DESIGN AND CONSTRUCTION OF AN ELECTRONIC WATER LEVEL INDICATOR

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ABSTRACT

The increasing availability of low cost semiconductor devices has led to the rapid proliferation of economical electronic devices applicable to all aspects of life. However, in Sri Lanka, though there is a large market for electronic devices of all types, design and development of new electronic devices remain a weak sector.

For those who depend on water from an overhead tank, it is important to know the amount of water available in the tank. This is particularly important when the main water supply is not reliable. The possibility to know the amount of water in an overhead tank without having to frequently access it, is therefore important and useful. Commercially available water level indicators are expensive and needs frequent care and maintenance.

The aim of this project is to design and construct an electronic water level indicator using readily available low cost electronic devices and materials. In designing the instrument special emphasis was laid on minimising cost without compromising accuracy. At the same time a special effort was made to make the instrument simple and thereby reducing the need for maintenance.

INTRODUCTION

The water level indicator discussed here is based on the capacitance variation of a cylindrical capacitor with the water level. The selection of capacitance variation to measure water levels was based on several factors. First and foremost the permittivity of water does not vary significantly with the quality of water. This ensures consistent performance regardless of the quality of water. Secondly the high value of relative permitivity of water enables to make measurements with a high degree of accuracy. This instrument consists of a probe which is a collection of seven cylindrical capacitors and an electronic circuit. The electronic circuit indicates the water level based on the capacitance of the probe.

THEORETICAL ASPECTS OF THE DESIGN OF THE PROBE

Cylindrical capacitor configuration

This system consists of two coaxial metal cylinders. The inner cylinder is insulated to prevent the capacitor from discharging, through the water column between the two cylinders. Fig. 1 shows the cross sectional view of this system and here a, b, c, are the radii of the inner cylinder, the inner cylinder with the insulator and the outer cylinder respectively. As the water level varies, the amount of dielectric medium in the space between the two cylinders varies. As a result the capacitance of the cylindrical capacitor changes with the water level.

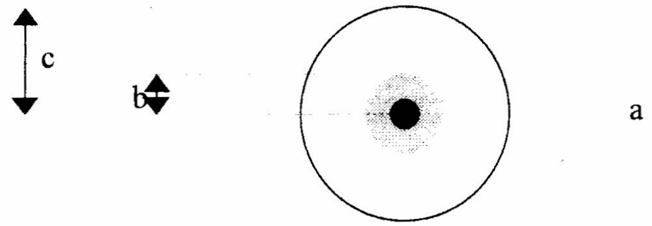

Fig. 1. Cross sectional view of the cylindrical capacitor

The capacitance variation of the cylindrical capacitor with the height of the water level is given by Eq. (1)

$$C = 2\pi\varepsilon_0 \frac{(\varepsilon_w - \varepsilon_a)}{\ln(c/b)} h + 2\pi\varepsilon_0 \left[\frac{\varepsilon_i l}{\ln(b/a)} + \frac{\varepsilon_a l}{\ln(c/b)}\right] \quad (1)$$

where,

- l - Height of the probe
- h - Height of the water level
- ε_0 - Permittivity of free space
- ε_a - Relative permittivity of air
- ε_w - Relative permittivity of water

According to the above equation it is clear that the variation of capacitance of the cylindrical capacitor with the height of the water level is linear. Therefore this system is suitable as a probe.

CONSTRUCTION OF THE PROBE

The basic element of the probe is a long cylindrical capacitor. The capacitor consists of two coaxial metal cylinders, each measuring about 90 cm in length (Fig. 2). The inner conductor is an insulated brass rod, and the outer conductor is an aluminium tube. The brass rod was covered with a cylindrical, coaxial polythene layer (insulator) in order to prevent the capacitor from discharging through the water column between the two cylinders. Brass rods and aluminium tubes were used as they could be purchased easily from a hardware store.

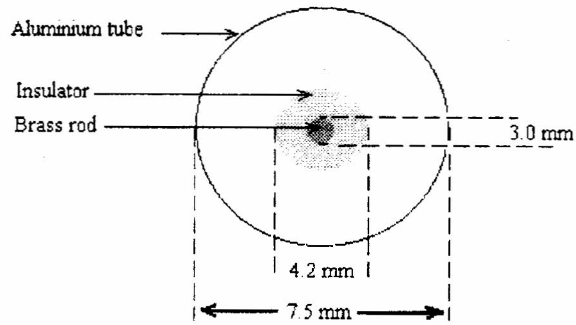

Fig. 2. Cross-sectional view of an element

The change of capacitance of a single element was found to be 6 pF per 1 cm rise in water level. Measurement of such a small variation requires complicated electronics as well as special protection from stray capacitance. To avoid these complications, the sensitivity of the probe was increased by integrating several of such cylindrical capacitors. The final version of the probe contains seven such elements, connected in parallel as shown in Figs. 3 and 4.

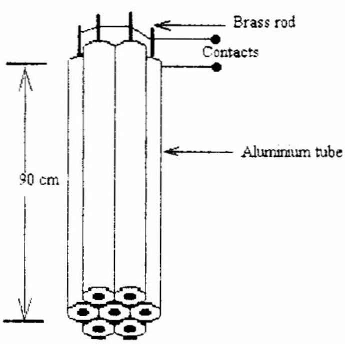

Fig. 3. Side-on view of the probe

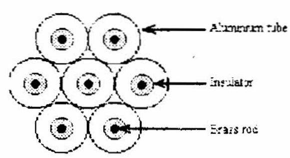

Fig. 4. Cross sectional view of the probe

THE OPERATION OF THE ELECTRONIC CIRCUIT

At the heart of the circuit are two oscillators. One of these oscillators generates a square wave of constant frequency. This signal is used to drive a counter. The other oscillator is used to generate a low frequency pulse train. The time interval for one cycle of this low frequency signal is directly proportional to the external capacitance (probe) connected to that oscillator. Using this signal, two control signals are generated to control the counter and the display driver, so that the display shows the number of pulses generated by the constant frequency oscillator during one cycle of the low frequency oscillator. By adjusting the frequencies of the two oscillators appropriately, the value of the external capacitor can be measured.

CONTROL SIGNALS

(I) Reset signal

The reset signal controls the counter. When the counter receives a reset signal the counter is set to zero, and restarts counting. The time interval between two reset pulses is directly proportional to the capacitance of the probe which in turn is proportional to the height of the water level. The frequencies of the two oscillators were adjusted so that the number of counts between two reset pulses equalled the height of the water level in centimetres

(II) **Latch signal**

The latch signal controls the display driver. When the latch signal goes high the display driver reads the value of the counter and displays it. When the latch signal goes low, the display driver holds the value it is displaying, until the latch pulse goes high again. The latch pulse is timed so that the display driver latches on to the value of the counter just before the counter is set to zero by the reset signal. By changing the frequency of the latch signal subjected to the above condition, the rate at which the water level measurements are displayed can be adjusted.

A 555 timer was used to generate a low frequency square wave (Fig. 5).This pulse was used to control the frequency of the latch pulse. The clarity of the L.E.D. display was increased by this adjustment. The pulses generated by the circuit are shown in Fig. 6.

The counter employed in this circuit is a dual BCD counter, and the display is driven by two BCD - to - 7 segment latch decoders.

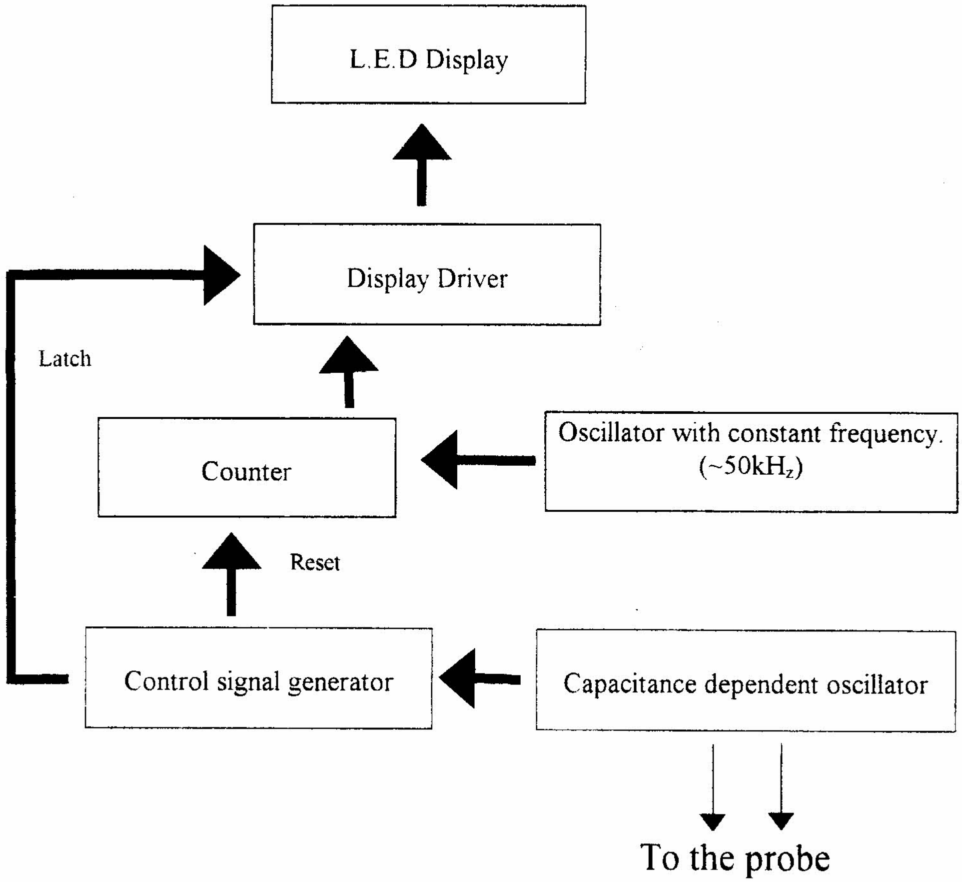

Fig. 5. Block diagram of the circuit

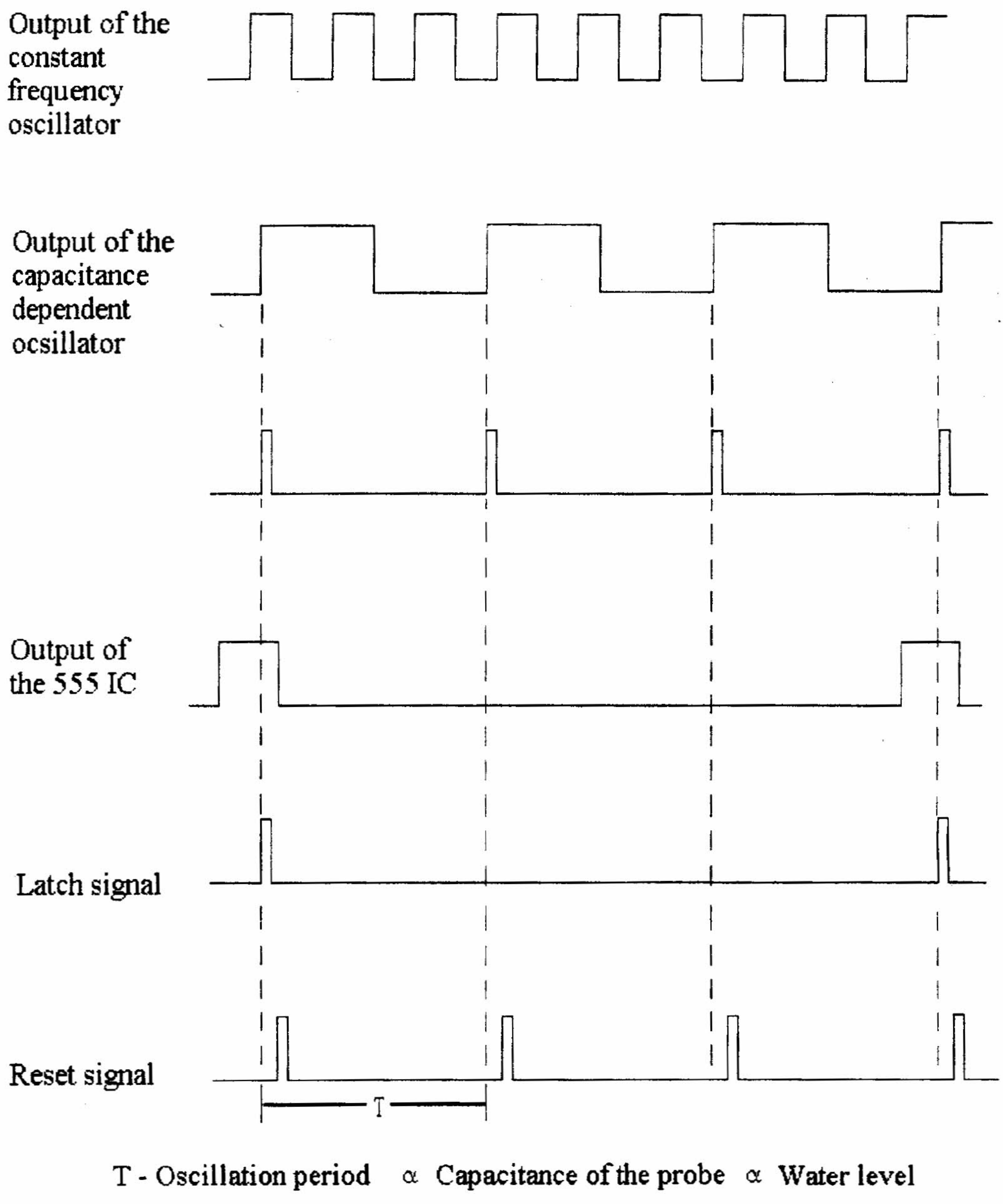

Fig. 6. Pulses generated by the circuit

RESULTS

The performance of the probe

The performance of the probe was studied using an L.R.C. analyser. The main interest was to measure the capacitance variation of the probe with the height of the water level. The results of the study are given graphically in Fig. 7.

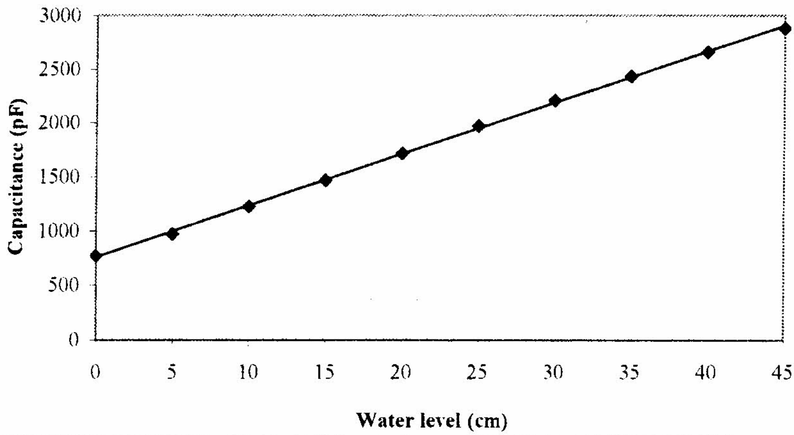

Fig. 7. Variation of the capacitance of the probe with the water level

According to the graph, the variation of capacitance with the height of the water level shows excellent linearity. Furthermore, the capacitance reading was stable and constant, regardless of the quality of the water.

Performance of the device

The performance of the device was studied for distilled water and pipe borne water. The results for distilled water are given in Table 1. The results of water level measurements agreed with those for pipe borne water.

Table 1. Performance of the device

Actual water level (cm)	Reading of the device (cm)
0	0
5	5
10	10
15	15
20	20
25	25
30	30
35	35
40	40
45	45

Water level measurements were also made by varying the separation between the probe and the circuitry of the instrument. For a normal twisted pair of wires, the maximum possible separation between the probe and the circuitry, without compromising the accuracy was 10 m. For lager separations both the accuracy as well as the stability of the readings were poor.

CONCLUSIONS

The instrument designed and constructed during the course of this project has many required features. The instrument is a portable unit that is easy to use, and requires minimum maintenance. The instrument can be constructed for under Rs.750/-. The instrument has flexibility in its power needs as well. It can be operated with voltages ranging between 7V - 15V.

Though this instrument was designed to measure height of water levels, it can also be used to measure the heights of other liquids without any modifications. With some minor changes this can be used to measure the permittivity of liquids such as well.

REFERENCES

Horowitz P. and H. Winfield 1995. *The Art of Electronics, 2nd edition,*25, Cambridge university press, Cambridge,U.K.