Signal Processing of ECG Using Matlab

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Abstract- The ECG signal, even rest ECG, is often corrupted by artifacts produced by varies sources of either artificial or biological nature. Main artificial artifacts are power line interference, Impulse noise, Electrostatic potentials and noise of electronic devices. The main biological artifacts are motion artifacts and muscle artifacts (EMG signal) The present work introduces the digital filtering method to cope with the noise artifacts in the ECG signal. The ECG lead-II signal is taken. The butterworth IIR filter and FIR type1 filters are applied on the ECG signal. The basic bandwidth used for the ECG monitoring is from 0 .5 Hz to 100 Hz.

***Index Terms*-** ECG (Electrocardiogram), IIR (Infinite impulse response), FIR (finite impulse response

I. Introduction

The biomedical signal in the present work is the ECG signal and the filtering technique suggested is Butterworth filter or simply FIR Type-1 filter. This ECG gets corrupted due to different kinds of the artifacts. The different types of artifacts are Power line interference, motion artifacts, base line drift and instrumental noise. Due to these types of the artifacts ECG gets corrupted and correct information not transfers to the cardiac specialist. The care must be taken to nullify the artifacts to avoid wrong diagnosis. Certain type of the noise may be filter directly by time domain filters using signal processing techniques or digital filters. The advantage of the time domain filtering is that the spectral characterization of the filter may not be required (at least in the direct manner). Different researchers are working on noise reduction in the ECG signal. Wu Y, Yang Y in his article given new method for the ECG noise reduction by using 50 persons ECG based on Levkov method [22]. The Wang H, Dong X has suggested filter method with in filtered QRS wave can be exactly regarded as the mark identifying other physiological Signal. [23]. The method for the removal of the power line interference suggested by ferd Jallah M, Barr RE based on iterative division or multiplication of a set of frequencies centered at 60 Hz[17]. The Choy TT, Lenng PM has suggested in his literature the real time microprocessor based notch filter for ECG[9]. The Mc manus CD, Neubert KD has compared the digital filtering methods[6,17]. The technique for suppressing transient states of ECG the IIR notch filter is investigated by Pie SC and T Seng CC [18]. The work on the ECG beat detection using filter bank is carried out by the Tompkins W J and Luos [1]. Other method like Signal averaging for line interface reduction is also suggested by the scientists [11,13].

1.1. The ECG Leads

Two electrodes placed over different areas of the heart and connected to the galvanometer will pick up the electrical currents resulting from the potential difference between them. For example, if under one electrode a wave of 1 mV and under the second electrode a wave of 0.2 mV occur at the same time, then the two electrodes will record the difference between them, Le. a wave of 0.8 mV. The resulting tracing of voltage difference at any two sites due to electrical activity of the heart is called a "LEAD" (Figs1.1 (a) - (d).)

Bipolar Leads*:* In bipolar leads, ECG is recorded by using two electrodes such that the final trace corresponds to the difference of electrical potentials existing between them. They are called standard leads and have been universally adopted. They are sometimes also referred to as Einthoven leads (Fig1.2 (a)).

In standard lead I, the electrodes are placed on the right and the left arm (RA and LA). In lead II, the electrodes are placed on the right arm and the left leg and in lead III, they are placed on the left arm and the left leg. In all lead connections, the difference of potential measured between two electrodes is always with reference to a third point on the body. This reference point is conventionally taken as the "right leg". The records are, therefore, made by using three electrodes at a time, the right leg connection being always present.

In defining the bipolar leads, Einthoven postulated that at any given instant of the cardiac cycle, the electrical axis of the heart can be represented as a two dimensional vector. The ECG measured from any of the three basic limb leads is a time-variant single-dimensional component of die vector. He proposed that the electric field of the heart could be represented diagrammatically as a triangle, with the heart ideally located at the centre. The triangle, known as the *"***Einthoven triangle***"*, is shown in the fig 1.3. The sides of the triangle represent the lines along which the three projections of the ECG vector are measured. It was shown diat the instantaneous voltage measured from any one of the three limb lead positions is approximately equal to the algebraic sum of the other two or thai the vector sum of the projections on all three lines is equal to zero.

In all the bipolar lead positions. *QRS* of a normal heart is such that the *R* wave is positive and is greatest in lead II.

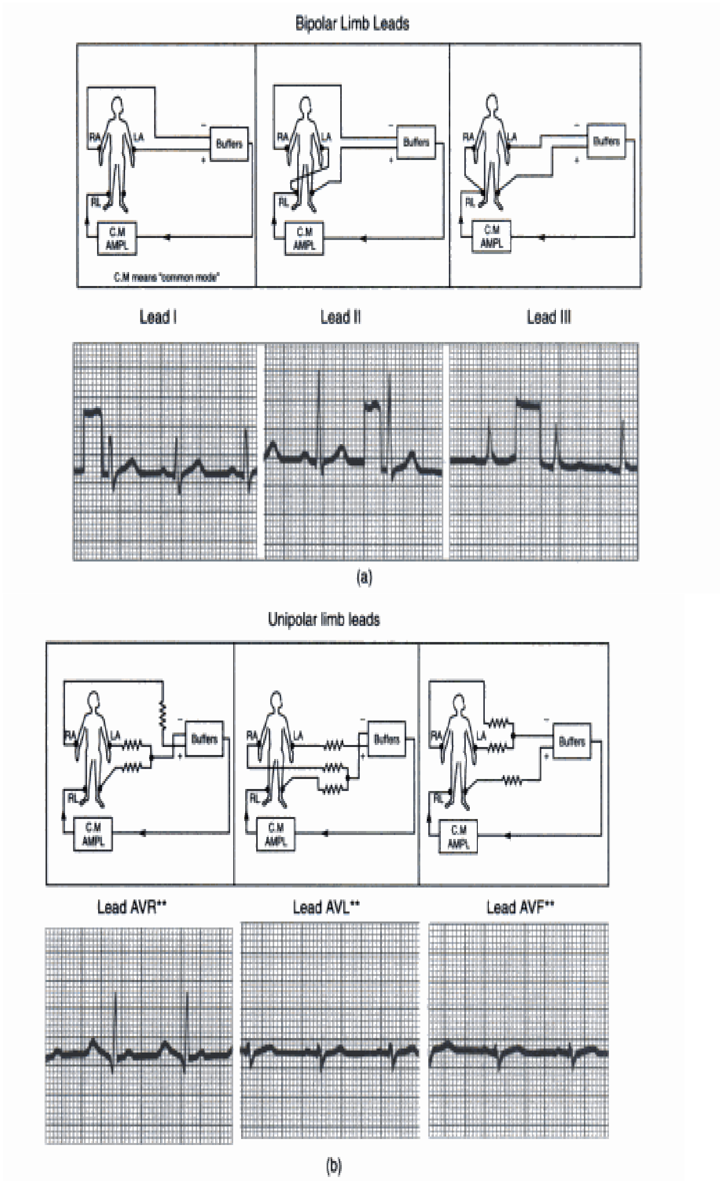


Fig1.1- Types of lead Connection with typical ECG waveforms
(a) Bipolar limb leads
(b) Unipolar Limb Leads

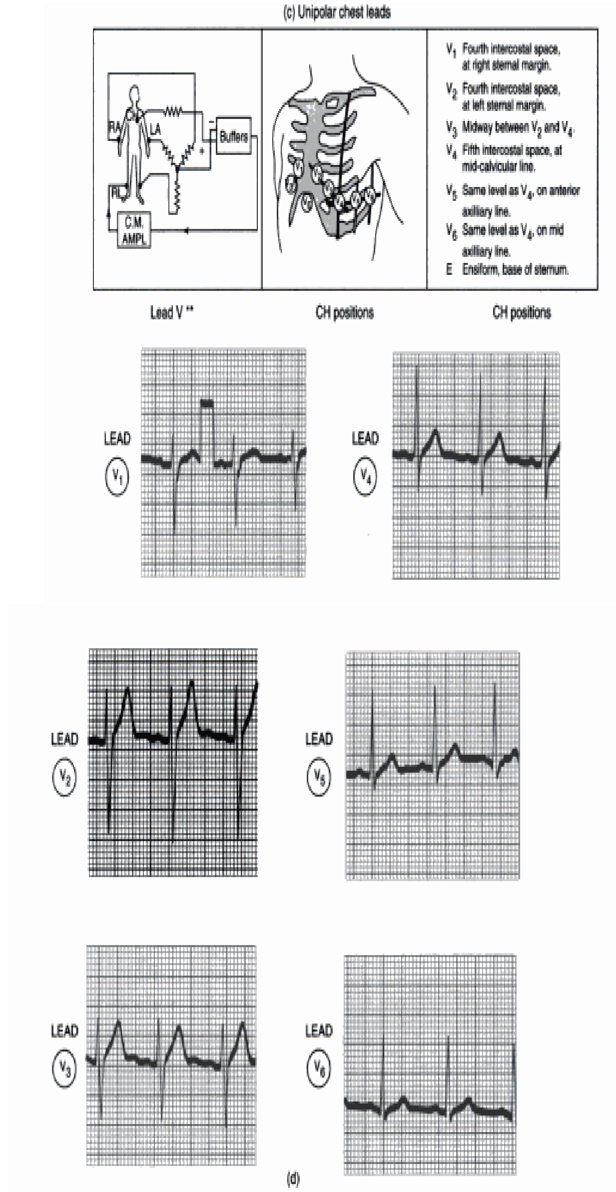


Fig 1.2- Types of lead Connections with typical ECG waveforms
(c) Position of chest lead in unipolar pericardial lead recording (d) C Leads

Unipolar Leads (V Leads): The standard leads record the difference in electrical potential between two points on the body produced by the heart's action. Quite often, this voltage will show smaller changes than either of the potentials and so better sensitivity an be obtained if the potential of a single electrode is recorded. Moreover, if the electrode is placed on the chest close to the heart, higher potentials can be detected than normally available at the limbs. This led to the development of unipolar leads introduced by Wilson in 1894. In this arrangement, the electrocardiogram is recorded between a single exploratory electrode and the central terminal, which has a potential corresponding to the centre of the body. In practice, the reference electrode or central terminal is obtained by a combination of several electrodes tied together at one point. Two types of unipolar leads are employed which are: (i) limb leads, and (ii) pericardial leads.

(i) **Limb leads** In unipolar limb leads, two of the limb leads are tied together and recorded with respect to the third limb. In the lead identified as AVR, the right arm is recorded with respect to a reference established by joining the left arm and left leg electrodes. In the AVL lead, the left arm Is recorded with respect to the common junction of the right arm and left leg. In the AVF lead, the left leg is recorded with respect to the two arm electrodes tied together. They are also called augmented leads or 'averaging leads'. The resistances inserted between the electrodes-machine connections are known as 'averaging resistances'.

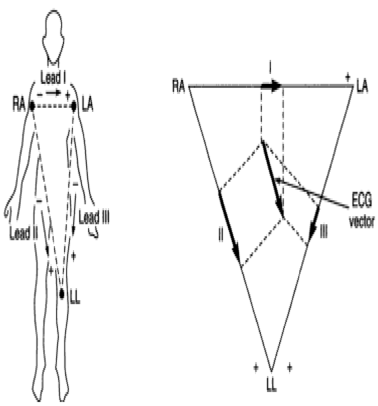


Fig 1.3- The Einthoven triangle for defining ECG Leads

(ii) **Precordial leads** the second type of unipolar lead is a pericardial lead. It employs an exploring electrode to record the potential of the heart action on the chest at six different positions. These leads are designated by the capital letter 'V followed by a subscript numeral, which represents the position of the electrode on the pericardium. The positions of the chest leads are shown in Fig. 1.3.

1.2 Effects of Artifacts on ECC Recordings

Abnormal patterns of ECG may be due to pathological states or on occasion they may be due to artifacts. To diagnose the presence of undesirable artifacts on the ECG trace, a few recordings are illustrated below:

Interference from the Power Line*:* Power line interference is easily recognizable since the interfering voltage in the ECG would have a frequency of 50Hz . This interference may be due to the stray effect of the alternating current on the patient or because of alternating current fields due to loops in the patient cable. Other causes of interference are loose contacts on the patient cable as well as dirty electrodes. When the machine or the patient is not properly grounded, power line interference may even completely obscure the ECG waveform.

The most common cause of 50 Hz interference is the disconnected electrode resulting in a very strong disturbing signal. It is often strong enough to damage the stylus of an unprotected direct writing recorder, and therefore needs quick action.

Sometimes static charges on the synthetic uniform of the operator may result in a random noise on the trace. This noise is very difficult to remove except in those machines which have very high CMRR. The noise can be reduced by partially shielding the patient by means of the bed springs. Connection of the springs to the instrument case helps to compensate for a poor CMRR (Spooner, 1977).

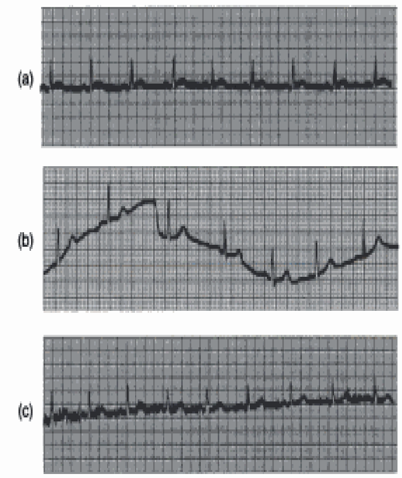


Fig1.4 (a) ECG Recording with regular spreading of the curve with super imposed 50 Hz power line interference signal
(b) Recording with irregular trembling of the ECG trace without wandering of the base line but otherwise normal ECG Trace
(c) ECG Trace without wandering of the base line

Electromagnetic interference from the power lines also results in poor quality tracings. Electrical equipment such as air-conditioners, elevators and X-ray units draw heavy power-line current, which induce 50 Hz signals in the input circuits of ECG machines. Due to unbalanced linkages, common mode rejection circuits almost prove ineffective against them. A practical solution to minimize this problem is physical separation between the interference causing sources and the patient. Levkov *el at* (1984) developed a method of digital 50 Hz interference elimination by computing the interference amplitudes and subtracting these data from the original signal, thereby greatly reducing the requirements of amplifiers, shielding, earthing, electrode quality and application procedures.

Electrical power systems also induce extremely rapid pulses or spikes on the trace, as a result of switching action. Use of a transient suppressor in the mains lead of the machines helps to solve this problem.

Shifting of the Baseline*:* A wandering baseline but otherwise normal ECG trace is usually due to the movement of the patient or electrodes. The baseline shift can be eliminated by ensuring that the patient lies relaxed and the electrodes are properly attached. Baseline wander is usually observed immediately after application of the electrodes. It is due to a relatively slow establishment of electrochemical equilibrium at the electrode-skin interface. This can be minimized by selecting the proper electrode material, which will reach equilibrium quickly with a good electrode jelly.

Muscle Tremor. Irregular trembling of the ECG trace, without wandering of the baseline occurs when the patient is not relaxed or is cold. It is generally found in the case of older patients. Muscle tremor signals are especially bothersome on limb leads when a patient moves or the muscles are stretched. Therefore, for long-term monitoring, the electrodes are applied on the chest and not on the limbs. For normal routine ECG recordings, the patient must be advised to get warm and to relax so that muscle tremor from shivering or tension is eliminated.

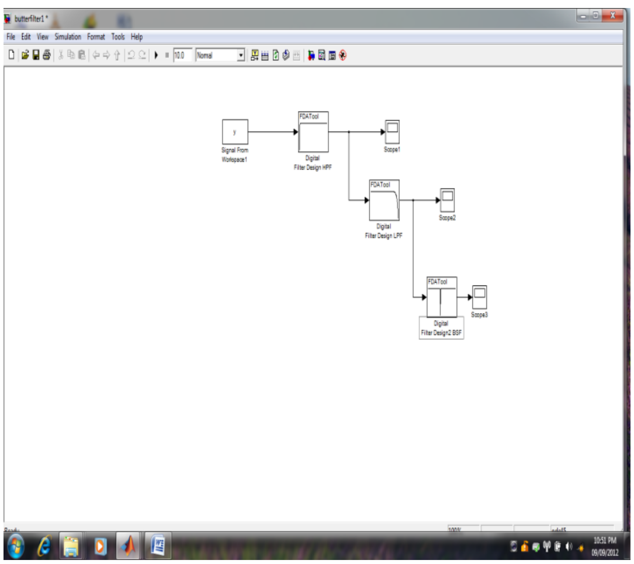
The most critical component of the ECG recorder is the patient cable. The conventional PVC insulation gets degraded and becomes rigid and breakable because of the arification of the softener. Some manufacturers supply a patient-cable made of silicon-rubber, which provides better elasticity over long periods

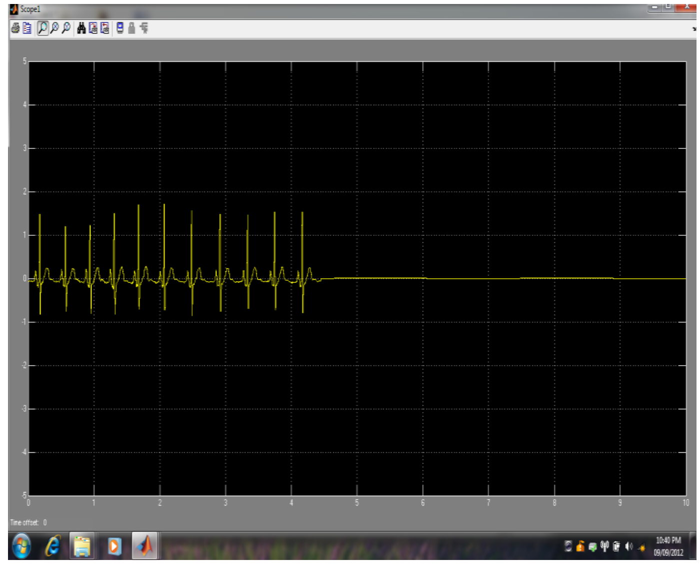
II. Simulation Result

Design of IIR filter (Butterworth):-

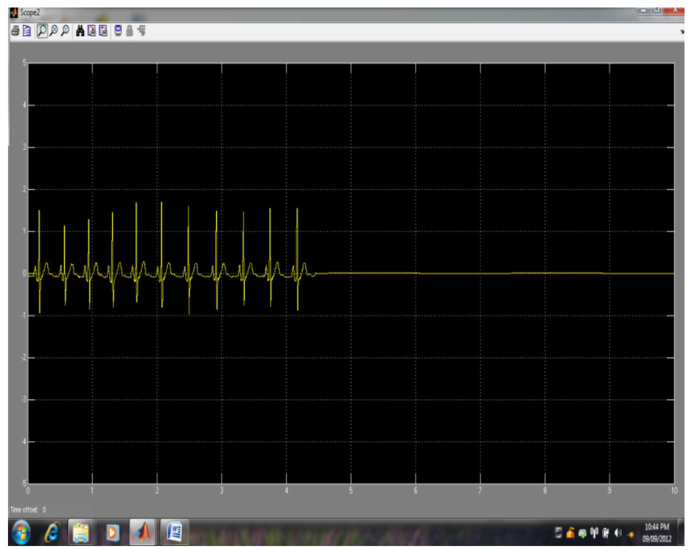
IIR filter have infinite duration impulse response, hence they can be match to analog filter , all impulse of which generally have infinitely long response .Therefore the basic technique of IIR filter design transforms well know analog filter into digital filter using complex value mappingdesigned to have linear phase ,no distortion.

FDA Butterworth Filter

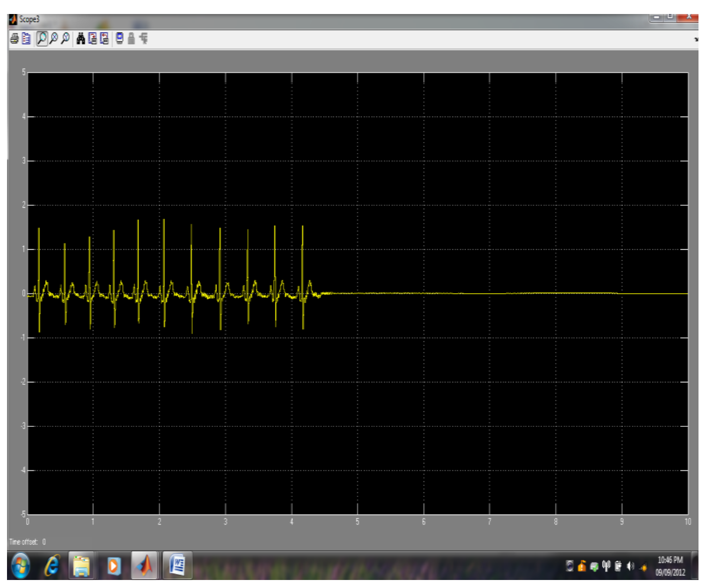




FDA Butter HPF, Scope



FDA Butter LPF, Scope-1

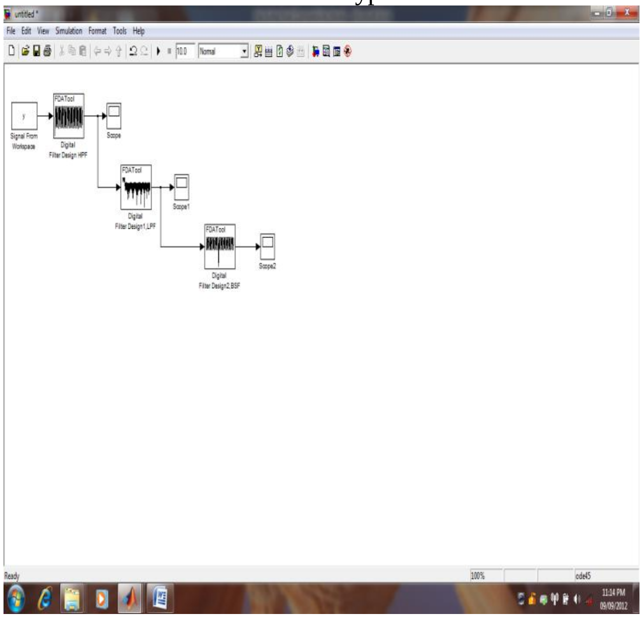


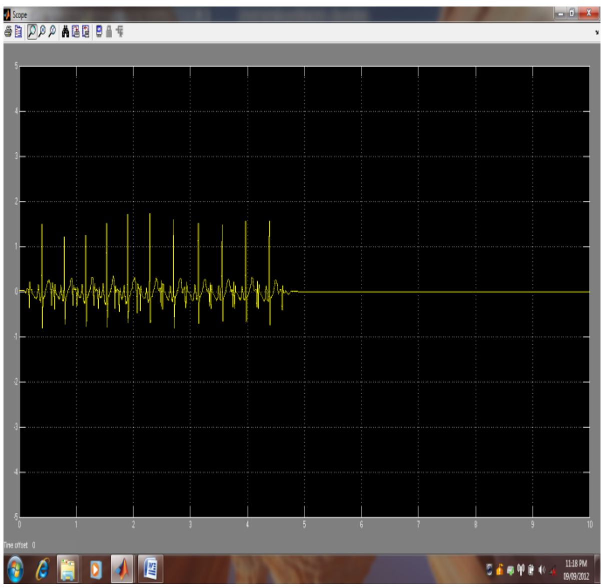
FDA Butter BSF, Scope-2

Design of FIR Type -1 filter:-

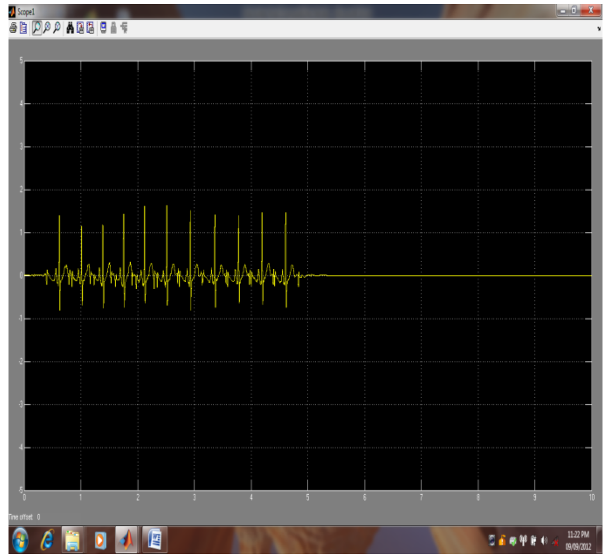
FIR filter involves finding the coefficient h(n) that result in frequency response that satisfies a given set of filter specification. FIR filter have two important advantages over IIR filte ,first they are generated to be stable, even after filter coefficient have been quantized ,second they may be easily constrained to have linear phase.

FDA FIR Typr-1

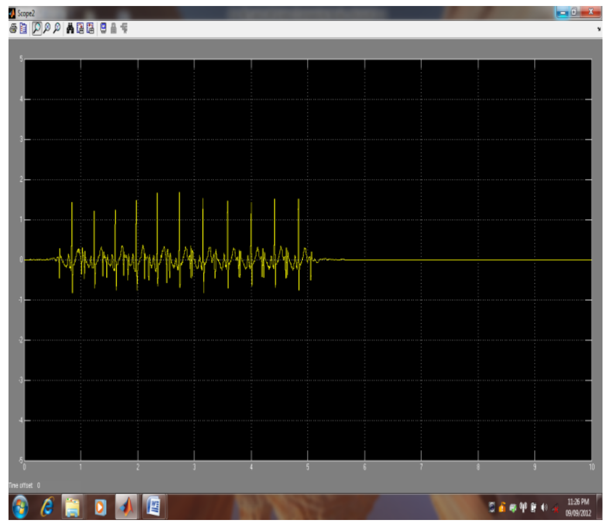




FDA FIR Type-1 HPF Scope



FDA FIR Type-1 LPF Scope-1



FDA FIR Type-1 BSF Scope-2

Comparison of Butterworth & FIR-Type1 filter for HPF,LPF&BSF

Types of Filter	Filter order	Effects on PQRST Wave form
Butterworth filter	2	Modified
FIR-Type1 filter	100	Less modified

III. Conclusion

The present work introduces the digital filtering method to cope with the noise artifacts in the ECG signal. The butterworth

IIR filter and FIR type1 filters are applied on the ECG signal.From the result to see that both the filter reduces the low and high frequency noise.It is seen that tip of the QRS complex is distorted in case of Butterworth highpass filter of order two. Where as in case of FIR type-1 QRS complex is less modified.

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