The known monostable multivibrator of the speed signal transmitter **385** produces, for each ignition moment, a pulse of a duration independent of the speed, which is conducted from point **408** over resistor **395** to the base of the power-amplification transistor **397** which operates in an emitter circuit. The emitter of the transistor **397** is connected via point **409** with negative potential to the terminal **386,** while the collector is connected via point **410,** resistor **402,** point **411, 412** with the positive potential to the terminal **388** of the circuit **403.** The collector of the transistor **397** is connected via point **410,** resistor **398** to the base of the transistor **399** which operates in emitter circuit for further power amplification and the emitter of which is connected via point **409** to the terminal **386.** The collector of the transistor **399** leads via point **413,** resistor **400,** points **414, 411, 412** to positive potential at the terminal **388,** and on the other hand via point **413,** the temperature-dependent resistor **401,** the points **414, 411, 412** to the terminal **388.** The speed signal transmitter **385** is connected with the terminal **388,** point **384** with the terminal **357** of the series regulator **350** for supply with positive potential, while the terminal **386** is connected via point **382** of negative potential from the terminal **383** of the circuit **403.** The output **387** of the speed signal transmitter **385** extends over the terminal **366** of the speed control member **380** to one end of the photodiode **381,** while the other end is connected via point **407** with the terminal **364** of the speed control member **380.** The terminal **364** of the speed control member **380** is connected via the points **363, 382** with the negative potential of the supply at terminal **383** of circuit **403.** The series regulator **350** in known circuit consists of the transistor **351,** the resistor **353,** the Zener diode **354** and the capacitor **352.** The unregulated positive supply voltage is brought from the terminal **376** of circuit **403** to the terminal **356.** The terminal **357** is the reference point for the controlled positive supply voltage. The terminal **355** of the series regulator **350** is connected via the points **358, 360, 363, 382** with the negative potential of the terminal **383** of the circuit **403.**

FIGS. **21** and **22** show the structural development of the speed control member **380** in the circuit **403** of FIG. **20.**

FIG. **21** shows the inclusion of the photoresistors **69** and **201** and of the photodiode **381** in the housing **416.** The photocoupling between the photoresistors **69** and **201** and the photodiode **381** can be obtained by lightpermeable sealing composition in the housing **416** or by the insertion of light-conducting material and in addition light-conducting sealing material.

FIG. **22** shows the photoresistors **69** and **201** and the additionally provided photodiodes **417** and **418** which can be limited to the action of further process variables of the internal combustion engine or environmental data on the photoresistors **69** and **201.** The photoconductive connection is produced in the manner described in FIG. **21.**

FIG. **23** shows the cooperation of the circuit **277** with the rest of the ignition system of FIG. **23** via the galvanic separating members **338** (see FIG. **25**), **339** (see FIG. **26**) with galvanically separated supply of the circuit **277** by the d.c. voltage transformer **349.** The galvanic separating members **338, 339** can optionally be developed as a transformer solution (see FIG. **25**) or as optical solution (see FIG. **26**). The d.c. voltage transformer **349** is supplied with positive potential of the battery **3** via the terminal **320,** point **319,** point **11,** from the terminal **10** of the ignition switch **8.** The terminal **321** of the d. c. voltage transformer **349** is connected via point **322** and point **461** with the terminal **4** for supply with the negative potential of the battery **3.** The output voltage of the d.c. voltage transformer **349** is present on the terminals **324, 323.** It is galvanically separated from the battery voltage. The d.c. voltage transformer **349** can be developed as a singleended transformer (see FIG. **27**) or as a push-pull transformer (see FIG. **2**). The positive potential leads from the terminal **324** to the input terminal **106** of the filter device **102** and from the output terminal **103** thereof via point **332** to the terminal **329** of the galvanic separating member **338,** from point **332** via point **333** to the terminal **308** of the circuit **277,** and from point **333** to the terminal **341** of the galvanic separating member **339.** The negative potential of the d. c. voltage transformer **349** is conducted from the terminal **323,** point **325** to the terminal **105** of the filter device **102,** and from point **325,** point **337** to the terminal **335** of the galvanic separating member **338,** from point **337** via point **347** to the terminal **278** of the circuit **277,** from point **327** to the terminal **344** of the galvanic separating member **339.** The positive potential of the battery **3** is conducted from terminal **10** of the ignition switch **8** via point **11, 319,** point **462** to the terminal **342** of the galvanic separating member **339,** from point **462,** point **330,** point **331** to the terminal **328** of the galvanic separating member **338,** from point **330** to the terminal **85,** from point **331** to terminal **84** of the ignition-moment transmitter **46.**

The negative potential of the terminal **4** of the battery **3** extends over point **461,** point **322,** point **463,** point **348,** point **346** to terminal **345** of the galvanic separating member **339,** from point **346** via point **336** to the terminal **334** of the galvanic separating member **338** and from point **336** to terminal **81** of the ignition-moment transmitter **46.**

The output signal of the terminal **80** of the ignition-moment transmitter **46** leads to the input terminal **326** of the galvanic separating member **338** whose output terminal **327** is connected with the input terminal **247** of the circuit **277.** The output terminal **262** of the circuit **277** leads to the input terminal **340** of the galvanic separating member **339** whose output terminal **343** is connected with the input terminal **61** of the switch stage **42.**

FIG. **24** shows the cooperation of the timing members **45, 44** and pulse generator **281** with the rest of the ignition system of FIG. **24** via the galvanic separating members **338** (see FIG. **25**), **339** (see FIG. **26**) with galvanically separated supply of the timing members **45, 44** and of the pulse generator **281** by the d.c. voltage transformer **349.**

The galvanic separating members **338, 339** can be developed either as a transformer solution (see FIG. **25**) or as an optical solution (see FIG. **26**).

The d. c. voltage transformer **349** is supplied with positive potential of the battery **3** via the terminal **320,** point **319,** point **11** from terminal **10** of the ignition switch **8.** The terminal **321** of the d.c. voltage transformer **349** is connected via point **322,** point **461** with the terminal **4** for supply with the negative potential of the battery **3.** The output voltage of the d.c. voltage transformer **349** is present on the terminals **324, 323.** It is galvanically separated from the battery voltage. The d.c. voltage transformer **349** can be developed as a single-ended transformer (see FIG. **27**) or as a push-pull transformer (see FIG. **2**). The positive potential leads from the terminal **324** to the input terminal **106** of the filter device **102** and from its output terminal **103** over point **332** to the terminal **329** of the galvanic separating member **338,** from point **332** via point **464** to the terminal **75** of the timing member **45** and from point **464** via point **465** to the terminal **68** of the timing member **44,** from point **465** via point **466** to the terminal **64** of the pulse generator **281,** and from terminal **466** to terminal **341** of the galvanic separating member **339.** The negative potential of the d.c. voltage transformer **349** is conducted from the terminal **323,** point **325** to the terminal **105** of the filter device **102** and from point **325,** point **337** to the terminal **335** of the galvanic separating member **338** and from point **337** via point **467** to the terminal **82** of the timing member **45,** from point **467** over point **468** to the terminal **83** of the timing member **44,** from point **468** via point **469** to the terminal **222** of the pulse generator **281** and from point **469** to the terminal **344** of the galvanic separting member **339.** The positive potential of the battery **3** is brought from the terminal **10** of the ignition switch **8** via point **11,** point **319,** point **462** to the terminal **342** of the galvanic separating member **339,** from point **462,** point **330,** point **331** to the terminal **328** of the galvanic separating member **338,** from point **330** to the terminal **85,** from point **331** to terminal **84** of the ignition-moment transmitter **46.** The negative potential of the terminal **4** of the battery **3** extends over point **461,** point **322,** point **463,** point **348,** point **346** to terminal **345** of the galvanic separating member **339,** from point **346** via point **336** to the terminal **334** of the galvanic separating member **338** and from point **336** to terminal **81** of the ignition-moment transmitter **46.**

The output signal at terminal **80** of the ignition-moment transmitter **46** leads to the input terminal **326** of the galvanic separating member **338,** its output terminal **327** to the input terminal **79** of the timing member **45,** and the output terminal **74** to the input terminal **73** of the timing member **44.** The output terminal **67** of the timing member **44** is connected with the input terminal **66** of the pulse generator **281** whose output terminal **62** is connected with the input terminal **340** of the galvanic separating member **339** whose output terminal **343** is connected to the input terminal **61** of the switch stage **42.**

The galvanic separating member 338 is shown in FIG. 25.

It consists of the transistors 420, 431, 439, the resistors 419, 421, 428, 430, 434, 436 the diode 426 and the transformer 459.

The galvanic separation is obtained by the transformer 459 which has a transformer ratio of 1:1 to 1:3, and preferably 1:1. Primary and secondary windings 422, 423 are wound jointly and arranged either on a ferrite-core bar or in a ferrite pot core. The rectifier 426 dampens switching peaks which occur upon pulse-like transformation. The resistor 421 dampens switching peaks on the primary side, the resistor 428 is the operating resistor of the rectifier 426 and, simultaneously with resistor 430, the base resistor of the transistor 431. Resistor 434 is the operating resistor of the transistor 431 operating in emitter circuit, resistor 436 is the operating resistor for the emitter circuit with transistor 439. Resistor 419 serves for resistance matching to the signal source.

The input signal comes from the terminal 326 and is conducted over resistor 419 to the base of the transistor 420 operating in emitter circuit, whose emitter is connected via the terminal 334 to the negative potential of the supply.

The collector of the transistor 420 is connected via point 424 to the one end of the resistor 421 and to the one end of the primary winding 422 of the transformer 459. The other end of the resistor 421 is connected via point 425, terminal 328 with the positive potential of the supply. The other end of the primary winding 422 of the transformer 459 is connected via point 425 to the supply with positive potential at the terminal 328. The one end of the secondary winding 423 of the transformer 459 is connected over rectifier 426, point 427, resistor 430 to the base of the transistor 431 which operates in emitter circuit. The other end of the secondary winding 423 of the transformer 459 extends over point 429, 432 which is also connected with the emitter of the transistor 431, point 438 which is also connected with the emitter of the transistor 439, to the terminal 335 for supply with negative potential. One end of the resistor 428 is connected to point 427 and its other end to point 429. The collector of the transistor 431 is connected over point 433, resistor 434, point 435 to the terminal 329 for supply with positive potential. The collector of the transistor 431 is connected via point 433 with the base of the transistor 439 whose collector is connected via point 437 with the one end of the resistor 436 and the terminal 327. The other end of the resistor 436 leads via point 435 to the terminal 329 for supply with positive potential.

FIG. 26 shows the galvanic separating member 339.

It consists of the transistors 440 and 454, the phototransistor 447, the photodiode 443 and the resistors 456, 441, 446, 451, 452.

The galvanic separation is obtained by optical coupling between photodiode 443 and phototransistor 447. Photodiode 443 and phototransistor 447 are obtainable as a structural unit on the market. Resistor 441 determines the current dimensioning for the photodiode 443. Resistor 456 serves for resistance matching to the signal source. Resistor 446 is the base resistor of the phototransistor 447. Resistor 451 is the corresponding working resistor in the collector circuit. Resistor 452 is the working resistor for the transistor 454 in the collector circuit.

The input signal comes from the terminal 340 and is brought via resistor 456 to the base of the transistor 440 which operates in emitter circuit and whose emitter is connected via the terminal 344 to the negative potential of the supply. The collector of the transistor 440 extends over resistor 441, point 442, photodiode 443, point 444 to the terminal 341 for supply with positive potential. The base of the phototransistor 447 extends over point 445, resistor 446 and point 449 which is also connected via point 448 with the emitter of the phototransistor 447, over point 455 which is also connected with the emitter of the transistor 454, to the terminal 345 for supply with negative potential. The collector of the transistor 447 is connected via point 450, point 458 which is also connected with the one end of the resistor 451, to the base of the transistor 454. The other end of the resistor 451 leads via point 457 to the terminal 342 for supply with positive potential. The collector of the transistor 454 is extended to the terminal 343 over point 453 which is also connected with the one end of the resistor 452. The other end of the resistor 452 leads via point 457 to the terminal 342 for supply with positive potential.

In FIG. 27 the d.c. voltage transformer 349 is shown in a known embodiment as a single-ended transformer. A push-pull transformer 20 of known embodiment can also be used (see FIG. 2).

The input supply of the d.c. voltage transformer 349 is supplied in positive potential via the terminal 320 and in negative potential via the terminal 321. The output d.c. voltage which is galvanically separated from the input voltage is given off in positive potential by the terminal 324 and in negative potential by the terminal 323.

What is claimed is:

1. In combination with an internal combustion engine having a crank shaft and a cylinder containing a piston, an ignition device comprising:

a. an ignition transformer;

b. a timing member for providing an output which is a function of the position of said piston in said engine cylinder;

c. a pulse generator, coupled to said timing member, including an astable multivibrator having first and second NAND gates each having first and second inputs and an output, a first inverter and a first capacitor coupled between the first input of said first NAND gate and the second input of said second NAND gate, second and third inverters and a second capacitor coupled between the output of said first NAND gate and the second input of said second NAND gate, first and second resistors coupled between the input of said first inverter and the input of said third inverter, and a fourth inverter and third capacitor coupled between the first input of said second NAND gate and the second input of said first NAND gate, said timing member turning on and off said pulse generator;

d. a switching transistor coupled to said pulse generator, said switching transistor coupling said ignition transformer to a source of d.c. voltage, the switching frequency of said transistor being determined by said pulse generator to control the start, end and duration of the production of ignition arc energy; and

e. a half-wave rectifier circuit including a rectifier coupled with a secondary winding of said ignition transformer.

2. An ignition device as defined by claim 1 wherein said pulse generator provides output pulses which have a substantially rectangular shape.

3. An ignition device as defined by claim 1 which further comprises a d.c. voltage transformer coupled to said source of d.c. voltage, said d.c. voltage transformer increasing the nominal voltage of said d.c. voltage source from about 12 volts to a value within the range of 50 to 100 volts.

4. An ignition device as defined by claim 1 which further comprises a current regulating unit and a voltage regulating unit coupled between said d.c. voltage source and said ignition transformer.

5. An ignition device as defined by claim 1 which further comprises a breaker switch coupled to said crank shaft and actuated as a function of said piston position, said breaker switch initiating production of said ignition energy.

6. An ignition device as defined by claim 1 which further comprises a contact-lens transmitter for initiating the production of said ignition energy.

7. An ignition device as defined by claim 5 which further comprises a time-delay member coupled to said breaker switch.

8. An ignition device as defined by claim 6 which further comprises a time-delay member coupled to said contactless transmitter.

9. An ignition device as defined by claim 1 wherein said ignition transformer is provided with a closed core for magnetic flux.

10. An ignition device as defined by claim 9 wherein said ignition transformer is a wideband transformer.

11. An ignition device as defined by claim 10 wherein said ignition transformer has a ferrite core and at least one disk winding on a secondary side.

12. An ignition device as defined by claim 11 which further includes an un-closed Faraday cage on high-voltage insulation for said ignition transformer.

13. An ignition device as defined by claim 12 wherein said Faraday cage comprises a layer of graphite sprayed on said high-voltage insulation.

14. An ignition device as defined by claim 4 wherein said current regulator comprises a plurality of series-connected potentiometers for controlling the output of said regulator as a function of operational and environmental data.

15. An ignition device as defined by claim 1 wherein said ignition transformer comprises at least two ferrite cores, at least two primary windings surrounding each of said ferrite cores, and a single secondary winding surrounding one leg of each of said ferrite cores, and further comprising winding transistors coupled to each of said primary windings, respectively.

16. An ignition device as defined by claim 15 wherein the collector of each of said winding transistors is coupled to a corresponding primary winding and the emitters are coupled together; and which further comprises auxiliary transistors coupled in a Darlington circuit, the collector and emitter of each auxiliary transistor being coupled to the collector and base respectively of a corresponding winding transistor, and the bases of said auxiliary transistors being coupled together.

17. An ignition device as defined by claim 16 wherein a resistor is connected in series with the base of each of the auxiliary transistors associated with said Darlington circuit.

18. An ignition device as defined by claim 15 wherein the collector of each of said winding transistors is coupled to a corresponding primary winding and the emitters are coupled together; and which further comprises auxiliary transistors having their collectors coupled together and the emitter of each auxiliary transistor coupled to the base of another of said auxiliary transistors; and a plurality of resistors, one end of each of said resistors being coupled to the base of a corresponding winding transistor and the other end to an emitter of one of said auxiliary transistors, said auxiliary transistors providing control power for said winding transistors.

19. An ignition device as defined by claim 15 wherein each of said ferrite cores is provided with an air gap.

20. An ignition device as defined by claim 9 wherein the switching frequency of said transistor is in the range of 1 to 20 kilocycles.

21. An ignition device as defined by claim 5 which further comprises means for suppressing chatter of said breaker switch.

22. An ignition device as defined by claim 1 which further comprises an ignition moment transmitter coupled to said timing member, said timing member being provided with a plurality of series-connected potentiometers for determining the duration of said ignition energy as a function of operating and environmental data.

23. An ignition device as defined by claim 1 which further comprises a speed signal transmitter having an output corresponding to the speed of rotation of said internal combustion engine, a photodiode coupled to said speed signal transmitter, and photoresistive means within said timing member and said pulse generator and optically coupled to said photodiode for controlling said pulse generator as a function of operating and environmental data.

24. An ignition device as defined by claim 1 which further comprises a d.c. voltage transformer, galvanic separating members and a time-delay member, said galvanic separating member, time-delay member, timing member and pulse generator being supplied by said d.c. voltage transformer.

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