SAE The Engineering Society For Advancing Mobility Land Sea Air and Space® INTERNATIONAL
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AEROSPACE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

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SELECTION AND APPLICATION OF RELAYS FOR PROPER PERFORMANCE

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1. SCOPE:

1.1 This SAE Aerospace Recommended Practice (ARP) provides information to guide in the selection of electromechanical relays to be used in electronic circuits for application in aerospace, ground, and shipboard systems to achieve proper performance.

1.2 Relays intended for use in aerospace industry and military applications are substantially different from those produced for industrial applications.

Most industrial relays are designed so that the user can convert contact sets from NO to NC (and vice versa); add and replace auxiliary contact sets; change or replace coils; use coils on systems up to 600 V 50 to 60 Hz and expect relays to last for many operations.

Aerospace relays are designed to be nonrepairable with fixed contact configurations, relatively short life, and generally for systems not exceeding 200 V and 400 Hz. A family of relays is approved by the Military for applications not exceeding 270 VDC. All of these relays are sealed. Adjustment is not possible. A user can make no changes after relays leave the producing facility.

These relays are high-performance, low volume and low mass types with short life, when compared to industrial types, and have little margin to tolerate an application or selection error.

1.3 Relays approved for Aerospace by the Military are summarized in MIL-STD-1346. This standard provides a current listing of Military Standard relays. The user may then evaluate those relays to determine which relays are most suitable for the application at hand and select the military relay part number from the detail specification sheet. Each of the manufacturers employ a staff of Applications Engineers who should be consulted if there is uncertainty in matching a relay to a specific application.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 National Association of Relay Manufacturers (NARM) Publications: 9454 N. Broadmoore Rd., Milwaukee, WI 53217.

Engineers' Relay Handbook

2.1.2 ANSI Publications: 11 West 42nd Street, New York, NY 10036-8002.

ANSI C83.16
ANSI Y32.2

2.1.3 Hayden Press - 1969, Frank S Oliver, Practical Relay Circuits

2.2 Definitions:

2.2.1 TERMS: For a list of common terms used in the rating and design application of relays, refer to the NARM Engineers' Relay Handbook. For relay definitions and terminology, refer to ANSI C83.16.

3. APPLICATION INFORMATION:

3.1 General:

This section contains general guideline information to assist the application engineer or circuit designer in choosing the appropriate relay.

3.2 Relay Selection and Application:

CAUTION: The use of any coil voltage less than the rated coil voltage may compromise the operation of the relay. Choosing the proper relay depends primarily on matching the relay to the load, power supply, and environment. Selection should be limited to items that meet the following requirements.

CAUTION: When latching relays are employed in a circuit, the latch and reset coils should not be pulsed simultaneously. Coils should not be pulsed with less than the nominal voltage and the pulse width should be at least three times the specified operate time of the relay.

a. Contacts must be rated for the load. Current rating, type of load (resistive, lamp, motor, inductive, and so forth), impedance range, voltage rating, DC or AC, frequency, single phase or polyphase, load balance, and type of switching or transfer should all be considered. Each of the following switching and transfer functions places a different requirement on the relay contacts and must be considered when selecting a relay with the proper contact rating:

(1) On-off switching - DC, AC (single phase or polyphase).

(2) Motor reversing (AC or DC).

(3) Transferring load between phases of same source.

(4) Transferring load between unsynchronized AC sources.

3.2 (Continued):

b. Power supply characteristics must be taken into account. Voltage regulation, variations in frequency, ripples and spikes, as well as steady state conditions, should be included. If more than one power supply is involved, not only must each be suitable but any interaction between them also should be investigated.

c. Coil (or coils) should be rated to insure proper operation under all anticipated conditions.

d. Consideration of the environmental conditions anticipated throughout the service life, as well as those expected during storage and transportation before installing the relays in the equipment, is mandatory. Electrical parameters, environmental factors, mechanical stresses, and proper relay application are among the categories which must be investigated.

e. The circuit in which the relay is used, the interlocking feature employed, the wiring harness, and the associated components should all be investigated to assure suitability.

f. Relays should be hard wired, whenever possible, to avoid the additional contact points associated with the relay plug-in socket arrangement and therefore lower the reliability. Plug-in relays, if used, should be types that "lock" to their sockets and are specifically intended for use with that relay. Relays with tin plated or solder dipped terminals are designed to be soldered and are not suitable for use in sockets.

g. Care should be exercised in handling, lead forming, and lead cutting of hermetically sealed relays, since extremely close cover-to-frame spacing and fragile glass seals make these types of relays susceptible to physical damage, if not handled properly.

h. When it is required to provide "safe" isolation of the relay circuit in the OFF condition, and eliminate an electrical shock hazard, an electromechanical switching device should be placed between the positive terminal of the power source and the relay coil.

   Proper transistor control of the relay coil requires a stable reference voltage. This can be done by connecting the plus side of the coil to the positive side of the power source. the minus side of the relay coil to the collector of an NPN transistor, the emitter of the transistor to the grounded side of the power source, and the transistor base to the control voltage; for example, MIL-R-28776/1.

   Any switching device controlling the relay coil circuit must be capable of withstanding, without damage, the sum of the maximum coil circuit voltage and the peak value of transient voltage that results when the coil field collapses. For example, a switch controlling a relay coil that is fed by a 28 VDC line and subjected to a transient voltage suppressed to 42 V must be capable of withstanding 28 V + 42 V, i.e., 70 V surges without damage.

i. In selecting solid state electronic switching devices to control relay coil circuits, care must be used in selecting a solid state device with a leakage current (in the "off" state) that is sufficiently low to guarantee that the relay will drop out.

3.2 (Continued):

j. Control of the relay coil circuit by other than step-function switching may invalidate published relay performance properties such as pickup and dropout voltages (latch/reset) and pickup, dropout (latch/reset) times, and bounce times.

3.2.1 On-Off Load Control: On-off control of loads is a typical relay function. Where practical, one side of every load, including relay coils, should be connected to a common line (the grounded conductor of their power supply). All contacts will be on the hot side with respect to the loads. No contact shall be connected to ground. The switching should be done in the hot side of a circuit to prevent electrical shock, to decrease the possibility of circuit malfunction, and to reduce the number of contacts. Figures 1A, 1B, 1C, 1D, 1E, 1F, and 1G illustrate the problems that can be avoided by proper circuit design.

a. Figure 1A is an example of a control problem resulting from not connecting all loads to the same common terminal. With three relays in series across the line, each has approximately one-third voltage available to it continuously. In addition to the power drain, the relays will be sensitive to temperature, vibration, and mechanical shock causing spurious operation. Relay K1 is energized when switch A is closed. Relay K3 is energized when switch B is closed. Relay K2 is energized when switch A and switch B are both closed. If switch A is closed and then reopened, relay K1 may remain in the energized mode due to the back circuit through coils K1, K2, and K3. Similarly, relay K3 may stay energized when switch B is opened. This uncertainty is corrected by the circuit of Figure 1B, in which all voltage is removed from the relay coils to be deenergized.

b. Figure 1C - The opening ground lead does not open both relays; it places both in series.

c. Figure 1E - Two relays in parallel will interact on dropout; if one relay is much larger, the smaller relay may false cycle. Transient protection on either relay coil will suppress both, whether or not desired. With two relay coils in parallel, if one has an internal series diode and the other is not suppressed, the diode may break down from the coil transients on dropout.

d. Figure 1G - A common example of poor practice is motor dynamic braking with form C contacts. Contacts may handle run current but often fail to interrupt inrush and cause a line-to-ground fault through the switch. It is improper circuit design to have both line and ground on the stationary contacts.

3.2.2 Transfer Operation: Relays used in transfer operations are subject to greater electrical stresses than relays used for on-off load control. Typical transfer applications are those in which relays are used to reverse motors, reverse load polarity, or connect alternate power supplies to a load. Form C contact configurations are particularly susceptible to failure in transfer modes. Fast operation of a transfer contact can short circuit a power supply by making contact at one voltage before ionization from a previous voltage has decayed.

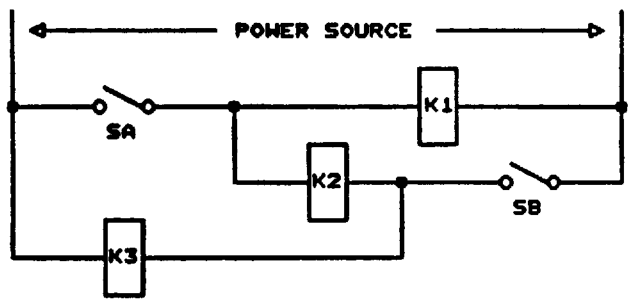

FIGURE 1A - Improper Circuit Design

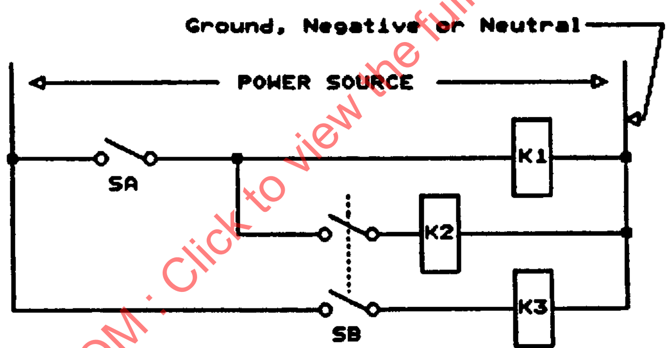

FIGURE 1B - Properly Designed Circuit

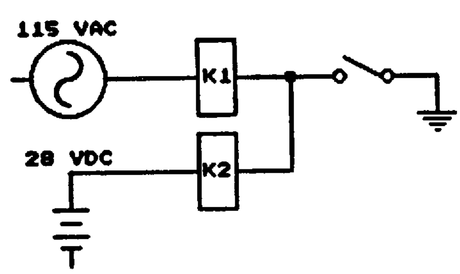

FIGURE 1C - Improper Circuit Design

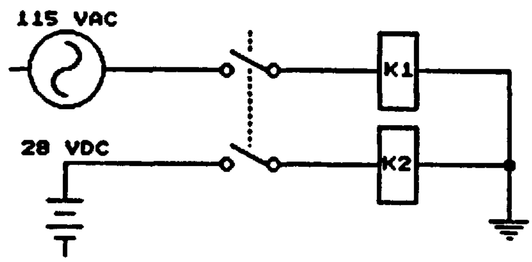

FIGURE 1D - Properly Designed Circuit

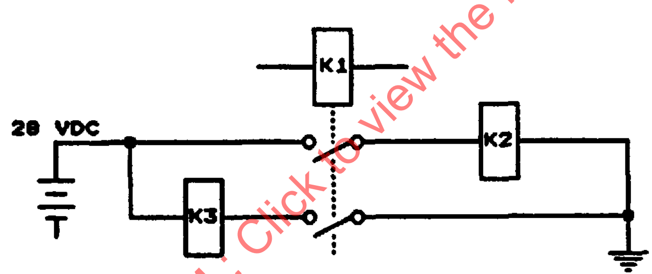

FIGURE 1E - Not Recommended Relay Open Ground

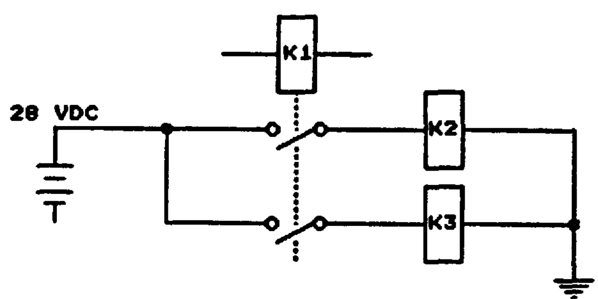

FIGURE 1F - Preferred Design, Two Controlled With No Adverse Interaction on Dropout

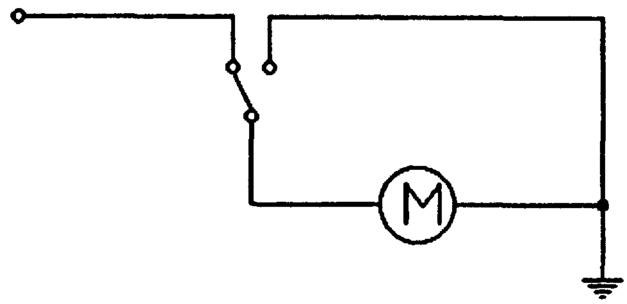

FIGURE 1G - Improper Motor Braking

3.2.2 (Continued):

a. Operate time, release time, contact air gap, spacing between contact poles, type of load, andpower supply characteristics are factors that must be considered. Some manufacturers offer relays with form C contacts, properly derarted, for transfer applications. Because of the uncertainties which arise, even with the best designed circuits, users should be aware of the possibility of failures. The reason may be no more sophisticated than overvoltage applied to the coil, resulting in abnormally fast pickup. Mechanical interlocking will not protect form C contacts used for transfer operations.

   Figure 2A illustrates polarity reversal of a load by form C contacts. If a contact arc persists for the operate or release time of the relay, the power supply is short circuited. The circuit shown in Figure 2B is preferred.

b. Failures can be reduced by using either three-position relays with form K contacts or separate relays, mechanically interlocked. Electrical interlocking of each coil is an accepted circuit design practice with both options.

   Figure 3 illustrates polarity reversal of a load by form K contacts. Interlocking can be used effectively to protect the form K contacts. The time required to complete the transfer of contacts can be increased to assure that contact arcing has been extinguished.

c. During the transfer of a load from one source to another, there are additional potential pitfalls to be considered. These do not necessarily damage the relays used for the transfer.

   (1) High currents circulating between sources, if the two sources are interconnected during the transfer operation.

   (2) High currents circulating between the load and a source.

   (3) High mechanical stress of rotating equipment (Lenz's law).

   (4) Secondary effects of the first three, for example: High field voltage, voltage regulation, and hunting by regulators and governors.

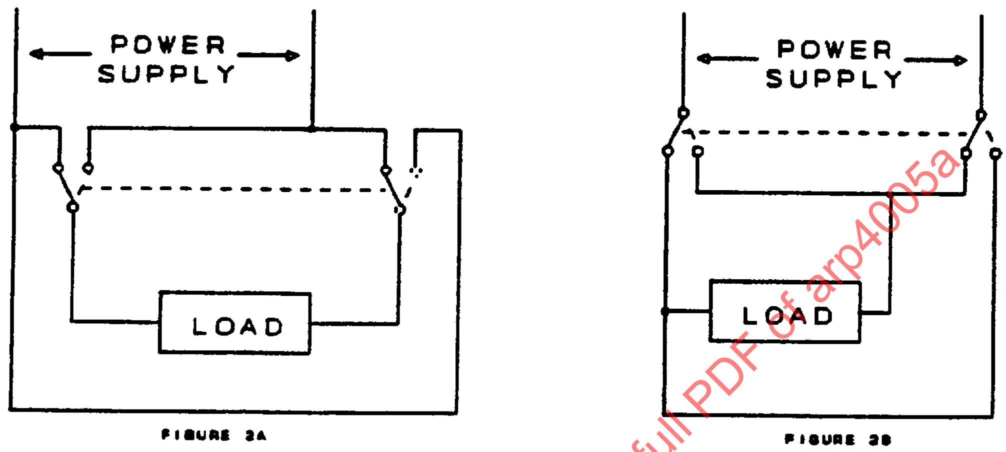

FIGURE 2 - Polarity Reversal, Form C Contacts

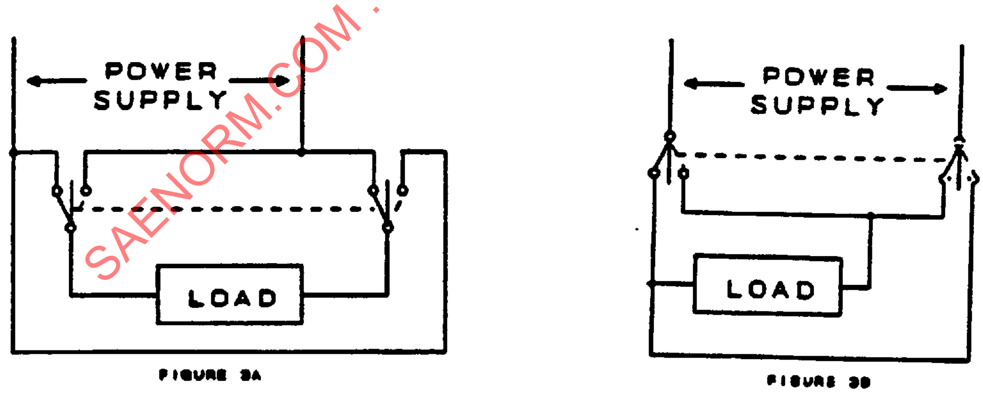

FIGURE 3 - Center Off Polarity Reversal, Form K Contacts

3.2.2 (Continued):

d. With AC sources feeding rotating machines, the following recommendations are made:

(1) If the load is a synchronous motor, it will accelerate to lock-in with the source frequency. Likewise, synchronous machines, used as sources, will tend to synchronize if they are interconnected. The transient voltages, currents, and torques are usually high, depending on the designs and mechanical and electrical couplings involved. This is especially true if the transfer between sources takes place when the source voltages are out of synchronization causing the motors to suddenly accelerate (or decelerate) into step.

(2) If the load is an induction motor, care should be exercised to assure that the frequency to which the motor is transferred is no less than the frequency minus slip; otherwise, the motor will be severely braked, as it performs as an asynchronous generator, with resultant mechanical and electrical transients.

(3) When AC circuits are switched, consideration should be given to the detrimental effects on the loads or the generators, or both. The proper functioning of the relay is important, but no more important than the damage to associated equipment.

e. When switching AC circuits, relay contacts should be adequately rated for twice normal voltage to accommodate out-of-phase switching. Also, inrush current considerations could be up to four times those expected when energizing the load.

3.2.3 Multiple Relay Operation: When more contacts are required than are practical on a single relay, multiple relays must be used. When this is necessary, cascading (see Figure 4) rather than paralleling (see Figure 5) should be considered. A contact on the first relay is used to energize the second; a contact on the second is used to energize the third. Each relay is energized in turn by a contact on the preceding relay in the string. A contact on the last relay is used as the interlock or holding contact for the entire array.

3.2.4 Coil Transient Suppression: Voltage induced in relay coils can cause arcing of the contacts that control the relay. Spikes in the transient induced voltage may result in electromagnetic interference. Several methods are available to cope with these problems. Nearly all of them slow the armature dropout and result in increased release time. Furthermore, the hammer blow action of the armature necessary to break tack welds will then be unavailable. A way to suppress the coil and retain the fast break away and retain the hammer blow is by using back-to-back zener diodes or a zener diode with a blocking diode.

3.2.4.1 Diode shunts:

CAUTION: The transient voltage spike developed by one relay coil may be reduced by using a diode shunt, but because of the increased release time, the contact of that relay may have a drastically reduced life. When two or more relay coils are in parallel, a diode across one affects the operation of the others; also, the inductive voltage spikes from other paralleled relay coils may destroy shunt diodes.

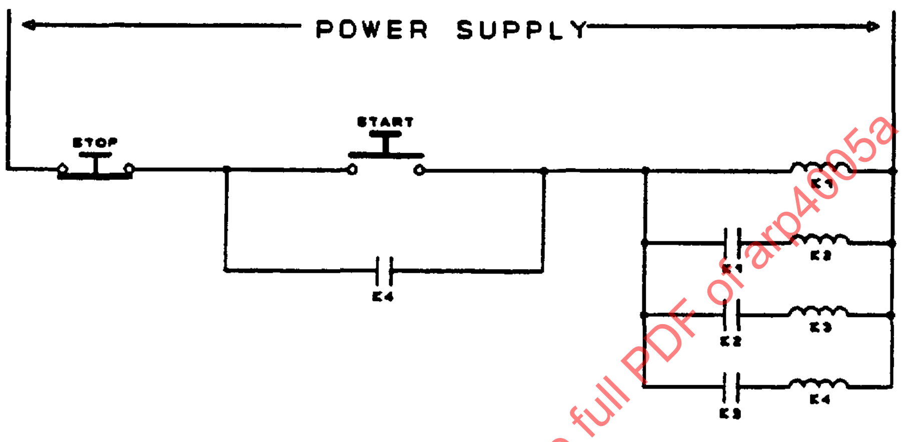

FIGURE 4 - Concurrent Relay Operation, Cascade Method

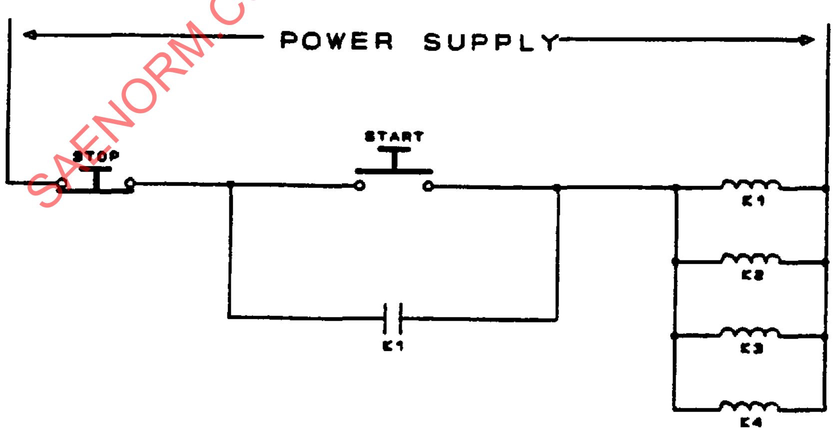

FIGURE 5 - Concurrent Relay Operation, Parallel Method

3.3 Relay Contact Configurations:

An important consideration for relay application is the contact arrangement. The contact arrangement is the various combinations of different basic contact forms that make up the entire relay switching structure. Relay contact notations are given in the following order:

a. Poles - Each movable contact and its associated normally open and normally closed contacts of a relay constitute a pole of the relay.

b. Throws:

(1) Single throw (ST) - Normally open or normally closed contacts.

(2) Double throw (DT) - Transfer (form C or Z) contacts are a combination of two stationary contacts and a movable contact that engages one of the stationary contacts when the coil is energized, and engages the other when the coil is unenergized.

c. Normal position - A combination of a stationary contact and a movable contact that is engaged when the coil is deenergized, is referred to as back, break, form B, or normally closed contact (NC). A combination of a stationary contact and a movable contact that is engaged when the coil is energized is referred to as front, make, form A, or normally open contact (NO).

d. Double break (DB) - A double break is a combination in which a movable contact simultaneously makes and breaks connection between two stationary contacts. All contacts are single break except when noted as double break. Example: DPST NCDB designates double pole, single throw, normally closed, double-break contacts.

e. Multiple combinations - Relays having several sets of differently functioning contacts will have the contact forms listed in alphabetical order of their letter symbols as shown on Figure 6; for example; 1B3C refers to SPST NC contacts and 3PDT contacts.

3.4 Relay Misapplication:

Electromechanical Relays are subject to both electrical and mechanical failure. Some causes of failure are poor contact alignment; open, contaminated, or pitted contacts; loss of resiliency in bearings; and open coils. Contact failure can result from high inrush or sustained high currents, or from arcing when an inductive circuit is opened. High inrush currents occur in loads composed of motors, lamps, heaters, capacitive input filters, transformers, magnetization current, or other devices that have low starting impedance compared to operating impedance. However, the greatest cause of relay failure is misapplication. As in all designs, the circuit design, the components (relays), and the application must be closely matched. The complex nature of the loads typically driven by relays as well as the complex nature of the relay as a load are factors that are often overlooked or difficult to accurately specify in the design of an application. System testing is often beneficial in determining failure modes and preventing in-service failures. The following are typical relay misapplications that may lead to relay failures.

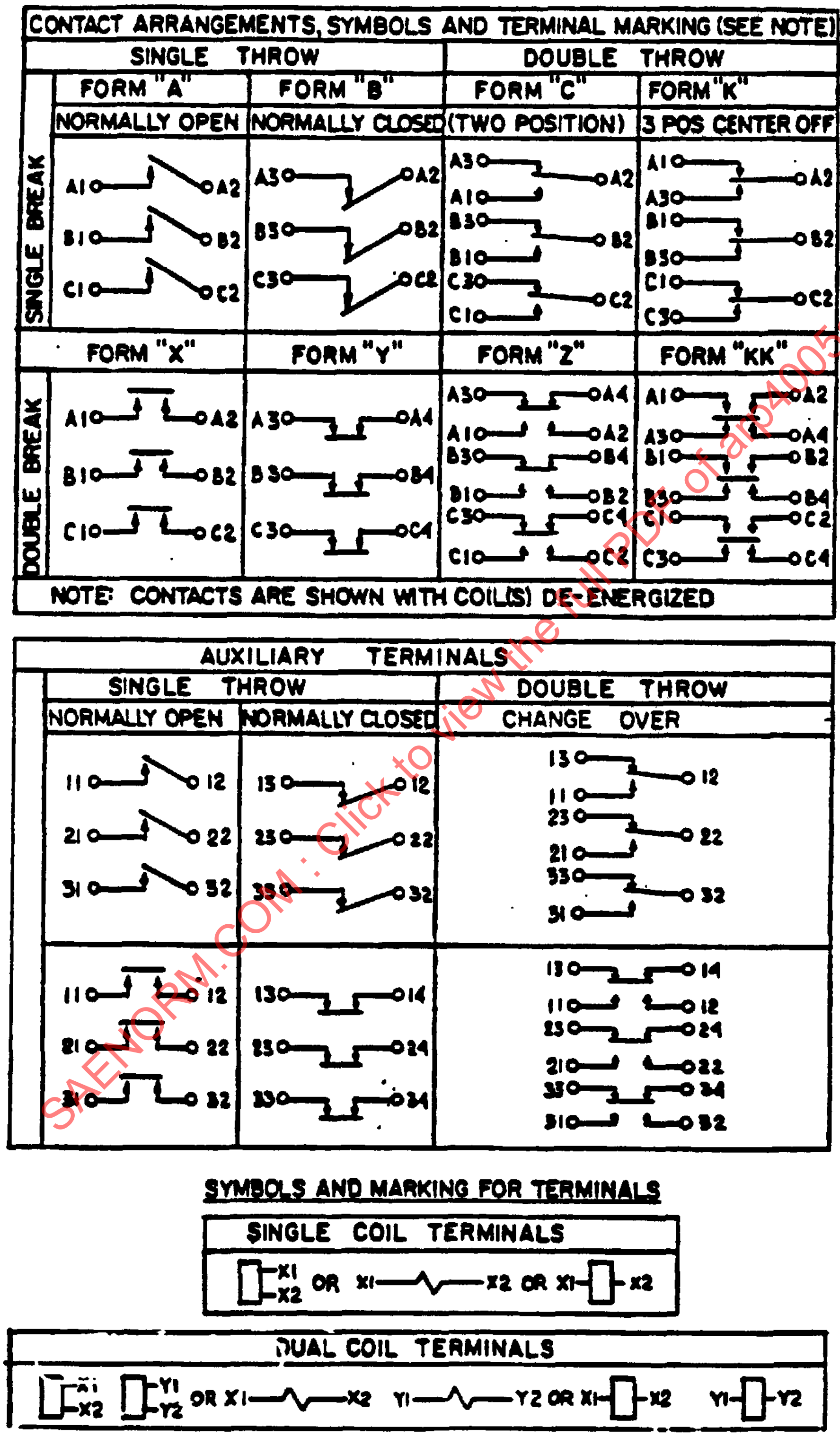

FIGURE 6 - Symbols and Markings for Contact and Coils

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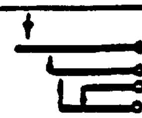
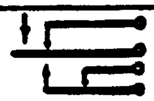
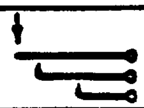
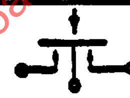
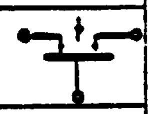
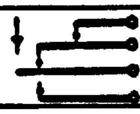
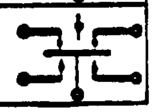
OTHER CONTACT ARRANGEMENTS AND SYMBOLS					
FORM	DESCRIPTION	SYMBOL	FORM	DESCRIPTION	SYMBOL
D	Make, Break or Make-Before-Break, or SPDT (M-B), or "Continuity Transfer"		J	Make, Make, Break, or SPST (M-M-B)	
E	Break, Make, Break, or Break-Make-Before-Break, or SPDT (B-M-B)		L	Break, Make, Make, or SPST (B-M-M)	
F	Make, Make SPST (M-M)		U	Double Make, Contact on Arm, SP ST NO DM	
G	Break, Break or SPST (B-B)		V	Double Break, Contact on Arm, SP ST NC DB	
H	Break, Break, Make, or SPST (B-B-M)		W	Double Break, Double Make, Contact on Arm, ST DT NC-NO (DB-DM)	
I	Make, Break, Make, or SPST (M-B-M)				

NOTES:

1. Symbols are in accordance with ANSIC83.16-1971 and Y32.2-1975

2. Contacts are shown with the coil(s) de-energized; however, contacts of latching relays remain in the position attained as the result of the last energization.

3. The arrow in the symbol indicates the direction of motion of the moving contact in response to energization of the relay winding.

FIGURE 6 - (Continued)

3.4 (Continued):

a. CAUTION: The use of a coil voltage less than the rated coil voltage may compromise the operation of the relays.

b. Improperly using an existing relay specification by erroneous interpretation or even using the incorrect specification altogether. A given specific set of conditions is given in the specifications. Variations from these conditions will affect performance of the relay accordingly.

c. Caution should be employed when combining contacts to increase capacity. Contacts will not always make or break simultaneously, therefore, one contact pair carries all the load current for paralleled contacts, and all of the voltage for series contacts. Contacts can be combined for redundancy to improve system reliability. Consult the manufacturer if there is a question.

d. Circuit transient surges. Circuit designers must not expect relays to handle circuit transient surges in excess of their ratings.

e. Using relays under load conditions for which ratings have not been established. Contact ratings should be established for each type of load. Many relays will work from low level to rated load; however, the relay should not be expected to do both. Many relays possess high level and low level load capabilities; however, relays previously tested or used at high level loads shall not be used for low level load application. High capacitive inrush currents and inductive break voltages may require oversized contacts. The cold filament of a lamp draws very high currents until warmed up. Contacts that switch lamps must be able to take the inrush current.

f. Using relays to switch higher voltages than those for which they were designed. For example, switching 300 V power supplies with relays only rated 115 V maximum.

g. Contact ratings with grounded case. Some relays, with small internal spacing or lack of arc barriers, when switching in excess of 40 V (AC or DC) with grounded case, must have the contact ratings reduced significantly lower than in the ungrounded case mode of operation. Typically, the maximum AC rating of such a nominally rated 28 VDC, 2 A resistive relay, is of the order of 0.150 A. Relays with sufficient spacing or arc barriers may be used at full rating at voltages over 40 V (AC or DC) or 115/200 V, three-phase 400 Hz with case grounded when so rated in the detail specification or MS standard. Switching high voltage with the relay case ungrounded results in a potential hazard to personnel. **WARNING!!**

h. Transferring load between unsynchronized power supplies with inadequately rated contacts. When the load is switched, the voltages can range from being in-phase to 180° out-of-phase; therefore, the relay contact voltage may vary from 0 V to two times the peak voltage and exceed the maximum voltage and current ratings.

i. Switching polyphase circuits with relays tested and rated for single phase only. A typical misapplication is the use of small multipole relays (whose individual contacts are rated for 115 V single phase AC) in 115/200 V three-phase AC applications. Phase-to-phase shorting at rated loads is a strong possibility in these instances with potentially catastrophic results.

3.4 (Continued):

j. Using relays with no established motor ratings to switch motor loads. In addition, caution should be used in applying relays to reverse motors, particularly where the motor can be reversed while running, commonly called "plugging". This results in a condition where both voltage and current greatly exceed normal. Many power relays are rated for "plugging" and reversing service but a relay should not be utilized in potential "plugging" situations unless so rated by the manufacturer.

k. Using relays with no established intermediate current (minimum current) capabilities. It must not be assumed that because a relay is used in an application considerably below its rated contact load that the consideration of intermediate current capability can be ignored. This is especially true if there is no established level of intermediate current for the relay.

l. Using relays rated for 115 VAC only on 28 VDC (or higher voltage) applications. If contacts in these devices are of the single break form A type, rather than Form X, it may be necessary to derate severely for use on DC applications at 28 V or higher.

m. Effects of ambient temperature and coil temperature rise (I^2R heating) on coil overdrive. Many users do not consider that more voltage is required to operate a relay at elevated temperatures and are surprised to find that they have marginal operation at elevated temperatures. A relay is a current-operated device (ampere-turns) and the coil resistance increases at the rate of 0.004 Ω/Ω/°C because of the temperature coefficient of copper. Therefore, with a given voltage applied to a relay coil, operating force decreases as the temperature elevated. Temperature rise will also occur within the relay as a function of self heating. If this is not taken into account, misapplication occurs. When rated voltage is specified and the user must consider the maximum ambient temperature condition, self heating, and the effect upon the voltage must be considered.

n. Relay-race involves conditions, where, for proper operation, one relay must operate prior to another in separate drive circuits. Relay-race circuits should be avoided; but where they must be used, ambient temperature, drive power, operate and release times, coil suppression circuitry, and wear consideration must be made carefully.

o. Another less common problem is encountered when a relay coil is operated by a slowly rising current. When conditions are right, the relay operates at a point during the increasing drive current. Back electromotive forces (EMF's) are produced when the armature closes to the pole face. The new voltage, being opposite in polarity to the driving voltage, may cause the relay to release and then reoperate. This condition prevails until a sufficient amount of drive current is available to overcome the back EMF's.

p. Relays with coils rated for 50/60 Hz and not rated for 400 Hz should not be used at 400 Hz. Relays rated for 400 Hz and not rated for 50/60 Hz should not be used at 50/60 Hz.

3.4 (Continued):

q. Use of a relay to switch an inductive load which exceeds its inductive rating. While AC inductive circuit requirements and relay capabilities can be properly matched in terms of current, voltage, frequency, and power factor, no such positive comparison method exists for DC inductive circuits. Special care must be given in selecting a relay for DC inductive load, to stay within the rating and/or millihenry limitation.

r. Using coil transient suppression when suppression is not required. Suppressing coil transients can affect load switching capability and relay life. Using maximum possible suppression will increase relay dropout time. Increased dropout time can reduce the amount of current that can be switched and the relay life. Increased dropout time can also adversely affect relay logic circuits.

s. Coil voltage is the voltage across the relay coil terminals. Voltage drops that occur in control circuits, series diodes, control transistors, long wires, etc. must be taken in to account by the user.

t. Contact load effect on coil voltage. In an application with high current load or high inrush current which greatly depresses coil voltage, the user must consider the possibility of relay chatter, rapid make and break cycling, with possible damage and lesser contact life.

3.5 Relay Application Checklist:

A serious cause of relay failure in circuits results from misapplication. A frequent cause of the misapplication is selecting a specific relay for an application before a complete understanding of relay requirements are known. Many of these problems could be avoided if the circuit designer had been more systematic in identifying the relay requirements. It is suggested that a tabular listing or check list of requirements be made, similar to the following:

a. COIL -
Voltage available:
Current available:
Latching required (pulse energy, amplitude, duration)
Coil suppression required (Max. allowable negative spike)
Type of coil power (AC or DC): 50 Hz, 60 Hz, 400 Hz
Duty cycle:

b. LOAD -
Number poles: (1, 2, 3, etc.)
Number throws: (ST, DT, off position)
Load Frequency (DC, AC, 50 Hz, 60 Hz, 400 Hz)
Load RF, VSWR
Switching action: Carry or switch and carry
Relay transfer time
Load voltage magnitude:
Load current magnitude:

3.5 (Continued):

Load type: Resistive, Inductive-transient suppressed or not, RF-watts and frequency, lamp, motor or capacitive
Possible loads under circuit failure modes:(Rupture, Overload, Time-Current characteristics)
Load life requirements:
RF load: crosstalk, insertion loss, frequencies
Operate time:
Release time:
Bounce time:
Case grounded:

c. ENVIRONMENT -
Relay ambient temperature requirements:
Shock: (peak value, duration, waveform)
Vibration: Random or sinusoidal
Thermal EMF requirements: Operational
Insulation resistance:
Dielectric withstanding voltage required: Sea level: specific altitude
Seal requirements: (Humidity, Salt Spray, etc.)

d. OTHER -
Mounting requirements:
Terminal type: (Compatible Materials)
Footprint:
Acceptance testing requirements:
Special performance requirements: (Such as must operate at 70% of nominal coil power at temperatures under 65 °C)
Applied Torque to terminals and mountings

4. CONTACT LOAD CAPABILITIES:

Relays provide the flexibility for switching a wide range of AC and DC voltages or currents. The voltages may be switched from the millivolt range to several hundred volts, AC or DC at current levels from dry circuit to hundreds of amperes. The relay corresponds to a low loss switching device with tremendous gain whose output level is unaffected by the input level. Most relays require continuous power when they are energized, but latching relays require power only for the few milliseconds required to drive them to the set or reset positions.

This section discusses contact switching in the following areas:

4.1 Transformer Loads
4.2 Power Switching
4.3 Low Level Switching
4.4 Dry Circuit Switching
4.5 Intermediate Current Switching
4.6 Alternating Current Switching
4.7 Arcing and Transient Loads
4.8 Overload Considerations

4.1 Transformer Loads:

A transformer with an open circuit secondary may have a very high in-rush current on the first half cycle of supply voltage. Core saturation depends upon the supply voltage phase at turn-on relative to its phase at turn-off. (With average transformers, this in-rush current can be 40 to 50 times greater than the rated current). The worst case surge current at turn-on would be equal to the peak supply voltage divided by the circuit impedance. The circuit impedance would be the DC resistance of the primary winding on the transformer in series, with the wire resistance, the power supply impedance and any other elements in the primary circuit. In selecting a relay for a transformer load it is recommended that a relay with a motor load rating that is greater than 18% of the peak surge current be used.

4.2 Power Switching:

Power switching applications (resistive load, inductive load, motor load, and lamp load) are generally considered to be those where there is sufficient voltage and current to cause significant contact arcing as the contacts make and break the current. The arc melts and vaporizes the contact surfaces causing erosion, pitting and transfer of contact material from one contact surface to the other. The contact life is limited by the amount of contact material loss during operation. Sufficient power and heat from the arc is normally available to burn through any foreign films and "blast" carbon deposits out of the contact area to keep the contact resistance low during and after life.

Microscopic-sized foreign particles that could migrate into the contact make area are usually blown free, burnt-up or vaporized by the arc in power applications. Since this "self-cleaning" action is not present in low level applications, it may be generally more desirable to specify a low level run-in test on units to be used for low level applications.

4.3 Low Level Loads Switching:

Low level applications are those where the relay contacts make and break the load current but the energy level switched does not disturb the contact surfaces. This area is defined as energy levels which result in contact voltage drops less than the softening voltage of the contact material (approximately 0.080 V for gold and 0.090 V for silver). Contact life is much longer than it is for power switching. Low level screening or run-in tests are used in the industry to identify and eliminate infantile failures. A common screening test consists of 5000 operations at an open circuit potential of 10 to 50 mV with contact current of 10 to 50 μA, and each contact operation monitored for a specified miss level between 33 and 100 Ω with no misses allowed. One miss is cause for rejection of that particular unit, and it is not shipped with the production lot.

4.4 Dry Circuit Switching:

The term dry circuit has frequently been misapplied in describing low level tests or applications. A dry circuit test or application is one in which a relay contact does not make or break the current. The contacts are first closed before the power is applied through the contacts. Power is then removed before the contacts are permitted to open. The contact load can be any value within the thermal or dielectric strength capability of the relay. Since the relay contacts do not make or break the load energy, there is no arc to clean the contacts by erosion or disruption of the contact surface.

4.5 Intermediate Current Switching:

Intermediate current loads, sometimes referred to as minimum current loads, are those in the low end of the normal power switching range, and typically range from about 0.025 to 0.5 A and 3 to 30 V. At these levels, arcing does not effectively remove carbon residues that are created as the arc burns organic vapors present on the contact surface or in the relay atmosphere. As a result, contact resistance can increase to objectionable levels unless the relay is free of volatile organic materials.

Since contact resistance can vary during its life, and may be erratic. an effective intermediate current test requires monitoring of each contact operation during its life to a predetermined maximum permissible contact resistance level. The increasing or erratic contact resistance phenomena of contacts that carbonize must be taken into consideration when applying relays to intermediate or minimum current loads.

4.6 Alternating Current:

Contacts will usually switch higher currents or voltages with alternating current loads than with direct current loads since the arc will usually be terminated when the current passes through zero and reverses at the end of the first half cycle following contact separation. It is a common practice to use arc-resistant contact material, particularly in a relay in which the contacts separate slowly, and let the arcing be terminated by the reversal of the current rather than by the continuing separation of the contacts. The current reversal effect can be supplemented by magnetic or air blowout, multiple break contacts, arc gap cooling labyrinths, or evacuating the contact chamber.

NOTE: These techniques are also used for direct current high power loads when required. In AC circuits, contact material is often deposited outside the contact area on surrounding materials. The metal that condenses in these other areas can degrade the insulation systems of contact circuits.

4.7 Arcing and Transient Loads:

A capacitor load, or any load having a capacitor in parallel, can theoretically sustain an infinite current during switching transients. For capacitive loads, contact damage is caused frequently by the huge current inrushes at or just after the instant of closure, at a time when the contact forces are light and the load current is many times the steady-state value. During this interval, contact bouncing takes place, resulting in short arcs that may melt the metal sufficiently to form a solid weld as the contact reclose causing a relay failure. Since the break current is very low, the build-up is like a stalactite and leaves a corresponding cavity in the mating contact. After a number of cycles, the stalactite will catch on the opposite contact, again causing a failure.

The total circuit must be analyzed to determine the circuit impedance including wire resistance, power supply resistance in series with the capacitor and the peak supply voltage (AC or DC). In order to insure that the current will not weld the contacts, a relay should be selected which has a motor load rating that is greater than 18% of the peak switching current.

4.7 (Continued):

Under some moderate arcing conditions, contact life might be increased by shunting the load with a resistor-capacitor combination in which the time constant is equal to that of the load. Shunt protection adds two or four or more components to the circuit with the inherent reduction in reliability. Also, transients voltages may be high enough to cause breakdown of other circuit components and cause interference in adjacent or associated circuits.

The network in Figure 7 makes the load characteristics essentially resistive. For 115 VAC service, the diodes should have P.I.V. ratings of 600 V, the capacitor should have a DC working voltage of 200 VAC and a resistor value of 100 kΩ (1 w dissipation). The capacitor discharge time after switch closure may be as long as 1 s. The transient voltages developed when contacts open an inductive load may cause dielectric breakdown and arcing between contacts and other parts of the relay if it isn't motor load rated for the specific application.

For increased system reliability, it is recommended that a relay be selected with a rating to handle the load directly without shunting components. Because it is not possible to predict life cycles for loads that are capacitive in nature, it is strongly suggested that the suitability of the relay selected be verified by tests duplicating the conditions of the load.

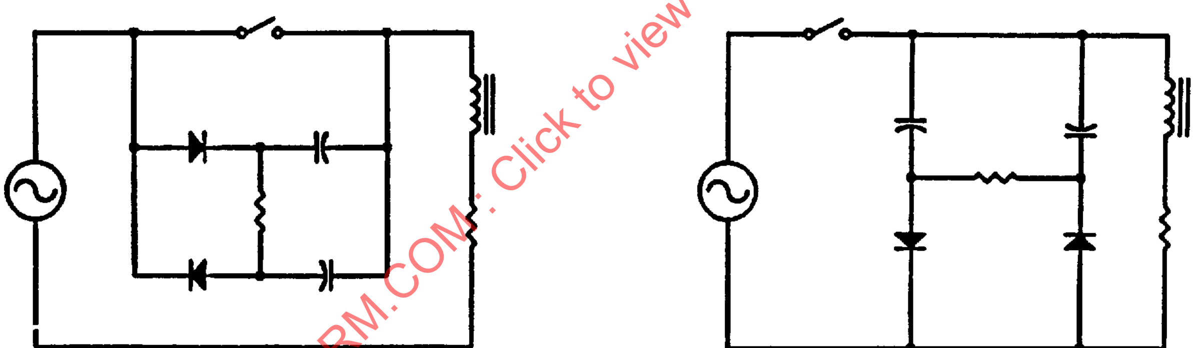


Figure 7A

Figure 7B

FIGURE 7

4.8 Overload Capability Considerations:

Circuit conditions may impose loads on the contacts that considerably exceed their normal rating. There are standard tests that evaluate contact performance for overload and rupture rating for a very limited number of cycles (not over 100). These tests are defined in MIL-STD-202 and the military specification for the specific type relay.

4.8 (Continued):

Overload and rupture requirements should take into consideration:

(1) Type and magnitude of the load.

(2) Permissible contact resistance.

(3) Number of cycles

(4) Case-grounding requirements.

(5) Ambient temperature.

(6) Post test requirements.

(7) Compatibility with circuit protecting devices

Other considerations include:

(1) Whether all contacts of a multiple relay are loaded and tested simultaneously.

(2) Monitoring means.

(3) Monitoring for sticking contacts.

5. COIL OPERATION DATA:

5.1 Operate Voltage (coil):

Operate voltage refers to the voltage required to be applied to the relay coil, or coils, to cause the relay to operate. Application of the operate voltage to the coil will cause the relay to change state and pickup. Application of the Operate voltage to the latch (set) coil of a latching relay will cause the relay to be in the latch position. Subsequent application of the operate voltage to the reset coil will cause the relay to change to the reset position. Latch relays may use a single polarized coil in place of a two coil arrangement. Latching relays are normally switched by pulsing the coil.

5.1.1 Rated Voltage (coil): Rated voltage is the coil terminal voltage, which the relay is rated normally to operate at or near to; and the voltage used during qualification of design and verification of product, unless otherwise required by specification. Maximum operate and minimum operate coil voltages available throughout the environment range in a given application should be established for circuit design, and a relay chosen with adequate coil voltage ratings.

5.1.2 Abnormal Voltages (coil): Maximum coil voltage will have the longest dropout time and the worst self-heating effect. Minimum coil voltage will have the longest pickup time and least margin-over-actual pickup voltage for vibration and shock environments.