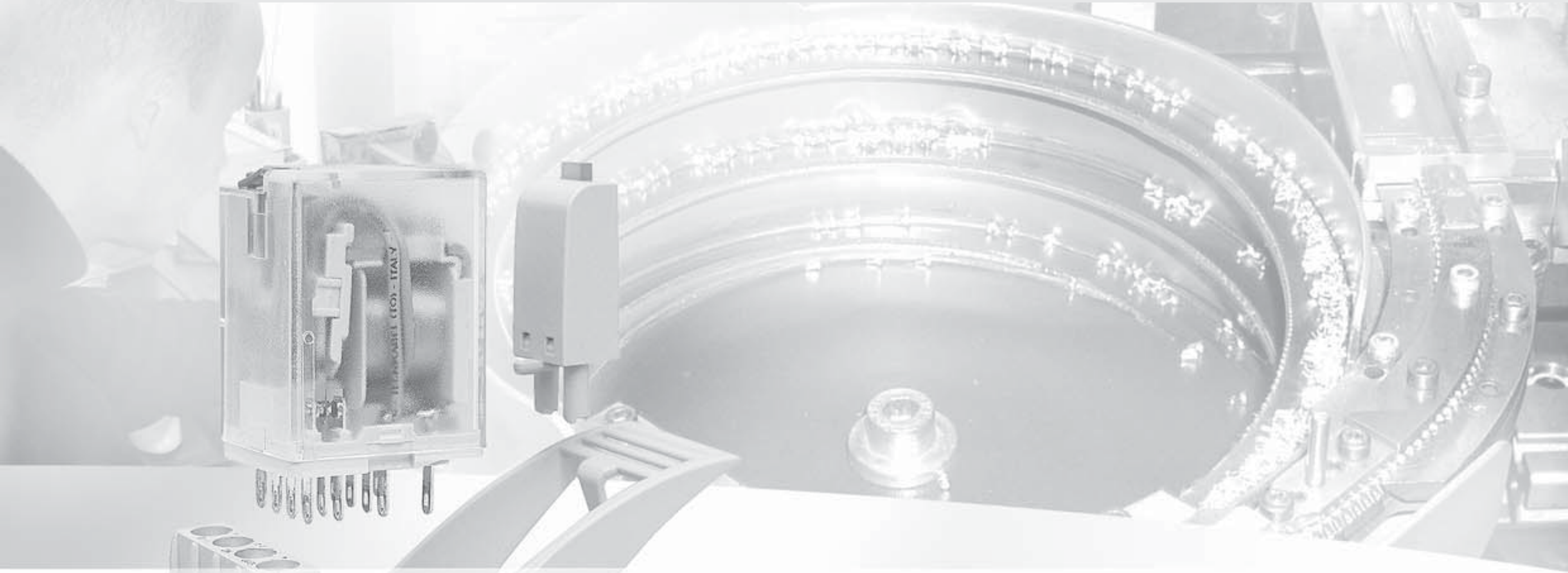
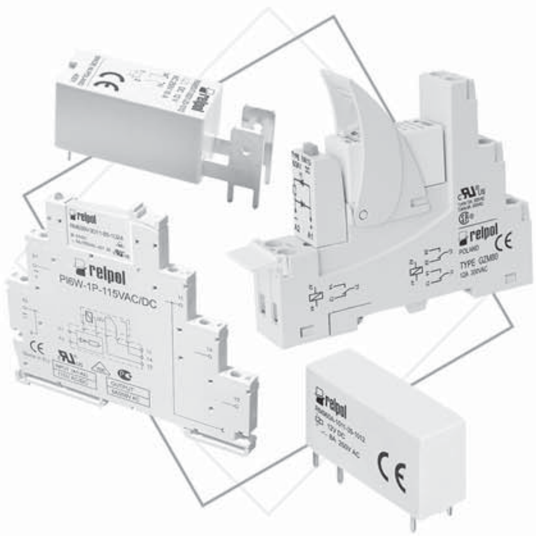


relpol® S.A.

According to USASI (United States of America Standards Institute) a relay may be defined as an electrically controlled device which opens and closes an electrical circuit in order to affect the operation of other devices in the same or another circuit. Relays are a significant element in the contemporary industrial processes.
Dozens of milliards of relays operate nowadays in the world as an interface between control circuits and electrical load. The technological development has brought miniaturization of mono-, bi- and tri-stable relays that need a low or even no supply voltage to carry a high power through the contacts.



Relpol S.A. - almost 50 years of the Company's activities and more than forty years of experience in production of highest-quality relays.

Function of the relay

The relay performs two crucial tasks:
- galvanic separation (isolation) of the control section and switching section.
- switching of high-power loads with high voltage and/or current of high intensity at low energy consumption (low voltage / low current intensity) even at low electrical signals.

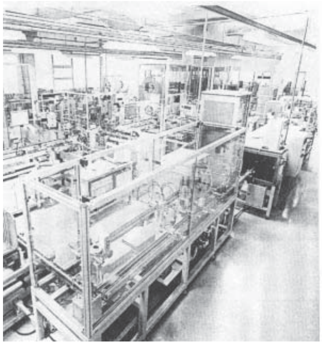
There are numerous applications of relays. Whenever satisfactory operation is needed in electronic and electromechanical conditions, a relay is necessary, e.g. for control equipment, time relays, temperature control, etc.

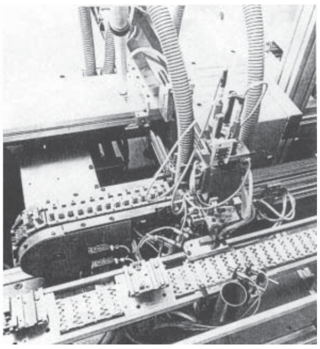
There are two kinds of the device, i.e. electromechanical relay and solid-state relay (SSR).
In the case of an electromechanical relay, there is a high level of isolation between the open contacts while switching which not the case with SSR. This means different approaches to the issue of safety. However, there is no contact vibration in SSR (no moving parts), and the switching time is very short. Moreover, the relation between the cost of the device and the switched power is much less advantageous for SSR than for the electromechanical relay.
The SSR has been invented for special applications where high switching frequency with no contact wear is important.

Main parts of the relay

The electromechanical relay consists of an electromagnetic switch and an electric one.

The former is the control section, and the latter is the switching section which is directly connected to the electrical load. The electromagnet transforms the electrical current into a magnetic stream that generates the force which moves the switching part.





Elektromagnet

Fig. 1 shows a classic electromagnet unit which consists of the four basic parts:
- The coil which consists of one or more windings of a copper wire that is usually wound around a spool made of insulating material.
- Ferromagnetic core.
- Ferromagnetic yoke.
- Movable ferromagnetic armature.
- Additional parts:
  - fixed and movable contact springs,
  - contacts,
  - pusher,
  - mounting terminals and coil terminals,
  - contact plate,
  - anti-dust cover.

Fig. 1. Classic electromagnet unit

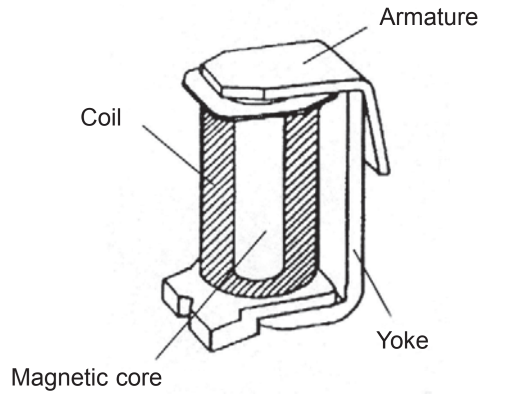
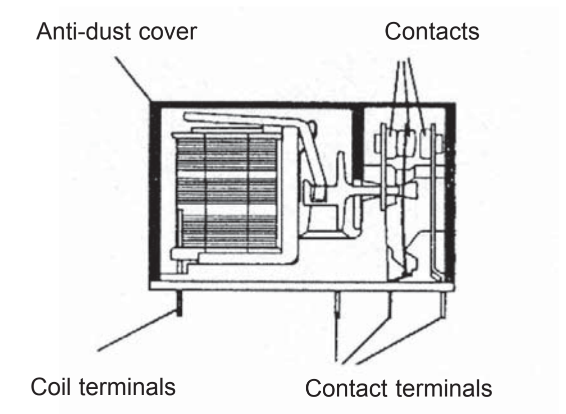


Fig. 2. Classic design of a relay

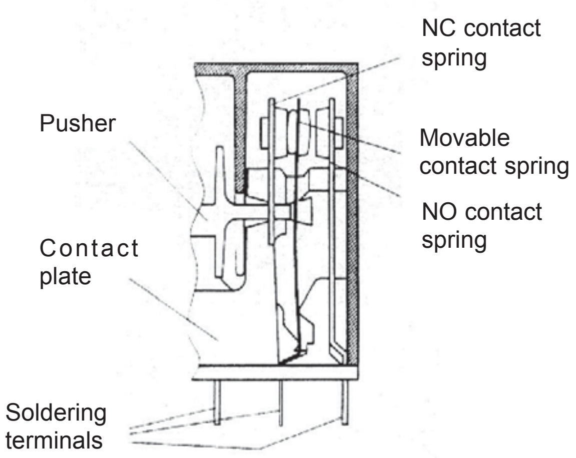


Switching section

A classic arrangement of the switching section refers to a diagram of one changeover contact. It has been used in the explanation below, as it is a basic diagram referred to by all the other diagrams.

Fig. 3 shows the switching section of a relay with one change-over contact.
The figure presents the following parts:
- fixed normally closed (NC) contact unit,
- movable contact unit,
- fixed normally open (NO) contact unit,
- pusher,
- contact plate,
- soldering terminals.

Fig. 3. Switching section of a relay



Types of relays

Monostable and bistable relays are the basic types of electromechanical relays.

Monostable and bistable relays

Monostable relays
A monostable relay is an electric one which changes its state as affected by the appropriate supply value, and returns to the original state when the said value ceases or changes appropriately.

Bistable relays
A bistable relay changes its state as affected by the appropriate supply value, and remains in the changed state even after the value has ceased. Another application of the appropriate supply value is necessary for the relay to change its state again and return to the previous state.

Further classification of relays may be based upon the functions they perform, e.g.:
- all-or-nothing relays,
- step relays,
- polarized relays,
- remanence relays,
- reed relays.

All-or-nothing and step relays

All-or-nothing relays
The term identifies the relays designed for operation at the value that is:
- higher than the make value, or
- lower than the return value.

This type of relays must be supplied by a particular range of voltage (or current). They may be energized by supply or disconnection of voltage (or current) within a given range.

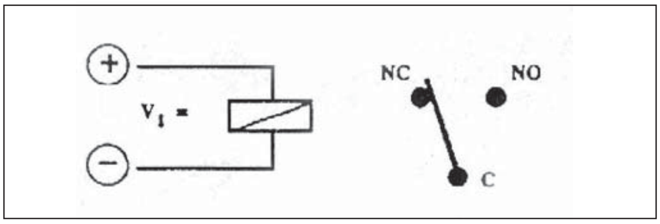
Step relays
The relays have two or more rotational positions, and they move from one step to another in consecutive operations with the use of the energizing pulse. They usually move the contacts with the use of cams.

Latching relays

The latching relay is a non-polarized bistable relay. It changes its state at the supply value and remains in the position after the value has ceased.
In order to change the state of the relay again, another actuation is necessary. The crucial part of the latching relay is the core made of special magnetic iron, which remains magnetized ever after a voltage pulse has been applied. The core consists of the nickel base with aluminum, titanium or niobium added (55-85% Co, 10-12% Ni).

Function:
Energizing condition: OFF state
As the wiring is supplied with a voltage pulse of direct current V_1 (selected from the recommended supply voltage range) for the duration of t_i, the electromagnetic field grows immediately, the core becomes magnetized and the relay is energized (the normally open contact closes). When the pulse declines, the relay remains in the ON state owing to the permanently magnetized core (Fig. 4).

Fig. 4. Latching relay, electrical circuit

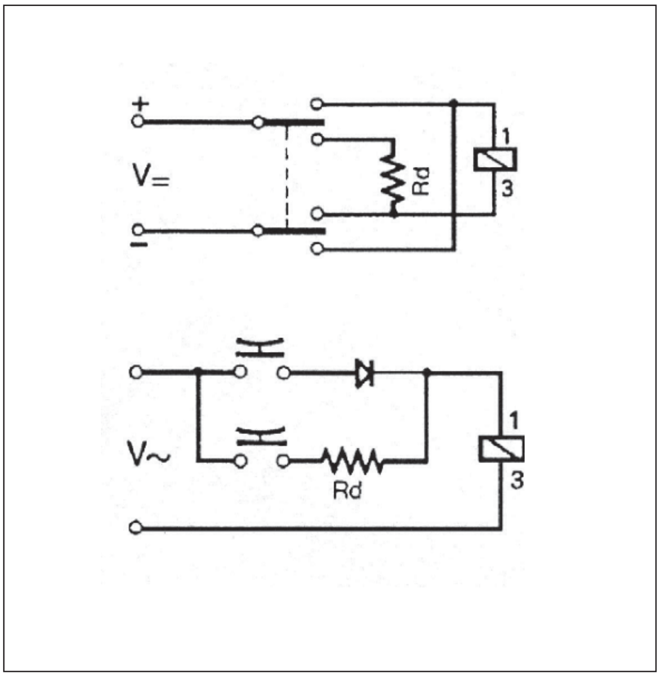


Thus, the magnetic polarization of the relay depends on the polarity of the supply voltage. The relay switches to the OFF state on supply of the voltage of the opposite polarity which changes the magnetic polarization of the core.
The sole change of the supply polarity will not cause the release of the relay. This requires a change of the polarity, and the value of the energy supply must be within the range of the actuation (energizing) values.

The circuit applied
There are two different types of the latching relays:

• Single winding latching relays with the external release resistance to limit the current intensity, e.g. RMB631 (Fig. 5).

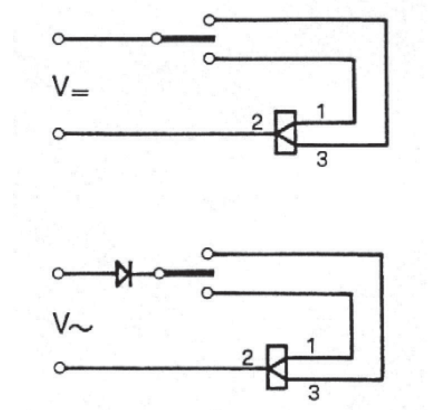
Fig. 5. Circuits with single winding latching relays (R1 version)



• Latching relays with two windings and two different voltage ranges for ON / OFF operation, e.g. RMB632 type (Fig. 6).

It is important to bear in mind that for the appropriate operation the relays require a minimum pulse of 10 ms. In order to avoid overheating, the maximum time of supply is usually limited, too. The aforementioned relays may also be supplied with alternating voltage owing to the external diode which rectifies the alternating current to the pulses of minimum duration of 10 ms (half of the period). The applications of latching relays are the same as the applications of the normal version relays.

Fig. 6. Circuits with two windings latching relay (version R2)



Polarized and reed relays

Polarized relay

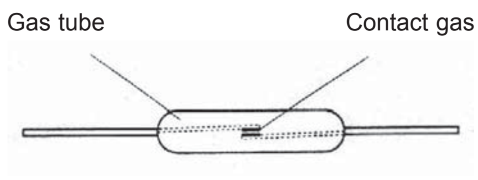
This is a relay with permanent magnet which provides additional magnetic force that reduces the energy consumption. The magnetic field required for pulling the armature is partly generated by the coil and partly by the magnet. The magnetic streams overlap.

The supply value must be of the appropriate polarity, i.e. the same as the polarity of the magnet. There are mono- and bistable versions of these relays.

Reed relays

The remarkable advantage of the reed relays is that they are hermetically sealed and, thus, resistant to atmospheric corrosion. They are very fast (10 to 20 times faster than electromechanical relays) and at the range of the rated contact load they offer highly reliable switching operations, and extremely long life. The fundamental part of a reed relay is a hermetic glass tube, commonly called the magnetic (reed) contact.

Fig. 7. Hermetic contact



The magnetic (reed) contact consists of two flat, ferromagnetic lap contacts of the reed relay separated by a small air-clearance, hermetically closed in a glass tube. The contacts of the reed relay are fixed to the ends of the glass tube and, thus, they serve as supports. If the free ends of the reed contacts are exposed to the magnetic field, the stream in the clearance between the reed contacts will make them cooperate. When the magnetic field ceases, the reed contacts will part from each other as a result of the stress of the spring placed in the contacts. This way, the contacts provide an operating magnetic clearance, and they close and open the electrical circuit.

Types of relays manufactured by Relpol S.A.

Relays for PCB mounting, RM84, RM85, RM87

monostable • sealed and tight versions • DC and AC coils • current-carrying capacity of the contacts from 8 to 16 A • up to 2 changeover contacts • with enhanced insulation 4 kV / 8 mm • surface-mount versions (SMT).

Plug-in industrial relays and miniature power relays for sockets
R2, R3, R4

anti-dust cover • DC and AC coils • current-carrying capacity of the contacts up to 12 A • up to 4 changeover contacts • PCB-mounting versions.

Subminiature relays
RSM850, RSM850B, RSM822, RSM832, RSM954, RSM957

subminiature relays for PCB mounting • tight versions - for flow soldering and washing • DC monostable and bistable (RSM850B) coils • current-carrying capacity of the contacts from 0,01 mA to 3 A • up to 2 changeover contacts • high sensitivity.

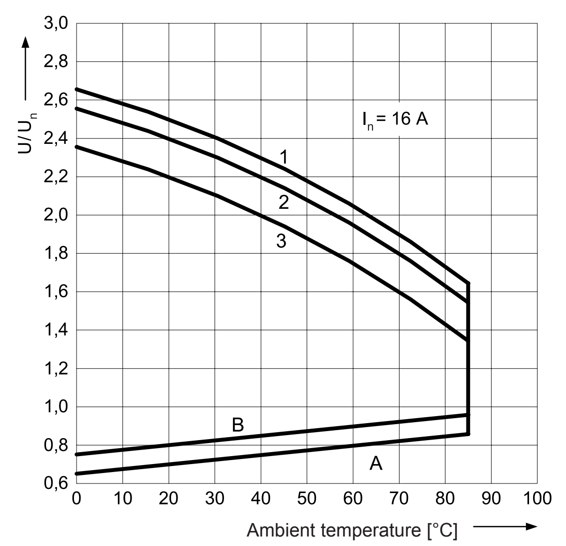
Plug-in time relays for sockets
T-R4

anti-dust cover • DC and AC coils • current-carrying capacity of the contacts 6 A • 4 changeover contacts • single function.

Coil operating voltage range

The admissible operating voltage range for the coil as the function of the ambient temperature is shown in the chart for RM85 relay.
The maximum operating voltage of the coil is limited by the increase of the coil temperature caused by the heating of the winding. The increase shall not exceed the admissible temperature defined for insulation materials. The switching voltage is the minimum operating voltage of the coil. The switching voltage grows along with the increase of the winding temperature. Since the resistance of the copper wire changes by 0,4% per Centigrade, the growth of the coil temperature caused by a higher ambient temperature or by contact load results in the drop of the coil current and, thus, the increase of the voltage required for the relay electromagnet to operate.

Fig. 8. Admissible coil operating voltage range - direct voltage



A - switching voltage in the function of ambient temperature at no contact load. Prior to the relay switching, the ambient temperature is the same as the coil temperature. The switching voltage will not exceed the voltage indicated on Y-axis, expressed as the ratio of the rated voltage.
B - switching voltage in the function of ambient temperature after the coil has been heated with 1.1 Un voltage and the contacts loaded with continuous current In.
The curves **1**, **2**, **3** allow to read (Y-axis) the admissible ratio value of the coil rated voltage with which the coil may be overloaded at given ambient temperature value and at given contact load:
1 - no contact load
2 - contacts loaded with half the rated current
3 - contacts loaded with rated current.

Coils - overvoltage protection

While using electromagnetic relays in electric circuits, it should be borne in mind that coils are the source of significant overvoltage which may disturb the operation of the equipment in which electromagnetic relays are applied. Furthermore, due to overvoltage the equipment in which electromagnetic relays are used may not meet the requirements of electromagnetic compatibility.

Relay coils have high inductance during operation, which causes a rapid increase of the coil voltage on switching off. Such a situation occurs in both DC and AC voltage coils. If, for example, the coil is switched off by a transistor, the latter may be damaged. Moreover, such pulse disturbances my affect negatively the nearby electronic systems.

Fig. 9. DC coil voltage during switching off

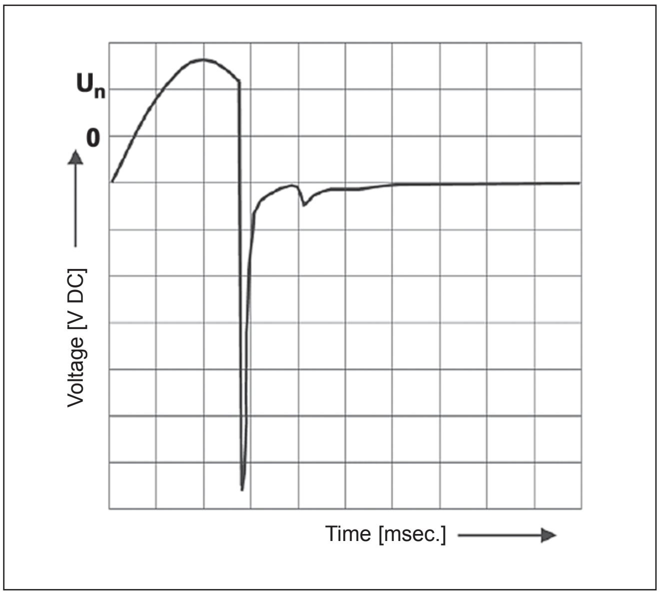
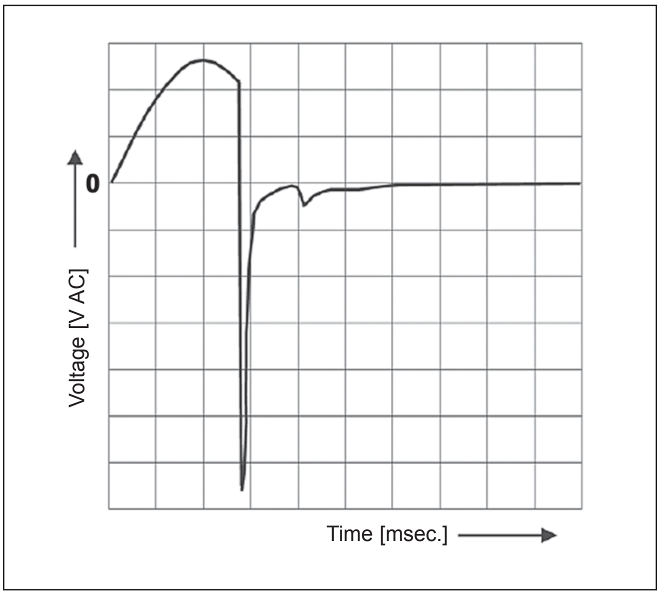


Fig. 10. AC coil voltage during switching off



For coils supplied with DC voltage, the best and simplest solution of the problem is a parallel connection of a standard rectifying diode to the coil terminals. During the current flow, the diode has a reversed bias due to the voltage drop on the coil. On switching off the coil voltage, the diode starts conducting which results in the coil voltage increase merely by the voltage drop on the conducting diode. Designers of electronic systems with electromagnetic relays practically always use suppressing diodes connected in parallel to the relay coil. The 1N4007 diode is a perfect solution in most of such cases. Diodes remove overvoltage extremely efficiently, they are a cost-effective and reliable way of suppressing coil self-induction voltage, which does not involve complicated calculations The only weak point of the diode system is a remarkable (threefold) increase of the relay release time. The release time may be reduced by connecting an additional resistor in serial to the diode in which case, however, the over-voltage value grows while the coil is being switched off.

The diode protection cannot obviously be used with AC coil relays. In such cases, two types of protection are commonly used, i.e.:

- varistor protection, and
- R-C two-terminal network protection.

Metal-oxide varistors have similar current-voltage characte-ristics to that of a bidirectional Zener diode. When the voltage between the varistor terminals exceeds a given limit value, it starts conducting, and, thus, it shunts the inductive load (the relay coil) with its differential resistance. The maximum overvoltage value on switching off depends on the limit voltage of the varistor.

Furthermore, when the varistor is supplied from the mains, the varistor protects also the relay coil from being damaged by the voltage pulses that occur in the mains. The varistor protection may be also applied in DC coil relays. However, the overvoltage values on switching off are much higher than in the case of protection with the use of a suppressing diode.

Another way to limit the overvoltage values during coil switching off is a parallel connection of an R-C two-terminal network to the coil. The network limits the overvoltage well, it is inexpensive, and it only slightly increases the relay release time.
No ceramic capacitors should be used whereas it is recommended to use foil capacitors. On selection of a resistor, it should be taken into consideration that quite a large amount of power dissipates on it during the transition process and, thus, the resistor's power shall not be less than 0,5 W.
Relpol offers both relays with integrated overvoltage protection elements (diodes or varistors) and ready-to-use overvoltage protection modules to be mounted in plug-in sockets.
R2, R3 and R4 relays with DC coils are also in the version with suppressing diode mounted inside the relay. However, varistors are not mounted inside these relays. Ready-to-use overvoltage protection modules of M series may be used with the relays and then the modules are mounted in GZT and GZM series plug-in sockets. Modules with a diode (DC coils) or with a varistor (DC or AC/DC coils) are available.

R15 relays are manufactured solely with the overvoltage protection element integrated, i.e. with the suppressing diodes for DC coils (two-, three-, and four-pole versions) and with varistors for AC coils (two-, and three-pole versions).

In the case of a suppressing diode as the overvoltage protection element, the coil supply polarity must be as follows: A1 terminal "+", A2 terminal "-".

Ordering codes of the overvoltage protection elements integrated in the relays (as add-on equipment) are as follows:
- D - suppressing diode;
- V - varistor.

While using an overvoltage protection element, the user may be assured that the overvoltage that occurs on switching the coil off will not affect negatively the coil control circuits or any other electric and electronic circuits.

Switching section: main diagrams and mechanical solutions

There are various contact configuration diagrams related with different application requirements, i.e. normally open contacts (NO), normally closed contacts (NC) and changeover contacts. These are the basic configurations used for designing all the contact diagrams of relays. With the use of the basic contacts, many relay circuits may be built in order to apply relays successfully. The only theoretical limitations are the dimensions of relays, electromagnetic energy, switching energy and the complexity of drawings. The contact configurations available in a relay are determined by the number of poles, type of the contacts (changeover or normally open/closed), and normal position of the contacts (normally open or closed).

Below, symbols depicting exact type of contacts are listed:

Contact type	Relpol's marking	Zettler's marking	USA
C/O	1	C	SPDT
NO	2	A	SPST-NO
NC	3	B	SPST-NC

SP = single pole
ST = single contact (normally open or normally closed)
NO = normally open contact
NC = normally closed contact
DP = two contacts
DT = changeover contact

Other manufacturers of relays use a different classification (e.g. Feme). The code of the contacts is defined with three digits. The configuration of the contacts is defined with a X Y Z code, i.e.:
- X - number of NO contacts
- Y - number of NC contacts
- Z - number of changeover contacts

Thus, for example, the following configurations may occur:
100 = SPST - NO (1 normally open contact)
010 = SPST - NC (1 normally closed contact)
001 = SPDT = 1d (1 changeover contact)
200 = DPST - NO (2 normally open contacts)
020 = DPST - NC (2 normally closed contacts)
002 = DPDT = 2c (2 changeover contacts) etc.

Contacts and shapes of contacts

Contact pressure

When two contacts come together to close the electrical circuit, they touch each other within the area that depends on the shape of the contacts. The force (N) with which the contacts push against each other as measured on the contact axis, divided by the area of the contact (mm^2) equals the contact pressure (N/ mm^2). It is practically impossible to determine the real contact area as it depends also on the roughness of the contact surface. The contact pressure is determined by the contact force. In order to obtain a large contact area, the contact force must be increased so that the contact area roughness may be deformed. A low force means a few effective contact points and a small area of the contact (i.e. a high contact resistance).
On the other hand, a stronger force increases the number of contact points and the total contact area (lower contact resistance). The contact force may be increased only to the limit defined by the mechanical strength of the parts and as much as it is allowed by the supply voltage sensitivity. Manufacturers of relays use different shapes of contacts according to the relay designs and applications.

Fig. 11. Effect of the contact force

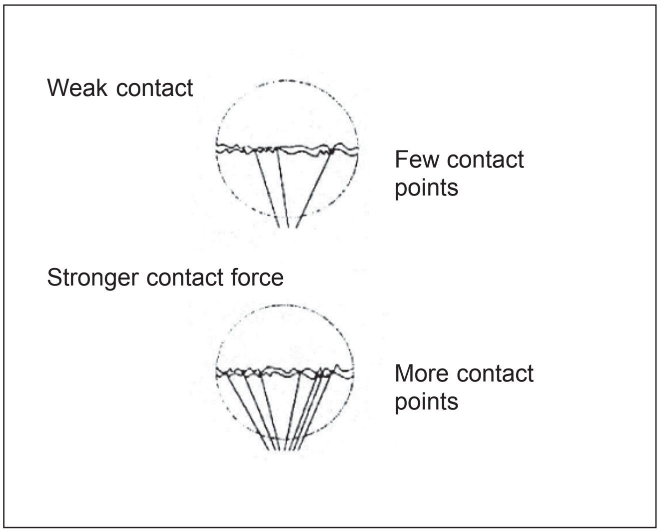
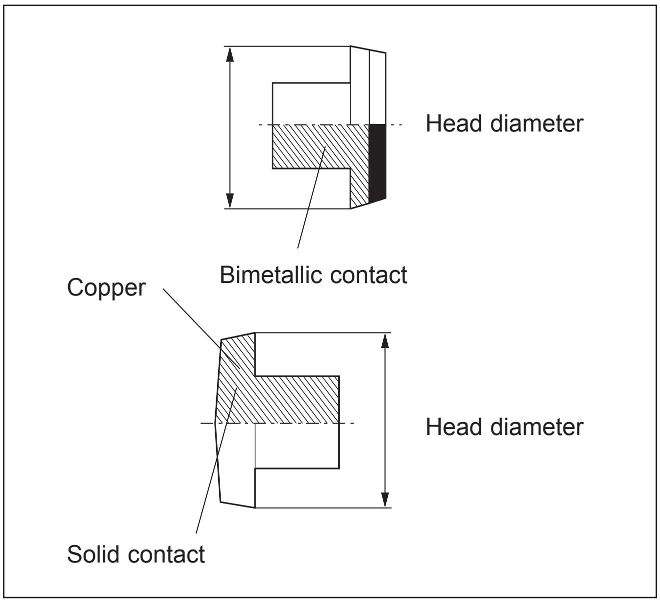


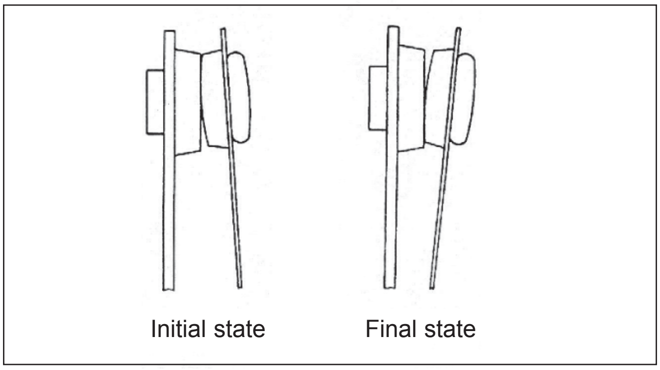
Fig. 12. Shapes of contact rivets



Cylindrical contact rivets

Cylindrical contact rivets are usually used in their bimetallic, solid or other versions, similarly to the contact parts of miniature relays owing to their optimal switching capabilities and easy assembly. Normally, the contacts are connected between the flat surface of the fixed contact and the spherical surface of the movable contact (the common contact). Principally, the common contact is a solid one whereas the fixed contacts (NC and NO, when in switching operation) are bimetallic ones (Fig. 12). The head of the central solid contact is ready to use on one side, and it is shaped during assembly on the other side. The flat-spherical connection between the contact surfaces is necessary for the reduction of the area of connection with the simultaneous increase of the contact pressure. Moreover, relative surface movement (roll) occurs then, which is useful in terms of enhanced contact performance (Fig. 13).

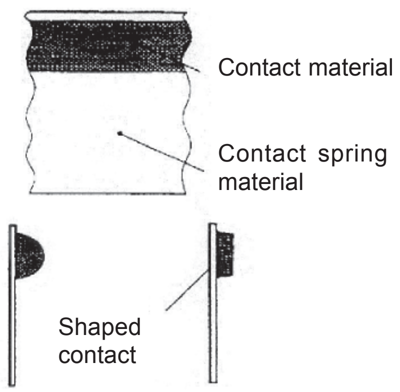
Fig. 13. Contact movement



Small-profile contact

A pressed strip of metal or contact alloy is automatically welded to the spring material prior to the cutting process. During the cutting process, the spring strip is cut together with the contacts, and the contact is formed to the required shape (Fig. 14). This solution is useful as it provides avoiding a dangerous voltage drop on the spring-contact connection. This allows the appropriate selection of the contact shape.

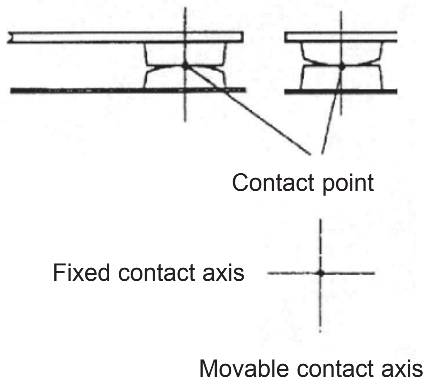
Fig. 14. Small-profile contact



Cross contacts

While using small-profile contacts it is possible to design a contact coupling with cylindrical surfaces and perpendicular axes. This way, a limited contact area and high contact pressure may be obtained. Moreover, during switching, two contacts operate like "two knives", thus maintaining a very clean contact surface.

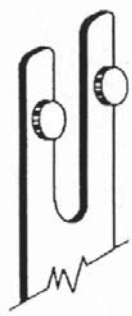
Fig. 15. Cross contact



Twin contacts

For some applications (e.g. low-level signals - safety systems), in order to enhance the contact reliability, twin contacts are used. Small-profile rivets or contacts are placed one next to another on the same forked spring (springs of fixed and movable contacts). Thus, duplication of the contact points may reduce the probability of error occurrence by half.

Fig. 16. Twin contact



Contact materials

In the issues related with switching, contact materials and special alloys play an important role, and each application requires the appropriate assessment of the electric load, ambient conditions and other information in order to make the proper choice.

Surface finishing

Precious contact materials are widely used due to their high conductivity. However, it is silver and its alloys that are exposed to the effects of the surface corrosion caused by sulfur contaminations in the atmosphere (SO_2 - sulfur dioxide). Layers of sulfur deposit on the contact surfaces, which is highly harmful to the contact resistance. The aforementioned materials may be plated with gold or another noble metal (metals that are more resistant to corrosion and/or oxidation, i.e. platinum, palladium, etc.).

Cleaning

Cleanliness is very important for the process of relay assembly due to the necessity to keep the internal parts of relays free of dust and other particles which may affect the area between the contacts and disturb the proper course of switching operations. That is why contacts, working parts and (in some applications) the whole relay without a dust cover are cleaned immediately prior to their enclosing.

Plastic contaminants

Due to temperature, internal parts of the relay made of plastic may produce gases and vapors. If they are not removed from the relay, they may deposit on the contact surface, which will increase the contact resistance. This is often the case in tight relays where it may appear extremely dangerous if the plastic has not been previously treated in a special manner. The treatment consists in high-temperature degassing process in which, at low atmospheric pressure, plastics emit gases and vapors. The process ends with stabilization of the ambient pressure which allows avoiding reactions inside the relay that might occur in the presence of humidity and oxygen.

Contact resistance and influencing factors

The main function of electric contacts is to close an electric circuit to provide flow of current (I) at voltage (U). This "simple" operation requires certain special characteristics of contacts, which depend on materials, shapes, mechanical parameters, etc. When current (I) flows through an electric circuit, the circuit resistance (R) reacts against the current flow according to the following rule:

$$U = R \times I$$

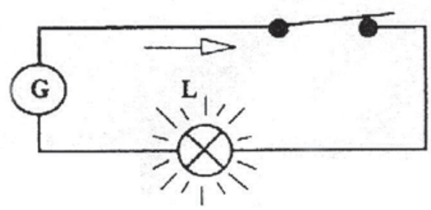
The value of R consists of two different resistances: **circuit resistance R_c and contact resistance R_r.**
Thus,

$$R = R_c + R_r \text{ i } U = I \times (R_c + R_r)$$

The dissipated power P_w **in the whole circuit** equals:

$$P_w = P_c + P_r = (R_c + R_r) \times I^2$$

Fig. 17. Basic circuit



G = Generator L = Load

The value of the circuit resistance R_c usually spreads evenly along the length of the circuit (cables, wires, printed circuits, etc.), and P_c dissipates in the same manner (low increase of temperature).

On the other hand, however, R_r is entirely concentrated inside the relay (problems related with the temperature rise). This proves the extremely important role of maintaining the relay contact resistance on as low a level as possible. This is important in applications of both high and low power. In the first instance, there is the problem of temperature rise inside the relay whereas in the second case high contact resistance may disturb the proper operation of the device.

Problem:
Find the values of power (W) dissipation in the relay contact circuit under the following circumstances:
Electric load: I = 5 A, U = 250 V AC.
Relay contact resistance (mΩ):
a) 10 mΩ
b) 50 mΩ
c) 300 mΩ
Solution:
a) $R_c \times I^2 = 10\ m\Omega \times (5\ A)^2 = 0,25\ W$
b) $R_c \times I^2 = 50\ m\Omega \times (5\ A)^2 = 1,25\ W$
c) $R_c \times I^2 = 300\ m\Omega \times (5\ A)^2 = 7,50\ W$
Based on the above, it may be stated that the power dissipation inside the relay reaches undesirable levels at high contact resistance.

Problem:
Find the value of the voltage drop caused by the relay contact resistance in the next circuit under the following circumstances:
Electric load: I = 1 mA, U = 5 mV
Relay contact resistance (mΩ):
d) 10 mΩ
e) 100 mΩ
f) 400 mΩ
Solution:
The voltage drop on the contact equals:
d) $R_c \times I = 0,01 \times 0,001 = 0,01\ mV$
e) $R_c \times I = 0,10 \times 0,001 = 0,10\ mV$
f) $R_c \times I = 0,40 \times 0,001 = 0,40\ mV$
High values of resistance cause a significant percentage of voltage drop which may be dangerous in some devices. This is important because high contact resistance usually means instability of the contact resistance. In applications of low-level signals (measurements, etc.) the capability of reaction to the contact resistance is a fundamental requirement. The following factors affect the contact resistance:
- contact pressure,
- materials,
- surface finishing,
- cleaning,
- internal contaminations of the plastic relay parts.

Each individual influence must be taken into account.

Alloys and contact materials

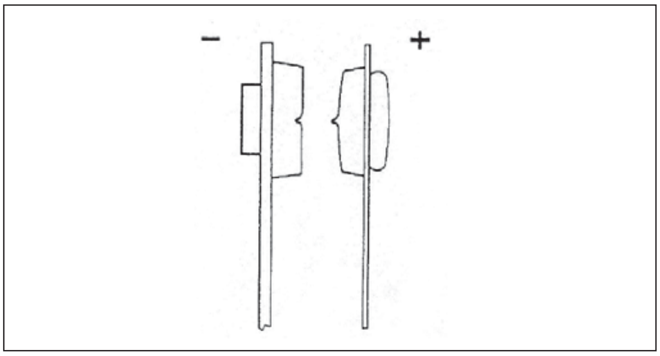
The choice of the contact material depends on the application. The following are the most commonly used materials:

Silver Ag
Pure silver (99% Ag) is of the highest electrical and thermal conductivity as compared to any other known metal, and it proves good resistance to oxidation but it is affected by the presence of sulfur in the atmosphere. The sulfur forms silver sulfide which increases the contact resistance. In order to avoid the problem, the contact surface is plated with gold (5 μm) as the latter remains free of silver sulfide (no chemical reaction). This is a good version of the contact widely used for switching low-level loads from μV to 24 V DC and AC, and from μA to 0,2 A, and in any case with no electric arc as it might damage the layer of gold and expose silver to the harmful presence of sulfur.

Silver - cadmium oxide AgCdO
This compound (90% Ag - 10% CdO) has a wide range off applications in power loads owing to its good resistance to welding and the effect of electric arc suppression. The compound may be used from 12 to 380 V AC and from 100 mA to 30 A. It is used particularly for resistive and inductive applications such as motor loads, heating resistors, lamp loads, solenoids, etc. The material is a standard one to meet most of the requirements of the customers. The problems related to sulfur do affect it but the presence of electric arc and relatively high voltage and intensity of current make the problem imperceptible (the electric arc and voltage pierce the sulfide layers).

Silver - nickel AgNi
The alloy (90% Ag - 10% Ni) is the most suitable one for switching DC loads and avoiding material transfer that appears at DC and at medium voltage and intensity of current (1 - 10 A; 6 - 60 V DC). This is a physical phenomenon of moving the material from one contact to the other (from cathode (-) to anode (+)). This results in quick wear of contacts and dangerous reduction of the contact clearance.

Fig. 18. Transfer of contact material



Tungsten
This is the hardest material, highly resistant to sticking. It has, however, a relatively high contact resistance. Because of these characteristics it is usually used in electric circuits where short current peaks appear, and where the material prevents the contacts from welding to each other: leading loads, motor loads, lamp loads (especially fluorescent lamps), etc. It is applied from 24 to 500 V AC and from 0,5 to 5 A.

Silver + tin oxide (tin dioxide) - $AgSnO_2$
The $AgSnO_2$ material is of similar properties to those of AgCdO. However, the former has a higher thermal stability and better resistance to transfer of material from one contact to the other, which provides longer life in DC applications. The $AgSnO_2$ contacts wear evenly and they are recommended for applications at the loads that create inrush current and at inductive loads.
The contact ratings depend to a great extent on the level of the oxide in the compound, the manufacture method and the presence of admixtures which are used by contact materials manufacturers mainly to reduce the contact resistance and to enhance the resistance to material transfer.
The $AgSnO_2$ material offered by Relpol in miniature relays contains a low admixture of indium oxide (In_2O_3) and it is a universal material. Apart from good results achieved at lamp loads, the material performs perfectly at resistive loads and switching currents up to 16 A.

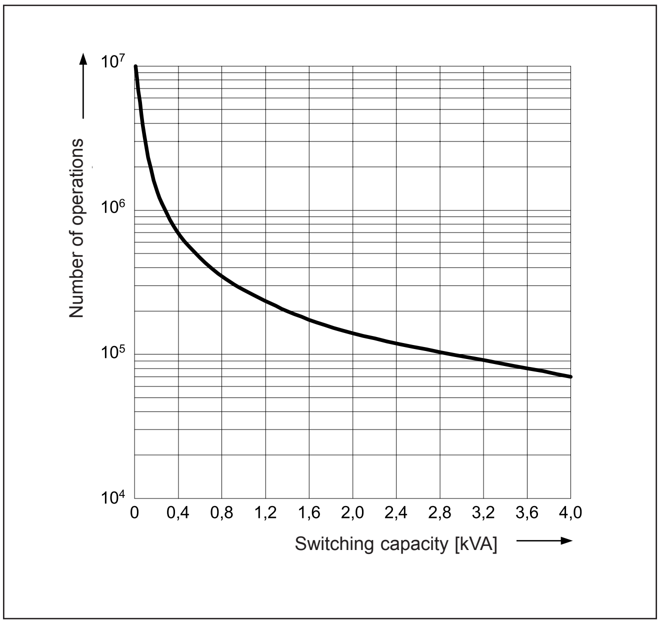
Gilding - Au
Contact gilding with 0,2-0,5 µm gold layer is usually applied in order to protect the basic material from oxidation during product storage. The protective gilding is not resistant to mechanical wear and it is quickly destroyed in course of the relay switching.
Contact gilding with 3-5 µm layer of gold is used as protection from corrosion and to enhance signal circuits switching. Thick gilding provides the lack of microscopic pores, perfect resistance to corrosion and to formation of non-conductive layers.
However, gold is very soft, easily becomes mechanically worn, and its low melting point may limit the electric life of the contacts which switch high currents.

Electric life of relays

The electric life or switching capacity is expressed as the minimum number of cycles which the relay may perform at a given load and under certain circumstances. The ”cycle” means a full switching operation from OFF state to ON state and to OFF state again. The electric life ends when the contacts are no longer capable of switching electric load within the range of the contact resistance (or contact voltage drops) which stops the switching operations after it has reached a higher value (the limits depend on the application). The specifications of relays indicate the electric life as the number of cycles at rated current and voltage, and at constant frequency and ambient temperature.

For example, the electric life of the RM85 relay is:
Number of cycles: 7 x 10^4 at 16 A and 250 V AC - 50 Hz, resistive load, 600 cycles/hour - ambient temperature 85 °C.
In practice, customers require electric life also at lower values of current intensity. Thus, on the basis of tests, the curve of electric life is defined and the curve shows the dependence of electric life (number of cycles) on switching capacity (Fig. 19).

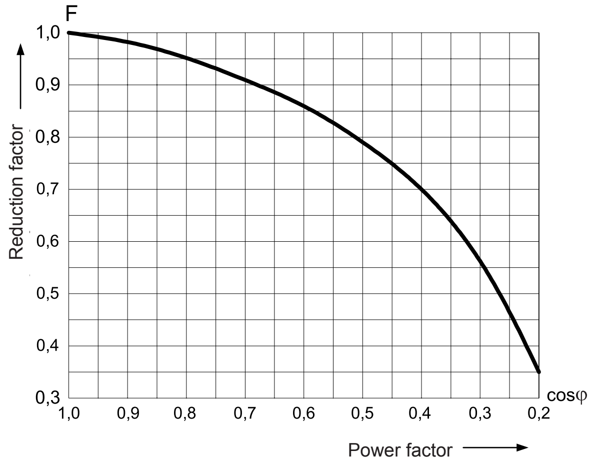
Fig. 19. Chart of a relay electric life



Inductive loads cause high contact wear which reduces the relay life. The reduction has been defined on the basis of tests, and it is expressed as the correction factor for resistive electric life (depending on the load power factor) which should be used to define the projected life.

Question:
What is electric life of the RM85 type relay for the following electric load: 8 A / cosϕ = 0,4 / 250 V AC; 600 cycles/hour. The chart in Figure 19 shows that the projected life is approximately 150,000 cycles at resistive load (cosine = 1). The chart presented in Figure 20 proves that at the cosine power factor which equals 0,4 the correction factor is 0,7. Thus, the projected electric life under the aforementioned conditions is 150,000 x 0,7 = 105,000 cycles.

Fig. 20. Dependence of the correction factor on the power factor

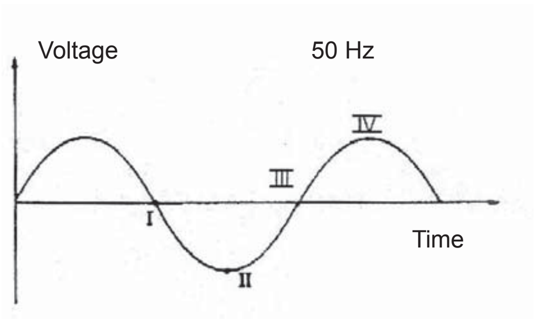


$N_{\cos\varphi} = N \times F$

Switching at alternating and direct current

Various problems occur at switching AC and DC loads of high power, and various aspects shall be taken into account in order to understand the nature of the phenomenon. I_n AC current circuits (of the frequency approx. 50 - 60 Hz), the relay contacts may open in two possible states of the operating voltage due to the course of the voltage and the phenomenon of the electric arc (see Fig. 21).

Fig. 21. Switching states (I, II) at alternating current of 50 Hz



Switching at point I:
Voltage value is close to zero.
No electric arc occurs.
Switching between points I and II:
There may be two situations in which the voltage grows or drops. In both cases, arc discharge occurs but it is suppressed due to the transfer of the voltage via the zero value. The electric arc discharge depends on the voltage value, contact clearance, current intensity, shape of contacts and on materials. Due to these reasons, in miniature relays there are physical limits related to the above parameters, which reduce the maximum AC switching voltage to approximately 380 V.
The inductive loads of AC are worse as compared to the resistive loads due to contacts wear since the load inductivity grows, a constant arc appears together with its harmful effects. Arc suppression circuits are sometimes used in order to reduce the phenomenon: a resistor and capacitor placed at the load.

The following relations occur between U, I, R and C:

$$C = \frac{I^2}{10} = (\mu F)$$

$$R = \frac{E}{10(I)^{\alpha}} = (\Omega)$$

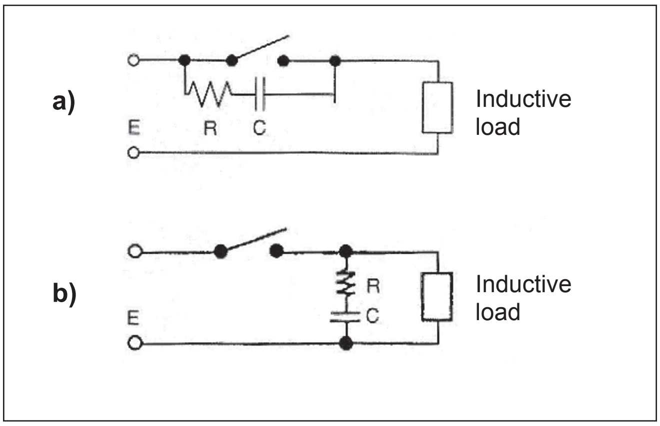
$$\alpha = (1 + \frac{50}{E})$$

where:
E - source voltage immediately prior to contact closing
I - load current immediately prior to contact opening
C - capacity of the capacitor (F)
R - resistance of the resistor (Ω)

The circuit is useful at AC and DC inductive loads with the following arrangements:
- Parallel to the contacts (Fig. 22a):
for the voltage of the "E" source of more than 100V (the impedance RC must be insignificant as compared to the impedance of the load if the source voltage is in AC).
- Parallel to the load (Fig. 22b):
for the voltage of the "E" source of less than 100V (alternating and direct current).

The two-wire main cable affects the DC switching.

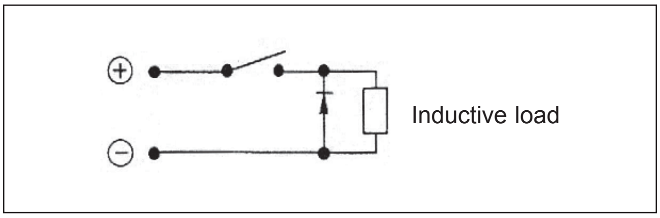
Fig. 22. R-C system is an arc suppression circuit



Arc breaking

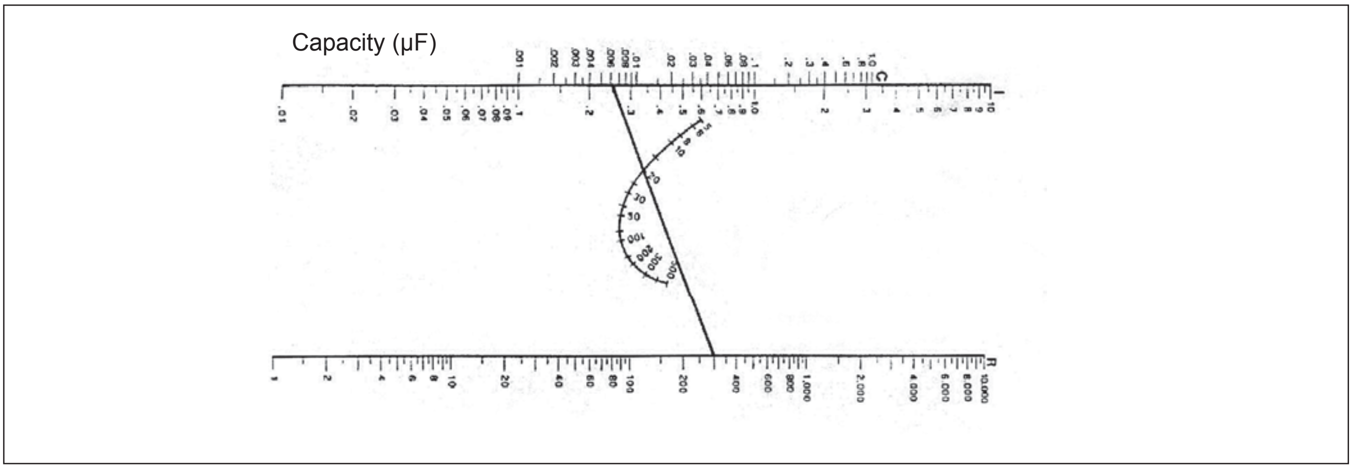
In DC devices, the arc breaking is a crucial problem because the voltage does not transfer via the zero value as it does at alternating current. Thus, when the electric arc appears, only the contact clearance and the properties of the contact materials contribute to the arc suppression. Relays usually have a physical limit that depends on the above parameters which make the relays incapable of switching the load at current intensity and voltage higher than the specified values. The values are expressed in the form of a curve which defines the maximum switching energy (U x I) at the constant time value L/R of resistive and inductive loads while L (inductance) is expressed in henries and R (resistance) in ohms.
L/R is principally expressed as a value that equals 40 ms (milliseconds) for inductive loads, i.e. a mean value for devices.

Fig. 23. Diode placed in parallel to the load



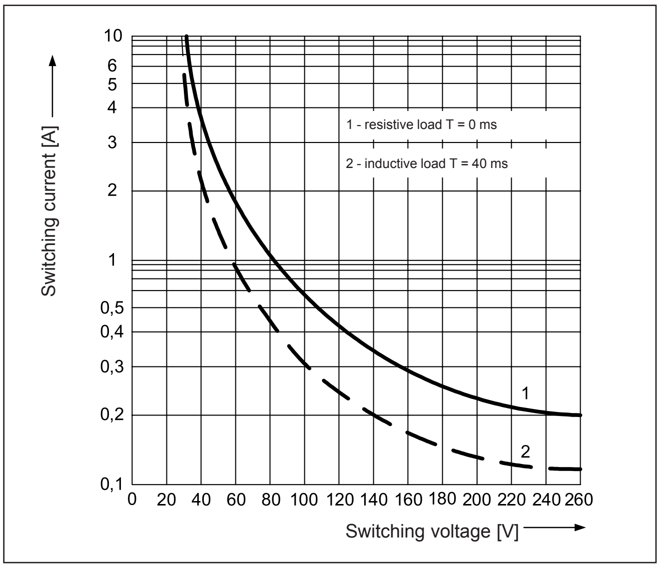
The most common method of arc suppression in DC circuits is using a diode in parallel to the load. This is an efficient and cost-saving solution applicable at various values of the load.

Fig. 24. Nomogram for defining optimal values of R and C



Example (Fig. 25):
The maximum admissible switching intensity of direct current for the R3 relay at 230 V DC at resistive and impedance loads are 210 mA and 120 mA respectively. The values assure the arc suppression. Suppressing circuits are also useful for alternating current devices.

Fig. 25. Maximum switching capacity at direct current



Special loads

Bulb load

Closing of the contact with bulb loads (a lamp with tungsten fiber) causes problems due to high current peaks related with the low resistance of the fiber when it is cold. For example, a 60 W - 220 V AC bulb has the ”cold” resistance of approximately 60 which corresponds with a current intensity of 3,66 A (for a few milliseconds). On the other hand, the current intensity of a hot bulb is 0,273 A (the ratio is then 1:15). This illustrates the high load that occurs on the contacts during the bulb switching (a hazard of contact welding). The following must be taken into account for bulb load switching: maximum load of the bulb and contact material.
For example, for the RM96 relay with AgCdO contacts the maximum admissible bulb load is some 1,000 W which corresponds with the current intensity of 4,5 A and the alternating current voltage of 220 V. In other relays of higher loads the contacts are made of $AgSnO_2$.

Motor loads

The motor loads are inductive loads which operate in a particular manner while switching on. A current peak occurs as a result of the motor inertia which is related with the mechanical load used in the motor, and which in the starting phase is 5-10 times higher than the current in the steady state. Furthermore, when the motor is being switched off, harmful action related with impedance loads occurs. Thus, the correct choice of contact material is related with the aforementioned load characteristics, especially when the capacitor is connected to the motor. In such particular cases, the contacts are made of tungsten and $AgSnO_2$. The motor load is usually expressed in HP (horsepower) where 1 HP equals approximately 745 W.
Example:
R15 relay - the rated motor power of the contact is 1/2 HP.

Capacitance loads

This is the worst contact load as for switching on due to a sudden increase of the current intensity peak which occurs when the capacitor is discharged (a phenomenon similar to a short circuit). The current intensity at the peak to be switched on may reach the values of hundreds of Amperes in a very short time (microseconds). The problem of contact welding may be avoided in two ways: via using the $AgSnO_2$ contacts, or via reduction of the current intensity peak by introduction of a resistor to limit the current.
The same problem occurs at contacts closing with a charged capacitor, i.e. a rapid discharge occurs.

Switching time and contact bounce

On the relay coil supply during opening and/or closing, the operation lasts in time depending on the electric and mechanical inertia of the parts. The delay between the coil supply impulse and the preset closing and/or opening of the contacts is the sum of the effect of the electromagnetic system and the switching section.

Electromagnetic system

The current flows through the coil with the delay caused by the coil inductance which resists to the current stream. Furthermore, the movable parts such as the armature and the pusher react to the movement due to the action of the magnetic stream.

Switching section

The elastic forces stored in the contacts and springs, and their elastic strain, react to the movement of the relay parts. The phenomenon is also affected by the inertia of the contacts mass. The delay times of the miniature relays usually reach the value of a few milliseconds (5-15 ms) during the switching phase. During the release phase the operating time is shorter due to the absence of the magnetic circuit delay. It is really so that on removing the supply voltage from the terminal, the current that flows through the coil wire stops suddenly and the relay is released with the elastic energy stored in the contacts.

Fig. 26. Switching time

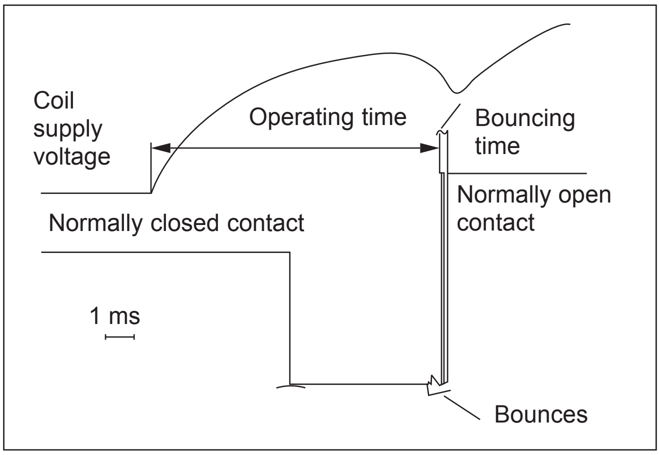
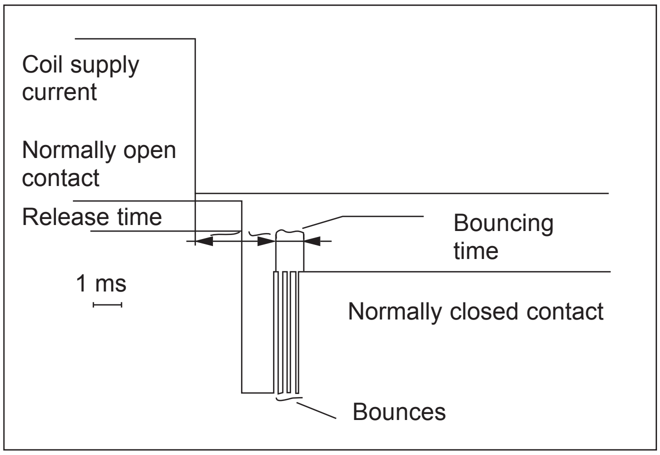


Fig. 27. Release time



The operating time of an inactive relay is the time interval from the moment of the supply of the voltage to the relay coil to the time of the first closing (or opening) of the contact.
If the relay has more than one contact, the time of closing (or opening) of the last of the contacts is taken into account. The operating time includes the time of opening the normally closed contact and the time of closing the normally open contact.

The release time of the active relay is the time interval from the absence of the supply voltage to the first opening (or closing) of the contact.
If the relay has more than one contact, the time of opening (or closing) of the last of the contacts is taken into account.

Bouncing

In the phases of switching and release, when the contacts close, they never perform the operation at the same time but the clash between two contacts makes the contacts bounce. The „contact bouncing" cause constant closing and opening of the contacts. This particularly affects the contact ratings such as electric life and signal switching.

Sinusoidal vibrations

The electromechanical relay is strongly affected by dynamic phenomena which may change its projected characteristic constantly or temporarily. The devices in which vibrations occur must be thoroughly tested so that we might find out the quality and essence of the stress. Machine tools, automotive devices, assembly machines, and principally every instrument in which the electronics of the drive is affected by the presence of movable parts (motors, vibrators, valves, etc.), may be exposed to the consequences of the problem. Relpol usually tests the relays via exposing them to sinusoidal vibrations at the constant acceleration (G) within a particular range of frequency. Moreover, the relays are tested along the main axes (X, Y, Z) and in two basic directions for each axis. As a rule, the relays are tested with the printed circuit board mounted (sockets, materials, etc.).
The tests are made in two stages, i.e. resonant test and fatigue test. The relays are tested at the states where the coil voltage is on or off. The contact continuity is monitored with an oscilloscope at a low-level load on the contacts. The test allows defining of the frequency range (Hz) and maximum value of the acceleration, at which the relay may operate with no loss of contact continuity (interval of 10 s) or without any durable damage. The standard values (which meet the requirements of a wide line of devices) for miniature relays reach 10 G at the frequency range from 25 to 100 Hz. The values refer to the worst case which usually occurs in the most critical test conditions (the relay with no supply in a given axis of vibrations). For tests at a low frequency range (a few hertz), instead of the constant acceleration, a constant movement is simulated which corresponds with a given value of acceleration (e.g. from 10 to 25 Hz for the amplitude of 2.5 mm). The tested frequency at which the constant movement changes into the constant acceleration is called the "transition frequency", e.g. at 55 Hz 10 G it corresponds with 1,5 mm.

Current surges

The maximum value for miniature relays is 10 G for maximum peak acceleration and 11 ms of the impulse duration. As for the sinusoidal vibrations, the sample shall be subject to an ohm test for surge both at the ON and OFF states within the arrangement of the three main axes (X, Y, Z), in two basic directions for each axis. Three surges shall be applied to each state. The tested relay shall not open the contacts (10 s interval), and it must operate perfectly at the end of the test.

Hermetic relays - soldering and cleaning

The necessity to use tightly closed and hermetic parts in devices arises from two different reasons, i.e. (contacts, mechanisms, wires) from penetration of the stream in the process of soldering and cleaning, and protection of the internal parts from atmospheric contamination.

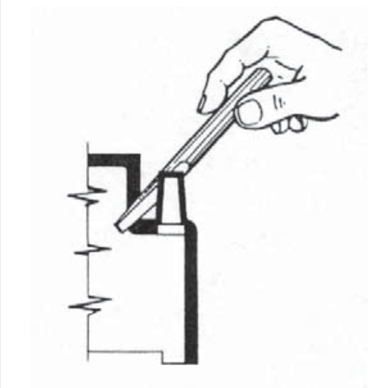
Soldering process

The contemporary electronic technology widely uses automatic soldering processes for mounting elements on printed circuit boards. This allows soldering of the whole circuit at one stage. The melted tin in a special machine forms a wave that "touches" the bottom side of the circuit to solder the terminals (pins) of the elements with the copper paths of the circuit. Prior to this operation, the circuit is sprinkled with a liquid (stream) which supports soldering via prevention from copper oxidation. There are many various types of such liquids composed of organic and non-organic acids, but all of them are more or less harmful to the internal parts of the relay and for other elements. Thus, it is important that the circuit should be cleaned following the soldering process. The most popular methods of cleaning are washing with hot water or washing with fluorocarbons with or without the use of ultrasounds. It is obvious that the materials used for the construction of relays (anti-dust cover, sealing resin, print paints) must be physically and chemically resistant to the cleaning chemicals which they contact. With each individual application, it is important to know the processes and sometimes the reactions between the relay and the chemicals must be examined.

Environmental contamination

The environment of the relay may adversely affect its operation. Humidity, industrial air, dust and particles that penetrate the inside of the relay may affect the contacts, internal parts and isolation. The environmental conditions in which the relay and the device will be used shall be analyzed in order to avoid such problems as resistance growth and corrosion of the metallic parts.
If the ambient conditions are not arduous and/or the electric load of the contacts is not critical (cleaning presence of the arc), it is better to open the relay following the soldering and cleaning processes to allow the useful exchange of the air with the external atmosphere.
What is important for the thermal exchange (high switching power) is the gas emission caused by the electric arc and the residual contaminations with plastics. As explained before, the process of sealing the relay includes degassing of plastics, filling the relay with inert gas (nitrogen), and the process of label closing or other methods.

Fig. 28. Opening of the relay



International standards

Relays manufactured by Relpol S.A. are designed and tested in compliance with the requirements of the following international standards:

PN-EN 61810-1 Electromechanical non-specified time all-or-nothing relays. Part 1: General requirements.
PN-EN 61810-5 Electromechanical non-specified time all-or-nothing relays. Part 5: Insulation coordination
PN-EN 60664-1 Insulation coordination for equipment within low-voltage systems. Part 1: Principles, requirements and tests.
PN-EN 116000-3 Generic Specification: Electromechanical all-or-nothing relays. Part 3: Test and measurement procedures.
Plug-in sockets manufactured by Relpol S.A. are designed and tested in compliance with the requirements of the following international standard:
PN-EN 61984 Connectors - Safety requirements and tests.

Insulation

The classification of insulation groups to define the properties of insulation of the device in compliance with the insulation coordination was previously done according to the VDE 0110 Standard.
Electric devices were classified in insulation categories A, B, C or D due to their application and possible reduction of the insulation properties caused by the impact of the environment, i.e. dust, humidity, aggressive gases, insulation clearance and creepance.
The insulation category was indicated together with the reference voltage which was the basis for defining of the requirements related to the insulation distances for rated voltage up to the reference voltage value.
At present, while dimensioning the insulation distances in accordance with the PN-EN 60664-1 Standard, the overvoltage category and the ambient pollution degree must be defined. The latter indicates the expected pollution of the microenvironment. The transient overvoltage values are the basis for defining the rated surge voltage which determines the minimum contact clearance related with the insulation coordination.

The following overvoltage categories are defined:
IV - devices at the front of the installation
III - devices in fixed installation in cases where reliability and availability of the device is subject to special requirements
II - receiving devices supplied from the fixed installation
I - devices connected to circuits where measures have been taken (either in fixed installation or in the equipment) to limit transient overvoltage to the appropriately low level

Four pollution degrees have been defined to estimate the contact creepance and clearance:
1 - no pollution or only dry and non-conducting pollution; the pollution has no effect
2 - only non-conducting pollution occurs; the vapor condensation, however, may be expected to cause temporary conductivity of the pollution from time to time
3 - conductive pollution or dry and non-conductive pollution occurs which may become conductive due to condensation
4 - the pollution proves constant conductivity caused by the conductive dust, rain or snow

The rated surge voltage is defined on the basis of the overvoltage category and the rated voltage of the device.

The rated voltage of the supply system according to PN-IEC 60038		Voltage line-to-neutral derived from nominal voltages AC or DC up to and including	Rated impulse voltage			
			Overvoltage category			
Tree-phase	Single-phase		I	II	III	IV
	120-240	150	800	1500	2500	4000
230/400		300	1500	2500	4000	6000

The insulation creepance are dimensioned on the basis of the following factors:
- root-mean-square value of rated voltage
- pollution degree
- group of insulation materials

Insulation materials are divided into four groups with reference to the value of the indicator of resistance to creeping current:

Group I $600 \leq CTI$
Group II $400 \leq CTI \leq 600$
Group IIIa $175 \leq CTI \leq 400$
Group IIIb $100 \leq CTI \leq 175$

Protection from ambient effect

As for the protection from ambient effect, the PN-EN 116000-3 Standard distinguishes the following types of relays:

RT0 - open relay - a relay without protective cover

RTI - dustproof relay - a relay with cover to protect its mechanism from dust

RTII - relay resistant to soldering alloy - a relay adapted to automatic soldering process which prevents soldering alloy from spreading beyond indicated areas

RTIII - liquid-proof relay - a relay soldered automatically and then subject to washing process for the purpose of removal of the residue of the liquid soldering alloy where the relay cover is prevented from being penetrated by the solder or the washing liquid

RTIV - tight relay - a relay equipped with a cover with no ventilation openings; all the gaps are filled with a sealing compound to prevent penetration of liquids in course of production, flow soldering or washing. The tightness of relays is tested with a submersion test according to PN-EN 60068-2-17 Standard. During the test, the relays are submerged in distilled water of 85 °C for 1 minute while no air bubbles shall be released from the relay.

RTV - hermetic relay - a tight relay of enhanced tightness level, in a metal cover, terminals sealed with glass, gas-filled.

Cover protection degrees according to PN-EN 60529 Standard:
The first digit refers to the protection from foreign solids penetration. The second digit refers to the protection from water penetration.
Examples of indications:
IP 40 - Protection from penetration of solids of 1 mm diameter and larger, no protection from water penetration.
IP 67 - Dustproof protection, protection from the effects of momentary submersion in water.

Electric load

Electromagnetic auxiliary relays manufactured by Relpol S.A. are designed for a wide range of applications and for switching several loads of diversified characteristics.
Electric loads are classified according to their nature (resistive, capacitive or inductive loads), type of supply (DC or AC), load value and the current curve course shape (lamp, motor, electromagnetic, etc. loads).

Contact application categories according to PN-EN 116000-3 Standard

Application category	Voltage [V]	Current [A]
0 (CA 0)	< 0,03	< 0,01
1 (CA 1)	0,03 < U < 60	0,01 < I < 0,1
2 (CA 2)	5 < U < 250	0,1 < I <1
3 (CA 3)	5 < U < 600	0,1 < I < 100

Application categories according to PN-EN 60947-4-1 and PN-EN 60947-5-1 Standards

Application category	Typical application
AC1	Switching resistive loads or loads of low inductivity
AC3	Start-up and switching off the operation of squirrel-cage motors
AC15	Control of electromagnetic loads (> 72 VA)
DC1	Switching resistive loads or loads of low inductivity
DC13	Control of electromagnets

Certifications

Compliance with national and international standards provides for safe use of the product, and proves high quality and durability of the product.
In some countries (e.g. USA, Canada, Russia), the product certification to prove its compliance with the requirements of appropriate national standards is obligatory, and the product must undergo the procedure of compliance assessment at certifying agencies in order to be approved for sale. In other countries it is the manufacturer's responsibility to provide the compliance of the design and production with the requirements of appropriate standards (e.g. the countries of the European Union). Certification agencies carry out the testing procedure in accordance to applicable standards, and then they regularly audit the production process in order to confirm that the requirements are observed in current production of the certified product. The European Union applies European Standards (EN) as set forth by the European Committee for Electrotechnical Standardization (CENELEC), and international standards set forth by the International Electrotechnical Commission (IEC).

The products manufactured and offered by Relpol S.A. have numerous certifications issued by renowned research institutions such as VDE, UL, CSA International, GOST or BBJ-SEP.

The electromagnetic relays have been certified to comply with the following standards:
- EN 60255-1 and EN 61810-1 - VDE, BBJ-SEP
- UL508 - Underwriters Laboratories
- C22.2 - CSA International

Apart from the certifications which prove the safety and high durability of the products, some of Relpol's products have certifications required for applications of relays in special conditions, e.g. Lloyd's Register certification which acknowledges compliance with the requirements for electrotechnical products to be used on vessels and in devices which operate in adverse climatic conditions.