

## **ECG MONITORING SYSTEM BASED ON MICROCONTROLLER**

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**ABSTRACT:** - Health monitoring systems becomes a hot topic and important research field. Electrocardiogram (ECG) signal is a diagnoses tool that measures and records the electrical activity of the heart, taking care of patient's health. Therefore, monitoring this signal becomes a necessary need to take care of human health.

In this paper, two procedures are proposed; first, monitoring the ECG signal, second for sending the signal of monitoring patients and ECG data through Serial communication port to the other pc or nurse. AT89C51 microcontroller uses to perform these procedures including all the necessary connections of the microcontroller with other components and programming the microcontroller using assembly language to send the signal serially. At both transmitting and receiving sides, the signal was gives the same setting of baud rate, stop bits, number of data bits, parity to ensure secure arrival of data without any lossless.

**Keywords:** *ECG monitoring system, microcontroller.*

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### **1- INTRODUCTION**

The Electrocardiogram (ECG) has an essential diagnostic tool that measures and records the electrical activity of the heart. A wide range of heart conditions has detected when interpreting the recorded ECG Signals. These qualities have make the ECG a perfect instrument for patient monitoring and supervision. The commonly for using ECG-machine has used for diagnosis and supervision at the present to consider expensive and stationary<sup>(1)</sup>.

The normal heart beat has begun as an electrical impulse generated in the sinoatrial node of the right atrium. From there, the electrical activity has spread as a wave over the atria and arrives at the atrioventricular node about 200ms later. The atrioventricular node has the electrical only connection between the atria and ventricles. In approximately 100ms, the wave front has emerge on the other side and rapidly spreads to all parts of the inner ventricular surface via the His-Purkinje system<sup>(2)</sup>. A typical ECG tracing of a normal heartbeat (or cardiac cycle) has consisted of a P wave, a QRS complex and a T wave as show in Figure (1) An interesting line of research has focused on how to use the microcontroller to monitor the ECG signal as well as all the aspects have related to the microcontroller such as the connections, programming and also how to send this signal.

### **2- THE INTEL 8051 MICROCONTROLLER**

The Intel 8051 microcontroller has originally designed in 1980 and has remained highly popular to this day. Dozens of variants of the original 8051 have released by various semiconductor manufacturers, with added features, speed, or both, tailored for specific tasks. The 8051 and its many derivatives have the world's most popular microcontroller family.

The 8051 is a Harvard architecture microcontroller, in its base form featuring four 8-bit I/O ports and the ability to access external instruction or data memory through the I/O ports,

among many other features<sup>(3)</sup>. Figure (2) has shown the pin diagram and architecture of 8051 microcontroller.

### 3- ECG MONITORING SYSTEM BASED ON MICROCONTROLLER

In this section all the stages and components that has used for presenting to transmit and monitor the ECG signal by using serial transmission, RS232 starting with how to import the ECG signal files and ending to receive the signal serially, to display it and has included converting and digitizing the ECG files to transmit.

The first three stages of the system have designated for using proteus simulation which includes the ECG signal generator, analog to digital convertor and the microcontroller while the last two stages implemented by MATLAB simulation included for performing the programming to receive the data from serial port and displaying the signal on monitor section. Now we have divide the stages into two groups, first group has listed in the transmitting side while the second group has listed in the receiving side. Each part of the system has explained separately as stated below. General block diagram of the system has shown in Figure (3).

#### 3.1 Transmitting side

This part has built by using proteus simulation in the first pc which has considered to be the transmitting side. The construction of this part has consisted of the following stages:

##### 3.1.1 The electrodes

This is the first stage of the system that has attached to the human skin and from this part the ECG signal has taken from the human body. There are several types of electrodes one of them consists of a metal usually silver and a salt of the metal (usually silver chloride). In addition, some form of electrode paste or jelly has applied between the electrode (normally a flat silver disc) and the skin. This part has enable the system to extract the signal from the skin which has very weak signal. The electrodes circuit has consisted of two rows each of them contains capacitors, resistors and bioelectric generator.

##### 3.1.2 Instrumental Amplifier Stage

This stage is used for the differential bioelectrical amplifier in the ECG-sensor. The parts of this stage are built in proteus simulation. The important parts of the instrumental amplifier are divided into the following:

- **Buffer amplifier**

In this part the formed unwanted voltage on the both negative and positive sides and also amplifies the output signal.

- **Differential amplifier**

The output signal from the buffer amplifier has entered this stage to be amplified because when this signal reaches at this stage it have weak and need to be amplified.

- **Dc Restoration stage**

This is the third stage that is used to eliminate the DC offset in the bioelectrical amplifier. The circuit diagram and all the stating before has built in proteus simulation.

- **Variable gain and filter**

Variable gain has implemented in to the last step in the ECG-amplifier so that the output can be adjusted for the individual differences in signal strength obtained from the leads approximate 0.5mV – 3mV.

The buffer amplifier stage has a gain of 3, and the differential amplifier stage has a gain of -2.13. Therefore the overall gain of the instrumental amplifier is -6.4. The circuit diagram of the instrumental amplifier is shown in figure (4).

##### 3.1.3 Analog to digital convertor stage

The ADC0808 offered high speed, high accuracy, minimal temperature dependence, excellent long-term accuracy, repeatability, and consumes minimal power. These features make this device ideally suited to applications from process and machine control to consumer and automotive applications.

After the analog to digital conversion process the digital data has brought to the microcontroller stage to be transmitted serially. AT89C51 microcontroller has used to perform this task. The connection of the microcontroller and ADC requires programming the microcontroller to control the operation of ADC. The complete interfacing circuit consisting of ECG signal generator, ADC0808, AT89C51 microcontroller, communication port and USB to RS232 adapter, are shown in Figure (5).

ADC0808 can accept more than one input depending on the logic state of A, B and C respectively Programming the microcontroller AT89C51 includes the following steps:

Step 1: Select an analog channel by providing bits to A=1, B=1, and C=0 addresses. This lead to input the ECG signal from the input3 channel of ADC0808. The output digital data of the ADC0808 are connected directly to port1 of the Microcontroller, then this data will inter the AT89C51 for processing.

Step 2: Activate the ALE (address latch enable) pin. It needs an L-to-H pulse to latch in the address.

Step 3: Activate SC (start conversion) by an L-to-H pulse to initiate conversion.

Step 4: Monitor EOC (end of conversion) to show whether conversion is finished. H-to- L output indicates that the data is converted and is ready to be picked up.

Step 5: Activate OE (output enable) to read data out of the ADC chip. An L-to-H pulse to the OE pin will bring digital data out of the chip.

The flowchart of interfacing 8051 microcontroller with ADC0808 is shown in Figure (6).

### **3.1.4 Serial communication port**

The microcontroller receives data from the ADC0808 and transmits it to RS232 across the serial RS232 connector. The Microcontroller was connected to serial communication port by connecting TXD pin (pin 3.1) to the TXD (pin3) of the RS232 connector. For sending data the TMOD register was loaded with 20H value to operate in mode2 to send 8bit in each cycle with one start bit. The transmitted data will be received also serially by MATLAB. The data was sent with baud rate of 9600 bit per second.

### **3.1.5 USB to RS232 adapter**

Using USB to RS232 (female) adapter to make the USB port of the PC as a communication port to connect it with the RS232 then connecting the RS232 (female) with RS232 (male) to USB adapter to connect to the other PC which is the receiving side that receives the signal serially by using MATLAB program.

## **3.2 The receiving side**

In the receiving side, the ECG signal has received and displayed through three stages.

### **3.2.1 USB to RS232 adapter**

As mentioned in the receiving side, the RS232 has used to transfer data from; the first PC to; the second PC but this transmission has done with another RS232 on the receiving side, where the first RS232 in the transmitting side has female and the other in the receiving side is male.

The same setting done in the transmitting has implemented in the receiving side to enable receiving the signal in organized form and to ensure the integrity of the arrival of data.

### **3.2.2 Processing of MATLAB**

In MATLAB programming when the data has received. It has important to make the baud rate 9600 bps, 8 bit data, one stop bit and none parity. As we have stated in the transmitting side the ECG signal files was converted from mat extension file to ASCII files to import them in protues simulation. Therefore, in the receiving side the received ECG signal files must be converted from ASCII files to the mat extension files.

### 3.2.3 The Serial port session

The serial port session has performed by MATLAB. Figure (7) shows the flowchart of opening serial port of pc in MATLAB programming. This session has comprised the following steps:

- **Create a serial port object** – creating a serial port object for a specific serial port has used the serial creation function. Properties can be configured during object creation.
- **Connect to the device** – connecting the serial port object to the device has used the fopen function. After the object has connected, device settings can be altered by configuring property values, read data, and write data.
- **Configure properties** – to establish the desired serial port object behavior, values have assigned to properties for using the set function or dot notation. In practice, many of the properties have configured at any time including during, or just after, object creation.
- **Write and read data** – now, data has written to the device using the MATLAB functions (fprintf or fwrite), and read data from the device using the MATLAB functions (fgetl, fgets, fread, fscanf). The serial port object behaves according to the previously configured or default property values.
- **Disconnect and clean up** – the serial port object has not needed, it will be disconnected from the device by using the MATLAB function (fclose), to remove it from memory using the delete function, and to remove it from the MATLAB workspace using the clear command.

## 4. MATLAB PLOTTER OF ECG SIGNAL

After receiving the ECG signal by MATLAB programming it has displayed to be monitored. As a result the plotter of the MATLAB has used to display the signal. When the original signal has treated in MATLAB programming of the transmitting side, the number of the samples of the signal have determined to be ready to send. Because the capacity of the buffer for the transmitting and receiving sides has limited and also to make the signal displayed in the plotter window in acceptable form and to be evident for monitoring.

## 5. SIMULATION RESULTS

The signal samples for many people are shown in figure 8 to figure 9 that have been taken for monitoring. Each represents normal or abnormal state depending on the signal state as explained in each figure. The figure has captured from a PC connected to the receiver unit.

## 6. CONCLUSION

The microcontroller has used to implement the monitoring system to monitor the ECG signal which represents one of the important signals that, gives the electrical activity of the human heart. This work has implemented with the help of two computers, one has used to implement the transmitter part built in proteus simulation and, the other has for the receiving side. The microcontroller has programmed to transmit the signal serially and monitor it. In receiving side, MATLAB programming has used to open the COM port of the computer and to display the received signal.

## 7. REFERENCES

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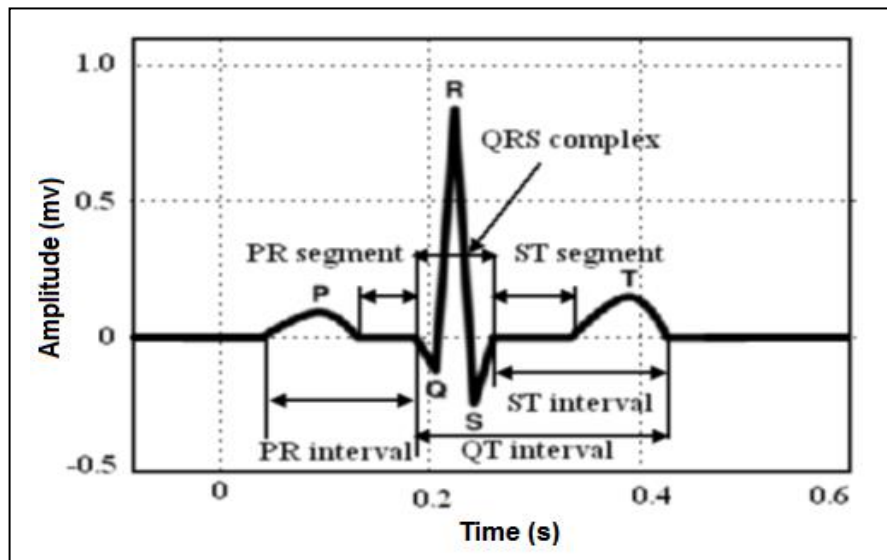


Figure (1): Schematic representation of normal ECG waveform <sup>(1)</sup>

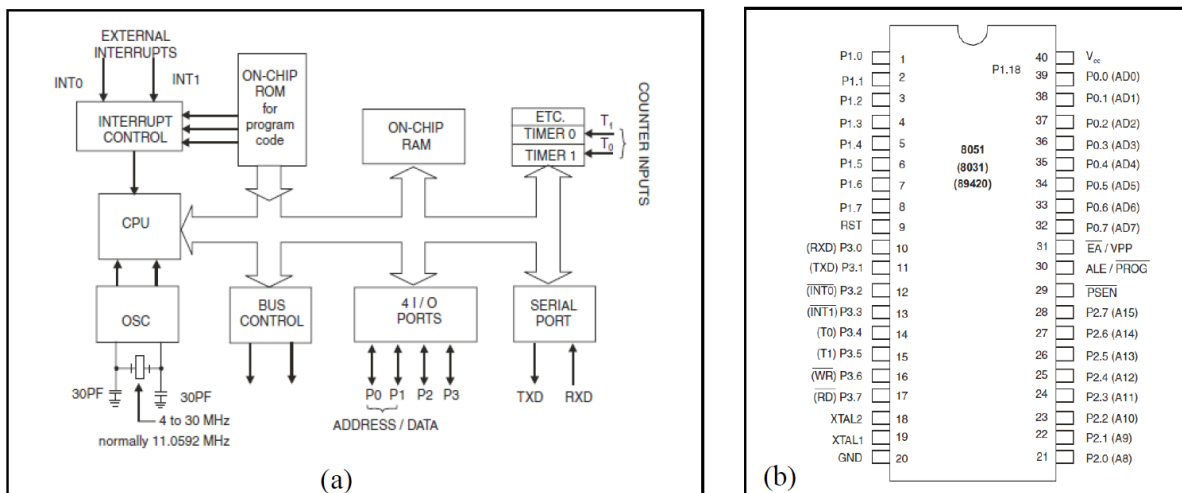


Figure (2): a) 8051 architecture, b) Pin diagram of 8051

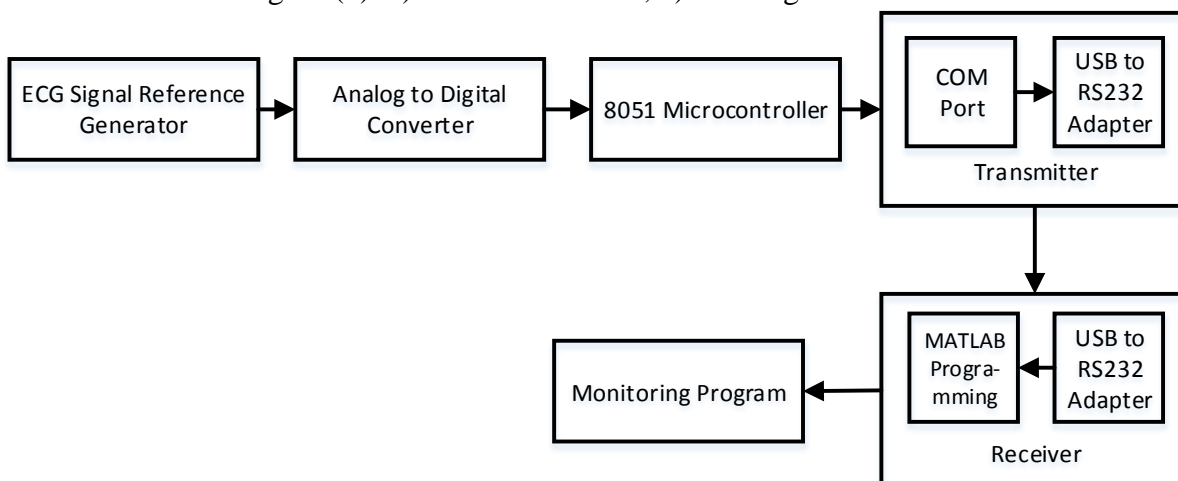


Figure (3): General block diagram of the proposed design.

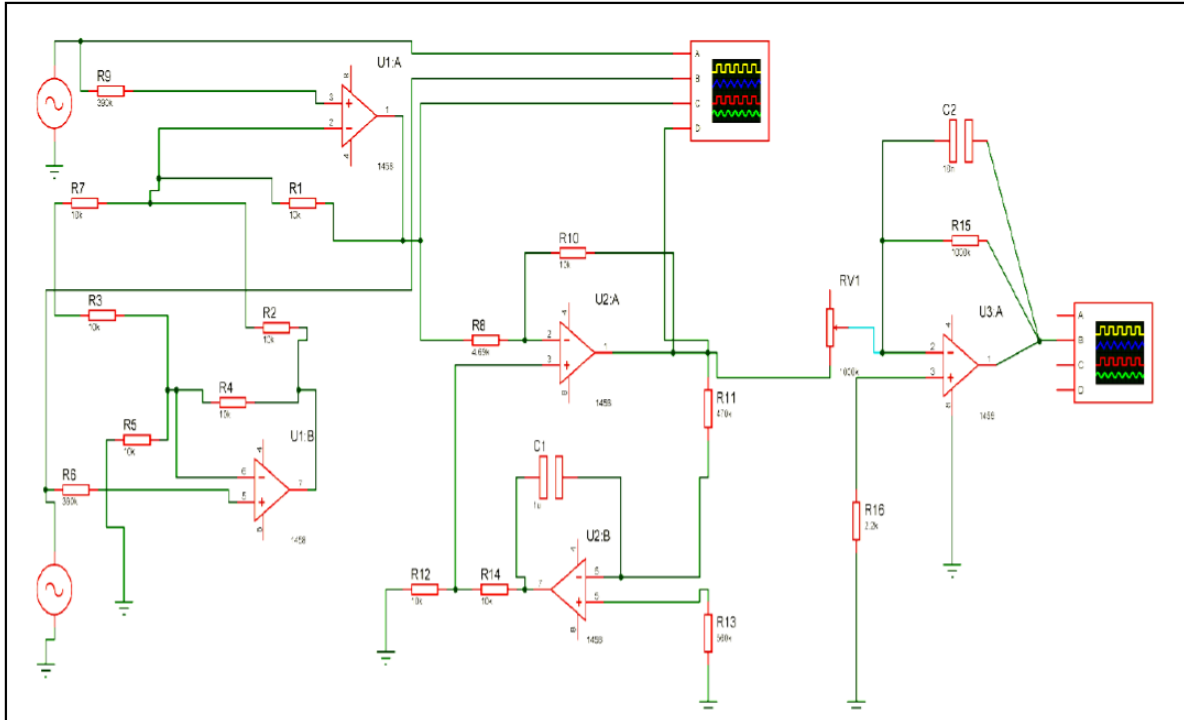


Figure (4): Instrumental amplifier circuit diagram.

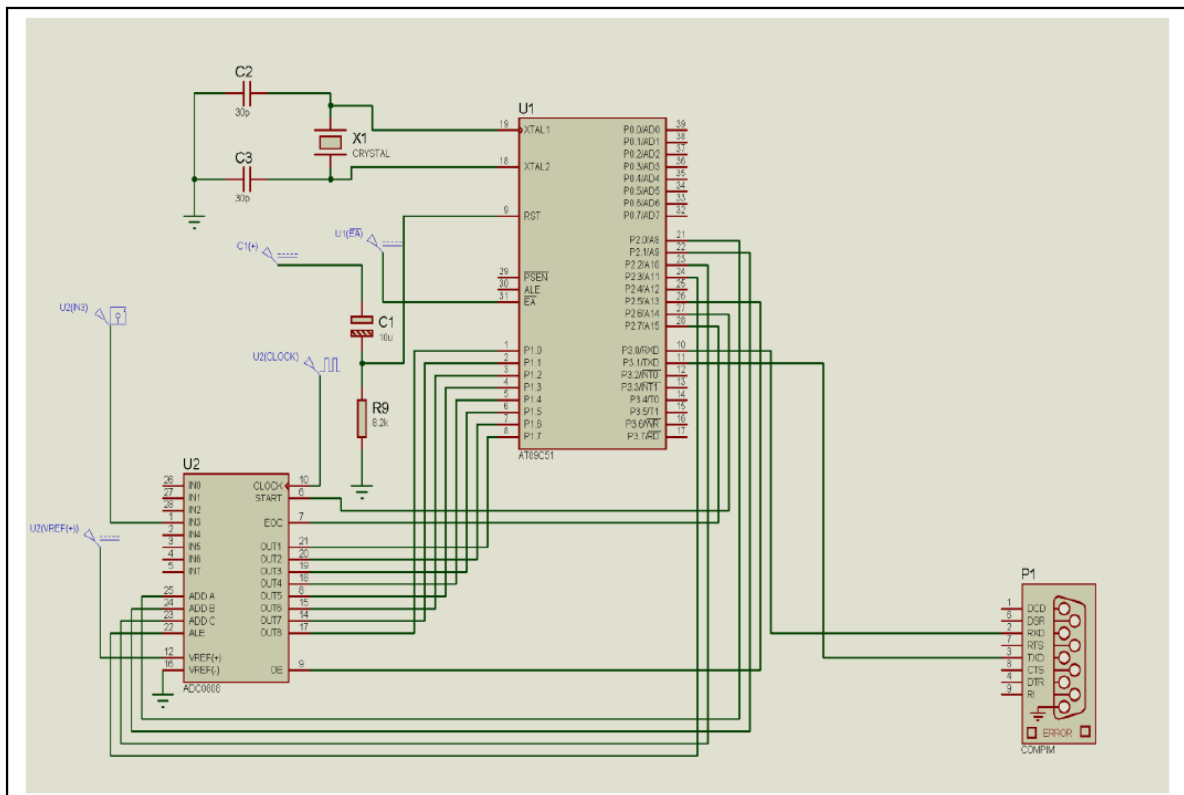


Figure (5): Interfacing circuit of AD0808 with 8051 microcontroller.

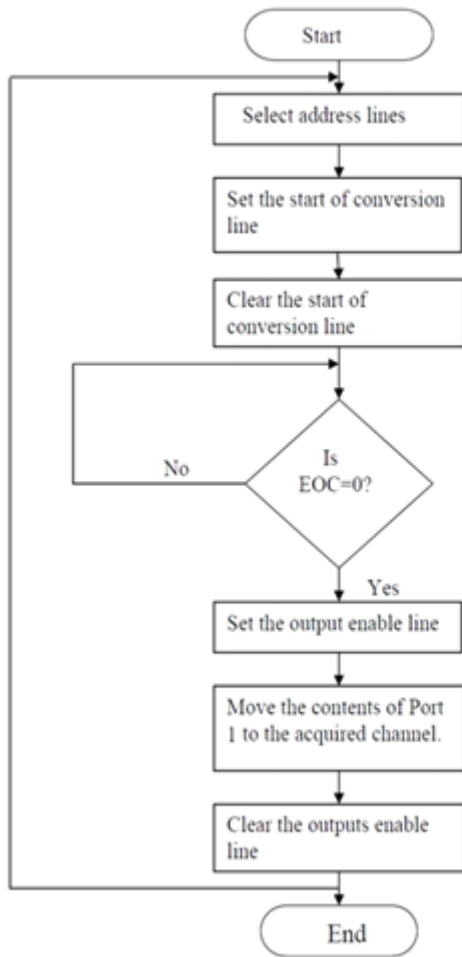


Figure (6): Flow chart of the interfacing ADC0808 with 8051 microcontroller.

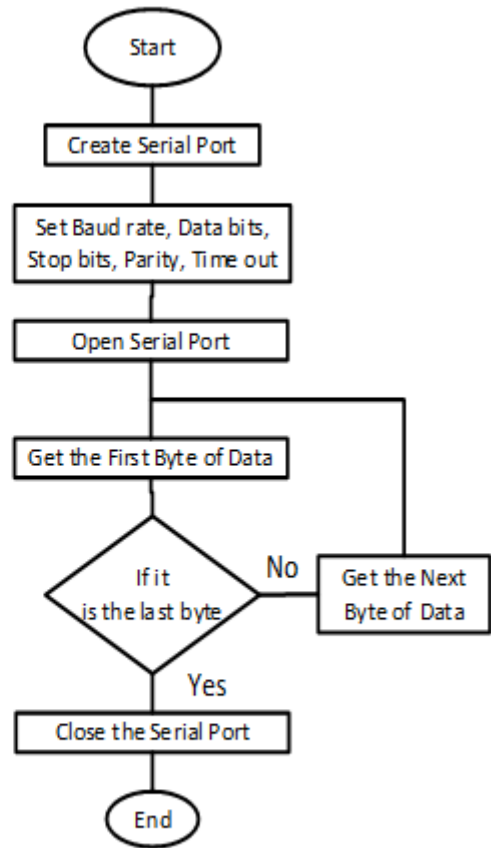


Figure (7): Flowchart of opening serial port

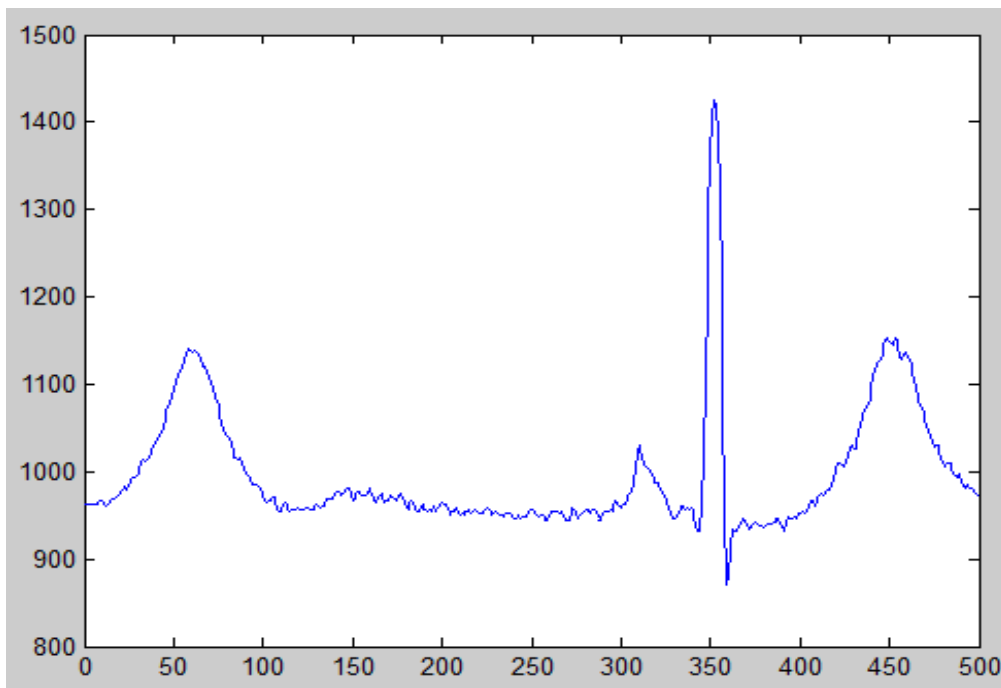


Figure (8): The received signal with 500 sample for Female patient with age 24.

The statistics of this signal listed below:

| Rhythm                  | Rate   | Duration |
|-------------------------|--------|----------|
| Normal sinus rhythm     | 49-87  | 22:36    |
| Ventricular bigeminy    | 55-103 | 7:15     |
| Ventricular trigeminy   | 57-90  | 0:13     |
| Ventricular tachycardia | 121    | 0:02     |

| Beats  | Before 5:00 | After 5:00 | Total |
|--------|-------------|------------|-------|
| Normal | 271         | 1236       | 1507  |
| PVC    | 60          | 460        | 520   |
| Total  | 331         | 1696       | 2027  |

| Feature     | Duration (msec) | Amplitude(mv) |
|-------------|-----------------|---------------|
| PR interval | 180             | ---           |
| ST interval | 360             | ---           |
| QRS complex | 120             | R= 0.75       |
| S=-0.23     |                 |               |
| T wave      | 163             | 0.4           |
| P wave      | 93              | 0.27          |

Medications: Inderal

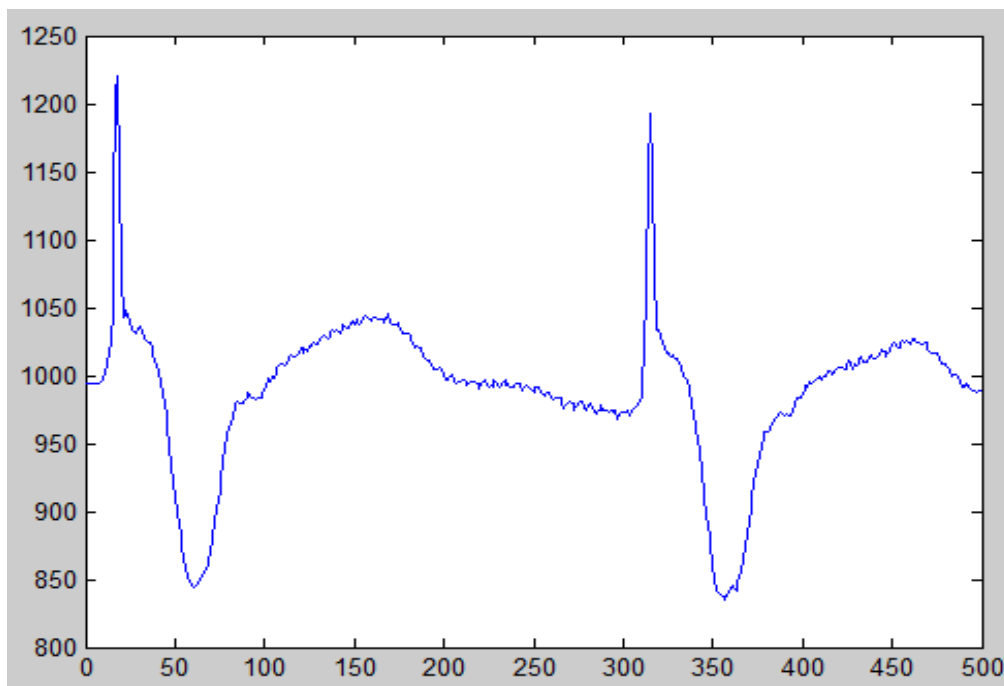


Figure (9): The received signal with 500 sample for Female patient with 66 age

The statistics of this signal listed below:

| Rhythm              | Rate  | Duration |
|---------------------|-------|----------|
| Normal sinus rhythm | 69-82 | 3:52     |
| Paced rhythm        | 70-78 | 26:13    |



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| <b>Beats</b>     | <b>Before 5:00</b> | <b>After 5:00</b> | <b>Total</b> |
|------------------|--------------------|-------------------|--------------|
| Normal           | 65                 | 98                | 163          |
| PVC              | 1                  | 1                 | 2            |
| Paced            | 197                | 1183              | 1380         |
| Pacemaker fusion | 104                | 562               | 666          |
| Unclassifiable   | 5                  | 13                | 18           |
| Total            | 372                | 1857              | 2229         |

| <b>Feature</b> | <b>Duration (msec)</b> | <b>Amplitude(mv)</b> |
|----------------|------------------------|----------------------|
| PR interval    | 120                    | ---                  |
| ST interval    | 330                    | ---                  |
| QRS complex    | 160                    | R= 0.66<br>S=-0.62   |
| T wave         | 157                    | 0.32                 |
| P wave         | ---                    | ---                  |

Medications: Digoxin, Pronestyl

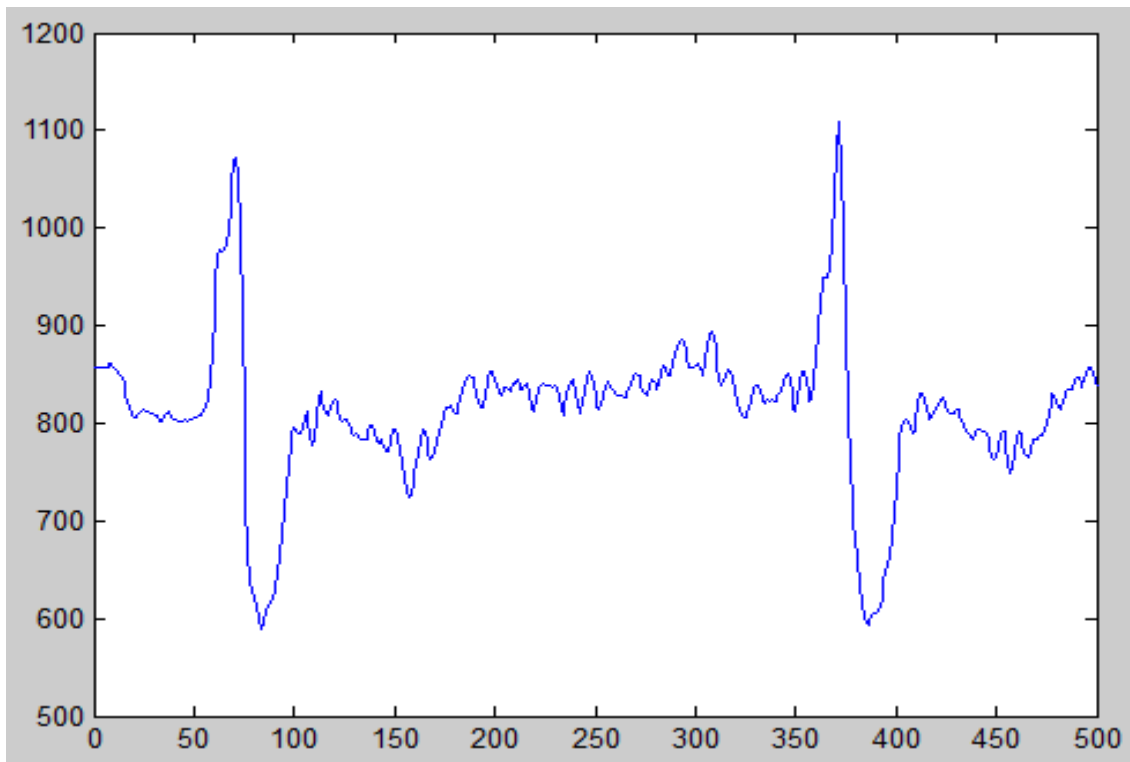


Figure (10): The received signal with 500 sample for Male patient with age 69.

**The statistics of this signal listed below:**

| <b>Rhythm</b>       | <b>Rate</b> | <b>Duration</b> |
|---------------------|-------------|-----------------|
| Normal sinus rhythm | 54-91       | 30:06           |

| <b>Beats</b> | <b>Before 5:00</b> | <b>After 5:00</b> | <b>Total</b> |
|--------------|--------------------|-------------------|--------------|
| Right BBB    | 349                | 1817              | 2166         |
| APC          | 10                 | 86                | 96           |
| PVC          | 3                  | 13                | 16           |
| Blocked APC  | 3                  | 7                 | 10           |
| Total        | 365                | 1923              | 2288         |

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| <b>Feature</b> | <b>Duration (msec)</b> | <b>Amplitude(mv)</b> |
|----------------|------------------------|----------------------|
| PR interval    | 160                    | ---                  |
| ST interval    | 320                    | ---                  |
| QRS complex    | 80                     | R= 0.5<br>S=-0.3     |
| T wave         | 160                    | 0.06                 |
| P wave         | 120                    | 0.12                 |

Medications: Digoxin, Norpace.

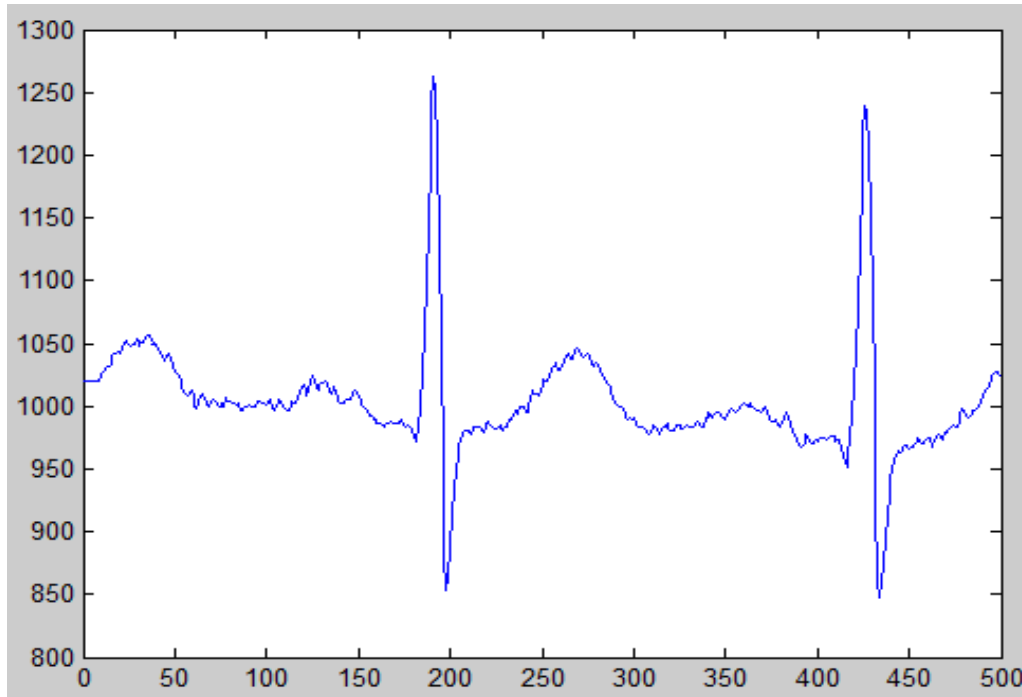


Figure (11): The received signal with 500 sample for Male patient with age 62.

**The statistics of this signal listed below:**

| <b>Rhythm</b>       | <b>Rate</b> | <b>Duration</b> |
|---------------------|-------------|-----------------|
| Normal sinus rhythm | 82-116      | 28:23           |

| <b>Beats</b> | <b>Before 5:00</b> | <b>After 5:00</b> | <b>Total</b> |
|--------------|--------------------|-------------------|--------------|
| Normal       | 475                | 2146              | 2621         |
| APC          | 11                 | 372               | 383          |
| PVC          | -                  | 1                 | 1            |
| Total        | 486                | 2519              | 3005         |

| <b>Feature</b> | <b>Duration (msec)</b> | <b>Amplitude(mv)</b> |
|----------------|------------------------|----------------------|
| PR interval    | 150                    | ---                  |
| ST interval    | 300                    | ---                  |
| QRS complex    | 70                     | R= 0.8<br>S= -0.3    |
| T wave         | 140                    | 0.26                 |
| P wave         | 110                    | 0.15                 |

Medications: Aldomet, Hydrodiuril, Inderal.

## نظام مراقبة لأشارة تخطيط القلب بالاعتماد على المسيطر الدقيق

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### الخلاصة

أصبحت أنظمة مراقبة الصحة موضوعا بارزا ومجال بحث مهم في الحاضر. حيث تفسر أشارة تخطيط القلب بأنها أداة تشخيص التي تقوم بقياس وتسجيل النشاط الكهربائي للقلب والعناية بصحة المريض. لذلك أصبحت مراقبة هذه الأشارة ضرورية للأهتمام بصحة الإنسان. تم في هذا العمل دراسة مراقبة هذه الاشارة و كيفية إرسالها باستخدام الأرسال المتوالي. تم استخدام المسيطر الدقيق لتنفيذ مراقبة الاشارة متضمنة برمجة المسيطر الدقيق بلغة الماكينة وأرسال الأشارة عن طريق الـ (TXD PIN) الى حاسبة اخرى ليتم تحليل الاشارة ورسمها باستخدام حزمة الماثلاب. في كلا جانبي الارسال والاستلام تم اعطاء نفس (Baud Rate), (Stop Bits), (Number of Data Bits) لضمان وصول الاشارة بدون اي خسارة. تم اختيار عدد محدود من الـ (Samples) لمحدودية حجم الـ (Buffers) في كلا الجانبين.