Digital to Analog Converters

Study on Metrics & Parameters

Presenter :

Vignesh SenthilKumar T-1768

Contents

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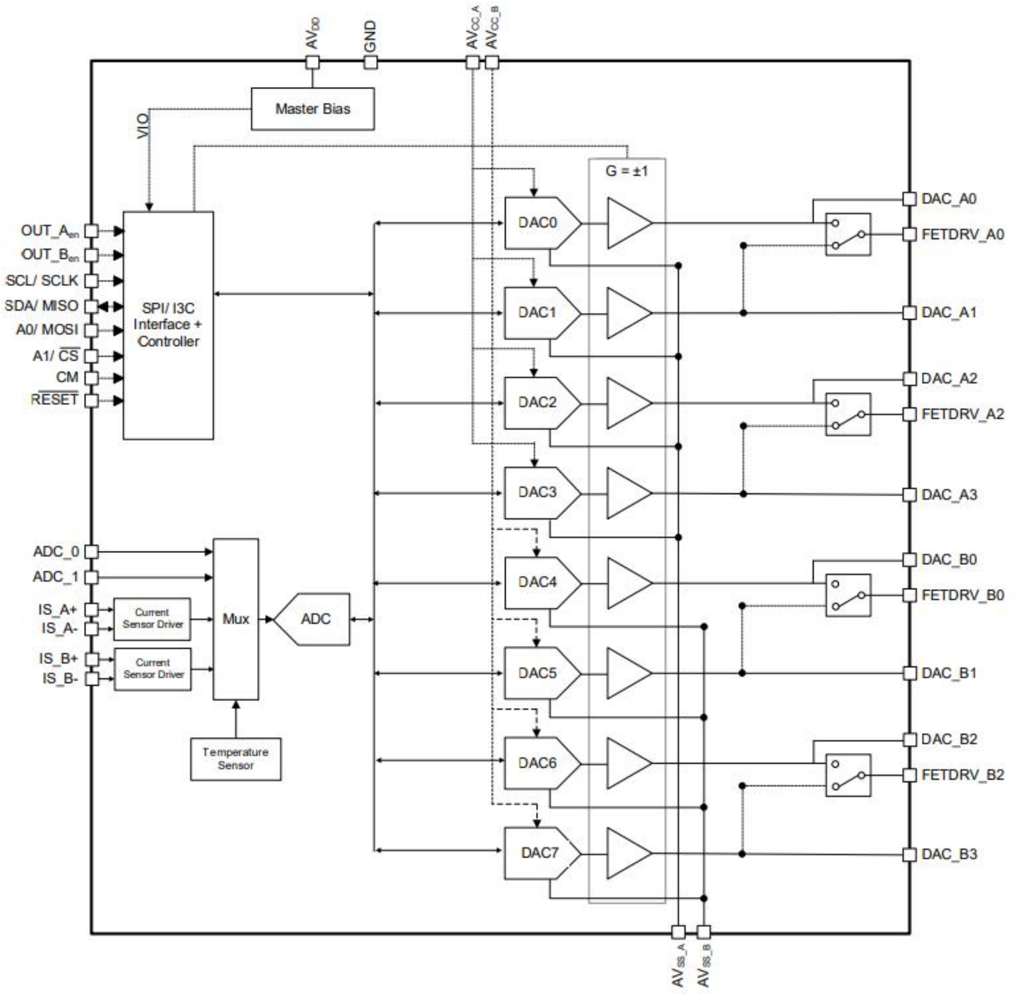
F1594- RF Power-Amplifier Bias Controller



- DAC Modules

  Consists of 8 monotonic 12-bit DAC output channels with positive and negative modes of Operation with Output On/Off Control with FET Drive

- ADC Module

  Consist of 13-bit SAR ADC

- Temperature Sensor

  Consist of Internal Temperature Sensor with th range of - 40C to +125C

- Current Sensor

  Consists of Two Current Sensors

- SPI Communication

  SPI/I3C Interface Controller for Internal and External Communication

02 DAC Validation

- Primary focus now to evaluate and validate DAC performance across different conditions.

Key Observations in DAC Performance Validation

- Static Parameters such as Offset, Gain, INL, and DNL are critical for ensuring accuracy.
- Dynamic Parameters like Settling time, Slew time and Delay Time plays a major role in high-speed applications.
- To validate these DAC behavior whether it deviates from ideal specifications due to process variations, temperature shifts.

03 DAC Performance Metrics

1. Resolution & Accuracy

- Resolution can be defined as the number of bits in the data word of the converter.An accuracy specification describes the worst case deviation of the DAC output

2. Concept of LSB

- LSB is the smallest possible change in output voltage corresponding to a one-bit change in the digital input. It represents the resolution of the DAC.

Why is LSB Important?

1.Defines Resolution:

- Higher N (more bits) → Smaller LSB → Higher resolution
- Lower N (fewer bits) → Larger LSB → Lower resolution

2.Affects Accuracy:

- Errors in the DAC (DNL, INL, noise) are often measured in LSB.If errors exceed 1 LSB, produce a non-monotonic response, leading to distortion .

Consider a 10-bit DAC with a 5V reference voltage:

LSB Size =5V/2^10=4.88mV

- If the DAC has a DNL of ±0.5 LSB, the error is ±2.44 mV.
- If the DAC has a DNL of ±1.2 LSB, the error is ±5.86 mV, which means the DAC could miss codes (bad performance).

DAC Performance Parameters

DAC Parameters

Static Parameters

The DC specifications for an DAC provide an understanding of the device behavior for dc or a very-low frequency input signal

Dynamic Parameters

The AC Specification for an DAC define the DAC performance with Dynamic input are mostly specified using single input frequency

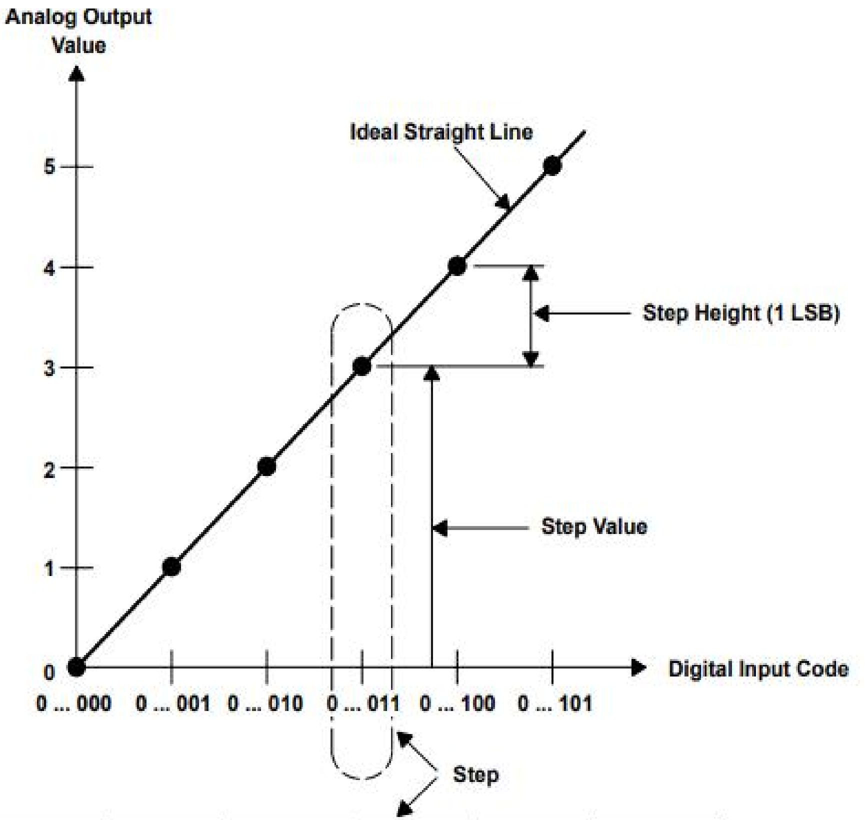
04 Static Parameters

Transfer Characteristics

- The DAC ideal transfer function would be a straight line with an infinite number of steps but practically it is a series of points that fall on the ideal straight line

Kinds of Static Parameters

- **Offset Error**
- **Gain Error**
- **Linerity Error**



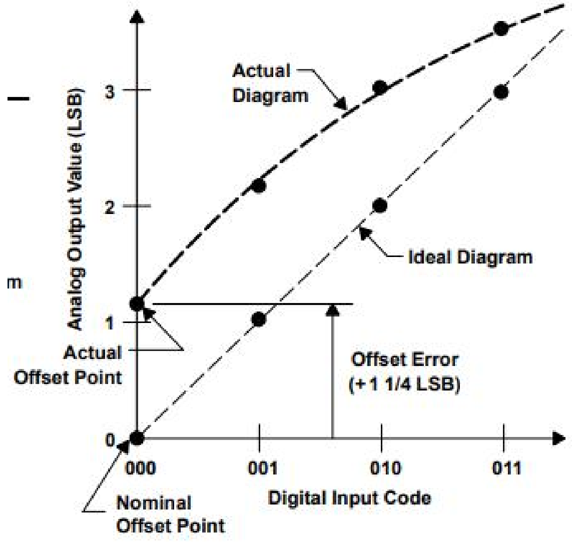
CONVERSION CODE

Digital Input Code	0 ... 000	0 ... 001	0 ... 010	0 ... 011	0 ... 100	0 ... 101
Analog Output Value	0	1	2	3	4	5

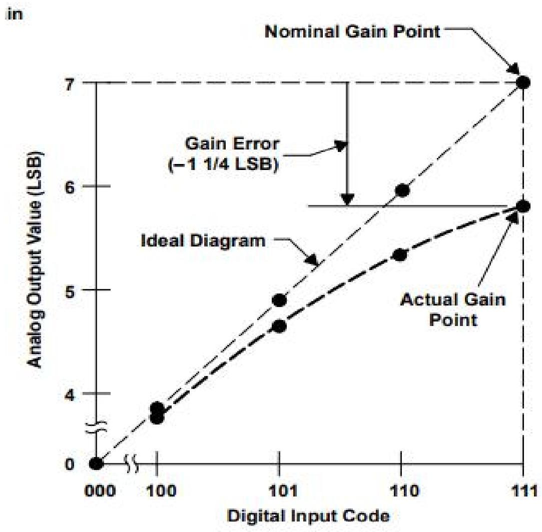
Elements of Transfer Diagram for an Ideal Linear DAC

04 Static Parameters

- ### Offset Error
  - The offset error is defined as the difference between the nominal and actual offset points. In shortly **it is the step value when the digital input is zero.**
  - measured in Least Significant Bits (LSB) or %Full Scale Value (%FSV)

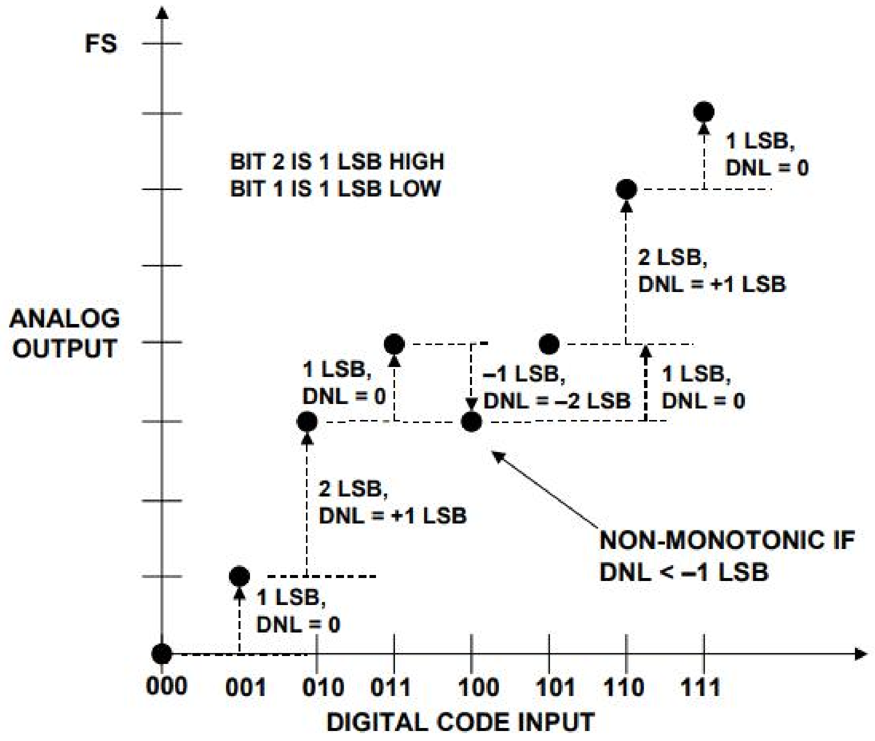


- ### Gain Error
  - The gain error shown in Figure 4 is defined as the difference between the nominal and actual gain points on the transfer function after the offset error has been corrected to zero or it **is the step value when the digital input is full scale**
  - It is measured in Least Significant Bits (LSB) or %Full Scale Value (%FSV)



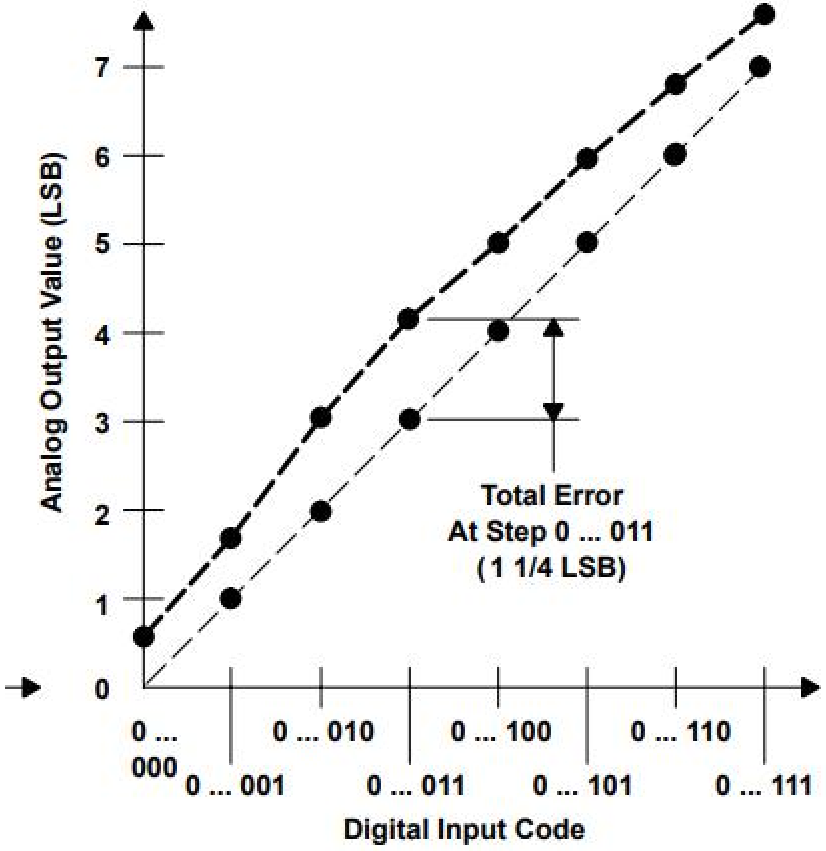
04 Static Parameters

- **Differential Non-linearity (DNL) Error**
  - The differential nonlinearity error is the difference between an actual step height and the ideal value of 1 LSB.
  - Therefore if the step **height is exactly 1 LSB,** then the differential nonlinearity error is **zero**
  - If the DNL exceeds 1 LSB, there is a possibility that the converter can become **nonmonotonic**.
  - This means that the magnitude of the output gets smaller for an increase in the magnitude of the input.



- **Integral Non-linearity (DNL) Error**

  - The integral nonlinearity is the deviation of the values on the actual transfer function from a straight line.
  - It is measured in Least Significant Bits (LSB) or %Full Scale Value (%FSV)
  - It is Calculated for each Step in DAC



Dynamic Parameters

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- ## Settling Time
  - Settling Time is the amount of time required from the start of a transition until the DAC output settles its new output value to within the specified accuracy
- ## Skew Rate
  - Slew rate is the maximum rate of change of the output voltage in response to a change in the input. It is typically measured in V/µs (volts per microsecond)
  - It represents how fast the DAC can transition between output levels.
- ## Delay
  - Time variation between input code change and corresponding output response.

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Key Observations

- ✓ **Linearity** defines DAC accuracy—Integral Nonlinearity (INL) measures deviation from the ideal transfer function, while Differential Nonlinearity (DNL) checks uniform step sizes.
- ✓ **Monotonicity** ensures smooth output transitions—a DAC is monotonic if increasing digital input always results in an equal or higher analog output.
- ✓ **Errors in the DAC (DNL, INL, noise) are often measured in LSB**.If errors exceed 1 LSB, produce a non-monotonic response, leading to distortion .
- ✓ Validation should be focuses on minimizing INL/DNL errors to ensure predictable, stable, and high-accuracy DAC performance