UEENEEG109A

Develop and Connect Electrical Control Circuits

UEENEEG109A Develop and connect electrical control circuits

C O N T E N T S

Work Completed:

Section	***Topic***	Completed
1		
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Section	Topic	Completed
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12		
13		
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References

- AS/NZS 3000 (Current edition) – Wiring Rule (Standards Australia)
- AS/NZS 3017 (Current edition) – Electrical Installations – Testing and Inspection
- H B 301 – 2001 Electrical Installations: Designing to the Wiring Rules
- AS/NZS 3008.1.1 (Current edition) – Electrical Installations- Selection of Cables
- WA Electrical Requirements (2014)
- WA Distribution Connections Manual (4th ed.)
- Electrical Wiring Practice (7th ed.) Pethebridge, K. & Neeson, I.

UEENEEG109A Develop and connect electrical control circuits.

Competency Standard Units

Prerequisite Units

Granting competency in this unit shall be made only after competency in the following units has been confirmed.

UEENEEE101A	Apply Occupational Health and Safety regulations, codes and practices in the workplace
UEENEEE102A	Fabricate, dismantle, assemble of electrotechnology components
UEENEEE104A	Solve problems in d.c circuits
UEENEEE105A	Fix and secure electrotechnology equipment
UEENEEE107A	Use drawings, diagrams, schedules, standards, codes and specifications
UEENEEG006A	Solve problems in single and three phase low voltage machines
UEENEEG063A	Arrange circuits, control and protection for general electrical installations
UEENEEG101A	Solve problems in electromagnetic devices and related circuits
UEENEEG102A	Solve problems in low voltage a.c. circuit
UEENEEG106A	Terminate cables, cords and accessories for low voltage circuits

Elements and Performance Criteria Pre-Content

Elements describe the essential outcomes of a unit of competency	Performance criteria describe the required performance needed to demonstrate achievement of the Element. Assessment of performance is to be consistent with the evidence guide.

ELEMENT	PERFORMANCE CRITERIA
1 Develop and prepare to connect electrical control circuits.	1.1 OHS procedures for a given work area are identified, obtained and understood. 1.2 Established OHS risk control measures and procedures in preparation for the work are followed. 1.3 Safety hazards, which have not previously been identified, are noted and established risk control measures are implemented. 1.4 Control scenarios are determined from discussions with appropriate person(s) and documented in accordance with established procedures. 1.5 Agreement for the control scenarios is sought from appropriate person(s) and documented in accordance with established procedures.

ELEMENT	PERFORMANCE CRITERIA
	1.6 Schematic arrangement of control circuits that complies with agreed scenarios is documented in accordance with established procedures.
	1.7 Materials needed to connect control circuits are obtained in accordance with established procedures and checked against job requirements.
	1.8 Tools, equipment and testing devices needed to connect control circuits are obtained in accordance with established procedures and checked for correct operation and safety.
	1.9 Preparatory work is checked to ensure no damage has occurred and complies with requirements.
2 Connect and test electrical control circuits.	2.1 OHS risk control measures and procedures for carrying out the work are followed.
	2.2 The need to test or measure live is determined in strict accordance with OHS requirements and when necessary conducted within established safety procedures.
	2.3 Circuits/machines/plant are checked as being isolated where necessary in strict accordance OHS requirements and procedures.
	2.4 Control circuit components are connected to comply with the agreed control scenario.
	2.5 Control circuit operation is tested for agreed functionality and in strict accordance with OHS requirements and established safety procedures.
	2.6 Non-compliant control functions are rectified to comply with the agreed control scenario.
	2.7 Unexpected situations are dealt with safely and with the approval of an authorised person.
	2.8 Control circuits are connected and tested efficiently without unnecessary waste of materials or damage to apparatus, circuits, the surrounding environment or services and using sustainable energy practice.
3 Completion and document circuit development activities.	3.1 OHS work completion risk control measures and procedures are followed.
	3.2 Work site is cleaned and made safe in accordance with established procedures.

ELEMENT	PERFORMANCE CRITERIA	
	3.3	'As-connected' control circuits are documented using standard drawing conventions and an appropriate person or persons notified in accordance with established procedures.

Required Skills and Knowledge – KS01-EG109A Electrical control devices and circuits

Evidence shall show an understanding of selecting cables and ensuring co-ordination between protection device and conductors in electrical installations that comply with the Wiring Rules, Selection of cables standards and Service Rules to an extent indicated by the following aspects:

T1 Basic relay circuits encompassing:

- Identification of given circuit diagrams (schematic) symbols and explain the operation of the components represented labelling wires and terminal (numbering systems)
- control relay - operating principles, basic contact configurations and identification and common applications
- push button - switching configurations and common applications
- selecting pushbuttons/pilot lamps from manufacturer's catalogues for specific applications
- development of simple stop-start relay circuit that incorporates pilot lights and latching circuit.
- connection and testing of control circuits

T2 Relay circuits and drawing conventions encompassing:

- circuit diagram drawing conventions
- selecting relays from manufacturers' catalogue for specified applications
- circuit development of electrical control circuit in accordance with a written description (specification) and list the sequence of operation of the circuit
- connecting simple electrical control circuit from circuit diagrams
- applying safe working practices when testing an electrical control circuit

T3 Remote STOP-START control and electrical interlocking encompassing:

- operation of local and remote start-stop control of relays
- operation of an electrically interlocked relay circuit
- development of a relay circuit incorporating local and remote start and stop buttons and electrical interlocking.
- connecting electrical circuits with local and remote start-stop control and with electrical interlocking.
- applying circuit checking and testing techniques to an electrical control circuit.

T4 Time delay relays encompassing:

- timers - operating principles, basic contact configurations and identification and common applications
- selecting timers for specified functions from manufactures' catalogues
- development of timer controlled circuits from a written description and list the sequence of circuit operation
- connecting a timer controlled circuit using a circuit diagram as a guide.
- timer circuit checking and testing procedures.

T5 Circuits using contactors encompassing:

- contactors - operating principles, basic contact configurations and identification and common applications
- thermal overloads - operating principles, basic contact configurations and identification and common applications
- circuit diagram symbols
- circuit development using a contactor
- using contactors for motor control.
- compliance requirements for devices for isolating circuits.

T6 Jogging and interlocking encompassing:

- purpose and application of jogging control of motors
- operation of motor control using start, stop and jog buttons
- purpose and application of electrical/mechanical interlocking
- developing a multiple motor starting circuit from a description of the circuit operation including jog and interlock functions.
- selecting circuit components using manufacturers' catalogues for appropriate duty ratings
- connecting and testing a multiple motor starting circuit which incorporates start, stop and jog control.

T7 Control devices encompassing:

- common control devices used in automatic control circuits: limit switches, proximity switches, photoelectric cells, pressure switches, float switches, light sensors and temperature sensors
- basic operating principles of common control devices
- advantages and disadvantages of common control devices
- applications for common control devices
- selecting control devices using manufacturers' catalogues for specified applications
- connection of control devices into control circuits

T8 Programmable relays encompassing:

- programmable relays - advantages over electromagnetic relay circuit control.
- typical applications of programmable relays.
- block diagram representation and basic operating principles
- input and output parameters, listing, connections and output types.
- connecting input and output devices to a programmable relay using a diagram
- basic programming of ladder circuits consisting of inputs, outputs i.e. stop-start circuit
- using the monitoring facility of the programmable relay to verify each ladder circuit operation.
- programming timers and using the monitoring facility of the programmable relay to check the values of the timer
- external devices
- implications of programming normally closed field devices
- conversion of control circuits
- installation of programmable control relays

- common faults and their symptoms

T9 Three-phase induction motor starters encompassing:

- reasons for limiting the starting current of large motors.
- requirements of the wiring rules (AS/NZS 3000) and the local supply authority service rules, with regard to starting and control of induction motors.
- DOL starter operating principles, applications and circuits
- electronic (soft) starter operating principles, applications and circuits
- connecting a DOL motor starter and testing the operation of the power and control circuits
- installation of DOL and soft starters

T10 Three-phase induction motor starters- reduced voltage encompassing:

- star-delta starter operating principles and circuits
- primary resistance starter operating principles and circuits
- auto-transformer starter operating principles and circuits
- secondary resistance starter operating principles and circuits
- common applications for each starter type
- comparison of motor starters basic characteristics
- selecting the most suitable motor starter for a given situation
- connecting motor starter power and control circuits for correct operation
- measuring starting current and torque of selected motor starters
- installation of reduced voltage starters

T11 Three-phase induction motor reversal and braking encompassing:

- reversing operating principles and control circuits
- plug braking operating principles and circuits
- dynamic braking operating principles and circuits
- regenerative braking operating principles and circuits
- eddy current brakes operating principles and circuits
- mechanical brakes operating principles and circuits
- comparison of the difference braking methods used.
- typical applications for each braking method.
- connecting a circuit with a braking feature to operate a three-phase motor.
- installation of motor braking control circuits

T12 Three-phase induction motor speed control encompassing:

- pole changing operating principles and circuits
- variable frequency drives operating principles and circuits
- slip-ring motors operating principles and circuits
- installation of motor speed controllers.

G109A Work Performance Tasks:

Q-Tracker requirements: 200 hours of practical training.

UEENEEG109A – Develop and connect electrical control circuits
1. Performance requirements: **1a. Related to the following elements:** **1. Develop and prepare to connect electrical control circuits.** **2. Connect and test electrical control circuits.** **3. Completion and document circuit development activities.** **1b. For each element demonstrate performance:** – across a representative body of performance criteria, – on at least 2 occasions, – autonomously and to requirements, – within the timeframes typically expected of the discipline, work function and industrial environment. **2. Representative range includes the following:** **All listed tasks related to performance across a representative range of contexts from the prescribed items below:** **The minimum number of items on which skill is to be demonstrated** **Item List** **Group No** **A.** **At least four of the following:** **Control circuit types** • Multiple light switching circuit • Master control circuit • Single stop-start circuit • Multiple stop-start circuit • Time controlled circuit • Machine interlocked circuit • Motor jogging circuit • Machine safety circuit. **B.** **Using at least five of the following: Devices** • Multi-way switches • Switches with more than two positions and off • Push buttons • Electromagnetic relays • Programmable relays • Contactors • Reversing contactors • Three-phase starters. • Reduced voltage starters **C.** **Using at least two of the following: Transducers/sensors** • Timers • Limit switches • Proximity switches • Photoelectric cells • Pressure switches • Float switches • Light sensors • Temperature sensors

Workplace Rules:

Rule 1	Follow the instructions
Rule 2	Tolerate ambiguity
Rule 3	Meet your obligations

Note: This information and current details of critical aspects for this competency standard unit (CSU) UEENEEG109A can be found at the Australian Training Standards website www.training.gov.au.

UEENEEG109A Develop and connect electrical control circuits

Learning and Assessment Plan

Name of Lecturer: ____

Contact Details: ____

Delivery Mode/s: □ Face to Face □ On-Line □ Blended Delivery □ Other

Using:

- AS/NZS 3000 (Current edition) – Wiring Rule (Standards Australia)
- H B 301 – 2001 Electrical Installations: Designing to the Wiring Rules
- AS/NZS 3008.1.1 (Current edition) – Electrical Installations- Selection of Cables
- WA Distribution Connections Manual (4th ed.)
- WA Electrical Requirements (2014)
- Electrical Wiring Practice (7th ed.) Pethebridge, K. & Neeson, I.

Session	***Nominal Duration***	**Program of Work (Topics to be covered)**	**Primary Reference**
1	4 hours	Introduction to UEENEEG109A Recognition of Prior Learning	Resource Book
2	2 hours		Resource Book
3	2 hours		Resource Book
4	2 hours		Resource Book
5	32 hours		Resource Book
6	2 hours		Resource Book
7	4 hours		Resource Book
8	2 hours		Resource Book
9	8 hours		Resource Book
10	2 hours	**Written Assessment**	RSAK – KS01 – EG109A
11	2 hours	**Observed Practical Assessment**	UEENEEG109A Elements

I acknowledge that I have received and read this Delivery and Assessment Plan

Student Name:________________________Signature: __________________________ Date: __________

Lecturer Name	Lecturer Signature	Date

Assessment Strategy

Conditions of Assessment:

Normally learning and assessment will take place in an integrated classroom/ laboratory environment.

It is essential to work through the worksheets and activities in this workbook and follow the guidance of your lecturer. The worksheets and practical activities will provide the required skills and knowledge outlined in this Unit and assist you in achieving competency.

Assessment Methods:

Written Assessment – based on the Require Skills and Knowledge (RSAK). You must achieve a mark of 75% or more in this assessment.

Observed Practical Assessment – based on the Elements and Performance Criteria of this Competency Unit UEENEEG109A. You must achieve a mark of 100% in this assessment.

On-Job Training:

It is expected that the off-job component of this competency unit to be complemented by appropriate on-job development involving exposure to re-occurring workplace events and supervised experiences (See Work Performance Tasks). You are required to log your on-job training in your 'Q-Tracker' account.

Sufficiency of Evidence:

In all instances, competency is to be attributed on evidence sufficient to show that a person has the necessary skills required for the scope of work. These include:

- Task skills - performing individual tasks
- Task management skills - managing a number of different tasks
- Contingency management skills - responding to irregularities and breakdowns in routines
- Job/role environment skills - dealing with the responsibilities and expectations of the work environment including working with others.

Evidence must demonstrate that an individual can perform competently across the specified range of activities, and has the required skills and knowledge underpinning the competency.

LABORATORY SAFETY INSTRUCTIONS

Students working in Laboratories at this campus do so on condition that they agree to abide by the following safety instructions. Failure to observe the safety instructions may result in immediate suspension.

1. No circuit is to be plugged in or switched on without specific permission of the lecturer in charge of the class. A circuit must be switched off and tested for zero volts before any connection leads are removed. The DANGER TAG PROCEDURE must be used at all times.
2. Do not leave any circuit switched on any longer than necessary for testing. Do not walk away and leave the circuit switched on.
3. Report any broken, damaged or unserviceable equipment to your lecturer.
4. All of your wiring must be disconnected at the end of each practical class or as each project is completed.
5. Make all connections in a safe manner with an appropriate connecting device. Unshielded, 4mm banana plugs are not to be used for wiring.
6. Switch off, remove the plug from the socket, and attach your danger tag to the plug top before working on the project. It is not sufficient to simply turn the supply switch off.
7. When disconnecting your wiring from a connection made under a screw, undo the screw - do not cut the wires off.
8. Observe the correct colour code for all wiring projects.
9. Check your circuit for short circuits with your multimeter before asking your lecturer to switch on. Check the checker before and after EACH check.
10. Skylarking is not permitted at any time.
11. Proper clothing and footwear must be worn at all times when you attend this campus. Thongs, sandals and singles alone are not permitted. **Safety boots or safety shoes must be worn in workshops, laboratories and installation skills areas**.
12. Where a project sheet is issued for a practical project, complete each step in the Procedure before moving on to the next step.
13. Draw all diagrams in pencil so that they can be easily changed or corrected. Mark off each connection on your circuit or wiring diagram as it is made.
14. Check the function and range before taking a reading with a multimeter.
15. Make sure that it is YOUR plug before you insert it into a socket outlet.
16. Always switch a multimeter OFF or to the highest possible AC volts range when you have finished using it.

Student's Signature ______________________________ Date: ____________________

WORKSHOP SAFETY INSTRUCTIONS

Students working in workshops and installation skills areas at this college do so, on condition that they agree to abide by the following safety instructions. Failure to observe the safety instructions may result in immediate suspension.

1. Personally owned eye protection must be worn AT ALL TIMES. Other safety equipment including hearing protection must be worn when applicable to a particular task.
2. Loose clothing must not be worn when working on fixed or portable machines. Hairnets must be worn where applicable. Clothing must cover the upper arms and body.
3. Enclosed footwear must be worn at all times on this campus. Thongs or sandals are not permitted. **Safety boots or safety shoes must be worn in workshop and installation skills areas**.
4. Tools and safety equipment are issued from the tool store on request. It is your responsibility to ask for the correct item (Size, Type and Tool). Check to see that you have been given the correct item before using it. If in doubt ask your LECTURER, not the store person.
5. Report any broken, damaged or unserviceable equipment to your Lecturer. Do not use damaged tools or machines.
6. Clean down the machines immediately after use. All tools must be cleaned before returning them to the store.
7. Skylarking is not permitted at any time.
8. Always use protective vice jaws when cutting off material in a bench vice.
9. Accidents resulting in cuts, abrasions or other personal injury must be reported to your Lecturer immediately - no matter how minor they may seem. A first-aid kit is available in the tool store.
10. Never leave a machine unattended when it is running. Do not allow yourself to be distracted when operating a machine.
11. Read all safety signs and notices and follow the instructions.
12. Do not use a fixed or portable machine unless you have been instructed in its proper use.
13. Read all risk assessment documentation provided (JSAs) and conduct a relevant risk assessment process before performing any task.

Student's Signature ____________________________ Date: ___________________

Danger Tag Procedure

Use of Danger Tags

If you have a practical task to do and there is a possibility that you could be injured if someone turns on the electricity, then you **MUST** fasten a red danger tag to the machine main isolation switch, circuit-breaker or the equipment plug top.
Each danger tag you use must clearly show; your name, your section (class) and the date.
Nobody must operate the danger tagged switch or control point until the job is made safe and the danger tag has been removed.
Your lecturer will check your task before you are allowed to remove your danger tag.
Only the person, who is named on the tag and attached the tag, is allowed to remove it.

Points to Watch

Make absolutely sure the switch/circuit-breaker/plug top is the correct one to tag. If you have any doubts, ask your lecturer.

Make sure that you have switched the isolator to **OFF** position before you attach your danger tag.
Fasten the danger tag securely.
The purpose of using Danger Tags is to prevent electrical accidents from happening.
Failure to follow Danger Tag Procedures when working on practical activities and practical assessments will result in a '**Not yet competent'** comment recorded for this Unit of Competency – UEENEEG109A

Student's Signature ____________________________ Date: ___________________

1. Identify the internal components of a typical three phase magnetically operated DOL starter.

2. Design, connect and test a single direct-on-line (DOL) magnetic starter circuit for a 415 volt three phase squirrel cage induction (SCI) motor.

3. Design, connect and test a direct-on-line (DOL) magnetic starter circuit which controls a 415 volt three phase squirrel cage induction (SCI) motor from either of two stop-start stations.

4. Design, connect and test a DOL magnetic starter circuit which controls two 415 volt three phase SCI motors and incorporates a time-delay relay.

5. Design, connect and test a relay circuit which incorporates electrical interlocking.

6. Design, connect and test a DOL magnetic contactor circuit which provides forward and reverse operation of a 415 volt three phase SCI motor and incorporates limit switches.

7. Design, connect and test a DOL magnetic contactor circuit which provides forward, reverse and jogging operation of a 415 volt three phase SCI motor and incorporates limit switches.

8. Design, connect and test a press safety circuit and describe its operation.

9. Convert a wiring diagram of a typical basic control circuit to a circuit diagram.

10. Locate the fault in a typical basic control circuit and describe how it should be corrected.

11. Carry out PLC project as directed by your lecturer depending on which campus you are attending.

Electromagnetic Relays and Electrical Diagrams

Task:

Demonstrate an understanding of the operation of a basic electromagnetic relay and contactor and to recognise commonly used drawing symbols for electrical components and draw simple circuits using the conventions of electrical drawing.

Why:

It is essential for an electrician to have an understanding of electrical control circuits using electromagnetic relays or contactors. An electrician needs to know what they are, what they do and how they do it. An electrician also needs to be able to read electrical diagrams which make use of electrical drawing symbols and conventions so that you can understand the operation of control circuits.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a competency test for each Learning Outcome.

2. You must correctly identify the internal components of a typical direct-on-line motor starter which incorporates a magnetic contactor.

3. You must correctly identify instances of where common electrical drawing conventions have not been followed in a wiring diagram.

4. You must draw a wiring diagram of a given DOL motor starter using the conventions of electrical drawing.

Equipment:

Three phase DOL motor starters.
Multimeter.

References

* Electro-technology Practice Hampson.
* Australian Standards AS 1102 and AS 1103.
* Manufacturer's handbooks and data sheets.

Electromagnetic Relays and Electrical Diagrams

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

Electrotechnology Practice

Section 3 Electrical Drawings and wiring system
Control circuits – page 97

Australian Standards AS 1102 and AS 1103

For reference as required

2. Read the Summaries, and practise answering the questions provided on the Work Sheet. Refer to other relevant texts if you feel it is necessary. Visit your college library and examine AS 1102 and AS 1103 to see the type of information they contain and the number and classifications of electrical drawing symbols and diagrams.

3. Answer the questions given on the Work Sheet. Use a separate answer sheet. Note that you are required to answer ALL questions correctly.

4. Complete the projects in this manual.

5. Submit your answers to the Work Sheets and your completed project reports to your Lecturer for discussion and assessment.

Electromagnetic Relays and Electrical Diagrams

Relays

A relay is a device which opens and/or closes electrical contacts when specified conditions are met to effect the operation of other devices in the same or another electrical circuit. Opening or closing of the contacts can be achieved in a variety of ways, including:

a. **Electromagnetically.**
   An electromagnet attracts an armature (a moving portion) causing the attached contact or contacts to open or close (e.g. a signal relay).

b. **Thermally.**
   A bi-metallic strip mechanism is used to sense the temperature of a device or component. When the temperature of the bi-metallic strip changes within designed limits, contacts open and/or close (e.g. a overload relay).

c. **Magnetically.**
   When the relay is in the presence of a specified magnetic field, contacts open and /or close (e.g. a reed relay).

d. **Mechanically.**
   A small mechanical driving mechanism such as an electric motor or clockwork motor causes contacts to open and/or close after a specified amount of time has elapsed (e.g. a time-delay relay).

There are many variations of each type of relay.
The main focus in this module is on electromagnetically operated relays as used in circuits which provide electrical control of various industrial processes.

Electromagnetic Relays

A typical electromagnetic relay has of a coil of insulated copper wire wound on a bobbin or former; the coil is positioned over a soft-iron magnetic core.
Another magnetically soft-iron component known as an armature is positioned so that if the core is magnetised the armature is attracted to it - the movable armature is mechanically linked to one or more sets of contacts which change from open to closed (or vice versa) when the armature moves.

A simplified form of electromagnetic relay is shown in Figure 1.

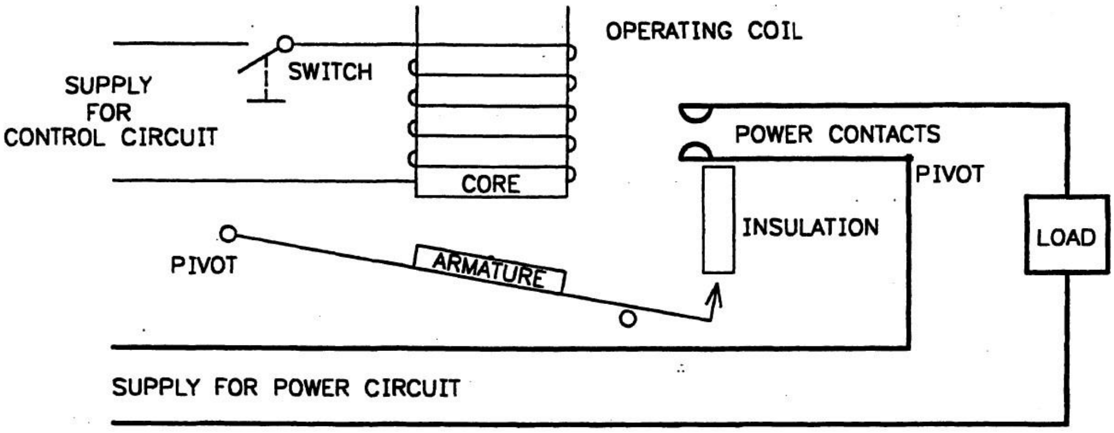


Figure 1 - Simplified electromagnetic relay circuit.

When the switch in Figure 1 is closed, the relay coil is energised and the movable armature is attracted to it.
Movement of the armature causes the contacts to close, and allow current to flow in the load.

The switch and operating coil form what is known as the 'control circuit', and the main contacts and load form what is known as the 'power circuit'.
All electromagnetically operated relays have a control circuit and a power circuit, but the components in each circuit can vary widely.

Electromagnetic relays are available in many different shapes and sizes - they differ in electrical characteristics such as the coil voltage, the current rating of the contacts, number of contacts, contact configurations, type of enclosure, mounting configuration and so on.

Larger relays are often referred to as magnetic contactors - there is no clear distinction between a relay and a contactor.

Most electrical circuits make use of symbols to represent components.
Contacts in electrical drawings are always shown as they would be on the device when it is NOT operating (i.e.de-energised) - they are described as being 'normally open' or 'normally closed'.

The relay circuit in Figure 1 could be drawn using symbols - see Figure 2.

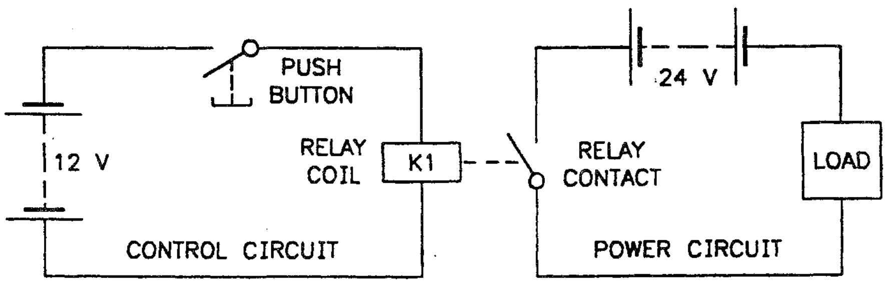


Figure 2 - A simple relay circuit in symbol form.

The relay circuit shown in Figure 2 has separate voltage sources for the control circuit and the power circuits.

The same voltage source can be used for both the control circuit and the power circuit, but, since both circuits are in parallel, they are electrically independent of each other.

A simple relay circuit in which the control circuit and the power circuit share the same voltage source is shown in Figure 3.

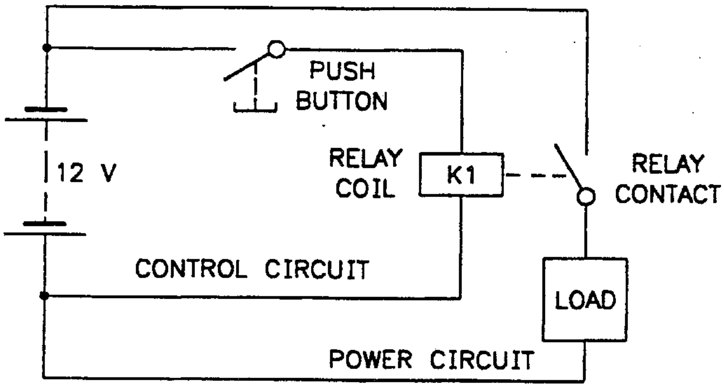


Figure 3 - Relay circuit with a shared voltage source.

The advantages of using a relay or contactor to control a circuit rather than a mechanically operated switch include:

a. Multiple control - More than one switch can be used to control the load using a single relay.

b. Small control currents can be used to control large currents in the power circuit.

c. Remote control is possible.

d. Small control voltages can be used to control circuits which operate at higher voltages - e.g. a 24 volt d.c. control circuit can be used to operate a 415 volt three phase contactor to start a large a.c. motor.

e. The control circuit can be completely isolated from the power circuit.

f. Relays operate faster than mechanical switches.

g. Relays are more appropriate when a large number of operations per hour are required.

h. Relays and contactors can automatically provide under-voltage protection for the circuit.

The disadvantages of using relays or contactors include:

a. Relays have more moving parts and are more prone to mechanical or electrical failure.

b. Relays use electrical energy to operate the coil. Although the amount of energy is usually quite small it can be significant where a large number of relays is involved.

The current flowing in the relay coil also generates heat which must be considered if large numbers of relays are installed in the same enclosure.

c. Relay contacts often require maintenance.

Silver contacts must not be filed or lubricated, they may need to be replaced.

Relay and contactor coils are available for a range of a.c. or d.c. voltages (the coil voltage rating is usually marked on the coil).

Typical coil voltages include:

6, 12, 24, 32, 50 and 110 volts d.c.

24, 32, 48, 110, 240 and 415 volts a.c.

The coil voltage and frequency must be appropriate for the application - coils designed for a.c. operation are not suitable for d.c. and vice versa.

The control voltage required to operate a relay or contactor satisfactorily, is known as the 'pick-up' voltage, and the voltage at which it will drop out, is known as the 'drop-out' voltage.

Pick-up voltages are typically about 85% of the rated voltage and drop-out voltages are typically round 50% of the rated voltage.

The fact that a 415 volt contactor coil may not drop out if the operating voltage is reduced to 240 volts while the contactor is energised, is an important safety factor in the design of some industrial control circuits.

In general, extra-low voltage relay or contactor coils are more prone to failure due to variations in supply voltage than higher voltage coils.

In any relay circuit, the control circuit current depends on the current drawn by the relay operating coil.

The control circuit current is usually much lower than the power circuit current - a typical current for a 415 volt contactor coil is about 20-30 milliamps.

If the control circuit voltage is different to that of the power circuit, a voltage reducing device such as a transformer would be required to supply the control circuit (except in the case of three phase circuits in which 415 volts or 240 volts is usually readily available).

Utilisation Categories

Contactors are often assigned a utilisation category which specifies the type of duty for which the contactor has been designed - this affects the current rating of the contacts under various operating conditions.

The most common alternating current (AC) utilisation categories are:

AC 1 - Light switching duty such as resistive loads.
AC 2 - Normal switching duty such infrequent starting and stopping of squirrel cage and slip ring motors.
AC 3 - Severe switching duty such frequent starting and stopping of squirrel cage and slip ring motors.
AC 4 - Extreme switching duty such jogging, plugging, rapid reversal, counter current braking of motors.

A particular contactor may have a current rating of 20 amps when used for AC 1 switching duty, but the current rating could be reduced to 6 amps if it is to be used for AC 3 switching duty.

This information is available in manufacturers' catalogues, and it is often included in the markings on particular contactors.

Selection of Relays or Contactors

17. The main factors to be considered when selecting a relay or contactor for a particular application include:

a. The operating coil voltage and frequency.
b. The number of normally open and normally closed contacts.
c. The current rating of the contacts.
d. The overall voltage rating of the relay or contactor.
e. The physical size of the relay or contactor.
f. The type of mounting.
g. The contact configuration – 'makes before break' or 'breaks before make'.
h. The utilisation category of a contactor.

North Metro TAFE Electrical Trades	Develop and Connect Control Circuits Electromagnetic relays Section 1	Worksheet 1	JD/ER 7/14 G109A

1. Name four ways the opening and closing of contacts is achieved in electromagnetic relays or contactors.
2. What are the two types of circuits in a typical circuit diagram?
3. How are contacts in electrical circuit diagrams shown?
4. Is it necessary to have the same voltage source for the power and control circuits in a relay or contactor circuit?
5. Name 5 advantages of using a relay or contactor circuit over a mechanically operated switch.
6. Name two disadvantages of using a relay or contactor over a mechanical switch.
7. Explain 'pick-up' voltage and 'drop-out' voltage in electromagnetic circuits.
8. What is the typical operating current of a 415 volt contactor coil in a control circuit?
9. Explain "utilisation categories", AC-1, AC-2, AC-3 and AC-4.
10. Can an AC-1 rated contactor be used to replace an AC-4 category contactor?
11. Can an AC-4 rated contactor be used to replace an AC-1 category contactor?
12. Name 5 factors that need to be considered when selecting a contactor or relay for a particular application.

Electrical Diagrams and Conventions

A large number of types of electrical diagrams exist, such as block diagrams, wiring diagrams, circuit diagrams, interconnection diagrams, terminal diagrams and Single Line Diagrams.

This workbook will concentrate on two types - Wiring Diagrams and Circuit Diagrams, with most examples directed towards motor control circuits which utilise magnetically operated contactors or relays and associated devices.

The symbols and conventions used in this module are based on Australian Standard 1102.

Wiring Diagrams (Sometimes called Connection Diagrams)

Wiring diagrams show the physical relationship between components, the actual location of the connecting terminals and the wiring between them.

They are used to number terminals and show connections at terminals and the relative position of components on, for example, a control panel or motor starter, and the wiring between actual terminals.

Some equipment suppliers provide wiring diagrams which show the terminals and terminal markings without showing the internal electrical detail, while others show relevant internal detail in symbol form as well as the terminals and terminal markings.

The terminals are shown as they appear on the actual component, although in some cases they may be offset if, for example, one component is physically located on top of another.

Not all suppliers follow the same format or symbols, but the same information should be conveyed by all wiring diagrams.

A simple example of a wiring diagram is shown in Figure 1.

The components, terminals and wiring are shown as they would be on the actual device, although they may not be to the same scale.

Other examples with exercises are provided later in this unit.

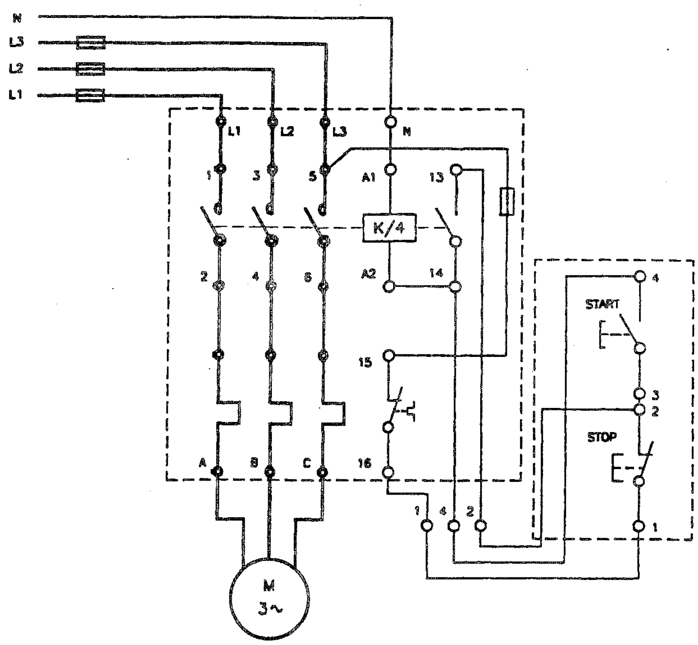


Figure1. Simple wiring diagram of a DOL motor starter

Circuit Diagrams (Sometimes called Schematic Diagrams, Elementary Diagrams or Key Diagrams).

These diagrams show the electrical functions of the circuit in its simplest form without showing the relative location of the components.

The electrical components are almost always shown as symbols.

Circuit diagrams are usually used to determine the detailed operation of the circuit, and are commonly used for diagnosing and locating faults in circuits.

A simple example of a circuit diagram is shown in Figure 2 - it is the same device represented in Figure 1.

Notice that the circuit diagram is shown in two parts - the power circuit and the control circuit, and it is much easier to follow the operation of the circuit.

Other examples with exercises are provided later in this workbook.

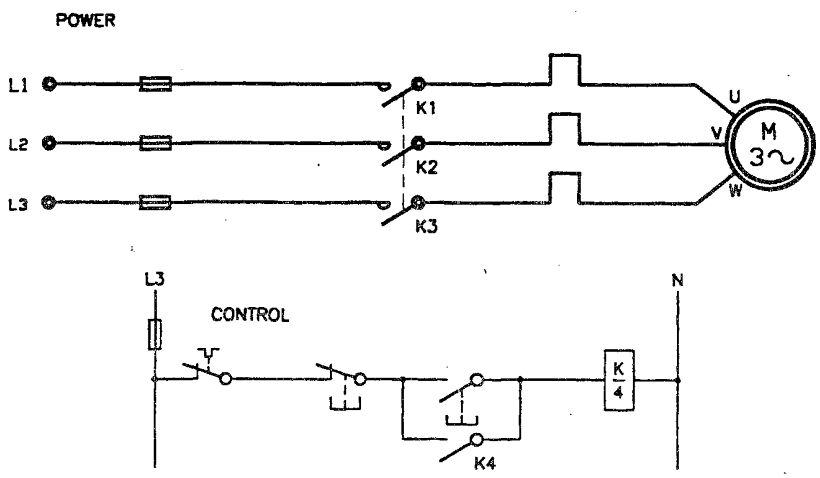


Figure 2. Simple circuit diagram of a DOL motor starter.

Reading Circuits

In order to be able to read and understand electrical circuits, it is necessary to know the meanings of the drawing symbols which are used to represent various components.

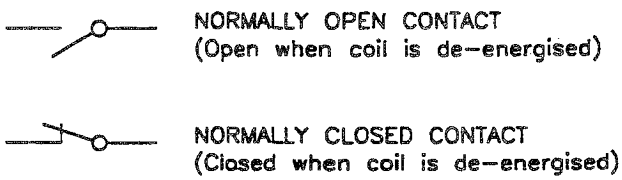
It is also necessary to be aware of several basic conventions of electrical drawing - if you know the basic symbols and conventions, you will often be able to read an electrical diagram even if it is drawn with notations in a foreign language.

Circuit Conventions

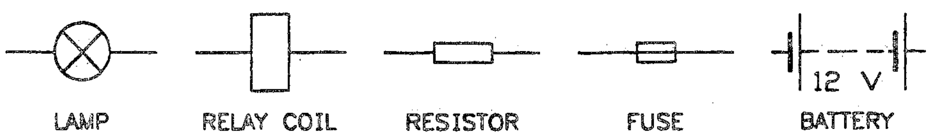
The most commonly used conventions of electrical drawing are:

a. All components (contacts, coils, switches etc.) are shown in the OFF or UNOPERATED position.

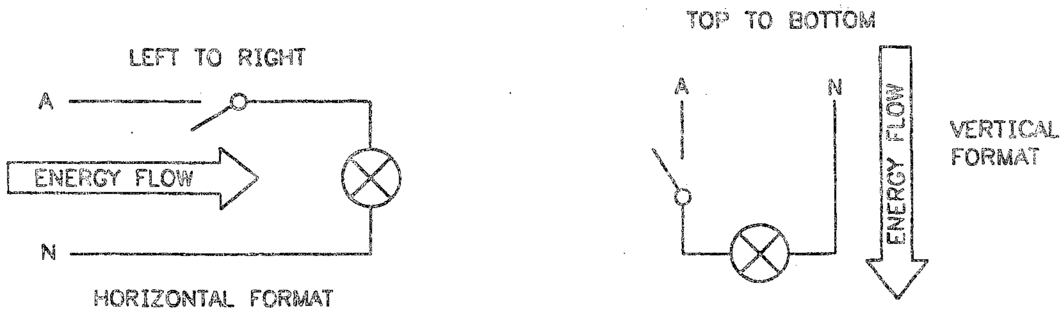
This is the most important convention - if you are not aware of this, you would not know whether a particular contact was meant to be open or closed.



b. All electrical components are represented by symbols. You should always use Australian Standard symbols when you draw an electrical circuit diagram unless there is a specific reason for doing otherwise.

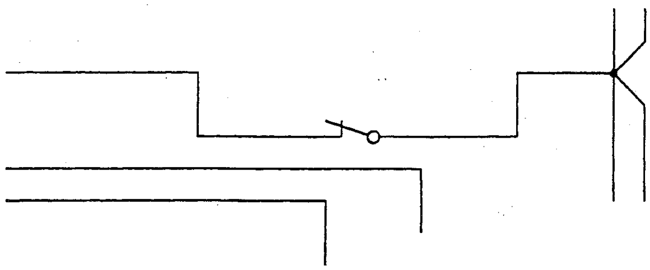


c. Cause and effect (energy or signal flow) is shown from left to right, top to bottom.

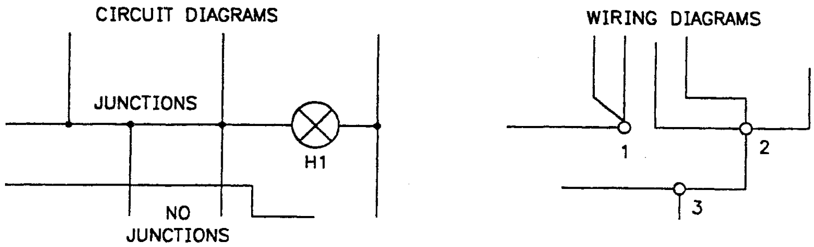


d. Conductors are represented by vertical or horizontal lines where possible.

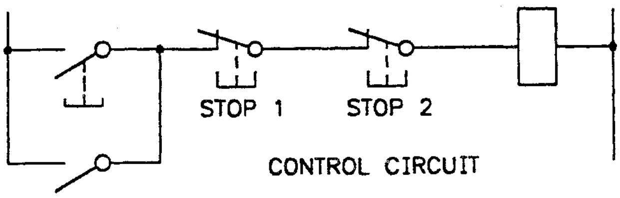
Short oblique angled straight lines are acceptable where they cannot be avoided, but lines representing conductors should NEVER be drawn as curved lines - even when you are making a sketch of a circuit.



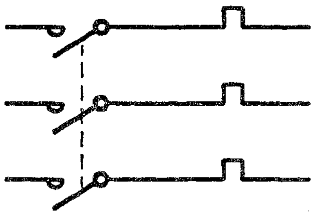
e. Junctions are shown in conductors in circuit diagrams, but at component terminals in wiring diagrams.

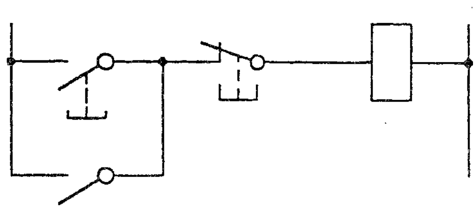


f. Components with specific symbols (e.g. stop or start buttons) are not necessarily named on a circuit, unless there is more than one of the same component in the same circuit.



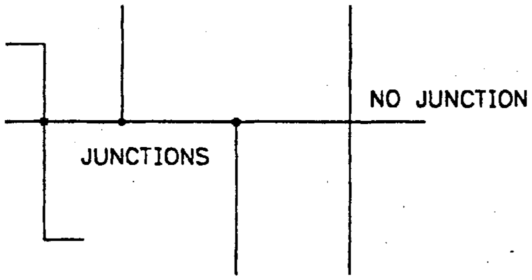
g. Line thickness can be used to differentiate between circuits - such as power and control circuits. Heavier lines are usually used for higher current circuits.

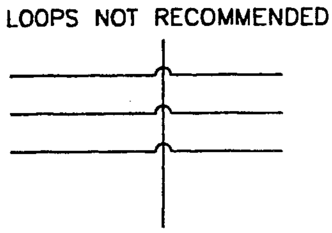




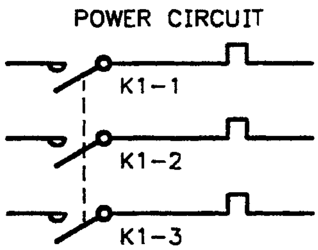
h. Conductors joined in circuit diagram are shown with a dot.

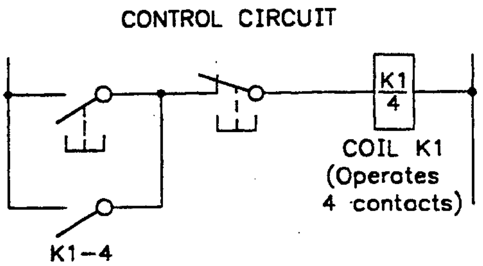
According to Australian Standards, conductors crossing are NOT shown as a loop, although this practice is fairly common in some non-standard electrical diagrams.



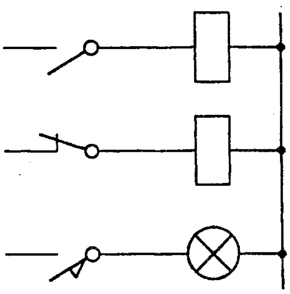


i. The number of contacts operated by a contactor or relay is shown under the abbreviation of the contactor coil. (e.g. K/4 means that the contactor coil K operates four contacts). K1, K2, K3 etc. are the individual contacts operated by the coil K.

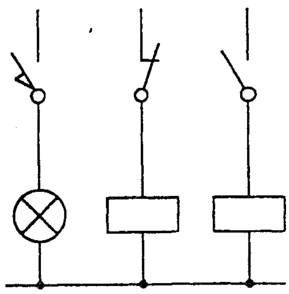




j. All coils, lamps or other output devices should be drawn (where possible) in a straight line, e.g. for ladder form, in a vertical line one under the other.



HORIZONTAL FORMAT

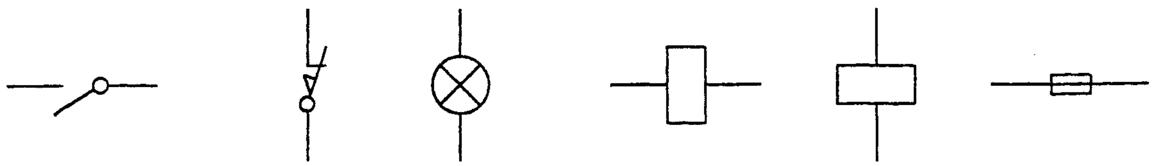


VERTICAL FORMAT

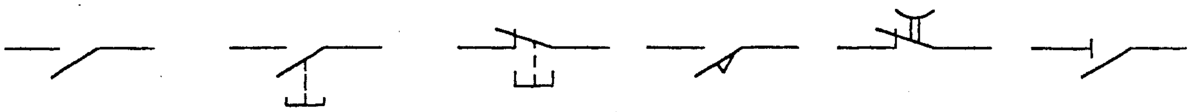
k. Lines representing conductors in circuit diagrams should not change direction at a switch contact - the line should be extended a short distance in the same direction as the orientation of the switch before the direction is changed.

l. The line representing the movable portion of a switch or contact should always be shown so that it moves in a clockwise direction when it is operated.

m. Symbols for components can be drawn in any orientation vertically or horizontally.
The size of symbols is relatively constant - size does not increase in proportion to the size of the drawing sheet.

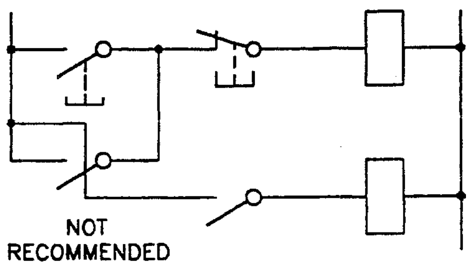


n. The small circle representing the 'hinge' in open and closed contacts can be omitted - as long as all symbols in the drawing are consistent.



o. The 'hinged' portion of a contact symbol should be on the load side of the symbol in a circuit diagram (i.e. the right-hand side if the circuit is drawn using the horizontal format).
This convention is derived from common practice - it is not a recommendation in AS 1102.

p. Conductors should be drawn so that they pass around symbols - not through them.



Symbols

Standard electrical drawing symbols are given in Australian Standard 1102, but very few commercial drawings use all of them as they are not standard in other countries (although AS 1102 has been aligned with the International Electro-technical Commission (IEC) 617 series as modified to suit Australian conditions and CAD requirements).

Many companies use a common set of symbols in their own drawings.

In most cases however, it is possible to determine what a particular symbol means by looking at where it is placed in a circuit.

A selection of commonly used standard symbols is given at the end of this section.

You will need to be able to recognise, draw and use all of these symbols before the end of this unit.

Arrangement of Symbols

There are three common methods of indicating the relationship between different parts of a single item of equipment (such as a relay operating coil and its associated contacts) - these are:

a. Attached representation.
b. Semi-attached representation.
c. Detached representation.

Attached Representation

In attached representation, the individual components such as coils and their contacts are shown close to each other, with dashed lines to indicate that a mechanical linkage exists between them.

This enables related components to be identified, but it can result in wiring with more cross-overs and changes of direction than necessary for easy analysis of a circuit.

Semi-attached Representation

In semi-attached representation, individual components such as coils and their contacts are shown with dashed lines to indicate that a mechanical linkage exists between them, but they are not located close together.

This can enable conductors to be shown in a simplified format, but it means that there could be a confusing number of dashed lines on the diagram.

Detached Representation

In detached representation, no attempt is made to show the physical relationship between components - the relationship is indicated by labelling the symbols.

The circuit diagram in Figure 2 uses the detached representation method - this is very common in circuit diagrams.

It is not essential for all electrical diagrams to conform to only one of the types of representation described above. It is acceptable to use more than one method in a single diagram if necessary - the object is to convey the information so that the user will have no difficulty in interpreting it quickly and accurately.

Item Designations

In order to be able to label items on a circuit diagram so that they are readily identifiable, a list of recommended letter codes for various kinds of items has been developed.

Sample recommended letter codes for items typically found in electrical diagrams are shown below.

A more complete list can be found in SAA-HB3-1986.

Letter Code	Kind of Item
C	Capacitors
E	Miscellaneous
F	Protective devices
G	Generators, power supplies
H	Signalling devices
K	Relays, contactors
M	Motors
P	Measuring equipment
Q	Mechanical switching devices
R	Resistors
S	Switches, selectors
T	Transformers
U	Modulators, changers, converters
V	Semiconductors (discrete)
X	Terminals, plugs, sockets, links, joints

The item designations given above are not universally used, so you will see many diagrams in which some other coding system is used, but you should try to use the recommended designation system where possible.

Figure 3 shows typical symbols used in circuit diagrams, with sample item designation codes (the circuit is not intended to represent a particular practical application).

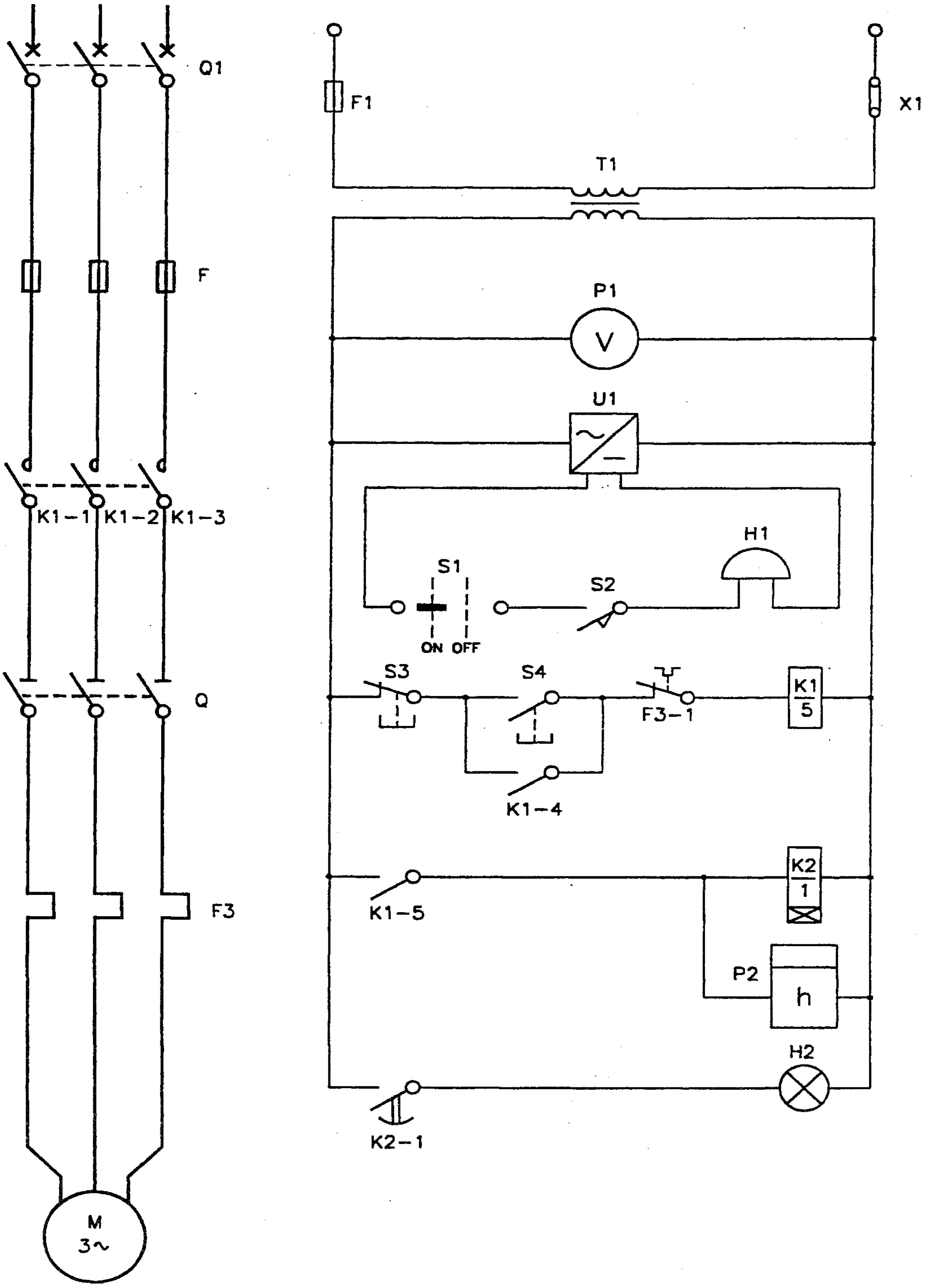
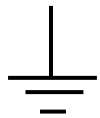
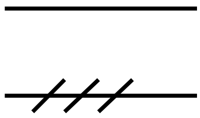
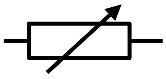
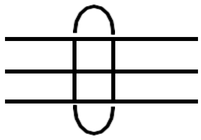
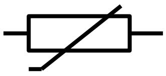
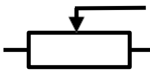
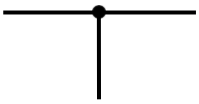
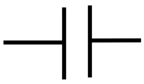
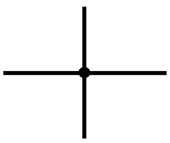
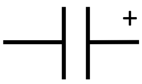
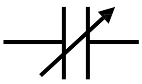
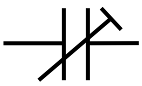
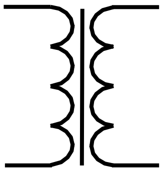
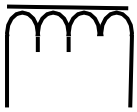
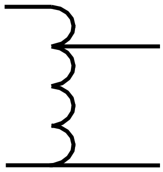
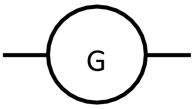
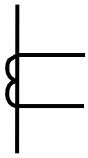
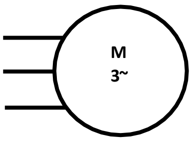
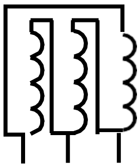
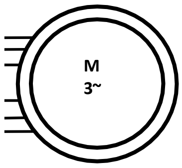
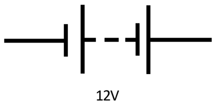
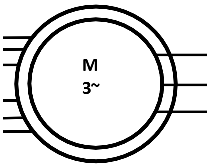
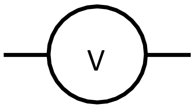
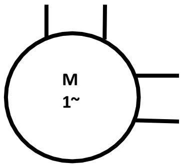
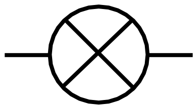
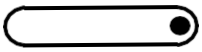
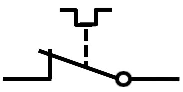
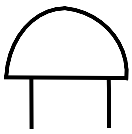
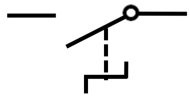
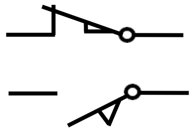
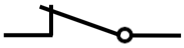
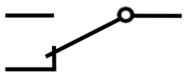
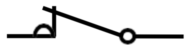
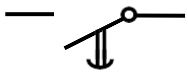
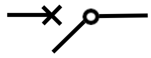
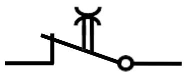
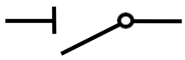
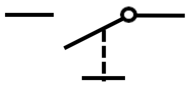
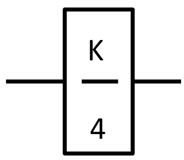
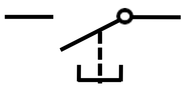
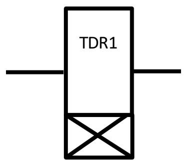
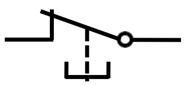
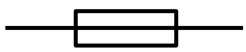


Figure 3 - Sample circuit diagram with item designation codes.

SHEET 1		SYMBOL SHEET			AS 1102 (1989)
1	EARTHGENERAL SYMBOL 102-15-01		10	RESISTOR GENERAL 104-01-01	
2	CONDUCTOR 3 CONDUCTORS 103-01-02		11	VARIABLE RESISTOR 104-01-03	
3	3 CONDUCTORS IN A CABLE 103-01-09		12	VOLTAGE DEPENDANT RESISTOR104-01-07	
4	TERMINAL 103-02-02		13	POTENTIOMETER WITH SLIDING CONTACT104-01-07	
5	JUNCTION OF CONDUCTORS 103-02-05		14	CAPACITOR GENERAL SYMBOL 104-02-01	
6	DOUBLE JUNCTION OF CONDUCTORS 103-02-07		15	POLARISED CAPACITOR 104-02-07	
7	CONDUCTORS CROSSING NO CONNECTION AS1102. 103 p9		16	VARIABLE CAPACITOR 104-02-07	
8	PLUG AND SOCKET(MALE AND FEMALE)103-03-05		17	CAPACITOR WITH PRE-SET ADJUSTMENT104-02-09	
9	CONNECTING LINK CLOSED 103-03-17		18		

SHEET 2		SYMBOL SHEET			AS 1102 (1989)
1	INDUCTOR COIL WINDING 104-03-01		10	TRANSFORMER WITH 2 WINDINGS MAG (CORE) 106-09=02	
2	INDUCTOR WITH TWO FIXED TAPPINGS 104-03-06		11	AUTOTRANSFORMER 106-09-07	
3	GENERATOR 106-04-01		12	CURRENT TRANSFORMER 106-09-11	
4	MOTOR 3 PHASE SQUIRREL CAGE 3 TERMINAL106-08		13	3 PHASE TRANSFORMER (DELTA) 106-10-08	
5	MOTOR 3-PHASE SQUIRREL CAGE 6 TERMINAL106-08		14	BATTERY (12V) 106-15-03	
6	MOTOR 3 PHASE WOUND ROTOR 106-08		15	VOLTMETER 108-02-01	
7	MOTOR 1 PHASE 106-08		16	LAMP GENERAL SYMBOL 108-10-01	
8	THERMAL OVERLOAD HEATER		17	DISCHARGE LAMP 108-10-A1	
9	THERMAL OVERLOAD CONTACT		18	BELL 108-10-06	

SHEET 3		SYMBOL SHEET			AS 1102 (1989)
1	MAKE CONTACT OR SWITCH 107-02-01(1)		10	TURN SWITCH LOCKING 107-07-04	
2	MAKE CONTACT OR SWITCH 107-02-02(2)		11	LIMIT SWITCHES N/O AND N/C 107-08-03/01	
3	BREAK CONTACT 107-02-03		12	CONTACTOR CONTACT N/O 107-13-02	
4	CHANGE OVER SWITCH (2 WAY) 107-05-02		13	CONTACTOR CONTACTS N/C 107-13-04	
5	MAKE CONTACT DELAY CLOSING 107-05-01		14	CIRCUIT BREAKER 107-13-06	
6	BREAK CONTACT DELAY OPEN AND CLOSE 107-05-05		15	ISOLATOR 107-13-06	
7	SWITCH MANUALLY OPERATEDGENERAL SYMBOL 107-07-01		16	OPERATING CONTACTOR OR COIL 107-15-08	
8	PUCH BUTTON SWITCH (START) 107-07-02		17	TIME DELAY RELAY 107-15-08	
9	PUSH BUTTON SWITCH (STOP)		18	FUSE 107-21-01	

Notes

Electrical Diagrams and Conventions

1. How many LINE or SUPPLY terminals are required on a typical 415 volt three phase DOL motor starter, and how would they be marked?

2. How many MOTOR terminals are required on a typical 415 volt three phase DOL motor starter, and how would they be marked?

3. What electrical drawing convention MUST be known in order to be able to read a circuit diagram accurately?

4. What are two advantages of using a magnetically operated DOL starter instead of a manually operated triple pole switch?

5. What are two of the main uses for a wiring diagram?

6. What are two of the main uses for a circuit diagram?

7. Which two pieces of information can be obtained from a wiring diagram, but not on a circuit diagram of the same circuit?

8. Which common type of electrical diagram shows junctions in conductors rather than at specific terminals?

9. What is the main advantage of using 'detached representation' in circuit diagrams?

10. What is another common name for a wiring diagram?

11. If a specific contact is designated as being 'normally open', when is it closed?

12. What is another common name for a circuit diagram?

13. List six of the 'conventions' of electrical drawing.

14. What is the preferred letter code used to label a relay or contactor according to Australian Standards?

Electrical Drawing Symbols

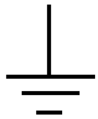
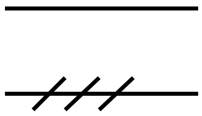
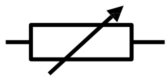
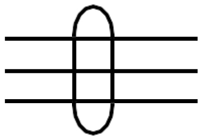
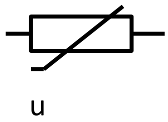
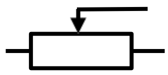
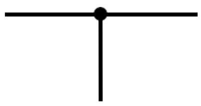
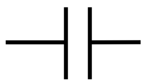
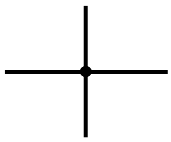
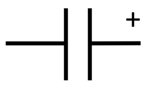
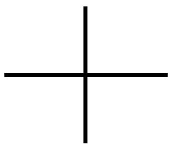
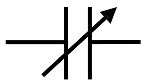
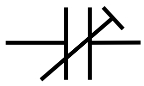
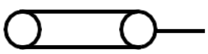
1. Draw the Australian Standard symbol for each of the electrical drawing symbols named on the attached sheets. The Symbols need to be drawn in pencil, free-hand, and the sizes need to be the approximate sizes recommended in AS 1102.

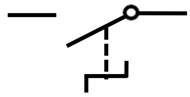
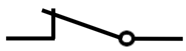
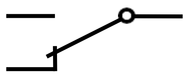
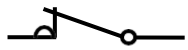
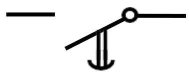
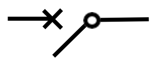
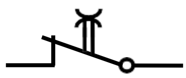
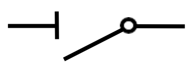
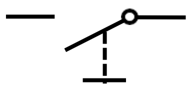
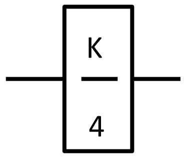
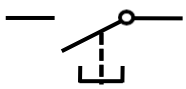
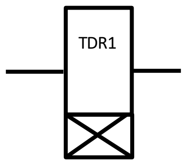
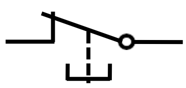
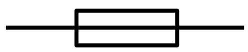
SHEET 3		SYMBOL SHEET			AS 1102 (1989)
1	LIMIT SWITCH N/O 107-08-01		11	CAPACITOR GENERAL SYMBOL 104-02-01	
2	LIMIT SWITCH N/C 107-08-03		12	INDUCTOR COIL WINDING 104-03-01	
3	CONTACTOR CONTACT N/O 107-13-02		13	INDUCTOR WITH TWO FIXED TAPPINGS 104-03-06	
4	CONTACTOR CONTACTS N/C 107-13-04		14	MOTOR 3 PHASE SQUIRREL CAGE 3 TERMINAL106-08	
5	CIRCUIT BREAKER 107-13-06		15	MOTOR 3-PHASE SQUIRREL CAGE 6 TERMINAL106-08	
6	ISOLATOR 107-13-06		16	MOTOR 3 PHASE WOUND ROTOR 106-08	
7	OPERATING CONTACTOR OR COIL 107-15-08		17	MOTOR 1 PHASE 106-08	
8	TIME DELAY RELAY 107-15-08		18	THERMAL OVERLOAD HEATER	
9	FUSE 107-21-01		19	THERMAL OVERLOAD CONTACT	
10	TRANSFORMER WITH 2 WINDINGS MAG (CORE) 106-09-02				

SHEET 3		SYMBOL SHEET			AS 1102 (1989)
1	MAKE CONTACT OR SWITCH 107-02-02(2)		11	EARTHGENERAL SYMBOL 102-15-01	
2	MAKE CONTACT OR SWITCH 107-02-01(1)		12	CONDUCTOR 3 CONDUCTORS 103-01-02	
3	BREAK CONTACT 107-02-03		13	3 CONDUCTORS IN A CABLE 103-01-09	
4	CHANGE OVER SWITCH (2 WAY) 107-05-02		14	TERMINAL 103-02-02	
5	MAKE CONTACT DELAY CLOSING 107-05-01		15	JUNCTION OF CONDUCTORS 103-02-05	
6	BREAK CONTACT DELAY OPEN AND CLOSE 107-05-05		16	DOUBLE JUNCTION OF CONDUCTORS 103-02-07	
7	SWITCH MANUALLY OPERATEDGENERAL SYMBOL 107-07-01		17	CONDUCTORS CROSSING NO CONNECTION AS1102. 103 p9	
8	PUCH BUTTON SWITCH (START) 107-07-02		18	CONNECTING LINK CLOSED 103-03-17	
9	PUSH BUTTON SWITCH (STOP)		19	RESISTOR GENERAL 104-01-01	
10	TURN SWITCH LOCKING 107-07-04		20	VARIABLE RESISTOR 104-01-03	

Electrical Drawing Symbol Recognition

1. Identify each of the Australian Standard electrical drawing symbols given on the attached sheets. Commonly used names are acceptable - it is not necessary to use the names or numbers given in AS 1102.

SHEET 1		SYMBOL SHEET			AS 1102
1			10		
2			11		
3			12		
4			13		
5			14		
6			15		
7			16		
8			17		
9			18		

SHEET 3		SYMBOL SHEET			AS 1102
1			10		
2			11		
3			12		
4			13		
5			14		
6			15		
7			16		
8			17		
9			18		

Project

Three Phase DOL Starter Component Identification

Objective

To identify the internal components of a typical three phase magnetically operated DOL motor starter.

Equipment

Three-phase DOL starter (with a stop/start station and overloads)
Multimeter
Manufacturer's information relating to the DOL starter.

Procedure

1. Draw a neat pencil sketch showing the location of the following parts of the DOL starter. (Use an arrow from the name of each part to show its approximate location). Show the terminal markings on the components.

<u>Neat Pencil Sketch</u>

Input line terminals

Motor terminals

Earthing terminal

Stop button connections

Start button connections

Retain contacts

Operating coil

Auxiliary contacts

Overload contacts

Overload adjusting mechanism

Overload reset button

2. Examine the parts of the DOL starter, and answer the following questions (use a continuity tester where required).

a. What are the markings on the supply terminals?

____

b. What are the markings on the load terminals?

____

c. Are the main start button contacts normally open or normally closed?

____

d. Are the main stop button contacts normally open or normally closed?

____

e. Are the ‘retain’ or ‘latching’ contacts normally open or normally closed?

____

f. Does the operating coil require a neutral?

____

g. How many overload contacts are there, and are they normally open or normally closed?

____

h. What is the range of current settings for the overload heaters?

____

i. What is the maximum current rating of the main power contacts (for AC 1 applications)?

____

3. Submit your answers to your Lecturer for checking and comment.

Questions

1. How many LINE or SUPPLY terminals are required on a typical 415 volt three phase DOL motor starter, and how would they be marked?

____

2. How many MOTOR terminals are required on a typical 415 volt three phase DOL motor starter, and how would they be marked?

____

3. A three phase DOL starter is to be connected to a typical 415 volt single speed three phase squirrel cage induction motor which has a standard SIX terminal block. How should the motor be connected at the terminal block?

____

Electrical Drawing Conventions

Objective

To examine a given wiring diagram, and identify instances where the conventions of electrical drawing have not been followed.

Equipment

Sample wiring diagram.

Procedure

1. The wiring diagram on the attached sheet has instances of where the conventions of electrical have not been followed.

2. Alter the diagram so that it conforms to the conventions - using pencil throughout. Make the corrections as neatly as possible.

3. Submit your corrections to your Lecturer for comment and assessment.

Questions

1. What electrical drawing convention MUST be known in order to be able to read a circuit diagram accurately?

____

2. Neatly sketch two other non-standard drawing symbols for each of the following components:

   a. Normally open contacts.

   b. Normally closed contacts.

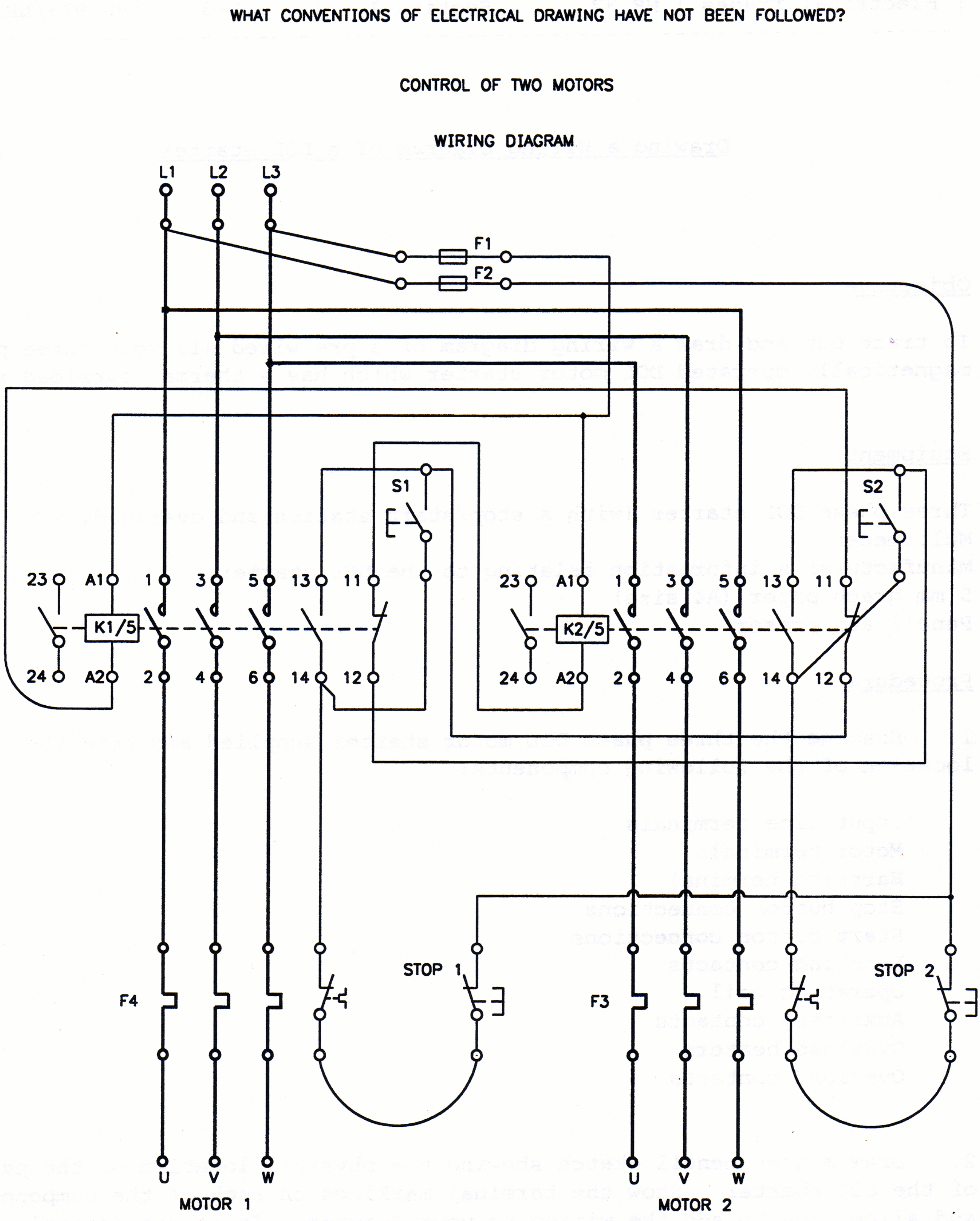
   c. Overload heater.

   d. Control circuit fuse.

   e. Start button.

   f. Stop button.

Wiring diagram to be corrected.



Drawing a Wiring Diagram of a DOL Starter

Objective

To trace out and draw a wiring diagram of a pre-wired 415 volt three phase magnetically operated DOL motor starter which has a thermal overload relay.

Equipment

Three phase DOL starter (with a stop/start station and overloads).
Multimeter.
Manufacturer's information relating to the DOL starter.
5mm graph paper (A4 size).
Pencil and eraser.

Procedure

1. Examine the three phase DOL motor starter supplied and note the location of the following components:

   Input line terminals
   Motor terminals
   Earthing terminal
   Stop button connections
   Start button connections
   Latching contacts
   Operating coil
   Auxiliary contacts
   Overload heaters
   Overload contacts

2. Draw a neat pencil sketch showing the physical location of the parts of the DOL starter. Show the terminal markings on each of the components, and allow room to add the wiring to your diagram. It is not essential to draw the components to an exact scale, but the approximate relative proportions should be maintained. A neat freehand sketch is preferred.

3. Draw a wiring diagram showing all wiring between terminals within the starter. All lines representing conductors must straight, and they must be horizontal or vertical as recommended by Australian Standards. Note that it is acceptable to show the wires in a slightly different position to that in which they appear on the starter to reduce the number of crossovers.

4. Use your eraser to adjust the position of the lines representing conductors to minimise cross-overs and unnecessary bunching.

5. Have your wiring diagram checked by your Lecturer.

6. Draw a circuit diagram of the power and control circuits of the starter using the horizontal format and Australian Standard electrical drawing symbols.

7. Submit your circuit diagram to your Lecturer for comment and assessment.

Questions

1. Which electrical drawing convention MUST be known in order to be able to read a circuit diagram accurately?

___

2. What are two advantages of using a magnetically operated DOL starter instead of a manually operated triple pole switch?

___

___

3. What are two of the main uses for a wiring diagram?

___

___

4. What two pieces of information can be obtained from a wiring diagram, but not from a circuit diagram of the same circuit?

___

5. What is another common name for a wiring diagram?

___

6. What is another common name for a circuit diagram?

___

Drawing Connections for a DOL Starter

Objective

To draw the connections necessary to wire up a three phase contactor and thermal overload relay as a three phase DOL motor starter.

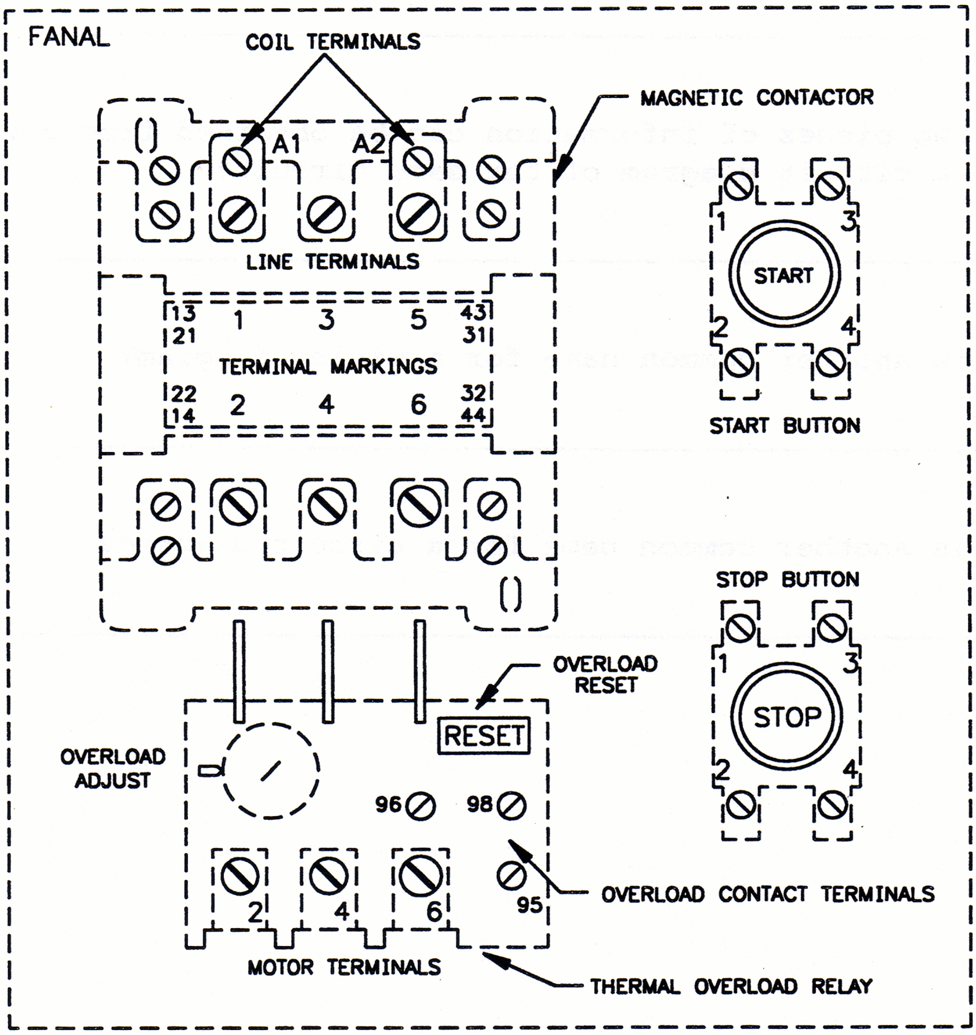
Equipment

Pencil and eraser.

Procedure

1. Diagram 1 below represents the internal components of a typical three phase DOL motor starter, with terminal labels as provided by the manufacturer.

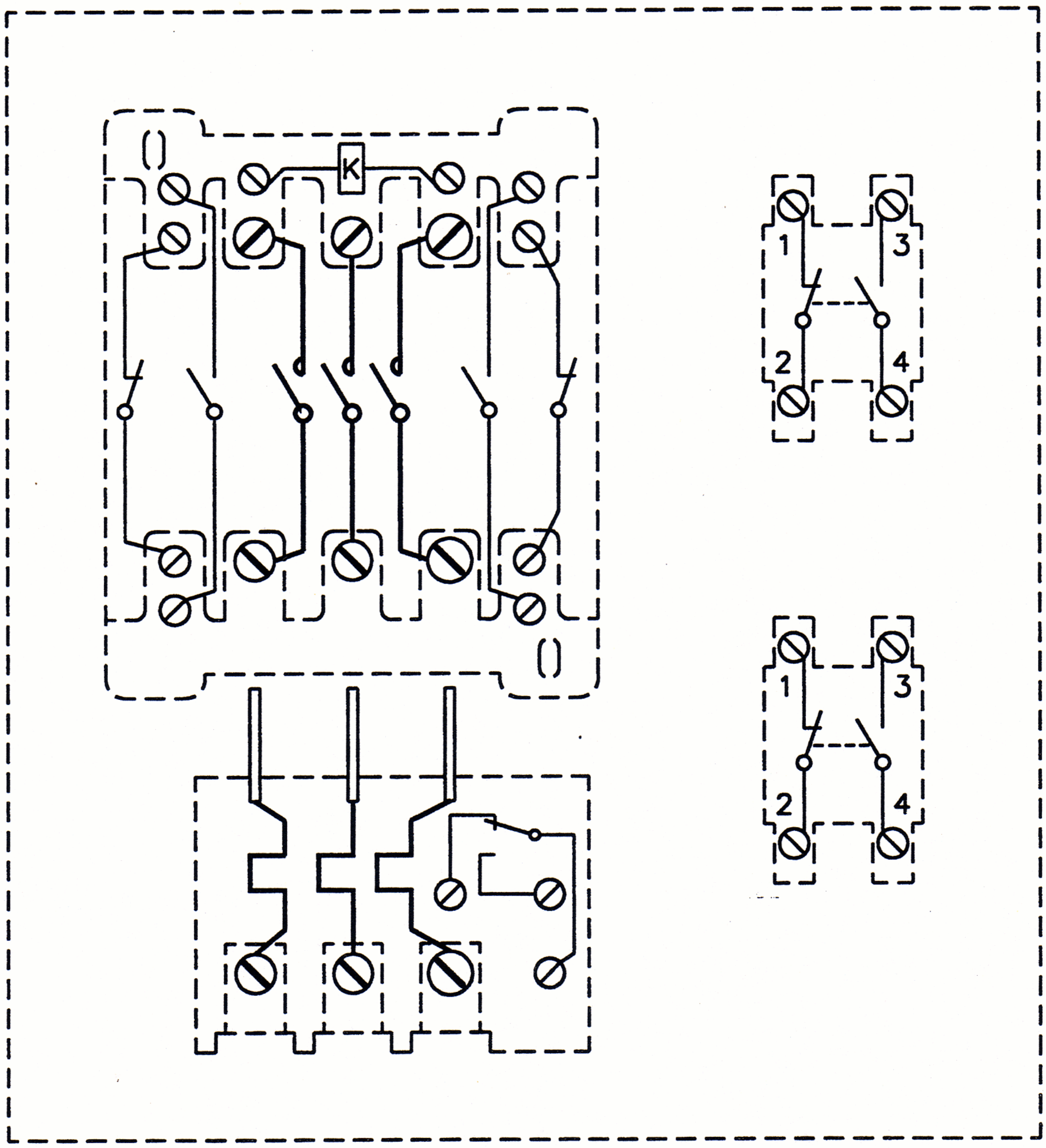
Diagram 1



FANAL
COIL TERMINALS
A1
A2
MAGNETIC CONTACTOR
LINE TERMINALS
13
21
1
3
5
43
31
TERMINAL MARKINGS
22
14
2
4
6
32
44
START
1
3
2
4
START BUTTON
STOP BUTTON
STOP
1
3
2
4
OVERLOAD RESET
RESET
OVERLOAD ADJUST
96
98
2
4
6
95
OVERLOAD CONTACT TERMINALS
MOTOR TERMINALS
THERMAL OVERLOAD RELAY

2. Diagram 2 shows the connections to the internal components in the same starter.

Diagram 2



3. Draw the connections necessary to connect the starter to a three terminal, three phase squirrel cage induction motor.

4. The contactor coil voltage is 415 volts.
   Label the incoming line terminals and the motor terminals.

5. Submit your completed diagram to your Lecturer for assessment and comment.

Questions

1. Did you use all of the available contacts in the contactor and the overload relay? If not, what would you do with the unused contacts?

2. What has been omitted from Diagram 2 to indicate that all of the contacts in the contactor operate at the same time?

Designing Control Circuits

Task:

To design, connect and test basic electrical control circuits to meet specified operational requirements.

Why:

Being able to design a basic electrical control circuit will enable you to understand the reasons why components are connected in a particular way. This is so that you can interpret more complex control circuits to determine how they work, and use the information to locate operational faults if they occur.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a competency test for each theory Learning Outcome.

2. You must design and draw basic electrical control circuits to suit given operational conditions.

3. You must identify common electrical components which perform a particular function, or sense a given condition in a control circuit.

Equipment:

Three phase DOL motor starters.
Three phase SCI motors.
Electrical control devices including thermostats, proximity switches, time delay relays, pressure switches, humidistats, limit switches, thermal overload relays, start buttons, stop buttons, jog buttons, photo-electrical detectors, lanyard switches, float switches and flow switches.
Samples of component mountings - including DIN rail, G rail, surface mounting, flush mounting and plug-in mounting.

References

* Drawing for Electrical Trades, 2nd Ed. James F. Rowe.
* Electrical and Electronic Drawing Practice for Students (SAA HB3-1986).
* Manufacturer's handbooks and data sheets.

Designing Control Circuits

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

   a. Electrical Principles Volume 1 and 2 6th editions - Jenneson

   b. Australian Standards AS 1102 and AS 1103

2. Read the Summary, and practise answering the questions provided on the Work Sheet.

3. Refer to other relevant texts if you feel it is necessary.

4. Examine AS 1102 and AS 1103 to see the type of information they contain, and the number and classifications of electrical drawing symbols and diagrams.

5. Answer the questions given on the Work Sheet. Use a separate answer sheet. Note that you are required to answer ALL questions correctly.

6. Complete the projects in this manual.

7. Submit your answers to the Work Sheet and your completed project reports to your Lecturer for discussion and assessment.

Designing Control Circuits

Control Circuit Components

An electrical control circuit is a specific arrangement of components which are intended to control, regulate or monitor a particular process.
In any control circuit there is a cause and an effect. Components which respond to a change in the operating environment are known as INPUTS, and those which are changed as a result of the process, are known as OUTPUTS.

A circuit in which a lamp is controlled by a manually operated switch is a simple example of a control circuit.

When the switch is operated, the lamp lights up; the switch is the input, manual operation of the switch is the process, and the lamp is the output.

Typical input devices in electrical circuits include start buttons, stop buttons, limit switches, overload contacts, thermostats, pressure switches and float switches.

Typical output devices include solenoids, relay or contactor coils, indicator lamps and alarm bells.

The inputs provide the INFORMATION which is to be processed, and the outputs take the necessary ACTION in accordance with the design of the circuit.

In many cases it is not sufficient to only have inputs and outputs. It may be necessary to produce an output only if a particular combination of inputs is present.

Consider the example of a thermostat controlling the temperature of a wall oven. The heating element is only required to come on if the main switch is on AND the contacts in the oven thermostat are closed.

The circuitry which results in an output if certain conditions are met, is known as the DECISION-MAKING component of the circuit or the 'control logic'.

Other types of decision making components in control circuits include timers (for causing a time delay to occur before the next operation), counters (for counting the number of occurrences of a particular event), and many types of sensors which are capable of sensing conditions such as speed, direction, level, pressure, flow and position.

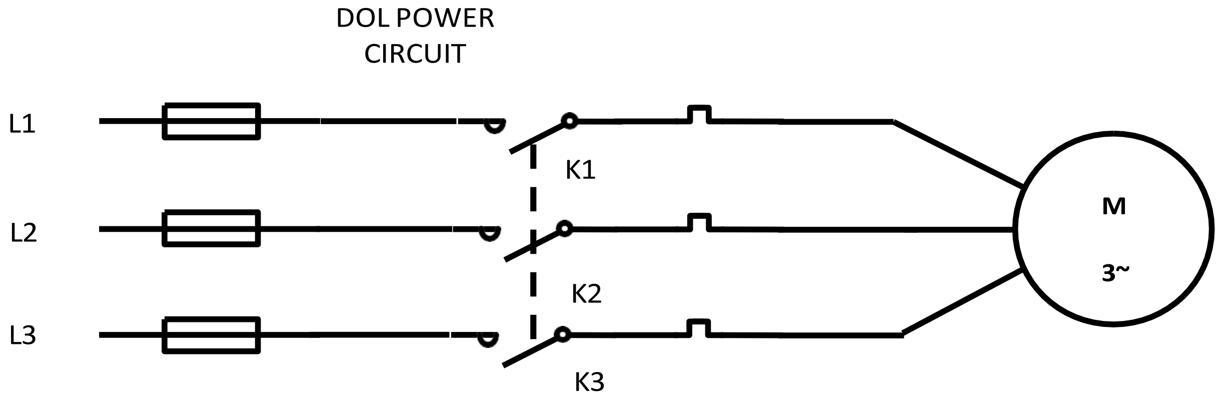
Thus, most control circuits have inputs (for information), outputs (for causing specific action) and decision making components (for deciding when the output is required).

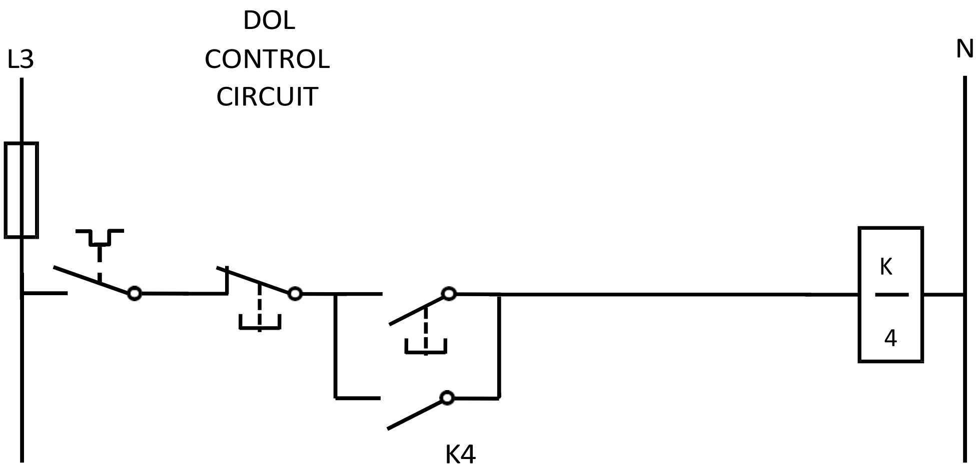
A common method of implementing such control circuits is by using magnetic relays or contactors in conjunction with various types input, output and decision making devices.

DOL Starter Circuit

A common example of the use of magnetic contactors is in a three phase direct on line (DOL) magnetic starter.

Figure 1 is a circuit diagram of a 5 kW, three phase magnetically operated DOL motor starter with a 240 volt control circuit, an inbuilt stop/start station, and a thermal overload relay.





Operation of circuit

a. When the start button is pressed, contactor coil K/4 is energised via the normally open start button, normally closed stop button and normally closed overload contacts.

b. When K/4 is energised, the normally open contacts K1, K2 and K3 close and the motor starts.

c. At the same time the normally open contact K4 closes, retaining (or latching) the coil K/4 so that the start button can be released.

d. The motor continues to run until the normally closed stop button is pressed, the normally closed overload contacts open, or the supply is switched off.

The main features of the circuit in Figure 1 are:

a. The power circuit and the control circuit are electrically separate and operate on different voltages (415 volts and 240 volts).

b. When the contactor coil is energised, it causes contacts to be made in both the power and control circuit.

c. The overload heaters are connected in the power circuit, but the overload auxiliary contacts are connected in the control circuit.

d. The cables in the power circuit would be much larger than those required in the control circuit.

e. The components in the circuit are:

A contactor which operates four contacts.

An overload relay consisting of a sensing mechanism (thermal) and a set of normally closed contacts.

A normally open start button.

A normally closed stop button.

A 5 kW, three phase motor.

f. The latching (or retain) contact K4 operates at the same time as the main contacts. The stop button and the thermal overload relay contacts can be connected anywhere on the left side of the contactor coil, as long as they are in series with the contactor coil, but where possible they should be after the start button and retain contact if the coil voltage is 240 volts. This is so that the minimum number of internal components are live when the starter is not operating.

g. All internal components are 'hard wired' inside the starter enclosure.

In Figure 1 the three types of component in the CONTROL circuit are:

Inputs	**Control Logic**	**Output**
Start button	Latching contact, (decision making)	Contactor coil
Stop button		
Overload contacts		

The 5 kW motor is not classified under one of the headings, because it is controlled by one of the outputs.

The overload heaters are not classified under one of the headings because they are simply the part of the overload mechanism which causes the contacts to open.

It is important for you to be able to sketch the circuit for a magnetic contactor used as a DOL starter, because it forms the basis of many other types of control circuit.

Time Delay Relays

A very common type of decision making component in relay or contactor control circuits is the time delay relay.

A basic time delay relay (TDR) is a device which causes contacts to open or close at a pre-determined time after the operating mechanism has been energised.

The symbol for the operating coil of a time delay relay is the standard symbol for a relay or contactor coil with an additional qualifying component to indicate a delay on operating or a delay on releasing.

The symbol for a time delay relay contact is a normally open or normally closed contact with a semicircle to represent the direction in which the time delay occurs - either opening or closing - as shown in Figure 2.

Delay on Energising (DOE) Delay on De-energising (DDE)

Delay on Energising (DOE) Delay on De-energising (DDE)

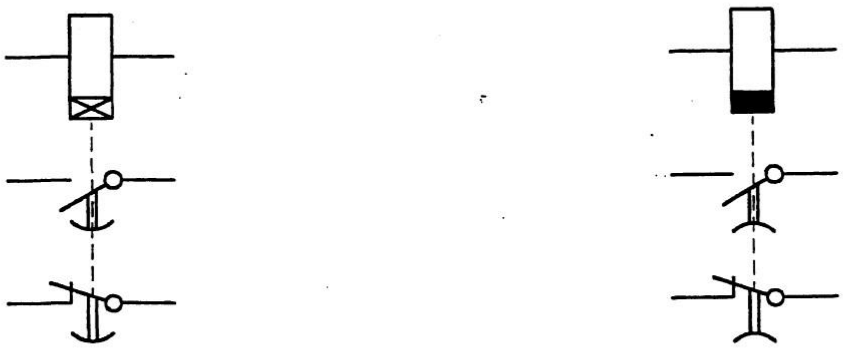


Figure 2 - Time delay relays and associated contacts.

The DOE timer (or delay-on timer) causes the contacts to operate a specified time after the operating mechanism has been energised.

The DDE timer (or delay-off timer) causes the contacts to operate a specified time after the operating mechanism has been de-energised.

Both types can have different combinations of normally open or normally closed contacts, but the usual arrangement is one of each type of contact.

Another type of time delay relay provides both an on-delay and an off-delay function - the contact symbols are shown in Figure 3.

Figure 3 - Time delay opening and closing contacts.

The time delay is achieved in a variety of ways including:

Pneumatically

When the operating coil of the timer is energised, air is forced through a small adjustable hole - the time taken for the air to pass through the hold governs the time delay.

Electronically

When the operating coil of the timer is energised, a capacitor is discharged through an adjustable resistor to provide a variable time delay.

Electromechanically

When the timer is energised, a small clockwork or other motor mechanism begins to operate and provide an adjustable time delay.

Designing a Control Circuit

The first step in designing a control circuit, is to make sure that you have a clear understanding of what the circuit is required to do. This is known as the circuit description.

Circuit Description

A 10 kW, 415 volt three phase motor is to be started using a two-step primary resistance starter. Also, the motor is to be started and stopped from either of two stop/start stations.

When the motor starts, two large resistors are connected in series in each line to limit the starting current.

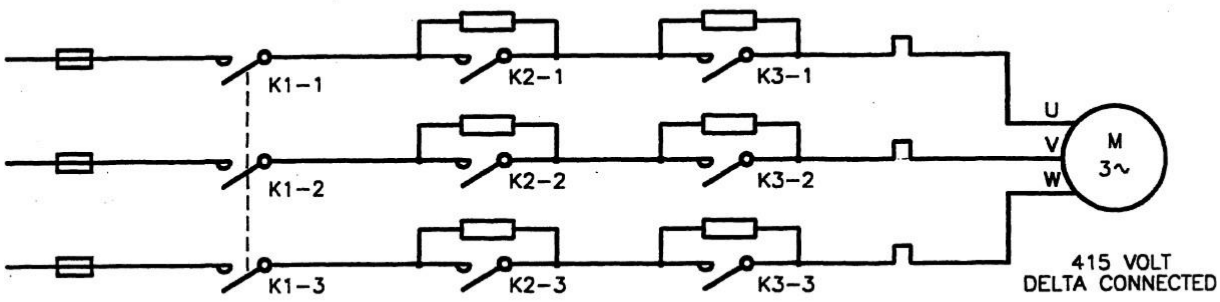
Five seconds after the motor starts, a contactor operates, and short circuits three of the resistors individually.

Five seconds later another contactor operates and short circuits the other three resistors individually so that the motor is then running direct on line.

The coil voltages are to be 240 volts.

The power circuit is shown in Figure 4. (This arrangement is known as a 'Two-Step Primary Resistance Starter').

Figure 4

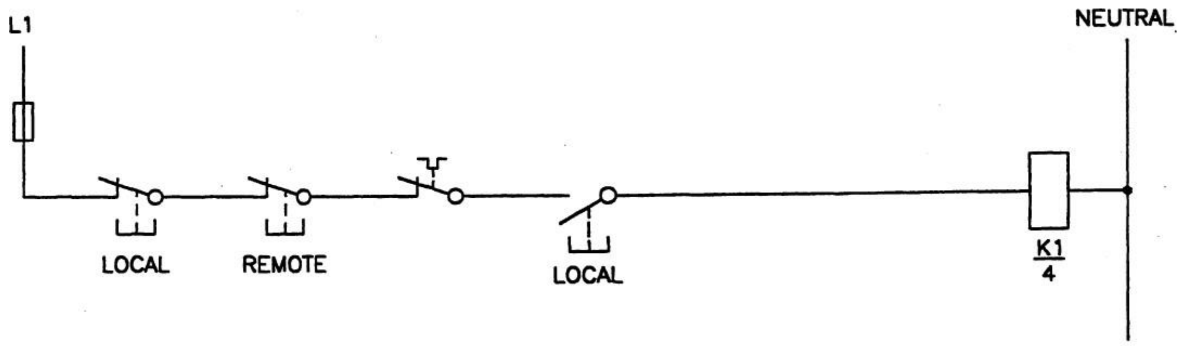


19. **Typical Design Steps**

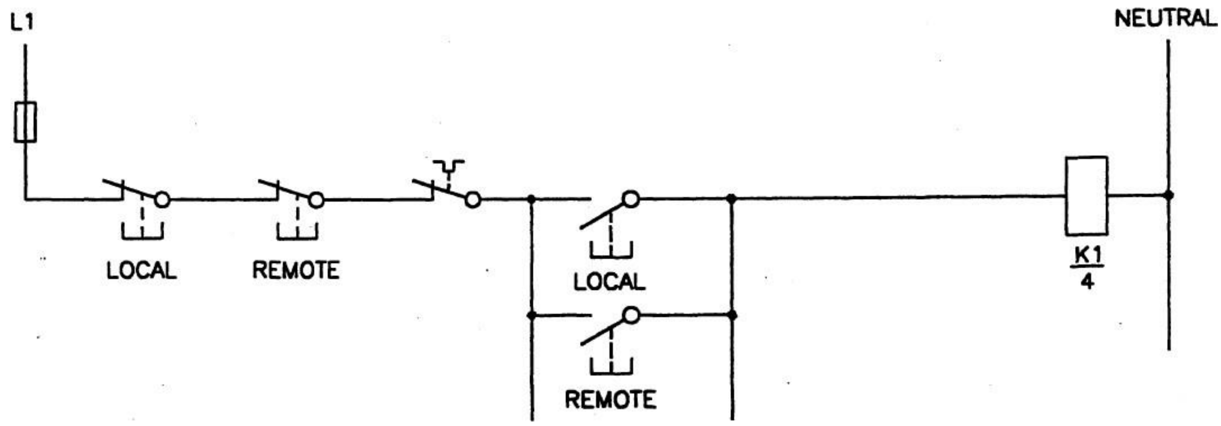
a. The first step is to draw two vertical lines about 120mm apart to represent the supply 'rails' (L1 and neutral).

Show a fuse in series with L1 and the contactor coil K1 connected to the neutral (K1 is the main line contactor so it must be energised first).

b. Three normally closed components are required to be in series with the main line contactor (two stops and an overload contact), and a normally open local start button - so add these to the circuit in series with K1.

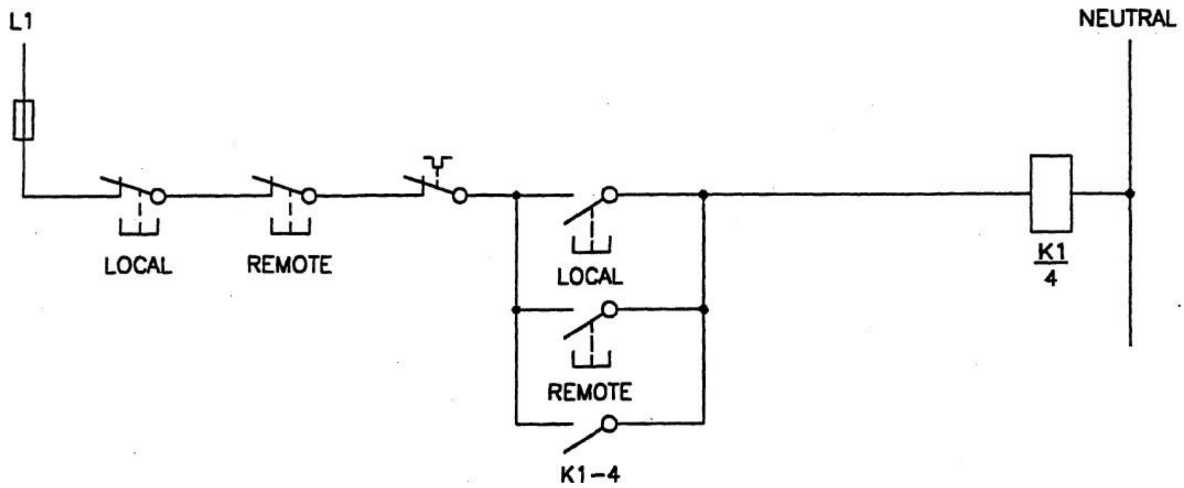


c. There are to be two start buttons, so add a remote start button in parallel with the local start button (multiple start buttons must be connected in parallel).

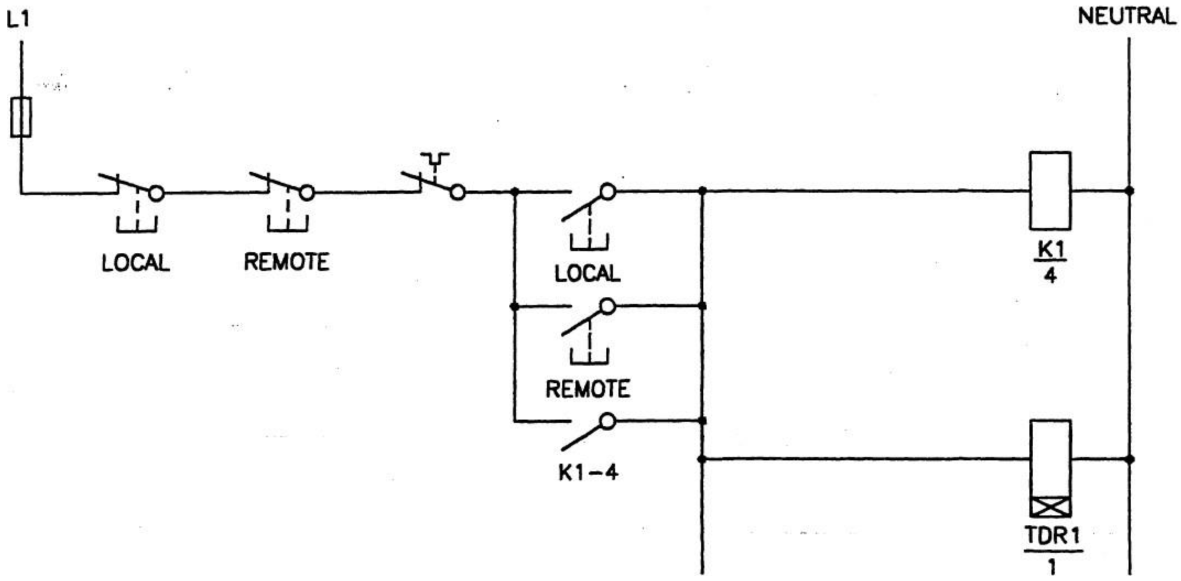


d. The contactor coil K1 must be retained after the start button is released, so use one of the normally open auxiliary contacts of K1 and connect it in parallel with the start buttons.

The first three contacts of K1 are used in the power circuit, so label the retain contact as K1-4.

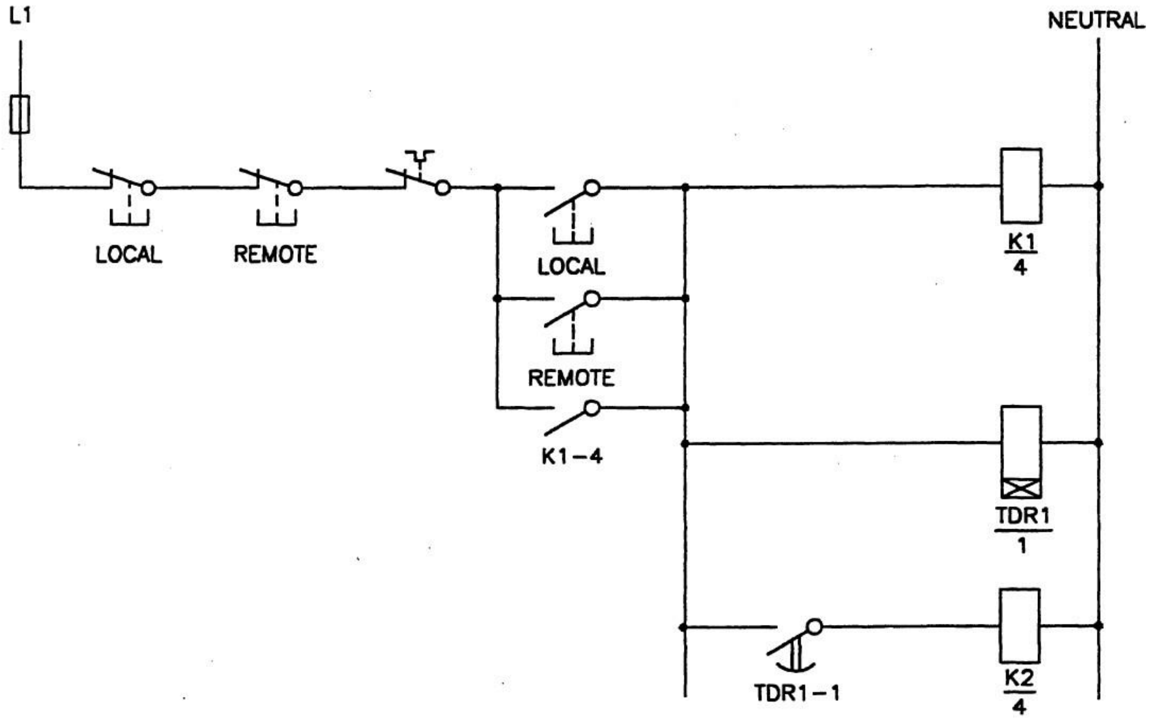


e. Timer 1 is required to start timing as soon as the main line contactor is energised, so connect it in parallel with the contactor coil K1, and label it as TDR1.



e. When Timer 1 has timed out, it is required to energise the 'accelerating' contactor K2 to short circuit the first bank of three resistors, so connect a normally open contact from TDR1 in series with the coil for K2.

The supply for K2 needs to be removed if either a stop button is pressed, the overload

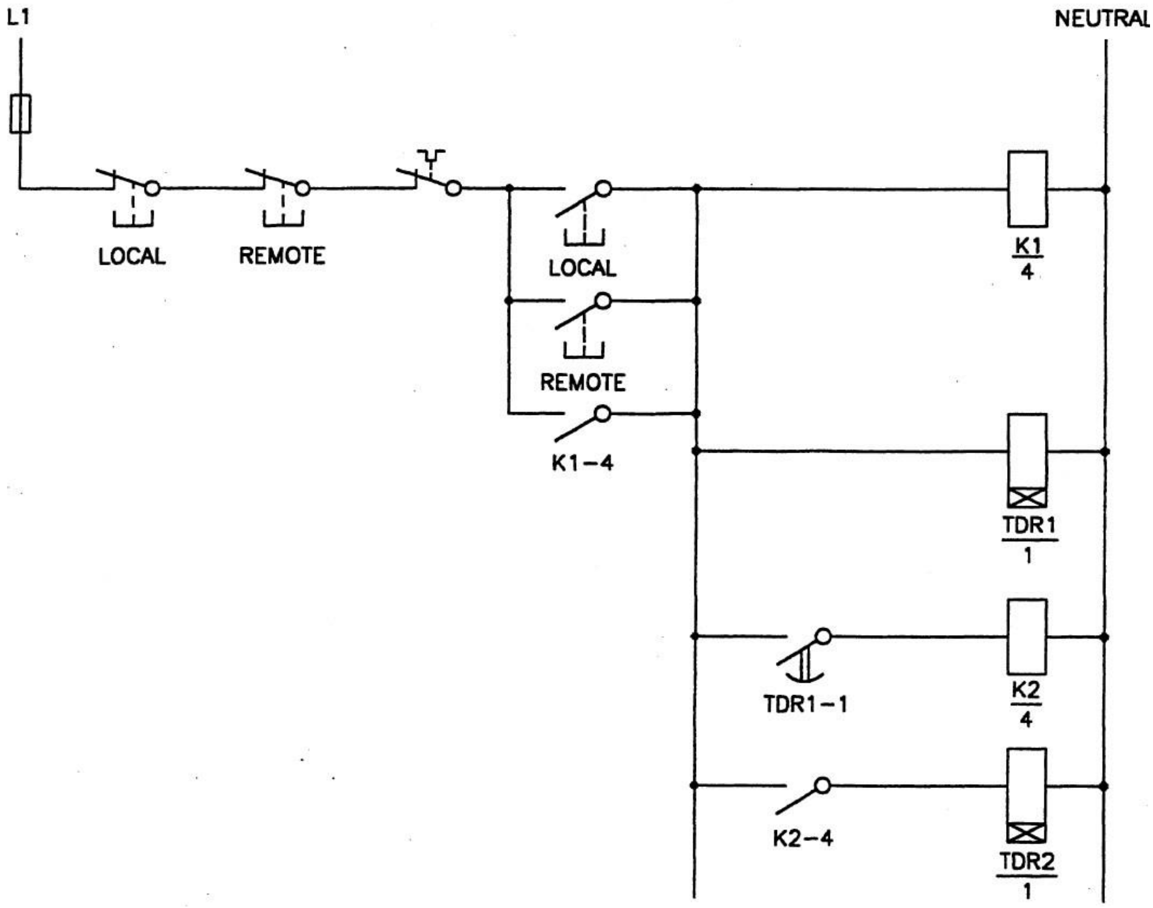


contact opens, or the retain contact is opened, so it needs to come from the load side of the retain contact (via the TDR1 contact).

f. Timer 2 is required to start timing as soon as contactor K2 is energised, so connect a normally open auxiliary contact from K2 in series with it and label it as K2-4.

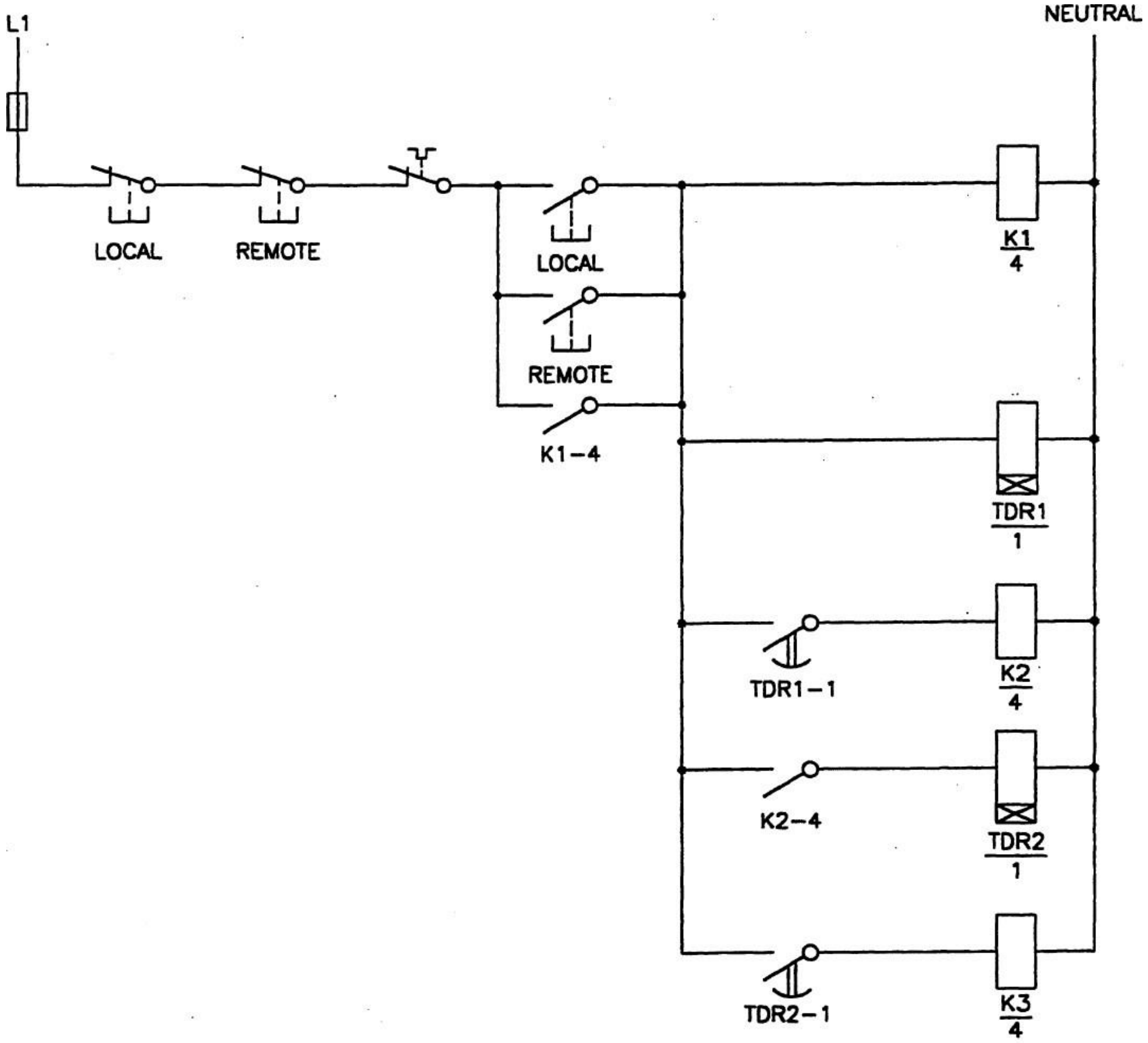
Label Timer 2 as TDR2.

The supply for TDR2 needs to come from the load side of the retain contact (as for K2).



g. When Timer 2 has timed out, it is required to energise the second 'accelerating' contactor K3 to short circuit the second bank of three resistors, so connect a normally open contact from TDR2 in series with the coil for K3.

   The supply for K3 needs to be removed if a stop button is pressed, the overload contact opens, or the retain contact is opened, so it needs to come from the load side of the retain contact (via the TDR2 contact).



h. Check the circuit to see that it meets the specifications in the circuit description and all relevant components are appropriately labelled.

Check to see that the circuit is 'lock-out-stop' i.e. - if any start button is pressed while a stop button is pressed the motor must not start.

If it is correct, the circuit is complete.

This process of considering each rung of the ladder diagram in sequence can be applied to simple circuits, but for more complex circuits, much more sophisticated design techniques must be used.

Other techniques will be introduced in later modules.

Indicator Lamps

It is often necessary to shown the status of particular relays or contactors in a control circuit - either adjacent to the equipment being controlled or on a 'mimic panel' in a control room.

Indicator lamps are usually connected in the control circuit (not the power circuit) so that they operate when the contacts of the associated relay or contactor are in a particular condition.

It is customary to operate indicator lamps in control circuits using auxiliary contacts of relevant relays or contactors rather than connecting them in parallel with the relay or contactor coil.

If an indicator lamp is connected in parallel with a relay coil, and the relay coil is open circuited, the indicator lamp could come on when a voltage was applied to the coil, giving a false indication.

A wide range of electronic and mechanical switching devices are available to provide input to a control circuit when particular physical conditions are met.

They are usually referred to as 'field' devices, because they are physically located 'in the field' or away from the panel on which the associated relays and control equipment is mounted.

In many cases the devices are digital in nature, that is, they only have two operating conditions - off or on, in or out, true or false, etc.

The most common field input devices include:

a. Thermostats - devices which operate one or more sets of contacts when the temperature of the device or an associated sensor reaches a pre-set value.

b. Thermocouples – there are various types of thermocouples that convert heat to voltage and are widely used in industry.

c. Proximity Switch - devices which operate one or more sets of contacts when an object comes near them, without the object having to actually touch the proximity sensor.

d. Interlocks Contacts from one relay connected in the control circuit of another relay, so that the controlled relay can only operate if the interlocking contacts are in a particular condition. (Can also be mechanical interlocks - see star-delta starters). Most interlocking is done within a control panel rather than using field devices.

e. Pressure Switches - devices which operate one or more sets of contacts when the pressure in an associated sensing mechanism reaches a pre-set value.

   Different types are available to sense gas pressure, air pressure or liquid pressure.

e. Humidistats - devices which operate one or more sets of contacts when the humidity (moisture content) of the surrounding air reaches a pre-set value, regardless of the ambient temperature of the air.

f. Limit Switches - devices which operate one or more sets of contacts when a mechanical mechanism reaches a particular position - often at the end of the designed travel.

g. Photo-electric Switches - devices which operate one or more sets of contacts when a beam of visible or invisible (infra-red) light is interrupted by the presence of a solid object.

h. Solenoids Magnetic - devices in which a movable armature is attracted into the centre of an electromagnetic coil when the coil is energised, thus causing some other mechanical device (such an air or hydraulic valve) to operate.

i. Jog (Inching) Buttons - push-buttons which have two sets of contacts, one set normally open and one normally closed.
   They are normally used in conjunction with magnetic DOL starter circuits.

The controlled relay or contactor is energised when the jog button is pressed, and de-energised when the button is released, but the relay or contactor operates from an adjacent normal start or stop button in the usual way.

j. Lanyard switches - a switch which is connected to a rope so that the switch can be operated by pulling on the rope from any position - they are often used for emergency stop switches beside long conveyers.

k. Float Switches - switches which are arranged so that they operate one or more normally open or normally closed contacts when the level of liquid in a container reached a pre-set position.

l. Flow Switches - switches which are designed to operate one or more normally open or normally closed contacts when a liquid or gas flows through an associated pipe or duct.

m. Time Switches - switches which are designed to operate one or more normally open or normally closed contacts at a particular time each day (or week etc.).

(Time switches are different from time-delay relays which operate at a pre-set time after they are energised.)

Mounting Positions

23. Input devices such as those listed above are virtually always located away from the main control panel, so they must be hard wired into the control circuit.

Other devices such as relays, contactors, timers and counters are usually located on the associated control panel.

The most common methods of mounting equipment on control panels include:

a. DIN Rail.
b. G Rail.
c. Plug-in mounting.
d. Surface mounting (bolted direct to the control panel).
e. Flush mounting (only the actuating mechanism visible).

24. You will get the opportunity to see and connect control circuits and associated components during the laboratory segment of this module.

Designing Control Circuits - 1

1. Name four electrical components which would be classified as 'input devices' in a control circuit.
2. Name four electrical components which would be classified as 'output devices' in a control circuit.
3. What is the 'decision making' component of a typical three phase magnetic direct-on-line motor starter?
4. What are the names given to the two parts of any magnetic relay circuit?
5. In which part of a typical three phase motor starter circuit would the start and stop buttons be connected?
6. A particular solenoid operated valve has an operating coil voltage of 24 volt d.c. Would it be safe to connect the solenoid in a 24 volt a.c. control circuit?
7. Could a 415 volt, 20 amp DOL starter with a utilisation category of AC1 be used to control a 415 volt, 20 amp three phase motor which was subject to frequent reversing?
8. What effect would it have on the operation of a magnetic DOL motor starter if the latching or retain contact was open circuited?
9. If a relay or contactor control circuit is to have multiple start buttons, how must they be connected?
10. If a relay or contactor control circuit is to have multiple stop buttons, how must they be connected?
11. What is the advantage of using a magnetic contactor and two stop- start stations to control a motor from two positions, rather than start using two triple pole switches connected in parallel?
12. How must start buttons be connected in relation to the relay or contactor COIL they control?
13. How must stop buttons be connected in relation to the relay or contactor COIL they control?
14. What is the purpose of an electrical interlock?
15. How does a magnetic motor starter circuit provide under-voltage protection for the motor?
16. What is the operational difference between an 'on-delay' timer and an 'off-delay' timer?
17. What is the disadvantage of connecting an indicator lamp in parallel with the associated contactor or relay coil?
18. What causes a 'normally closed' contact to be closed?
19. Approximately how much current would normally flow in the control circuit of a typical magnetic three phase 415 volt DOL motor starter which has a 415 volt operating coil?

20. What commonly used type of push-button is 'normally closed'?

21. What commonly used type of push-button is 'normally open'?

22. Which part of a typical magnetic contactor circuit would need to be wired with the largest size conductors?

23. One component on a circuit diagram of a magnetic contactor is marked K/4, and another is marked K4. What type of component would each marking usually represent?

24. What are the two main functional components in an 'overload relay'?

25. What is the purpose of a 'latching contact' in a typical magnetic contactor or relay circuit?

26. Would it be possible for a 415 volt a.c. magnetic contactor coil to be replaced with a 24 volt a.c. coil if the control voltage in the circuit was to be reduced to 24v a.c.?

Control Circuit Component Identification

Objective

To select control circuit components suitable for performing specified functions.

Equipment

Individual components.
Multimeter.
Manufacturer's information relating to the components.

Procedure

1. The Table which follows shows a function to be implemented in an electrical control circuit for an industrial process. Write the name of one device which could be used for the purpose given.

   Select a sample of the type of device from the components supplied, or from a manufacturer's catalogue, and complete the 'Number of Contacts' and 'Resistance' columns of the Table where applicable.

   Use a multimeter to determine the status of the contacts where applicable, and show the result in symbol form in the Table.

Function Table

Required Function	Name of Device	No of Contacts	Resistance
Operate a remote air valve			
Close when the water level reaches a given			
Close when water flows in a pipe			
Close when the temperature reaches a pre-set level			
Open when the cords pulled from any one of 10 positions			
Open when the air pressure in air receiver reaches a pre-set level			
Close a contact at 8.00am each day and			

open it at 8.30am on the same day			
Close when the humidity in a room reaches a pre-set level			
Close contacts 15 seconds after the device is energised			
Open when a hoist reaches the upper limit of its travel			
Close contacts as a box on a moving conveyor passes through an invisible light beam			
Close contacts when a steel object passes within 20mm of a single sensor			
Open one contact and close another when the button is pressed			

2. Examine the components on the component mounting project board and determine how each one is held in position.

   Name the component and the type of mounting used for each:

Component 1: ____________________ Mounting: ________________________

Component 2: ____________________ Mounting: ________________________

Component 3: ____________________ Mounting: ________________________

Component 4: ____________________ Mounting: ________________________

Component 5: ____________________ Mounting: ________________________

Component 6: ____________________ Mounting: ________________________

Component 7: ____________________ Mounting: ________________________

Component 8: ____________________ Mounting: ________________________

3. Have your results checked by your Lecturer.

4. Return all of the equipment to its proper place.

Questions

1. What are six of the factors which should be considered when selecting a relay, contactor or other electrical component for use in a control circuit?

   1. ______________________________
   2. ______________________________
   3. ______________________________
   4. ______________________________
   5. ______________________________
   6. ______________________________

   ____

2. A particular solenoid operated valve has an operating coil voltage of 24 volts d.c. Would it be safe to connect the solenoid in a 24 volts a.c. control circuit?

   Give a reason for your answer.

   ____

   ____

Converting Wiring Diagrams to Circuit Diagrams

Types of Diagrams

The main uses for a wiring diagram are to wire up a circuit, trace existing wiring, and determine the location of components on a control panel or in a motor starter.

The location of the components is relatively fixed, junctions are shown at terminals, and the wiring If a circuit diagram is not available, determining the operation of the circuit, and locating operational faults, can be a very time-consuming process, so it can be useful to draw a circuit diagram from an actual circuit or from a wiring diagram.

For the purposes of this module, the main focus is on converting an existing wiring diagram into a circuit diagram.

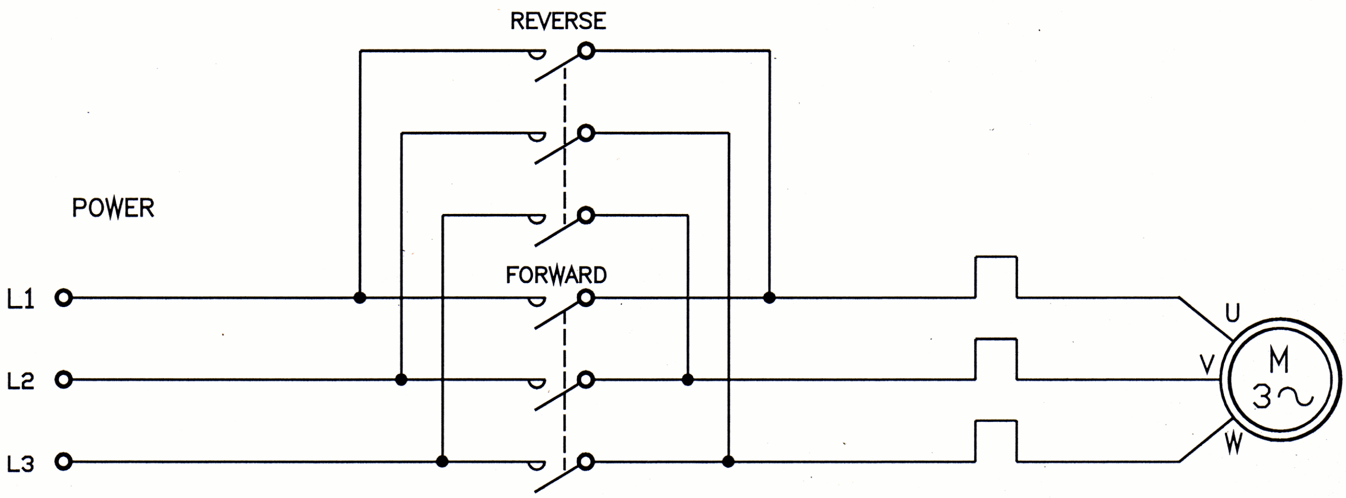
When drawing a circuit diagram of a control circuit, it is usually best to use the horizontal ladder diagram format, in which the main sequence of events is shown in horizontal lines similar to the rungs of a ladder.

A power circuit can be drawn in either the horizontal format or the vertical format, but it is usually more convenient to use the horizontal format.

The three basic steps required are

1. Identify active and neutral,
2. Number the conductors,
3. Identify components.

Figure 1 is an example of a typical power circuit in horizontal format, with the corresponding control circuit in ladder diagram format. It is provided as a model of the type of circuit diagrams you are expected to produce during this module (numbering of conductors will be required later).


REVERSE
POWER
FORWARD
L1
L2
L3
U
V
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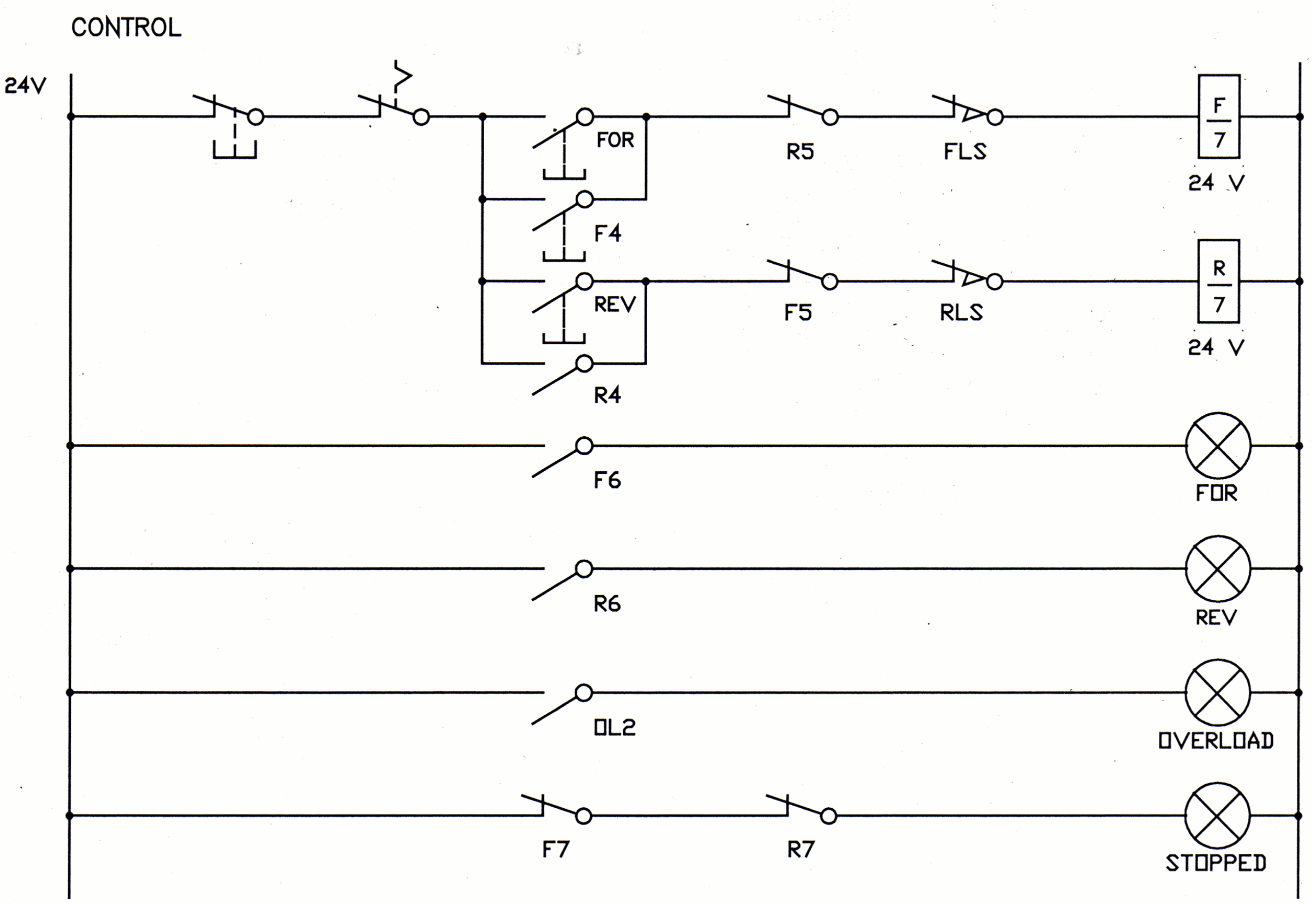
M
3~


CONTROL
24V
FOR
F4
REV
R4
R5
FLS
F5
RLS
F
7
24 V
R
7
24 V
F6
FOR
R6
REV
OL2
OVERLOAD
F7
R7
STOPPED

Converting a Wiring Diagram to a Circuit Diagram

To describe the process of converting a wiring diagram to a circuit diagram, we will use the three phase DOL starter with two stop-start stations shown in Figure 2.

You should use a pencil when converting diagrams, because you will need to erase parts of the circuit to make changes as you progress.

5 mm square graph paper is also useful.

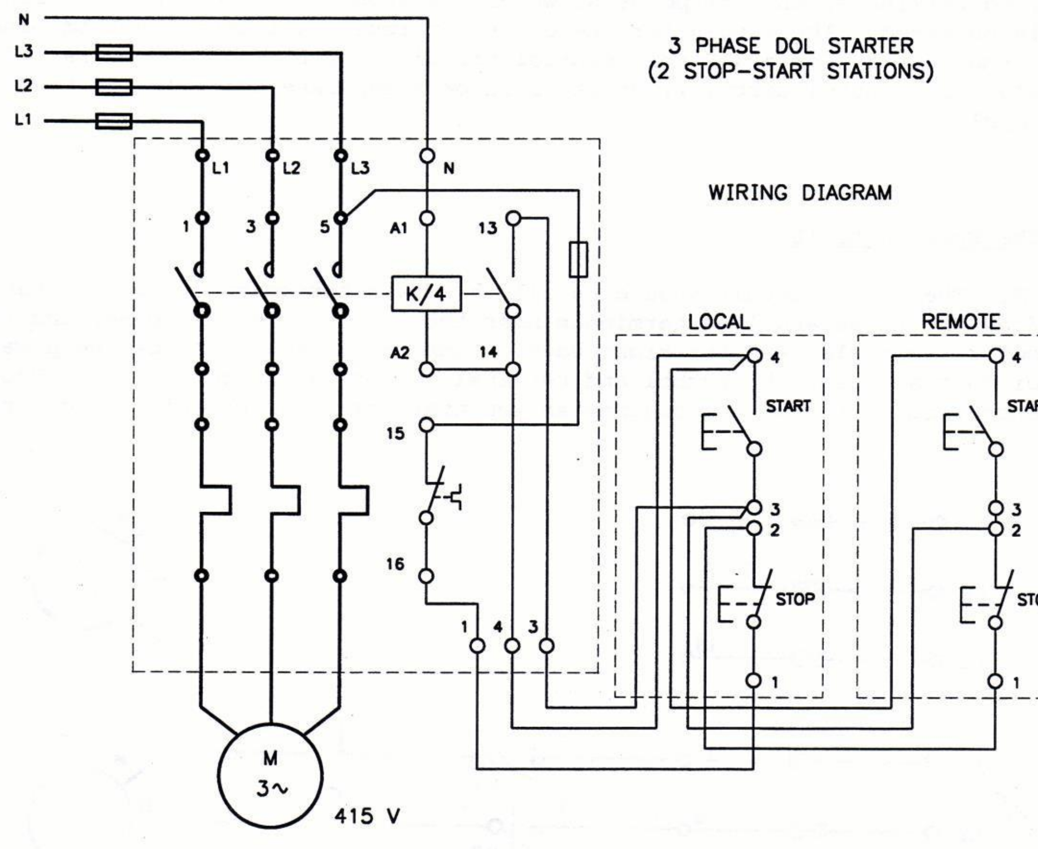


Figure 2 - Wiring diagram to be converted.

Identify the Components

You can see that all the terminals at which connections are made are numbered - if this was not the case you would need to allocate a number to each terminal, making sure that the number you assign to each terminal on a single component is different.

Notice also that the three line fuses are external to the actual starter, but it is common to include them in the circuit diagram.

The next step is to ensure that you know what each symbol on the wiring diagram represents.

The sample diagram used standard symbols, so you should be able to recognise them, but in many cases manufacturers use non-standard symbols.

If you were in any doubt in a practical situation, you would be able to examine the actual component to see that you had correctly identified it.

The next step is to ensure that you can see which contacts are operated by each component.

This may not always be obvious, particularly on wiring diagrams which show components close together.

If there is any room for doubt, you should indicate the relationships by drawing a line around components and their associated contacts, and assign a unique label to each contact if they are not already labelled.

You should also note the position of the incoming line terminals, the load terminals, and the point at which the supply for the control circuit is obtained.

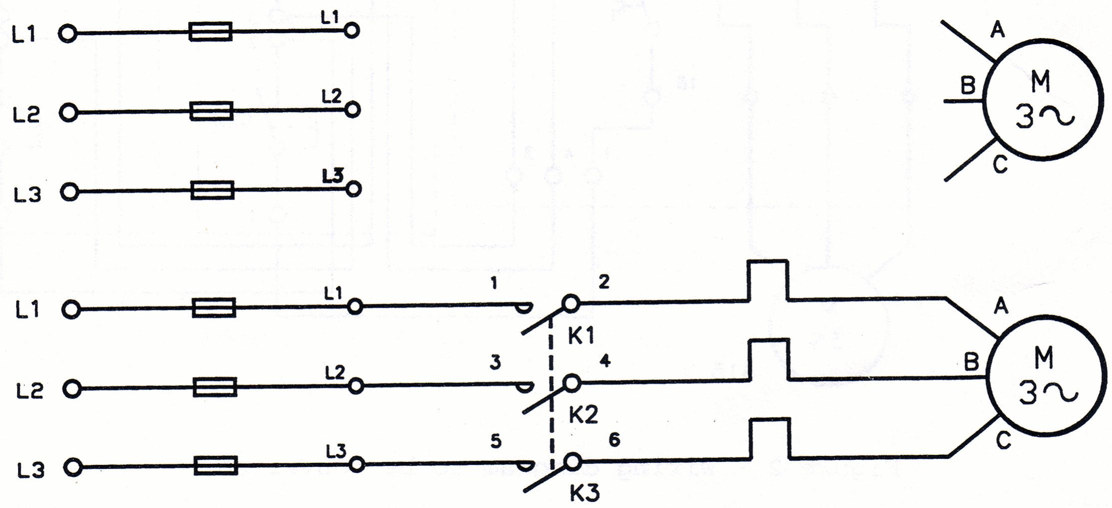
The supply for the control circuit will often be from Line 1 and Line 3 (for a 415 volt control circuit), or Line 3 and Neutral (for a 240 volt control circuit), or it could be a separate extra-low voltage supply.

The Power Circuit

The power circuit should usually be drawn horizontally, so you can draw the fuses and line terminals near the left edge of the paper, and the motor terminals near the right edge.

Then, trace each phase of the power circuit, and draw the symbol and terminal number as you come to it.

Cross each wire on the wiring diagram as you transfer it to the circuit diagram.

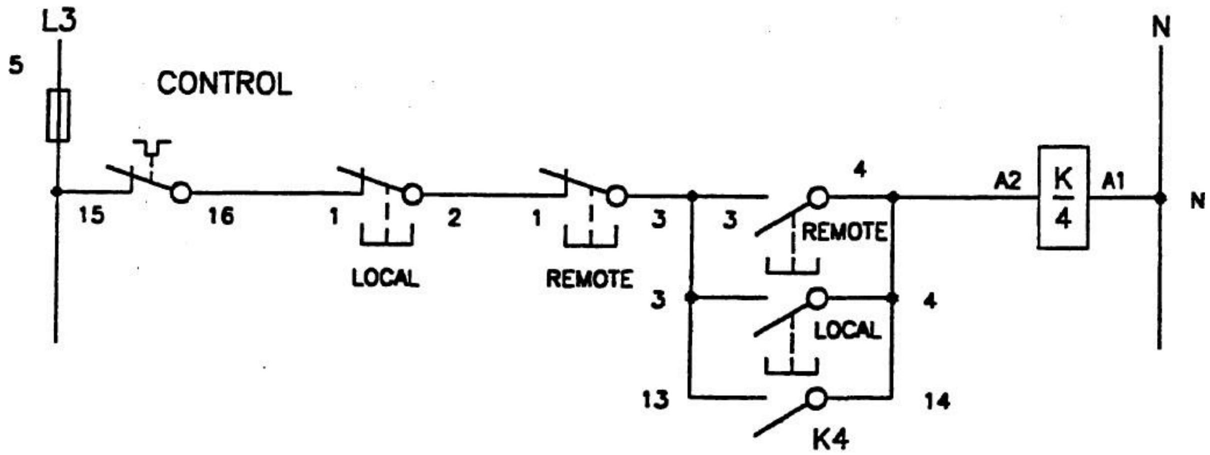


The Control Circuit

To draw the control circuit, you should draw a vertical line at each side of your paper to represent Line 3 (on the left) and Neutral (on the right).

Show the fuse(s) and the components being controlled (in this case the contactor coil K).

Trace the remainder of the control circuit conductors in turn, marking each one off as you go and labelling each component as you draw it. When you come to a terminal which has more than one wire connected to it, show a junction then continue to follow one of the wires. When you reach the controlled component, return to the junction and follow other conductor(s) to their destination.



When you have traced the complete circuit, it will usually be necessary to erase parts of the circuit and re-draw them to minimise cross-overs, and show the circuit in its simplest form. Each successive rung of the ladder should indicate the general sequence of events in the circuit where possible.

Checking the Operation of the Circuit

The next step is to describe the operation of the circuit from your circuit diagram to make sure that it operates as it should.

There are numerous methods of describing the operation of a control circuit (often called a 'circuit explanatory') - the following is typical:

When the remote start is pressed, current flows from L3, through the normally closed overload contacts, through the normally closed stop buttons, through the now closed start button, through the contactor coil, and out to neutral.

When K/4 is energised, the three line contacts in the power circuit close, and current flows to the motor via the fuses and the overload heaters - the motor starts.

At the same time, the normally open retain contacts K4 close to hold the contactor coil in, so the start button can be released.

When any stop button is pressed, or the overload relay operates, the circuit to the contactor coil is broken, and the contactor drops out.

This opens the power contacts to the motor and the retain contacts in the control circuit, so the motor stops.

The same general process can be applied to converting any wiring diagram into a circuit diagram.

The task is easier if you know in advance what the circuit is intended to do, but it is not essential.

In some cases it may be necessary to accurately convert the wiring diagram to a circuit diagram before the operation of the circuit can be determined.

Legends

If a particular circuit has special components for which standard symbols are not available, or when the labels on components are intended to convey information relating to their function, you should provide a legend which details the meaning of any special symbol or label.

Storage

When you have converted a wiring diagram into a circuit diagram, you should check it carefully, and then store it in a place where it will be accessible to others in the future.

Notes

Converting Wiring Diagrams to Circuit Diagrams

1. What is the essential difference between a circuit diagram drawn in the horizontal format, and a circuit diagram drawn in the vertical format?
2. Why is a 'ladder diagram' so called?
3. What is the common name given to the vertical lines which represent the incoming supply in a ladder diagram?
4. What are the three most important steps to take when starting to convert a wiring diagram to a circuit diagram?
5. Why is it important to mark of each conductor as you go when converting a wiring diagram to a circuit diagram?
6. What is the common name of the written or verbal description of a circuit based on a circuit diagram?
7. What is a legend when used in association with a circuit diagram or wiring diagram?

Converting a Wiring Diagram to a Circuit Diagram

Objective

To convert a given wiring diagram to a circuit diagram, and write a circuit explanatory for the circuit using your circuit diagram.

Equipment

Sample wiring diagram(s).
5 mm square graph paper.
Pencil, eraser and ruler

Wiring Diagram

The diagram on the following page is a wiring diagram of a circuit which controls two 415 volt three phase squirrel cage induction motors.

Procedure

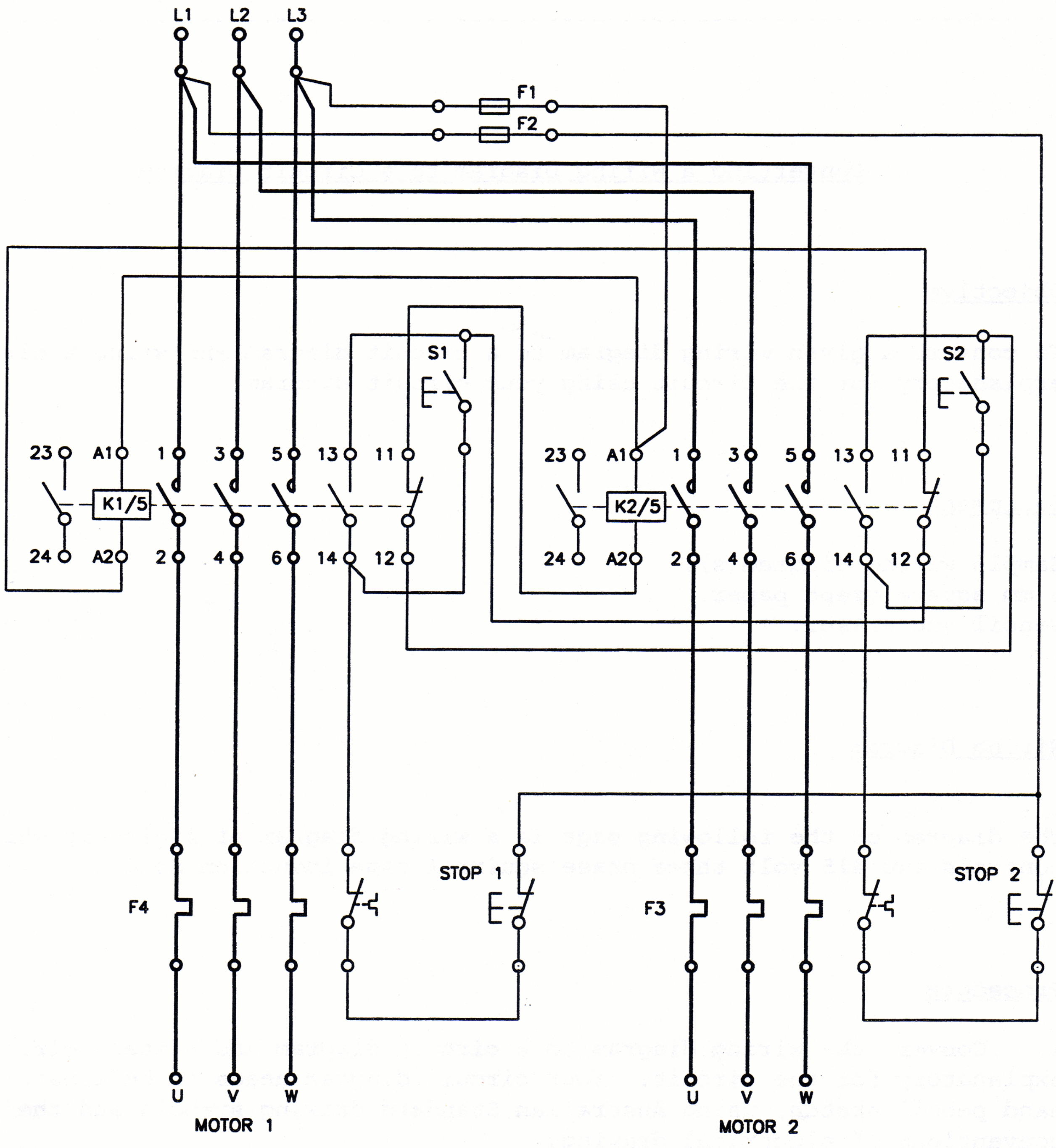
1. Convert the wiring diagram to a circuit diagram and write a circuit explanatory for the circuit.

   Your circuit diagram needs to be a neat drawing using a ruler and pencil, using Australian Standard drawing symbols and the conventions of electrical drawing.

2. Submit your circuit diagram and circuit explanatory to your Lecturer for assessment and comment.

CONTROL OF TWO MOTORS

WIRING DIAGRAM



Converting a Wiring Diagram to a Circuit Diagram
(Non-Standard Drawing Symbols)

Objective

To convert a given non-standard wiring diagram to a circuit diagram, and write a circuit explanatory for the circuit using your circuit diagram.

Equipment

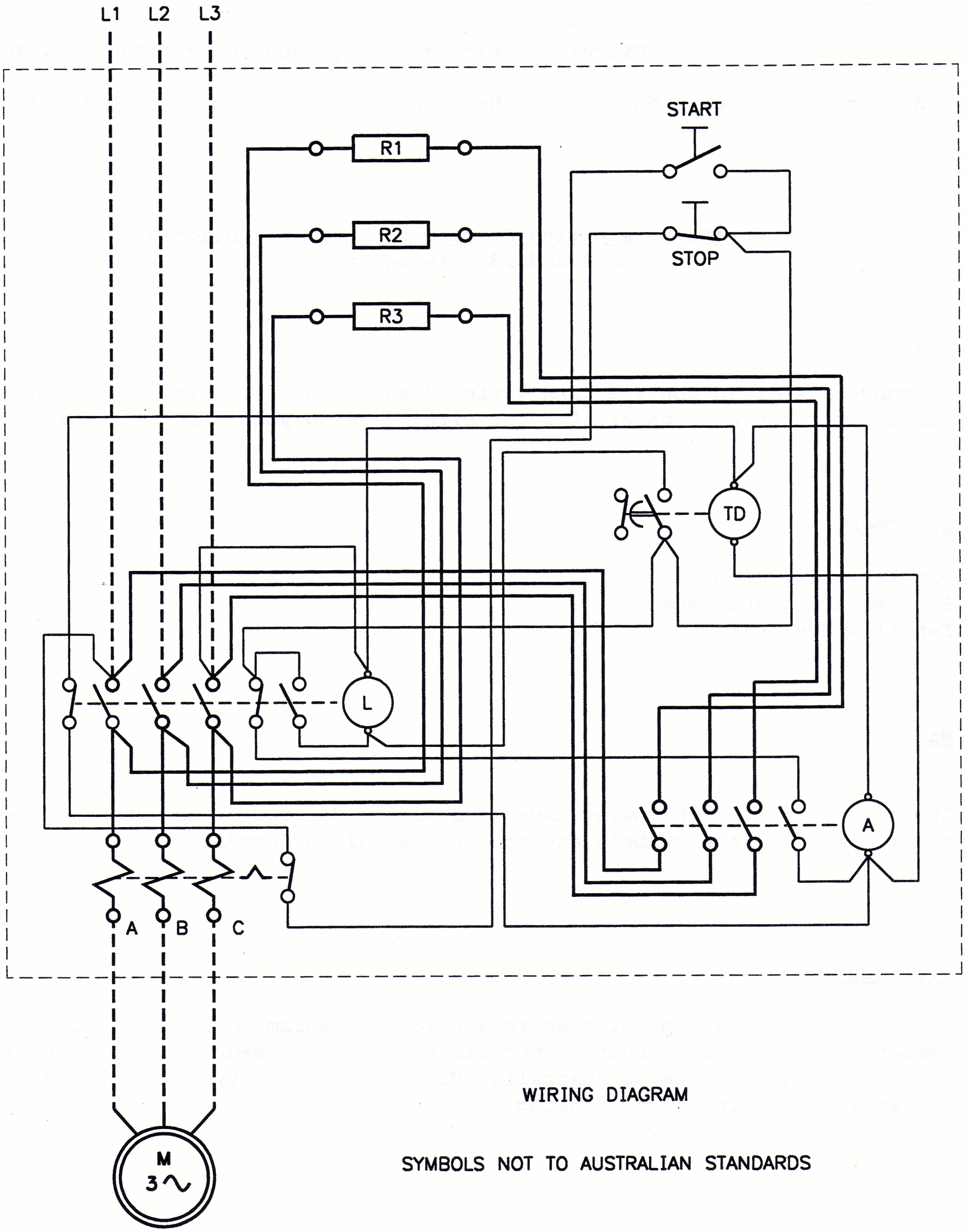
Sample wiring diagram(s).
5 mm square graph paper.
Pencil, eraser, ruler.

Wiring Diagram

The diagram on the following page is a wiring diagram of an unknown type of motor starter - the symbols are not to Australian Standards.

Procedure

Convert the wiring diagram to a circuit diagram and write a circuit explanatory for the circuit. Your circuit diagram needs to be a neat diagram using a ruler and pencil, using Australian Standard drawing symbols and the conventions of electrical drawing.



WIRING DIAGRAM

SYMBOLS NOT TO AUSTRALIAN STANDARDS

Submit your circuit diagram and circuit explanatory to your Lecturer for assessment and comment.

Single DOL Stop-start Circuit

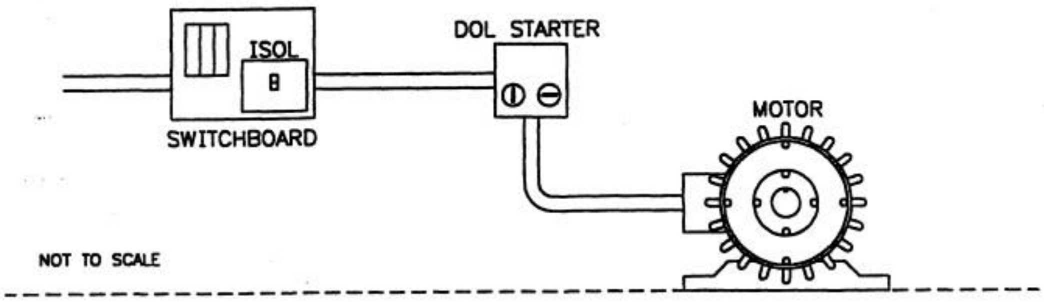
Objective

To design, connect and test a single direct-on-line (DOL) magnetic starter circuit for a 415 volt, three phase squirrel cage induction (SCI) motor.

Equipment

Three phase DOL starter with a single stop-start station and a thermal overload relay.
Three phase 415 volt SCI motor - 5 A or similar.
Multimeter.
A.C. Clamp meter.
3 phase board and 4mm shielded banana plug connecting leads.

Circuit Description



A 415 volt, three phase squirrel cage induction motor on an air blower is to be controlled by a magnetic direct-on-line (DOL) starter.

The starter is to have a single stop-start station located on the cover.

The motor is to start when the start button is pressed and continue to run until either the stop button is pressed, a motor overload occurs, or the three phase supply is removed.

If the start button is pressed while the stop button is pressed, the motor must not start.

A typical thermal overload relay is to be included in the circuit. The operating voltage for the contactor operating coil is to be 240 volts.

The circuit must provide no-volt protection for the motor.

Short circuit protection for the control circuit is to be provided.

Short circuit protection for the motor and associated cables is provided by HRC fuses on a nearby sub-switchboard.

Procedure

DANGER TAG PROCEDURE REQUIRED

1. Draw a neat pencil sketch of the power and control circuit required to control the motor as described in the Circuit Description.

   Show a 0-100 milliamp a.c. ammeter connected in the CONTROL circuit.

   Australian Standard drawing symbols and conventions are to be used throughout.

Circuit Diagram (Control and Power)

2. Have your circuit diagram checked by your Lecturer.

3. Examine the DOL starter and make sure that the current ratings, voltage rating and utilisation category are appropriate.

4. Connect the power and control circuit according to your diagram.

   Mark each connection off on your diagram as you make it.

5. Test the power and control circuits for short circuits with a multimeter - check the multimeter before and after the test.

6. Have your wiring checked by your Lecturer.

   Remove your danger tag and test the circuit for correct operation (including lock-out stop).

   Note and record the reading on the ammeter in the control circuit.

   Control circuit current: _______________

7. Switch the circuit off and remove the plug from the outlet.

8. Attach your danger tag to the plug.

9. Have your results checked by your Lecturer.

10. Disconnect your wiring and return all of the equipment to its proper place.

Questions

1. How much current was passing through the stop button when the circuit was operating?

____

2. How much current was passing through the contactor coil when the circuit was operating?

____

3. How much current was passing through the start button when the circuit was operating (after the start button had been released)?

____

4. Could the DOL starter used for this project safely be used to control the same motor if the utilisation category was AC4?

____

5. What effect would it have on the operation of the starter if the latching or retain contact was open circuited?

____

6. Why is it undesirable to connect the stop button or the overload contacts AFTER the contactor coil in a 240 volt control circuit?

____

DOL Stop-start Circuit- Two Stop-start Stations

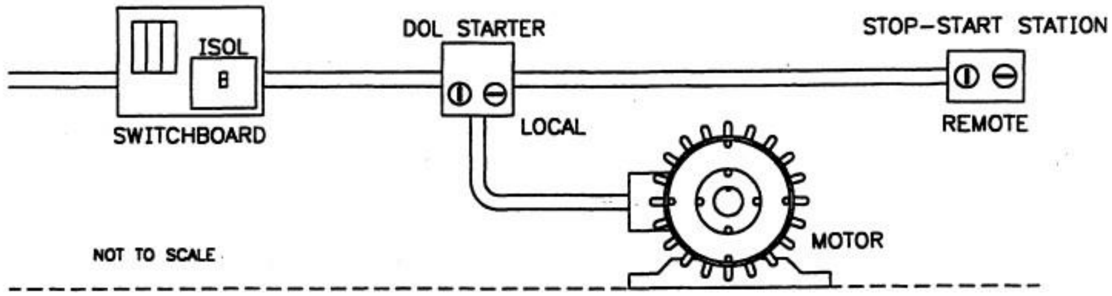
Objective

To design, connect and test a direct-on-line (DOL) magnetic starter circuit which controls a 415 volt, three phase squirrel cage induction (SCI) motor from either of two stop-start stations.

Equipment

Three phase DOL starter with a single stop-start station and a thermal overload relay.
An additional stop-start station.
Three phase 415 volt SCI motor - 3 kW or similar.
Multimeter.
Three phase lead and 4 mm shielded banana plug connecting leads.

Circuit Description



A 415 volt, 3 kW three phase squirrel cage induction motor on a centrifugal pump is to be controlled by a magnetic direct-on-line (DOL) starter.

The starter is to have a local stop-start station located on the cover, and a remote stop-start station located about 5 metres away.

The motor is to start when either start button is pressed and continue to run until either stop button is pressed, a motor overload occurs, or the three phase supply is removed.

If any start button is pressed while any stop button is pressed the motor must not start.

A typical thermal overload relay is to be included in the circuit. The operating voltage for the contactor operating coil is to be 240 volts.

The circuit must provide no-volt protection for the motor.

Short circuit protection for the control circuit is to be provided.

Short circuit protection for the motor and associated cables is provided by HRC fuses on a nearby sub-switchboard.

Procedure

DANGER TAG PROCEDURE REQUIRED

1. Draw a neat pencil sketch of the power and control circuit required to control the motor as described in the Circuit Description. Australian Standard drawing symbols and conventions are to be used throughout.

Circuit Diagram (control and power)

2. Have your circuit diagram checked by your Lecturer.

3. Examine the DOL starter and the stop-start stations to make sure that the current ratings, voltage rating and utilisation category are appropriate.

4. Connect the power and control circuit according to your diagram. Mark each connection off on your diagram as you make it.

5. Test the power and control circuits for short circuits with a multimeter - check the multimeter before and after the test.

6. Have your wiring checked by your Lecturer.

7. Remove your danger tag and test the circuit for correct operation (including lock-out stop).

8. Switch the circuit off and remove the plug from the outlet. Attach your danger tag to the plug.

9. Have your results checked by your Lecturer.

11. Disconnect your wiring and return all of the equipment to its proper place.

Questions

1. If a relay or contactor control circuit is to have multiple start buttons, how must they be connected?

____

2. If a relay or contactor control circuit is to have multiple stop buttons, how must they be connected?

____

3. What is the advantage of using a magnetic contactor and two stop-start stations to control a motor from two positions rather than using two triple pole switches connected in parallel?

____

4. Could the DOL starter used for this project safely be used to control the same motor if the utilisation category was AC1?

____

5. Would it be possible to stop the motor from either stop button if the three main contacts in the contactor welded closed as a result of a fault?

____

6. To what current should the overload relay be set in this circuit?

____

7. What is the minimum number of cables required between the remote stop-start station and the DOL starter in this circuit if all wiring was enclosed in galvanised metal conduit or PVC conduit?

DOL Stop-start Circuit- with Timer

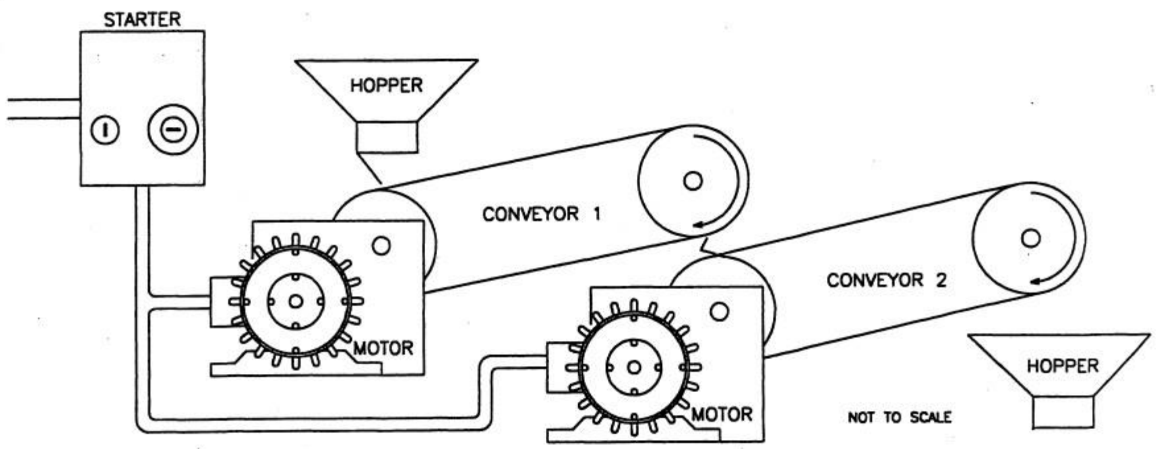
Objective

To design, connect and test a DOL magnetic starter circuit which controls two 415 volt, three phase SCI motors and incorporates a time-delay relay.

Equipment

Two three phase DOL starters, each with a thermal overload relay.
One stop-start station.
A 240 volt time-delay relay.
Two three phase three terminal 415 volt SCI motors - 2 kW or similar.
Multimeter.
Three phase lead and 4mm shielded banana plug connecting leads.

Circuit Description



Two 415 volt, 2 kW three phase squirrel cage induction motors on a conveyor system are to be controlled by magnetic contactors.

The contactors and other control equipment are located in a metallic enclosure which has a single stop-start station located on the cover.

Conveyor 2 is to start as soon as the start button is pressed.

Conveyor 1 is to start automatically 10 seconds after Conveyor 2 has started.

Both conveyors are to continue to run until either the stop button is pressed, an overload on either motor occurs, or the three phase supply is removed.

A thermal overload relay is to be included in the circuit for each motor.
The operating voltage for the contactor operating coils is to be 240 volts.

The circuit must provide no-volt protection for the motors.

Short circuit protection for the control circuit is to be provided.

Short circuit protection for the motors and associated cables is provided by HRC fuses on a nearby sub-switchboard.

Procedure

DANGER TAG PROCEDURE REQUIRED

1. Draw a neat pencil sketch of the power and control circuits required to control the conveyors as described in the Circuit Description.

   Australian Standard drawing symbols and conventions are to be used throughout.

   Circuit Diagram (power and control)

2. Have your circuit diagram checked by your Lecturer.

3. Examine the DOL starters and the stop-start station to make sure that the current ratings, voltage rating and utilisation category are appropriate.

4. Connect the power and control circuit according to your diagram. Mark each connection off on your diagram as you make it.

5. Test the power and control circuits for short circuits with a multimeter - check the multimeter before and after the test.

6. Have your wiring checked by your Lecturer.

7. Remove your danger tag and test the circuit for correct operation (including lock-out stop).

8. Switch the circuit off and remove the plug from the outlet. Attach your danger tag to the plug.

9. Have your results checked by your Lecturer.

10. Disconnect your wiring and return all of the equipment to its proper place.

Questions

1. What is the largest three phase motor which may be installed without overload protection according to AS/NZS 3000? (Give the Clause number.)

____

2. If the conveyor control circuit was required to have one or more emergency stop buttons or land yard switches, where should they be connected?

____

3. If each contactor coil drew a current of 50 milliamps, and the timer drew a current of 20 milliamps, how much current would be flowing through the stop button and overload contacts while both conveyors were running normally?

____

4. To what current should the overload relays be set in this circuit?

____

INTERLOCKING RELAY CIRCUIT

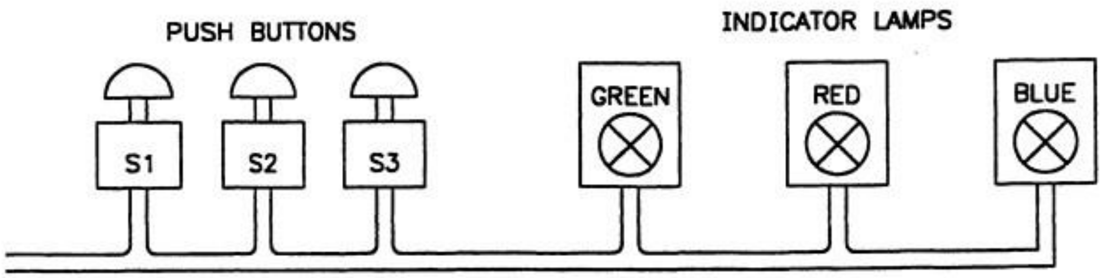
Objective

To design, connect and test a relay circuit which incorporates electrical interlocking.

Equipment

Neon light boxes or three lamps and lamp holders.
Three 240 volt relays.
Multimeter.
Single phase lead and 4mm shielded banana plug connecting leads.

Circuit Description



Three indicator lamps are each to be controlled by a push-button via a magnetic relay.

When the push-button S1 is pressed, the green lamp lights up and remains lit up until the stop/reset button is activated

S2 controls the red lamp and S3 controls the blue lamp in a similar way.

The circuit is to be interlocked so that if any lamp is on, neither of the other lamps can come on.

Procedure

Draw a neat pencil sketch of the control circuit required to control the lamps as described in the Circuit Description. Australian Standard drawing symbols and conventions are to be used throughout.

Circuit Diagram (Control circuit only)

2. Have your circuit diagram checked by your Lecturer.

3. Connect the control circuit according to your diagram. Mark each connection off on your diagram as you make it.

4. Test the control circuits for short circuits with a multimeter - check the multimeter before and after the test.

5. Have your wiring checked by your Lecturer.

6. Test the circuit for correct operation on a 240 volt a.c. power supply.

7. Switch the circuit off and remove the power supply plug from the outlet.

8. Have your results checked by your Lecturer.

9. Disconnect your wiring and return all of the equipment to its proper place.

Questions

1. What is the purpose of an interlock?

____

2. What are the two types of interlock used in association with electrical devices?

____

DOL REVERSING CONTACTOR CIRCUIT

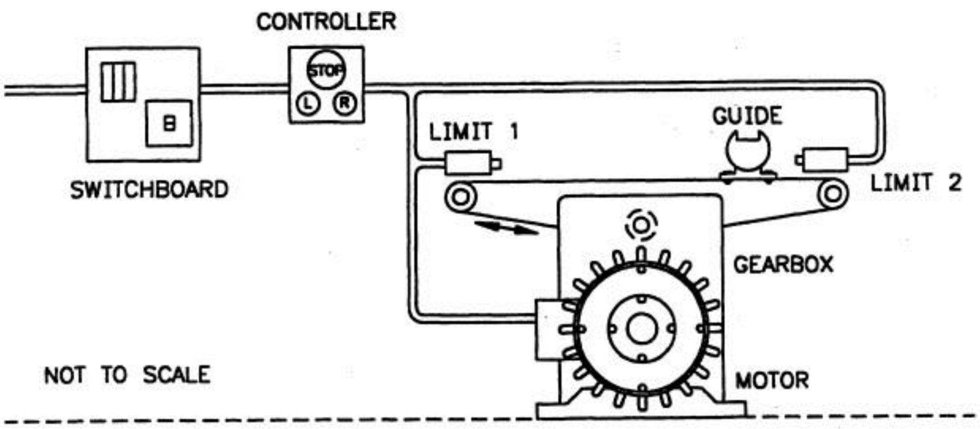
Objective

To design, connect and test a DOL magnetic contactor circuit which provides forward and reverse operation of a 415 volt, three phase SCI motor and incorporates limit switches.

Equipment

Two three phase magnetic contactors.
One thermal overload relay.
One forward-reverse-stop push-button station.
One 415 volt SCI motor - 2kW or similar.
Multimeter.
Three phase lead and 4mm shielded banana plug connecting leads.
Additional stop buttons to simulate limit switches.

Circuit Description



A 415 volt, three phase squirrel cage induction motor is to be used to position a GUIDE anywhere between two limit switches.

The motor is to be controlled by magnetic contactors - one labelled LEFT and the other labelled RIGHT.

The contactors and other control equipment are located in an enclosure which has a push-button to control movement of the GUIDE to the left, a button to control movement of the GUIDE to the right, and a stop button which stops the GUIDE in any intermediate position.

The circuit is to be arranged so that left contactor and the right contactor cannot be energised at the same time.

The maximum travel in either direction is to be limited by limit switches.

A thermal overload relay is to be included in the circuit for the motor.

The operating voltage for the contactor operating coils is to be 240 volts.

The circuit must provide no-volt protection for the motor.

Short circuit protection for the control circuit is to be provided.

Short circuit protection for the motors and associated cables is provided by HRC fuses on a nearby sub-switchboard.

Procedure

DANGER TAG PROCEDURE REQUIRED

Draw a neat pencil sketch of the power and control circuit required to control the motor as described in the Circuit Description.

Australian Standard drawing symbols and conventions are to be used throughout.

Circuit Diagram (power and control)

2. Have your circuit diagram checked by your Lecturer.

3. Examine the contactors and the push-buttons to make sure that the current ratings, voltage rating and utilisation category are appropriate.

4. Connect the power and control circuit according to your diagram. Mark each connection off on your diagram as you make it. Connect the motor in star.

5. Test the power and control circuit for short circuits with a multimeter - check the multimeter before and after the test.

6. Have your wiring checked by your Lecturer.

7. Remove your danger tag and test the circuit for correct operation (including lock-out stop).

8. Switch the circuit off and remove the plug from the outlet. Attach your danger tag to the plug.

9. Have your results checked by your Lecturer.

10. Disconnect your wiring and return all of the equipment to its proper place.

Questions

1. What would happen if the LEFT and RIGHT contactors were energised at the same time?

____

2. Are all 'limit switches' the same in terms of physical construction?

____

3 What is the minimum number of overload relays required in any DOL forward-reverse circuit for a three phase motor?

____

4. How does your circuit provide under-voltage protection for the motor?

____

REVERSING-JOG CONTACTOR CIRCUIT

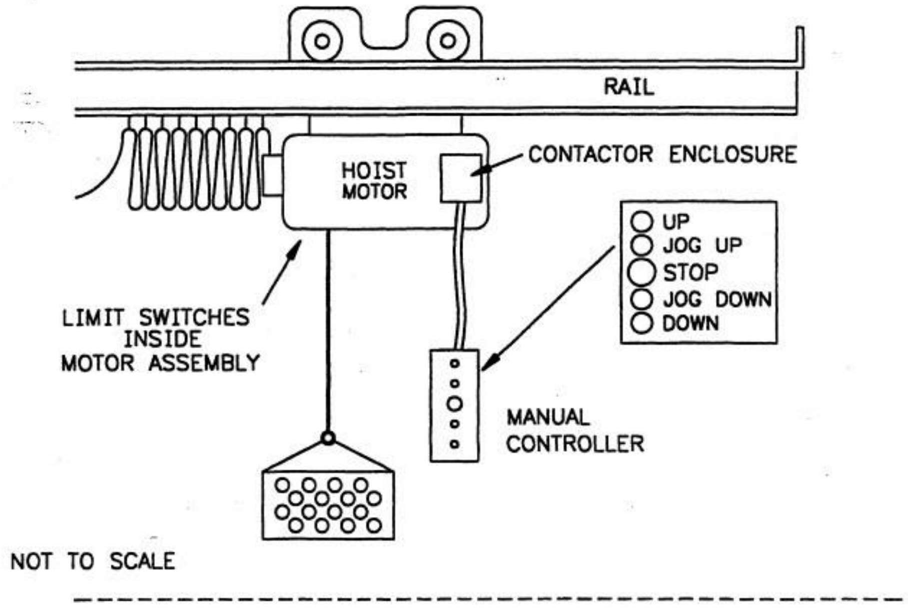
Objective

To design, connect and test a DOL magnetic contactor circuit which provides forward, reverse and jogging operation of a 415 volt, three phase SCI motor and incorporates limit switches.

Equipment

Two three phase magnetic contactors.
One thermal overload relay.
One push-button station which includes reversing and jogging buttons.
One three phase 415 volt SCI motor - 2kW or similar.
Multimeter.
Three phase lead and 4mm shielded banana plug connecting leads.

Circuit Description



A 415 volt, 2 kW three phase squirrel cage induction motor is to be used to operate a lifting hoist motor.

The motor direction is to be controlled by magnetic contactors - one labelled UP and the other labelled DOWN.

The contactors and other control equipment are located in a metallic enclosure which has a push-button controller to allow the following functions: UP, JOG UP, STOP, JOG DOWN and DOWN.

The maximum travel up or down is to be limited by limit switches (simulated by stop buttons).

When the UP button is pressed, the hoist lifts the load up until the STOP button is pressed or the UP limit is reached.

When the JOG UP button is pressed, the hoist lifts the load until the operator releases the button or the UP limit is reached.

The DOWN buttons provide the same functions, but the hoist lowers the load.

The circuit is to be arranged so that UP contactor and the DOWN contactor cannot be energised at the same time.

A thermal overload relay is to be included in the circuit for the motor.

The operating voltage for the contactor operating coils is to be 240 volts.

The circuit must provide no-volt protection for the motor.

Short circuit protection for the control circuit is to be provided.

Short circuit protection for the motors and associated cables is provided by HRC fuses on a nearby sub-switchboard.

Procedure

DANGER TAG PROCEDURE REQUIRED

1. Draw a neat pencil sketch of the power and control circuit required to control the motor as described in the Circuit Description. Australian Standard drawing symbols and conventions are to be used throughout.

Circuit Diagram (control and power)

2. Have your circuit diagram checked by your Lecturer.

3. Examine the contactors and the push-buttons to make sure that the current ratings, voltage rating and utilisation category are appropriate.

4. Connect the power and control circuit according to your diagram. Mark each connection off on your diagram as you make it.

5. Test the power and control circuit for short circuits with a multimeter - check the multimeter before and after the test.

6. Have your wiring checked by your Lecturer.

7. Remove your danger tag and test the circuit for correct operation (including lock-out stop).

8. Switch the circuit off and remove the plug from the outlet. Attach your danger tag to the plug.

9. Have your results checked by your Lecturer.

10. Disconnect your wiring and return all of the equipment to its proper place.

Questions

1. What would happen if the UP and DOWN contactors were energised at the same time?

____

2. What type of mechanism must be included in the hoist motor assembly to prevent the weight of the load causing the load to be lowered when the motor was not energised in either direction?

____

PRESS SAFETY CIRCUIT

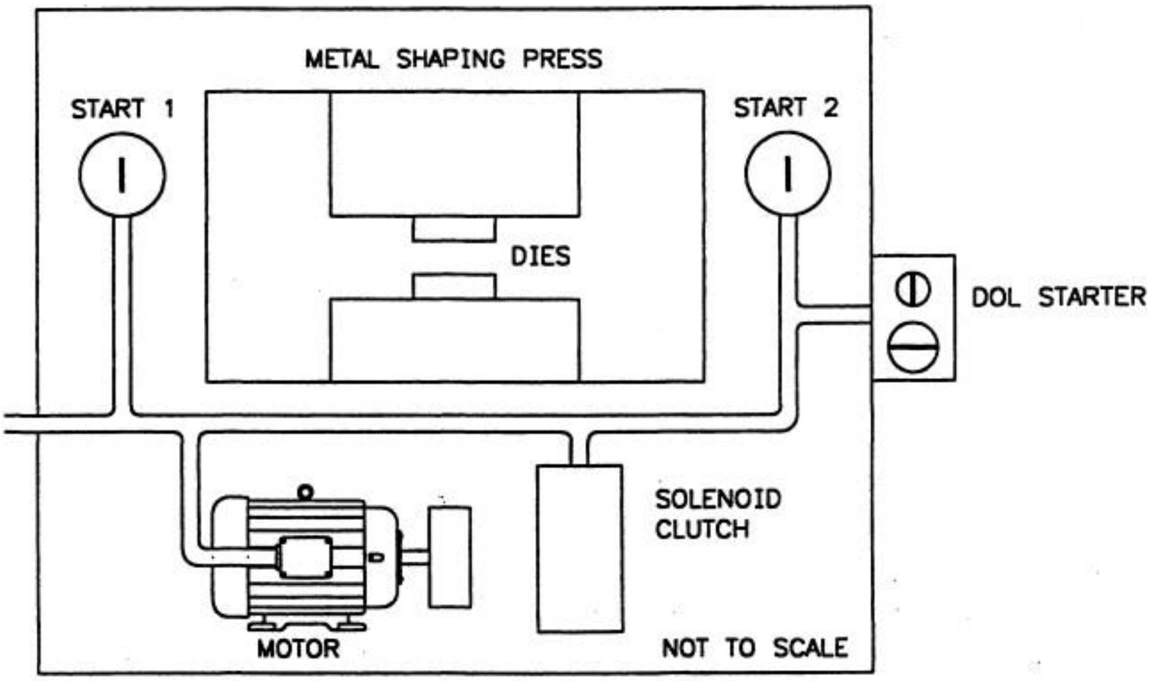
Objective

To design a DOL magnetic contactor circuit which provides for safe operation of a potentially hazardous machine press.

Equipment

5mm square graph paper.
Pencil and eraser.

Circuit Description



A 415 volt, 2kW three phase squirrel cage induction motor is to be used to drive a machine press which forms shaped sheet-metal parts between two matching dies.

The 2kW driving motor drives a flywheel and is to run all the time when the machine is in use.

When the operator has positioned the sheet-metal blank, he/she is to energise a solenoid clutch mechanism which causes the press to operate and shape the metal between the dies.

In order to be able to energise the solenoid clutch without having his/her hand in the press, the operator must press TWO push-buttons to operate the solenoid clutch - one button on each side of the press.

When both buttons are pressed, the press completes one cycle and returns to the ready position the solenoid clutch mechanically disengages, provided the solenoid is not still energised.

A thermal overload relay is to be included in the circuit for the motor. The operating voltage for the contactor operating coils is to be 240 volts.

The circuit must provide no-volt protection for the motor.

Short circuit protection for the control circuit is to be provided. Short circuit protection for the motors and associated cables is provided by HRC fuses on a nearby sub-switchboard.

Procedure

1. Draw a neat pencil sketch of the power and control circuit required to control the motor as described in the Circuit Description. Australian Standard drawing symbols and conventions are to be used throughout.

Circuit Diagram (power and control)

2. Submit your circuit diagram to your Lecturer for assessment and comment.

Question

1. If the circuit was to be modified so that the press would not operate unless a safety guard was in position (using an appropriately positioned micro-switch which had one normally closed contact and one normally open contact), which pair of contacts should be used, and where should they be connected in the circuit?

BRAKING SYSTEMS

Mechanical

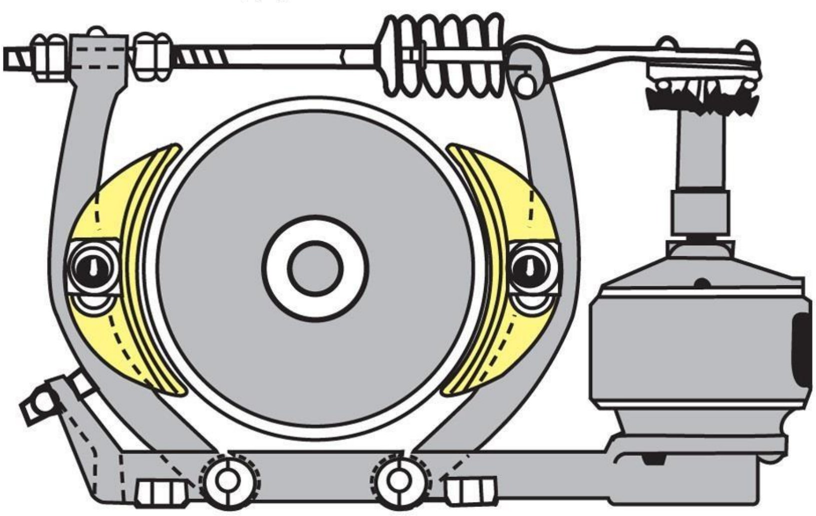


Fig 8.14

The principle of mechanical braking is to bring equipment to a complete halt and act as a parking mechanism.

Generally, mechanical braking consists of creating deliberate friction between rotating and stationary components.

Machine braking systems might use more than one braking method. For example, an overhead crane might use the dynamic method for slowing down a load, and a solenoid-operated mechanical brake for holding the load stationary.

In the interests of safe working, the mechanical brake has to be fail-safe by being applied automatically when power is removed.

This is a protection in the event of a power failure. Travelling cranes commonly use this form of solenoid braking on all directional movements.

In Figure 8.14, the brake shoes are held in the ‘on’ position against a flat pulley by a substantial spring.

An application of power to the motor also energises the solenoid, which releases the brake and allows the pulley to rotate.

Three-phase motors can be supplied by the manufacturer with a mechanically operated disc-brake as an integral part of the motor.

Dynamic Braking

In AC motors, dynamic braking is often achieved by disconnecting the rotating motor from the power supply and applying DC to the windings.

Because the rotor is still moving, circulating currents are generated within the rotor.

These form a load on the machine and slow the motor rather more quickly than just coasting to a halt.

A mechanical braking system is still needed as a holding brake.

A typical circuit is shown on page 106.

During the stopping process, the stop button must be held in the ‘stop’ position for a short period to activate the braking system.

The direct current is usually obtained from a rectified AC supply.

A typical use for dynamic braking is in electric trains, where the driving motors are used as generators and the energy generated is dissipated in banks of resistors.

Some large cranes also use this system but, as with other applications, a system of mechanical braking is also required for bringing all movement completely to rest.

Plug Braking

Plug braking with three-phase motors is the system of reconnecting a motor to rotate in the reverse direction while still rotating in the forward direction.

It is a sudden and almost violent method for bringing a motor to a complete stop.

The actual time taken depends on the amount of inertia in the accompanying machine.

In order to use plugging as a stopping mechanism, some means must be provided to remove all power from the motor at the instant of change in direction.

This can be done with a friction-operated single-pole changeover switch mounted on the motor driving shaft. (Zero-speed switch).

The starter circuit has push-buttons to activate rotation in the required direction, and the movement of the shaft closes the appropriate contact and allows the main contactor for that direction to energise.

A stop button allows the contactor in use to drop out and also activates the contactor for the opposite direction.

This is latched in until the first amount of reverse movement occurs.

This movement opens the holding-in contact of the starter and removes all power from the motor.

A circuit for a three-phase motor using the plugging method of braking is shown on page 108 and 109.

Circuit explanatory

(Standard Drawing Symbols)

Objective

To explain the operation of a given standard Dynamic braking circuit diagram.
Write a circuit explanatory for the circuit on next page.

Equipment

Sample circuit diagram.
5mm square graph paper.
Pencil, eraser, ruler.

Circuit Diagram

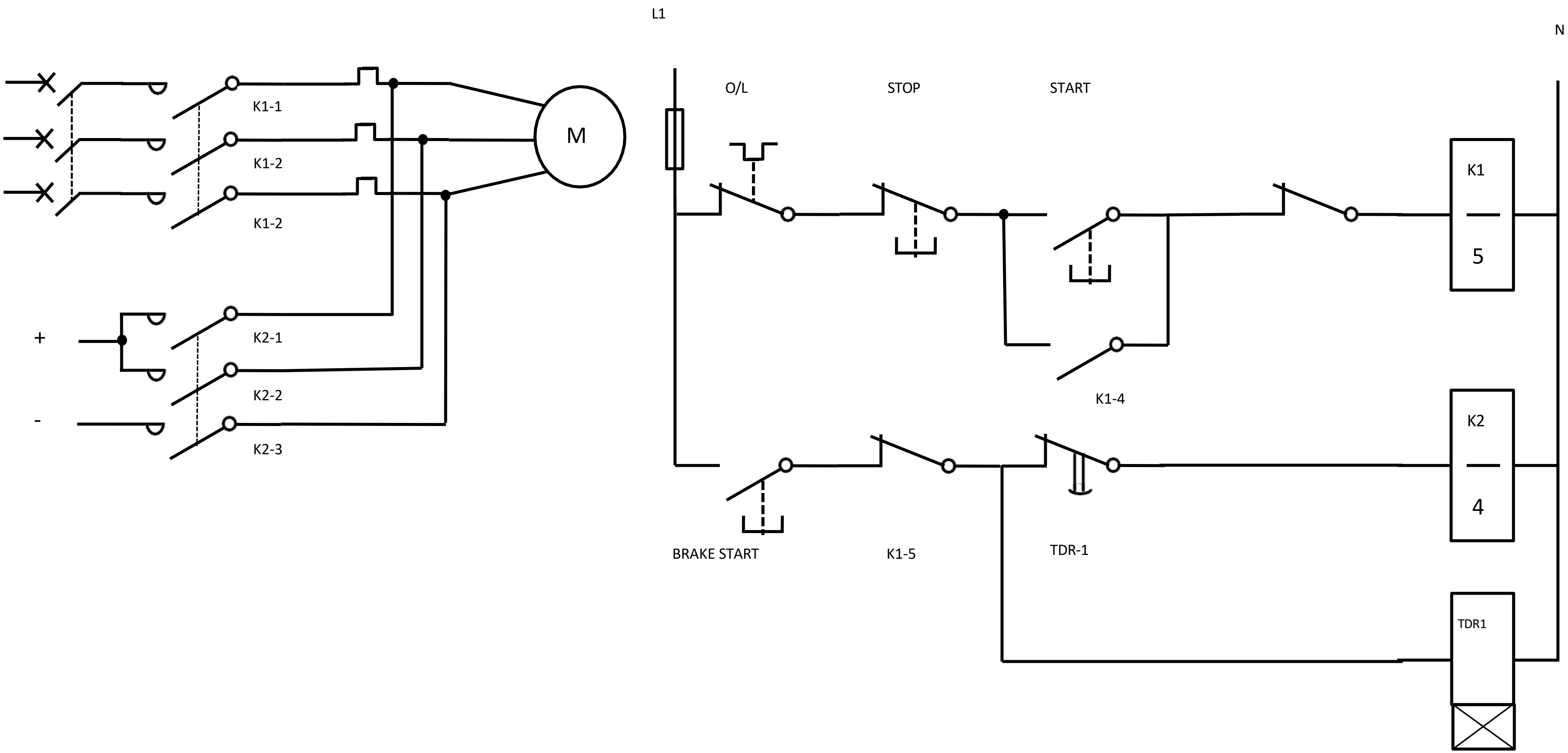
The circuit diagram on the following page is of diagram of a Dynamic braking circuit, the symbols are to Australian Standards.

Procedure

1. Write a circuit explanatory on how the circuit works. Explain the starting sequence and the braking sequence.

2. Submit your circuit explanatory to your Lecturer for assessment and comment.

DYNAMIC BRAKING CIRCUIT



Circuit explanatory
(Standard Drawing Symbols)

Objective

To explain the operation of a given standard symbol Plug braking circuit diagram.
Write a circuit explanatory for the circuit on next page.

Equipment

Sample circuit diagram.
5mm square graph paper.
Pencil, eraser, ruler.

Circuit Diagram

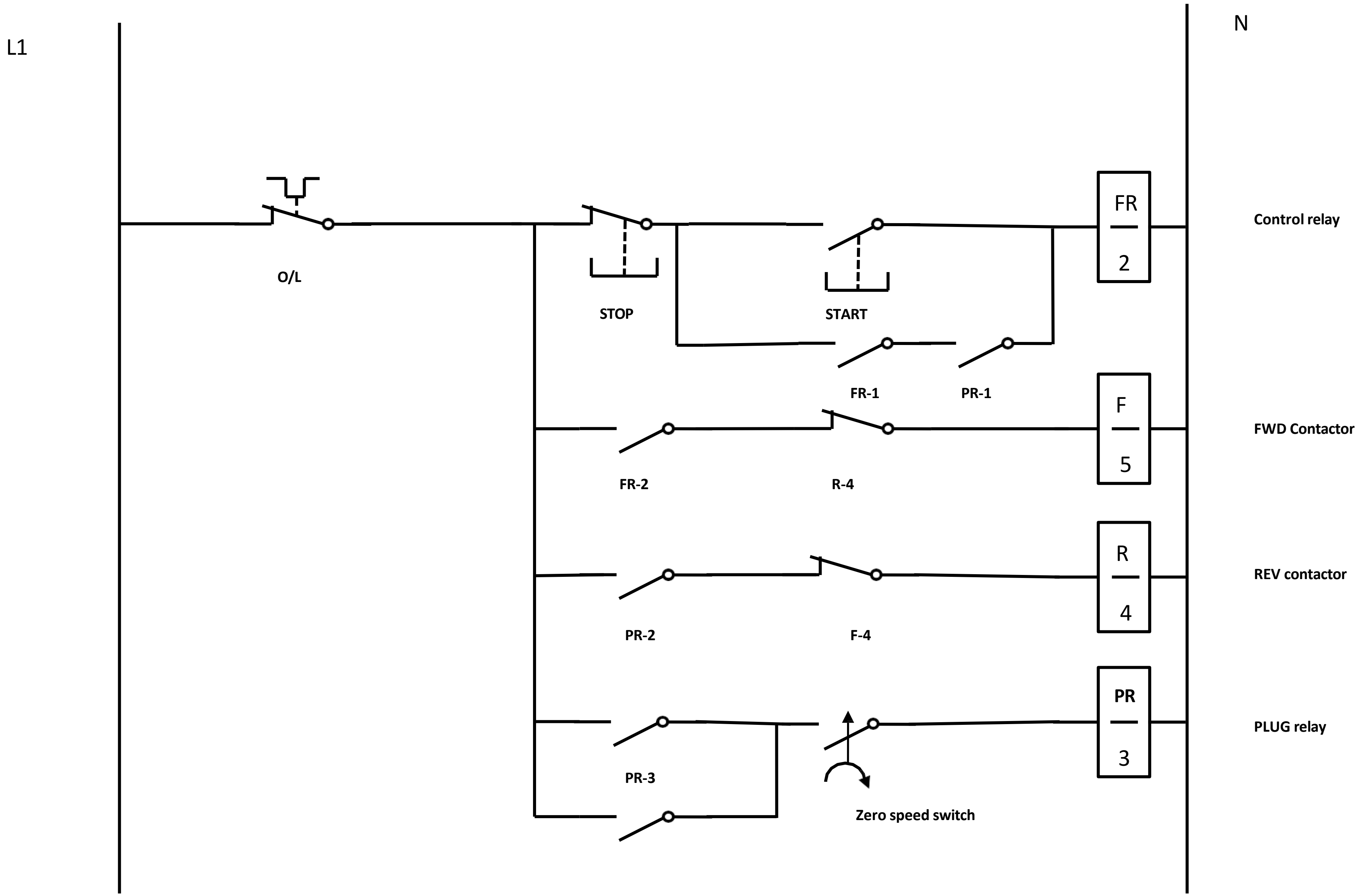
The circuit diagram on the following page is of diagram of a Plug braking circuit, the symbols are to Australian Standards.

Procedure

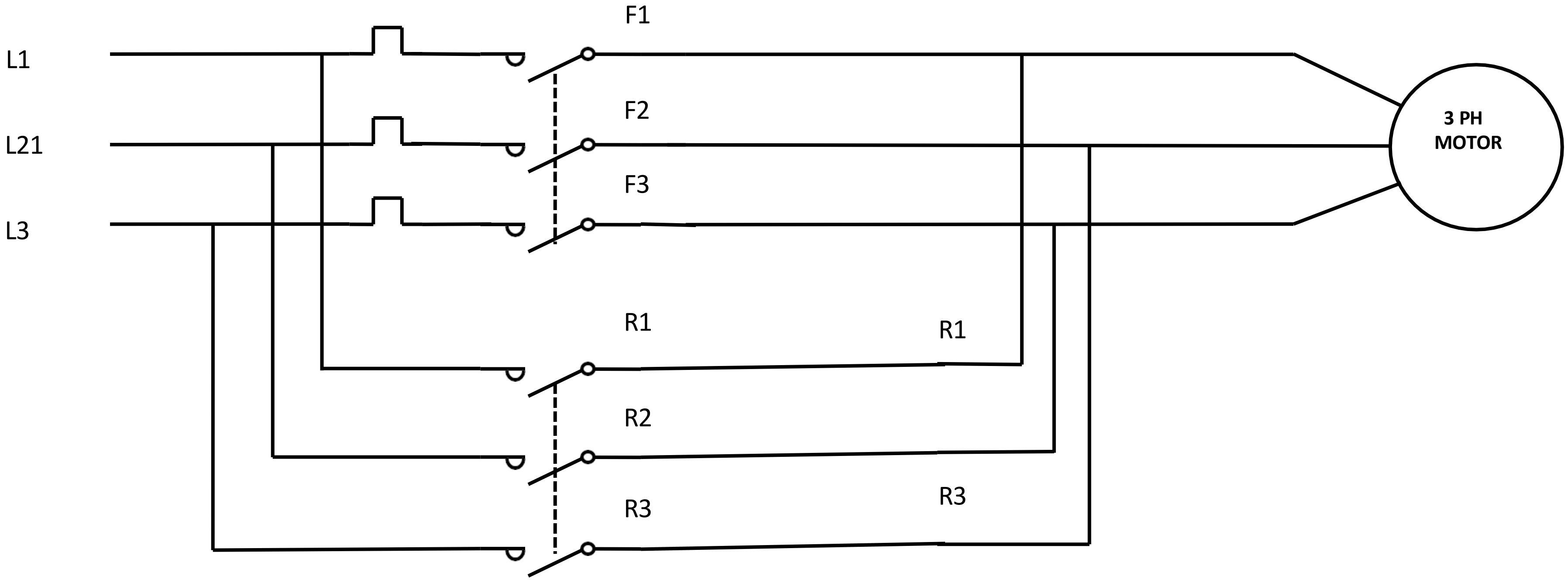
3. Write a circuit explanatory on how the circuit works. Explain the starting sequence and the braking sequence.

4. Submit your circuit explanatory to your Lecturer for assessment and comment.

Plug braking circuit



Plug Braking



Notes

Fault Finding in Electrical Circuits

Task

To locate the faults in operational control circuits which involve electromagnetic relays and contactors.

Why

A significant amount of an electrical tradesperson's time in a maintenance environment is spent locating and correcting operational faults or carrying out activities intended to minimise the number of faults which may occur.

You need to be able to locate and correct faults in a minimum of time to minimise the amount of undesired lost production time in a given installation.

To Pass

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a competency test for each theory Learning Outcome.

2. You must correctly locate faults in operational control circuits.

3. You must correctly determine the most likely fault in a given control circuit from a verbal or written description of the symptoms.

Equipment:

Faults boards with electrical control circuits with operational faults.
Multimeter.

FAULT FINDING IN ELECTRICAL CONTROL CIRCUITS

Suggested Self-Study Guide

1. Read the Summary and practise answering the questions provided on the Work Sheets.
2. Refer to manufacturer's data sheets and other relevant texts if you feel it is necessary.
3. Answer the questions given on the Work Sheet.
4. Use a separate answer sheet or sheets.
5. Note that you are required to answer ALL questions correctly.
6. Complete the projects in this manual.
7. Submit your answers to the Work Sheet and your completed project reports to your Lecturer for discussion and assessment.

FAULT FINDING IN ELECTRICAL CONTROL CIRCUITS

Fault finding in electrical control circuits is extremely important to the electrical industry, because electrical faults may result in such things as:

a. Damage to electrical equipment.
b. Damage to mechanical equipment.
c. Loss of production time.
d. Loss of wages for employees.
e. Wastage resulting from a partially completed process.
e. Wastage resulting from the ability to process perishable raw materials in a given time.

Electrical faults can usually be classified as being catastrophic (total failure) or intermittent.
In both cases a systematic approach to identifying and locating the fault is desirable so that it can be corrected as quickly as possible.

Fault Finding Techniques

A typical methodical approach to fault finding is as follows:

a. Collect evidence about the fault
b. Analyse the evidence
c. Locate the fault
d. Determine and correct the cause of the fault
e. Check the system for correct operation.

Evidence Collection

This involves gathering all the available evidence about the fault to determine the symptoms - such as:

a. What equipment or unit is not operating correctly?
b. Where and when the fault occurs.
c. When the fault became noticeable.
d. Does the fault occur in a cycle of events - if so when in the cycle?
e. What appears to trigger the fault?
f. Is there any physical evidence of burning, overheating or mechanical damage?
g. Is the fault related to the operation of any built-in circuit or component protection device?
h. What voltages are present and when?

Collecting the evidence usually involves using circuit diagrams, process descriptions and test equipment to ensure that all of the symptoms are identified.

The first series of checks should include checking to see that there is a voltage at the supply terminals and checking to see if an overload has tripped.

Evidence Analysis

Analysis of the evidence with knowledge of what the circuit is intended to do should enable parts of a circuit to be logically excluded from further consideration, until the fault is isolated to a particular component or section.

Fault Location

When the most probable component or section has been identified, further visual or electrical checks can be carried out if required in order to precisely identify the fault.

Removal of the Cause

When a fault has occurred, it is usually the result of a clearly identifiable fault condition or faulty component.

Faults in the original design of a circuit or component are also possible, but such faults should usually only be considered after all other possibilities have been exhausted.

In any case, it is essential to remove the cause of the fault before attempting to re-energise the circuit.

Checking Operation

When the fault has been detected and corrected, the operation of the circuit should be checked for at least one complete cycle.

Keeping Records

It is a sound practice to keep a record of details of every fault which occurs - particularly in large installations.

Some faults can re-occur, or they may follow a particular pattern, and it may save time if details of previous faults are recorded - particularly in cases where different people may be responsible for electrical maintenance at different times.

Proper recording of the cause of a fault, and the action taken to repair it, can also be useful in detecting design faults in equipment.

In complex control circuits, it is sometimes necessary to modify the circuit in some way to overcome a particular fault, or to improve the operation of the circuit.

In such cases it is essential to make appropriate modifications to the relevant diagrams, and inform your supervisor so that information relating to the changes can be recorded for future reference.

Test Equipment

The most useful device for locating electrical faults in power and control circuits is the multimeter set to an appropriate voltage range.

With multimeters, sometimes small variations in voltage at a particular point in the circuit can provide a clue to the location of the fault, and digital meters can take a finite amount of time to update the display, so important information may be missed. This is where an analogue multimeter in your toolbox is handy.

Devices such as voltage sticks or combination testers can also be used to check for the presence of a voltage at a particular point in the circuit, but a multimeter is much more accurate.

You need to take particular care when using a multimeter in a circuit protected by a residual current device (or core balance earth leakage circuit breaker), because connecting a test device between active and earth could cause sufficient current to flow to unintentionally trip the RCD and shut down other parts of the installation.

It is sometimes necessary to check the resistance or continuity of a particular part of the circuit using an analogue multimeter set to a low resistance range (usually ohms x 1), or digital multimeter on auto range or low ohms range.

In these cases it is essential to make sure that there is no voltage applied to the circuit, and there are no other components connected in parallel with the one under test.

If a multimeter is being used to check continuity and/or measure voltage, it is essential to ensure that the multimeter is set to an appropriate range before attempting to measure voltages - most multimeters set to an ohms range will be permanently damaged if they are connected to a voltage source.

Some modern digital multimeters have built-in protection against this type of faulty usage, but this feature should not be used as protection against bad testing techniques.

All multimeter and test instrument probes have bare ends so that they can make proper electrical contact at the point being tested.

The bare ends often extend back up to about 25mm from the point of the probe so that it can be inserted in sockets and other confined spaces.

You need to take extreme care when using such probes. KEEP FINGERS BEHIND KNURLS OR SHOULDERS. If you do not have an adequate grip on the probes, your fingers can slip down and come in contact with a live conductor, or if you position the probe carelessly it may provide a short circuit between adjacent metallic parts and result in the unexpected operation of a part of the circuit or, in the case of a short circuit to earth, an explosion.

Interpreting Voltmeter Readings

One of the most common methods of detecting an electrical fault in a control or power circuit is to measure the voltage across various parts of the circuit, and use the information to make deductions about the condition of related components.

It is therefore vital that you interpret the readings correctly.

As a general principle, if an operational circuit consists of two or more components connected in series, and one of the components is open circuited, the supply voltage will appear across the open circuit.

This principle is illustrated in Figure 1.

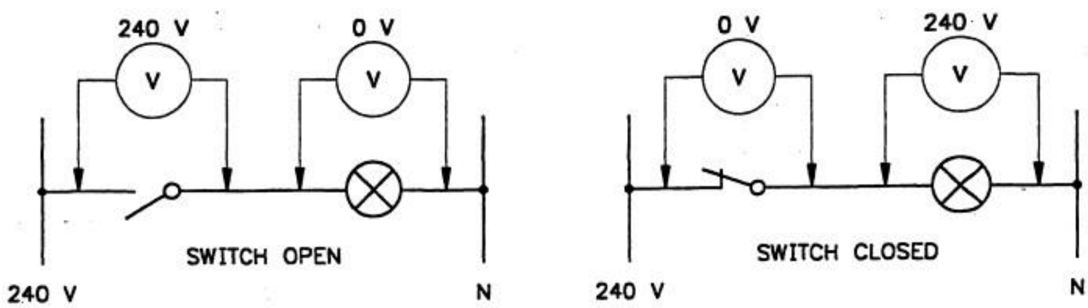


Figure 1 - Voltmeter readings across a switch

The voltage across the open switch in Figure 1 is shown as 240 volts.

Since the voltmeter and the lamp form a series circuit, and current must be flowing in the circuit to operate the voltmeter, there must be a potential difference (or volt drop) across the lamp (V = I.R from Ohm's Law).

Since the resistance of the voltmeter is much higher than the resistance of a 100 watt lamp, the voltage across the voltmeter would be much higher than the voltage across the lamp, and the voltmeter would indicate almost 240 volts - the voltage drop across the lamp is insignificant and can be ignored.

Similarly, the voltage across the closed switch is shown as 0 volts.

In fact there would be a small volt drop across the switch because it must have a small resistance, but the voltage is insignificant and can be ignored when using a voltmeter.

The 'Neutral Back' Method

A systematic method of locating a fault in a control circuit with a voltmeter or multimeter is what we will call the 'neutral back method'.

This consists essentially of confirming the presence of a supply voltage at the extremities of the part of a circuit under test, then, leaving one test probe on the neutral (or equivalent), and working back towards the active and taking voltage readings at each point - operating switches where necessary.

In order to be able to use the neutral back method, you need to know what each component is, and the electrical relationship between them - usually in the form of a circuit diagram. In some cases it may be necessary to create a circuit diagram from the existing wiring.

Figure 3 shows the general principle of the neutral back method in diagram form using a simple series circuit.

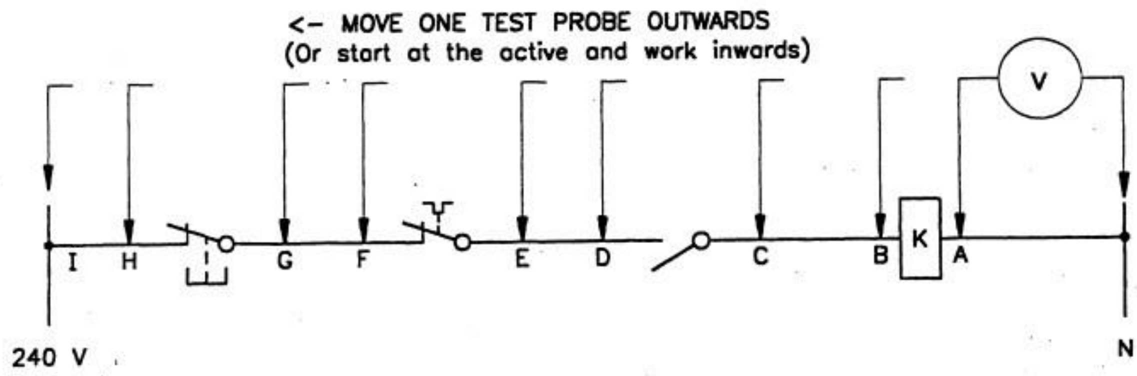


Figure 3 - Using the 'neutral back method'

You should note that it may be necessary to safely disconnect the power circuit while the control circuit is being tested - to prevent unwanted operation of machines.

In a circuit such as the one shown in Figure 3, the most likely faults could include the following, and each could be found by systematic testing and interpretation of the results.

a. An open circuited contactor coil.
b. A broken wire.
c. A loose terminal.
d. A high resistance joint in a cable lug.
e. Normally closed contacts open circuited or partially open.
f. Contacts welded closed.
g. Normally open contacts not closing.
h. A high resistance fault in a cable.

Interpretation of Readings

The following examples show how the voltmeter readings between particular points in Figure 3 can be interpreted - in all cases it is assumed that the supply voltage of 240 volts is connected to the circuit:

Symptom	Likely Fault
a. The voltage between H and N is 240 volts, and between G and N it is zero volts.	Open circuit in the stop button.

b. The voltage between C and N is zero with the normally open contact closed.	The normally open contact is not making contact.
c. The voltage between B and N is 240 volts with the normally open contact closed, but the coil does not energise.	The contactor coil may be open circuited or terminal A may be loose.
d. The voltage between B and N is 240 volts with the normally open contact closed, but the coil does not energise. The voltage between A and N is 240 volts.	The cable between A and N may be open circuited, or a terminal at A or N may be loose.
e. The voltage between F and N is 240 volts with the normally open contact open, and the voltage between E and N is 150 volts	A high resistance contact in the normally closed overload contacts.

Using an Ohmmeter

If live testing is not possible or desirable, you can use an ohmmeter or multimeter set to the ohms x 1 range to detect faults in control or power circuits.

The method is similar to live testing in that you usually leave one probe on one of the terminals and work back through the circuit, then you interpret the readings.

There are two serious limitations with using an ohmmeter.
One is the danger of connecting the ohmmeter across a voltage source, and the other is the possibility of obtaining inaccurate readings if other components are connected in parallel with the one being tested. Another weakness is the possibility of obtaining inaccurate resistance readings if the multimeter is set to one of the high ohms ranges.

Prevention of Faults

When a fault occurs, it is necessary to consider the symptoms, carry out checks and tests to locate the fault, then correct it.
The cause of the fault should be clearly established so that action can be taken to prevent it occurring again.

Submit your answers to the Work Sheet and your completed project reports to your Lecturer for discussion and assessment.

A motor be reported as 'continually stopping', the possible causes could be:

1. A Type 'C' circuit breaker has been installed instead of a type 'D'
2. Thermal overload maybe set too low
3. Latching contact not connected

All these possibilities should be eliminated during the fault finding process.

Note: Type 'D' circuit breakers are designed to absorb motor inrush current, and Type 'C' circuit breakers should not be used on motors.

Many faults can be prevented by implementing a programme of preventative maintenance, i.e. regularly checking equipment and maintaining it in good working condition so that faults are less likely to occur.

A typical preventative maintenance programme would include such activities as:

a. Checking the tightness of connections.
b. Checking the tightness of mounting bolts and screws.
c. Checking insulation resistance in motors and heating elements.
d. Cleaning accumulated dust out of motors and other equipment.
e. Examining components for evidence of overheating.
f. Examining contacts for evidence of excessive arcing.
g. Replacing contacts where necessary (never file silver contacts).
h. Lubricating bearings (but not electrical contacts).
i. Checking safety components for correct operation.
j. Checking to see that all cooling passages are unobstructed.
k. Checking to see that all indicator lamps are serviceable.
l. Noting any comments in an operator's log book.

FAULT FINDING IN ELECTRICAL CONTROL CIRCUITS

1. What are the five general steps in the sequence of events for locating and correcting a fault in control circuit wiring?
2. An analogue multimeter is to be used to check a conductor for continuity in a control circuit which has been safely isolated. To what function and range should the multimeter be set?
3. What voltage should be measured across an open switch in an operational 240 volt lighting circuit in which the switch is controlling a single lamp?
4. List five of the possible faults which could occur in the control circuit of a typical three phase magnetic DOL motor starter which has a built-in stop start-station.
5. What are two of the limitations of using an ohmmeter to find a fault in an electrical control circuit?
6. A typical magnetic DOL starter with an overload relay has an open circuit in the retain contact. What symptoms would be evident if the circuit was tested for correct operation?
7. What is the main purpose of 'preventative maintenance'?
8. Why is it essential to correct the CAUSE of a fault rather than simply repair the failed component?

FAULT FINDING IN ELECTRICAL CONTROL CIRCUITS

Objective

Locate the electrical fault in an operational circuit, given the actual faulty circuit and a circuit diagram thereof.

Equipment

Fault finding project board (pre-wired).
Circuit diagram of a 2 stage primary resistance starter
Multimeter.

Procedure

DANGER TAG PROCEDURE REQUIRED

Examine the circuit diagram provided and determine how the circuit is intended to operate.

Explain the operation of the circuit to your Lecturer.

Test the circuit for short circuits using a multimeter.

Energise the circuit and record the symptoms.

Symptoms:

____

____

____

- Switch the circuit off and remove the plug from the outlet.
- Examine the circuit diagram provided and predict the most likely location(s) of the fault.
- Locate fault using multimeter on ohms or volts.
- Ensure you follow Danger Tag and safety procedures.

The Fault is:-

____

____

- Switch the circuit off and remove the plug from the outlet.
- Submit your results to your Lecturer for assessment and comment.
- Return all of the equipment to its proper place.

Question

1. List the five basic steps which should be taken to locate and correct a fault in an electrical control circuit.

1. ____
2. ____
3. ____
4. ____
5. ____

SPEED CONTROL OF AC INDUCTION MOTORS

Torque is produced in an induction motor through the interaction of two magnetic fields.

The first rotating magnetic field is created by currents flowing in the stator windings.

This rotating field cuts the conductors in the rotor and induces a voltage in them.

The rotor voltage causes currents to flow in the rotor and produce a second magnetic field.

The two magnetic fields interact with each other and cause the rotor to rotate in the direction of the rotating stator field.

It accelerates to approximately 96 per cent of the speed of the rotating stator field.

This 4 per cent difference in speed on full load is the slip speed.

Without slip, an induction motor cannot develop torque.

The speed of an induction motor is always governed by the rotating magnetic field in the stator.

This stator field always rotates at a synchronous speed governed by two factors:

1. The number of pole pairs
2. The frequency of the supply

The synchronous speed can be found from:

$$n = \frac{120f}{p}$$

where n = synchronous speed
f = line frequency.

The number 120 is derived from the product of the number of seconds in a minute and the fact that magnetic poles always come in pairs.

The other two quantities are called variables.

It is important to note that there are only two variables.

If the frequency increases, the speed increases:

$$n \propto f$$

If the number of poles increase, the speed decreases:

$$n \propto \frac{1}{p}$$

These two basic principles are the only factors that can affect the change in speed of an induction motor, although the methods adopted to achieve this are many.

SPEED CONTROL BY CHANGING THE NUMBER OF POLES

Changing the number of poles in a stator winding always involves an abrupt step change from one speed to another.

On a 50Hz supply, a two-pole motor will rotate at 3000 rpm (ignoring slip speed). If a change is made to a four-pole stator, the speed will quickly change to 1500 rpm.

The change in speed can transmit minor transients into the supply lines. With larger motors, a short time delay should be introduced when changing from one winding to the other.

The most common method is to design windings that can be interconnected to change the number of poles.

It is always a “1:2 ratio” in that a two-pole winding converts to a four-pole winding, or a four-pole to an eight-pole winding, and so on.

Figure 8.23(a) illustrates the principle and connections involved for a four-pole to eight-pole conversion.

Only one phase is drawn; small rectangles are used to represent pole-phase groups and the arrows indicate the sense of winding direction.

It is necessary that the pole windings be connected in pairs opposite each other as shown.

Series-parallel connection for a two-speed motor

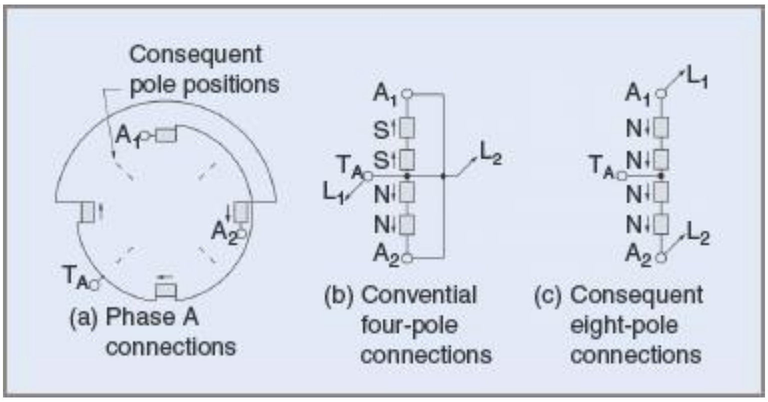


Figure 8.23 Series-parallel connection for a two-speed motor

Note that the center-tap (T_A) of the winding has been brought out so that it can be accessed externally.

In Figure 8.23(b), the four pole-phase windings have been redrawn in a vertical line. If A1 and A2 are bridged and connected to line L2, and the center-tap T_A connected to line L1, the motor will have four conventional poles as indicated by the arrows.

In Figure 8.23(c) the bridge has been removed. A1 is reconnected to line L1 and A2 left connected to line L2.

As indicated by the arrows, the current flows through all four pole-groups in series and all give the same polarity, for example, as shown there would be four north poles.

The magnetic flux is diverted in the stator and exits between the north poles as indicated by the broken lines.

The resulting magnetic circuit of the motor is that of an eight-pole machine.

To get around this 1:2 ratio limitation, some stators have been designed to accommodate two electrically separate windings.

Only one winding is used at a time.

These windings need not be in the ratio of 1:2, but can be any reasonable relationship. For example, one winding could be a two-pole winding, the other a six-pole winding.

Activating the two-pole winding would cause the motor to rotate at 3000 rpm.

During this period the other winding, if not connected in star configuration, must have the delta bridges open-circuited to prevent induced currents flowing in the unused winding.

When provided with a suitable switch, the windings could be exchanged without stopping the motor or its coupled machine.

The motor would then change speed to 1000 rpm.

Step speed control with pole amplitude modulation (PAM) is a rather lesser known system.

It was developed for close speed ratios, such as changing a four-pole to a six-pole and an eight-pole to a ten-pole.

It relies on the principle of unequal coil groupings within the motor when manufactured. Connections are made with special contactors to control speed steps.

PAM windings are covered by copyright but can be manufactured under licence.

PAM motors are made as small as 0.5kW but have been made in sizes up to 7MW.

SPEED CONTROL BY CHANGING FREQUENCY

One important aspect of this method of speed control is that, at higher frequencies, the standard induction motor runs at speeds well above the base design value.

At increased speeds, air circulation is improved, resulting in improved cooling.

Better cooling permits higher current densities to be used, even though there is an increased friction and windage loss due to higher speeds.

There are also increased iron losses due to the higher frequencies. At higher frequencies, the impedance of the windings is also increased and, to ensure a constant flux density in the air gap, a higher supply voltage is required.

At constant flux density in the air gap, torque is proportional to current flow.

Since power is dependent on both torque and speed, it can be seen that the power output of the motor increases at a faster rate than the speed increase.

Increasing the frequency of a complete plant would ensure all motors ran at a faster speed and this might not always be desirable.

Decreasing the frequency would ensure that all motors ran more slowly, and produce the same undesirable result.

In general then, frequency changing as a method of speed control is limited to specific machines or groups of machines, as in a series of transport rollers in a steel mill.

Variable speed drives or VSDs vary frequency to control the synchronous speed on a motor.

There are two main methods for frequency changing.

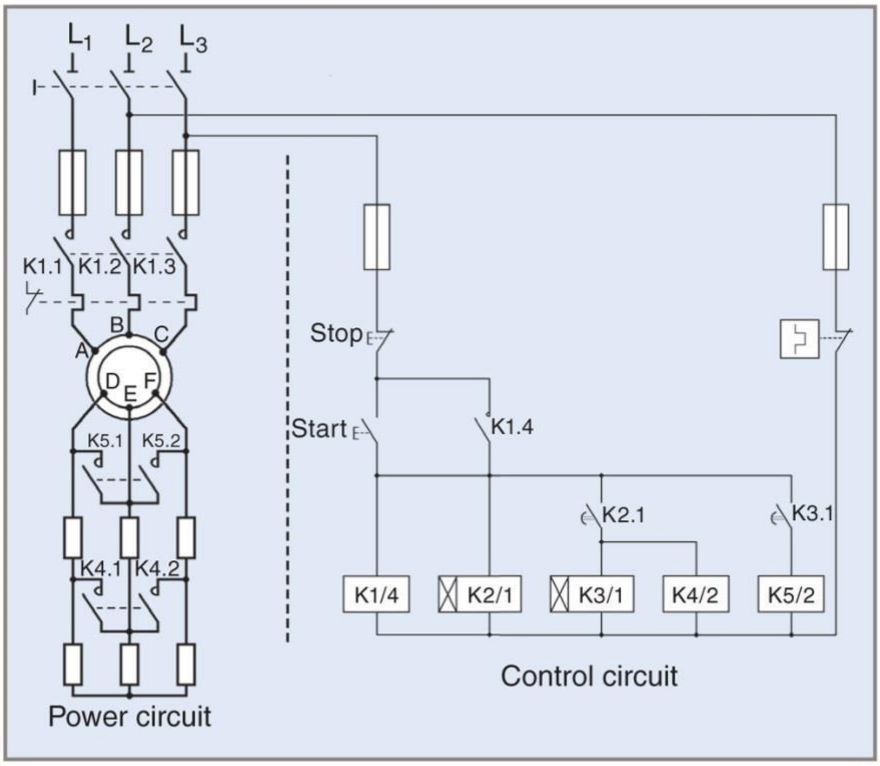
The first uses rotating machinery to achieve the desired result. It is expensive, although less efficient than some other methods, but experience has shown it to be extremely reliable, with minimal maintenance problems. Therefore, it is still in considerable use.

The second method uses electronic switching to synthesize an irregular-shaped alternating current wave from DC. It is a comparatively new procedure and has become very popular.

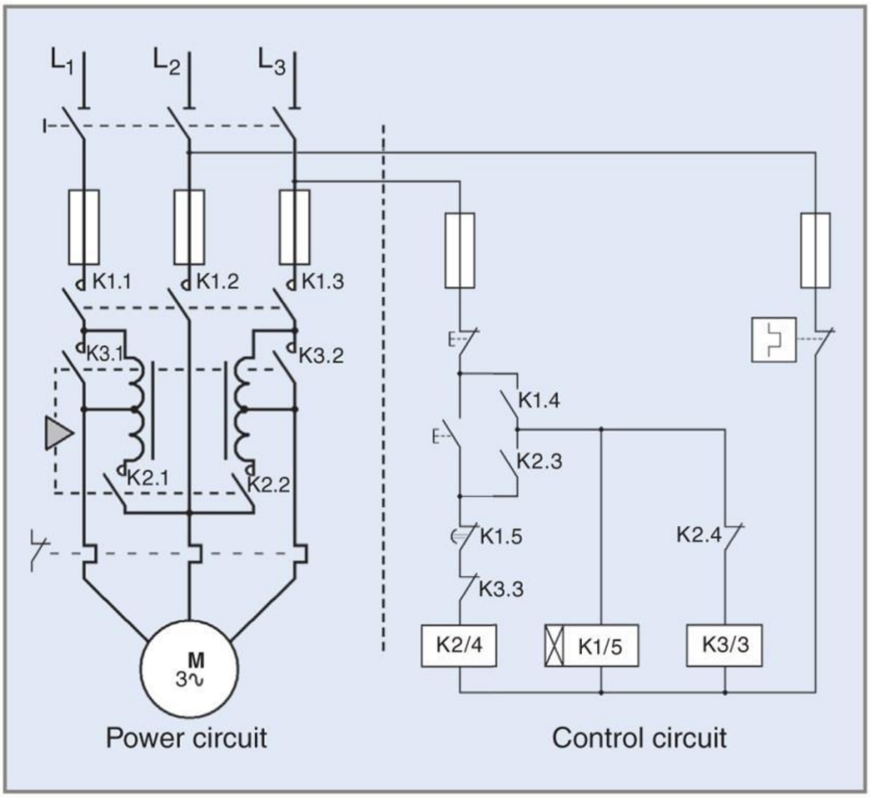
Below is a table of Three phase induction motor starter applications.

STARTING METHOD	STATOR VOLTAGE AT START	START CURRENT %FL	START TORQUE %FLT	No. OF STEPS	CURRENT SURGE DURING STARTING	TYPE OF LOADS	EXAMPLE LOADS	COMMENTS
direct on line	line volts	700%	150%	1	n/a	light inertia loads	centrifugal pumps: lathes	start torque greater than full load torque
primary resistance starter	reduced	300%	40%	2+	no	almost no load	fans	poor start torque
star/delta	reduced	200%	33%	2	yes	light loads	motor generator units	start torque 1/3 full load torque
autotransformer	reduced	300%	80%	2	yes	substantial proportion of full load	hydraulic pumps and conveyors	start torque slightly less than full load torque
secondary resistance	line voltage	100	100	2+	yes	high inertia loads	shock loads presses shears	rotor resistance adjusted to give Ts=FLT

Operation of all the starter types in this table will be demonstrated during this course.



Three Phase wound rotor motor – Secondary resistance starting – 3 stage



Three phase motor – Autotransformer Starter – 2 coil

Speed control of AC induction motors

1. What creates torque in an induction motor?
2. Where are the two magnetic fields generated in an induction motor?
3. At what speed does the rotating magnetic field of a stator rotate?
4. What two variables affect the speed of an induction motor?
5. If the number of poles in an induction motor increase, what effect does it have on the speed?
6. Name one advantage and one disadvantage of running an induction motor at higher than design frequencies.
7. Describe two types of frequency changing for induction motor speed control.
8. What motor control system is best suited for heavy loads?

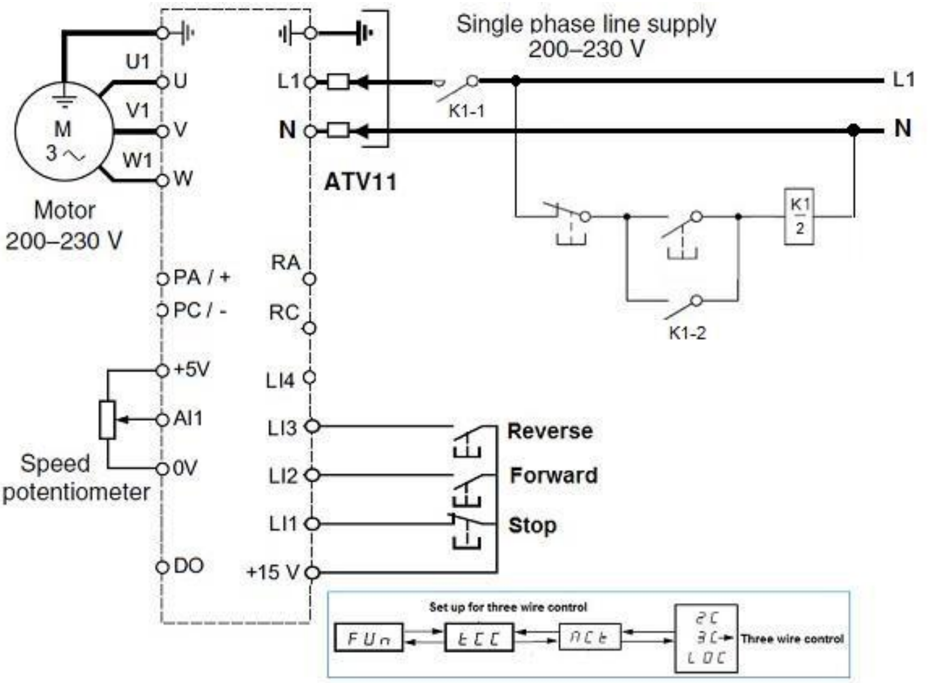
Connect and Configure an Altivar Variable Speed Drive

Objective
To connect and configure the range of variables for a variable speed drive.

Equipment
Altivar variable speed drive.
Altivar 11 User's Guide
Connecting leads
Multimeter
Insulation resistance tester

Procedure:
DANGER TAG PROCEDURE REQUIRED

Connect the variable speed drive as per the connection diagram.



Carry out all appropriate tests as per the AS/NZS3000:2018:

Have your circuit checked by the lecturer: Lecturer sign off: _______________

Remove danger tag and energise the circuit:

Record the following information:

What is the power range rating on the Altivar 11? ____________________________

What is the programmed acceleration time? ______________________________

What is the programmed de-acceleration time? ______________________________

List the menu tree that you would access to enter the motor rating information:

To which terminals would you connect a braking resistor module?
____

To which terminals would you connect a fault relay? ______________________________

Run the motor and from the SUP display menu, observe and record the following:

Frequency – Set this to 45 Hz

Motor current: ________________

Line voltage: ________________

Motor thermal state: ________________

According to the AS/NZS 3000 - Wiring Rules, is the stop function incorporated with this VSD suitable for the purpose of emergency stopping?

State the clause number: ______________________________

Manual Star-delta Starter (Marked)

Objective

To connect a manually operated star-delta starter with marked terminals to a three phase squirrel cage induction motor with six marked terminals.

Equipment

Manual three phase star-delta starter.
Three phase squirrel cage induction motor, delta, six marked terminals.
Multimeter.
Connecting leads.
Three phase lead.

Procedure

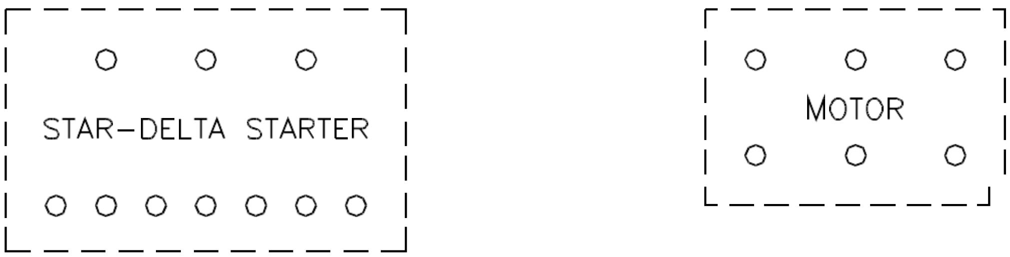
DANGER TAG PROCEDURE REQUIRED

1. Open the cover of the starter and examine all of the internal components. Locate the following parts.

   a. Line terminals
   b. Terminals for motor leads (on starter)
   c. Main contacts
   d. Hold in coil
   e. Overload heaters
   f. Overload contacts and adjusting mechanism
   g. Stop button
   h. Mechanical delta interlock
   i. Overload reset button (if fitted)

2. Draw a diagram on a separate sheet showing the approximate relative position of each of the parts listed above.

3. Draw a diagram similar to the one below, showing the terminal markings on the starter and the motor, and the external connections required to correctly run the motor.



4. Have your diagrams checked by your Lecturer.

5. Wire up the circuit according to your diagram.

6. Check your wiring for short circuits with a multimeter.

7. Have your wiring checked by your Lecturer.

8. Plug the circuit into a three phase outlet and check the motor and starter for correct operation. Measure and record the PHASE voltage and the LINE voltage in the STAR position.

Phase voltage ______________________

Line voltage ______________________

9. If the motor operates correctly, switch the circuit off, remove the plug from the outlet and disconnect all of your wiring.

10. Return all of the equipment to its proper place.

Questions

1. What is the main purpose of a star-delta starter?

____

2. What is the disadvantage of a star-delta starter compared to a DOL starter, disregarding cost?

____

3. What is the voltage per phase applied to a motor in the start position? Express this voltage as a percentage of the line voltage.

____

4. What percentage of LINE current could you expect the motor to draw in start, compared to the current it would draw if started DOL in delta?

____

5. What percentage of starting torque would you expect the motor to develop in the start position, compared to the starting torque obtained if the motor was started DOL in delta?

____

6. Why was the hold in coil energised in the delta connection only?

____

7. What was the range of overload settings on the starter used for this project?

____

8. Would you expect this type of starter to cause a relatively high transient current when switched from star to delta?

____

9. What value would you set the overload heaters to in the starter used for this project - the line current or the coil current?

____

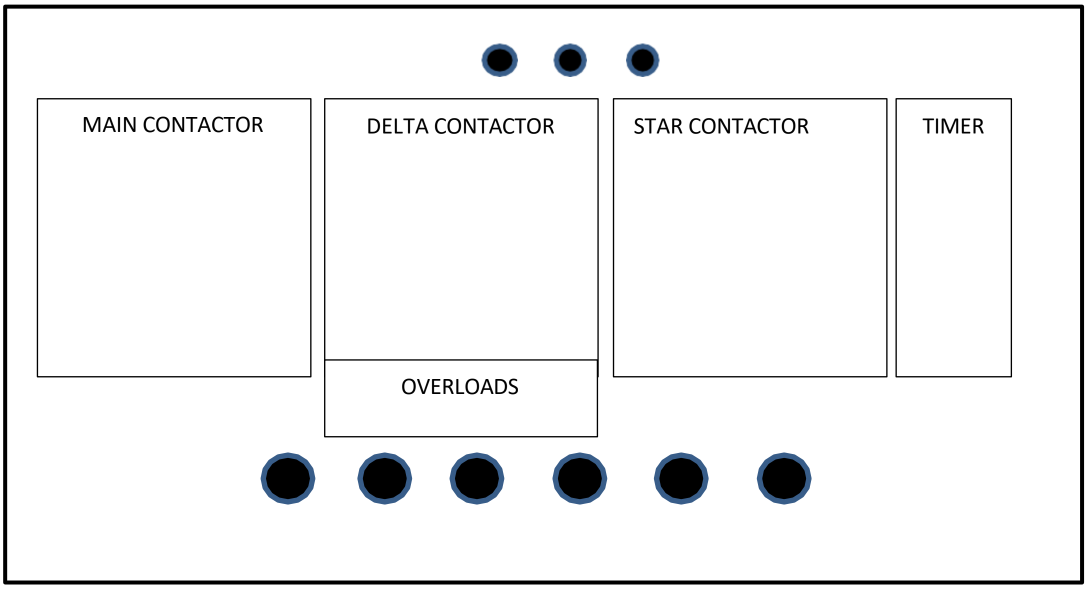
Automatic Star-delta Starter Connections

Objective

To connect an automatic star-delta starter to a suitable three phase supply and test it for correct operation.
Automatic star-delta starter.
Three phase motor (6 terminal type).
Multimeter.
Three phase lead.
Circuit diagram of the starter as supplied by the manufacturer.

Typical Layout

An automatic star-delta starter has three terminals for the incoming phases and six terminals for the motor. A typical layout of the internal components is shown below:



Procedure

DANGER TAG PROCEDURE REQUIRED

1. Note the number and type of internal components shown in the layout diagram above. Locate an automatic star-delta starter in the electrical laboratory. The starter can by identified by:

a. Markings on the nameplate or inside the starter.
b. The number and type of internal components (although their actual location in the starter can vary).
c. The number of motor terminals on the starter.

2. Locate the three terminals for the incoming three phase supply, and the terminals to which the motor has to be connected.

3. Draw a neat freehand sketch (similar to the layout diagram given), showing the layout of the internal components, the location of the line and motor terminals and the markings on or near each of the components. DO NOT attempt to show the internal starter wiring.

4. On your sketch, show the wiring necessary to connect the three phases to the starter, and the starter to a suitable three phase motor.

5. Have your sketch checked by your Lecturer.

6. Connect the three phase supply and the three phase motor to the appropriate starter terminals using a correct colour code. Provide earthing connections where required.

7. Check your wiring for short circuits with a continuity tester then, have your circuit checked by your Lecturer.

8. Energise the circuit and test it for correct operation. Note the time it takes to switch from START to RUN.

9. Have the operation of the starter checked by your lecturer.

10. Switch the circuit off and remove the plug from the outlet.

11. Disconnect your wiring and return all the equipment to its proper place.

Primary Resistance Starters

1. A primary resistance starter has a switching arrangement whereby the motor is first connected to the line with a resistor in series, then after it has accelerated it is switched directly on line. The value of the starting current is limited by the value of the series resistor in each phase.

2. The line resistors can be cut out in steps to provide controlled acceleration if a suitable control circuit is used. Figure 1 show a typical circuit for a one step primary resistance starter.

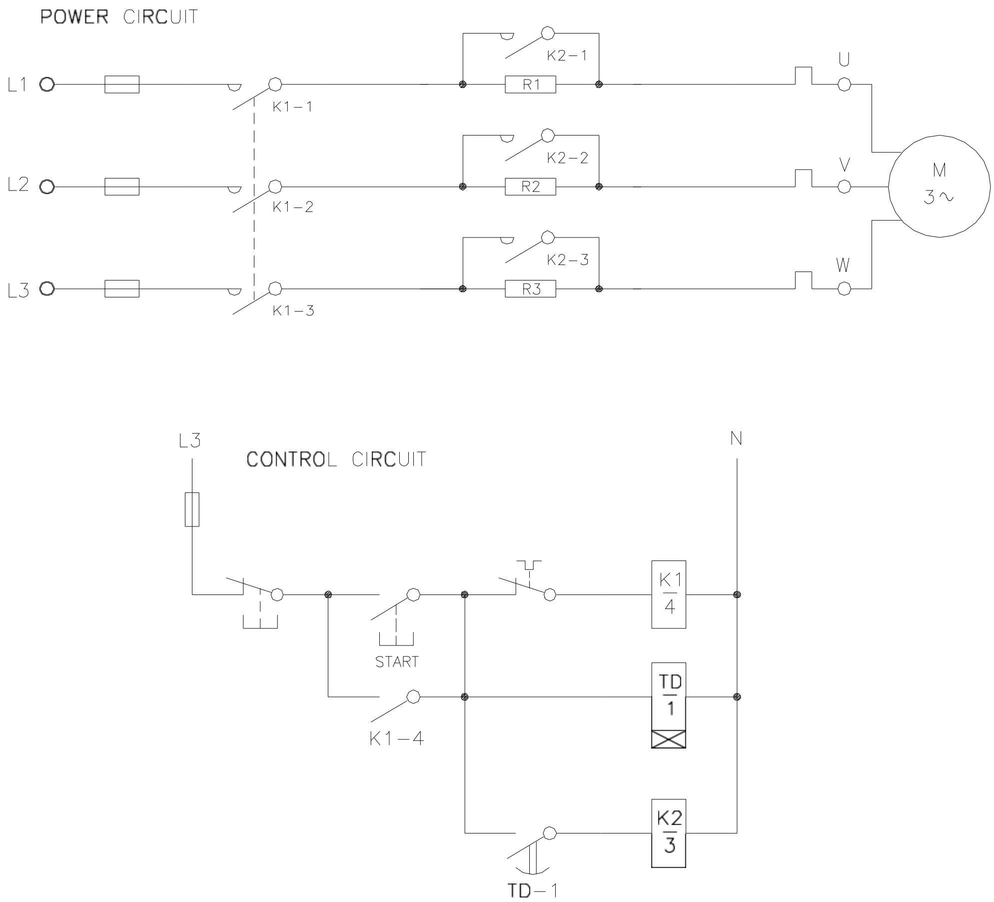


Figure 1 - A one step primary resistance starter circuit.

3. The motor will start when the line contactor (K1) is closed. After a definite time delay (provided by a time-delay relay) the accelerating contactor K2 closes and short circuits the three line resistors; the motor is then running direct-on-line.

4. This starter can be used with any three phase motor regardless of whether it is star or delta connected, but it has the disadvantage that maximum volt drop occurs across the resistors at the instant the motor is switched on (due to the high current flowing - V = I.R), so the starting torque is low.

5. The torque of an induction motor is proportional to the square of the applied voltage, so if the applied voltage at the motor terminals is halved at the instant the motor is switched on, the starting torque would be one-quarter (1/4) of full load torque (50% of 50% is 25%).

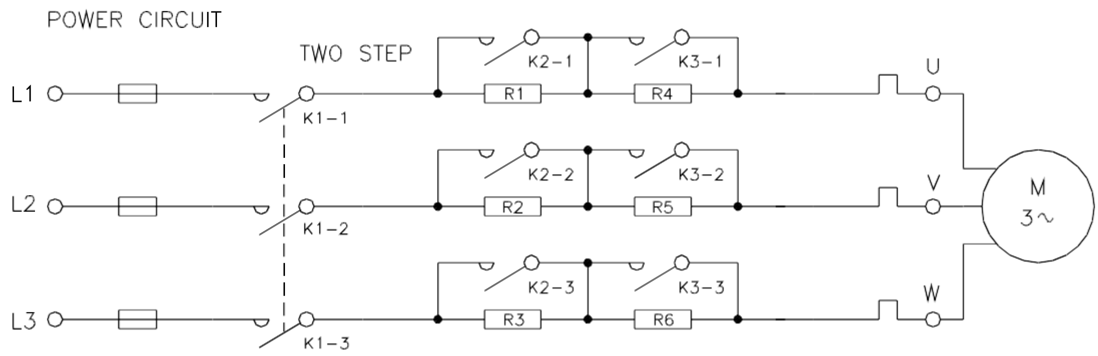
6. A feature of this starter is that it is simple in construction; therefore it has a comparatively low initial cost and requires little maintenance.

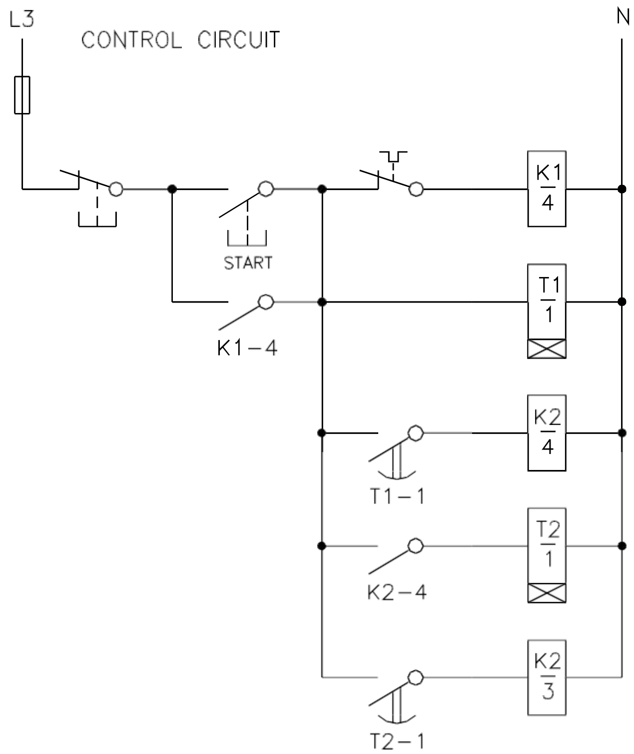
Line Resistors

7. In one type of primary resistance starter, the series resistors in the line circuit are heavy wire wound resistors mounted in multiples of three (depending on the number of accelerating stages), inside the starter enclosure.

Two-Step Primary Resistance Starter

8. Figure 2 shows a circuit diagram of a typical two-step primary resistance starter. If you compare this circuit with the one in Figure 1, you will see that they are very similar - the two-step starter has an additional bank of series resistors in the power circuit and an additional timing stage in the control circuit. Other steps could be added to provide a smoother acceleration if required.





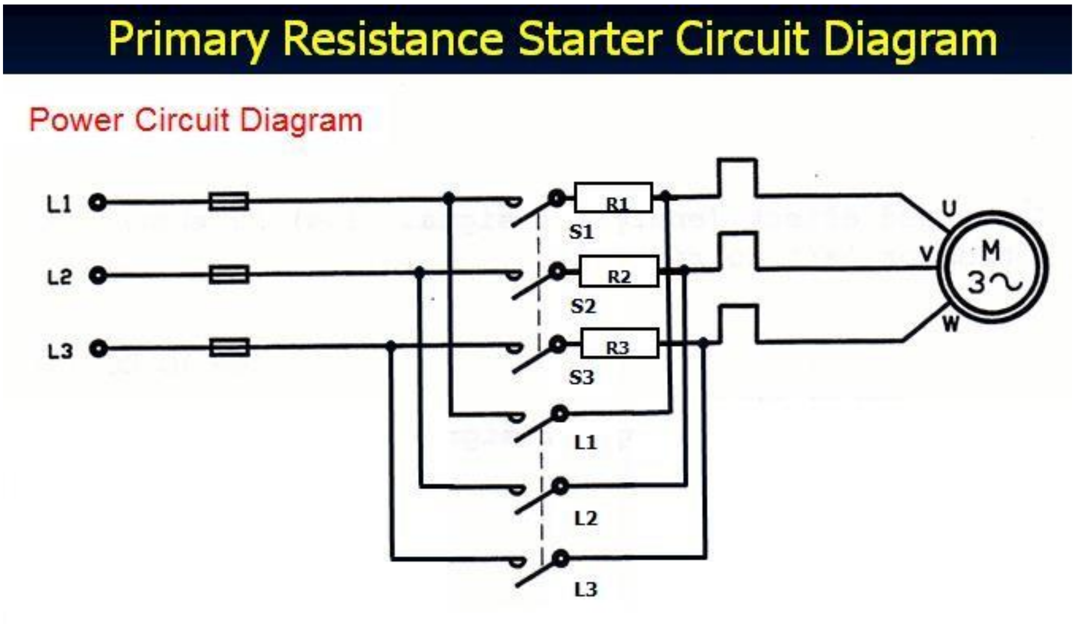
Applications

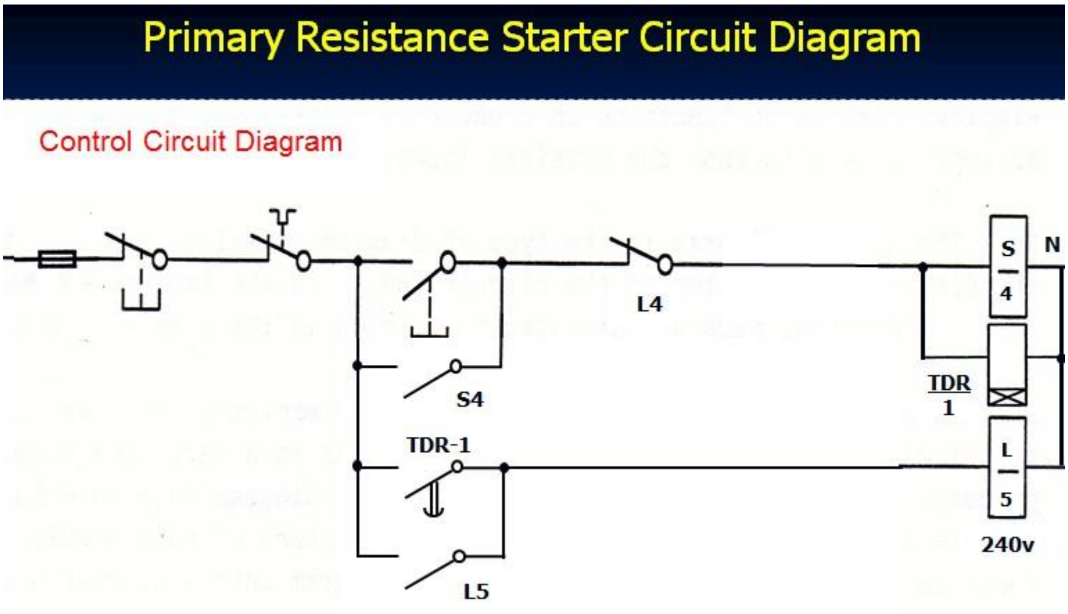
9. Since a primary resistance starter has very low starting torque, it can only be used in applications which start on little or no load - such as fans and blowers.

Sequence of Operation of a 'One Step' Primary Resistance Starter

Study the sequence of operation of the primary resistance starter below.

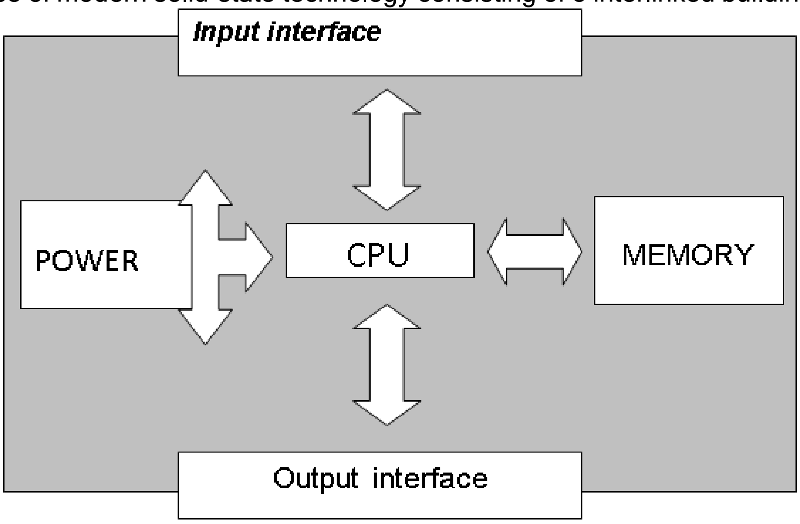
Using this information, write a sequence of operation for the following Primary Resistance Starter circuit.





‘Programmable logic controllers.’
PLC’s are used throughout industry and take many forms from large Newspaper printing mills to simple garden reticulation programmers. The PLC is an " Industrial computer " that uses a (Central processor unit) CPU with an instruction set and does away with complex programs and files in comparison with a desktop computer. Programs can be quickly modified to accept new situations with a minimum of re-wiring and reduced costs.
A big advantage with PLC's is the simplified physical hard wiring technique's to connect external devices to the PLC. With conventional wiring techniques contactors have to be retained by a normal open auxiliary contact across a start button etc. in a PLC the retaining of a contactor can be done without the use of an external auxiliary contact by making use of internal relays on the PLC itself.
The main advantages are listed below:-
Reduces the Hardware wiring
The System can be made compact
Contact Failure rate is reduced
Speed of operation is very high
Easy for Trouble shooting
Reduces the Maintenance cost.

The PLC makes use of modern solid-state technology consisting of 5 interlinked building blocks:



1.) Processing unit (CPU)
2.) Memory unit
3.) Input interface
4.) Output interface
5.) Power supply

The flow of information within the PLC will follow a very simple path, similar to the sequence list below.

The CPU will read the memory unit. (The program in the unit)
Check the “Input Interface” status.
Update the CPU status.

The Central processing unit (PCU)
The CPU is the brains of a PLC. The program is retrieved from the memory unit and processed by the CPU.
Processing can be described as running the program. What actually happens is that the program is “Scanned”, this means the program is checked from start to finish and new information is updated.

This is often referred to as the scan time of the PLC, but is actually more related to the program operating time. One scan of a program typically takes 70 milliseconds, but this depends on the program length and complexity.

Input interface

This is where all the input signals are connected. The input signals are all the field devices like limit switches, stop buttons, start buttons, auxiliary contacts etc. Input signals are usually 24 v DC or 110 v to 220 v AC. Most PLC's the input connections are on top and the output connections are the bottom. All input connections are designated by indicators in the form of light emitting diodes LEDs. This feature comes in handy when doing fault-finding whereby you can literally see the status of the input signals.

Later, it can be seen that the CPU is directly connected to the input interface. To protect the CPU from harmful high voltages and currents the input terminals are isolated. The isolation method is by means of internal Optical couplers, switched by optical (light) pulses. These optical couplers are devices that couple signals from one circuit to another by means of electromagnetic radiation, usually infrared or visible. A typical optical coupler uses a light emitting diode to convert the electric signal of the primary circuit into light and a photo transistor in the secondary to reconvert the light back into an electric signal.

Output interface

This is where all the output signals originate from. The output signals are connected to all the hardware and components like contactors, relays, sirens and many more. The CPU is directly connected to the output interface. Because harmful voltages can damage the CPU it must be isolated Three methods are used to " buffer " the CPU from the inputs;

1. Relay protected (switched)
2. Transistor protected
3. Triac protected

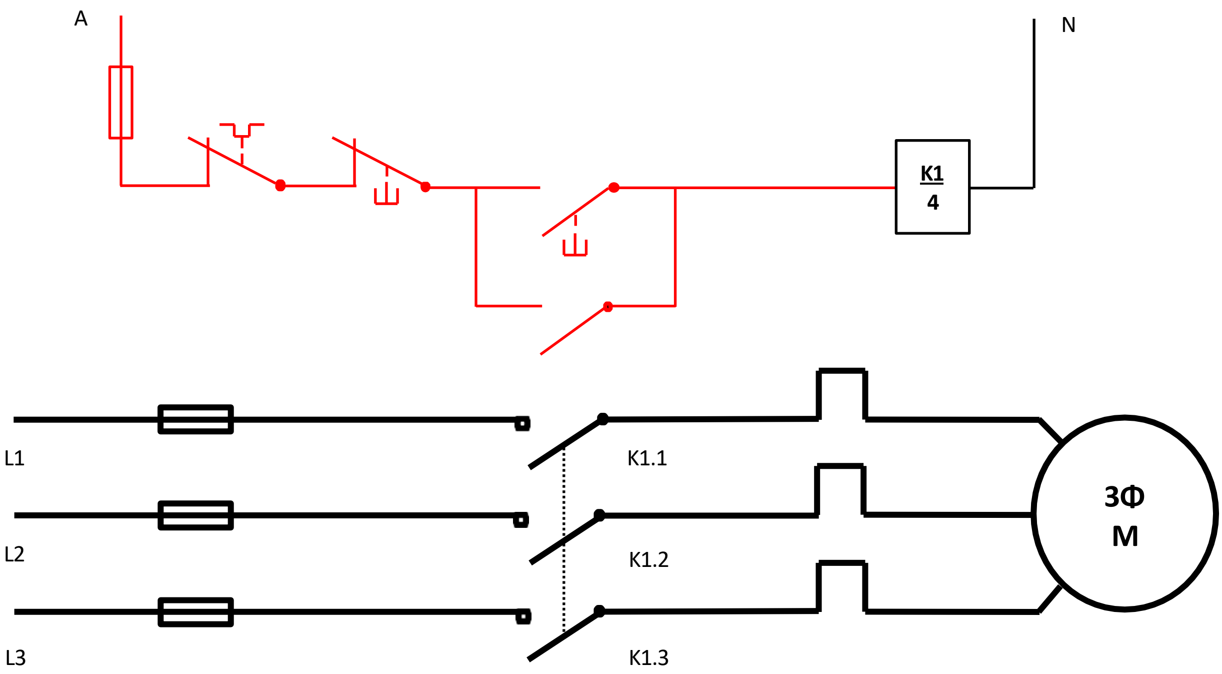
This can be best shown in a table

Switch device type	Operating voltage	Approximate switching times
Relay	250 V AC / 30 V DC	10 ms
Transistor	5 V to 30 V DC	0.2 ms
Triac	85 V to 240 V AC	ON: 1 ms / OFF: IO ms

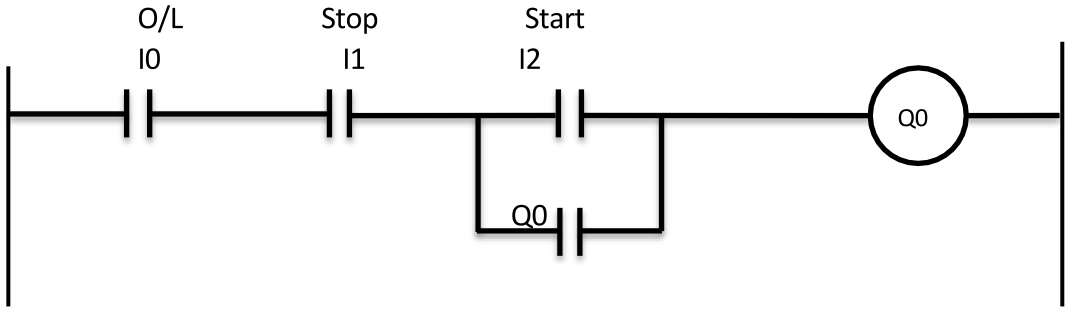
Both the transistor and the triac units use opto-isolation. The relay units have natural isolation in the sense that the output is mechanically switched as the coil of the relay is energised or de-energised. All the output connectors, found at the bottom are numbered, starting from 0 to the total number of outputs.

Memory Unit

On most PLC's there are two types of memory available
RAM (Random Access Memory)
ROM (Read Only Memory)
Only one type of memory unit can usually be accessed at any one time. RAM is usually built in to the PLC, while ROM is available as add on.
The drawing of a simple direct on line circuit is shown below. The control circuit comprises of an overload auxiliary, stop and start button. It can be seen that the circuit consists of a main and control circuit. The student must realise that the main circuit will be wired in the standard way and that the PLC is only involved in the control circuit.



In the circuit below the control devices have been assigned to the PLC input and output numbers.

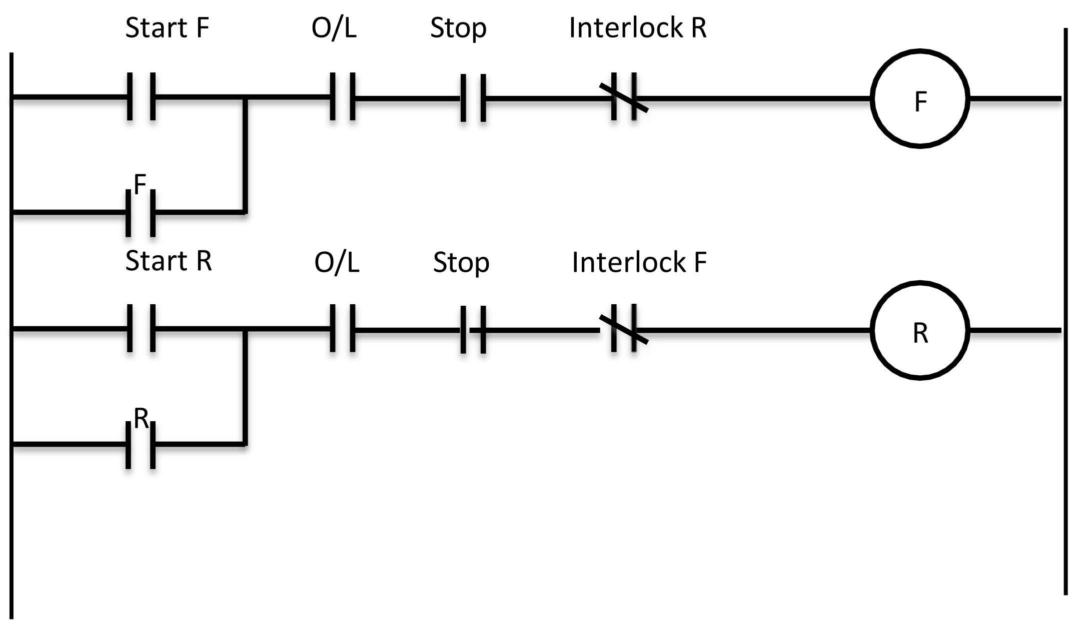


An important point to make is that fail-safe design is very important in PLC-controlled systems. One should always consider the effects of failed (open) wiring on the device or devices being controlled. In the motor control circuit example, we have a problem: if the input wiring for the “Stop” switch were to fail open, there would be no way to stop the motor!
The solution to this is a reversal of logic of the stop “contact” inside the PLC program and the actual “Stop” pushbutton switch:
When the normally-closed “Stop” pushbutton switch is not operated, the PLC’s stop input will be energized, thus “closing” the Stop “contact” inside the program. This allows the motor to be started when Start pushbutton is pressed. When the “Stop” pushbutton is pressed, the Stop input will de-energize, thus “opening” the stop “contact” inside the PLC program and shutting off the motor.

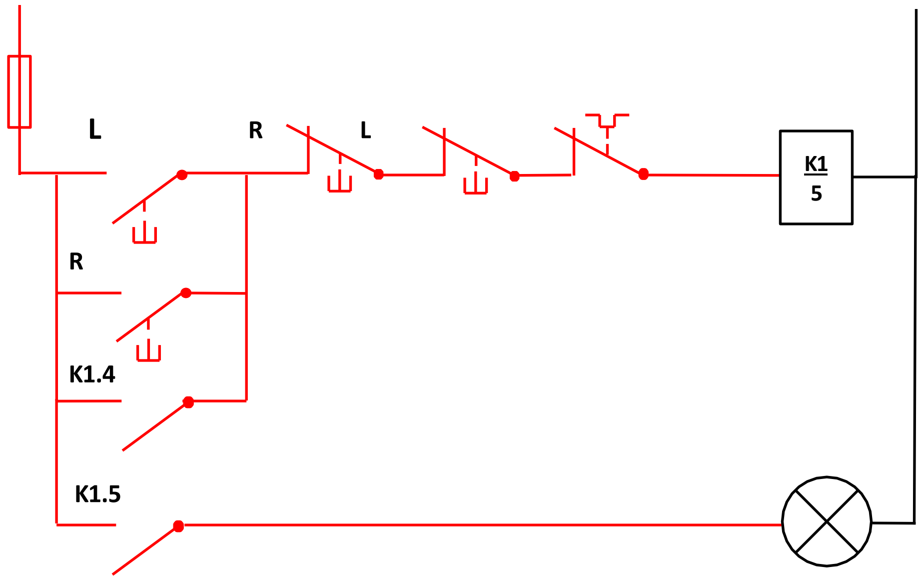
If the input wiring on input Stop pushbutton were to fail open, the Stop input would de-energize in the same manner as when the “Stop” pushbutton is pressed. The result, then, for a wiring failure on the Stop input is that the motor will immediately shut off. This also applies to Overload contacts.

Programing devices
The programmer is the device you use to enter a program into the PLC. This provides the user with a means of communicating with the PLC in order to enter a program. The program can be fully tested off line, and then down loaded to the PLC. The most common one are:-
Hand held programmer (HH)
Computer programmer (PC)

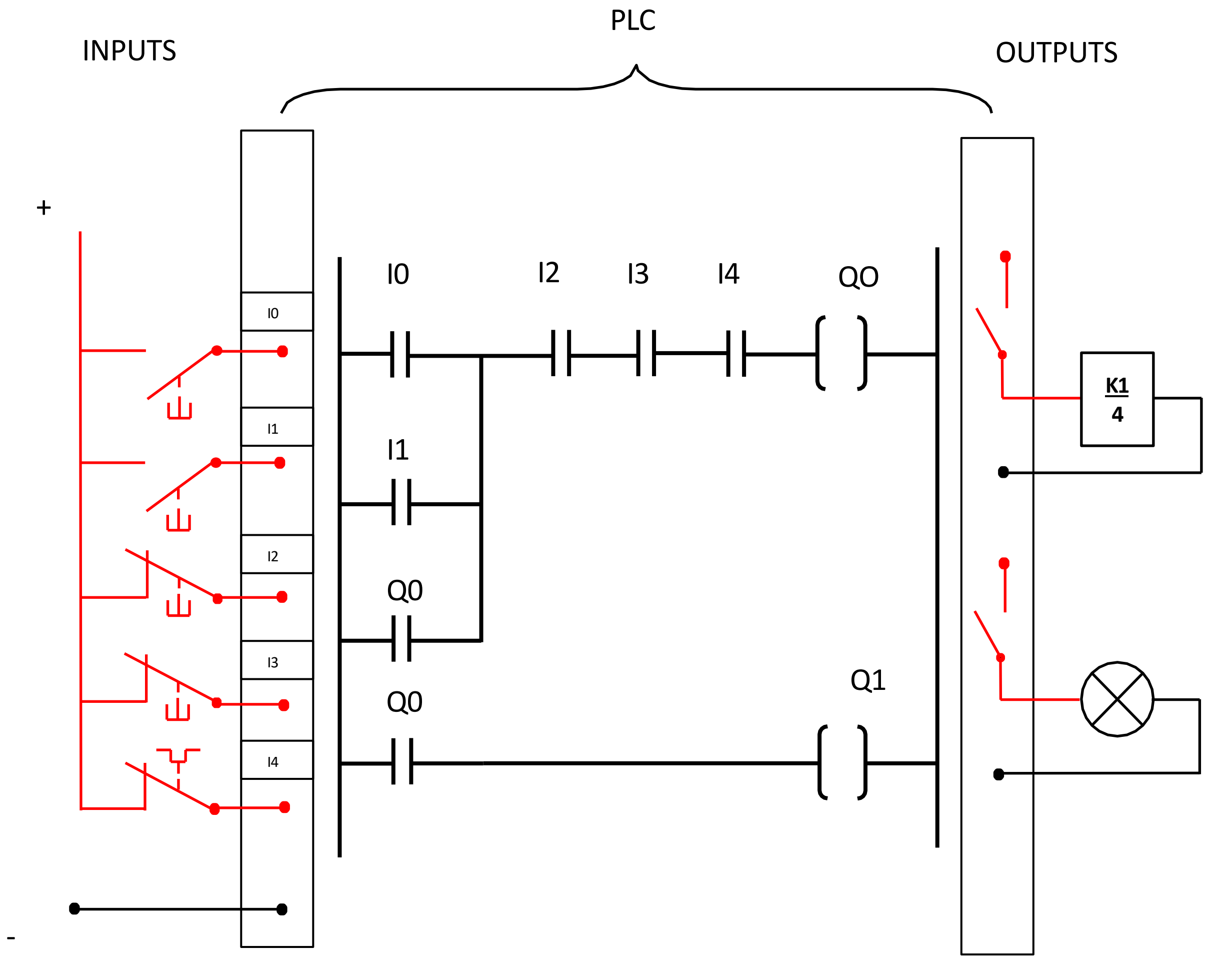
Ladder diagrams
The ladder diagram, which can also be referred to as a schematic or elementary diagram is used to show simply how a circuit works. To simplify the circuit and thus help understand its configuration, the power portion of the circuit is shown separately from the control portion. No attempt is made to show the actual physical location of the components. By not showing the power portion of the circuit, a ladder diagram can be developed showing only the control portion of the diagram.
The power required for the control circuit is always shown as two vertical lines, while the actual lines of logic are drawn as horizontal lines. The power lines are called the rails as they are like vertical sides of a ladder, whereas the horizontal logic lines are like rungs of a ladder. Figure on next page shows a typical ladder diagram with two lines of logic (two rungs).



Programming the PLC with ladder diagrams
The programming of PLC's is made simple by using the form of ladder logic and ladder programmes, which were formerly used for hard-wired relay systems. In the past the circuit for control switches, contactors and so on were drawn in the form of a ladder diagram as shown by the Figure below. The electrician would wire up the equipment as given by the diagram.



With the PLC program you can draw the circuit diagram on a PC and enter this as the PLC program. The PLC processor will then act on the circuit to produce the same result as that obtained by the hard-wired relay system. The PLC system however has many advantages. It is smaller, faster, more reliable and efficient and it can be simply rewired by entering a new program (in the form of a ladder diagram).



Address system
All components in the PLC have a specific letter and number, address. Different manufacturers use different address systems so when working with PLC's you need to refer to data supplied by the manufacturer.
Addressing can be divided into;

- Input
- Output
- Timers
- Counters
- Internal relays

Real I/O addressing identifies a program element (such as N/O contact or coil) which is connected to an actual input or output device in the plant. These addresses must therefore refer to the terminal which supplies that particular input or output device. We refer to one terminal because the other is a common terminal as shown in the figure above.
The first digit indicates the type of component. For example, "Q" indicates an output coil or its auxiliary contact. "I" indicates an input contact. The last digit indicates progressive components, which are programmed in. That is, the input contacts will be I0, I1 and so on. The outputs will be Q0, Q1 etc.
NB Some PLC inputs are "X001, X002...." and outputs "Y001, Y002...."

FAULT FINDING

Once you understand the basics of PLC principles, fault-finding shouldn't be too difficult, provided you keep a few golden rules in mind.

1. There should be detailed drawings and programs. The drawings must include all the PLC designated inputs and outputs. The programs should have proper captions or descriptions of the program steps.
2. Bear in mind that about 90 % of all PLC related faults are due to breakdowns in the field wiring it is a simple task of measuring the status of the field devices. The status of the input / output LEDS should help with the fault finding process.
3. If in doubt you can download the program onto the programmer, ensuring the validity of the program and simulate the working of the program until you reach the defective stage.
4. The process of fault finding involves a thorough knowledge of the basic principles and a lot of common sense.
5. It can happen that the PLC itself can be at fault. All modern PLC's have built-in self-diagnostic procedures that will indicate an error code. Keep a list of all the error codes nearby.

CHECKING ERRORS WITH THE LEDS

If a problem occurs while the PLC is running, check the power supply voltage, the PLC terminal screws and the I/0 devices for loose connections or other abnormalities.

The LEDs on the PLC will help you to determine if the PLC is faulty or if an external device is causing the problem. Check the input and output LEDs and the input and output voltages.

POWER INDICATOR - POWER LED OFF

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Questions

1. What does "PLC" mean?
2. Sketch a basic PLC block diagram.
3. Name TWO types of input signals that can be used to operate a PLC.
4. Name FOUR advantages of a PLC control system over a hard-wired relay control system.
5. Name the THREE basic sections a PLC consists of.
6. Name TWO types of programming devices.
7. What is meant by optical isolation?
8. Name TWO advantages of optical isolation.
9. How is a normally closed stop push button entered in a PLC program and why?

PLC Exercise.

Your individual Training Facility will demonstrate a particular brand of PLC and you will be introduced to programming simple control circuits which will vary from each Training Facility.

As the command structure could possibly differ from manufacturer to manufacturer the learner must obtain the related command set for the specific PLC that he is going to work on.