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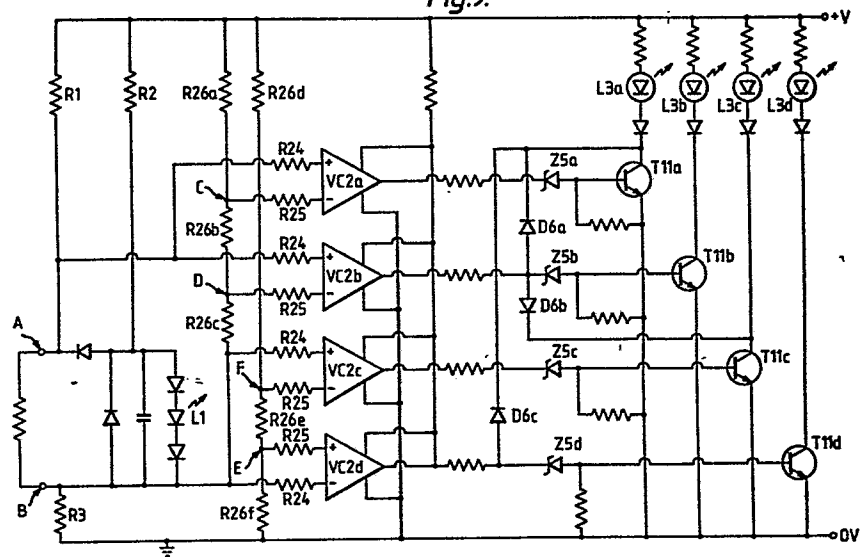
(54) Trip apparatus.

(57) In trip apparatus of the type wherein a trip signal applied to the trip apparatus inputs by an input field circuit causes the output signal, applied by the trip apparatus outputs to the output field circuit, to change the 'health' of the input and/or output field circuits is monitored to detect malfunction, or potential malfunctions, resulting from e.g. abnormal field circuit resistance, earth leakage and/or application of high voltages, by monitoring the potential difference across the trip apparatus inputs and/or outputs and/or between said inputs and/or outputs and earth, so that an alarm signal is given should the monitored potential difference vary from within preset limits.

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Fig.9



Trip apparatus

This invention relates to a trip apparatus. In the operation of machinery, chemical or other processes, it is often desirable to monitor a parameter, e.g. temperature, pressure, 5 degree of travel, so that, when the parameter reaches a predetermined value, a device, e.g. a valve, motor, or brake, is operated. For simplicity we will hereinafter refer to the device as a solenoid although it will be appreciated that a wide range of other devices could be employed.

10 In particular a trip system of high reliability is required to enable shut-down or modification of the operation in the event of said monitored parameter reaching e.g. as a result of failure or malfunction of equipment, a predetermined limit for safe operation.

15 Sophisticated electrical trip systems of high internal reliability are known. However we have found that the majority of faults in trip systems, often resulting in operation of the solenoid even when the monitored parameter has not reached the predetermined value, occur in what is hereinafter termed the field 20 circuits, i.e. the circuit, including the monitoring means, connected to the trip system input and the circuit, including the solenoid, connected to the trip system output. Thus short or open circuits, earth leakages, accidental application of high voltages, may result in malfunction of the input circuit, either giving a false indication 25 of the parameter reaching the predetermined level, with consequent tripping of the system and operation of the solenoid, or with the

risk that should the parameter being monitored reach the predetermined value, the malfunction of the input circuit will result in no actuating signal being received by the trip system and consequently no operation of the solenoid. Likewise faults in the
5 output circuit, e.g. short or open circuits may cause premature operation of the solenoid or the risk of non-operation thereof in the event of a genuine trip signal being received by the trip system.

The trip system of the present invention is of the type
10 wherein an input field circuit is connected to the input terminals of a trip apparatus which forms the rest of the input circuit. The trip apparatus in turn has output terminals, for connection to complete an output field circuit. Normally the input and output terminals of the trip apparatus provide the power source for supply-
15 ing electrical current to the input and output field circuits. When the parameter being monitored reaches its predetermined trip value, a signal in the input circuit reaches a predetermined level which then causes a signal in the output circuit to change.

In the correct functioning of the trip system when no
20 trip signal has occurred the potential difference across the input terminals of the trip apparatus, and the potential difference between the input terminals and earth will lie within preset limits. On production of a trip signal one or more of these potential differences will change. Malfunction of the input field circuit, e.g.
25 as a result of accidental application of high voltages, earth leakage, abnormal field circuit resistance, will cause these potential differences to vary from these preset limits. Likewise malfunction of the output field circuit, e.g. abnormal field circuit resistance will cause the potential difference across the output terminals,
30 and/or between the output terminals and earth to vary from preset limits. If these potential differences are monitored, in effect the "health" of the appropriate field circuit is monitored.

In the present invention the potential difference across the input terminals and/or between the input terminals and earth
35 and/or across the output terminals and/or between the output

terminals and earth are continuously monitored, so that if the monitored potential difference varies from preset limits, an alarm signal is generated.

- Accordingly the present invention provides a trip
- 5 apparatus for operating a device when a monitored parameter reaches a predetermined trip value comprising
- (i) input means for connection to an input field circuit which, together with said input means, forms an input circuit for receipt of an electrical input
10 signal from means monitoring said parameter,
 - (ii) output means for connection to an output field circuit which, together with said output means, forms an output circuit for providing an electrical output signal to said device which is
15 arranged to operate when the output signal has a predetermined trip value,
 - (iii) means to change the output signal to its trip value when said input signal has a value indicative that the monitored parameter has reached its predetermined trip level,
20
 - (iv) means for continuously monitoring at least one of
 - (a) the potential difference across said input means,
 - (b) the potential difference between said input
25 means and earth,
 - (c) the potential difference across said output means,
 - (d) the potential difference between said output means and earth, and
 - 30 (v) means responsive to said monitored potential difference to provide an alarm signal should said monitored potential difference vary from within preset limits, variation of said monitored potential difference to outside said preset limits being indicative of malfunction or potential malfunction of the appropriate field
35 circuit.

The trip system is preferably of the fail-safe type wherein, in the non-tripped condition, the input and output signals are not zero and change, e.g. decrease, when the system is tripped. The means monitoring the parameter preferably includes a pair
5 of contacts connected in series with the input field circuit with the contacts closed in the non-tripped condition. In this case monitoring the potential difference across the input means enables high contact resistance, i.e. a malfunction, to be detected.

10 The apparatus may also be arranged for use with an input field circuit producing an analogue signal, i.e. a signal that increases, or decreases, gradually as the monitored parameter approaches its trip value.

The trip apparatus may be arranged for use with more
15 than one input circuit and/or more than one output circuit. In this case the health of the field circuit of at least one input and/or output may be monitored.

As will be explained hereinafter, the means for monitoring the potential differences are preferably substantially isolated,
20 e.g. by high impedances, from the main trip circuit so that alarm signals indicating malfunction of the input and/or output field circuits do not interfere with the operation of the main trip circuit, and cause unnecessary operation of the solenoid.

It will be appreciated that the potential difference
25 across the terminals need not be monitored directly: thus the potential difference between one terminal and earth may be monitored and compared with the potential difference between the other terminal and earth. Likewise since the potential difference across a pair of terminals is dependent on the current flowing in the circuit includ-
30 ing those terminals, the potential difference across the terminals may be monitored by monitoring the potential difference across another component in the circuit.

In a complex system, as may often be employed in a chemical plant, input signals may be obtained from several parameter
35 monitoring means. Thus several parameters may each be monitored and

the system tripped should any one or more of said parameters reach its predetermined value. In other cases it may be desired to trip the system only if two or more parameters reach their predetermined levels.

5 Alternatively or additionally, it may be desired to have a plurality of means monitoring the same parameter and the system arranged to trip when any particular combination of one or more of the monitoring means is activated. For example three devices responsive to the same parameter may be employed and the
10 system arranged to trip when

- (a) any one,
- (b) any two, or
- (c) all three devices actuate.

By this means it can be arranged that malfunction of one or more
15 of the parameter monitoring devices will, or will not, as may be the case, cause the system to trip.

Likewise it may be desirable to have a plurality of output circuits, each controlling the operation of one or more process modifying devices, e.g. solenoids. Furthermore it may be desired
20 to operate one or more solenoids when one monitored parameter, or combination of parameters, trips, while when another parameter, or combination of parameters, trips another solenoid, or combination of solenoids, is actuated.

In the following embodiment of the invention circuitry
25 enabling such arrangements to be achieved, together with various safety devices, is described with reference to the accompanying circuit diagrams Figures 1 to 14.

The trip system is built up on a modular solid state system comprising a plurality of printed circuit cards, bearing
30 the appropriate solid-state circuits, which can be inserted into slots in racks provided with points for connection to the appropriate input and output field circuits.

There are three basic types of cards, primary cards, matrix cards, and secondary cards. However, as will be described
35 hereinafter, further cards termed inter-trip cards may be employed

in some cases.

For convenience the trip circuit will be described first, together with various refinements, followed by a description of the circuits for monitoring the field circuit health.

5 The primary cards contain part of the trip circuit and the input field circuit monitoring circuit. The secondary cards contain the remainder of the trip circuit and the output field circuit monitoring circuit. The matrix cards act as a means for connecting in a desired combination the outputs from the primary
10 cards to the inputs of the secondary cards.

POWER SUPPLY

The illustrated embodiment is designed to operate from a nominal 50 volts supply obtained from either a battery or from a 3 phase full-wave rectified AC supply; the supply negative is
15 earthed. The nominal value of 50 volts was chosen as it represents a good compromise between higher voltages which introduce personnel safety problems and lower voltages which introduce problems such as voltage drops in cables and the long term deterioration of initiating contacts.

20 The system has been designed to accommodate DC supply varying between 42 and 57 volts, thus avoiding the complications of constant voltage supply systems.

Operation on rectified AC may be used in systems where plant shutdown due to loss of mains supply would not be serious
25 or where independent supplies of acceptable reliability are available. No smoothing is required so avoiding the need to use large electrolytic capacitors and their inherent unreliability.

As will be described hereinafter, transient loss of supply has been catered for; the system will withstand inter-
30 ruptions in supply of up to 250 milliseconds (ms).

PRIMARY CARD TRIP CIRCUIT

The basic primary card trip circuit is shown in Figure 1 and employs an optical-electrical coupling comprising a light-emitting-diode (LED) L1 coupled to a photosensitive transistor T1.

35 The input circuit field circuit, i.e. that within dotted

box I contains a pair of contacts IC, termed initiating contacts, which open when the parameter being monitored reaches its pre-determined value. During normal, i.e. non-tripped, operation the initiating contacts IC are closed, diverting current from
5 the LED L1 of the opto-coupler L1, T1. This causes transistors T1 and T2 to remain off, i.e. non-conducting; R5 holds down the base of transistor T3 which is thus also switched off. Since no current flows through T3, the potential difference (p.d) across R6 is zero so the output is at the line voltage of e.g. 50v.

10 When the initiating contacts IC open, i.e. the system trips, R2 charges C1 until L1 conducts and opto-couples a signal to switch on T1. R1 and R3 allow the voltage at the contacts IC to reach about 40 volts to keep the contacts clean. The switching on of T1 causes T2 to switch on driving current into the base
15 of T3 thereby switching on T3. The p.d across T6 increases and so the output voltage drops to approximately 1 volt. This is the trip condition. Zener diode Z1 is provided to protect T1 from excessive voltages.

A normally closed defeat switch DS, usually remote from
20 the primary card, is provided so that the output can be maintained when DS is opened even though the initiating contacts are open. This is of use when it is required to test or replace the means monitoring the parameter: it may also be required to be operated when the process covered by the whole trip system is being started
25 up or changed from one mode of operation to another.

The defeat switch DS is in series with the output and operates by not allowing T3 to pass current when its contacts are open. This causes the output to remain high, i.e. the 'normal' condition. An LED L2 local to the defeat switch indicates when
30 the primary card is defeated and extinguishes when the defeat switch is closed.

In Figure 2 a modification of the circuit of Figure 1 is shown to provide for the use of more than one input field circuit to the card. In the embodiment illustrated, three inputs are used
35 and arranged so that the system trips only when two or more of the

inputs become open circuit, e.g. as a result of the initiating contacts of two of the inputs opening. For this system the portion of Figure 1 within Box II is repeated three times but for simplicity only T1, T2 and R4 thereof are shown in Figure 2.

5 The emitters of the three transistors T2a, T2b, and T2c, all drive into a common resistor R7. When one initiating contact opens, say that of circuit a, T2a will conduct and drive a current "i" mA through R7 producing "x" volts across it. When two initiating contacts open, say those of circuits a and b, T2a and T2b will each conduct and each drive i mA through R7 producing 2x volts across it. Similarly when all three contacts open 3x volts is produced across R7. The voltage across R7 is compared with say 1.5x volts, produced by potential divider R8, R9, by a voltage comparator VC 1. The output of VC 1 is low when 0 or 1
10 contacts are open and high when 2 or 3 contacts are open.

It will be seen that the comparator VC 1 is looking at the corners of a bridge so that the circuit will operate for any value of supply voltage.

The output of the comparator VC 1 is fed via a zener diode Z2 and current limiting resistor R10 to drive the base T3.
20

Since the 'low' output of the comparator VC 1 has a value somewhat above 0 volts, the zener diode Z2 is required to ensure that T2 is switched off when the comparator's output is 'low'.

25 It can be seen that, by changing the comparator reference level, it is possible to use the card for the following logic options in addition to any two out of three.

- (i) any one out of three
- (ii) all three

30 Further logic functions e.g. a and b; a and c; b and c; can be achieved by changing the values of R4a, R4b, R4c appropriately.

In Figure 3 another modification of the circuit of Figure 1 is shown to provide for a time delay where it is desired that a trip will only occur if the initiating contacts have remained open for a
35 continuous pre-set time 't'. If the contacts close before 't' has

elapsed the system will reset so that if the contacts then re-open, the previous portion of time 't' that the contacts were open is not counted towards the period 't'. This is achieved by interposing a timer chip TC between T2 and T3. It will be appreciated that this time delay may also be used in the modification of Figure 2. In this case the timer TC is interposed between the comparator VC1 and T3. Input to the timer is via potential divider R11, R12. This provides the correct input voltages for the timer from all options.

10 The duration of 't' can be preset e.g. by selection of a suitable value for the timing capacitor C2.

Careful design of the primary card layout permits the same printed circuit to be used for the various options. Different options are achieved by including extra components and using different values of resistors.

MATRIX CARDS

These enable a number of primary cards, e.g. up to 20, to be connected with a number of secondary cards, e.g. up to 16. The matrix card is illustrated by Figure 4 and consists of a double sided printed circuit board having vertical input tracks on one side and horizontal output tracks on the other connected to input and output pins respectively.

Each input pin of the matrix card is wired to an individual input slot in the rack. Each output of the matrix card is connected to two pins; one pin is wired to an output slot in the module; the other pin may be wired to the appropriate channel on an inter-trip card as described hereinafter.

The output of each primary card is connected to an input pin of the matrix card and the input to each secondary card is taken from an output pin of the matrix card. Holes are drilled in the board to allow connections, via diodes, to be made between input tracks and output tracks. Where it is desired that a particular input should, when tripped, provide a trip signal to any particular secondary card, a diode is connected between the respective input and output tracks of the matrix card where they intersect. Thus

in the example shown in Figure 4, three inputs A - C and three outputs D - F are shown. It is desired that a signal from input A provides a signal to output E, that a signal from input B also provides a signal to output E, and that a signal from input C provides a signal to both outputs D and F. Diodes are thus connected between tracks A and E, B and E, C and D, and C and F. Thus the solenoid operated by output E will operate if a trip signal is produced by either of inputs A and B while the solenoids operated by outputs D and F will both operate if a trip signal is given by input C.

SECONDARY CARD TRIP CIRCUIT

The secondary card contains the remainder of the trip circuit and is arranged to:

- (a) To latch 'off' when it receives a trip signal from the matrix card.
- (b) To latch 'off' if its output current exceeds a certain value, e.g. 5A indicative of a short circuit in the output field circuit.
- (c) To survive an interruption of supply voltage for up to e.g. 250 ms but then to latch 'off' if the interruption continues, and remain latched 'off' when the supply is restored.
- (d) To remain latched 'off' when the secondary card is inserted into the rack.
- (e) To latch 'on' only when it receives a fleeting signal from its reset switch and there is no trip signal from the matrix card.

The circuit is shown in Figure 5. The latching action is provided by means of a thyristor T5. The trip signal received by the input of the secondary card via the matrix card from the output of a primary card is a reduction in the voltage, normally to a value of less than 2 volts, from the normal, i.e. non-tripped, line voltage. The input to the secondary card includes an input filter R13, C3, R14, C4 which requires the input signal to persist for nominally 5 ms before the card latches 'off'. The input filter

immunity against spurious electrical signals.

As the filter capacitors C3, C4 are charged, the voltage at the junction of R14 and R15 drops with respect to the +V rail. When this voltage reaches 10 volts below the supply voltage,

5 zener diode Z3 conducts and current flows through R15. As the voltage at the junction of R14 and R15 drops further, the current through R15 increases causing the voltage at the junction of R19 and the base of transistor T4 to fall until transistor T4 conducts.

10 T4 drives current into the R16, C5 filter at the gate of thyristor T5 which switches on. This filter at the gate is to prevent firing of the thyristor by spurious electrical signals.

T5 conducting clamps the base of transistor T6 to 0 volts and T6 switches off. This removes the base drive to transistor T7
15 which also switches off. This removes the base drive from the output transistor T8 which, in turn, switches off and de-energises the output to the output field circuit containing solenoid SV. T7 switching off also 'starves' thyristor T5 of holding current thereby switching it off.

20 The circuit is now in a stable latched 'off' condition. Removal of the trip input signal will only remove the gate signal to thyristor T5; this has no effect as T5 has switched off due to lack of holding current.

To provide a latch 'off' when an excessive current passes
25 through the output field circuit, two 1 ohm resistances R17, R18 are connected in parallel to provide a resistance R_p of about 0.5 ohm in line with the output of transistor T8. As the current through the output field circuit, and hence through T8 increases, the p.d across R_p (i.e. R17, R18) increases which causes the voltage at the base of T8 to drop.
30

As the p.d across R_p increases, current will start to flow through R19, Z4, D1, until T4 is switched on. This causes the output to latch 'off' in the same way as would a trip input signal.

35 In the event of the output being short circuited, C6

limits the rate of rise of current through T8 by diverting its base current as the voltage at the base of T8 falls. This continues until T8 current reaches 5 amps; D1, Z4 and T4 then conduct enough to switch on T5 on the output is latched 'off' in the usual way. The time delay in this mode is about 250 - 300 micro seconds; this is long enough to prevent spurious operation of the overcurrent trip, but will not drive T8 into the secondary breakdown area of its operating characteristic.

To provide for interruption in the power supply, C7 provides base current to hold T6 switched on if the supply is interrupted. C7 is sized to allow for an interruption of 250 ms; if the supply interruption lasts longer than this, C7 will become discharged and T7, T6 will switch "off", causing latching "off".

If power returns within the 250 ms delay, T6 would remain switched on and would reset T7 and T8 as described hereinafter.

If the output from the secondary card has been tripped, it is necessary to reset the trip system.

When the reset switch RS contacts (normally closed) are opened, C8 is charged via field effect transistor T9 and provides a signal to the base of T6 which starts to conduct. T6 conducting provides base drive to T7 which switching on provides base drive to T8 and feedback to T6. Thus T7, T6 form a positive feedback loop and rapidly latch themselves on. T8 then has a continuous base drive and the output is latched 'on'.

Once C8 is fully charged, no further signal can be coupled through it to T6; thus the reset switch must be closed again before it can re-operate. This ensures that, if the reset switch or its connections has gone open circuit, reset will not automatically occur when the trip signal that causes latching 'off' is removed.

If the secondary card is latched 'on' and the reset switch is operated, there is no effect since T6 is already switched on.

Reset action must only occur when:

- (a) there is no input trip signal to the secondary card and

(b) the reset switch is operated.

If there is an input trip signal, T5 conducts and prevents this reset action.

If an output is latched 'off' it is important that the
5 output is not latched 'on' whenever a card that has been removed,
e.g. for replacement if faulty, is inserted into the rack. Latch-
ing 'on' under these circumstances is prevented by means of the
field-effect transistor T9 which causes the 50 volts supply only
to be applied slowly to the normally closed reset switch RS at a
10 rate determined by R20 and C9.

Should the reset switch RS, or its cabling, be faulty,
or the board connection to the switch RS not make until after the
0 volts and 50 volts connections, this slow rise of the 50 volts
is insufficient to couple through C8 to the base of T6 and latch
15 'on' the output.

Likewise, should the faulty cabling or switch be accom-
panied by a power failure of 1 second or more duration, re-estab-
lishment of the power does not reset the output latch.

Also incorporated on the secondary card there may be a
20 solenoid test circuit which is described in patent application
filed on the same day as this application bearing the
reference B 31785 and claiming priority from UK patent application
8111143. To provide for this facility relay contacts RL actuated
by the test circuit are provided to connect the base of T8 to the
25 line voltage, thus depriving T8 of base drive and so switching
T8 off.

INTER-TRIP CARDS

As mentioned hereinbefore, in addition to primary,
secondary, and matrix cards, there may also be inter-trip cards.
30 In any system there is a limit, presented by the number of input
and output tracks on a matrix card, on the number of primary
cards that can be coupled to secondary cards, and vice versa.
Inter-trip cards may be provided to enable a trip signal from
an output of a matrix card to be used as a trip signal for the
35 input of another primary card connected, for example, via another

matrix card, to further secondary cards.

This arrangement is shown in Figure 6. Primary card 1, and/or other primary cards, drives secondary card 2 via the matrix card 3; the drive to secondary card 2 is also connected via the
5 inter-trip card 4 to primary card 5.

In normal operation, the drive to secondary card 2 and the input to the inter-trip card 4 are high, since the transistor T3 on the primary card 1 is off. Thus base current is fed to transistor T10 via R21 and R22. T10 is connected to the positive
10 and negative power rails by the input resistors R1, R3 of primary card 5 and thus a complete circuit is formed. T10 is switched hard on by the base drive through R21 and R22, and acts as a closed switch across the input terminals of primary card 5.

Transistor T3 on primary card 1 switching on pulls the
15 input to the inter-trip card 4 low via the appropriate matrix diode D2, and so the voltage at the intersection of R21 and R22 drops to about 2.5 volts, which is lower than the voltage at the junction of T10 and R3 of primary card 5. Transistor T10 is thus switched off. T10 thus acts as open contacts for primary card 5
20 and allows its opto-coupler LED L1 to conduct. This maintains the voltage at the junction of T10 and R3 of primary card 5 at about 7 volts and thus ensures that T10 is held switched off. Diode D3 protects the base-emitter of T10 from excessive reverse voltage.

Since the input of the inter-trip card 4 is connected to
25 the input of the secondary card 2, diode D4 is provided to isolate the cards when the drive to secondary card 2 is high, i.e. when there is no trip signal fed from primary card 1.

Inter-trip cards may also be employed to enable a trip signal from the output of a secondary card to be used as a trip
30 signal, often via a time delay, for another primary card: in this way two solenoid valves can be de-energised, the second a set time interval after the first. This can be achieved by using the inter-trip card as shown in Figure 7. The output drive to the first solenoid valve SV is taken from secondary card 6, via the inter-
35 trip card 7, to a primary card 8 which carries the timer option

previously described with reference to Figure 3. A further secondary card, actuated by primary card 8, then de-energises the second solenoid valve after the time interval set on the timer. This takes advantage of the latching action of the first secondary card 6 to prevent the timer being reset by the initiating contacts, here provided by the inter-trip card 7 driven by secondary card 6, closing. In this form of the inter-trip card a resistor, R23, replaces diode D4, and R21 is removed. With the solenoid valve energised, the base drive to T10 is supplied via T8 on the secondary card 6.

De-energising the solenoid valve SV, i.e. tripping of secondary card 6, removes the base drive to T10 and the circuit functions as described above.

PRIMARY CARD FIELD CIRCUIT MONITORING

The monitoring circuits on both primary and secondary cards involve the use of bridge circuits with a voltage comparator 'looking' at the corners of the bridge. The use of a bridge is desirable to minimise the effect of fluctuations in the supply voltage.

The comparator is well buffered i.e. substantially isolated from the main trip circuits, by using large value input resistors: this is to prevent any fault in the monitoring circuits from affecting the correct operation of the trip circuit.

Each primary card is provided with a number of monitoring circuits, each generally of the type shown in Figure 8, taking a monitoring voltage from a desired position in the circuit of Figure 1, via a high resistance R24, to a voltage comparator VC2 wherein it is compared, via a resistance R25, with reference voltage obtained from a potential divider R26m, R26n. Under normal operating conditions, the output from the comparator VC2 is low, below the threshold voltage of zener diode Z5 and so transistor T11 has no base drive. A change in input conditions causing the comparator VC2 to switch over causes transistor T11 to switch on. This allows current to flow through the LED L3 which lights and through isolating diode D5 from any extra outputs, e.g. alarm bells.

In Figure 9 the input field circuit monitoring circuits on the primary card are shown in more detail.

The field wiring has a resistance and opening or closing of the initiating contacts, or faults in the field circuit, in effect vary the field circuit resistance. In Figure 9 therefore, the initiating contacts have been replaced, for ease of explanation, by a resistance R_f denoting the field circuit resistance.

When a current flows through the field wiring/initiating contact combination, i.e. when there is no trip signal, a potential difference will be developed across the input to the primary card, and, because of R_3 , between the inputs and earth. Therefore monitoring the potential difference between points A and B and between point B and earth (see Figure 9) enables the state, i.e. the "health" of the input field circuit to be monitored.

The potential difference across the inputs, i.e. between points A and B is monitored by comparing the voltage at point A with reference voltages obtained from potential dividers (R_{26a} , $R_{26b} + R_{26c}$) and ($R_{26a} + R_{26b}$, R_{26c}) connected between the positive rail and point B.

R_{26a} is made N times R_2 (R_1 - see Figure 1 - is much greater than R_2) and R_{26b} and $R_{26b} + R_{26c}$ are selected to be N times the field circuit resistance limits that are indicative of normal, i.e. non-tripped, resistance and high, but not open-circuit, resistance respectively. R_2 and R_{26a} are selected so that R_{26a} is much greater than $R_{26b} + R_{26c}$. Typically a normal, non-tripped, field resistance would be less than 30 ohms which is a nominal value corresponding to approximately 50 m of 0.75 sq mm or 1000 m of 1.5 sq mm cable. However, in the event of the input field circuit resistance R_f increasing, e.g. as a result of high contact resistance at the initiating contacts, the voltage at point A will rise. The voltage V_a at point A is thus compared, by comparator VC2a with the voltage V_c at point C and, by comparator VC2b with the voltage V_d at point D.

Since $R_{26a} \gg R_{26b} + R_{26c}$

if $V_a = V_c$

$$R_f \approx \frac{R_2}{R_{26a}} (R_{26b} + R_{26c})$$

and, if $V_a = V_d$

$$R_f \approx \frac{R_2}{R_{26a}} (R_{26c})$$

Hence

- 5 (i) if $V_a < V_d$, the output of comparator VC2b is low, causing T11b to remain off, and hence LED L3b unlit, indicating "normal" field resistance with the initiating contacts closed.
- (ii) if $V_d < V_a < V_c$, the output of VC2b is high, causing LED
10 L3b to light, but the output of VC2a is low.
- This is indicative of high, but not open circuit, input field circuit resistance.
- (iii) if $V_a > V_c$, the outputs of both VC2a and VC2b are high,
15 indicative that the input field circuit resistance is above a predetermined level assumed, for monitoring purposes, to denote that the initiating contacts have opened. Since, in this case, it is desired that only L3a lights, diode D6a is provided to divert the "high" output of VC2b to the collector of the conducting
20 transistor T11a so that the threshold voltage of zener diode Z5b is not reached, and so transistor T11b does not conduct.

Any shunt resistance to ground, i.e. earth leakage, will cause a lower p.d. between the initiating contacts and earth, and
25 consequently between point B and earth. A monitoring circuit is thus provided to compare the voltage at point B with that at point E created by the potential divider $R_{26d} + R_{26e}$ and R_{26f} . The comparator VC2d of this monitoring circuit is arranged to change state to a high output, causing L3d to light when an earth leakage
30 equivalent to a shunt resistance of, for example 15 kohms appears between point B and earth. This gives adequate warning as a trip will not be prevented, if suitable values are chosen for R_2 and R_3 , until a much lower shunt resistance, e.g. 250 ohms, has developed.

35 When the initiating contacts open, the voltage at point B

will also drop, causing comparator VC2d to give a "high" output. Since, in this case, it is not desired that the "earth leakage" LED, L3d should light, the "high" output of VC2d is diverted by diode D6c to the collector of T11a which will be conducting if the initiating contacts are open. Hence T11d is prevented from conducting.

The input circuit is not completely immune to high common mode voltage (CMV) and warning of the onset of this is provided. In normal operation point B is held at a suitable voltage, e.g. about 8 volts, above ground potential by R3. A "High Voltage" monitoring circuit therefore compares the voltage at point B with the voltage at point F created by the potential divider R26d and R26e + R26f. The comparator VC2c of this circuit gives a "high" output, causing L3c to light, at a positive CMV of greater than about 4 volts with respect to point B. The 'Earth Leakage' comparator can also detect a negative CMV of greater than about 0.5 volts with respect to point B. AC CMV greater than about 4 volts peak-to-peak would cause both LEDs L3c and L3d to be lit. A positive CMV applied to the input field circuit will also cause the voltage at point A to increase which could cause comparator VC2b, to give a high output. Hence, to avoid the "high resistance" LED L3b lighting, the "high" output of comparator VC2b is diverted, via diode D6b, to the collector of transistor T11c which will be conducting if a CMV is present. T11b is thus disabled.

When the circuit is operating normally with no trips, the base of the output transistor (T3 Figure 1) is held at ground. When a trip occurs, current is fed into the base and it rises above ground potential. This change is used to switch a comparator circuit of the type shown in Figure 8 monitoring the voltage at point G to illuminate a "Trip output" LED.

When the defeat switch DS is opened, the output transistor T3 is no longer connected to ground via the isolating diode and the defeat switch DS and so the cathode of the diode is pulled to 50 volts. This change is used to switch a comparator circuit of the type shown in Figure 8 monitoring the voltage at point H and hence

illuminate a "Defeat" LED. As mentioned hereinbefore, a separate circuit, as shown in Figure 1, is used to provide an LED, L2, indication alongside the Defeat Switch DS which may be remote from the primary card.

5

SECONDARY CARD MONITORING

The monitoring circuits for "trip input" and "high" and "low" current in the output field circuit are shown in Figures 10 and 11 and are analogous to those of the primary card but compare the monitored voltage with a reference voltage given by a potential divider (R27, R28 Figure 10) or (R27, R28 + R29 or R27 + R28, R29 Figure 11) by a voltage comparator VC3. However since the comparisons are made with respect to the positive volts rail, a low output from the comparator VC3 causes a transistor T12 to conduct which thus supplies base drive to a second transistor T13 to cause the latter to conduct, thus illuminating LED L4.

15

The output signal from the matrix card is monitored at point J (Figure 5) by a monitoring circuit of the type shown in Figure 10. The LED L4 remains lit for as long as there is such an input signal to the secondary card, e.g. for as long as the initiating contacts causing the trip signal on the associated primary card remain open.

20

The monitoring circuit of Figure 11 is used to detect "high" and "low" current through the output field circuit, i.e. through solenoid valve SV. This current passes through the resistance Rp. The p.d. across Rp, i.e. at the point K (Figure 5) is monitored by the circuit shown in Figure 11 using reference voltages, obtained via potential divider R27, R28, R29 which are preset to suit the normal load current of the solenoid valve SV. Comparator VC3a lights its LED L4a when the current through Rp is low while LED L4b is lit when the current through Rp is high. When the current through Rp is normal, i.e. between the "high" and "low" limits, neither L4a nor L4b is lit.

25

30

The response of a secondary card to a trip signal is to de-energise the solenoid valve SV. When this happens the potential across the solenoid valve SV drops to zero. This potential is

35

monitored at point L (Figure 5) by a comparator circuit of the type shown in Figure 8. Zener diode Z6 (Figure 5) is present to limit the signal to the comparator VC2 of this monitoring circuit.

5 When "tripped", the "low current" LED L4a would also light. If desired this can be disabled via a diode D7 connected to the collector of the transistor T11 of the circuit monitoring "trip output" at point L. Where disablement of LED L4a is not required, zener diode Z6 can be omitted.

10 A closed reset switch RS holds the base of T14 (see Figure 5) near ground. T14 conducts and lights LED L5 when the reset switch or its associated wiring is open circuit.

Thus provision is made on the primary cards for monitoring the following "health" factors of the input field circuit.

- 15 (i) high resistance
 (ii) open circuit
 (iii) earth leakage
 (iv) high common mode voltage.

Also monitored on the primary card are

- 20 (v) trip output
 (vi) open "defeat" switch.

On the secondary card, provision is made for monitoring the following "health" factors of the output field circuit

- (vii) high current, i.e. low resistance
25 (viii) low current, i.e. high resistance

Also monitored on the secondary card are

- (ix) trip input
 (x) trip output
 (xi) open circuit reset circuit.

30 In the system described hereinbefore, the trip system is of the fail-safe type where a current flows through the input field and output field circuits in the non-tripped condition, and, on tripping, these currents decrease, generally to zero.

 In some cases however it may be necessary to use an input
35 field circuit having normally open contacts, i.e. having zero

current in the non-tripped condition.

In Figure 12 there is shown a modification of the primary card circuit that can be employed in such cases. On tripping, the initiating contacts IC close, shorting R30, and
5 so causing the voltage at point B to increase. This voltage increase can be used to generate the trip signal fed to the opto-coupler 11. Again the "health" of the input field circuit can be monitored by monitoring the voltages at points A and B. In this case however low input field circuit resistance can be
10 monitored, as well as earth leakage and CMV.

Similarly the secondary card circuitry can be modified, for example as shown in Figure 13, to provide for energising the output field circuit solenoid SV only in the event of a trip signal. In this modification, the output field circuit is con-
15 nected in parallel with output transistor T8 and an additional resistance R31. In the non-tripped condition T8 conducts and diverts current through R31 so that the residual current through the solenoid SV is insufficient to energise it. On receipt of a trip signal T8 switches off so removing the shunt and causing
20 the solenoid SV to energise.

Obviously, because of the need to make R31 small in relation to the output field circuit resistance and to avoid unnecessarily high currents through T8, R31, this circuit modification is more suitable for output field circuits having a
25 relatively high "normal" resistance.

Alternatively the circuit shown in Figure 14 could be used: here the secondary card circuit has to be modified (by means not shown) to provide that T8 is non-conducting in the non-tripped condition and switches on upon receipt of a trip signal.
30 When T8 is switched on, R32 is shunted thus allowing the current in the output field circuit to increase to energise the solenoid SV.

Since, in the non-tripped state, some residual current flows through the output field circuit in the embodiments of Figures 13 and 14, monitoring the voltage at point K enables the "health"
35 of the output field circuit to be monitored.

In a trip system having a plurality of input and/or output field circuits, it will be appreciated that some can be of the fail-safe type while others may be of the type wherein the field circuit current increases, or only flows, in the trip
5 condition.

In a trip system employing a plurality of input field circuits and/or a plurality of output field circuits, while it is preferred that in each input field circuit at least the resistance, and preferably at least also earth leakage, are monitored,
10 and in each output field circuit the resistance is monitored, it will be appreciated that it may not always be necessary to monitor these parameters in every input and/or output field circuit. In particular, where a further input "field circuit" is formed by the output of a primary or secondary card, e.g. where "inter-trip"
15 cards are employed as described above in relation to Figures 6 and 7 or directly by an output field circuit, monitoring of the "health" of this further input "field circuit" may not be necessary.

Normally one side of the output field circuit will be earthed, as shown in Figure 5, and so it is not necessary to
20 monitor the output field circuit for earth leakage. However, where the output field circuit is not earthed, as in the modification of Figure 13, but is maintained at a potential above earth by means of R33, earth leakage can be monitored by monitoring the voltage at point L.

25 The trip system may also be coupled to a computer in which a model of the whole trip system is carried: the computer may be arranged to check on the operation of the trip system by feeding a signal from the input monitoring circuits into the model and comparing the actual monitored output signals with those
30 predicted by the computer from the model contained therein.

1. Trip apparatus for operating a device when a monitored parameter reaches a predetermined trip value comprising
 - (i) input means for connection to an input field circuit which, together with said input means, forms an input circuit for receipt of an electrical input signal from means monitoring said parameter,
 - (ii) output means for connection to an output field circuit which, together with said output means, forms an output circuit for providing an electrical output signal to said device which is arranged to operate when the output signal has a predetermined trip value,
 - (iii) means to change the output signal to its trip value when said input signal has a value indicative that the monitored parameter has reached its predetermined trip level,
 - (iv) means for continuously monitoring at least one of
 - (a) the potential difference across said input means,
 - (b) the potential difference between said input means and earth,
 - (c) the potential difference across said output means,
 - (d) the potential difference between said output means and earth, and
 - (v) means responsive to said monitored potential difference to provide an alarm signal should said monitored potential difference vary from within preset limits, variation of said monitored potential difference to outside said preset limits being indicative of malfunction or potential malfunction of the appropriate field circuit.
2. Trip apparatus according to claim 1 in which the means for continuously monitoring said at least one potential difference comprises, for each monitored potential difference, a voltage

comparator which compares the monitored potential difference with a reference potential difference, and said means to provide an alarm signal comprises means responsive to the change in state of said voltage comparator as the monitored potential difference varies in relation to the reference potential difference.

3. Trip apparatus according to claim 1 or claim 2 in which, in the non-tripped condition, an electrical current flows through the input field circuit and changes when the monitored parameter reaches its predetermined trip value.

4. Trip apparatus according to any one of claims 1 to 3 in which, in the non-tripped condition, an electrical current flows through the output field circuit and changes, so as to actuate the device, when the monitored parameter reaches its predetermined trip value.

5. Trip apparatus according to any one of claims 1 to 4 wherein the potential difference across the input means is monitored to provide an alarm signal should the input field circuit resistance reach a predetermined value.

6. Trip apparatus according to any one of claims 1 to 5 wherein the potential difference between the input means and earth is monitored to provide an alarm signal should the earth leakage resistance fall below a predetermined value.

7. Trip apparatus according to any one of claims 1 to 6 wherein the potential difference between the input means and earth is monitored to provide an alarm signal should a voltage above a predetermined value be imposed upon the input field circuit.

8. Trip apparatus according to any one of claims 1 to 7 wherein the potential difference across the output means is monitored to provide an alarm signal should the current in the output field circuit vary from within predetermined limits.

9. Trip apparatus according to any one of claims 1 to 8 in which one side of the output means is earthed and means for monitoring the potential differences, and to produce alarm signals, are provided to monitor the potential differences across the input means, between the input means and earth, and across the output means.

10. Trip apparatus according to any one of claims 1 to 9 having a plurality of input and/or output means and the means for monitoring the potential differences and to produce alarm signals are provided to monitor the potential differences across each output means and across at least each input means whose input field circuit does not include the output means associated with another input means.

1/8
Fig. 1.

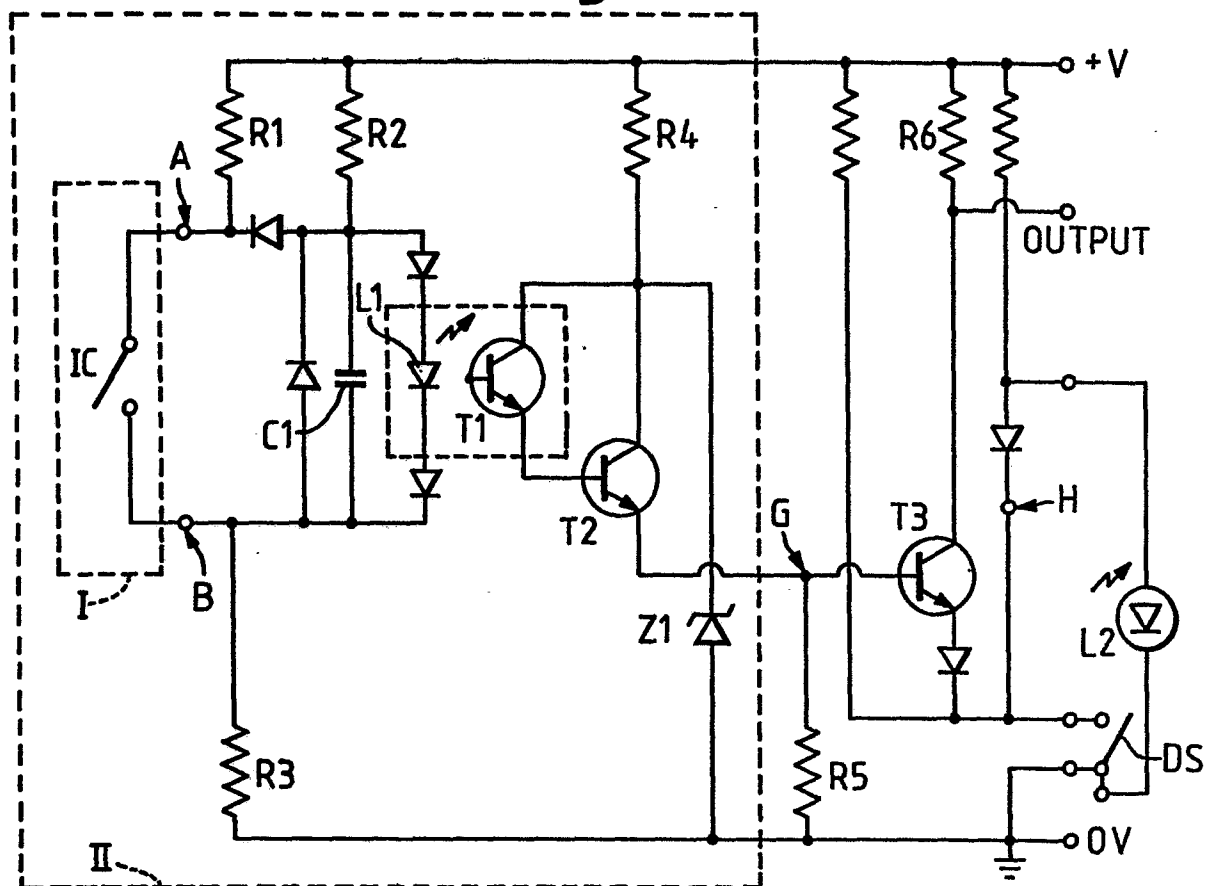
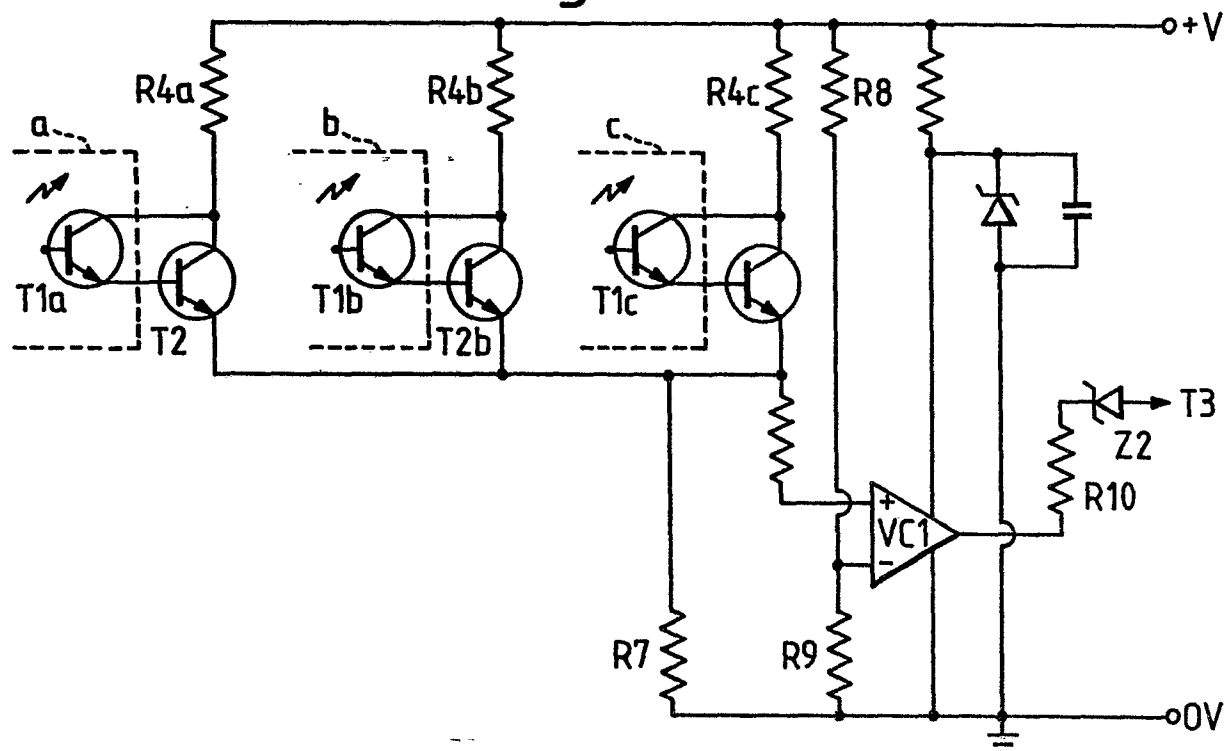


Fig. 2.



2/8

Fig.3.

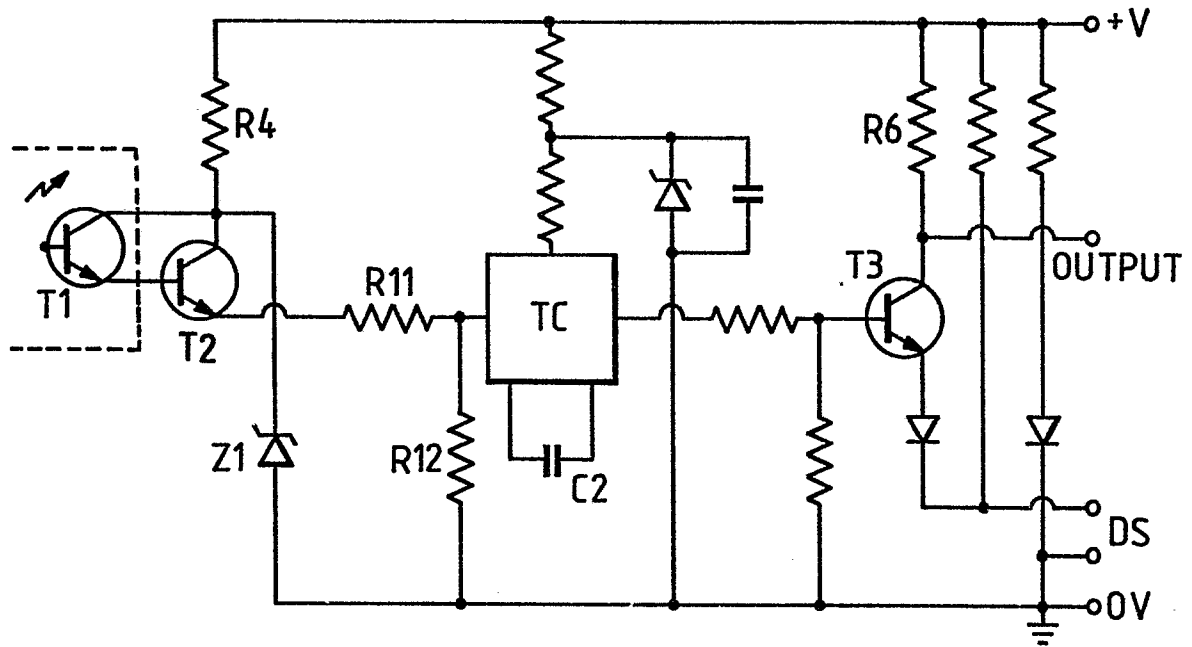


Fig.4.

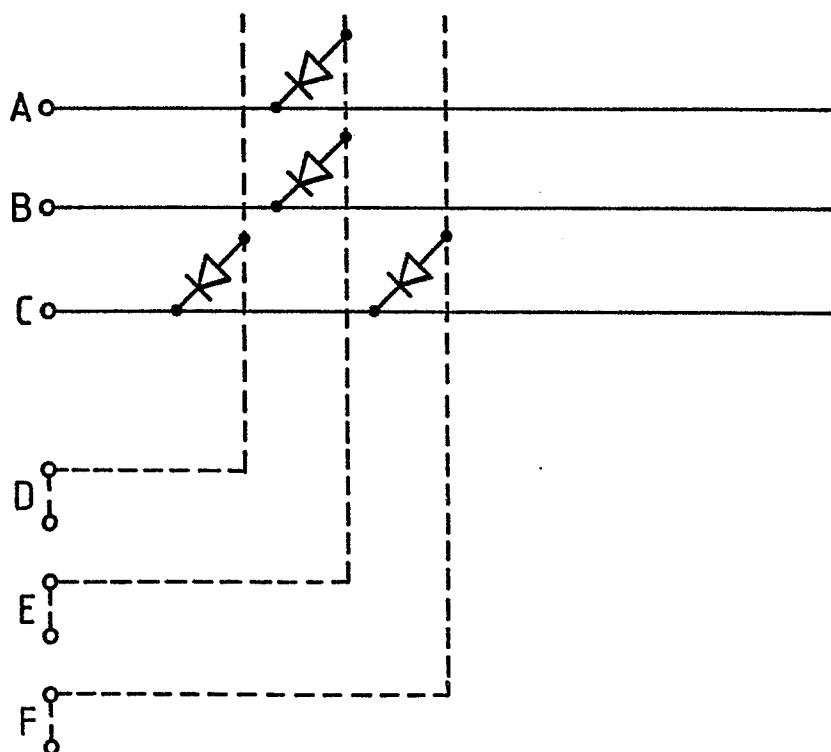


Fig.5.

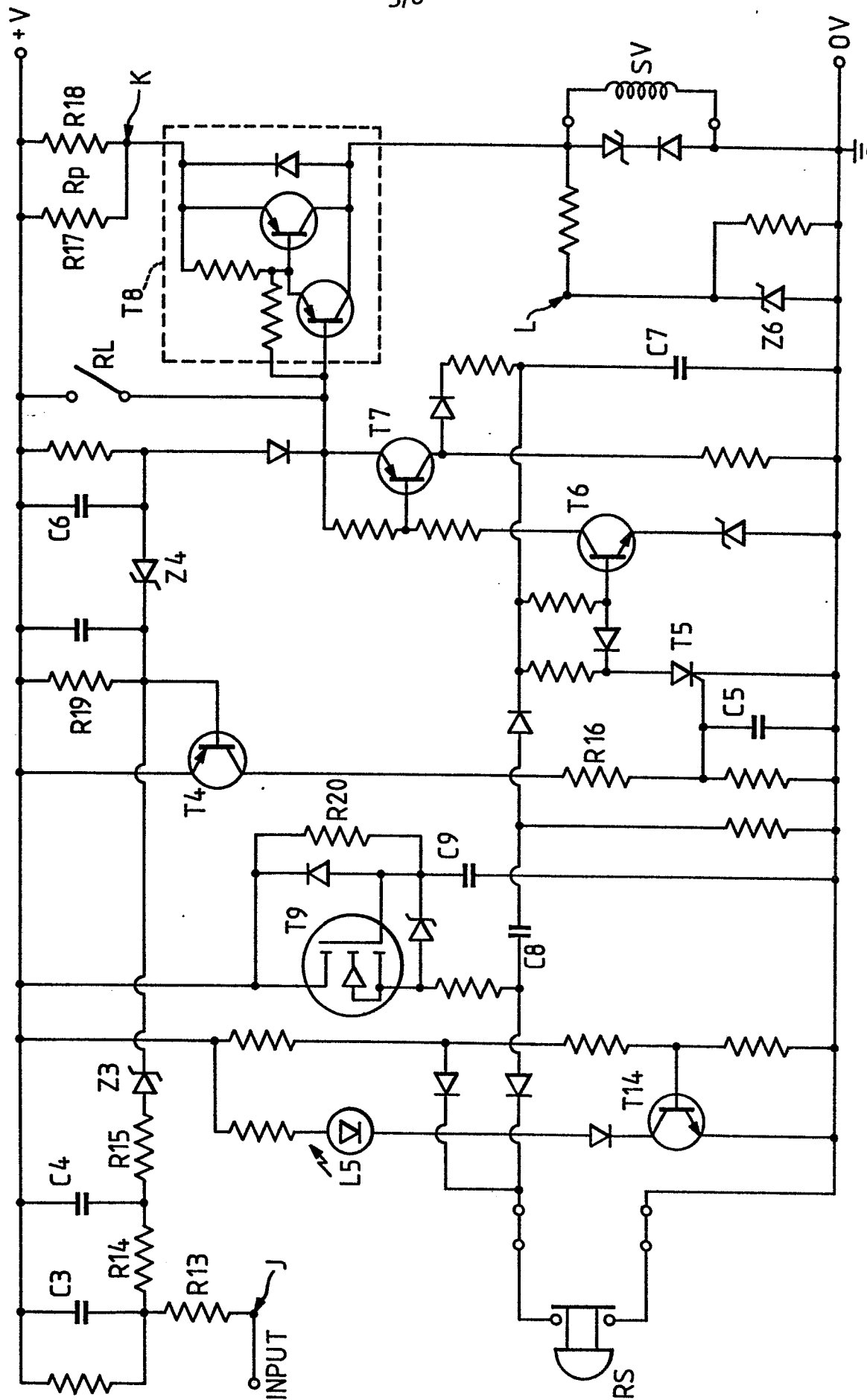
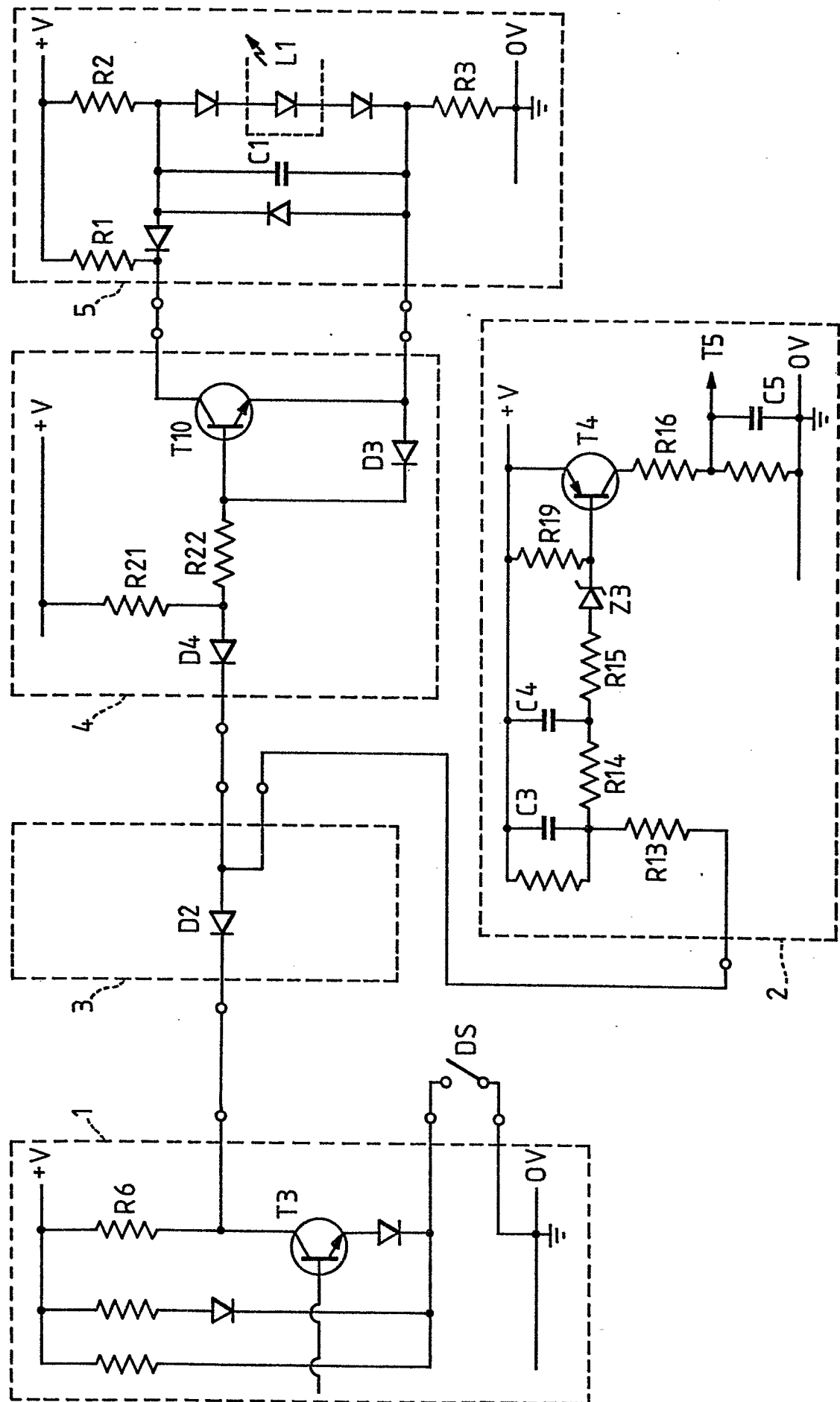


Fig.6.



5/8

Fig.7.

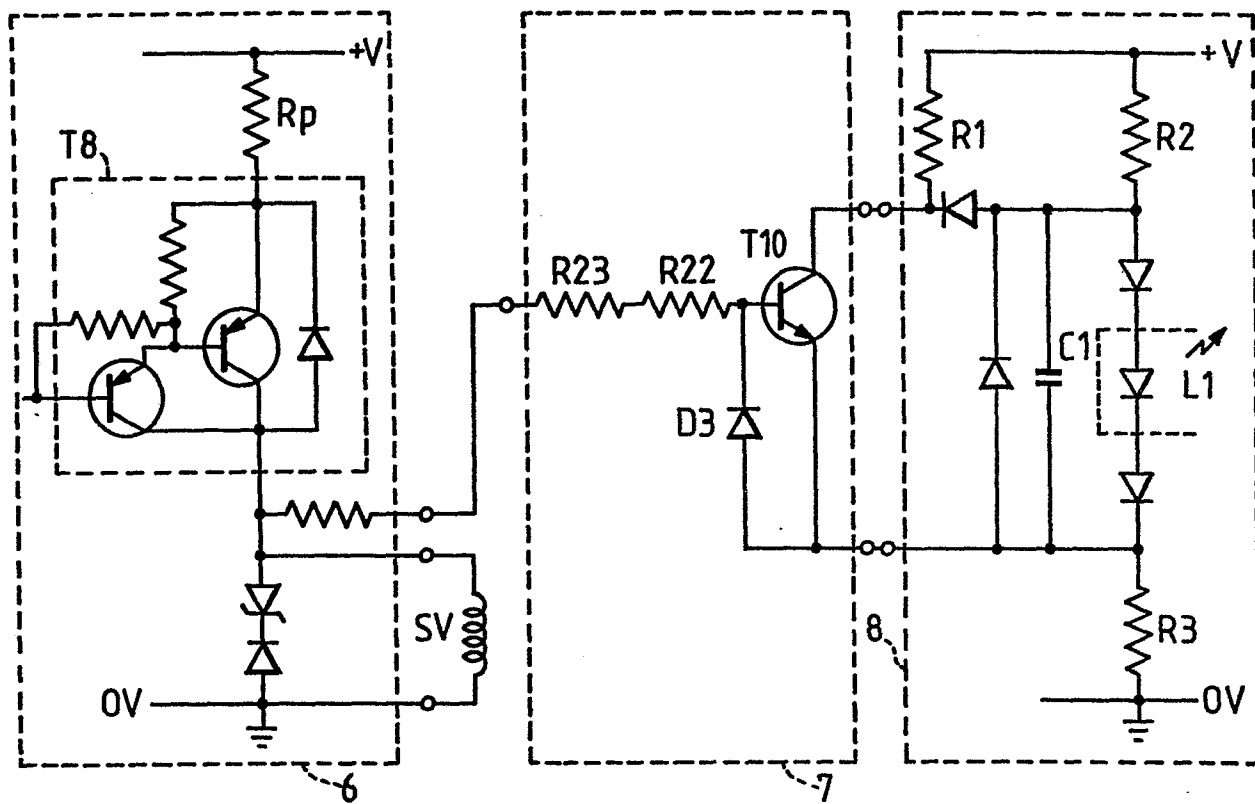


Fig.8.

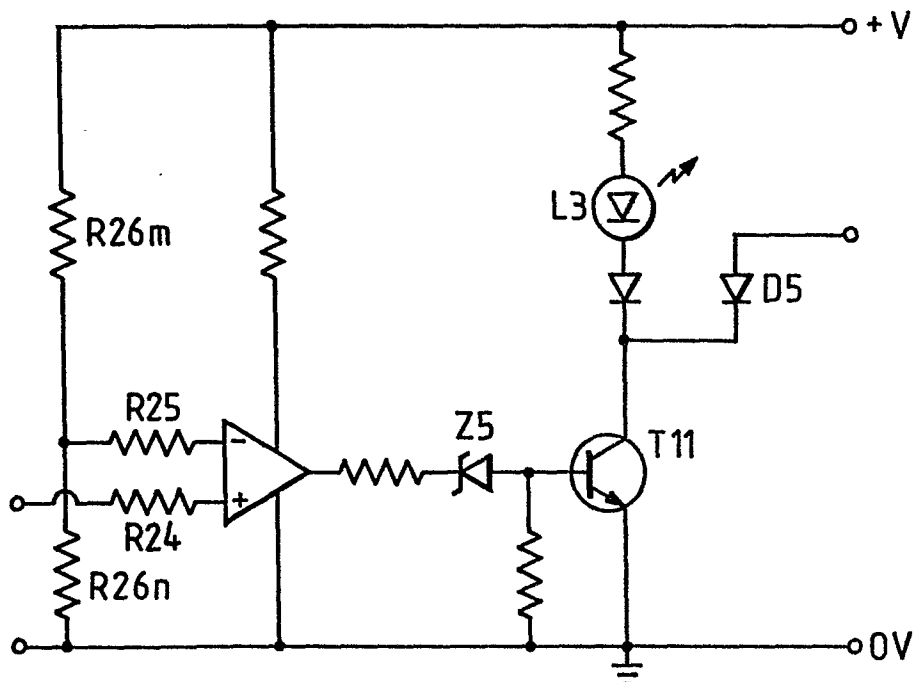
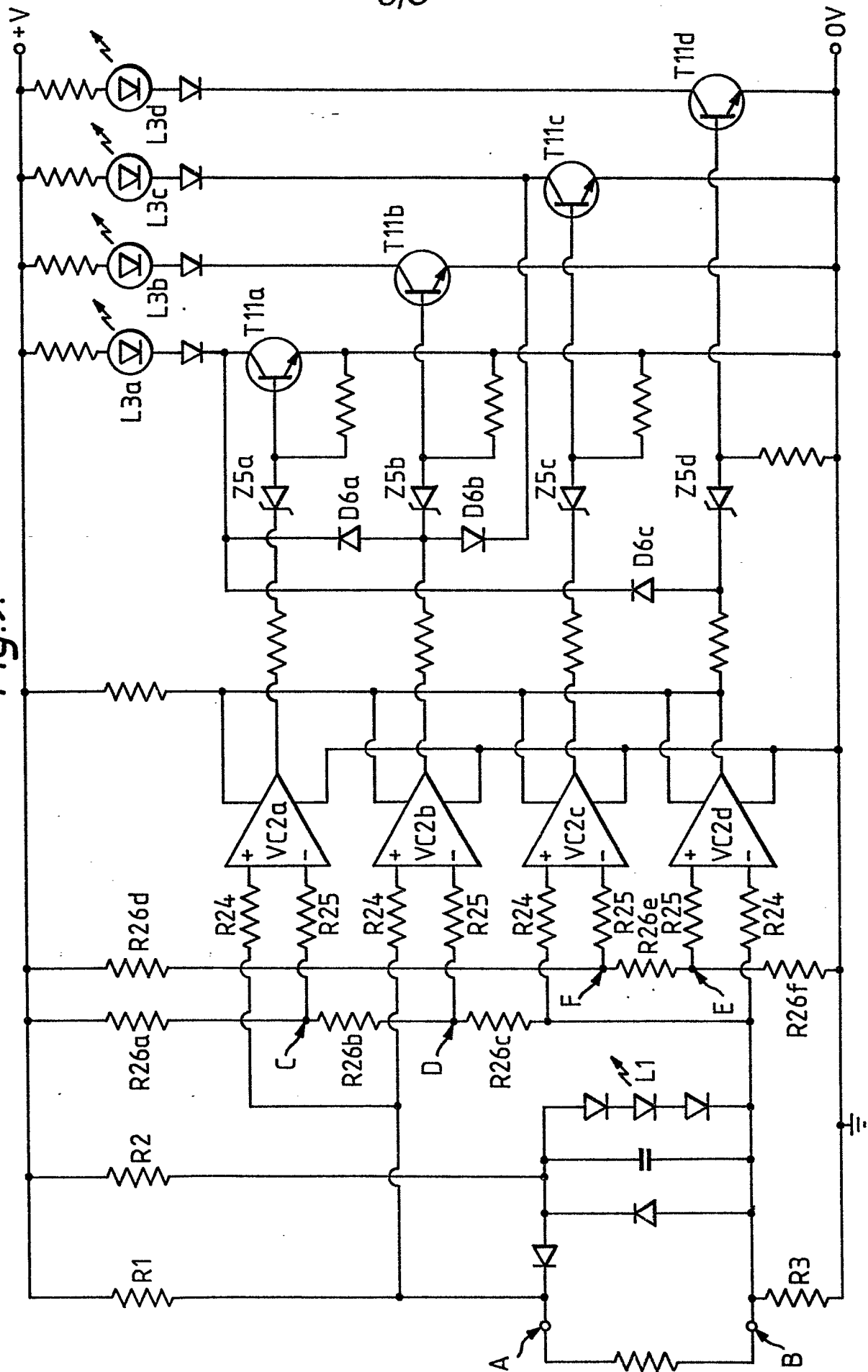


Fig.9.



7/8
Fig. 10

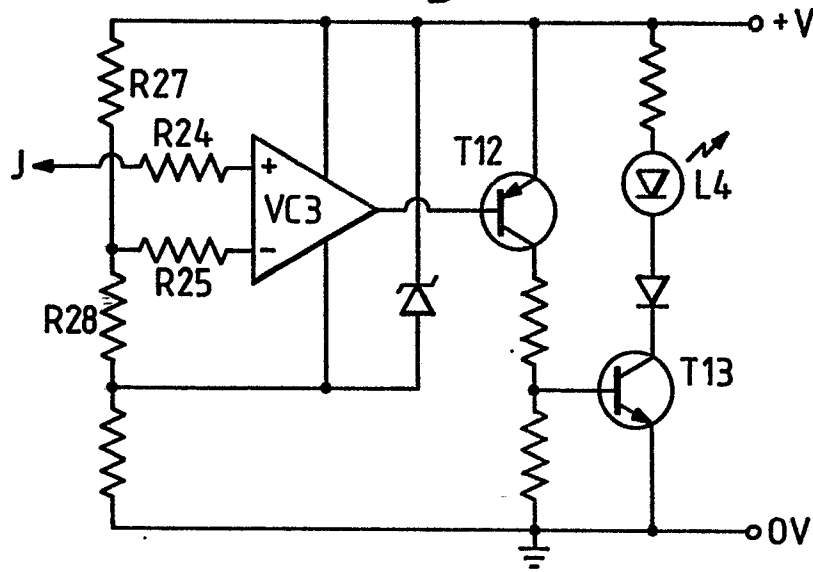
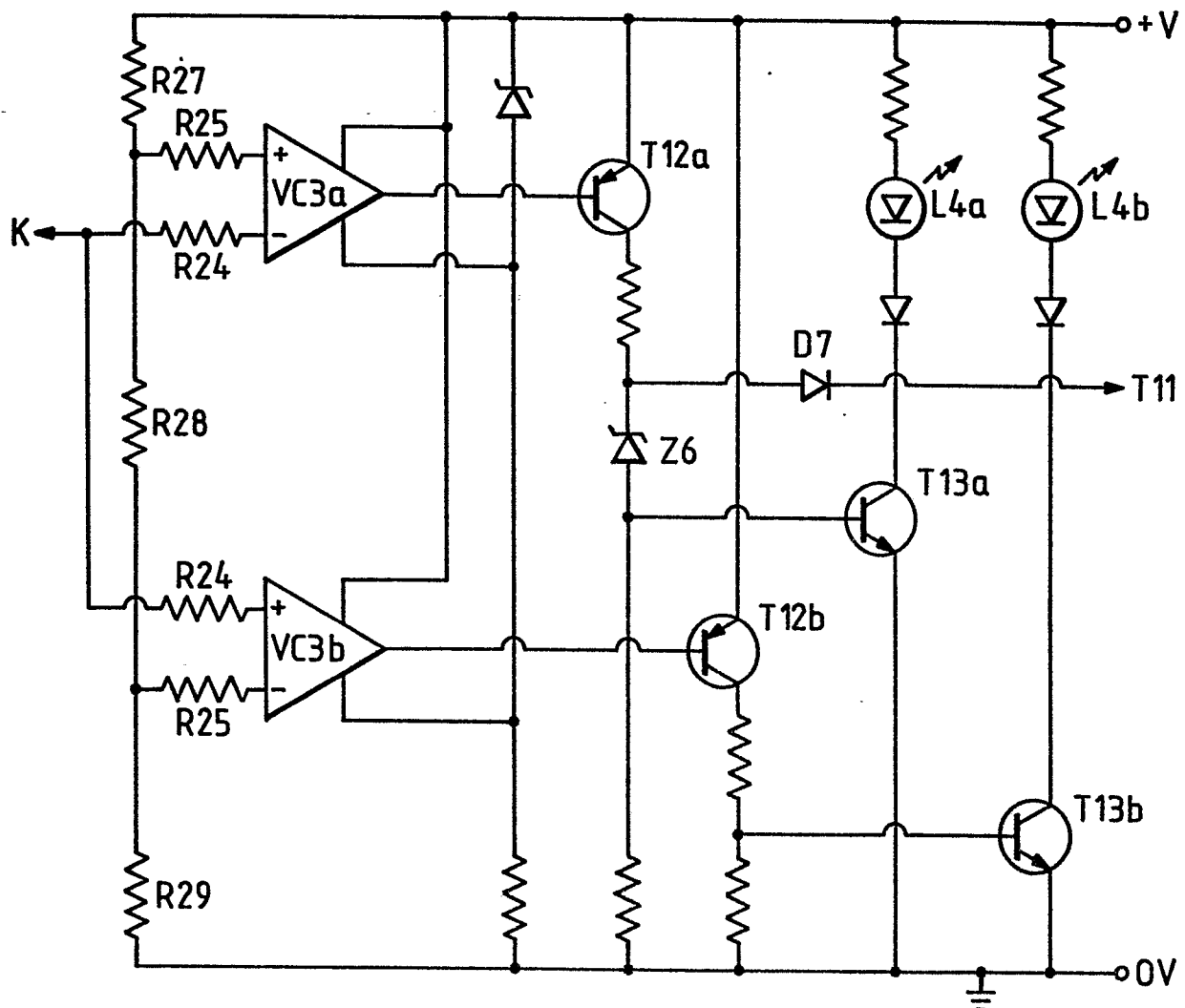
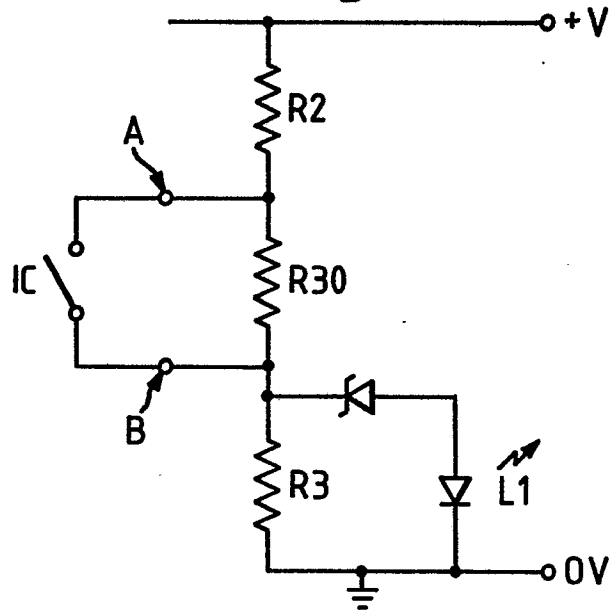
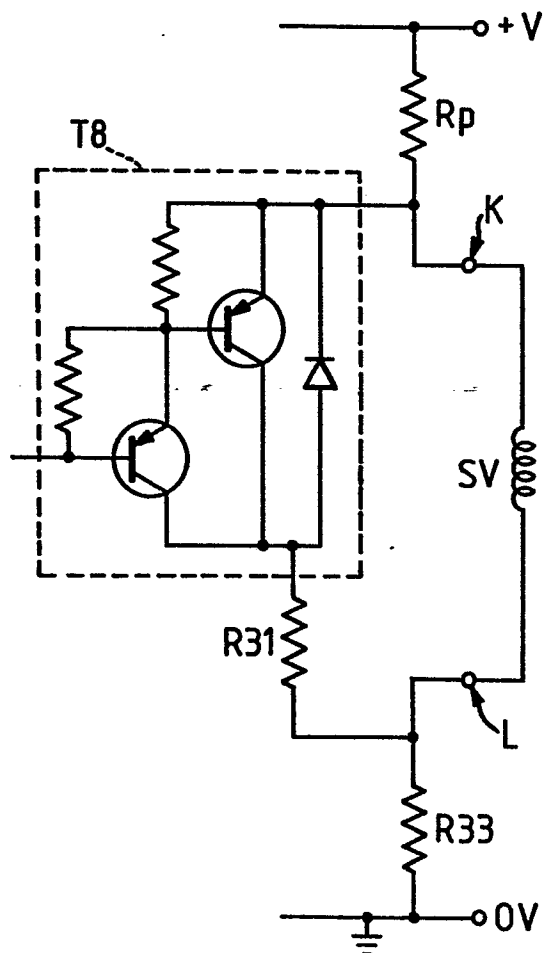


Fig. 11.



8/8

Fig.12.*Fig.13.**Fig.14.*