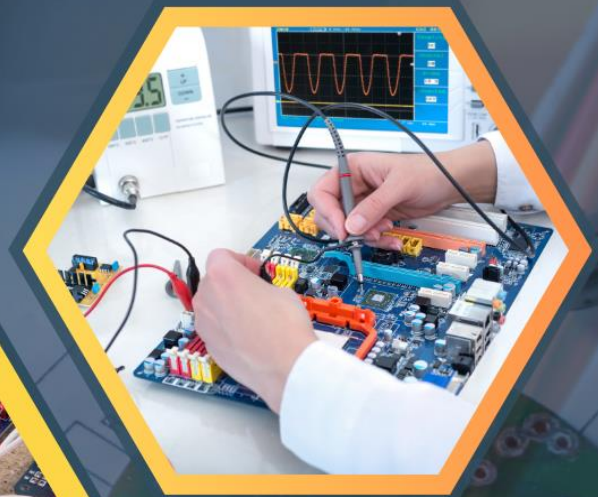An Enlightment On

# INDUSTRIAL
# ELECTRONICS

Mohd Nazrulazlan Bin Abd Rasid       Mohamad Nadzhar Bin Jjom

# An Enlightment On

# INDUSTRIAL ELECTRONICS

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# PREFACE

This e-book is created and developed as Continual Quality Improvement (CQI) for Industrial Electronics course. The Course Outcome Review Report (CORR) findings stated that course notes and in class activities should be improved and updated with suitable and effective teaching method and materials. This book is aligned with the curriculum of DJM30062 for the students of Diploma in Mechatronic Engineering to improve their understanding to attain a good result. This book is the result of years of experience of the authors teaching this course. It is also a platform for the authors to share the knowledge with other lecturers. Hopefully, this e-book is able to be a useful resource in understanding the concept and application of Mechatronics. Finally, the prayer of God so that this effort is accepted as one of the practices that bring pleasure and reward, as well as able to help spread knowledge, especially to the community. The authors apologize for any shortcomings and errors that may be found in the publication of this e-book. Thank you. Enjoy reading and gaining knowledge.

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# ACKNOWLEDGEMENT

# ABSTRACT

Industrial Electronic is ONE of the main components of Mechatronics. This E-book discuss the devices used in Mechatronics. This book is a quick reference to help students grasp the basics of mechatronic devices in terms of principles and applications. This eBook edition has three chapters and sample questions that are accessible to show understanding of the topic. It can also assist students in exercising and testing their knowledge.

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# CHAPTER 1: INTRODUCTION

## 1.1  Introduction of mechatronic devices

There are many opinions about introducing the term Mechatronics, but majority agreed that everything started in the late 1960s by Japan's Yasakawa Electric Company. The term is derived from the observation of the synergy achieved through the integration of mechanical and electronic technologies, Yasakawa, subsequently released trademark rights to the name after 1982.

In other words, Mechatronics refers to a multidisciplinary approach to product and manufacturing system design. It represents the next generation of machines, robots and smart mechanisms for carrying out work in a variety of environment automation. Automation covers home, factory and office environment. For example, at home, we use washing machine, electronic watches and rice cooker. There are many CNC machines used in the factory. Computers, telephone and printers are used in the office. In short, Mechatronics is applied everywhere in our daily lives.

Therefore, the advantages of industrial electronics provide are:

- ✓ High dimensional accuracies
- ✓ Increased productivity on the shop floor
- ✓ Enhances the quality of products
- ✓ High level of precision and reliability
- ✓ New function and capabilities

## 1.2  Mechatronic devices

There are many mechatronic devices used in the industry. Several types of mechatronic devices will be discussed which are in used by working design. The types of mechatronic devices used are switches, relay, solenoid, transducer and data acquisition. These types of devices will be discussed in this book.

## a) Switch

The switch is a mechanical, electrical or electronic device that opens or closes a circuit.  The closing of a switch is called making the circuit.  The opening of switch is called breaking the circuit.  Switching may also be called making or breaking the circuit. Types of switches vary based on the mechanism and material used. Example of switch as shown below:

| | | |
|---|---|---|
| Toggle Switch | Rocker Switch | Slide Switch |
| Microswitch | Key Switch | DIP Switch |
| Rotary Switch | Push Button Switch | |
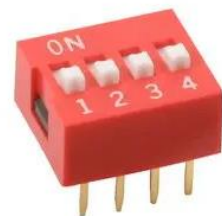
Switches are often described by the number of poles and throws, such as:

    i.     SPST (single pole, single throw)

    ii.    SPDT (single pole, double throw)

    iii.   DPDT (double pole, double throw)

    iv.   3PDT (3/triple pole, double throw)

    v.    4PDT (4/quadruple pole, double throw)

In switch terminology, the number of poles is the number of separate connection circuits the switch controls. The number of throws is the number of possible output connections that can be made.

## b) Relay

The relay is an electromechanical device. Relay functions as a simple ON/OFF switching action and response to a control signal. The main component of relay is coil and the contacts. Relay works when a current flows through the coil of wire then magnetic field is produced. The magnetic field pulls an armature that forces the contact to open or close the circuit.
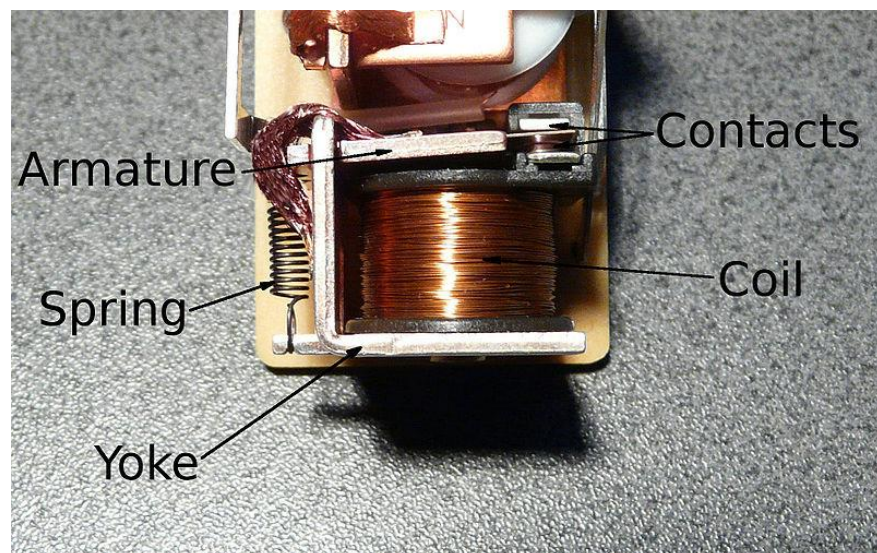
The example of relay as shown below:



The symbol of relay is shown below:



SPST

SPDT

DPST

DPDT
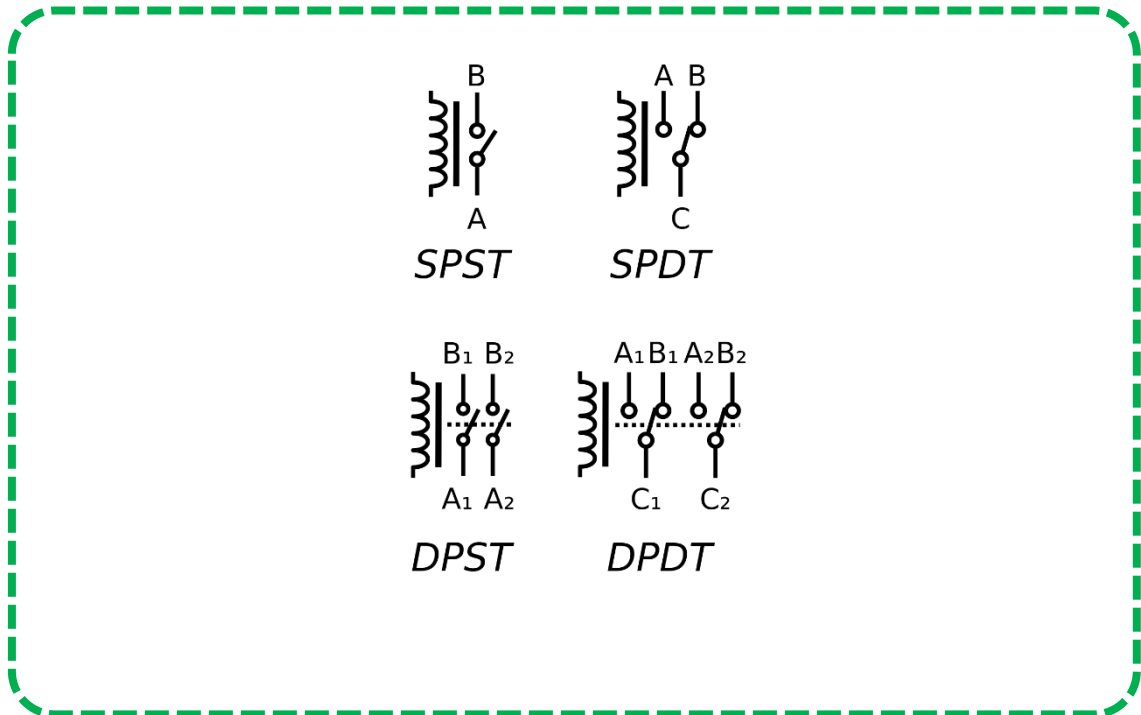
## c) Solenoid

Solenoid is an electromechanical device which is used to magnetically cause mechanical movement using electrical energy. A solenoid consists of a coil with an iron core and moveable iron plunger. The plunger is attracted by the coil when the coil is energized. The motion of the plunger can be used to activate another mechanism. The solenoid is used in many electrically activated devices such as valves, locks, punches and marking machines. The example of solenoid as shown below:



Solenoid Valve

Solenoid Door Lock

## d) Sensor and Transducer

Transducer is a device that changes from one quantity to another quantity. It has a few elements which can change a signal quantity to another signal quantity, for example the displacement to the electrical movement force and others. In other words, a transducer is a device that relates the electrical to the non-electrical. Transducer converts physical parameters to electrical signals acceptable by the acquisition system. Some typical parameters include temperature, pressure, acceleration, weight displacement and velocity. Sensor is a part of transducer. Sensor is a device that responds to a change in physical phenomenon. Classification of sensor are visualized in the diagram below:
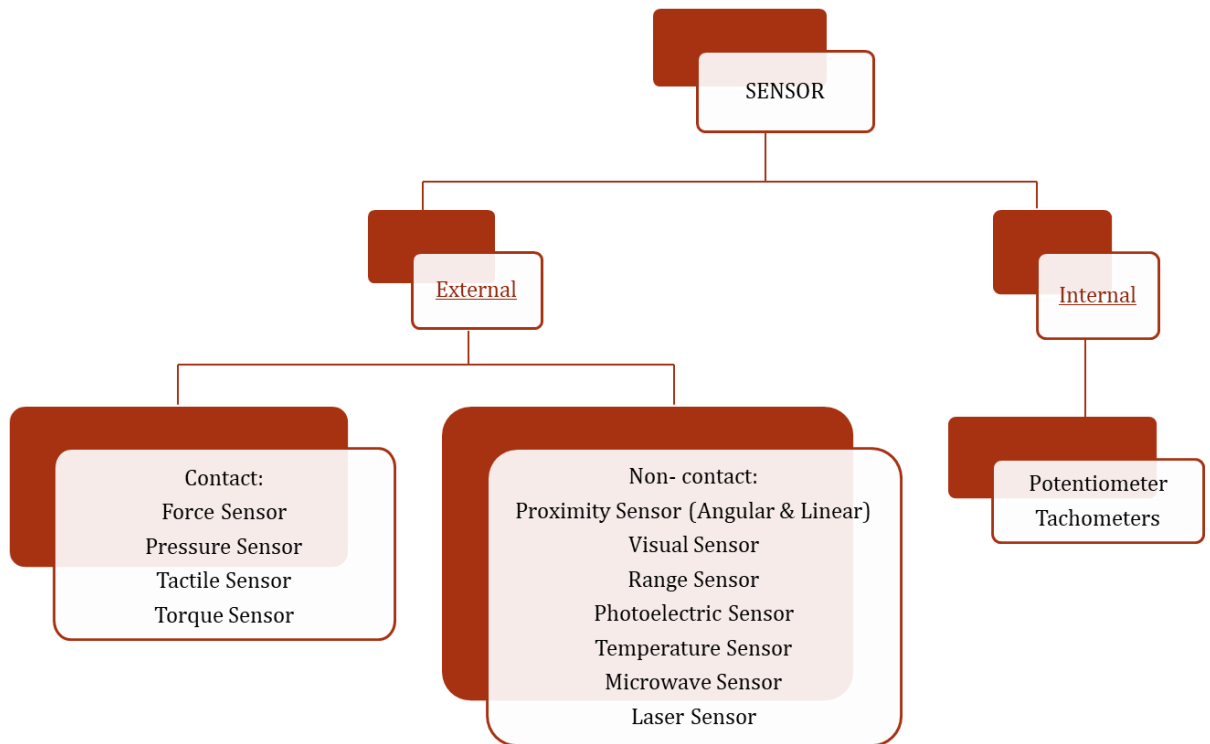
**External sensor** is located out of manipulator. This sensor is used to set the operation between manipulator and other tools in the workplace. It can be classified as contact and non-contact sensor. Contact sensors sense through touching but non-contact sense the presence of an object through change in pressure, temperature or electromagnetic field, without contact.

The main component of the **contact sensor** is a tactile mechanism. The tactile element can be from many types of sources such as pressure, force and torque.

i.      Force Tactile Sensor
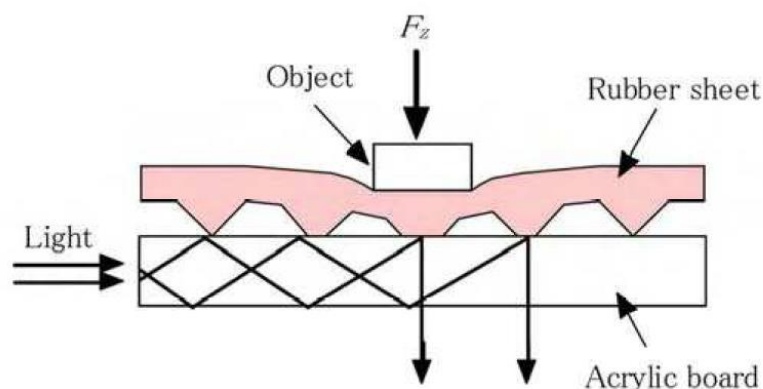
ii.　　Pressure Tactile Sensor



fixed boundaries

bent membrane under uniform pressure

A–A' cross-section
(stress along y-axis)

B–B' cross-section
(stress along x-axis)
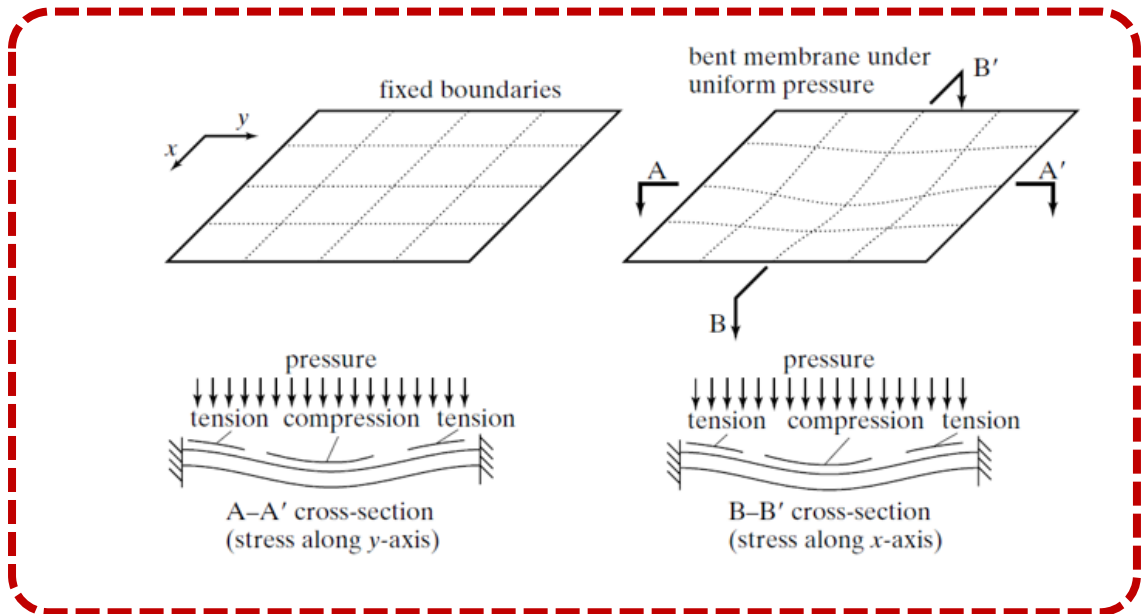
The **non-contact sensor** is usually used in proximity detection which can be in linear or angular movement. Proximity detection using different types of sources such as visual, photoelectric, microwave and laser sensor. Then, the data of velocity and acceleration can be manipulated using the proximity data from the sensor. Temperature sensors sense the environment temperature directly.

i.　　Optical Angular and Linear Sensor



Light source

Light detector

Vane with opaque slits

Rotating shaft

Counting the number of pulses, give the amount of displacement
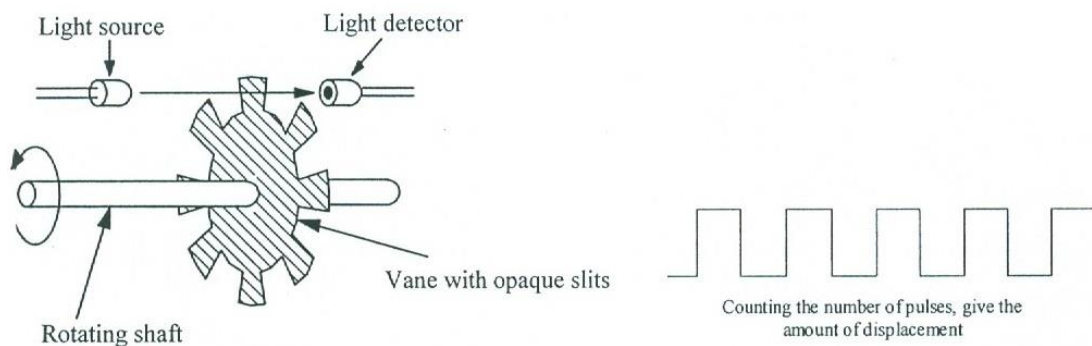
ii. Sagnac Interferometer Velocity Sensor
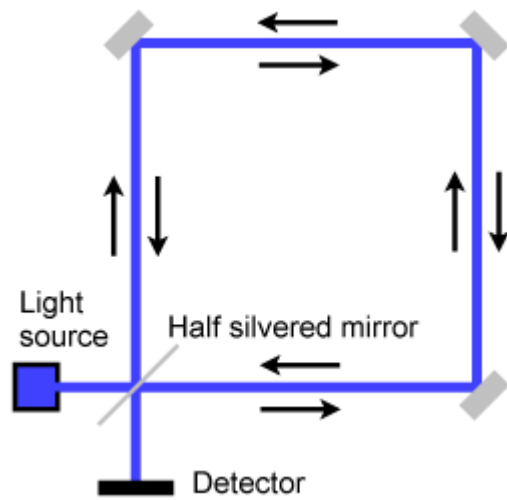


iii. Laser Distance Sensor
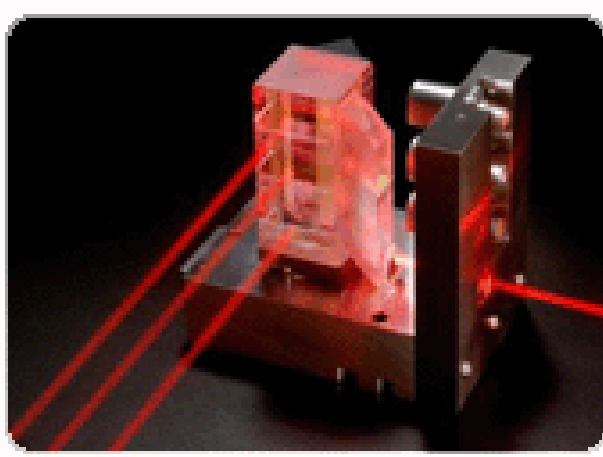


iv. Time of Flight Distance Sensor (Photoelectric)
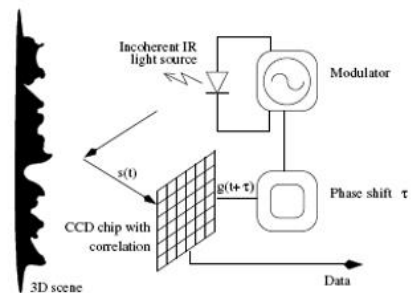
**Internal sensor** is located at all joints of robot usually used to control position and speed of 'tool-center point'. It was a closed-loop control system which has feedback between control unit and manipulator. The sensor will identify the position and speed of manipulator and send it to the controller to be processed.

    i.      Potentiometer
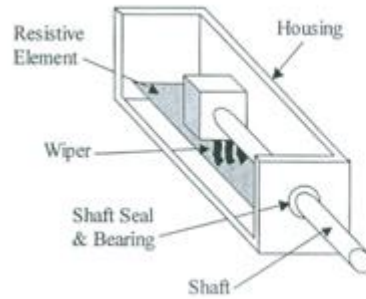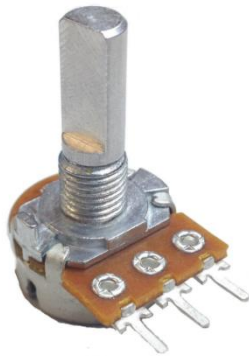


    ii.     Tachometer
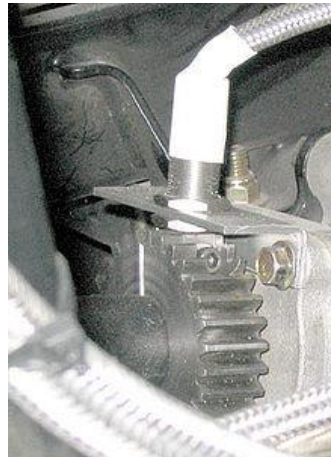


# e) Telemetry and Data Acquisition

**TELEMETRY**

Telemetry means the transmission of data for monitoring and control over long distances. Data can be sent directly as a DC voltage or current up to a few meters. At long distances, noise becomes a serious problem and speed is severely limited. The starting of telemetry by original Morse trans-Atlantic cables of 19th century used DC which transmitted at less than one word per minute.

For longer distances, DC voltage or current was converted to audio tones and sent over wire. This process was called modulation and demodulation and vice versa and performed by a modem.

In Industrial Electronics, sensors in telemetry systems generate electrical signals which change in some way in response to changes in physical characteristics.

## DATA ACQUISITION

Data acquisition system is used to measure and record signals obtained in basically two ways:

i. Signals originating from *direct measurement* of electrical quantities, these may include DC and AC voltages, frequency or resistance and are typical found in such areas as electronic component testing, environmental studies and quality analysis work.

ii. Signals originating from transducers such as strain gage and thermocouple.

Data acquisition is divided into two types, analog data acquisition and digital data acquisition. Below is the comparison of analog and digital data acquisition:

| Analog Data System | Digital Data System |
|---|---|
| Wide bandwidth | Narrow bandwidth |
| Lower accuracy can be tolerated | High accuracy and low per-channel cost is required |
| Less complex than digital | Range in complexity |
| Not require converts to change analog voltages into discrete digital quantities or numbers | Require converts to change analog voltages into discrete digital quantities or numbers |
| Defined as a continuous function | Consist of a number of discrete and discontinuous pulse |

**MULTIPLEXING SYSTEM**

Multiplexing is the process of simultaneously transmitting two or more individual signals over a single communication channel. Multiplexing has the effect of increasing the number of communication channels so that more information can be transmitted.

There are two basic types of multiplexing, frequency *division multiplexing (*FDM*)* and *time division multiplexing (*TDM*).* Generally speaking, FDM systems are used to deal with analog information and TDM systems are used for digital information.

# CHAPTER 2: APPLICATION

## 2.1 Introduction

Internet of things (IoT) is widely used in our daily life. IoT is a fast-growing worldwide network of interconnected variety of objects. (MSI et al. 2019) Internet has become one of the needs today. IoT generally refers to network connectivity and computing capability which are integrated to objects, sensors, allowing these devices to generate, exchange and consume data with minimal human intervention. (Rupali et al. 2021). (Paul et al. 2022) mentioned that the study of the IoT with cloud computing give a better managing data captured using microcontrollers which consumed low power and cost. IoT provides many benefits where it can save cost and time because people do not have to meet each other. Many things can be done remotely from anywhere and the quality of the product or process can be improved by using IoT.

Vital signs measure the body's basic functions. These signs usually indicate the condition of patients for the medical staff reference. The main vital signs are body temperature, blood pressure, pulse and breathing rate. Pulse is referred to the heart rate of the body.

Slow handling in patient examination is one of the factors that causes high mortality in heart disease (R. R. Adiputra, et al, 2018). The medical staff need to handle the high number of patients at one time. The staff need some time to examine the patients in turns. One of the downsides of a healthcare monitoring system is the expensive cost of equipment. (Govind, et al, 2020). At the same time, the lack of modern equipment also contributes to the slow handling of patients. The equipment currently used was lower time efficiency and do not provide the real time data. (Monirkhan, et al, 2022)

This project proposed synchronous vital monitoring which is focusing on ECG (electrocardiogram) and PPG (photoplethysmography) sign as one of the Industrial Electronics application where it is a process of data acquisition from human to the database wirelessly.

## 2.2 Materials and Method

The flow chart of overall methodology is shown in figure below. In phase I, coding for the system were constructed and simulated. After that, the coding was integrated with the hardware and testing were done to verify the output of the system.
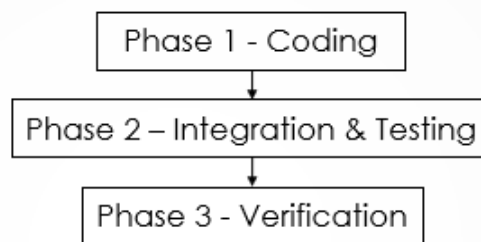


**Methodology Flow Chart**

## i. **Phase I**

Program development using the C language is carried out and then combined with the selected hardware. The use of different hardware requires the development of other programs. In this phase, Arduino IDE was used as a platform to write and verify the code. The coding was written in the main console in Arduino IDE.

**Main console Arduino IDE display**

The data obtained from the sensor can be monitored by using serial plotter and monitor in the Arduino IDE. Serial monitor will show the data in numbers while the serial plotter will graphically show the data.

ii. **Phase II**

The system testing process will take place in parallel with system development. The selection of hardware used is also affected by performance in displaying data continuously and receiving data at a high sample frequency at a certain time. The use of unstable hardware will cause the data obtained to be irrelevant and untrue.
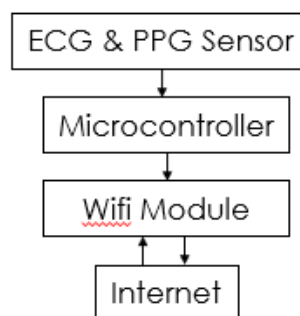


**Flowchart of the system**

The flowchart above shows the main components of vital sign monitoring that have been built. By referring to the diagram, the input to this system is the ECG and PPG sensors that will be connected to the human body. The microcontroller will process the data obtained from the sensor and then put it on the Internet through the Wi-Fi module.

To measure the PPG and ECG, MAX 86150 sensor is used which include both sensors on a board. For ECG, it has a little chip on board and measured the electrical activity of the heart. For PPG, it has an LED where the fingers will be put on it to detect the sign.

## 2.3 Hardware Description

- MAX 86150

MAX86150 from Maxim rolls three devices into one for easy measurement of vital signs: an ECG frontend, an optical pulse oximeter and an optical heart rate sensor. It integrates the PPG and Pulse oximeter (SPO2), ECG and Heart rate sensor module into the same chip.
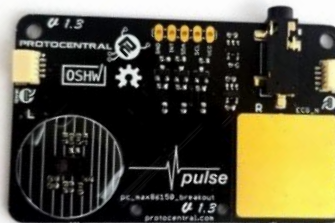


**MAX 86150 device**

- Microcontroller (ESP32)

    The ESP32 is a series of low-cost and low-power System on a Chip (SoC) microcontrollers developed by ESPRESSIF that include Wi-Fi and Bluetooth wireless capabilities and dual-core processor. ESP32 is recognized based on the ESP8266 which is loaded with lots of new features and better specification compared to the ESP8266.



**ESP32 device**

- ECG Electrode

    ECG electrodes will be attached to the human body to obtain the output of ECG waves. 3 electrodes will be used at a time. All these electrodes will be connected to the cable connected to the ECG sensor.



**ECG electrodes**

# iii. <u>Phase III</u>

Once the system design has been finalized, sample data collection will be carried out. This sample data will be used in the next stage which is data testing to determine the validity of the data obtained from the system whether it is relevant or not for use. Data validation will be conducted by comparing data from the system with data from existing equipment. The data was collected from 20 samples. The data will be undergoing the process as shown in flowchart below using the MATLAB software.

```
┌─────────────────┐
│     Denoise     │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│  Peak Detection │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│ Extractor Features │
└─────────────────┘
```
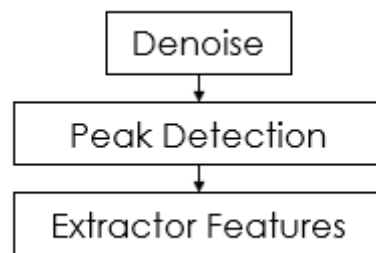
**Flowchart of the verification process**

## **2.4** Schematic Circuit and Program

i.Interfacing of Wi-Fi module ESP32 and MAX 86150
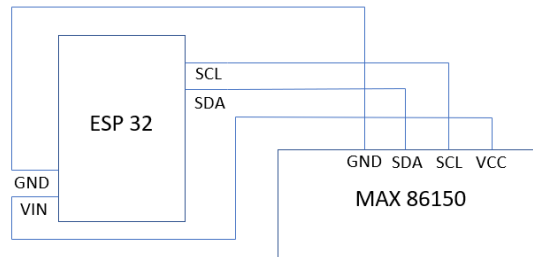


Schematic circuit of the system

The figure above shows the schematic circuit of the IoT based Vital Signs Monitoring System. ESP32 was the microcontroller used in this system. It has a built in Wi-Fi module on this board. ESP32 connected with the MAX 86150 (the board that has ECG and PPG sensor on one chip) through the I2C port or alternatively using serial clock (SCL) and serial data (SDA) port. Results of the measured physiological parameters were saved in the cloud or database and the WI- FI module is used to perform IoT applications or the internet of things applications so that the microcontroller can access the WI-FI. ESP32 was coded by Arduino IDE in C language.

ii.    Arduino IDE

From the serial monitor and plotter in the Arduino software, the data from the device can be retrieved. Data is shons in number and waveform from the device.
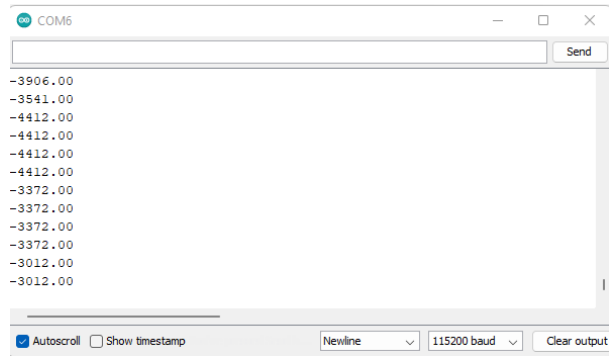
Serial monitor console in Arduino IDE
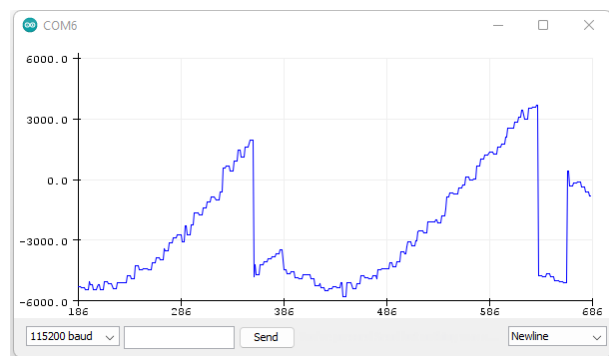


Serial plotter console in Arduino IDE

iii.    Node-RED

For system connection with the Internet, Node-RED software is used. Node-RED is a flowchart-based software for visual programming for wiring together hardware devices and online services as part of the IoT. Node-RED provides a web browser-based stream editor, which can be used to create JavaScript functions. By using Node-RED, data from this system can be displayed on the website and at the same time recorded in the browser's computer. The figure below shows the connection diagram of the Node-Red flowchart of the system.
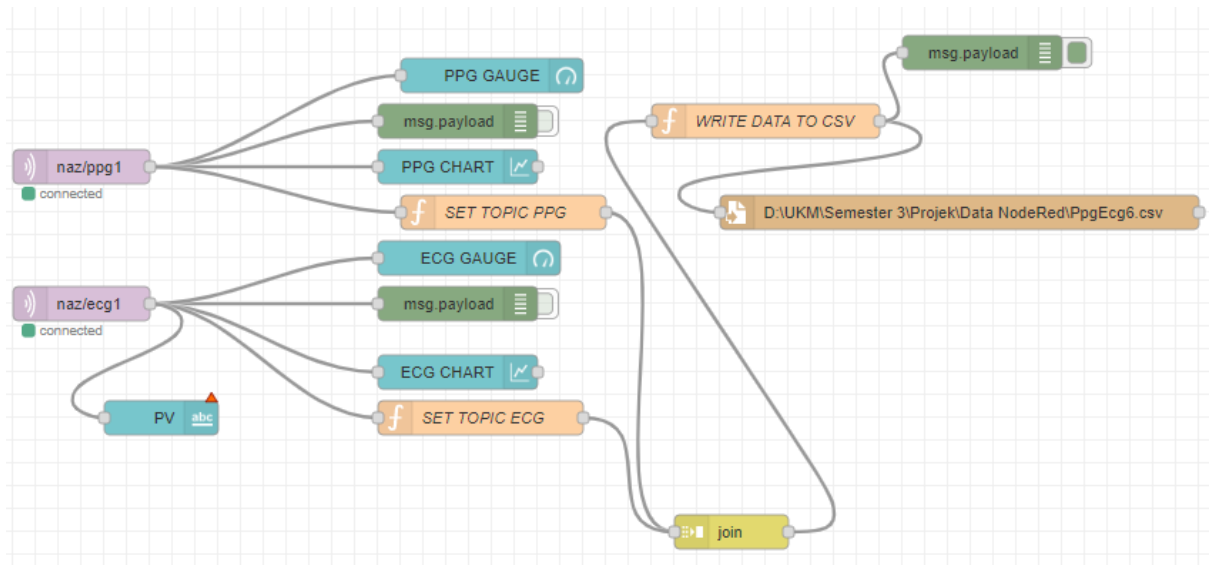
Node-RED flowchart of the system

## 2.5 Output

Data acquisition from the sensor will be saved in the assigned server in the form of Microsoft Excel Format as shown below. These data can be retrieved by the person who can access the server. The data will be analyzed by the medical staff to know the condition of their patients.



Data in Microsoft Excel

# SAMPLE QUESTIONS

OBJECTIVE QUESTIONS

1.
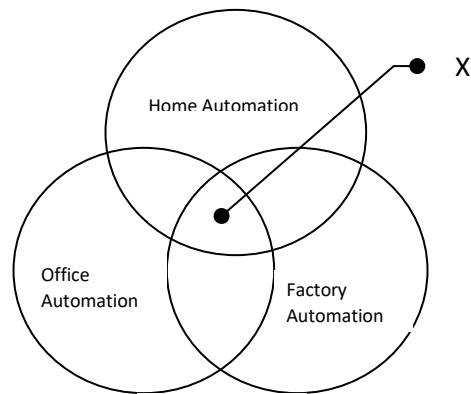


Figure 1

Refer to figure 1, X is

A.          Mechanical

B.          Mechatronic

C.          Electrical

D           Electronic

2.          The switches function as a device that opens or closes a circuit. The closing of a switch is called ____X____ the circuit. The opening of switch is called ___Y__ the circuit. What is X and Y?

|     | X | Y |
| --- | --- | --- |
| A. | Compiling | Discharging |
| B. | Discharging | Compiling |
| C. | Breaking | Making |
| D. | Making | Breaking |

3.      Switch A activated by ball bearing moving to open or close a circuit.

Switch A refers to

A.      Blade Switch

B.      Slide Switch

C.      Toggle Switch

D.      Rotary Switch

4.      The mechatronic device that makes or breaks a circuit in response to a control signal is

A.   Switch

B.   Relay

C.   Solenoid

D.   Rectifier

5.      A circuit function based on specification as shown below:

Maximum voltage: 15 V, Current rate: 200mA

The most suitable switch for that circuit is

| Switch | Voltage | Current |
|--------|---------|---------|
| A.     | 18 V    | 250mA   |
| B.     | 15 V    | 250mA   |
| C.     | 15 V    | 200mA   |
| D.     | 12 V    | 150mA   |

6.   List the application of relays in industries

i.      Grinding operation

ii.      Boring operation

iii.      Milling operation

iv.      Heating operation

A.        i and ii

B.        i, ii and iii

C.        i, ii, iii and iv

D.        iv only

7.      Below are the advantages of relays EXCEPT

       A.      Used for high voltages switching

       B.      Used for large current switching

       C.      Used for AC and DC switching

       D.      Used for rapidly switching

8.      For the relay that conducts at 100V, the minimum voltage drop is

       A.      85V

       B.      15V

       C.      185V

       D.      115V

9.      Which is the symbol of Normally Open relay contact?

       A.                            C.

                CR

       B.                            D.

                TR
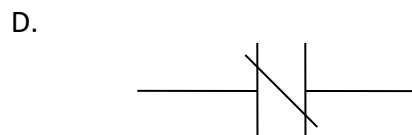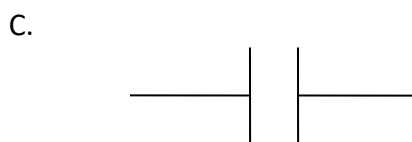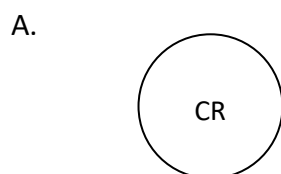
10.
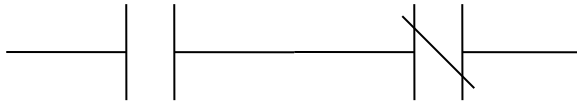


Figure 2

Figure 2 shows one of relay circuits. This circuit refers to

A.  OR circuit

B.  NOR circuit

C.  NAND circuit

D.  AND circuit

11.  In the solenoid principle, _____X_____ movement will have produce _____Y_____ from _____Z_____ energy.

|     | X | Y | Z |
|-----|-----------|-------------|-------------|
| A.  | mechanical | electrical | magnetically |
| B.  | mechanical | magnetically | electrical |
| C.  | magnetically | electrical | mechanical |
| D.  | electrical | mechanical | magnetically |

12.  The process of converting alternating current into direct current is called

A.      Rectification

B.      Conversion

C.      Application

D.      Destruction

13.  The power electronics semi-control rectifier circuits can be classified into

i.       DC – AC converters

ii.      Diode Rectifier

iii.     AC – DC converters

iv.      DC – DC converters

A.     i and ii

B.     ii and iii

C.     iii and iv

D.     ii and iv

14.     Harmonics are generated at the input and load side of the chopper, and these noise can be reduced by

A.     Oscillator circuit

B.     Controller circuit

C.     Filter circuit

D.     Regulator circuit

15.     All these are electrical principles most commonly used in the measurement of displacement sensor EXCEPT

A.     Capacitive

B.     Resistance

C.     Ionization

D.     Oscillation

16.     In this type of sensor, the measurement of force is accomplished by the change in the inductance ratio of a pair of coils. This sensor refers to

A.     Capacitive sensor

B.     Inductance sensor

C.     Resistive sensor

D.     Heating sensor

17.     All of these equipment need the temperature sensor EXCEPT

A.     Electric iron

B.     Air Conditining

C.     Electric Kettle

D.     Microwave oven

18. What is the advantage using a photoelectric sensor?

   A.    Adaptability to measuring both static and dynamic conditions

   B.    Has short term stability

   C.    Responds to low frequency light variations

   D.    Requires a large displacement of the force summing device

19. What is the advantage of using platinum wire than a copper wire in the temperature sensor?

   A.    High stability

   B.    High Linearity

   C.    Wide operating range

   D.    High accuracy in ambient temperature range

20. All these types of sensors are always used in car EXCEPT

   A.    Displacement sensor

   B.    Temperature sensor

   C.    Velocity sensor

   D.    Contact sensor

21. What types of sensor that can be used in the industry to measure product quantity?

   i.     Contact sensor

   ii.    Pressure and level sensor

   iii.   Displacement sensor

   iv.    Visual sensor

   A.    i, ii and iii

   B.    ii, iii and iv

   C.    i, iii and iv

   D.    i, ii, iii and iv

22. Which of the following are types of data acquisition system

          i. Digital system

          ii. Analog system

          iii. Computer system

          iv. Communication system

A. i and ii

B. i, ii and iii

C. i, iii and iv

D. iii and iv

23. Telemetry means the transmission of data for monitoring and control over long distance. For longer distance telemetry converts DC voltage or current to audio tones and send them over wire. This converting process was called as _____

A. multiplex

B. demultiplex

C. modulation

D. demodulation

24. Telephone system is one type of telemetry system. What are the type of signal that are used in Malaysia?

          i. GSM

          ii. GPRS

          iii. CDMA

          iv. HSDPA

A. i, ii and iii

B. ii, iii and iv

C. i, iii and iv

D. i, ii, iii and iv

25. Multiplexing is the process of simultaneously transmitting two or more individual signals over a single communication channel. Multiplexing has the effect of increasing the number of communication channels so that more information can be transmitted.

All of these appliance shows the multiplexing process EXCEPT
A. Telephone
B. Printer
C. Fax Machine
D. Traffic Light

# STRUCTURES / ESSAY

## QUESTION 1

(a)     Write the definition of switch.                               (3 marks)

(b)     Explain the following switches:

     i.    Limit switch.

     ii.    Toggle switch.

     iii.   Rocker switch.                               (12 marks)

(c)     Explain why DC switch cannot be used to replace AC switch.     (3 marks)

(d)     Select a switch configuration and illustrate a solution for the following control problem:

A switch should start a 110V AC motor and control two 12V DC indicator lamp. An illuminated red lamp indicates that the motor is not powered, and an illuminated green lamp indicates that the motor is powered

(7 marks)

## QUESTION 2

(a)     Describe briefly the mechanism principle of relay.            (3 marks)

(b)     A control motor system contains an AC power supply 240V with current fuse 5A. The system controlled by two push buttons for starting and stopping the operation. The single phase motor is used which will be turn ON for 15 minutes and the indicator lamp turn ON after the motor turn OFF by pressing the push button 'start'. By using the component such as push button, relay, time delay relay, motor and indicator lamp, sketch the ladder diagram.

(c)     Describe the step operation in the ladder diagram of solenoid in the figure below:
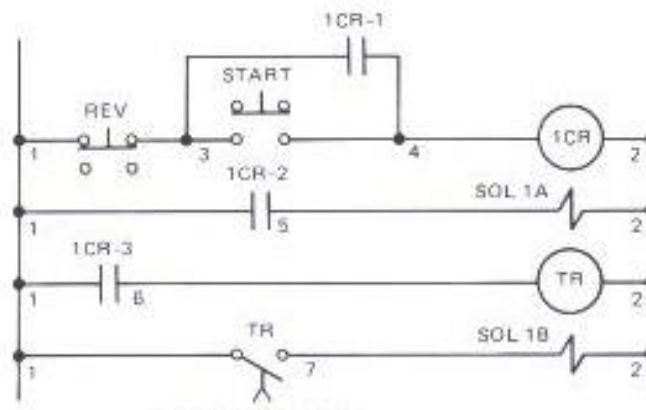


(9 marks)

**QUESTION 3**

(a)     State FOUR (4) types of sensor that are commonly used in mechatronic system and give an example for each type.          (8 marks)

(b)     With the aid of a basic thermocouple circuit, explain the basic operation of a thermocouple.          (6 marks)

(c)     Explain the purpose of signal conditioning in measurement and telemetry system.          (5 marks)

(d)     Explain the definition of:
        i.      Multiplexer
        ii.     Time Division Multiplexing

(6 marks)

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# ANSWER OBJECTIVES

| | | | | |
|---|---|---|---|---|
| 1. | B | | 14. | C |
| 2. | D | | 15. | B |
| 3. | C | | 16. | B |
| 4. | B | | 17. | C |
| 5. | A | | 18. | A |
| 6. | C | | 19. | C |
| 7. | D | | 20. | D |
| 8. | B | | 21. | D |
| 9. | C | | 22. | A |
| 10. | D | | 23. | C |
| 11. | B | | 24. | D |
| 12. | A | | 25. | D |
| 13. | B | | | |

# ANSWER STRUCTURES / ESSAY

ANSWER 1 (a)

The switch is a mechanical, electrical or electronic device that opens or closes a circuit. Switching may also be called making or breaking the circuit.
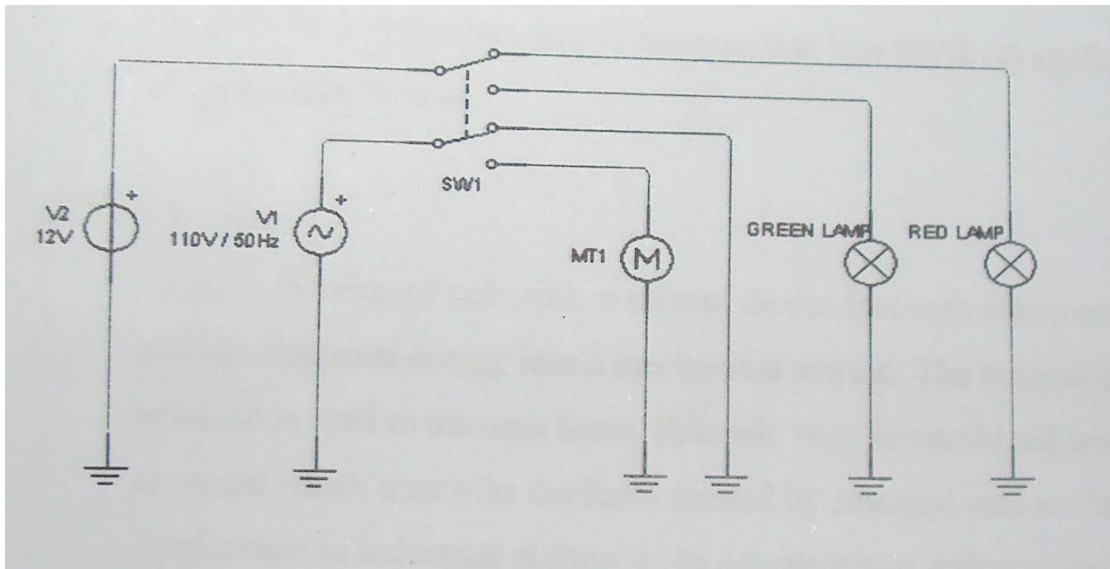
ANSWER 1 (b)

i.  A limit switch is a low-power snap-action device that opens or closes a contact, depending upon the position of mechanical part. Other limit switches are sensitive to pressure, temperature, liquid level, direction of rotation and so on.

ii.  A toggle switch is a switch activated by ball bearing moving for open or closes a circuit. The movement of roller makes a contact to open or close a circuit when the toggle is depressed.

iii.  A switch activated by 3 fingers which includes 2 fingers push button for opening and closing of 2 circuits. Two contacts open or close for 2 circuits when the button are pressed and depressed.

ANSWER 1(c)

Because the AC switch cannot afford the current increasing rapidly. In the AC switch, the current increases according to frequency.
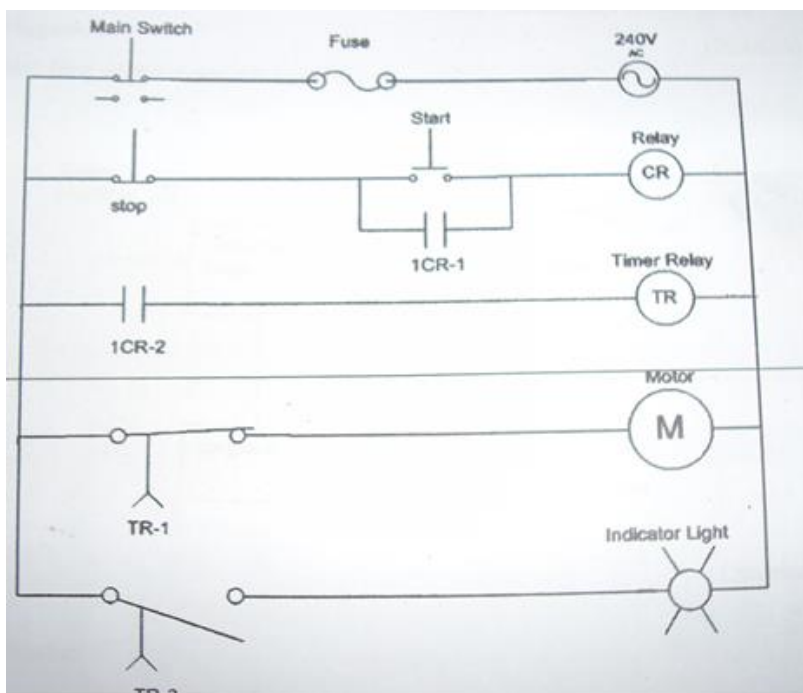
ANSWER 1(d)



ANSWER 2(a)

When current flows through the coil of wire, a magnetic field is produced. This

pulls a movable arm that forces the contact to open or close.

ANSWER 2(b)

ANSWER 2(c)

Operating the START push button switch closes the circuit to the coil of relay 1CR.

The coil is now energized. Contact 1CR-1 closes, interlocking around the START

push button switch. Contact 1CR-2 closes, energizing solenoid 1A. contact 1CR-3

closes, energizing the coil of timing relay 1TR. After a time, delay, as set on the

timing relay, the timing constant contact closes, energizing solenoid 1B. The

circuit can be de-energized by operating the REVERSE push-button switch. Note

that if for some reason the REVERSE push button switch is operated before the

time set on the timing relay expires, solenoid 1B will not be energized, as the

timing relay coil will be de-energized. With the relay coil de-energized, the timing

contact remains in the normal open condition.

ANSWER 3(a)

    i.      Displacement sensor – capacitive sensor, inductive sensor

    ii.     Pressure and level sensor – Bourdon tube pressure gauge

    iii.    Temperature sensor – thermistor, thermocouple

    iv.    Distance sensor – infrared sensor

ANSWER 3(b)
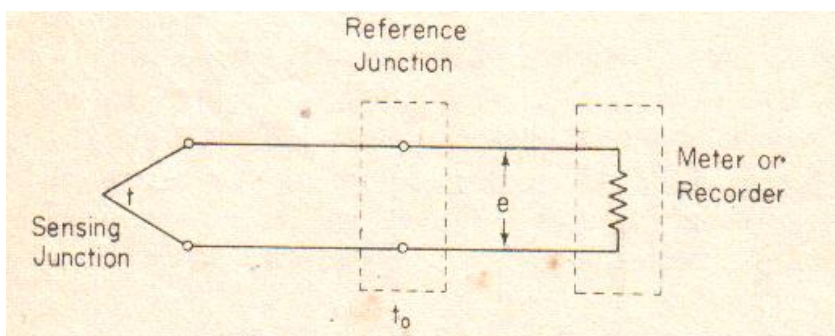
A thermocouple consists of pair of dissimilar metal wires joined together at one end ( sensing, or hot, junction) and terminated at the other end (reference, or cold, junction) which is maintained at a known constant temperature (reference temperature). When a temperature difference exists between the sensing junction and the reference junction, an emf is produced that causes a current in the circuit. When the reference junction is terminated by a meter or recording instrument, the meter indication will be proportional to the temperature difference between the hot junction and the reference junction. This thermoelectric effect, caused by contact potentials at the junctions, is known as the Seeback Effect.

ANSWER 3(c)

A signal conditioning takes the signal from the sensor and manipulates it into a condition which is suitable for either display or in the case of a control system, for use of exercise control. Thus, for example, the output from thermocouple is a rather small e.m.f and might be fed through an amplifier to obtain a bigger signal. The amplifier is the signal conditioner.

ANSWER 3(d)

i. Multiplexing is the process of simultaneously transmitting two or more individual signals over a single communications channel. Multiplexing has the effect of increasing the number of communication channels so that more information can be transmitted.

ii.     In Time division multiplexing, each signal can occupy the entire bandwidth of the channel. However, each signal is transmitted for only a brief period of time. In other words, the multiple signals take turns transmitting over the single channel.

Industrial Electronics book is aligned with the curriculum of Politeknik Malaysia for students who pursuing Diploma in Mechatronic Engineering as a guide to improve their knowledge in electronics field. This book is a dedication of the authors with years of experience teaching this course