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AUTOMATION IN ANESTHESIA ADMINISTRATION USING FIELD PROGRAMMABLE GATE ARRAY

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Abstract –This paper concentrates on aiding anesthetist for administering anesthesia to the patient in a permissible rate. Administering anesthesia at a slight excess range may cause fatal effect to patient, so it is with the anesthetist to keep it in safe limit. In past few years the death toll due to improper anesthesia administration has increased, so it is high time to provide support to medical field in this aspect.

Keywords – depth of Anesthesia, biomedical parameters, FPGA – Field Programmable gate array, syringe infusion pump

I. INTRODUCTION

Patients are kept in unconscious stage during surgical procedure to avoid pain. Surgery may continue for few or several hours the anesthetic drug cannot be injected in high volume so the anesthetist takes care of injecting the drug to keep patient unconscious with good care. If dosage exceeds stipulated limit its fatal. If sufficient dosage is not administered the patient may not be in desired unconscious stage.

Administering low that set value may not keep patient in unconscious state for required time and over dosage may lead to patient death. So few milliliters can only be injected

In order to prevent such issues, the automationanesthesia injecting machine using field programmable gate array is effective. Through keypad amount of anesthetic drug to be injected is provided to the systemby anesthetist, and the injecting mechanism will administer the set dosage to the patient.

The four stages of anesthesia were described[2] [9],

- Stage 1 anesthesia, also known as the "induction", is the initial stage of loss of consciousness. During this stage patient starts transiting into unconscious state.
- Stage 2 anesthesia, also known as the "excitement stage", during this stage there will be uncontrolled changes in biomedical parameters and condition of patient hence this stage is made to pass quickly by providing addition drug that fastens the effect.
- Stage 3, "surgical anesthesia". During this stage patient is ready to undergo surgical procedure as the patient may not feel the pain. Biomedical parameters are stabilized and in safe zone
- Stage 4, "overdose". Results in death.

II. METHODOLOGY

A. Present Method

- Anesthetist checks the biomedical parameters of the patient.
- Anesthetist injects the drug into patient and monitors the parameters and watches over as the patient transit through stages to reach unconscious state. Different composition of anesthetic drug is chosen as per patient's medical record.
- He manages to keep the patient in unconscious state and in good condition throughout the surgical procedure.
- If over dosage of drug is administered that may lead to fatal effects and there may be some side effects after the surgery is complete which may affect the patient's day to day life. Certain effects may remain a scar throughout his life.
- The manual procedure relies completely on human characteristics and hence there may be random fault that may cause unpredictable effects.

B. Proposed Method

Automation is necessary to do an operation in controlled and defined way. In this automated system Field programmable gate array is used instead of processors, as it provides parallel processing and hardware reconfigurable. Multiple biomedical parameters like pulse oximetry signal, respiration rate, body temperature and EEG signal are monitored []. These signals are used to access the conscious level of patient. The system receives these signal analyze and administers the anesthetic drug to patient through syringe infusion pump whose pump movement is controlled by stepper motor rotation. Hence the amount of drug injected into patient is highly controlled and prevent over dosage. As a better approach bispectral index is considered.

C. Automatic Anesthesia Injector (AAI)

AAI is Automatic anesthetic drug injector, this automation system monitors multiple biomedical parameters and injects the set level anesthetic drug to patient in a controller manner avoiding any fault that may lead to over dosage. All time the system checks and keeps patient parameters in safe region. Thus protecting from future side effects and fatality.

The following is the functional block diagram of AAI system shown in the figure 1.

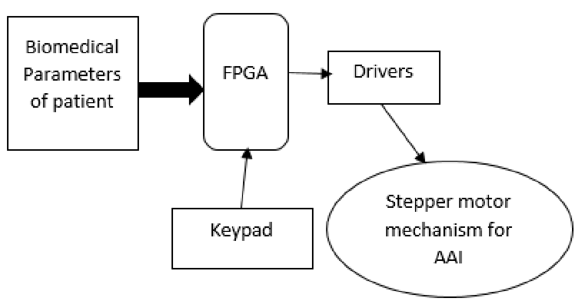

Figure 1. Block diagram of Automatic Anesthesia Injector

D. FPGA

A Field Programmable Gate Array can be configured by user.Hardware description language such as Verilog or VHDL is used to program FPGA. It can be used to perform several operations similar to ASIC or any other processor.It can be reconfigured any number of times this increases its application compared to ASIC [3].

FPGAs consists of logic blocks, interconnects, memory elements and global clock that can be used to implement any logic even processors core can be implemented using FPGA's. Their advantages and applications are vast as well as versatile

III. ANALYSIS

List of biometric parameters considered for monitoring [4],

- Body temperature
- Heart beat rate
- Respiration rate
- EEG

Depth of anesthesia monitored by using these parameters is precise and more accurate.

A. Monitoring Body Temperature

Before anesthesia, normal body temperature is 98.4F since the measure is obtained from skin surface it can be around 96 – 98F [7], body temperature is measured using LM35.Refer figure 2 for temperature dependent response of patient when in unconscious stage and in active stage. Body of patient responses when awake to very slight change in temperature.

When patient is anesthetized the responses to temperature change is gradual and temperature at which vasodilation and vasoconstriction occur has considerable difference [12].

During anesthesia the body temperature may increase or decrease according to the drug used and likewise respiration, rate and heartbeat will also be changing from its normal value.

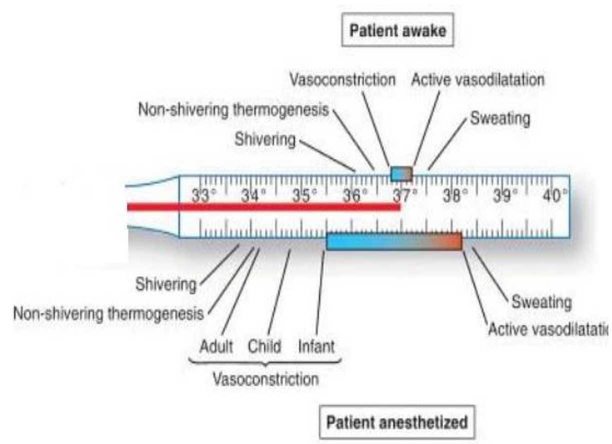

Figure 2. Conditions of patient when awake and anesthetized at different body temperature

B. Monitoring heart rate

Normal heart beat 72 per minute and respiration rate is 14- 16 per minute are considered to be normal [8].

Pulse oximetry is used to measure heart beat rate. This is placed either in patient finger or ear lobe where vessels activity can be sensed properly.LED and LDR are used to provide and pickup light that passes through the finger or earlobe.Theintensity of light varies as the blood vessels dilate and contract. If vessels are with low blood volume intensity of light is high.This variation in intensity is used in pulse oximetry to generate pulse that can provide heart rate.Heart rate can be measured accurately from the signal generate by pulse oximetry as well as respiration rate can be obtained by using special algorithm.

Considering the biomedical parameters like body temperature and respiration rate, EEG and ECG signals are difficult to obtain and several computation has to be made on the resultant signals to arrive accurate values that indicates the conscious level of patient.

C. Monitoring Respiration rate

Respiration rate is affected greatly due to the anesthetic drug and this is used to assess patient vital condition during anesthesia. Normal respiration rate of human is 14-16 per minute is considered to be normal it may reduce to 10-12 during anesthesia stage. Measurement is done using strain gauge type sensor tied around chest region by monitoring the variation in chest region during inhalation and exhalation.

C. Monitoring EEG

EEG is Electro encephalon graph that gives exact details of brain electrical activity from which patient condition can be monitored and analyzed effectively. As obtaining EEG signal by usual way is complicated only few electrodes are used and appropriate locations in the head region are decided after considering several biological aspectsto pick up brain wave effectively. During anesthesia stage the EEG signal frequency slows down and amplitude increase as shown in the figure 4.

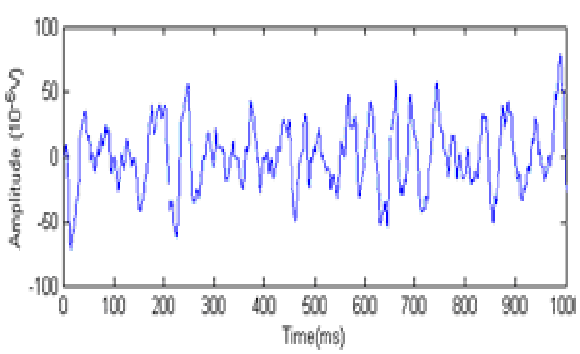

Figure 3. EEG Signal before injecting anesthesia dosage to patient

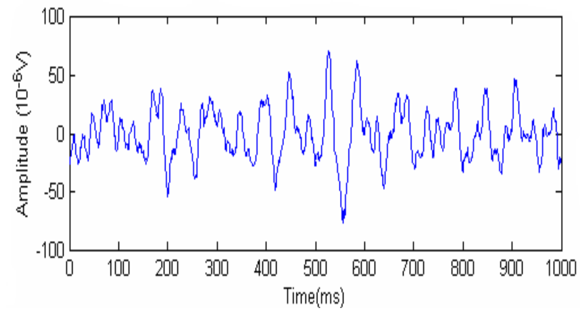

Fig.4 EEG Signals after injecting anesthesia dosage of anesthesia

D. Calculation of BIS

BIS is obtained from EEG signal after signal condition through sufficient filtering and removing undesired frequencies [6]. The unwanted artifacts may occur in the EEG signal that are not desired.The Cross correlation technique reduces such artifact as an initial process of the EEG epoch with a template pattern of an ECG waveform, secondly eye blink is detected, relying on their shape to match a template with cross correlation. Several filters are designed to remove undesired frequencies.

The bispectral index is calculated based on the Fourier transform of EEG data:

$$B(f_1, f_2) = |X(f_1)\cdot X(f_2)\cdot X(f_1+f_2)| \qquad (1)$$

$X(f_1)$,$X(f_2)\cdot$ are the values of EEG data at $f1$ and $f2$ infrequency domain.

Bispectral index (BIS)is complex parameter obtained from EEG signal that has time domain, frequency domain and high order sub parameters [5]. It isone of the several technologies to effectively monitor depth of anesthesia in patient. It is a value that ranges from 100 (awake) to 0 (isoelectric EEG).The BIS correlates patient responsiveness and thus able to obtain conscious state of person and how the patient is responding to the anesthetic drug can be monitored effectively. This helps the system to adjust the amount of anesthetic agent as per the patient needs. Refer figure no.5 for bispectral index level.

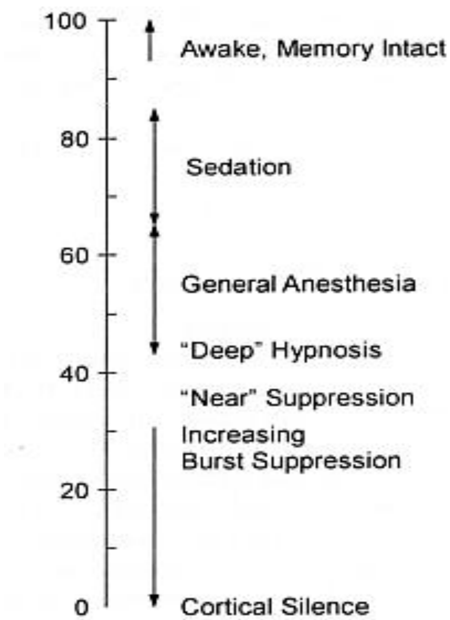

Figure 5. Bispectral Index obtained from EEG Signal

IV. RESULT

The multiple biomedical parameters obtained from patient body is then given to the hardware implemented in FPGA, the parallel processing access the data and process them in a much faster way as each parameter can be accessed and processed parallel. After analyzing the parameters, the mechanism is activated this in turn controls the syringe infusion pump. With more accuracy in injecting the amount of anesthesia to patient reduces risk of over-dosage and in turn its dreadful effects. Among the monitored parameters EEG is the most effective parameter and Bispectral index is considered to access the depth of anesthesia in patient [9] [10].

In the simulated output, first aninitial dosage is set to administer indicated by reset then the biometric parameters are monitored if the parameters are within safe limit the dosage is administered. Mostly the first dosage will be administered without any problem. when second dosage is ready to be administered the parameter are again monitored if the parameters are within normal range the dosage is administered. But still the patient cannot fell the pain he may be at the verge of gaining his consciousness. In the simulation the second dosage was failure because patient body temperature and pulse rate was abnormal which indicate the patient condition is not good to continue the operation anesthetist must see to this and bring the patient's condition back to normal.

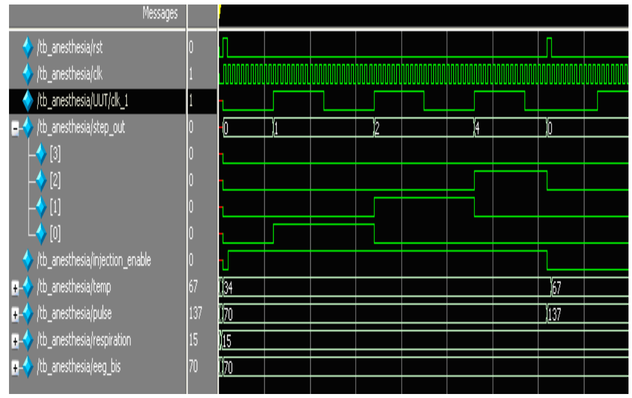

Figure 6. Simulated result for motor control signal generated by FPGA.

Stepper Motor

A stepper motor converts pulses into step wise rotation through which accurate and controlled horizontal motion can be attained. There is significant relation between electrical pulse and the motor step wise rotation. It is as similar as switching operation in electronic devices. Excitation of winding is controlled by providing values through FPGA which governs the step wise rotation of motor, this action is like switching operation of corresponding winding section. It has a wound stator and a non-exited rotor. Stepper motors are classified as 2-phase, 3-phase or 4-phase depending on the number of windings on the stator.

Syringe Infusion Pump

The Syringe infusion pump is designed in such way that it diffuses anesthetic drug into patient in a controlled manner. The amount of drug to be administered for each dosage is fed to FPGA through keypad as it may vary from patient to patient. By considering the number of rotation the amount of drug injected is computed and once it gets depleted an alarm is initiated to indicated that the drug in infusion pump is depleted. Any syringe varying from 1ml to 30 ml can be used. Since it accepts different size of syringe, flow rate can be varied.

Software Details

A program is required to be fed into FPGA [3], which will be used to configure the Logic Array Blocks according to the project needs. This is like emulating a hardware on an emulator. It favors parallel processing. Provides good performance and execution time is faster.

FPGA reads the biomedical parameters over a specific interval and checks for correctness of parameter values with the reference value that are entered in the program.

Calculate the stepper motor movement with the parameters provided by the sensors. Quartus is used to implement the design in Altera FPGA by creating a bit file that is loaded into the FPGA.

V. CONCLUSION

Multiple biomedical parameters are monitored and automation of the anesthetic agent injecting system is effectively controlled by field programmable gate array which provides hardware configurable parallel execution. Among the monitored parameters BIS obtained from EEG signal is effective in monitoring depth of anesthesia in patient as mentioned in papers [10]& [11]. Thus administering over dosage of drug to patient is controlled and patient is protected from various hazardous outcomes. As a future enhancement advanced methodologies of monitoring biomedical parameters can be adopted to effectively monitor the conscious level of the patient and can reduce the number of sensors exploited to gather the information of biological electrical activity happening in the body during anesthesia stages. This model effectively supports anesthetist to administer proper dosage of anesthetic drug to the patient.

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