

## 1.1 General ADC calibration

A calibration performed as a part of the production test will improve the performance of the ADC as several error sources mentioned earlier are eliminated.

The calibration should be performed in surroundings which are as equal as possible to the environment the product will be used in. This includes external circuits affecting input noise, supply voltage and temperature.

A simple way of calibrating the ADC is a two-point calibration where two known input values are converted by the ADC. By extracting an equation for a straight line from these points, both external mismatch and internal offset and gain errors will be eliminated. The following procedure is an example of how it can be done:

Choose two input voltages in the interval of interest,  $X_0$  and  $X_1$  and set the reference voltage  $V_{ref}$  to what it will be in the final product. Perform conversions of voltages  $X_0$  and  $X_1$  and store the conversion codes  $S_0$  and  $S_1$ .

The equation for a straight line is found as:

$$S = aX + b$$

Here, S is the conversion code, a is the slope of the calibration curve, X is the input value and b is the interception point(offset) at  $X=0$ .

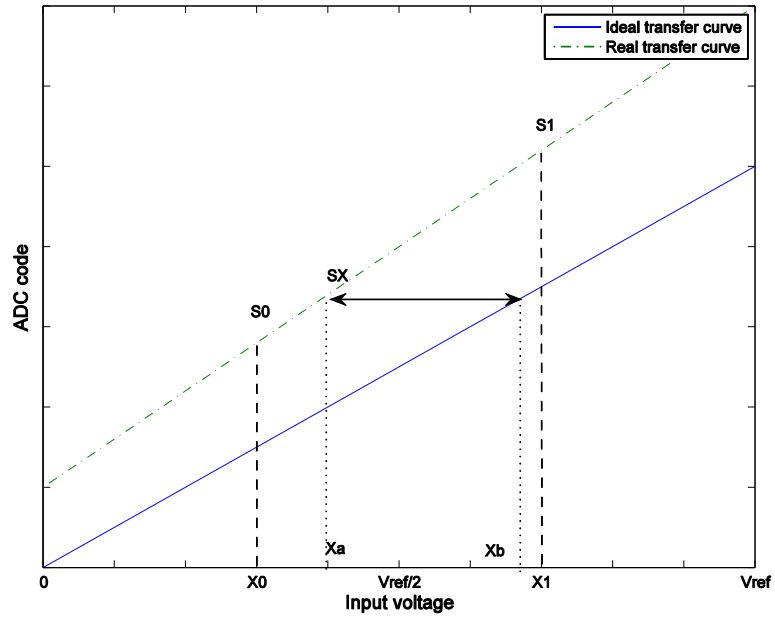
The calibration constants  $a_c$  and  $b_c$  can be calculated in calibration as:

$$a_c = \frac{S_1 - S_0}{X_1 - X_0} \text{ and } b_c = S_{0,1} - a \cdot X_{0,1}$$

With these two values, all that is needed to calculate the correct input in the application code is one division and one subtraction:

$$X_{calibrated} = \frac{S_{conversion} - b}{a}$$

Figure **Error! No text of specified style in document.**-1 shows an exaggerated example of a real vs. an ideal transfer curve. If a two-point calibration is not performed, the converted code  $S_x$  will be calculated to represent the voltage  $X_b$ . Instead when a calibration has been performed, the correct voltage  $X_a$  will be calculated instead.



**Figure Error! No text of specified style in document.-1. Ideal vs actual conversion**

Most users are interested in the calibrated code value instead of the voltage. To find this, the production calibration needs to calculate a few other variables instead.

Consider when a conversion of the voltage  $V_{in}$  is performed. Then, the ideal code output  $S_{ideal}$  of a N-bit converter can be found as:

$$S_{ideal} = \frac{V_{in}}{V_{ref}} \cdot (2^N - 1), \quad 0 < V_{in} < V_{ref}$$

Let's name the ideal conversion codes corresponding to the voltages  $X_0$  and  $X_1$  as  $S_{0i}$  and  $S_{1i}$ . The ideal slope  $a_i$  of the transfer curve is then found as:

$$a_i = \frac{S_{1i} - S_{0i}}{X_1 - X_0}$$

The ideal calibrated code output  $S_{calibrated}$  which corresponds to the converted code  $S_X$  is then found by geometry to be:

$$S_{calibrated} = S_{0i} + a_i \cdot (X_{calibrated} - X_0)$$

Let's define the constants  $c = \frac{S_{1i} - S_{0i}}{S_1 - S_0}$  and  $d = S_{0i} - c \cdot S_0$ .

If you insert the expression for  $X_{calibrated}$  above into the expression for  $S_{calibrated}$  and rearrange, this will yield the simple expression:

$$S_{calibrated} = S_{0i} + c \cdot (S_X - S_0) = (S_{0i} - c \cdot S_0) + c \cdot S_X$$

$$S_{calibrated} = d + c \cdot S_X$$

Compared with the expression for  $X_{calibrated}$ , the operation that will need to be performed at run-time to find the correct code is then one multiplication and one addition.