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Design and Implementation of Liquid Level Detector using Ultrasonic Sensor

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Abstract:- This research paper is about the design and implementation of a liquid level detector using ultrasonic sensor that utilizes high speed microcontroller (PIC16F887) as well as other instrumentation required. It utilizes water as its process and shall be measured from a calibrated reservoir using ultrasonic sensor for measuring the level of the process in the calibrated reservoir and displaying it using 16x4 Liquid crystal display.

This device is applicable in processing industries where liquid measurement is of importance.eg breweries, oil and gas industries.

Keywords:- *Calibration, Display, Level, Microcontroller, Sensor.*

I. INTRODUCTION

Measurement is that the estimation of the magnitude of some attribute of an object, like its length or weight, relative to a unit of measuring.

Measurement typically involves employing instrument , like a ruler or scale, that is graduated to check the object to some standard, like a meter or a kilo Measurements are crucial in purposes such as in science and in engineering. Measurements always have errors and therefore uncertainties. In fact, the reduction not essentially the Elimination of uncertainty is central to the idea of measuring. Measurement Errors are often assumed to be normally distributed about the true value of the measured Quantity .Since accurate measurement is essential in many fields, and since all Measurements are essentially approximations, an excellent deal of effort should be taken to form measurements as correct as possible.

A. Level Measurement and Control

Level measurement entails the determination of quantity of materials in a container in terms of unit of height. It gives information about the amount of material available or the quantity of finished products at hand especially when the need arises in the industries such as petroleum and allied industries to determine the quantity of liquids.

In many applications, it is practically impossible to view the interior of the vessel or container. This occurs in cases where the container is buried underground or submerged in water or it may be at high elevation. This however results to the application of a number of techniques which are applied to accurately measure and control the level of liquids either

B. Importance of Level Measurement

Level measurement is important in the industry as it gives information about the quality of inputs and the finished product available. It enables manufacturers to know the amount of quantity of various inputs, chemical, liquid, solid etc available for production and therefore to determine how long they will operate before the next supply is due. In the petroleum and petrochemical industries, level measurement is important in sales of crude and finished products.

Also, level measurement is essential in Water Company since it allows for automatic control and packaging quantity of water. When liquid is to be sold, its volume is measured in quantity and a price tag is attached accordingly.

C. Task Facing Level Measurement Engineer and Technology

Level measurement seems to present a simple problem, but a closes look reveals of variety of problems that must be solved. The materials may be very corrosive, it may be at very high or low temperature, it may be tend to solidify is in molten sulphur or coal far, it may vaporise or create other difficulties.

In many cases, we are required to determine the level of the materials continuously and in other cases, we may determine the level of materials at some fixed points for information and control purposes. Either case possess its constraints and problems.

In either case, level measurement devices are available which give contours or single point measurement. Single point level measurement devices are frequently used as control devices to prevent overflow or cut of materials by sounding alarm or operating other control mechanisms.

D. Scope of the Project

The project scope of execution are as follows:

- Calibrate the signal from the level sensor into data in the microcontroller.
- Feed the calibrated data from the microcontroller to the liquid crystal display.
- Determine the best level point to activate and de-activate the FCE.
- Calibrate the process reservoir for manual level reading.

E. Block Presentation of Liquid Level Detector

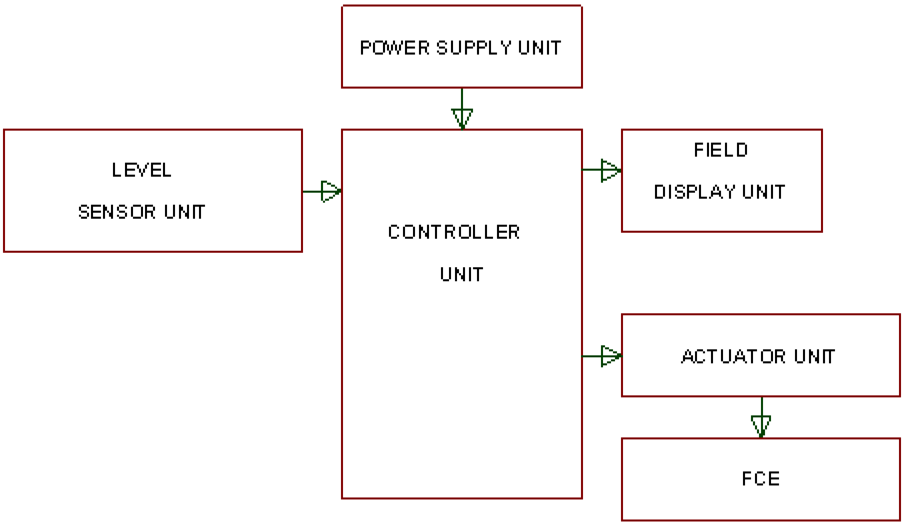

Fig 1:- Block Diagram of a Liquid Level Detector

- *The Power Supply Unit*

This unit supplies the required 5V/12V DC of the components in the system. It connects to the 220.230V AV Mains. It was implemented with a 220/12v Step down transformer, Bridge rectifying diode, capacitor with voltage regulators.

- *The Level Sensor Unit*

This unit measures the level of the process in the calibrated reservoir and produces a electric signal that is proportional to the measured level. This produced signal is feed to the controller unit for analysis and calibration then to the display unit.

- *The Field Display Unit*

This unit connected directly to the controller unit, gives a digital display of the level of the process in the calibrated reservoir. The values displayed on this unit ought to match that of the calibrated scaled fitted to the process reservoir.

- *The Actuator Unit*

This unit enables the controller unit to effectively control/drive the FCE i.e. the water pump. It can be implanted with a 12V DC 30A Relay, transistor with a resistor. The controller drives this unit, which in-turn drives the FCE.

- *The Final Control Element*

The FCE was implemented with a ½ horse power 220V AC water pump. The pump lifts the process from the storage tank into the process calibrated reservoir.

- *The Controller Unit*

This unit performs the logic of the entire system. It receives signal from the level sensor unit, calibrates the signal then sends the data to the field display unit and also activates or deactivates the FCE when the process is low on full in the calibrated reservoir. It was implemented with the high speed processor microcontroller i.e. PIC16F887.

II. METHODOLOGY

The liquid level was constructed using electronic components like Pic microcontroller, ultrasonic sensor, relay, LCD etc.

The approach employed in this research work experiment and case study of other existing work done.

A. Design Specification

This System has the following Design Specifications:

- Input Voltage: 220/230V AC @ 50Hz.
- Level Sensor Type: Pressure Transmitter Sensor
- Level Measurement Range: 0CM to 100CM
- Display: Supports Visual Presentation of the Level 16x4 liquid crystal display (LCD).
- Pump Type: ½ HP (500watts), Centrifugal Water Pump.
- Process Type: WATER.
- Controller Type: PIC16F877A Microcontroller from Microchip Corporation.

B. The System design

➢ *The Level Sensor Unit*

This unit measures the liquid level in the Reservoir.

Requirements of the Level Sensor

- It should be able to measure the process level within the specified range i.e. 0 to 100cm
- It should be easily to use and requires less biasing components
- The power requirements should be reasonable
- it should be cost effective and readily available

Selection of the Level Sensor

The US-100 Ultrasonic sensor was used to implement the level sensor. Below are the choice for the selection of the level sensor:

- Measuring range: 0 to v 400cm, which is greater than the required specification (100CM).
- Easy interface to the Controller and Easy principle of operation.
- It require 5V DC to operate
- Cost.
- Availability.

The US-100 Ultrasonic sensor operates on the principle of transmitting sound wave and receiving the reflected wave when it meets an obstacle or there is a change in density. The sensor has a Transmitter and Receiver section. The transmitter sends the 40 kHz sound wave, when the wave encounters a change in density or an obstacle, it reflects back to the receiver section. The time taken for the wave to transmit and reflect is calculated to get the distance.

Below is a mathematical illustration for the ultrasonic level sensor.

This Unit is Directly Connected to the Controller Unit i.e. PIC16F877A Microcontroller through PIN 29 and PIN 30, i.e. the Trigger and Echo PIN Respectively.

The reservoir is cylindrical in shape with the following dimensions:

Diameter: 20CM; Height: 100CM
The Velocity of sound in AIR is approximately: 360m/s
Assuming the Process level in the Reservoir is 50CM
From Velocity = Distance/Time where Distance = 50CM i.e. 0.5m; Velocity = 360m/s
Time = distance/velocity = 0.5/360 = 0.001389 seconds i.e. 1.4ms

But the Time = Time of Transmission + Time of Reflection of the sound wave
Time=1.4/2 = 0.7ms.

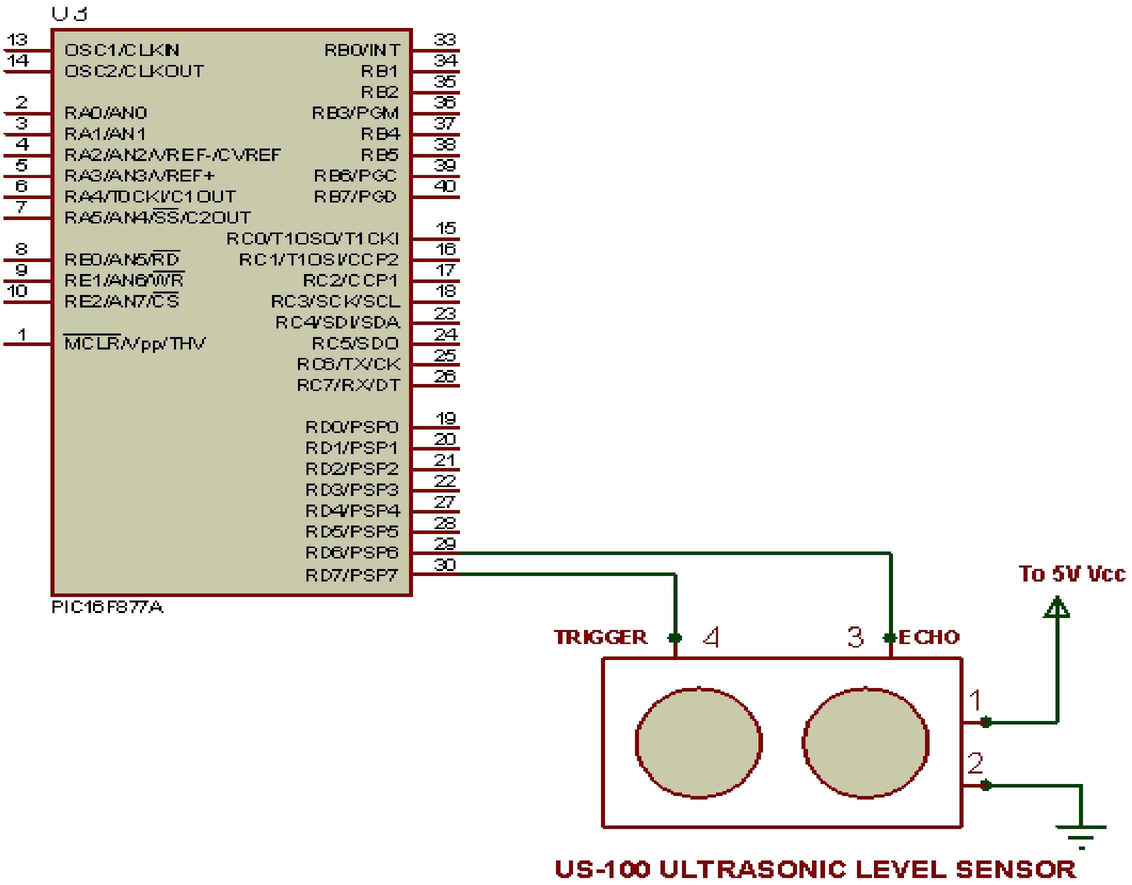

Fig 2:- Level Sensor Interface with the Controller Unit

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➢ *The Final Control Unit*

The Final control element (FCE) was implemented with a 220V AC 1/2hp Water pump. The FCE Control unit is a switching circuit that assist the Controller unit to switch the Pump ON and OFF. Below are the requirements of the unit:

Requirement of the Switching Circuit

- It should not be a complex switch circuit.
- It should be able to Power the Pump.
- It should be easily controlled by the controller unit i.e. easy connection interface.
- The components involved should be available and cost effective.

Selection of the Switching Circuit

The transistor switching circuit was selected. It was implemented with the Following Components:

- 12V 30A Relay
- BC547 NPN Transistor
- Biasing Resistor

The transistor switching circuit was selected because it meant the above requirements. This Unit is directly controlled by the Microcontroller through PIN 15. Below is the Circuit diagram of the entire Unit.

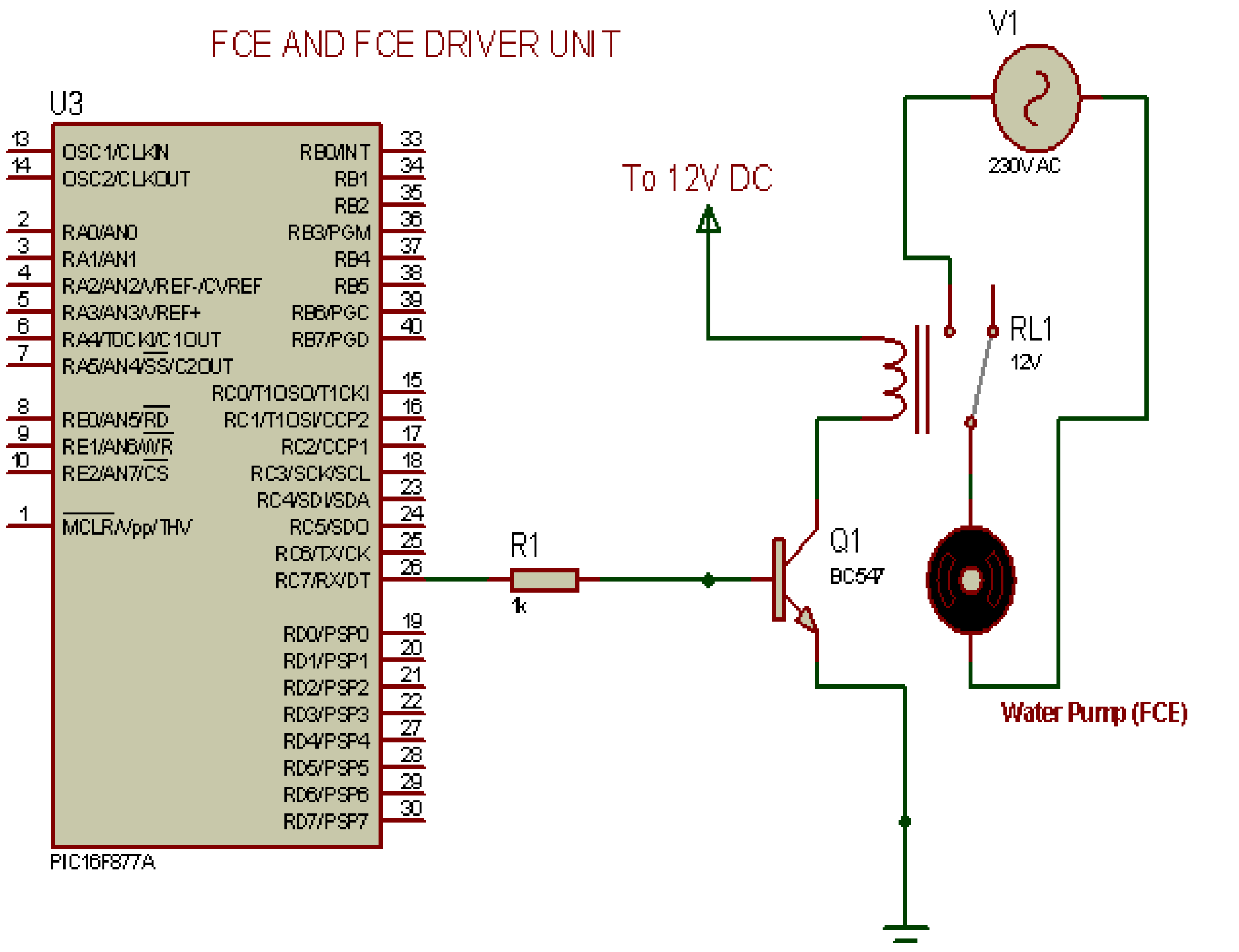

Fig 3:- Final Control Unit

Selection of the Switching Transistor

The choice of the switching transistor is based on:

- The supply voltage
- The maximum collector current

To determine the collector current, Collector current = relay coil current.

$$\text{Relay coil current} = \frac{\text{Relay coil voltage}}{\text{Relay coil resistance}}$$

$$= \frac{12v}{275\ \Omega} = 0.04A$$

$$= 40mA$$

The general purpose transistor BC547 was used.

The BC 547 has the following specifications:
Gain (ß) = 120
V_{BE} = 0.7V
I_C(max) = 60mA

Selection of the Relay

The choice of the relay is based on:

- Supply voltage
- Relay contact current
- The Watts requirement of the Pumps

Pump used has the following specification:

Input voltage: 220v AC.
Watts: 500 watts (1/2 Hp).
Using a Relay of 12V 30A DC (JQX12)
Supply voltage in the circuit = 12V.
Power Of the relay: P=IV = 30A x 220V = 6600watts = 6.6KW

Therefore the Relay power is greater than the Pump Power requirements i.e. 6.6KW > 500Watts

III. FLOW CHART

The flow chart gives a graphical representation of the sequence of program execution.

The flow chart for the system is given in figure 4 below.

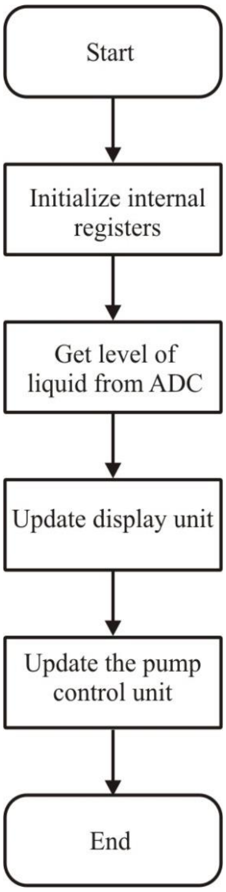

Fig 4:- Flow Chart

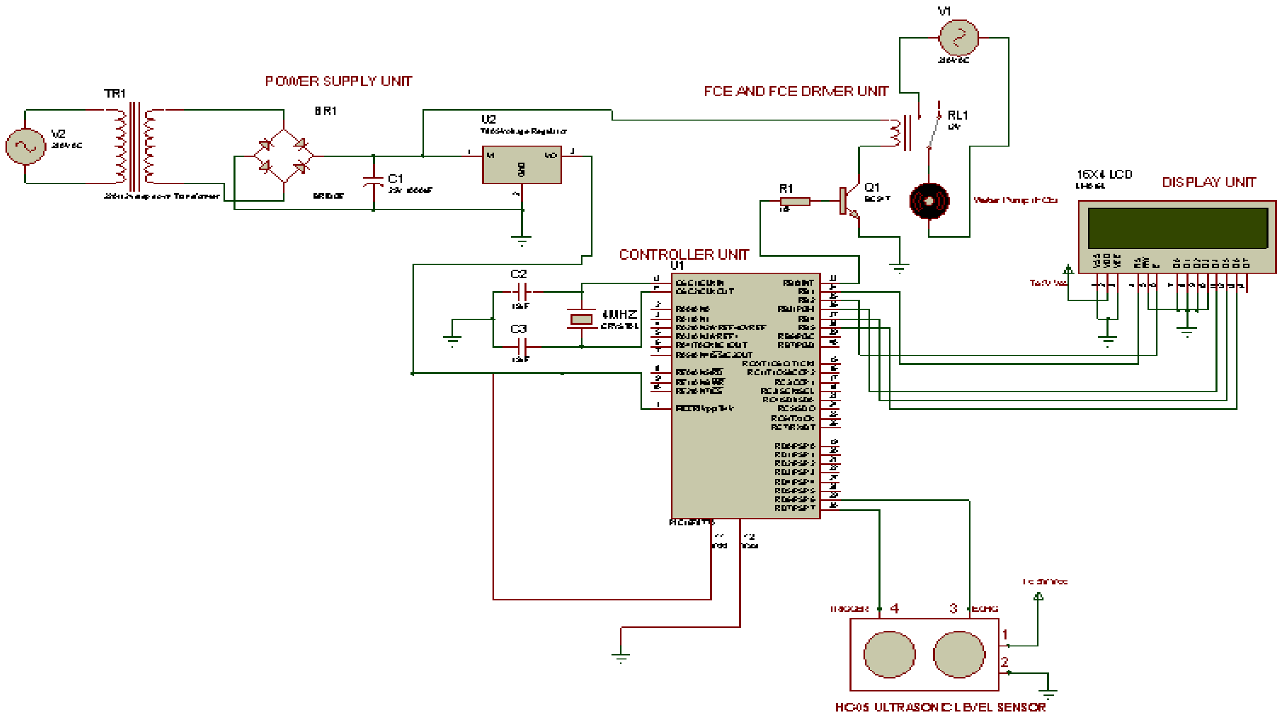

Fig.5. Working Circuit Diagram

➢ *Principle of Operation*

When the switch is turn ON, the power supply unit supplies 5V DC to the circuit, the pic16f877a (microcontroller) initializes its internal registers, configures Pin 29 to 30 as digital input pins that connects directly to the US-100 Level sensor, when done, initializes the LCD display and sends a value of “000” to the displays. The controller outputs High (5v) at PIN33 to activate the FCE, then it also Performs ADC conversion to get the output of the pressure transmitter, the microcontroller computes the level from ADC output, and then update the LCD display. the microcontroller then compare the distance with the height of the reservoir , if it is equal, the controller deactivate the FCE, then output high at PIN19, to activate the ALARM Unit.

IV. RESULT

This research detected liquid level using ultrasonic sensor with high speed microcontroller (PIC16F887) as well as other instrumentation required. The implemented work utilized water as its process and measured from a calibrated reservoir using ultrasonic sensor for measuring the level of the process in the calibrated reservoir.

All relevant industrial standard test and procedure was carried out to ensure the level process measuring meets the required design. The various tests include:

- Calibration
- Functionality Test
- Loop Test
- Continuity Test
- Leakage Test
- Mechanical completion inspection

V. CONCLUSION

A research approach was adopted in the implementation of this system, from whence a workable circuit was designed. The design was done using embedded system technology. This is to reduce component count, keep the system simple and cost effective. . The system is capable of enhancing level measurement and control. The completed work had been tested and worked satisfactory.

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