Digital Measurement of Flow Time for Electro-Conductive Liquid in a Glass Capillary Viscometer

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***Abstract*— A viscometer is an instrument used to measure the viscosity and flow parameters of a liquid. Viscosity of a liquid is directly proportional to the flow time through a capillary tube. In glass capillary viscometer the time required for the liquid level to drop from one mark to another is generally measured by a stop watch. As the liquid flows quickly through the glass tube, accurate measurement of time by a stop watch is very difficult. To solve this problem a digital watch is constructed which automatically start at upper mark and stop at lower mark of the viscometer. This apparatus works for electro conductive liquid and gives good results. 2-input EX-OR gate is used for automatic start and stop operations of this digital watch. A new electronic method is used here to measure time of rise or time of fall of liquid level automatically.**

***Index Terms:* viscosity, viscometer, flow time, digital measurement, automatic digital watch.**

I.INTRODUCTION

The internal property of a fluid for its resistance to flow is known as viscosity. A viscometer is an instrument used to measure the viscosity and flow parameters of a fluid. A glass capillary viscometer is a commonly used viscometer, which consists of a U-shaped glass tube held vertically. For more accurate measurements it is held in a controlled temperature bath. A liquid is allowed to flow through its capillary tube between two etched marks and the time of flow of the liquid is measured using a stopwatch. The dynamic viscosity η is calculated using the formula:

$$\eta = KPt \qquad (1)$$

Where K is a constant and $K = \frac{\pi r^4}{8VL}$.

Where t is the time of flow of liquid, V is the volume of the liquid, P is the hydrostatic pressure, and L is the distance travelled by the liquid during time t and r is the radius of the capillary tube. In glass capillary viscometer the measured distance the liquid travels, L will be always a constant; the radius, r will always be a constant; and by procedure the volume of liquid, V will also be constant.

The hydrostatic pressure is P proportional to the density of the fluid being measured. We are measuring the mass of equal volumes of liquid so that the viscosity is proportional to the masses measured. Therefore we have the relation:

$$\eta \propto Kmt \qquad (2)$$

Where K and t are defined above and m is the mass of the liquid.

For finding the viscosity of liquids it is important to calibrate the viscometer using a reference liquid. Water is a commonly used reference liquid. The viscosity of water at 30.0 °C is 0.8007 centipoise (cP). Knowing the values for the reference liquid and relation (2), we get:

$$\frac{\eta}{\eta_w} = \frac{mt}{m_w\, t_w} \qquad (3)$$

Where η_w is the viscosity coefficient of the reference sample (water), m_w is the mass of the reference sample, and t_w is the flow time of the reference sample. The other variables are the viscosity coefficient, mass, and flow time of the sample respectively. With glass capillary viscometer we can measure the time flow of a liquid (mass can be measured using standard laboratory procedures, e.g. a relative density bottle and a scale) and determine its viscosity by solving equation (3) for η.

Accurate measurement of time is very important in this method. In the simplest case the flow time is measured using a stop watch. Glass viscometers manufactured for this purpose have annular measurement marks burnt in above and below the measurement sphere. The disadvantages of this method are obvious:

(1) Subjective observation errors or differences in the reaction time of the operator at the beginning and end of the timing.

(2) In the case of opaque substances the meniscus cannot be seen.

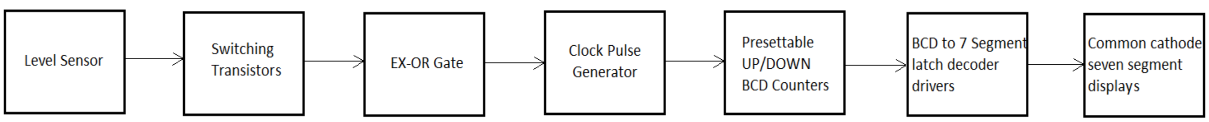
To solve these problems automatic measurement of time is required. Based on logic function of EX-OR gate a digital watch is constructed which starts automatically when liquid level just leaves upper mark and stops automatically when liquid level leaves lower mark because the output of an Ex-OR gate is a logic '1' whenever the number of 1's in the input combination is odd and a logic '0' whenever the number of 1's in the input combination is even. For 2-input EX-OR gate Boolean expression is

$$Y = \overline{A}B + A\overline{B}$$

Where A and B are inputs and Y is output. Functional table of a 2-input EX-OR gate is shown below.

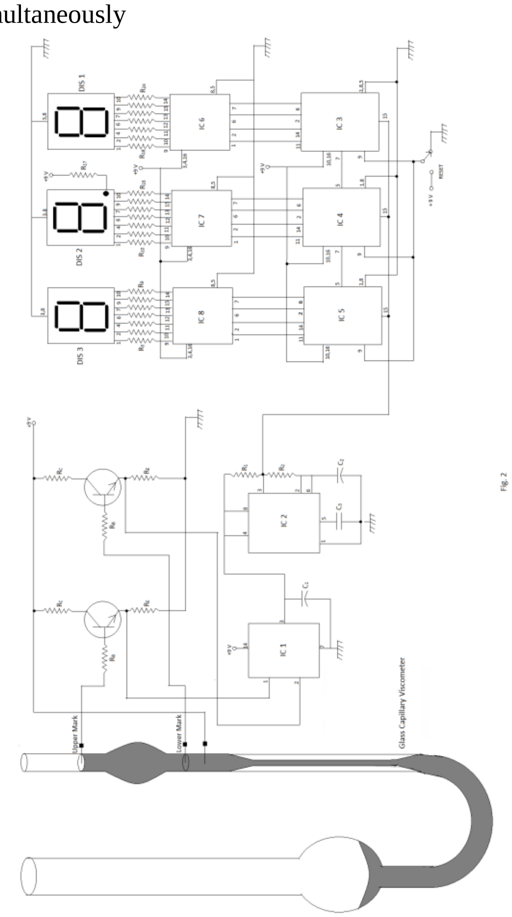
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Clock pulse of frequency 10 Hz is generated from 555 timer only when output voltage of EX-OR gate is high. The display reading gives the time interval between the start and stop operations of clock pulse generator. Different components of automatic digital watch are represented in a block diagram shown in fig.1.



II. CIRCUIT DESCRIPTION

Automatic digital watch circuit for measurement of flow time from one mark to another mark in a glass capillary viscometer is shown in fig.2. In this circuit level sensor is conducting wires which are inserted into the upper and lower marks of the viscometer through air tight narrow holes and a power supply (+9V DC) wire is inserted below the lower mark. Two other terminals of the level sensor are connected to the base resistor R_B (100K) of two npn switching transistors (2N2222). The collector terminal of each transistor is connected to +9V DC through R_C (1K) resistor. Emitter resistor R_E (10K) is connected between emitter terminal and ground of each transistor. Output voltages will be available from the junction of emitter and emitter resistor of two transistors. Outputs of two transistors act as two inputs (pin 1 and pin 2) of IC 1 which is an EX-OR gate (CD4070B). Output voltage from pin 3 of EX-OR gate is the power supply voltage of IC 2 (NE555) which act as a clock pulse generator. To provide pure constant dc supply voltage for IC 2 a bypass capacitor C_1 is connected between pin 3 and ground of IC 1. IC 2 is a simple circuit for astable operation of timer IC555 which produces 50% duty cycle. The output at pin 3 of IC 2 is HIGH during the charging process and LOW during the discharging process of the capacitor. In this circuit, the capacitor discharges through the resistor R_2 and the output transistor connected to pin 3 inside the timer IC. In conventional astable circuit the capacitor discharges through the discharge transistor connected to pin 7 of the timer IC. The trigger terminal (pin 2) and threshold terminal (pin6) are coupled together and are simultaneously



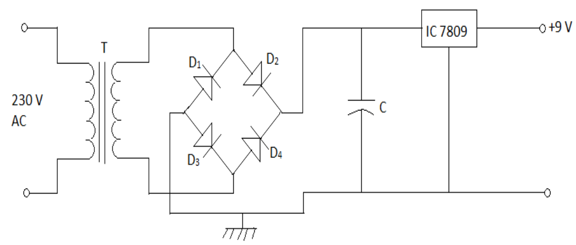


Fig. 3

driven by the capacitor voltage. The control voltage terminal (pin 5) is ground connected through a capacitor C_3 (0.01µF). Supply voltage from pin 3 of EX-OR gate is provided between + V terminal (pin 8) and ground terminal (pin 1). Reset control terminal (pin 4) is connected to positive terminal of supply voltage. Output is taken from output terminal (pin 3). The frequency of the output waveform is $f = \frac{1}{1.38\, R_2\, C_2}$.

Taking C_2 = 3.3µF and R_1 = 1K, value of R_2 is adjusted to get 10Hz output frequency. Therefore, this digital watch could count time in steps of 0.1s.

IC 3, IC 4 and IC 5 are presettable UP/ DOWN BCD decade counters (CD4510B). These counters are connected in cascade arrangement. The RESET switch is single pole double throw (SPDT) type and it is used to reset the counter to all zeros. Usually the Reset terminal is connected to ground, to reset the counter it is momentarily connected to +9V.

IC 6, IC 7 and IC 8 are BCD to seven segment latch decoder drivers (CD4511B). These ICs can directly drive common cathode seven segment LED displays (DIS 1, DIS 2 and DIS 3). R_3 to R_{24} are current limiting resistors of 470Ω resistance. Decimal Point (DP) of DIS 2 is connected to +9V supply voltage through 470 Ω resistance for display of DP.

Power Supply circuit: This apparatus needs +9V constant voltage power supply. The circuit shown in fig. 3 produces regulated output DC voltage of +9V and it is capable of delivering a load current of 1A. Transformer T (0 -12 volts, 1A mains transformer) steps down 230V AC to 12V AC. Diodes D_1 to D_4 (1N4001) constitute full wave bridge rectifier and capacitor C (1000µF, 25V electrolytic) is the filter capacitor. IC 7809 is a three terminal regulator which produces a fixed regulated output voltage of +9 volt.

III. WORKING OF THE CIRCUIT

When the liquid level in the viscometer is above the upper mark then both transistors are in the ON state. Therefore voltage level applied at both inputs of EX-OR gate are HIGH. As a result output becomes LOW. When the liquid level just leaves upper wire of level sensor then the corresponding transistor goes to OFF state but the second transistor remains in the ON state. These states give one input voltage level LOW and other input voltage level HIGH of EX-OR gate. In this case output becomes HIGH. This high level voltage is the Power supply voltage of NE 555 timer which generates clock pulses when used as an astable multivibrator with 50% duty cycle. For the chosen component values of R and C the frequency of the output waveform from timer becomes 10Hz. Thus clock START automatically when liquid level leaves upper mark of the viscometer. Clock STOP automatically when liquid level just leaves the lower mark of the viscometer. This is because when liquid level goes below lower mark of the viscometer then both transistors are in the OFF states. Which in turn gives both inputs of EX-OR gate LOW. Therefore output becomes LOW. As a result 555 timer stops working because there is no power supply voltage of 555 timer.

The time required for the liquid level to drop from upper mark to lower mark of the viscometer is displayed in a digital meter. The digital meter is constructed by two types of ICs (4510 and 4511) and common cathode 7 segment displays (LT 543). The number of clock pulse generated by clock pulse generator is counted by a cascade arrangement of three BCD decade counter (IC: 4510). It is used as a UP counter that count upwards i.e. every count increments the counter output by connecting +9 V at pin 10 of this counter IC. The counters also have a CLEAR facility where the counter output can be reset to 000 (for 3-bit counters) when desired. Output of the counter is fed to another IC (IC: 4511) which is a decoder driver IC. This IC converts the BCD output of the counter into a decoded output for the seven segment display. For three BCD decade counters there are three decoder drivers and three seven segment displays.

Pin connection diagrams of CD4070B, NE555, CD4510B, CD4511B, and LT 543 are shown in Figs. 4(a), 4(b), 4(c), 4(d), 4(e) respectively

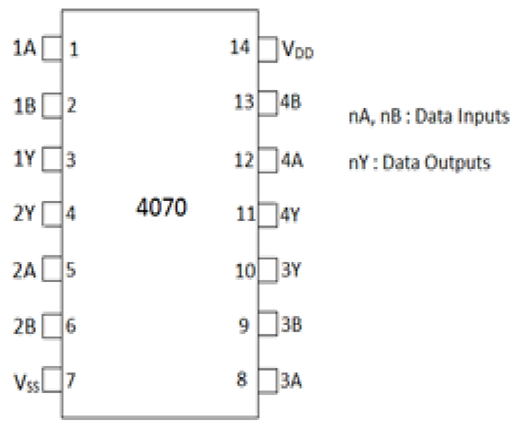


Fig. 4(a): Quad 2-input EX-OR

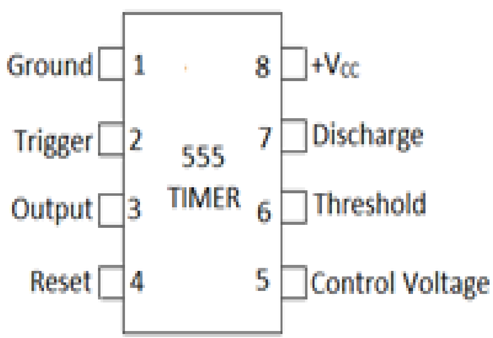


Fig. 4(b): 555 Timer IC

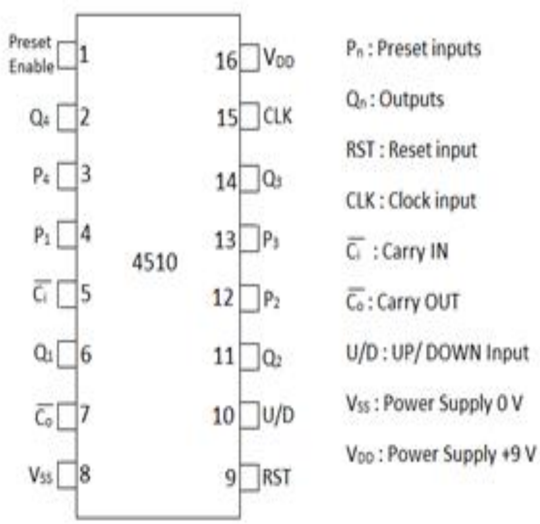


Fig. 4(c): Presettable UP/DOWN BCD Counter

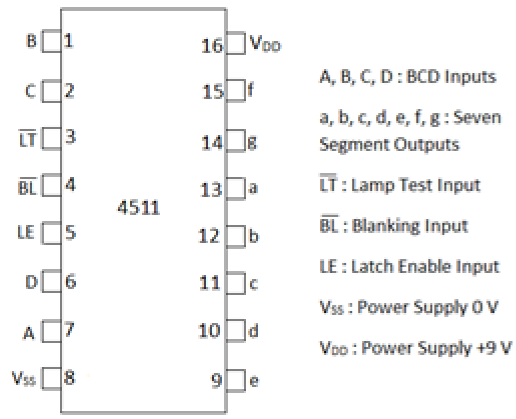


Fig. 4(d): BCD to 7 Segment Latch Decoder Driver

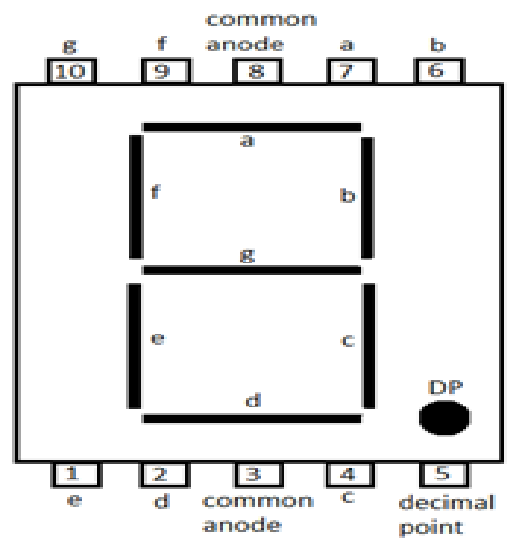


Fig. 4(e): Common Cathode Seven Segment Display (LT 543)

IV. CONCLUSIONS

Flow time of liquid between two marks in a glass tube is measured accurately with this automatic digital watch. Kinematic viscosity is directly proportional to the flow time of the liquid. Capillary viscometers come with a manufacturer-supplied conversion factor which allows calculation of the kinematic viscosity directly from the flow time. Flow time taken by an operator using a stop watch gives some observational errors or differences in the reaction time of the operator. These problems are eliminated in newly constructed automatic digital watch. One disadvantage of this method is that the sample must be electro-conductive for working of the circuit.

REFERENCE

[1] http://www.fairchildsemi.com/4070.html.
[2] http://www.doctronics.co.uk/4510.html.
[3] http://www.doctronics.co.uk/4511.html.
[4] http://embedded-lab.com/seven segment.jpg
[5] LM555 Data sheet, National semiconductor
[6] S. Salivahanan and S. Arivazhagan, Digital Electronics and Circuit Design
[7] Wilke, Kryk and Hartman, Theory and Praxis of Capillary Viscometry