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Biomedical Signal Monitoring and Anesthesia Injector Automation using FPGA

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ABSTRACT: This particular paper will be very much useful to physicians to see the current position of anesthesia level in patients. Automation of an anesthesia machine based on biomedical parameters of patient using FPGA. The level of anesthesia should be monitored carefully and the impacts in patient are monitored by monitoring their biomedical signals with much more accuracy. There are several ways to monitor these parameters effectively and various other derived values from these signals may be used effectively in sensing the patients status and may be used to keep them in surgical anesthesia stage by administering proper dosage of anesthetic agents.

KEYWORDS: depth of Anesthesia, biometric parameters, FPGA, syringe pump

I. INTRODUCTION

In the hospitals when any major operation is performed, the patient must be in anesthetize condition. If the operation lasts for a long time, say for suppose for 4 or 5 hours, complete dose of anesthesia cannot be administered in a single stroke. It may lead to the patient's death. If lower amount of anesthesia is administered, the patient may wakeup at the middle of the operation.

To avoid this, the anesthetist administers few milliliters of anesthesia per hour to the patient. If the anesthetist fails to administer the anesthesia to the patient at the particular time interval, other allied problems may arise.

To overcome such hazardous problems the design of an automatic operation of an anesthesia machine based on a micro-controller is effective. In this system a keypad is provided along with the microcontroller and syringe infusion pump. The anesthetist can set the level of anesthesia in terms of milliliters per hour to administer anesthesia to the patient with the help of keypad.

The four stages of anaesthesia were described,

- Stage 1 anaesthesia, also known as the "induction", is the period between the initial administration of the induction agents and loss of consciousness. During this stage, the patient progresses from analgesia without amnesia to analgesia with amnesia. Patients can carry on a conversation at this time.
- Stage 2 anaesthesia, also known as the "excitement stage", is the period following loss of consciousness and marked by excited and delirious activity. During this stage, respirations and heart rate may become irregular. In addition, there may be uncontrolled movements, vomiting, breath holding, and papillary dilation. Since the combination of spastic movements, vomiting, and irregular respirations may lead to airway compromise, rapidly acting drugs are used to minimize time in this stage and reach stage 3 as fast as possible.

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- Stage 3, "surgical anesthesia". During this stage, the skeletal muscles relax, and the patient's breathing becomes regular. Eye movements slow, and then stop, and surgery can begin. It has been divided into 4 planes:
 1. eyes initially rolling, then becoming fixed
 2. loss of corneal and laryngeal reflexes
 3. pupils dilate and loss of light reflex
 4. intercostals paralysis, shallow abdominal respiration, dilated pupils
- Stage 4 anaesthesia, also known as "overdose", is the stage where too much medication has been given relative to the amount of surgical stimulation and the patient has severe brain stem or medullar depression. This results in a cessation of respiration and potential cardiovascular collapse. This stage is lethal without cardiovascular and respiratory support.

II. METHODS

A. Present Method

At present anesthetist controlled manual operation is employed, which may cause many difficulties such as,

- Level of anesthesia may get varied and there is a chance of getting side effects in future.
- If suppose the anesthetist fails to administer the level of anesthesia during the predetermined period, the patient may be disturbed during the operation.
- Other systems developed to administer anesthesia operates by sensing the consciousness level of the patient and not by measuring his overall body conditions.

B. Proposed Method

Now days, embedded systems are used in many applications in medical field for controlling various biomedical parameters. In this design, a FPGA is used for controlling the anesthesia machine automatically, depending upon the various biomedical parameters such as body temperature, heart rate, respiration rate etc.

Major operations are performed to remove or reconstruct the infected parts in the human body. These operations lead to blood loss and pain. Therefore it is necessary to arrest the pain and the blood loss. Anesthesia plays important role in the part of painkilling. Hence, anesthesia is very essential in performing painless surgery. Advantages of using the proposed system are,

- Great guide for an anesthetist
- Level of anesthesia is not varied, so the future side effects are eliminated.

C. Automatic Anesthesia Injector (AAI)

AAI can be defined as "Automatic administration of anesthesia based on the bio-medical parameters of the patient, eliminating future side effects and the need for an anesthetist."

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Anesthesia is very essential in performing painless surgery and so an Automatic administration of Anesthesia is needed for a successful surgery.

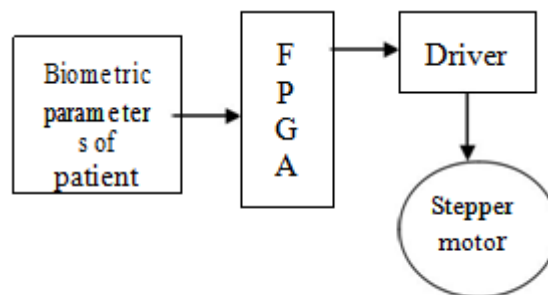


Fig 1. Block Diagram

D. FPGA

A field-programmable gate array (FPGA) is an integrated circuit designed to be configured by the customer or designer after manufacturing—hence "field-programmable". The FPGA configuration is generally specified using a hardware description language (HDL), similar to that used for an application-specific integrated circuit (ASIC) (circuit diagrams were previously used to specify the configuration, as they were for ASICs, but this is increasingly rare). FPGAs can be used to implement any logical function that an ASIC could perform. The ability to update the functionality after shipping, partial re-configuration of the portion of the design and the low non-recurring engineering costs relative to an ASIC design (not withstanding the generally higher unit cost), offer advantages for many applications.

FPGAs contain programmable logic components called "logic blocks", and a hierarchy of reconfigurable interconnects that allow the blocks to be "wired together"— somewhat like a one-chip programmable breadboard. Logic blocks can be configured to perform complex combinational functions, or merely simple logic gates like AND and XOR. In most FPGAs, the logic blocks also include memory elements, which may be simple flip-flops or more complete blocks of memory.

III. ANALYSIS

- List of biometric parameters considered for monitoring,
 - Body temperature
 - Heart beat rate
 - Respiration rate
 - EEG (Bispectral Index)

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

Before anesthesia, normal body temperature is 98.4F since the measure is obtained from skin surface it can be around 96 – 98F; similar way heart beat 72 per minute and respiration rate is 14- 16 per minute are considered to be normal.

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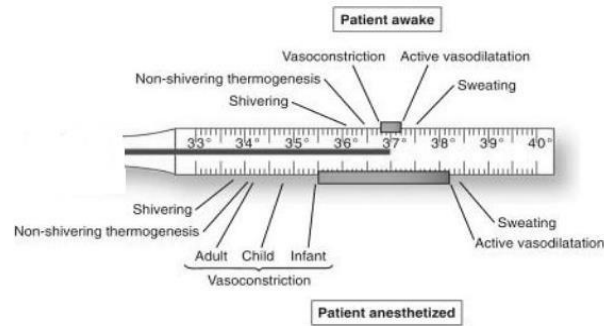


Fig.2 Body Temperature conditions

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.

Heart rate is our body's way of telling how hard it is going. It is very vital that heart beat has to be in normal while administering anesthesia to the patient. Normal heart beat is 72 beats per minute. A sensor is designed for monitoring the changes in the heart beat of the human body. The *pulse signal* refers to the flow of blood that passes from the heart to the limbs and the peripheral organs once per beat. Usually, the physician looks for the pulse on the wrist of the patient. The artery is near the surface of the skin and hence easily palpable.

When a patient places his finger in between LED and LDR the light is restricted by the finger. The intensity of light penetration decreases if the blood is pumped into the finger. If the blood is not pumped then the light intensity is high. This high and low light intensity helps to measure heartbeat.

Actually light falling on LDR cuts due to blood movement. The duration of light disturbed is measured which gives the time duration of each heart beat pulse, inverse of this time gives the heartbeat count per minute.

Respiration rate decreases with an increasing anesthetic depth.

EEG –Electroencephalograph is the recording of electrical activity along the scalp produced by the firing of neurons within the brain.

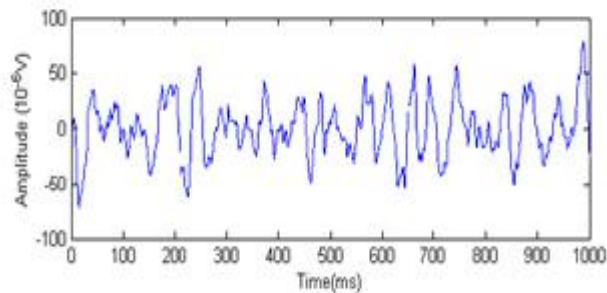


Fig. 3 EEG Signals before infusion (SychnFastSlow = - 7.8,B-Ratio =1.92)

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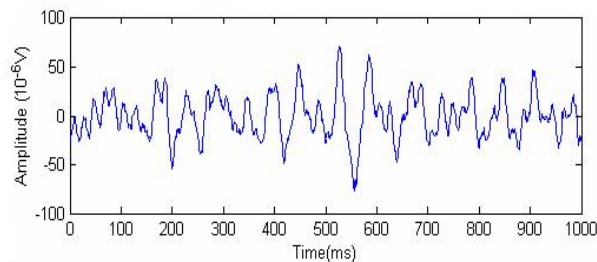


Fig.4 EEG Signals during anaesthesia (SynchFastSlow = -9.2, B-Ratio = -2.7)

sense that it integrates several disparate descriptors of the EEG into a single variable, based on a large volume of clinical data to synthesize a combination that correlates behavioral assessments of sedation and hypnosis, yet is insensitive to the specific anesthetic or sedative agent chosen. It is a numerical index, ranging from 100 (awake) to 0 (isoelectric EEG). The BIS correlates well with the level of the responsiveness (responsiveness scores of modified observer's assessment of alertness/sedation level) and provide an excellent prediction of the level of consciousness with propofol, midazolam and isoflurane anaesthesia.

A. Calculation of BIS

The calculation of BIS begins from sampled EEG data that is filtered to exclude high- and low-frequency artifacts and divided into epochs of 2-s duration. Then the signals are filtered to remove artifacts. The first phase of artifact handling uses a cross correlation of the EEG epoch with a template pattern of an ECG waveform. Next eye blink event are detected, again relying on their stereo typical shape to match a template with cross correlation. Surviving sweeps are checked for wandering baseline, and if this is detected, additional filtering to reject low frequencies is applied.

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

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

$X(f_1)$, $X(f_2)$ are the values of EEG data at f_1 and f_2 in frequency domain.

Bispectral index (BIS) is a statistically based, empirically derived complex parameter that is composed of a combination of time domain, frequency domain and high order spectral sub parameters. It is unique in the

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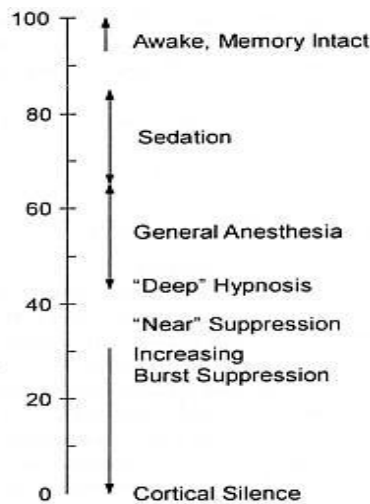


Fig.4 Bispectral Index

IV. RESULT

The 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. After analyzing the parameters the stepper motor is activated this in turn controls the syringe infusion pump.

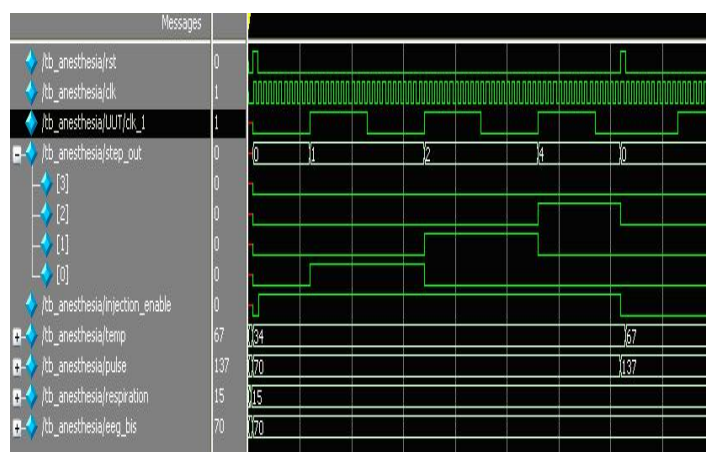


Fig 4. Simulated result

In the simulated output, first a initial dosage is set to administer indicated by rst then the biomedical 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

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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.

Stepper Motor

A stepper motor transforms electrical pulses into equal increments of rotary shaft motion called steps. A one-to-one correspondence exists between the electrical pulses and the motor steps. They work in conjunction with electronic switching devices. The function of switching device is to switch the control windings of the stepper motor with a frequency and sequence corresponding to the issued command. 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 provides uniform flow of fluid by precisely driving the plunger of a syringe towards its barrel. It provides accurate and continuous flow rate for precisely delivering anesthesia medication in critical medical care. The pump will stop automatically with an alarm when the syringe is empty. Glass and plastic Syringes of all sizes from 1ml to 30ml can be used in the infusion pump. The flow rates can be adjusted from 1ml to 99ml/hr. Since it accepts other syringe size also, much lower flow rate can be obtained by using smaller syringes.

Software Details

A program is required to be feed into FPGA, which will be used to configure the Logic Array Blocks according to the project needs. This is like emulating hardware on a 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.

V. CONCLUSION

Modern technologies have developed that promotes comfortable and better life, which is disease free. PREVENTION IS BETTER THAN CURE and protection is intelligent than prevention. Multiple biomedical parameters are monitored and used to do automation in anesthesia injector using FPGA is one of the efficient models in protecting system.

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