DESIGN AND ANALYSIS OF TRANSMITTER MODULE FOR INTRA-BODY COMMUNICATION (IBC) BASED ON HEALTH MONITORING SYSTEM

`Abdul Hakim Bin Ayub, Abdul Karimi Halim, Abdul Hadi Abdul Razak

***Abstract*— This paper presents the design and development of a transmitter module for a Body Area Network (BAN) health monitoring system based on Intra-Body Communication. Intra-body Communication (IBC) is a communication technique that uses the human body as a medium for electrical signal communication. One of the visions in the healthcare industry is to provide autonomous and continuous self and the remote health monitoring system. This can be achieved via BAN, LAN and WAN integration. The BAN technology itself consists of short range data communication modules, sensors, controller and actuators. The information can be transmitted to the LAN and WAN via the RF technology such as Bluetooth, ZigBee and ANT. There are several limitation of the current RF technology in IBC products such as high power consumption, low battery lifetime and high electromagnetic interference signal attenuations. One of the solutions for Medical Body Area Network (MBANs) to overcome these issues is by using an IBC technique because it can operate at lower frequencies and power consumption compared to the existing techniques. The main objectives is to design a low frequency IBC transmitter between range 21MHz to 24MHz by using discreet component. The specifications of the modules such as frequency, data rate, and modulation system will be defined. The individual module been designed and tested separately. The modules is integrated as an IBC transmitter system and tested for functionality then implemented on the PCB. The signals from the transmitter can be viewed via external devices such as oscilloscope. The signals such as heartbeats or pulses can also be displayed on LCD. In conclusion, all the sub-modules ADC, shift register, and modulation been tested in software simulation separately and operate correctly. For hardware testing ADC and shift register module work properly but BFSK modulator cannot produce exact frequency.**

***Index Terms*— IBC, BAN, LAN, WAN, RF, PCB, discreet components, modulation, demodulation.**

I. INTRODUCTION

Nowadays there are several products of Intra-Body Communication (IBC) used in medical department. IBC is a short range wireless communication technique that use human body as a transmission medium. Electrical signal transmit back and forth inside human body to monitor such as heartbeats, heart rates, and respiratory rates. It is a comprehensive monitoring system that beneficial to the human healthcare. IBC was originally proposed by T.G. Zimmerman [1]. The concept of IBC is to utilize the human body as a medium for transmission. The signals will pass through the human body using induced electric field which is exists around the human body. There are several limitation on the current RF technology such as high power consumption, low battery lifetime and high electromagnetic interference.

Influence of electromagnetic noise and interference on the transmissions signal is the most problem because the output signal can be manipulated by the external electromagnetic force [2]. The main problem of IBC is the usage of a low frequency such as 21MHz in order to transmit the signal through the human body and display it in a proper waveform. This is because the frequency of 21 MHz is the center of the operating frequency band of IBC with a scalable data rates of 164 – 1312.5 kB/s according to the IEEE 802.15.6 standard of Wireless Body Area Network (WBAN) [3]. The challenge of this project is to design a hardware setup, which are the transmitter and the receiver of IBC that can satisfy the IEEE 802.15.6 standard of WBAN.

The main objective of the project is to design IBC transmitter module operate between 21MHz to 24MHz using off-the-shelf component. The second objective is to design and test sub-modules of transmitter separately. The third objective apply BFSK technique in the modulator module. The fourth objective is to implement all the sub-modules on PCB and lastly to design a portable and wearable application IBC module.

This health monitoring system consists of four sub-modules in the transmitter which are sensor, ADC, shift register, and modulator. The sensor read or detect the signals such as heartbeats or pulse, then the signals is transmitted. The external device such as oscilloscope will be used to display the signals.

IBC is suitable solution for MBANs in a mobile health care system because of the low power requirement of the IBC itself. The IBC has a characteristic of high transmission quality, high data rate, easy network access and no communication bandwidth problem which has made the IBC are better compared to the other near field electromagnetic waves protocol [4]. Figure 1.1 shows two

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example of IBC technique which are using Electric Field method and Electric Current method.

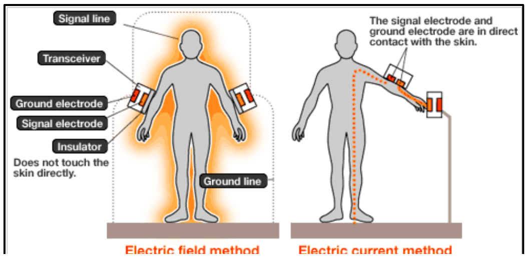

Figure 1.1: Example of measurement setup of IBC

IBC is one of the categories in short range wireless communication protocol. Furthermore, IBC has several advantages compared to the current RF technique. The first advantage is the use of cables is no longer needed [5]. Second advantage is the transmission of the signal area easily to conduct since the transmission of the signal can be formed only when the human body is touching the terminal [5]. Third advantage is the electromagnetic noise and interference have less influence on the transmissions of the signal because the signal does not leak through the skin of the human body [5]. Fourth advantage is the human body can use the communication channel exclusively, which make the large-throughput data communication is highly possible [5].

There are some techniques can be used to design the modulator module inside transmitter. The techniques are Binary Amplitude Shift Keying (BASK), Binary Frequency Shift Keying (BFSK), and Binary Phase Shift Keying (BPSK). The technique that been proposed is Binary Frequency Shift Keying (BFSK). Input signal is modulated into two different frequency which are when input is at logic 1, the output will produce 24MHz frequency and when input is at logic 0, the output will produce 21MHz.

There are advantages and disadvantages of using these three techniques. The advantages using of using BPSK is less susceptible to error than BASK. It is also more efficient use of bandwidth with higher data rate. But the disadvantages of BPSK is more complex detection process than BASK and BFSK. Its amplitude rapidly change between symbols due phase discontinuity. Besides that its output signal is unclear [6].

The advantages of BASK is it much easy. Both modulation and demodulation process is cheaper. This technique commonly used to transmit digital data over fiber optic. The transmitters of BASK are very simple and its current is lower than BFSK. The most important is it need less bandwidth than BFSK. Unfortunately, BASK is linear and sensitive to atmospheric noise, distortion, propagation condition on different routes in Public Switched Telephone Network (PSTN). It requires excessive bandwidth and is therefore a waste of power [7].

The advantages of BFSK is less susceptible to error compared to BASK. The receiver looks for specific frequency changes over the number of intervals, so the voltage or noise spikes can be ignored [8]. Besides that BFSK is relatively easy to implement because it requires simple circuit. It also has noise immunity that BASK. Therefore the probability of error free reception of data is high [9]. But the major disadvantage is its high bandwidth requirements. Therefore it is extensively used in low speed modems having bit rates below 1200 bits/sec. it is not preferred for the high speed modem because with increase in speed will increase the bit rates [9].

It is anticipated that the success of this project will help in the advancement of wireless biomedical and wireless sensor network market which encompasses every layer of the society. The benefit will include in wearable system, health-coming monitoring devices and even sport performance analysis just to name a few. Therefore, it is reasonable to pursue designing such device due to its potential contribution to the community.

II. DESIGN AND METHODOLOGY

The main idea of this project is design a transmitter module for intra-body communication. It consists of some sub-modules such as analog-digital converter (ADC), parallel load 8-bit shift register, and BFSK modulator. Each modules is tested separately before integrate them in one system. All sub-modules is combine and implemented in this project to perform intra-body communication.

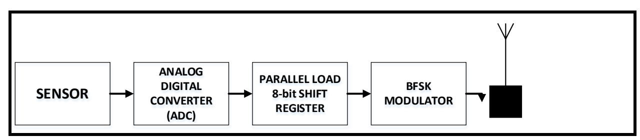

Figure 2.1: Block diagram transmitter module using off-the-shelf component

Figure 2.1 shows the block diagram of the transmitter module.

a) Analog-digital converter (ADC)

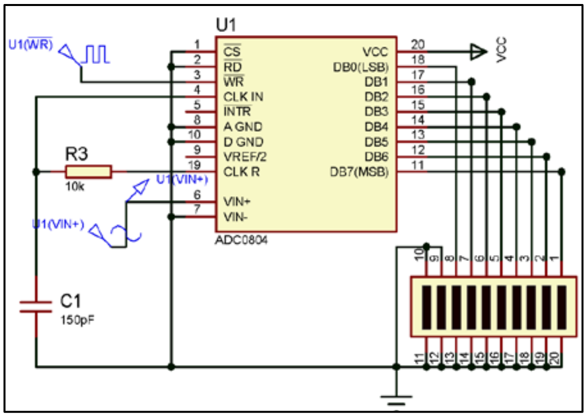

Figure 2.2: ADC module setup

Figure 2.2 shows the setup to test functionality of the ADC module. 8 bits ADC is used in this project. The function of this module is to digitize the analog signal from sensor. Input pin 6 vary between +5V to -5V using sine wave signal to get analog value. The function of sine wave is to act as input signal read from sensor that produce analog signal. Pin 3 ADC is connected to the external clock. The clock is set at 1kHz. Every positive edge 1kHz clock the ADC read the analog value and convert it into digital. Output of the ADC pin 11 till pin 18 is connected to LED for easy verify the correctness it operate.

The output ADC reading can be calculated using this formula:

$$\frac{\text{Resolution ADC}}{\text{System voltage}} = \frac{\text{ADC output reading}}{\text{Analog voltage input}} \qquad [11]$$

The output of the ADC is defined by using the above formula. Assume Vin equal to 1.75V analog and it produce 01011001_2 8 bit digital.

$$Vin = 1.75V$$

$$\frac{2^8}{5} = \frac{ADC}{1.75}$$

$$ADC = \frac{2^8 \times 1.75}{5}$$

$$ADC = 89.25 \approx 89$$

$$89_{10} = 01011001_2$$

b) Parallel load 8-bit shift register

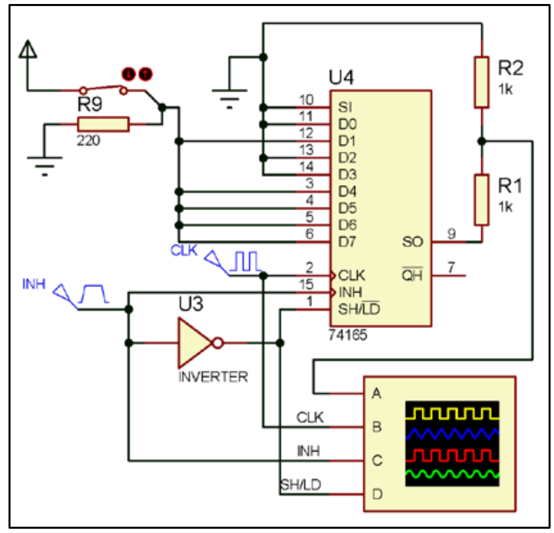

Figure 2.3: Shift register module setup

Figure 2.3 shows the setup for shift register module. The function of this module is to convert 8 bit data parallel from ADC output into series. The 8 bits data from ADC is shifted one bit by one bit to make it series. D0 to D7 are the 8 bits data input of the shift register which are connected to output of the ADC module. Pin 1, pin 2 and pin 15 is clock configuration. Its function is to provide sequent to read and write data.

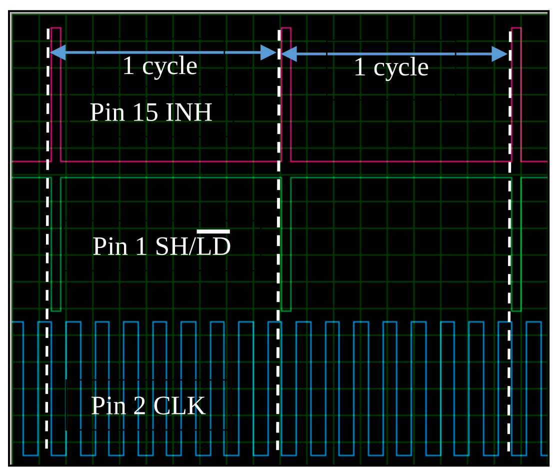

Figure 2.4: Clock setup for shift register

Figure 2.4 shows clock configuration for the shift register to work. The shift register operation clock (CLK) is set at 8kHz frequency. Pin 1 and pin 15 clock is set at 1 kHz frequency but in PWM form which is 96% duty cycle and 4% duty cycle respectively. At the first clock cycle pin 1 receive low signal, it gives the shift register permission to load the data form ADC into it. Then pin 1 receive high signal so that in the balance clock cycle the data is shifted out through pin 9 as output pin.

c) BFSK modulator

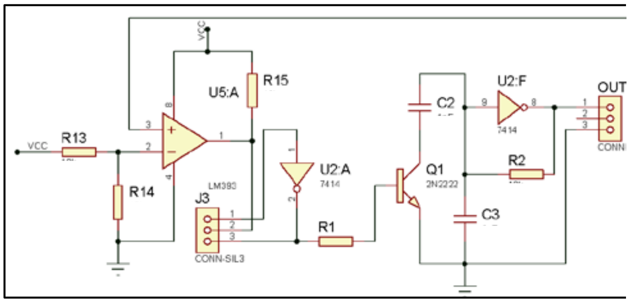

Figure 2.5: BFSK modulator module setup

Figure 2.5 shows the schematic diagram of the BFSK modulator. The modulator using Schmitt trigger inverter circuit concept. The output from shift register go through inverter U2:A of modulator module to invert the signal. The frequency of the modulator is determine by using the following formula:

$$f = \frac{1}{T} = \frac{1}{-2RCln\left(\frac{V_{cc} - V_{T+}}{V_{cc} - V_{T-}}\right)}$$

Assume Vcc = 5V, V_{T+} = 1.7V, V_{T-} = 0.9V, R2 = 10KΩ, C2 = 1pF, C3 = 10pF.

$$f = \frac{1}{-2(10K \times \mathbf{11p}) \ln\left(\frac{5 - 1.7}{5 - 0.9}\right)}$$

$$\underline{f \approx 21Mhz}$$

$$f = \frac{1}{-2(10K \times \mathbf{10p}) \ln\left(\frac{5 - 1.7}{5 - 0.9}\right)}$$

$$\underline{f \approx 23Mhz}$$

When input of the modulator is high the transistor is OFF state, capacitor value is 10pF because the capacitor not parallel. So it produce 23MHz output. While when input is low the transistor is ON state, capacitor C2 and C3 is parallel become 11pF. So the output produce 21MHz.

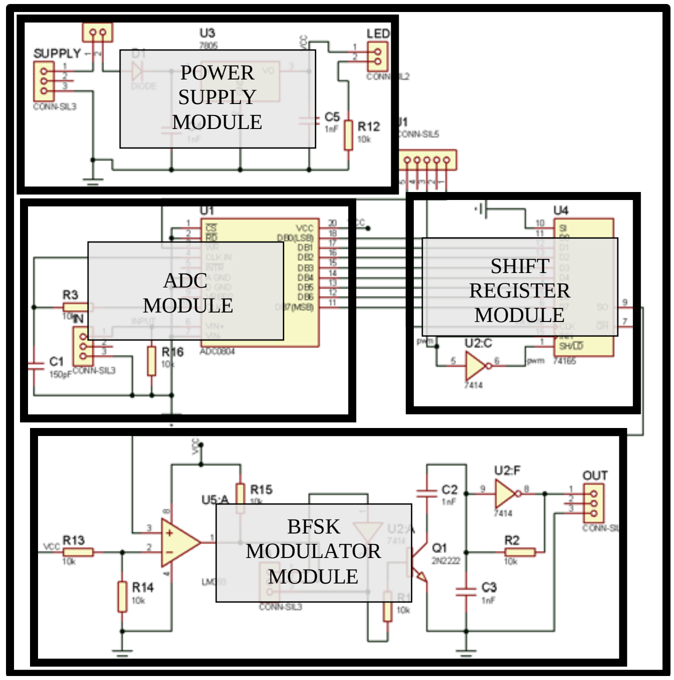

Figure 2.6: Implementation of transmitter module

Figure 2.6 shows the schematic diagram of transmitter module. Each sub-module is integrated in one circuit diagram. The schematic diagram is designed using Proteus software ISIS.

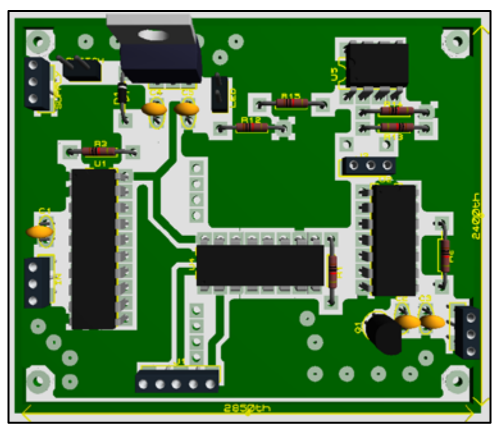

Figure 2.7: Transmitter module circuit layout

Figure 2.7 shows the circuit layout of the transmitter module generated by Proteus.

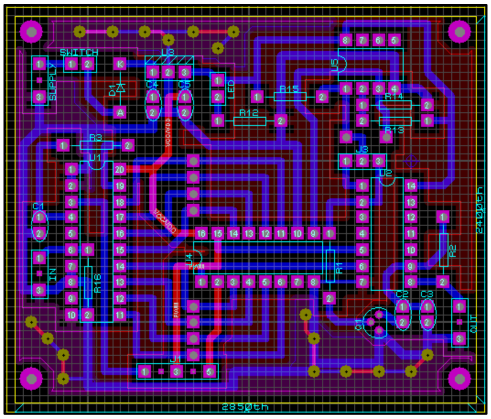

Figure 2.8: PCB layout for transmitter module

Figure 2.8 shows PCB layout of transmitter module designed by myself using Proteus Ares.

III. RESULT AND DISCUSSION

The design been tested and simulated in the simulation software to perform the design behavior of each module before proceed to design using off-the-shelf component.

a) Analog-digital converter (ADC) module

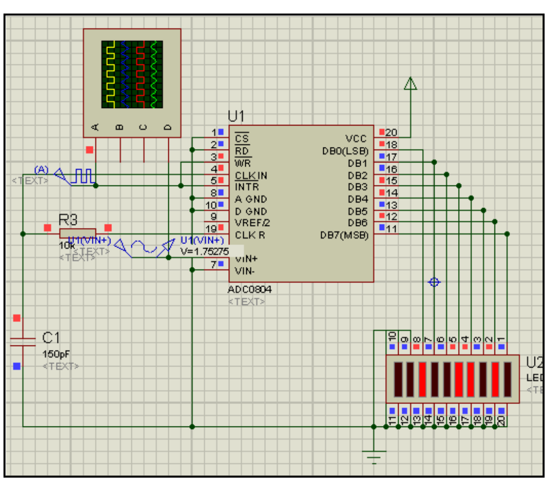

Figure 3.1: ADC design circuit diagram and output data

Figure 3.1 shows the result simulation of the ADC module. The input of the ADC is 1.75V. Based on the calculation in the methodology part it proved that the output of the ADC is the same as calculation. So the ADC module function properly.

b) Parallel load 8-bit shift register module

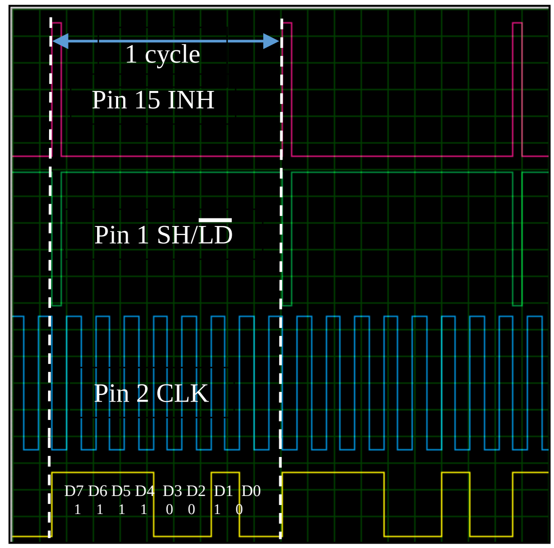

Figure 3.2: Waveform data output

Figure 3.2 shows the result simulation of the shift register module. Based on figure 2.3 the input of the shift register is set to 11110010_2. The result in figure 3.2 has prove that the shift register module work properly.

c) Binary frequency shift keying modulator (BFSK) module

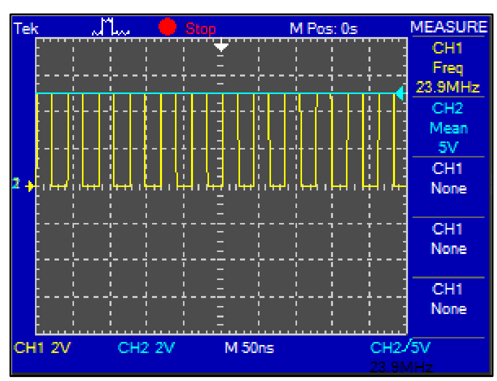

Figure 3.3: 23.9MHz frequency produced at high signal input

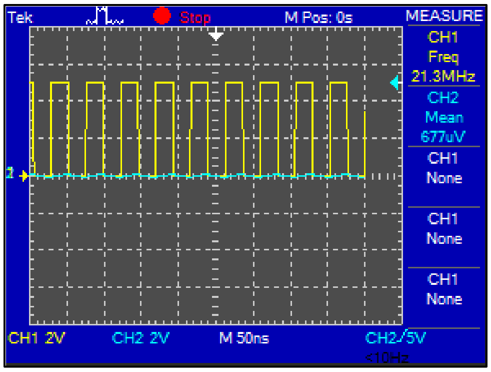

Figure 3.4: 21.3MHz frequency produced at low signal input

Figure 3.3 and 3.4 show the result simulation of the BFSK modulator module. From the simulation the signal produced by the BFSK is 23.9MHz for high input signal and 21.3MHz for low input signal.

Figure 3.5: 10.4MHz frequency produced at high input signal

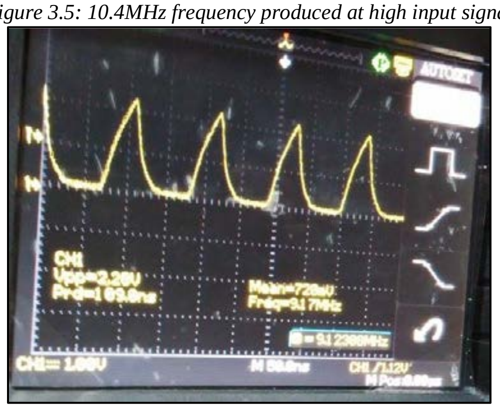

Figure 3.6: 9.1MHz frequency produced at low input signal

Figure 3.5 and 3.6 show the result hardware simulation of BFSK modulator. In the hardware simulation the output produced by the BFSK modulation is between 9.1MHz and 10.4MHz.

IV. CONCLUSION

In conclusion, the software simulation for all sub-modules work and function properly as desired. The ADC module able to digitize the signal form sensor. Shift register module able to shift out the parallel 8 bits input from ADC into series. And lastly the BFSK modulator module able to modulate the input signal into 24MHz and 21MHz. for the hardware simulation ADC and shift register module work properly but the BFKS modulator module only produce 10.4MHz and 9.1MHz instead of 24MHz and 21MHz. Seen like in the hardware part is a bit difficult to get the exact value of the output frequency. Impedence in the designing the PCB circuit need to be consider in order to minimise the difference between hardware and software result. For the future recommendation the PCB board need to be use is RS4 because it can minimise the impedence of the circuit. It also suitable for the high frequency circuit.

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