101 BASICS SERIES

LEARNING MODULE 18:
TERMINAL BLOCKS, RELAYS & TIMERS

Cutler-Hammer

EATON

WELCOME

Welcome to Module 18, which is about *terminal blocks*, *relays* and *timers*.

TERMINAL BLOCKS are modular, insulated blocks that secure two or more wires together and consist of an insulating body and a clamping device. Their flexibility allows wiring to be centralized and makes it easier to maintain complex control circuits.

FIGURE 1: TERMINAL BLOCK

RELAYS are switches that open and close circuits electromechanically or electronically.

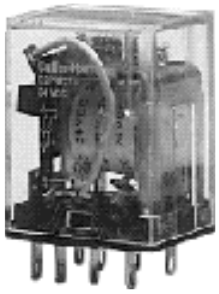


FIGURE 2: RELAY

TIMERS control timing in applications where functions need to be delayed, or loads need to be maintained for a predetermined period of time.

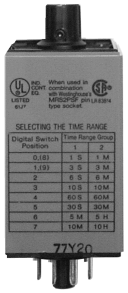


FIGURE 3: TIMER

Like the other modules in this series, this one presents small, manageable sections of new material followed by a series of questions about that material. Study the material carefully, then answer the questions without referring back to what you've just read. You are the best judge of how well you grasp the material. Review the material as often as you think necessary. The most important thing is to establish a solid foundation to build on as you move from topic to topic and module to module.

A Note on Font Styles

Key points are in bold.

Glossary items are italicized and underlined the first time they appear.

Viewing the Glossary

You may view definitions of glossary items by clicking on terms and words that are underlined and italicized in the text. You may also browse the Glossary by clicking on the Glossary bookmark in the left-hand margin.

WHAT YOU WILL LEARN

This book is divided into three sections: Terminal Blocks, Relays and Timers. Each section starts with an overview to introduce you further to the main points about these devices, and the parts that make them up. Here is the information we'll cover:

WHAT YOU WILL LEARN (CONTINUED)

INTRO-DUCTION TO TERMINAL BLOCKS

What is a Terminal Block?

Today's control wiring systems are growing increasingly **complex** as **equipment is confined to smaller and smaller spaces,** and industry simultaneously demands **more responsiveness and higher levels of automation.** For example, these days a packaging system may have a number of points on the conveyor line monitored by sensors. Imagine the hassle involved with running wire from each device to the next, thus creating a spiderweb of wiring. Instead, put a terminal block assembly inside a centralized control panel. You have now centralized and reduced the wiring so that a maintenance crew can quickly assess the status of the system and verify its performance.

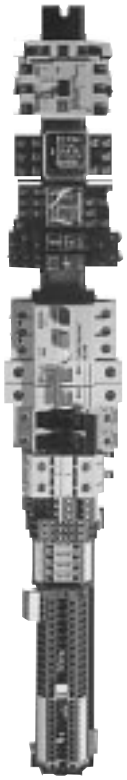


FIGURE 4: TERMINAL BLOCK ASSEMBLY

Within the control panel, these handy modular components can be snapped securely into place on a mounting rail. The designer can also mix and match a variety of application-specific terminal blocks with distinctive shapes, colors and termination markings. When you open the control box door, a quick scan of the wiring is all that's needed to verify the layout and eliminate guesswork for maintenance and troubleshooting.

When changes in the circuit need to be made, **terminal blocks can be easily added or pulled off the rail without disrupting other wire terminations**.

Along with reducing the complexity of control wiring, the plastic bodies of terminal blocks also prevent shorts and therefore provide greater safety to installers and maintenance crews.

IN THE WORKPLACE

National Metals received shipment of a new 100-foot long metal polishing system for handling cylindrical stock. The equipment manufacturer's field installation crew arrived with the equipment and was ready to start setup. "One of the first things I need to know," said the head of the crew to National's production manager, "is whether the existing control box can handle wiring for the new machine." The crew's electrician wanted to know if the box had room to handle the equipment's power needs and other control devices, or if an additional box needed to be installed. "Great," he thought as he saw there was sufficient room on the terminal block rail.

FIGURE 5: CONTROL BOX CAPACITY

PARTS OF A TERMINAL BLOCK

A terminal block secures two or more wires together to set up a circuit. Basically, there are just two parts: an insulating body and the current carrying parts.

Insulating Body

The insulating body houses the current carrying parts. The body **insulates the wire termination to minimize heat** generated when current passes through the wires. **It also provides a base for the clamping mechanism and other parts such as switches and fuses**. The body of the terminal block has specially designed holes for access to the clamping screws.

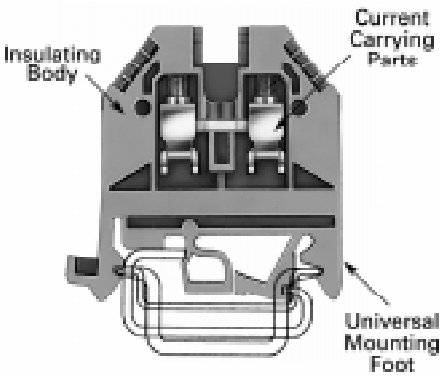


FIGURE 6: TERMINAL BLOCK PARTS

The body also has a mounting foot that enables the terminal block **to be snapped on and off the mounting rail** without being weakened.

The space efficient design of a typical modular block permits high-density circuits to fit in a standard control panel. A 5 mm wide block can provide up to 60 terminations per linear foot. Standard 6 mm single level blocks yield up to 50 terminations per linear foot; double level blocks can handle up to 100 terminations per foot.

Body Materials

Mounting block bodies can be constructed from any of the materials described in the following list.

Polyamide 6.6. A rugged thermoplastic material, designed to work under any environment and remain elastic and fracture proof from -40°C to 105°C. This material offers high insulation, tracking resistance and a high flammability rating. The strength and ease of handling of this material makes it the most commonly used.

Melanine 150. A resin-based thermoset plastic with an organic filler. Although it is a far more delicate material than Polyamide 6.6, Melanine has a high resistance to heat radiation. It is recommended for applications where the continuous operating temperature is between 110°C and 140°C.

Ceramic. This highly rugged material can be used in very high temperatures approaching 250°C. Ceramic blocks can also function in industrial plants with heavy dust deposits and unusually corrosive atmospheres.

Current Carrying Parts

The current carrying parts include a *current bar* and a clamping device. The current bar, at the center of the insulating body, is made of copper or brass.

The clamping device secures the wire in the terminal block and makes an electrically sound connection between the wire and the current carrying bar.

The size of these current carrying parts differs in relation to amperage/wire size and the configuration of the block itself, i.e. — single feed-through, dual tier and triple tier.

Depending upon terminal block design, wires can be clamped in place using screws, a combination of screws and *pressure plates*, wire cages or spring clamps.

A **screw** is the simplest method of connection: A screw is used to tighten the wire against the current bar.

With **screws** and a **pressure plate**, the wire is held in place with a metallic plate, which secures the wire when the screw is tightened.

With a **wire cage**, when the screw is tightened, a cage pulls upward and presses the conductor against the current bar. **The large contact surface provides excellent contact properties**. Since the screw does not come in direct contact with the conductor, wire damage is avoided. Even fine stranded wire can be connected without the use of additional *ferrules* or wire pins.

Spring clamps need a tool to open. The clamp closes on the wire to provide dynamic clamping. This extra holding action withstands vibration.

FIGURE 7: SCREW

FIGURE 8: PRESSURE PLATE

FIGURE 9: WIRE CAGE

FIGURE 10: SPRING CLAMP

IEC VS. NEMA TERMINAL BLOCKS

Terminal blocks are classified as DIN (IEC) or NEMA, depending on characteristics, which include panel mounting method, standards and approvals and design features**.**

DIN are IEC terminal blocks, which originated in Europe. DIN refers to the channel or rail that the terminal block mounts on. **The design offers more terminations per linear foot,** which meets industry demands to maximize the number of terminations in a control panel. These blocks are easier to install, wire and mark than NEMA style blocks. Rails are available in 15 mm, 32 mm and 35 mm widths. DIN blocks are generally interchangeable between manufacturers because the rail is standard and can be designed to handle a wide variety of applications.

IEC (DIN) TERMINAL BLOCK

DIN RAIL

FIGURE 11

Nearly 60% of the terminal blocks used in the U.S. are DIN type. Most designers prefer them because they offer:

- space saving, small compact design — more units per foot
- wide range of block types for design flexibility
- worldwide acceptance.

NEMA terminal blocks, known as American-style, have self-lifting pressure plates, binder head screws or box lug connectors. They are more commonly used for heavy-duty applications. However, NEMA blocks take up more panel space and provide fewer terminations per linear foot. Also, rail dimensions differ across manufacturers, restricting the user's choices.

FIGURE 12: NEMA TERMINAL BLOCK

NEMA blocks:

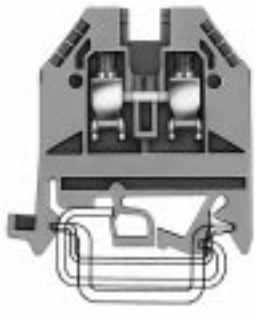
- can be cost-effective for some applications
- generally have more options for high current applications
- have open construction, which can allow easier wiring.

APPLICATION SPECIFIC BLOCKS

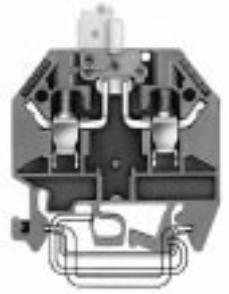
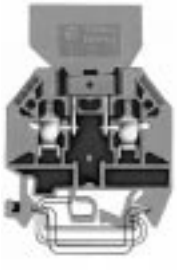
Rail-mounted DIN terminal blocks are available with built-in components for expanded capabilities, rather than simply being passive junction points. You can select from an array of application-specific blocks to perform a variety of functions.

Application-Specific Block Chart

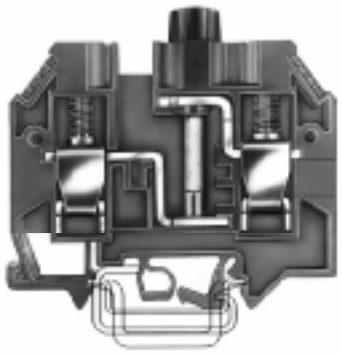
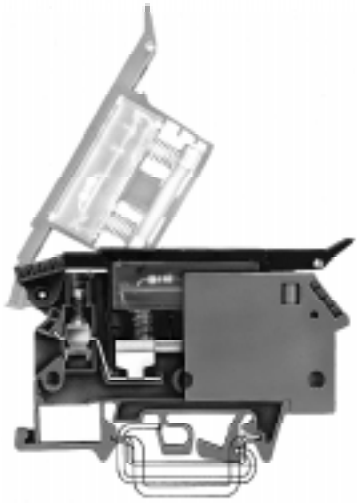
The table below explains the different types of application-specific terminal blocks available and how to use them:

DIN Terminal Block	Example	Application
Feed-Through	 **FIGURE 13**	Type of basic terminal block used for wire to wire connections where the wire feeds through one side and out the other.
Dual-Level Feed-Through	 **FIGURE 14**	Two-level feed-through in one block. Tiers may be bridged creating four common connections. LED/Neon indicating lamps, diodes and resistors available.
Three-Level Feed-Through	 **FIGURE 15**	Tall terminal block reduces installation time. Three-wire devices such as sensors can be installed in a single block. LED versions are available.

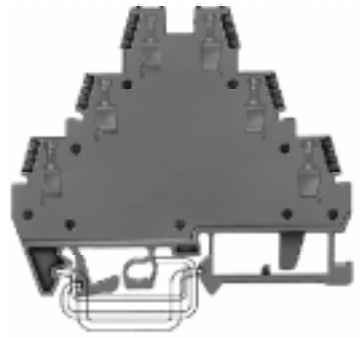
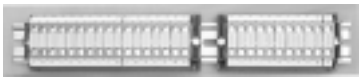
Application-Specific Block Chart (Continued)

DIN Terminal Block	Example	Application
Ground Terminal	 FIGURE 16	Interchangeable with standard block. These units can be inserted as needed. Permits grounding of components that run to a specific piece of equipment.
Knife Switch Disconnect	 FIGURE 17	A lever type of control handle that allows a circuit to be easily disconnected.
Fuse Block and Holder with Blown Fuse Indicator	 FIGURE 18	Provides a convenient point in the circuit for mounting the fuse. This block protects the electrical circuit, and can handle power up to 10A/300V. When a short circuit occurs, only the portion of the circuit connected to this block is affected. This can also be a disconnect block if dummy fuses are inserted instead of standard fuses. A light gives visual indication of fuse condition.

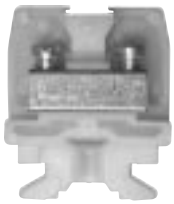
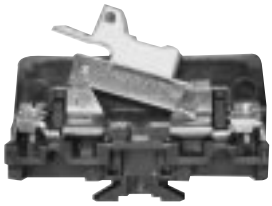
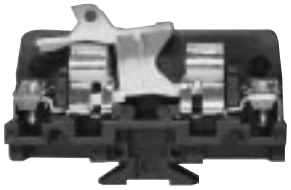
Application-Specific Block Chart (Continued)

DIN Terminal Block	Example	Application
Screw Cap Fuse Block		Most secure way to mount fuse. Fuse can not be accidentally opened. Designed for high power applications up to 15A/600V. Ideal for use on mobile equipment.
	FIGURE 19	
Knife Switch Fuse Block		Isolates circuit manually or when a power surge or short circuit occurs. Fully enclosed block requires no end plates. The lever employs a positive locking device, which ensures stability in either the fully open or fully closed position.
	FIGURE 20	
Thermocouple Block		For connecting to thermocouples. Provides consistent metal type connections for thermocouple sensors to measure temperature.
	FIGURE 21	

Application-Specific Block Chart (Continued)

DIN Terminal Block	Example	Application
Sensor Blocks	 FIGURE 22	Handles three-wire or four-wire proximity sensors, three- or four-wire photoelectric sensors, or any other type of three- or four-wire device. Also enables high-density terminations. Can be used in place of two or three terminal blocks to save space. An indicating light can be included for a fast check of circuit status.
I/O Blocks	 FIGURE 23	Provides communication between a controller, usually a PLC or IPC, and some type of sensor level devices. This communication takes place over a standard field bus connection, i.e. — DeviceNet™, Profibus-DP, Modbus +, etc.
Custom Rail Assembly	 FIGURE 24	Terminal block manufacturer pre-assembles rail assemblies complete with marking tags, cross connectors and other accessories to a customer's specification.

Application-Specific Block Chart (Continued)

NEMA Terminal Block	Example	Application
Feed-Through	 FIGURE 25	Open construction for easier wire to wire connections. Available in Screw, Tubular and Tubular Pressure Plate clamping devices.
Fuse Block	 FIGURE 26	Isolates circuit manually or when a power surge or short circuit occurs.
Switch Block	 FIGURE 27	A switching device that allows a circuit to be easily turned ON or OFF.

IN THE WORKPLACE

Rod, a member of the maintenance crew at Picture Perfect Graphics, was working on a forklift on the loading dock. He received a call from the press foreman. “Rod, we just started up the press and noticed that the level sensor in the cyan ink font is not reading. Could you check it out?”

Rod headed directly for the control box for the number two press. Looking at the diagram on the control box cover, he immediately spotted the terminal block for the cyan ink font and the blown fuse. Tracing and fixing the problem took only minutes.

FIGURE 28: TROUBLESHOOTING A SENSOR MALFUNCTION

REVIEW 1

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you've already read.

1. The portion of the terminal block which conducts current is the _____.

2. Match the terminal block material with the benefit it provides:

a. Polyamide 6.6 ___	1. High resistance to heat radiation.
b. Melanine 150 ___	2. For very high temperatures.
c. Ceramic ___	3. For general use, most common.

Which application-specific terminal block would be suitable for the following applications:

3. Temperature measurement. _____

4. Mobile equipment. _____

5. Photoelectric sensor terminations. _____

6. Circuits where you need to provide protection against occasional power surges. _____

7. To isolate a section of a control unit. _____

TERMINAL BLOCK ACCESS-ORIES

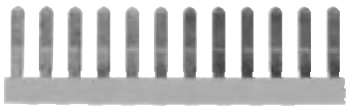
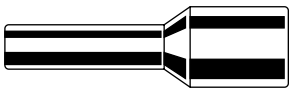
A variety of accessories adds to the versatility of terminal blocks. They expand terminal block capabilities and facilitate circuit maintenance.

Accessory	Example	Description
DIN Rail	 FIGURE 29	Enables snap-in/snap-out component mounting. Available in 35 mm, 32 mm, and 15 mm widths. Steel or aluminum, Slotted or solid.
End Stop	 FIGURE 30	Holds blocks and prevents them from shifting position or sliding off the rail.
End Plate	 FIGURE 31	Covers exposed contact block side or end block of an assembly. Should also be used when a change in block sizes occurs. Has exact same shape/contour as block.
Partition Plate	 FIGURE 32	Attached to block. Snap-in version available. Provides electrical and visual separation of adjacent terminal blocks and bridges. Also used between blocks of different polarity or voltages.

Terminal Block Accessories (Continued)

Accessory	Example	Description
Cross Connectors		Connect adjacent terminal blocks. Available in various pole configurations with or without insulation.
	FIGURE 33	
Rapid Mounting Tool		Picks up ten blocks at one time, greatly reducing installation time.
	FIGURE 34	
Dead Front Cover		A protective insulated cover on a terminal block that prevents shocks or shorts. Regulation VDE 0113 requires a cover on all main line blocks that remain live after main switch is off. The covers are removable only with a tool.
	FIGURE 35	
Switchable Connecting Link		Provides easy, temporary connection of two adjacent blocks for maintenance and testing. The link screws directly into the current carrying bar.
	FIGURE 36	

Terminal Block Accessories (Continued)

Accessory	Example	Description
Marking Tags	 FIGURE 37	Enable fast and easy identification of terminations. These easy-to-read labels mount on the side or top face of the terminal block body.
Jumper Comb	 FIGURE 38	Provides common connection of adjacent blocks. Individual jumper connections may be removed to skip over terminal blocks. The jumper comb is inserted with the wire into the wire cage. Comb jumpers are available in insulated and uninsulated form.
Test Plug	 FIGURE 39	Provides an electrical connection that permits accurate testing of circuits when necessary. A socket mounts in top of terminal block, providing a receptacle for the test plug.
Plotter	 FIGURE 40	Provides the end user the capability to custom mark blank tags for identifying terminal blocks, connectors wires and switching devices.
Ferrules	 FIGURE 41	Are used to capture the stranded ends of wire to provide protection to the wire and an electrically sound connection with all types of clamping bodies.

HOW TO SELECT THE RIGHT TERMINAL BLOCK

Choosing the correct terminal blocks is straightforward. Just follow the steps below:

1. Determine current, voltage and wire size (*AWG)* to be used for the individual wire runs in the control or power distribution application.

2. Define any special space constraints imposed by the application.

3. Considering the first two steps, select the appropriate rated feed-through terminal types to satisfy the electrical and space requirements. Select block widths. Double the block level and wire size if necessary to meet space requirements.

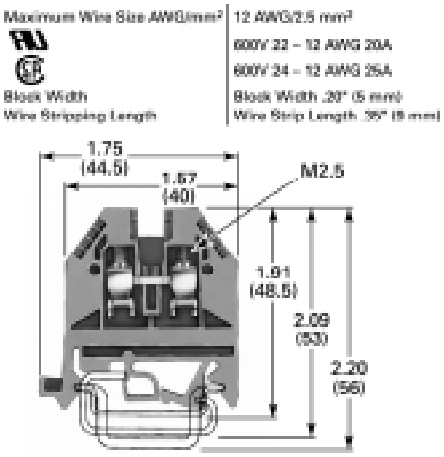
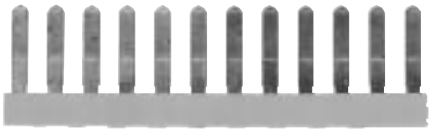


FIGURE 42: BASIC WIRE AND BLOCK REQUIREMENTS

4. Determine how many blocks (number of *poles*) are needed, whether any blocks need to be jumpered and how the jumper connections should be made (which plane), i.e., top — cross connector/side — jumper comb.

CROSS CONNECTOR



JUMPER COMB

FIGURE 43: CONNECTION TYPE

5. Select special function block (ground, disconnect, fuse, indicating types, switch) based upon application requirements.

FIGURE 44: SPECIAL FUNCTION BLOCKS

6. At the end of each terminal block assembly, wherever a change in terminal block size occurs or when a side of a terminal block is not used, specify an end plate. Unused sides of terminal blocks must not be left uncovered and exposed.

FIGURE 45: END PLATES

HOW TO SELECT THE RIGHT TERMINAL BLOCK (CONTINUED)

7. Determine where isolation partitions are needed to provide visual separation or to contain creepage within the terminal assembly. To ensure safety, isolation partitions separate blocks with different amperage ratings or voltages to prevent current/voltage jumping from one to another. Partitions also indicate to maintenance crew or electricians that there may be a different voltage in each of the groupings of blocks.

FIGURE 46: ISOLATION PARTITIONS

8. For rail mounted blocks, select the type of rail for mounting. Calculate the length required by totaling the individual widths (thicknesses) of the terminal blocks, end plates, isolation partitions and end stops.

FIGURE 47: RAIL TYPE

9. Mark wire terminations using marking tags.

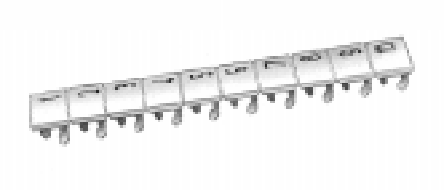


FIGURE 48: MARKING WIRE TERMINATIONS

REVIEW 2

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you've already read.

1. When assembling a terminal block assembly, a change in terminal block size requires a _____.
2. Terminal blocks of different amperage ratings can be grouped next to one another.

   TRUE FALSE
3. What is the only way possible to remove a dead front cover?

   _____

   _____

Which accessory would you use for the following functions?

4. To enable identification of the terminations. _____
5. To temporarily connect two adjacent terminal blocks for maintenance testing. _____
6. What are partition plates used for?

   _____

   _____

INTRO-DUCTION TO RELAYS

What Is A Relay?

Relays are generally used to switch smaller currents in a control circuit and do not usually control power consuming devices except for small motors and *solenoids* that draw low amps. Nonetheless, relays can "control" larger voltages and amperes by having an amplifying effect, since a small voltage (24V) applied to a relay's coil can result in a large voltage (460V) being switched by the contacts.

FIGURE 49: GENERAL PURPOSE RELAY

Relays are widely used to switch starting coils, heating elements, pilot lights and audible alarms. In addition to home dishwashers, refrigerators, heating and air conditioning systems, relays control the operation of machine tools, industrial assembly lines and commercial equipment.

Relays are the electrical workhorses that control one electrical circuit by opening and closing *contacts* in another circuit. When a relay contact is *Normally Open* **(NO)**, there is an open contact when the relay is not energized. When a relay contact is *Normally Closed* **(NC)**, there is a closed contact when the relay is not energized. In either case, applying electrical current to the contacts will change their state.

While relays make things happen, they can also keep things from happening. Protective relays can prevent equipment damage by detecting electrical abnormalities, including overcurrent, undercurrent, overloads and reverse currents.

IN THE WORKPLACE

The maintenance crew arrives to replace a damaged panel on a dragline in an open pit mine in British Columbia. The job calls for the crew to bring out the welding equipment. Several relays on the welding equipment switch transformers and solenoids to feed wire and operate the gas valves. The heavy-duty relays can withstand the extreme cold and rough handling to which they are subjected.

FIGURE 50: RELAYS IN HEAVY-DUTY MINING APPLICATION

ELECTRO-MECHANICAL RELAYS

Relays are either electromechanical or solid-state. In an electromechanical relay, contacts are opened or closed by a magnetic force. With a solid-state relay, there are no contacts and switching is totally electronic.

We'll cover electromechanical relays first.

FIGURE 51: SOLID-STATE RELAY

There are three main types of electromechanical relay: general purpose relays, machine control relays and reed relays. Let's look at each of them in turn.

General Purpose Relays are electromechanical switches, usually operated by a magnetic coil. General purpose relays operate with AC or DC current, at common voltages such as 12V, 24V, 48V, 120V and 230V, and they can control currents ranging from 2A – 30A. These relays are economical, easy to replace and allow a wide range of switch configuration.

FIGURE 52: GENERAL PURPOSE RELAY

Machine Control Relays are also operated by a magnetic coil. They are heavy-duty relays used to control starters and other industrial components. Although they are more expensive than general purpose relays, they are generally more durable.

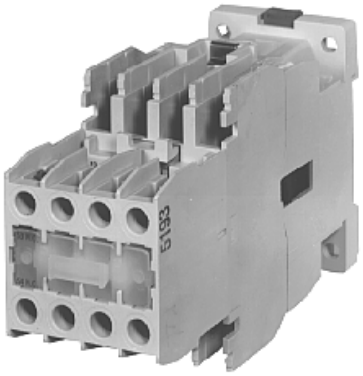


FIGURE 53: MACHINE CONTROL RELAY

The biggest advantage of machine control relays over general purpose relays is that you can easily expand the function of this type of relay by adding accessories. A wide selection of accessories are available for machine control relays, including additional poles, convertible contacts, transient suppression of electrical noise, latching controls and timing attachments.

Reed Relay

The fast operating *Reed Relay* is a small, compact, switch design with one contact, which is NO. The relay is hermetically sealed in a glass envelope, which makes the contacts unaffected by contaminants, fumes or humidity, allows reliable switching, and gives contacts a high life expectancy. The ends of the contact, which are often plated with gold or another low resistance material to increase conductivity, are drawn together and closed by a magnet. Reed relays are capable of switching industrial components such as solenoids, contactors and starter motors.

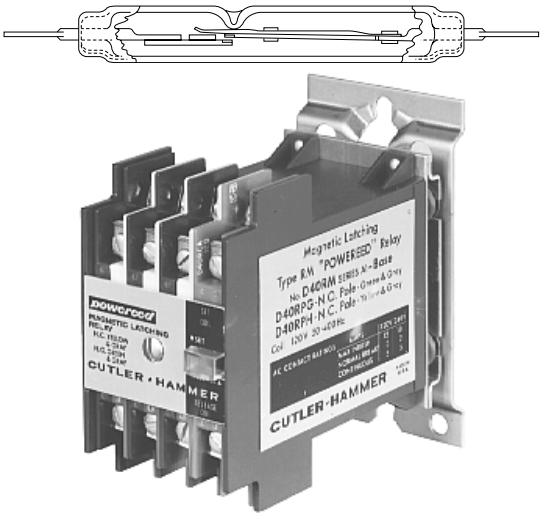


FIGURE 54: REED RELAY

IN THE WORKPLACE

At Riley Pharmaceuticals, a small batch packaging system sends bottles of their new sinus medicine down the conveyor for packaging. The system is programmed and set to operate when a pre-determined number of bottles are set on the belt. When the program is ready, it signals a solid-state relay to start the motor and move the bottles to a waiting carton.

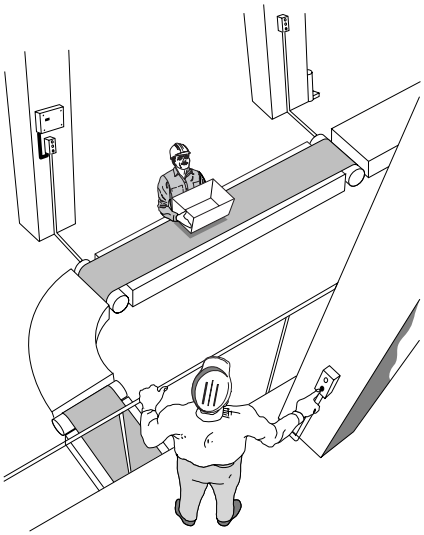


FIGURE 55: RELAYS IN A PACKAGING APPLICATION

Reed Relay (continued

A reed relay consists of two reeds. When a magnetic force is applied, typically by an electromagnet or coil, it sets up a magnetic field in which the ends of the reeds assume opposite polarity. When the magnetic field is strong enough, the attracting force of the opposite poles overcomes the stiffness of the reeds and draws them together. When the magnetic force is removed, the reeds spring back to their original, open position. These relays work very quickly because of the short distance between the reeds.

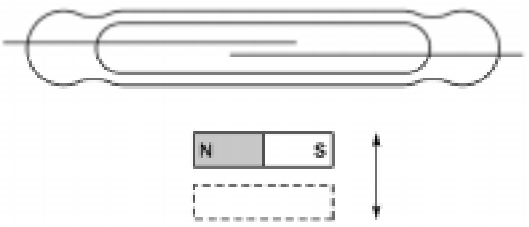


FIGURE 56: REED RELAY

Electro-mechanical Relay Parts

The basic parts of a coil relay include:

FRAME. Heavy-duty frame that contains and supports the parts of the relay.

COIL. Wire is wound around a metal core. The coil of wire causes an electromagnetic field.

ARMATURE. The moving part of the relay that opens and closes the contacts. An attached spring returns the armature to its original position.

CONTACTS. The conducting part of the switch that makes (closes) or breaks (opens) a circuit.

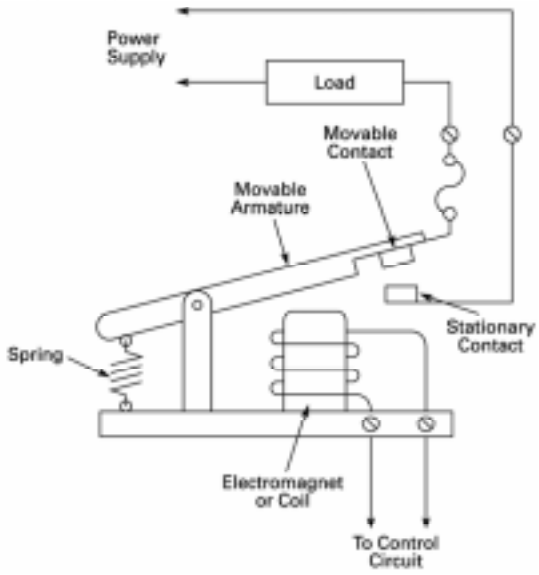


FIGURE 57: ELECTROMECHANICAL RELAY

A relay involves two circuits: the energizing circuit and the contact circuit. The coil is on the energizing side; and the relay contacts are on the contact side.

When a relay coil is energized, current flow through the coil creates a magnetic field. Whether in a DC unit, where the polarity is fixed, or in an AC unit where the polarity changes 120 times per second, the basic function remains the same: the magnetic coil attracts a ferrous plate, which is part of the armature. One end of the armature is attached to the metal frame, which is formed so that the armature can pivot, while the other end opens and closes the contacts.

Relay Contacts

Contacts come in a number of different configurations, depending on the number of *breaks,* poles and *throws* that make up the relay. For instance, a relay might be described as Single-Pole, Single-Throw (SPST), or Double-Pole, Single-Throw (DPST). These terms will give you an instant indication of the design and function of the relay. The descriptions below introduce you to breaks, poles and throws.

BREAK. This is the number of separate places or contacts that a switch uses to open or close a single electrical circuit. All contacts are either single break or double break. A single break (SB) contact breaks an electrical circuit in one place, while a double break (DB) contact breaks it in two places. Single break contacts are normally used when switching lower power devices such as indicating lights. Double break contacts are used when switching high-power devices such as solenoids.

POLE. This is the number of completely isolated circuits that a relay can pass through a switch. A single-pole contact (SP) can carry current through only one circuit at a time. A double-pole contact (DP) can carry current through two isolated circuits simultaneously. The number of poles can go up to a maximum of 12, depending upon relay design.

THROW. This is the number of closed contact positions per pole that are available on a switch. A switch with a single-throw contact can control only one circuit, while a double-throw contact can control two.

RELAY FORM IDENTIFICATION

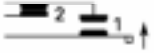
Design	Sequence	Symbol	Form
SPST-NO	Make (1)		A
SPST-NC	Make (1)		B
SPDT	Break (1) Make (2)		C
SPDT	Make (1) Before Break (2)		D
SPDT (B-M-B)	Break (1) Make (2) Before Break (3)		E
SPDT-NO	Center OFF		K
SPST-NO (DM)	Double Make (1)		X
SPST-NC (DB)	Double Break (1)		Y
SPDT-NC-NO (DB-DM)	Double Break (1) Double Make (2)		Z

FIGURE 58: BREAKS, POLES AND THROWS

Relay Contact Life

The useful life of a relay depends upon its contacts. Once contacts burn out, the contacts or the entire relay has to be replaced. *Contact life* can be estimated. Mechanical Life is the number of operations (openings and closings) a contact can perform without electrical current. The mechanical life of a relay is relatively long — up to 1,000,000 operations. Electrical life is the number of operations (openings and closings) the contacts can perform with electrical current at a given current rating. Contact electrical life ratings range from 100,000 to 500,000 cycles.

Arcing is one enemy of contact life. Arcing occurs when an electric switch is opened and current discharges across the contact gap. Arcing can be minimized by using the correct contact material for the application, or by using an arc suppressor, a device that dissipates energy across the open contacts.

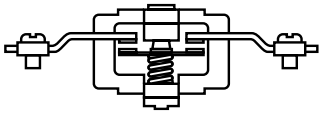


FIGURE 59: RELAY CONTACTS

Contacts are available in fine silver, silver-cadmium, gold-flashed silver and tungsten. While fine silver has the highest electrical and thermal properties of all metals, fine silver contacts are subject to sulfidation, or the formation of film, on the contact surface. This accumulation leads to increased contact resistance and diminished response.

Sulfidation is burnt off by circuits that call for switching several amperes at more than 12V. Sulfidation can be avoided, therefore, by checking that an application provides enough current to burn off contaminants or by using contacts made of alloys. Under-power and over-power conditions can also shorten contact life. The film that can form on a contact from sulfidation, oxidation or contaminants is normally removed by arcing or by contacts wiping each other during operation. In under-powered circuits, this cleaning process may not take place.

When excessive power is applied, surges cause pitting that reduces contact life. Contacts should be oversized when surges are expected.

REVIEW 3

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you've already read.

1. Name three types of electromechanical relay.

   a. _____

   b. _____

   c. _____

2. The moving portion of an electromechanical relay is called a _____.

3. What is the function of the relay frame?

   _____

   _____

4. The single-throw switch on a reed relay is NC.

   TRUE FALSE

5. The two circuits on an electromechanical relay are the _____ circuit and the _____.

6. What types of relay are activated by the presence of a magnetic field?

   _____

   _____

7. Do general purpose relays normally have more than one set of contacts?

   YES NO

8. Do general purpose contacts normally have NC contacts?

   YES NO

SOLID-STATE RELAYS

A solid-state relay consists of an input circuit, a control circuit and an output circuit.

Input Circuit

The Input Circuit is the portion of the relay to which the control component is connected. The input circuit performs the same function as the coil of an electromechanical relay. The circuit is activated when a voltage higher than the relay's specified *pickup voltage* is applied to the relay input.

The input circuit is deactivated when the voltage applied is less than the specified minimum *dropout voltage* of the relay. The voltage range of 3 VDC to 32 VDC, commonly used with most solid-state relays, makes it useful for most electronic circuits.

Control Circuit

The Control Circuit is the part of the relay that determines when the output component is energized or de-energized. The control circuit functions as the coupling between the input and output circuits. In an electromechanical relay, the coil accomplishes this function.

Output Circuit

The Output Circuit is the portion of the relay that switches on the load and performs the same function as the mechanical contacts of an electromechanical relay. Solid-state relays, however, normally have only one output contact.

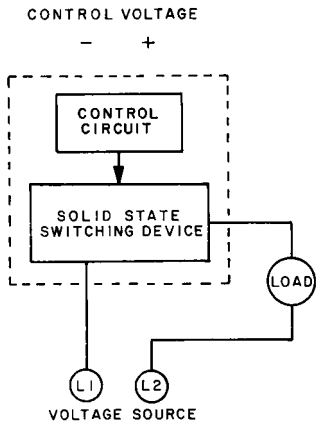


FIGURE 60: SWITCH CIRCUITS

IN THE WORKPLACE

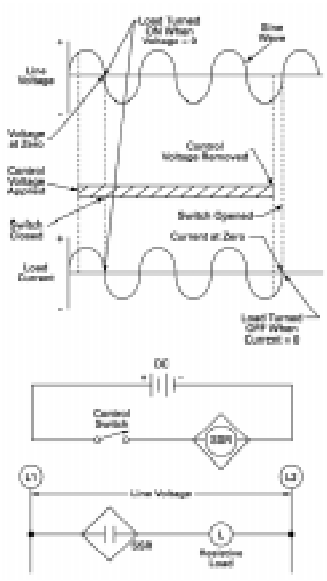
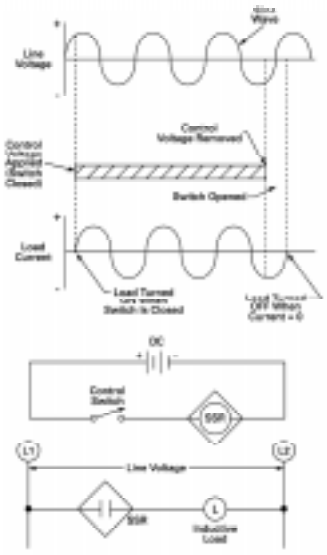
The teams will be ready in an hour to hit the floor of the arena for the championship game. The facilities crew pulls the switches to turn on the bank of HID (High Intensity Discharge Lighting) lamps nestled in the massive ceiling.

During start-up, the solid-state relay is closed, turning on the standard fixture. As current demand for the HID fixture increases, the relay finally pulls in, shutting off the conventional fixture.

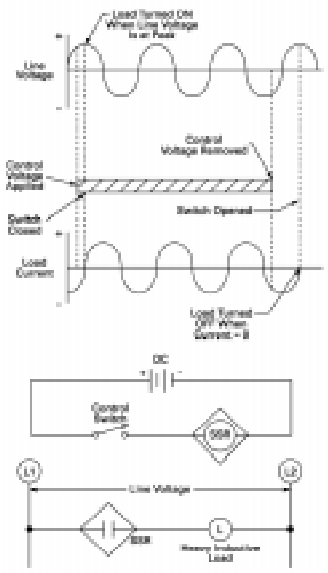
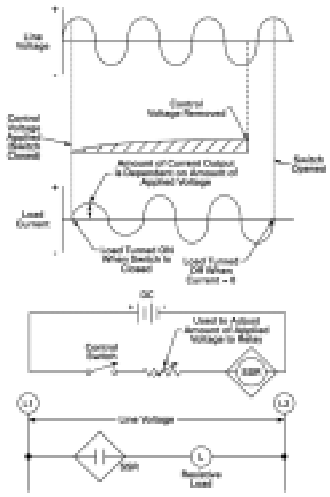
FIGURE 61: RELAYS IN A LIGHTING APPLICATION

Comparison of Solid-State Relay Types

The type of solid-state relay used in an application depends upon the load to be controlled. The chart below provides you with a comparison of each type and describes situations where they are used.

Switching Method	Illustration	Description	Application
Zero Switching		Turns ON the load when the control (minimum operating) voltage is applied and the voltage of the load is close to zero. The relay turns OFF the load when the control voltage is removed and the current in the load is close to zero. This relay is the most widely used.	To control resistive loads, such as the temperature of heating elements, solder irons, incubators and ovens. These relays control the switching of incandescent lamps, tungsten lamps, flashing lamps and programmable controller interfacing.
	FIGURE 62		
Instant ON		Turns ON the load immediately when the pickup voltage is present. This allows the load to be turned ON at any point in its up and down wave pattern.	To control inductive loads such as contactors, magnetic valves and starters, valve positioning, magnetic brakes, small motors, lighting systems (fluorescent and HID) and programmable controller interfaces.
	FIGURE 63		

Comparison of Solid-State Relay Types (Continued)

Switching Method	Illustration	Description	Application
Peak Switching		Turns ON the load when the control voltage is present, and the voltage of the load is at its peak. The relay turns OFF when the control voltage is removed and the current in the load is close to zero.	To control transformers and other heavy inductive loads. These relays control the switching of transformers, large motors, DC loads, high inductive lamps, magnetic valves and small DC motors.
	FIGURE 64		
Analog Switching		This relay has an infinite number of possible output voltages within the relay's rated range. An analog switching relay has a built-in synchronizing circuit that controls the amount of output voltage as a function of the input voltage. This allows a *ramp-up* function of time to be on the load. The relay turns OFF when the control voltage is removed and the current in the load is near zero.	Designed for closed loop applications, for example, a temperature control with feedback from a temperature sensor to the controller.
	FIGURE 65		

RELAY STYLE COMPARISON

The decision to use an electromechanical or solid-state relay depends on an application's electrical requirements, cost constraints and life expectancy. Although solid-state relays have become very popular, electromechanical relays remain common. Many of the functions performed by power-hungry heavy-duty equipment need the switching capabilities of electromechanical relays.

Although a Solid-State Relay (SSR) accomplishes the same result as an Electromechanical Relay (EMR), its physical structure and the way it functions are different. An SSR switches current using non-moving electronic devices such as silicon controlled rectifiers.

These differences in the two types of relay systems result in advantages and disadvantages with each system.

Since an SSR does not have to either energize a coil or open contacts, less voltage is required to "turn" an SSR on or off. Similarly, an SSR turns on and turns off faster because there are no physical parts to move.

While the absence of contacts and moving parts means that SSRs are not subject to arcing and do not wear out, contacts on EMRs can be replaced, whereas the entire SSR must be replaced when any part becomes defective.

Because of the construction of SSRs, there is residual electrical resistance and/or current leakage whether switches are open or closed. The small voltage drops that are created are not usually a problem, however, EMRs provide a cleaner ON or OFF condition because of the relatively large distance between contacts, which acts as a form of "insulation."

Electro-mechanical Relays

The chart below summarizes the advantages and limitations of both relay styles.

Strengths	Weaknesses
• Normally have multi-throw, multi-pole contact arrangements. • Some types (e.g. reed) can handle harsh environments. • Contacts can switch AC or DC. • Low initial cost. • Very low contact voltage drop, thus no heat sink is required. • Very resistant to *voltage transients*. • No *OFF-state* leakage current through open contacts. • Some EMRs allow replacement of contacts.	• Contact wear-out. • Rapid switching application or high current loads will shorten contact life. • Generates electromagnetic noise and interference on power lines. • Poor performance when switching high inrush currents.

Solid-State Relays

Strengths	Weaknesses
• Very long life when properly applied. • No contacts to wear out. • No contact arcing to generate electromagnetic interference. • Resistant to shock and vibration because they have no moving parts. • Logic compatible to programmable controllers, PLCs, digital circuits and computers. • Very fast switching capability. • Different switching modes (zero switching, instant ON, etc.).	• Normally only one contact available per relay. • *Heat sink* required due to voltage drop across switch. • Can switch only AC or DC. • OFF-state leakage current when switch is open. • Normally limited to switching only a narrow frequency range such as 40 Hz to 70 Hz. • Environmental considerations (heat, dust, dirt, water).

REVIEW 4

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you've already read.

1. What does SPDT stand for? _____
2. What does 3PDT stand for? _____
3. A reed relay can have 3PDT contacts.

   TRUE FALSE
4. How many breaks can contacts have? _____
5. What is the maximum number of poles a standard relay can have? _____
6. What is the name of a contact which can carry current through two circuits simultaneously? _____
7. How many circuits can a single-throw contact control? _____
8. Does an electromechanical relay normally have a higher electrical life rating than a solid-state relay?

   YES NO
9. What is sulfidation? _____
10. What type of solid-state relay is designed to control resistive loads?

    _____
11. What type of SSR turns on immediately when the control voltage is present?

    _____
12. What is the ramp-up function? _____
13. In the following circumstances, would you choose electromechanical or solid-state relays:
    a. Fast switching _____
    b. Multi-pole applications _____
    c. To avoid contact wear _____
    d. In applications with high vibration _____
    e. To handle AC or DC with a single unit _____

INTRO-DUCTION TO TIMERS

What Is a Timer?

All timers function to create a time delay in an electrical circuit. To handle a variety of conditions, three timer styles are available:

- Dashpot
- Clock
- Solid-State

Let's take a look at how each style operates.

DASHPOT TIMER. This timer uses air or liquid, which passes into or out of a contained space through an opening with either a fixed or variable diameter. The smaller the opening, the longer the time delay.

One type of dashpot timer is a **pneumatic** timer. It uses a magnet to move an operating pin or shaft, which pushes against a diaphragm, which in turn pushes air out of the space in the cavity. The amount of time it takes atmospheric pressure to "return" air to the cavity constitutes the time delay.

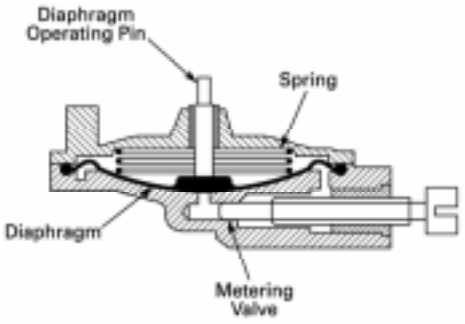


FIGURE 66: PNEUMATIC TIMER

CLOCK TIMER. This timer opens and closes a circuit depending upon the position of the hands of its clock. A **synchronous** clock motor operates the timer on AC power, controlled by generally accurate power company line frequency.

FIGURE 67: CLOCK TIMER

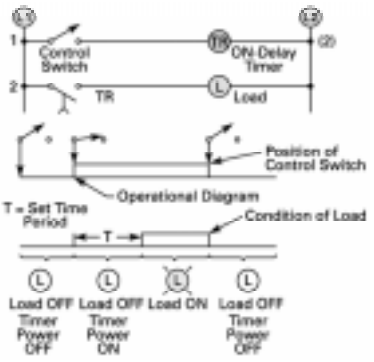
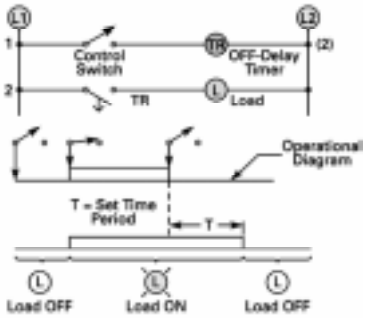
SOLID-STATE TIMERS. This is a very accurate method of timing. A variety of solid-state electronic devices, enclosed in the timer, provide the time delay. Solid-state timers can control timing functions ranging from a fraction of a second to hundreds of seconds.

Solid-state timers are less expensive than the above two styles, however, they are normally not repairable.

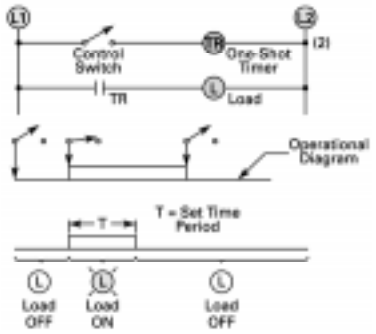
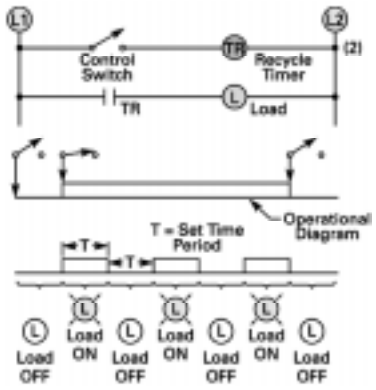
FIGURE 68: SOLID-STATE TIMER

TIMING FUNCTIONS

Solid-state timers offer a variety of timing functions and are available to meet the many different requirements of time-based circuits. In addition, a solid-state timer can be modified to deliver a different timing function. Pneumatic and synchronous clock timers are capable of just ON-delay and OFF-delay. The chart below outlines the attributes of each of the major timing functions.

Timing Function	Illustration	Description
ON-Delay		When power is applied to the timer, a preset period of time must pass before the contacts open or close. The timer may be used to delay turning a load ON or OFF, depending on the way the timer contacts are connected into the circuit. When an NO contact is used, the load energizes after the preset time delay. When an NC contact is used, the load de-energizes after the preset time delay.
	FIGURE 70	
OFF-Delay		In this circuit, when power is removed from the timer, the contacts immediately open or close and the load is energized. A preset period of time must pass before the timer contacts return to their normal position and the load is de-energized.
	FIGURE 71	

TIMING FUNCTIONS (CONTINUED)

Timing Function	Illustration	Description
One-Shot		When power is applied to the timer, the contacts change position immediately and remain changed for the set period of time after the timer has received power. After the set period of time has passed, the contacts return to their normal position.
	FIGURE 72	
Recycle		In the recycle timer circuit, the closing of the control switch starts the cycling function. The load continues to turn ON and OFF at regular time intervals as long as the control switch is closed. The cycling function stops when the control switch is open.
	FIGURE 73	

IN THE WORKPLACE

A forklift triggers a presence sensor as it approaches a closed door separating the dock from the warehouse. The sensor signals the door to automatically open. To prevent the door from closing on the vehicle as it passes through, a timer starts, preventing the door motor from operating for a set period of time. When the time elapses, the door closes.

This is just one of the many jobs timer devices perform to ensure the orderly operation of machinery and systems.

FIGURE 69: TIMER IN A WAREHOUSE APPLICATION

REVIEW 5

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you've already read.

1. What are the three major categories of timer?

   _____

   _____

   _____

2. How does a pneumatic timer develop a time delay?

   _____

   _____

3. How does a synchronous timer develop a time delay?

   _____

   _____

4. How does a solid-state timer develop a time delay?

   _____

   _____

5. What is an ON-delay timer?

   _____

   _____

6. What is a one-shot timer?

   _____

   _____

GLOSSARY

Armature	Moving part of an electromechanical relay that moves when the relay is energized and opens a set of contacts.
AWG	American Wire Gauge, a wire thickness unit and system of measurement.
Break	The number of separate places on a contact that open or close an electrical circuit.
Contacts	The conduction part of a relay that opens and closes an electrical circuit.
Contact Life	The number of cycles a contact can be opened and closed or energized.
Current Bar	Conductor at the center of a terminal block that carries current from termination(s) in the terminal block to the field wiring.
Dropout Voltage	The voltage level at which a circuit becomes inoperative.
Ferrule	A metal sleeve that joins or helps strengthen two parts.
Heat Sink	A protective housing made up of material that dissipates heat.
Normally Closed	The contacts are normally closed or making contact. They open only when the relay or timer is energized.
Normally Open	The contacts are normally held open. They close only when the relay or timer is energized.
OFF-State	Voltage that is present in a circuit when the supply voltage to that circuit is connected but turned off.
Pole	The number of completely isolated circuits that a relay can switch.
Pickup Voltage	The minimum amount of voltage required to activate a circuit.
Pressure Plate	Component within a terminal block for making a secure termination.
Ramp-Up	The amount of time required to go from zero voltage to operating voltage in a solid-state system.
Reed Relay	Two reed contacts hermetically sealed in a glass envelope.

Relay	A device for switching circuits electromechanically or electronically.
Solenoid	An electromechanical device typically consisting of an electromagnet and a plunger. The electromagnet causes the plunger to either move towards it or away from it, thus opening or closing a circuit.
Terminal Block	A device to terminate two or more wires.
Throw	The number of closed contact positions per pole.
Timer	A device for switching a circuit ON or OFF based on a time delay.
Voltage Transient	Voltage that spills over from one circuit to another or the residual current in a circuit.
Zero Switching	Switching a relay when the voltage is near zero, typically used to prevent damage or wear from current surges.

REVIEW 1 ANSWERS

1. current bar
2. A3, B1, C2
3. thermocouple block
4. screw cap fuse block
5. sensor blocks
6. knife switch fuse block
7. switch block

REVIEW 2 ANSWERS

1. end plate
2. true, with isolation partitions
3. with a tool
4. marking tags
5. switchable connecting link
6. provide electrical separation

REVIEW 3 ANSWERS

1. a. general purpose
   b. machine control
   c. reed relay
2. armature
3. support
4. false
5. energizing, contact
6. electromechanical
7. yes
8. both NO and NC

REVIEW 4 ANSWERS

1. single-pole double-throw
2. three-pole double-throw
3. false
4. 1 or 2
5. 12
6. double pole
7. one
8. no
9. film on contact surface
10. zero switching
11. instant ON
12. time to go from 0 volts to operating volts
13. a. SSR
    b. EMR
    c. SSR
    d. SSR
    e. MMR

REVIEW 5 ANSWERS

1. dashpot, clock, solid-state
2. pushing a diaphragm to change air pressure
3. position of hands on clock
4. electronics within the timer
5. preset period before contacts change state
6. contacts remain changed for a set period of time

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