**Power management: analog control vs. digital**

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To shed light on various aspects of the analog and digital control of power management, we'll clarify the fundamental differences between the technologies and determine how they affect system performance.

There is no clear answer as to which approach is better. However, the needs of ever-growing complex systems have paved the way for a digital approach to power management—an idea that seemed far-fetched not long ago. Unfortunately, the success of certain digital power products has painted an unrealistic picture of what digital systems can do. And while overblown claims about this technology should subside as it matures, the question remains: What is the best approach right now?

In general, there is no such thing as a purely analog or purely digital approach to power management. The first IC to feature the analog control scheme called pulse-width modulation (the SG1524, designed by Bob Mammano) incorporated such digital circuitry as latches and clocks. Today, three decades later, digital PWM controllers include such obvious analog blocks as A/D converters, references and even amplifiers. Clearly, the right answer depends on a suitable partitioning of the circuit functions, and the right partition depends on the available technology and the current system requirements. Thus, the partition we draw today may be different tomorrow.

Today's ideal system provides the high accuracy necessary for meeting tight error budgets, which are imposed on power supplies by the small geometries and less-forgiving processes associated with the giant microprocessors and ASICs used in high-speed processing and communications. The traditional benchmark was 1 percent accuracy; seldom was anything better required. The latest processor and ASIC specifications, however, force an error budget of no more than a few millivolts. At low supply voltages, that translates to much better than 1 percent accuracy. Note that this accuracy must be maintained over temperature, and most systems are designed to operate over a range of 0°C to 85°C or higher.

By the same token, supply voltage tracking and sequencing is of great importance, because, the small geometries associated with I/O and multiple processor cores are less forgiving of the "latchup" caused by improper differential voltages. The latest complex boards require many supply voltages and therefore have a more stringent need for accurate sequencing and tracking. While those functions are difficult to implement in the analog domain, a digital approach can provide an accurate and simple solution.
In high-end systems that require near-zero downtime, it is important to monitor redundant systems—to ensure their good health, to understand why and how a power supply goes down and to take prompt corrective action when required. The analog domain, however, requires lots of discrete components or dedicated boards, or both, to achieve even a limited degree of monitoring. Many systems are less reliable because engineering doesn’t want to deal with the size, cost and complexity of a proper monitoring system.

By contrast, digital systems provide monitoring almost for free. The needed information must already be in digital format for the digital engine to work, and it is easy to add a communications capability to a digital system.

In the rush to capture markets and support existing products, ASICs are often developed in a hurry and then deployed in the field without having undergone a complete evaluation. That poses a dilemma. On one hand is the expensive proposition of recalling the units and modifying them. The other option is to tolerate field units with the reliability of a ticking bomb. Both options defeat the purpose of a zero-downtime system.

In many cases, the answer is a digital, field-programmable system, whose upgrades can be transparent to the user.

One look at current systems and emerging requirements makes it obvious that the all-analog approach will not be sufficient as we move forward. But not all functions are best implemented entirely in analog or entirely in digital. Each has inherent benefits and drawbacks. Thus, a correctly partitioned system can lead to the best available solution for today's circumstances.

The PWM circuit, for example, is probably the best kept in the analog domain. Its components usually consist of a reference, an error amplifier, a comparator and a voltage ramp (derived either from the ripple current or from an oscillator). Other alternatives include hysteretic topologies, but in any case, analog remains the best approach for this basic circuit block. It generally takes up a small amount of silicon area and is therefore inexpensive. A PWM controller includes many other blocks, but most are unaffected by the digital or analog format of the PWM circuit.

The need for protection circuits has not changed, but fault events must be serviced as quickly as possible, often within nanoseconds. Even the fastest flash A/D converters contribute a latency in digitizing the data, and more latency resides in the decision-making engine, whether processor or state machine. When you add a further propagation delay inherent in the driver chain, the overall delay can become unacceptable.

For reading current, we generally need a differential amp with low offset, high linearity and high common-mode rejection. Those requirements are not affected by whether we digitize data at the output. They are tough requirements and are generally implemented only in good analog processes. Similar considerations apply in reading temperature. Regardless of whether the data is digitized, current and temperature monitoring are analog problems, solved by analog circuits.

The reference, a complete analog circuit, is also required, whether the system is analog or digital. In
digital systems, it provides a reference voltage for the A/D converter circuit, which is also more analog than digital. The A/D converter's data output is digital, but all the elements that make the part accurate and linear are analog.

The communications block is an obvious candidate for the digital side, as is the nonvolatile memory used to store settings for the power supply. The brain of the digital approach, which is either a processor or a state machine, is also obviously digital.

D/A converters include a lot of analog components, but the presence of digital circuitry also looms large.

Another valued digital technique is the slow loop, used to maximize analog output accuracy. That task, which is not possible with analog circuits, is accomplished with an accurate and complex calibration based on a high-performance A/D converter.

This is a true mixed-signal situation, marrying accurate analog and flexible digital circuits. Although the scheme requires an A/D converter, that converter doesn't compare with the one used in a digital PWM.

The PWM A/D converter must have high resolution and compatible speed, but we know that speed, accuracy and low cost are not qualities to be had simultaneously in an A/D converter. In general, the PWM A/D must be a flash device to provide the necessary speed, but flash topologies are not practical beyond 8 bits, and 8-bit accuracy is far lower (16 times lower) than that of a 12-bit A/D converter. Therefore, the 12-bit SAR A/D converter is preferred, since it provides accuracy with reasonable speed at low cost.

Once the data is digitized, you can set multiple thresholds for the detection of overvoltage, undervoltage, overcurrent and overtemperature. Analog is necessary to obtain a fast response for gross levels of these events, but for extremely accurate thresholds, you should implement this function digitally. Digital circuits can set multiple thresholds for these events and service each one in various ways.

Warning and fault thresholds, for example, can simply be flagged, or they can cause the output to shut down.

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