Power Line Communication

Technical Implementation of Power Line Communication from Narrowband to Broadband

Texas Instruments

Your Presenter:

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Besides being monitored via Power Line Communication as an infant Christian looks into the Power Line Communications Market for Texas Instruments since 2007 observing trends and standards and trying to identify product fits or gaps in our portfolio.

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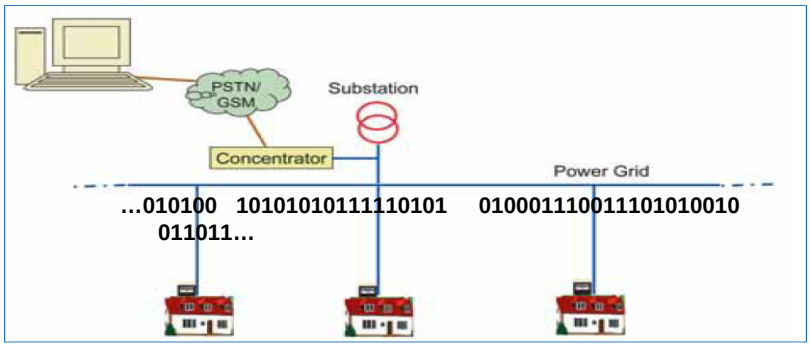
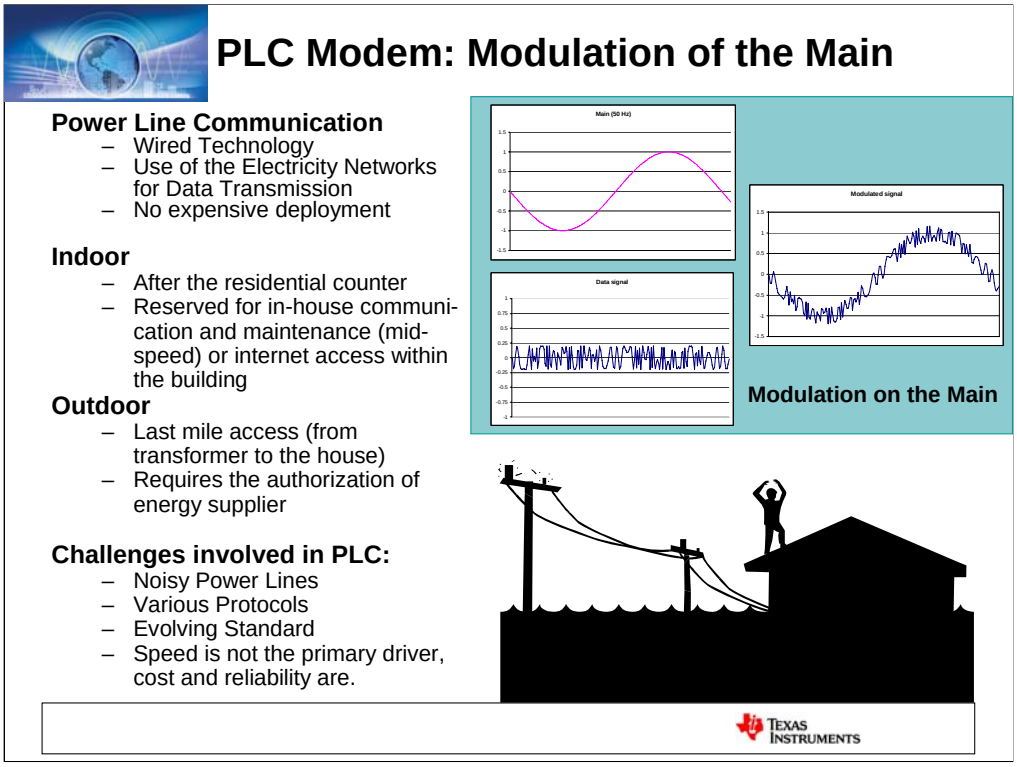
Our Agenda for today:

1. What is Power Line Communication?
   - Definition
   - History
   - Market
2. PLC Standard(s)
3. Focus Applications
   - Broadband
   - Narrow Band
4. Key Care Abouts & TI-based Solution
5. Q&A

What is Power-Line Communication?

- The carrier communicates the data by superimposing an analog signal over the standard 50/60 Hz AC current.
- Communication without any additional cables, wires or radio links!
- The 'mains' i.e. the power-line is used as the communication media.





The ‘mains’ i.e. the power-line is used as the communication media. The carrier communicate the data by superimposing an analog signal over the standard 50 Hz AC current. Communication without any additional and expensive cables, wires or radio links!

Use of an existing media

Ready to be used now

No expensive deployment

On April the 19th, Intel announced that they will integrate PLC technology in their chipset (based on Homeplug standard). Hence CPL and WIFI will allow connectivity in any configuration (resp. wired / non-wired)

View back on History

Power line communication (PLC), also called power line carrier, mains communication, power line telecom (PLT), or power line networking (PLN), are terms describing several different systems for using electric power lines to carry radio signals for communication purposes.

Narrowband power line communications started soon after the beginning of wide-spread electrical power supply. **Around the year 1922** the first carrier frequency systems began to operate over high-tension lines in the frequency range 15 to 500 kHz for telemetry purposes, and this continues to the present time. **Consumer products** such as baby alarms have been available at least **since 1940**.

View back on History

Sometimes PLC was and is used for transmitting **radio programs** over power lines or over telephone lines. Such devices were in use in Germany, where it was called "Drahtfunk" and in Switzerland, where it was called "Telefonrundspruch" and used telephone lines.

In the USSR PLC was very common for broadcasting, because PLC listeners cannot receive foreign transmissions. In Norway the radiation of PLC systems from power lines was sometimes used for radio supply. These facilities were called Linjesender. In all cases the radio program was fed by special transformers into the lines. In order to prevent uncontrolled propagation, filters for the carrier frequencies of the PLC systems were installed in substations and at line branches.

Side Track / Future of PLC?

Automotive:

Power-line technology enables **in-vehicle network communication** of Data, Voice, Music and Video signals by digital means over Direct Current (DC) battery power-line. Advanced digital communication techniques tailored to overcome hostile and noisy environment are implemented in a small size silicon device. One power line can be used for multiple independent networks.

Prototypes are successfully operational in vehicles, using automotive compatible pro-tocols such as CAN-bus, LIN-bus over power line (DC-LIN) and DC-bus. Automotive Applications include Mechatronics (e.g. Climate control, Door module, Immobilizer, Obstacle detector), Telematics and Multimedia.

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Home Control (Narrow Band)

Power line communications technology can use the household electrical power wiring as a transmission medium. **INSTEON** and **X10** are the two most popular, de facto standards utilizing power line communications for home control. This is a technique used in home automation for remote control of lighting and appliances without installation of additional control wiring.

Typically home-control power line communications devices operate by modulating in a carrier wave of between **20 and 200 kHz** into the household wiring at the transmitter. The carrier is modulated by digital signals. Each receiver in the system has an address and can be individually commanded by the signals transmitted over the household wiring and decoded at the receiver. These devices may either be plugged into regular power outlets or else permanently wired in place. Since the carrier signal may propagate to nearby homes (or apartments) on the same distribution system, these control schemes have a "house address" that designates the owner.

Home Networking (Broadband)

Power line communications technology can also be used to interconnect (network) home computers, peripherals or other networked consumer peripherals, although at present there is no universal standard for this type of application. Standards for power line home networking have been developed by a number of different companies within the framework of the HomePlug Powerline Alliance and the Universal Powerline Association.

Internet Access (Broadband over Powerlines, BPL)

Broadband over power lines (BPL), also known as powerline internet or Powerband, is the use of PLC technology to provide broadband Internet access through ordinary power lines. A computer (or any other device) would need only to plug a BPL "modem" into any outlet in an equipped building to have high-speed Internet access.

BPL seems, at first glance, to offer benefits relative to regular cable or DSL connections: the extensive infrastructure already available would appear to allow people in remote locations to have access to the Internet with relatively little equipment investment by the utility. Also, such ubiquitous availability would make it much easier for other electronics, such as televisions or sound systems, to hook up.

However, variations in the physical characteristics of the electricity network and the current lack of IEEE standards mean that provisioning of the service is far from being a standardized, repeatable process, and the amount of bandwidth a BPL system can provide compared to cable and wireless is in question. Some industry observers believe the prospect of BPL will motivate DSL and cable operators to more quickly serve rural communities.

Home Networking Solutions

Table 2: Technology by Home Networking Segment

Home Networking segments	Command and Control	Point to Point	Data Networking	Multi-Media Networking
	Best Effort	(no contention)	Best Effort-unmanaged	Managed QoS
Home Network Technology	<4kbps to 250Kbps	250Kbps to 4Mpbs	2Mpbs to 10Mbps	>50Mbps
802.11a,b,g	E	M	M	NA
802.11n	E	E	M	L
UWB	M	M	NA	NA
Zigbee	M	NA	NA	NA
Power Line	E	E	E	M
Coax	E	E	E	E
Phone line	E	E	E	M
Cat. 5, fiber, (Ethernet)	E	E	E	E

NA: Not applicable

L: Limited set of requirements

M: Meets requirements

E: Exceeds requirements

Source: ISuppli Corp. | November 2008

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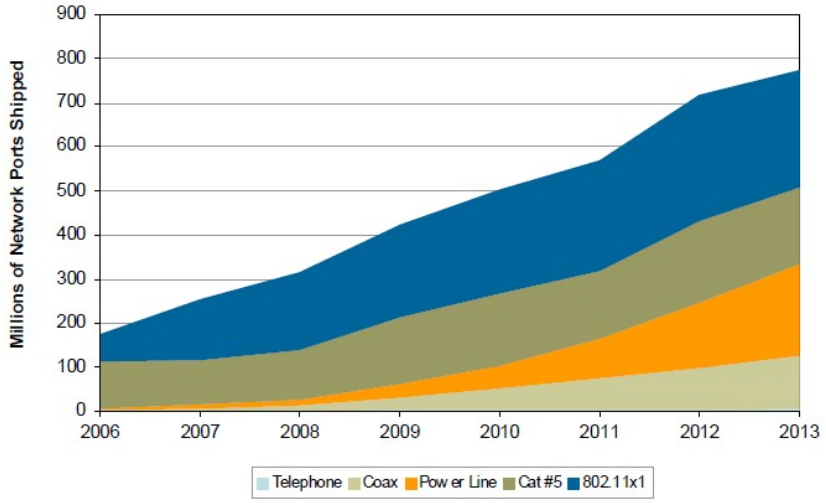
Home Networking Market

Figure 4: Wi-Fi Growth vs. Wired-based Growth of Home Networking Ports 2006-2013



Source: iSuppli Corp. | November 2008

Power Line Communication: Standards

- Narrow Band
- Broadband

Smart Grid Developments

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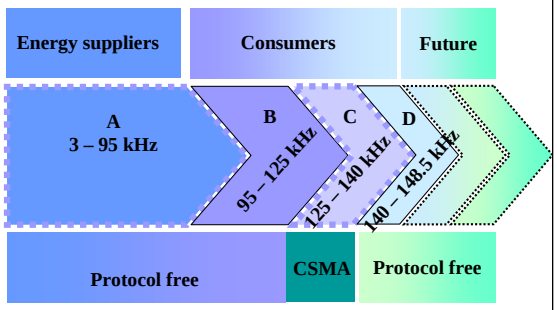
Initial Standards
(as identified April 28/29, 2009)

Standard	Application
AMI-SEC System Security Requirements	Advanced metering infrastructure (AMI) and Smart Grid end-to-end security
ANSI C12.19/MC1219	Revenue metering information model
BACnet ANSI ASHRAE 135-2008/ISO 16484-5	Building automation
DNP3	Substation and feeder device automation
IEC 60870-6 / TASE.2	Inter-control center communications
IEC 61850	Substation automation and protection
IEC 61968/61970	Application level energy management system interfaces
IEC 62351 Parts 1-8	Information security for power system control operations
IEEE C37.118	Phasor measurement unit (PMU)communications
IEEE 1547	Physical and electrical interconnections between utility and distributed generation (DG)
IEEE 1686-2007	Security for intelligent electronic devices (IEDs)
NERC CIP 002-009	Cyber security standards for the bulk power system
..NIST Special Publication (SP) 800-53, NIST SP 800-82	Cyber security standards and guidelines for federal information systems, including those for the bulk power system
Open Automated Demand Response (Open ADR)	Price responsive and direct load control
OpenHAN	Home Area Network device communication, measurement, and control
ZigBee/HomePlug Smart Energy Profile	Home Area Network (HAN) Device Communications and Information Model

Multiple Frequencies Band Requesting Flexibility

- **Frequency bands for PLC in Europe**
  - defined by the CENELEC:
  - The range of 3 kHz – 9 kHz and band A are exclusively for energy providers.
  - Bands B, C, D are open for end-user applications.
  - Bands A, B and D are protocol free
  - Band C is regulated – CSMA access
- **Frequency bands for PLC in USA**
  - Single wide band – from 150 to 450 kHz
  - No access protocol
  - FFC band 10kHz – 490kHz
- **Frequency bands for PLC in Japan**
  - ARIB band 10kHz – 450kHz



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CENELEC: **European Committee for Electrotechnical Standardization - Comité Européen de Normalisation Electrotechnique**. www.cenelec.org

CSMA = Carrier Sense Multiple Access.

The devices connected to the main access to the communication line one after the other without rule.Any node can try to access during a silent slot.It is random access based so that the communication attempts are spread over time after a frame.

CSMA steht für: Carrier Sense Multiple Access

PLC PHY Standards Overview

Standard	Tech-nology	Band Occupied	Data Rate range	FEC type	Benefits	Challenges
PRIME	OFDM	42-90 kHz	21-128 kbps	64-state conv code	Targets high data rates	Tree MAC structure may not work for indoor lighting applications
EDF G3	OFDM	35-90 kHz	2.4-34 kbps	Concatenated code Reed Solomon code + 64-state conv code + repetition if reqd	Implementation similar to PRIME	Robust for low data rates
Homeplug SE highband	OFDM	2-30 MHz	3.8 Mbps	Only the mini-ROBO mode in Homeplug AV	Can support very high data rates > Mbps	DSP based implementation not possible, need dedicated h/w
Homeplug SE lowband	OFDM	120-380 kHz	12-350kbps	Turbo code (May change to concatenated code)	Maximum data rate is low (compared to HPSE high band)	High band implementation mandatory for HomePlug compliance
Plan FSK	FSK	60-76 kHz	1.2-2.4kbps	None	Deployed in France for e-metering market. easy to implement, estimating 10-15 MIPS	
HP C&C	DCSK	3-95 kHz, 95-125 kHz, 120-400 kHz	0.625-7.5 kbps	Block coding		IPR issues with Yitran Spectrally inefficient – broad analog for low datarate
Echelon	NRZ-BPSK	131.579 kHz	5.48245 kbps	1 bit parity encoding	Well-established for lighting applications	IPR issues

- PRIME designed for low voltage lines with low noise → targets higher data rates, less robustness
- G3 designed for medium voltage lines → lower data rates, more robust compared to PRIME
- Homeplug Smart Energy still being standardized
  - Highband is mandatory, based on Homeplug AV
  - Lowband mode is optional, similar to Homeplug AV but with smaller bandwidth
- DCSK for command and control

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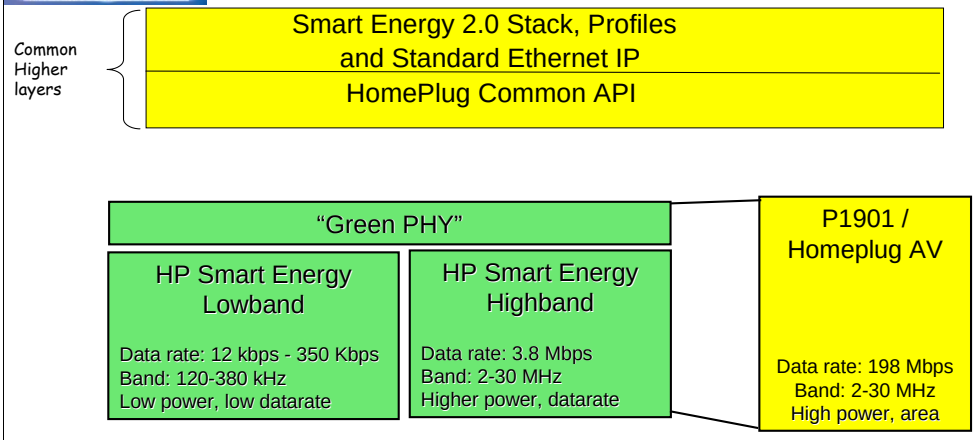
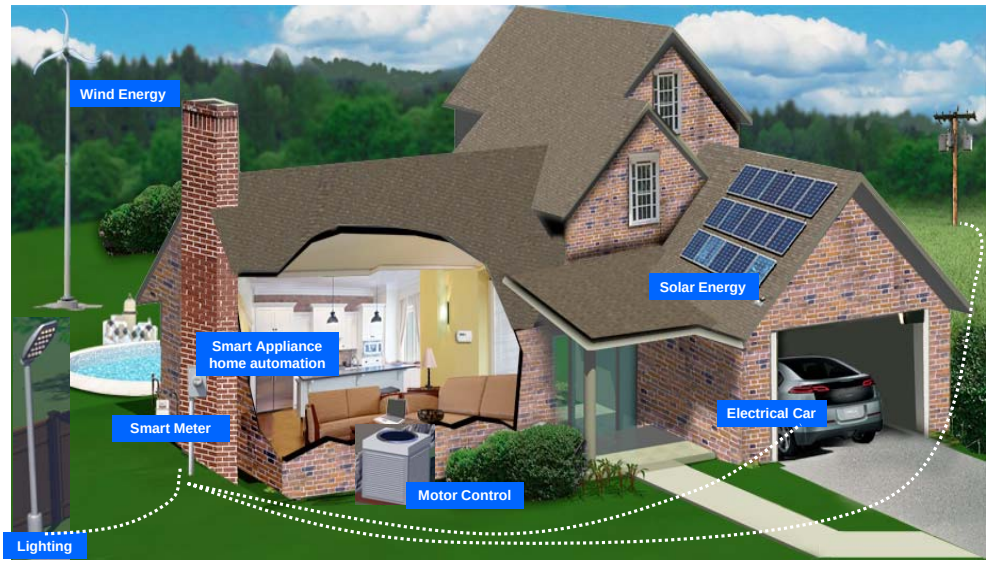
Homeplug Smart Energy



- **MRD approved - Q2 2009, Specifications target – Q4 2009**
- **Homeplug SE high band is mandatory, interoperates with Homeplug AV and P1901**
- **Homeplug SE low band optional, enables low power operation**

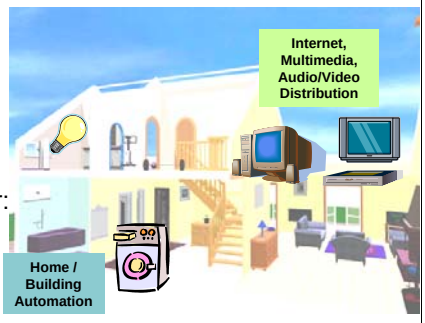
Power Line Communication: Applications

Applications



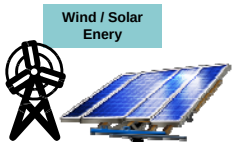
PLC Modem Applications

- **Indoor Applications:**
  - Home Automation
  - Home Networking
  - Building Automation
  - Heating and Air Conditioning
  - Light Fixture Control
  - Room Scenario Programming and Security
  - Remote Monitoring of devices using AC power:
    - Refrigerator, Thermostat, Smoke Detector



- **Outdoor/Industrial Applications:**
  - Street Lighting Control
  - Remote Data Collection from Electricity Meter
  - Remote Power Station Monitoring

- **Automotive**



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Power Line Communication: TI-based Solutions

Multiple PLC Standards requesting Flexibility

32-bit MCU focuses on narrowband (kilo bit per second kbps range)

- **Low Speed (bps)**
  - **TurtleTech/TWACS**
    - **<10 Hz modulation, freq division multiplexing, ~3bits/hour data rate.**
    - **Utility automatic meter reading. Very long reach.**
  - **X-10**
    - **Modulate at 120 kHz for 1 msec at 60 Hz zero-cross**
    - **Aimed at home automation, 120 b/sec.**
  - **Universal Power-Line Bus (UPB)**
    - **Pulse position modulation on each half sine wave**
    - **Aimed at home automation, 240 b/sec**
- **Mid Speed (kbps)** ***32-bit MCU Focus***
  - **FSK (ST7537/ST7538)**
  - **Konnex (KNX)**
  - **SFSK**
  - **iTRAN 800 (CENELEC)**
  - **CEA-709.2 (Echelon/LonWorks)**
  - **EIA-600 (CEBus/Intellon)**
  - **iTRAN 800 (US FCC)**
  - **OFDM (IEC 61000-3)**

Implemented

- **High Speed (Mbps)**
  - **Home-Plug**
    - **Broadband over power lines, 1.8 Mb/s**
    - **OFDM modulation. Subcarrier frequencies from 4.5 to 20.7 MHz**
  - **DS2**

Addressable by
TI F28x™ 32-bit MCU
Software flexible solution

Targeted Application:

- ***Home automation***
- ***Smart appliance***
- ***Control Systems***
- ***Electricity meter***
- ***Lighting***
- ***Solar***
- ***Drives***

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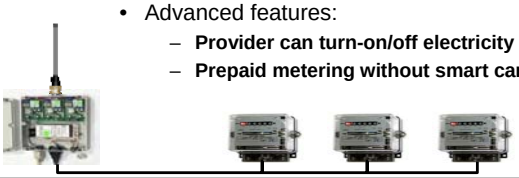
PLC Narrowband applications

- **Inhouse Communication:**
  - Smart home appliances: monitoring, energy management,…
- **Outdoor**
  - Urban facilities:
    - Lighting/streetlighting and ballast system
    - Traffic light
  - Industrial:
    - Solar field
    - Drives..
  - Automatic Meter Management (AMM):
    - Automatic Meter Read
    - Advanced features:
      - **Provider can turn-on/off electricity supply / monitoring.**
      - **Prepaid metering without smart cards**



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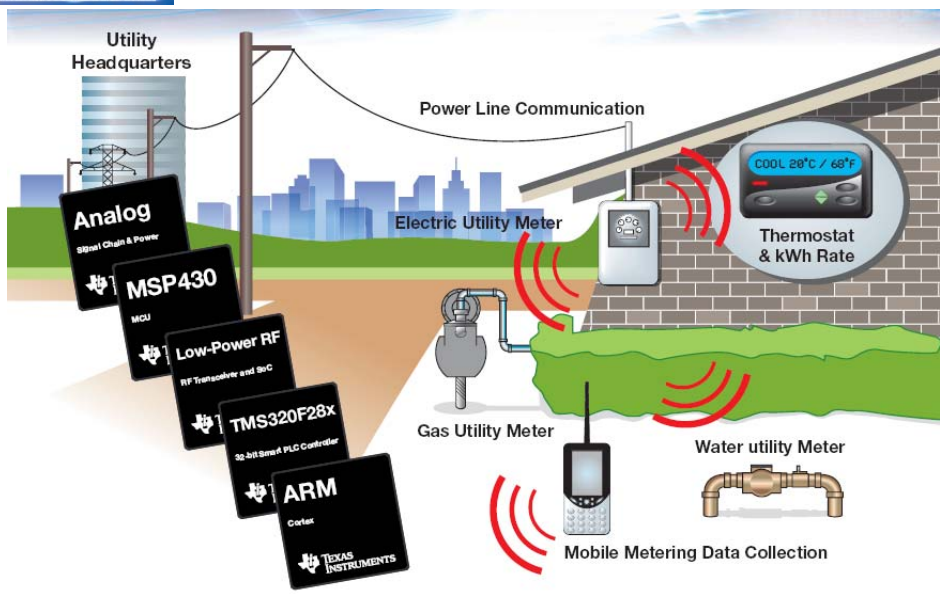
TI Offer contains all ingredients for Optimized PLC Modem solutions



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Some TI Technologies for PLC Modem related applications

Microcontrollers

16-bit

MSP430

Ultra-low Power

Up to 25MHz

Flash 1KB to 256KB

RTC, ADC, MPY, USART

Measurement Metrology MCU

ARM 32-bit

Stellaris M3

Industry Std Low Power

< 100 MHz

Flash 64KB to 256kB

USB (H/D/OTG), ENET(PHY, 1588), ADC, PWM, QVGA

Electricity CPU Communication

32-bit Real-time

C2000

Power Line Communication

Protocol Stack & Modem

Embedded Flash f. upgrade

Appropriate peripherals

Multi- Modulation

SFSK-OFDM, etc

+ Application

Memory

FeRAM

FR

Replace Flash & SRAM

Ultra Low Power

Faster writes than Flash

Smaller size than SRAM

Good fit with MSP430

Complementary Analog

Low-Power RF

CC

RF SoC Transceiver

433 to 2500 Mhz

Flash for SoC

Appropriate peripherals

Mesh-RF Zigbee, WM-Bus

Analog

OPA, THS, ADC

Amp, LD, PGA ADC, DAC

Full range

Various Technologies

Measurement PLC

Saving Power

TPS, UCC

AC/DC, DC/DC, LDO

Full range

Ultra Low-Power High Efficiency

Metering Saving Power

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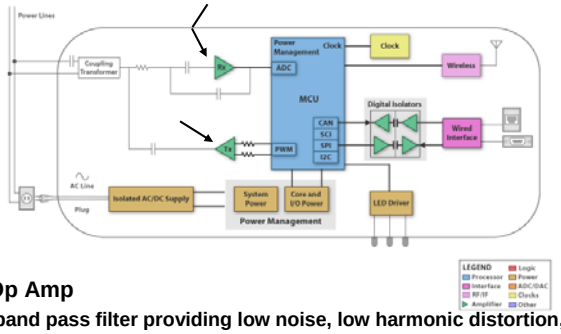
TI-PLC Solution

Receive and Transmit stage



Receive Stage Op Amp

- **TL074 - Active band pass filter providing low noise, low harmonic distortion, low input bias**
- **OPA564 - High current amplifier 1.5A into reactive loads, wide Vin**

Power line/DSL Transmit Line Drivers

- **OPA2673, OPA2674 - Dual, Wideband, High Output Current Operational Amplifiers**
- **OPA561 - High Current Op amp**
- **THS6043, THS6093 - ADSL CPE Line Drivers with Shutdown**

- **Microcontroller**
  The signal converts to a digital form for processing at the Piccolo™ microcontroller which comes in 2 variants:

➢ **TMS320F28023, F28027**

Piccolo A group of devices support BPSK or SFSK or OFDM modulation schemes

➢ **TMS320F28033, F28035**

Piccolo B group of devices support BPSK, SFSK, OFDM schemes on the same device (Samples available)

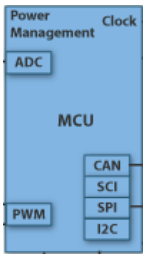
Features:

- High Performance CPU

- upto 60 MHz performance

- single cycle 32 bit MAC

- fast interrupt response and minimal latency



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Control Law Accelerator

- 32-bit floating point math accelerator that operates independent of the CPU
- Frees main CPU to handle I/O and feedback loop metrics
- Hence 5x increased performance for common control loop applications

Intelligent architecture and peripherals

- 150-picosecond resolution on PWM frequency and duty cycle
- High-accuracy on-chip oscillators (10MHz)
- 12-bit ratio-metric ADC with individual channel triggers
- Two analog comparators with 10-bit reference
- Single 3.3V supply with BOR/POR supervision
- Serial communication interfaces
- Up to 22 general purpose I/Os

Single Chip programmable and flexible **Solution** that supports the PHY, MAC and Application Layers

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Output Stage:

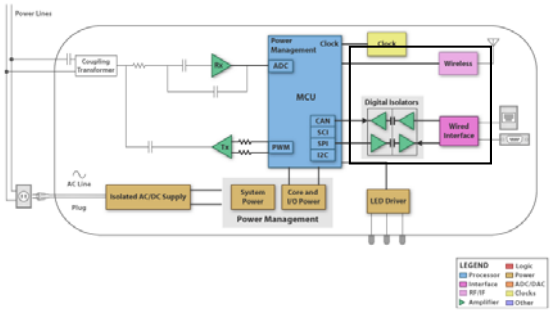
Processed signals directly communicate with outside systems via Piccolo's serial interfaces: CAN, I2C, LIN, SPI, SCI

Isolation

- ISO7221 Dual Channel Digital Isolator
- ISO7241 Quad Channel Digital Isolator with 4kV ESD protection/ isolation

Interfaces

- Wireless Interface
  - 2.4GHz
  - Sub 1 GHz
  - ZigBee
- Wired Interface
  - RS232
  - RS485
  - I2C
  - CAN



Power Management

Isolated AC/DC Power Supply

PWM Power supply Controller, Voltage reference, Power factor correction ICs

System Power

Wide input range non-synchronous buck DC/DC Controller, Single channel LDO

Core & I/O Power

Single and Dual channel LDOs respectively

Status LEDs

3 or 4 LEDs to blink for Power, Ports I/O or Receive/Transmit, Activity and/or Fault, Customer defined function (as necessary)

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Key Care Abouts

✓ Scalability	Solutions based on a single PLC stack (s/w) and module (h/w) with enough resources to support application/network layers.
✓ Flexibility & Upgradeability	To any of the new and evolving standards
✓ Interoperability	New terminals may need to be added to existing network or existing solutions may need to be replaced.
✓Solution Cost	Integration and Single Chip solution

TI's Piccolo based Solution Benefits:

- Complete solution with 3 main parts- MCU + Line Driver + Amplifier
- All signal processing done by a single DSP
- BPSK, SFSK, OFDM modulation schemes supported
- Scalability, flexibility, upgradeability and interoperability
- Other functions like PFC, motor control, inverter and monitoring can be integrated on same DSP

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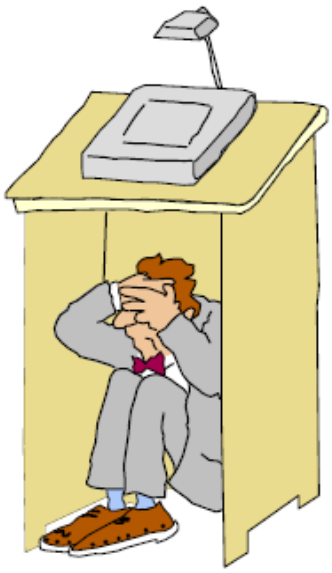
Conclusions

- TI is investing in PLC solution for metering market
- Broad portfolio of Analog and Digital components enabling smart and flexible PLC communication
- TI works closely with associations involved in current industry standardization to develop and promote PLC solutions

Questions?



Thank you for attending:

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Technical Implementation of Power Line Communication from Narrowband to Broadband

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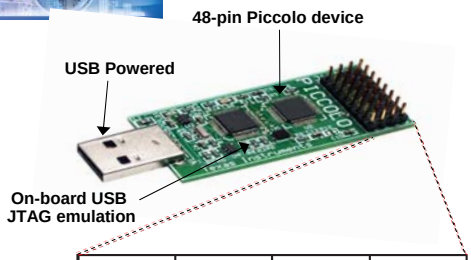
Getting Started on F28x platform

$39 Piccolo MCU controlSTICK



1 ADC-A7	2 ADC-A2 COMP1 (+VE)	3 ADC-A0 Vref-HI	4 3V3
5 ADC-A4 COMP2 (+VE)	6 ADC-B1	7 EPWM-4B GPIO-07	8 TZ1 GPIO-12
9 SCL GPIO-33	10 AUC-B6	11 EPWM-4A GPIO-06	12 AUC-A1
13 SDA GPIO-32	14 ADC-B7	15 EPWM-3B GPIO-05	16 5VD
17 EPWM-1A GPIO-00	18 ADC-B4 COMP2 (-VE)	19 EPWM-3A GPIO-04	20 SPISOMI GPIO-17
21 EPWM 1B GPIO-01	22 ADC B3	23 EPWM 2B GPIO-03	24 SPISIMO GPIO-16
25 SPISTE GPIO-19	26 ADC-B2 COMP1 (-VE)	27 EPWM-2A GPIO-02	28 GND
29 SPICLK GPIO-18	30 GPIO-34 (LED)	31 PWM1A-DAC (Filtered)	32 GND

Access to all Piccolo control peripherals through header pins

Allows designers to evaluate Piccolo MCUs quickly, easily and for only $39

Kit Includes:

- **Piccolo™ controlSTICK USB evaluation tool**
- **USB extension cable**
- **Jumpers and patch cords necessary for example projects**
- **Full version of Code Composer Studio with 32kB code size limit**
- **Example projects showcasing Piccolo MCU features**
- **Full hardware documentation, including bill of materials, schematics and Gerber files**

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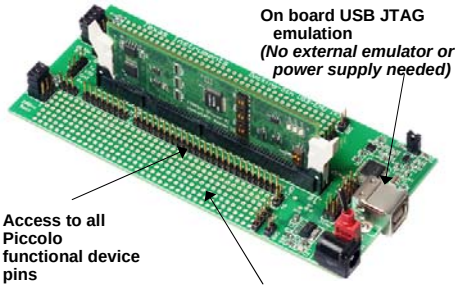
39

$79 USB Experimenter's Kit

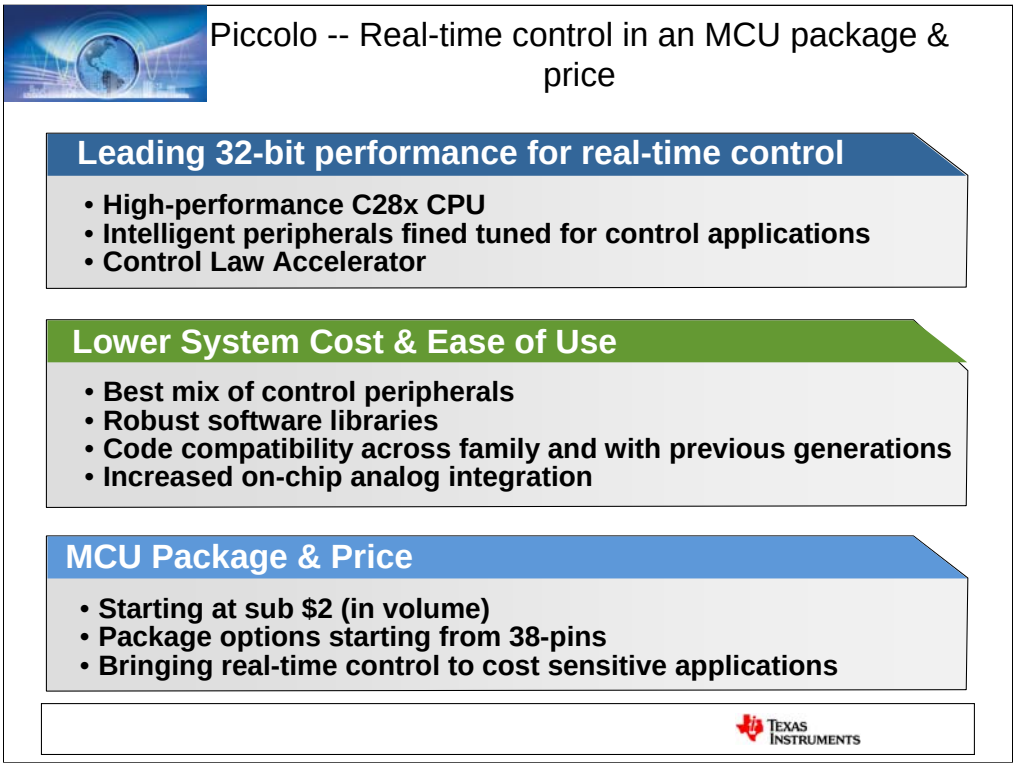
Standard controlCARD pinout; compatible with all other C2000 controlCARDs.



Robust development tool starts at $79, helps developers launch Piccolo MCU-based designs quickly and easily

Kit Includes:

- Piccolo™ controlCARD
- Docking station with onboard USB JTAG emulation
- Access to all controlCARD pins and prototyping area
- Full version of Code Composer Studio with 32kB code size limit
- Full hardware documentation, including bill of materials, schematics and Gerber files
- controlCARD also sold separately ($49)



On-chip peripherals offer lower system cost

Same high-perf core, throttled performance, same efficiency, code compatible, math algorithms
(Alex will provide benchmarks for the core and core + CLA)

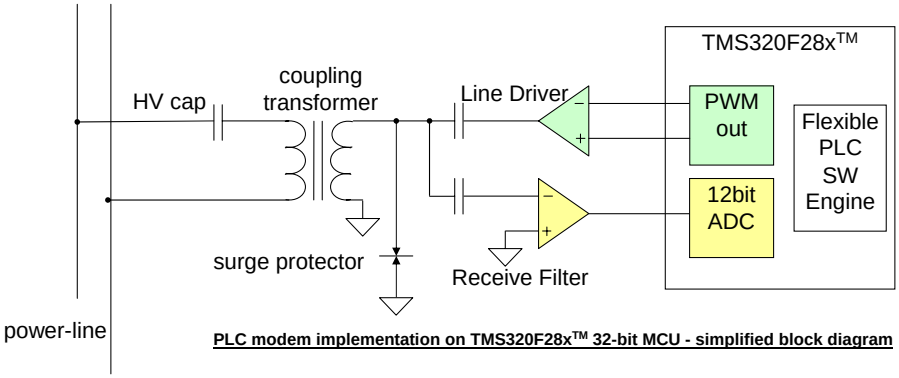
PWM ease of use example

(ADC, Sampling and conversion time, PWM, duty cycle and period)

CPU benchmarks for control/math algorithms

F28x™ 32-bit MCU PLC Modem solution

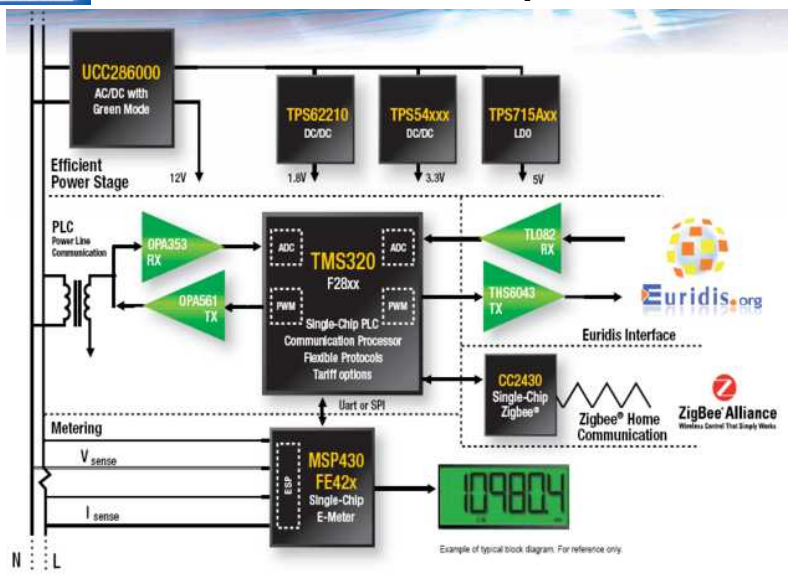
SW flexible implementation - *application integration*



PLC modem implementation on TMS320F28x™ 32-bit MCU - simplified block diagram

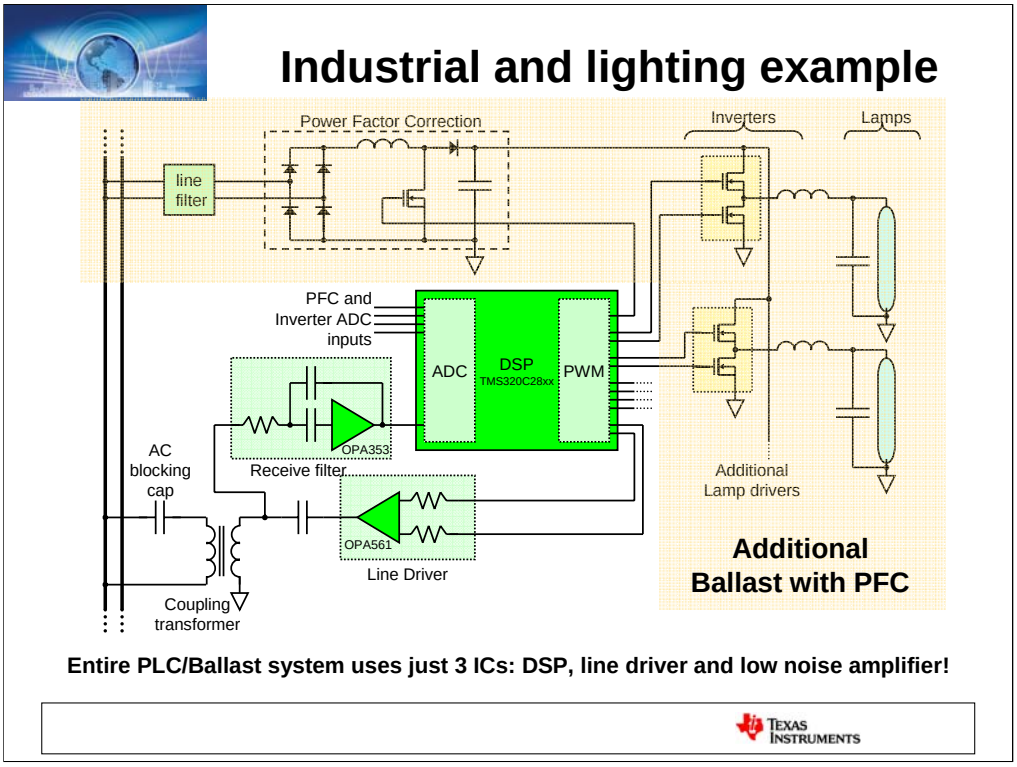
- **Ready and flexible for future standards:**
  - Resources left for evolving, more demanding modulation schemes.
  - New code = new standard with the same hardware!
- **Additional functions can be implemented in same processor:**
  - PFC, solar, lighting, power monitoring, inverters, motor control,…

Metering: 1-phase Electricity meter example



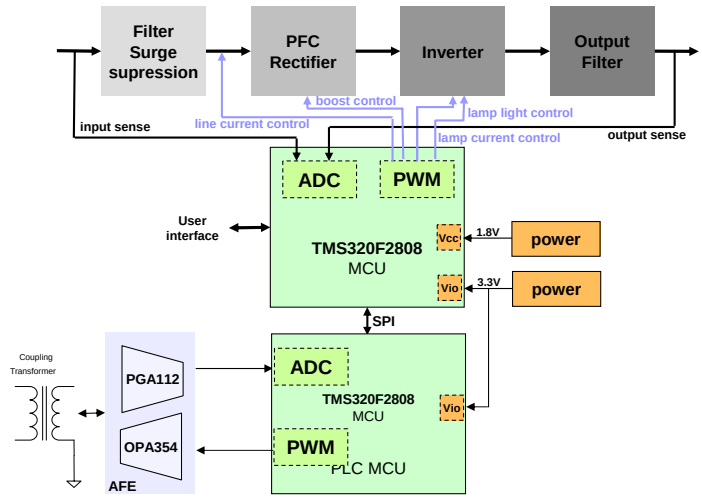
one-phase smart e-meter

- **metrology**
- **PLC communication**
- **Zigbee**
- **possible other functions (field bus/Euridis…)**



The diagram shows a C2x based PL-modem with PFC and inverters which control lamps – this all is done with only one DSP!

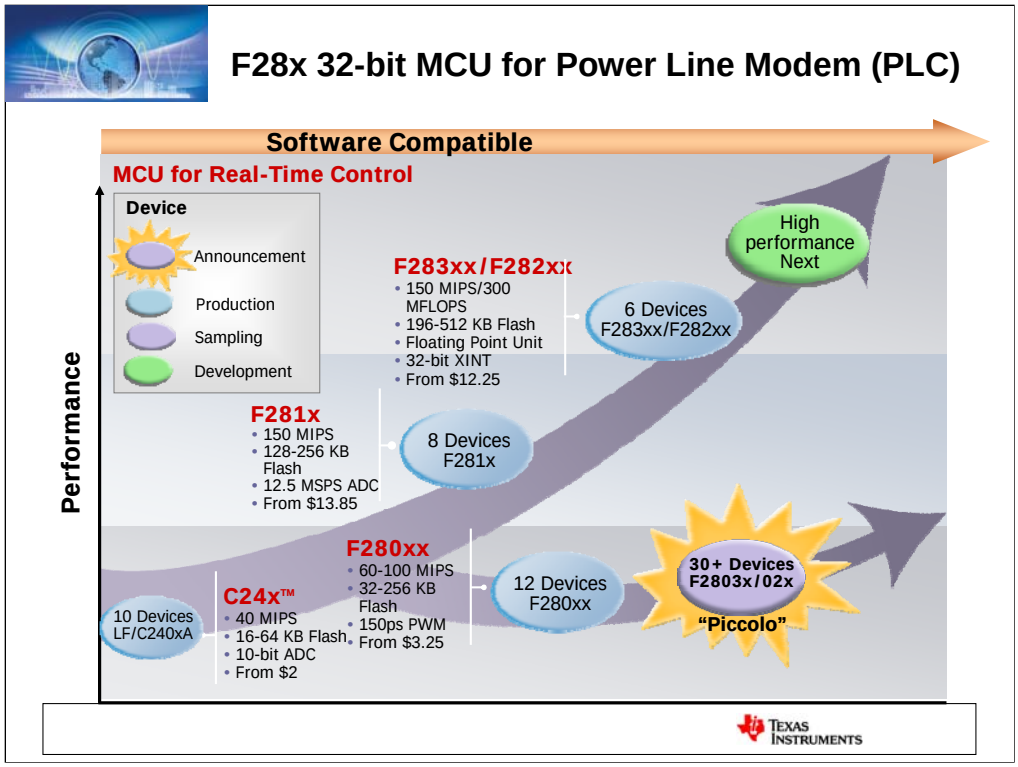
PLC modem example in Lighting



TMS320F28x™ 32-bit MCU

- **Single chip programmable and flexible solution that supports:**
  - **PHY layer**
  - **MAC layer**
  - **Application layers**
  - **Security (Data : encryption, IP : flash protection)**
  - **Same H/W platform for low-cost S-FSK to OFDM migration path**
- **Flexible software programmable solution:**
  - **Multi protocol support**
  - **Field update options**
  - **Support standards evolution**
- **Easy interfacing with Metrology and wireless bus**

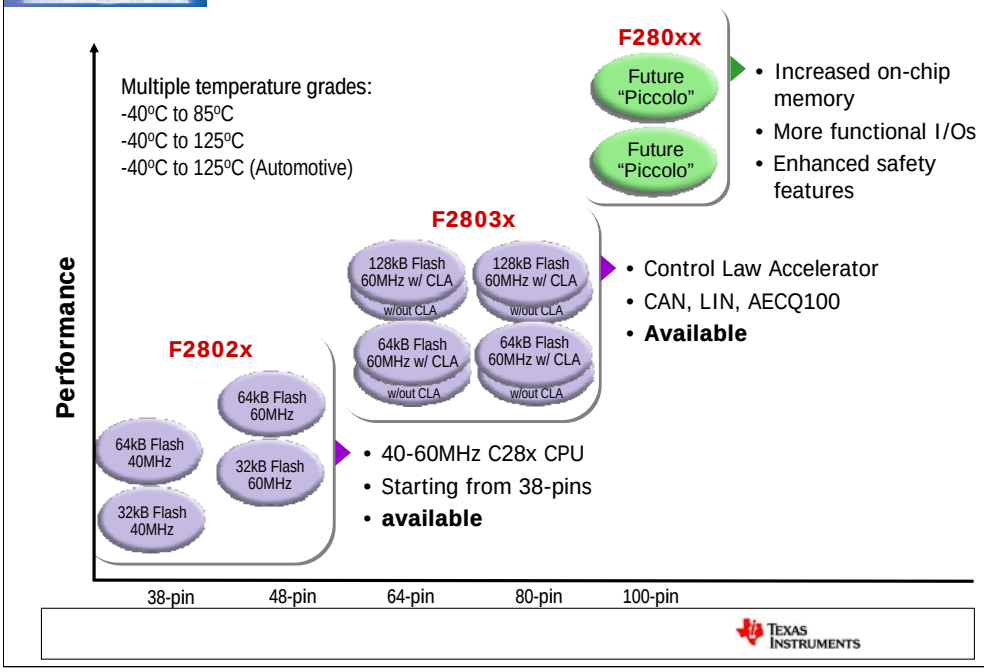
Texas Instruments



C2000 has been the leading performance in the real-time control space. Now the Piccolo famliy helps us address a gap in the portfolio specifically targeting the cost sensitive real-time control applications.

We are significantly investing in the area – with the addition of over 30+ devices with future additions planned.

More than 30 new scalable F280xx MCU solutions



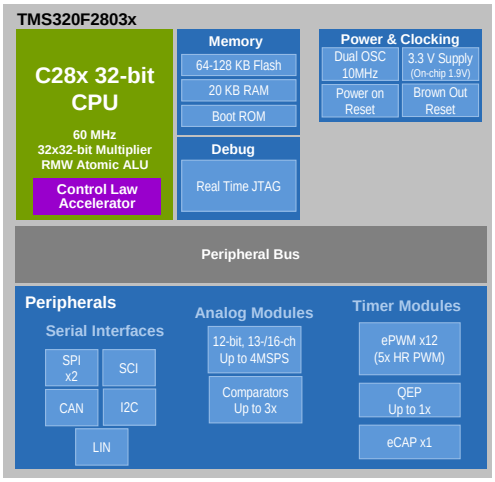
TMS320F28x™ 32-bit MCU Family key benefits for PLC

PERFORMANCE
- up to 150 MHz CPU
- new HW Control Law Accelerator on Piccolo
  - 120 MIPS equivalent performance
  - OFDM reduced power consumption (400mW)
  - Data security flexibility
  - Multi-protocol support

FLEXIBILITY
- SW compatibility across all F280xx
  - Easy migration across device family
  - leverage investments
- Interoperability via SW

INTEGRATION
- 12-bit ratio-metric ADC with individual channel triggers
  - more accurate resolution - limit drift errors
- 3 Analog comparators with 10-bit reference
  - zero crossing detection/synchronization
- Dual On-chip oscillators
  - intelligent clocking system monitoring
- On-chip Flash up to 512kB

COST OPTIMIZATION
- Single 3.3V supply available in the family
  - Cost and board space saving
  - Save 1.8V power and SVS
- Multiple package options down to 32-pin
  - board space saving

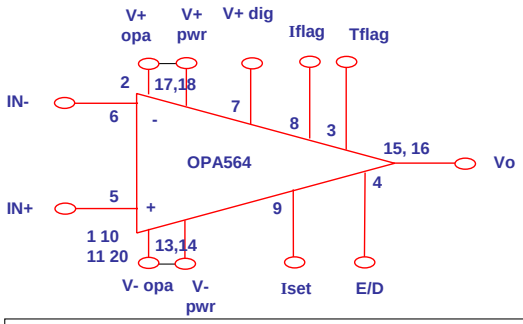


Piccolo device block diagram example

Analog Front End - *Transmission*
Rx - OPA564 – Line Driver
1.5A, 26V, 4MHz Power Op Amp

Features

- Single or Dual Supply: ±3.5V(7V) to ± 13V(26V)
- Large Output Swing: 22Vpp@ 1.5A (24V supply)
- Thermal and over-current warning
- Adjustable current limit
- Output Enable/Disable Control
- 20V/µs slew rate



Benefits

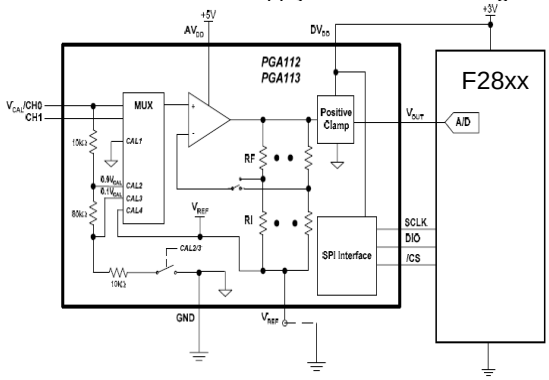
- Enables design flexibility
- Desirable for demanding applications
- Protects in over-temp and over-current conditions
- Provides accurate, user selected, current limit
- Saves power and protects the load
- Allows 230kHz full-power bandwidth and excellent linearity

Texas Instruments

Analog Front End - *Reception*
Tx - PGA112 – Programmable Gain Amplifier
RRIO, Single Supply, Single Ended, PGA w/2 ch Mux

Features

- •Zero Drift and RRIO
- • Binary gain : 1, 2, 4, 8, 16, 32, 64, 128
- • 4 internal calibration channels
- • Software shutdown (Iq < 4µA)
- • AVDD and DVDD supply in 2.2V to 5.5V range
- •VCLAMP pin to clamp output
- • Low noise, low Ib, low offset, low Iq
- •Extended -40°C to +125°C Temp Range
- • 10-MSOP Package w/ SPI interface

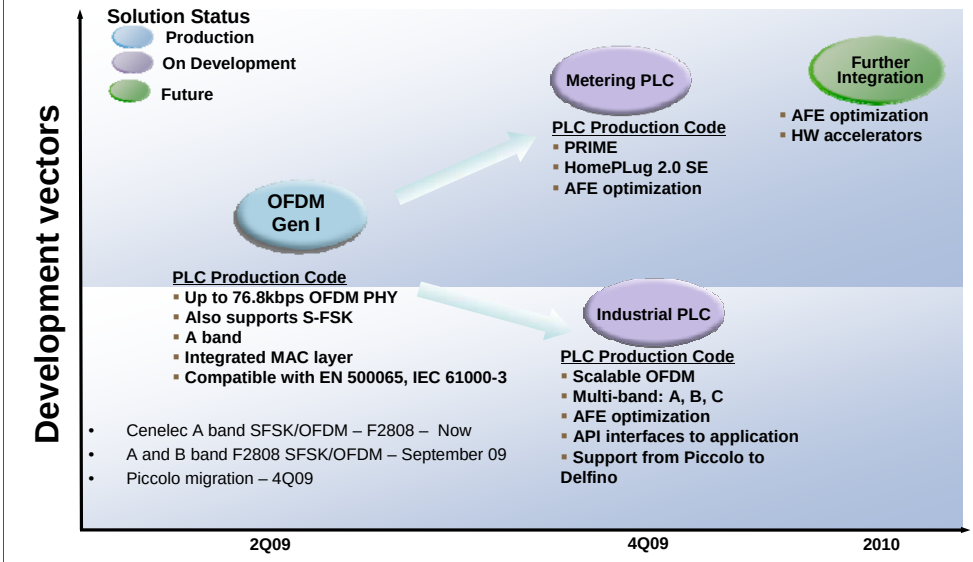


Benefits

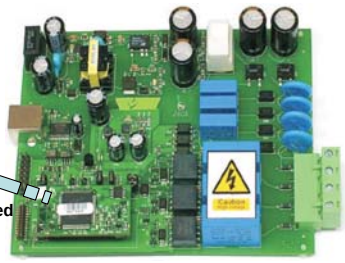
- **Best for low offset, RRIO, wide BW, single supply apps**
- **Allows for optimum A/D range matching for a wide variety of input signal amplitudes**
- **Allows easy system calibration for gain and offset**
- **Ideal for power sensitive applications**
- **Perfect for mixed voltage systems**
- **Prevents downstream latchup in mixed voltage systems**

Texas Instruments

TI Power Line Communication Solution Roadmap



OFDM GEN I
TI PLC modem development kit (PLC-DK)



PLC System On Module (SoM)

- **TMS320F280x 32-bit Micro-controller based**
- **I2C , SPI, SCI ports available for Host controller**
- **Gerber and Schematics available**

PLC Modem development Kit (PLC- DK) – comes with

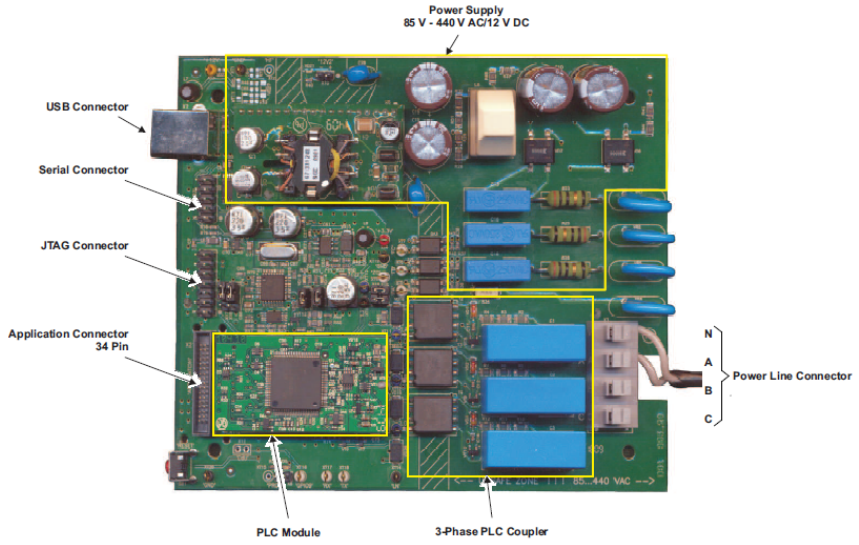
- **2 Modem s**
- **2 PLC System On Module**
- **Cables (USB and power)**
- **GUI and documentations**
- **Plastic cover box**
- **Part # TMDSPLCKIT-V1**
- **SRP $449**
- **Available Now**

http://focus.ti.com/docs/toolsw/folders/print/tmdsplckit-v1.html

- Robust Narrowband communication over low-voltage power line
- OFDM and S-FSK
- Data rates up to 76.8 kbps for one phase
- Phase selection provided
- Encapsulated libraries solution with interface to host controller (I2C, SPI, SCI)
- Compatible to standards EN50065 (Cenelec), IEC 61000-3
- Operating frequency range 24-94.5kHz (Cenelec A band)
- B band support under development
- Easy integration into end-point or network devices of AMR/AMI systems
- Easy integration in industrial application (lighting, solar..)
- NRE and Royalties FREE

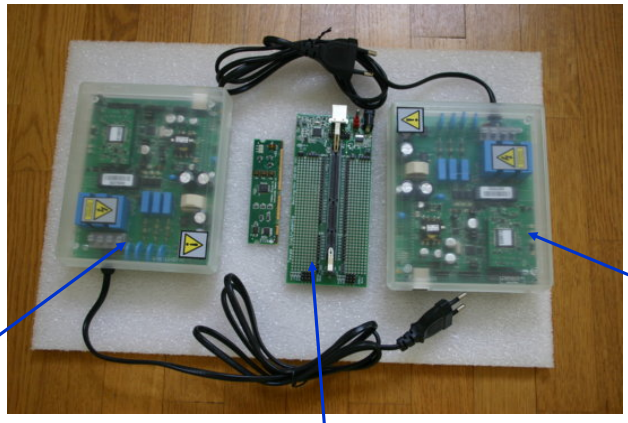
Texas Instruments

PLC-DK highlight

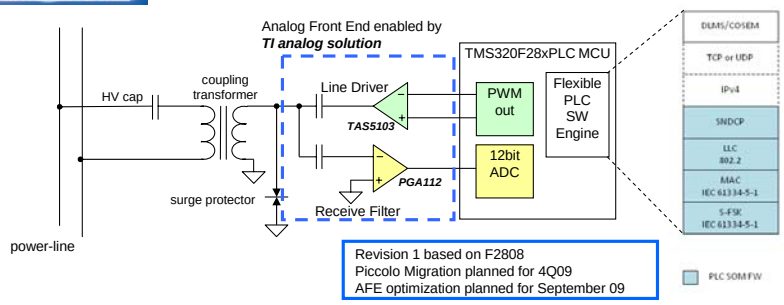


Download documentation at http://focus.ti.com/docs/toolsw/folders/print/tmdsplckit-v1.html

Kit content Highlight



PLC Modem development path



Prototype Phase

- *Experience* **and demo on the PLC-DK**
- *Interface* **with application**
  - **Interfaces available for host controller using serial port (I2C, SPI, SCI)**
- *Integrate* **into the final application**
  - **Option 1: Plug PLC SoM in application (interface definition provided)**
  - **Option 2: Merge SoM in application (schematic and Gerger File Available)**

Production Phase

- *Order specific***TMS320F28xPLC device from TI: contact TI representative**

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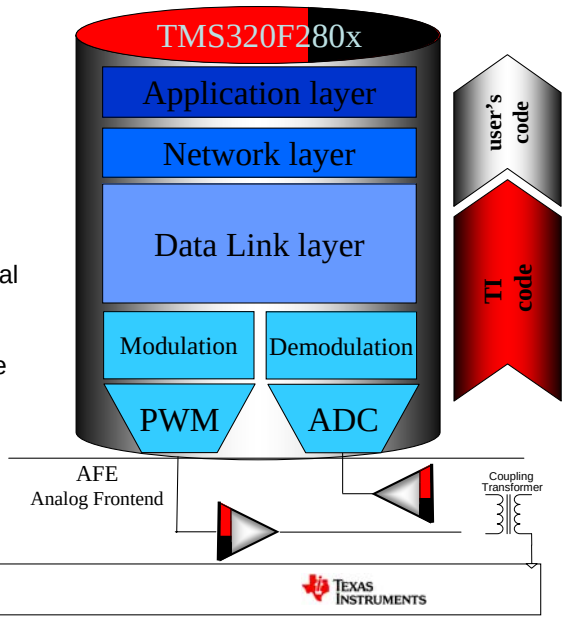
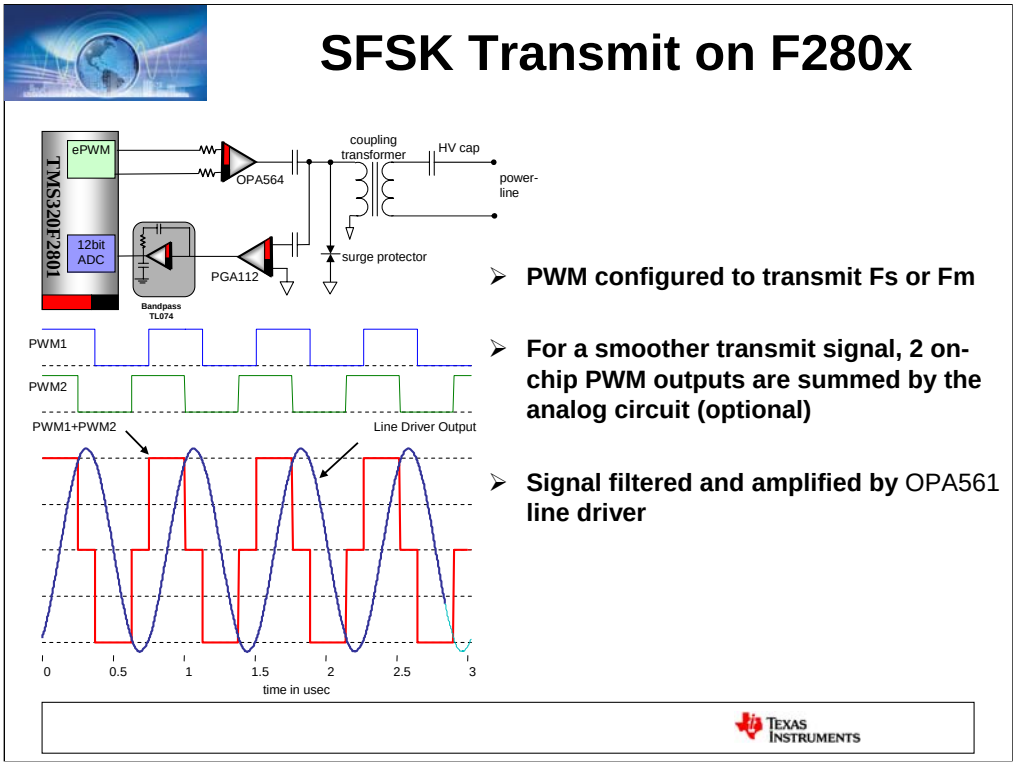
F280x – PLC node architecture

- **Upper protocol layers**
  - protocol agnostic
  - resources available for upper layer development and application support
- **Low layers**
  - free source code for physical and data link layers
  - modulations upgrade/enhancement possible
- **Analog Frontend**
  - schematics available





The PLC transmitter uses one hardware Event Manager in the TMS3230C28xx to generate a transmit clock running in continuous up/down counting mode. The transmit clock value depends on the bit to transfer:

- the Space frequency 74 kHz (2.5 MHz / 33.783)
- the Mark frequency 63.3 kHz (2.5 MHz/39.494)

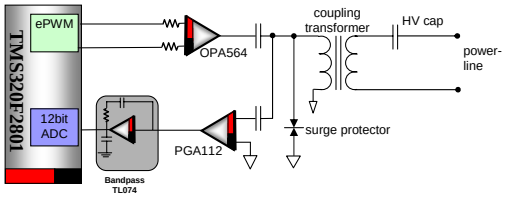
The PWM period registers (TBPRD) are setup so that they run at the space/mark transmit frequency.

This clock is fed to two full-compare units. One compare unit is set to generate an output with 33.3% duty cycle, the other is set for 66.6% duty cycle.

The outputs of the two compare units are summed together by the analog circuitry on the power line driver amplifier. By adding these two signals together and then filtering the sum at the transmit line driver, a mark or space sine wave carrier signal is produced.

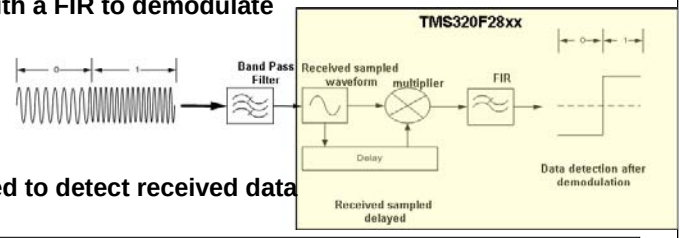
Use another PWM channel to transmit in phase opposite. Its enhances the receiver sensitivity.

SFSK Receive on F280x



- The received signal is amplified and bandpass filtered with an **OPA353** based circuit

- **The ADC samples the filtered signal at 60.9kHz. This "down samples" the signal to a 1.2kHz waveform.**
- **Each sample filtered with a FIR to demodulate autocorrelation.**



- **Software logic is utilized to detect received data structure.**

TEXAS INSTRUMENTS

The AGC (Automatic Gain Control) that is implemented on TI demo, can be removed and replaced by sampling a second channel with and external fixed gain. Then the energy on both path (non amplified and amplified) is compared and the most adequate channel is kept for signal detection.

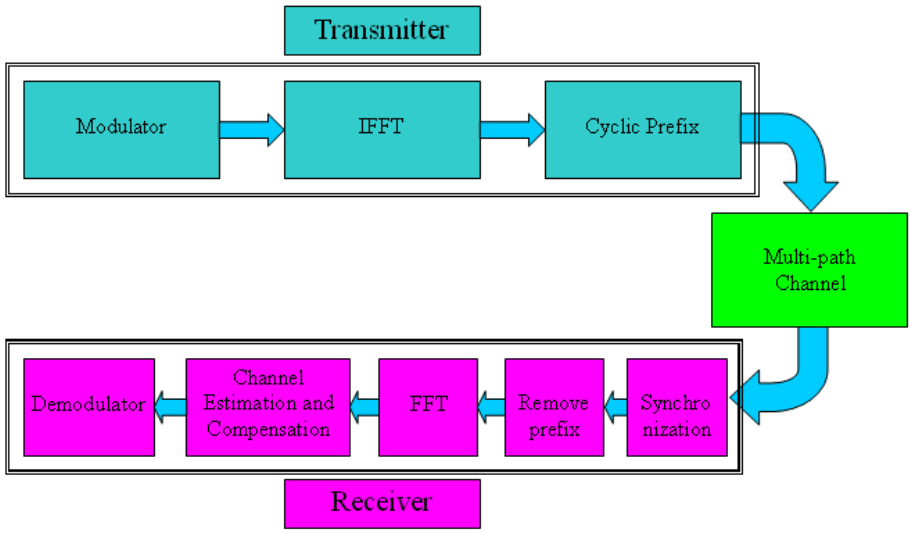
OFDM: higher data rate, better performance versus noise

Depending on the modulation scheme and coding options the following calculations may be presented for one phase:

	DBPSK		DQPSK		D8PSK		D16PSK	
FEC	1/2	-	1/2	-	1/2	-	1/2	-
Information bits per subcarrier	**0,5**	**1**	**1**	**2**	**1,5**	**3**	**2**	**4**
Information bits per symbol	**24**	**48**	**48**	**96**	**72**	**144**	**96**	**192**
Raw data rate (with REF symbol in each window), kbps	**7,2**	**14,4**	**14,4**	**28,8**	**21,6**	**43,2**	**28,8**	**57,6**
Raw data rate (no REF symbol in each window), kbps	**9,6**	**19,2**	**19,2**	**38,4**	**28,8**	**57,6**	**38,4**	**76,8**

Examples of data rates on 48 Carriers

OFDM – modem synoptic



Conclusions

- **New PLC modem kit available**
  - **Additional development in the pipe for metering and industrial**
- **Broad portfolio of Analog and Digital components enabling smart and flexible PLC communication**
- **Broad portfolio of Analog and Digital components enabling Smart and Flexible Solutions:**
  - **Power Line Communication**
  - **RF**
  - **Metrology**
  - **Application processor**
  - **Analog**

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