“ ECG SIMULATION USING FOURIER SERIES EXPANSION ”

A Signals and Systems Lab Report

Submitted in Partial Fulfillment of the Requirements

For the award of the Degree of

Bachelor of Technology

in

Electronics & Computer Engineering (ECM)

By

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CERTIFICATE

This is to certify that the Lab project entitled **"ECG SIMULATION"**, submitted by **K.SAI DARSHAN (17311A1990)** towards partial fulfillment for the award of Bachelors Degree in Electronics & Computer Engineering from Sreenidhi Institute of Science & Technology, Ghatkesar, Hyderabad, is a record of bonafide work done by him. The results embodied in the work are not submitted to any other University or Institute for award of any degree or diploma.

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DECLARATION

This is to certify that the work reported in the present Signals and System Lab titled **"ECG SIMULATION"** is a record work done by me in the **Department of Electronics and Computer Engineering, Sreenidhi Institute of Science and Technology, Yamnampet, Ghatkesar.**

The report is based on the project work done entirely by me and not copied from any other source.

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ECM-B

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ABSTRACT

An electrocardiogram (ECG) signal is a test to measure the electrical activities of the heart by applying electrical impulses. This paper proposed a remote ECG simulation to assisting vital signs in healthcare, namely ECG Simulation using Fourier Series approximation. A single period of an ECG signal that contains P, Q, R, S, T and U waves is in sinusoidal/triangular shapes, periodic and satisfies Dirichlet's conditions. Periodic Fourier Series also satisfies the condition and is expressed in terms of sine and cosine functions, thus Fourier Series is used to represent the ECG signal. All waves in the ECG signal are analyzed in choosing suitable representation of the shape. The combination of all waves which yields the ECG signal is calculated and programmed in Microsoft Visual Basic 2008 (MSVB2008). The results obtained could be run remotely on mobile devices using Microsoft Remote Desktop. Further details of results might be improved by proper consultations from medical practitioners.

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1.INTRODUCTION

The heart is an internal organ that beats in rhythm to pump the blood through the body. The heart diseases have become more frequent and fatal to the population. Though having a heart disease, it does not mean a patient is unhealthy to perform other activities. Due to bulky monitoring equipment in size, however, a patient is tied to a bed or chair in order to monitor continuously and as a result the patient has limited mobility. Besides, it will cost more in monitoring every potential patient's heart without reducing the size and power consumption. By reducing the monitoring system size, this will provide better mobility that is necessary for many potential patients.

The *Electrocardiogram* (*ECG*) is widely used to monitor a patient's heart condition. It was put to clinical use in 1913 with Einthoven's invention of the string galvanometer. Einthoven's recording (triangle) is known as the "three lead" *ECG* with measurements taken from three points on the body, as shown in Figure 1. The difference between potential readings from point 1 and point 2 is used to produce the *ECG* output. The point 3 connection is needed to establish a common ground for the body and the recording device**.** It is a non-invasive diagnostic tool to measure electrical signals of the heart. The study of these signals could help in determining abnormalities related to the heart's function. Figure 2 shows the *ECG* waves [2] which are labeled in order as *P* wave, *Q* wave, followed by the *QRS* complex *S* wave, *ST* segment, *T* wave and *U* wave. A point to be noted that is not every *QRS* complex contains a *Q* wave, an *R* wave, and an *S* wave. By convention, any combination of these waves can be referred to as a *QRS* complex.

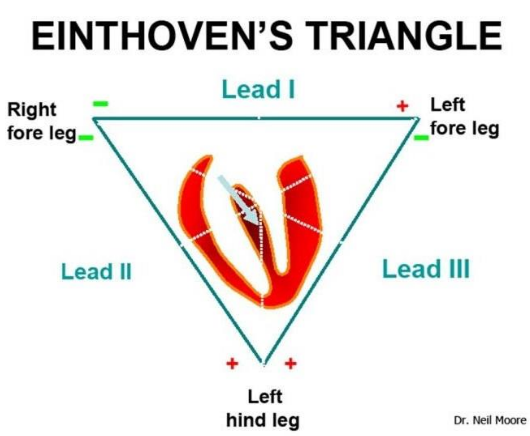

Fig. 1

2.DESCRIPTION

- The ***P wave*** is the first positive deflection on the *ECG* and it represents atrial depolarization. The duration is generally less than 0.12 sec and the amplitude less than 0.25 mV. PR interval includes the *P* wave as well as the *PR* segment. It is measured from the beginning of the P wave to the first part of the *QRS* complex (*Q* wave or *R* wave). The length of the *PR* interval changes with heart rate, but is normally 0.12 to 0.20 sec. The *PR* interval is shorter at faster heart rates (sinus tachycardia) which are due to sympathetic enhancement tone of atrio-ventricular nodal conduction. It is longer when the rate slows down as a consequence of slower AV nodal conduction resulting from withdrawal of the tones. The normal sinus *P* wave when present shows a morphology (smooth contour) and *PR* interval may suggest sinus, atrial, junctional or even retrograde from the ventricles. If *P* wave is absent then it might suggest a sinus arrest or atrial fibrillation.

- The ***QRS complex*** represents the time for ventricular depolarization and is the combination for three graphical deflections *Q*, *R*, and *S* waves seen on a typical *ECG*. These waves occur in rapid succession, reflect a single event and do not all appear in all leads, thus usually considered as one. A *Q* wave is a negative deflection after the *P* wave. An *R* wave follows as a positive deflection, and the *S* wave is a negative deflection after the *R* wave. An entirely negative *QRS* complex is called a *QS* wave. If the cardiac rhythm is regular, the interval between successive *QRS* complexes determined from the *ECG* grid can be used to determine heart rate. However, the entire *QRS* duration in adults which normally lasts for 0.06 to 0.12 seconds is not influenced by heart rate.
- The ***Q wave*** may be present or absent in a normal *ECG***.** Small *Q* waves are often seen as a result of initial septal depolarization and are considered normal. The initial negative deflection represents the normal left-to- right depolarization of the inter-ventricular septum. For this reason, they are referred to as septal *Q* waves. Normal *Q* waves are defined as having deflection amplitude of 0.2 mV and duration at 0.04 sec. Pathologic *Q* waves occurs when the electrical signal passes through stunned myocardium and as such, they are usually markers of previous myocardial infarctions with subsequent fibrosis. It is defined as having a deflection more than normal amplitude (> 0.2 mV) and duration (> 0.04 sec) or more than 25% of *QRS* complex's depth. The *Q* waves are only significant if they are

present and have larger amplitudes.

- The first positive deflection of the *QRS* complex is called the ***R wave***. It represents the left ventricular myocardium since its mass is much greater than the right ventricle. The negative deflection following the *R* wave is the *S* wave which represents terminal depolarization of the high lateral wall. The *R* wave should progress in size across the pre-cordial leads. Normally the *R* wave is small. However, due to more left ventricular forces**,** the *R* wave amplitude grows to reach its greatest amplitude. The increase in *R* wave's amplitude while *S* wave becomes smaller in the pre- cordial chest leads is called *R wave progression*. Usually when the *R* wave is disturbed, there are also unusual reciprocal changes in the *S* wave.
- The **QT interval** consists of the QRS complex, the ST segment and T wave. The QT interval is primarily a measure of ventricular repolarization and used in most clinical situations. The increment in QRS complex duration may cause an increase in the QT interval but this does not reflect a change in ventricular repolarization. A widened QRS must be considered if a prolonged QT interval is being evaluated. The time for ventricular repolarization is dependent upon the heart rate; it is shorter at faster heart rates and longer when the rate is slower. Thus, the QT interval has to be corrected for heart rate based on Bazett's formula. This is simple; however it is inaccurate at heart rate extremes and results in over-correcting at high rates and under-correcting at low ones. Other approaches to correct the QT interval yield the normal value for the QTc = 0.44 sec for men and = 0.46 sec for women.
- The **S wave** is the first negative deflection of the QRS complex that occurs after the R wave. An S wave may not be present and its presence or absence does not have major clinical significance. The morphology of the S wave is examined to determine if ventricular tachycardia or supraventricular tachycardia with aberrancy is present. In some normal cases such as sinus tachycardia, the J point is depressed and the ST where segment is rapidly positive within 0.08 seconds after the end of the QRS complex.
- The **T wave** is the positive deflection after the QRS complex and follows the S wave. It represents the period of ventricular repolarization. Since the rate of repolarization is slower than depolarization, this wave is wide with slow upward and rapid downward movements. This makes the T wave asymmetric and the amplitude varies [9]. The T wave is

usually smooth up and down. The variations in the atrial ST segment and T wave may occur with other pathologies, such as atrial infarction or atrial tumor invasion. The T wave vector on the ECG normally is in the same direction as the major deflection of the QRS. This means that the QRS and T wave axes are generally harmonious.

- A ***U wave*** follows the *T* wave. The exact cause uncertain, though it has been suggested that it represents repolarization. The amplitude of the *U* wave is typically less than 0.2 mV and is clearly separated from the *T* wave such as in hypokalemia and bradycardia. The *U* wave may merge with the *T* wave when the *QT* interval is prolonged or may become very obvious when the *QT* interval is shortened (hypercalcemia).

The above described waves can be described by using the fourier series expansion as stated below :

P, *T* and *U* waves:

$$af(x)=a\left(\frac{2}{b\pi}+\sum_{n=1}^{\infty}\frac{4b}{(b-2n)(b+2n)\pi}\cos\left(\frac{n\pi}{b}\right)\cos\left(\frac{n\pi x}{L}\right)\right)$$

$$,n=1,2,3,\ldots \qquad (14)$$

Q and *S* waves (negative gradient):

$$-f(x)=-\left[\frac{a}{2b}+\sum_{n=1}^{\infty}\frac{2ab}{(n\pi)^2}\left[1-\cos\left(\frac{n\pi}{b}\right)\right]\cos\left(\frac{n\pi x}{L}\right)\right],$$

$$n=1,2,3,\ldots \qquad (15)$$

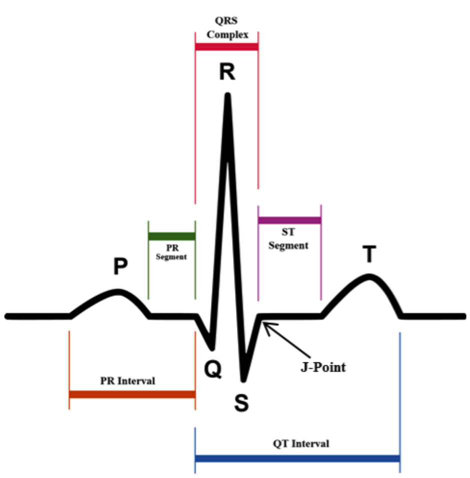

Fig. 2

3.EXAMPLE

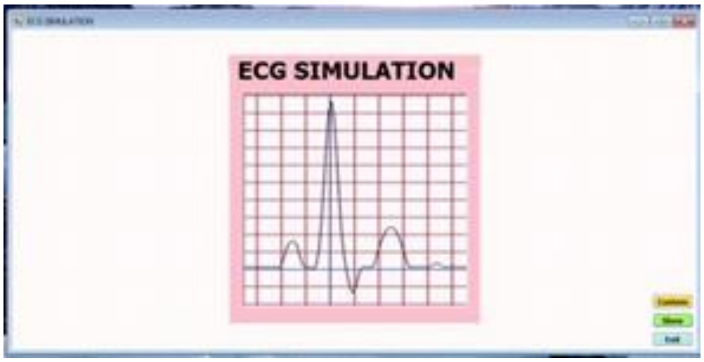

Fig. 3

Fig. 4

Fig. 5

4.MATLAB COMMANDS USED

1. **input() :** The response to the input prompt can be any MATLAB expression, which is evaluated using the variables in the current workspace. user_entry = input('*prompt*') displays *prompt* as a prompt on the screen, waits for input from the keyboard, and returns the value entered in user_entry. user_entry = input('*prompt*', 's') returns the entered string as a text variable rather than as a variable name or numerical value.

2. **fprintf() :** fprintf(fid,format,A,...) formats the data in the real part of matrix A (and in any additional matrix arguments) under control of the specified format string, and writes it to the file associated with file identifier fid. fprintf returns a count of the number of bytes written.

3. **function creation and calling :** function [y1,...,yN] = myfun(x1,...,xM) declares a function named myfun that accepts inputs x1,...,xM and returns outputs y1,...,yN. This declaration statement must be the first executable line of the function. Valid function names begin with an alphabetic character, and can contain letters, numbers, or underscores.

You can save your function:

- In a function file which contains only function definitions. The name of the file should match the name of the first function in the file.
- In a script file which contains commands and function definitions. Functions must be at the end of the file. Script files cannot have the same name as a function in the file.

Files can include multiple local functions or nested functions. For readability, use the end keyword to indicate the end of each function in a file. The end keyword is required when:

- Any function in the file contains a nested function.
- The function is a local function within a function file, and any local function in the file uses the end keyword.
- The function is a local function within a script file.

5.MATLAB CODE

```
x=0.01:0.01:2;
default=input('Press 1 if u want default ecg signal else press 2:\n');
if(default==1)
      li=30/72;

      a_pwav=0.25;
      d_pwav=0.09;
      t_pwav=0.16;

      a_qwav=0.025;
      d_qwav=0.066;
      t_qwav=0.166;

      a_qrswav=1.6;
      d_qrswav=0.11;

      a_swav=0.25;
      d_swav=0.066;
      t_swav=0.09;

      a_twav=0.35;
      d_twav=0.142;
      t_twav=0.2;

      a_uwav=0.035;
      d_uwav=0.0476;
      t_uwav=0.433;
else
    rate=input('\n\nenter the heart beat rate :');
    li=30/rate;

    %p wave specifications
    fprintf('\n\np wave specifications\n');
    d=input('Enter 1 for default specification else press 2: \n');
    if(d==1)
        a_pwav=0.25;
        d_pwav=0.09;
        t_pwav=0.16;
    else
       a_pwav=input('amplitude = ');
       d_pwav=input('duration = ');
       t_pwav=input('p-r interval = ');
       d=0;
    end


    %q wave specifications
    fprintf('\n\nq wave specifications\n');
    d=input('Enter 1 for default specification else press 2: \n');
    if(d==1)
```

```
    a_qwav=0.025;
    d_qwav=0.066;
    t_qwav=0.166;
else
   a_qwav=input('amplitude = ');
   d_qwav=input('duration = ');
   t_qwav=0.166;
   d=0;
end



%qrs wave specifications
fprintf('\n\nqrs wave specifications\n');
d=input('Enter 1 for default specification else press 2: \n');
if(d==1)
    a_qrswav=1.6;
    d_qrswav=0.11;
else
   a_qrswav=input('amplitude = ');
   d_qrswav=input('duration = ');
   d=0;
end



%s wave specifications
fprintf('\n\ns wave specifications\n');
d=input('Enter 1 for default specification else press 2: \n');
if(d==1)
    a_swav=0.25;
    d_swav=0.066;
    t_swav=0.09;
else
   a_swav=input('amplitude = ');
   d_swav=input('duration = ');
   t_swav=0.09;
   d=0;
end


%t wave specifications
fprintf('\n\nt wave specifications\n');
d=input('Enter 1 for default specification else press 2: \n');
if(d==1)
    a_twav=0.35;
    d_twav=0.142;
    t_twav=0.2;
else
   a_twav=input('amplitude = ');
   d_twav=input('duration = ');
   t_twav=input('s-t interval = ');
   d=0;
```

```
    end


    %u wave specifications
    fprintf('\n\nu wave specifications\n');
    d=input('Enter 1 for default specification else press 2: \n');
    if(d==1)
        a_uwav=0.035;
        d_uwav=0.0476;
        t_uwav=0.433;
    else
       a_uwav=input('amplitude = ');
       d_uwav=input('duration = ');
       t_uwav=0.433;
       d=0;
    end



end
 pwav=p_wav(x,a_pwav,d_pwav,t_pwav,li);

 %qwav output
 qwav=q_wav(x,a_qwav,d_qwav,t_qwav,li);

 %qrswav output
 qrswav=qrs_wav(x,a_qrswav,d_qrswav,li);
 %swav output
 swav=s_wav(x,a_swav,d_swav,t_swav,li);

 %twav output
 twav=t_wav(x,a_twav,d_twav,t_twav,li);

 %uwav output
 uwav=u_wav(x,a_uwav,d_uwav,t_uwav,li);
 %ecg output
 ecg=pwav+qrswav+twav+swav+qwav+uwav;
 figure(1)
 plot(x,ecg);
```

```
function [pwav]=p_wav(x,a_pwav,d_pwav,t_pwav,li)
l=li;
a=a_pwav;
x=x+t_pwav;
b=(2*l)/d_pwav;
n=100;
p1=1/l;
p2=0;
for i = 1:n
    harm1=(((sin((pi/(2*b))*(b-(2*i))))/(b-
(2*i))+(sin((pi/(2*b))*(b+(2*i))))/(b+(2*i)))*(2/pi))*cos((i*pi*x)/l);
    p2=p2+harm1;
end
```

```
pwav1=p1+p2;
pwav=a*pwav1;

function [qrswav]=qrs_wav(x,a_qrswav,d_qrswav,li)
l=li;
a=a_qrswav;
b=(2*l)/d_qrswav;
n=100;
qrs1=(a/(2*b))*(2-b);
qrs2=0;
for i = 1:n
    harm=(((2*b*a)/(i*i*pi*pi))*(1-cos((i*pi)/b)))*cos((i*pi*x)/l);
    qrs2=qrs2+harm;
end
qrswav=qrs1+qrs2;

function [qwav]=q_wav(x,a_qwav,d_qwav,t_qwav,li)
l=li;
x=x+t_qwav;
a=a_qwav;
b=(2*l)/d_qwav;
n=100;
q1=(a/(2*b))*(2-b);
q2=0;
for i = 1:n
    harm5=(((2*b*a)/(i*i*pi*pi))*(1-cos((i*pi)/b)))*cos((i*pi*x)/l);
    q2=q2+harm5;
end
qwav=-1*(q1+q2);

function [swav]=s_wav(x,a_swav,d_swav,t_swav,li)
l=li;
x=x-t_swav;
a=a_swav;
b=(2*l)/d_swav;
n=100;
s1=(a/(2*b))*(2-b);
s2=0;
for i = 1:n
    harm3=(((2*b*a)/(i*i*pi*pi))*(1-cos((i*pi)/b)))*cos((i*pi*x)/l);
    s2=s2+harm3;
end
swav=-1*(s1+s2);

function [twav]=t_wav(x,a_twav,d_twav,t_twav,li)
l=li;
a=a_twav;
x=x-t_twav-0.045;
b=(2*l)/d_twav;
n=100;
t1=1/l;
t2=0;
for i = 1:n
```

```
    harm2=(((sin((pi/(2*b))*(b-(2*i))))/(b-
(2*i))+(sin((pi/(2*b))*(b+(2*i))))/(b+(2*i)))*(2/pi))*cos((i*pi*x)/l);
    t2=t2+harm2;
end
twav1=t1+t2;
twav=a*twav1;

function [uwav]=u_wav(x,a_uwav,d_uwav,t_uwav,li)
l=li;
a=a_uwav
x=x-t_uwav;
b=(2*l)/d_uwav;
n=100;
u1=1/l
u2=0
for i = 1:n
    harm4=(((sin((pi/(2*b))*(b-(2*i))))/(b-
(2*i))+(sin((pi/(2*b))*(b+(2*i))))/(b+(2*i)))*(2/pi))*cos((i*pi*x)/l);
    u2=u2+harm4;
end
uwav1=u1+u2;
uwav=a*uwav1;
```

6.OUTPUTS

Press 1 if u want default ecg signal else press 2:

1

Press 1 if u want default ecg signal else press 2:

1

a = 0.0350

u1 = 2.4000

u2 = 0

a = 0.0350

u1 = 2.4000

u2 = 0

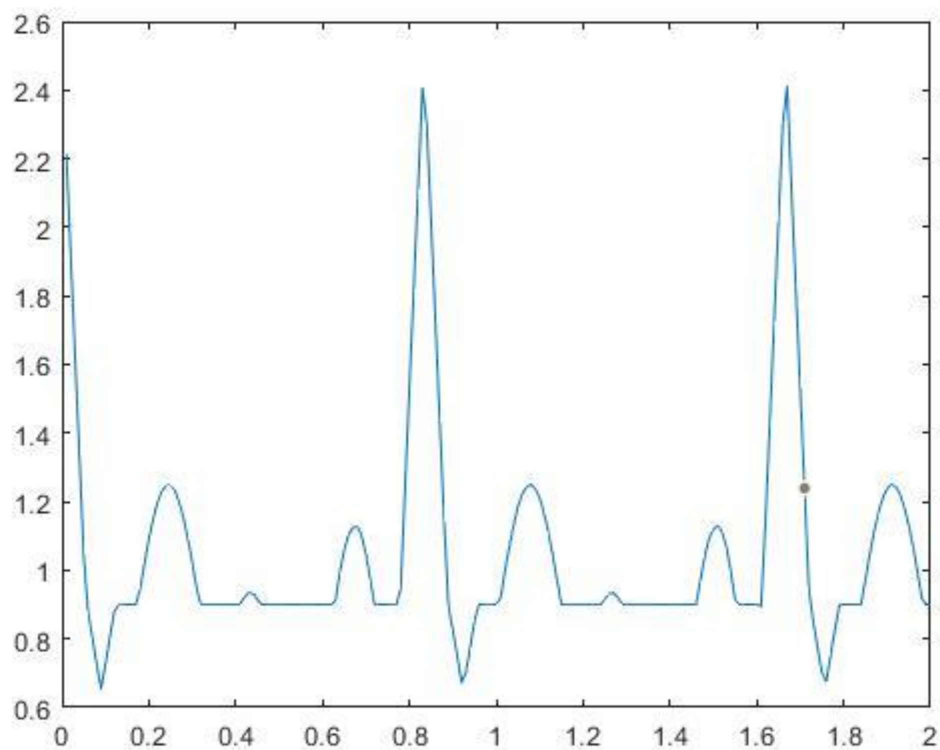

Fig. 6

7.APPLICATIONS

- This project provides the base for a software development which analyses the data and simulates the ECG signal of the patient.
- After the software development updates can be made to detect the heart beat rate and categorize the patient as Bradycardia , normal , Tachicardia
- It can also be used to detect diseases like Arrhythmia based on the concept of correlation by detecting the R-peak in the ECG wave.

8. ADVANTAGES

- Reduces the size of the equipment required for the testing of ECG
- Helps remote people get access to the cardio testing with just a basic software and a very few hardware components.
- The written code is accurate and did not show any deviations from the actual ouput which was observed during the testing

9. CONCLUSION

ECG Simulation is a kind of interactive simulation (an *ECG*-like movement) that enables anyone to observe the effect on the *ECG* pattern by selecting the preset values on the system. It may serve as an aide in basic aspects of *ECG* for any patient prior to seeking medical treatments. As it can be accessed remotely and in the presence of mobile devices, this can become a good companion for users.

The results have shown the outcomes for different heart rate and other values in the waves' portion; however, other hypotheses might be derived and included upon receiving some clear input from medical practitioners. As a research tool, this might also be useful to test any hypothesis they may have regarding the manifestation of cardiac malfunctioning in the *ECG* wave forms. This *ECG* Simulation only provides a simulation and some brief explanations. Further enhancement can be undertaken depending on the needs in the future.

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