Design and Construction of Distance Meter Based on PIC Microcontroller

Yi Yi Swe*, Maung Maung Soe**

Abstract

The distance meter is designed and constructed using HC–SR04 ultrasonic sensor module, PIC 16F887 microcontroller, 16 x 2 line liquid crystal display (LCD) module and other electronic components. The ultrasonic sensor module consists of ultrasonic transmitter and receiver circuits. The ultrasonic signal is sent to the target by the control of the microcontroller and the echo signal is received by the ultrasonic receiver. The time taken by the ultrasonic signal to travel from the sensor to the target and then back from the target to the sensor is measured by the microcontroller circuit. The distance between the sensor and the target is then calculated by the microcontroller. The measured distance in "cm" and in "inches" is then displayed on the LCD module. The constructed meter can be measured the distance up to 3 meters (about 10 fts).

Key words: HC–SR 04 ultrasonic sensor, microcontroller, liquid crystal display (LCD)

Introduction

Nowadays, length measurement is used in every sphere of life to enable fair trading conditions and to develop new and improved products and processes that enhance our standard of living. This ranges from the production of microscopic electronic devices with circuit dimensions made the accuracies of some ten thousand millionths of a metre, and millimetre accuracy in distance measurement in construction over many kilometres. But this also extends to everyday life where we rely on accurate length measurement to ensure, for example, that our clothes fit or our self–assembly furniture goes together. There are several ways to measure distance without contact. One way is to use the laser and the other is to use ultrasonic waves.

A laser distance meter sends out a finely focused pulse of light to the target and detects the reflection. The meter measures the time between those two events, and converts this to a distance. The formula is simple: Distance = ½ (Speed x Time). However the speed of light is 300,000 km per second, so to resolve differences of 1 cm, the meter must measure time intervals of the order of billionths of a second. A laser distance meter can measure distances of up to 30m with an accuracy of ±3 mm.

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An ultrasonic distance meter works on a similar principle, but instead of light, it uses sound with a pitch too high for the human ear to hear. The speed of sound is only about ⅓ of a km per second, so the time measurement is easier. In this method 40 kHz ultrasonic signal is used for distance measurement. Ultrasonic transducers measure the amount of time taken for a pulse of sound to travel to a particular surface and return as the reflected echo.

The main component of the distance meter is the HC SR04 ultrasonic sensor module. This type of sensor module consists of ultrasonic transmitter and receiver pairs. The ultrasonic transmitter produces the ultrasonic signals with the frequency of about 40 kHz and an echo signal from the target is received by the receiver. The time between transmitting the signal and receiving the signal is measured by the help of the microcontroller. The velocity of the ultrasonic signal (or wave) is the same as that of the sound velocity. The distance can be calculated from the measured time and known velocity. The calculated distance is sent to the 16 x 2 lines LCD module. The LCD displays the measured distance in both “cm” and “inches”. The block diagram of the ultrasonic distance meter is shown in Fig. 1.

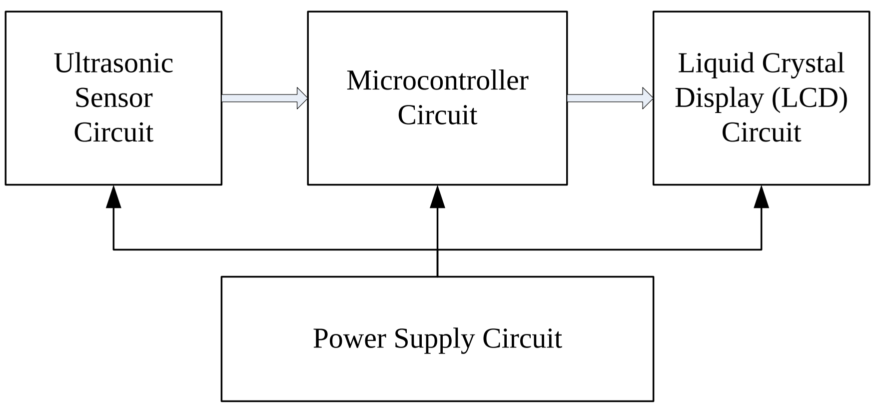

Fig.1 The functional block diagram of the constructed distance meter.

Electronic Devices Used in this Research Work

The constructed distance meter mainly consists of the PIC 16F887 microcontroller, ultrasonic sensor module (HC–SR04), 16 x 2 lines LCD module, 7805 voltage regulator and other electronic components. The general features and necessary theory background of the components used in the present research work will be presented in this section.

The PIC 16F887 Microcontroller

Microcontrollers contain all the components required for a processor system in one chip: a CPU, memory and I/O. A complete system can therefore be built using one MCU chip and a few I/O devise such as a keypad, display and other interfacing circuits. Now, it will be seen how this is done in our typical microcontroller.

The PIC16F887 is a 40–pin device and is one of the popular microcontrollers used in complex applications. The device offers 8192 x 14 flash program memory, 368 bytes of RAM, 256 bytes of non–volatile EEPROM memory, 36 I/O pins, 14 analogue capture and comparator circuits, USTART, and external interrupt facilities. The pin configuration of the PIC16F887 is shown in Fig.2.

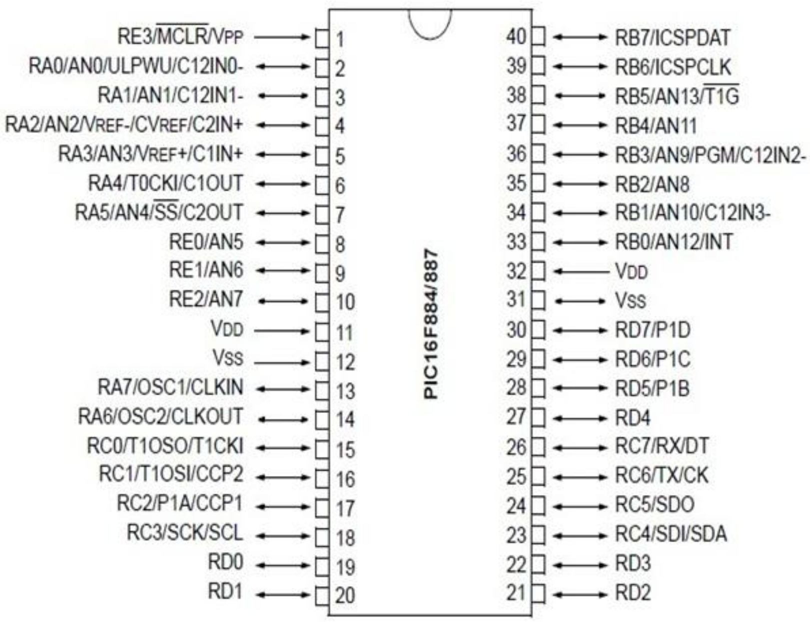

Fig.2 The pin configuration of the PIC16F887 microcontroller

The HC–SR04 Ultrasonic Sensor Module

A short ultrasonic pulse is transmitted at the time 0, reflected by an object. The senor receives this signal and converts it to an electric signal. The next pulse can be transmitted when the echo is faded away. This time period is called cycle period. The recommend cycle period should be no less than 50 ms. If a 10 μs width trigger pulse is sent to the signal pin, the Ultrasonic module will output eight 40 kHz ultrasonic signal and detect the echo back. The measured distance is proportional to the echo pulse width and can be calculated by the formula above. If no obstacle is detected, the output pin will give a 38 ms high level signal. The HC SR04 ultrasonic sensor module is shown in Fig. 3. The performance of the sensor depends on the angle between the sensor and the target.

Fig.3 The HC SR04 ultrasonic sensor module

The 16 x 2 Lines LCD Module

A liquid crystal display (LCD) is an electronic device that can be used to show numbers, texts and measurement data. There are two main types of LCD display, numeric displays and alphanumeric text displays.

The display is made up of a number of shaped 'crystals'. In numeric displays these crystals are shaped into 'bars', and in alphanumeric displays are shaped into 'dots'. Each crystal has an individual electrical connection so that each crystal can be controlled independently. When no current is passed through the crystal, it reflects the same amount of light as the background material, and so the crystals cannot be seen. When the crystal has an electric current passed through it, it changes shape and so absorbs more light. This makes the crystal appear darker to the human eye and so the shape of the dot or bar can be seen against the background.

The LCD display used in the circuit is GDM 1602A module. It can display 16×2 characters and it is possible to produce a readout using 8 × 80 pixels of the display. The LCD can displays a standard ASCII set of characters plus Japanese, Greek and mathematical symbols.

The 7805 Voltage Regulator

This series of fixed–voltage integrated–circuit voltage regulators is designed for a wide range of applications. These applications include on–card regulation for elimination of noise and distribution problems associated with single–point regulation. Each of these regulators can deliver up to 1 A of output current. The internal current–limiting and thermal–shutdown features of these regulators essentially make them immune to overload. In addition to its use as fixed–voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents, and also can be used as the power–pass element in precision regulators.

Design and Construction of the Distance Meter

The complete circuit diagram of the constructed distance meter is shown in Fig. 4. The HC SR04 ultrasonic sensor module mainly consists of ultrasonic transmitter, ultrasonic receiver and control circuitry. The operation of the module is controlled by the four terminals. Two terminals (VCC and GND) are used to made electronic circuits inside it work. Other two terminals (Trigger and Echo) are used to send and receive ultrasonic signals under the control of the microcontroller. The trigger pin of the ultrasonic sensor module is connected with the RB0 pin of the microcontroller. The echo pin of the sensor is connected with the RB1 pin of the microcontroller.

The PIC 16F887 microcontroller is the main part of the circuit. It is operated with 4 MHz clock signals produced using crystal oscillator. The port B pin (RB0) of the microcontroller is configured as an output pin. The port B pin (RB1) is programmed as an input pin. The port C pins are set as output pins. The Port C pin RC2 is connected with the RS pin of the LCD module. The Port C pin RC3 is connected with the E pin of the LCD module. The Port C pins (RC4–RC7) are connected with the data pins (D4–D7) of the LCD module. The RB0 pin is connected with the trigger input pin of the sensor. The RB1 pin is connected with the echo output pin of the sensor. The microcontroller sends 10 µs trigger pulse to the sensor to produce a burst of ultrasonic signals. The logic “HIGH” echo signal is received by the RB1 pin of the microcontroller. The logic “HIGH” level time depends on the distance of the target from the sensor. Near objects produce shorter “HIGH” level time and far objects produces longer “HIGH” level time. The “HIGH” level time taken to enter the RB1 pin from the echo pin of the sensor is recorded by the microcontroller. The time is incremented with the 10 µs time intervals. The time is then converted into the distance using the formula:

$$\text{Distance} = (\text{high level time x sound velocity (340 m/s)}) / 2$$

The measured distances are both converted into “cm” and “inches” with the program control. The converted distance is sent to the LCD module through the Port C pins.

The main task of the LCD display circuit is to display the distance readings. The LCD module is configured to work in 4–bits mode to safe useful microcontroller pins. Higher 4–bits of the LCD data pins (D4–D7) are used to accept the data from the microcontroller circuit. Unused data pins (D0–D3) are grounded. At the start of the power “ON”, the upper line of the LCD module displays the message “DISTANCE METER”. After one second, the upper line of the LCD module is programmed to display the measured distance in “cm” as

"D = --- cm" and the lower line is programmed to display the measured distance in "inches" as "D = --- inches".

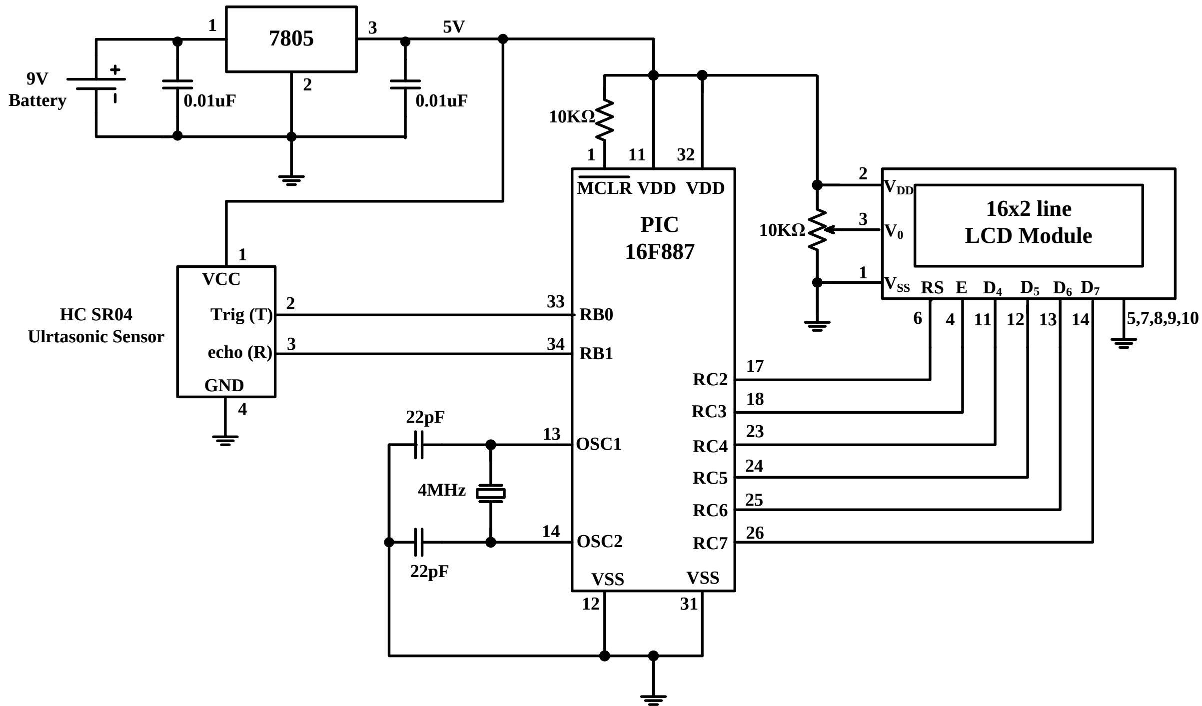

Fig.4 The complete circuit diagram of the distance meter.

The Flowchart of the Distance Meter

The flowchart of the ultrasonic distance meter is shown in Fig. 5. The program starts by setting the port direction of the microcontroller. Port B pin (RB0) is set as trigger input pin. Port B pin (RB1) is configured as echo input pin. Port C pins (RC0–RC7) are set as output pins.

Microcontroller sends the trigger signal of about 10 µs to the ultrasonic sensor module. Then, the echo signal is received from the sensor. The logic "HIGH" time of the echo signal is measured by the timer circuit of the microcontroller. The distance of the measured target is calculated by the microcontroller. Then the measured distance is displayed on the LCD module for a while. The process is repeated as long as the power of the meter is turned ON.

Results and Discussion

The distance meter has been constructed and tested in various distances up to 4 meters. The measured distances in "cm" and in "inches" are displayed on the 16 x 2 line

LCD module. The constructed meter uses non–contact method to measure distances. Ultrasonic sensor is the main component of the meter. The distance is measured by sending and receiving the ultrasonic signals. The velocity of the ultrasonic signal is the same as that of the audible sound wave. The constructed meter can measure the distance up to 3 meters (about 10 fts) with good accuracy. The measure values of distance of the meter are compared with the values of meter stick.

Although the manufacturer data sheet described the range of the sensor to be applicable up to 5 meters, we only get up to 3 meters for the reliable measurement. Moreover the target to be measured must be a good reflector for the ultrasonic signal to obtain the reliable distance measurement. Photographs of the different views of the constructed distance meter are shown in Fig. 6 (a) and Fig. 6(b), respectively.

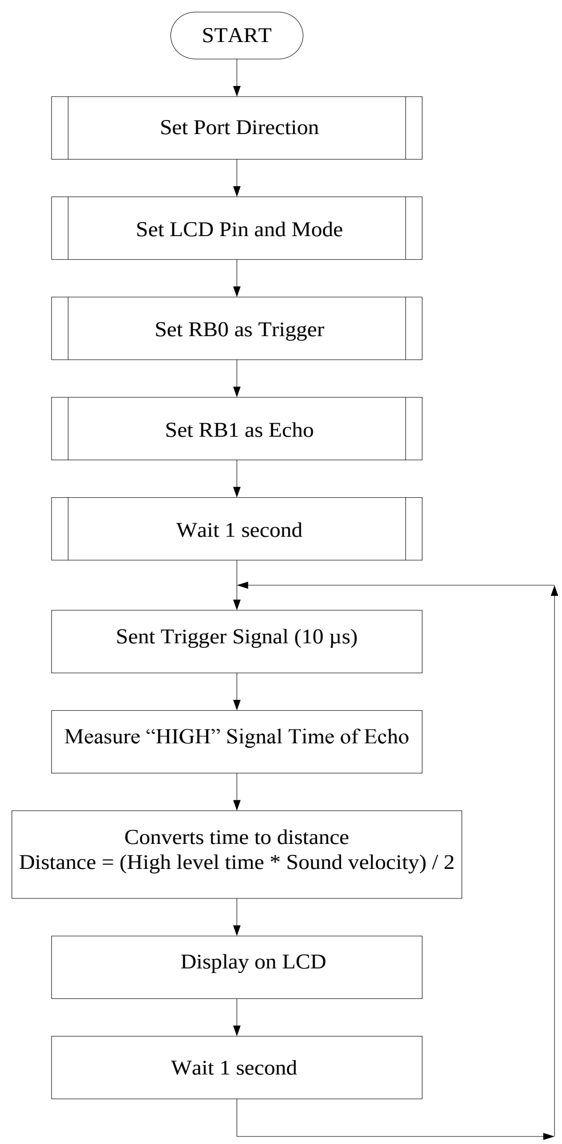

Fig.5 The flow chart diagram of the distance meter

(a) upside view (b) front view

Fig.6 The photograph of the constructed distance meter

Conclusion

The distance meter designed and constructed works quite satisfactorily but it still has some limitations such as range of the distance is short, type of the target to be good reflector for the ultrasonic signals. To overcome these limitations, lasers or other more reliable signal source should be used in the place of ultrasonic sensors. In addition, the constructed distance meter can be modified to record some useful information such as time, date and places together with the measured distance.

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