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Design and Development Efficient Pressure Generating System at Expiratory End in a Bubble CPAP System

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ABSTRACT: Application of Continuous Positive Airway Pressure (CPAP) in neonate with respiratory distress is associated with reduction of respiratory failure, reduced complications and mortality. Devices used to generate CPAP include conventional ventilators, the "bubble bottle" system and the infant flow driver. CPAP supports the breathing of preterm infants in a number of ways. It splints the upper airway and reduces obstruction and apnea, assists expansion of the lungs, and prevents alveolar collapse. But when we consider using Bubble CPAP system in Emergency Medical Services like Air Ambulance, it is extremely difficult to maintain constant back pressure created by bubbles in water bottle to the expiratory end of nasal prongs of an infant. So in order to provide constant back pressure, there is a need to replace water bottle which produce back pressure by bubble at expiratory end with a Electro-Mechanical constant pressure generating system. A Proportional solenoid valve based Electro-Magnetic Pressure Generator device is proposed, which produce constant back pressure of 5-10cmH_2O Pressure and Pressure versus Voltage relationship is studied which shows pressure generated is proportional to input Voltage.

KEYWORDS: bubble CPAP, Low Pressure Generation, Electro-mechanical device, Expiratory End.

1 INTRODUCTION

Acute respiratory infections are the leading cause of global child mortality. In the developing world, nasal oxygen therapy is often the only treatment option for babies who are suffering from respiratory distress. Without the added pressure of bubble Continuous Positive Airway Pressure (bCPAP) which helps maintain alveoli open, babies struggle to breathe and can suffer serious complications, and frequently death.

Continuous positive airway pressure (CPAP) is a non-invasive and spontaneous breathing form of positive ventilation. Bubble CPAP (**c**ontinuous **p**ositive **a**irway **p**ressure) supports spontaneous breathing by delivering a continuous, pressurized gas flow to an infant's airway. The gas is usually humidified air, enriched with oxygen, and is delivered to the infant's nose though a breathing circuit and nasal prongs. The pressure of the delivered gas is controlled by simply adjusting the depth of a partially submerged tube attached to the end of the infant's breathing circuit. B-CPAP may provide additional benefits over conventional nasal CPAP systems because as gas exits the submerged tube it forms bubbles that create small airway pressure oscillations. These oscillations are transmitted to the patient's lungs and are thought to improve gas exchange, enhance lung recruitment and reduce the work of breathing.

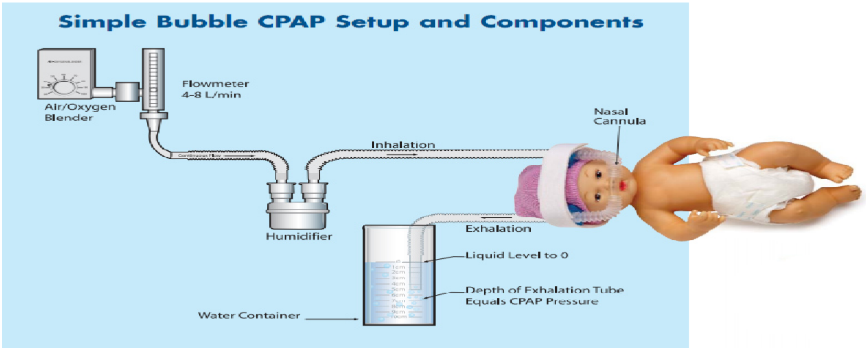


Fig.1: Infant under Bubble CPAP System

The vibration and pressure created by the combination of the humidified air and water column is why doctors like the CPAP system. A new born's lungs are sensitive organs and can be easily damaged by a mechanical ventilator. The CPAP opens the lungs without the use of the pressure created by the mechanical ventilator. The CPAP creates only the pressure needed to open the baby's lungs for proper air flow and, unlike a mechanical ventilator, it doesn't force a new born to breathe.

2 METHODOLOGY

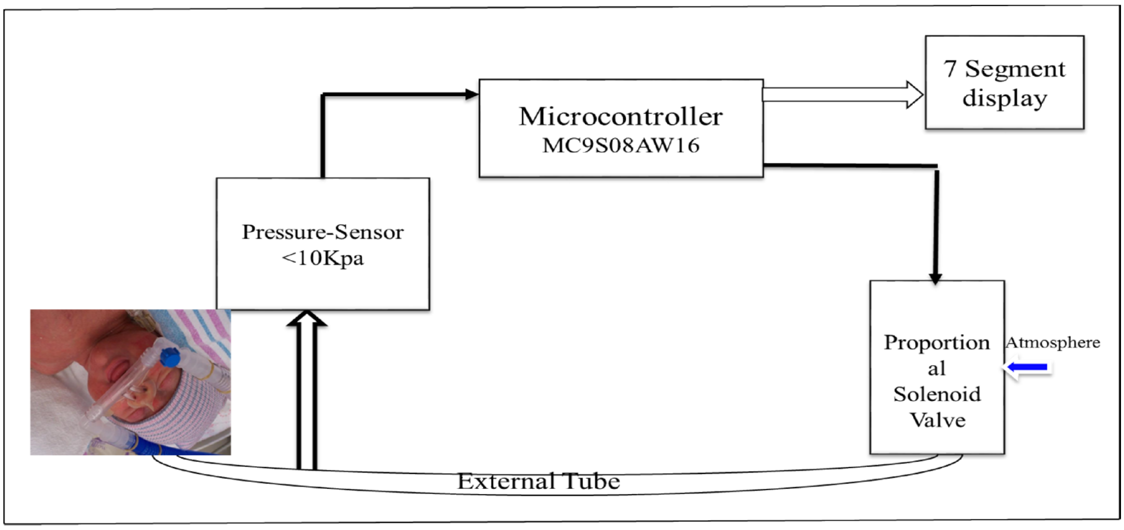


Fig.2: System Block Diagram

The block diagram below depicts the steps involved in the implementation of the project. Microcontroller digital ON or OFF output drive the Miniature Solenoid Valve and able to produce desired Pressure,

The Pressure Generated by normally opened Miniature solenoid Valve is validated by using differential Pressure Sensor. The output analog voltage from Pressure Sensor is converted into digital value using inbuilt 10 Bit-ADC. The ADC result is converted into appropriate standard Pressure Value and displayed in seven segment display.

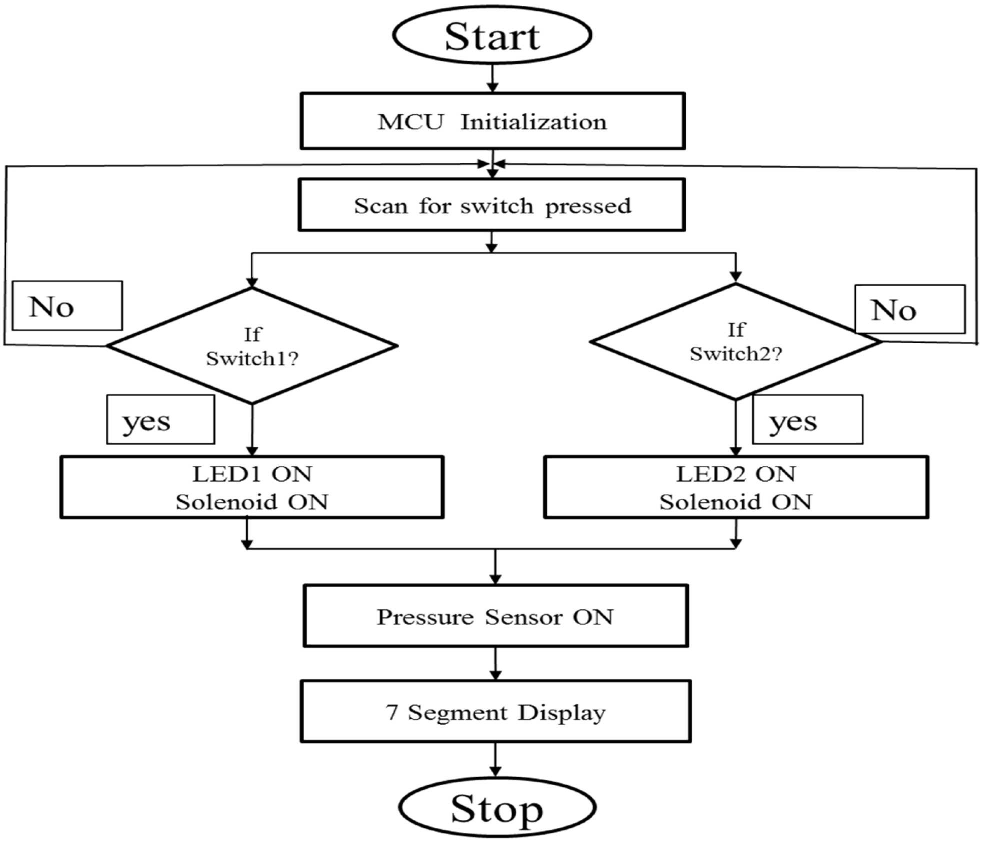


Fig.3.Flowchart

3 RESULTS

Stage-1

Initially, the pressure created by bubble in water bottle is measured by pressure sensor, the pressure sensor converts pressure into analog voltage. This voltage is given to ADC Pin of free-scale microcontroller and displayed in seven segment display.

The relation between Pressure and Voltage is studied and tabulated below

V_{out} = (5±1.275) (0.009x P)………………………………………………… (6.1)

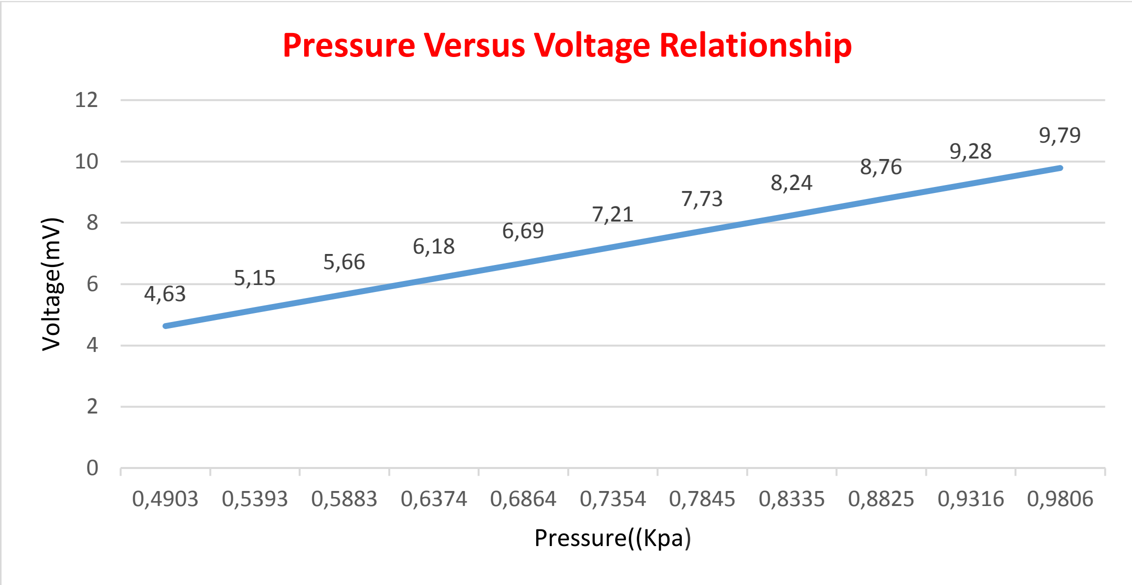
$P_{in\ KPA}$ = V_{out} + (.5) x 0.095 ……………………………………………… (6.2)

V_{out} = Output Voltage

$P_{in\ Kpa}$ = Pressure in unit Kilo-Pascal

Tabular Column of pressure and voltage reading

Pressure value in cm of water(cm H_2o) unit	Pressure value in Kilo-Pascal(Kpa) unit	Analog Voltage(mV)
5	0.4903	4.63
5.5	0.5393	5.15
6	0.5883	5.66
6.5	0.6374	6.18
7	0.6864	6.69
7.5	0.7354	7.21
8	0.7845	7.73
8.5	0.8335	8.24
9	0.8825	8.76
9.5	0.9316	9.28
10	0.9806	9.79



According to above graph, it can be shown that pressure and voltage are directly proportionally. So display of voltage value in seven segment display is directly proportional to pressure produce by 'bubble' in water bottle system.

Stage-2

Proportional solenoid valve is connected to pressure sensor and make it ON and OFF.

With altering delay in time (ms), we can able to achieve desired pressure which is equal to pressure produced by 'bubble' in water bottle.

Tabular Column of delay, pressure and voltage reading

Solenoid with different delay(ms)	Pressure value in Kilo-Pascal(Kpa) unit	Analog Voltage(mV)
15000	0.4903	4.63
14150	0.5393	5.15
13300	0.5883	5.66
12450	0.6374	6.18
11600	0.6864	6.69
10750	0.7354	7.21
9900	0.7845	7.73
9050	0.8335	8.24
8200	0.8825	8.76
7350	0.9316	9.28
6500	0.9806	9.79

4 CONCLUSION

In the Proposed model, efficient portable electro-mechanical pressure generating system for a bubble CPAP system is possible and constant pressure of about 5-10cm H2O (0.490-0.980Kpa) produced and is equal to pressure produced by 'bubble' in water bottle which is attached to an expiratory end of nasal prong attached to infant nose Thus these proposed system can be used as portable system in emergency medical system like air ambulance and makes maintenance easy compare to present bubble CPAP system .

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