# Monitoring of Intravenous Drip Rate

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*Abstract*—**A drip rate meter, for monitoring intravenous infusion, is developed using minimal number of circuit components. It is designed to work for different type of fluids used in IV infusion and drip chamber walls of different optical transmittivity. It operates with varying supply voltage from the battery without needing a regulator in order to conserve power.**

*Index Terms*—**drip photo sensing, intravenous infusion monitor, IV drip rate meter.**

## I. INTRODUCTION

During intravenous (IV) infusion of fluid, the flow rate is obtained as the product of the drip rate (fluid drops per minute) and the drip factor of the tubing (number of drops / ml). The drip rate is set by regulator on the tubing, and it is monitored by visually counting the drops over 15 or 30 seconds to work out the rate per minute The rate set by the nurse may change due to several reasons. It is affected by dilation or contraction of the patient's veins as they warm up. Tissue forming in the needle may block the flow. As the fluid volume in the bag reduces, the pressure due to gravity decreases and it results in a decrease in the drip rate. Every 15 to 20 minutes, a drip has to be checked to make sure it is flowing at the correct rate.

The drip chamber is generally transparent and a photo-sensor assembly clipped around it can sense the drops falling in it. A drip rate meter that senses the drops in the drip chamber and displays the drip rate is very useful for setting the desired drip rate as well as for monitoring. The meter may be a hand held device that the nurse uses for checking and setting the drip rate. For given tubing, each drop is of the same volume, and hence the instrument can monitor the total volume of fluid that the patient has received, or the fluid volume remaining in the bag. The instrument can be designed to give an alarm if the IV drip rate remains beyond the set limits of tolerance beyond a certain time, or when the fluid volume in the bag decreases below a set value.

## II. DESIGN APPROACH

A drip rate meter has been developed using minimal number of circuit components, using the techniques of microcontroller based embedded system design [1]. It can be used for monitoring the drip rate of different types of fluids used in IV infusion and drip chamber walls of different optical transmittivity. It is designed to operate with varying supply voltage from the battery without needing a regulator in order to conserve power.

Block diagram of a drip rate meter is shown in Fig.1. The sensor assembly clipped around the drip chamber senses the fluid drops in it. On one side of the cylindrical drip chamber, the sensor assembly has a red or infrared light source giving a light beam across to a photo-sensor on the other side. The beam is broken each time a drop falls, which results in a change in sensor output. Comparator output gives a pulse for each drop. Counter counts the number of clocks between successive pulses, as a measure of drip interval. The drip rate calculator averages the period count for a certain number of periods and converts it into drip rate, which is digitally displayed. Compared to visual counting, drip rate meter gives a much more accurate measurement, and its response time can be set to just a few drops, which is very convenient for monitoring the drip rate during its setting.

Variation in transmittivity of drip chamber wall and transmittivity of different fluids make it difficult to set a fixed reference input to the comparator. Obtaining the reference from low pass filtered output of the sensor can solve the problem. This also takes care of, to a certain extent, the variations in the sensor output due to variations in the light output from the source and the photo sensor sensitivity.
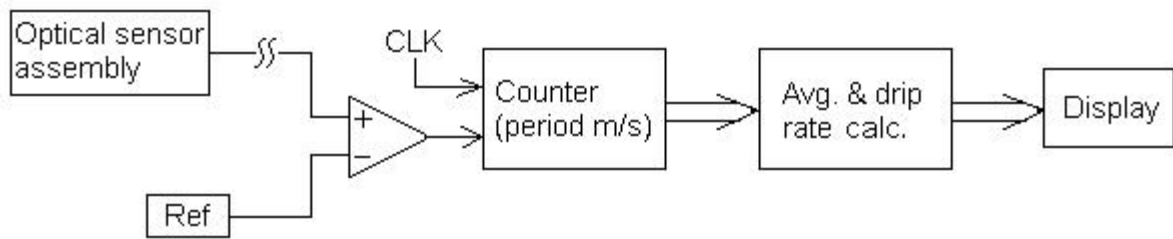
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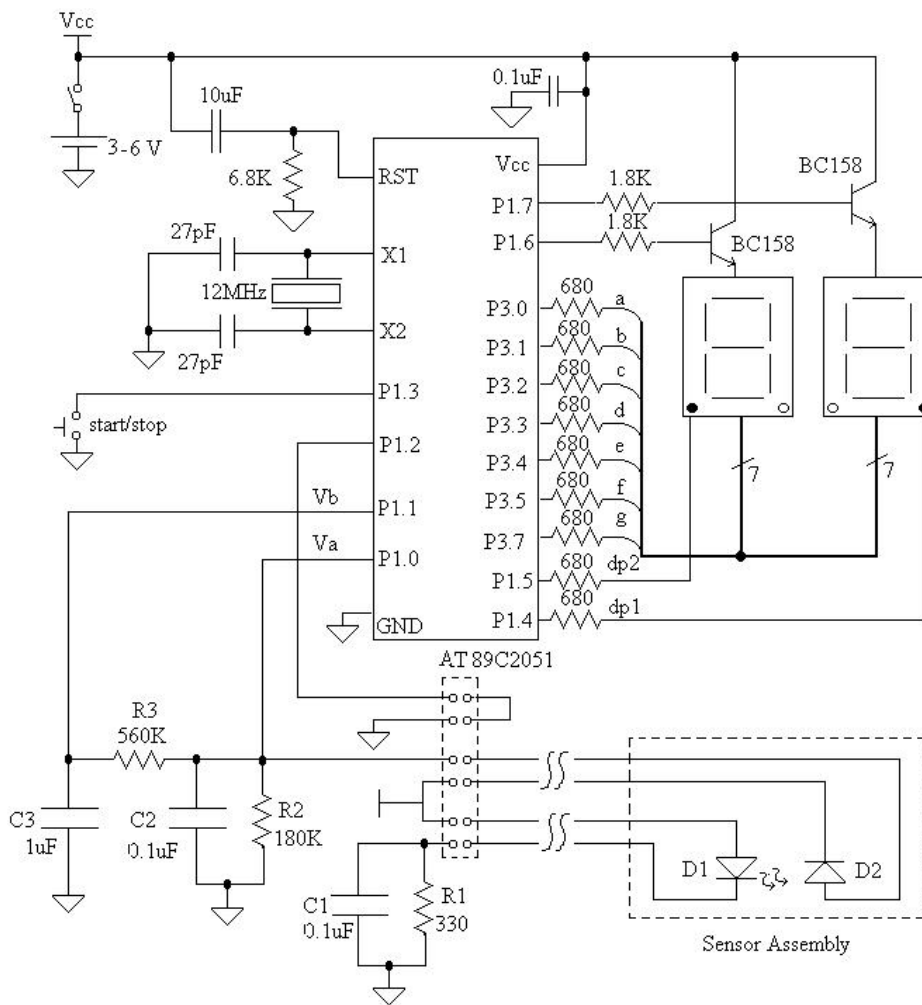
**Fig.1. Block diagram of a drip rate meter**



**Fig.2. Circuit diagram of the instrument**

Start:
> Initialize timer/counter T0 for periodic interrupts (every 6 ms) for "Display".
> Initialize timer/counter T1 for periodic interrupts (every 50 ms) for time interval measurement in stop watch / drip rate modes.
> Start timer T0 for display.

Mode Check:
> If mode input = high, clear status flag & go to "Stop Watch Mode".
> If mode input = low, set status flag & go to "Drip Rate Mode".

Stop Watch Mode:
> Check status flag. If high go to "Start" else check for P1.3 (start / stop pulse)
> If P1.3 low, complement status of timer T1.
> If timer is "OFF", hold display static "00".
> If timer is "ON", reset timing register, start timer T1 and store time in s in "stop watch display buffer".
> Poll for pin P1.3 (start / stop pulse).
> If low go to "Stop Watch Mode" else go to "Mode Check".

Drip Rate Mode:
> Poll for comparator output = low (drop in sensor voltage) for > 60 us.
> Turn on drop sense indicators (DP1, DP2).
> Store the period value in the old locations.
> Store the interval count as the new period value.
> Calculate the average of old period count and new period count.
> Calculate drip rate, rounded to integer in 0-99 range.
> Store result in "rate display buffer".
> Wait for 200 ms.
> Poll for comparator output = high for > 60 us.
> Turn off drop sense indicators (DP1, DP2).
> Check status flag. If high go to "Drip Rate Mode" else go to "Mode Check".

**Fig.3. Algorithmic description of the main program**

Display Subroutine:
> Check mode control pin P1.2.
> If "low", go to "Flagre".
> If "high", clear the status flag and check overflow flag.
> If overflow flag = 0, convert contents of "Stop watch display buffer" to BCD form and send it to port P1.
> If overflow flag =1, display "OL".

Flagre:
> Set status flag.
> Check the contents of "rate display buffer (3dh)". If value is greater than 100, display "OL" else convert the contents of "rate display buffer (3ch)" to BCD form and then send it to port P1.

**Fig.4. Algorithmic description of the display routine**

Timer0 (T0) Service Routine (for display):
        Load timer T0 with 6 ms count for display.
        Call display subroutine.
        Output the anode pattern on port P3.
        Output transistor base enable pattern on port P1
        Compare "decimal point indicator" register CH3.
        If CH3=01, set DP1 & and clear DP2.
        If CH3=02, clear DP1 & set DP2.
        If CH3=03, clear both DP1 & DP2.
        Check whether multiplexing cycle is over.
        If multiplexing cycle is over, go to "Ahead" else initialize the display to "00".
Ahead:
        Start timer T0 again.
        Return from the interrupt.

**Fig.5. Algorithmic description of timer T0 routine**

Timer1 (T1) Service Routine (for measuring interval):
        Load timer T1 with 50 ms count for measuring time interval.
        Start timer T1.
        Check for mode control pin P1.2.
        If pin P1.2 is "low", go to "Rate".
        If pin P1.2 is "high", update the "stop watch display" buffer.
        Check for overflow of "stop watch display" buffer.
        If overflow exists, increment "decimal point indicator" register (CH3).
        If CH3 = #04h, then set overflow flag else go to "Carry".
Rate:
        Increment LSB of "rate display" buffer (30h).
        If it overflows, increment MSB of "rate display" buffer (31h).
Carry:
        Return from interrupt.

**Fig.6. Algorithmic description of timer T1 routine**

### III. INSTRUMENT DESIGN

By using a microcontroller with appropriate number of I/O pins, internal program and data memory, and internal timer/counter, the operations of counting, drip accumulation or low pass filtering, drip rate calculation, and displaying can be handled by a single chip. Our instrument circuit has been designed using MCS-51 family [2] 20-pin microcontroller AT89C2051 [3]. In addition to meeting the requirements for digital I/O and processing, it has an internal analog comparator.

The instrument circuit is shown in Fig.2. The sensor assembly uses an infrared LED – photodiode pair to sense the passage of drops through the drip chamber. Use of infrared sensor reduces the effect of ambient light and also the effect of variation in transmittivity of different fluids. Normally the light from diode D1 after passing through the chamber is incident on the reverse biased photodiode D2 resulting in voltage $V_a$. When a drop passes through the chamber, the passage of light is interrupted, resulting in a voltage drop. Voltage $V_b$, obtained by low-pass filtering $V_a$ using R3-C3, serves as reference input to the microcontroller's internal analog comparator. Dipping of $V_a$ below $V_b$ results in a pulse at the comparator output.

Sensing of the pulse, 2-period moving average filtering, drip rate calculation, and result display are handled in software by the program loaded in the flash programmable on-chip ROM of the microcontroller. The instrument has two 7-segment LEDs with two decimal points. The drip rate in drops/min is shown as 2-digit integer. Sensing of each drop is indicated by glowing of the two decimal points. The displays are driven in scanned mode using microcontroller port pins [1], doing away with latches, decoders, and drivers.

An additional feature incorporated in the instrument is that it can also be used as a stopwatch with 0-399 s range and 1 s resolution, with a single push button providing start/stop input. Sensor assembly is connected to the electronic circuit via a 6-pin connector. As shown in Fig.2, two of the pins are shorted on the sensor side. These are used by micro- controller port pin P1.2 to detect the presence of sensor assembly and provide the mode input for setting the instrument in drip rate or stop watch mode.

The microcontroller used can operate over 2.7 - 6 V supply. The circuit is powered without a regulator to save on the battery power. The instrument can be powered by 4 pencil cells, dry or rechargeable. As the battery voltage decreases with time, the display gets fainter. No separate low battery indication is required.

An algorithmic description of the main program is given in Fig.3. The display is handled by a display routine, described in Fig. 4, that is periodically invoked at intervals of approximately 6 ms, by interrupts from timer T0. An algorithmic description of timer T0 is given in Fig 5.The program senses the mode input and branches to the stopwatch or the drip rate mode. Both the modes make use of timer T1 for measuring the interval and put the number to be displayed in the display buffer. An algorithmic description of timer T1 is given in Fig. 6 The display routine takes the value, decodes, and sets the display pins by scanning the two digits alternately.

### IV. CONCLUSION

The instrument is designed using the technique of embedded system design for achieving reliable operation with minimal number of circuit components. A prototype has been assembled, as a handheld device (with the circuit and batteries inside it) with a photo-sensor assembly to be clipped around the drip chamber. The instrument works satisfactorily for sensing the drops in the drip chamber and measuring the drip rate.

### REFERENCES

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