# SM2400

## N-PLC Transceiver
## Multi-Standard Narrowband Power Line Communications Modem

# PRODUCT BRIEF

## Overview

The SM2400 is the ultimate Narrowband Power Line Communication (N-PLC) modem that combines cost-effective design optimized for PLC applications with high level of programmability to address multitude of communications schemes and evolving standards. Extremely flexible the SM2400 system-on-chip (SoC) features a dual core architecture for dedicated PHY signal processing and MAC layer functionality to guarantee superior communication performance while maintaining very high levels of flexibility and programmability for OFDM based and other open standards and fully customized implementations. It contains a high-speed 256bit AES-CCM* engine to ensure standard compliance and secure communication, and all the necessary mixed signal components, such as A/D, D/A, OpAmp's, PGA to yield a cost-effective N-PLC system design for any IoT application.

## Features

- Dual core architecture with custom N-PLC optimized DSP and Data Link Layer 32-bit controller
  - Supports a multitude of communication schemes via firmware loads
- High performing custom DSP engine with embedded turnkey firmware featuring:
  - Configurable operational band within 10-500 kHz range compliant with CENELEC and FCC
  - OFDM and FSK modulations
  - PHY firmware options compliant with IEEE 1901.2, PRIME, G3-PLC, PLC4TRUCKS (SAE-J2497), ANSI-709.2 with alternative carriers
  - Proprietary extra-robust operation modes: XXR, Full Band
  - Selectable differential and coherent BPSK, QPSK, 8PSK and coherent 16QAM modulations
  - Configurable data rate up to (or over) 600 kbps depending on communication mode
  - Programmable frequency notching to improve coexistence
  - Jammer cancellation
  - Adaptive tone mapping (on-off sub-band bit loading)
  - FEC - Convolutional, Reed-Salomon and Viterbi decoding
  - CRC16
  - Carrier RSSI, SNR and LQI indicators for best channel adaptation and L2/L3 metrics

    - Zero-crossing detector
- Programmable 32bit RISC protocol engine featuring:
    - Data Link Layer firmware options compliant with IEEE 1901.2, G3-PLC, PRIME, IEC61334-4-32, PLC4TRUCKS (SAE-J2497) and others
    - IP adaptation layers - IPv4, 6LoWPAN
    - Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) channel access
    - Automatic Repeat Request (ARQ)
    - Meshing and self-discovery mechanisms
- CCM* with AES128 / AES256 encryption core
- On-chip Peripheral Interfaces:
    - SPI (slave) / UART host interface
    - Up to 2 additional SPI slaves for metering, wireless transceiver or other devices
    - SPI master for external flash
    - 5 GPIO's (additional GPIO's can be made available if other interfaces are unused)
    - Special purpose control signals: Data Rx LED (PHYLED), External AGC (RXRANGE1), External Power Amp. (TXEN), External AFE (AFEEN)
    - JTAG
- Seamless interface to an external line driver for optimal system performance:
    - Integrated A/D and D/A
    - Integrated OpAmp's for RX and TX
    - Integrated Programmable Gain Amplifier (PGA)
- Low power operation modes
    - Off-line mode
    - Listen mode
    - Receive mode
    - Transmit mode
- 3.3V (5V tolerant) digital I/O
- Receiver sensitivity of -80dBV
- -40 °C to +105 °C operating temperature range
- LQFP64 package

## Benefits

- Single-chip integrating Physical Layer (PHY) and Media Access Controller (MAC)
- Multitude of operation modes addressing all common standards including full compliance with IEEE 1901.2, G3-PLC, PRIME, PLC4TRUCKS (SAE-J2497), ANSI-709.1/ANSI-709.2 with alternative carriers
- Extremely robust proprietary modes of communication optimized for noisy power line environment
- High flexibility to address standard evolution, new standards and special proprietary modes
- Cost optimized system solution with integrated A/D, D/A, 2 OpAmp's, PGA
- Low power consumption

## Applications

- Smart grid communication
- Advanced Metering Infrastructure (AMI)
- Automated Meter Reading (AMR)
- Street lighting control and smart ballasts
- Solar and alternative energy management
- Smart home energy monitoring
- Factory and Building Automation (BA)
- Supervisory Control and Data Acquisition (SCADA)
- Tractor/Trailer communication
- Railroad and In-Train Communication

# 1 DESCRIPTION

The SM2400 is a highly programmable FSK and OFDM based N-PLC modem combining PHY and MAC with mixed signal components for optimal system cost and performance. The SM2400 combines the benefits of programmable architecture with power and cost efficiency by utilizing a DSP core configured specifically for N-PLC modulations and a dedicated 32bit core that runs protocols. With its high level of programmability, the SM2400 addresses multitude of communications schemes and can accommodate application specific communication schemes and evolving standards.

The SM2400 comes with a set of firmware options implementing IEEE 1901.2 compliant PHY and MAC layers, a 6LoWPAN data link layer as well as PRIME, G3-PLC, PLC4TRUCKS (SAE-J2497), ANSI 709.2 and other special modes tailored for Industrial IoT applications.

Proprietary and patented modes (XXR and XR modes) enable robust communication in harsh conditions for applications where standards compliance is not required. The SM2400 can achieve data rates of up to 600Kbps over 500KHz frequency band.

The SM2400 enables secure communication featuring a 256-bit AES encryption core with CCM* mode support. Integrated analog front end featuring ADC, DAC, gain control and two OpAmp's allows for a very efficient system design with a low cost BOM.

The SM2400 executes its firmware from internal memory. The code is loaded at the boot time. The SM2400 can boot either from an external SPI flash or from a host MCU, if such is present in the system, via UART or SPI, with the host MCU being the master.

For a definition of acronyms used throughout this document, refer to the glossary of terms at the back of this document.

# 2 TYPICAL APPLICATION DIAGRAM

Figure 1 shows a typical PLC communications module using the SM2400 device.

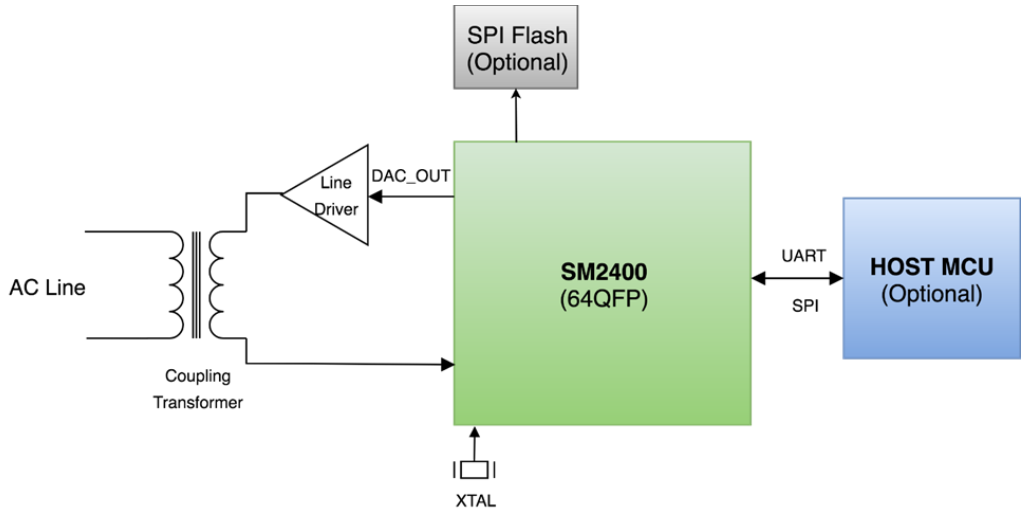


*Figure 1 - PLC Communications Module Using the SM2400*

# 3 SM2400 BLOCK DIAGRAM

Figure 2 shows a high-level block diagram of the SM2400 device.

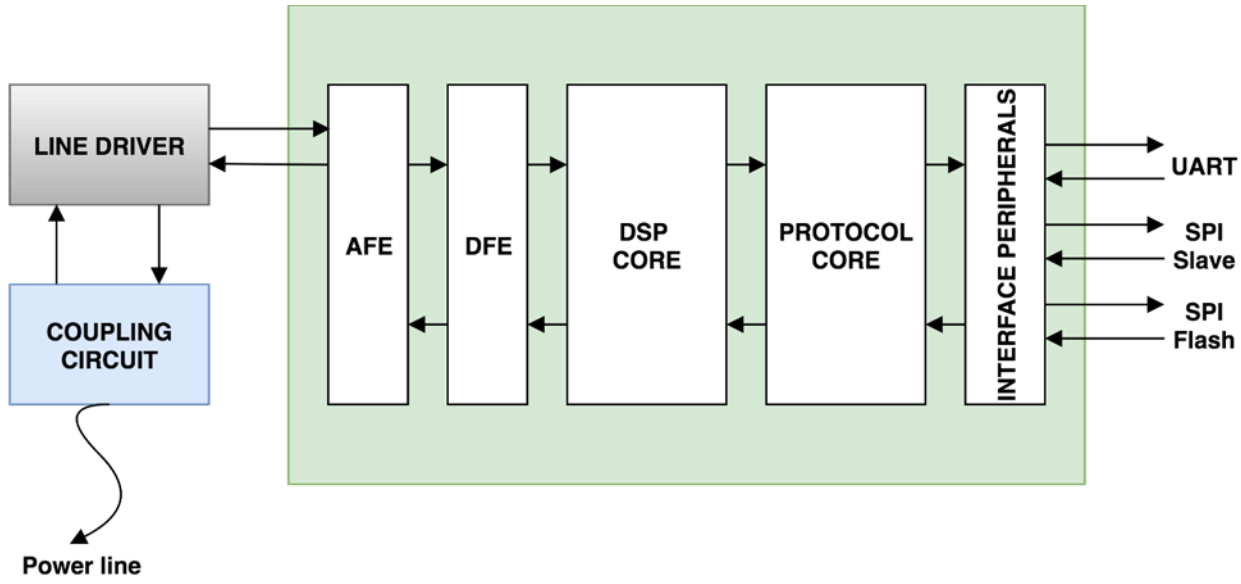


*Figure 2 -SM2400 Block Diagram*

## 3.1 ANALOG FRONT-END (AFE)

The SM2400 integrates an AFE optimized for N-PLC communication. It includes ADC, DAC, PGA and two OpAmp's to achieve the best signal power with minimum external BOM. External components include coupling circuitry and high voltage line driver that can vary for different applications and for different operational bands.

To enable most cost-effective system design, the SM2400 includes an internal voltage regulator. To achieve best power efficiency, external power regulation is recommended.

## 3.2 DIGITAL FRONT-END (DFE)

The SM2400 integrates a DFE which includes dedicated hardware accelerators such as Preamble Detector, Decimation and Interpolation Filtering, Tone cancellers and Zero Crossing Detector to provide performance and flexibility without compromising cost or power.

## 3.3 DSP CORE

The DSP Core implements the PHY function of the various PLC communication modes and standards. It is fully programmable and is designed specifically to accommodate a variety of OFDM based as well as FSK and other N-PLC PHY's to optimize performance and power consumption. The DSP Core is generally not available for customer programming. Some key functions implemented in the DSP core are listed below.

### 3.3.1 Selectable Modes and Modulations

By using different firmware images, the SM2400 can be configured to operate in one of several modes, such as: G3-PLC-FCC, G3-PLC-CENELEC A, PRIME, IEEE 1901.2, XXR, PLC4TRUCKS (SAE-J2497), ANSI-709.2, etc. Different

modes may imply different operational frequency bands (such as FCC, CEN-A/B/C) with a different number of carriers.

The SM2400 with its OFDM engine allows for configurable modulations per carrier. While in the case of standard based modes of operation (such as. G3-PLC-FCC) the configurations are implied by the standard, the SM2400 offers a number of proprietary modes tunes for best performance or specific application needs. As an example, XXR mode offers unique robustness in the presence noise with relatively low data rates 1-4kbps), while Full-Band PLC mode is similar to G3-PLC, but utilizes the entire 30-500kHz band to achieve much higher bit rates in similar channel conditions. ANSI-709.2 supports alternative carrier for CEN-A band ((carrier frequencies 86.207kHz or 131.579kHz).

In general, the following modulations are available: Differential and coherent BPSK, QPSK, 8PSK and coherent 16QAM. From time to time, additional modes are created depending on customer requirements.

Note that using different frequency bands (such as FCC or CENELEC) may require different passive components on the board.

### 3.3.2 Forward Error Correction (FEC)

The SM2400 supports a number of FEC schemes: Reed-Solomon (255,239) and (255,247); rate half Convolutional coding with constraint length 7 (generator polynomial is [133,171]). In G3 and IEEE 1901.2 modes Convolutional coding is concatenated with RS to achieve the best reliability. As with modulations, special FEC modes that include extra repetition coding for increased robustness and puncturing for increased data rate on capable channels are added from time to time based on customer requirements

### 3.3.3 Communication Medium Metrics

The SM2400 provides several metrics to assist L2 and L3 channel adaptation and routing. These metrics are: RSSI, SNR and LQI, which is a measure of the data rate. The RSSI is an estimate of received signal strength. Each packet received can be interrogated for its estimated signal strength. This is very useful to determine the signal to noise ratio of different nodes on the network. It may be that the noise in a particular band is low but the signal is also attenuated significantly making data transmission unreliable. Network management systems can also interrogate each node for signal to noise ratios to create a database of all transmission path conditions. This produces a deterministic way of finding where repeaters are needed in a difficult environment even if they are dynamic.

## 3.4 PROTOCOL CORE

The Protocol Core is designed to implement the MAC and routing functions of the various PLC protocols along with general control functions. It is based on a 32-bit RISC CPU with some customized hardware blocks (e.g., CRC accelerator). The Protocol Core includes dedicated Watchdog timer and high-performance program and data memory.

### 3.4.1 Security

The Protocol Core includes a dedicates Advanced Encryption Standard (AES) engine, which conforms to FIPS 197 standard. It is used for efficiently implement data encryption and authentication protocols. Key sizes of up to 256 bits are supported. The AES engine supports the following modes.

- Electronic Code Book (ECB) encryption

- Cipher Block Chaining (CBC) encryption
- AES Counter with CBC-MAC (CCM*) authenticated encryption
- Counter (CTR) encryption mode

### 3.5 Peripheral Interfaces

The SM2400 includes several peripheral interfaces for adding optional system components, such as host MCU, flash memory, telemetry devices, etc. Those interfaces include:

- UART – Serves as the main host interface
- SPI Slave – Connects to host MCU (alternative to UART)
- SPI Master – Flash and general purpose. Extends to two additional devices that can be used for telemetry or to interface to a wireless transceiver
- Special purpose control signals
- GPIO's
- JTAG

## 4 Boot Options

The SM2400 can be configured to boot in one of three ways using the 3-bit mode control bus.

Table 1 lists the possible boot mode configurations.

*Table 1 - Boot Mode Configurations*

| Boot Mode | MODE[2:0](1) | Description |
|---|---|---|
| SPI Master | 000 | Boot from SPI Master SSb0 (i.e., external SPI Flash) |
| CI SPI Slave | 001 | Bootloader over SPI interface allows directly download firmware (boot from HOST) or in-system programming of an attached SPI Flash. |
| CI UART | 010 | Bootloader over UART interface allows directly download firmware (boot from HOST) or in-system programming of an attached SPI Flash. |
| Reserved | 011 | Reserved |
| Reserved | 1xx | Reserved |

(1) It is recommended that the MODE[2:0] pins are pulled to the desired state via pull-up and/or pull-down resistors rather than tied directly to VDDIO or VSSIO.

## 5 Contact Information

For additional information regarding the SM2400 including technical data sheets, application notes, sample enquiries, demonstration modules, pricing and ordering, please contact:

**Semitech Semiconductor Pty. Ltd.**
http://www.semitechsemi.com

# 6 GLOSSARY OF TERMS

| Acronym | Definition | | Acronym | Definition |
|---|---|---|---|---|
| 16QAM | Quadrature Amplitude Modulation | | FSK | Frequency Shift Keying |
| 8PSK | High order PSK | | GPIO | General Purpose Input/Output |
| ADC | Analog to Digital Converter | | IEEE | Institute of Electrical and Electronics Engineers |
| AFE | Analog Front End | | IoT | Internet of Things |
| AES | Advanced Encryption Standard | | JTAG | Joint Test Action Group |
| AMI | Advanced Metering Infrastructure | | LPC | Low Pin Count |
| AMR | Automatic Meter Reading | | LQFP | Low Quad Flat Pack |
| ARIB | Association of Radio Industries and Businesses | | MAC | Media Access Controller |
| ARQ | Automatic Repeat-Request | | MCU | Microcontroller Unit |
| BA | Building Automation | | OFDM | Orthogonal Frequency-Division Multiplexing |
| BPSK | Binary Phase Shift Keying | | PGA | Programmable Gain Amplifier |
| CBC | Cipher Block Chaining | | PHY | Physical layer device |
| CCM | Counter with CBC MAC | | PLC | Power Line Communications |
| CENELEC | European Committee for Electro-technical Standardization | | PLL | Phase Locked Loop |
| CRC | Cyclic Redundancy Check | | QPSK | Quadrature Phase Shift Keying |
| CTIA | Cellular Telecommunications Industry Association | | RAM | Random Access Memory |
| CTR | Counter mode | | RISC | Reduced Instruction Set Computer |
| DAC | Digital to Analog Converter | | ROM | Read Only Memory |
| DFE | Digital Front End | | | |
| DSP | Digital Signal Processor | | RSSI | Received Signal Strength Indicator |
| ECB | Electronic Code Book | | SCADA | Supervisor Control and Data Acquisition |
| FCC | Federal Communications Commission | | SNR | Signal to Noise Ratio |
| FEC | Forward Error Correction | | SRAM | Synchronous Random Access Memory |
| FFT | Fast Fourier Transforms | | UART | Universal Asynchronous Receiver Transmitter |
| FIR | Finite Impulse Response | | XOR | Exclusive OR logical function |


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