Effect of Finite Word Length for FIR Filter Coefficient in Electrocardiogram Filtering

Vaibhav M Dikhole[#1]
Dept of E&TC
SSGMCOE
Shegaon, India (MS)
vaibhav.1624@gmail.com[#1]

Snehal R.Deshmukh[#2]
Dept. of E&TC
MGI-COET
Shegaon, India (MS)
snehdeshmukh23@gmail.com[#2]

Nishant W. Labade[#3]
Dept. of E&TC
,MGI-COET
Shegaon, India (MS)
nishantlabade@gmail.com[#3]

Pranali P.Chavan[#4]
Dept. of E&TC
MGI-COET
Shegaon, India (MS)
pranalichavhan750@gmail.com[#4]

Nilesh M.Verulkar[#5]
Dept. of E&TC
MGI-COET
Shegaon, India (MS)
nileshverulkar@gmail.com[#5]

Abstract: In Digital Signal Processing (DSP) applications, filter coefficients play an important role. Therefore word length optimization of Digital filter coefficient is desirable to minimize cost and power requirement. In this paper a brief study of effects of different word lengths on ECG signal is discussed.

***Keywords**: word length, Data representation, Digital filter, Electrocardiogram (ECG), FDA tool.*

*****

I. INTRODUCTION

A rapid development in electronic technologies is taking place today. The Digital signal processing (DSP) applications demand high speed and low power digital filters. In order to meet these requirements, the order of the digital filter must be kept as small as possible and the number of bits required to represent filter coefficients should be optimum. DSP applications are represented by floating-point data types but they are usually implemented in embedded systems with fixed-point arithmetic in order to minimize cost and power consumption. An optimization algorithm is required for floating-to-fixed point conversion, to determine a combination of optimum word-length for each operator.

II. DATA REPRESENTATION

It is important to decide carefully whether fixed- or floating point is more appropriate for the given problem. In general it can be assumed that fixed point implementations have higher speed and lower cost, whereas floating point implementations have higher dynamic range and no need of scaling which may be attractive for more complicated algorithms [1].

Integers are whole numbers or fixed-point *n*umbers with the radix point fixed after the least-significant bit. In contrast to real numbers or floating-point numbers, the position of the radix point varies. It is important to note that integers and floating-point numbers are treated differently in computers. In Computers an integer is represented by using fixed number of bits . The commonly-used bit-lengths for integers are 8-bit, 16-bit, 32-bit or 64-bit. Besides bit-lengths, there are two representation schemes namely unsigned and signed integers [2].

Most floating point systems comply with the published single precision and double precision floating point formats. A standard floating point word consists of a sign bit S, exponent e, unsigned normalized mantissa arranged as follows:

S	Exponent e	Unsigned mantissa

Algebraically a floating point word is represented as given in equation 1.

$$X= (-1)^S\, 1.m^{\,2e\text{-}bias} \qquad (1)$$

Where bias= 1023 for double precision floating point representation and 127 for single precision floating point representation [4].

III. DESIGNING A DIGITAL FILTER

A digital filter is a system that performs mathematical operations on a sampled, discrete-time signal to reduce or enhance certain aspects of that signal.

- Types of digital filter:

a) Finite Impulse Response
b) Infinite Impulse Response

Finite Impulse Response:

$$y(m)=\sum_{k=0}^{M} b_k x(m-k)$$

The response of such a filter to an impulse consists of a finite sequence of M+1 samples, where M is the filter order. Hence, the filter is known as a Finite-Duration Impulse

ISSN: 2321-8169
266 - 271

Response (FIR) filter. The output y(m) of a FIR filter is a function only of the input signal x(m).

Infinite Impulse Response:

A IIR filter has feedback from output to input, and in general its output is a function of the previous output samples and the present and past input samples as described by the following equation:

$$y(m) = \sum_{k=1}^{N} a_k y(m-k) + \sum_{k=0}^{M} b_k x(m-k)$$

When a IIR filter is excited by an impulse, the output persists forever ,thus it is known as an Infinite Duration Impulse Response (IIR) filter.

IV. ECG SIGNAL DETAILS

The ECG records the electrical activity that results when the heart muscle cells in the atria and ventricles contract atrial contractions show up as the P wave. Ventricular contractions show as a series known as the QRS complex. T wave is the third and last common wave in an ECG. This is the electrical activity and is produced when the ventricles are recharging for the next contraction (repolarizing). Interestingly, the letters P, Q, R, S, and T are not abbreviations for any actual words but they were chosen for their position in the middle of the alphabet many years ago. The electrical activity results in P, QRS, and T waves that are of different sizes and shapes. These waves can show a wide range of abnormalities of both the electrical conduction system and the muscle tissue of the hearts 4 pumping chambers when viewed from different leads [3].

INTERVAL	Time(mS)
R to R interval	0.60 to 1.2 sec
P wave	80
PR interval	120 to 200
PR segment	50 to 120
QRS complex	80 to 120
ST segment	80 to 120
T wave	160
ST segment	320
QT interval	420 in hear rate of 60bpm

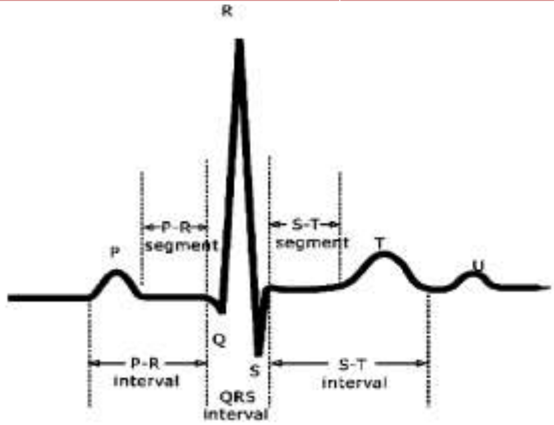

Figure 1: Standard Ecg Signal

V. DESIGN OF FIR FILTER USING FDA TOOL

The sampling rates for ECG are varied according species. For human it is 0.01 to 300Hz.So for the filter specification the sampling frequency is chosen as 800 Hz and accordingly other parameters.

Filter Parameter	**Value**
Pass band frequency	50Hz
Pass band attenuation	1dB
Stop band attenuation	30dB
Stop band frequency	350Hz
Sampling frequency	800Hz

VI. EFFECT OF WORDLENGTHS:

The designed filter stimulation for various word length is as described below:

1. *Double Precision Floating Point:*

The design of filter is done in FDA tool of matlab and the filter arithmetic type is set to double precision floating point. Fig.2(a) shows the FDA tool design for double precision floating point. The frequency response for double precision floating point is as shown in Fig.2 (b). The coefficient generator for specified order are five which have fraction wordlength equal to 18 as shown in Fig.2(c) .The noise ECG signal is shown in Fig.2(d) where as Fig.2(e) show the filtered ECG signal.

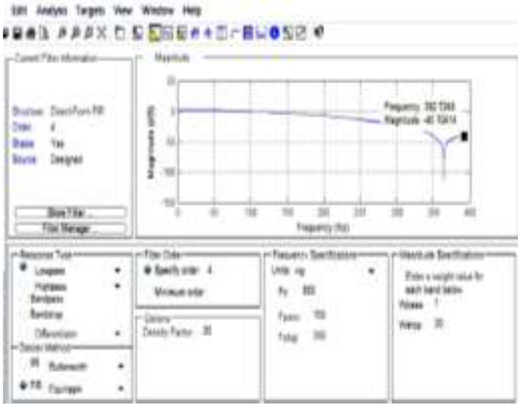

Figure 2(a): FDA tool For Double Precision Floating Point(Q18)

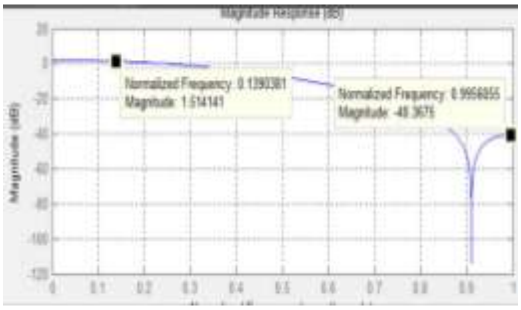

Figure 3(b): Magnitude Response(QWl=18)

Numerator:
-0.042741708955518654
0.28414825469722432
0.6196316726082618
0.28414825469722432
-0.042741708955518654

Figure 3(c): Coefficient(Q18) For Double Precision Floating Point

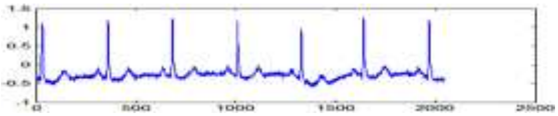

Figure3(d):Noise Ecg Signal For Double Precision Floating Point

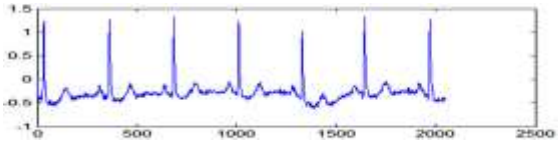

Figure 3(e):Filtered Ecg Signal For Double Precision Floating Point

2. *Single Precision Floating Point:* Fig.3 (a) shows the FDA tool design for single precision floating point. The frequency response for single precision floating point is as shown in Fig.3 (b). The reference coefficient and the quantized coefficient for single precision floating are as shown in Fig.3(c). From Fig.3(c) we can see one digit difference in single precision floating point and double precision floating point fractional coefficient word length. Fig.3(c) show the filtered ECG signal with coefficient arithmetic set to single precision. When the arithmetic type of filter is keep to single precision we get fractional coefficient word length equal to 17.

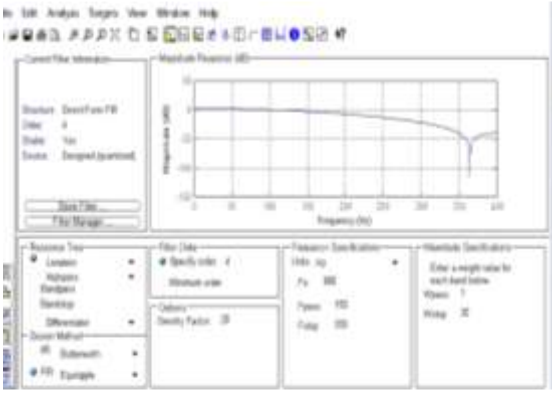

Figure 3(a): FDA tool for single precision floating point(Q18.17)

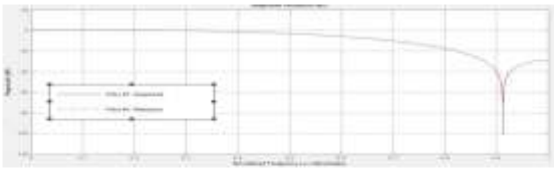

Figure 3(b): Magnitude Response (Q18.17)

Quantized Numerator:
-0.04274170845746994
0.28414824604988098
0.61963164806365967
0.28414824604988098
-0.04274170845746994

Reference Numerator:
-0.042741708955518654
0.28414825469722432
0.6196316726082618
0.28414825469722432
-0.042741708955518654

Figure 3(c): Coefficient(Q18.17) For Single Precision Floating Point.

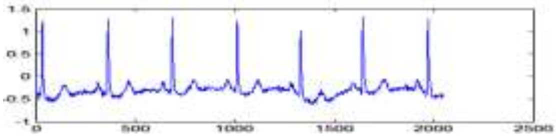

Figure 3(d): Filtered Ecg Signal For Single Precision Floating Point(Q18.17)

3. *Fixed point:* The design of filter for fixed point arithmetic is also done in FDA tool. Fig.4 (a) shows the FDA tool design for the coefficient having word length equal to 15. The magnitude response and filtered ECG signal is as shown in Fig.4(c) and Fig.4 (d) respectively.

a*)For coefficient having wordlength Q16.15:* The designed filter is quantized to a Q16.15 fixed point numeric representation format as shown in Fig.4(b) in reference coefficient we can see that except third coefficient all other have fractional wordlength equal to 15.

ISSN: 2321-8169
266 - 271

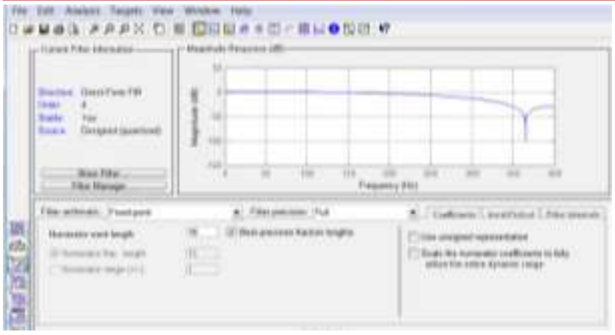

Figure 4(a): FDA tool For Fixed Point(Q16.15)

Quantized Numerator:
-0.042755126953125
0.284149169921875
0.61962890625
0.284149169921875
-0.042755126953125

Reference Numerator:
-0.04274170895518654
0.28414825469722432
0.6196316726082618
0.28414825469722432
-0.04274170895518654

Figure 4(b) :CoefficientQ16.15) For Fixed Point

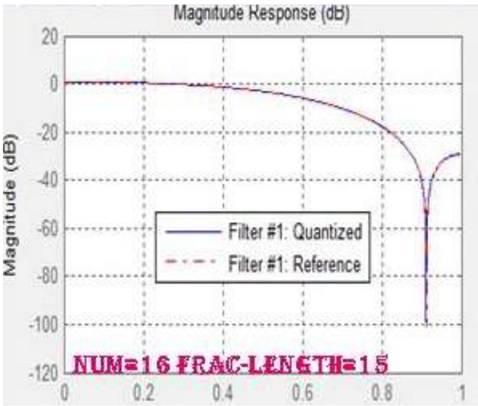

Figure 4(c):Magnitude Response For Fixed Point (Q16.15)

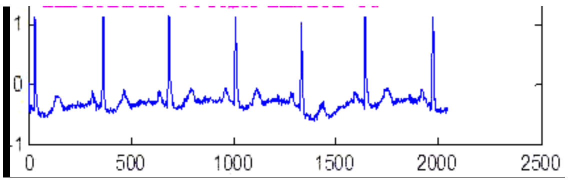

Figure 4(d):Filtered Ecg Signal For Fixed Point(16.15)

b)*For coefficient having wordlength Q11.10:* The designed filter is quantized to a Q11.10 fixed point numeric representation format. In Fig.5 (a) we can see that second, third and fourth coefficients have fractional wordlength 10. The magnitude response and filtered ECG signal is as shown in Fig.5 (b) and Fig.5(c) respectively.

Quantized Numerator:
-0.04296875
0.2841796875
0.6201171875
0.2841796875
-0.04296875

Reference Numerator:
-0.04274170895518654
0.28414825469722432
0.6196316726082618
0.28414825469722432
-0.04274170895518654

Figure 5(a):Coefficient(Q11.10) For Fixed Point

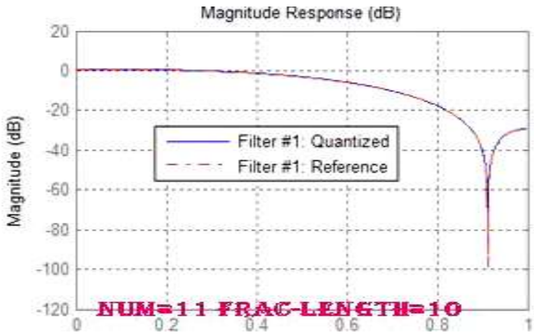

Figure 5(b):Magnitude Response For Fixed Point(Q11.10)

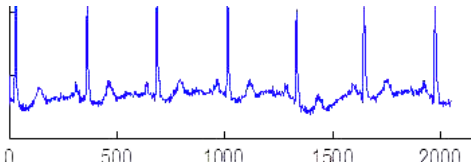

Figure 5(c):Filtered Ecg Signal For Fixed Point(QWl=Q11.10)

d)For Coefficient having wordlength Q7.6: Designed filter is quantized to a Q7.6 fixed point numeric representation format. In Fig.6 (a) we can see that second and fourth coefficient have fractional wordlength 5. The first and fifth coefficient have fractional word length 6 where as third coefficient have fractional wordlength 3. The magnitude response and filtered ECG signal is as shown in Fig.6 (b) and Fig.6 (c) respectively.

ISSN: 2321-8169
266 - 271

```
Quantized Numerator:
-0.046875
 0.28125
 0.625
 0.28125
-0.046875

Reference Numerator:
-0.042741708955518654
 0.28414825469722432
 0.6196316726082618
 0.28414825469722432
-0.042741708955518654
```

Figure 6(a):Coefficient(Q6.7) For Fixed Point

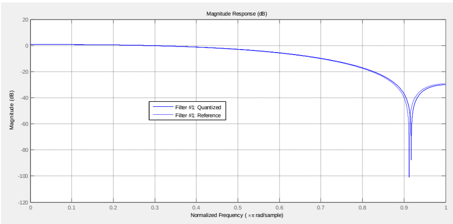

Figure 6(b) Magnitude Response For Fixed Point (Q6.7)

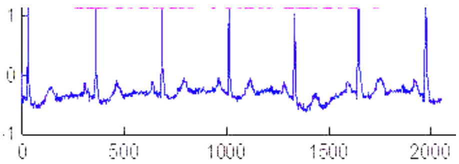
Figure 6(c):Filtered ecg signal for fixed point(Q6.7)

c) For Coefficient having wordlength Q3.2: Designed filter is quantized to a Q3.2 fixed point numeric representation format. In Fig.7 (a) we can see that second and fourth coefficient have fractional wordlength 2. The first and fifth coefficients have fractional word length zero where as third coefficient have fractional wordlength 1. The magnitude response and filtered ECG signal is as shown in Fig.7 (b) and Fig.7 (c) respectively.

```
Quantized Numerator:
0
0.25
0.5
0.25
0

Reference Numerator:
-0.042741708955518654
 0.28414825469722432
 0.6196316726082618
 0.28414825469722432
-0.042741708955518654
```

Figure 7(a):Coefficient(Q3.2) For Fixed Point

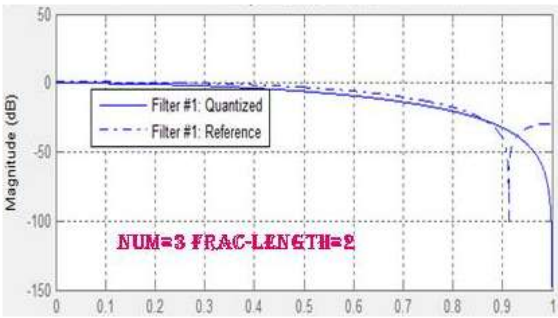

Figure 7(b):Magnitude Response For Fixed Point(Q3.2)

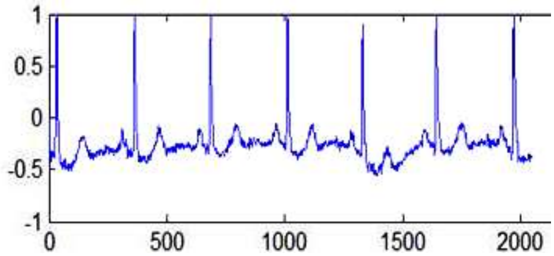
Figure 7(c):Ecg Signal For Fixed Point(Q3.2)

I. CALCULATION RESULT:

PASS BAND AND STOP BAND ATTENUATION CALCULATION

[illegible]	[illegible]	[illegible]
Double precision floating point	2.198544	40.4318
single precision floating point	2.041829	40.3675
19	-1.443532	40
18	-1.443532	40.309088
17	-1.443532	39.86639
16	-1.443532	39.86639
15	-1.443532	38.988597
14	-1.443532	39.48771082
13	-1.443532	38.81952278
12	-1.443532	38.81950278
11	-1.443532	39.8721542
10	-1.443532	39.151598
9	-1.443532	41.355
8	-1.443532	39.3888
7	-1.443532	39.18528
6	-1.443532	38.85981755
5	-1.443532	41.18977
4		38.74839
	-1.443532	
3	-1.443532	25.13488
2	-1.5252	43.4456
1	+10.8348	37.8853

Table 1: Passband And Stopband Attenuation For Various Coefficient Wordlengths

CONCLUSION**:** Different digital filter require different wordlength.This paper discusses the effect of various coefficients wordlengths on ECG signal. It is possible to construct designs for different quantization requirements without manual iteration. In this paper the magnitude response for different coefficient wordlength is shown. The Passband attenuation and stop band attenuation for optimize wordlength is shown through experiments.

From calculation results we can see that for coefficient having one wordlength the pass band attenuation increases, while for double precision and single precision floating point it is more as compare to fixed point wordlength. While stop band attenuation is greatest for coefficient having wordlength equal to nine. Moreover, we have studied fixed-point DSP characteristics in order to understand the techniques for implementing a floating-point algorithm on a fixed-point processor.

REFERENCES:

[1] U.Meyer Baese, "Digital signal processing with FPGA", Springer Publications.

[2] A Tutorial on Data Representation Integers, Floating-point Numbers, and Characters: December, 2011

[3] NATIONAL INSTRUMENTS: Publish Date: Aug 16, 2012(http://ni.com/legal/termsofuse/unitedstates/us/).

[4] Floating-Point Number Specification) IEEE 754 (1985), "IEEE Standard for Binary Floating-Point Arithmetic

[5] Keshab K. Parhi, Fellow, IEEE "Approaches to Low-Power Implementations of DSP Systems" IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS—I: FUNDAMENTAL THEORY AND APPLICATIONS, VOL. 48, NO. 10, OCTOBER 2001

[6] Design and Implementation of Custom Low Power DSP blocks for Biomedical Applications Dr. K.B.Khanchandani:Published in International Journal of Advanced Engineering & Application, Jan 2011 Issued