Understanding the Details of DAC Performance

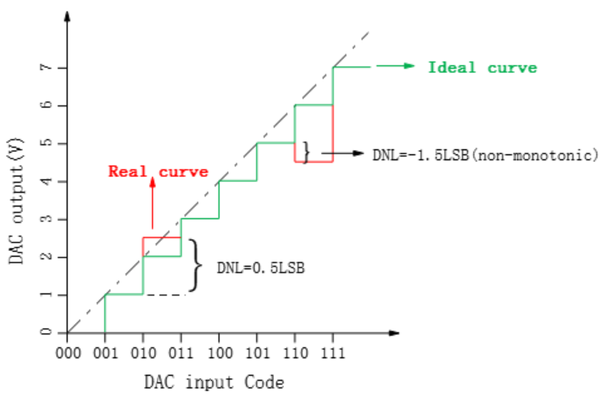
In electronic systems, the function of the digital-to-analog converter (DAC) is to convert digital codes into analog voltage or current signals. DACs are the core devices for analog quantity transmission and control. In the fields of industrial automation, test and measurement, and instrumentation, DACs are mostly used to output signals close to DC, with high precision (12~16 bits) and low speed (< 10 MHz). This kind of DAC is generally called precision DAC. Below we briefly introduce the main parameters of precision DAC.

1. Static Parameters of DACs

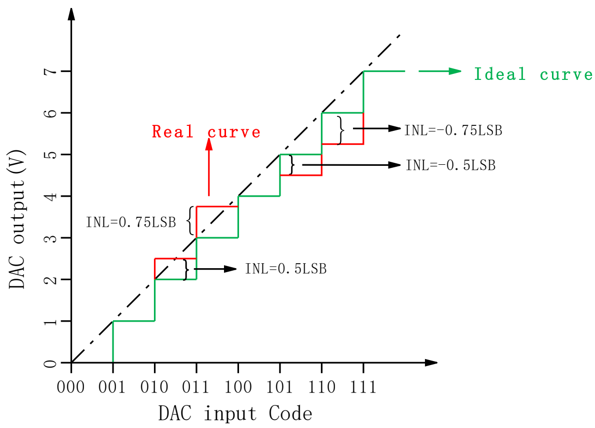
Static parameters are primarily used to measure the output difference between an actual DAC and an ideal DAC with the same bits.

The first parameter is linearity. The linearity of the DAC is generally limited by the matching error of semiconductor devices inside the chip, such as the matching error between resistors. A high-precision DAC needs to be calibrated during the factory test.

The following two figures show the difference in linearity between the actual and ideal 3-bit DAC output waveforms (the red is the actual output curve):

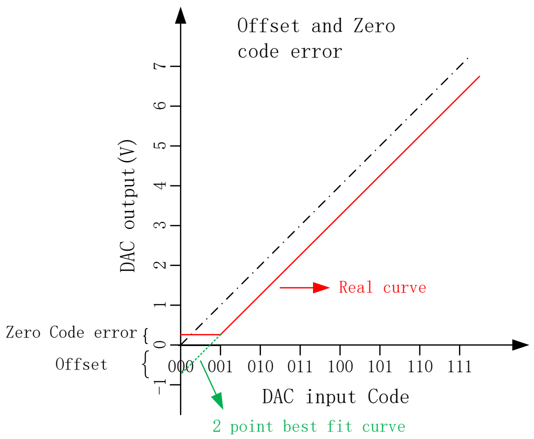


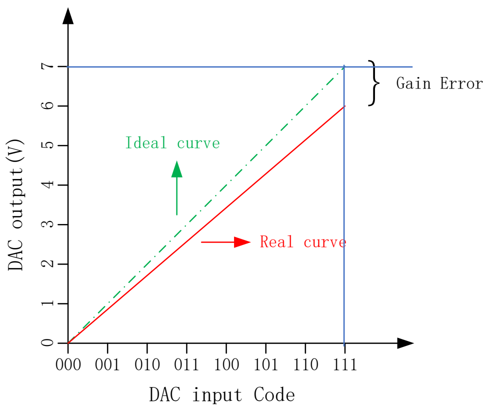
DNL is differential nonlinearity, which refers to the deviation of the difference between two adjacent output levels relative to the ideal minimum step size (1LSB). As shown in the figure above, if DNL< −1LSB, the output of the DAC is non-monotonic, which means the output of the DAC may decrease as the digital code value increases. This is unacceptable in many closed-loop system applications. In such cases, choosing a device with DNL > −1LSB is necessary.



INL is the integral nonlinearity, which refers to the difference between the actual output and the ideal DAC output, also known as relative accuracy. This parameter represents the accuracy of the DAC output. In open-loop applications, the INL parameters should be given special attention.

In addition to the above two linearity parameters, the actual output curve of the DAC also has several other non-ideal characteristics, as shown in the following two figures:





Gain error stands for the deviation of the output characteristic of a DAC from the ideal straight-line slope.

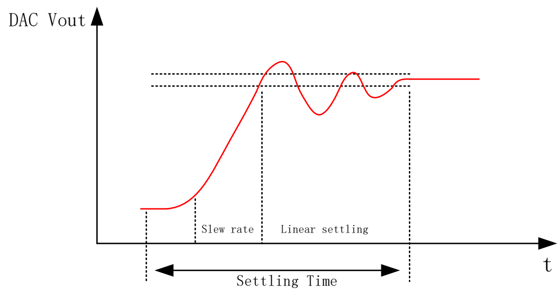
Offset error stands for the deviation of the output characteristic of a DAC from the ideal straight line offset upwards or downwards.

Zero code error is used to calibrate the deviation of the DAC output when the code is 0. Because the internal circuit is close to saturation (especially the DAC with output buffer), the output is not the ideal 0 V.

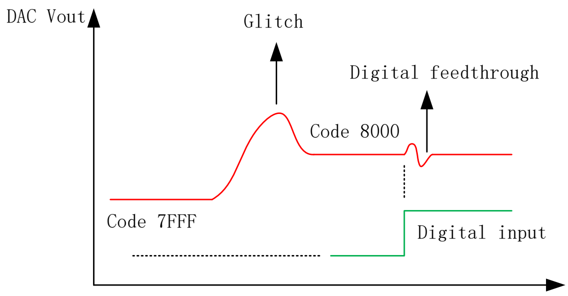
In addition, gain error and offset error also change with temperature, known as gain shift, and offset error shift. If the customer is very sensitive to temperature characteristics, these two parameters should be given special attention.

2. Dynamic Parameters of DACs

The following figure shows a typical DAC output waveform that jumps from around 0 to full swing:



Settling time is an important parameter to measure the speed of a precision DAC. The DAC output mainly goes through two stages from the beginning of the change to its stabilization: one is slew rate, and the other is linear settling. The **slew rate** reflects the ability of the output to change significantly, while the **linear settling** mainly depends on the small signal bandwidth of the output.



If the user requires the DAC output to be as stable as possible when changing, then the Glitch and Digital feedthrough parameters need to be given attention.

Glitch is mainly related to the switching of the DAC core. Due to the impact of parasitic charges and the inability to synchronize ideally when the internal nodes of the DAC are switched, the output jitters. Generally, when the high-order MSB of the DAC changes, a large glitch occurs. The size of the glitch is also related to the structure of the DAC. The glitch of the R-string is generally smaller than the glitch of the R2R structure.

Digital feedthrough stands for the effect of the digital communication signal on the analog output. Digital IO signals or clocks on the digital bus are coupled to the output through internal signal paths or power ground. Good design can keep this value small.

DAC output noise is also a very important parameter. The noise of a DAC can be divided into several parts: VREF (if there is an internal reference source, flick noise + thermal noise), internal resistor string (resistor thermal noise), and output buffer (flick noise + thermal noise). Users need to calculate the impact of output noise at different bandwidths according to the application and limit the bandwidth of the DAC output signal to suppress unnecessary noise. In general, the output accuracy of the DAC is not limited by in-band noise.

3. Introduction to 3PEAK DACs

3PEAK has launched several series of precision DAC products with 12 to 16-bit and 1 to 8 channels.

DAC products from 3PEAK cover R-string and R-2R types. These DAC products not only ensure monotonicity (DNL< ±1 LSB), but also achieve the integral nonlinearity within ±1 LSB. Some products have built-in high-precision reference sources and output buffers.

It adopts industrial-grade manufacturing processes and packaging, and the operational temperature range is from −40°C to 125°C. It is suitable for use in PLC/DCS, servo control, analog output, 4 to 20-mA transmission, and other fields.

DAC products of 3PEAK have been widely used in industrial and communication fields for nearly 10 years. The performance and reliability have been fully proven. The products have the advantages of high cost-effectiveness and high performance. Readers who are interested can contact the company to obtain samples and detailed information.

DAC Product Series from 3PEAK

Part Number	Resolution (bit)	Channel	INL max (LSB)	Reference	Output	Output Buffer	Output Range (V)	Package
TPC112S1	12	1	1	Ext	Voltage	Yes	0~5	MSOP8
TPC112S4	12	4	1	Ext	Voltage	Yes	0~5	TSSOP16
TPC112S8	12	8	1	Ext	Voltage	Yes	0~5	TSSOP16, QFN4X4-16
TPC114S1	14	1	4	Ext	Voltage	Yes	0~5	MSOP8

TPC116S1	16	1	16	Ext	Voltage	Yes	0~5	MSOP8
TPC116S4	16	4	16	Ext	Voltage	Yes	0~5	TSSOP16
TPC116S8	16	8	16	Ext	Voltage	Yes	0~5	TSSOP16, QFN4X4-16
TPC2160	16	1	1	Ext	Voltage	No	0~5	SOP8
TPC2161	16	1	1	Ext	Voltage	No	-5~5 (with external buffer)	SOP14
TPC2190	16	8	2.5	Int/Ext	Voltage	Yes	0~5	QFN4X4-16, WLCSP
TPC2192	12	8	1	Int/Ext	Voltage	Yes	0~5	QFN4X4-16, WLCSP