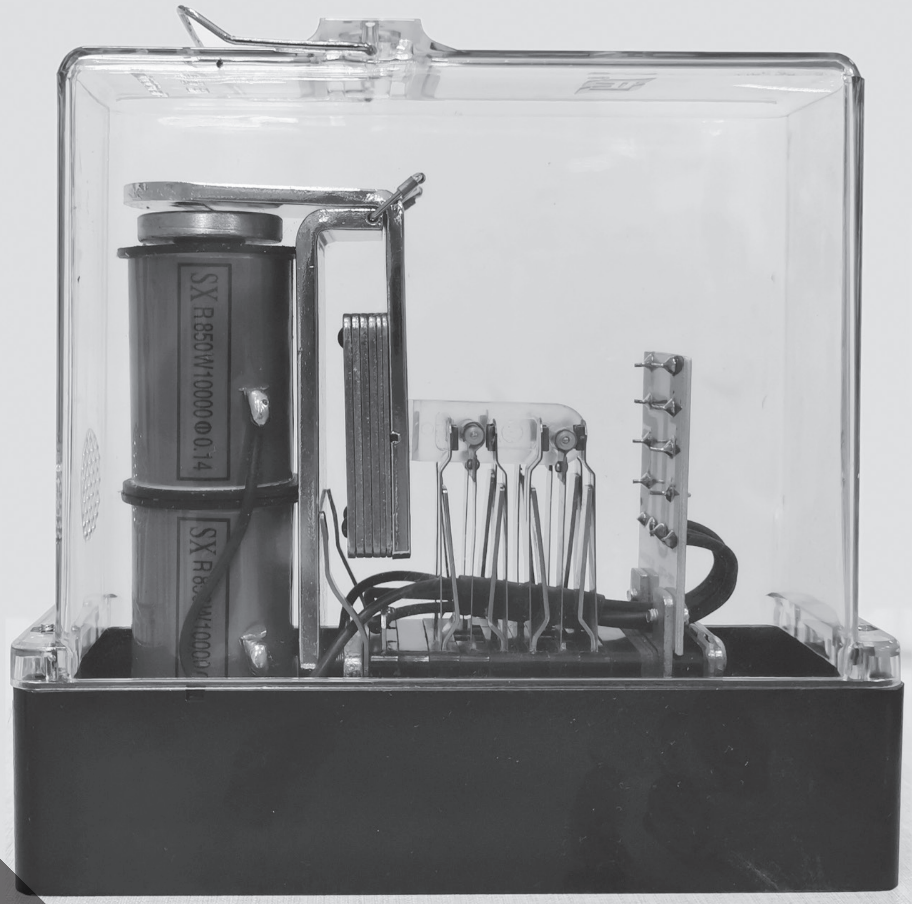


Unit 1 Signal Relay

Learning Objectives

After learning this unit, you'll be able to understand:

1. the working principle and classification of relays
2. the structure, working principle and functions of safety relays
3. how to analyze a circuit diagram and carry out a circuit experiment independently

Part One Lead-in

The relay is an electrical component of an automatic control circuit or a remote control circuit used for switching on and off the circuit to issue control commands and reflect the state of the equipment. Relays are used extensively in automatic control systems.

The relay, when used with railway signal technology, is called signal relay (relay, for short). It is an important part of railway signal technology, not only as the core component of the relay signal system, but also as the interface component of the electronic or computer-based signal system. The reliability of the relay operation directly affects the reliability and safety of the signal system.

Part Two Reading Materials

Material A

Introduction to Railway Signal Relay

The signal relay is the general name of relays used in railway signals, and it is an indispensable component of various signal control systems.

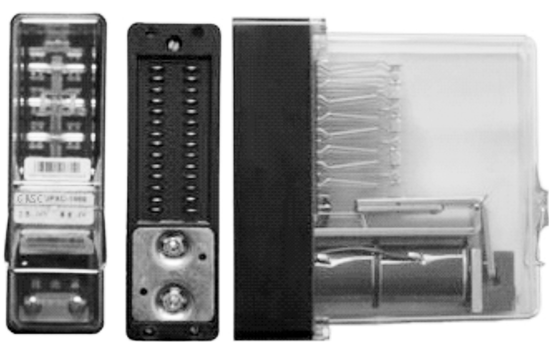


Figure 1-1 Signal Relay

1 Requirements for Signal Relay

The signal relay is the main (or important) device in the railway signal system, whose safe and reliable operation is a prerequisite for the normal operation of various types of signal equipment. Therefore, signal relays must meet the following requirements:

(1) reliable and accurate operation;

(2) long service life;

(3) capacity to close and disconnect the circuit;

(4) stable electrical characteristics and time characteristics;

(5) high-level electrical insulation to be maintained when the temperature and humidity of the surrounding medium vary greatly.

2 Functions of Signal Relay

With the rapid development of electronic technology, electronic devices, especially microcomputers, because of their high speed, small size, large capacity and powerful functions, have gradually replaced relays to a great extent in automatic control and remote control systems. However, compared with electronic devices, relays still have their advantages, such as good switching performance (small impedance when closed and large impedance when disconnected), fail-safe performance (being safety-oriented in case of failure), ability to control multiple circuits, strong lightning resistance, no noise, and immunity from ambient temperature. Therefore, relays will still have broad applications for a long time.

At present, signal relays play a key role in the systems supported by relay technology such as the all-relay interlocking and relay semi-automatic block. These systems exist in large quantities and will remain in use for a long period of time. In the systems composed of electronic components and microcomputers, including the computer-based interlocking, automatic block system with miscellaneous messages, general locomotive signal and hump automation, the signal relay serves as their interface component to connect the system host with executive components such as the signal, track circuit, and switch machine. Although a fully electronic system has emerged, it will take quite a long time for relays to be completely replaced. Therefore, signal relays always play an important role in the field of railway signal now and also in the future.

3 Basic Principle of Signal Relay

The relay is an electromagnetic switch. Although relays differ in types, functions and structures, they all consist of two major parts: the electromagnetic system and contact system. The former consists of a coil, a fixed iron core and yoke, and a movable armature; and the latter includes heel contact and normal contact. When an electric current is fed into the coil, an electromagnetic field is generated through electromagnetic effect or induction and the armature is activated to make or break a connection and thus reflect the condition of the input current.

The simplest electromagnetic relay is shown in Figure 1-2(a). It is an electromagnet with contacts, working according to a similar principle to that of an electromagnet. When an electric current passes through the coil, a certain amount of magnetic flux is generated between the armature and the iron core. The magnetic flux and its flowing path (including the iron core, armature, yoke, and air gap) form a closed magnetic circuit. Then a magnetic force is generated between the iron core and the armature, but the magnitude of the force depends on the current rating. When the current rating is increased, the magnetic force will be increased until it overcomes the resistance of the armature's movement to the iron core (mainly the dead weight of the armature), and the armature will be activated to move to the

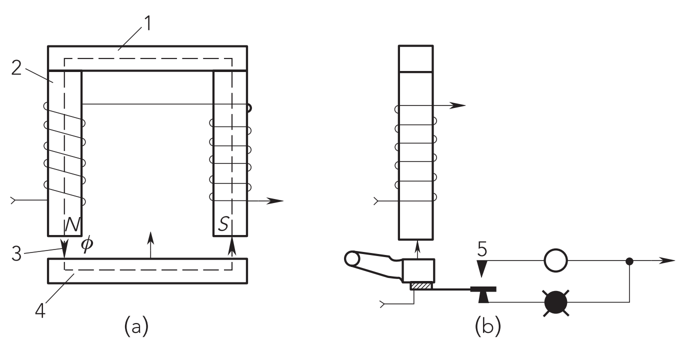


Figure 1-2 Basic Principle of the Electromagnetic Relay

Notes: 1-Yoke; 2-Iron core entwined with coil; 3-Air gap; 4-Armature; 5-Contact iron core. The heel contact that moves with the armature moves, too, to make connection with the normally open contact (hereinafter referred to as the front contact). This state is called the relay being excited or energized (hereinafter referred to as "being energized").

The magnetic force reduces with the decrease of the current rating. When it is not strong enough to overcome the dead weight of the armature, the armature falls down to its relaxed position (which is called "being released"). With the movement of the armature, the heel contact disconnects from the front contact and connects with the normally closed contact (hereinafter referred to as the back contact). This state is called the relay being released or de-energized (hereinafter referred to as "being de-energized").

In brief, the relay serves as an electrically operated switch by making or breaking connection with its contacts in a control or indication circuit. As shown in the signal light circuit in Figure 1-2(b), the green light will be turned on if the front contact is connected, and the red light will be turned on if the back contact is connected.

Exercise A

1. Directions: Translate the following terms into Chinese.

(1) signal relay

(2) electrical insulation

(3) all-relay interlocking

(4) relay semi-automatic block

(5) computer-based interlocking

2. Directions: Fill in the blanks.

(1) The relay consists of two major parts: the ________ and contact system.

(2) The reliability of the relay operation directly affects the ________ and ________ of the signal system.

(3) The relay is an electrical component of a(n) ________ or a(n) ________ used for switching on and off the circuit to ________ and ________.

(4) The magnitude of the magnetic force of the iron core to the armature depends on the ________ rating.

Mini-project A

1. Discuss why the first level relay is used for the railway signal relay.
2. Describe the working principle of the signal relay.

Material B

Types of Railway Signal Relay

There are various types of signal relays due to the variety of relays. Generally, signal relays can be classified as follows:

1 Electromagnetic Relay and Induction Relay

In terms of the operation principle, there are electromagnetic relays and induction relays.

For the electromagnetic relays which are most widely used, electromagnetic force is generated in the air gap (between the iron core and the armature) of the magnetic circuit when a current is applied to the coil of the relay. Then the armature moves to the iron core to make a connection with the contact. As for the induction relays, an alternating magnetic field is created when a current passes through the coil, which interacts with the current induced by another alternating magnetic field in the wing to generate an electromagnetic force that causes the wing to rotate.

2 DC Relay and AC Relay

In terms of the current type, there are DC relays and AC relays.

As to DC relays powered by a direct current, there are non-polarized relays, polar-biased relays and polarized relays according to the polarity of the current. All DC relays are electromagnetic relays. AC relays, powered by an alternating current, can be either electromagnetic relays or induction relays according to their working principle. In addition, the rectifier relay is basically a DC relay, for it, although used in an AC circuit, rectifies the alternating current into a direct current with a rectifying component.

3 Current Relay and Voltage Relay

In terms of the physical properties of the input, there are current relays and voltage relays.

The current relay reflects the change of the current and its coil must be connected in series in the reflected circuit where the reflected devices are motor windings, signal lamps, etc. The voltage relay reflects the change of the voltage, whose coil excitation circuit is a separate structure.

4 Normal-acting Relay and Slow-acting Relay

In terms of the action speed, there are normal-acting relays and slow-acting relays.

Most signal relays fall into normal-acting ones, for which the energizing time for the armature action is 0.1-0.3 s. For a slow-acting relay, the energizing time for the armature action exceeds 0.3 s. There are slow pick-up relays and slow release relays. The time delay relay realizes slow pick-up with a pulse delay circuit or by software setting while the slow release relay makes use of the magnetic flux generated in a short circuit copper ring to realize slow acting.

5 Common Contact Relay and Enhanced Contact Relay

In terms of the contact structure, there are common contact relays and enhanced contact relays.

A common contact relay is designed to connect and disconnect low power contacts in a general signal circuit. Most relays are common contact relays, so it's not necessary to specifically refer to them as such.

The enhanced contact relay has the ability to connect and disconnect high power contacts in a signal circuit with either a higher voltage or a higher current.

6 Safety Relay and Non-safety Relay

In terms of the operation reliability, there are safety relays and non-safety relays.

The safety relay (N-type) works independently, whose structure meets all safety requirements. The working state of its contacts in the circuit needs no supervision. For an N-type relay,

(1) when the coil is de-energized, the armature can be released by its own weight, and the front contact is reliably disconnected;

(2) either the suitable contact material guarantees a non-welding front contact, or the special structure such as the fuse or series connection prevents the contact from welding;

(3) when a group of back contacts, which should not be closed, remain closed, they can structurally prevent the closing of all front contacts.

For a non-safety relay (C-type), the operating status of its contacts in the circuit should be always under supervision so as to ensure the safety. For a C-type relay,

(1) it is not mandatory to use non-welding materials for armature contacts, for relays shall always check whether the armature is released correctly;

(2) when a group of front contacts, which should not be closed, remain closed, they can structurally prevent the closing of all back contacts, and vice versa.

The N-type relay, also known as the gravity type, mainly relies on the armature's own gravity to release the armature. The C-type relay, also known as the spring type, mainly relies on the force of the spring to release the armature. In general, N-type relays are safer and more reliable than C-type ones.

Exercise B

Directions: Answer the following questions.

(1) What is the electromagnetic relay?

(2) According to the current type, how can relays be classified?

(3) What is the energizing time for the armature action of a normal-acting relay?

(4) How does the slow release relay realize slow acting?

(5) Is the safety and reliability of N-type relays generally higher or lower than that of C-type ones?

Mini-project B

1. Group survey: Which type of signal relay is broadly used in railways?
2. Group discussion: Why is this type of signal relay broadly used according to the survey?

Part Three : Further Development

Material C

AX Series Safety Relay

The AX series safety relay is designed and manufactured independently in China based on the desk-type relay and the large plug-in relay. Compared with the previous two types, the AX series safety relay is light and small with a new structure. Decades of application proves that the AX series safety relay is safe, reliable and stable, and can meet various requirements of signal circuits for relays. It, as the main typified signal relay, enjoys the widest application in Chinese railways.

1 Overview of Safety Relay

Safety relays are typically non-polarized relays and 24 V series heavy-spring-type DC electromagnetic relays. Other types of relays are also derived from the non-polarized relay. Therefore, most parts can be used interchangeably between different types of relays.

1. Plug-in Type and Non-plug-in Type

As to safety relays, there are plug-in ones and non-plug-in ones. Plug-in relays are often used independently, while the non-plug-in ones are often installed in a modular box with a dust cover. The only difference between the two types is that the former has a transparent dust cover (made of polymethyl methacrylate or polycarbonate), and is installed on a bakelite base made of phenolic plastic to be used along with the plugboard. A plug-in non-polarized relay is shown in Figure 1-3. In fact, plug-in relays are used more often for the convenience of maintenance.

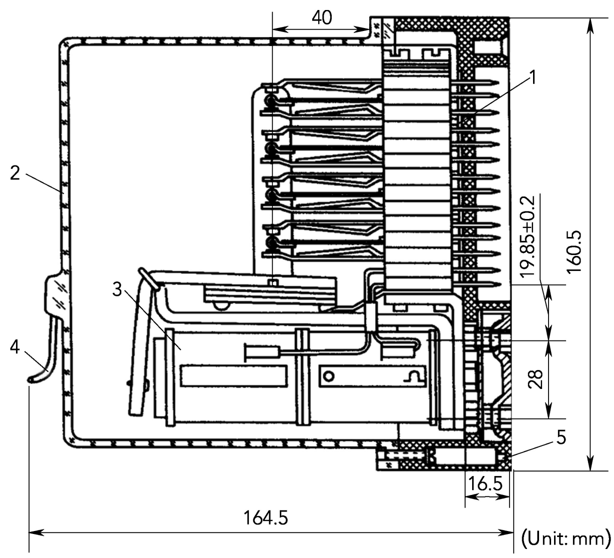
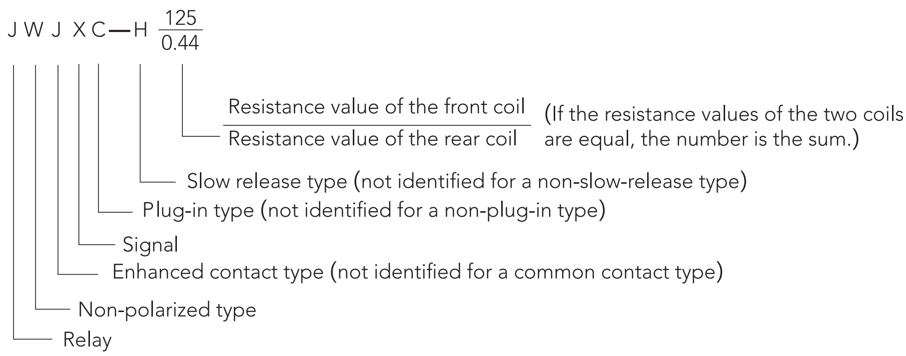


Figure 1-3 Plug-in Non-polarized Relay

Notes: 1-Dust-proof pad; 2-Dust cover; 3-Coil; 4-Handle; 5-Seal

2. Specification of Safety Relay Model

The specification of a safety relay model consists of Chinese pinyin letters and numbers: the former for relay types while the latter for the resistance values of the coils (unit: Ω). The following is an example of the relay codes and their meanings.



3. Types and Applications of Safety Relay

There are nine types of safety relays, namely non-polarized, non-polarized enhanced contact, non-polarized slow release, non-polarized enhanced contact and slow release, rectifier, polarized, polarized enhanced contact, polar-biased and single closed magnetic. With different characteristics and coil resistance values, they play different roles in signal circuits. In a circuit diagram, the relay whose fixed position is the state of being energized is marked with a " ↑ " symbol on both the coil and the contact; the relay whose normal position is the state of being released is otherwise marked with a " ↓ " symbol.

4. Relay Socket

To make a plug-in safety relay, a plugboard is required. The structure of a safety relay plugboard is shown in Figure 1-4.

There are many types of safety relays. The contact number next to the plughole is that of the non-polarized relay. However, the position and number of the contact system of other types are different. To prevent the insertion of a wrong type, a discriminator is riveted in the discriminator hole at the lower part of the plugboard.

5. Characteristics of Safety Relay

In the railway signal system, safety relays must be used in all relay circuits for safe train operation. The structure of the safety relay must conform to the fail-safe principle: the possibility of a safety-side fault is much greater than that of a danger-side fault (A safety-side fault refers to the fault conducive to

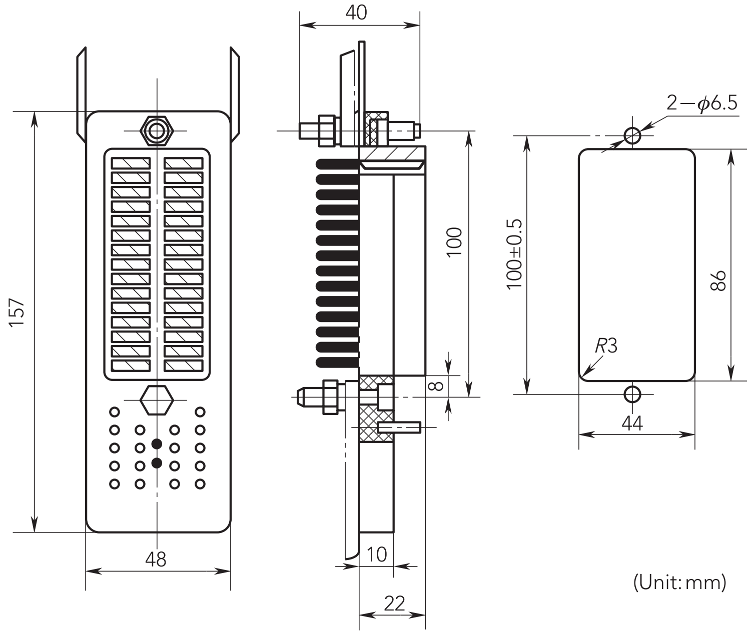


Figure 1-4 Safety Relay Plugboard

safe running because it is identified during the non-operation state; a danger-side fault refers to the fault jeopardizing safe running because it occurs during the operation state.). A safety relay is an asymmetrical device for faults where the possibility of closing the front contact in the event of a fault is much less than the probability of closing the back contact. In this way, the front contact can show the danger-side information while the back contact the safety-side information.

In order to meet the fail-safe requirements, safety relays must have the following structural features:

(1) The material for the front contact is of high melting point and good electrical conductivity, which will not melt and stick;

(2) The weight of the armature is increased so that its constant gravity can forcibly disconnect the front contact when the coil is switched off;

(3) The magnetic circuit system is made of ferromagnetic material with small residual magnetism, and a non-magnetic stop piece of a certain thickness is set between the armature and the pole shoe. Under this

condition, when the armature is energized, there remains an air gap to prevent the residual magnetic force from attracting the armature;

(4) The armature should not get stuck in the energized state due to any mechanical failure.

6. Service Life of Safety Relay

The service life of a relay, including the electrical life and mechanical life, depends on the service life of the contacts. The electrical life is specified as 2×10^6 connection times for a common contact and 2×10^5 times for an enhanced one; 1×10^5 connection times and 1×10^3 disconnection times for the enhanced fixed position contact and reverse position contact of a polarized relay. The mechanical life is 10×10^6 times.

2 Structure and Working Principle of Safety Relay

1. Structure of Non-polarized Relay

The non-polarized relays include JWXC-2000, JWXC-1700, JWXC-1000, JWXC-7, JWXC-2.3, JWXC-370/480, and slow-release types such as JWXC-H600, JWXC-H340 and JWXC-500/H300.

(1) Non-polarized Relay

The non-polarized relay is composed of the DC electromagnetic system and contact system. The coils of the electromagnetic system are installed horizontally on the iron core. They are divided into the front coils and the rear coils, which can be connected or used separately. The armature, which can move flexibly, is fixed to the blade of the yoke by the butterfly-shaped steel wire clip. The heavy hammer piece is riveted on the transmission part of the armature to ensure that the relay armature is returned mainly by gravity. The number of heavy hammer pieces is determined by the structure of the relay contact system, so that the weight of the armature is in correspondence with the rear contact pressure. The upsetting pole boots are fixed at the end of the iron core in order to facilitate magnetic conduction. There are two small holes in the pole boot for easy disassembly and assembly of the iron core. There is a stop clip on the armature, which increases the magnetic resistance and reduces the influence of residual magnetism, ensuring the relay to fall down in the right place.

The contact system is on top of the electromagnetic system. Through the contact frame, the screw is fastened to the yoke, and the two become a whole. The lower stop, the power supply unit, the silver contact unit, the moving contact unit and the pressing plate are assembled orderly on the contact frame with screws. Before fastening the screw, the push rod, the insulation shaft, the moving contact shaft and the moving contact should be assembled. And then the armature drives the movement of the moving contact through the transmission of the push rod.

(2) Working Principle of Non-polarized Relay

For a non-polarized relay, its magnetic system is branchless, as shown in Figure 1-5. After a DC voltage is applied to the coil, the current in the coil magnetizes the iron core, and produces a working magnetic flux Φ in the iron core, which enters the armature through the main working air gap δ at the pole shoe. Then it passes through the second working air gap δ', enters the yoke, and returns to the iron core. A closed magnetic circuit is formed. At the working air gap δ, the magnetic flux Φ produces an electromagnetic force F_D between the iron core and the armature. When F_D is strong enough to overcome the mechanical load resistance F_j (mainly the dead weight of the armature), the armature will pick up the iron core. At this moment, the pull rod pulls the heel contact to connect the front contact and disconnect the back contact.

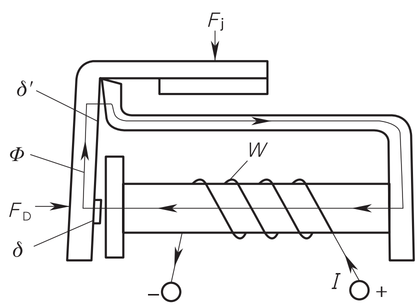


Figure 1-5 Magnetic Circuit of a Non-polarized Relay

When the current in the coil is reduced, the magnetic flux in the iron core decreases accordingly, and so does the attraction. The current continues to reduce until the induced attraction is smaller than the mechanical force, and then the armature is released from the iron core. At this moment, the pull rod drives the heel contact to disconnect the front contact and connect the back contact.

2. Polarized Relay

There are two stable states for the polarized relay according to the polarity of the current in the coil: normal position and reverse position. Either state can be maintained when the current is cut off in the coil, so the polarized relay is also called the polarity-maintaining relay. A polarized relay includes permanent magnet steel in its magnetic system. When the current of predetermined polarity passes through the coil, the relay is energized and remains in the energized position after the power is turned off. When the current is reversed, the relay is released and remains in the released position after the power is turned off.

For polarized relays, there are models such as JYXC-660, JYXC-270, JYJXC-J3000 with enhanced contacts and JYJXC-135/220 with enhanced contacts.

(1) Structure of Polarized Relay

The magnetic circuit structure of a polarized relay is basically the same as that of a non-polarized one, except that a permanent magnet steel bar with a blade-shape end replaces a part of the yoke of a non-polarized relay. The magnet steel and the yoke are connected by screws.

The connection of the coil lead with the power supply chip and the contact system of a polarized relay are the same as those of a non-polarized relay. The normal position and reverse position of the armature of a polarized relay are defined as follows: when the gap between the armature and the pole shoe of the iron core is the smallest (i.e. the energized state), the position is the normal position, and the closed contact is called the fixed position contact (represented by the symbol D, which is considered as the front contact); when the gap between the armature and the pole shoe of the iron core is the largest (i.e. the released state), the position is the reverse position, and the closed contact is called the reverse position contact (represented by the symbol F, which is considered as the back contact).

(2) Working Principle of Polarized Relay

The magnetic circuit system of a polarized relay is composed of a permanent magnetic circuit and an electromagnetic circuit. It is an asymmetric parallel magnetic circuit, as shown in Figure 1-6.

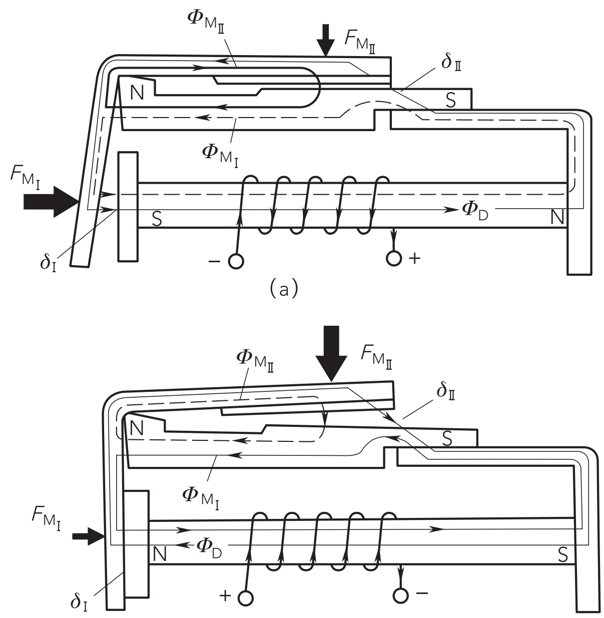


Figure 1-6 Magnetic Circuit of the Polarized Relay

Notes: (a)-The direction of the magnetic flux changing from the reverse position to the fixed position;

(b)-The direction of the magnetic flux changing from the fixed position to the reverse position

The magnetic flux in the permanent magnet steel is divided into Φ_{MI}, and Φ_{MII} in two parallel circuits. Φ_{MI} starts from the N pole, passes through the armature, the first working air gap δ_I, the iron core, the yoke, and arrives at the S pole; Φ_{MII} starts from the N pole, passes through the upper part of the armature, the counter weight piece, the second working air gap δ_{II}, and reaches the S pole. These two circuits are asymmetrical, and the imbalanced magnetic circuit results in a big difference between the forward pole-changing value and the reverse pole-changing value of the polarized relay.

When the armature is in the released state (the reverse position), $\delta_{\mathrm{I}} >> \delta_{\mathrm{II}}$, so $\Phi_{\mathrm{MII}} >> \Phi_{\mathrm{MI}}$. The attraction force F_{MII} generated from Φ_{MII}, together with the gravity of the armature and the pre-pressure on the heel contact, overcomes the sum of the attraction force F_{MI} generated from Φ_{MI} and the back contact pressure, so the armature can be kept steady in the released position. On the contrary, when the armature is in the energized state (the normal position), $\delta_{\mathrm{I}} << \delta_{\mathrm{II}}$, so $\Phi_{\mathrm{MI}} >> \Phi_{\mathrm{MII}}$. The attraction force F_{MI} generated from Φ_{MI} overcomes the sum of the attraction force F_{MII} generated from Φ_{MII}, the gravity of the armature and the reaction force of the contact, so the armature can be kept steady in the energized position.

Obviously, the shift of the polarized relay from a stable position to another stable position can be realized by the electromagnetic force. As shown in Figure 1-6, the electromagnetic flux Φ_{D} passes through a branchless magnetic circuit consisting of the iron core, yoke, δ_{II}, counter weight piece, armature, δ_{I} and pole shoe. The direction of the flux is determined by the polarity of the current applied in the coil. For electromagnetic flux, the permanent magnet steel performs as a large magnetic resistance, like an air gap.

Figure 1-6(a) shows how a polarized relay shifts from the reverse position to the fixed position. The relay is originally in the reverse position. When a current of positive polarity passes through the coil, the direction of the electromagnetic flux Φ_{D} is the S pole at the pole shoe. At this time, Φ_{D} and Φ_{MI} are in the same direction at δ_{I} and the magnetic flux is enhanced ($\Phi_{\mathrm{D}}+\Phi_{\mathrm{MI}}$). Φ_{D} and Φ_{MII} are in the opposite direction at δ_{II}, and the magnetic flux is weakened ($\Phi_{\mathrm{MII}}-\Phi_{\mathrm{D}}$). When Φ_{D} is increased until it's strong enough, $\Phi_{\mathrm{D}}+\Phi_{\mathrm{MI}}>\Phi_{\mathrm{MII}}-\Phi_{\mathrm{D}}$ and $F_{\mathrm{MDI}}>F_{\mathrm{MDII}}$, which means that F_{MDI} will overcome the sum of F_{MDII}, the gravity of the armature and the contact reaction force, and the armature will be energized at the moment. In the process of armature pick-up, $F_{MDI}>>F_{MDII}$ with the continuous decrease of δ_{I} and the continuous increase of δ_{II}. As a result, the armature will move quickly to the pick-up (energized) position.

If the polarity of the current in the coil is changed, as shown in Figure 1-6(b), the direction of the electromagnetic flux Φ_{D} in the iron core will change accordingly, and it is the N pole at the pole shoe. When Φ_{D} and Φ_{MI} are in the opposite direction at δ_{I}, the magnetic flux is weakened ($\Phi_{MI}-\Phi_{D}$). When Φ_{D} and Φ_{MII} are in the same direction at δ_{II}, the magnetic flux is enhanced ($\Phi_{MII}+\Phi_{D}$). When $\Phi_{MII}+\Phi_{D}>\Phi_{MI}-\Phi_{D}$, then $F_{MDII}>>F_{MDI}$, which means that the armature will return to the de-energized position under the joint action of F_{MDII}, the gravity of the armature, and the contact action force.

3. Polar-biased Relay

The JPXC-1000 and JPXC-400 polar-biased relays are designed to identify the current polarity in signal circuits. Unlike the non-polarized relay, the energized state of the armature depends on the polarity of the current in the coil, and the armature is energized only when a current of the specified direction passes but doesn't move when the current is in the opposite direction. Unlike the polarized relay, there is only one stable state for a polar-biased relay, that is, after being energized by the electromagnetic force, the armature will be released once the power is cut off, and the released state is the stable state.

(1) Structure of Polar-biased Relay

The magnetic system of the polar-biased relay is basically the same as that of the non-polarized relay, as shown in Figure 1-7. However, the pole shoe of the iron core is square, and the permanent magnet steel is fixed by two screws under the square pole shoe, so that the armature is between the pole shoe and the permanent magnet steel, biased to the released position under the permanent magnetic force. Due to the existence of the permanent magnetic force, only one counter weight piece is installed on the armature, and the pressure on the back contact is produced by the combination of the permanent magnetic force and the counter weight piece.

The iron core is made of electrical pure iron, and the square pole shoe is welded to the iron core after impact molding.

Since the iron core is square, a square armature is used instead of the commonly used semicircular one in order to increase the magnetized area while reducing the magnetic resistance of the air gap.

The permanent magnet steel is made of AlNiCo with the N pole at the upper end and the S pole at the lower end.

The two coils are connected in series in the same way as that of a non-polarized relay.

Moreover, the contact system is identical to that of a non-polarized relay, with an 8QH contact group.

(2) Working Principle of Polar-biased Relay

The magnetic circuit system of the polar-biased relay is composed of a permanent magnetic circuit and an electromagnetic circuit, as shown in Figure 1-7. The magnetic flux of the permanent magnet Φ_M starts from the N pole and enters the armature through the third working air gap δ_{III} and is then divided into two parallel branch circuits: Φ_{M1}, a part of the magnetic flux, enters the square pole shoe through the first working air gap δ_I, and then directly returns to the S pole; Φ_{M2}, the rest magnetic flux, enters the yoke through the second working air gap δ_{II}, passes the iron core and then returns to the S pole. Because $\delta_I > \delta_{II}$, $\Phi_{M2} > \Phi_{M1}$; and $\Phi_M = \Phi_{M1} + \Phi_{M2}$, so $\Phi_M >> \Phi_{M1}$. Thus, the permanent magnetic force F_M generated from Φ_M at δ_{III} is much bigger than the permanent magnetic force generated from Φ_{M1} at δ_I, which enables the armature to keep in a stable released position.

Once the coil is powered, the electromagnetic flux Φ_D is generated in the iron core, and the magnetic circuit of Φ_D is the same as that of the non-polarized relay, as shown in Figure 1-7(a). If the direction of the current in the coil produces an electromagnetic flux with its S pole at the pole shoe, Φ_D and Φ_{M1} are in the same direction at δ_I at this moment, the total magnetic flux is

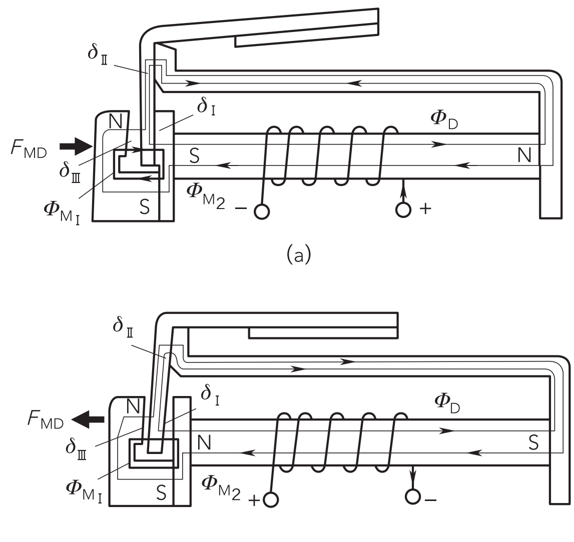


Figure 1-7 Magnetic Circuit and Working Principle of the Polar-biased Relay

Notes: (a)-The permanent magnetic circuit and the electromagnetic circuit when the armature is picked up;

(b)-The permanent magnetic circuit and the electromagnetic circuit when a power of reversed polarity is applied

the sum of Φ_D and Φ_{M1}, and the corresponding total electromagnetic force F_{MD1} increases; if Φ_D and Φ_{M2} are in the opposite direction at δ_{II}, the total magnetic flux is the difference between Φ_D and Φ_{M2}, and the corresponding total electromagnetic force F_{MD2} decreases. Due to the large difference in the arms of force, the effect of the increase in F_{MD1} is much greater than that of the decrease in F_{MD2}, and therefore, the total attraction force F_{MD} to the armature increases. When $F_{MD} > F_M$, F_{MD} overcomes the reaction force between F_M and the contact, so that the armature is picked up.

After the armature is picked up, the air gap of the magnetic circuit changes, that is, $\delta_{III} >> \delta_I$, and the permanent magnetic flux in the magnetic circuit as well as FM decreases greatly. At this time, as long as there is current, the armature will remain in the energized state.

When the coil power supply is disconnected, the gravity of the armature and the reaction force of the contact will jointly make the armature return. During the return of the armature, δ_{I} increases while δ_{II} decreases, and the permanent magnetic flux Φ_{M} increases rapidly to accelerate the return of the armature until the armature is blocked by the lower stop piece.

When the coil is applied with a current of reverse polarity, as shown in Figure 1-7(b), the direction of the electromagnetic flux Φ_{D} is reversed, so the total flux is $\Phi_{\text{D}}-\Phi_{\text{M1}}$ at δ_{I}, but $\Phi_{\text{D}}+\Phi_{\text{M2}}$ at δ_{II}. As a result, the total electromagnetic attraction decreases, and the armature will not be picked up. In this way can the polar-biased relay identify the polarity of the applied current.

However, it is conditional that the armature will not be picked up with a current of reverse polarity. If the current of reversed polarity is increased continuously until the electromagnetic flux is big enough to overcome the attraction of the permanent magnet, that is, $F_{\text{D}}-F_{\text{M1}}>F_{\text{M}}$, the armature can be picked up, which is not allowed for a polar-biased relay. Therefore, to ensure the reliability of the polar-biased relay, there must be a special requirement for its electrical characteristics, that is, the armature must not be energized when a voltage of 200 V is applied in the reverse direction.

4. Rectifier Relay

To improve the serialization and generalization of the AX relays, the AC relays with completely different structure should not be used. Instead, rectifier relays are used in AC circuits, converting alternating current into direct current through the internal half-wave of full-wave rectifying circuits.

The models of rectifier relays include JZXC-480, JZXC-0.14, JZXC-156, JZXC-H18 and the derived JZXC-H18F.

(1) Structure of Rectifier Relay

The structure of the electromagnetic system and the contact system of a rectifier relay is the same as that of a non-polarized relay, and all their parts can be used interchangeably. Otherwise, the structural parameters of the magnetic circuit and the serial numbers of the contacts are different.

(2) Working Principle of Rectifier Relay

The working principle of a rectifier relay is the same as that of a non-polarized relay. However, after rectification of the AC power supply, a full-wave or half-wave pulsating DC power is applied to the coil, and the alternating component causes pulsation on the electromagnetic force, which makes noise and adversely affects the normal operation of the relay.

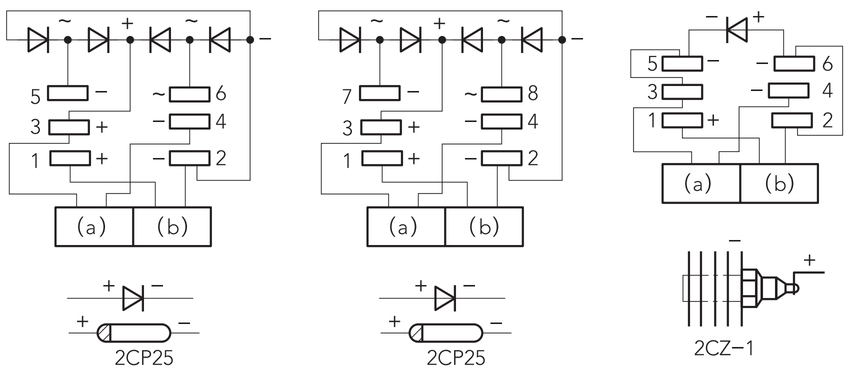


Figure 1-8 Connection of Coils, Rectifier and Power Supply Piece of a Rectifier Relay

Notes: (a)-Front coil; (b)-Rear coil

3 Usage of Relay Coil

For a relay with two coils of the same parameters, the coils can be connected in a few ways: connection in series with power chips 2 to 3, or 1 to 4; connection in parallel with power chips 1 to 3, or 2 to 4; separate connection with power chips 1 to 2, or 3 to 4; or one coil working alone.

No matter in which way the two coils are used, the working ampere-turns and release ampere-turns of the relay must be guaranteed for the reliable operation of the relay. For example, for a JWXC-1000 relay, both its front coil and rear coil have 8000 turns. When the two coils are used in series and the working voltage is not higher than 14.4 V, the working current is not higher than 14.4/1000=0.0144 A and the working ampere-turns is no more than 2×8000×0.0144=230.4 A. When a single coil is working, in order to secure the same ampere-turns, the operating voltage applied to the two coils shall be 230.4/8000×500=14.4 V respectively. When the two coils are connected in parallel, to achieve the same ampere-turns, the required operating voltage shall be 115.2×2×250=7.2 V.

It can be seen that in order to ensure the same working ampere-turns, the current passing through the coil while using a single coil must be twice as large as that passing through two coils in series, and the power consumed shall also be doubled. At this time, the larger the power supply capacity is, the more easily the coil heats up. Therefore, the two coils in series are usually used for most relays. However, when required by the circuit, the coils can also be used separately. When the two coils are used in parallel, the required voltage will be half of that for two coils in series. So two coils in parallel are generally used in circuits with a lower voltage input.

Part Four : Workshop

Directions: Design and build a sequential logic circuit with relays, using a set of nodes of each relay together with a light-emitting diode (LED, for short) to realize the effect of a revolving cast of lamps.

Requirement

3-4 relays

Tips

1. The effect of a revolving cast of lamps: 3 LED lamps will be turned on and off in a circular manner. When one lamp is turned on, the other one that is currently on will be turned off.

2. The resistance-capacitance device is used to realize the slow release of the relay. In other words, a charging and discharging circuit is needed for the relay coil: when the relay coil is powered off, the lamps will be kept on for a certain period of time.

3. A start switch is necessary.

Self-assessment

Directions: Check the box (☺, 😐 and ☹) given for each learning objective and tick the one that best matches your performance.

Learning Objectives	My Performance		
	☺	😐	☹
Master the requirements of the railway signal system for relays and the functions of relays.			
Master the classification of signal relays.			
Master the working principle of safety relays.			
Grasp the analytical methods of relay circuits.			