Meeting the Integration Challenge in Smart Meters

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Executive Summary

In many countries, the smart grid is quickly progressing from vision to reality. Thanks to fiscal incentives and government mandates, utilities have advanced from pilot projects to full-scale rollouts, and they're beginning to realize the benefits of advanced metering infrastructure (AMI) and other smart grid technologies.

However, a number of countries are still sitting on the sidelines evaluating their options. The European Commission recently conducted a benchmark study of Member States investigating why 40% do not plan on initiating large-scale rollouts before 2020. The study concluded that without fiscal incentives, the business case for smart meters is far from clear.[1]

The fact of the matter is that utilities are pinched between massive outlays for smart grid infrastructure and declining CapEx spending. Understandably, they are taking a hard look at their deployment costs versus ROI, and in many cases these numbers don't support deployment. When explaining why they are not proceeding with an AMI rollout, utilities cited two reasons: 1) the meters themselves are still too expensive; 2) their lifespans are too short, sometimes as little as 8 years. Meaning utilities would be forced to replace the meters before they've recouped their original deployment costs.

> "The business case for rolling out smart metering is not yet overwhelming throughout Europe."
>
> European Commission

This is a critical insight for meter manufacturers. Focusing exclusively on unit cost can leave you with a product that won't meet utility requirements for lifespan and, therefore, won't sell. To win in this market, you need to strike a balance between sticker price and meter capabilities. Utilities will continue to focus on unit cost, because when meter rollouts run in the billions, every dollar in BOM reduction can deliver millions in CapEx savings. However, you should not overlook the importance of meter lifespan in the final cost-benefit analysis conducted by utilities.

ENGINEERS

42%

of engineers in this market say their biggest challenge is delivering more functionality without increasing cost[2]

This raises a considerable challenge for meter designers. Extending meter lifespan requires adding more memory, processing power, and capabilities than needed for today's applications. Yet, you must do this while carefully managing unit cost. Meter manufacturers who master these competing demands will find themselves on the winning side of cost-benefit analyses, and enjoy greater share of this multibillion dollar opportunity.

This white paper takes a closer look at the capabilities demanded by utilities and the integration challenges they raise. Read on to learn how new developments in analog integration can help you close the gap between meter requirements and cost.

1 European Commission, "Benchmarking smart metering deployment in the EU-27 with a focus on electricity" (Brussels: June 17, 2014).
2 TechValidate, "Analog Integration Market Study" (Sept. 9, 2014).

Capitalizing on the Smart Grid Opportunity

The smart grid represents a tremendous opportunity for meter manufacturers, with an estimated 800 million meters expected by 2020.[3] Yet, competitive pressures continue to increase as fiscal incentives expire and meter manufacturers are forced to contend with the cold, hard math of utility cost-benefit analyses.

Smart meter deployments can cost billions of dollars, and utilities simply can't afford to replace the meters every ten years. The European Commission found that short meter lifespans are one of the top reasons cited for non-deployment. Utilities want meters that will last at least twenty years, are flexible enough to support evolving industry standards and protocols, and adaptable enough to meet as-yet-undefined usage requirements.[4]

For meter engineers this raises a formidable challenge: how do you design a meter that will be relevant in 20 years when you can't be sure what will be needed or even possible then?

Consider how much the consumer market has evolved over the last two decades. We've seen entire product categories rise and fall in just a few years. Frequently, it's hard enough just to keep up with technology. Staying ahead of it raises a host of additional challenges—especially for manufacturers still wedded to designs that depend on assembling a meter from discrete electronic components and multiple processors.

Meeting tomorrow's requirements will require the most of today's technology. Fortunately, recent advances in analog integration can help meter designers "future proof" their designs without the traditional cost penalties. This so-called system-on-chip (SoC) approach can give manufacturers the leverage they need to tip cost-benefit analyses in their favor and fully capitalize on new market opportunities.

The Growing Integration Challenge

As solid-state meters evolve from simple automatic meter reading (AMR) functions to more advanced smart meters the number of functions continue to increase. Utilities today are asking smart meters to do more. And they're sometimes asking for laundry lists of advanced capabilities such as:

- Instantaneous voltage/current
- Peak voltage/current
- RMS voltage/current
- System frequency
- Phase displacement
- Power factor
- Instantaneous apparent and reactive power
- Energy use/production
- Harmonic voltage distortion
- Total harmonic distortion
- Remote disconnect
- Time-of-use tariffs
- Power-outage notification
- Power-quality monitoring
- Nonintrusive load monitoring
- HAN management
- Multiple communication protocols

All of these features have an impact on meter design. They require more components—more memory, faster CPUs, more power, faster sampling rates, and added communications circuitry. Even using the latest solid-state technology, it's difficult for a meter design that relies on discrete components and multiple processors to accommodate all these build requirements without exceeding price targets or form-factor constraints.

3 Navigant Research (2014).
4 European Commission, "Benchmarking smart metering deployment in the EU-27 with a focus on electricity" (Brussels: June 17, 2014).

Securing It All

The biggest integration challenge is securing meters against the many threats they face. Because they're networked to critical power infrastructure and end customer equipment, smart meters represent an attack vector that can expose both utility and customer assets.

Several high-profile cases have demonstrated the vulnerability of smart meters to both physical and electronic attacks. In 2009, for example, IO Active successfully reverse engineered a smart meter, demonstrating the ability to inject a worm that would grant a hacker full control over grid devices. The tests also revealed that the worm could spread like wildfire throughout the grid, potentially allowing hackers to shutdown massive portions of electricity to major cities, critical infrastructures, and government agencies.[5] And in Puerto Rico, hackers altered unencrypted data in smart meters, causing the meters to underreport electricity usage and costing the utility an estimated hundreds of millions of dollars annually.[6]

Engineers are challenged to create designs that keep pace with evolving security standards while guarding against data loss, data modification, and data exposure. We all know that an enterprising hacker can worm his way through the smallest software hole. But even hardware solutions can be vulnerable to tampering and data eavesdropping if they're not carefully architected to thwart such attacks.

For instance, multichip designs that pass unencrypted data from the metrology chip to the communications module can leave the meter vulnerable to logic probes and network analyzers—ultimately, compromising the longevity of the design.

> "The FBI warns that insiders and individuals with only a moderate level of computer knowledge are likely able to compromise meters with low-cost tools and software readily available on the Internet."
>
> — KrebsOnSecurity

The Hidden Costs of Discrete Solutions

Figure 1 shows a traditional smart meter using discrete components and multiple processors. This approach employs one chip for the analog front-end (AFE), a second chip for meter processing, a third chip for the application, a microcontroller to handle communication and storage and additional external circuitry. There might be other ICs for NAN or HAN communication, while adding new functions like security can ratchet up the IC tally still more.

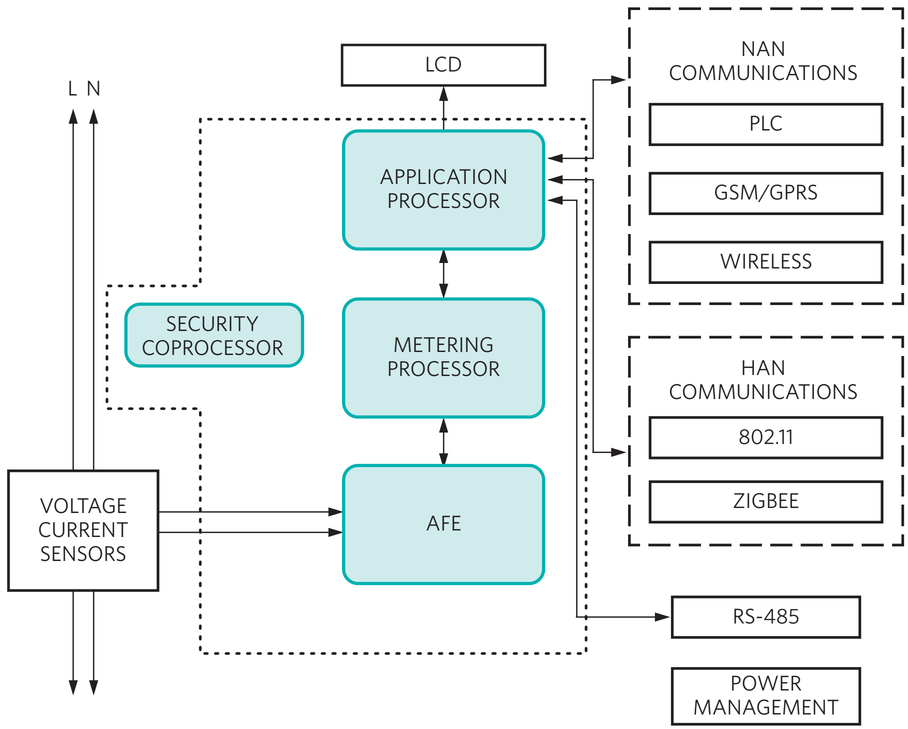

Figure 1: Multiple ICs in a typical discrete smart meter design

5 "Smart Grid Privacy and Security Risks Loom for Agencies," Breaking Energy (August 5, 2011).
6 "FBI: Smart Meter Hacks Likely to Spread," KrebsOnSecurity (April 9, 2012).

On the surface, this approach can look attractive because the components are highly commoditized and available from multiple sources, providing purchasing with greater pricing leverage. However, once you total the bill of materials, factor in the added engineering and testing costs, and account for the impact on overall meter lifespan, discrete approaches become a lot less attractive.

When architecting a meter, it is important to take all of these costs into consideration, and then select solutions that strike the right balance between BOM cost and meter lifespan. Features such as the ability to handle multiple communication protocols, upgrade firmware easily, and utilize a single platform worldwide make the smart meter that much more attractive to its purchaser.

System designers should carefully consider the utility's final cost-benefit assessment, bearing in mind that a $100 meter that lasts for twenty years is a much better proposition than a $50 meter that needs to be replaced in ten.

Advantages of an Integrated Approach

Advances in analog integration now enable advanced metrology, security and, communications to be combined into a single integrated circuit—in effect, replacing many discrete ICs, multiple processors and/or microcontrollers with a single-chip solution. Such an integrated approach, known as a system on a chip (SoC), allows savvy designers to achieve the perfect blend of size, cost, flexibility, and future proofing.

Figure 2 illustrates an integrated smart meter SoC (Zeus) from Maxim Integrated. Zeus unites the security coprocessor, application processor, and metering processor, together with the analog front-end and a digital signal processor (DSP) for accurate voltage and current measurements—all in a single IC. This approach has a number of advantages over the traditional implementation shown in Figure 1.

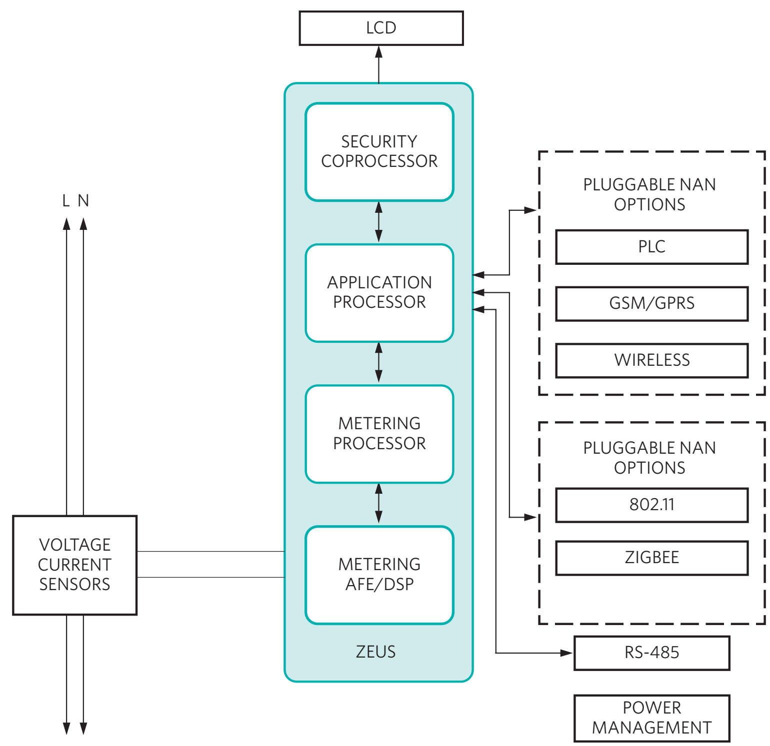

Figure 2: Maxim's award-winning Zeus SoC replaces multiple chips with a single IC.

Smaller, More Capable, and Lower Cost

For the smart meter OEM, using an integrated SoC can help deliver the reduced form factor and lower cost so prized by customers. The meter's size can be slashed by as much as 45%, reducing both enclosure and PCB costs. Moreover, Zeus provides all the benefits of state-of-the-art technology, while reducing BOM cost by as much as 29% compared to the traditional approach. When combined with lower manufacturing complexity and reduced R&D expenses, the business case for adopting an integrated approach has never been clearer.

"Zeus is a complete smart-meter system-on-a-chip (SoC) that offers highly accurate metrology, multiple layers of security, and processing horsepower for today's advanced communication protocols."

— EDN Network, October 22, 2012

Zeus was built to handle whatever utilities ask of it and support multiple markets with a single flexible platform. The SoC integrates three independent 32-bit processors that provide ample processing power, not just for today's applications but also tomorrow's. The firmware can easily be upgraded to add future capabilities. Another advantage of this design is that the communication capabilities are provided by plug-ins, leaving a path to accommodate future protocols and standards.

Better Security

From a security standpoint, the integrated approach as exemplified by Maxim's Zeus meter has several advantages over other designs. Its multiple layers of security include:

- **Communications security.** Messages transmitted by the SoC cannot be intercepted by others. Messages to the SoC cannot be forged by an impostor.
- **Data security.** Data stored in external media (I2C or SPI connected EEPROM, for example) is stored in such a way that even if the device is removed from the meter, the data stored on the device cannot be used.
- **Software security.** Software loaded onto the ARM core will be executed only if it is appropriately signed by a party with a secret key corresponding to a public key stored in the SoC. The secret key can be loaded by the customer using Maxim-provided software, or can be loaded by Maxim at final test. And since the ARM core loads the MAXQ core on each reset event, the software for the ARM core is implicitly protected.
- **Metrology security.** Accumulated energy usage and other metrology results can be embedded in a security envelope. This envelope can be passed through the communication protocol layers so that the end recipient can be sure the results are authentic.
- **Physical security.** A dynamic tamper detection system ensures that if the meter is tampered with, the SoC records the event and takes appropriate countermeasures. These can include everything from alerting an operator to destroying cryptographic keys to render the meter inert.

Using an integrated approach to building in such hardware-level security during manufacture has the added benefit of being much less expensive than trying to add security or upgrade the meter at a later time.

Figure 3: The Capistrano reference platform gives customers a convenient way of evaluating the capabilities of Zeus.

Bringing It All Together

Maxim has developed a smart meter reference platform (Capistrano) to demonstrate the capabilities of Zeus, reduce customer development, and optimize system accuracy (**Figure 3**).

Benefits of Capistrano

- **High integration.** Integrates an applications processor, metering microcontroller, metering front-end/DSP, and a secure coprocessor
- **Advanced security.** Integrates physical-attack detection, a secure bootloader, and advanced cryptography schemes including elliptic curve; supports secure in-field software upgrades
- **Excellent performance.** Offers independent ADC channels for metrology; 0.1% accuracy over an 8000:1 range
- **Flexibility.** Easily connect Capistrano to PRIME, G3-PLC™, GPRS, and other modems; enough processing power to handle future application requirements
- **Simplifies and speeds designs.** Start designs for next-generation smart grid products with the most integrated reference platform and optimized BOM cost

Seize the Integration Advantage

As market and competitive pressures increase, smart meter designers need to pursue new design strategies to meet utility demands for more capabilities at lower costs. The key to success will be striking the right balance between meter sticker price and lifespan, as this can help tilt cost-benefit analyses in favor of deployment.

Today, new developments in analog integration enable system designers to deliver a host of value-added features without all the added costs. The Zeus SoC and associated Capistrano reference platform provide customers with a roadmap for success in this highly competitive market. This integrated approach closes the gap between meter requirements and cost, helping to make the smart grid more affordable for all.

Explore Our Solutions

Transform analog into your biggest competitive advantage with Maxim Integrated:

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