Introduction of an Auto-circuit in Magnetic Float Densitometer using Semiconductor Devices

DR. PATHAK R.N.*, DR. SAXENA I., DR. MISHRA A.K., KUMAR R., SINGH N

Department of Chemistry, Lucknow University, Lucknow-226007, India.
E-mail: rnpk@sify.com

Abstract

In the present modified version of magnetic float densitometer, an auto-circuit, comprising of 12V auto-on and 1.5V auto-off device, having a time delay of about 20 and 10 sec. respectively, is incorporated to regulate the electric currents in the solenoids. The currents in the main and pull down solenoids are simultaneously controlled by one switch only. This makes the magnetic float densitometer easy operating without affecting the mathematical working of the instrument.

Keywords: Magnetic Float Densitometer, Semiconductor, Auto-circuit

Introduction

The accurate measurement of density of solutions is a strong need of the day in many research areas of Chemistry as many physico-chemical aspects such as viscosity, surface tension, molar refraction, apparent molar volumes, etc. are directly or indirectly related with the density. The accuracy of measurement of such physical property depends on the accuracy with which the density measurements are made. The survey of the literature[1-15] on density measurements of solutions reveals that there have been several methods to measure it, namely, density-bottle, pyknometer, dilatometer etc. None of these methods gave, very accurately, the density of solutions, atleast, in very dilute region. In order to find a better solution for this problem, scientists used more and more improved methods. Lande and his co-workers[1] used bicapillary pyknometer method, Banipal and his co-workers[2] used vibrating tube digital densitometer, Choudhary and her co-workers[3] used simple technique Ostwald Sprengel type pyknometer, Gupta and Singh ; Parmar, Sharma and Dhiman used an apparatus[4,5,6] similar to one described by Ward and Millero[7] to measure the densities of different solutions. Many other workers, namely, Franks and Smith[8], Geffchen, Beckmann and Kruis[9], Hidnert and Peffer[10], Lamb and Lee[11] and Millero[12] used the technique magnetic float densitometer to measure the density of solutions. These magnetic floats were differing very slightly with each other. Some workers[9,13,14] modified Lamb and Lee version[11] of magnetic float densitometer. They used a magnetic core inside the float. However, in principle, the method was the same. Millero[12] further improved the method and made it more sensitive and modest in cost. It was then thought that one should attempt to design a better and more improved technique of experimental determination of density of solutions. The Millero's model[12] was, therefore, further improved in our laboratory by making few changes in his design, the description of which is given elsewhere[15]. These changes improved the working and efficiency of the instrument considerably and enabled the user to use it conveniently. The above version[15] of magnetic float densitometer was further modified by replacing a major part of the circuit along with batteries by "A 12V auto-on and 1.5V auto-off electronic circuit" consisting of semiconductor active components and some other electrical non-active components. The main advantage of this modification is that this electronic unit operates by only one switch, making the use of the magnetic float densitometer still simpler and easier and reduces the cost of the instrument by eliminating the use of two big size 12V lead accumulators and a 1.5V battery. The electronic components used in the circuitry is of very low cost.

Description of the model

The description of the recently modified version of magnetic float densitometer is divided into following parts; description of the magnetic float densitometer, description of push button and electronic-circuits, working of electronic circuit, working and procedure, experimental and discussion.

Description of the magnetic float densitometer

The basic design and different components used in the densitometer are almost the same as given earlier[12], except few changes which were needed for the modification. Hence a brief description of magnetic float densitometer is as follows-

The blue fused glass, used at the lower end of the float earlier by Millero[12], was not giving clear visibility of the field so it is replaced by a fine platinum point. A light focusing arrangement is also made to view the tip of the platinum wire when it touches the bottom. This arrangement comprises of a light source and a telescope. For increasing the working efficiency of pull down and main solenoid, a ferrite core is also introduced at the centre of the brass support. The ferrite core concentrates the magnetic lines of force at the centre and thus provides sufficient magnetic attraction on the float to ease it to come down to the bottom in the solution container (Figure 1).

Description of push button and electronic –circuits

Push button-circuit

For changing the range and sensitivity of the instrument, the provision of three options for the number of turns in the main solenoid has been given. Three push buttons, each having six pins, are used to choose the number of turns (100, 200 or 700) of main solenoid. These three push buttons are coupled with each other in such a way that if one is pressed down, the down button automatically comes up as shown in Figure 2 in the push button block. One has to use only one of the above three options according to need. In the present case 700 turns were used in the main solenoid. The resistance bridge, used to change the current in the main solenoid, was inserted in the main line between main solenoid and push buttons. The values of the components used in the bridge are shown in Figure 2 and more clearly in Figure 4. The berg pot, R2, 0-2000 Ω was used as a 'Coarse' and R3, 0-100 Ω as ' Fine' adjustment of the float level.

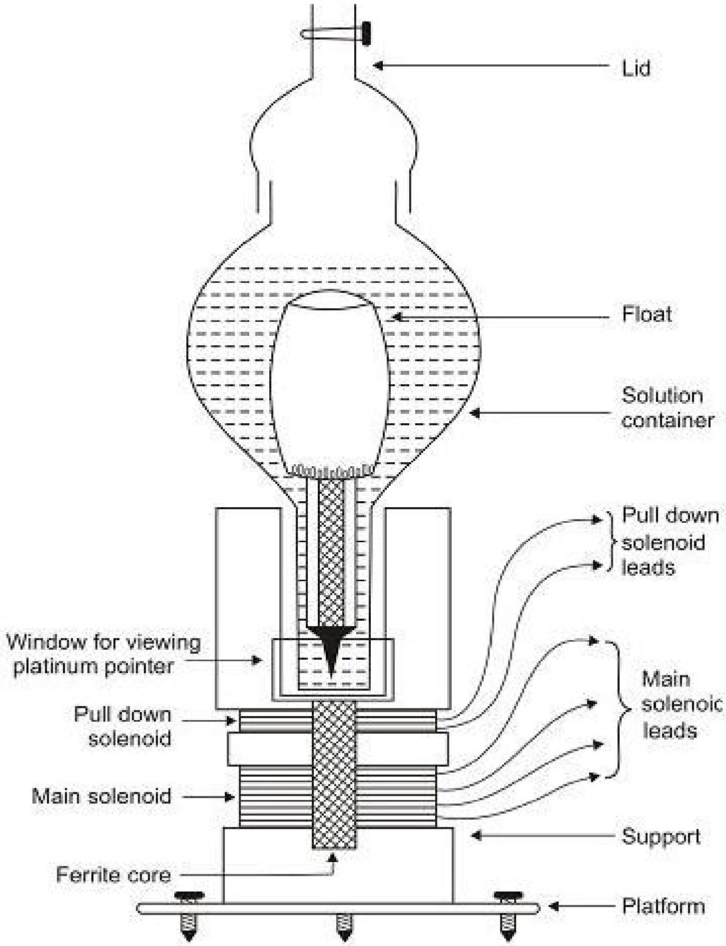

Figure 1 Modified magnetic float densitometer.

Electronic circuit

Figure 3:-

Details of components used: Main Transformer (T), Semiconductor diodes (D_1-D_8; No. IN406), Electronic relays (RLY-1 single switch & RLY-2 double switch; 5A,18V and 500 Ω each), Trigger transformers (TrT_1 and TrT_2), Red LED (R)– (L_1&L_2), Green LED (G) –(L_3&L_4), Semiconductor diodes (D_9-D_{18}; No. IN4007), Transistors (Tr_1&Tr_2 , PNP-Type, No.– BC557), Transistors (Tr_3 & Tr_4, NPN-Type, No.–BC547), Electrolytic condensers (C_1-C_6; 100µf and 40V & C_7-C_8; 1000 µf and 40V), Zener diodes (ZD_1 and ZD_2; No. 09V1 ST), Resistances R_1, R_2 =1K; R_3, R_4 = 4.7 K; R_5 - R_9 =1.1K; R_{10} = 200K (Tolerance ±5%, 0.25W); R_{11}, R_{12} =1K (Tolerance ±10%, 3W).

Working of electronic circuit

The working of the assembled circuit using above components can be explained as follows- As main switch is switched on, current reaches the primary coil of one of the trigger transformers TrT_2.The trigger transformer TrT_1 is connected to the mains through relay RLY-2 so it does not operate in the beginning while TrT_2, being directly connected to the mains, starts working. Thus TrT_2 transformer is always 'on' while TrT_1 transformer is controlled by the relay, RLY-2.

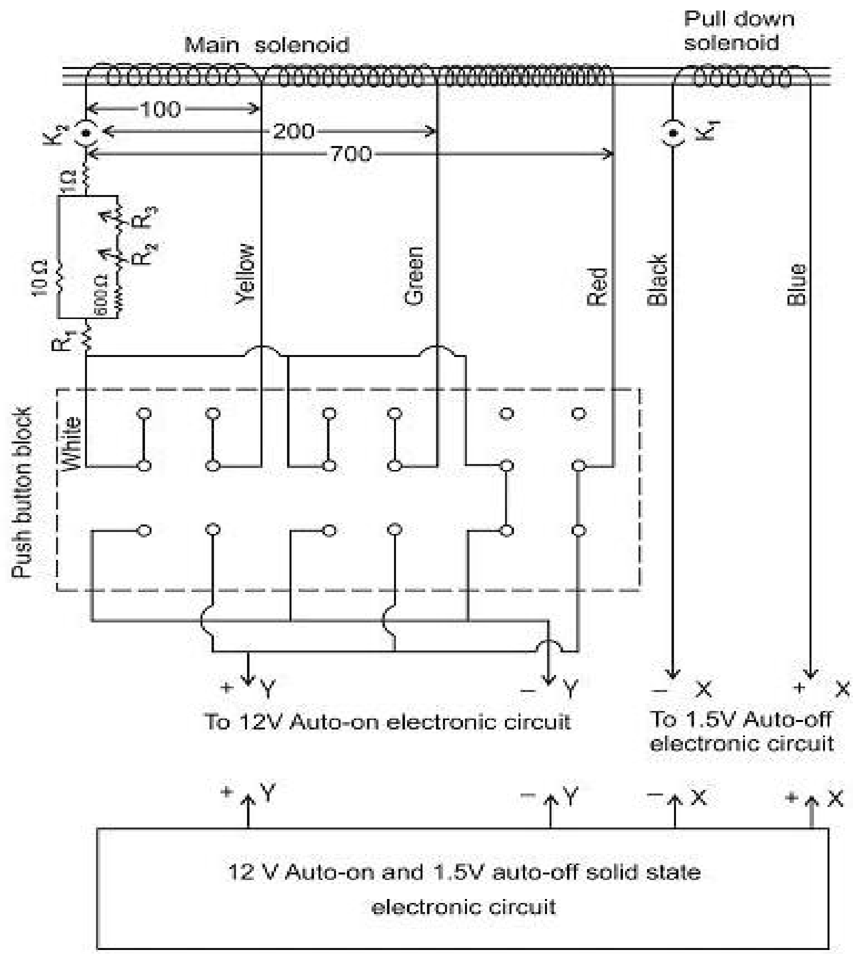

Figure 2 – Electrical and electronic circuit lay out for magnetic float densitometer.

At this time the current passes through Green LED (L_3) in the above circuit and through Red LED (L_2) in the lower circuit. Thus 1.5V output is obtained at points X-X (Green LED- L_3 is on) while no output is obtained at points Y-Y (Red LED- L_2 is on). Since current is flowing in TrT_2 trigger transformer, the lower belt of transistorized circuit becomes active. But due to delay time circuit composed of the capacitors and the resistors across the transistor Tr_4 (the delay period is about 20 sec.), it will trigger on the relay RLY-2 only after 20 sec. when the current reaches the coil of this relay. The triggering action of RLY-2, connects the points 1 and 2 & 4 and 5. The connection of 1 and 2 causes the current to flow through Green LED (L_4) while the Red LED (L_2) goes off. Thus at this time, 12V out put is obtained at Y-Y ends,(Green LED-L_4 is on). The 1.5V out put is still coming at X-X ends in the upper belt of the circuit. The connection of 4 and 5 causes the trigger transformer

TrT_1 to get energized and becomes 'on'. Thus the upper belt of the transistorized circuit now becomes active. This circuit has 10 sec. delay time due to the capacitors and the resistors across the transistor Tr_3. This means, though this circuit has become active , it will trigger on the relay RLY-1 only after a lapse of 10 sec. Till then both the out puts, 1.5V at X-X ends and 12V at Y-Y ends will be obtained. After 10 sec. the upper electronic circuit triggers the relay RLY-1, when the current passes in its coil. The triggering action of relay RLY-1, connects the points 7 and 8, which causes the current to flow through Red LED (L_1) and the Green LED (L_3) goes off. The out put voltage (1.5V) across X-X now stops (Red LED- L_1 - on, Green LED- L_3 -off). The 12V out put at Y-Y ends is still being received (Green LED- L_4- on and Red LED- L_2-off). As the time advances, the situation will remain unaltered for rest of the time. That is 1.5V circuit remains 'off ' and 12V circuit remains 'on'. X-X terminals of the electronic unit are connected to X-X ends of the pull down solenoid while the Y-Y terminals, to the Y-Y ends of the push button unit, which is subsequently connected to main solenoid through push buttons and the resistance bridge (see Figure 2 also).

As is clear from the above description, the electronic unit has been designed in such a way that when the main switch is switched on, 1.5V circuit becomes on and remains on for about 20 sec. then it automatically goes off. 12V circuit does not conduct initially and remains off for about 10 sec. then it starts conducting automatically. Thus about 10 sec. duration is common when both the circuits supply the current to the densitometer coils simultaneously. Thus the electronic unit works as 1.5V auto-off and 12V auto-on circuits. Once the 12V circuit becomes 'on', it remains on permanently till the observations are recorded. The pull down solenoid brings the magnetic float down into the region of main solenoid. Then the main solenoid takes the control of the float. Now the action of pull down solenoid is over.

Working and Procedure

The laboratory set-up for operation of magnetic float densitometer is shown in Figure 4. The modifications done in the instrument do not affect the mathematical working, so the detailed procedure is avoided here as it has already been given earlier elsewhere[15].

The instrument was calibrated before using it for measuring the density of the solutions. The calibration was done at 298.15 K with distilled water using following equation

$$w = -\left[\frac{f \times I}{(1 - d_{H2O}/d_{Pt})}\right] + \frac{(d_{H2O}\, V - W)}{(1 - d_{H2O}/d_{Pt})} \qquad (1)$$

Here w = Platinum weights used on the float , V = volume of the float, W = weight of the float (77.4240g), d_{H2O} = density of water[16] (0.997071 g/ml) and d_{Pt} = density of Platinum[17] (21.482 g/ml) at 298.15 K, f =weight equivalent of current (in g/A), I = current in main solenoid in ampere. A calibration curve was obtained by plotting 'w' against 'I' values. It came out to be a straight line, the float parameters ‘f ’and ‘V’ were calculated using equation (1), and came out to be as f =1.644 g/A and V = 82.365 ml. Once ‘f ’ and ‘V’ were known , the density of the solution was calculated using following equation

$$d = (W + w + f \times I) / (V + w / d_{Pt}) \quad (2)$$

‘I’ values were taken across 1 ohm standard resistance by measuring the voltage drop across it in mV which gave the ‘I’ values (in mA) directly.

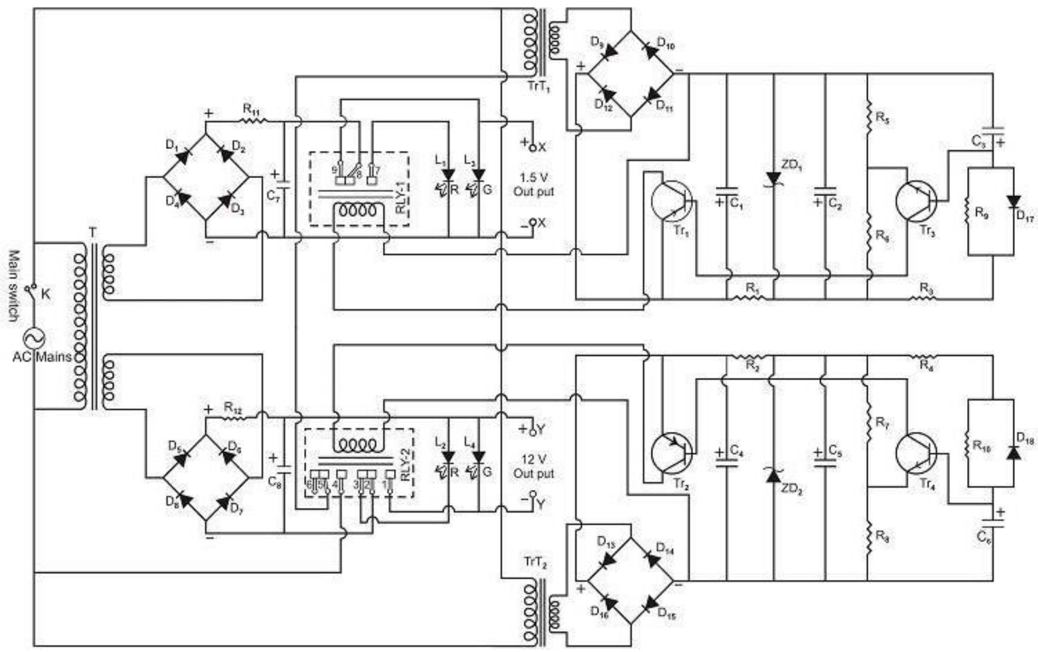

Figure 3 – 12V Auto-on and 1.5V auto-off electronic circuit.

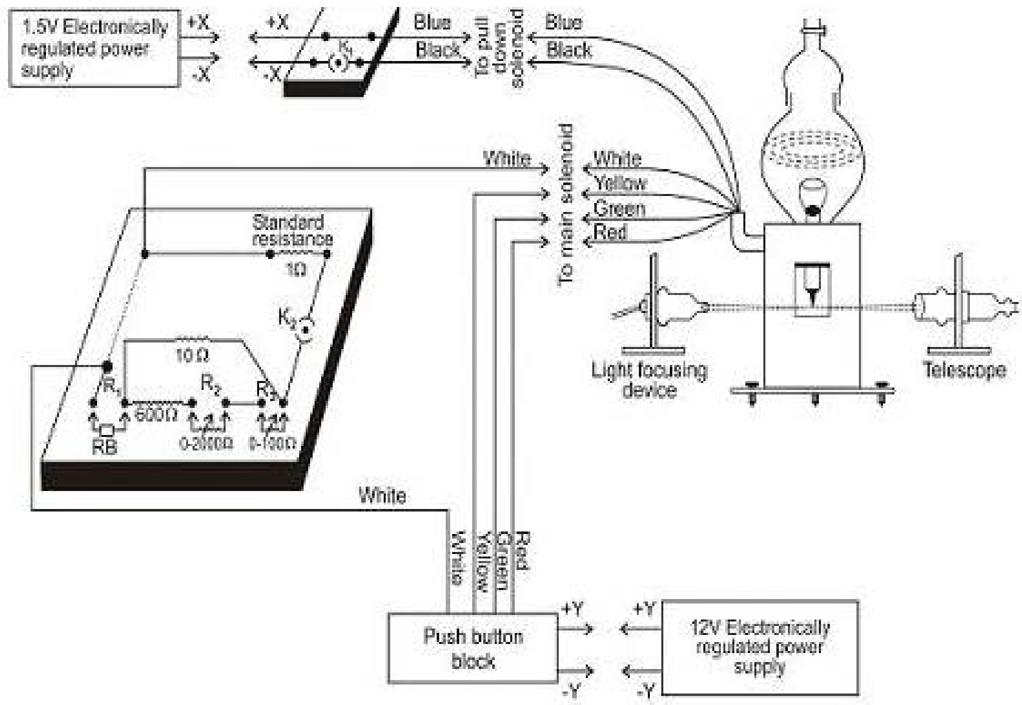

Figure 4 – Laboratory set up for the operation of magnetic float densitometer.

Experimental

After selecting the number of turns of main solenoid by push button block (here in our experiment the number of turns selected was 700; third push button down), the electronic unit (referring Figure3) was connected to 220V AC mains. Then the instrument was calibrated at 298.15 K by the method as explained above making use of electronic circuit. After calibration, the solution was taken in the solution container. The temperature of the solution was maintained at 298.15 K throughout the experiment by Toshniwal constant temperature bath to the accuracy of $\pm 0.01\ ^0$C. Some weights were put on the hovering float so that it was just about to sink in the solution. Then the electronic unit was switched on. When the 1.5V out put was switched off and the 12V out put was only in action, the different resistances in the resistance bridge were adjusted in such a way that the platinum point touched the bottom of the solution container. The observations were taken at this point of time. The weights and the corresponding current, flowing across 1Ω standard resistance, were noted down.

Discussion

The Millero's model [12] of magnetic float densitometer had blue fused glass attached to the bottom of the float. While doing experiment it was viewed by a magnifying glass. Here the design of the float is changed. The thick Pt-wire pointed at one end is fixed at the bottom of the float in place of blue fused glass. The light focusing arrangement, consisting of a source of light falling on the window in the form of focused beams, is fixed at one end and a telescope to view the Pt-point fixed at the opposite end. A ferrite rod is used to enhance the electrostatic force of attraction exerted by the coils on the float . The ferrite rod concentrates the magnetic lines of force at the centre and thus exerts greater force of attraction on the float . The push button unit has proved to be very useful in changing the number of turns of coils any time during the experiment, if one feels like so, without any disturbance just merely by pushing another button of one's choice. For this one does not need to disconnect or reconnect the wires. The Electronic unit, 'a 12V auto-on and 1.5V auto-off circuit', has made the magnetic float densitometer easier to use and more simplified. Only one switch starts sending currents in both the solenoids of the densitometer. One of the two circuits becomes auomatically off. This modification reduces the cost of the instrument and the maintenance. The electronic unit & push buttons are cheaper than lead accumulators and battery being used earlier. In addition to this, these require maintenance. The accuracy and precision of the instrument was verified by recording the density of some standard NaCl solutions. The values obtained are in good agreement with those obtained by Millero[12]. The density of those solutions can be determined by this instrument, whose density is greater than 0.940011g/ml, the density of the float. Another float is needed for measuring densities of solvents and solutions having density values lower than 0.940011g/ml.

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