Hitachi America, Ltd.

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Application Engineering

TechNotes

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A/D Converter Specifications

Hardware Manuals for the H8 family A/D converters list a host of analog specifications which must be interpreted by digital designers. What do these specs mean in real life ? Hitachi squotes five types of parameters for the A/D converters: maximum conversion time, A/D input capacitance, source signal impedance , resolution and errors.

Resolution - This is the number of bits in the output code. 8 bits for the 300 series and 10 bits for the 500 series. What's the difference ? More bits in the output code allows you to detect or resolve finer differences in input voltage levels for a given range. For example: If you set AVcc at 5V and AVss at ground a valid input falls between 0 and 5V. Now, if the resolution is 8 bits, there are 256 possible output codes to describe the 5 volt spread or 256 divisions in the spread. Hence 5V/256 = 20 mV resolution or 20 mV per division. Likewise, if the A/D has 10 bit resolution: 5V/1024= 4.88 or about 5 mV differences can be resolved.

This bring us to the next term: **LSB. -** LSB refers to the lowest order bit in the output code carrying the smallest weight. For the 8 bit example the LSB represents 20 mV. The 10 bit LSB represents 5mV.

O.K. so much for theory. The reality is that the voltage level detection process and the quantization process (the process of dividing the voltage spread into discrete steps) introduce errors to the A/D conversion and limits the accuracy of the output code. All errors are expressed in terms of LSBs. Refer to figure 1.

Hitachi's manuals specify five A/D error types or five different ways of looking at A/D deviation from ideal behavior. It's important to keep this last statement in mind. These are just different ways of measuing the same deviation from ideal behavior. An analogy would be to measure the mass of an object by weighing it and dividing by the earths gravitational pull, measuring the objects displacement in water and multiplying by the objects density or weighing the object in free space. All methods give the object's mass.

Non-Linearity (Relative Accuracy)- If we plot the transition points (bits) versus the output code and draw a straight line between the first and last points for both ideal and actual results, non-linearity is the deviation of the graph of actual transition points from the ideal line.

Offset Error - This is the difference between the actual voltage which sets the first transition point (or bit) and the ideal voltage (AVss + 1/2LSB) which sets the first transition point. In our 8 bit example ideally we would expect the first bit in the output code to be set when the input = 20mV.

If the bit actually sets at 30 mV the offset is 10 mV.

<u>Full-Scale Error (Gain Error)</u> - Like the offset error but at the other end of the scale, full-scale error is the difference between the actual voltage which sets the last transition point and the ideal voltage (AVcc - 3/2LSB) which sets the last transition point . Full-scale error is measured after correcting for the offset error.

<u>Quantizing Error</u> - The Step-Compare (Quantizing) process for digitizing analog values inherently introduces an error of +/- 1/2 LSB. When you divide the voltage spread into sections or bits the furthest a measurement can be from the center of the band and still be associated with the band is +/- 1/2 LSB.

<u>Absolute Accuracy</u> - This is the final difference between the actual voltage level required to produce a given output code and the theoretical (ideal) voltage required to produce the same code. Since there is a band of voltages which produce each code the theoretical value is taken as the mid-point of the band. Absolute accuracy includes or takes into account full-scale error, offset error and non-linearity.

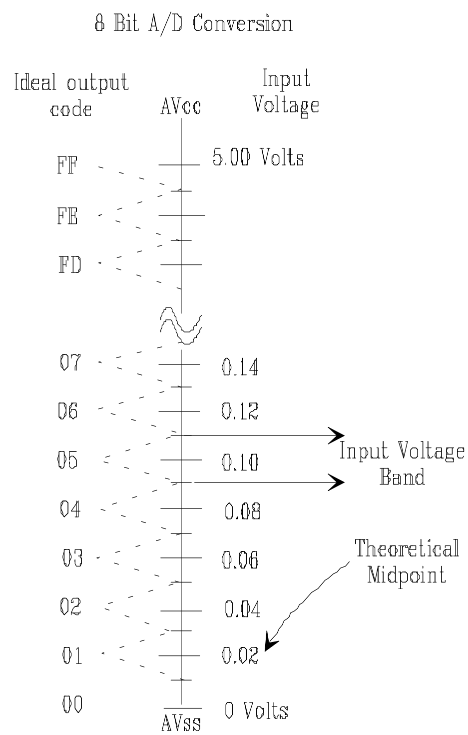

Figure 1

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