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ADC/DAC Redundancy Design Using Fibonacci Sequence

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New Idea Learning from the Past

Research Background and Objective

Automotive Electronics are more and more gathering attention

ADC/DAC are required better performance

- high-resolution
- high-speed
- high-accuracy
- high-reliability
- low-cost
- low-power
- small-chip

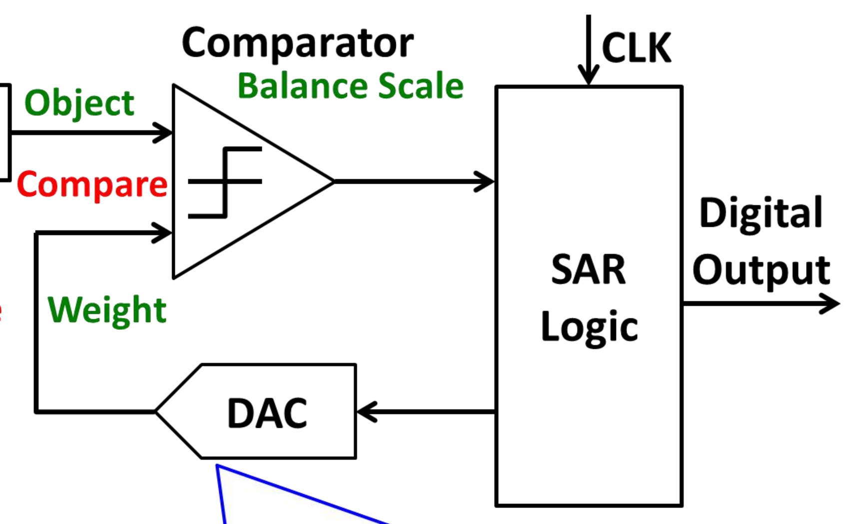
ADC : Analog-to-Digital Converter
DAC : Digital-to-Analog Converter

Objective

Design high-reliability ADC/DAC by using redundancy theory !

SAR ADC

SAR ADC : Successive Approximation Register type A-D Converter

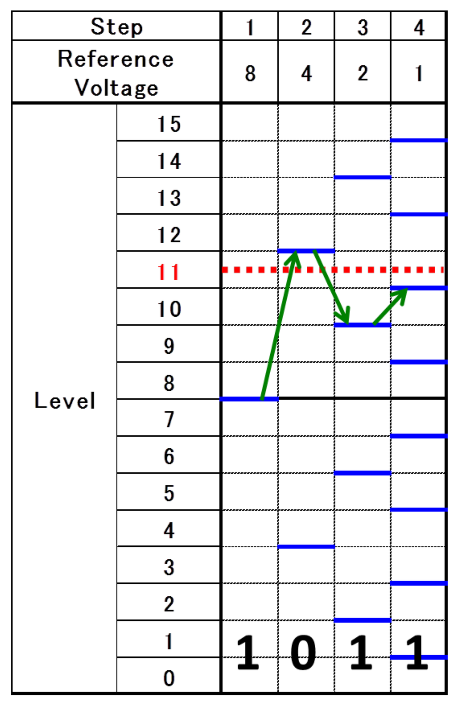


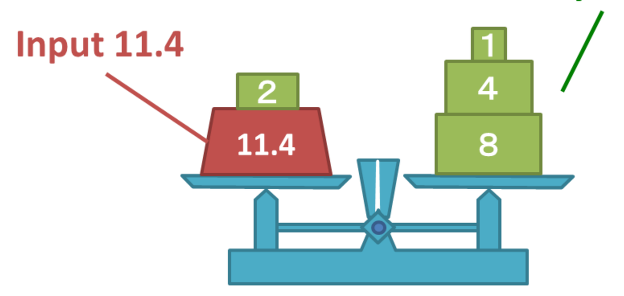
Balance Scale

Generally use binary weight (1 , 2 , 4 , 8 , 16 , 32, 64 …)

Binary Search SAR ADC Operation

Comparator repeats comparison





Dout = 1011

8 + 4 – 2 + 1 + 0.5 – 0.5 =11

One-to-one correspond between Decimal and Binary codes

1 Misjudgment leads to incorrect output

Proposed Redundancy Design using Fibonacci Sequence

SAR ADC Redundancy Design

Redundancy : Surplus , Extra

Apply to SAR ADC

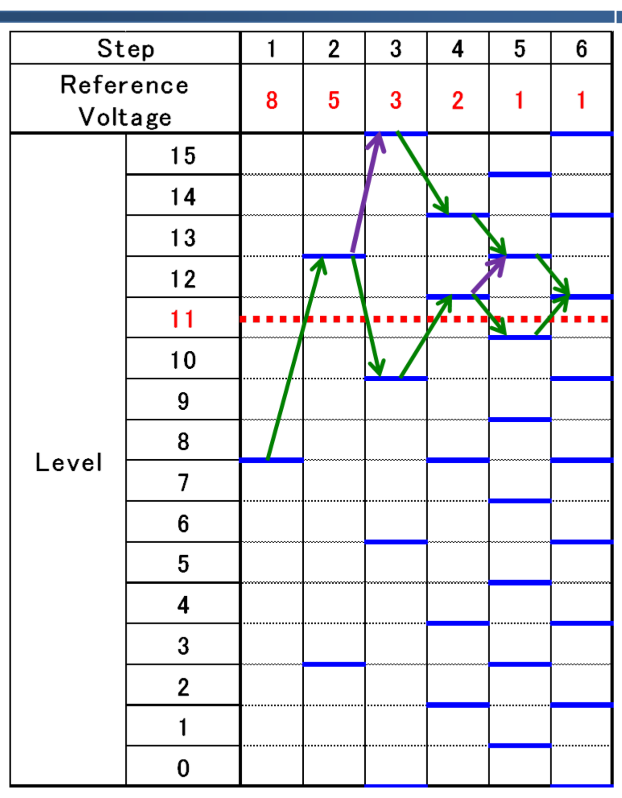
Using Time Redundancy

- ◆Increase comparison steps
- ◆Change reference voltage values

Increase number of output expressions

$(11)_{10} = (110000)_2, (101100)_2, (101010)_2$

Enable digital error correction



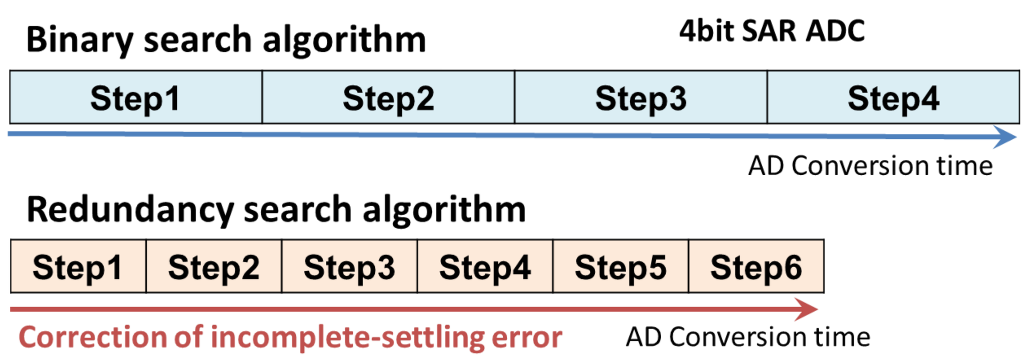
Redundancy Design Advantages

◆ **High-reliability**

Later steps can compensate for misjudgment of previous steps

Get correct output

◆ **High-speed**



Digital calibration realizes short conversion time

Fibonacci Sequence

Definition (n=0,1,2,3…)

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

$$F_0 = 0 , F_1 = 1$$

Example of numbers (Fibonacci number)

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

Property

➢Closest terms ratio converges to " Golden Ratio "

$$\lim_{n\to\infty} \frac{F_n}{F_{n-1}} = 1.61803398874\ldots$$

Advantages of Fibonacci sequence usage

Weight of Redundancy design SAR ADCs

– Should be **Sub-binary weight** and **Integer**

◆**Conventional method**

– Determined freely by SAR ADCs designer

 • Inefficient

– Radix of square root of two (= 1.4…)

 • Too much redundancy

◆**Proposed method (Fibonacci method)**

Get radix of 1.6 weight by Integer terms

⇨ **Moderate Redundancy**

Method of getting Fibonacci weights

Three proposed methods

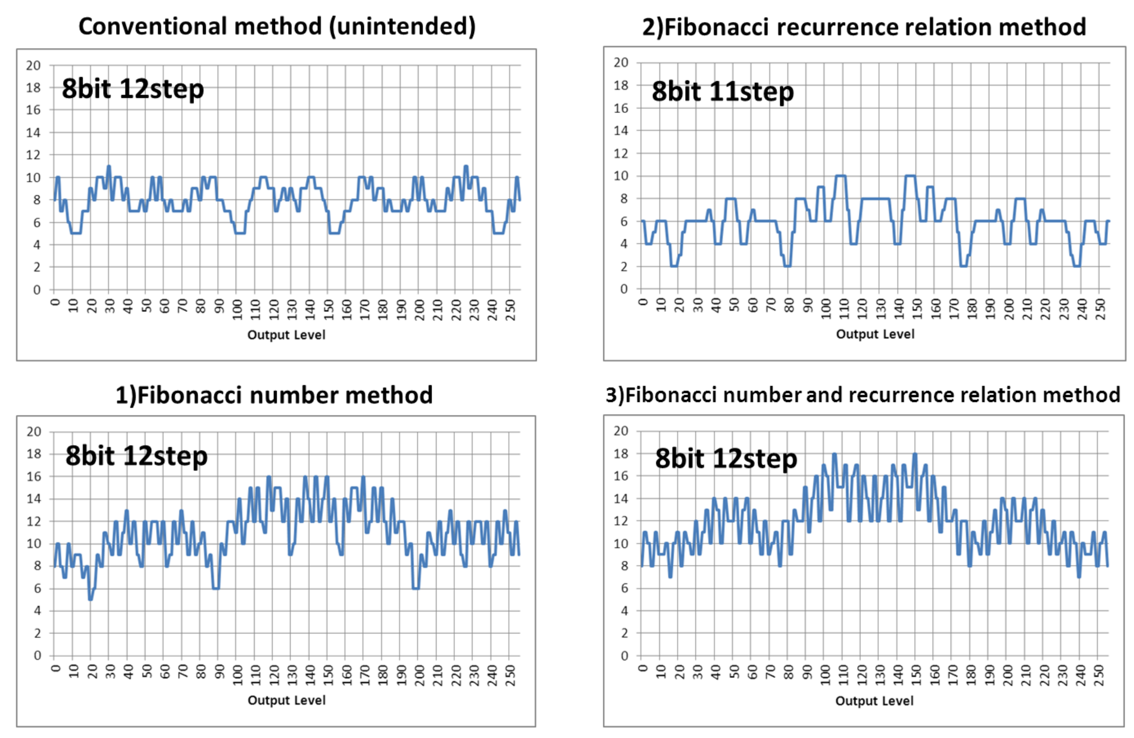
Method	Description
1)Fibonacci number method	• Realize radix of 1.6 weight by using Fibonacci number
2)Fibonacci recurrence relation method	• Using Fibonacci recurrence relation
3)Fibonacci number and recurrence relation method	• Using method 1 and method 2

Example. 8bit SAR ADC weight design

Conventional	12step	1 , 2 , 3 , 5 , 9 , 16 , 26 , 45 , 72 , 100 , 115 , 128
method1	12step	1 , 1 , 2 , 3 , 5 , 8 , 13 , 21 , 34 , 55 , 89 , 144
method2	11step	1 , 1 , 2 , 4 , 7 , 11 , 19 , 30 , 49 , 79 , 128
method3	12step	1 , 1 , 2 , 3 , 5 , 8 , 11 , 19 , 30 , 49 , 79 , 128

Number of Combinations

Many combinations at all output Levels

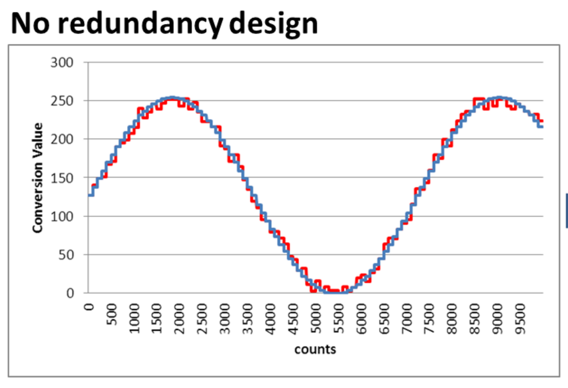


Simulation Result

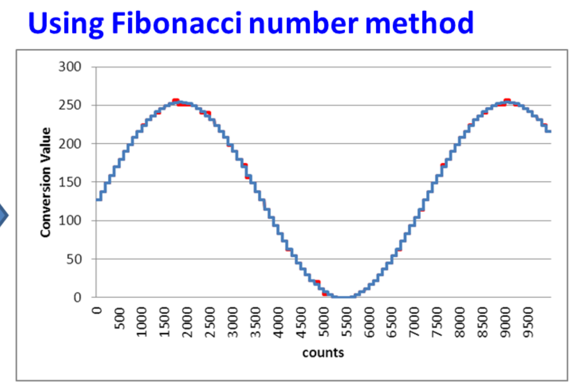
8bit SAR ADC Simulation Condition

Use C programming language
Input : FS sine-wave Number of Conversion : 100 times
Comparator in 1step to 6step occur misjudgment with 40% possibility at difference between input voltage and reference voltage is 10 or less

No redundancy design



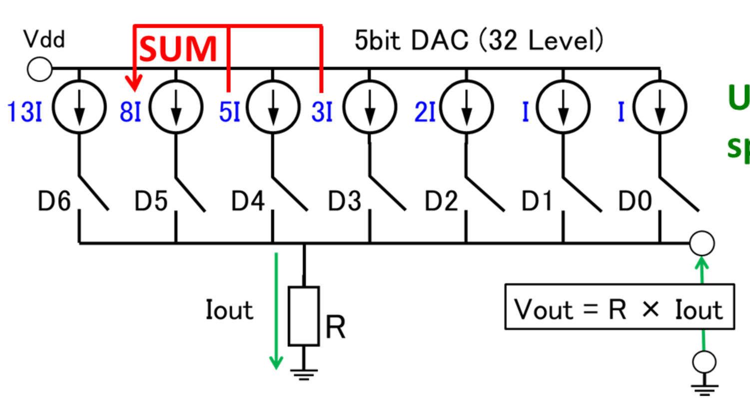
Using Fibonacci number method



Compensate 89.0% error !

Apply to Current-Steering DAC

Current-steering DAC { Increase number of current sources / Change current value



Using space redundancy

Fibonacci structure enables Selection of some combination and Current value comparison

- ◆ Improving Linearity
- ◆ Improving SFDR
- ◆ Reducing Glitch

◆ Self-Calibration

summary

Conclusion

- ◆Showed effectiveness of ADC/DAC redundancy design
- ◆Obtained moderate redundancy using Fibonacci sequence
- ◆Future works
  - Applying of Tribonacci sequence
  - Applying of " Golden section search " to SAR ADC

References

[1] Alfred S.Posamentier, Ingmar Lehmann, Syunsuke Matsuura: "*Husigina suuretsu fibonacci no himitsu*[The Fabulous FIBONACCI NUMBERS]", NikkeiBP, (Aug.2010)

[2] T. Ogawa, H. Kobayashi, Y. Takahashi, N. Takai, M. Hotta, H. San, T. Matsuura, A. Abe, K. Yagi, T. Mori : "SAR ADC Algorithm with Redundancy and Digital Error Correction", IEICE Trans. Fundamentals, vol.E93-A, no.2, (Feb. 2010).