6 MECHANICAL COMPONENTS

6.1 Moving parts

Mechanical indicator

Some power relays have a mechanical indicator fitted. The indicator is connected to the armature, actuator or contact springs to show the actual switching position of the contacts.

Mechanical indicators, therefore, indicate the actual switching state, whereas electrical indicators, such as LEDs, only indicate that voltage is applied to the coil terminals. Depending on the circuit, this may not give information as to the actual switching state of the relay, e.g. in case of a broken coil.

Mechanical Components

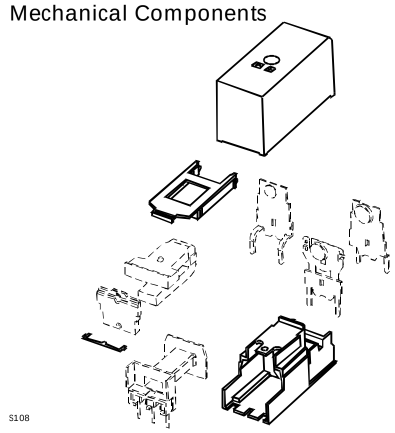

fig 6.1

Mechanical system

Wear and tear

Movement of parts within the relay, like the armature, actuator, mechanical indicator and contacts will cause wear, which may in turn lead to changes in the operational characteristics of the relay (such as pull in voltage).

In addition, the generation of particles caused by the rubbing motion of these parts can affect contact reliability.

Corrosion

When using sealed relays for switching medium to high loads with a high level of arcing, corrosion may result. The combination of NO_x generated by the arc and water vapour absorbed from the ambient humidity forms highly corrosive nitric acid inside the relay. Accelerated corrosion of the internal metal parts such as the yoke, armature and contact springs may adversely affect reliable operation of the relay.

Vibration/shock

Vibration resistance:

is the ability of a relay to withstand a sinusoidal acceleration without mechanical failure or alteration of its characteristics. Within the specified limits, the duration of forced opening of closed contacts is less than 10µs. Permanent operation of relays under these conditions can cause premature contact failure (contact wear) caused by induced vibration and mechanical damage due to the excessive wear of moving parts.

Shock resistance:

is the maximum half sine wave acceleration for a duration of 11ms, causing the opening of closed contacts for less than 10µs and without causing any changes to the relays' characteristics.

The testing procedures for vibration and shock resistance are specified in IEC-68-2-6. The tests are carried out with the relay mounted in its least favourable position, usually the direction of contact actuation. Better results may be obtained if the relay is mounted perpendicular to this direction.

Vibration resistance is given for a defined frequency range, in general from 30 to 150Hz. The resonant frequency of the relay system normally lies within this frequency range.

As the contact pressure for N/O contacts is higher than for N/C contacts, the resistance against forced opening of contacts and vibration/shock resistance may differ giving better results for the N/O contact.

Some relay designs, such as those with pivoting armatures, are better suited to high vibration environments. Having the pivot point at the center of gravity helps to eliminate the generation of rotational moments when subjected to vibration.

Also worth of considering is that when relays are mounted on a PCB, although the PCB by itself is not a source of vibration or shock, it can amplify (resonant frequency) or prolong any external vibration and shock. For example, if a relay and a switch are mounted next to each other, the shock caused by operating the switch, may cause the relay contacts to separate momentarily, resulting in false relay operation.

Maximum vibration and shock:

is the maximum value for vibration and shock resistance, which can be withstood by the relay during transport, processing or use, without causing damage or change to the relays operating characteristics.

If these values are exceeded, e.g. by violent movement/handling or dropping from a height of 50cm or more, significant damage within the relay may occur.

Mechanical life

Mechanical life is the number of switching cycles at a maximum specified frequency that a relay can achieve, without contact load, under normal ambient conditions.

Maximum mechanical life is reached when the effect of wear leads to a substantial change in the operational characteristics of the relay. During the test period the relay has to maintain all guaranteed specifications.

Failure criteria for mechanical life tests are:

- increase of pull in voltage by more than 20%
- reduction of the drop-out voltage to less than 10% of the nominal voltage
- reduction of the dielectric strength by more than 25%
- decrease of the insulation resistance to a value 10% below the value specified for a new relay.

In general the mechanical life is given as a guaranteed minimum value. This is because switching with no load is not usual for power relays and because a mechanical endurance test of 10 to 30 million operations is time consuming, expensive and does not give useful data.

6.2 Case

Electrical function

Insulation

The primary function of the relay case is to insulate the electrical terminals of the relay, separate the primary and secondary circuits and reduce the hazard of electric shock.

Insulation resistance is the electrical resistance of insulation materials measured between conductive elements. A high voltage pulse is applied across the insulation, the resulting leakage current is converted to a resistance value.

Insulation category

According to VDE 0110 minimum isolation properties are defined to prevent danger to people and property from various currents and voltages.

Equipment is classified in isolation categories A_0, A, B, C and D with regard to:

- application and the respective reduction of insulation properties caused by environmental influences such as dust, dirt, humidity, condensation, ageing and aggressive gases
- possible effects of insulation failure
- creepage distances and clearances according to the expected voltages.

INSULATION CATEGORY			
Insulation group	Insulation reduction due to environ-mental influence	Stresses through excess voltage	Application example
A_0	low	very small	radio equipment (walkie-talkies)
A	low	small	electrical measurement equipment
B	medium	medium	domestic appliances, lighting, the inner parts of sealed relays
C	large	large	electrical equipment; machine tools, relays and contactors
D	very large	large	electrical track vehicles (engine room)

fig 6.2

Creepage distances and clearances are safety distances between live components and of live components to ground, and are generally defined as follows:

- the clearance is the shortest straight line distance in air between the two reference points.
- the creepage distance is the shortest path along the surface of an insulating material between two reference points.

Together with the isolation category, the reference voltage has to be taken into consideration. These reference voltages are the basis for the requirements of creepage and clearance distances to give sufficient insulation for nominal voltages up to the reference voltage, e.g. B250 indicates that the relay can be used for applications according insulation category B and the creepage/clearances are sufficient up to voltages of 250VAC.

Protection categories

Several protective measures are specified by international standards (e.g. VDE, UL), to guard against electrical shock when using electrical appliances. Some categories require connection of accessible parts to a protective conductor (neutral), while others, such as VDE class II, requires double or reinforced insulation.

Mechanical function

Several types of protection are available to meet the requirements for various mounting and production processes used for different types of power relays.

Enclosure type

Open
Because of cost, some relays are supplied without a case. Once installed, however, the relay may be in an overall enclosure or protective environment. Any cost advantages may be negated by increased costs due to damage during handling and production.

Dust cover
Most relays are provided with a dust cover. This protects the relay, the contacts and the magnetic system from contamination by large particles, and serves as protection against electrical shock and damage during handling and production.

Flux resistant
Also called flux free, this design has the gaps between the relay pins and the base and between the base and case sealed, generally with adhesive, to prevent flux entering the relay by capillary action causing contact contamination and corrosion. Washing or immersion cleaning is not recommended with this type of enclosure.

Fully sealed or washable
Also called immersion proof,(according to IP67, see protection class). As above, all gaps are filled with adhesive to prevent ingress of solvents or particles during production, flow soldering or washing. The difference between fully sealed and flux resistant types is purely the integrity of the seal. The seal is generally tested to IP67 (see protection class).

Enclosure Types

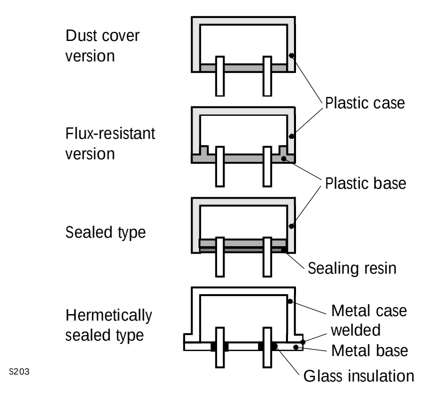

fig 6.3

The term immersion proof does not imply that the relay is hermetically sealed. A slow diffusion process and an exchange of gas molecules through the plastic cover occurs over a period of time.

Printed circuit boards fitted with these relays may be immersion cleaned, varnished or encapsulated. Suitable cleaning solvents have to be used and limits of cleaning time, temperature and the frequency of ultrasonic cleaning must be adhered to.

To test the sealing of washable relays usually the "bubble test" according IEC-68-Qc2 is performed. During the test relays are submerged in distilled water at a temperature of 70-85°C for 1 minute. During this time no bubbles must escape from the relay.
The appearance of bubbles indicates a leak as the gas inside the relay expands when subjected to the increase in temperature.

This test procedure, if repeated, may destroy the seal.

These relays are also suited for operation under harsh environmental conditions as contact resistance is more stable for small and medium loads.

The effect of corrosion has to be considered, however (see corrosion).

Hermetically sealed

In hermetically sealed relays the cases are made of metal and the relay pins are sealed into the relay base by glass providing an impervious barrier.

Improved contact life may be achieved by filling the relay with inert gas.

Because of this construction, hermetically sealed relays are expensive and their applications therefore limited to areas such as avionics and military technology.

Protection

Protection category

DIN40050 specifies the extent to which covers, housings, encapsulation etc. provide protection against external influences such as water, moisture, dust and accidental contact.

The protection category is indicated by a code consisting of "IP" followed by two digits.

The first digit indicates the resistance to the ingress of particles and the degree of protection against accidentally touching live parts. The second indicates the degree of sealing against water.

Environmental test requirements with regard to temperature changes, high and low temperatures, humidity, barometric pressure and atmospheric influences are described and classified in DIN40040 and IEC68.

Protection requirements are different for production, application and storage.

PROTECTION CATEGORY according DIN40050			
Pro-tection classes	Live part protection (1st number)	Foreign body protection (1st number)	Protection against water (2nd number)
IP00	no protection against contact with live parts	no protection against ingress of solid foreign bodies	no protection
IP20	protection against contact with the fingers	protection against ingress of foreign bodies with ∅>12mm	no protection
IP40	protection against contact with tools wires etc. with diameter >1mm	protection against ingress of granular foreign bodies with ∅>1mm	no protection
IP41	protection against contact with tools wires etc. with diameter >1mm	protection against ingress of granular foreign bodies with ∅>1mm	protection against drip water falling vertically
IP50	complete protection against contact with live parts	protection against harmful deposits of dust	no protection
IP53	complete protection against contact with live parts	protection against harmful deposits of dust	protection against spray water falling at any angle up to 60° from vertical
IP54	complete protection against contact with live parts	protection against harmful deposits of dust	protection against splash water from any direction
IP55	complete protection against contact with live parts	protection against harmful deposits of dust	protection against water jets from any direction
IP65	complete protection against contact with live parts	protection against ingress of dust	protection against water jets from any direction

fig 6.4

Climate

Ambient temperature data specifies the minimum and maximum temperatures for use and/or storage of a relay. This usually takes into account factors such as self heating of the coil and contacts. The temperature for storage and application must not exceed the respective catalogue data.

In general the following tests according to IEC 68 or IEC 255-7 are performed to guarantee the proper function of relays under defined environmental conditions such as high humidity and high and low temperatures to ensure that the relay will withstand humidity and temperature shocks and cycles.

Climate tests consist of:
- dry heat
- damp heat, constant
- damp heat, cyclical
- cold
- temperature cycles
- low barometric pressure

After the tests, no abnormalities are permitted for contact resistance, pick up and drop out voltage, insulation resistance, and other operational characteristics. Additional care needs to be taken with regard to effects such as oxidation, formation of cracks, chemical reactions, softening and other reductions in mechanical and insulation properties.

Humidity

Humidity reduces the insulation properties and accelerates corrosion of metal parts. Condensation due to high humidity and temperature changes must be avoided for all relays except hermetically sealed types. For a limited time sealed relays may be used under such conditions.

In the case of condensation, the insulation resistance on the outside of the relay, the pc board, sockets or other terminals will be degraded drastically and short circuits and leakage currents may render the equipment unusable.

Dust

Relays are extremely dust sensitive components. Dust on the contacts may cause contact failure (see contact reliability), dust on the moving parts or adhering to the magnetic circuit can lead to relay operation failures. For dusty environments sealed relays should be used.

Gas

Industrial environments may contain dust, oil, organic or sulphur gases, silicone or other contaminants which may have a negative effect on the relay contacts and system. For applications in such environments, the use of sealed or hermetically sealed relays should be considered.

Material

Insulation and creepage resistance.

The most important tests concerning insulation materials for electrical equipment are the tests for insulation resistance and creepage resistance.

A creepage path is the shortest distance between two points along the surface of a part made of insulating material which may lead to a current flowing between those two points. The creepage properties are categorized according to the "comparative tracking index" CTI, or to the "proof tracking index" PTI. Both indices give relative creepage resistance of insulation materials subjected to contaminated water and a test voltage.

The most important standards relating to creepage paths are VDE0110 and IEC 664.

The insulation category and voltage rating according to VDE0110 is determined by considering the operating voltage and dimensions of creepage paths together with specific creepage resistance of the insulating material used.

Resistance to fire

Plastic materials are categorised according to UL94 based on fire resistance, their self extinguishing properties and the potential spread of burning droplets.
The flammability categories are:

- V-0 which is the highest resistance to fire
- V-1, V-2 and HB which have certain limits to fire resistance and flame spreading speed.

The selection of plastic material is of the highest importance for the correct functioning of the relay. Under the influence of temperature and arc the internal plastic parts may emit gases and vapours. These vapours may be deposited on the contact surfaces, increasing their resistance. This is especially the case with sealed relays when untreated plastic materials are used.

Design

Power relays are produced in a wide variety of designs and dimensions.

They may be categorized according to relay size (e.g. miniature power relays, industrial relays, etc.), to their physical appearance (flatpack, slim, cubic types, etc.), their pinning (dual in line relays) or to their terminal design (plug in types, PCB relays, etc.)

Mounting

The most common mounting methods used for power relays are:

- sockets, with or without retaining clip
- special plug designs
- a variety of mounting brackets
- DIN rail mounting
- PCB relays
- SMT

Snap-on Mounting

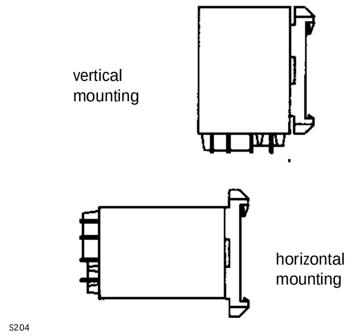

fig 6.5

Mounting orientation

Relays can generally be mounted in any direction or position.

To increase contact reliability, the relays should be mounted so that contact surfaces (fixed or movable) are vertical, preventing the adhesion of particles or contact material debris.

Switching high and a low loads in one relay is not recommended. If, however, the switching of two different load levels in one relay cannot be avoided, the relay should be mounted with its high load contacts located below the low load contacts to help prevent contact material debris from the former contaminating the latter.

There are also preferred mounting positions in applications with high vibrations or shock in one or two directions. The relay should be mounted so that the movement of the contacts and movable parts is perpendicular to the direction of vibration or shock.

Dense packing

Relays should be mounted to achieve the highest possible cooling effect either by ventilation or convection. Care has to be taken when relays are densely packed in a rack or on a printed circuit board. Energization of the coils thermally effect each other and the effective cooling surface is reduced, leading to considerably higher relay temperatures.

6.3 Terminals

Mounting techniques (solder, plug, SMT)

There is a wide variety of terminal designs including screw, threaded stud, Faston, pierced or wire solder lug, octal base and other plug-in types, terminals for PCB or surface mount technology. This variety gives the designer a wide range of design options.

Different types of terminals

Faston connection (Faston is a registered trademark of the AMP company) is a solderless and non threaded plug type connector and gives reliable contact. The connection is crimped.

Relay Terminals

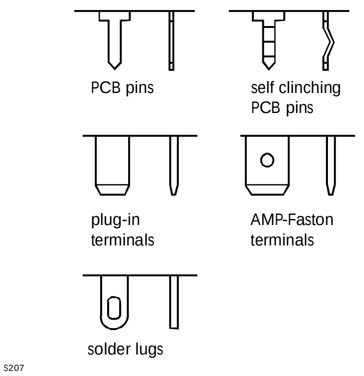

fig 6.6

Cable sizes

The minimum cable gauge has to be established depending on the load, in order to keep wire resistance and the heat generation low and to allow heat dissipation from the contact system to the wire.

Sockets

A socket provides an interface between the relay and the system in which it is incorporated. However, there is additional resistance in the load circuit due to additional contact resistances of the relay pins to the socket terminals. The resistance of a good plug in type socket is between 1-4mOhms.

There are three main mounting styles of relay sockets available:

- printed circuit board mounting
- screw terminal DIN rail mounting
- solder terminal

Advantages of using a socket:

- relays may be easily substituted if a change of application requires a different contact material or coil voltage
- easier mounting and simplified wiring
- the socket can be used as a test point before the relay is fitted, so the drive circuit can be checked without the load

- the PCB can be flow soldered and immersion cleaned with the socket in position and then an unsealed relay inserted
- the relay is not thermally stressed during the soldering process
- the PCB is not damaged if the relay has to be changed being switched. This can also aid any fault diagnosis
- simple exchange and replacement of the relay, if the relay's life is less than the expected life of the host equipment

The above advantages cover all relay types. When using a socket with a PCB mounted relay there are additional advantages:

Important considerations when selecting a socket:

- if a particular relay has been chosen for it's international approval the use of an unapproved socket will compromise that approval. For example, a relay may have been selected for a minimum isolation requirement between contact and coil of 4kV/8mm to comply with VDE 0110 but the socket may not comply with this specification.
- is there adequate space to accommodate the extra height when a relay is used with a socket? The length and width of the socket may be greater than the relay. This will be an important consideration when laying out a PCB, or panel for the screw terminal sockets.

PCB

Different grid designs

For standardized layout and design of boards and equipment, the electrical connections of components are arranged in a standard grid system. The commonly used space between the grid lines for printed circuits is 2.5mm or 0.1"≈2.54mm. Most relays are designed for a mean grid system of 2.52±0.02mm to fit both systems.

The recommended pin spacings and hole diameters according to DIN 40803 (medium tolerance level) should be observed so that the connecting pins are not unduly stressed on insertion as this may damage the relay or degrade the pin seal.

Pinnings

The necessary spacing between conductors is given by the required dielectric strength and insulation resistance according to applicable standards.

Standard pinnings for PCB relays are 2.5mm (0.1"), 5mm (0.2"), 3.5mm, and, for some modern miniature power PCB relays a pinning grid of 3.2mm is offered. All, apart from the 2.5mm pinning ensure sufficient creepage distances on the print to comply with C250 according to VDE 0110.

Industrial plug in relays have a number of standard pinnings, the most common of which are the octal and undecal base (8 and 11 pins). Other compatible layouts use Faston connections.

Pinning Configurations

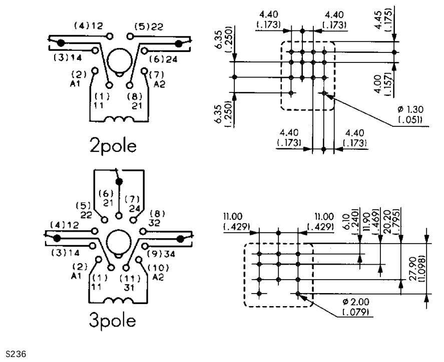

fig 6.7

Factors like electrical interference, thermal effects and the necessary distance to prevent short circuits occuring during soldering also influences the choice of pinning.

The width of the track is determined by the required current capacity, temperature rise and mechanical stability.

PCB Design
Temperature rise

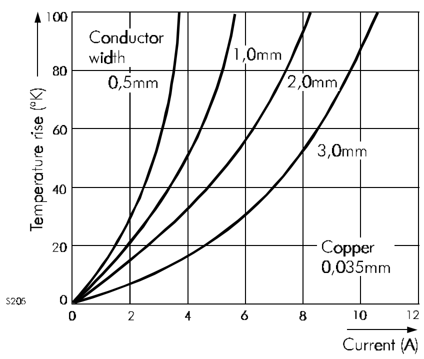

fig 6.8

PCB CONDUCTOR WIDTH according DIN40802				
max. load (A)	70µm Cu ss (mm)	70µm Cu ds (mm)	35µm Cu ss (mm)	35µm Cu ds (mm)
16	8	5	-	-
14	6.5	4	-	-
12	5	3	7.5	5
10	3.5	2	6	4
8	2.5	-	4	2.5
6	1.5	-	2.5	1.5
4	1	-	1.5	1
2	0.7	-	1	-

fig 6.9

When using high power relays the current capacity of the PCB track is an important but often neglected point. The cross section of the tracks should be large enough to restrict temperature rise and aid dissipation of heat from the contact system.

Undersized tracks may lead to excessive heating of contact blades and to a derating in the electrical life of the relay.

PCB layout

Copper clad laminates have distinct longitudinal and lateral parameters with respect to expansion and contraction. The layout and component orientation therefore should be designed to avoid extra mechanical stress on the terminals of the relay. The expansion, contraction and distortion in the longitudinal direction due to heat is 1/15 to 1/2 that of lateral direction.

PCB Pinnings

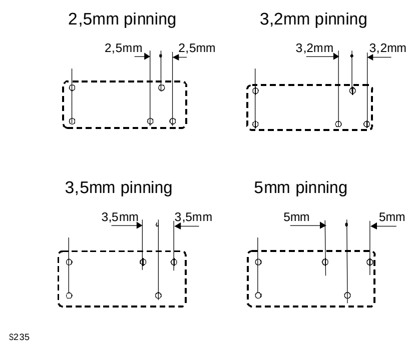

fig 6.10

6.4 Selection of mechanical components - summary

MECHANICAL COMPONENTS			
PARAMETER	CHARACTERISTIC	SELECT	CHECK
enclosure	size, dimensions	✔	
	type	✔	
	terminals	✔	
mounting	fixing and soldering terminals	✔	
	mounting method	✔	
insulation	dielectric strength		✔
	insulation resistance		✔
mechanical life			✔
environment	ambient temperature		✔
	humidity		✔
	atmosphere		✔
	vibration and shock		✔
others	standards		✔
	special specifications or conditions		✔