Delta sigma modulation: An option for isolated digital power

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Why is a first order sigma-delta modulator mode built into the switch cap block of a PSoC, and why is it useful for power designs? Here's a conversational look at what it could mean to you and your design. A colleague of mine, Chris Keeser, was exploring PSoC 5LPs switch-cap block a little and ran into one of probably several hidden features of the device. There is no mention of the feature in PSoC Creator, the design entry tool for PSoC, and the reference manual does mention it but does not provide more than just a mention. What is it you might ask? There is a first order sigma-delta modulator mode built into the switch cap block.

So why would this be useful for power designs? Ok, let me build up to that. If you take a look around your home or office you can find any number of electrical systems and most of them, maybe all of them, will have a power supply to transform the higher AC voltage provided to you to a lower DC voltage. For safety, this conversion process is heavily isolated. Thus if you consider this dilemma a bit, most switching power supplies have to regulate an output across a gap where no DC current flows. How can the output be regulated then? A common and pretty classical approach to this problem is to combine an error amplifier and compensation network with a biased optocoupler as shown in Figure 1 to bridge the safety gap. Ok, so this is a pretty simplified example and doesn't exactly depict all possible isolated designs, but it gets the point across.

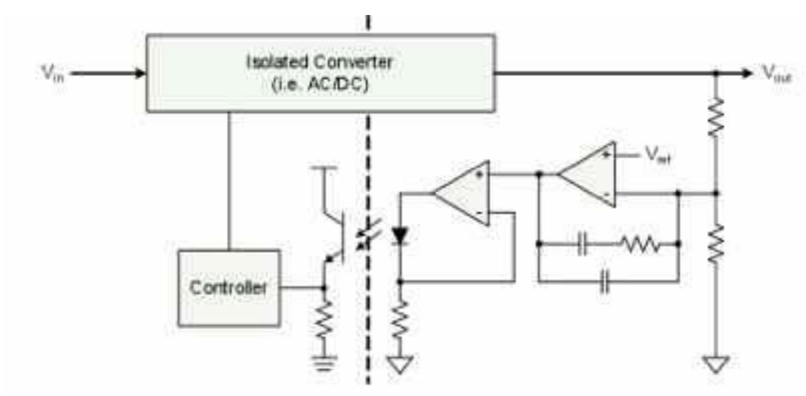

Figure 1: Isolated Control with Basic Compensation

With proper design an optocoupler can be and is often used quite successfully, but (as you probably already know) they are fickle beasts. One optocoupler to the next with the exact same part number can have wide varying transfer characteristics (normal manufacturing part variation). The transfer characteristics can change significantly as the part ages. Plus in a biased configuration such as the example shown in Figure 1, the transfer characteristics are often non-linear leading to another condition to watch, the stability of the entire system. All of these make designing a mass producible and long lasting power design a serious challenge.

Digital isolators have an advantage over an ordinary optocoupler; the input to output relationship is basically always one to one, and it doesn't change. Plus information is transferred at a considerably higher rate. The technical hurdle with the digital isolator is the binary nature of the digital isolator versus the example shown in Figure 1. The digital isolator favors passing data rather than a raw analog signal. This is where the sigma-delta modulator idea can play quite nicely.

Fundamentally the sigma-delta modulator simply translates an analog signal bounded to a certain range into a high speed stream of bits, a density stream, which represents the analog signal. Keep in mind that this is not packets of data; this is a raw stream of bits. Figure 2 shows an example. Note that I have drawn the figure right to left to make life a little easier; it follows the control signal flow of all the other diagrams in this brief article. An analog signal is driven into the modulator. The sigma-delta modulator transforms the signal into a high speed stream of ones and zeros that have an average weighting proportional to the input signal. The original signal can then be reconstructed on the other end through digital processing (IIR, decimation, or some other filtering) or even simple analog filtering.

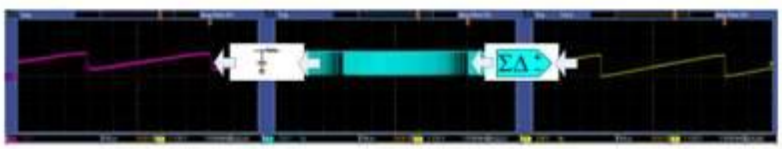

Figure 2: Analog Control Signal ← Digital Density Stream with Compensation ← Voltage Sense

Thus the analog idea in Figure 1 is transformed into a digital idea shown in Figure 3. The optocoupler is replaced with a digital isolator where there are minimal concerns about biasing or part variations, at least not in the digital isolators that I have worked with. The biasing circuitry is eliminated. The sigma-delta modulator is integrated with analog compensation and programmable reference generation to form a compact, mixed digital and analog control strategy for power applications. The beauty of all of this is that the functionality is integrated on a single programmable SoC. And, the integration doesn't stop here, with a programmable SoC there includes the digital processing capability as well as the programmable digital.

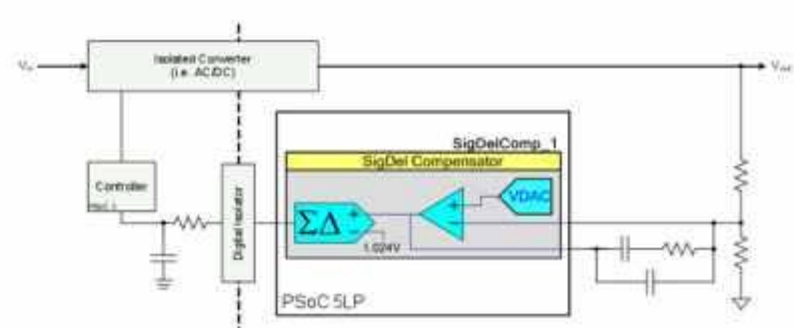

Figure 3: Digital Isolated Control with Basic Compensation

Of course, it is unlikely that using the combination sigma-delta modulator and digital isolator to pass analog information is ideal for all designs, especially on the extreme end of cost sensitive applications with relatively low performance requirements. However, the continuing proliferation of digital techniques and the constant drive for integration makes such an idea far more attractive in certain systems. This is especially true for dense and complex systems such as server power supplies and microinverters. In these systems more than one channel is necessary for passing a combination of digital and analog information across the isolation boundary. Thus individual optocouplers can be completely eliminated in favor of a single multi-channel digital isolator to pass a mix of analog and digital information. Figure 4 generalizes this with a four channel isolator passing two higher speed sigma-delta transformed analog signals and a pair of signals for full-duplex UART communications.

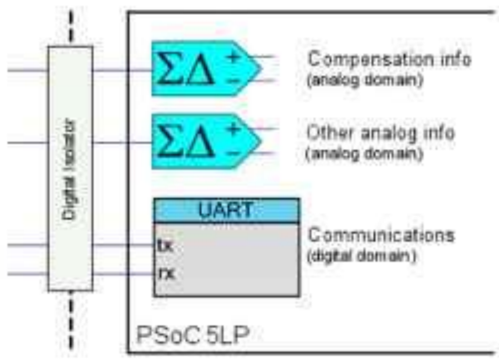

Figure 4: Moving Combined Digital and Analog Information from a SoC across Isolation

Every power platform I worked on was consistently driven to lower cost, increase density, and increase efficiency. Ultimately this leads to an integration strategy that must be enabling, enabling in a sense that allows for making changes to improve while removing components, and a programmable SoC fits this need handily. Personally, from this engineer's perspective (myself) the sigma-delta modulator is a cool feature that adds to the integration trend, especially for power applications.

About the Author

Ross M. Fosler *is an Applications Engineer and Member of the Technical Staff at Cypress Semiconductor Corporation, a leading supplier of innovative Programmable System on Chip technology. He has more than 12 years of diverse professional experience covering a wide variety of applications including embedded systems and firmware design, digital design, and power systems control and management design. For over 20 years he has been programming small processors and microcontrollers and has lead teams and personally developed many successful solutions for 8-bit and 16-bit embedded systems in the power, industrial, and consumer markets. Mr. Fosler's research interest resides in control theory, power electronics, and high performance real-time embedded processing. Mr. Fosler has 8 patents credited to him. He is also a veteran of the US Air force as well as a member of IEEE, HKN, AOC, and other organizations.*