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H. H. SCHWARTZ

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RELAY CIRCUIT

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FIG. 1

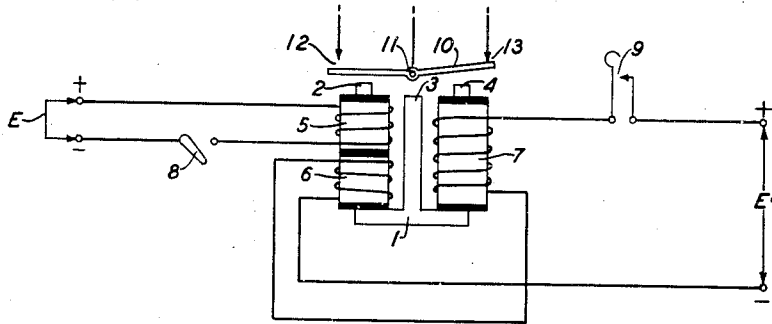
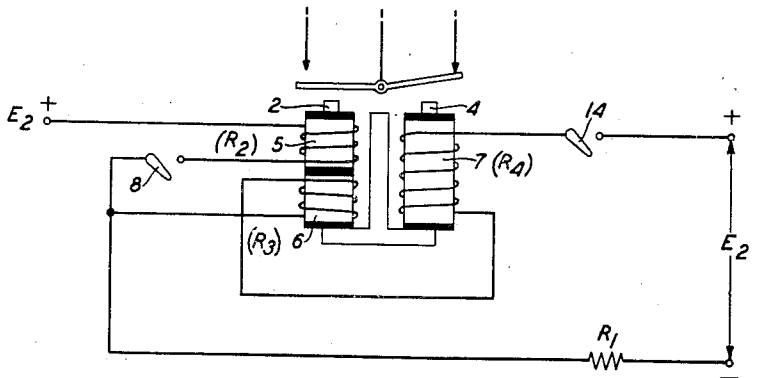


FIG. 2



INVENTOR
H. H. SCHWARTZ
BY
P. C. Smith

ATTORNEY

UNITED STATES PATENT OFFICE

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RELAY CIRCUIT

Harry H. Schwartz, Montreal, Quebec, Canada,
 assignor to Western Electric Company, Incorporated,
 New York, N. Y., a corporation of New York

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This invention relates to relay circuits and more particularly to circuits in which relays may be continuously energized.

The invention is particularly concerned with relays which operate on the flux neutralizing principle, that is a relay which is normally energized through one winding to hold a pivoted armature in one position and is operatively energized by two windings, the flux in one of which serves to neutralize the flux in the normally energized winding and in the other of which serves to move the armature into its alternate position.

In accordance with the present invention, means is provided to permit continuous energization of such a relay to hold the armature in either position.

More particularly the invention provides a resistance in series with both energizing circuits of such value as to prevent the relay from overheating.

The invention will be more clearly understood from a consideration of the following detailed description in connection with the drawing in which:

Fig. 1 shows a known relay adapted for intermittent operation; and

Fig. 2 shows a similar relay adapted according to the present invention for continuous operation.

The relay of Fig. 1 has a core 1 having three pole-piece legs, 2, 3 and 4. Windings 5 and 6 are wound on leg 2 and winding 7 is wound on leg 4. Winding 5 is energized from source E when switch 8 is closed while windings 6 and 7 are energized in series from source E' when key 9 is operated. The armature 10 is pivoted at the point 11 and controls two contacts 12 and 13. Switch 8 is normally closed to hold armature 10 against leg 2 and close contact 13. The flux generated in winding 6, when key 9 is operated, opposes that in winding 5, neutralizing the attraction of leg 2 on the armature 10 and permitting winding 7 to attract armature 10 against leg 4, to close contact 12.

This arrangement has the advantage that there is a magnetic holding force in both positions and therefore the armature is held securely in either position, since the magnetic force is greatest when the displacement is least. Such a relay operates very well in locations subject to vibration.

To adapt such a relay to function with either a single winding or all three windings energized a number of factors must be considered.

The necessary mathematical calculations are based on four fundamental relationships expressed in equations, all of which appear in or are readily derived from equations appearing in Sec-

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tion 5 of the Standard Handbook for Electrical Engineers, Seventh edition, published by McGraw Hill Book Company, Incorporated 1941.

These equations are:

$$V = \frac{l \cdot a \cdot n}{S} \quad (1)$$

in which

V = the volume available for winding
 l = length of a mean turn of the winding
 n = number of turns on the winding
 a = cross-sectional area of the wire
 S = space factor of the coil winding

$$R = \frac{r \cdot l \cdot n}{a} \quad (2)$$

in which l, n and a are defined above and

R = total resistance of the winding

r = specific resistivity of the coil conductor

$$H = knI \quad (3)$$

in which n is defined above and

H = ampere turns per inch

I = coil current in amperes

k = a constant or factor of proportionality

$$P = \frac{E^2}{R} \quad (4)$$

in which R is defined above and

P = coil dissipation in watts

E = applied voltage in volts.

Equations 1 and 2 may be combined to eliminate the factor a, resulting in

$$R = \frac{r l^2 n^2}{V S} \quad (5)$$

Equation 3 from Ohm's law may also be written

$$H = \frac{knE}{R} \quad (6)$$

and similarly Equation 4 may also be written

$$P = I^2 R \quad (7)$$

From Equation 5 may be derived a value for n,

$$n = \sqrt{\frac{RVS}{rl^2}} \quad (8)$$

Substituting (8) in (6)

$$H = \frac{kE}{R} \sqrt{\frac{RVS}{rl^2}} \quad (9)$$

and combining (9) with (4)

$$H = \frac{k}{l} \sqrt{\frac{PVS}{r}} \quad (10)$$

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As pointed out in the Handbook, above referred to, total flux density across the pole face of a magnet is directly proportional to the ampere turns, while the force exerted is proportional to the square of the flux density. Therefore, the force, represented by F , may be expressed by

$$F = k_1 H^2 \quad (11)$$

where k_1 is another proportionality factor, or, substituting (10) in (11)

$$F = \frac{k_1 k^2}{l^2} \cdot \frac{P \cdot V \cdot S}{r} \quad (12)$$

For convenience $k_1 k^2$ may be represented by a single proportionality factor k_2 .

From Equation 12 it may be readily seen that for a given winding space, the force is directly proportional to the power dissipated in the coil. Hence to keep the temperature rise down when the relay is operated continuously, some modification of the circuits over those shown in Fig. 1 is required. These modifications consist in redesigning the coils and inserting a series resistance as shown at R_1 in Fig. 2.

Referring more particularly to Fig. 2, current is supplied to the relay from a source having a voltage E_2 . The windings 5 and 6 on core 2 may be assumed to have resistances R_2 and R_3 , while the winding on core 4 has a resistance R_4 . With switch 8 closed to energize winding 5 and hold the armature in the position shown, the power in that coil may be expressed as $P5C$. With switch 14 closed to also energize windings 6 and 7 the current drain through windings 6 and 7 increases the current and thereby the voltage drop through resistance R_1 , in turn lowering the voltage drop across coil 5 and hence also lowering the power dissipated in it to a value which may be expressed as $P5d$. If the total power dissipated in coils 5 and 6 is limited to the value $P5C$, the temperature rise should be approximately constant for either condition of operation. The power dissipated in coil 7 should be slightly greater than $P5C$ to allow for incomplete neutralization by coils 5 and 6 owing to individual coil variations. However, for simplicity it will be considered equal to $P5C$ for the purposes of these calculations.

From Equation 7 and the well-known laws relating to resistances

$$P5C = \left(\frac{E_2}{R_1 + R_2} \right)^2 R_2 \quad (13)$$

The combined resistance of the windings of the relay as they appear in the circuits with both switches 8 and 14 closed may be expressed as

$$R_P = \frac{R_2(R_3 + R_4)}{R_2 + R_3 + R_4} \quad (14)$$

Therefore the power dissipated in winding 5 with both switches closed may be stated as

$$P5d = \left(\frac{E_2 R_P}{R_1 + R_P} \right)^2 \frac{1}{R_2} \quad (15)$$

Similarly, the power dissipated in winding 6 is

$$P6d = \left(\frac{E_2 R_P}{R_1 + R_P} \right)^2 \left(\frac{R_3}{R_3 + R_4} \right)^2 \frac{1}{R_3} \quad (16)$$

while the power dissipated in winding 7 is

$$P7d = \left(\frac{E_2 R_P}{R_1 + R_P} \right)^2 \left(\frac{R_4}{R_3 + R_4} \right)^2 \frac{1}{R_4} \quad (17)$$

As stated above

$$P5C = P7d \quad (18)$$

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and from the design of the relay and the fact that winding 6 must neutralize winding 5

$$P5d = P6d = \frac{1}{2} P7d = \frac{1}{2} P5C \quad (19)$$

Substituting the values of $P6d$ and $P7d$ from Equations 16 and 17 in Equation 19, it results that

$$R_4 = 2R_3 \quad (20)$$

Similarly, substituting the values of $P5d$ and $P7d$ from Equations 15 and 17 in Equation 19 the result is obtained.

$$R_2 \cdot R_3 = (R_3 + R_4)^2 \quad (21)$$

Wherefore, using the value of R_4 obtained in Equation 20

$$R_2 = 9R_3 \quad (22)$$

Substituting the values of $P5C$ and $P6d$ in Equation 19, results that

$$\frac{R_2}{(R_1 + R_2)^2} = \frac{2}{R_2} \left(\frac{R_P}{R_1 + R_P} \right)^2 \quad (23)$$

$$R_2 = \sqrt{2} R_P \left(\frac{R_1 + R_2}{R_1 + R_P} \right) \quad (24)$$

From Equations 20 and 22 the value of R_P as defined in Equation 14 may be obtained in terms of R_3 , that is

$$R_P = \frac{9R_3(R_3 + 2R_3)}{9R_3 + R_3 + 2R_3} \quad (25)$$

$$= 2.25R_3 \quad (26)$$

Employing this value of R_P , Equation 24 may be restated

$$9R_3 = 2.25\sqrt{2}R_3 \left(\frac{R_1 + 9R_3}{R_1 + 2.25R_3} \right) \quad (27)$$

which may be readily solved to give

$$R_1 = 1.44 R_3 \quad (28)$$

Therefore all of the resistance values for the relay windings and series resistance have been stated in terms of R_3 .

Returning to Equation 13 this equation may now be stated as

$$P5C = \left(\frac{E_2}{1.44R_3 + 9R_3} \right)^2 9R_3 \quad (29)$$

$$= 0.032 \frac{E_2^2}{R_3} \quad (30)$$

For a known voltage, the proper resistance to be employed for a desired power consumption may easily be determined from Equation 30. For example, if a relay were desired which would use 5 watts at 30 volts,

$$R_3 = \frac{0.082 \times 30 \times 30}{5} = 14.8 \text{ ohms} \quad (32)$$

From the foregoing it will be apparent that a single external resistance may be employed to render the power, dissipated by a relay of the type shown, independent of the number of windings energized.

What is claimed is:

1. A relay comprising two cores, two windings on one of said cores, a single winding on the other of said cores, a pivoted armature arranged to be attracted alternatively by either core, a first circuit including one of said two windings for attracting said armature to said one core, a second circuit including the other of said two windings and said single winding in series for attracting said armature to said other core, and a common resistance included in both circuits, the resistance of said one winding, said single winding and said common resistance being respectively substan-

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tially nine times, substantially two times and substantially one and one-half times the resistance of said other winding.

2. A relay comprising two cores, two windings on one of said cores, a single winding on the other of said cores, a pivoted armature arranged to be attracted alternatively and oppositely in a pivotal sense by either core, a first circuit including one of said two windings for attracting said armature to said one core, a second circuit including the other of said two windings and said single winding in series for attracting said armature to said other core, and a common resistance included in both circuits, effective to prevent overheating of said relay in either condition of attraction of said armature, the resistances of said one winding, said single winding and said common resistance being respectively substantially nine times, substantially two times and substantially one and one-half times the resistance of said other winding.

3. A relay comprising two cores, two oppositely poled windings on one of said cores, a single winding on the other of said cores, a pivoted armature arranged to be attracted alternatively and oppositely in a pivotal sense by either core, a first circuit including one of said two windings for energizing said one core for attracting said armature to said one core, a second circuit including the other of said two windings and said single winding in series for substantially neutralizing the energizing effect of said one winding on said one core and for energizing said second core for attracting said armature to said second core, and a common resistance included in both circuits, effective to prevent overheating of said relay in either condition of attraction of said armature, the resistances of said one winding, said single winding and said common resistance being respectively substantially nine times, substantially

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two times and substantially one and one-half times the resistance of said other winding.

4. A relay comprising two cores, two oppositely poled windings on one of said cores, a single winding on the other of said cores, a pivoted armature arranged to be attracted alternatively and oppositely in a pivotal sense by either core, a first circuit including one of said two windings for energizing said one core for attracting said armature to said core, a second circuit including the other of said two windings and said single winding in series, said other winding provided for substantially neutralizing the energizing effect of said one winding on said one core and said single winding for energizing said second core for attracting said armature to said second core, and a common resistance included in both circuits, effective to render the power dissipation by said relay the same when said first circuit is closed alone and when both circuits are closed, the resistances of said one winding, said single winding and said common resistance being respectively substantially nine times, substantially two times, and substantially one and one-half times the resistance of said other winding.

HARRY H. SCHWARTZ.

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