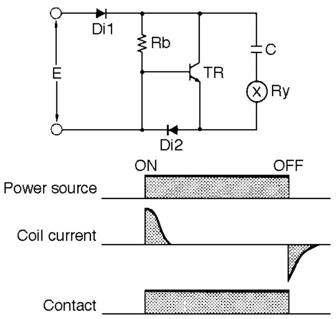
Notes on Correct Use

Designing Power-Conserving Driver Circuit with Single-Winding Latching Relay (Pat. 1239293)

This section introduces a patented drive circuit for the single-winding latching relay that can be driven on several milliwatts. This drive circuit not only allows the relay to be used in the same manner as semiconductor devices but also offers a wide range of applications.

Operating principle



Set

When a specified voltage is applied across E, the current flows through the circuit in the sequence of diode Di1, capacitor C, relay Ry, and diode Di2.
C is then charged, setting the relay.

Energization

When C has been fully charged, the relay is biased by the current flowing from Di1 to Rb. C does not discharge. The power consumption at this time is very small, several milliwatts at best, and its value can be calculated as follows:

$$P = (E-VF)^2/Rb$$

where,
P: power consumption
VF: voltage drop across diode Di1

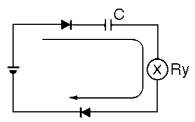
The current that is to flow through Rb at this time is dependent on the transfer ratio hfe of transistor TR which is required for TR to turn ON.

Reset

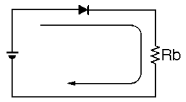
When the voltage placed across E is removed, the electricity charged in C is discharged, causing the current to flow through the circuit in the sequence of Rb, the base, and the emitter of TR. In this way, the relay is reset by the current flowing in the direction opposite to when the relay is set.

The following equivalent circuits respectively illustrate the current flows when the relay is set, energized, and reset.

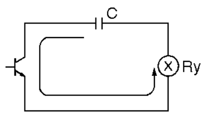
Set



Energization



Reset



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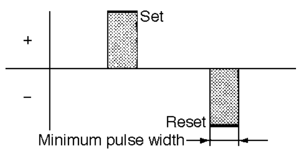
Circuit design

Fundamental

Generally, the latching relay is set and reset when a pulse having a square waveform is applied to it for a short time. The minimum pulse width required to set and reset the relay is predetermined.

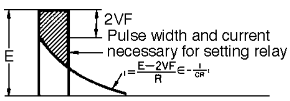


The charging current shown in the above equivalent circuit diagrams, has a sawtooth waveform that can be expressed by the following formula, because it is the primary circuit of C and R.

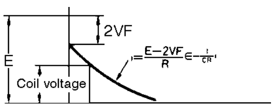
$i = E\text{-}2VF/R \in - 1/CRt$

(2 Forward voltage diode drops)

If applied voltage E and the rated coil voltage of the relay are the same, the current to the relay falls short by the quantity indicated by the shaded portion in the following figure.

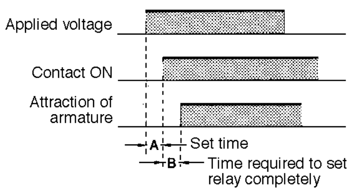


Therefore, the current must be applied to the relay as follows when designing this driver circuit.



Time constant

When the rated voltage is applied to the relay, time A in the timing chart below is required to turn ON the contacts. After this time has elapsed, time B is required until the armature attraction to the magnet is complete.

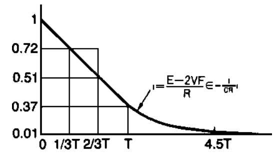


Therefore, it is apparent that time constant T obtained as the product of C and R must be equal to or longer than the sum of A and B. Actually, however, T should not be equal to the sum of A and B but must be longer than that to ensure the stable operation of the circuit. Thus,

$T = A + B + X$

where X is the time margin.

The set time A of OMRON's moving-loop relays (with a pickup power of 200 mW) is rated at about 3 milliseconds. Time constant T for them should be about three times that of A. The following graph illustrates this. This graph indicates that, if C is completely charged (I_{PEAK}), it takes 4.6T to discharge I to 1%. Note that time constant T is broken down into three segments. The first 1/3T equals A, the second 1/3T, B. The remaining 1/3T is the time margin expressed as X in the above equation. T is three times A.



Voltage drop E1 across the total resistance of the capacitance C's resistance and relay coil's internal resistance is the difference between the supply voltage E and voltage drops across two diodes:
Di1 and Di2. Hence,

$E1 = E – 2VF$

Assuming the supply voltage to be 5 V and VF to be 0.6 V,

$E1 = 5 – 2 \times 0.6 = 3.8$ V

From E1 and the above graph, the required coil voltage of a relay can be obtained. Again assuming the E, i.e., the supply voltage of a single-winding latching relay is 5 V, the coil voltage is:

$3.8 \times 0.72 = 2.7$ V

At this time, the capacitance of C is 246.9 µF, according to the equation shown in the above graph.

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Coil ratings and capacitance of C

In the example, the coil voltage obtained by calculation is 2.7 V, which is 0.3 V less than the value at which the coil voltage of commercially available standard latching relay is rated. The standard coil voltages of relays at a supply voltage of 6, 9, 12, and 24 V can be respectively calculated in the same way. Table 1 compares the results of the calculation and the coil voltages of standard relays.

The calculated coil voltages significantly deviates from the standard values. It is therefore necessary to determine the time constant of the relay by adjusting the capacitance of C when the relay coil is to operate on the standard voltage.

As an example, calculate the capacitance of C and time constant T of a relay with a rated supply voltage of 5 V. The coil voltage E_1 has been calculated above (3.8 V). To determine how much current I flows through the coil at 3.8 V, from Table 1, note that the coil resistance is 45 Ω. So,

I = 3.8/45 = 84.4 mA

Therefore, the peak current of capacitor C to be used must be 84.4 mA.

Remember, that time A of an OMRON relay is 3 ms. Capacitance C must be a value that allows 66.6 mA to flow through 3 ms after 5 V is applied to the relay. Thus,

$66.6 = 84.4 \in {}^{1}/_{cx45}{}^{3x10^{-3}}$

From this,

C = 280 μF

At this time, time constant T is:

$280 \times 10^{-6} \times 45 = 12.6$ ms

By calculating the C of each of the relays listed in Table 1, the values in Table 2 are obtained.

Again, these calculated capacitances deviate from the commercially available standard capacitors. There is no problem in using standard capacitors but, if the cost and circuit space permit, it is recommended to use two or more capacitors so that a capacitance as close to the calculated value as possible is obtained. At this time, pay attention to the following points:

Table 1

Supply voltage	Coil voltage (calculated)	Standard voltage	Coil resistance
5 V	2.7 V	3 V	45 Ω
6 V	3.5 V	3 V	45 Ω
9 V	5.6 V	5 V	125 Ω
12 V	7.8 V	6 V	405 Ω
24 V	16.4 V	12 V	720 Ω

Table 2

Supply voltage	Coil voltage (calculated)	Coil resistance	Capacitance of C
5 V	2.7 V	45 Ω	280 μF
6 V	3.5 V	45 Ω	142 μF
9 V	5.6 V	125 Ω	54 μF
12 V	7.8 V	405 Ω	40 μF
24 V	16.4 V	720 Ω	6.5 μF

- Confirm that the relay operates normally even when the supply voltage is brought to 80%-120% of the rated value.
- Even if a voltage of two or three times the rated voltage is applied to this driver circuit, the coil wire will not sever. That is why, for example, when the driver circuit is mounted in an automobile where a supply voltage of 12 VDC is available from the battery, it is recommended to use a relay whose coil voltage is rated at 6 VDC, taking a voltage fluctuation of 8 to 16 VDC into consideration.

Determining Rb

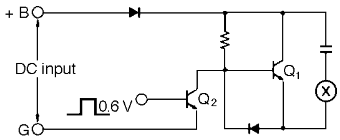
The current flows into Rb should be enough to turn ON TR when the relay is reset. When determining value of Rb, the following points must be noted:

- TR must be sufficiently turned ON even when T equals the time constant.
- Give adequate consideration to changes in hfe due to changes in ambient temperature.

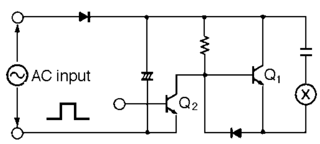
Simple as it is, the driver circuit introduced here can efficiently control the relay, consuming a tiny amount of power.

An experiment reveals that the relay sufficiently operates with a capacitance of 100 μF + 47 μF where the relay is rated at a supply voltage of 5 VDC and a coil voltage of 3 VDC. It can therefore be said that the capacitance can be lower than the calculated value. This is because the time constant is determined with a relatively wide margin. So it is recommended to perform experiments to determine the time constant.

Application circuit example



The TTL output of a solid-state switch can be used as Q_2.



Half-wave rectified AC power is applied to the circuit. Q_1 is the output of a TTL, and drives the relay.