2018/2019

MECHATRONICS SYSTEMS DESIGN LAB

LABORATORY MANUAL

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INTRODUCTION TO THE LAB

The Lab continues the concepts learned in the Mechatronics Systems course about selection and sizing of various elements in mechatronics systems. The course is designed to teach students through practical sessions and case studies how to design basic systems and select components of a mechatronics system. The lab methodology aims to make students involve more in the design process and to develop the skills of collecting information and selecting components to satisfy some design requirements, involves reading data sheets and extracting information from them.

Gathering technical information about different types of components used in Mechatronics Systems including transducers, controllers and actuators is the main objective of the lab.

LABORATORY SAFETY RULES

Laboratory safety is of paramount importance. That's exactly why this safety rules have been made, to encourage and promote safe and efficient working practices in the lab. On going attention and reinforcement of safety procedures is required when working in the lab for any reason. Without the right precaution taken, there's the significant risk of endangering yourself and others around you

Emergency Response

1. It is your responsibility to read safety and fire alarm posters and follow the instructions during an emergency.
2. Know the location and function of all lab safety equipment including First Aid box and fire extinguisher.
3. Notify your instructor immediately after any injury, fire or explosion.

General Safety Rules

1. Read all directions for an experiment and follow the directions exactly as they are written, if in doubt, ask the teacher.
2. Always obtain permission before experimenting on your own.
3. Never handle any equipment unless you have specific permission.
4. Pay particular attention to moving or rotating objects like motors, gears and pistons.
5. Never eat, drink, or smoke while working in the laboratory.
6. You have long hair or loose clothes, make sure it is tied back or confined.

Electrical Safety

1. Obtain permission before operating any high voltage equipment.
2. Make sure electronic equipment is OFF when plugging or unplugging from an outlet.
3. Make sure the working area for electrical equipment is clean and dry.
4. Avoid using extension cords whenever possible. If you must use one, obtain a heavy- duty one that is electrically grounded, with its own fuse, and install it safely. Never, ever modify, attach or otherwise change any high voltage equipment.
5. Always make sure all capacitors are discharged before touching high voltage leads or the "inside" of any equipment even after it has been turned off. Capacitors can hold charge for many hours after the equipment has been turned off.

End of Laboratory activity rules

1. Clean all laboratory equipment and return to their locations
2. Unplug and store properly any electrical device.
3. Wash your hands after every experiment.
4. Clean up your work area before leaving.

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EXPERIMENT 1: THE PRINCIPLES OF SWITCHING

OBJECTIVES

In this experiment, you are expected to achieve the following objectives:

- Understand the basic principles of switching and switching devices.
- Introduced to electromechanical switching as well as solid state switching.
- Understand the advantages and disadvantages of each type.
- Gain an appreciation of the relative speed of different type of switches.

INTRODUCTION

A switch is a device used to control the flow of current in a load. A switch can be a mechanical device (e.g., a manual switch or a contactor) or a solid state device (e.g., a thyristor. Switching is needed in three applications:

1. Interruption of power to a load (example the use of a contactor).
2. Processing of logic functions (e.g., use of logic gates such as TTL or CMOS; use of relays for implementing logic control). This was used in many industrial process plants, in some cases using pneumatic or hydraulic gates, rather than electrical gates.
3. Routing of data (e.g., use of relay switching to direct telephone calls in old telephone switching centres).

IDEAL VERSUS PRACTICAL SWITCHES:

Any device used to interrupt the flow of current to a load from a voltage source is called a switch. Any switch is made of a pair of contacts. This could either be a manual switch, a relay, a contactor, a thyristor, a triac, a transistor or any other device which achieved a similar function. Figure 1 shows a typical arrangement of a switch controlling the current flowing into a load. The load could either be a pure resistive load, a resistive/inductive load or a resistive/capacitive load.

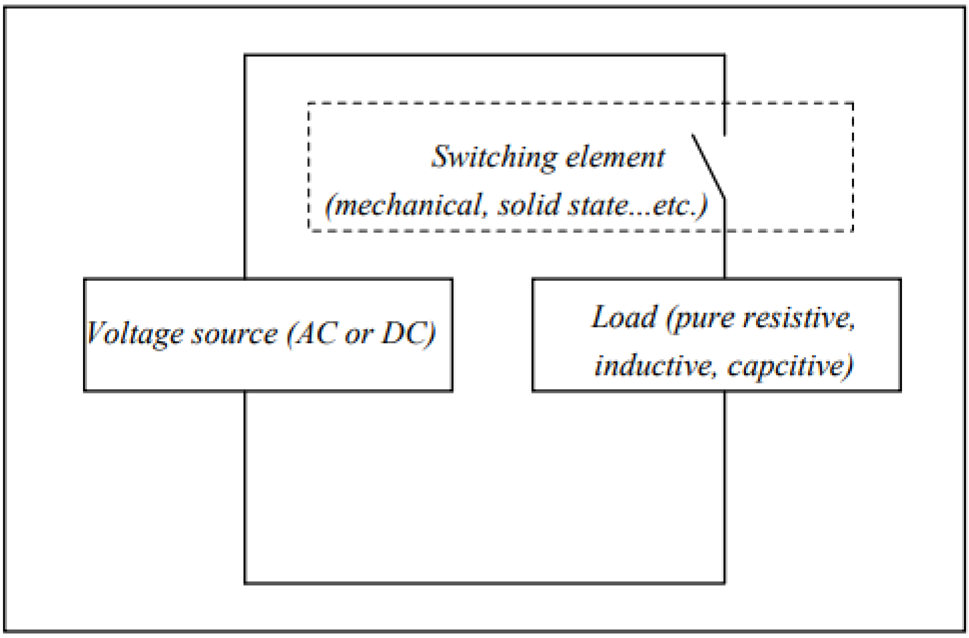

Figure 1: Typical arrangement of switching a load from a voltage source.

An ideal switch has the following characteristics:

- The switching times of the state transitions between 'on' and 'off' should be zero.
- The 'on' state voltage drop across the device should be zero.
- The 'off' state current through the device should be zero.
- The power-control ratio (the ratio of device power handling capacity to the control electrode power required to effect the state transitions) should be infinite.
- The 'off' state voltage withstand capability should be infinite.
- The 'on' state current handling capability should be infinite.
- The power handling capability of the switch should be infinite.

These characteristic do not exist as such in a real device. However, manufacturers strive to get as near as possible to achieving these requirements in a switching device (e.g., a silicon controlled rectifier). As a real device cannot achieve the first three characteristics, it undergoes internal losses generated as heat (called incidental dissipation). These have to be kept to a minimum, otherwise the temperature of the device will rise until it fails.

MECHANICAL SWITCHES

One of the most widely used forms of mechanical switches is relays and contactors. A contactor is an electromechanical device that has a coil and a moving armature, whereby the moving armature actuates a number of normally open and normally closed switches. A diagram of the coil and the armature is shown in Figure 2. With no power applied the armature stays open due to the force of the mechanical springs. When an AC or DC voltage is applied to the coil (Figure 3) the armature halves are attracted.

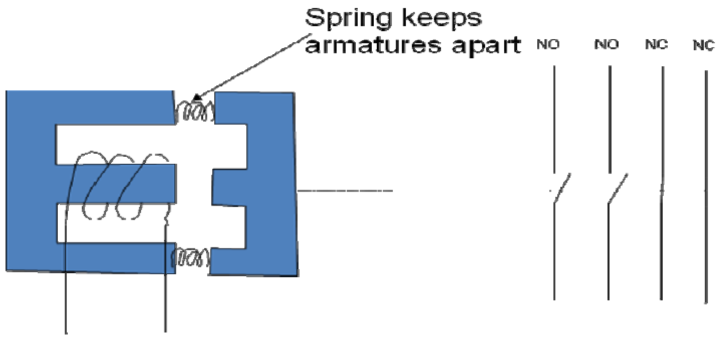

Figure 2: When the contactor is in the inactive state, the normally open contacts are open and the normally closed contacts are closed.

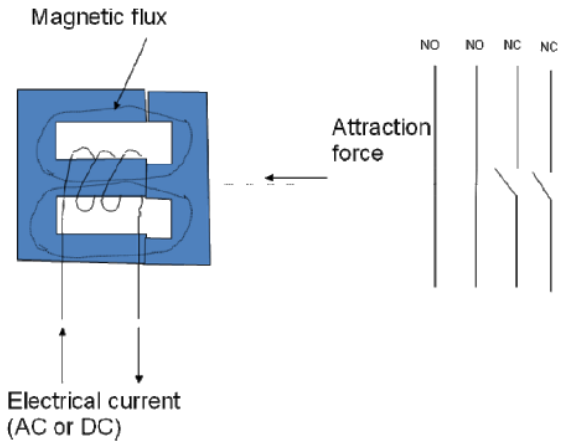

Figure 3: When the armature is attracted to the other half, the NO and NC contacts changes state.

THE TRANSISTOR AS A SWITCH

A transistor can be used as a solid state switch. When a transistor is to be used as a switch, it has to be operated either in the cut-off mode (when it is not to conduct) or saturation region (when it is to conduct), but not in the active region. The transistor has a control side and a power side, as shown in Figure 4 (showing a BJT: bipolar junction transistor). The transistor switching losses take place when it is passing through the active region moving from cut-off to saturation and vice versa.

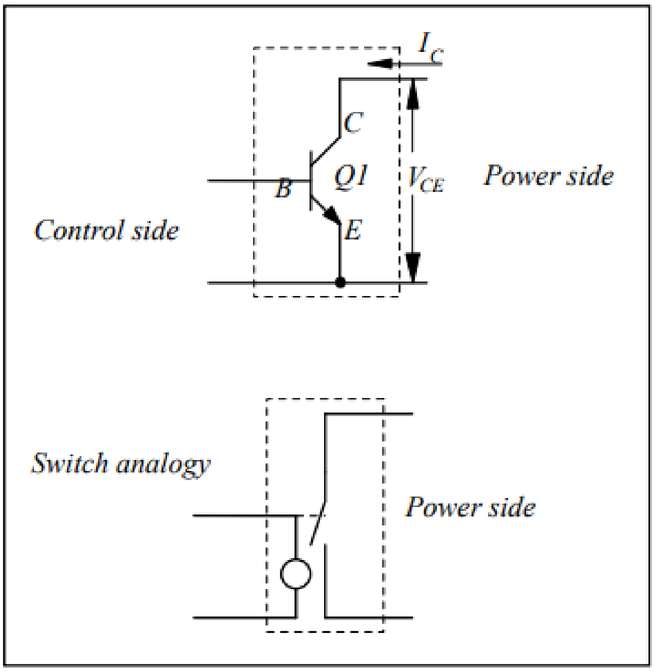

Figure 4: The transistor as a switch, with the switch analogy.

Figure 4 also shows the analogy between a transistor and a switch. Each side of a transistor is called a port. Thus the control side is the input port and the power side is the output port. The power dissipated in the transistor is the product of the V_{CE} and I_c. For this reason, it is necessary for the value of V_{CE} to be as low as possible when the transistor is conducting, and for the value of I_c to be as low as possible when the transistor is off. Both of these conditions are achieved if the transistor is operated in the saturation and cut off regions respectively. The collector current, I_c is controlled by the base current, Ib. The ratio between the two currents is a parameter of the transistor, usually referred to as h_{FE}. In order to check that the transistor is fully saturated, the following inequality has to be satisfied:

$$\boxed{\frac{I_C}{h_{FE} \times I_b} < 0.85}$$

If the transistor is operating in the saturation region, then V_{CE} takes on its minimum value (0.2 V for small signal transistors but can be as high as 3 V for power transistors depending on collector current).

So the steps in designing the transistor as a switch are as follows:

1. Using the value of the load and the voltage between the collector-emitter saturation voltage calculate the collector current.
2. Divide the collector current by the transistor current gain h_{FE}. This represents the minimum base current that is sufficient to just place the transistor on the edge between the active region and the saturation region.

3. Divide the minimum base current by 0.85 (in order to push the transistor slightly in the saturation region). This gives the design base current.
4. Select the size of the base resistor required to achieve the design base current, assuming the base emitter voltage to be 0.7 V.

APPARATUS:

- Digital Storage Oscilloscope.
- Power Supply.
- Function generator.
- 24 V DC relay (Finder, Type 40.52).
- Breadboard.
- Digital multimeter.
- Transistor BC141 NPN (BJT)
- Resistors (various)

PROCEDURE

1) RELAY SWITCHING

1. Examine the relay provided.
   - How many terminals does it have? Identify the function of each of the terminals?
   - What is the meaning of N.O. (normally open) and N.C. (normally closed)?
   - Based on your examination, draw a schematic diagram of the relay coil and Contacts.

Figure 5: Relay (24V, 8A, 250 VAC).

2. Unplug the relay and measure the resistance of its coil using the multimeter. Record the value of resistance.
3. Using the relay provided, connect it to the variable voltage power supply. Turn the power supply voltage down to minimum ensuring that the relay switches off (you can hear it click). Monitor the voltage of the power supply using a Multimeter (i.e., independently of the indication on the power supply).
   - Turn the voltage up very slowly until you hear the relay turn on. Record the voltage of the power source.
   - Increase the voltage to 24 V and notice the state of the relay.
   - Turn the voltage down very slowly until you hear the relay switch off. Record the voltage at which the relay drops.
   - Reduce the voltage until it drops to zero volts and notice the state of the relay.

- Plot these results on the curve below.
- What is the shape of the resulting curve? What do we call this phenomenon?
- What do we call the voltage at which the relay switched on?
- What do we call the voltage at which the relay dropped off?

2) TRANSISTOR SWITCHING

In this section we shall use the transistor as a switch instead.

- What do you think are the main advantages and disadvantages of using a transistor as a switch compared to a relay?
- You are required to use the transistor BC141 as a switch to switch load at 24 V DC from a 5 V input signal. To do this design the circuit needed, finding the value of the required based resistor (R_b). Assume that the transistor will be switching a resistive load of value 820Ω.
- You will need to add a tie down resistor. What is a suitable value for the tie down resistor and what is the purpose of the tie down resistor?

3) SWITCHING SPEED

Transistor Switching Speed

We now want to identify the switching speed of the transistor as a switch.

- Use a function generator to generate a square wave of equal duty cycle at a 5 V peak value. Enter the square wave signal to the input of the transistor switch.
- Observe the output of the circuit by connecting the oscilloscope to the collector of the BJT transistor. Keep on increasing the frequency of the function generator until the square wave signal at the output disappears.
- Record the frequency of the signal at this point.
- Why does the signal disappear the output?
- Add an LED in the output circuit of the transistor to show the status of the transistor. Make sure to calculate the suitable value of a series resistor with the LED to allow good lighting. You will need around 20 mA of current passing through the LED to give a clear visible light.

Relay switching speed

We now want to establish the switching speed of the relay to compare it to the switching speed of the transistor. Remove the load R_L and replace it with the relay and connect it as shown in the circuit below. A normally open contact from the relay is used to send a signal to the oscilloscope signifying the status of the relay.

- Start from low frequency on the function generator (e.g., 5 Hz) and start increasing the frequency gradually until the signal to the scope disappears. Record the frequency at this happens.
- What is the reason that the signal disappears in this case. How does this differ from the transistor case?

4) THE USE OF FREE-WHEELING DIODE

In this part we want to understand the effect of switching an inductive load on the switch itself. We are using the transistor as a switch and the relay as a load.

- Use a function generator to generate a square wave of equal duty cycle at a 5 V peak value. Enter the square wave signal to the input of the transistor switch.

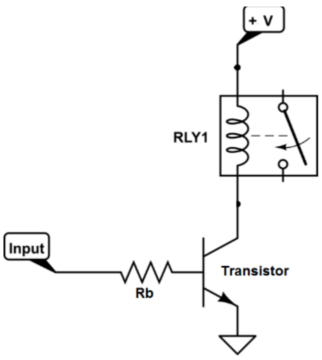

Figure 6: Schematic circuit for using transistor to switch an inductive load.

- Observe the output of the circuit by connecting the oscilloscope. Whenever you switch the relay off, record the shape of the waveform on V_{ce} on the digital storage scope. What do you notice? Plot the waveform that you see.
- Now connect a diode (1N4148) across the relay terminal, making sure to connect it in the correct polarity. Repeat the previous step and notice the shape of the new waveform. ***Comment on the result.***

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EXPERIMENT 2: STEPPER MOTOR CONTROL

OBJECTIVES

In this experiment, you are expected to achieve the following objectives:

- Understand the basic principles of operation of stepper motors.
- Identify different kinds of steppers motors and test them.
- Controlling the position, speed and direction of stepper motors.
- Design a driver for a specific stepper motor.

INTRODUCTION

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. The shaft or spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence. The motors rotation has several direct relationships to these applied input pulses. The direction of motion of the motor is directly controlled according to the sequence of the applied pulses. Whereas the frequency of these input pulses controls the speed, and the length of rotation is directly related to the number of input pulses applied.

Figure 1: Stepper Motor.

Applications where we need to control rotation angle, speed, position and synchronism where controlled movement is required, a stepper motor is considered a suitable choice. Because of the advantages listed previously, stepper motors have found their place in various positioning applications. Some of these include printers, plotters, hard disk drives, medical equipment, fax machines, CNC machines, automotive and many more. Stepper motors can be classified into two groups:

• Permanent-magnet (PM) stepper motor: in this type of stepper motors, the rotation is created by the forces between a permanent magnet and an electromagnet created by electrical current. This type of motors exhibits some magnetic resistance to turn even when it is not powered,

• Variable-reluctance (VR) stepper motor:, The VR stepper motor does not have a permanent-magnet and creates rotation entirely with electromagnetic forces. Unlike the PM stepper motor, this motor does not exhibit magnetic resistance to turning when the motor is not powered.

There are two types of stepper motors: the unipolar stepper motor and the bipolar stepper motor. A bipolar motor with two phases has one winding/phase and a unipolar motor has one winding, with a center tap per phase. In the unipolar stepper motor, current can only flow in one direction where the unipolar motor driver always energize the phases in the same way: One lead, the "common" lead, will always be negative. The other lead will always be positive. Unipolar drivers can be implemented with simple transistor circuitry. The disadvantage is that there is less available torque because only half of the coils can be energized at a time.

On the other hand, the bipolar stepper motor has current flowing in both directions of the coil and thus bipolar drivers use H-bridge circuitry to actually reverse the current flow through the phases.. A two phase bipolar motor has 2 groups of coils. A 4 phase unipolar motor has 4. A 2-phase bipolar motor will have 4 wires: 2 for each phase. Some motors come with flexible wiring that allows you to run the motor as either bipolar or unipolar.

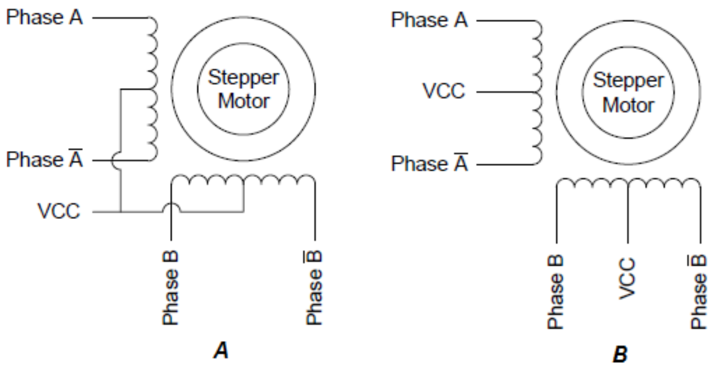


Figure 2: a) 5 wire unipolar stepper motor, b) 6 wire unipolar stepper motor,

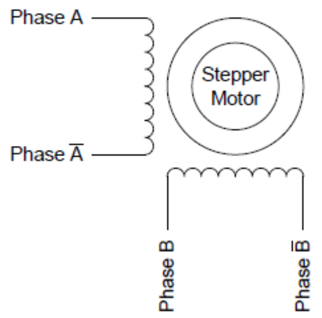


Figure 3: Bipolar Stepper Motor.

Usually stepper motors have two phases, but three- and five-phase motors also exist. Sometimes the unipolar stepper motor is referred to as a "four phase motor", even though it only has two phases. Motors that have two separate windings per phase also exist, these can be driven in either bipolar or unipolar mode.

In stepper motors, both the rotor and the stator have poles, a pole is a region in a magnetized body where the magnetic flux density is concentrated. Figure 4 shows an inside view for a stepper motor. In reality the structure of stepper motors contains several poles in the rotor and stator, this will increase the number of steps per revolution, or in other words to provide a smaller basic (full step) stepping angle.

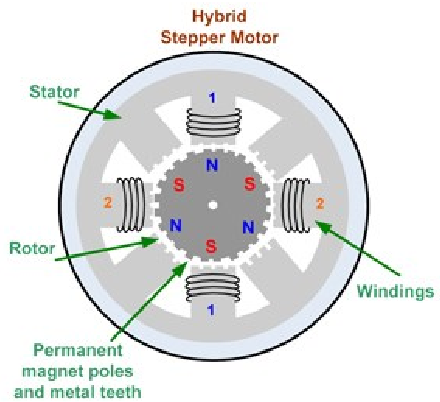


Figure 4: inside view of Stepper Motor showing the poles in stator and rotor.

MOTOR SELECTION

There are a wide variety of stepper types that have different characteristics. When selecting a stepper motor for a certain application you have to consider the following:

- In the first place you have to ask yourself if the motor has the strength to do what you want. As you know motors have different torque and power ratings where larger motors are capable of delivering more power that small ones. Stepper motors come in sizes ranging from smaller sizes to big NEMA 57 monsters.
- Another thing you need to look at is the positioning resolution you require. This is commonly known as the number of steps per revolution which often ranges from 4 to 400. Commonly available step counts are 24, 48 and 200.

Resolution is often expressed as degrees/step. For example: a 1.8° motor is the same as a 200 step/rev motor. The trade-off for high resolution is speed and torque. High step count motors top-out at lower RPMs than similar size. And the higher step-rates needed to turn these motors results in lower torque than a similar size low-step-count motor at similar speeds.

- High positioning resolution can also be achieved with gearing. Consider a 32:1 gear-train connected to the output of an 8-steps/rev motor, this will result in a 512 step motor. Gearing increases the torque of the motor, some small geared steppers have high torques, but Geared stepper motors are generally limited to low RPM applications.

APPARATUS:

- Power Supply.
- Stepper motor kit.
- Arduino/PIC Microcontroller.
- Breadboard.
- Digital Multimeter.
- ULN2003 Driver IC
- H Bridage Driver IC
- Resistors (various)
- Transistors (various)

PROCEDURE

1) IDENTIFICATION OF STEPPER MOTOR

- Try to rotate the motor shaft by your hand,.What do you notice.
- Depending on the wire's number, what is the type of this motor?
- Identify the wires of the motors by measuring the resistance between the wires.

2) CONTROLLING SPEED, POSITION AND DIRECTION OF STEPPER MOTOR

- Write a program to change the direction of rotation (CW or CCW) using one or two push buttons.
- Edit the program you have written to control the speed and direction, it's required to have minimum three speeds (use push buttons to change the speed).
- Find the resolution of the stepper motor (deg/step) by counting the steps needed to rotate the motor 360 degrees. [Hint: connect LED to one of the phases and count the pulses].
- Write a code to rotate the motor to reach 36 degrees then 261 degrees.

3) DRIVING THE STEPPER MOTOR

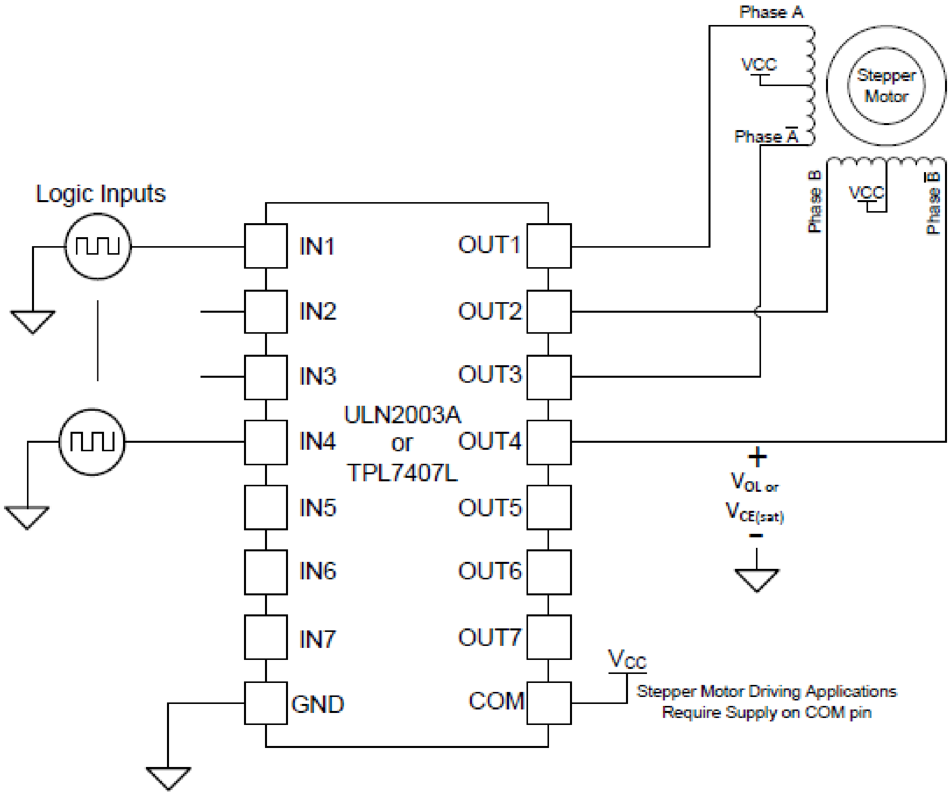


Figure 5: Driving circuit for unipolar Stepper Motor.

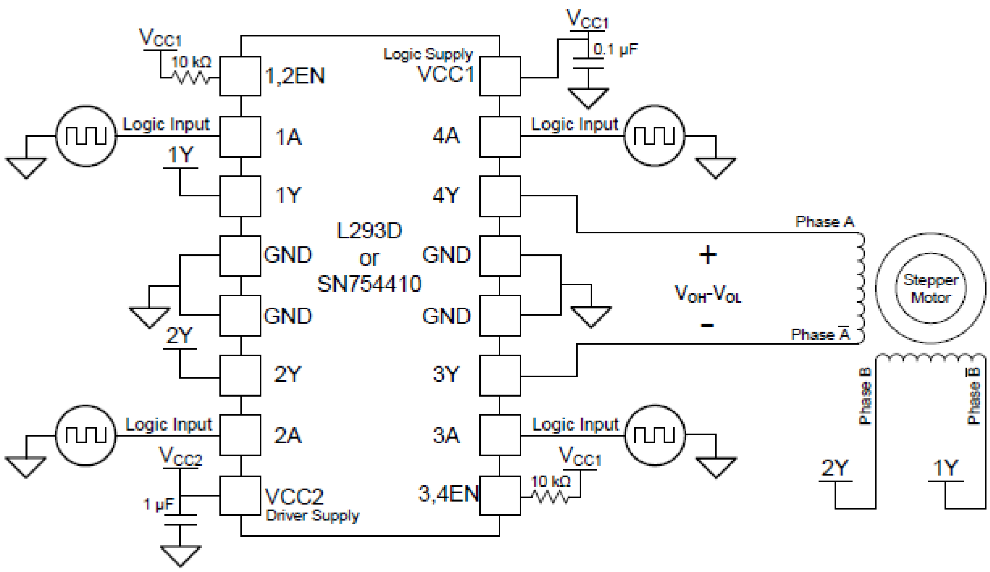


Figure 6: Driving circuit for bipolar Stepper Motor.

4) DESIGN OF STEPPER MOTOR DRIVER

Refer to the following datasheets to design a suitable driving circuit for a selected stepper motor as asked in the task given by your instructor.

ULN2003 Datasheet:

https://www.diodes.com/assets/Datasheets/ULN200xA.pdf

L293D H Bridge:

http://www.ti.com/lit/ds/symlink/l293.pdf

NEMA Stepper Motors:

http://www.pbclinear.com/Download/DataSheet/Stepper-Motor-Support-Document.pdf

EXPERIMENT 3: DC MOTOR SPEED- CONTROL USING PWM

OBJECTIVES

In this experiment, you are expected to achieve the following objectives:

- Understand the principles of pulse width modulation PWM.
- To control the speed of a DC fan using PWM, in open-loop system.
- To control the speed of a DC fan using PWM, in closed-loop mode, and to check that the speed stays constant in case of a disturbance such as the increase or decrease of the power supply voltage (e.g., 10 V or 14 V instead of the 12 V originally set).

INTRODUCTION

Pulse-width modulation (PWM) or duty-cycle variation methods are commonly used in speed control of DC motors. The duty cycle is defined as the percentage of digital 'high' to digital 'low' plus digital 'high' pulse-width during a PWM period.

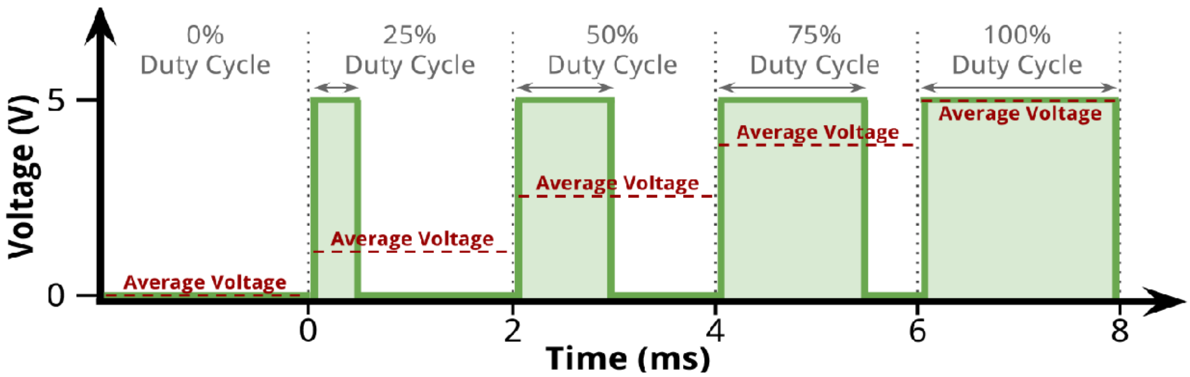


Figure 1: 5V pulses with 0% through 50% duty cycle

Figure 1 shows the 5V pulses with 0% through 50% duty cycle. The average DC voltage value for 0% duty cycle is zero; with 25% duty cycle the average value is 1.25V (25% of 5V). With 50% duty cycle the average value is 2.5V, and if the duty cycle is 75%, the average voltage is 3.75V and so on. The maximum duty cycle can be 100%, which is equivalent to a DC waveform. Thus by varying the pulse-width, we can vary the average voltage across a DC motor and hence its speed. The average voltage is given by the following equation:

$$\bar{Y} = D.\ Y_{max} + (1-D)\ Y_{min}$$

But usually y minimum equals zero so the average voltage will be:

$$\bar{Y} = D.\ Y_{max}$$

The circuit of a simple speed controller for a mini DC motor, such as that used in tape recorders and toys is shown in Figure 2.

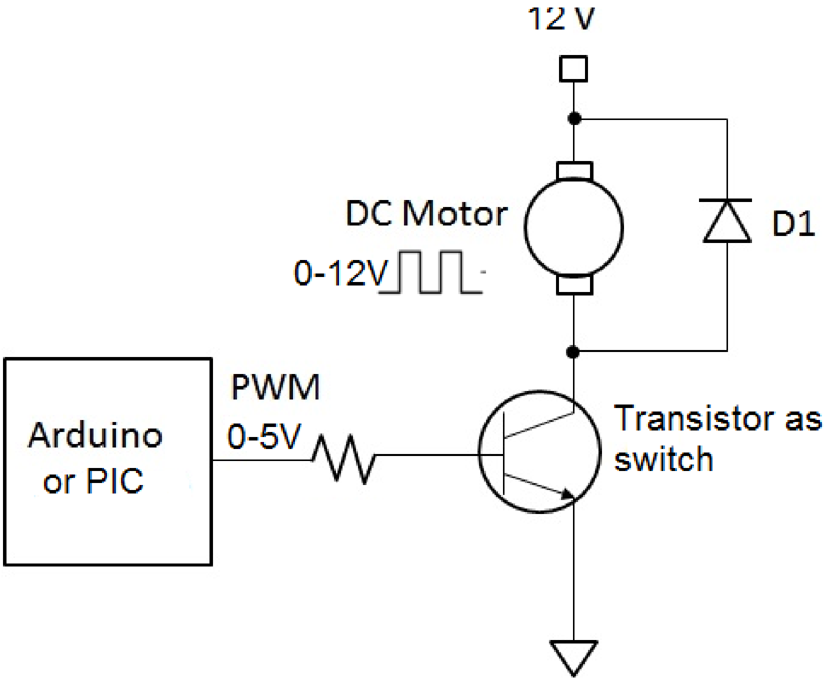


Figure 2: DC motor speed control using PWM method

In order to be efficient in during the lab please do the following before you come to the Lab :

1. Read the PIC16F87X data sheet especially the PWM section, and the A/D Converter

1. Referring to the switching experiment, design a driving circuit for the PC fan that uses PWM to control its speed, knowing that the fan specification are: (12V, 0.16A), you can use any switching technique you want, but you must specify the type and value for each component.
2. Read the extra resources.

APPARATUS

- 2-wire PC brushless DC fan with driver.
- DC power supply.
- Multi-meter.
- Oscilloscope.
- Bread board
- ARDUINO/PIC, and any other needed components.

PROCEDURE

1) OPEN LOOP SYSTEM

a) Using PIC16F876A or ARDUINO write a program to generate a PWM with a frequency of 1 kHz and a duty cycle of 50%, and watch your signal on the oscilloscope.
b) Now connect your signal to the fan driver and watch what happens.
c) Draw the block diagram for the open loop system.

SETUP FOR PWM OPERATION in PIC Microcontroller

The following steps should be taken when configuring the CCP module for PWM operation:

1. Set all three ports, A, B and C, to output ports, Port C is the most important, as it shares an output with CCP1, the pin form which the PWM output will emerge,
2. Set the PWM period by writing to the PR2 register.
3. Set the PWM duty cycle by writing to the CCPR1L register and CCP1CON<5:4> bits.
4. Make the CCP1 pin an output by clearing the TRISC<2> bit.
5. Set the TMR2 prescale value and enable Timer2 by writing to T2CON.
6. Configure the CCP1 module for PWM operation.

The PWM period is specified by writing to the PR2 register. The PWM period can be calculated using the following formula:

PWM period = [(PR2) + 1] • 4 • TOSC • (TMR2 prescale value)

The following equation is used to calculate the PWM duty cycle in time:

PWM duty cycle =(CCPR1L:CCP1CON<5:4>) • TOSC • (TMR2 prescale value)

2) CHANGING THE SPEED USING POTENTIOMETER

In this part, we are going to use the potentiometer on the board connected with the supply voltage to produce a variable DC voltage. This voltage will be digitized using the A/D converter. The digitized value is used to pulse width modulate a signal connected to the Motor and the speed of the motor get a visual indication of the effect of the digitized value on the PWM signal.

ANALOG-TO-DIGITAL CONVERTER (A/D) MODULE

The Analog-to-Digital (A/D) Converter module has five inputs for the 28-pin devices and eight for the 40/44-pin devices. The A/D module has high and low voltage reference input that is software selectable to some combination of VDD, VSS, RA2, or RA3.

The following steps should be taken when configuring the (A/D) MODULE for the Analog-to-Digital (A/D) Converter operation:

1. set PORTA to input ports, to enter the analog value from potentiometer
2. Set the value for ADCON0 register, the ADCON0 controls the operation of the A/D module.
3. Set A/D Conversion Clock Select bits (ADCON0 bit 7-6) (Fosc/8).
4. Set Analog Channel Select bits (ADCON0 bit 5-3).
5. Set A/D enabled (ADCON0 bit 0) .
6. Set A/D Result Format Select .bit (ADCON10 bit 7).

1 = Right justified. Six (6) Most Significant bits of ADRESH are read as '0'.

0 = Left justified. Six (6) Least Significant bits of ADRESL are read as '0'.

The ADRESH: ADRESL register pair is the location where the 10-bit A/D result is loaded at the completion of the A/D conversion. This register pair is 16-bits wide. The A/D module gives the flexibility to left or right justify the 10-bit result in the 16-bit result register. The A/D

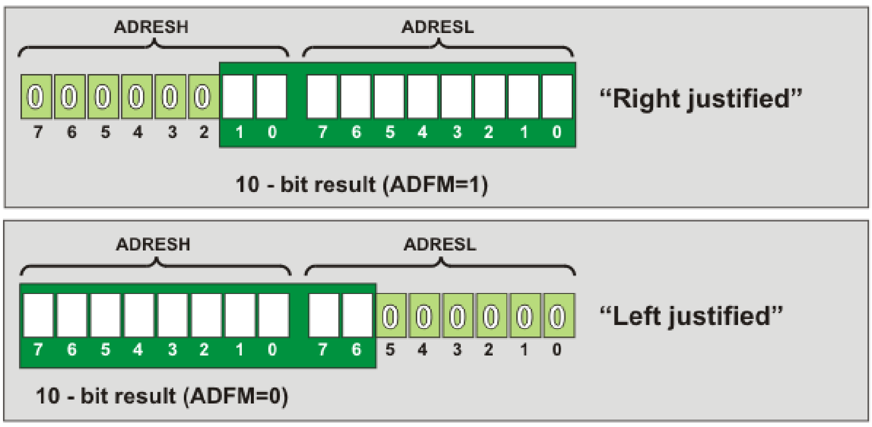


Figure 3: ADCON Register in PIC16F877A

7. Set A/D Conversion Clock Select bit (ADCON10 bit 6) (Fosc/8) .
8. Set A/D Port Configuration Control bits (ADCON10 bit 3-0).
9. Start conversion, set GO/DONE bit (ADCON0 bit 2).
10. Wait for A/D conversion complete, by Polling for the ADIF bit (PIR1) be set.
11. Read A/D result register pair (ADRESH: ADRESL), clear bit ADIF.
12. Put A/D results in the Duty Cycle variable.
13. Do it again to enter new analog value from potentiometer.

3) DC MOTOR CLOSED LOOP SPEED CONTROL

In the last parts, you ran the dc motor at a pre-defined speed, by using pulse width modulation principle. The main disadvantage with that system was that it operated under open loop conditions. Any disturbance (e.g., change of supply voltage or an increase in mechanical friction) would cause a change in the set speed. In this experiment you will use the reflective slotted switch provided on the circuit to measure the actual speed of the dc motor and compare it to the desired speed of 1200 rpm, and adjust the effective output voltage (i.e., the duty cycle of the output waveform) to keep the speed at 1200 rpm.

PROCEDURE

Use the same setup you had used (DC MOTOR SPEED CONTROL USING PWM), but make sure you also connect the two wires +5 V (to activate the reflective slotted switch and the Schmitt trigger inverter that sharpens the signal) and the feedback speed signal to the breadboard.

SPEED DETECTION

Shaft encoders use infrared emitters and detectors that are placed fairly close to each other (about half an inch or less). When there is a direct line of sight between them the detector is “on”’ and produces a voltage (normally around 1 to 3 volts). When the line of sight is blocked the detector doesn’t pick up any infra red light so is “off”, producing 0 volts.

Hints for Motor Speed Testing:

There are two ways to measure speed:

Method 1: Counting holes in a given period of time. Timing can be done with Timer 0 or any of the other timers in the chip. Count Overflow interrupts to measure a period of one second while counting the number of holes that pass by using an external interrupt.

Method 2: Measuring time for a complete revolution of the wheel (or several revolutions to average things out). Set up the timer to time over an appropriate period. Wait for the first external interrupt to indicate the first hole and record the timer value. After four more external interrupts you know that 1 revolution has occurred. Find the difference between the start and end times (you may also need to count the number of timer overflows) and you can calculate the period of rotation for the wheel. From this value you can work out how many revolutions could occur in a second and display it.

Whichever method you choose is up to you. The Detector can be read by an interrupt. The detector usually will output a 1 when there isn't a hole, so you can use the falling edge of the detector to trigger an interrupt to count a hole

What to do?

Write a program that controls a dc motor in closed loop, along with the following procedure:

1) You will use the interrupt RB0/INT as the input from the slotted switch to read the pulses representing the speed.
2) Set up a timer loop (using three nested counters) to give you a delay of 0.5 second. This will be the period during which the microcontroller will wait for an input from the slotted switch to measure the speed.
3) Setup a special register that will contain the number of pulses received (e.g., call it COUNTER).
4) Setup another special register that will contain the desired speed (i.e., desired number of pulses). For example call it SPEED1.
5) Every time the 0.5 second delay expires, disable interrupts, and read the value in COUNTER.
6) Compare the value in COUNTER with SPEED1. If equal do nothing. If more than then decrement duty cycle register (CCPR1L). If less than then increment duty cycle register.
7) Remember to set upper and lower limit checks on the value in the duty cycle register to prevent overflow and underflow (i.e., you should not decrement if the value in CCPR1L is zero, and you should not increment if the value in CCPR1L is 255 (decimal)).
8) Clear COUNTER and enable interrupts and then go back to start of 0.5 second delay.
9) Set up the interrupt in software by doing the following:
    a. In location 0x04 (org 0x04) write a *goto* statement to your interrupt service routine, using a suitable label (e.g., isr).
    b. Enable global and the RB0/INT interrupt by enabling bits 7 and 4 of INTCON.
    c. Setup pin 0 of RB as an input pin.

d. Write the interrupt service routine that will check the status of the interrupt (RB0/INT) by checking the status of bit 1 of INTCON. If not set, return from interrupt (RETFIE). If set then clear it and increment a special register that contains the number of pulses received during 0.5 second period (COUNTER).

10) Once finished, connect the setup and run the system.

11) The motor should run at 1200 rpm.

12) Now check the actual speed of the motor using the scope (e.g., set the scope to automatically measure the frequency of the reflective slotted switch as a representation of the motor speed in rpm).

MAKING A DISTURBANCE

13) Change the supply voltage to 10 V and observe what happens.

14) Then change the supply voltage to 12 V and observe what happens.

15) Now completely remove the feedback connection to the breadboard and observe what happens. Explain.

The University of Jordan
School of Engineering
Mechatronics Engineering Department
MSD Lab

EXPERIMENT 4: DESIGN OF TEMPERATURE CONTROL SYSTEM

OBJECTIVES

In this experiment, you are expected to achieve the following objectives:

- Selection and sizing of electrical heaters best suited to satisfy certain design requirements.
- Design a temperature closed loop control system.
- Understand how to build a physical control system.
- Understand the principles of Solid State Relays.
- Gathering information and reading Datasheets of various components in mechatronics system including heaters, TRIACS and Solid State Relays.

INTRODUCTION

This experiment is designed to provide students with a clear practical understanding of the essentials of physical process control loop and how to select the components of the particular plant or process. The student will be involved in the design, and implementation of a Temperature Control System that is a typical industrial process control system.

This experiment will enable the student to specify , design and apply the essential building blocks in automatic control loop including: feedback elements, signal conditioning, control method and the introduction of power electronics driving elements in control loops.

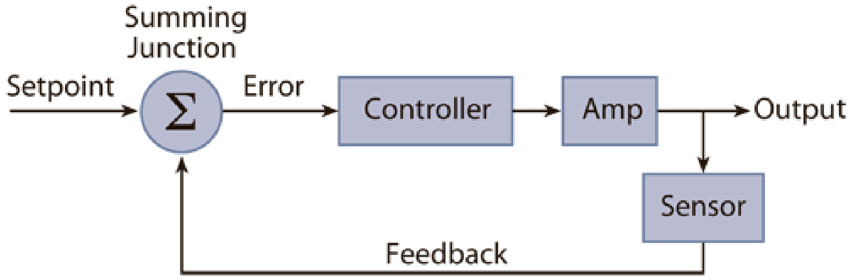


Figure 1: block diagram for the closed loop control system.

The selection and sizing of electrical heaters best suited to satisfy certain design requirements is an essential step in the design of a heating process, the student is introduced to the selection steps of the sizing of industrial heating elements provided by **CCI Thermal Technologies Inc**. as a leader in heating and filtration solutions.

SELECTION OF HEATERS

Electric heaters are typical types of actuators used in chemical plants and other process control systems, it seems useful to learn about these actuators in terms of their sizing, selection and design parameters. Here we introduce you to an interesting design and selection procedure provided by the **CCI Thermal Technologies Inc**.

Selection

Most tubular elements are made-to-order. The following procedure (Step 1 to Step 9) will simplify the selection of the element best suited to your needs. If you need assistance we will, without obligation, determine your kW requirements and provide design sketches.

Step 1 - Determination of wattage requirements.
Refer to Section D of the Caloritech™ catalog for technical data and sample calculations.

Step 2 - Selection of voltage rating and phase.
Remember that, for any fixed voltage, the higher the wattage rating, the higher will be the current. If you have a choice of available voltages try to specify the higher voltage, especially if the required wattage is above 6 kW.

STEP 3 - Selection of sheath material.
Sheath material selection is based on the highest expected sheath temperature and also the ability of the metal to withstand corrosion.

Copper - For immersion heating of water and noncorrosive aqueous solutions.

Steel- For immersion heating of oil or paraffin or casting into iron.
Incoloy® - For heating air and other gases; clamping-on to tanks and platens; immersion into salt solutions, soft metals, oils, most mildly corrosive chemical solutions; for radiant heating.
Other Materials - Refer to the Corrosion Guide recommendations in Section D of the Caloritech™ catalog.

See Table 1 for common sheath materials and maximum allowable sheath temperatures.

TABLE 1 Sheath Materials vs. Temperature

STANDARD SHEATHS	MAX ALLOWABLE TEMP. °C	°F
Copper	177	350
Bundy®	400	750
Incoloy®	815	1500
Stainless 304, 321	760	1400
Steel	400	750
SPECIAL SHEATHS	**MAX ALLOWABLE TEMP. °C**	**°F**
Incoloy®	870	1600
Monel	450	900
Stainless 316	760	1400
Titanium	540	1000

Step 4 - Selection of sheath diameter.
Select sheath diameter from Table 2. Remember that smaller diameter sheaths are the most economical, but their use is restricted at the higher voltages.

HX and IK

TABLE 2 Sheath Diam. vs. Max. Allowable Voltage

STANDARD DIA. in	mm	MAX. VOLTS	SPECIAL DIA. in	mm	MAX VOLTS
.260	6.6	250	.112	2.8	120
.315	8.0	600*	.160	4.1	250
.430	10.9	600	.205	5.2	250
.475	12.1	600	.375	9.5	600
			.540	13.7	600

*Note:
.315 (8 mm) diameter elements above 300V require special terminals.

Step 5 - Determination of allowable watt density.
Below is a partial listing of maximum recommended watt densities. Refer to Section D for a more complete listing encompassing most applications.

Maximum Watt Density Ratings

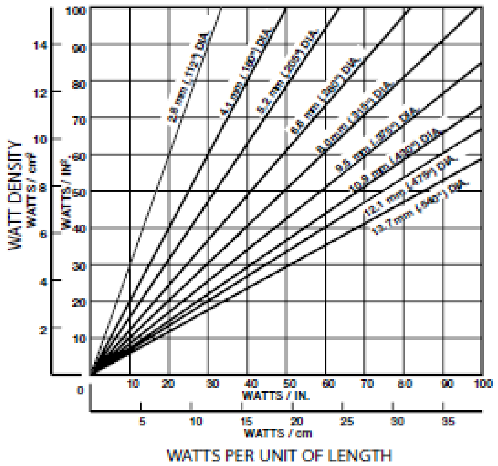
These are suggested ratings only and will differ when flow velocity, heat transfer rate, or operating temperature vary.

TABLE 3 Maximum Watt Density Ratings

MATERIAL BEING HEATED		MAXIMUM WATTS PER SQUARE INCH	OPERATING TEMPERATURE °C (°F)
Acid Solution		40	82 (180)
Alkaline Solution		40	100 (212)
Ammonia Plating Solution		25	10 (50)
Degreasing Solution, Vapor20		275	
Electroplaing Solution		40	82 (180)
Fatty Acids		20	66 (150)
Freon		3	149 (300)
Gasoline		25	149 (300)
Glycerine		40	10 (50)
Lead-Stereotype Pot		35	316 (600)
Linseed Oil		50	66 (150)
Molasses		4-5	38 (100)
Oils	Bunker C Fuel	8	71 (160)
Oils	Dowtherm A	20	316 (600)
Oils	Dowtherm E	12	204 (400)
Oils	Fuel Preheating	9-14	82 (180)
Oils	Machine (SAE 30)	18-24	121 (250)
Oils	Mineral	20-26 16-18	93 (200) 204 (400)
Oils	Vegetable	30-50	204 (400)
Paraffin or Wax		16-22	66 (150)
Potassium Hydroxide		25	71 (160)
Water		55-80	100 (212)

Step 6 - Determination of total required heated length.
Using the maximum allowable watt density from Step 5 and the selected diameter from Step 4 refer to Figure 1 below to determine the wattage per unit of length.

Figure 1 Surface Watts vs Linear Watts



$$\text{OHMS/UNIT LENGTH} = \frac{\text{VOLTS}^2}{\text{WATTS x HEATED LENGTH}}$$

TABLE 4 Sheath Diameter vs. Maximum Length and OHMS/Unit Length

SHEATH DIAMETER in (mm)	MAXIMUM LENGTH in (mm)	OHMS PER MINIMUM OHMS/in (mm)	HEATED LENGTH MAXIMUM OHMS/in (mm)
.112 (2.8)	55 (1400)	.300 (.0118)	3.2 (.126)
.160 (4.1)	120 (3050)	.230 (0090)	9.0 (.354)
.205 (5.2)	155 (3940)	.170 (.0066)	12.0 (.472)
.260 (6.6)	102 (2590)	.056 (.0022)	10.0 (.395)
.315 (8.0)	106 (2700)	.035 (.0014)	13.0 (.512)
.375 (9.5)	146 (3710)	.040 (.0016)	13.0 (.512)
.430 (10.9)	285 (7240)	.025 (.0010)	14.0 (.551)
.475 (12.1)	285 (7240)	.025 (.0010)	14.0 (.551)
.540 (13.7)	106 (2700)	.025 (.0010)	14.0 (.551)

NOTES:
(1) .260" (0.66 mm) & .315" (0.80 mm) Diam. elements are available in lengths up to 285" (7240 mm) in low volume runs (check factory).
(2) Lengths beyond maximums shown above can be increased by splicing. Check factory for limitations.

Next divide this number into the required wattage as determined in Step 1. This gives you the total heated length required.

Step 7 - Determination of the cold end length
Ideally, the cold end should not be less than 1-1/2" (40 mm) for sheath lengths up to 80" (2000 mm) and 2-1/2" (65 mm) for sheath lengths over 80" (2000 mm). It shall not terminate within a bent section of the element. For immersion, the cold end must always terminate below the minimum liquid level. For higher temperature, "clamp-on", or air heating applications, increasing the cold length will result in lower terminal temperatures.

Step 8 - Determination of element configuration and total sheath length.
Refer to page A8 for some of the more common shapes for elements. For other shapes, forward to us a hand sketch showing all critical dimensions. In selecting an element shape you may have to use more than one element to meet the following conditions:

(a) to distribute heat over a large surface or tank;
(b) if required sheath length is greater than maximum available length shown in Table 4;
(c) if element heated length, voltage and wattage selected are outside of minimum and maximum ohms per unit of length as shown in Table 4.

Step 9 - Selection of element terminal and optional hardware.
Refer to page A12 for standard element terminal types and to page A16 for optional hardware.

Types AA and AB terminals can be supplied with 1" (25 mm) length on request.

When Ordering Specify

- number of elements
- element voltage
- element wattage
- sheath diameter
- sheath length
- sheath material
- length of cold ends
- terminal type
- optional hardware
- forming dimensions (send sketch)

DETERMINATION OF REQUIRED WATTAGE

DESIGN CASE STUDY

An open steel tank, 2 ft. wide, 3 ft long, 2 ft deep and weighing 270 lbs, is filled with water to within 6 inches of the top. bottom and sides have 3 inches of insulation. Water is to be heated from 50°F to 150°F (10°C to 66°C) within 2 hours.

(Ref: Caloritech™ Section D, CCI Thermal Technologies Inc.)

Power Requirement for Initial Heat-up

From Table 1 on Caloritech™ Section D page D42**:**
Specific Heat of Steel: 0.12 Btu/lb - °F

From Table 3 on Caloritech™ Section D Page D43**:**
Specific Heat of Water: 1.0 Btu/lb - °F

From Table 3 on Caloritech™ Section D page D43**:**
Weight of Water: 62.5 lb/cu. ft. (8.3 lb/gal)

Water in Tank:
(2 x 3 x 1.5) cu. ft. x 62.5 lb/cu. ft. = 563 lb

From Figure 3 on Caloritech™ Section D page D45**:**
Water surface loss at 150°F (66°C): 270 W/sq. ft.

From Figure 4 on *Caloritech™ Section D page D45***:**
Insulated wall loss at 100°F (38°C) rise: 7 W/sq. ft.

Initial Heat-Up Requirement

To heat water:
563 lb x 1.0 Btu/lb-°F x (150 - 50)°F/3412 Btu/kWh

To heat tank:
270 lb x 0.12 Btuf/lb-°F x (150 - 50)°F/3412 Btu/kWh

Heat of fusion or vaporization: None

Average water surface loss:
6 ft2 x 270 W/ft2 x 2 hrs./1000 W/kW x 2

Average tank surface loss:
26 ft2 x 7 W/ft2 x 2 hrs./1000 W/kW x 2

Safety factor:
20% (16.5 + 0.95 + 1.62 + 0.18) = 3.85 kWh

Total Heat requirement = 23.10 kWh

Power required for Initial Heat-up:
23.10 kWh/2hrs. = **11.55 kW**

Technical Data - Heat Losses

Figure 3 Heat losses from liquid surfaces. Assumed external ambient temperature of 70°F (21°C).

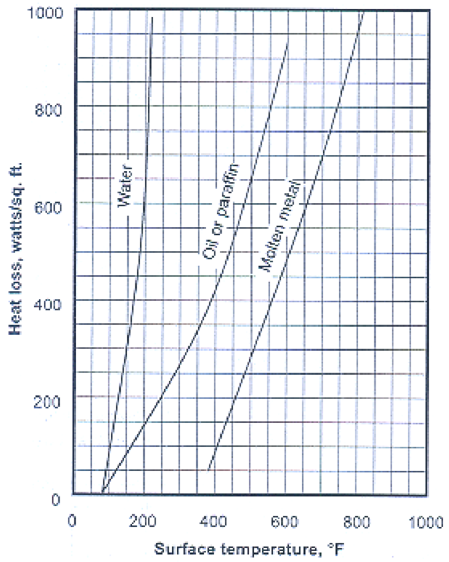
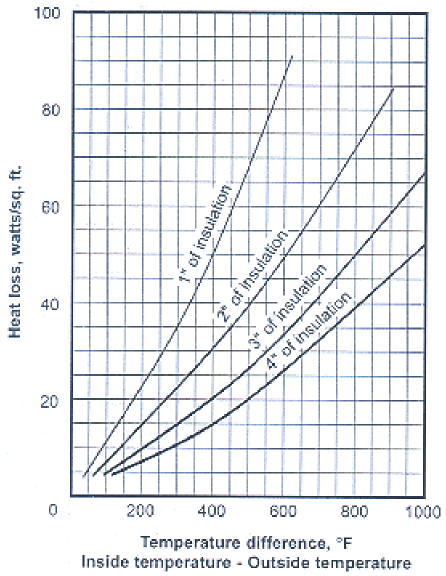


Figure 4 Heat losses from insulated walls. Curves are for standard high-grade material, such as 85% magnesia, Rockwool, etc.



Wind Velocity and Heat Loss

Wind velocity will increase surface heat losses. Table 1 can be used as a guide for estimating the factors to be applied to the still air heat losses from Figures 1, 2, & 4.

TABLE 1 Wind Velocity Factors

Wind Velocity (MPH)	Well Sealed Insulated Surface			Uninsulated Surface Temperature (°F)		
	1" (25 mm)	2" (51 mm)	3" (76 mm)	200	600	1000
5	–	–	–	1.7	1.5	1.3
10	–	–	–	2.1	1.7	1.4
15	1.1	–	–	2.4	2.0	1.6
20	1.2	1.1	–	2.7	2.3	1.7
25	1.3	1.2	1.1	3.0	2.6	1.8
30	1.4	1.3	1.2	3.3	3.0	1.9

Heat Losses From Insulated Pipes

To find the heat loss from the insulated pipes, in watts/ft. multiply the appropriate factor from Table 2 by the °F difference between the pipe holding temperature and the minimum ambient temperature.

If the pipe holding temperature is above 200°F (93°C), multiply the above answer by 1.2

TABLE 2 Heat Loss Factors For Pipe

Pipe Size	Insulation Thickness and Factors						
	1/2" (13 mm)	1" (25 mm)	1 1/2" (38 mm)	2" (51 mm)	2 1/2" (64 mm)	3" (76 mm)	4" (102 mm)
1/2	0.086	0.054	0.043	0.037			
1/4	0.102	0.062	0.048	0.041			
1	0.123	0.073	0.056	0.047			
1 1/4	0.142	0.083	0.063	0.052			
1 1/2	0.164	0.094	0.070	0.058			
2	0.192	0.109	0.081	0.066			
2 1/2	0.229	0.128	0.093	0.076			
3	0.259	0.142	0.107	0.083			
3 1/2	0.287	0.157	0.113	0.091			
4	0.316	0.172	0.123	0.098	0.083	0.073	0.060
4 1/2	0.347	0.189	0.134	0.107	0.090	0.079	0.065
5	0.417	0.219	0.155	0.121	0.103	0.089	0.073
6	0.472	0.250	0.174	0.136	0.114	0.099	0.080
7	0.526	0.275	0.192	0.151	0.126	0.109	0.088
8	0.571	0.305	0.212	0.166	0.137	0.119	0.095
9	0.634	0.338	0.234	0.183	0.151	0.130	0.104
10	0.634	0.338	0.234	0.183	0.151	0.130	0.104
12	0.776	0.397	0.275	0.212	0.175	0.149	0.119
14	0.834	0.431	0.298	0.230	0.190	0.162	0.128
16	0.961	0.498	0.334	0.258	0.212	0.181	0.142
18	1.088	0.555	0.379	0.289	0.289	0.200	0.156
20	1.190	0.598	0.416	0.319	0.319	0.219	0.171
24	1.430	0.731	0.490	0.374	0.374	0.259	0.200

SOLID STATE RELAYS

The Solid State Relays SSR are used to control large resistance heaters in conjunction with temperature controllers. Solid State relays are SPST, normally open switching devices with no moving parts, capable of millions of cycles of operation. By applying a control signal, an SSR switches “on” the AC load current, just as the moving contacts do on a mechanical contactor. Three-phase loads can be controlled using two or three SSR’s. Use three SSR’s for “Y” or “star” 3-phase loads using a neutral line Two SSR’s will control “delta” loads with no neutral line. Three solid state relays are also used when there is no neutral load to provide redundancy and extra assurance of control. “Switching” takes place at the 0 voltage crossover point of the alternating current cycle. Because of this, no appreciable electrical noise is generated, making SSR’s ideal for environments where there are apparatuses susceptible to RFI.

In comparing SSR’s with mechanical contactors, the SSR has a cycle life many times that of a comparably priced contactor. However, SSR’s are more prone to failure due to overload and improper initial wiring. Solid state relays can fail, contact closed, on overload circuits. It is essential that a properly rated, fast blowing I^2T fuse be installed to protect the load circuit.

- ***It is recommended to refer to the provided datasheet ‘Technical Explanation for Solid-state Relays’ by OMRON for more details about the operation, types and technical data for SSRs.***

Figure 1: Solid State Relay.

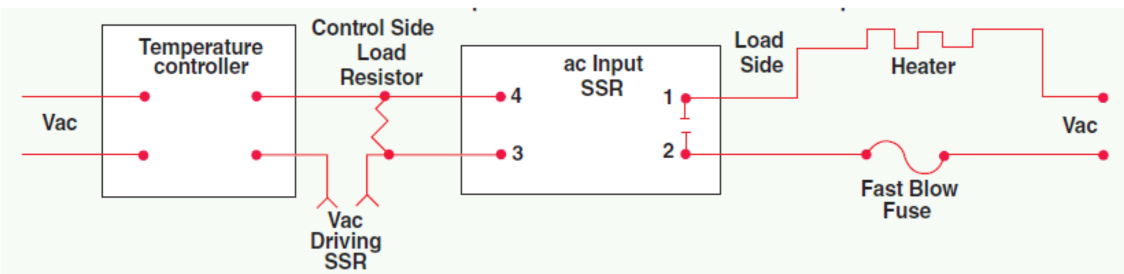


Figure 2: typical usage of SSR in controlling heaters.

DESING OF TEMPERATURE CONTROL SYSTEM

APPARATUS:

- Power Supply.
- Single Phase AC heater.
- Solid-state relay.
- Relays.
- RTD PT100.
- Breadboard.
- Digital Multimeter.
- AD620 instrumentational amplifier
- Resistors (various)
- Transistors (various)

PART 1: DESING IN TEAMS

Each group should spend the first part of the lab session designing the essential building blocks in the temperature control loop including: feedback elements, signal conditioning, and the driving elements in the control loop making use of the items previously listed in the apparatus.

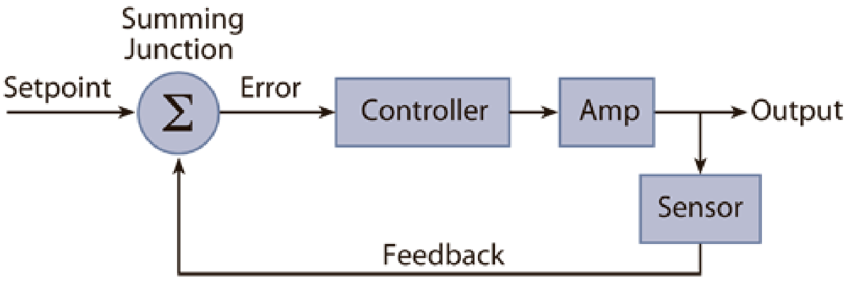


Figure 1: block diagram for the closed loop control system.

PART 2: DISCUSSION

In the next part of the lab, we will have a discussion about your presented designs. The following discussion points are to be addressed:

- Describe your design and explain the choices you made.
- How to physically implement a closed loop control system. The idea of converting a control signal to the AC heater load.
- Discuss the properties of Solid State Relays and understanding the datasheet.
- Comparing your designs and correcting mistakes.

PART 3: PRACTICAL PART

In the next part, you have to practically implement the system.

EXPERIMENT 5: DESIGN OF SIMPLE HYDRAULIC PRESSER

OBJECTIVES

In this experiment, you are expected to achieve the following objectives:

- Design a simple hydraulic system that satisfies certain design requirements.
- Understand the Datasheets of various components in Hydraulic systems including pumps, cylinders and valves.

INTRODUCTION

This experiment is designed to introduce students to the design process of hydraulic systems through simple design case study of a simple hydraulic presser. Hydraulic systems are commonly used in many industrial applications and it is essential for mechatronics engineer to be familiar with these systems due to their importance and wide applications.

The selection and sizing of pumps and cylinders best suited to satisfy certain design requirements is an essential step in the design of a hydraulic system, this experiment will enable the student to design and select the suitable pump, cylinder, prime mover and valves to satisfy given design requirements from the provided datasheets by the **REXROTH Company.**

Hydraulic cylinders are linear mechanical actuators that are used to create either a pushing or pulling force in a straight line, they get their power from the pressurized hydraulic fluid to produce mechanical force and linear motion. The hydraulic cylinder consists essentially of a piston and rod assembly contained within a cylindrical bore.

The proper selection of a hydraulic cylinder requires the consideration of numerous factors influenced by the expected application. Those factors include the amount of force required, cylinder mounting style, stroke length, speed, operating pressure, direction of force, and means of stopping the work load after it is put in motion. Consideration to all these factors is necessary to adequately determine the required cylinder specifications to meet any given application.

Figure 1: Hydraulic Cylinders.

Factors to Consider in the Selection of a Hydraulic Cylinder

Reference: Hydraulic Selection Guide, BERENDSEN Company

BERENDSEN FLUID POWER
Australia's Leading Hydraulics Company

***Mass**: The first and most critical step is to determine the amount of mass you wish to move. Once your mass is known, you must then consider the effect that the mass will have on the force required to move it. For example, a 1-ton load being pushed straight up will require just over 1 ton of force, however, a 1-ton load being pushed across the ground will require only enough force to overcome friction and acceleration. Regardless, the force of the cylinder should always be high enough to allow for margin of error.

Geometry: Once you know the nature of the mass being moved you then need to consider the geometry involved in moving it. For a machine such as a hydraulic press, which moves typically up and down, the geometry is simple and requires no further consideration. However, when the centre of the load being moved is not centered on the point of lift force and at perpendicular angles to that point of lift force, the force required by the cylinder changes. If you have a crane, for example, the cylinder pushes on the boom often very far from the load. In most cases the load distance (distance from load to fulcrum) can be up to ten times the lift force (distance from lift force to fulcrum), and sometimes more. So the closer your point of lift is to the fulcrum the more force is required by the cylinder to lift the load.

Bore Size: Once you arrive at the force required by your cylinder, the next step is to calculate the bore size required of the cylinder. The force produced by the cylinder is simply the product of the system pressure multiplied by the area of the internal piston surface upon which that pressure acts. This formula is used to calculate the bore size needed to achieve that force.

Rod Size: Once a minimum cylinder bore size is determined the next step to the selection of a hydraulic cylinder is to select an appropriate rod size. Most standard off the shelf cylinders usually come with one or two rod options. Selecting the required rod size requires careful consideration of the stroke length required which affects the rod buckling strength.

In addition to rod buckling, bearing loads is another important consideration in the selection of a hydraulic cylinder. As the stroke length of a cylinder increases, the resultant bearing loads on the piston rod also become greater. To keep these bearing loads from exceeding design limitations stop tubes are usually used. Generally, for applications with strokes greater than 1000 mm, stop tubes are required.

When selecting from standard rod options it is recommended that the smaller rod for a given bore only be used for short stroke push loading or reduced pressure applications, and the larger rod offered be used when wanting to obtain maximum reliability and fatigue life of the rod. However, if it is determined that the required rod diameter exceeds that of the largest available within the selected cylinder bore size, it would then be necessary to reconsider design parameters. Alternatively, it may mean that the application warrants the design of a custom made hydraulic cylinder.

Cushions: Once the bore, rod and stroke sizes have been determined another consideration is to whether internal cushions at the end of the cylinder stroke are required. The use of cushions is recommended for deceleration of high speed rods to reduce the energy of the impact of the piston assembly against the cylinder end cap. Cushions are optional and can be supplied at either one or both ends of the cylinder as desired. The use of cushions does not affect cylinder envelope or mounting dimensions.*

Reference: Hydraulic Selection Guide, BERENDSEN Company

DESIGN CASE STUDY

As a part of designing a 300 ton hydraulic presser, you are required to select a suitable cylinder, pump, prime mover and pressure relief valve.

- The hydraulic presser has a steel plate of 0.75m*0.5m*0.1m.
- The presser has a stroke of 0.7 m.
- The presser should travel within 1 min.
- A safety factor of 20%.
- Make sure to select a suitable rod diameter in order to avoid buckilng or failure. Assume L=4*D, where D is the stroke).

PART 1: DESING IN TEAMS

Each group should spend the first part of the lab session designing this simple hydraulic presser taking into account the given design requirements.

PART 2: DISCUSSION

In the next part of the lab, we will have a discussion of your presented designs. The following discussion points are to be addressed:

- Describe your design and explain the choices you made.
- Design aspects in hydraulic systems. What are the factors you need to consider in order to select the right hydraulic cylinder and pump for this application?
- Learning how to read the datasheets of pumps and cylinders.
- Understanding the numeric values and formulas used in datasheets.
- Comparing your designs and correcting mistakes.

EXPERIMENT 6: DATASHEETS ANALYSIS OF INDUTRIAL SENSORS

OBJECTIVES

In this experiment, you are expected to achieve the following objectives:

- Be familiar with reading datasheets of industrial sensors.
- Analysis of sensor data to obtain its characteristics.
- Understand the factors affecting the selection of sensors and transducers.

INTRODUCTION

Sensors/Transducers are essential parts in any mechatronics system. Many factors affect the proper selection of sensors in a certain application. There are several different types of sensors available, each with special capabilities and each requires a different type of transducer to work most effectively. For optimum performance, it is very important to match the transducer to your application or design requirements. You, as a mechatronics engineer, have to make sure that you know how to select transducers.

In this lab, we will read, analyse and understand the datasheets of two different sensors, the first is **Flow sensor type 210 from Huba Control Company** and the other is a **pressure and temperature transmitter from EMERSON Company.**

Figure 1: Flow sensor from Huba control

Figure 1: Pressure Transmitter from Emerson.

For the Flow sensor type 210 from Huba Control Company:

- Read carefully the datasheet.
- What are the main characteristics of this sensor? What points make you consider this sensor in a certain application?
- What is the principle of measurement this sensor is based on?
- Analyse carefully the datasheet to understand the characteristics, types of output signals, operating conditions and other factors.
- Study the effect of viscosity on the characteristics of the sensor.
- Study the wiring of this sensor.
- Sketch the wiring diagram if you want to connect this sensor with an ARDUNINO/PIC microcontroller.

Flow sensor type 210 datasheet

https://www.emerson.com/en-au/catalog/paine-220-11-0010-pressure-and-temperature-trasnmitter

Exercise:

Study the datasheet of the pressure sensor from EMERSON given below:

https://www.emerson.com/documents/automation/220-11-0010-series-pressure-transmitter-en-80298.pdf

EXPERIMENT 7: ANALYSIS OF MECHATRONICS SYSTEM: THE ROBOTINO

OBJECTIVES

In this experiment, you are expected to achieve the following objectives:

- Analysis of a typical mechatronic system.
- Be familiarised with the fundamentals of electrical drive technology and the omnidirectional 3-axis drive.
- Closed-loop control of a mechatronic system.
- Graphic programming of applications for a mobile robot system.
- Analysis of sensor data to obtain its characteristics.

INTRODUCTION

A mobile robot is an automatic machine that is capable of movement in a given environment. Mobile robots have the capability to move around in their environment and are not fixed to one physical location. In contrast, industrial robots usually consist of a jointed arm (multilinked manipulator) and gripper that is attached to a fixed surface.

Mobile robots may be classified by: The environment in which they travel: Land or home robots. They are most commonly wheeled. Aerial robots are usually referred to as unmanned aerial vehicles (UAVs). Underwater robots are usually called autonomous underwater vehicles (AUVs).

ROBOTINO is the mobile robot platform for research and education. With its omnidirectional drive, sensors, interfaces and application-specific extensions, ROBOTINO can be used very flexibly. The most important programming languages and systems are available for programming individual applications.

Figure 1: The ROBOTINO mobile robot.

ROBOTINO DRIVE SYSTEM

There ROBOTINO is a fully functional, high quality mobile robot system with omnidirectional drive. The three drive units allow for motion in all directions – forward, backward and sideways – and the robot can be turned on the spot as well. It is also equipped with a webcam and several types of sensors, analogous to distance measurement, for example binary for collision protection and digital to check the actual speed. This assures that all of the wide ranging demands placed upon systems of this type are fulfilled. The system can be placed into service immediately – without a PC. The drive system consists of:

- 3 drive units consists of the following components
- DC motor
- Gear unit with a gear ratio of 16:1
- All-way roller
- Toothed belt
- Incremental encoder

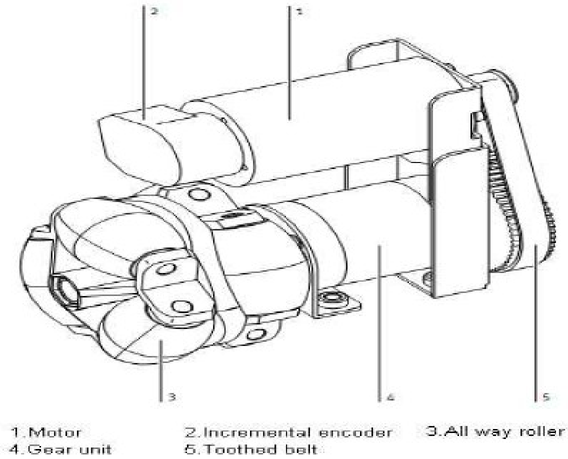


Figure 2: the drive system of the ROBOTINO.

SENSORS

- 9 Infrared distance measuring sensors
- 3 Incremental encoder
- The anti-collision sensor (bumper)

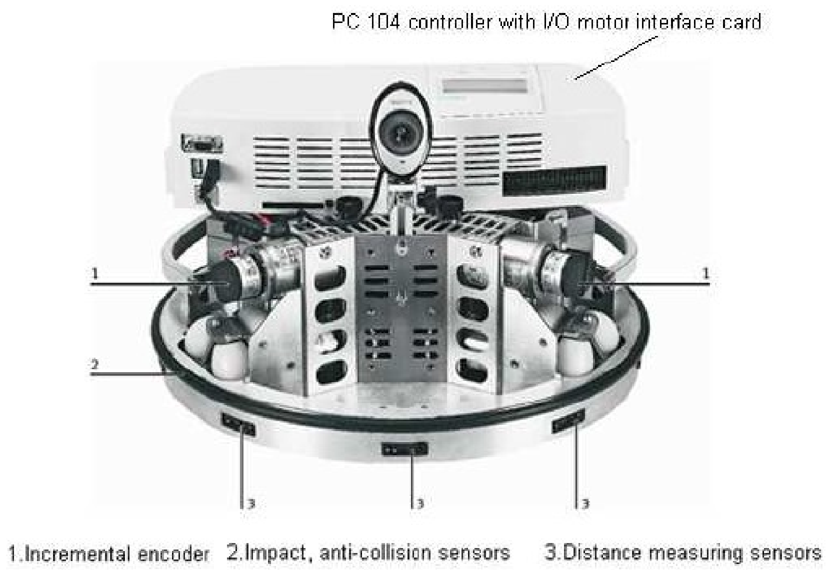


Figure 3: the nine IR distance sensors of the ROBOTINO.

PROCEDURE

1) LINEAR TRAVELLING OF A MOBILE ROBOT SYSTEM IN ANY DIRECTION

Actuation of motor, forward movement of robot system

1. Open ROBOTINO view from program menu.
2. Open a blank function block diagram in ROBOTINO View as you see the screen is separated to two areas the first one on the left hand is the programming area the right hand one contains blocks for the the robot drive unit, sensors motors and for different logic and mathematic operations.
3. Drag the constant block from generators as shown in the picture.
4. Drag the three motors and then connect the blocks as shown in the following figure.

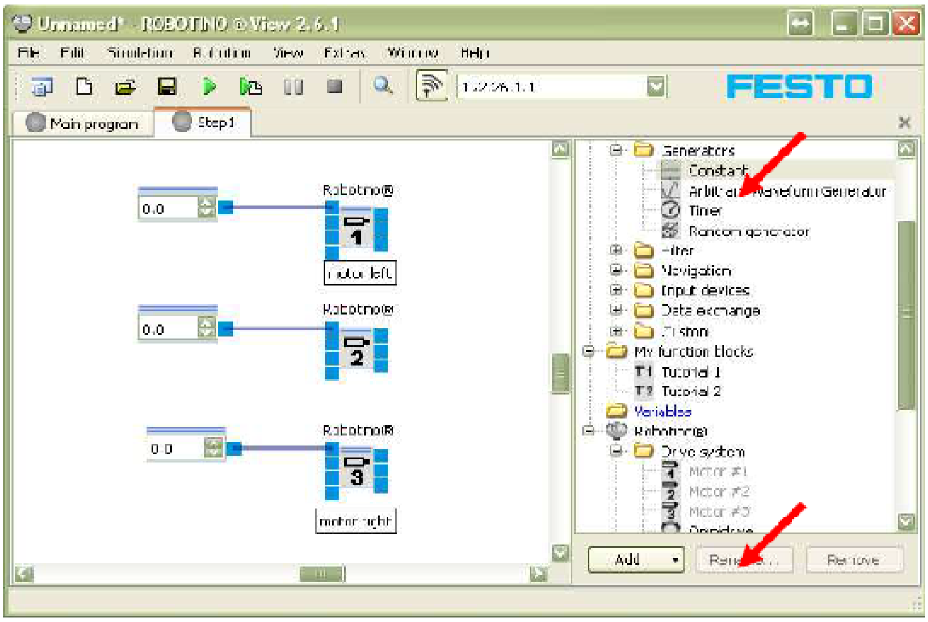


Figure 4: Actuation of motor in Robotino View software.

Now move the robot in the forward direction what do you notice about the three motors speed and direction? What is the constants suitable values that moves the robot in the forward direction.

- ***Note that the speed is in rpm and that negative sign indicate the direction.***

Let the speed be 100 rpm now set the suitable values for the constants block and then start connection by pressing on the button shown in the following figure. Make sure that the IP address for the ROBOTINO is correct. When it converts to green instead of gray, that means the connection is establish now run the program by pressing on start main program button avoid collision and press stop when needed.

2) OMNIDRIVE

1. Open a new blank function block diagram in ROBOTINO view.
2. Drag the three motors and omnidrive block (from ROBOTINO-drive system) and constant from generators and connect the blocks as in the following figure.

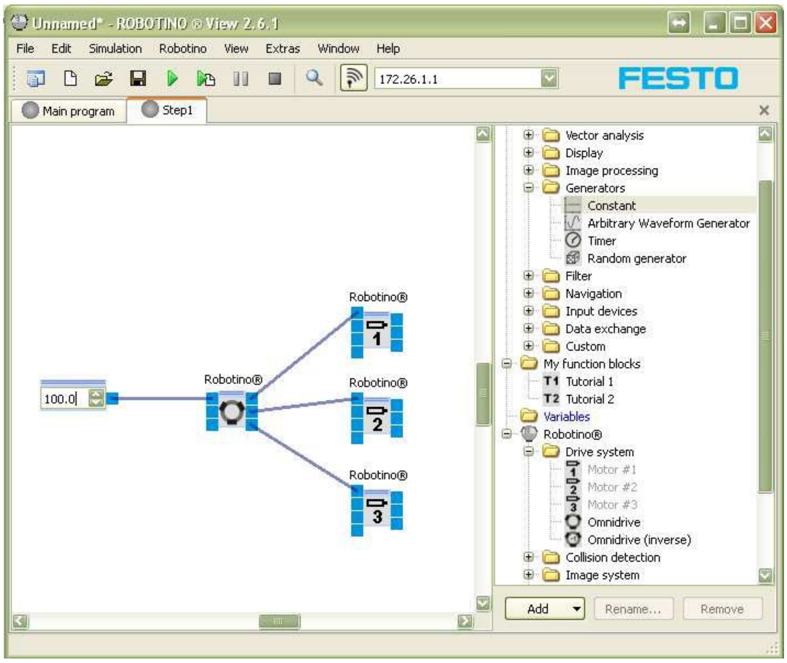


Figure 5: Using Omni drive to drive the robot in x direction.

3. Right 100 in the constant block this means 100 mm/s. run the program and notice the motion.
4. Change the constant value to -100 mm/s and notice the motion again.
5. Now connect between the blocks as in the following figure:

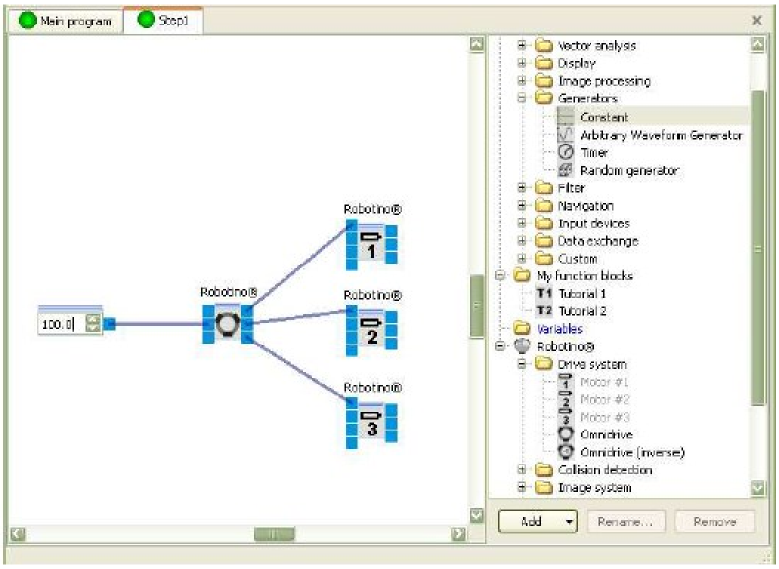


Figure 6: Using Omni drive to drive the robot in y direction

➢ ***Exercise 1: Now let the robot moves in 45 º with speed 100 mm/s.***

3) COLLISION PROTECTION

Now you are going to move the ROBOTINO in the forward direction and add collision protection to the program.

1. Open the forward program, on the right menu click right on the variables the following window will appear.

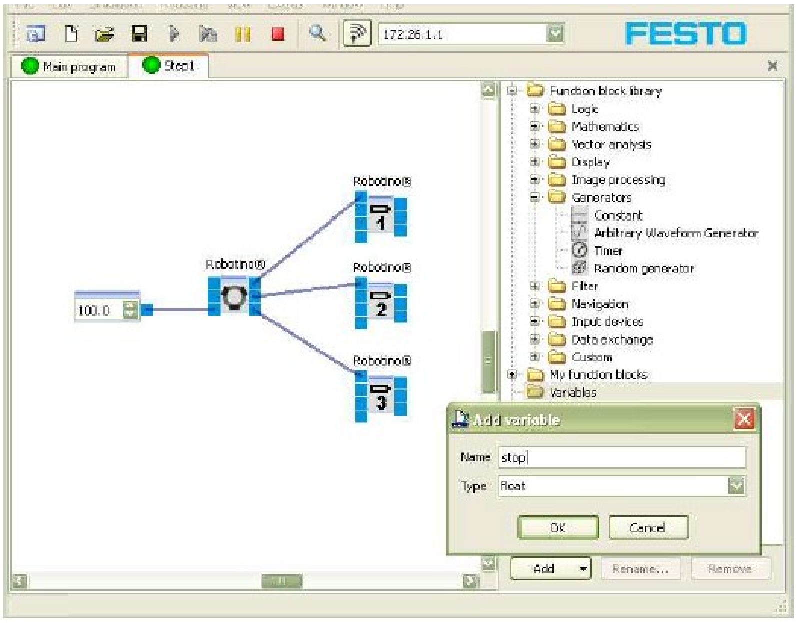


Figure 7: Adding variable in ROBOTINO View.

2. Write stop for the name then click ok.
3. Two blocks will appear stop reader and stop writer, drag the stop writer block to the blocks function window.
4. Drag bumper block from ROBOTINO collision detection menu and connect between the blocks as in the following picture.

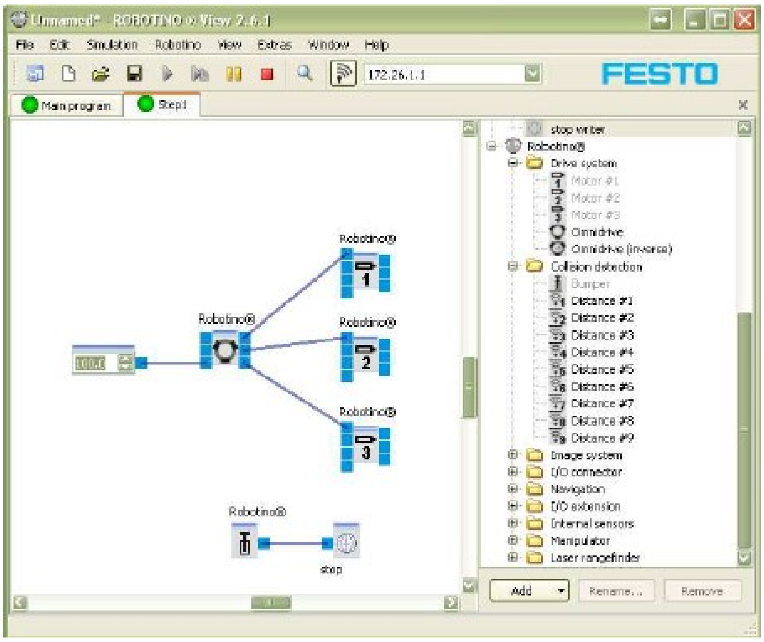


Figure 8: Writing to the bumper sensor.

5. Now open the main program on the left of the function block window change false to stop==1and initial to TERMINATE. Run the program and notice what happens.

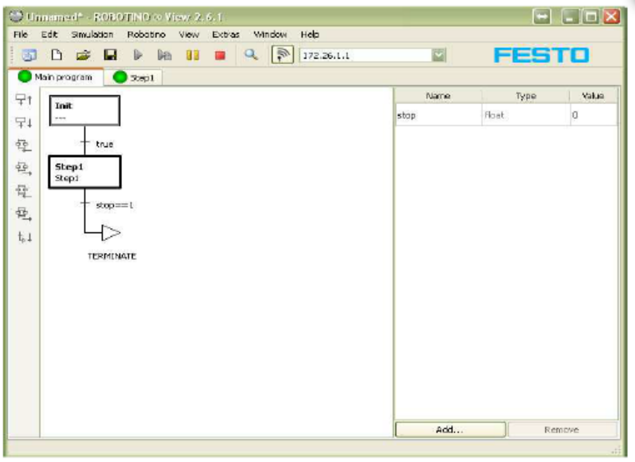


Figure 9: Main program sequence.

4) DISTANCE SENSORS

The position of a sensor is determined by visualizing its output value. The data display can be turned on in ROBOTINO View by (Ctrl-D). An obstacle is placed in front of the sensor. If the output value of the sensor changes, the sensor position is determined and its function tested.

1. Create a program in ROBOTINO View to determine the position of the distance sensors “distance 1” to “distance 9"and save the program.
2. Jacked up the ROBOTINO and switch it on.
3. Open a blank function block diagram in ROBOTINO View.
4. Drag a distance sensor onto the function block diagram.
5. Assign one of the distance sensors to the function block by opening the function block dialogue via a double click onto the distance sensor symbol from view menue click –show connector values.

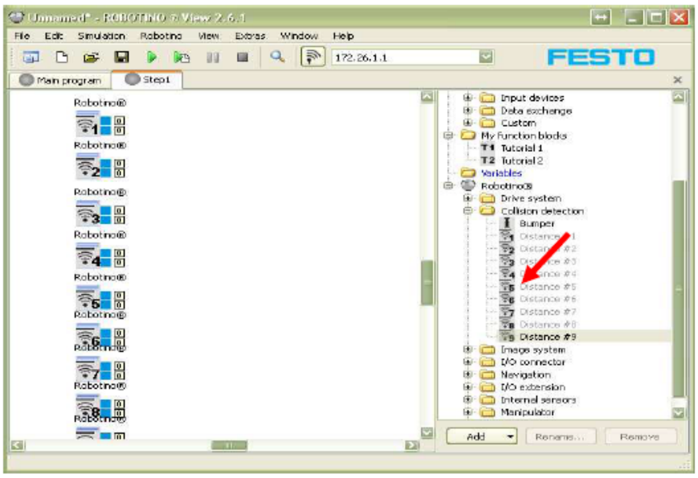


Figure 10: Adding the nine distance sensors in ROBOTINO View.

For different distances, the respective sensor value needs to be determined. A characteristic curve of the distance sensor must be recorded:

1. Create and start a program with a distance sensor. Switch on the display of values in ROBOTINO View.
2. Place an obstacle directly in front of the selected distance sensor (1). Distance this obstacle from the sensor in steps of 1 cm and record the output values of the sensors.
3. Transfer the pairs of values determined to a coordinate system and link these with a curve.
4. Represent the characteristics in the form of a curve using MS-Excel. Enter the coordinate of the determined pairs of values in an Excel table and represent these in the form of a diagram.
5. Determine the characteristic curve area required for the exercise given. Linearize the characteristic curve within this area and enter the linearized characteristic curve in your drawing or represent it in an Excel diagram.

Distance (cm)	Voltage(V)	Distance (cm)	Voltage(V)
1		21	
2		22	
3		23	
4		24	
5		25	
6		26	
7		27	
8		28	
9		29	
10		30	
11		31	
12		32	
13		33	
14		34	
15		35	
16		36	
17		37	
18		38	
19		39	
20		40	

6. Now drag the constant block sensor 1 and scale block from math-function as follows.

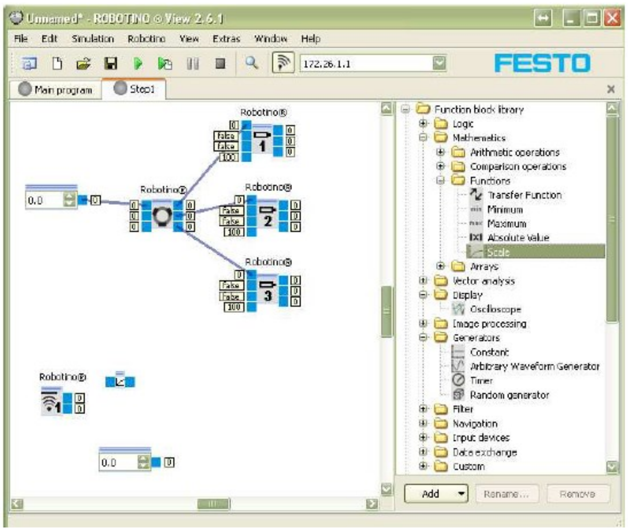


Figure 11: Using scale to convers IR sensor voltage to distance.

Exercise:

- Now complete the program so that ROBOTINO moves in the forward direction then it stops when sensor 1 detects objects 20 cm far and remains 20 cm far even if you decrease the distance (use arithmetic operations).

- Complete your program so the ROBOTINO moves in the forward direction till it reach a wall and follow the it (remember the closed loop control).

The University of Jordan
School of Engineering
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EXPERIMENT 8: VFD & SPEED TIME PROFILING

OBJECTIVES

In this experiment, you are expected to achieve the following objectives:

- Learn how to generate speed time profiles.
- Be familiarised with reading device manuals like variable frequency drive.

INTRODUCTION

Most variable speed drive systems are closed loop feedback systems. They will monitor the speed of the motor. They will then compare the actual value of the speed to the required value (sometimes called the reference value) of the speed, and will drive or brake the motor according to the relative value of these two signals. In order to know what the speed should be at any point in time, a profile of the desired speed of the motion control system has to be either available or generated. This profile represents the value of the speed at which the load should travel at any point in time; it does not necessarily mean that it is the speed at which it has actually travelled. The actual value from the speed feedback device represents the speed at which the load is actually travelling. In an ideal situation, the two profiles should be identical.

When a motion control system attempts to move the load from one point to another, one important criterion is time: To move the load between the two points in the minimum possible time. Hypothetically speaking, the load would attain top speed, v_{max} in zero time, would travel to the destination at v_{max} and then would be brought to a halt in zero time. We will refer to this as Case I. This case is the optimum for minimising travelling time, but requires theoretically infinite acceleration, which is impossible. This is shown graphically in Figure 1, where it takes time t_l to move the load. Obviously this is not possible, as we cannot have infinite acceleration, for three reasons:

1. A high value of acceleration requires excessively high values of torque from the motor, which is not possible. This also necessitates high values of current that would trip the power supply protection.

2. High acceleration values lead to high shock forces on the equipment and could lead to mechanical failure.

3. Human safety and comfort: The human body cannot be subjected to high values of acceleration for safety and comfort reasons. For example, jet pilots who are subjected to high values of g forces suffer blackouts. High acceleration forces could lead to miscarriages for pregnant women.

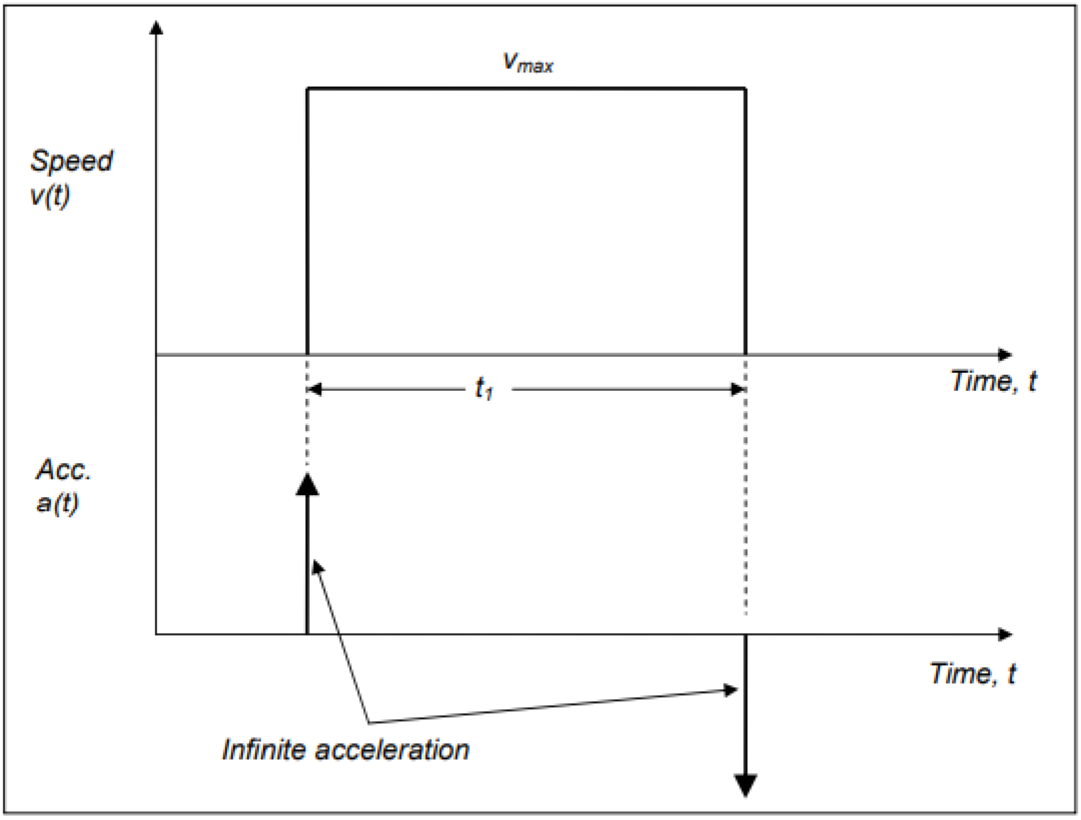

Figure 1: Case I, where the acceleration has an infinite value.

So in order to avoid infinite (or extremely large) values of acceleration we must allow the load to accelerate towards the top speed, $v_{max.}$ This attains a maximum value of acceleration during the acceleration phase, which we will denote as a_{max}. This case will be denoted as Case II, in which the top speed is attained via a finite value of acceleration, a_{max}. This has removed the problem of high acceleration values, and has thus removed the requirement for high torque values, high starting currents and shock forces on the mechanical equipment. This is thus suitable for moving inanimate loads. The time taken in this case to move the load has risen to t_2 where $t_2>t_1$. This case is shown graphically in Figure 2.

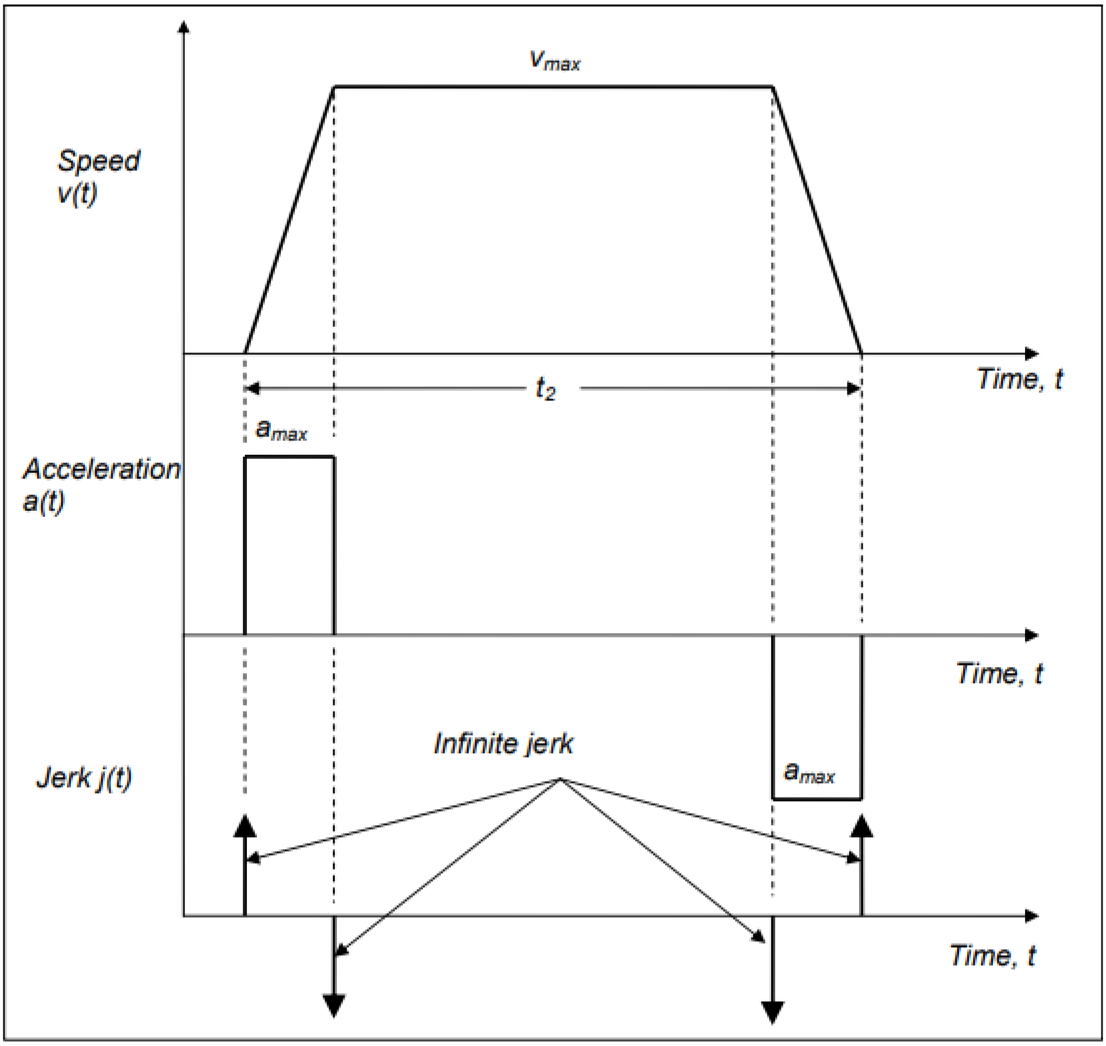

Figure 2: Case II in which the acceleration is limited in value, but the value of jerk is inifinte.

However, it can be noticed that infinite values of jerk are experienced under case II (see the jerk values in Figure 2). When moving human this abrupt change form zero acceleration to maximum acceleration causes a noticeable level of discomfort. It is thus desirable to have a gradual change in the value of acceleration by limiting the top value of the jerk to j_{max}. This can be done by 'filleting' the speed-time profile at the 'corner' points.. This is sometimes referred to as the S-curve facility, and is an important feature of many of the modern variable speed drive systems*.

Reference: Speed Time Profiling, Chapter 2, Electrical Dries Course, Lutfi Al-sharif

VARIABLE FREQUENCY DRIVES

How to Select a Variable Frequency Drive: Sizing a variable frequency drive (VFD) based on horsepower only is tempting. In fact there are other factors we should consider to ensure that we specify the correct AC drive for our application:

1. **Full Load Amperage:** The first step in this process is making sure the drive can handle the motors current demands. Check the motor nameplate for the Full Load Current requirement, then find a drive that's rated for at least that much current. If you are feeding the drive with single-phase power, be sure to use the drive ratings for single-phase. Variable frequency drives are significantly derated for single-phase operation. *NOTE: All AC motors used with VFDs must be three-phase motors. VFDs always create three-phase output for the motor, even when the drive is powered with single-phase power.*

2. **Overload:** Be sure the drive can handle any overload conditions you may expect during startup or intermittent extra loading. You may need to upsize the drive until you find one that can handle it. Many applications experience temporary overload conditions due to starting requirements or impact loading. Most AC drives are designed to operate at 150% overload for 60 seconds. If the application requires an overload greater than 150% or longer than 60 seconds, the AC drive must be oversized.

3. **Application Type:** There are two application types: variable torque (VT) and constant torque (CT) and separate ratings for each. Use VT ratings for fans and pumps or consult the CT ratings for conveyors and general machine control. It is important to know the application type because the drive specifications are organized accordingly. If you aren't sure which one to use it's recommended to go with CT.

4. **Temperature:** AC drives generate a significant amount of heat and can cause the internal temperature of an enclosure to exceed the temperature rating of the drive. Enclosure ventilation and/or cooling may be required. Make measurements/calculations for the maximum expected ambient temperature. *NOTE: GS4 drives are 'flange mountable'. This through-the-wall mounting technique puts the drive's heatsink fins on the outside of the enclosure. This drastically reduces the thermal load inside the enclosure.*

5. **Carrier Frequency:** Generally, you want to look for the lowest carrier frequency your motor can handle. Most of the time the default carrier frequency will work fine, but if you need to reduce the audible noise, the heat dissipation or the power consumption, then make sure you are able to modify the carrier frequency for the drive.

PROCEDURE

1. HOW TO READ VFD MANUAL.

In this part you will introduced to the VFD, which is one of the common used devices in mechatronics systems and in many applications in industry like: elevator systems, conveyor belts, pumping applications and many others.

In the lab, we will consider the **OMRON VS mini J7** that is a compact general-purpose inverter.

Figure 3: OMRON VS min J7 VFD

- Check the nameplate of the device.

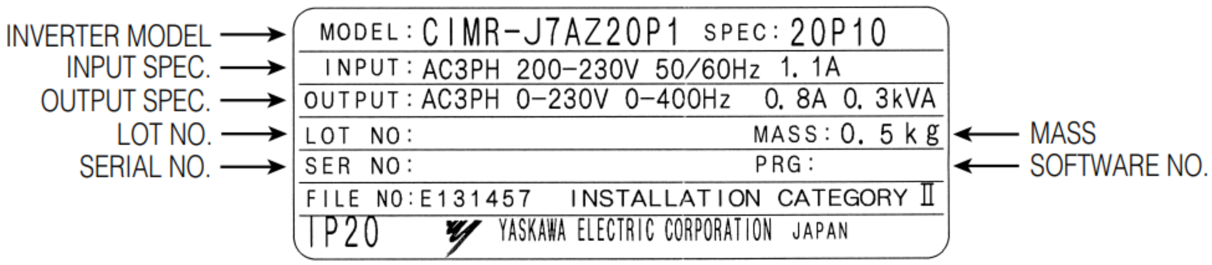

Figure 3: Nameplate of the OMRON VS mini VFD.

- Open the manual and familiarize yourself with the sections and topics considered.
- Make a simple run of the device.
- Change the reference frequency.
- Apply acceleration and deceleration time on the device and notice their effects.
- What is V/F pattern and study the patterns given in the datasheet.

Figure 3: Conveyor belt system driven by 3-phase induction motor.

2. GENERATION OF SPEED TIME PROFILE

In this section, you will apply various speed time profiles on a conveyor system driven by a three-phase induction motor. You will connect the inverter to PLC in order to construct the speed time profile.

- Read the nameplate of the motor and make sure it is suitable to be driven by the VFD.
- Find the max speed of the motor.
- Make the desired calculations desired to generate triangular speed profile.
- Do the desired settings in the VFD.
- Try a trapezoidal speed profile.

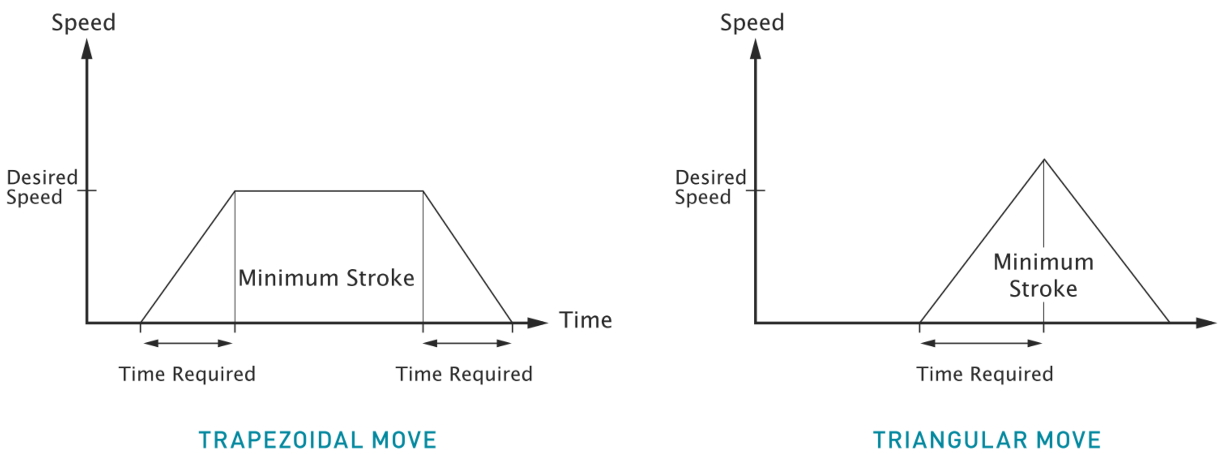

Figure 3: Triangular and trapezoidal speed time profiles.