ISSUE 3 | 2012

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ROBUST POWERLINE COMMUNICATION (PLC) DEVELOPMENT MADE EASY

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Powerline communications (PLC) is a global technology with worldwide interest in its development. The ability to modulate communication signals over existing powerlines enable devices to be networked without introducing any new wires or cables. This capability is extremely attractive across a diverse range of applications, including utility meters, home area networks, lighting and solar, which can leverage greater intelligence and efficiency through networking.

Powerline communication actually comprises several standards focusing on different performance factors and issues relating to particular applications and operating environments. In addition to PRIME, another popular standard is G3, which is managed by the G3 Alliance. Given the varied environments in which PLC can operate and the different kinds of interference present in them, the robustness of G3 (and its cousin IEEE P1901.2) to withstand noise often makes it a more compelling choice for worldwide deployment.

G3 operates over the CENELEC-A band (3-95 kHz) in Europe and can be extended across the full FCC band to provide a higher data rate in other countries. G3 is bi-directional with an effective data rate of 20-40 kbps in the CENELEC-A band and up to 200-400 kbps across the FCC band (G3-FCC). While use of the FCC band is prohibited in Europe, support for G3-FCC is anticipated to be quite useful in many other regions. It co-exists with S-FSK and other legacy PLC technologies and seamlessly supports DLMS/COSEM (IEC 62065 series) as well as offers layer 2 128-bit AES for CCM to provide extra data security. Support for IPv6 currently enables G3 to converge IPv4 and IPv6 devices and networks in an efficient manner.

G3 uses Orthogonal Frequency-Division Multiplexing (OFDM) modulation to provide high resiliency to interference and attenuation. As a result, it can achieve reliable communications up to 10 km while crossing between medium voltage transformers. The standard also enables communications over the low voltage and medium voltage (LV/MV) transformation crossing for a total distance up to 4-5 km, depending on the channel condition.

The ability to pass through a transformer is an important capability for G3, especially in rural areas where population density is low. Specifically in North America, the low voltage transformation between the house and utility may only extend 3 to 4 meters. Placing a concentrator before this transformer simply cannot achieve the necessary density to justify the cost of the concentrator. G3 was designed to address this issue by enabling PLC signals to pass through the low voltage transformer and out to the medium voltage line. This allows the concentrator to be placed in a location where it can aggregate data from substantially more locations, thus improving the cost-effectiveness of connecting the home/business with a utility.

In order to support increased data rates and coverage, G3-FCC utilizes the coherent modulation option. Effectively, when the channel can be reliably estimated through the use of pilots, performance can be improved over differential modulation. G3-FCC supports coherent demodulation for Robo-mode, BPSK, QPSK, 8PSK, and 16-QAM and provides up to 5 dB gain. Known challenges associated with coherent modulation include crystal oscillator drift and managing channel changes within an AC-cycle.

BEYOND G3

In searching for the most appropriate PLC technology, many countries – and in turn developers – are evaluating how well G3 serves under noisy operating conditions typical to the region. As an example, many cables in Korea are installed underground. The utility initially planned to use broadband PLC technology through these cables, but did not realize that reliability suffers when used underground. A narrowband implementation such as G3 is more suited to those operating conditions.

While a number of countries have already standardized on G3, notably France, some like Spain have chosen other technologies. The real battle of the standards, however, has just started. Countries such as China, Indonesia and Japan have yet to standardize on a particular flavor of PLC.

Developers building products that can support multiple standards will be in a position to better capitalize upon these emerging market opportunities, but few solutions exist to help developers create products for all major PLC standards. Texas Instruments introduced its PLC-Lite solution so developers could take advantage of its flexibility to optimize an implementation to specific channel characteristics. This method improves link robustness in environments where G3 and PRIME experience difficulty because interference on the line requires exceptional handling.

With a maximum data rate of 21 kbps PLC-Lite is designed to provide added robustness to certain types of interference, including narrowband interference that can affect G3 links. It contains a simple CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) MAC which can be integrated with any application specific stack. Because of its simplicity and lower data rate, it can be implemented at a substantially lower cost per link. PLC-Lite also offers tremendous flexibility and allows developers to customize channel links outside the constraints of an industry standard.

PLC-Lite is appropriate for very cost sensitive environments and applications where the complexities of G3 and PRIME are not required, but a robust communications channel is still needed. In the same way that a television remote does not need the full capabilities of Wi-Fi to change channels and adjust the volume, not every application needs the advanced functions and data rate of PRIME and G3. It is especially well-suited for devices beyond the power meter, including solar converters, home and industrial lighting, and network appliances.

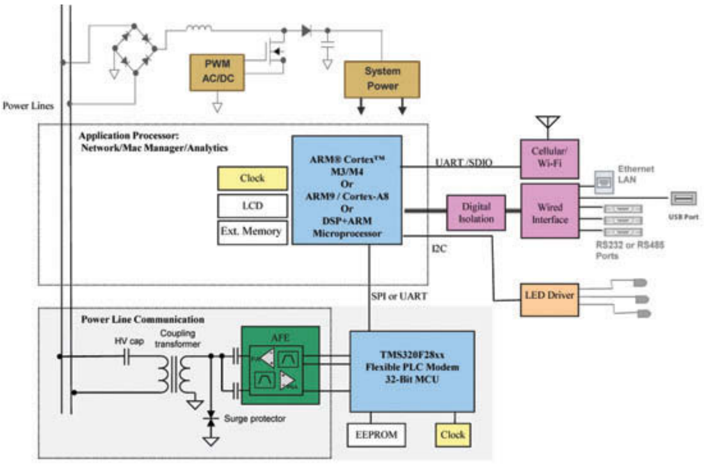

Figure 1 – Block diagram for a typical data concentrator solution

A single concentrator supporting both PLC-Lite and G3 could manage multiple nodes and send the consolidated data to a central aggregation point using G3 for maximum robustness. Finally, the central aggregator could bridge the G3-FCC network to the utility company's PRIME network.

In addition to considering the hardware required to process PLC signals, there is also an array of analog components that further improve robustness. Developers can include an analog front end (AFE) with an integrated power amplifier that provides superior performance and increases overall system reliability and range.

The purpose of an AFE is to interface between the digital signal processor and the AC mains or DC bus, providing both a transmit and receive signal path. The AFE receives digital inputs from an MCU, converts the digital inputs to an analog signal, filters them and provides a high voltage, high current output to drive into the low impedance bus. The receive side of an AFE consists of a low noise amplifier with programmable gain and filter. The filtered analog signal is then converted to a digital signal for further processing within the digital domain.

Discretely implemented AFEs can consist of over 100 passive and active components and challenge a solution provider to design a robust transmitter that will deliver the appropriate power level while meeting regulatory requirements with regards to conducted emissions. Another challenge for solution providers is the complex nature of the low noise receive signal path. The AFE031 from Texas Instruments solves solution providers' challenges for both the transmit and receive paths, shortens the design cycle and allows for a fully compliant PLC solution to be developed independently of the standard chosen (PRIME, G3 or PLC-Lite) or the type of signal modulation (SFSK or OFDM). Fully configurable through an SPI interface, the AFE031 can be configured to operate within the CENELEC A, B, C or D bands and also accept signals from either a PWM source or a digital stream. The integrated power amplifier can easily source or sink up to 1.5 A of current and when not transmitting, the AFE031 can be configured to consume only 14 mW in receive mode. The wide input range of 10 V_{PP} and low noise of the AFE031 receive amplifiers (14 μV_{RMS} typ in the CENELEC A band) allow for a wide dynamic range, exceeding 100 db. User configurable interrupts allow for short circuit and thermal overload detection and integrated temperature sensing diodes allow for accurate power amplifier temperature monitoring, providing additional system information. Housed in a thermally enhanced QFN package, the AFE031 power amplifier can dissipate over 2 W of power without requiring an external heatsink.

SMART GRID INFRASTRUCTURE

PLC technology has been widely implemented in e-metering and grid infrastructure equipments. For example, a data concentrator, at several points in the grid infrastructure, securely collects data from a manageable number of meters and sends it to the utility servers. Removing the need for additional wired or wireless networking to enable advanced metering infrastructure (AMI) and automatic meter reading (AMR) systems, PLC technology helps developers lower the cost of connecting the smart grid.

In a typical data concentrator system, a high performance microprocessor provides all physical layer (PHY) and lower MAC signal processing or a microcontroller is used to offer upper MAC and application functions. The block diagram in Figure 1 includes a Texas Instruments C2000™ microcontroller because the family of devices has maximum flexibility to support all PLC technologies.

Beyond the hardware considerations for PLC implementations, developers need to consider the software needs for their system. In addition to a full PLC software stack, developers can use a complete implementation of the IEC 62056 DLMS/COSEM protocol stack, which allows AMI/AMR vendors to jumpstart development of data concentrators and metering head end nodes and accelerates time-to-market. As an example, the IEC62056 DLMS/COSEM protocol stack from Aricent Group optimized on the TI Data Concentrator platform supports over 100 simultaneous connections for electric meters, water and gas metering.

There are many considerations when starting to develop a system with PLC capabilities. Developers need to decide which aspects of the technology are most important to them and whether their device is targeting a local or global implementation. With a fully programmable approach to PLC, Texas Instruments is uniquely positioned to provide the flexibility developers need to leverage a base PLC design across a range of applications, standards and markets. Texas Instruments is the global systems provider for innovative, secure, economical and future-proof solutions for the worldwide smart grid. TI offers the industry's broadest smart grid portfolio of metrology expertise, application processors, communication systems, wireless connectivity and analog components in readily available silicon, with advanced software, tools and support for compliant solutions in grid infrastructure, utility metering and home or building automation. MI

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