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DAC Architecture with Fibonacci Sequence Weighted Current Sources

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Mathematics is Queen of Technology

Research Objective

Digital-to-Analog Converter (DAC)
precision improvement

This Research

- Applying Fibonacci Sequence Theory
- Modest Redundancy
- Lateral Thinking World-first approach

Proposed Three methods

Current-steering DAC

- High-Speed
- Current Source mismatch

This methods

- **Current Source Calibration**
- **Current Source Selection**
- **Dyamic Matching**

Proposed DAC with Fibonacci Sequence Weighted Current Sources

8 bit DAC with Fibonacci Sequence Weighted Current Sources ➡ 12 steps

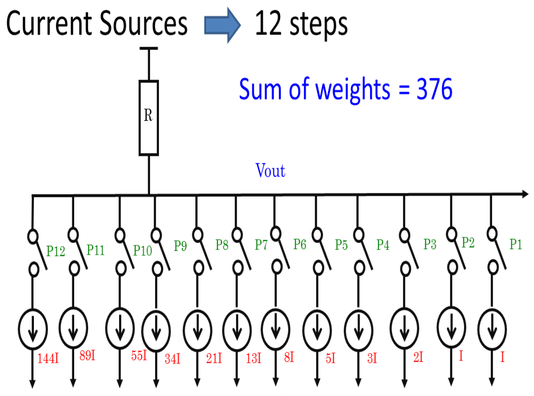


Fig.1 Current-steeering DAC weighted with Fibobnacci sequence numbers.

Application of Number Theory to DAC Design

- Fibonacci sequence

$F_n = F_{n-1} + F_{n-2}$

- Fibonacci numbers are

0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610…

- $\lim_{n\to\infty} \frac{F_{n+1}}{F_n} = 1.6\ldots$

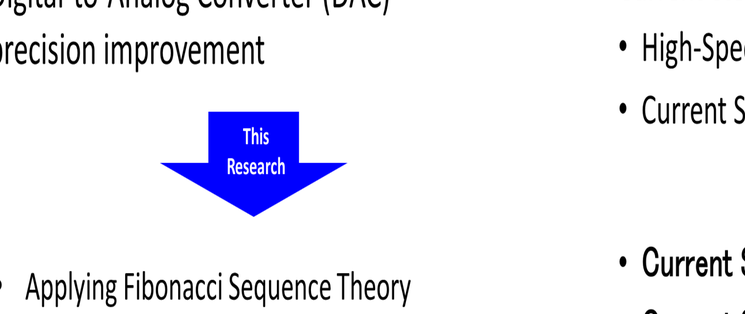
Our Approach (1) (2)

Method 1

Current Source Calibration

k+2-th current source I_{k+2} is calibrated by
k+1-th and k-th current sources
Using property of Fibonacci Sequence

$I_{k+2} = I_{k+1} + I_k$



Method 2

Selection of Optimal Current Source Combination

Redundancy of Fibonacci Sequence

Several combinations of ON switches for each input
In case Input 9

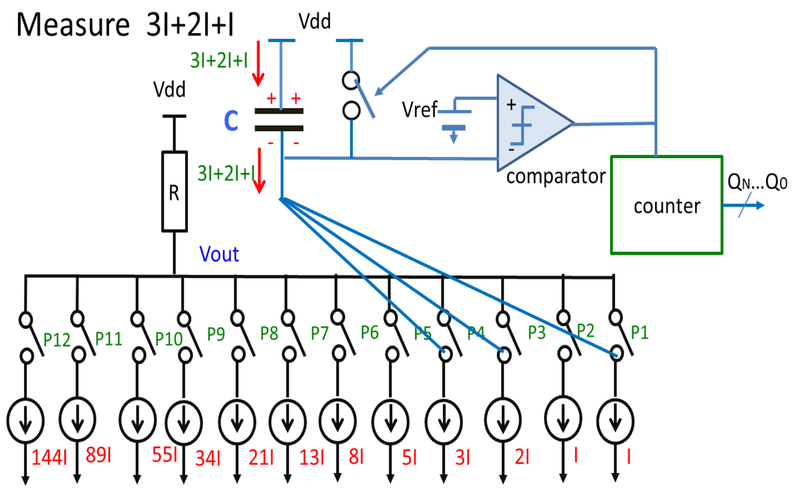
① (P5, P4, P1) 5I+3I+I=9I
② (P5, P4, P2) 5I+3I+I=9I
③ (P5, P3, P2, P1) 5I+2I+I+I=9I
④ (P6, P1) 8I+I=9I
⑤ (P6, P2) 8I+I=9I

Actual value deviates from ideal value

Step 1 Measure each current source ➡ **Step 2** Choose medium value ➡ Better Linearity

Measurement Circuit of Current Sources

Measure 3I+2I+I



Our Approach (3)

Method 3

Comparison of Current Sources

When the counter output of
$(3I+\Delta I4)+(2I+\Delta I3)+(I+\Delta I1) = 6I + \Delta I4+\Delta I3+\Delta I1$
is larger than
the counter output of
$(5I+\Delta I5)+(I+\Delta I2) = 6I + \Delta I5+\Delta I2$

$6I + \Delta I_4+\Delta I_3+\Delta I_1$ (ideal + error) $>$ $6I + \Delta I_5+\Delta I_2$ (ideal + error)

Comparison with digital method

Dynamic Matching of Current Sources

Redundancy of Fibonacci Sequence

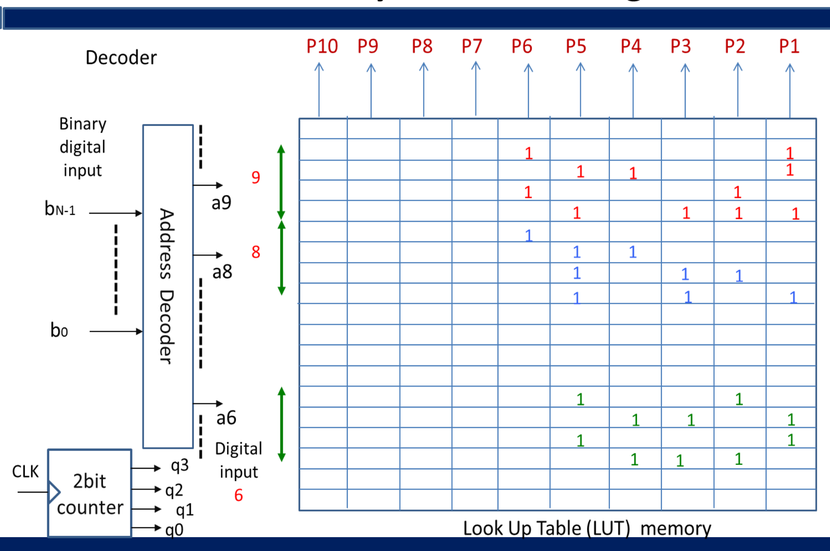
Several combinations of ON switches for each input
① (P5, P4, P1) 5I+3I+I=9I
② (P5, P4, P2) 5I+3I+I=9I
③ (P5, P3, P2, P1) 5I+2I+I+I=9I
④ (P6, P1) 8I+I=9I
⑤ (P6, P2) 8I+I=9I

For digital input 9, combinations above are applied sequentially, for example, in order of ①→②→③→④→⑤→①→②…

SFDR is improved as impact of current source mismatch is spread in frequency domain.

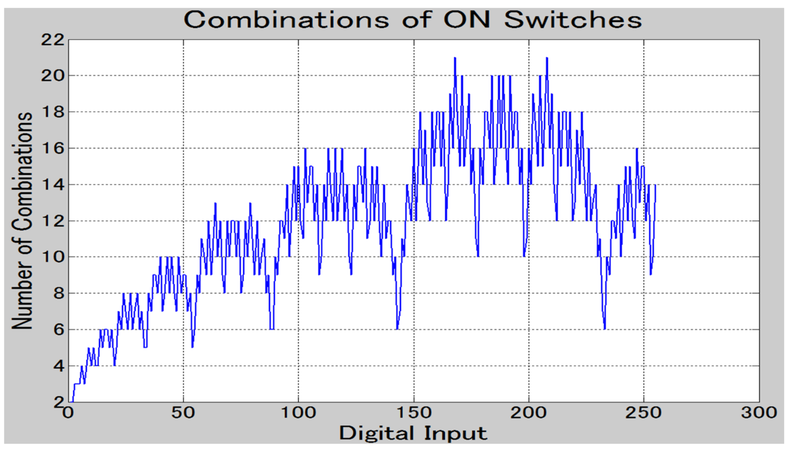
- Suitable for digital signal processing
- No need for measuring mismatch of current sources

Current Source Dynamic Matching Circuit



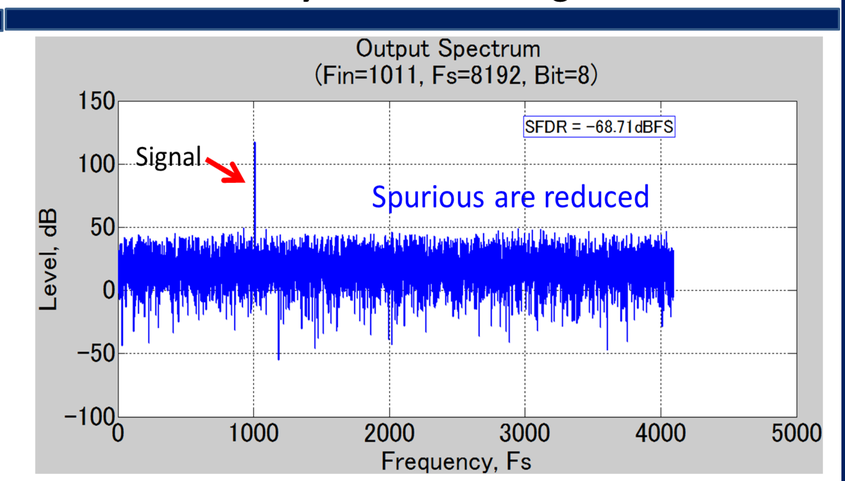
Simulation Result

Combinations of ON Switches



Multiple combinations of ON switches for a digital input

Dynamic Matching



SFDR charactersistics is improved to 68.7dB

Conclusion

By exploiting Fibonacci Sequence Theory

- **Calibrate current sources**
- **Achieve better linearity**
- **Improve SFDR**

Current-Steering DAC precision improvement