Design of Parallel Linear Phase FIR Digital Filter of Odd Length based on Fast FIR Algorithm

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Abstract: ***Based on published Area efficient VLSI implementation for parallel linear phase FIR digital filter of odd length based on fast FIR algorithm, this paper proposes a parallel FIR filter structure with less hardware complexity. In previous paper using carry save adder are replaced by ripple carry adder which can reduce the area.***

Keywords: Fast FIR algorithms (FFA), ripple carry adder (RCA), carry save adder (CSA), symmetric convolution.

1. Introduction

The demand of high performance and low power digital signal processing (DSP) is getting higher and higher in multimedia application. The FIR filter one of device which performed in DSP system, ranging from wireless communication to video and image processing. Some application need to operate fir filter at high frequency such as video processing and other need high throughout with low power such as multiple-input multiple-output. In brief here, parallel FIR digital filter will be discussed. Because its linear increase in hardware implementation cost will increase because of increasing the block size L, there is few papers success to reduced the complexity of the fir filter [1]-[11]. In this the first [1]-[4] using polyphase decomposition, by cascading or iterating constructed first the small sized and then larger block sized parallel fir filter. In [1]-[3] using FFA they implemented L parallel filter using (2L-1) subfilter blocks which length is N/L. Using this FFA, it can reduces the required number of multipliers. The fast linear convolution is used to develop the small sized filtering structures and then a long convolution is decomposed into several short convolution in paper [5]- [9].

In [10] , they designed for symmetric convolution based on even length and in [11] based on odd length. In both they are using carry save adder, but we can show that by using ripple carry adder we can reduce the area. The brief is organized as follows, introduction of FFA is reviewed in section 2, the proposed parallel FIR filter architecture are presented in section 3,and in section 4 the conclusion is given.

2. FFA

The general form of an N-tap FIR filter can expressed as

$$y(n) = \sum_{i=0}^{N-1} h(i)x(n-i),\ n = 0, 1, 2, .., \infty \quad (1)$$

where x(n) = input sequence of infinite length and h(i) = filter coefficients. As [3], the L-parallel FIR filter can be derived using polyphase decomposition.

$$\sum_{p=0}^{L-1} Y_p(z^L)z^{-p} = \sum_{q=0}^{L-1} X_q(z^L)z^{-p} \sum_{r=0}^{L-1} H_r(z^L)z^{-r}$$

Where (2)

$$X_q(z) = \sum_{k=0}^{\alpha} z^{-k} x(LK + q),$$

$$H_r(z) = \sum_{k=0}^{\frac{N}{L}-1} z^{-k} h(LK + r)$$

And

$$Y_p(z) = \sum_{k=0}^{\alpha} z^{-k} y(LK + p)$$

2.1 3 ×3 FFA

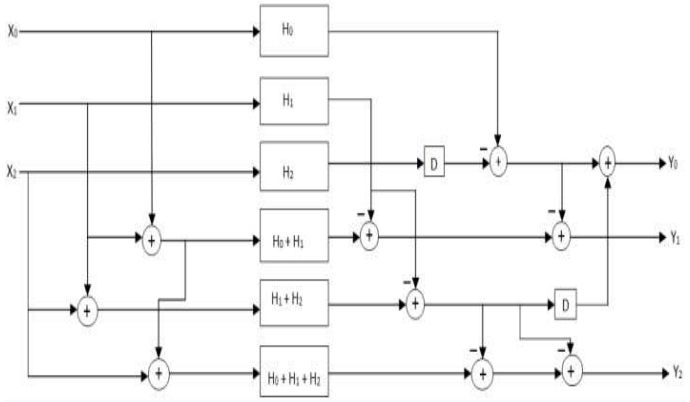


Figure 1: Three parallel FIR filter implementation using the FFA.

As [1], [3] a three parallel FIR filter using FFA can expressed as

$$\begin{aligned}
Y_0 &= H_0X_0 - z^{-3}H_2X_2 + z^{-3}[(H_1 + H_2)(X_1 + X_2) - H_1X_1] \\
Y_1 &= [(H_0 + H_2)(X_0 + X_2) - H_1X_1] - [H_0X_0 - z^{-3}H_2X_2] \\
Y_2 &= [(H_0 + H_1 + H_2)(X_0 + X_1 + X_2)] - [(H_0 + H_1)(X_0 + X_1) - H_1X_1] \\
&\quad - [(H_1 + H_2)(X_1 + X_2) - H_1X_1] \quad (3)
\end{aligned}$$

The implementation from (3) is shown fig. 1.

3. Proposed structure

The new three parallel FIR filter structure are proposed, which enables more multipliers sharing in the subfilter section and therefore can save more hardware cost.

1) Proposed structure 3A using RCA,((N mod 3=0))

In odd length N for a symmetric coefficients, when (N mod 3 = 0), (4) which is presented from (3) can earn two more subfilter block which containing symmetric coefficients as [11],by using ripple carry adder we can reduce the area . The implementation is shown in fig. 2. and the Comparison of Subfilter between Existing FFA and the proposed structure 3A is shown fig.3.

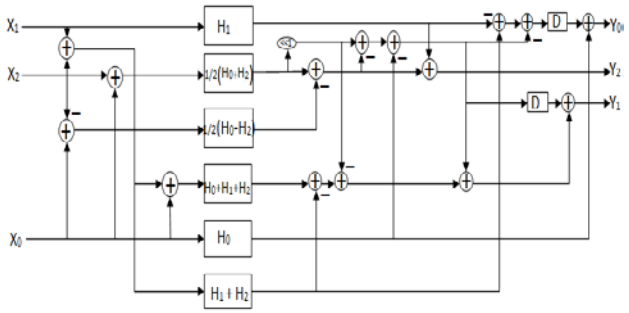


Figure 2: Implementation of the proposed structure 3A.

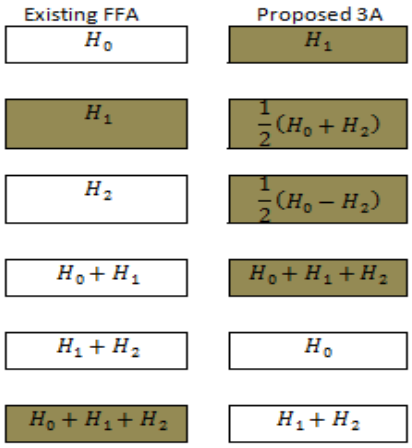


Figure 3: Comparison of Subfilter between Existing FFA and proposed structure 3A.

$$Y_0=H_0X_0+z^{-3}\left\{(H_1+H_2)(X_1+X_2)-H_1X_1-\left\{(H_0+H_2)(X_0+X_2)-H_0X_0-\frac{1}{2}[(H_0+H_2)(X_0+X_2)-(H_0-H_2)(X_0-X_2)]\right\}\right\}$$

$$Y_1=(H_0+H_1+H_2)(X_0+X_1+X_2)-(H_1+H_2)(X_1+X_2)-(H_0+H_2)(X_0+X_2)+\{(H_0+H_2)(X_0+X_2)-\frac{1}{2}$$

$$\times[(H_0+H_2)(X_0+X_2)-(H_0-H_2)(X_0-X_2)]-H_0X_0\}+z^{-3}\{(H_0+H_2)(X_0+X_2)-\frac{1}{2}[(H_0+H_2)(X_0+X_2)$$

$$-(H_0-H_2)(X_0-X_2)]-H_0X_0\}$$

$$Y_2=H_1X_1+\frac{1}{2}[(H_0+H_2)(X_0+X_2)-(H_0-H_2)(X_0-X_2)] \quad (4)$$

After applying the proposed structure in figure 2, the proposed system can save area.

2). Proposed structure 3B with RCA,((N mod 3=1)).

In odd length N for a symmetric coefficients, when (N mod 3 = 1), which is presented in (5) can earn one more subfilter block which containing symmetric coefficients as [11], by

using ripple carry adder we can reduce the area. The implementation is shown in fig.4. and the comparison of Subfilter between Existing FFA and the proposed structure 3B is shown fig.5.

$$Y_0=H_0X_0+z^{-3}\left\{\frac{1}{2}(H_1+H_2)(X_1+X_2)-(H_1-H_2)(X_1-X_2)\right\}$$

$$Y_1=(H_0+H_1+H_2)(X_0+X_1+X_2)-(H_1+H_2)(X_1+X_2)-(H_0+H_1)(X_0+X_1)+\{(H_1+H_2)(X_1+X_2)-\frac{1}{2}$$

$$\times[(H_1+H_2)(X_1+X_2)-(H_1-H_2)(X_1-X_2)]-H_2X_2\}+z^{-3}H_2X_2$$

$$Y_2=(H_0+H_1+H_2)(X_0+X_1+X_2)-(H_1+H_2)(X_1+X_2)-(H_0+H_1)(X_0+X_1)+2(H_1+H_2)(X_1+X_2)-\frac{1}{2}$$

$$\times\{(H_1+H_2)(X_1+X_2)-(H_1-H_2)(X_1-X_2)]-H_2X_2\} \quad (5)$$

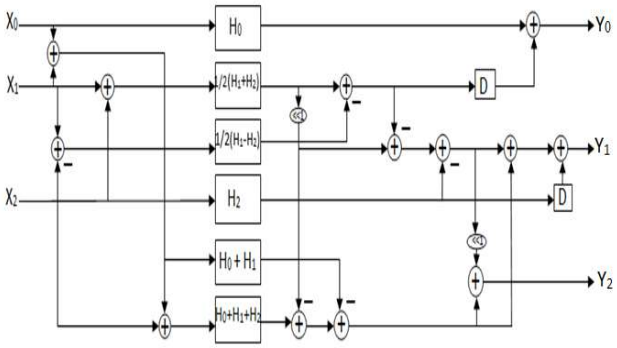


Figure 4: Implementation of the proposed structure 3B

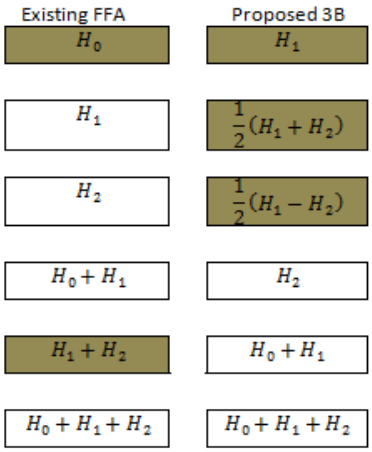


Figure 5: Comparison of Subfilter between Existing FFA and proposed structure 3B

3) Proposed structure 3C with RCA ((N mod 3 = 2)).

In odd length N for a symmetric coefficients, when (N mod 3 = 2), which is presented in (6) can earn one more subfilter block which containing symmetric coefficients as [11],by using ripple carry adder we can reduce the area . The implementation is shown in fig. 6 and the Comparison of Subfilter between Existing FFA and the proposed structure 3C is shown fig.7.

$$Y_0=(H_0+H_1)(X_0+X_1)-\frac{1}{2}[(H_0+H_1)(X_0+X_1)-(H_0-H_1)(X_0-X_1)]-H_1X_1+z^{-3}$$

$$\times\{(H_0+H_1+H_2)(X_0+X_1+X_2)-(H_0+H_1)(X_0+X_1)-[(H_0+H_2)(X_0+X_2)-\{(H_0+H_1)(X_0+X_1)$$

$$-\frac{1}{2}[(H_0+H_1)(X_0+X_1)-(H_0-H_1)(X_0-X_1)]-H_1X_1\}$$

$$Y_1=\frac{1}{2}[(H_0+H_1)(X_0+X_1)-(H_0-H_1)(X_0-X_1)]+z^{-3}H_2X_2$$

$$Y_2=H_1X_1+\left\{(H_0+H_2)(X_0+X_2)-\left\{(H_0+H_1)(X_0+X_1)-\frac{1}{2}[(H_0+H_1)(X_0+X_1)-(H_0-H_1)(X_0-X_1)]\right.\right.$$

$$\left.\left.-H_1X_1\right\}-H_2X_2\right\} \quad (6)$$

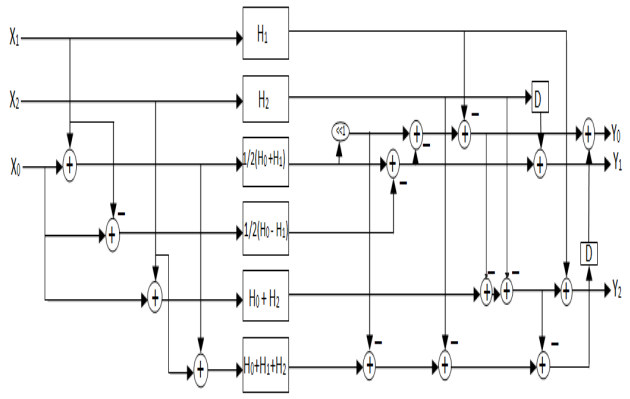


Figure 6: Implementation of the proposed structure 3C

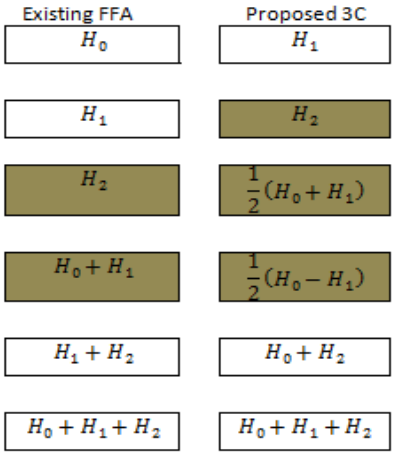


Figure 7: Comparison of Subfilter between Existing FFA and proposed structure 3C

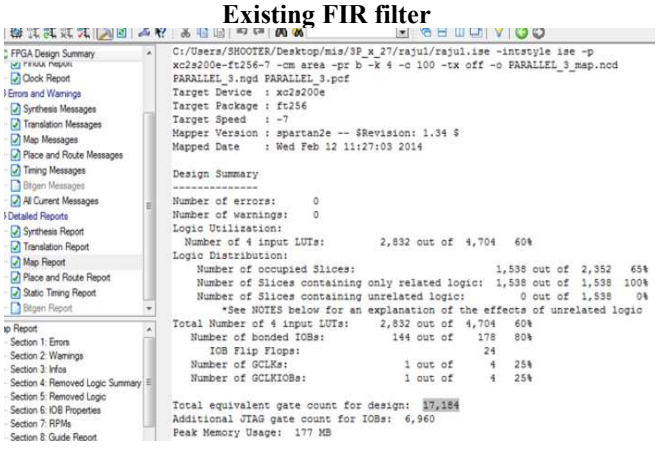
A comparison between the existing FFA and the Proposed FFA is shown in Table 1 below

Table 1: Synthesis results for Three parallel 27 tap FIR filter

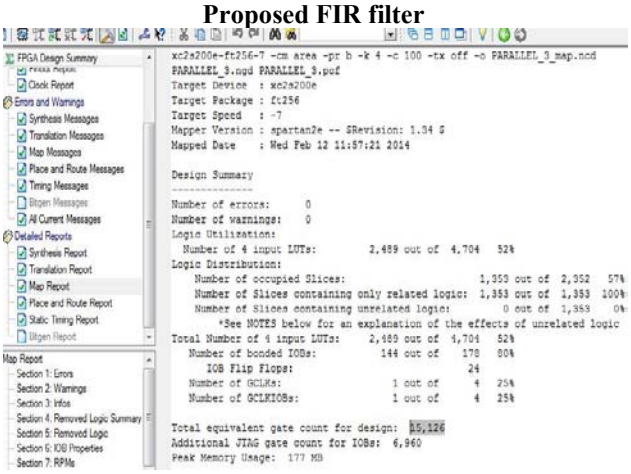
Structure	*CSA(Existing)*	*CA(Proposed)*
3-parallelFIR filter	17184	15124
FIR filter 3A	17133	14799
FIR filter 3B	16055	13794
FIR filter 3C	14841	12942

Simulation Results for comparing the existing and proposed structure is given below

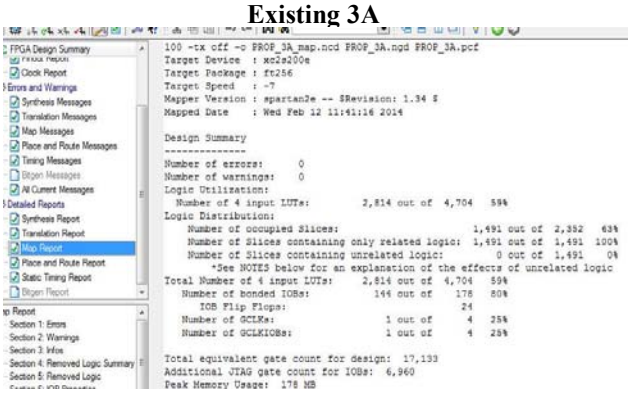
Existing FIR filter



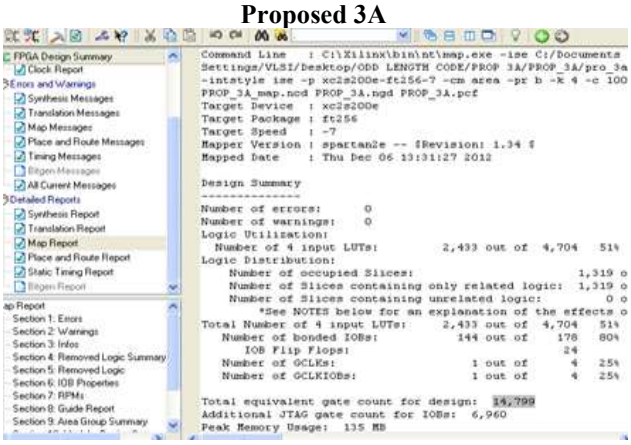
Proposed FIR filter



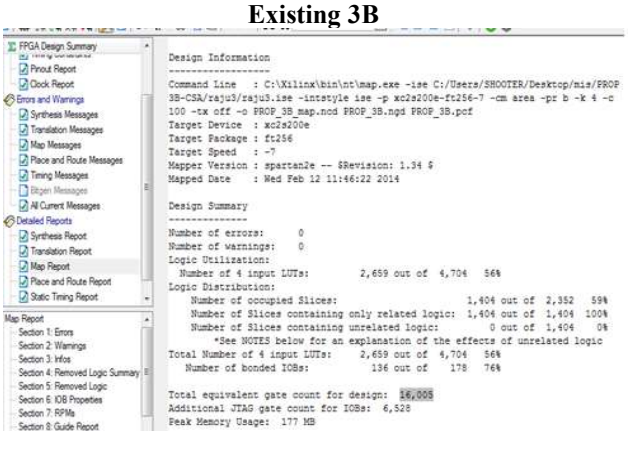
Existing 3A



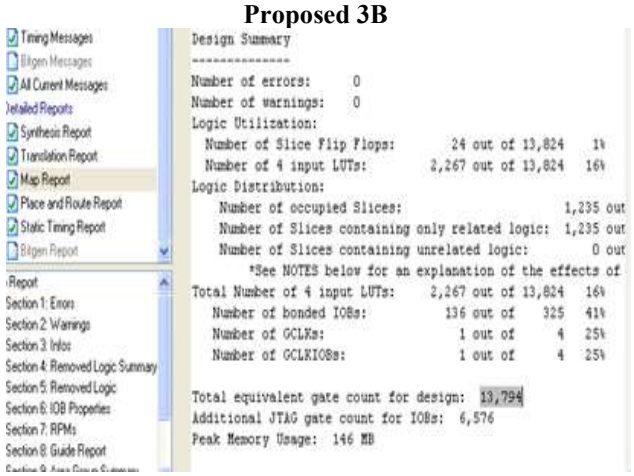
Proposed 3A



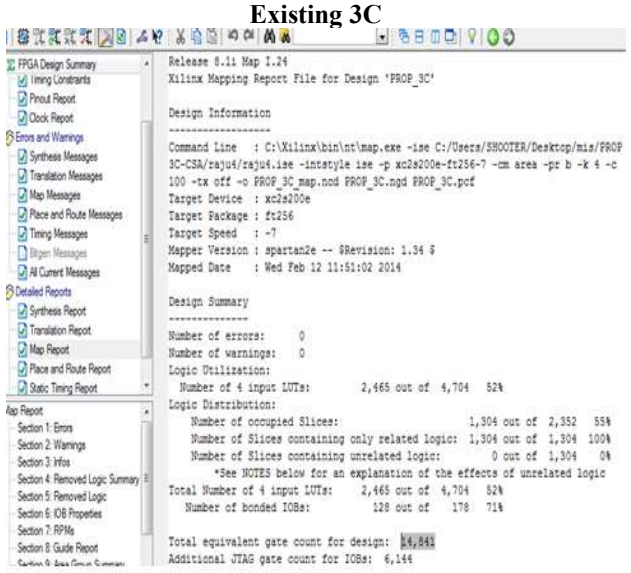
Existing 3B



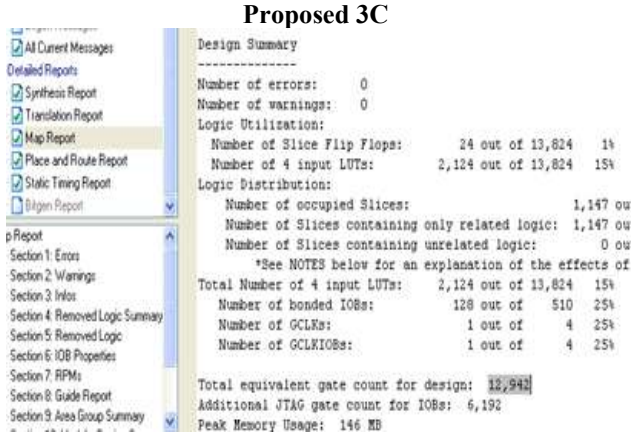
Proposed 3B



Existing 3C



Proposed 3C



4. Conclusion

In this paper we have brief, we have presented the parallel FIR structure which is reduced the area. Multipliers are major component which we can be replaced by using the fast FIR algorithm. In this paper we presented ripple carry adder in the odd length instead of carry save adder.

5. Future Scope

The future scope of this project lies in the further optimization of area and as well as power.

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