The BIS algorithm was developed to combine the EEG features (bi-spectral and others) which were highly correlated with sedation/hypnosis in the EEGs from more than 5,000 adult subjects. The four key EEG features that characterized the full spectrum of anesthetic-induced changes were the degree of high frequency (14 to 30 Hz) activation, the amount of low frequency synchronization, the presence of nearly suppressed periods within the EEG, and the presence of fully suppressed (i.e. isoelectric, “flat line”) periods within the EEG [2,3]. The algorithm enables the optimum combination of these EEG features to provide a reliable processed EEG parameter of anesthetic and sedative effect – the BIS Index (Figure 1). The BIS Index is a number between 0 and 100 scaled to correlate with important clinical endpoints and EEG states during administration of anesthetic agents (Figure2). BIS values near 100 represent an “awake” clinical state while 0 denotes the maximal EEG effect possible (i.e., an isoelectric EEG).

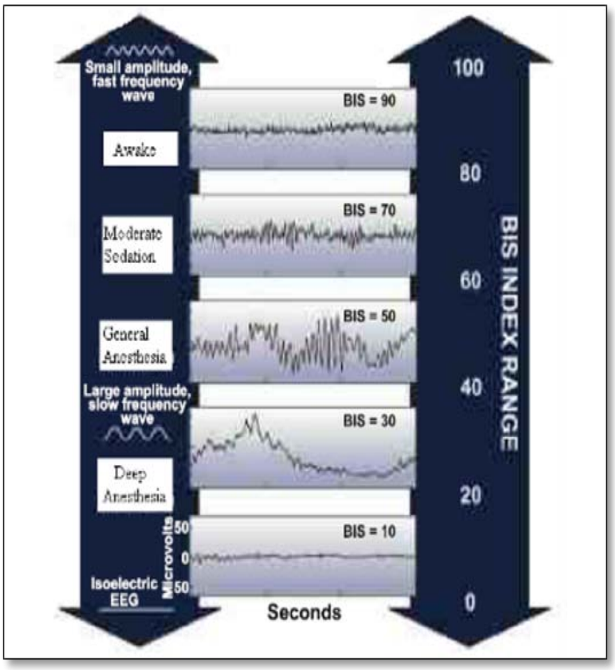

Figure 2: The BIS Index is scaled to correlate with important Clinical endpoints during administration of anesthetic agent

Since usage of BIS index is a difficult parameter for a small scale surgeries, hence we propose a novel method for small scale surgeries using monitoring of heart rate (HR), body temperature and respiration rate (RR).

3. Proposed Solution

In this paper we propose an algorithm which takes different vital signs as input and detects the response of the patient based on that the Anesthesia will be injection will be turned on or off. Vital signs are nothing but the Heart Rate (HR) measurement, Respiratory Rate (RR), and temperature of the patient body.

A. Heart Rate (HR) Measurement

Heart rate monitoring is performed by using pulse oximetry. The principle of pulse oximetry is as follows, “difference in absorbance of the IR signal by passing through the oxygenated blood as shown in figure 3. The Volume of the blood flowing through arteries varies during each heart-beat. Hence infrared radiation is incident on it, the absorbance of IR also varies according to heartbeat. These variations are determined by placing photo detector at receiver end [4].

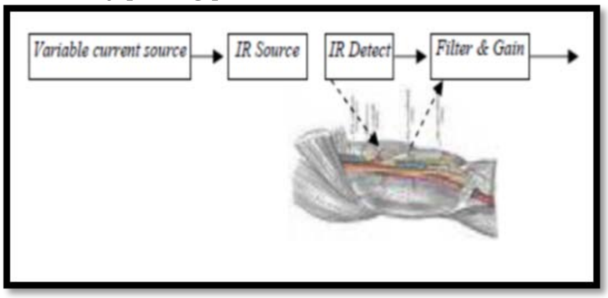

Figure 3: Principle of HR measurement

The received signal from photo detector will be passed through signal conditioning circuitry, as shown in figure 4. The o/p of the signal conditioning circuit is given to DAQ system to measure the analog voltage. The o/p signal, average voltage is 120mv, when it passed through oxygenated blood the signal undergoes for attenuation becomes 70-80mv.

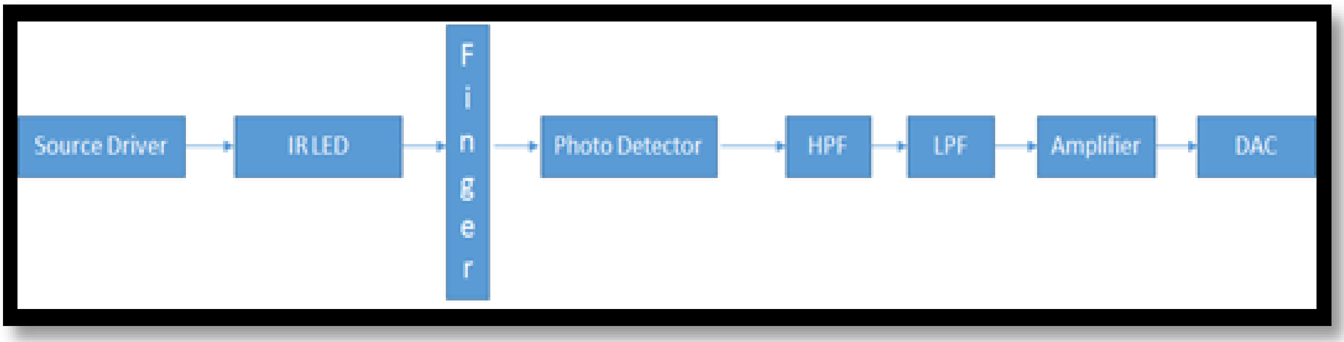

Figure 4: Block diagram of HR measurement

B. Temperature and Respiratory Measurement

TMP100 temperature sensor is used for the respiratory measurement. Principle here is temperature of the body will vary for every inhale and exhale during respiration by nasal activity. Change in temperature will be very small (~0.5°C), hence we had used a high precision temperature sensor. TMP100 sensor is interfaced to NI USB 8451 through I2C interface.

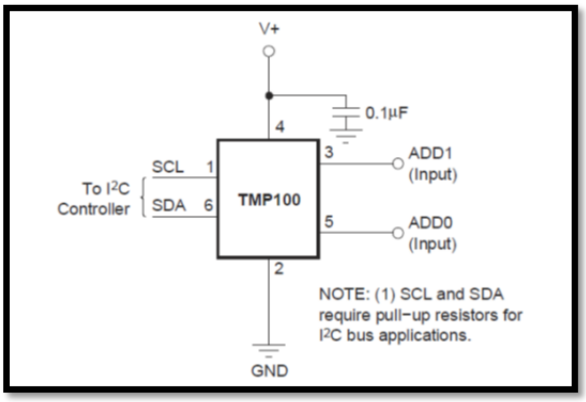

Figure 5: TMP100 temperature sensor

TMP 100 provides 9-12 bits of output, which can be interpret as a temperature by selecting the output resolution through Configuration register. Below we explain the internal register organization of TMP100. It consists of Pointer Register, Temperature register, Configuration register, T_{Low} register, T_{high} register and I/O control interface for I2C as shown in figure 6.

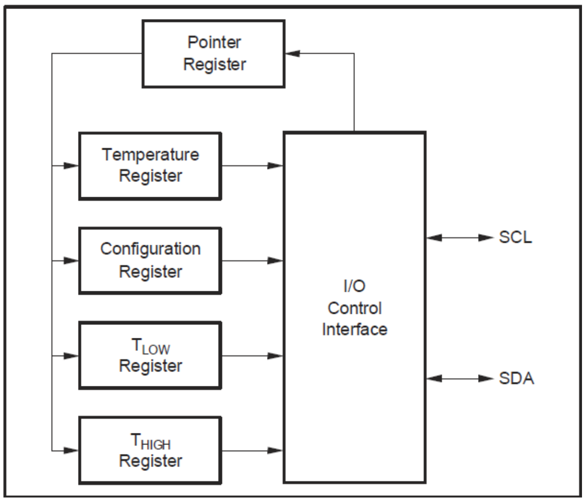

Figure 6: Internal structure of TMP100

TMP100 is configured to output of 12-bits using configuration register. The resolution of the output bits is 0.0625°C per step. The maximum temperature (128°C) can measured as 0111 1111 1111 bits from the Temperature register.

The temperature measurement of the body is given by Let **"T"** be temperature of the body and **"O_c"** output bits in decimal value [5, 6];

$T = O_c * 0.0625$ (°C)

Respiratory measurements can be done using the difference in temperature. If the temperature difference is ~0.5°C indicates the process of breathing. Read the temperature for temperature & respiratory measurements at sampling rate of 1 KHz [7].

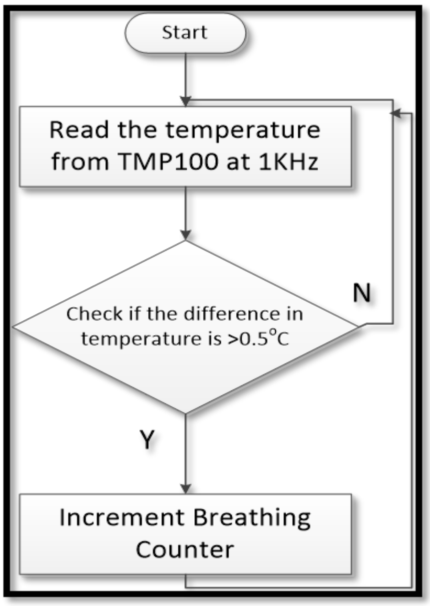

Figure 7: Flow chart for respiratory measurement

C. Algorithm for Controlling Anesthesia Syringe Infusion Pump Motor

In this section we will discuss about the how we control the Anesthesia syringe infusion pump motor, for the simplicity we assumed DC servo motor, similar to infusion pump motor. Heart rate in normal healthy persons will be given below in the table vs age [8].

Age	HR (Bpm)
<1 year	80-160
1-3 Years	80-130
3-5 Years	80-120
5-7 Years	75-15
7-10 Years	70-110
>10 years	60-100

The normal heart rate in adults is 60-100. Abnormal heart rate can be caused due to several factors during surgery. Typical medical names for the abnormal heart rate are **Tachycardia** (heart is beating too fast at rest usually over 100 Bpm) and **Bradycardia** (heart is beating slowly at rest less than 60Bpm). When a person is under sleep condition the heart rate will be less compared to normal HR (usually close to 50). If the HR is over 120, then it is treated as serious condition as per the medical science. Temperature of the body under normal conditions is given as 37°C or 98.4°F. The abnormal temperature of body and their consequence are given below [9].

Temperature (°C)	Effect
44	Almost Death, patient can sometimes survive up to 46.5
43	brain damage & cardio collapse
41-42	Very fast heart rate, Fainting
38-40	Severe Sweating, dehydration headache
37	Normal temperature
36	Mild shivering , may be normal temperature
34-35	Intensive shivering, Heart irritability
29-33	very slow heartbeat & loss of memory
28	Breathing stop, almost Death

Respiratory rate (RR) of the normal person is listed as 12-17 beats per minute. If the RR is above 20 bpm it is treated as Tachypnea and RR is below 10bpm it is called as Bradypnea.

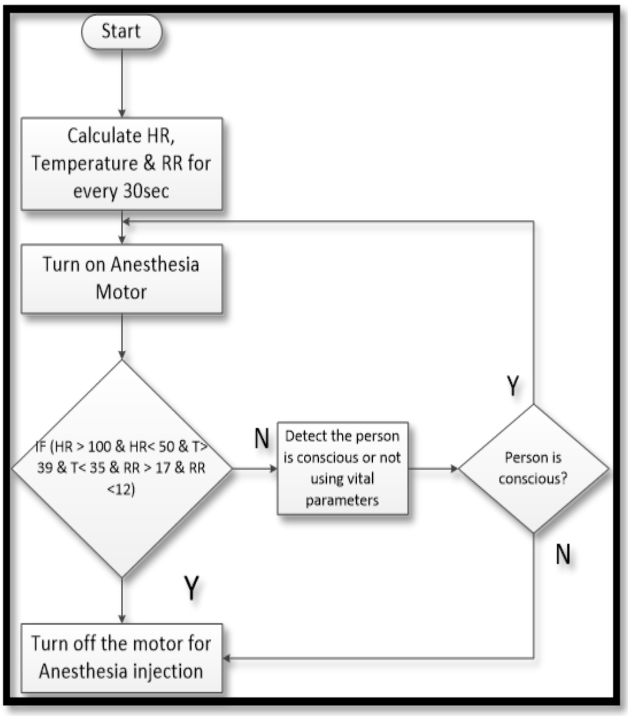

Figure 8: Algorithm to control pump motor

4. Real Time Implementation

In this paper we implemented a prototype for the real time implementation. The Heart rate is acquired pulse oximetry principle by using an analog input of USB NI DAQ 6289, the output bits of the TMP100 is acquired using USB NI 8451[10] and the output syringe infusion pump (DC Servo motor) is controlled using Analog output through H-Bridge [11]. Software program written in Labview acquires the HR, temperature & RR data and calculates the control for Servo motor configuration.

5. Conclusion

In this paper we proposed a novel method to control the anesthesia infusion pump based on the measured real time response of a patient. The algorithm here handles the case of a normal person, whereas this can also be improved by adding more data set of the vital parameters to control the anesthesia dose.

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