Hardware implementation of Airway pressure Monitoring system

Dr. Sunil Kumar Singla

Abstract: Pressure is one of the important parameters to be monitored and controlled in many situations such as in anesthesia ventilator. During the time of acute illness or indisposed state the human body is unable to follow the natural respiration process and thus compelled to undergo some artificial way of respiration. The exact amount of air is required during this respiration process. Thus the controlling and monitoring the airway pressure becomes very important. In this paper hardware implementation of airway pressure monitoring system of a ventilator has been discussed.

Keywords: **About four key words or phrases in alphabetical order, separated by commas.**

I. INTRODUCTION

Pressure is defined as force per unit area exerted by a fluid on the surface of the container. Absolute pressure is the fluid pressure above the reference value of a perfect vacuum or the absolute zero pressure. Gauge pressure represents the value of pressure above the reference value of the atmospheric pressure[1]. Pressure has several units such as centimeter of water, mm of Hg., N/m^2 , psi, etc. The relation between the different units is expressed as :

760 mm of Hg. = 101325 N/m^2 = 14.696 psi = 1041.30 cm of water

In the volume limited ventilators, the airway pressure differs from person to person depending upon the lung compliance and the air way resistance of the individual. Airway pressure is a very important parameter, as by observing its display the anesthesiologist can manually control the air way pressure to reach its maximum level. It also helps in calculating the other ventilatory parameters such as lung compliance and airway resistance.

The other advantages of measuring and displaying airway pressure are that it helps in monitoring the functions such as disconnection in the system, unrecognized leaks in the ventilator circuit etc. A sudden marked reduction in the airway pressure is an indication of leakage in the ventilator circuit. At the same time, a reduction in the airway pressure to the level of atmospheric pressure would indicate the disconnection of the device.

Dr. Sunil Kumar Singla is with Electrical and Instrumentation Engineering Department Thapar University Patiala, Email: sunilksingla2001@gmail.com

II. DESIGN REQUIREMENTS

The various requirements for the design of airway pressure monitoring system are:

Pressure range	=	0to +120 cm of water
Response time of sensor	=	10 ms
Resolution	=	5 cm of water, for graphic display
Time period	=	1 to 15 sec.
Display	=	Graphic
Function	=	Arbitrary

III. HARDWARE DETAILS OF DISPLAY SYSTEM

The block diagram used to display airway pressure of anesthesia ventilator is shown in Fig. 1. The detail of its various components is given below:

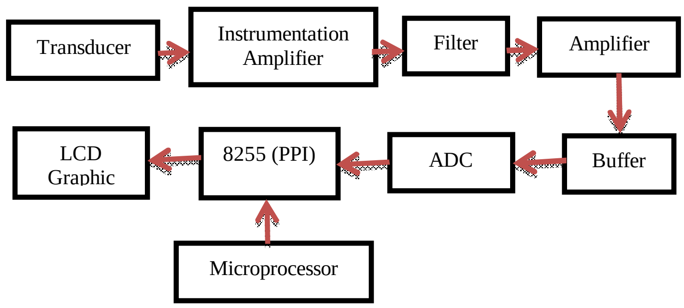


Fig. 1 Block diagram of Airway pressure monitoring system

A. Transducer

Transducer is the front end device which comes directly in contact with the quantity to be measured [2]. In ventilator display system, the choice of the transducer / sensor to measure the airway pressure, is very critical. Despite being capable of measuring the required pressure in the range of 0 to 1.71 psig or 0 to + 120 cm of water and having the required response time of 10 ms the transducer should have the properties of accuracy, high output, repeatability, long term stability, high input impedance, linearity, negligible hysteresis, temp. compensation, small size, etc.

The transducer should be chosen on the basis of its characteristics of stability, repeatability and response time, although it may give low electric output. One can have other transducers which may give higher output in volts, but they may have less stability of the order of ± 1% of FSO and repeatability of the order of ± 0.5 % of FSO. No doubt we need high output but the compromise cannot be made at the cost of stability and repeatability. Secondly, we can afford to have low electrical signal as it can easily be processed further.

B. *Instrumentation amplifier*

The output signal obtained from the transducer is of very low magnitude (from 0 to 17 mV). We thus need some amplification for its further processing. In case of precise low-level signal amplification where low noise, low thermal and time drifts, high input impedance and accurate closed loop gain are required the instrumentation amplifier is employed for the purpose of signal amplification [3]. In addition to the above, low power consumption, high common mode rejection ratio and high slew rate are the other features of an instrumentation amplifier. Circuit diagram of an instrumentation amplifier is shown in figure 2. There are two stages in an instrumentation amplifier. The first stage consists of two matched Op-Amps and offers very high input impedance to both the input signals. This stage also allows to set the gain. The input signals are applied to the non- inverting terminals of both the input Op-Amps as shown in Fig. 2. The second stage consists of only one Op-Amp. It is used as a differential amplifier with negative feedback.

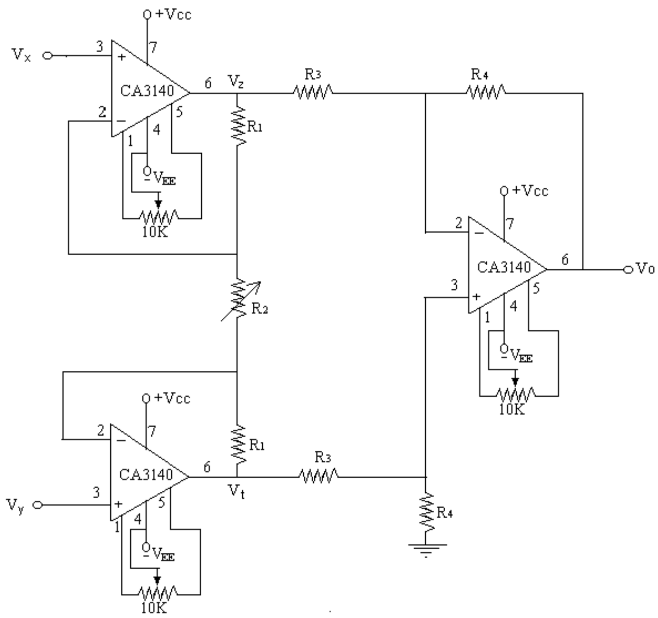


Fig. 2 Circuit diagram of an instrumentation amplifier[3]

The output of the operational amplifier is

$$V_o = \frac{R_4}{R_3}\left[\frac{R_2 + 2R_1}{R_2}\right](V_y - V_x)$$

B.1 Specifications

Input signal = 0-17 mV
Output signal required = 0 – 1.25V
Gain required = output/ input = 73

B.2 Design of instrumentation amplifier

Since we require a gain of 73 ,so

$$\frac{R_4}{R_3}\left[\frac{R_2+2R_1}{R_2}\right] = 73$$

Taking $R_4 = 100K$

& $R_3 = 10K$

We get , $\frac{R_4}{R_3} = 10$

Additional gain of 7.3 is to be provided by $\left[\frac{R_2+2R_1}{R_2}\right]$

Taking $R_1 = 27K$ then

$R_2 = 8.57\ K$

But a potentiometer (POT) of 20K has been used in order to have the flexibility in the design to achieve the required gain. In order to remove the offset a 10K POT is placed between pin No. 1 and pin No. 5 of each Op-amp and negative supply for the POT is taken from pin No. 4 is applied as shown in Fig 2.

C. *Filter Stage*

Filter is a device used to separate out the signals of undesired frequencies and to allow the signal of certain desired frequencies to pass [2]. In the present case time period of signal is 1 to 15 sec, so, maximum frequency of signal = 1 Hz. Thus, a low pass filter is required which will allow the signal of low frequencies to pass. So in this design active low pass filter with cut-off frequency of 20 Hz has been used. Fig. 3 shows the circuit diagram of the filter. The cut-off frequency (f_H) at which the gain of the filter rolls off at the rate of –40 dB / decade is

$$f_H = \frac{1}{2\pi\sqrt{R_1R_3C_2C_3}}$$

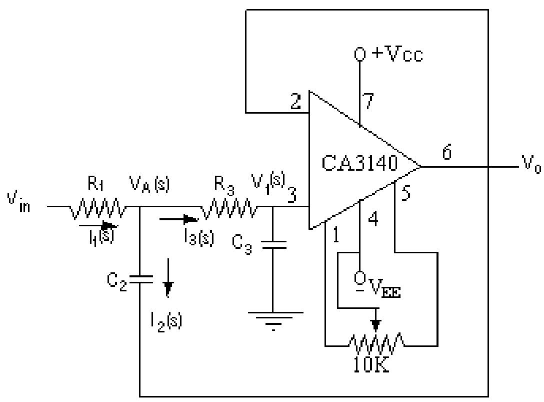


Fig.3 Circuit diagram of the Filter [2]

C.1 Filter design

Higher cut-off frequency f_H = 20 Hz

Taking $R_1 = R_3 = 20\ K$

& $C_2 = 2C_3$

Design equation:

$$f_H = \frac{1}{2\pi\sqrt{R_1 R_3 C_2 C_3}}$$

Substituting the values R_1, R_3, C_2 & f_H we get
C_3 = 0.28 µF and C_2 = 0.56µF

D. Buffer Amplifier

It is a unity gain amplifier also known as voltage follower. The circuit shown in figure 4 has a unity gain and very high input impedance. The input impedance is essentially the input impedance of the operational amplifier itself, which is about 0.5 tetra Ohm for CA3140. The output voltage is equal to the input voltage. In fact, the output voltage tracks the input voltage from positive to negative saturation. Current output is limited to the short circuit current of the operational amplifier and the output impedance is small, typically less than 100 Ohm.

The buffer amplifier is essentially an impedance matching device, which converts a voltage at high impedance to the same voltage at low impedance. The use of unity gain buffer amplifier reduces the loading effect in the measurement system.

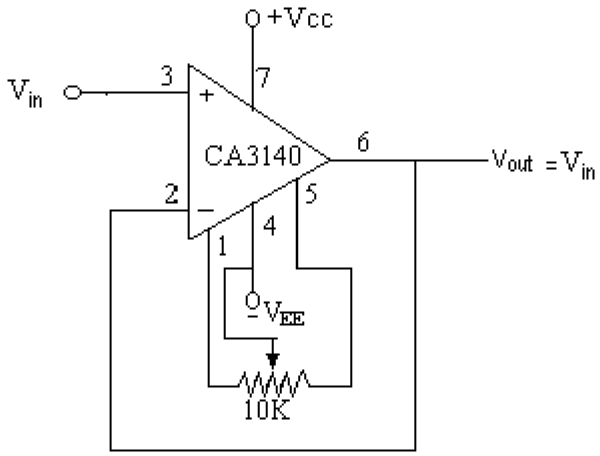


Fig.4 Circuit diagram of buffer amplifier [3]

E. Amplifier stage

The output signal of the instrumentation amplifier is in the range of 0 to 1.25 volts, for the full range of the pressure from 0 to +120 cm of H_2O. In order to have the signal of high magnitude we need to amplify this signal. Since, we are using the ADC 0808, which works satisfactorily in range up to 5 volts, we can amplify the signal by the factor of four. The operational amplifier in the non-inverting mode with feedback registers can be used for this purpose. The circuit diagram of operational amplifier in the non-inverting mode with feedback registers is shown in Fig. 5.

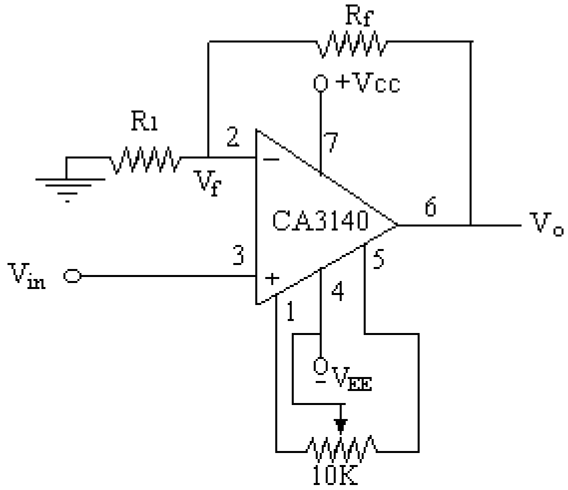


Fig. 5 Circuit diagram of non-inverting amplifier[3]

Output signal required = 5 V
Input signal to amplifier = 1.25 V
Gain required = 4

So $$\left[1 + \frac{R_f}{R_1}\right] = 4$$

Taking R_1 = 10 K
R_f = 30 K

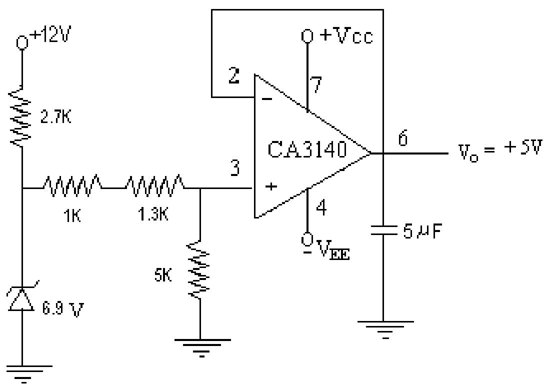
F. Programmable peripheral Interface (8255)

8255 is a programmable input-output device. It can be programmed to transfer data under various conditions from simple input-output to interrupt input-output. The 8255 has 24 input-output pins, which are divided into three ports of 8 pins each named port A, port B, and port C. Port A and port B bits can only be used in a group but the port C bits can be used as individual bits or can be grouped into four bit ports, C_{upper} and C_{lower} [4], [5].

G. Analog to digital converter (ADC)

The ADC 0808 is a 8-bit successive approximation analog to digital converter having 8-channel multiplexer and microprocessor compatible control logic. The 8-channel multiplexer can directly access any of the 8 single-ended analog signals. The ADC 0808 offers high speed, high accuracy, minimal temperature dependence, excellent long term stability and accuracy and consumes minimal power. It is a 28pin module having 8 pins (1 to 5 and 26 to 28) for the 8 channels [4]-[6]. The clock frequency is applied at pin no. 10 The clock frequency may vary from 10 Hz to 1280 kHz. Pin no. 6 is the start of conversion pin. When signal is applied to this pin, conversion starts and at the completion of the conversion pin no. 7 generates the signal giving indication of end of conversion. In order to have continuous conversion the start of conversion pin is connected directly to the end of conversion pin no.7. The pins numbering from 23 to 25 are used for the selection of the input channels. Pin no.

16 is the Ref. (-ve) pin which is connected to the ground. The voltage applied to the Ref. (+ve) pin number 12 is 5 V_{dc} and should be precise.



.

Fig.6 Circuit for obtaining precise reference voltage

The circuit shown in Fig.6 is a voltage stabilizing circuit, which will produce a precise +5V output voltage. The zener diode is of 6.9 V. When a voltage of +12V is applied as shown in the diagram, the voltage appearing at the non-inverting terminal of Op-Amp is +5V.

H. Oriole graphics LCD module

Oriole Graphics LCD module consists of LCD panel with CMOS LSIs for LCD driving. Since these modules have a full dot matrix graphic display, it is possible to display graphic as well as characters [7]. LCD Module 24064S has 240 X 64 dots.
The schematic diagram for interfacing the ADC and OGM LCD with the microprocessor is shown in Fig. 7

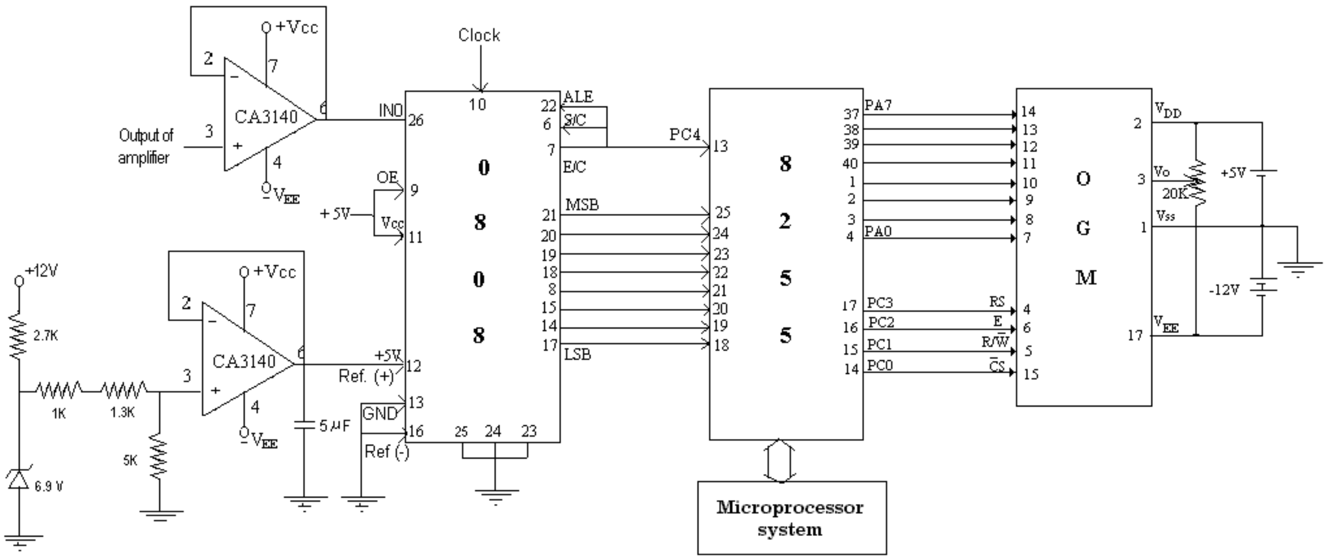


Fig.7 Schematic diagram for interfacing the ADC and OGM LCD with the microprocessor system

IV. Conclusion

Airway pressure remains a critical parameter to be monitored during the process of artificial respiration. In this paper a hardware implementation of the airway pressure monitoring system with all its practical aspects has been discussed. The system has been developed for a pressure range of 0 to +120 cm of water with a response time of 10 ms and resolution of 5 cm of water.

References

[1]. A K Sawhney, and Puneet Sawhney, Mechanical Measurements, Dhanpat Rai & Sons, New Delhi.
[2]. A K Shanwey, Electrical and electronic instrumentation, Dhanpat Rai & Sons, New Delhi.
[3]. Ramakant A Gayakward, (1995), Op-Amps. and linear integrated circuits, Prentice Hall of India Pvt. Ltd., New Delhi.
[4]. B Ram, (1996), Fundamentals of microprocessor and microcomputers, Dhanpat Rai & Sons, New Delhi.
[5]. Ramesh S Ganokar, Microprocessor architecture programming and applications, Wiley Eastern Ltd.,
[6]. http://www.ti.com/lit/ds/symlink/adc0808-n.pdf
[7]. http://www.docstoc.com/docs/96723106/ProjectReport1doc---Dept-of- EE_-IIT-Bombay

***Dr. Sunil Kumar Singla**: Born on Nov 3, 1976 in India. He did hisgraduation (with honors) in Intrumentation Engg from SLIET,Longowal, India in 1998. He did his post graduation Ininstrumentation and control from NITTTR (formally TTTI)Chandigarh in 2000. He did his Ph.D. in the field of Biometrics from Thapar University Patiala, India in 2011.He has 18 papers in various international and national journals of repute. Dr. Singla has 10 papers in various national and international conferences to his credit. His areas of interest are image processing, biometrics andVirtual Instrumentation.*