NON CONTACT FIBER OPTIC BASED RESPIRATION RATE MEASUREMENT SYSTEM

Buchade P.B.[*]

Abstract: The respiration rate is the number of breaths a person takes per minute. It involves counting the number of breaths for one minute by counting how many times the chest rises. There is an increasing interest in the noninvasive monitoring of respiratory function, and particularly in the measurement of chest wall movements. In the present study the chest movement was sensed by fiber optic displacement sensor for the measurement of respiration rate. The respiration rate of the infants was measured. An enunciator gives correct indication of over and under respiration rate. When the pulses are less than 10 for 30 seconds there was continuous beep where as when the pulses were 20 or more than 20 there was intermittent beep.

Keywords: Respiration rate, Fiber optic sensor, Intensity modulation,Multivibrator.

* Abasaheb Garware College, Karve Road, Pune - 411004.

Introduction: The respiration rate is the number of breaths per minute or, more formally, the number of movements indicative of inspiration and expiration per unit time. In practice, the respiratory rate is usually determined by counting the number of times the chest rises or falls per minute. The aim of measuring respiratory rate is to determine whether the respirations are normal, abnormally fast, abnormally slow, or nonexistent. The rate is usually measured when a person is at rest. It involves counting the number of breaths for one minute by counting how many times the chest rises. Respiration rates may increase with fever and with other medical conditions. Respiration rates substantially higher or lower than the normal range indicates medical emergency. Normal respiratory rates, by age are as follows:

Table 1: Normal respiratory rates

Human being	Respiration rate per minute
Newborns	40-48
Infants	20-40
Preschool children	20-30
Older children	16-25
Adults	14 - 18

There is an increasing interest in the noninvasive monitoring of respiratory function, and particularly in the measurement of chest wall movements. Among these measures is the objective assessment of the asynchronous behavior of the rib cage and abdomen during breathing, allowing qualification of chest wall distortion [1,2]. In the present study the chest movement was sensed by fiber optic displacement sensor[3,4] for the measurement of respiration rate.

Operating principle:

The resulting change in chest movement due to respiration was converted into voltage pulse using fiber optic probe and allied electronic circuit. The total pulses generated for 30 seconds are counted and displayed using two-digit seven-segment display. Figure 1 shows the block diagram of respiration rate measurement unit. Fiber optic probe was mounted on a stand near the chest of the person whose respiration rate has to be measured. The chest functions as a reflector. Due to respiration the chest moved up and down and correspondingly the probe output changed. The change in output was converted into pulses using a comparator having suitable reference voltage.

The generated pulses were counted for 30 seconds in the present study. Two alarms, one for excessive low and the other for high respiration rate were set. If the respiration rate is less than 10 for 30 seconds the low alarm was made active and when it was more than 20 over respiration rate alarm was made active. The respiration rates in the range of 20 to 40 per minute were considered as normal and displayed without sounding any alarm. Provision is made in the circuit for adjusting the low and high alarm thresholds. The designed and developed circuit for respiration rate measurement is described in the next section.

Design and construction of the electronic circuit:

The respiration rate unit consists of a fiber optic reflex displacement sensor probe along with signal conditioning – a comparator with provision for avoiding false triggering, a mono- shot of 30 seconds duration, counter, display, magnitude comparator and alarm generation circuit. The circuit is designed , which generates voltages pulses for every time when person respires during 30 seconds. The one shots were designed using dual non-re trigger able one-shot IC 74LS221.

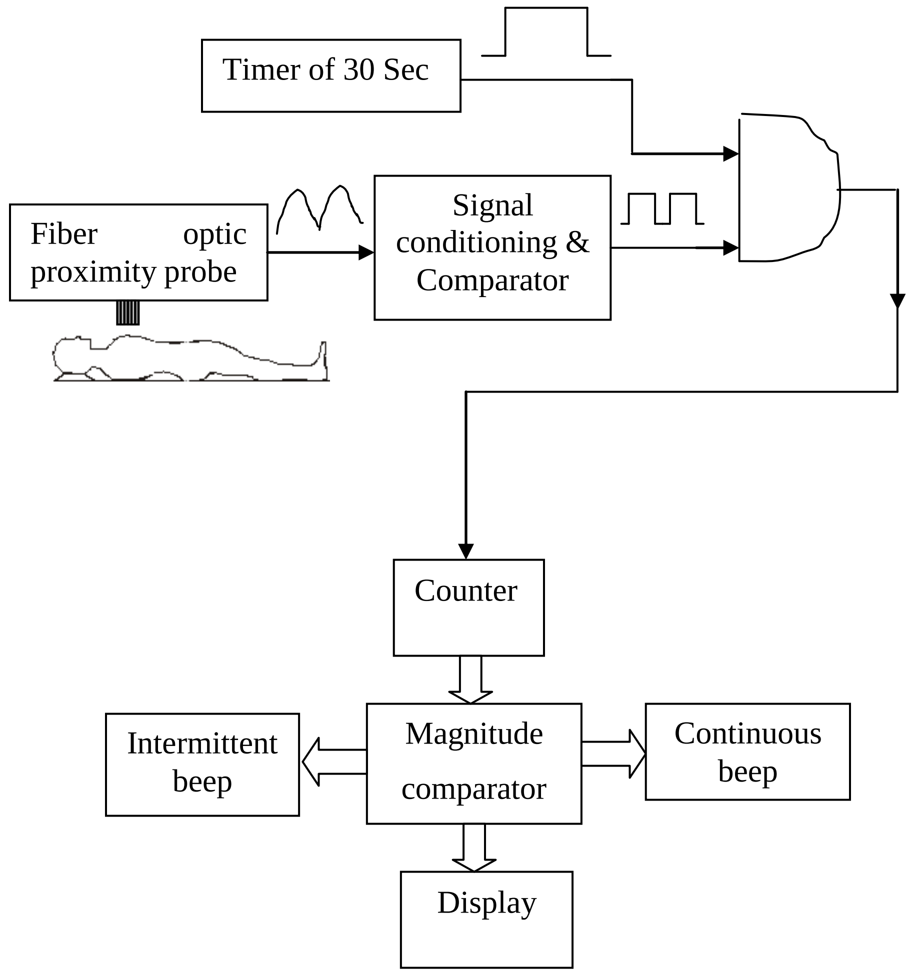

Fig.1: Block diagram of respiration rate measurement system

The quad OPAMP IC LM 324 and transistor 2N2222 generates a voltage pulse every time when chest moves up and down due to respiration. The pulse generated was fed to dual non-re triggerable one-shot IC 74LS221. The first one shot was designed for 0.5sec and triggered by the pulses from transistor T2. The purpose of this 0.5sec one shot was to avoid any false pulse generated by sensing circuit. Since respiration cannot produce a pulse earlier than 0.5sec. The second one shot was designed for 30 sec in order to count the respiratory pulses during this interval. The gating circuit was built using IC 7408 so that it passes the pulses only for 30 sec. The two-digit counter build using IC 7490 counts these generated pulses. The circuit for digital counter along with over and under respiration rate audio indicator is designed and build. The average respiration rate for newborns and infants is 20 to 40 per minute. Since the designed circuit counts the pulses for 30 seconds, the respiration rate of below 10 and above 20 for 30 seconds is abnormal and was indicated by designing an audio indicator circuit. After 30 seconds Q2 output from 74LS221 goes low, after inversion this pulse was used to set positive edge triggered D flip-flop with preset and clear facility. If the respiratory pulses were less than 10 for 30 second, the continuous beep was produced and if the pulses were 20 or above the intermittent beep was generated. Clearing the latch can stop the beep.

Experimental:

Figure 2 shows the unit of respiration measurement. To sense the respiration rate fiber optic probe is prepared. The probe consists of T-fiber and R- along with the signal conditioning circuitry [4]. Due to inhalation and exultation there is up and down movement of the chest/abdomen. The external intensity modulated fiber optic displacement sensor senses the reflected light from the reflector and the reflected light intensity is used for the estimation of the distance of reflector from the fiber tip. The fiber optic probe is mounted near the chest at a distance of 3 mm. Here the chest surface function as the reflector and due to breathing the distance between the fiber tip and chest changes. For one respiration there is single chest movement that is converted in to a pulse. The threshold of the pulse is set according to the reflectivity of the skin and ambient lighting. The distance between the fibers tip and body can be kept from 2 to 4mm since that being the linear range of the sensor and accordingly the set point of threshold changes. Due to respiration this gap changes and the circuitry produces a pulse. This pulse is then counted. A timer is set for 30 seconds and the resulting pulses during this time are displaced on two-digit seven segments LED display. The designed audio indicator indicates the abnormalities if any in the respiration by continuous or intermittent beep.

Fig.2 : Respiration rate measurement unit

Results and discussion:

The one shot multi-vibrator build using R1 = 71kΩ and C1 = 10µF with IC 74LS221 has timing of 0.497sec.The observed value is 0.5sec. The slight variation is due to component tolerance and measurement error. This value is not much critical since this duration is only to avoid false triggering of counter circuit. The one shot build using R2 = 428kΩ and C2 = 100µF with IC 74LS221 has timing of 30 sec. The observed value is also 30 sec on the stopwatch having least count of 1 sec.

The respiration rate of the infants was measured. An enunciator gives correct indication of over and under respiration rate. When the pulses are less than 10 for 30 seconds there was continuous beep where as when the pulses were 20 or more than 20 there was intermittent beep.

The distance between probe tip and the chest, skin reflectivity and the ambient light are the important parameters for the considerations. They can be addressed by properly adjusting the reference voltage of the comparator in the circuit. The instrument gave correct results as long as the baby position was steady. However false counting due to movement of the baby and the lack of proper steady adjustment of distance between chest and the probe was little critical.

Conclusion:

The application of fiber optic displacement sensor based respiration rate measurement unit are in agreement with the proposed theory. This developmental work can be used to commercialize various fiber optic sensors.

References:

1. **Tobin MJ, Jenouri G, Lind B, Watson H, Schneider** A, Sackner MA. Validation of respiratory inductance plethysmography in patients with pulmonary disease. Chest; 83 (1983) pp.615–620.

2. Sivan Y, Deakers TW, Newth CJL. Thoracoabdominal asynchrony in acute upper airway obstruction in small children. Am Rev Respir Dis; 142 (1990) pp. 540–544.

3. P.B.Buchade and A.D.Shaligram, ‘Simulation and Experimental Studies of Inclined Two Fiber Displacement Sensor’ Sensors and Actuators: A, 128(2006) pp. 312-316.

4. P.B. Buchade & A. D. Shaligram. Influence of fiber geometry on the performance of two-fiber displacement sensor. Sensors and Actuators: A, 136 (2007) pp. 199-204.