Design & Development of Real time Wireless Liquid Level Monitoring System

Bhagyajyoti , Immanuel J*., L. Shrimanth Sudheer, Parvathi C. S., and P. Bhaskar
Department of Instrumentation Technology, Gulbarga University P.G Centre,
Yeragera – 584 133. Raichur, KARNATAKA, INDIA.

Abstract:
In this paper the real time wireless liquid level measurement system using RF communication protocol is proposed. The main objective of the paper is to design and develop real time wireless measurement system for liquid level. The liquid level is measured by using SX05DN level sensor. The measured voltage corresponds to the liquid level is measured by the cygnal microcontroller using on-chip ADC module. The measured voltage is manipulated to the actual level and is transmitted by using RF transmitter module. The receiver is designed by using AT89C51 microcontroller and RF receiver module. The transmitted data is received at the receiver and is displayed on the LCD module. With this system the data can be transmitted /received within the range of 100 Mts. From the experimental results, it is observed that the system works within the stipulated range effectively.

Keywords: Wireless, Liquid Level, Transmitter, RF

1. Introduction

Measurement and frequent control of level of fluids (liquids and flowable bulk solids), contained in storage and processing vessels such as tanks, wells, reservoirs, ponds, bins, and hoppers, is one of the most common procedures in industrial instrumentation. The measurement of liquid levels in real time facilitates user to know actual liquid level in a tank at that instant as well as liquid level in the tank in past 24 hours by data logging.

Many processes involving liquids contained in a vessel such as distillation columns, reboilers, evaporators, crystallizers, and mixing tanks. The particular level of liquid in each vessel can be of great importance in process operation. A level which is too high, may upset reaction equilibria, cause damage to equipment or result in spillage of valuable or hazardous material. A level that is too low, may have equally consequences. Combined with such basic considerations, there is the advantage in continuous processing reducing storage capacity throughout the process. This reduces the initial cost of equipment, but less storage capacity accentuates the need for sensitive and accurate level measurement and control.

Effective measurement and control of level usually can be justified in terms of economy and safety. To the operator, knowledge of this variable provides data on

1. The quantity of raw material available for processing.
2. The available storage capacity for products in process
3. Satisfactory or unsatisfactory operation of the process.

S M. Khaled et al., reported the notion of water level monitoring and management within the context of electrical conductivity of the water. They investigate the microcontroller based water level sensing and controlling in a wired and wireless environment. This research work was to establish a flexible, economical and easy configurable system. They have been used a low cost PIC 16F84A microcontroller which is the key point to reduce cost [1-2]. The main goal of S. Noordeen et al., was to meet the requirement of user as it reduces even also avoids the manual operations of employee which produce or gives toxic liquids as outputs. A simple and cost-effective method of measuring the height of fluid in a tanker was by using ultrasonic waves. Which was cost-effective. Measuring liquid levels in real time, which facilitates user to know actual liquid level in a tank at that instant as well as liquid level in the tank in past 24 hours by data logging. They developed a computerized system to monitor and control toxic liquid level [3]. Samarth Viswanath et al., presents the architecture and initial testing results of a low power wireless system for tank level monitoring using ultrasonic sensors. The GSM module ensures that the accessibility of the network can be made use of making it more reliable for users. Enabling microcontroller low power modes and restricting transmissions to once a day, or when a trigger is activated, saves the power, extends battery life and ensures a system lifetime of > 2 years [4-6]. Giovanni Betta et al., proposes a digital microcontroller transducer for liquid level measurement based on two optical fibers. The adopted hardware and software strategies assure a low cost, high static and dynamic performance, good reliability, and the possibility of remote control. These features were confirmed by the experimental tests carried out on fuel liquids [7-8]. Ferran Reverter et al., describes the design and implementation of a liquid-level measurement system based on a remote grounded capacitive sensor. The system has been experimentally tested by measuring the level of tap water in a grounded metallic container. Over a level range of 70 cm, the system has a non-linearity error smaller than 0.35 mm and a resolution better than 0.10 mm for a measuring time of 20 ms [9]. From the literature it is observed that the most of the work is only on the real time liquid level measurement and control system. But less work has been reported on remote liquid level measurement. Here in this paper an attempt is made to design and develop remote liquid level measurement using RF transceiver protocol.

2. Block Diagram of the system

Fig. 1(a) & (b) shows the block diagram of transmitter and receiver for wireless liquid level measurement system.

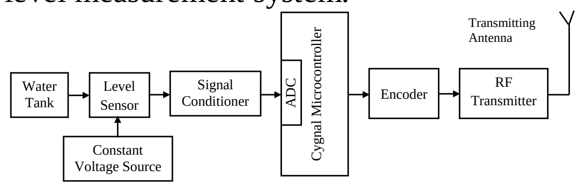

Fig. 1 Block Diagram of Transmitting Section

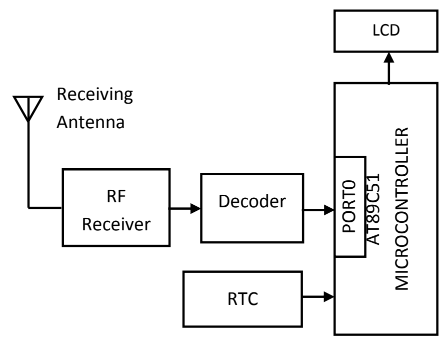

Fig. 1(b) Block Diagram of Receiving Section

It consists of Transmitting section and a Receiving section. Pressure transducer converts pressure into electrical signal. Basically transducer is of diaphragm type over which strain gauges are pasted. When pressure is applied, the diaphragm undergoes deformations (changes in dimensions). These dimensional changes are sensed by strain gauges. The resistance of strain gauges changes according to changes in dimension of diaphragm, which in turn is proportional to the applied pressure. These stain gauges are connected in Wheat stone bridge configuration to convert change in resistance to change in voltage. The change in voltage is directly proportional to the applied pressure. The output of Wheat stone bridge is usually very small, this small electrical signal is amplified by using instrumentation amplifier and the output of instrumentation amplifier is given to the "analog to digital converter" (ADC) in Cygnal microcontroller system.

Since Cygnal microcontroller is a digital device, it cannot receive analog signal. Therefore to convert analog signal into digital data, the analog signal is given to the on chip ADC there it converts the analog data into digital data. The role of microcontroller is to acquire data with the help of ADC from transducer. It does the suitable processing of the acquired data and it is given to encoder, encoder encodes the data and the output of the encoder is connected to the RF transmitter. There it transmits the signals through antenna.

At the Receiving section, receiver receives the signals sent from the Transmitter and the output of the receiver is connected to decoder which decodes the data and the output of the decoder is given to the microcontroller, since the signals are digital these signals can be directly given to Microcontroller. The role of microcontroller is to acquire data from the decoder. It does the suitable processing of the acquired data and displays parameter to be measured on the LCD display in terms of centimeters along with Real time clock (date and time).

3. Hardware Details:

The liquid level measurement system for present study consists of the following elements:

1. Level sensor
2. Excitation source
3. Instrumentation amplifier
4. Cygnal microcontroller with A/D and D/A Converters
5. DS 1307(Real Time Clock)
6. Encoder and Decoder
7. RF Modules (transmitter and Receiver)

3.1 Level Sensor:

A pressure transducer (SX05DN) is used as a level sensor[10]. A strain gauge is a small resistor whose value changes when it's dimension changes. Strain gages can be made of resistance materials, thin foils or semiconductor material. The strain gage generally consists of a wire of diameter between 0.0008cm to 0.00025cm, made of suitable material and of appropriate length. When it is strained within the elastic limit, it will have an increase in length and decrease in diameter or area. Obviously, this change in the physical dimension causes change in resistance of the wire, which can be found from the equation:

$$R \alpha l/a \Rightarrow R=\rho l/a$$

Where "R" is the resistance of the wire in the unstrained condition,

"ρ" is the resistivity of the material,

"l" is the length before strain

"a" is cross sectional area.

The ratio of change is resistance to the change in length is called gage factor (G)

$$G = \frac{\Delta R/R}{\Delta l/l}$$

Specifications

1. Range (operating pressure) : 0 to 5 PSID or PSIDG
2. Sensitivity : 3mvolt/volt/PSID
3. Full Scale Span: 50(min),75 (Typ),100(max)

3.2 Excitation circuit (constant voltage source):

The excitation voltage given to the strain gauge bridge should be constant. It consist of LM308, LM329 a reference zener diode, by using LM329 a constant voltage of 5v is produced by adjusting 10k pot and it is given to non -inverting terminal of LM308. Since the input voltage to the amplifier is derived from the temperature compensated zener diode, the output of the amplifier is stable even if there are variations in the environmental temperature. Output of the Op-Amp is given to a NPN transistor (2N2222), which gives required current for strain gauge Wheat stone bridge.

Since the output of strain gauge bridge is very small, this cannot be applied to ADC. Because ADC's will have limitations such as resolutions etc. Therefore the output of bridge is amplified using amplifier circuits such as differential amplifier or instrumentation amplifier.

3.3 Instrumentation Amplifier INA101:

Since the output of transducer is very small (in order of micro volts), and also the output of transducer is differential output. This can be amplified by using the instrumentation amplifier(INA101). The output of the basic differential amplifier is single ended output.

The important features of instrumentation amplifier are:

1. High gain accuracy
2. High CMRR
3. High gain stability with low temperature co-efficient.
4. Low dc offset
5. Low output impedance.

3.4 C8051f020 Microcontroller:

Features of C8051f020 Microcontroller[11]:

- High –speed pipelined 8051-compatible cip-51 Microcontroller core (up to 25 MIPS).
- In –system, full –speed, non –intrusive debug interface (on –chip).
- True 12 bit (c8051f020) or 10bit (c8051f022/3) 100 ksps 8channel ADC with PGA and analog multiplexer.
- True 8-bit DACs with programmable update scheduling.
- 64k bytes of in –system programmable FLASH memory.
- 4352 (4096+256) bytes of on chip RAM.
- External data memory interface with 64k byte address space.
- SPI, SMB bus /I^2C, and (2) UART serial interfaces implemented in hardware.
- Five general-purpose 16-bit timers.
- Programmable counter/ Timer array with five capture / compare modules.
- On –chip watchdog timer, VDD monitor, and temperature sensor.
- 64 –Digital port I/O's
- 2 – Analog comparators

3.5 Real-Time Clock (DS1307) :

The DS1307 I^2C based serial real-time clock (RTC) is a low power, full binary-coded decimal (BCD) clock/calendar plus 56 bytes of non-volatile. Address and data are transferred serially through an I^2C, bi-directional bus. The clock/calendar provides seconds, minutes, hours, day, date, month, and year information. The end of the month date is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The clock operates in either the 24-hour or 12-hour format with AM/PM indicator. The DS1307 has a built-in power-sense circuit that detects power failures and automatically switches to the backup supply. Timekeeping operation continues while the part operates from the backup supply.

Features

- Real-Time Clock (RTC) Counts Seconds, Minutes, Hours, Date of the Month, Month, Day of the week, and Year with Leap-Year compensation valid upto 2100
- 56-Byte, Battery-Backed, nonvolatile (NV) RAM for data storage
- I2C Serial Interface
- Programmable Square-Wave output signal
- Automatic Power-Fail detects and switch circuitry

- Consumes Less than 500nA in Battery- Backup Mode with oscillator running
- Optional Industrial Temperature Range: -40°C to +85°C
- Available in 8-Pin plastic DIP or SOIC, Underwriters Laboratory (UL) recognized

3.6 Encoder and Decoder:

Features of HT12E:

- Operating voltage 2.4V~12V .
- Low power and high noise immunity CMOS technology.
- Low standby current: 0.1A (typ.) at VDD=5V.
- Minimum transmission word: Four words for the HT12E.
- Built-in oscillator needs only 5% resistor.

Features of HT12D

- Operating voltage: 2.4V~12V.
- Low power and high noise immunity CMOS technology.
- Capable of decoding 12 bits of information.
- Binary address setting.
- HT12D: 8 address bits and 4 data bits.
- Built-in oscillator needs only 5% resistor.
- Easy interface with an RF or an infrared transmission medium.

3.7 RF Transmitter and Receiver:

Features of Transmitter

- Working voltage : 5V-12V.
- Data rate : 9600bps
- On-off keying (ook)/amplitude shift keying(ASK) data format.
- Saw based architecture.

Features of Receiver

- Working voltage : 4.5V-5V.
- Bandwidth : 12MHz
- Sensitivity : -103dBm.
- Data rate : 4800bps.
- Max. data rate : 9600bps.
- Standby current : 1,2ma

4. Working of the system

The complete circuit schematic of C8051F020 microcontroller based Remote liquid level measurement system is shown in fig 2 (a) & 2(b) The working of system outlines, the steps to be carried out by the system to measure and to transmit the measured level. The overall flow, involves data acquisition, processing, transmitting, receiving and displaying.

In order to measure the level of the water in tank, a differential pressure transducer (SX05DN) is placed at the top of the tank which senses pressure head proportional to level developed at the bottom of the tank and produces a differential voltage at its output as the level increase/changes, the sensor output also changes proportionally. It produces an output of 0.045mv/cm change in the level. This small voltage is further amplified by an instrumentation-amplifier (INA101) to produces an out of 0-5v/0-1mtr level. This voltage proportional to level is acquired by C8051F020 through its on chip ADC. The obtained digital data is sent to Encoder (HT12E) to encode the data and the data is given to the RF Transmitter (TX 433MHz) to transmit over a range of distance.

At the Receiving section, RF Receiver (RX 433MHz) receives the signal sent from the transmitter and it is given to the decoder(HT12D) to decode and then it is connected to the AT89C51 microcontroller. The microcontroller acquires and processes the data in terms of liquid level and it is displays on LCD module as a measured level in cm along with Real time clock.

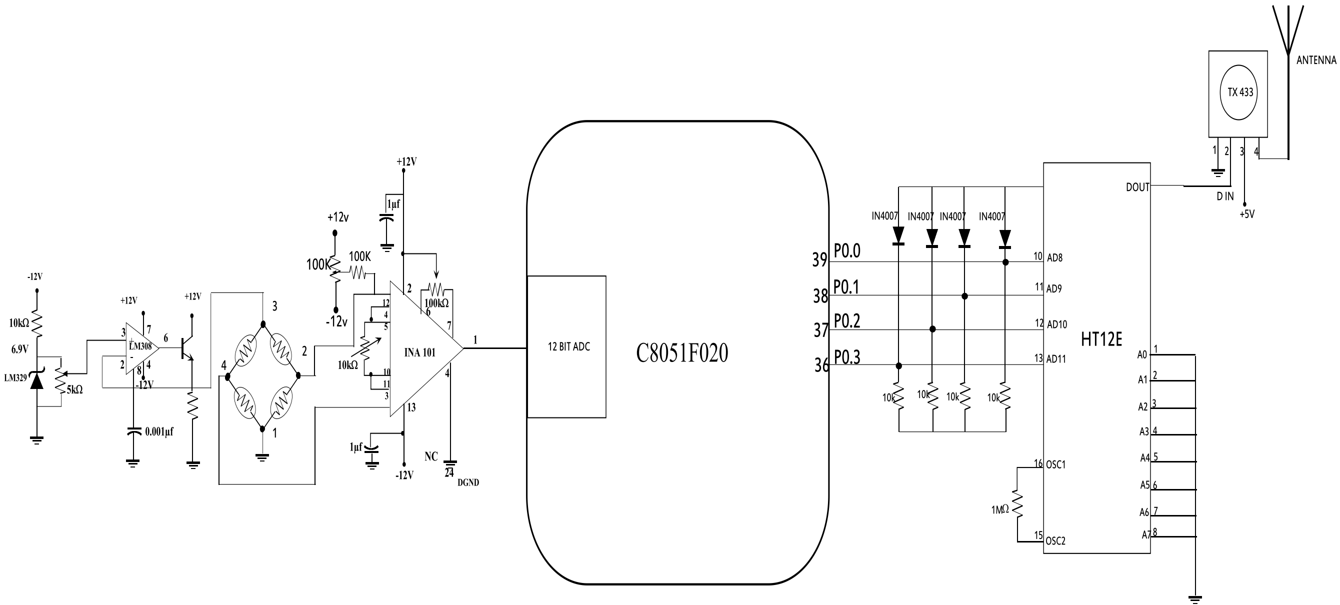

Fig 2.a Schematic diagram of Transmitting section

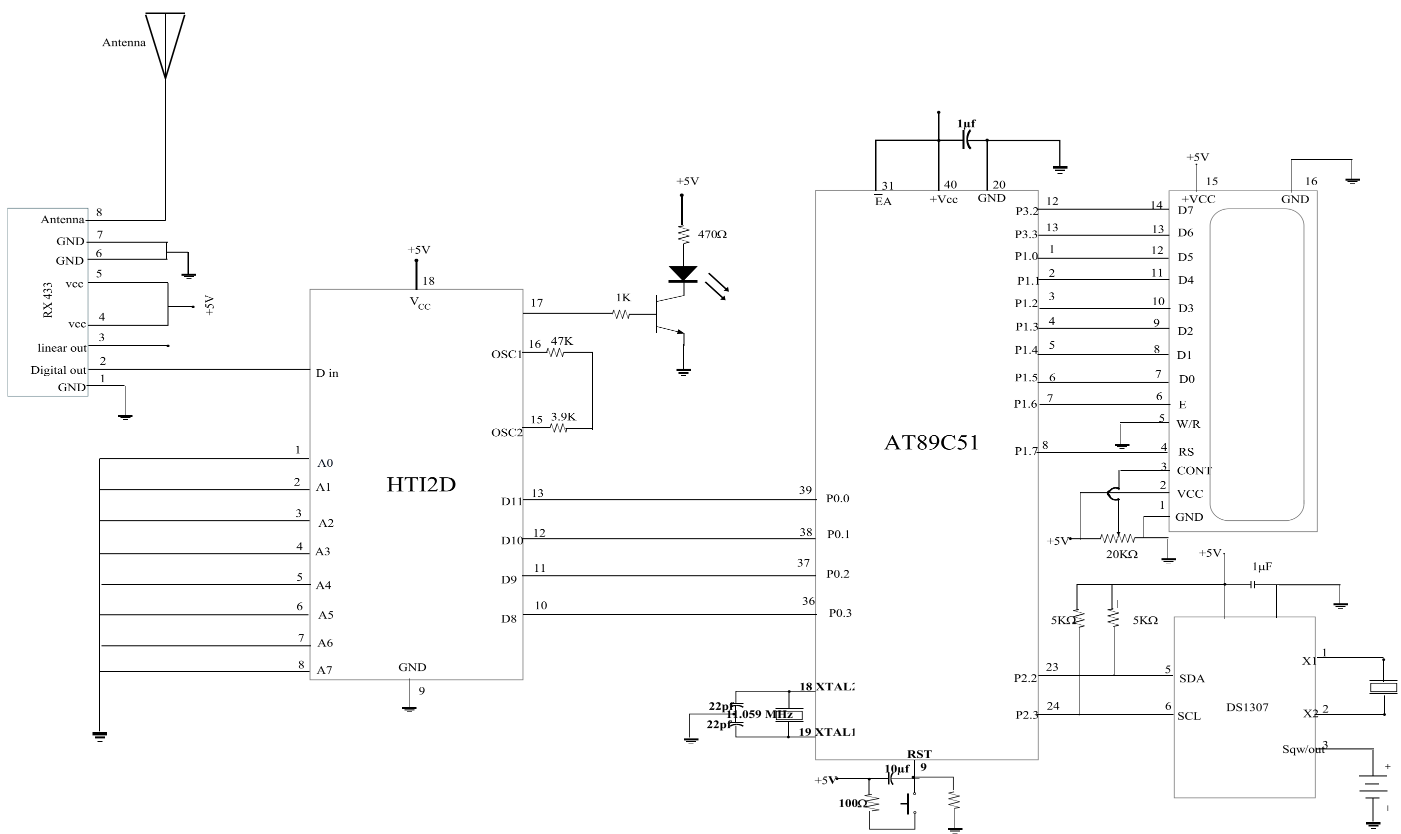

Fig 2.b Schematic diagram of Receiving section

5. SOFTWARE DETAILS:

Program Description

An embedded C language program is written in Silicon laboratories for cygnal microcontroller. The working of the software is given in the flowchart shown in fig 3(a). The software firstly initializes the on-chip peripherals of C8051F020 microcontroller and then initialize the functions and variables and call ADC to measure level in terms of voltage and convert the measured voltage into actual level in Cm and call the transmit subroutine by calling delay subroutine and repeat the process. An embedded C language program is written with Raisonance Integrated Development Environment (RIDE) for Atmel 8051 microcontroller. The working of the software is given in the flowchart shown in fig 3(b). The software Firstly initializes the LCD and RTC and then initialize the functions and variables and check for condition that if VT is high then call the receiver data subroutine then call level and RTC display subroutine and call delay and the delay subroutine and it is repeated.

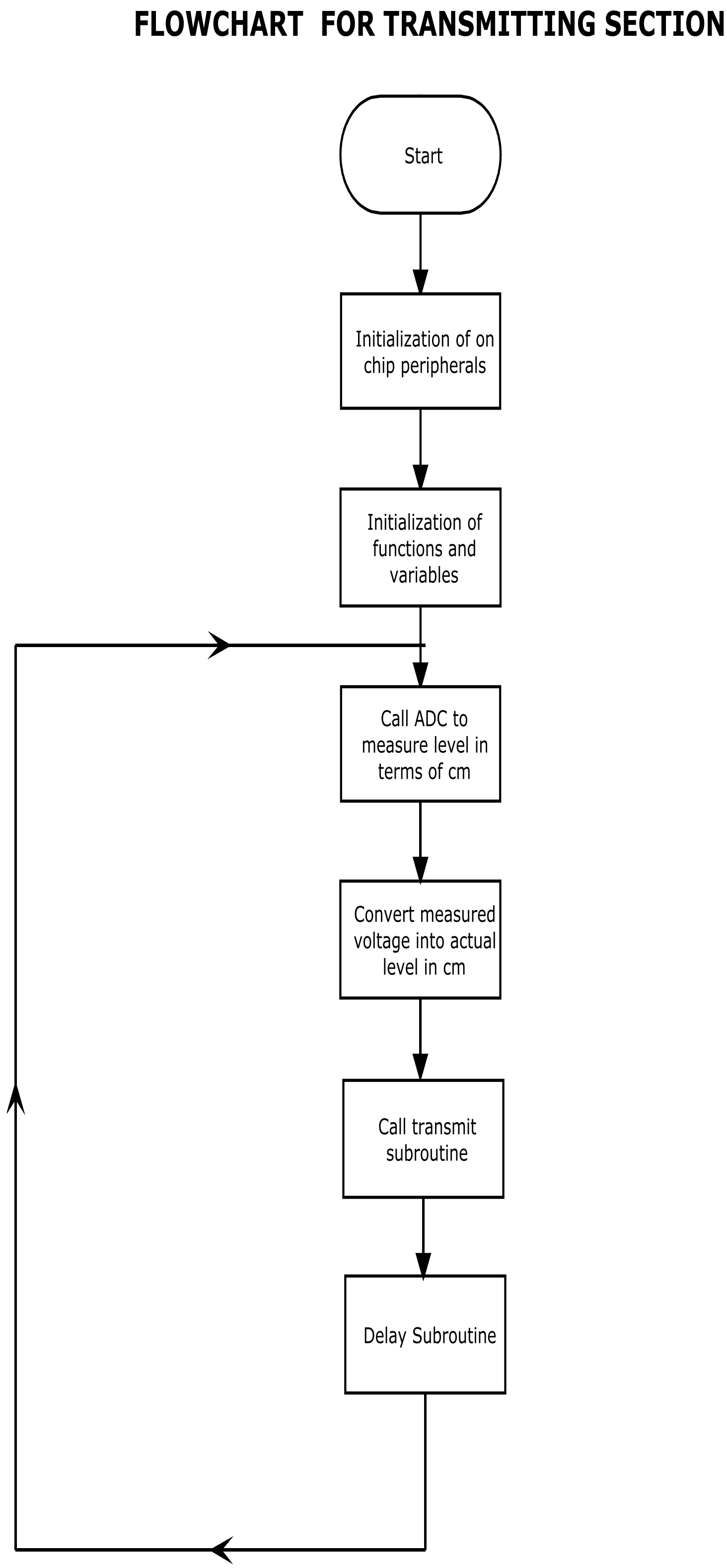

Fig 3(a) Flowchart of Transmitting Section

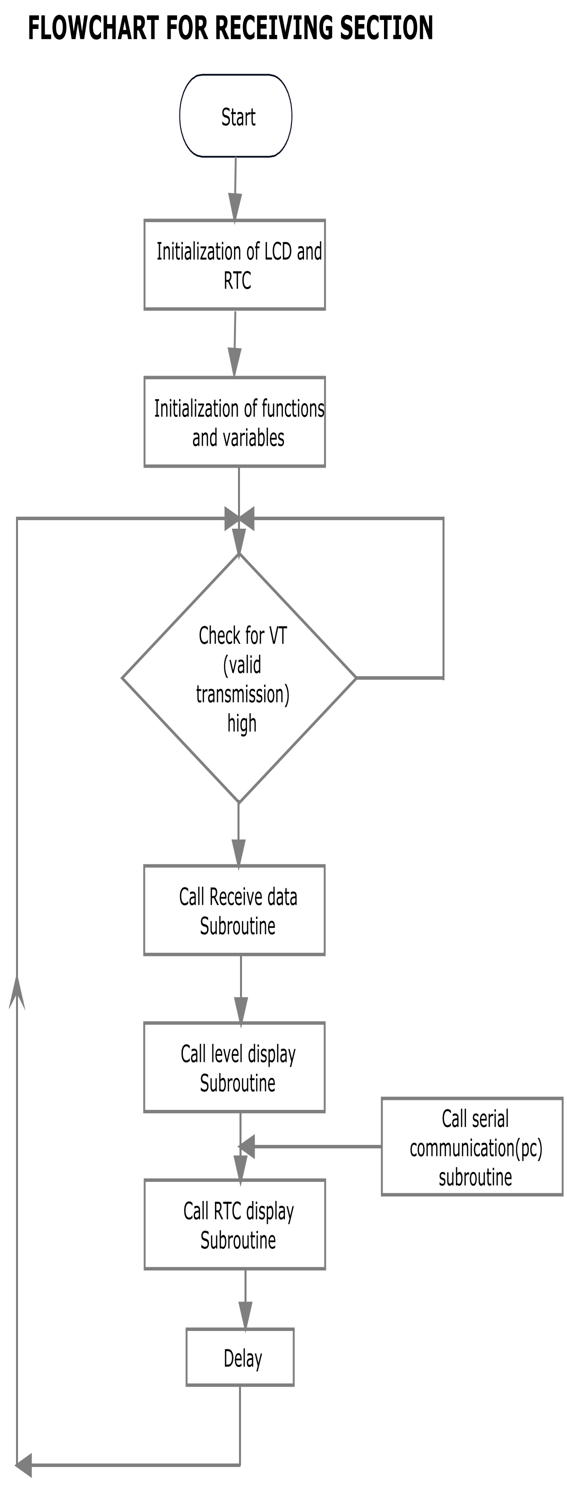

Fig 3(b) Flowchart of Receiving Section

4. RESULTS AND CONCLUSION

A microcontroller based remote liquid level measurement system is designed and fabricated. The designed system is practically implemented in the laboratory to measure the liquid level in a tank of one meter height. It is found that the system is working satisfactorily with an accuracy of ± 0.5cm over the distance of 100 meters. The measured values taken from the system are tabulated as shown in the following table 1.

Table 1: The Measured and Transmitted Data

Sl.No.	Liquid Level Measured at Transmitting Section	Liquid Level Measured at Receiving Section
1.	0 Cm	0 Cm
2.	10 Cm	10 Cm
3.	20 Cm	20 Cm
4.	30 Cm	30 Cm
5.	50 Cm	50 Cm

Conclusion:

A microcontroller based remote liquid level measurement system is designed and fabricated. The liquid level is measured and transmitted at the transmitting section and it is received at the receiving section and is displayed on LCD module in cm along with date and time. The designed system's cost is low due to implementation of Microcontroller compact in size. It can be used for controlling purpose if we use a set of transmitter and receiver on both the sides. This system is very useful to Industries in which the sources of variables are in inaccessible places or are in hazardous areas like radioactive reactor, high temperature furnaces etc. Useful for the process plants having large plant area.

References:

[1] S. M. Khaled Reza, Shah Ahsanuzzaman Md. Tariq, S.M. Mohsin Reza, “Microcontroller Based Automated Water Level Sensing and Controlling: Design and Implementation Issue” *Proceedings of the World Congress on Engineering and Computer Science 2010,* vol 1, WCECS 2010, October 20-22, 2010, San Francisco, USA.

[2] M. Javanmard, K.A. Abbas and F. Arvin, “A Microcontroller-Based Monitoring System for Batch Tea Dryer”, CCSE Journal of Agricultural Science, Vol. 1, No. 2, December 2009

[3] S. Noordeen, M. A. Noorul Parveen, Kaliyaperumal Karthikeyan, “Microcontroller Based Toxic Liquid Level Monitoring Control System’’*International Journal of Engineering Research & Technology (IJERT),*vol. 2 Issue 4, April – 2013 pp 388-397.

[4] Samarth Viswanath, Marco Belcastro, John Barton1, Brendan O’Flynn, Nicholas Holmes, Paul Dixon, Low-Power Wireless Liquid Monitoring System Using Ultrasonic Sensors”,*International Journal On Smart Sensing And Intelligent Systems,* vol . 8, NO. 1, MARCH, 2015 pp26-44.

[5] N. Giannoccaro and L. Spedicato, “Ultrasonic Sensors for Measurements of Liquid Level, Volume and Volumetric Flow in a Tank,” *Precis. Instrum. Mechanology*, vol. 1, no. 1, 2012, pp. 1–6.

[6] R. Barani and V. Jeya, “Oil Well Monitoring and Control Based on Wireless Sensor Networks using Atmega 2560 Controller,” *Int. J. Comput. Sci. Commun. Networks*, vol. 3, no. 6, 2013, pp. 341–346.

[7] Giovanni Betta, , Antonio Pietrosanto , Antonio Scaglione “Microcontroller-Based Performance Enhancement of an Optical Fiber Level Transducer” IEEE Instrumentation and Measurement Technology Conference Brussels, Belgium, June 4-6, 1996, pp 912-916.

[8] A. Wang, M.F. Gunther, "Fiber optic liquid level sensor," *Sensors And Actuators A*, vol. 35,1992, pp. 161-164,.

[9] Ferran Reverter, Xiujun Li and Gerard C.M. Meijer “Liquid-level measurement system based on a remote grounded capacitive sensor” Sensors and Actuators A Physical July, 2007, pp 1-30
[10] www.sensortechnics.com

[11] C8051f020 data manual.

[12] Kenneth J. Ayala, The 8051 Microcontroller Architecture Programming & Applications.