## Idea (1A)

- Time Multiplexed Architecture

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## The Butterfly Operations

$$
\begin{aligned}
& x_{0}^{\prime}=x_{0}+\omega^{k} x_{1} \\
& x_{1}^{\prime}=x_{0}-\omega^{k} x_{1}
\end{aligned}
$$



## The Butterfly Time Multiplexed Operations (1)

$$
\begin{aligned}
& x_{0}^{\prime}=x_{0}+\omega^{k} x_{1} \\
& x_{1}^{\prime}=x_{0}-\omega^{k} x_{1} \\
& x_{0}^{\prime}=x_{0}+\omega^{k} x_{1} \\
& x_{0}=x_{0}^{\prime}-\omega^{k} x_{1} \\
& x_{1}^{\prime}=x_{0}-\omega^{k} x_{1} \\
& \Rightarrow x_{1}^{\prime}=x_{0}^{\prime}-\omega^{k} x_{1}-\omega^{k} x_{1} \\
& x_{1}^{\prime}=x_{0}^{\prime}-2 \omega^{k} x_{1}
\end{aligned}
$$

## The Butterfly Operations (1)


$\square$

only one multiplier
is needed

## The Butterfly Operations

$$
\begin{cases}x_{0}^{\prime}=x_{0}+\omega^{k} x_{1} \\ x_{1}^{\prime}=x_{0}-\omega^{k} x_{1} \\ x_{0}^{\prime}=x_{0}+\omega^{k} x_{1} \\ x_{1}^{\prime}=x_{0}^{\prime}-2 \omega^{k} x_{1} \\ \text { add }\end{cases}
$$

## The Butterfly Time Multiplexed Operations (2)

$$
\left\{\begin{aligned}
x_{0}^{\prime}= & x_{0}+\omega^{k} x_{1} \\
x_{1}^{\prime}= & x_{0}-\omega^{k} x_{1} \\
x_{1}^{\prime}= & x_{0}-\omega^{k} x_{1} \\
& \omega^{k} x_{1}=\left(x_{0}-x_{1}^{\prime}\right) \\
x_{0}^{\prime}= & x_{0}+\omega^{k} x_{1} \\
y_{0} & x_{0}^{\prime}=x_{0}+\left(x_{0}-x_{1}^{\prime}\right) \\
x_{0}^{\prime}= & 2 x_{0}-x_{1}^{\prime}
\end{aligned}\right.
$$



Note that no multiplier is needed here.

## The Butterfly Operations (2)



| $x_{1}$ | $x_{1}^{\prime}$ |  |  |  |
| :--- | :--- | :--- | :--- | :--- |


| $x_{0}$ | $x_{0}^{\prime}$ |  |  |
| :--- | :--- | :--- | :--- |

only one multiplier is needed

$$
x_{1}^{\prime}=x_{0}-\omega^{k} x_{1} x_{1} \text { is available }
$$

## Micro-Pipelined CORDIC



Utilize adder in the CORDIC hardware?

Combining CORDIC architecture?
Some background survey on CORDIC + FFT Architecture
Different level of parallelism
High fanout - mux , adder

## References

[1] http://en.wikipedia.org/
[2] J.H. McClellan, et al., Signal Processing First, Pearson Prentice Hall, 2003
[3] A "graphical interpretation" of the DFT and FFT, by Steve Mann

