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# DESIGN AND AUTOMATION OF A MACHINING SYSTEM

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**ABSTRACT**
Walking through the path of modern automation and automatic control system this project introduces the control of an AC motor depending on the environmental and process variable. This is a project of designing and constructing the prototype of a sensor based control system of an AC motor. It handles three basic sensors- temperature sensor, proximity sensors and a tachometer. It also consists of the study of various methods of AC motor control system and automation system. In this project controlling a stepper motor, (by computer interfacing) which operates a voltage regulator covers AC motor control. This method of control system can also be applied into the field like heat transfer, fluid mechanics so on where the variation of power is required. The project has successfully completed with some limitations and further development is proposed in section 6.2.

**Keywords:** Control system, Parallel port, Interfacing.

## 1. INTRODUCTION

Main objective of this project is to design and construct such an electronic control system, which will be capable to operate a machine, depending upon some environmental variable.
The required features of this project are-

- Machine should remain stopped if the temperature of a material is less than the desired value and/or if any critical material is finished.
- The machine should be capable to synchronize with production rate. Therefore the speed control of an AC Induction Motor is needed to achieve desired speed.

### 1.1 Control System

Automatic control plays an ever-increasing role in our way of life, from the simple controls required in an automatic bread toaster to the sophisticated control systems necessary for space explorations. Control system frequently employs components of different types, e.g., Mechanical, Electrical, Hydraulic, Pneumatic and combinations of these.

#### 1.1.1 Control System Classification

- Open loop control system: output has no effect on control action.
- Closed loop control system: maintains a prescribed relationship between output and some reference input by comparing them andusing the difference as a means of control.
- Servomechanism: a feed back control system in which the reference input or the desired output is either constant or slowly varying with time and in which its primary task is to maintain the actual output at the desired value in the presence of disturbances.
- Process control system: an automatic regulating system in which the output is a variable, such as temperature.

### 1.2 Block Diagram Of The Control System Applied To This Project

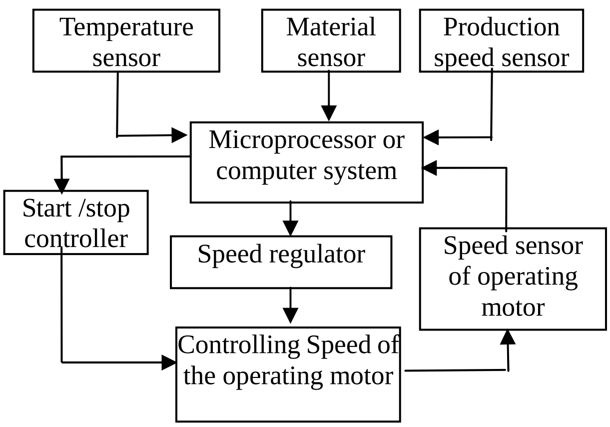



Fig 1. Block diagram of the control system applied.

From the figure 2 it can be determined that this control system is a combination of *"Closed-loop system"* and *"Automatic Regulating System"* . This is because the speed of the output motor is fed to the Microprocessor or Microcomputer. And then the microcomputer makes the decision to take necessary action to control the output motor according to the environmental and production variable using controller program.

## 2. DESIGN AND CONSTRUCTION

### 2.1 Power Supply

It is the most critical component of an electronic control system.

- It is typically non-redundant. Hence a failure of the power supply can cause the control system to fail.
- It usually contains high-voltage components. Hence, an isolation failure can create the potential for serious injury and fire.

### 2.1.1 Components

- Transformer (center tap 220v -12V)
- Diode (1N4007)
- Capacitor (4700µF)
- Power IC (7805, 7812, 7905, 7912)

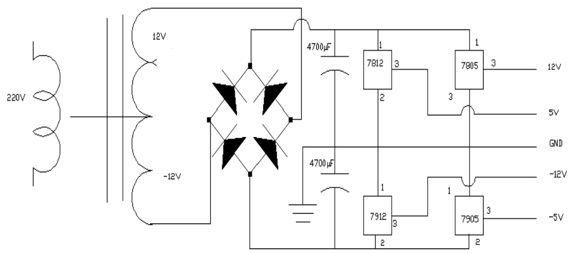



Fig 2(a). Power Supply

### 2.1.2 Working Principle

A step-down center tap transformer is used to convert 220v AC supply to 12 volt AC. 4 diodes are acting as a bridge rectifier to convert the power from AC to DC. Two 4700µF capacitors are connected to both (+ve) and (-ve) section of the power supply for DC filtration. Power IC 7805, 7812, 7905, and 7912 are used to regulate +5V, +12V, -5V, and -12V respectively.

In negative supply section capacitor's positive end should be connected to the GND and negative end should be connected to the negative output of the rectifier.

### 2.2 Temperature Measurement System

### 2.2.1 Components

- Thermocouple (K-type)
- JFET OP AMP (TL084)
- VAR (10K)
- Resistor (1M)

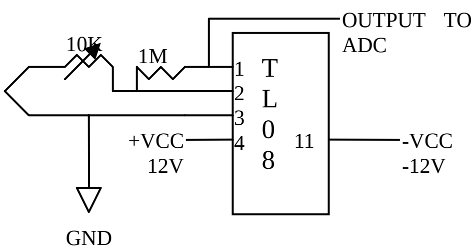



Fig 2(b). Temperature measurement circuit.

### 2.2.2 Working Principle

Due to Sea Beak effect the generated e.m.f. of the Thermocouple (generally in mV) varies according to the change in temperature. As the generated Voltages are within the mV range further amplification is required. JFET OP AMP TL084 is used to amplify the lower level signal to higher level signal. Gain of the OP AMP is varied by the 10K VAR.

- Highest output of the amplifier should not be more than 5V because this output will feed to the ADC later to convert the analog signal into digital signal.

Resolution of ADC= (Supply Voltage/$2^n$)

Where, n = number of bit of the ADC.

For this project,

$n = 8$

$V_{supply} = 5V$

Resolution = $5/2^8$

$=0.019V$

### 2.3 Material Detection System

### 2.3.1 Components

- 555 Timer IC.
- LDR.
- LED (Transparent)
- 0.01µF Capacitor.
- 10K VAR.

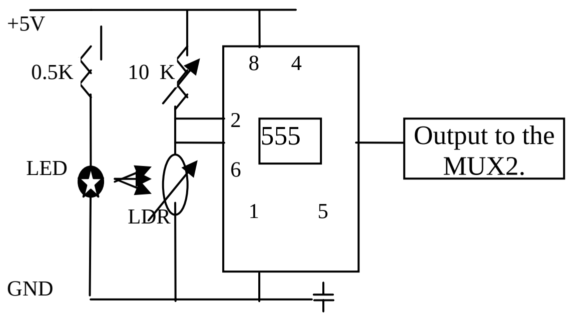



Fig 3. Material sensor.

### 2.3.2 Working Principle

An optical sensor is used to sense the presence of the hologram tape. When the tape is present the output of the sensor is low and when the tape is finished, the Timer IC is triggered and then output of the IC becomes high. Reset terminal of the IC is connected to the +VCC so that it is self-reset when the tape is placed again.

- +VCC of the timer should not be more than 5V because it acts as an input signal to the MUX as well as to the computer.

### 2.4 Motor Start/Stop System

### 2.4.1 Components

- MOSFET (IRFZ 64)
- Relay : Output -250 V, 10A, Input-12V
- 1K resistor
- Diode (1N4007)

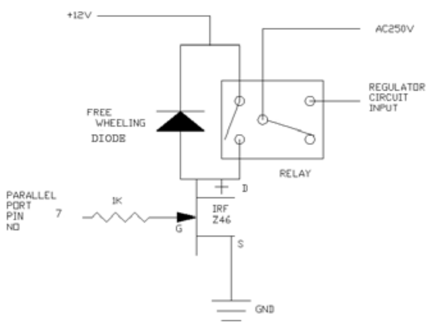



Fig 4. Motor start/stop circuit.

### 2.4.2 Working Principle

When the computer sends a signal to the Gate of the MOSFET, it will turn on and the relay supplies 250V AC to the regulator by changing its default switching position. When the computer stops sending signal to the Gate, the relay will get-back to its default switching position.

- A Free wheeling Diode should be connected across the position shown in fig.3-4. It will resist the back e.m.f. produced by the magnetic coil of the relay.
- To run a high power motor drive system the Relay must have higher rating in the output section.

## 2.5 Speed Regulator Circuit

### 2.5.1 Components

- Triac (BT 139)
- Diac (DB3)
- Capacitor (0.1µF, 250V)
- VAR (470K)

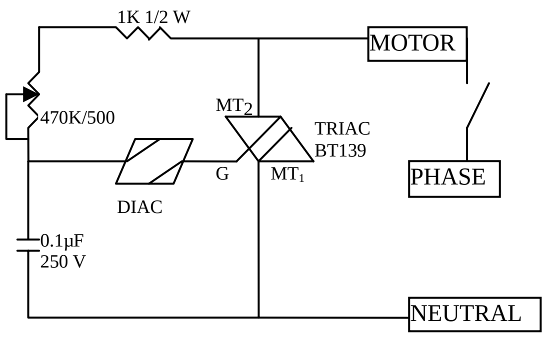



Fig 5. Speed regulation Circuit.

### 2.5.2 Working Principle

The Triac (BT139) cuts the AC supply at different angle depending on the VAR. Angle can be varied by changing the resistance of the VAR.

- It is a high voltage circuit, so more precautions are needed.

## 2.6 Steeper Motor Drive System

### 2.6.1 Components

- ULN2003
- Diode (1N4007).

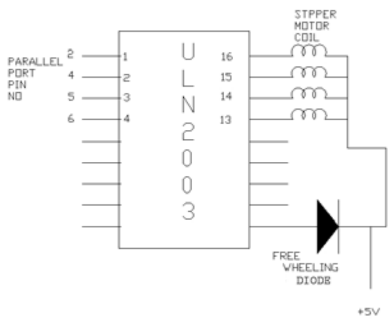



Fig 6. Stepper motor control.

### 2.6.2 Working Principle

Inputs of ULN 2003 generally come from the computer. ULN 2003 is used to send pulses to the coils of the stepper motor.

- A Free wheeling Diode should be connected across the position shown in fig 6. It will resist the back e.m.f. produced by the motor.
- ULN 2003 is used to drive steeper motors having current rating less than 500mA.

## 2.7 Tachometer

### 2.7.1 Components

- 555 Timers IC.
- LDR.
- LED (Transparent)
- 0.01µF Capacitor.
- 10K VAR.

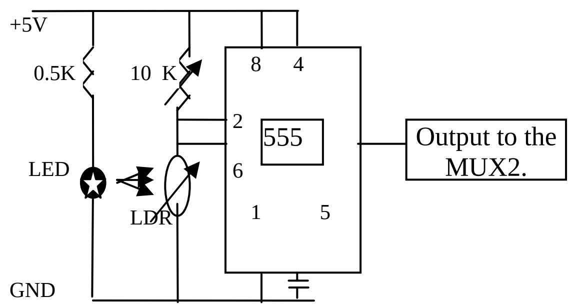



Fig 7. Tachometer.

### 2.7.2 Working Principle

An optical sensor is used to sense the speed of the operating motor. An obstruction is placed with the motor spindle to cut the light of the LED which falls on the LDR. When the obstruction is presented between LED and LDR then the output of the sensor is low and when the obstruction turn away, the Timer IC is triggered and the output of the IC becomes high. Reset terminal of the IC is connected to the +VCC so it that could be self reset when the tape is placed again. Measuring the number of pulses per min one can easily calculate the speed of the operating motor.

- +VCC of the timer should not be more than 5V because it acts as a direct input signal to the computer.

### 2.8 Computer Interfacing Circuit

#### 2.8.1 Components

- ADC (0804)
- MUX (LS74157)
- Capacitor (150 pF, 100pF)
- Resistor (10K)
- Zener Diode (4.76 V)

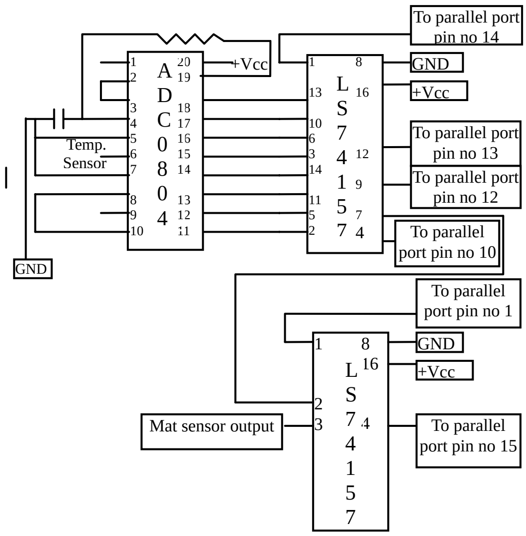



Fig 8. Interfacing Circuit.

#### 2.8.2 Working Principle

ADC 0804 is an 8 bit ADC which converts the output voltage of the temperature sensor into digital signals. These signals are fed to the MUX LS74157. It has 8 input channels and 4 output channels. Output can be changed by sending a clock pulse to the MUX pin no.1. Output of the pin7 goes to another MUX to read the signal of the Material detection sensor by using the same pin of the Parallel Port.

- A 5V Zener diode should be connected between the input of the ADC and the GND. This is because ADC 0804 has its maximum input limit to 5V.
- An input filter capacitor is placed between pin 6 of the ADC and GND for S/H purpose.

### 3. CODING ENVIRONMENT

The project incorporates a very simple interface with the computer. It uses the standard Parallel port that any IBM-compatible machine would have.

In this project programming environment is Visual Basic 6.0. As there is no built-in control for port access in Visual Basic 6.0, a DLL file named IO.DLL is used for coding. Windows API Viewer is also used to utilize some Window's built-in function. VB 6.0 is chosen for coding environment because of its aesthetic outlook and user friendly interface.

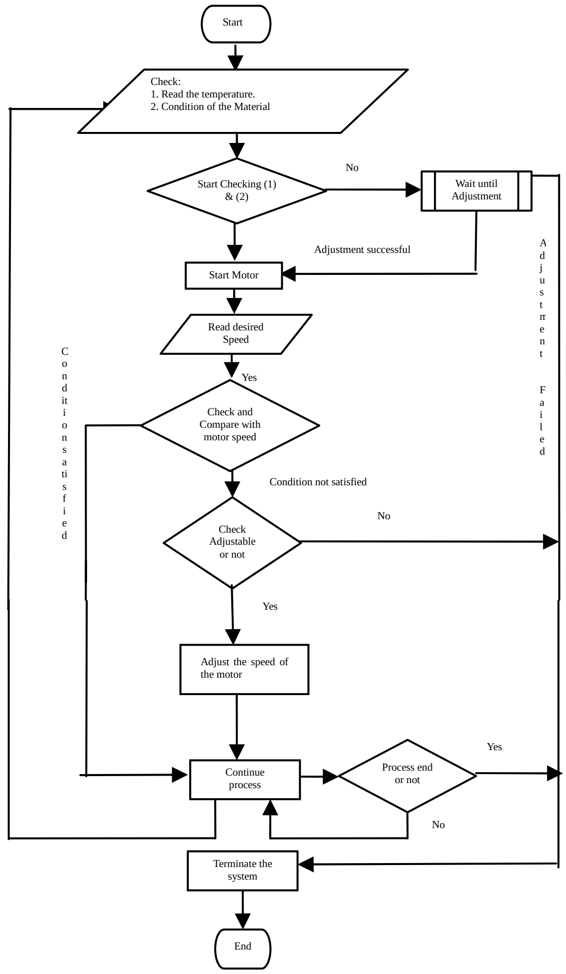



Fig 9. Flowchart of the program used.

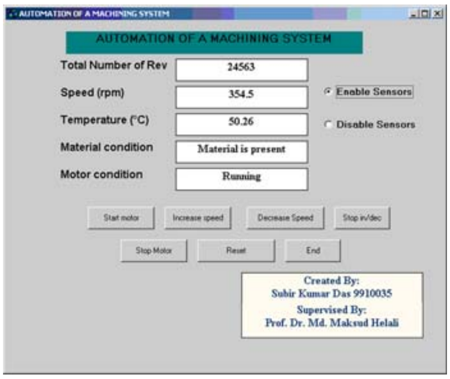
### 3.1 Parallel Port Pin Configuration

Table 1: Parallel Port pins Used.

| Pin number | Function |
|---|---|
| Pin 1,14 | Send signals for MUX2,MUX1 |
| Pin 2,4,5,6 | Send pulses to ULN2003 to drive steeper motor |
| Pin 7 | Send pulses to Relay to start or stop AC motor |
| Pin 10,12,13 | To take input from MUX1 |
| Pin 15 | To take input from MUX1 |
| Pin 11 | To take input from Tachometer |
| Pin 18-25 | Ground |

## 4. SOFTWARE DEMONSTRATION

This software reads and writes various inputs and outputs through the parallel port as mentioned in the table 1




This software measures following things:

- Total number of revolution of the AC motor
- Speed of the AC Motor
- Temperature of an operation material.
- Material condition (present or finished )
- Motor condition ( Running or Stopped)

It can perform several operations on the AC motor:

- It can start or stop motor independently
- It can increase or decrease the speed of the motor.
- It can run the motor with current speed terminating increment or decrement of the speed at any time.
- It can reset the total system at any time.
- It can operate the motor both enabling and disabling the sensors.

## 5. RESULTS AND DISCUSSION

This project work has successfully done with some limitations.

Following results are obtained:

- Machine remains stopped when the temperature of the material (Special type of glue) is less than the desired value (150°C) and/or if the critical material (Hologram Tape) is finished.
- The speed of an AC Induction Motor is controlled to achieve desired speed with a speed range (properly controlled: 250-600 rpm, only increased or decreased: 600-3000 rpm ) .

This Projects has following limitations:

1. Speed sensor cannot detect speeds more than 600 rpm due to slow speed of computer.
2. Because of 8bit ADC, it can not handle less than 0.019V change in signal level.
3. Accuracy is not as high as commercial automated system.

We can overcome the limitations following the ways mentioned below:

1. Running the computer program at Real Time Mode instead of Graphical User Interface (GUI) mode.
2. By using ADC with higher bits.
3. Using commercially available components instead of construction (for basic components).

## 6. CONCLUSIONS

The system is developed primarily for educational and instructional purposes. It is a working prototype demonstrating the main principles of operation of an automatic control system. It can find wide application especially in educational institutions for demonstration and training.

### 6.1 Advantages

1. Enhanced consistency in product quality
2. Greater manufacturing flexibility
3. Continuous monitoring to reduce manual inspection.
4. Ability to synchronize with production rate.

All advantages leads to higher productivity and greater edge of CNC machining over conventional machining system.

### 6.2 Proposal for Future Developments

Here AC motor control is accomplished by controlling the stepper motor which derives the VAR as well as the regulator.

If any feed back servomechanism is applied to determine the current value of the resistance of the VAR. The relation between the power can easily be derived i.e. speed output and position of the regulator in the form of a mathematical equation by a simple experimental procedure. With the help of this procedure desired speed can be achieved the desired speed by setting the regulator at certain position.

If the system is failed to achieve the speed then a P-controller is needed for the corrective action.

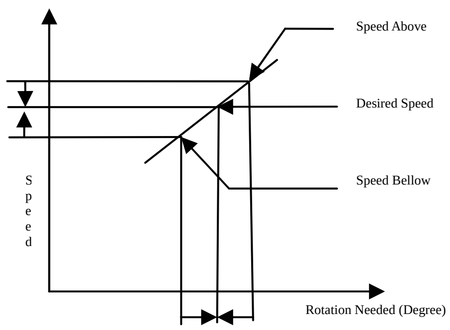



Fig 10. Proposed corrective Action

Two conditions may arise here

1. <u>Actual speed above the desired speed:</u> Then by the speed-position equation one can calculate the probable rotation needed i.e. number of pulses require in the sequence for which speed will be decreased.
2. <u>Actual speed below the desired speed:</u> By the above mentioned procedure one can achieve required speed only by changing pulse sequence.

The controller used for AC motor control can be used for other fields like heat transfer, Fluid mechanics where variable power is required such as required amount of heat can be supplied or the speed of the fluid flow can be varied.

## 8. REFERENCES


1. Howard L. Harrison & John G Bollinger *Automatic Control*, Second Edition Intertext Books.
2. M. Morris Mano *Digital Design*, Prentice-Hall of India Pvt. Limited, New Delhi, India, Third Edition 1999.
3. Serope Lalpakjian & Steven R. Schmid *Manufacturing Engineering and Technology,* Addison Wesley Longman (Singapore) Pte. Ltd. Indian Branch, First Indian Reprint 2000.
4. Charles A Schuler & William L. McNamee *Industrial Electronics and Robotics*, McGraw-Hill Book Company,Singapore, McGraw-Hill International Edition
5. Manish Jain, *Microprocessor Data Handbook,* BPB Publication, New Delhi, India, Revised Edition 2000.
6. Joseph Edward Shigley, *Mechanical Engineering Design* , McGraw-Hill Book Company, Singapore, International Edition 1986.
7. John Uffenbeck, *Microcomputer and Microprocessors*, Prentice-Hall of India Pvt. Limited, New Delhi, India, Third Edition 2002.
8. M. Anwarul Azim, *Elements of Machine Tools*, Bangladesh University of Engineering & Technology.
9. Adel S. Sandra & Kenneth C. Smith, *Microelectronic Circuits*, Oxford University Press, Forth Edition (Reprinted 2002).
10. ITP Strategic, *Oriental Motor Introduction Material*, Oriental Electronics, 2000.
11. W. Bolton *Mchatronics*. Second Edition Pearson Education.