Smart Energy Solutions for Home Area Networks and Grid-End Applications

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Introduction

Local networking of electronic devices in houses and buildings offer benefits in a number of areas, ranging from safety and security to energy efficiency and home entertainment features. Home area networks can be implemented via both wired and wireless solutions, using multiple different standards, and can be remotely controlled and monitored through a gateway to neighbor, wide area or smart grid networks. While smart grid deployments offer great opportunities for utilities to manage and control energy distribution to their customers, it also gives homeowners the opportunity to better manage their energy usage through smart energy management.

Home Area Networks (HAN)

A home area network is a dedicated network connecting devices in the home such as displays, load control devices and ultimately "smart appliances" seamlessly into the overall smart metering system. It also contains turnkey reference designs of systems to monitor and control these networks. Most of our high energy use today comes from heating/cooling, cooking, lighting, washing and drying. These home appliances are beginning to become smart with connectivity features that allow them to be automated in order to reap benefits that smart metering and variable tariffs bring. The utility companies are beginning to be able to better manage the energy demand and perform load balancing more efficiently.

Realizing long-term potential savings in a typical home environment through the smart grid means that technology, legislation and mindset must come together to drive a permanent change in the way that energy consumption is perceived by consumers. Figure 1 demonstrates how smart appliances are interconnected within a HAN.

HAN Market Trends

According to IMS Research, the installed base of smart home networks will increase from 1.5 million homes in 2009 to 14.7 million in 2014.[1] A Pike research press release suggests that smart meters are increasingly adopted by electric utility companies for energy efficiency and management and forecasts that the installed base of smart meters will reach 963 million units by 2020.[2] Companies like Google and Microsoft are moving towards smart energy by introducing devices such as Google power meters, Android@Home, Microsoft Hohm, etc.[3] According to a Pike Research estimate, the number of home energy management users is expected to reach 63 million by 2020.[4] These numbers indicate that there is a strong growth potential in the HAN market at least for the coming decade, as concerns for using energy efficiently are spreading across the globe.

Figure 1: Home Area Network (HAN)
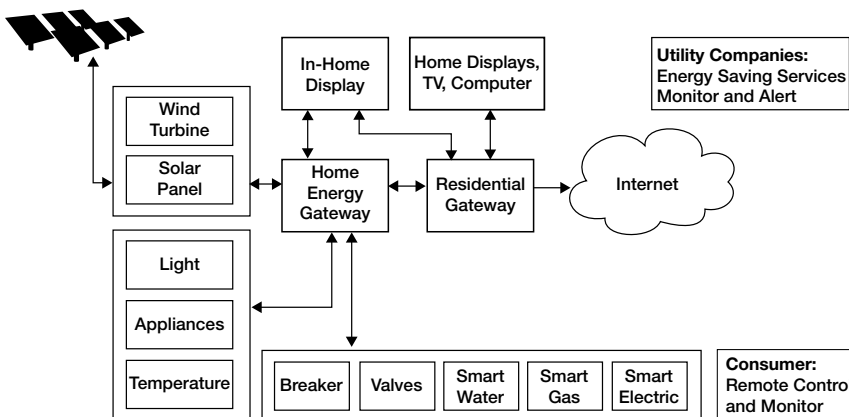
[1] Gamble, John, and Michael Markides. "The World Market for Components in Utility Meters." IMS Research - Electronics Market Research & Consultancy. IMS Research, 2008. Web. 07 Nov. 2011. **imsresearch.com/**
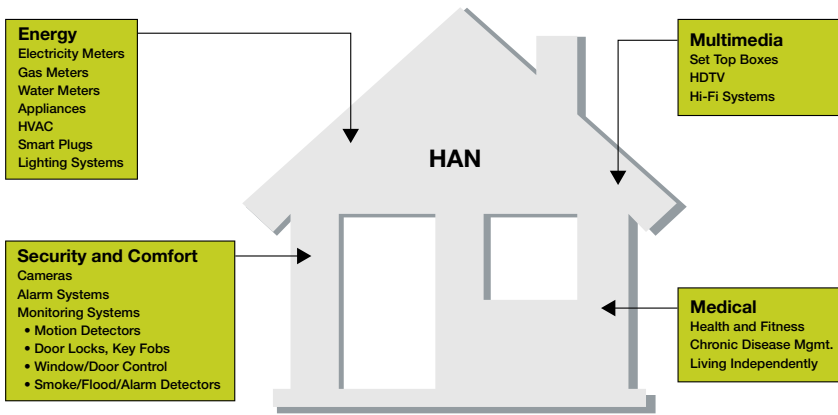
[2] "Global Installed Base of Smart Meters to Near 1 Billion Units by 2020 Pike Research." Pike Research. Pike Research LLC. 9 Aug. 2011. Web. 07 Nov. 2011. **pikeresearch.com/newsroom/global-installed-base-of-smart-meters-to-near-1-billion-units-by-2020**

[3] "Innovative Ideas Took Center Stage During Western Energy Institute Panel | The Burns & McDonnell World." Burns & McDonnell. Burns & McDonnell, 26 Oct. 2011. Web. 07 Nov. 2011. **burnsmcdblog.com/2011/10/26/innovative-ideas-took-center-stage-during-western-energy-institute-panel/**

[4] "Home Energy Management Users to Reach 63 Million by 2020 Pike Research." Pike Research. Pike Research LLC. 8 June 2011. Web. 07 Nov. 2011. **pikeresearch.com/newsroom/home-energy-management-users-to-reach-63-million-by-2020**

Figure 2: Smart Networked Home Forecast

Smart Home Equipment

Energy
Electricity Meters
Gas Meters
Water Meters
Appliances
HVAC
Smart Plugs
Lighting Systems

Multimedia
Set Top Boxes
HDTV
Hi-Fi Systems

HAN

Security and Comfort
Cameras
Alarm Systems
Monitoring Systems
• Motion Detectors
• Door Locks, Key Fobs
• Window/Door Control
• Smoke/Flood/Alarm Detectors

Medical
Health and Fitness
Chronic Disease Mgmt.
Living Independently

Some of the key market drivers and influencers for home energy management are:

- Growing energy prices
  - Reduce home energy consumption
  - Encourage smart consumption

- Service providers
  - Innovative services around energy management and home security
  - Utilities to take control of energy usage

- Consumers
  - Desire for monitoring/controlling
  - Remote access to home

- Technology enablers
  - Commoditization of LAN/WAN networks
  - Maturity of low-power technologies (ZigBee®, Wi-Fi®, Z-Wave, etc.)

- Standardization bodies
  - Individual protocol alliances (ZigBee, Z-wave, HomePlug, etc.)

- Application-oriented alliances:
  - OpenHAN from UtilityAMI
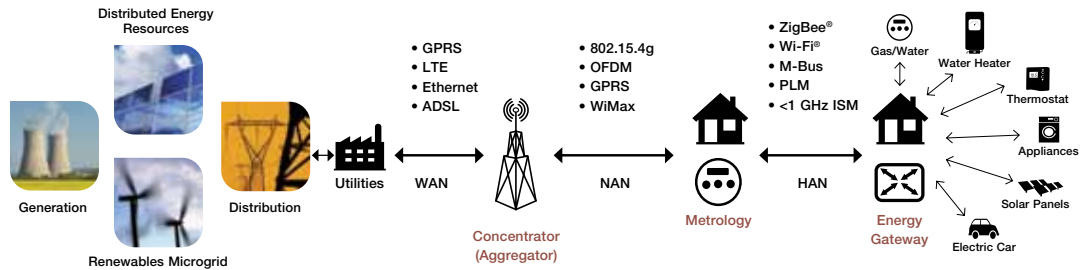 - AHEM
  - CECED from appliances

Challenges in Implementing HAN

The key challenge in implementing a HAN solution is to connect the entire house/building network to the "external world" for remote monitoring and control—and simultaneously to connect objects inside houses/buildings to offer smart interoperability features (refer Figure 2). A key challenge from the consumer's perspective is remote controlling and monitoring for surveillance companies, while the challenge from the service provider's perspective is remote metering for utility companies and security monitoring for surveillance companies.

One such example is connecting PIR sensors to heating, ventilation and air-conditioning (HVAC) and lighting systems to turn off heating when windows are open, or turn lights off when no presence is detected. Summing up, the challenge in implementing a HAN solution is to interconnect different technologies to offer smart services for:

- Comfort

- Automation

- Security

- Energy management

- Health

Freescale Smart Energy Solution

Freescale's smart energy solution consists of a HAN with smart appliances and electric meters on one end and grid-end applications such as data concentrator/aggregator, grid routers and grid power management and protection at the other end (refer Figure 3). The ZigBee smart energy application profile addresses communication from meter to the HAN for purposes of load control and demand response. Load control provides the ability for the utility to turn off loads for short periods of time in the customer premises during peak loads, while demand response is the ability for utilities to communicate with a home the changing utility rates during peak times and similar details. The user will then have an option of taking voluntary actions to reduce personal consumption.

Figure 3: Freescale Smart Energy Solution

Power Generation, Transmission Monitoring and Control

System solutons for monitoring and control

Monitoring and Control Systems
• MPC8xxx
• QorIQ

Grid Power Protection, Relay/Switch Control and Monitoring

Grid power supervision, control and network protection system solutions, protective relays and control switches for the power grid

Power Protection
• MSC9130

Relay/Switch Control
• 8-bit MCU
• 32-bit ColdFire
• 32-bit Kinetis
• MPC8xxx
• QorIQ

Data Concentrator (Aggregator):
Sends collected data (or commands) between the utility and the NAN or HAN

Data Concentrator
• MPC8308
• i.MX28
• P102x

Neighborhood Area Network (NAN):
Wired/wireless connection from meter to utility, either directly or via a data aggregator

NAN
Wired
• G3 OFDM PLC on metering comms SoC
Wireless
• MC12311
• Metering comms SoC

Metrology:
Hardware that measures and controls flow of energy to/from building

Low-End Meters
8-bit MCU
• 9S08LL/LH/AC

Smart Single- and Three-Phase Meters
32-bit MCU
• MK30
• MCF51EM256

Water, Gas and Heat
• 9S08LL
• 9S08GW64

Home Area Network (HAN):
Wireless/wired for load control and dynamic response by utilities
Load Control: Meter communicates with T-Stats, appliances, water heaters, pool pumps, electric hybrids
Demand Response: Send pricing signals to consumers for smarter energy consumption
Energy Gateway/Manager: interface to smart objects in home to monitor/control energy

Home Energy Management Systems
• i.MX, MPC8308, P10xx
• MK30/MK10

HAN Interfaces
• ZigBee (MC13224/6)
• M-Bus (MC12311)
• Wi-Fi, GPRS, HP-GP

Appliance Technology
• 8- and 32-bit MCU and DSC
• Touch sensor

RF4CE (wireless control)

Energy Gateway

An energy gateway is the interface between the utility-controlled smart grid and energy-consuming in-house objects. Energy gateways, also known as networked smart gateways, can be designed by using either Freescale's low-end processors, such as the MPC8308 using an e300 core, or high-end processors, such as the QorIQ P1010/P102x using an e500 core. For further details on energy gateway solutions, please refer to the article, "Networked Smart Gateways for Energy Management and Control" in *Beyond Bits: Power Architecture Edition*.

Grid-End Applications
Data Aggregators/Concentrators

Data concentrator is an important component in automatic meter reading (AMR). It creates the necessary network infrastructure by linking several utility meters (electricity, gas, water, heat) to the central utility server and captures

Figure 4: Typical Data Concentrator Setup
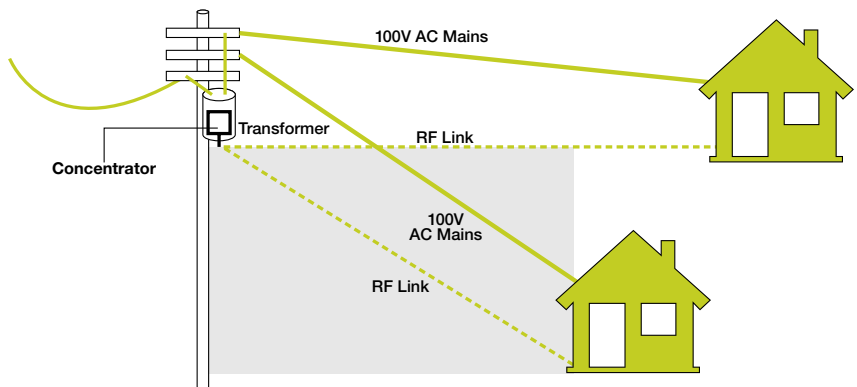
and reports vital data (Figure 4). It also helps synchronize the time and date data of utility meters to a central utility server and enables secure data transfer of user authentication and encryption information. Communication to utility meters is comprised of an RF or wired (power line modem) connection, enabling data transfers to the central utility server via GPRS, Ethernet, GSM, POTS or UHF/VHF networks.

Freescale offers a data concentrator reference design based on the MPC8308, supporting the DLMS/COSEM client/server stack.

Figure 5: Data Aggregator/Concentrator Implementation Using P1025
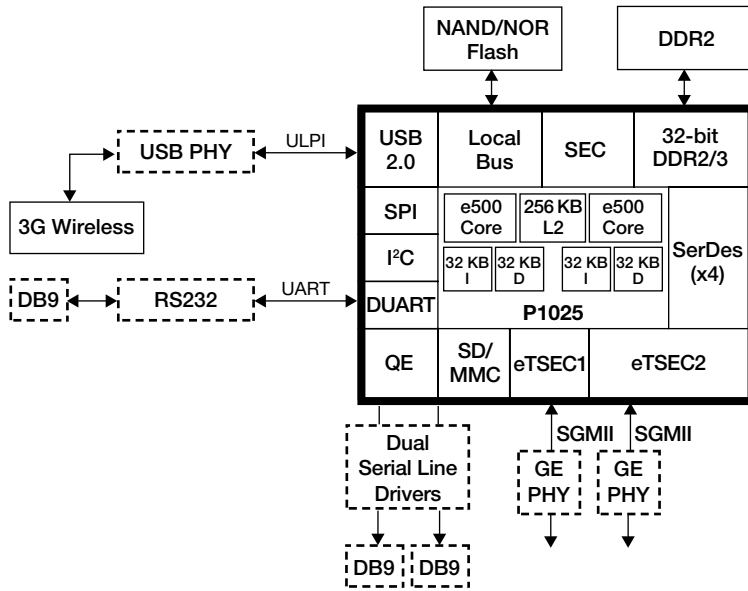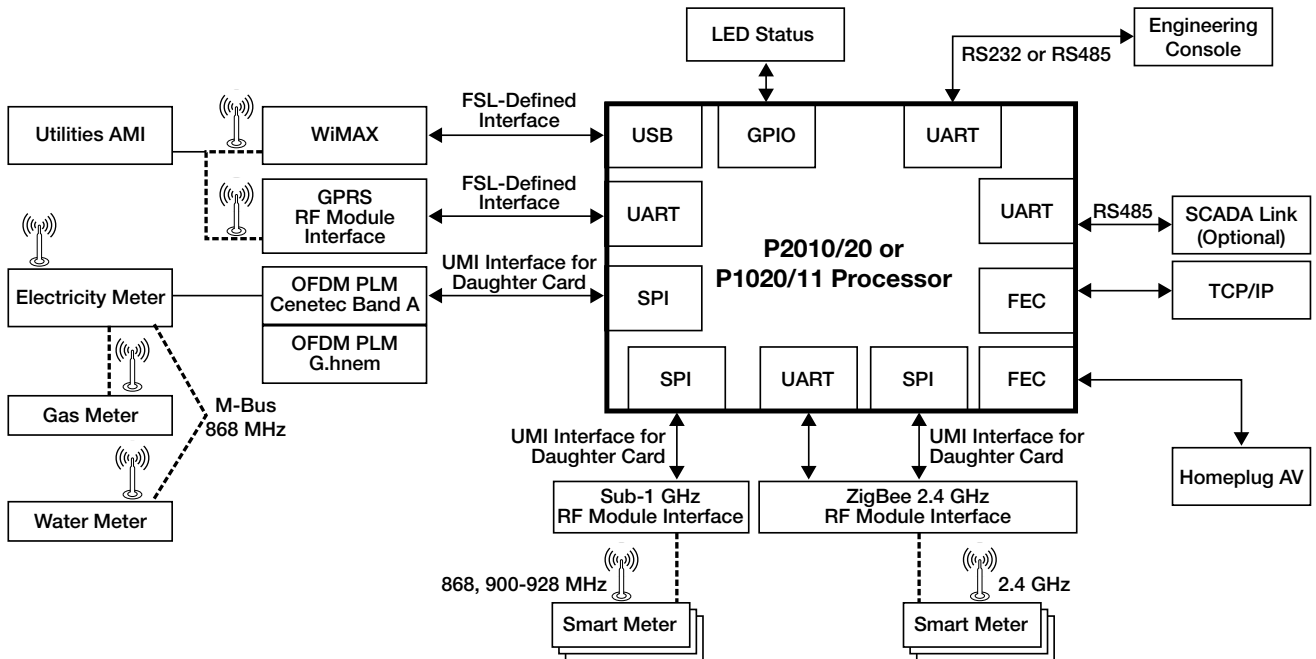

## Figure 6: Freescale's Grid-End Solutions Using P1 and P2 Series QorIQ Processors

The P1025, a QorIQ device built on Power Architecture® technology, offers a dual-core solution to allow communications and applications to coexist (see Figure 5). It provides a platform for a fully featured operating system and hypervisor support for a high-end data concentrator or aggregator application.

Figure 6 showcases Freescale's grid-end solution for concentrator and grid router using P1 or P2 series QorIQ processors.

Grid Routers

Figure 7: Grid Router Block Diagram
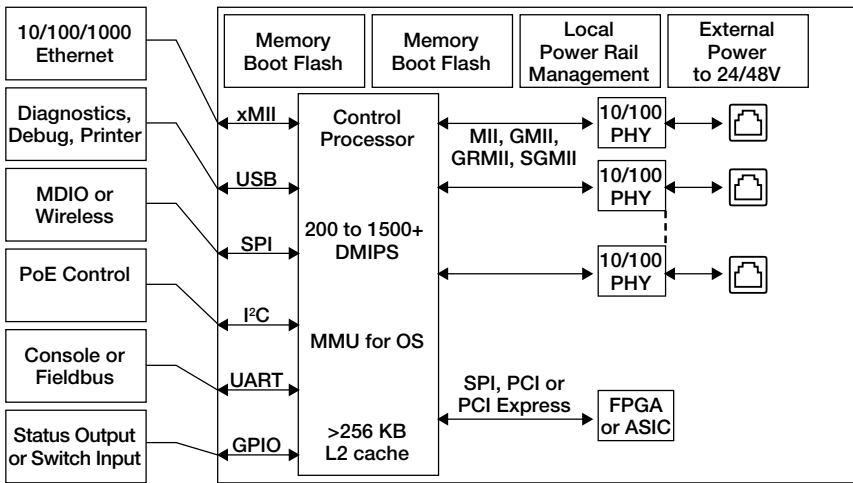
Router Function

The router's main function is to act as an interface between the smart meter and the utility network, performed using a grid router (sometimes referred to as a concentrator). The role of the router is to provide a link from the utility company to all local smart meters. At the heart of a router lies a powerful 32-bit processor, such as QorIQ P2010/P2020 or P1020/P1011 multicore processors, usually running a real-time operating system and providing high-level services such as communications stacks, prioritization of messages, store and forwarding, network routing and discovery.

Figure 7 demonstrates Freescale's grid router solution using QorIQ P1/P2 processors. Below are some of the key features that distinguish Freescale's grid router solution:

- High performance (100 up to 38,000 MIPs)
- Built-in security functions supporting public and private key cryptography
- Wide range of communication ports, including Gigabit Ethernet and fast serial ports, plus USB 2.0 for local on-board interfacing
- PCI Express® for FPGA interfacing

Freescale addresses two key concerns for grid routers solution—connectivity and security.

Connectivity

Depending on local needs, Freescale offers a range of options for local communication that include short range wireless (around 900 MHz) through Freescale's ZigBee alliance, power line communications (low frequency carriers typically below 500 kHz) using Freescale's power line modem solutions for local communications and options from longer range communications such as ZigBee, Wi-Fi, Ethernet, ISDN, HDMI, PLC, Bluetooth/BTLE, RF4CE, HomePlug, Z-Wave and GPRS through Freescale's strong alliance with several leading smart grid standards bodies and committees. For more details on Freescale product families supporting the above alliances, please visit **freescale.com/smartenergy**.

ZigBee and Smart Energy

ZigBee is a low-power wireless communications technology designed for monitoring and control of devices. Based on IEEE® 802.15.4 standard, ZigBee technology provides a robust and reliable solution in noisy radio frequency (RF) environments. ZigBee features include energy detection, multiple levels of security, clear channel assessment and the ability to cover large areas with routers and channel agility. These features help devices pick the best possible channel and avoid other wireless networks such as Wi-Fi while the message acknowledgement feature ensures that the data was delivered to its destination. Freescale also supports less than 1 GHz frequencies using the MC12311 wireless transceiver. Today, the WMBUS stack is supported on this device. Freescale provides the building blocks needed for both ZigBee and ZigBee Pro feature sets including hardware, software, tools and reference designs. One solution, one provider—built, tested, compatible and ready for integration.
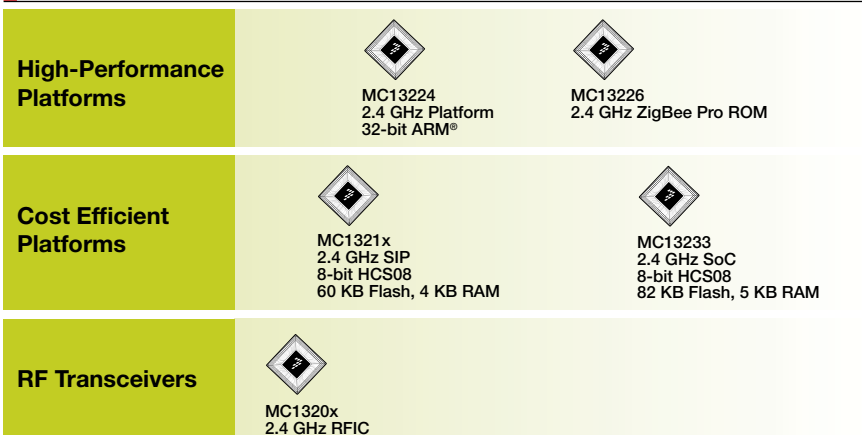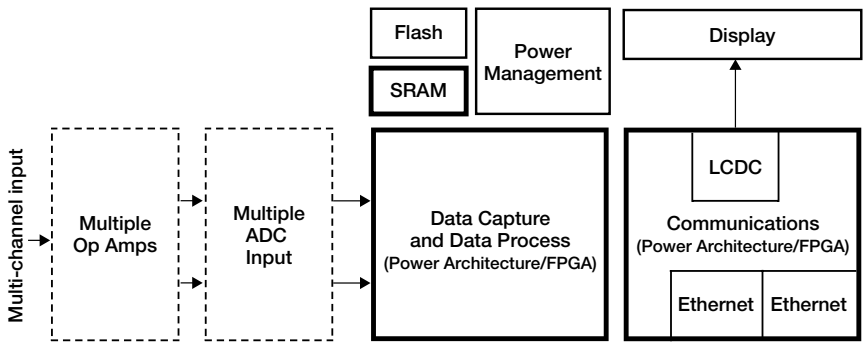
Figure 8: ZigBee® and Smart Energy

Figure 9: Power Breaker Controller Block

Security

With so many forms of communication, security of these communications and that of the grid is paramount. The PowerQUICC and QorIQ families support an expansive range of security protocols and functions for both private and public key cryptography to help ensure these links are protected from external attacks. For low data rate communication, AES and DES are commonly used. Since these are private key cryptography functions, extra care is needed to help to ensure system integrity. QorIQ MPUs provide secure on-board storage of the keys to provide enhanced security for local communication.

Grid Power Management and Protection

Electricity substations are under increasing pressure to provide functionality to actively manage the local grid. Deployment of new, high-performance power controller systems is now common across all regions as utility companies attempt to stay one step ahead of the technical challenges they face. Power relay controllers must manage surges and loading on the grid locally. Real-time control is essential to maintain grid integrity. This is accomplished using the IEEE® 1588 protocol, which is supported on many PowerQUICC and QorIQ families. A move toward cost-effective functional integration brings the focus toward multicore MPUs. Freescale's QorIQ families provide processors with up to eight cores. Today, dual core is adequate with products like the P1020 providing a cost effective, comprehensive range of fast serial communications and dual-core performance.

Adding power meter functions in the power breaker provides more information on grid performance and loading. MPUs run supervisory, control and data acquisition (SCADA) for substation control and must have fast response times for the management of transient events (such as surges).

Highly Efficient Power

Low power operation is also an important consideration for MPU choice. Fanless operation greatly improves overall system reliability as these units may be installed in remote substations and have a long maintenance cycle. Power Architecture products are highly efficient and many are designed for fanless operation delivering GHz class performance in under 3 Watts.

Conclusion

The need for more efficient use of energy has led to the growth of the smart grid. Companies and government are enabling this management through the deployment of devices designed to efficiently manage power in the home and on the grid network. With best-in-class development tools, an extended range of connectivity solutions and a broad partner ecosystem, Freescale offers the most appropriate solutions for smart homes.

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