RELAY BASICS

Relays

Relays are electro magnetically operated switches. An actuating current on a coil operates one or more galvanically separated contacts or load circuits.

The electro mechanical relay is a remote controlled switch capable of switching multiple circuits, either individually, simultaneously, or in sequence.

The primary functions of a relay are:

- The galvanic separation of the primary or actuating circuit and the load circuits
- Single input/multiple output capability
- Separation of different load circuits for multi-pole relays
- Separation of AC and DC circuits
- Interface between electronic and power circuits
- Multiple switching functions, e.g. delay, signal conditioning
- Amplifier function.

Applications of Relay

Typical applications for relays include laboratory instruments, telecommunication systems, computer interfaces, domestic appliances, air conditioning and heating, automotive electrics, traffic control, lighting control, building control, electric power control, business machines, control of motors and solenoids, tooling machines, production and test equipment.

Electromechanical Relays

In electromechanical relays the switching element is a mechanical contact, actuated by an electromagnet. This is the most widely used type of relay design. The principal internal functions of the electromechanical relay are:

- Conversion of electrical current (input, coil current) to a magnetic field
- Conversion of the magnetic field into a mechanical force
- This force operates the contacts (secondary side)
- Contacts switch and conduct electrical current (output, load current).

Electromechanical Relay Design

The most important components are:

Contact system or secondary side

- Fixed contacts
- Moving contacts (contacts being moved by the magnetic system to switch the load circuit)
- Contact springs (holding the contacts but sufficiently flexible to allow the contacts to move)

Magnetic system

- Coil (to generate the necessary magnetic field to actuate the armature and the contacts)
- Core (highly magnetic permeable - concentrates the magnetic field)
- Yoke (to establish the magnetic circuit)
- Armature (the moving part of the magnetic system which closes and opens the magnetic circuit and acts via an actuator o the moving relay contacts)
- Return spring (For quick return of the moving contact to normal condition on removal of the coil power)

Mechanical components

- Case & Base (to protect the relay against external influences and for protection against electric shock)
- Insulation (within the relay to separate the primary circuit from the secondary side and to provide the required

Actuator (used in some relay designs to translate the motion of the magnetic system to the contact system (Moving contacts). Must have insulation properties to isolate the primary circuit (coil, magnetic circuit) from the secondary side (contact system).

Pins or terminals (to connect between the contact system and the load)

Mounting devices (sockets / built in brackets / PCB)

Basic Relay Terminologies

AC Coil: Relays for direct energization with AC supply. Unless otherwise specified AC coils may be used with 50Hz supply.

Ambient Temperature: Temperature measured directly near the relay. The maximum allowed value may not be exceeded, otherwise there is a chance for relay failure. (e.g. Coil overheating)

Bounce Time: Time interval between the first and final closing (or opening) of a contact, caused by a mechanical shock process in contact movement. These shock processes are called contact bounce.

Break Contact: A contact that is closed in the rest state of the relay and open in the operating state. (refer Normally Closed Contacts)

Bridging Contact: Special contact assembly in which two stationary contacts are connected by a movable bridge. In open contact condition the bridge is separated on both its sides from the stationary contacts. Due to this double interruption a bigger contact gap can be achieved. This is of advantage especially at very high contact loads or when there are safety requirements. (refer Form Z type contacts)

Change Over Contact: Compound contact consisting of a make contact and a break contact with a common contact spring. When one contact circuit is open the other one is closed.(refer Form C type contacts)

Coil Current: The current (by design) drawn by the coil for generating the magnetic pull force. At the moment of switching the coil On, the current is higher than in continuous use.

Coil Resistance: Electrical resistance of the relay coil at reference temperature. Coil resistance varies with temperature. (refer Pick-up voltage change due to coil temperature rise)

Contact Forms: This denotes the contact mechanism and number of contacts in the circuit. Form A contacts are also called NO contacts or make contacts. Form B contacts are also called NC contacts or break contacts. Form C contacts are also called Changeover contacts

Contact Gap: Distance between the contacts in the open contact circuit condition.

Contact Rating: The current a relay can switch On and OFF under specified conditions of voltage and environmental parameters.

Contact Resistance: Electrical resistance of a closed contact circuit, measured at the terminals of the relay with indicated measuring current and voltage.

Continuous Current (Contacts): Maximum value of current (RMS value at AC), which a previously closed contact can continuously carry under defined conditions.

Creepage Distance: Closest distance between two conductive parts, measured along the surface of insulated parts.

Dielectric Strength: Voltage (RMS Value in AC Voltage, 50Hz 1 min) the insulation can withstand between relay elements that are insulated from one another.

Driver Protection circuit: When the coil energization is switched off, a very high negative peak voltage is produced by the coil and it may reach more than 10-20 times the nominal coil voltage. Possible destruction of the semiconductor device (Driver) the coil circuit is the result. A solution is provided by a driver protection circuit that is a damping component, which is connected in parallel to the coil. It protects the driver but does slow the release time of the relay. Also known as coil snubber circuit.

Dropout Voltage: The Voltage at or below which all the contacts of an operated relay must revert to unoperated position. Also known as release voltage.

Dust Proof Relays / Solder Proof Relay: Relay with case for protection against dust and touch. With specified solder conditions are kept, no harmful amounts of flux or solder vapor penetrate into the relay.

Electrical Endurance (Electrical Life): Number of operations until switching failure of a relay under defined Conditions of load and of ambient influences. The reference value specified for the life apply, unless otherwise specified, to a resistive load. At lower contact loads a substantially longer electrical life is achieved. At higher loads the electrical life is reduced substantially.

Hermetically Sealed Relays: Relay is equipped with metal case, its connecting pins are sealed with glass; it full fills highest requirements regarding sealing. (Refer series 30 relays)

Inrush Current: This value specifies the instantaneous current that may flow on the defined conditions. (Voltage, Power Factor, Duration) when the contact closes. Depends on type of load. (refer load inrush current and time diagram)

Insulation Resistance: Electrical resistance, measured between insulated relay parts at a test voltage of 500VDC.

Make Contact: A contact that is open in the rest state and closed in the operating state. (refer normally open contacts)

Material Transfer: During the switching procedure the arc heats up the two contacts differently, depending on the load and polarity. This result in a material transfer from the hotter to the cooler electrode. With a higher DC loads on the contact, a 'pip' is build up, the other contact looses material and it creates a crater.

Maximum Carrying Current: The maximum current which after closing or prior to opening, the contacts can safely pass without being subject to temperature rise in excess of their design limit.

Maximum Continuous Voltage: The maximum voltage that can be applied to relay coil continuously with out causing damage.

Maximum Switching Current: The maximum current that can safely be switched by the contacts.

Maximum Switching frequency: The maximum switching frequency which satisfies the mechanical or electrical life under repeated operations by applying a pulse train at the rated voltage to the operating coil

Maximum Switching Power: The maximum value that can be switched by the contacts without causing damage.

Maximum Switching Voltage: The maximum open circuit voltage that can be safely be switched by the contacts.

Mechanical Endurance (Mechanical Life): Number of switching operations without contact load during which the relay remains within the specified characteristics.

Mechanical Flag Indication: Mechanical indicator in relays (mostly industrial relays) which is linked to the contacts and shows their position. Refer series 51 relays

Nominal Coil Power: Power consumption of the coil at nominal voltage and nominal coil resistance. Also known as Rated Power.

Nominal Coil Voltage: The voltage by design intended to be applied to the relay coil. Also known as Rated Voltage.

Open Relay: Relay without case or cover.

Operating Power: Coil Power at which the relay operates

Operate time: The time from the initial application of power to the coil until the closure of the normally open contacts. It is excluding bounce time.

PCB Relays: Relays designed for soldering into printed circuit boards.

Pick-up Voltage: The value of the voltage that should be applied to an un-operated relay coil at or below which all the contacts of the relay should operate. Also known as Pull-in voltage / Must operate voltage.

Plug-in Relay: Relays that are held in the socket by flat Plug-in terminals (Round Pins for Series 1R, 2R & 51).

Release Time: The time from the initial removal of power from the coil until the re-closure of the normally closed contacts. It is excluding bounce time.

Sealed Relay: Plastic base and cover are sealed with epoxy resin, after soldering into the PC board the relay may be cleaned in liquid or coated with varnish. Provides a large measure of protection against aggressive

Sealing: See open relay / dust proof relay / sealed relay / Hermetically Sealed relay.

Shock Resistance: It specifies at which mechanical shock (multiple of gravitational acceleration 'g' at half since wave and duration 11 ms) the closed contact has still not opened (failure criteria: contact interrupted for $>10\mu S$ is) or no damage occurs.

Test Button: Test button (usually in industrial relays), which is accessible from outside: if it is actuated by hand

Or with a tool, it switches the contact circuit of a de-energized relay from Off to On condition. Some times it can be locked mechanically. The test button helps to trace the current path in a switchboard. Refer series 51 relays.

Vibration Resistance: It specifies the amplitude or the acceleration in a defined frequency range at which the

RELAY CONTACTS

The contacts are the most important element of relay construction. Contact performance is influenced by contact material, voltage and current values applied to the contacts, the type of load, frequency of switching, ambient atmosphere, form of contact, contact switching speed and of bounce.

The contacts are practically not clean because the surfaces are covered by thin layers of low conductivity, semiconductor properties or even isolating characteristics. These layers of oxides, sulphides and other compounds will be formed on the surface of metals by absorption of gas molecules from the ambient atmosphere within a very short time. The growth of these layers will be slowed down and eventually stopped as the layer itself prevents further chemical reaction. The resistance of these layers increases with their thickness. To get a reliable electrical contact these layers have to be destroyed. This can be done by mechanical or electro-thermal destruction.

Mechanical Cleaning

When the contacts are closing, the metal surfaces will collide and hit against each other several times (bouncing), causing elastic deformation of the contact area and mechanical destruction of the thin layers. With high contact pressure also this could be obtained.

The design of most of the relays allows the contact surfaces to wipe across each other destroying the non-conductive films on the contact surfaces. This contact wipe is often enough to clean the surface and reduce resistance to an acceptable level, as well as keeping the resistance stable through out the electrical life of the relay.

Electrical Cleaning

The low and non-conductive layers can also be destroyed by the effects of

a) electrical voltage (fritting)

b) current (heating of contact points)

c) thermal effects (high temperature due to electrical arc)

a) Fritting

The term fritting describes the electrical breakdown of oxide / foreign layer when a sufficiently high voltage is applied across a closed contact. Due to the applied voltage and very short distance between the low potentials a high electric field is generated. This electric field destroys the thin non-conductive layer and establishes a metal bridge electrically linking the two surfaces. The value of fritting voltage depends on the contact material, composition and thickness of layers, conductivity and composition of the contact surface.

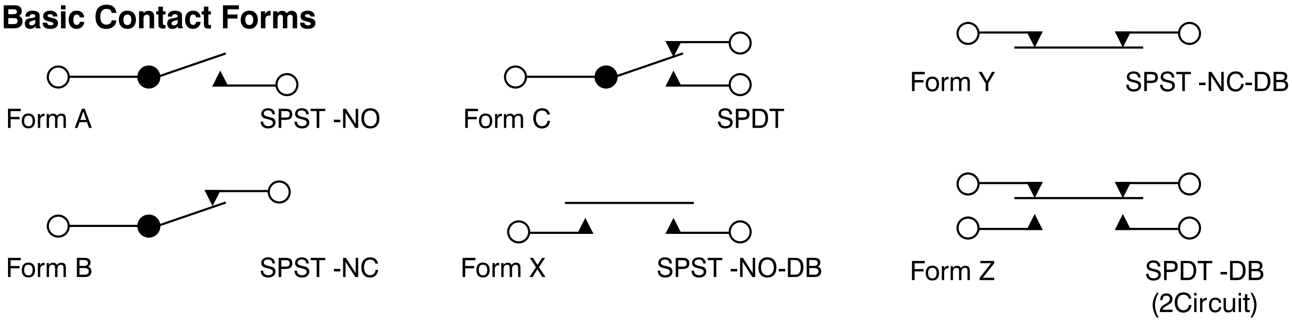
b) High Currents.

High continuous currents and increased contact resistance due to the layers causes heating of the contact. The layers will eventually be destroyed thermally and a larger effective contact area is created, reducing the constriction resistance.

c) Arc, sparks

Under certain circumstances an electric spark or arc will be generated during contact making or contact breaking under load. The extremely high temperature of these arcs may destroy the contact layers and burn or disintegrate other contaminants or particles in the vicinity of the point of contact.

Basic Contact Forms



Dry circuits, low level switching

The term dry circuit describes applications with extremely low loads. In these cases the current is too low to establish an electro-thermal cleaning effect and the voltage is below the fritting voltage. Hence the non-conductive layers are not destroyed. Also mechanical cleaning will not be sufficient. The correct choice of contact materials is critical in such cases for reliability.

Characteristics of Common Contact Materials

Characteristics of contact materials are given below. Refer to them when selecting a relay

Contact Material	Silver - Nickel AgNi 0.15	Good Electrical conductivity and thermal conductivity. Exhibits low contact resistance, and widely used. Easily develops a sulfide film in a sulfide atmosphere.
	Silver - Nickel AgNi 80:20	Used for switching loads in the rage of >100mA upto power switching. Good resistance to contact wear and contact welding. Slightly high contact resistance. Mainly used in DC Switching particularly in automotive applications where high inrush current occur.
	Silver - Cadmium oxide AgCdO	Very Good resistance to contact wear and welding. Good thermal and mechanical stability. Used for switching inductive or high current loads like Motors, Solenoids etc. High contact resistance and Sulphide films form easily.
	Silver Tin Oxide $AgSnO_2$	High melting point and high thermal stability and therefore high resistance to welding. Also contact erosion rate is lower because any arc spreads to the outside of the contact preventing creation of a local hot spot and potential weld. High contact life minimum material migration. $AgSnO_2$ is mainly used for application involving high inrush current like lamp loads or inductive DC loads.
	Palladium - Copper PdCu	Greater Hardness, low contact wear and stable contact resistance. Good corrosion and sulphidation resistance. Very low material migration compared to other contact materials. Expensive. Mainly used for Flasher applications in Automobiles.
	Tungsten W	Highest melting point, high wear resistance with heavy loads, little transfer of material, best suited for breaking heavy inductive loads. Not recommended
Surface Finish	Au clad (gold clad)	Au with its excellent corrosion resistance is pressure welded onto a base metal. Special characteristics are uniform thickness and the nonexistence of pinholes. Greatly effective especially for low level loads under relatively adverse atmospheres. Often difficult to implement clad contacts in existing relays due to design and installation.
	Au plating (gold plating)	Similar effect to Au cladding. Depending on the plating process used, supervision is important as there is possibility of pinholes and cracks. Relatively easy to implement gold plating in existing relays.
	Au flash plating (gold thin-film plating)	Purpose is to protect the contact base metal during storage of the switch or device with built-in switch. However, a certain degree of contact stability can be obtained even when switching loads.

Contact circuit voltage, current and load

Electric Arc Switching

An electric arc is a current intensive gas discharge which occurs when opening a switch or as a result of a flashover. Under certain circumstances the air path between two contacts are ionized due to very high electric field. Ionization causes the normally non-conducting air conductive and its conductivity is maintained if sufficient energy is supplied. The arc represents an additional resistive path in the load circuit. The minimum voltage and current required for generation and maintenance of a stable arc depends on the contact material and the length of the air gap. (Ionization of air happens if a potential of 32V or more is applied between two electrodes)

Due to extremely high temperature of the arc the surface of the contact will melt. Evaporation or sputtering of the contact material leads to wear and material migration reducing the service life of the contacts.

Arc in DC circuits

In DC circuits it is generally during contact breaking that arc occurs. When breaking contacts move further apart and as the gap between the contacts increases the minimum voltage to maintain the arc normally rises above source voltage and the arc is extinguished. If however the supply voltage / current is sufficiently high enough to maintain a stable arc across open contacts, the relay will be destroyed.

In DC inductive circuits, the counter emf generated whose magnitude is equal to L*I*I/2 (energy stored in the inductance) act as a secondary energy source which causes the arc to be maintained until the energy in the circuit has been converted to heat. This leads to considerably longer arc duration. To prevent destruction of the contacts and to keep the arc duration within limits, the switching voltage/current has to be within the maximum DC breaking capacity. (Higher the L/R ratio or lower the power factor of the load, the arc extinguishing time increases

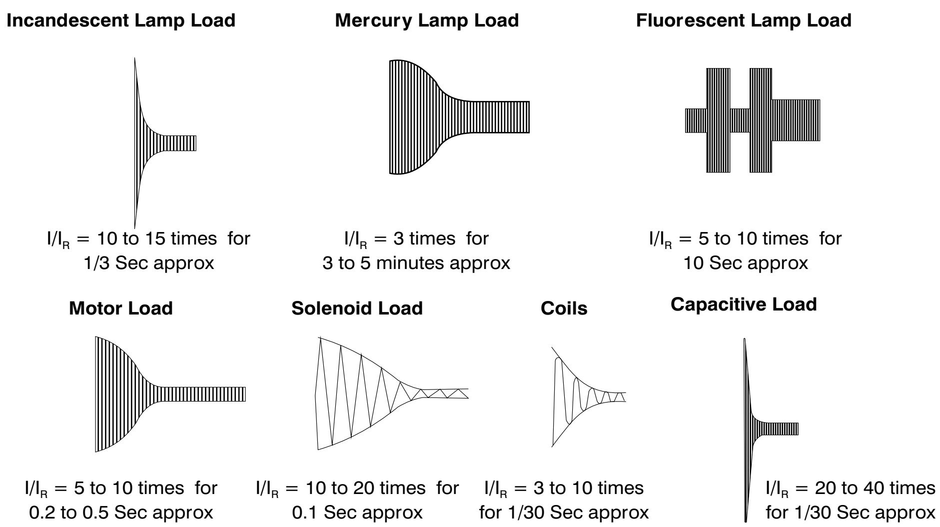
Arc in AC circuits

In AC circuits the supply helps to extinguish the arc as it will collapse when the current becomes zero.(every 10 ms for 50Hz supply) The arc may however be re-established if the supply voltage is above the maximum switching voltage for a particular relay or if the contacts at the current zero crossing are not completely opened. In this case the air gap is still relatively small and the electric field may be strong enough to cause electrical breakdown, especially with surge voltages associated with inductive loads. However after a few cycles, the contact gap will be sufficiently large and the energy in the circuit is too weak to re-ignite the arc.

Type of load and inrush current

The type of the load and its inrush current characteristics together with the switching frequency are important factors that cause contact welding. Particularly for loads with inrush currents, measure the steady state current and inrush current and select a relay that provides ample margin of safety. Table shown below illustrates the typical loads and corresponding inrush currents.

Load Inrush Current and Time



I/I_R = Inrush Current / Rated Current

Application Advice

AC-DC Switching

The switching capacity of a relay is lower for DC loads than for AC. Due to the lack of zero voltage crossing the arc discharge lasts longer. There is also a contact material transfer phenomena when switching DC loads, which may cause contact locking / welding.

Polarity Switching

The contact gap in relays with C/O contacts is rather small and the response time may be shorter than the arc extinction time.

This means the N/C contact could be closed before the arc to the N/O contact is extinguished. In this case the arc between the opening contacts will give an electrical connection to the closing contact. The N/C contact will be electrically connected to N/O contact causing a short circuit. Such circuits must be avoided under all circumstances.

Motor reversing

When reversing a motor by switching between two polarities, the arc between the opening contacts may short to the closing contacts leading to a short circuit of the power supply. As there is practically no load in the circuit, the current will be strong enough to maintain the arc and burn the relay contact system. An additional relay should be used to first disconnect the motor from the power source and then only reversing relay switched after the arc has extinguished.

Multi Pole relays

Loads and contacts should be connected with the same polarity and potential while using multi-pole relays.

If switching different potentials within one relay is unavoidable a type with sufficient dielectric strength has to be selected. Alternatively a large gap between two adjacent contacts should be created by interposing an unused contact set between the sets of switching contacts.

Connecting Contacts in Parallel

The switching capacity of a relay cannot be increased by connecting relay poles in parallel. The contacts will not switch simultaneously. Only one contact will switch the overload and be affected by the arc. The over load will increase contact wear or cause welding.

Phase synchronization of AC loads

If the switching of an AC load is synchronized with AC phase, the polarity of the contacts during the switching procedure will always be the same, leading to material migration and the mechanical locking effect as for DC switching.

Different contact loads in one relay

Switching two extremely different loads like high loads and micro current loads in one relay should be avoided.

Contaminants generated by switching high power may be deposited on the contacts switching the low load, as there is no electrical cleaning effect on these contacts, they increase the probability of contact failure, putting the reliability of the relay in question.

Dummy resistor

When switching low power and dry circuits there is no electrical cleaning effect, which may result in contact failure. Apart from using bifurcated contacts and suitable contact material, the electrical cleaning effect can be increased by adding a dummy resistor in parallel to the load increasing the switching current.

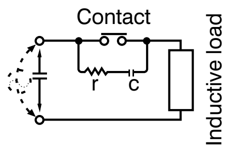
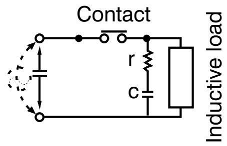
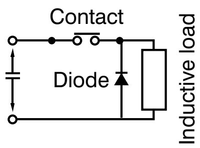
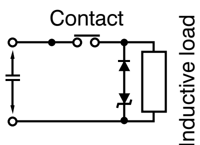
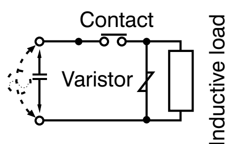
Contacts in Series

Arcs may be extinguished by providing a longer air path between the contacts. This can be achieved by connecting the contacts of a multi pole relay in series thus multiplying the air gap by the number of poles.

Contact Protection Circuit

Use of contact protective devices or protection circuits can suppress the Counter emf to a low level. However, note that incorrect use will result in an adverse effect. Typical contact protection circuits are given in the table below.

(O : Good x : No Good)

Circuit		Application AC	Application DC	Features / Others	Device Selection
CR circuit		k	O	If the toad is a timer, leakage current flows through the CR circuit causing faulty operation * If used with AC vottage, be sure the impedance of the toad is sufficiently smaller than that of the CR circuit.	As a guide in selecting r and c, r: 0.5 to 10per 1V contact voltage c: 0.5 to 1μF per 1 A contact current values vary depending on the properties of the load and variations in relay characteristics. Capacitor c acts to suppress the discharge the moment the contacts open. Resistor r acts to limit the current when the power is turned on the next time. Test to confirm. Use a capacitor with a breakdown voltage of 200 to 300V. Use AC type capacitors (non-polarized) for AC circuits.
		O	O	If the load is a relay or solenoid, the release time lengthens. Effective when connected to both contacts if the power supply voltage is 24 or 48V and the voltage across the load is 100 to 200V.	
Diode circuit		X	O	The diode connected in parallel causes the energy stored in the coil to flow to the coil in the form of current and dissipates it as joule heat at the resistance component of the inductive load. This circuit further delays the retease time compared to the CR circuit. (2 to 5 times the release time listed in the catalog)	Use a diode with a reverse breakdown voltage at least 10 times the circuit voltage and a forward current at least as large as the load current. In electronic circuits where the circuit voltages are not so high, a diode can be used with a reverse breakdown voltage of about 2 to 3 times the power supply voltage.
Diode and zener diode circuit		X	O	Effective when the release time in the diode circuit is too long.	Use a zener diode with a zener voltage about the same as the power supply voltage.
Varistor circuit		O	O	Using the stable voltage characteristics of the varistor, this circuit prevents excessively high voltages from being applied across the contacts. This circuit also slightly delays the release time. Effective when connected to both contacts if the power supply voltage is 24 or 48V and the voltage across the load is 100 to 200V.	

Magnetic system

The magnetic circuit consists of non-moving metal parts such as the core, yoke and a movable armature, and an air gap between the armature and the pole area of the core.

How it works

The magnetic field is generated by a coil consisting of copper wire wound in layers around the bobbin in which there is an iron core. If voltage is applied to the coil terminals a current (Ohms law I=U/R) flowing through the coil generates a magnetic field and hence magnetic flux. This induced magnetic field/flux is directly proportional to the coil current and the number of turns of the coil (H=n x I, H=magnetic field, n=number of turns, I=coil current).

When the magnetic field is strong enough, it will pull in the armature towards the core, closing the magnetic circuit and actuating the armature. The moving armature directly or indirectly operates the relay contacts.

Although the current is the primary factor in generating flux and the pull force in magnetic system, it is common practice to work with voltages to select and specify the relay coil.

Coil energization

The coil must be energized sufficiently by the power source to generate the required magnetic field and force to operate the system at all times and under various conditions. Together with the magnetic system, the coil design has a major effect on various parameters such as sensitivity, operating speed, power consumption, maximum operating temperature, etc.

The gradually increasing method of applying rated coil voltage to the coil should not be used. Rated coil voltage should be impressed fully by means of a switching circuit. To guarantee accurate and stable relay operation, the relay coil has to be energized with a stabilized power source.

DC Coil The power source for DC operated relays should be in principle be either a battery or a DC power supply with a maximum ripple of 5%. Incase where power is supplied by a rectification circuit, the operate, holding and dropout voltage may be higher and vary with the ripple percentage. With a pulsed coil supply the coil current has to be above the holding current at all times. If the current drops below this level, the armature will start to open and buzzing of the relay and increased contact wear will result.

AC Coil For reliable operation of the relay, the coil voltage supply should be with I the range of +10% to –15% of the rated voltage. Usually all voltages are given for 50Hz supply. For a 60Hz supply the coil impedance is higher, reducing coil consumption and altering the pick-up voltage (higher than for 50Hz supply). Due to additional losses in Ac coils the relay efficiency is lower and coil temperature raise is higher leading to a reduced coil operating range compared with DC coils. The waveform of the coil supply should be a sine wave.

The variation of coil resistance is $\pm$10% for low nominal coil voltages and up to $\pm$15% for high nominal coil voltages (e.g. 110 VDC) owing to variations in the diameter of the coil wire.

Coil inductance

As a result of the high number of turns, the soft iron magnetic circuit, and low magnetic resistance, relay coils have a relatively high inductance.

When switching off the supply voltage a high voltage peak will be induced in the coil due to the back EMF, making protection circuits necessary (such as flywheel diodes) to protect coil driving transistors and other electronic components.

In the case of a circuit with flywheel diodes the inductance keeps the coil current flowing after the coil voltage has been switched off and the induced coil current is sufficient to keep the relay in the pulled-in state delaying the dropout.

The AC coil impedance (resistance + reactance) is higher than the resistance and increases with the frequency of the coil supply. Thus, the coil current at 60Hz is lower compared to a 50Hz supply.

Power consumption

The coil, while energized, consumes power. The power for actuating the relay is dependant on relay design.

The power consumption for DC coils is the product of coil voltage and coil current or according to Ohms law i.e. $P=V*I=V^2/R=I^2R$, given in Watts.

The power consumption for AC coils is the product of coil voltage and current and the coil power factor cosø (due to the coil inductance) V x I x Cosø. The coil power is given in VA, usually for a 50Hz supply.

The lower the input power, lesser the heat generated. This can be particularly important in temperature critical applications such as those where relays are densely packed on a PCB.

Sensitive Coils:

The higher the coil resistance the lower the coil current for a defined nominal coil voltage. The lower the power consumption, the higher the sensitivity of the relay.

The advantages of high sensitivity are the possible use of smaller power supplies, lower heat generated by the relay, and the possibility of direct control by transistors. A disadvantage might be higher sensitivity to electrical and magnetic interference.

Equipment generating strong magnetic fields such as transformers and loudspeakers, situated near a highly sensitive or polarized relay, can cause variations in operating voltages. Often these problems can be solved by careful location/orientation of the relay or by providing shielding

Coil heating

A negative effect of power consumption is the heating of the coil and, in turn, the entire relay. The coil temperature is a result of:

Ambient temperature

Self heating (Due to coil Power consumption= V*I)

Induced heating (Due to heat generated by contact system)

Magnetization losses (Due to eddy currents)

Other sources (Due to components in the vicinity of the relay)

Due to coil heating coil resistance increases. Resistance at elevated temperature is expressed by

$R_t = R_0[(1+\alpha(T-23)]$

Where R_0 is the resistance at ambient temperature (23^0C), T is the elevated temperature and α is the temperature coefficient on winding wire (Copper)

During circuit design, care has to be taken that calculations are made under the respective “worst case” conditions, such as the highest possible coil temperature (ambient temperature, self heating of coil and induced heating with applied contact load) for pick-up voltage.

Pick up voltage change due to coil temperature rise.

Usually the nominal coil resistance of relay is given for an ambient temperature of 20 deg. C. A coil at this temperature is called cold coil. A coil heated by effects listed above is called a hot coil.

For a given coil, the pick-up current remains the same at any condition. The pick-up current depends on the coil resistance and the pick-up voltage ($I_{pick\text{-}up} = V_{pick\text{-}up} / R_{coil}$). Coils of most of the relays are made of copper wire. The resistance of copper wire increases or decreases by 0.4% per degree C. Due to the increase in coil temperature the coil resistance increases as per the ratio mentioned above. Hence the pick-up voltage for a hot coil should be higher to generate required pick-up current.

For example in series 61 relays the pick up voltage for 12VDC coil is 9.6 VDC and coil resistance is 400 Ohms at 20 deg. C. i.e. $I_{pick\text{-}up} = 24$mA

When the coil temperature is increased to 40 deg. C the coil resistance will be increased to 432 Ohms. Hence the pick up voltage will be 10.36 VDC (Pick-up current remains the same). i.e. an increase in temperature by 20 deg. C increases the pick up voltage by 0.76 VDC.

For relays operating with higher duty cycles, the pick-up voltage may increase slightly for each successive cycle due coil temperature rise.

Coil Drive circuit protection

Normally DC Relays are operated through semi conductor devices. Due to the inductance of the coil, high voltage peaks are induced (in the form of back emf) when the coil supply is switched off. To protect the relay control transistors or contacts of other control relays against this surge voltage, protection in the form of flywheel diodes or other more

Flywheel diodes are diodes connected parallel to the coil in reverse polarity to the coil supply. While discharging the back emf flywheel diodes provide a low resistance path protecting the driving circuit. The back emf dies gradually by forming loops. Using a flywheel diode increases the release time of a relay.

In automotive relays a high value resistor is connected across the coil to serve the purpose. The back emf will get dissipated in the resistor. The impact of parallel resistor on the release time will be less compared to flywheel diode.

AC Coils

AC relays are designed to be operated by alternating current. For the operation of AC relays the power source is almost always a commercial frequency of 50 Hz, with standard voltages of 6,12,24,48,115 and 230VAC

Since an alternating current decreases to zero every half-cycle (100 times per second for 50Hz), the relay armature tends to release every half cycle. This continual movement of the armature causes contact chattering and may lead to burning or welding of the contacts.

To avoid this chatter of the armature, part of the pole face is fitted with a shading or short circuit ring. The flux created in this short circuit is phase shifted to the main flux, preventing the total armature flux from periodically decreasing to zero.

Care is required where power source voltage fluctuations are caused by load switching. If the power source for the relay operating circuit is connected to the same supply line as motors, solenoids, transformers, and other heavy loads, the line voltage might drop when these loads are switched. In such cases buzzing might occur causing the relay or contacts to fail prematurely.

It is often necessary to drive DC relay from an AC Voltage source. This can be done using a rectifier circuits. Ripples caused by rectification should be kept to less than 5%. The operate and release voltage may vary depending on the percentage of ripple. To check this effect, testing should be carried out.

Basics on relay handling

Avoid ultrasonic type cleaning of all type of relays.

To obtain initial performance through out life, avoid dropping or hitting the relay

Case of the relays should not be removed.

Sealed relays should be used for installation where adverse environment conditions, presence of sulphides, organic chemicals etc.

Always apply rated voltage to relay coil.

Do not switch voltage & Currents that exceeds the designated values

Use flux resistant / Sealed relays for automatic soldering.