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MEDICAL EMBEDDED SYSTEMS

BRIDGING THE GAP BETWEEN MEDICAL & ELECTRONICS

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***Abstract*— embedded systems are popularly used terms in the automobile and telecommunication world. Medical field is often neglected in the study of embedded systems but we would like to bridge the gap of knowledge between the medical and electronic field. In this thesis, we would like to demonstrate some of our work that has been focused on the medical equipments and embedded systems. In regard of the same, we will discuss the following medical equipments to explain the use of embedded systems in the medical field.**

I. INTRODUCTION

In this thesis, we would like to bridge the gap between the electrical and the biomedical aspect of the devices. Many are unaware of the fact that the embedded systems are a core feature of the medical devices. Our different study backgrounds enable us to study the equipments and thereby prepare a concise thesis on it. Some features of embedded systems that make it the core element in the new age medical equipments are as follows:

a) Adaptable to meet individual need
b) Easy to use
c) Can work with external and environment sensors.
d) Power aware
e) Cost effective
f) Data Storage for further analysis and research

From the high profile equipments like MRI, CT, and PET to the small equipments like pulse oximeter, pacemaker, ECG, monitors all use embedded systems. We would like to demonstrate some of our research work that has been focused on design and analysis of medical embedded systems used in the medical devices.

A. FETAL MONITOR:

A foetal heart rate monitor as seen in fig no. 1 is a target application of digital stethoscopes. It provides an audible simulation of the heartbeat of a foetus inside the mother's womb and displays the number of beats per minute. Foetal heart rate monitors are increasingly being used in the home, allowing parents to listen to their baby's heartbeat.

Fig. No. 1: Foetal Monitor with the Doppler Probe

A fetoscope (a type of stethoscope) is the most basic type of external monitor. Another type of monitor is a hand-held electronic Doppler ultrasound device. These methods are often used during prenatal visits to count the foetal heart rate. A fetoscope or Doppler device may also be used to check the foetal heart rate at regular intervals during labor. Continuous electronic foetal heart monitoring may be used during labor and birth. An ultrasound transducer placed on the mother's abdomen conducts the sounds of the foetal heart to the embedded system. The rate and pattern of the foetal heart are displayed on the graphic LCD/TFT screen controlled by the microcontroller and printed onto special graph paper.

In the fig. No.2; the placement of the transducer used in the foetal heart rate monitor is shown. The transducer is pressed against the skin and moved around until the foetal heartbeat is located. You will be able to hear the sound of the foetal heart rate with Doppler or an electronic monitor. During labor, the foetal heart rate may be monitored intermittently or continuously, depending on your condition and the condition of your foetus. For continuous electronic monitoring, the transducer will be connected to the monitor with a cable. A wide elastic belt will be placed around your back to secure the transducer in place. The foetal heart rate will be recorded in the medical record. With continuous electronic monitoring, the foetal heart pattern will be displayed on a screen and printed onto graph paper.

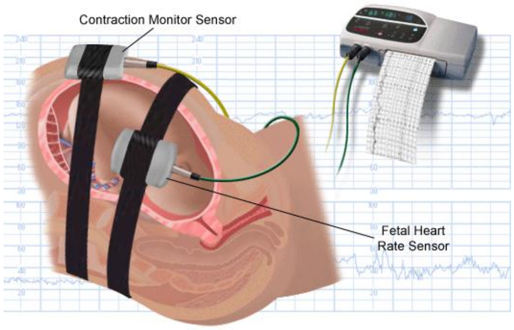

Figure No. 2: Placement of the Doppler Probe.

An ultrasonic probe is placed on the stomach of the mother. The fig No.3 illustrates the working of the fetal monitor. The sound waves received are conditioned and amplified. The user can input data to the embedded system and the desired data are displayed on the Graphic LCD. The data can also be sent to a different location with the help of wireless communication. This feature of embedded system helps in centrally monitoring the patients.

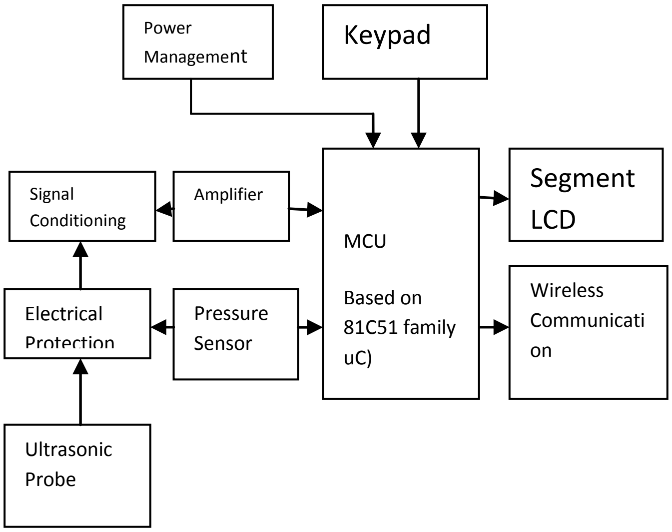

Figure No. 3: Block Diagram of Fetal Monitor

The Fetal Monitor is one of the applications of embedded system which is readily used by all the expecting mothers. With the use of foetal monitors, the doctors are able to administer successful deliveries. The expecting parents can use it at home also wherein the data about of the growing foetus can be sent to the doctors through the internet. This feature of embedded systems prove to be very useful as if any kind of complications occur, the doctor is informed well in advance.

B. PACEMAKER:

Pace makers is yet another application of embedded systems. As shown in fig. No. 4, pacemaker is a medical device that uses electrical impulses, delivered by electrodes contacting the heart muscles, to regulate the beating of the heart. The primary purpose of a pacemaker is to maintain an adequate heart rate, either because the heart's natural pacemaker is not fast enough, or there is a block in the heart's electrical conduction system.

Figure No. 4: Pacemaker

In the fig.5, it is shown where the pacemaker is placed in the body. The stimulus for the opening & closing of the valves is received at the right atrium and the right ventricles. Therefore when there is no stimulus received, the pacemaker senses the missing stimulus. The stimulus is given through the electrodes placed on the right atrium and right ventricle. Thereby, the beating of the heart is regulated. The pacemaker can have 2-3 electrodes based on the requirement of the patient.

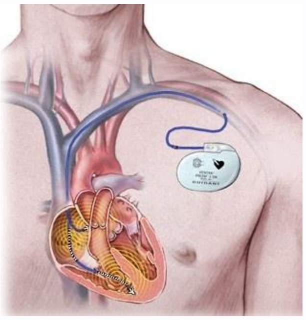

Figure No: 5 –Placement of the Pacemaker.

In the Figure No.6, the block diagram of the pacemaker is shown. The sensor placed on the heart valves detects any missing heart beat and thereby sends signal to the controller circuit. The Controller Circuit analyses the signal and then initiates the electrode system to stimulate the heart to produce the missed heart beat. The small tiny pacemaker has proved to have saved in numerous lives by providing the accurate heart beats. The pacemaker is a stimulating device that helps regulates the normal working of the heart. In some cases, three electrodes are placed depending on the patient requirement.

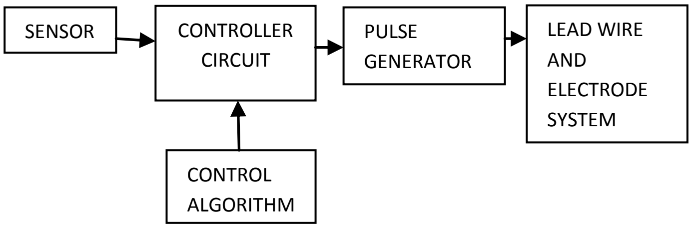

Figure No. 6: Block Diagram of Pacemaker

The pacemaker is proved to be a life saver device. Modern pacemakers are externally programmable and allow the cardiologist to select the optimum pacing modes for individual patients. The smaller the pacemaker, the more it is in demand.

C. PULSE OXIMETER:

Pulse oximetry as shown in the figure no. 7 is a simple, non-invasive method of monitoring the oxygen saturation of arterial capillary blood. It is now widely used in a number of healthcare settings and is often referred to as the fifth vital sign. The pulse oximeter is a convenient, cost-effective way to monitor the patient's oxygenation status and determine changes before they are clinically apparent. Pulse oximeter is available as hand held display as well as on a monitor.

Figure No. 7: Pulse Oximeter

For patients at risk of respiratory failure, it is important to monitor the efficiency of gas exchange in the lungs, ie how well the arterial blood is oxygenated (as opposed to whether or not air is going in and out of the lungs). Preferably, such information should be available to clinicians of a continuous basis (rather than every few hours). Both of these requirements can be met non-invasively with the technology of pulse oximetry. The technique is now well established and is in regular clinical use during anaesthesia and intensive care (especially neonatal intensive care since many premature infants undergo some form of ventilator therapy). Pulse oximetry is also being used in the monitoring of pulmonary disease in adults and in the investigation of sleep disorders. The oxygen saturation is estimated by measuring the transmission of light through the pulsatile tissue bed. This is based on the Beer-Lambert law:

Beer-Lambert law:

This is a combination of two laws describing absorption of monochromatic light by a transparent substance through which it passes:

Beer’s law: the intensity of transmitted light decreases exponentially as the concentration of the substance increases. Beer's Law is given by:

$$A=\ln(Io/I)$$

Isobestic point(Fig. No. : 8)

This is the point at which two substances absorb a certain wavelength of light to the same extent. In oximetry, the isobestic points of oxyhaemoglobin and deoxyhaemoglobin occur at 590 nm and 805 nm. These points may be used as reference points where light absorption is independent of the degree of saturation. Some earlier oximeters corrected for haemoglobin concentration using the wavelength at the isobestic points.

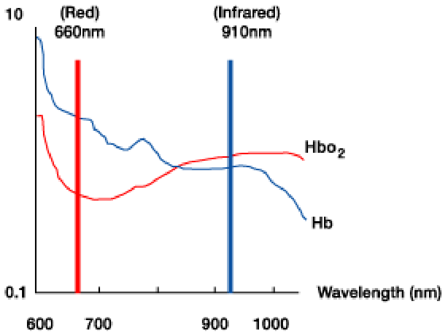

Figure No. 8: Isobetic point

This application is non-invasive because the optical sensor is composed of two LEDs that transmit light through the skin (finger or earlobe), as shown in fig. 9 below, to a photodiode. One LED is red with a wavelength of 660 nm and the other is infrared with a wavelength of 910 nm. The skin absorbs the light received by the photodiode. Each wavelength provides different data to calculate the percentage of haemoglobin. Deoxygenated and oxygenated haemoglobin absorb different wavelengths. Deoxygenated haemoglobin has absorption of around 660 nm and oxygenated haemoglobin has higher absorption at 910 nm. These signals depend on the actual blood pressure; therefore the heart rate can also be measured.

$$R = \frac{\log 10(\mathrm{Iac})\,\lambda\,1}{\log 10(\mathrm{Iac})\,\lambda\,2}$$

SaO2 as R

Iac= Light intensity at λ1 or λ2, where only AC level is present λ1 or λ2 are the wavelengths used.

In the figure No. 9 illustrates the block diagram of the pulse oximeter. The red and infrared light passes through the finger and the photodiode detects the signals. After these signals passed through the band pass filter, they are amplified and sent to the A/D converter. It is converted to digital and sent to the embedded system i.e. embedded system. The data are then sent to the monitor or 7segment display. The pulse oximeter has a RAM, where the patient data can saved for further review and analysis.

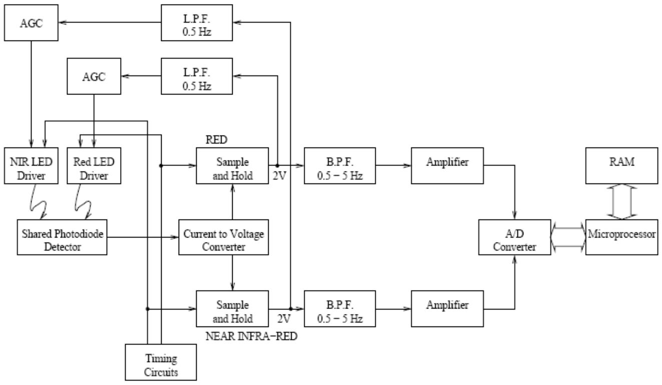

Figure No. 9: Block diagram of Pulse Oximeter

D. SYRINGE PUMP

Syringe pumps are required to administer small quantities of liquid medication (max. 50 ml) at low feed rates (normally up to 99.9 ml/h) with a high degree of accuracy and limited pressure. Syringe drivers are also useful for delivering IV medications over several minutes. In the case of a medication which should be slowly pushed in over the course of several minutes, this device saves staff time and reduces errors.

In the case of the syringe pumps, the intravenous solution is administered by the infusion system emptying a syringe and feeding it to the patient. The syringe volume (10, 20 or 50 ml) is continually transported by means of a linear feed drive (motor, gear and threaded rod). The linear feed drive can be used to empty one or more syringes, depending on the type of pump.

The most popular use of syringe drivers is in palliative care, to continuously administer analgesics (painkillers), antiemetics (medication to suppress nausea and vomiting) and other drugs. This prevents periods during which medication levels in the blood are too high or too low, and avoids the use of multiple tablets (especially in people who have difficulty swallowing). As the medication is administered subcutaneously, the area for administration is practically limitless, although edema may interfere with the action of some drugs.

The feed rate of syringe pumps as shown in figure no. 10 is directly proportional to the forward velocity of the piston, whereby the feed accuracy is mainly dependent on the construction of the linear drive.

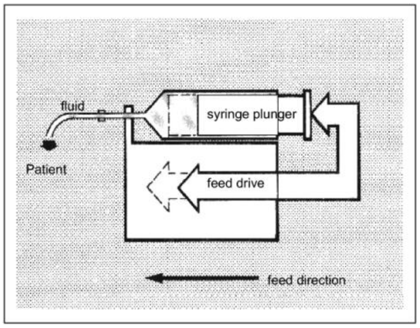

Figure No. 10: Syringe Pump Mechanism

Today's infusion pumps are equipped with a microprocessor-controlled precision drive which enables a feed accuracy of +/- 2%[5].As a result of the high feed accuracy, syringe pumps are mainly deployed in pediatrics and administering or dosing highly effective medications. Special syringe pumps, which have a high accuracy (up to +/- 1%), are used in order to administer analgesics and opiates. The so called PCA pumps (Patient Controlled Analgesia) as shown in fig. no. 11 enable the patient to control the administration of an infusion volume programmed by a doctor beforehand. The user interface of the infusion pump is locked following programming so that the patient has no opportunity of manipulating the machine.

Figure No. 11: Syringe Pump with PCA

In the fig no.12 the block diagram of the syringe pump is illustrated. With the help of keyboard, the flow rate and duration of the desired drug that is to be administrated is entered in the embedded system. Based on the given data, the motor drive is initiated for the linear pump displacement. The infused drug and the time are displayed on the display by the microcontroller. The syringe pump has various alarms like occlusion, end, near empty, battery low, etc.

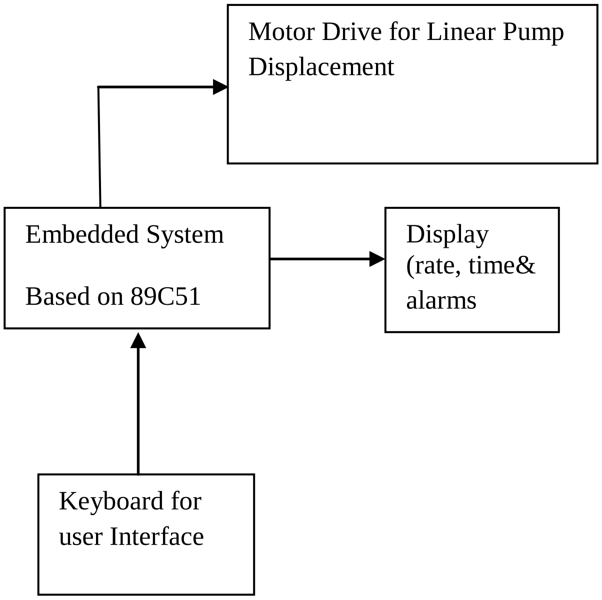

Figure No .12: Block Diagram of Syringe Pump

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