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ABSTRACT

This training module on electromechanical components contains 10 units for a two-year vocational program packaging system equipment control course at Wisconsin Indianhead Technical College. This module describes the functions of electromechanical devices essential for understanding input/output devices for Programmable Logic Control (PLC) applications through classroom lecture and laboratory settings. Objectives, outline, teaching methodology, and evaluation are discussed in the module overview. Each unit in the module outline is detailed with resource requirement, unit objective, content summary, and tools of evaluation sections. The following 10 units make up the module: (1) introduction to electrical control of circuits; (2) fuses and circuit breakers; (3) control transformers; (4) switches; (5) circuit application of switches using actuators; (6) relays and solenoids; (7) timers; (8) Packaging Machinery Manufacturer's Institute controls; (9) photoelectric sensing units; and (10) motors. (NLA)

High-Technology Training Module

Module Title: ELECTROMECHANICAL COMPONENTRY

Unit: UNITS I - X

Course: PACKAGING SYSTEM EQUIPMENT CONTROL

Grade Level (s): 2 YEAR VOCATIONAL PROGRAM (2nd Semester)

Developed by: DON LINDEMANN

Date: NOVEMBER 20, 1990

School: WISCONSIN INDIANHEAD TECHNICAL COLLEGE (WITC)

NEW RICHMOND, WI 54017

In Touch with High Tech

Developed as a part of the High-Technology Training Model for Rural Based Business and Industry, Technical Colleges and Local and State Educational Agencies under Grant No. V199A90151.

Title: Electro-Mechanical Componentry

School: Wisconsin Indianhead Technical College (WITC)
New Richmond, WI.

Grade Levels:

This module represents the content of a three credit course or 16 weeks of instruction in a regular semester. It is presented in the second semester of a 2 Year Vocational program offering an Automated Packaging Systems Diploma.

Developed by: Don Lindemann

Description:

This module is intended to make simple, the relatively complex functions of numerous electro-mechanical devices that are essential as a pre-requisite for understanding input/output devices for PLC applications. Students learn the function of each component through classroom lecture and laboratory settings. The module is part 1 of 3 intended to prepare the student for a thorough understanding of motion control/circuit control via PLC applications in Automated Machinery Systems.

This module is intended for use in any electro-mechanical componentry course. It is presently used as part of the electro-mechanical componentry course in an Automated Packaging Systems vocational diploma program at WITC.

The program is fortunate to have industry support in the form of over 5 million dollars in full scale packaging machinery including case packers, liquid fillers, powder fillers, cartoning lines, conveyors, shrink tunnels, wrappers, bundlers, coupon placers, check weighers, hot melt glue applicators, and many more too numerous to mention. Equipment is housed in an 8000 square foot shop set-up as a simulated production environment. Although it may not be necessary to have such equipment to teach an electro-mechanical course, it serves to bridge the theoretical training to the practical (hands-on) training for most students.

Students prepare for positions in maintenance, installation and building of Automated Packaging Machinery. Some students become technical representatives for their companies, traveling to the customers job site to solve technical problems with machinery.

Pre-requisite:

A basic understanding of the principles of electricity is essential. Completion of a 3 Credit Introduction to an AC/DC Circuits course or equivalent in a typical vocational school setting would be adequate.

Module Layout:

This module consists of several units of instruction outlined herein. The total module objectives, module outline, module teaching methodology, and evaluation methodology are discussed in the "Module Overview" Section. Each unit listed in the module outline is detailed with a resource requirement section, unit objective section, content summary section, and a tools of evaluation section.

MODULE OVERVIEW

Objectives

Upon successful completion of this module the student in accordance with the grading procedure will be able to:

1. Identify all the basic components outlined.
2. Explain the function of each component.
3. Identify each component in a schematic circuit utilizing ladder logic principles and in wiring diagrams.
4. Identify each component in an actual circuit as it relates to a ladder logic diagram.
5. Define the component relationships to each other in a system.
6. Create a working model of a circuit by physically hard wiring components identified and demonstrating a desired outcome for a given circuit drawing.
7. Articulate the relationship of a variety of electro-mechanical components as they might be used with a PLC application or how their functions might be replaced with a PLC application.

Content Outline:

Unit

I. A review of the principles of electricity and an introduction to electro-mechanical componentry.

II. Fuses and circuit breakers.

III. Control Transformers

IV. Switches

   A. Overview Discussions
   B. Oil Tight Units
   C. Limit Switches
   D. Proximity Switches
   E. Vane Switches
   F. Pressure Switches & Transducers
   G. Temperature Switches (thermostats) & Heaters
   H. Mercury Switches
   I. Transistor Switches

V. Circuit Application of switches utilizing actuators. (LAB EVALUATION)

VI. Relays and Solenoids

VII. Timers

VIII. PMMI Controls

IX. Photo-electric sensing units

X. Motors

Module Methodology and Activities

1. This semester long module is made up of 10 sequential units.

2. Students participate in a balance of lecture and lab activities.

3. As each component is introduced during a lecture, the appropriate symbol is shown in a circuit diagram using the chalkboard, overheads, examples in books, or handouts, whichever is most appropriate for a given situation. The circuit diagrams continuously evolve to become more complex as each component is added, like building blocks, throughout the module.

4. With the introduction of each component,

   a. actual examples are examined by each of the students, and its purpose and applications discussed.

   b. students observe the actual component operation on numerous fully operational automated packaging lines in simulated production environments.

   c. students observe each component in existent circuits discussed, noting the components position, the wiring, and the ordering of components in relationship to other components in the circuit.

   d. students analyze actual circuit based on the circuit being described in ladder logic diagrams, electrical schematics and in wiring diagrams. Students are required to follow the wiring through on actual circuits to gain an understanding of the relationship between logic diagrams and physical circuits.

5. When enough components have been introduced and the student has developed and demonstrated the requisite knowledge base

   a. they are teamed up in groups of two or three to develop operational circuits on a training board based on the schematic(s) provided.

   b. students select components, hard wire them, and achieving the desired outcome according to a given circuit diagram.

6. Students are given reading and homework assignments from each class period associated with the material discussed.

7. Classroom discussions are distinguished from lectures in that it is a time for dynamic interaction between the student and with the teacher.

8. It is essential to have all the electro-mechanical components to be discussed, on hand in quantities of no less than six each for each student.

9. It should be expected that students will occasionally burn up or smoke, a transformer or other components, inadvertently through improper or faulty wiring on the part of the students, as they learn how to wire them correctly.

10. The use of operational machinery demonstrating the wiring position and function of each component is recommended for maximum learning.

11. When solid state components are introduced a digital logic lab with a variety of CMOS chips with all the basic gates, switches, bread-boards, DC power supply and wiring is required.

Resources

Several books were researched for the High-Tech Project. It is the opinion of this author that the following book is among the best available and is used for the Electro-Mechanical course at WITC.

Rexford, Kenneth B. Electrical Control for Machines 3rd Edition, Delmar Publishing ISBN 0-8273-2792-7

For basic supplementary material:

Davis, C. Glenn Packaging/Converting Machinery Components Vol. 1 PMMI 2000 K. Street N.W., Washington, DC 20006

Davis, C. Glenn, Basic Electrical Components Vol. 3 PMMI 2000K. Street N.W., Washington, DC 20006

Evaluation

1. Students ultimately are evaluated on the basis of the success at which they are able to create a circuit according to a given schematic.

2. Students are orally examined upon completion of their actual circuits and circuit diagrams to determine their level of understanding. They are required to explain the operation and application of each component in the system as it becomes activated and explain what the expected results would be when the system is reconfigured.

3. A variety of quizzes and tests are used in conjunction with each instructional unit as well as at the end of each unit. Oral, written, and operational evaluations are designed to determine the students overall level of understanding of the application and function of each component and the various circuit designs.

Unit 1

Introduction to Electrical Control of Circuits

Content Summary

A. Basic steps in the development of circuits.

1. Know what work or function is to be performed.

   Examples: Lighting a lamp. Students are given a demonstration of a simple circuit in operation.

2. Know the operating conditions under which the starting, stopping and controlling of the process is to take place.

   Example: Position, Time, Temperature, Pressure

3. Begin the process of selecting dividing and/or isolating the circuit as required.

   Example: A circuit may be required to operate a machine under manual, semi-automatic, (single cycle) or fully- automatic (continuous cycle) operation.

B. Problems to overcome to understand electrical control circuit diagrams.

   1. Starting with a circuit too large or too complicated.

   2. Failing to carry a mental picture through into the electrical circuit.

   3. Failure to relate physical action to the job required into electrical signals through the components which in turn do the job.

   4. Failure to understand that an electrical circuit must perform those actions which must perform the correct functions while not performing those actions which are dangerous to the operator, or that will result in damaged components or faulty product.

Evaluation   Students take quiz.

   1. What are the three basic steps necessary to understand electrical control circuits?

   2. List some of the problems students have which hinder their progress in understanding electrical control circuits.

Unit II

Fuses and Circuit Breakers.

Content Summary

A. Objectives: The student will be able to:

1. Describe basic fuse construction.
2. List different fuse types and applications.
3. Identify four types of circuit breakers and their uses.
4. Explain the use of time delay fuses in certain circuits.
5. List voltage and current ratings for given fuses and circuit breakers.
6. Draw the symbols for protective devices.

B. Methodology

1. Discussion on how circuits are protected by fuses and circuit breakers.
2. Discussion on the construction and operation of fuses.
3. Discussion on the various fuse types and applications including:

a. One time fuses
b. Current limiting fuses
c. Time delay fuses
d. Considerations of voltage ratings, current ratings, and interruption capacities

4. Discussion on circuit breaker types and appropriate selection.

a. Non-automatic
b. Thermal and Thermal Magnetic
c. Magnetic

Evaluation of Unit Two

See Attached Test

Electro-Mechanical Componentry
Unit II Test
Fuses and Circuit Breakers

Name ________________

1. Draw the symbol for each of the following:

   a) Single fuse element

   b) Three-pole fused disconnect switch, ganged w/handle

   c) Three-pole circuit interrupter, ganged w/handle

   d) Three-pole thermal magnetic circuit breaker, ganged w/handle.

2. Explain the inverse time-current relationship function in a delay fuse.

3. In the time-current data chart below a curve has been drawn for a 100 ampere delay fuse. How long will it take for the fused to blow when:

   a) 1000 amperes of current are being drawn?

   b) 300 amperes of current are being drawn?

   c) 100 amperes of current are being drawn?

4. If you have to create a circuit requiring a circuit breaker and you are particularly concerned about <u>overload protection</u> will you select a

   a) thermal circuit breaker,
   b) a magnetic circuit breaker,
   c) a non automatic (circuit interrupter type) circuit breaker.

5. List at least five important factors to consider when selecting a protective device.

6. Draw a complete circuit showing a 480 3-phase 60 hz power source fused to protect the transformer wired in series with followed by another overload protector between the transformer and a selector switch wired in parallel with a maintained contact push button switch to a green pilot light. At what power will the main leads L1 & L2 be.

Unit III

Control Transformers

Content Summary

A. Objectives: The student will be able to:

1. Explain why industry practice has been to control machine systems with 120 volts.

2. Explain how transformers are able to obtain 120 volts from a higher line voltage.

3. Clarify the term turns ratio and regulation in a transformer.

4. Draw the symbols for a variety of transformer configurations including : A dual primary, single secondary control transformer in line with a higher voltage input and a 120 volt control circuit.

5. Explain the causes of temperature rises in transformers.

6. Calculate the size of a transformer for a given load.

B. Methodology

1. Discussion on what transformers are, how they work, the various types, and how they are selected for a given requirement.

2. Students observe actual transformers in circuits and see the correct wiring for parallel and series applications.

3. Students are shown the symbol for transformers on schematics and learn to trace the wiring on live circuits measuring the voltage changes in the circuit across the transformer.

C. Homework Assignment (Example) taken from Rexford's book Electrical Control for Machines is included below. Students use their books and any other resources to find answers to the problems.

1. What type of electrical energy is normally used to supply industry?
2. What are two important reasons for using 120V in machine control systems?

3. There is 480V AC available in a given plant. To obtain 120V what turns ratio is required between the primary and the secondary of the control transformer?

4. You find that under unusually heavy loads, the voltage in your plant drops to 456 V. What will the resulting secondary voltage be if a transformer with a 4:1 primary to secondary turns ratio is used.

5. Draw the symbol for a dual-primary, single secondary control transformer. Show all lead designations.

6. What parts in a transformer generally contribute to temperature rise?

7. What may happen to components that are energized in a control system if, due to poor transformer regulation, the voltage drops to an unusually low level?

8. Draw a complete circuit showing the primary of a dual primary control connected to a three phase, 480V power line, and the single secondary connected to a 120V control system.

9. In a given transformer the voltage is reduced from the primary to the secondary. This transformer is called a
   a. current transformer   b. step-up transformer
   c. step-down transformer

D. Critical Thinking Option

1. On a given job, you have calculated the total inrush current of all coils energized at any one time is 42 amperes. The calculated continuous or sealed current of all coils at the same time is 8 amperes. Using the first method discussed in class and explained in the text, determine the size of transformer you should use. The control voltage is 120. Commercially available transformers are 750, 1000, 1500, and 2000 VA.

Electro-Mechanical Componentry
Unit III Test
Control Transformers

Name:____________

1. What are transformers used for?

2. You have been asked to wire a wrapper requiring a 220 volt, 3 phase power supply. The wrapper also has a number of relays and control circuits requiring a 110 volt single phase power supply.

   Draw a schematic showing a transformer application for the above scenario. Be as specific as possible.

3. List two applications for a variable transformer.

4. What test procedure might be applied to determine whether or not a transformer is defective?

5. How will a transformer perform with DC voltage applied?

6. In a theoretical situation whereby the primary winding in a step down transformer has 500 turns and the secondary has 100 turns, what is the turns ratio?

7. If voltage is increased or decreased in a transformer, what happens to the current? Be specific.

8. What is an isolation transformer and in what application are they used?

9. How is a transformers efficiency determined?

10. When replacing a transformer what are the foremost rules to keep in mind?

Unit IV

Switches

Content Summary

A. Overview discussions

1. Oil Tight Units

a. Push-button switches

b. Selector switches

c. Multi-pole switches

d. Foot switches

e. Indicator lights

f. Drum switches

2. Limit switches

3. Proximity switches

4. Vane switches

5. Pressure switches and transducers

6. Temperature switches & heaters

7. Mercury switches

8. Solid state timer switches

9. Transistor switches

B. Objectives: The student will be able to:

1. Push-button switches

a. Describe methods of mounting push-button switches.

b. Identify operators and explain different operators color codes.

c. Draw the various symbols.

2. List several arrangements available for selectors.

3. Draw the symbols for foot switches, selector switches, limit switches including proximity switches in four different configurations, pressure switches, vane switches, time delay/relay switches, Timer reset-time-our configurations.

4. Discuss the purpose of push-to-test pilot lights.

5. Discuss the difference between selector switches and drum switches.

6. Draw simple basic circuits combining the knowledge of various components introduced to date.

7. Demonstrate a working knowledge regarding normally open and normally closed switches and combinations thereof on actual circuit development.

8. Describe the differences in the three basic limit switches and their functions.

9. Explain and identify circuits where the application of rotating cam limit switches is appropriate.

10. Define terms associated with various limit switches to include: operating force, release force, pre-travel or trip travel, over travel, differential travel.

11. Describe how proximity limit switches operate.

12. Describe applications for proximity switching and how it might be achieved.

13. Explain the operation of vane switches.

14. Identify applications where the use of mercury switches are warranted.

15. In a laboratory setting, apply the knowledge of transistors associated with the basic digital logic gates of OR, AND, NAND, NOR to create simple circuits with 5 volts to light diodes when the circuits are correctly wired.

C. Methodology

1. Lecture

a. Oil tight units. The concepts of normally open normally closed contact blocks are first introduced.

b. Review base mounting and panel mounting. Discuss the various operators to including recessed type buttons, mushroom heads, illuminated pull buttons and key lock types.

c. Color designations and safety.
Red - Stop or E-Stop
Yellow - Return
Black - Start motors etc.

d. Discuss the various positions available in selector switches are discussed along with the appropriate schematic representation. The concepts of multi-poled, double throw configurations are introduced.

e. Foot switches are discussed and shown in operation.

f. Indicator lights along with their color designations are reviewed.

Example:	Red	= Danger, Abnormal condition
	Amber	= Attention
	Green	= All Clear - Safe condition
	White or Clear	= Normal condition

g. Drum Switches also know as rotary pilot or transfer switches are introduced along with the appropriate schematic representation.

2. Students are given lab time to locate examples of each switch discussed to this point and allowed the opportunity to dismantle them, discuss their function on a machinery application. Watch them in action on virtually all packaging machinery and generally discuss any questions they might have about them.

3. Limit Switches are introduced with a discussion on their industrial applications. Mechanical type limit switches are reviewed noting the differences in linear motion and rotary motion switches.

4. Factors for selecting limit switches are discussed which include contact arrangement, current rating of the contacts, slow or snap action, isolated or common connections, spring returned or maintained, and the number of NO and NC contacts required.

5. An understanding of the various operators available and their applications are discussed including the definitions of the terms operating force, release force, pre-travel or trip-travel, over-travel, differential travel and total travel are required.

6. Students are given lab time to build on their limit switch understanding. They examine case packers, cartoners, bottle fillers all utilizing limit switches.

7. Proximity Switches are introduced with a lecture on magnetic fields, the hall effect and radio frequency fields capacitive fields, acoustic fields and light waves, all as methods to achieve proximity switching.

8. Students are given lab time to examine proximity switches.

9. Vane Switches are introduced and example of applications are reviewed.

10. Pressure switches and transducers are introduced with an opening lecture on the importance of pressure indication and control. The types of pressure switches which include the sealed piston, the bourdon tube, diaphragm, and the solid state variations are reviewed with example of each for examination. Electrical symbols for these shown along with circuits including each type in various applications.

11. Temperature switches (Thermostats) are introduced with a lecture on temperature control in film sealing applications on wrappers and baggers, heat shrink tunnel applications, and hotmelt glue applications.

12. Pyrometers, thermocouplers, bimetallic strips, potentiometric controllers, and liquid filled temperature controllers are reviewed. The concepts of ON/OFF and proportioning are introduced as a means of temperature control along with a discussion on the appropriate selection of heater elements necessary to achieve a desired outcome as a means of temperature control.

13. Heaters are covered at this time because they are so closely tied in with temperature controllers and there function needs to be understood to be clear on the thermostat function.

14. Mercury switches are introduced with a discussion on specific machinery applications where explosions are possible. Students observe mercury switches and the fact that they are enclosed within a glass casing containing sparks.

15. Solid State, Transistor or Microswitches are introduced with a primer on binary numbering systems, the basic gates including AND, NOR, OR & NAND with further discussion on exclusive ORs and exclusive Nors.

16. Applications are discussed including PLCs where timers, flip-flops, adders, counters and other functions are electronically performed to achieve a desired movement control on machinery.

17. A lab is conducted whereby the student builds a DC powered circuit implementing the basic gates to achieve a desired output. See lab attached.

D. Evaluation

See Attached Tests

Electro-Mechanical Componentry
Unit IV Test
Switches

Name____________________

1. Describe how one might base mount a push-button switch.

2. Describe how a selector switch might be panel mounted.

3. The low voltage in a pilot light is preferred because it

   a. Requires less voltage
   b. Is much smaller in size than convention lights
   c. Will withstand operating vibration
   d. Will not consume as much electricity

4. Draw the symbol for an extended head push-button switch (one contact block-two contacts; one normally opened, one normally closed.

5. Draw the symbol for a selector switch (one contact block-two contacts; one normally opened, one normally closed.

6. Draw the symbol for a foot operated switch that is normally closed and opens with foot pressure.

7. List three operators for switches.

8. List three examples of color coded operators and what the color coding indicates.

9. What colors are lens for pilot lights available?

10. Draw the symbol for a green push-to-test pilot light.

11. What are the various arrangements that can be achieved with different types of drum switches? How are they different from selector switches?

12. Describe briefly the operation of a vane switch.

13. Draw the symbol for a three position, four contact selector switch. Contacts 1 and 3 are open in position 1, all are open in position 2 and contacts 2 and four are open in position 3.

14. Draw a circuit showing a three position selector switch and a green-to-push test pilot light. The pilot light is to be energized when the selector switch is operated to position number 1.

15. Describe an application where the use of a mercury switch is warranted.

16. Some of the methods used to achieve the operation of proximity limit switches are:

    a. capacitive fields
    b. light rays
    c. low current imput
    d. magnetic fields

17. The speed of response for the proximity limit switch using the oscillator method in the output circuit is:

    a. the switch location
    b. the speed at which the object is being sensed.
    c. dependent upon the frequency of the oscillator

18. Draw the normally open and normally closed pressure switch symbols.

19. List four distinct types of pressure switches.

20. Why do Bourdon - tube type pressure switches sometimes require a dampening device?

21. Describe how switching is accomplished in a solid state pressure switch.

22. The differential pressure in a pressure transducer measured by:

    a. Applying a constant voltage to the bridge
    b. Calculating it, using data provided by the manufacturer
    c. estimating the change on rising pressure
    d. pressure gauges in line measuring the differential

Electro-Mechanical Componentry
Unit IV Test
Temperature Controllers and Heaters

Name:__________

1. What are the three basic types of temperature <u>sensing</u> devices?

2. Electronic heater controllers include on-off and proportioning type.

   A. The on-off is the simplest and oldest method of temperature control. Describe in some detail how it works.

   B. Time proportioning is presently the most common temperature controlling device. Describe in detail how it works.

3. If the band width in a 800 degree F temperature controller is set for 2% what is the band width in degrees?

4. Draw the symbols for a normally open and normally closed temperature switch contact.

5. In electric heaters __________ current is applied to ________ wires made of special materials. What is the most popular material discussed in class?

6. PMMI discussed four types of heaters. List each with a brief description below.

7. What is the most common cause of failure in electric heaters?

8. To check a heater suspected of being defective list the steps to check it using proper instrumentation.

Electro-Mechanical Componentry
Unit IV
Lab 1 - 2
Arithmetic Circuits - Adders

Objectives: To demonstrate and understand the operation and characteristics of the half-adder and the full-adder.

Materials:

Half-adder - 7408 IC
7486 IC
Full-adder - 7400 IC
7486 IC

Discussion: A half-adder is a circuit that accepts 2 binary bits as inputs and produces their sum and carry as outputs. A full-adder is a circuit that accepts 2 binary bits and a carry-in as inputs and produces their sum and carry as outputs.

PROCEDURE 1: Using the 7408 and the 7486 chips construct the circuit in Fig. 6-1. Inputs A and B will come rom data switches and the sum output and carry output can be connected to LEDs. Prove the truth Table I for the half-adder.

Using proper reference material, i.e. IC Master, find the proper pin configurations to use for all the following experimer.cs.

TABLE I

Inputs		Outputs	
A	B	Sum	Carry
0	0		
0	1		
1	0		
1	1		

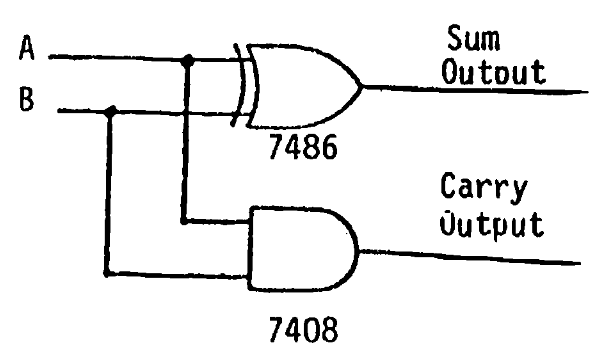


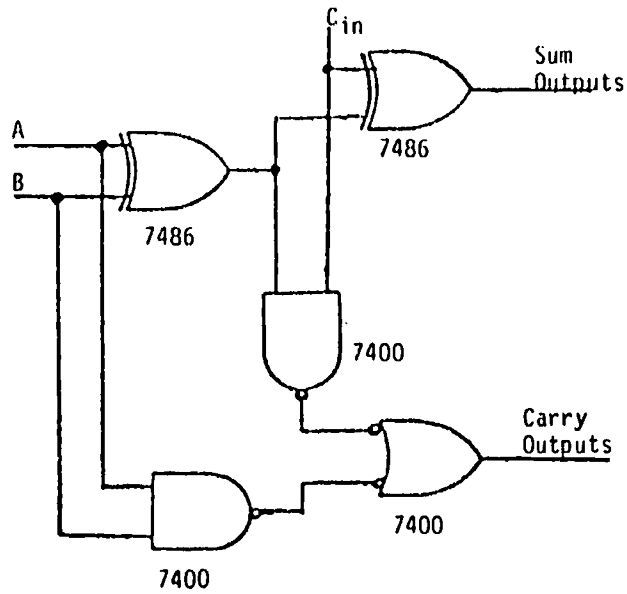
FIG. 6-1.

PROCEDURE 2: Using the chips 7400 and 7486 construct the circuit shown in Figure 6-2. Once again use data switches for the inputs Oin, A and B and LEDs for the outputs of Sum and Carry.

If for some strange reason these circuits shouldn't work properly, use your troubleshooting skills and find out why the circuit isn't functioning. You will <u>not</u> be allowed to say "This doesn't work!!!"

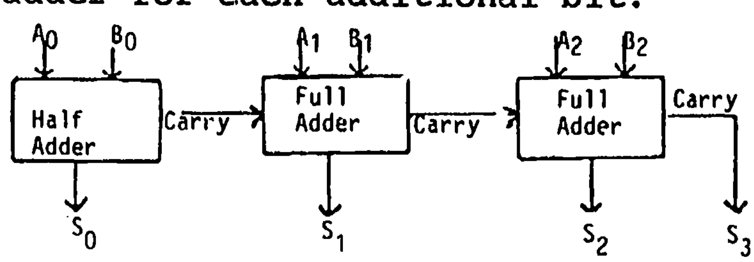
Table II

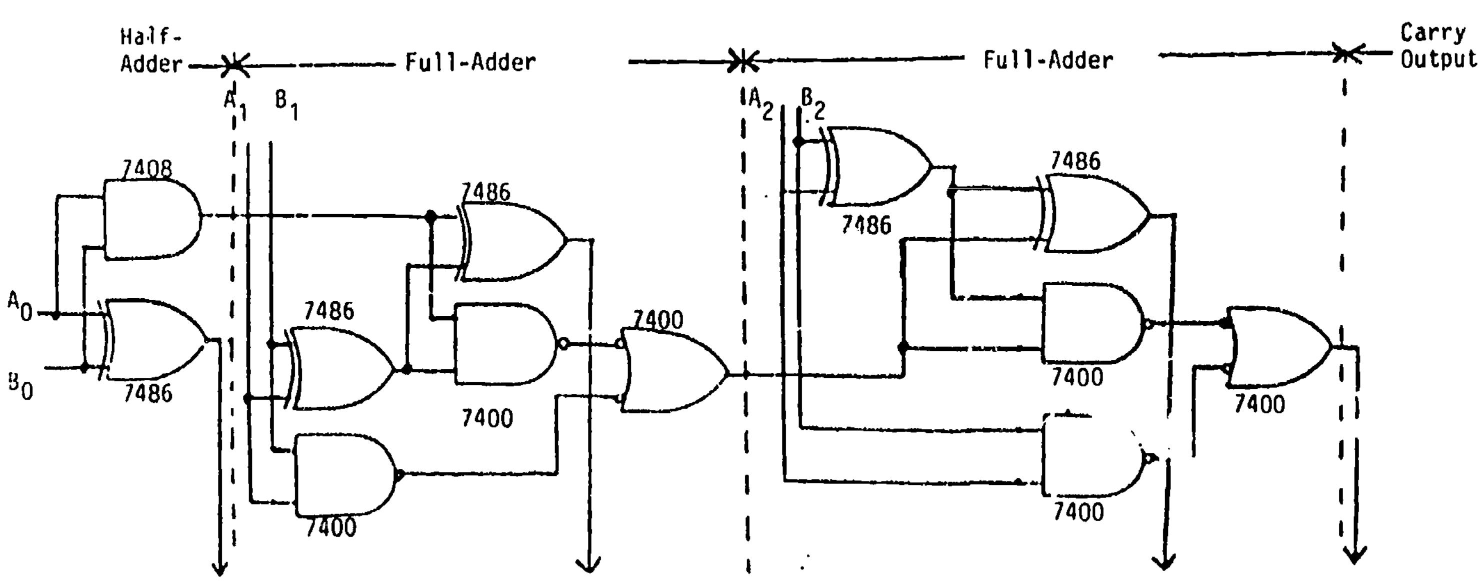
Inputs			Outputs	
Cin	A	B	Sum	Carry
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		



FULL-ADDER
FIG. 6-2

PROCEDURE 3: The following is an adder circuit for 3-bit numbers. It is composed of a half-adder and two full-adders. The MSB of the output is simply the carry of the second full-adder. You may want to experiment and attempt to hook up the following circuit. If you can't construct it, add 2 3-bit numbers using A0, A1, A2 and B0, B1, B2. Follow the logic through the circuit and see what the output will be. Adders for larger numbers can be built in this manner simply by adding another full-adder for each additional bit.





UNIT V

Circuit Application of Switches Utilizing Actuators

Content Summary

A. Objectives: The student will be able to:

1. Hard wire a control circuit according to a given schematic utilizing any or all the components detailed to date.

2. Troubleshoot a circuit using proper instrumentation to determine the cause of an unexpected output.

3. Reconfigure circuits to using different combinations of components to achieve the desired outputs.

B. Methodology

1. Students are teamed up into groups of two or three. Each group is given a different circuit problem with equal levels of complexity.

2. Students start with a 4 X 8 piece of 3/4 inch plywood paint it to a color of their choice.

3. A circuit is laid out on paper.

4. Each component is then mounted on the boards in any sensible configuration as long as the desired output is achieved.

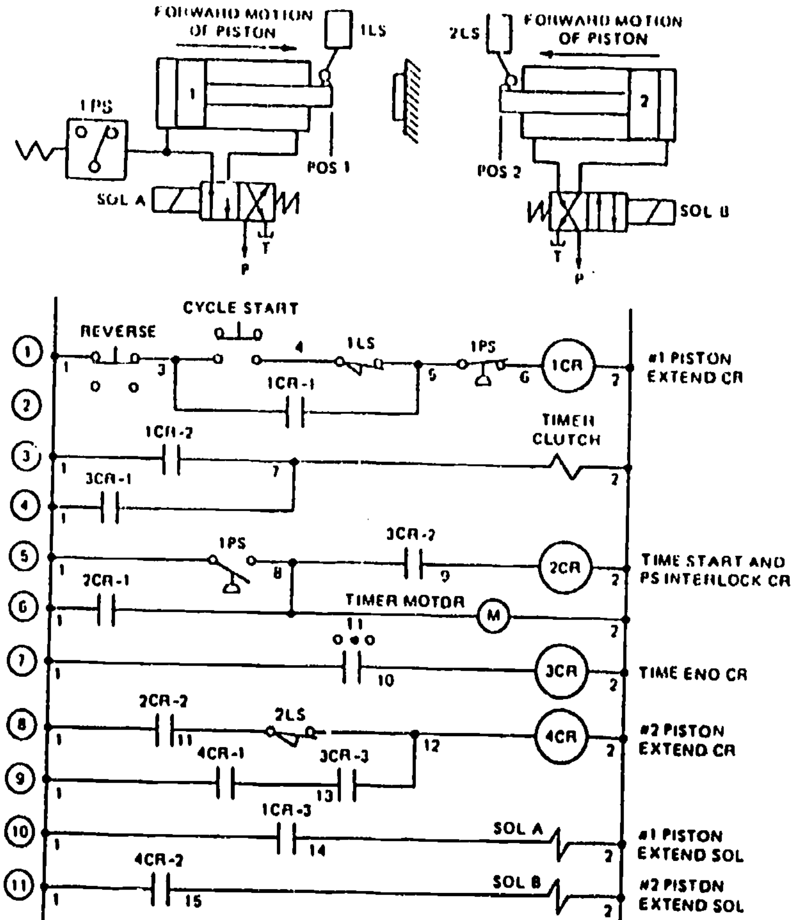
5. Students wire the components up learning the relationship between components, where the wires physically go, how to prepare them, the weight of wire to chose and all the many subtleties of wiring machinery that can only be learned by doing.

6. The students will work on their boards throughout the remainder of the semester, adding new relays solenoids and actuators as they progress through the remaining units receiving new circuitry instructions that expand the original design.

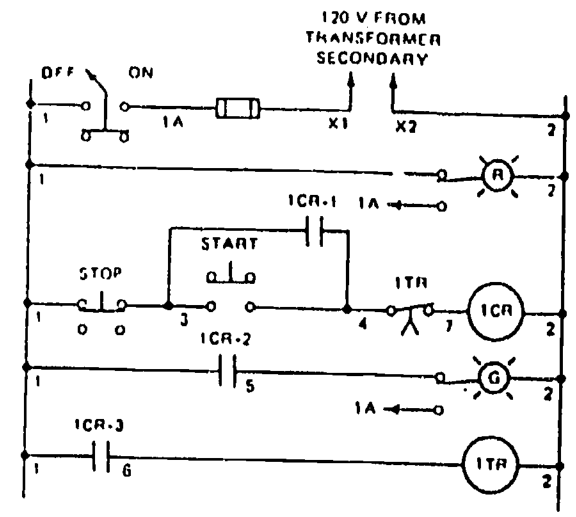
C. Evaluation

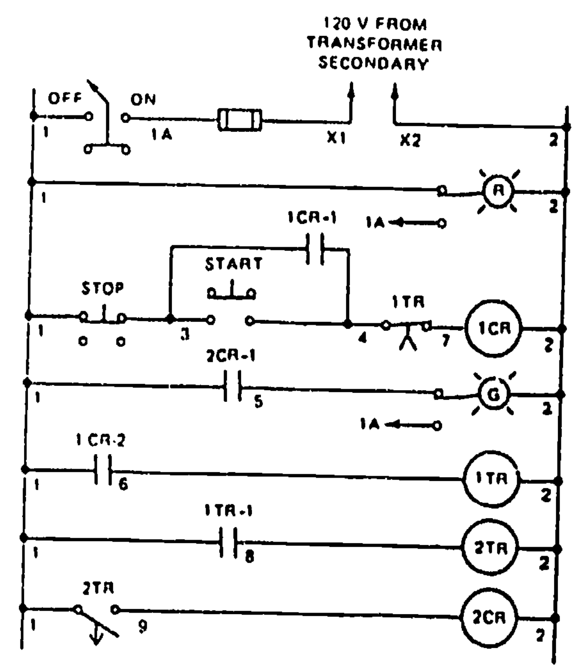
Students are evaluated by the success of achieving the desired output according to the schematics given to them. Students are also orally examined to determine the extent to which they understand the functions of each component in their systems. See attached photographs of completed boards.

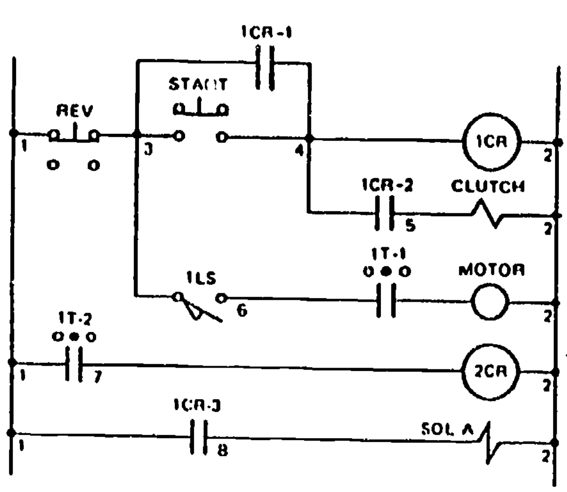
Examples of Control Circuits used to build Boards

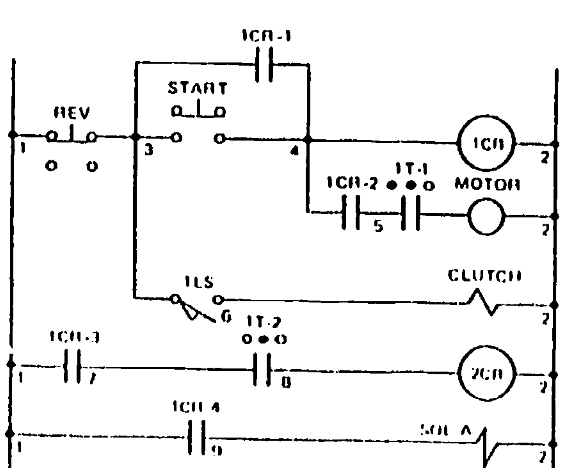


TIMER SYMBOL T1 CONTACT
O OPEN-TIMER DEENERGIZED
● CLOSED-TIMER CLUTCH ENERGIZED
O OPEN-TIMER MOTOR TIMED OUT









UNIT VI

Relays and Solenoids

Content Summary

A. Objectives: The student will be able to:

1. Identify the main uses for control relays.
2. List three published ratings for relays.
3. Explain why silver is used in relays.
4. Discuss several phenomenon or factors associated with relay operation such as contact bounce, overlap contacts, contact wipe, and bifurcated contacts.
5. Draw and create an interlock circuit and explain why it is used.
6. Draw the symbols for relay coils, contacts, time delay and relay contacts.
7. Explain inrush current vs. holding current in a relay and sealed current vs. inrush current in a solenoid.
8. Describe a latching relay.
9. List uses for the contactor.
10. Explain the necessity for a plunger in a solenoid to complete its stroke.
11. Discuss the two most important problems to consider in the application of solenoids.
12. Apply the function of solenoids to operating valves.
13. Draw the symbol for a solenoid and a relay.
14. Draw a variety of circuits showing the energizing of solenoids by closing relay contacts using control relays, switches and a solenoid.

B. Methodology

1. Combination lecture and lab as outlined in the overview section.

2. Students handle, disassemble, observe the operation of and trouble shoot actual problems on full scale packaging lines. They also add relays and solenoid actuated valves to their circuit boards.

C. Evaluation

See Attached Quiz and Test

Electro-Mechanical Componentry
Unit VI Test
Relays and Solenoids

Name________________________

1. What is the difference between inrush current and holding current in the coil of a control relay?

2. What are the three ratings generally published concerning control relay contacts?

3. Explain: How contact bounce can affect the operation of an electrical control circuit.

4. Show the use of a control relay contact in an interlock circuit. Use a control relay, two push button switches, and a red push-to-test pilot light.

5. What advantages can be obtained from the use of a time-delay relay as compared to a standard relay.

6. Identify the following time-delay relay contacts. Do they operate before or after the relay coil is energized? Indicate also whether each is normally open or normally closed.

A. 

B. 

C. 

D. 

7. Show the use of a time-delay relay contact in an interlock circuit. Use a control relay, two push button switches, and a green push-to-test pilot light. In this case, the green pilot light is to be energized two seconds after the relay coil is energized.

8. Describe how a latching relay operates. How is it different from a control relay? (applications, etc.)

9. Describe a contactor as fully as possible, including information on poles and the range of current carrying capacity and any additional information that distinguishes contactors from a regular control relay.

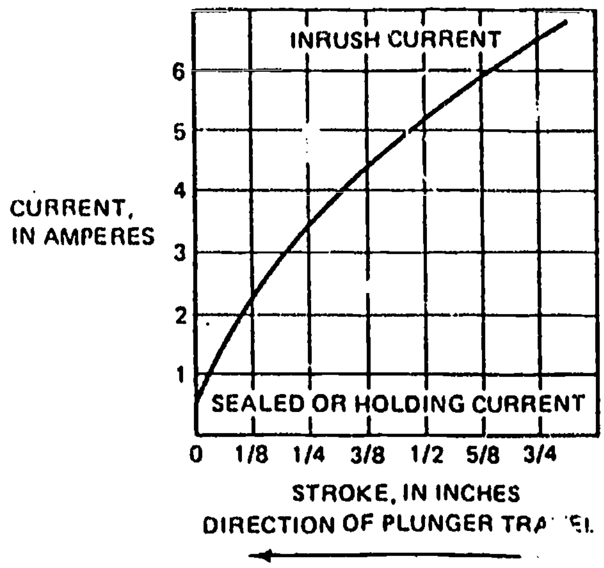
10. What is the major advantage of using plug-in relays?

11. What is the minimum standard determined by NEMA for relay manufacturers to maintain when designing a relay to not "drop out" when voltage falls to below what %?

12. If an electrically controlled, two way solenoid valve is leaking, what is the probable cause?

13. Why is silver used on some relay contacts?

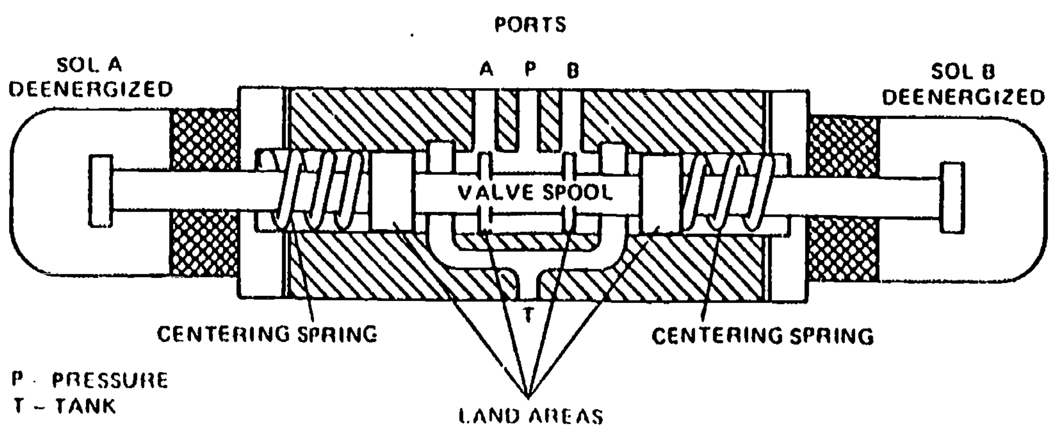
14. In the chart below a typical inrush to current ratio chart is shown. When the plunger is at the 1/4 inch position in its stroke, how much amperage will be required to maintain a sealed current?



15. Why must the pull of a solenoid exceed the load?

16. Draw a control circuit using two push button switches, a control relay, and a solenoid. The solenoid is to be energized when a normally open limit switch is operated. It will be de-energized when the moving part on a rotating cam completes its cycle.

17. The solenoid current in amperes with the plunger in the closed position is called ______________________________.



18. In the double solenoid operating valve pictured below describe the direction of flow from point to point when the valve is in the :

a) neutral position as shown

b) when solenoid A is energized

c) when solenoid B is energized

Electro Mechanical Componentry
Unit VI Quiz
Relays

Name: ______________

Match the relay type with the correct description. Some relays may have more than one right answer and will require all information to receive full credit.

1. Magnetic Overload Relay

2. Time Limit Overload Relays

3. Bimetallic Overload Relays

4. Instantaneous Trip Current Relays

5. Contactors

6. Thermostat Relays

7. Pneumatic Timers

8. Solid State Relays

9. Capacitor Time Limit Relay

10. Electronic Time Delay Relay

Describe as fully as possible using words and symbols the difference between Off-delay and On-delay relays.

UNIT VII

Timers

Content Summary

A. Objectives: The student will be able to:

1. Discuss the difference between a timer and a time delay relay.
2. Explain where and how timers are used.
3. List the different types of timers introduced in class.
4. Explain the concepts of reset, timing and timed out.
5. Draw simple control circuits showing various components being energized via the timer in a pre-set series or simultaneously.
6. Explain how multi-interval timers work.
7. Discuss the operation of the repeat-cycle timer.
8. Explain the operation of dash-pot and other pneumatic timers.

B. Methodology

1. Lecture on how and why timers are used to control the motion of packaging machinery with examples on the Doboy wrapper, Nordson Hot-melt equipment and Langen cartoner.
2. A discussion on the various types of timers is conducted with examples in hand.
3. The concept of timing with reset and timed out along with the electrical symbols for each is introduced.
4. Solid state timers are introduced along with pneumatic timers.
5. Circuits including timers are introduced and some students include timers in their control circuit boards.

C. Evaluation

See Attached Test

Electro-Mechanical Componentry
Unit VII Test
Timers

Name____________________

1. List the three types of timers applied most frequently in the industrial field.

2. In the following symbol for a timer, what function does each position in the contact represent?

3. What controls the movement of the diaphragm in a pneumatic timer?

4. Of all the reset-type timers discussed in class, which is used most frequently with programmable controllers?

5. On a control circuit diagram(or board), what must occur in the circuit for the timer clutch to be energized. (Be specific)(Student must examine circuit diagram or circuit board and give oral or written explanation.)

   A. This delay type overload relay makes use of the oil dashpot principle whereby a plunger immersed in oil is slowed down when current energizes a coil and tries to pull the plunger in. Oil passes through bypass holes in the piston.

   B. This subject of the relay family is actually an electromagnetic switch operated by pilot devices such as limit switches or thermostat and is merely a safe and convenient way to connect or interrupt branch circuits.

   C. This relay does not have an inverse time characteristic built into it. It has a plunger in a coil that requires a certain level of current draw before it will trip. They are adjustable. It might be used on a conveyor to stop a motor when there is a jam or blockage to eliminate the possibility of breakage.

   D. This relay has a slowly moving element which makes a contact for both the closed and open positions of the relay and requires a thermostat control device.

   E. This overload relay operated by current intensity and not heat. It must also be connected in series directly with the motor except for very large motors when it is indirectly connected by transformers.

F. This relay has a potentiometer built into the relay to adjust the amount of resistance as a means to control the delay function. It is one of the relays that use the resistance-capacitance (RC) theory the current in this coil decay slowly depending on the rating of the relay.

G. This overload relay is activated by heat and may be one of the reset type in that they automatically reset when cooled down and contacts open.

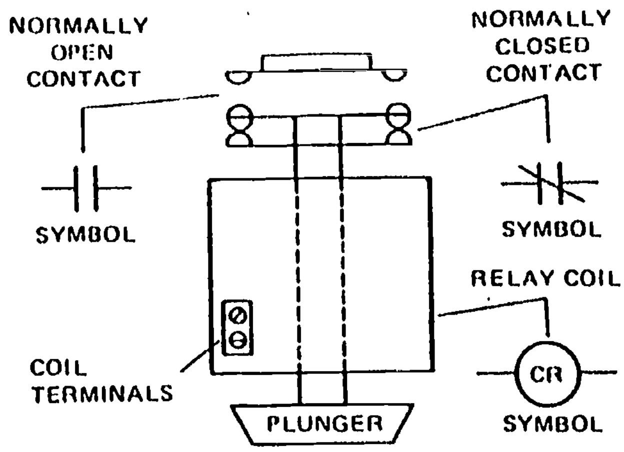
H. This relay typically has no moving parts and can be used to handle AC or DC current.

J. This relay has a feature known as zero switching which means that if it receives a signal in the middle of a cycle it will continue to act as a conductor until the voltage hits zero.

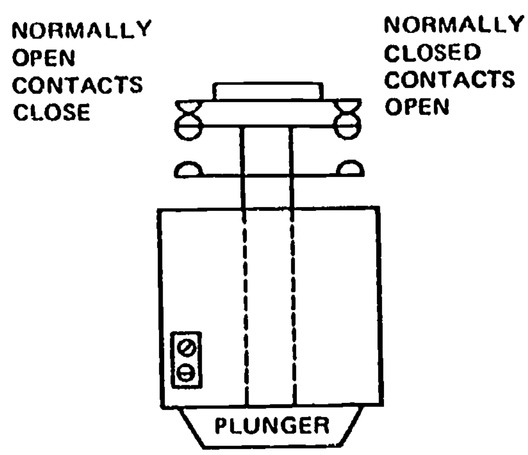
K. This relay operates by a rubber fellows or diaphragm and restricts the amount of fluid that passes through and orifice allowing the relay to function as a timer.

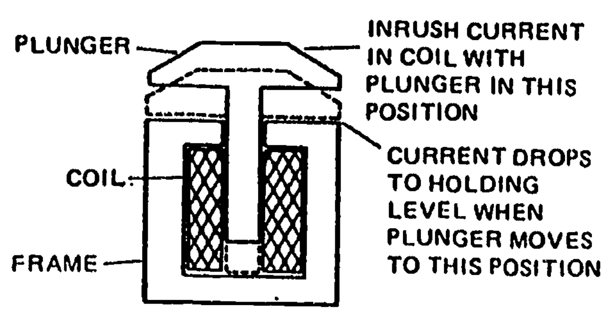
L. This relay uses a Quartz clock as the time base to function as a delay relay it uses a standard 8-pin socket. They are frequently used with programmable controllers.

A. Deenergized condition of relay; showing contact position



B. Energized condition of relay. With coil energized; magnetic force pulls the plunger up, operating the contacts





UNIT VIII

PMMI Controls

Content Summary

A. Objectives: The student will be able to:

   1. Discuss the controls outlined by the PMMI (Packaging Machinery Manufacturer's Institute) and application to specific pieces of equipment.

B. Methodology

   1. This unit is intended to tie the various components even more closely to specific applications on specific equipment according to the PMMI manuals recommended.

C. Evaluation

See Attached Test

UNIT VIII

PMMI Controls

Content Summary

A. Objectives: The student will be able to:

1. Discuss the controls outlined by the PMMI (Packaging Machinery Manufacturer's Institute) and application to specific pieces of equipment.

B. Methodology

1. This unit is intended to tie the various components even more closely to specific applications on specific equipment according to the PMMI manuals recommended.

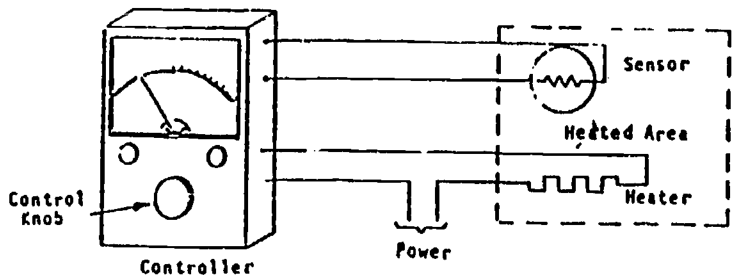
C. Evaluation

See Attached Test

Electro-Mechanical Componentry
Unit VIII Test
PMMI Control Systems

Name ______________________________

1. In the diagram below showing a controller for a shrink tunnel, the actual temperature for the oven is shown on the meter which is scaled in degrees F. What is the meter actually measuring? (Be specific)



2. Describe the construction, the operation and applications of a bi-metallic temperature sensitive strips.

3. Briefly discuss the oper::tion and application of pre-determined counters.

4. Describe a process using a weight controller in a filling line.

   A. How will it work?

   B. How might it control and intermittent motion of a conveyor?

   C. What other components are required to complete a control circuit?

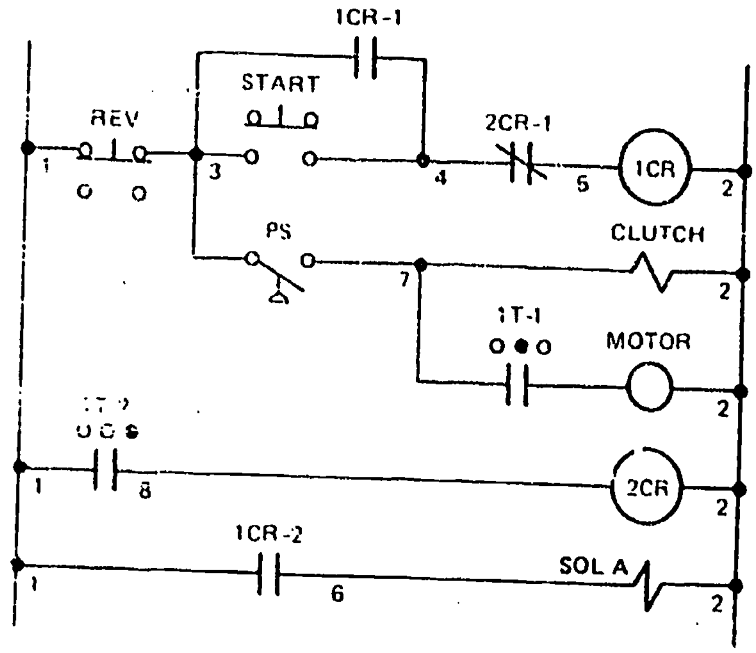
   D. How will it define and handle rejects?

5. Describe how registration marks can control motion on packaging machines.

6. What is the function of an alternator or sequence controller in a multiple line packaging operation?

7. Most control systems fail for two reasons as discussed in class. What are they?

8. In the control circuit shown below, what must occur in the circuit for the timer clutch to be energized. (Be specific)



UNIT IX

Photo-Electric Sensing Units

Content Summary

A. Objectives:

1. Discuss the principles by which photo-electric systems operate.

2. Identify several types of photo electric sensors.

3. Identify appropriate applications of photoelectric sensors as they might apply to a desired output.

4. Troubleshoot the malfunction of photoelectric sensors and/or the system in which it is set-up.

B. Methodology

1. A lecture on the operation of photocells, and the detection of lightwaves is followed by the component parts of the sensor and how it is used as an input signal which gets amplified to operate control devices such as solenoids on a given piece of machinery.

2. A discussion on the various types of photo-electric sensors is held in which on/off type, reflective type, time delay type, one shot and others are physically examined in the classroom followed by observing the sensors in operation detecting the registration marks on a web of film indicating that it is time to cut the web at the proper location.

3. Some students add photo-electric sensing units in their control circuit boards.

4. A discussion on troubleshooting a malfunctioning system is included whereby students measure the signal with an ohmmeter to determine the source of a given problem.

C. Evaluation

See Attached Test

Electro-Mechanical Componentry
Unit IX Test
Photo-Electric Sensors

Name: ______________

1. List four types of photo-electric sensors.

2. What three characteristics of an object must be considered when selecting a scanning technique.

3. What is meant by:

   a. direct scan
   b. reflective scan
   c. retro-reflective scan

4. The signal produced by a photo-electric cell normally goes directly to the ______________ ______________.

5. What is the purpose of an amplifier in a photo-electric sensor.

6. A time delay sensor set-up to detect jam-ups on a conveyor system:

   a. when the light beam is first broken
   b. when the angle of the deflection beam is first detected
   c. when the packages move faster than usual
   d. when the package moves slower than usual

7. Describe how the strength of a single in a photo-cell is usually measured.

8. Excess external light hitting a photo-cell will cause:

   a. the photo-cell to be more sensitive
   b. the photo-cell to not react when the beam is broken
   c. no noticeable effect on the photocell operation
   d. a stronger response from the photo-cell

9. Describe the following terms:

   polarized scan
   convergent beam scan
   fiber optic scan method
   specular scan
   diffused scan
   current sink output
   current source output

10. The resistance of a dark photo-cell should be ______________ times ______________ when the photo-cell is lighted.

UNIT X

MOTORS

Content Summary

A. Objectives: The student will be able to:

1. Identify the basic principles under which motors of all types operate.

2. Identify operating characteristics of different types of motors.

3. Select various methods for changing the direction of a motor.

4. Apply proper preventive maintenance procedures.

5. List the common causes of malfunctions, failures, and premature wear-out.

6. Understand current relationships in three phase wiring for motors.

7. Describe servo and synchro motors and their applications.

B. Methodology

1. A long lecturer on AC Motors is given including information on the basic operation, rotation of the stator field and magnetic field along with the principles of a rotating magnetic field. The concepts of split phase rotating fields, capacitor start rotating fields, centrifugal switch and the shaded pole rotating field are also introduced. Two phase and three phase rotating fields are also discussed.

2. A discussion on synchronous speed in two pole and four pole stators is conducted along with the general theory and operation of synchronous motors both single phase and three phase.

3. Induction motors are introduced with a discussion on and motor action, slip, and starting torque vs. operating torque characteristics. Multiple speed squirrel cage inducting motors are introduced AC commuter motors, repulsion motors and universal motors are also shown and discussed.

4. Students learn the differences in DC generators and AC alternators.

5. Wherever possible students observe the motors on equipment and review several motors on display in exploded views to understand motor construction.

6. Troubleshooting techniques are discussed.

C. Evaluation

See Attached Test

Electro-Mechanical Componentry
Unit X Test
Electric Motors

Name:____________________

1. The most common motors used on Packaging Systems are <u>three phase induction alternating current type</u>. Describe in some detail what the underlined portion of this statement means.

2. Describe three phase in the form of a sketch with a written explanation of their relationship to each other in degrees.

3-5. An AC induction motor is made up of two cylinders one within another both on the same axis. The inner cylinder is mounted in bearings on endbells. What is it called.________ The outer cylinder is the ____________ and is made of metal laminations as opposed to solid iron for the purpose of cutting down on ____________ caused by transformer action.

6. What will happen to a three phase motor is one of the supply wires is accidently disconnected while it is running?

7. If you have four wires from your stator in a standard 120V 60 HZ environment and each of the first three carry an equal current, how much current would you expect the fourth wire to carry? How will the fourth wire be used.

8. How will the rotor direction of a three phase induction AC motor be reversed.

9. An 24 pole 3-phase synchronous motor in a standard 60HZ, 120V environment will turn at what speed?

10. All single phase induction motors share the problem of how they get started. Select one type of single phase induction motor of which you are most knowledgeable and describe how it will get started. (5 points)

11. Which of the following can be a single phase induction motor? Explain why not for those that apply. (Be careful)

    Shaded Pole Motors
    Split Phase Motors
    Capacitor Start Motors
    Series AC Motors
    Synchronous

12. Shaded pole motors are either used for:

a) very low torque applications, or

b) very high torque applications

Select which is true and give an example of an application.

13. Explain how the direction of a shaded pole motor is changed.

14. Of all the single phase motors discussed in class, which is most applicable to high torque starting requirements? (Do not include repulsion motors in this answer)

15. Describe how a repulsion motor operates. (5 points)

16. Explain the function of a centrifugal switch, specifically in the application of capacitor start motors.

17. If a single phase motor hums, but does not turn, list two probable defects.

18. In what type motors are commutators used?

19. In what type motors are brushes used?

20. What is the greatest advantage of a Series AC/DC motor otherwise known as a universal motor? List one of the disadvantages.

21& 22. List two applications for a single phase synchronous motor. Include in your answer the unique feature of synchronous motors and why they are good for the applications selected.

23. If a single phase synchronous motor has 10 poles and is operated in a 60HZ, 240V environment what speed will it have?

24. How does a synchro system motor transfer power from one shaft to another?

25. What applications, ie; what specific needs require synchroservo motor systems?

26& 27. Describe the difference in slip rings and split rings, and where they are used differently.

28. You know that the speed of a given motor is 5252 revolutions per minute and you have measured the torque to be 10 ft-lbs. What horsepower rating will this motor have?

29. In classroom discussion motors limited to what horsepower are suggested for power sources of 120V?

30. In classroom discussion motors limited to what horsepower are suggested for power sources of 120V, 60AMP service?

31. What is the primary difference between generators and alternators?

32- 35. Three conditions must exist for a generator to convert mechanical energy to electrical energy. List them.

36& 37. Two methods are used to create the three conditions listed above. They are the rotating ____________ method and the rotating ____________ method.

38. The top speed of an AC/DC motor will run at as fast as ____________ rpm.

39. The top speed of a squirrel cage AC motor is approximately ____________rpm.

40. Briefly describe the difference in a four wire WYE configuration and a four wire DELTA configuration and where they will be used.