

Smart Grid & Energy Solutions Guide



- Grid Infrastructure
- Smart Grid Communications
- Smart Utility Meters
- Renewable Energy



distribution

transmission

management

communication

measurement

Smart Grid & Energy Solutions Guide

Introduction and Overview



Introduction

Texas Instruments provides innovative, economical and scalable products for grid infrastructure, utility metering, grid communication and renewable energy systems.

End-to-end products, tools and reference designs make the development process easier and meet standards for security, compliance and long term reliability - all backed by TI's global system expertise that effectively combines complementary components into solutions for a Smarter Grid.

Overview

Grid Infrastructure

- **Protection** functionality values reliability and consistency in response to faults. TI's programmable gain amplifiers (PGA), ADCs and processor solutions uniquely address the requirements of grid protection.
- **Monitoring and Control** requires the ability to accurately monitor currents and voltages on the grid, some times on battery based solutions. This requires sensitive operational amplifiers and low power MCUs like the MSP430™. In cases where heavier computation is required we have MCUs like C2000™.
- **Communication** in power grid is migrating from serial interfaces based towards high speed/low latency Ethernet based communication. TI provides state of the art solutions to meet bandwidth, redundancy, and real-time communication.
- **Power Quality** products from TI include multiple options for analog front end design, with up to eight channels ADC capable of up to 0.1% energy accuracy, or discrete solution with amplifiers, multiple channels ADC, and MCU to reach flexible system solution.

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Smart Grid & Energy Solutions Guide

Overview

Grid Communication

- **Data Concentrator** solutions from TI include a 3-chip solution and single-phase reference design system that supports both G3 and PRIME standards and NIB (Network Information Base) Management to handle 2000s PLC Service Nodes and switches. Linux™ OS on Cortex-A8 to support MAC and above software stack. Learn more at www.ti.com/lit/slyt431.
- **Ethernet communication** solutions include standard networking stacks offering and Industry specific protocols from third parties, such as IEC61850, IEC62439, PROFIBUS, EtherCAT, etc.
- **Serial Communication** from TI offers multiple options to meet different application scenarios, such as isolated RS485, non-isolated RS485, half- or full-duplex RS485, integrated RS232 driver and receiver, etc.
- **Zigbee®** hardware and software for the ZigBee-Compliant Platform (ZCP), certified by a ZigBee alliance-approved test house WiFi SimpleLink™ CC3000: Self-contained 802.11 b/g solution enables easy-to-implement Internet connectivity with SmartConfig™ technology; embedded Wi-Fi and networking software including drivers, stack and supplicant; allows Wi-Fi implementation quickly without previous Wi-Fi or RF experience.
- **6LoWPAN** Sub-1-GHz product family includes the CC1180 network processor, CC430 complete system-on-chip (SoC), CC1101/MSP430F5xxx platform and 6LoWPAN software stacks.
- **Wireless M-Bus** solutions from TI include Hardware and Software Support for Both 169MHz and 868MHz.

Energy Metering

Energy-measurement solutions from TI are designed to meet all requirements of ANSI C12.20 and IEC 62053 accuracy for Class 0.2 and Class 0.5 meters across the entire temperature range, with a full 2000:1 dynamic input range. TI's electric meter metrology solutions include sophisticated anti-tampering protection to protect meter integrity and reduce non-technical losses in the field. TI's solutions for AMI networks include both RF and PLC solutions, and also support most industry standards, including IEEE-802.15.4g, PRIME, G3-PLC, IEEE-1901.2 and ITU-G.990x. Find TI products dedicated to these and other e-meter systems at www.ti.com/metering.

Flow Metering

Flow meter solutions from TI cover a wide gamut of applications including Gas, Water, Heat meters and Heat Cost Allocators (HCA) used to measure the gas or liquid that passes through the meter. The solutions include Automatic meter reading (AMR) and advanced metering infrastructure (AMI) technologies adding an additional layer of intelligence to traditional meters. These technologies improve meter reading efficiency and provide accurate and timely billing. Discover TI products dedicated to these and other flow-meter systems at www.ti.com/flow.

Grid Security

Grid Security is an important topic at TI, which is current with worldwide smart grid NIST, BSI and FIPS 140-2 security requirements. From existing security software libraries to hardware modules and associated roadmaps, TI smart grid security solutions ensure that developers invest in future-proof solutions today.

Renewable Energy

Renewable Energy solutions from TI are transforming power through energy management innovation in areas such as energy generation, conversion, distribution and control of energy demand and resources. TI's dedicated energy lab is the focal point for intelligent energy conversion and management systems for accessible and cost-effective power delivery.

Industry Alliances

Industry alliances are a significant part of TI's dedication to the energy market. As a leader in the design and manufacturing of smart energy system components, TI maintains a leadership role in the worldwide community of alliances and regulatory organizations that support the global smart grid. (See back cover for listings)



TI offers a robust library of dedicated system and sub-system solutions for smart grid and energy applications. From protection and monitoring to energy measurement and communication, TI Designs delivers a number of expertly crafted reference designs that will help get your designs to market faster. www.ti.com/smartgrid-designs

Grid Infrastructure Protection

Challenges with protection in Grid Infrastructure

The ability to operate the grid reliably (without false trips) and yet respond quickly when a fault does really occur, is significant challenge to grid operators. This challenge and responsibility is amplified by the hugely expensive equipment that sits on the grid that would be damaged if a fault is not protected against. Trip time repeatability and consistency across temperature are some of the critical factors involved.

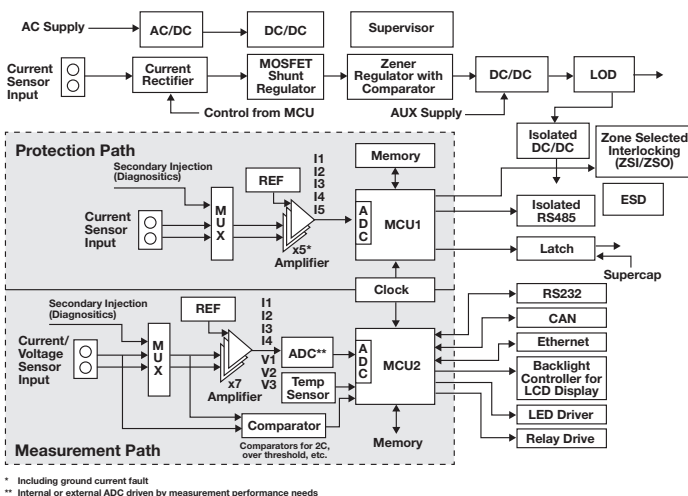
Solutions from TI

Compared with the majority of the electromechanical relays and circuit breakers that are still used for protection on our grid, the newer electronic solutions provide far more reliability and consistency in response to faults. Low latency and programmable thresholds are also important for breakers. An example of an Air Circuit Breaker system block diagram is shown below. TI has Op-Amps, ADCs and processor solutions that address several of the subsystems shown below.

Low Power/Low Noise AFE for Circuit Breakers

(TIDA-00128) is designed with high precision/low offset OpAmps. The solution enables pick-up accuracy at $\pm 10\%$ and time delay accuracy at 0 to -20% with better trip time repeatability for breakers.

Programmable Gain Amplifier based AFE for Circuit Breakers (TIDA-00130) uses zero drift PGAs to achieve size optimized solutions that are accurate across a wide temperature range.



Air Circuit Breaker System

Small Form Factor, 12W, Power Solution (TIDA-00227)

uses a fly back converter to achieve a high efficiency power solution that is capable of handling a an ultra-wide input for a variety of platforms.

Products for Protection Solutions

Device	Description
MSP430F6746	Metering SoC with integrated ADCs providing accuracy of better than 0.1%
ADC8688	8 channel, 16 bit SAR ADC capable of 500Ksps operating on a single 5V supply and handling input up to $\pm 10V$
ADS1248	24 bit ADC with on board low noise PGA and a precision Delta Sigma ADC coupled with low drift reference
PGA116/117	Provide 10 analog inputs and 4 pin SPI interface with daisy chain capability
LM293	Dual differential comparator with the ability to operate from a single or dual supply sources
TPS55010	Transformer driver designed to provide isolated power for isolated interfaces. 2W capable with 2.95V to 6V input handling
LM62	Precision temperature sensor. Linearly proportional to Celsius ($+15.5mV/C$)
UCC28710/20	Family of flyback controllers for AC/DC conversion. External FET allows usage to very high voltage/wattage levels
TPL7407L	Relay driver. High voltage, high current array of 7 drivers capable of 600mA/ch
AMC1305	Re-enforced isolated Delta-Sigma modulator handling isolation of 7KV peak and 10KV surge
ISO7142/41/40/31	Small-footprint, low power 2500 VRMS Quad and triple-channel digital isolators with noise filter
TPS3831/9	Ultra-low current 150nA, ultra-small, voltage supervisor
LM3671	2MHz, 600mA step-down DC/DC converter with adjustable output

TI Designs for Grid Protection

TI Design	Description
TIDA-00128	Low-power, low-noise analog front end design for circuit breakers
TIDA-00130	Programmable gain amplifier-based AFE for circuit breakers
TIDA-00307	Sensor inputs AFE for merging unit and protection relays
TIDA-00110	Non-isolated multi-channel RTD with SPI for transformer/generator protection
TIDA-00080	Isolated shunt based current/voltage measurement
TIDA-00127	30W ultra wide range power supply for protection relays
TIDA-00227	Small form factor, 12W, ultra wide range power supply for protection relay

View more information at www.ti.com/gridinfrastructure

Grid Infrastructure

Monitoring and Control

Challenges with Monitoring and Control in Grid Infrastructure

One of the critical aspects of the “smart grid” is the ability to monitor and control the grid enabling optimal management of assets. To do this grid operators need solutions that are able to detect faults but also respond to the fault. The challenges here include detection accuracy, handling the fault condition reliably, as well as communicate and operate in low power modes when running on back up battery.

Solutions from TI

TI has solutions and products for a wide range of monitoring and control applications, including protection relays and MCCBs.

Self/Dual Powered Supply for Grid Solutions (TIDA-00229)

The TIDA-00229 enables device powering through either CT or auxiliary power. It's a flexible solution, with a MOSFET based shunt to generate supply voltage needed.

Analog I/O and Digital Output Module for IEDs (TIDA-00310)

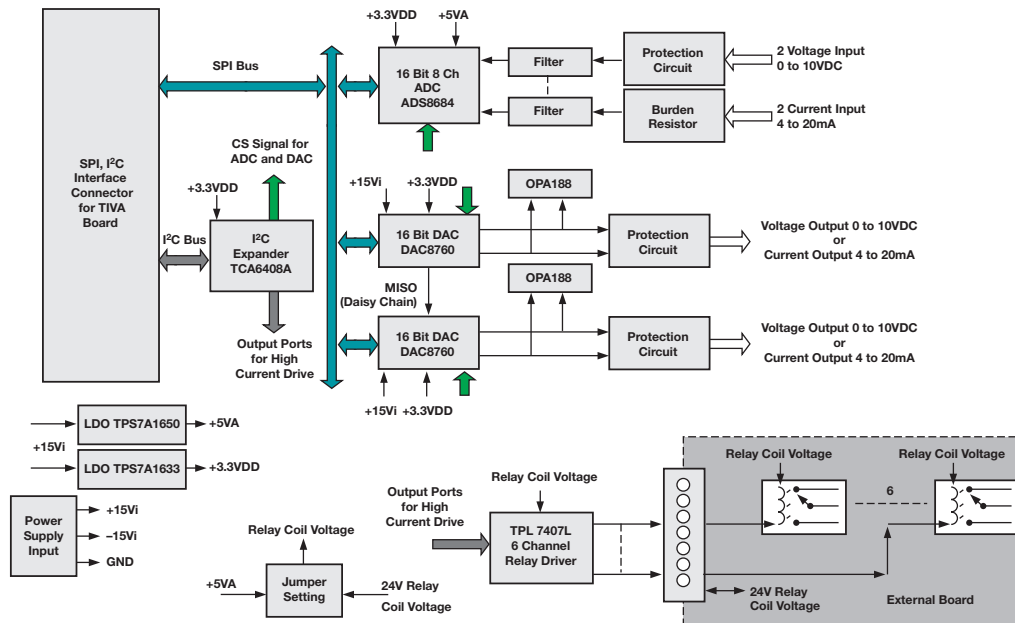
Analog I/O and digital output cards have been widely used for monitoring and control purposes in substation automation devices such as RTUs, bay controllers, MFPRs, etc. The TIDA-00310 enables excellent accuracy ($\pm 0.5\%$) for input signals with higher sampling rate (up to 500KSPS), and also implements a flexible analog output solution with a configurable current or voltage output. As to digital output, this design can support higher current drive capability (up to 500mA) for large relays with simplified isolation and connectivity design.

Products for Monitoring and Control Solutions

Device	Description
MSP430F5328	Ultra low power consumption, wake up from standby in 3.5uS, built-in ADC
OPA4314	Low power (Iq of 150uA/ch), low noise with wide bandwidth. Grad balance between cost and value
TMS320F28332	Up to 150MHz (6.67-ns cycle time), high-performance 32-Bit CPU with IEEE-754 single-precision Floating-Point Unit (FPU)
AM3357	800MHz ARM Cortex-A8, 2 PRU-ICSS Crypto accelerator, 2-port switch 10/100/1000, multiple IO and serial interfaces
TPS62740	360-nA Iq step-down converter with integrated load switch and 4-pin voltage select
DRV8837/ TPL7407L	Full bridge driver with low mosfet on resistance option Vs. High voltage, high current array of 7 drivers capable of 600mA/ch
SN65HVD7x	Half and full-duplex 3.3V transceivers, data rate options from 250Kbps to 50Mbps with high IEC ESD protection
LM4041	Precision voltage reference. Ideal for space constrained applications. Available in extended temperature range
UCC27524A	Dual channel, high speed, gate driver capable of up to 5A peak and extremely low propagation delay
UCC28910	700V Integrated FET, switcher for AC/DC conversion with primary side regulation
LP5907	250mA LDO with low noise, high PSRR and low Iq features
LM5017/8/9	100V, 600mA synchronous step down buck with excellent transient response

TI Designs for Monitoring and Control

TI Design	Description
TIDA-00229	Self/dual powered supply for grid solutions
TIDA-00222	Measurement module for branch circuit power monitor
TIDA-00221	Measurement module for branch current monitor
TIDA-00310	Analog I/O and digital output module for IEDs



Analog Input/Output and Digital Output Module Diagram

View more information at www.ti.com/gridinfrastructure

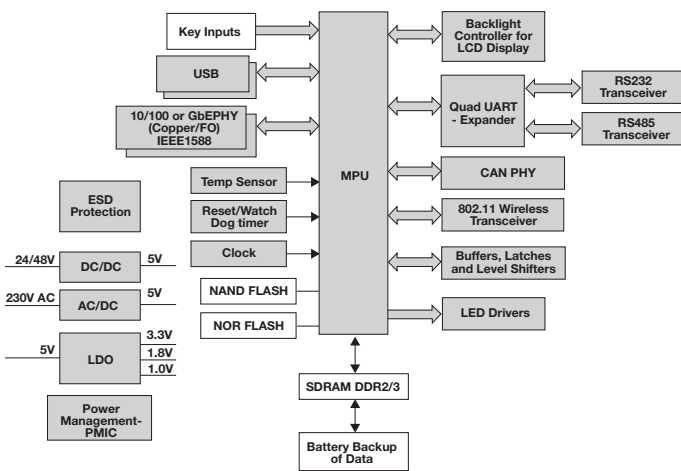
Grid Infrastructure

Communication

With large amounts of intelligent end points, peer to peer control, and distributed energy resources, modern grid infrastructure requires reliable, scalable, secured, high data volume and low latency communications. A variety of communication options could be chosen, such as microwave, wireless, fiber, Ethernet, or Satellite. The applications include IEC61850 Gateway, Protocol Convertor, Serials Servers, Copper to Fiber Convertor, GPS Time Master, Data Concentrator, GSM/GPRS Modem, etc.

Below is one example for IEC61850 Gateway, which is used for mapping signals between the IEDs and utility substations, providing reliable communication with IEC62439 redundancy, and supporting protocols conversion (such as Modbus TCP/Serial, DNP3, IEC60870, wireless, etc.)

One of the key design challenges is the MPU selection, which should have enough peripherals to handle different communication interface, and advanced networking stack processing capability. TI Sitara processor family enables developers to easily add multiple connectivity options including <1GHz (LPRF), general packet radio service (GPRS), ZigBee®, Wi-Fi, near field communication (NFC) and multiple PLC standards. Furthermore, ICSS-PRU (Industrial Communication Sub-System – Programmable Realtime Unit) engine can perform very low latency data packet processing to meet IEC62439 Ethernet redundancy requirement, at the same time, the IEC61850 substation stack could be running on the Sitara™ processor core. It will bring BOM and power consumption optimized SOC solution for most of IEC61850 gateway applications.



IEC61850 Gateway

Products for Communication Solutions

Device	Benefits
Sitara™ processors (AM335x Series)	<ul style="list-style-type: none"> Up to 1-GHz Cortex-A8 32-bit RISC microprocessor Extensive peripheral set (2× 10/100M Ethernet, CAN, USB, 8× UARTs extended from PRU, ...) Flexible communication protocols Linux® community, Android®, Windows® Embedded
Tiva™ C Series ARM Cortex-M4-Based MCUs (TM4C123x Series)	<ul style="list-style-type: none"> Up to 80-MHz core 256KB single-cycle flash, 32KB single-cycle SRAM Rich interface featuring 8× UARTs, USB, CAN, up to 43 GPIOs, etc. 2× 12-bit ADC with 12 analog input channels
CC3100	CC3100 SimpleLink Wi-Fi Consists of Wi-Fi Network Processor and Power-Management Subsystems
TMS320F28PLC83/F28M35	MAC & PHY layer processor for narrow band power line communication
UCC28720/UCC28740	PWM controller with external BJT with Primary side regulation/PWM controller with external FET with opto-coupler feedback
TPS562200/2210/3200/3210	4.5V to 17-V input 2-A and 3-A output respectively; DC/DC Step-Down Converter, adaptive on-time D-CAP2™ with advanced Eco-mode enabling high efficiency over load range, fast transient response, allows use of low ESR caps, SOT-23 package
TLV71310/11/12/15/18	Capacitor-Free, 150-mA LDO with 1.5% regulation over temp. This next generation LDO was designed to be stable without an o/p cap
SN65HVD231	3.3V CAN Transceiver with Sleep Mode
TPS65910A	PMIC - Integrated Power Management IC with 4 DC/DCs, 8 LDOs and RTC in 6x6mm QFN
DP83848K	10/100 Ethernet PHY, Error free to 130 meters, Auto-MIDX, supports MII & RMII
ISO3080/82/86/88	Isolated 5V half and full-duplex transceivers, provide 2500 VRMS of Isolation

TI Designs Associated with Grid Infrastructure Communication

TI Design	Description
TIDA-00224	Industrial Ethernet PHY Brick with Fiber-Optic Interface
TIDA-00190	EMI Compliant Industrial Ethernet PHY Brick Reference Design
TIDA-00226	Serial-to-Ethernet Converter
TIDA-00308	Small Form Factor Isolated RS485
TIDA-00306	Media Converter - RJ45 to Fiber Converter
TIDE0019	IEC 61850 Demonstration of Substation Bay Controller on Beaglebone Cape and Starter Kit

View more information at www.ti.com/gridinfrastructure

Grid Infrastructure

Power Quality

Power quality equipment is critical to analyze the power system and make decisions about purchasing, generation, cost reductions, and process optimization. Poor power quality can cost more on utilities and end users, from physical damage to equipment/system downtime, lower productivity yields increases in energy costs. In general, the key power characters will be measured and monitored, including current, voltage, real and reactive power, harmonic, waveform, energy use, cost of power, power factor and frequency. The applications include Power Quality Analyzer, Revenue Meter, Power Meter, Panel Meter & Sub Meter, ABT Meters, DC KWH Meters, Demand Indicator, VAR Compensation (PFC), Phasor Measurement Unit.

As one example of power quality devices, Smart Combiner Box (SCB) has been used in solar DC strings. SCB monitors current across solar DC strings (up to 48 strings) that are paralleled to generate the required power and has the features, such as Current Rating (30A/5A/10A/3A), Voltage Rating (600VDC to 1000VDC), Accuracy (1% for Voltage/Current, 2°C for Temperature), Power Supply (24V Auxiliary power or 600VDC ~ 1000VDC), Communication (Modbus, Low power RF, or Bluetooth®).

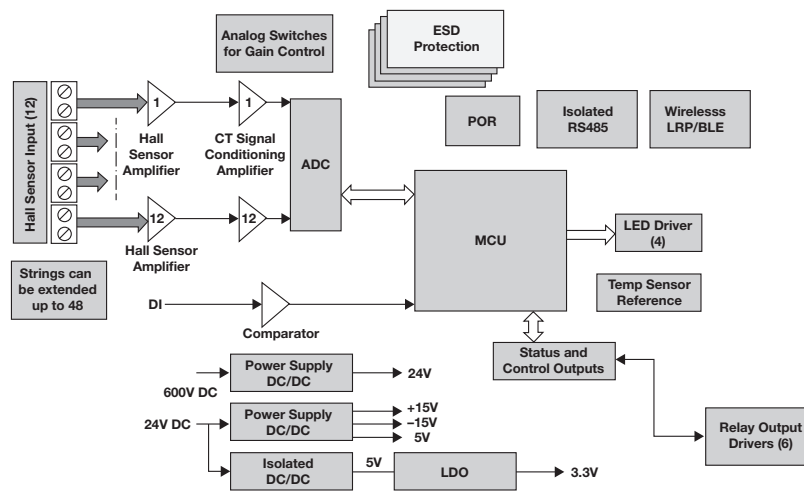
TI provided multiple options for analog front end design, such as SOC option with low power MSP430™ MCU with up to 8 channels ADC, or discrete solution with amplifiers, multiple channels ADC, and MCU to reach flexible system solution. A rich portfolio is also suggested from below table for AC/DC, DC/DC and LDO power solution, ESD protection and isolated communication interface.

Products for Power Quality Solutions

Device	Benefits
MSP430F6779	512KB flash, 320 segment LCD, RTC with battery back-up power management
Sitara™ processors (AM335x Series)	<ul style="list-style-type: none"> Up to 1-GHz Cortex-A8 32-bit RISC microprocessor Extensive peripheral set (2× 10/100M Ethernet, CAN, USB, 8× UARTs extended from PRU, ...) Flexible communication protocols Linux® community, Android®, Windows® Embedded
Tiva™ C Series ARM Cortex-M4-Based MCUs (TM4C123x Series)	<ul style="list-style-type: none"> Up to 80-MHz core 256KB single-cycle flash, 32KB single-cycle SRAM Rich interface featuring 8× UARTs, USB, CAN, up to 43 GIPOs, etc. 2× 12-bit ADC with 12 analog input channels
OPA4314	Quad, 3MHz, Low-Power, Low-Noise, RRI/O, 1.8V CMOS Operational Amplifier
ADS131E04/06/08	4/6/8-channel, up to 24-bit $\Delta\Sigma$, simultaneous sampling AFE for relay protection, power monitoring, power quality, up to 64 kSPS, 107-dB SNR
ADS8688	SAR ADC with 16 bits, 8 channels, 500 kSPS, and bipolar inputs off +5V supply
LM2733	0.6/1.6MHz Boost Converters with 40V Internal FET Switch in SOT-23
LP38691	500mA Low Dropout CMOS Linear Regulators Stable with Ceramic Output Capacitors
SimpleLink™ CC1200	Low-power, high-performance RF transceiver
SimpleLink™ CC2540T	SimpleLink CC2540T 2.4-GHz Bluetooth Low Energy Wireless MCU
ISO1176	Isolated PROFIBUS RS-485 Transceiver
CD74HCT4511	High Speed CMOS Logic BCD-to-7 Segment Latch/Decoder/Driver

TI Designs for Power Quality

TI Design	Description
TIDM-THREEPHASEMETER-F6779	High Accuracy Three-Phase Electricity Meter with Tamper Detection



Smart Combiner Box (SCB)

View more information at www.ti.com/gridinfrastructure

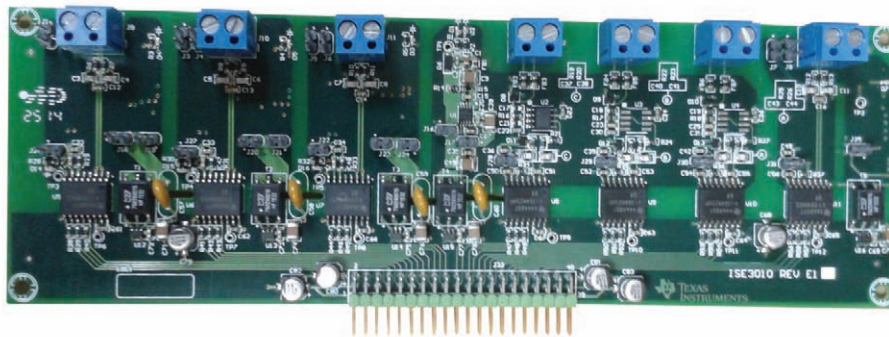
Grid Infrastructure

TI Reference Designs

Isolated Shunt based Current/Voltage Measurement

TIDA-00080

This isolated shunt based current measurement unit enables high accuracy current measurement without the use of Current Transformers (CT). The isolation is achieved through the use of AMC1304 that incorporates both high voltage isolation as well as the Delta-Sigma Modulator. This solution eliminates the need for the CT which customers value due to the decrease in board size, reduced product weight, mitigation of cross talk and EMI in the system, and potentially increases product life through lower mechanical issues by replacing the CT with a shunt.

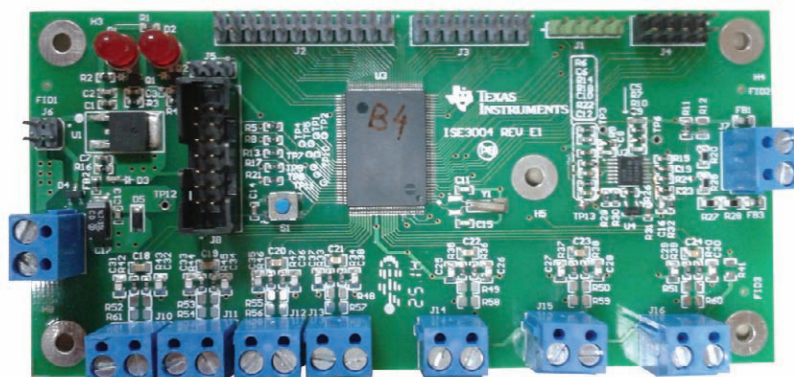


Get more information: www.ti.com/tool/TIDA-00080

Branch Circuit Power Monitor

TIDA-00222

This reference design targets measurement accuracy across the rated current range while at the same time being a cost efficient solution. This is achieved by using a highly integrated SoC device which has up to 7 channels of the 24-bit Delta-Sigma ADCs available for current measurement. For voltage measurement a 10-bit SAR ADC is used. With both current and voltage available, power measurement can now be made. This solution also has several options for communication supported such as UART, JTAG, etc. Applications include load management, sub-panels, etc.



Get more information: www.ti.com/tool/TIDA-00222

Solution Highlights

- High accuracy current/voltage measurement capability INL: 0.4ppm
 - 0.25% from 0.5A to 10A
 - 1% from 10A to 200A
- Eliminate the CT for current sensing
- Mitigates cross talk and EMI in system
- Extend product field life (reduce mechanical issues) and shrinks board size

Solution Highlights

- Precise current measurement through 7 channels of Delta-Sigma ADCs
 - <1% from 10% to 100% of rated current (controlled by CT and burden resistor)
- Voltage measurement enabled with integrated SAR ADC
- Extended temperature range operability of -40°C to +105°C
- Integrated single chip solution results in a cost and area efficient solution
- Large MSP Family and roadmap/scale performance, features, price
- Metering library available in source for use on MSPs
- Value conscious, easy to use development tools and reference designs/fast time-to-market

Grid Infrastructure

Development Tools

Reference Design Solutions

Name	Description	TI Design
Analog Front End Sub-System		
Isolated Current/Voltage Sensing Module with Delta-Sigma Modulators	This solution eliminates the need for the CT which customers value due to the decrease in board size, reduced product weight, mitigation of cross talk and EMI in the system, and potentially increases product life through lower mechanical issues by replacing the CT with a shunt	TIDA-00080
Low-Power, Low-Noise Analog Front End Design for Circuit Breakers (ACB/MCCB-ETU)	Utilizing a low cost op amp, this design provides a pick-up (A) accuracy $\pm 10\%$ and time delay (s) accuracy 0 to -20% . Additionally, this design takes harsh environment conditions in mind with features such as ambient insensitivity from -10°C to 70°C and high electromagnetic immunity	TIDA-00128
Zero drift PGA based Analog Front End Design for Circuit Breakers (ACB/MCCB-ETU)	Utilizing a zero drift programmable amplifier, this design provides a $\pm 10\%$ pick-up (A) accuracy and time delay (s) accuracy of 0 to -20% . Additionally, this solution was designed to handle harsh environment conditions by including features such as ambient insensitivity from -10°C to 70°C and high electromagnetic immunity	TIDA-00130
Non-isolated Multi-channel RTD with SPI for Transformer/Generator Protection	This design handles up to 4 RTDs, the architecture enables modular approach to expand the number of RTD. The measurement accuracy targets $<1^{\circ}\text{C}$ and wide temperature measurement range.	TIDA-00110
Analog Front End Design for Merging Unit and Protection Relay	This implementation is modular, allowing easy expansion of channels while at the same time keeping the connectivity to the processor minimal by using the SPI daisy chain feature in the TI's SAR ADC	TIDA-00307
Sensing Sub-System		
Analog I/O + Digital Output Module for Smart Grid IEDs	This design provides four Analog Inputs to measure two current inputs (0 to 20mA /0 to 24mA /4 to 20mA DC) and two voltage inputs (0 to 5V/0 to 10V DC). Two Analog DC output channels are configurable as either current output or voltage output. Accuracy can reach to $\pm 0.2\%$ at full scale value at 25°C .	TIDA-00310
Branch Circuit Power Monitor	This design uses a highly integrated SoC device which has up to 7 channels of the 24-bit Delta-Sigma ADCs for current measurement and a 10-bit SAR ADC for voltage measurement. It could be applied to load management, sub-panels, etc, applications.	TIDA-00222
Branch Current Monitor	This design uses a highly integrated SoC device which has up to 7 channels of the 24-bit Delta-Sigma ADCs available for current measurement	TIDA-00221
Power Sub-System		
30W Ultra Wide Range Power Supply for Protection Relays Reference Design	With ultra-wide range of both AC (88 to 276V AC) and DC (24V to 250V DC) inputs, this power supply module is designed to output industry standard voltages (such as $\pm 12\text{V}$ and isolated 6.75V) required in many Protection Relays while also providing excellent line and load regulation ($<\pm 3\%$)	TIDA-00127
Self or Dual-Powered Supply for Protection Relay, MCCBs and ACBs Ref Design	The solution handles the current inputs both from a Current Transformer and from an auxiliary source to provide maximum power design flexibility. The excellent load transient performance and very sharp turn-on characteristic is very important to circuit breaker ETU and relay design	TIDA-00229
12W Ultra Wide Range Power Supply for Protection Relay	With ultra-wide range of both AC and DC inputs, this solution has been engineered for high wattage with good efficiency and has also been pre-compliance tested for IEC61000-4 (EFT and Surge) and CISPR 11 Class A	TIDA-00227
Communication Sub-System		
32-bit ARM [®] Cortex [™] -M4F MCU based Small form factor Serial-to-Ethernet Converter	This design demonstrates bidirectional switching and transmission between serial port and Ethernet port, which enable legacy equipments only having serial communication in power grid still can communicate with new Ethernet based modernized equipments	TIDA-00226
Industrial Ethernet PHY Brick with Fiber-Optic Interface	This design features a low power, low cost design to meet different bandwidth and different transmission distance needs. IEC61000-4-2-Level 3 ESD performance has been tested on this design to comply with IEC specification	TIDA-00224
Industrial Ethernet PHY Brick with Fiber-Optic Interface	This design implements an isolated data converter that utilizes residual power from the interface to power itself. This removes the requirement for expensive power transmission across the isolation boundary.	TIDA-00163
Small Form Factor, Half-Duplex with Iso and Non-Iso RS485 Interface	This design will enable customers to quickly evaluate and design with TI RS485 devices for 3 different application scenarios, with an isolated power supply provided in this design	TIDA-00308
Media Converter – Copper to Fiber Optic Converter	This design uses the DP83849 evaluation board to implement a 10/100BASE-TX to 10/100BASE-FX media converter, which enables copper based legacy equipment to be easily connected to a fiber network	TIDA-00306
Isolated Serial Communication Module	This reference design provides a simple means through which to isolate I ² C or SPI type communication lines, which are often required in Grid Infrastructure applications where high voltages are involved	TIDA-00300
IEC 61850 Demonstration of Substation Bay Controller on Beaglebone Cape and Starter Kit	A low cost, simplified implementation of an IEC 61850 Substation Bay Controller is demonstrated by running the Triangle MicroWorks IEC 61850 stack efficiently on the TI AM335X platform	TIDEP0019

Grid Infrastructure

Other Recommended Products

Signal Chain

Device	Description and Benefits	Type
Digital Isolation		
IS07842/41/21	High performance, High immunity, 5700 VRMS Reinforced Quad and Dual-Channel Digital Isolators	Digital Isolation
IS07342/41	Robust EMC, Low power enhanced 3000 VRMS Quad-Channel Digital isolators with noise filter	Digital Isolation
RS485 (Isolated & Non-Isolated)		
SN65HVD308xE	Half and Full-Duplex 5V Transceivers, 200Kbps/1Mbps/20Mbps data rate options with very low supply current	RS485 Interface
Can Controller (Isolated & Non-Isolated)		
SN65HVD265/6/7	4.5V to 5.5V Supply voltage; -27V to 40V Bus fault voltage; Flexible Data rate (FD) up to 2Mbps	Can Interface
ISO1050	Galvanically isolated CAN transceiver that meets the specifications of the ISO11898-2 standard (up to 5000 VRMS for ISO1050DW)	Isolated Can Interface
Relay/Actuator Drivers		
DRV777	7 low o/p impedance drivers minimizing power dissipation, 140mA/Channel, 1A when tied together, 20V capable o/p pins	Relay
Ethernet PHY		
DP83630/40	IEEE 1588 Precision Time Protocol Transceiver for real time industrial connectivity. Packet time stamps for clock synchronization	Interface
SAR ADC		
ADS8558/7/6	12/14/16 bit 6-channel simultaneous sampling ADC, supports up to 730kSPS in parallel i/f mode, up to 91dB SNR	Interface
ADS8528/48/68	12/14/16 bit 8-channel simultaneous sampling ADC, supports up to 650kSPS in parallel i/f mode, up to 91dB SNR	Interface
Delta-Sigma ($\Delta\Sigma$) ADC		
ADS130E08	8 channel, up to 16bit, simultaneous sampling AFE for relay protection, Power Monitoring, Power Quality, up to 8kSPS, 103dB SNR	D-S A/D Interface
ADS1271/4/8	1/4/8 channel, up to 24bit, simultaneous sampling AFE for Power Monitoring, Quality and Protection, up to 144kSPS, 111dB SNR	Interface
Analog Isolation		
AMC1100	Fully-Differential Isolation Amp for Energy Metering, SiO2 barrier up to 4250 VPEAK and resistant to magnetic interference	Analog Isolation
AMC1204	20MHz, Second-Order, Isolated Delta-Sigma Modulator for Current-Shunt Measurement, SiO2 barrier up to 4250 VPEAK	Analog Isolation
AMC1305	Re-enforced isolated Delta-Sigma modulator handling isolation of 7KV peak and 10KV surge	Isolated A/D
Op Amps		
OPA4188/71/40	Wide Vs: +4.0V to +36V ($\pm 2V$ to $\pm 18V$), low offset voltage, near zero-drift, low Iq, high input impedance and rail-to-rail output swing	Interface
OPA4277	Vs: operate from $\pm 2V$ to $\pm 18V$, ultra low offset and drift, low Iq	Interface
External Reference		
LM4050	Precision Micropower shunt voltage reference, external stabilizing capacitor	Voltage Reference
LMV431	1.24V shunt regulators capable of adjustment to 30V	Voltage Reference
ESD		
TPD1E10B06/B09	Single channel ESD protection in small 0402 package, $\pm 30KV$ IEC air-gap, over $\pm 30KV$ contact, bipolar or bidirectional signal support	ESD protection
TPD4E1U06	Quad channel ultra low cap ESD device, offers $\pm 15KV$ IEC air-gap and $\pm 15KV$, suitable for multiple applications like USB	ESD protection
TPD2E007	2-channel ESD protection offers system level ESD solutions for wide range of industrial applications like RS485, RS232	ESD protection
Temperature Sensors		
TMP102	$\pm 0.5^\circ C$ accurate from $-20^\circ C$ to $+85^\circ C$ Two-Wire, serial output, Two-Wire and SMBus interface-compatible	Temp. Sensor
TMP006/7	IR MEMS temperature sensor. Enables contactless temperature measurement. Local accuracy $\pm 1^\circ C$ from $-0^\circ C$ to $+60^\circ C$	Temp. Sensor
TMP75/LM75A	$\pm 1.5^\circ C$ to $\pm 3^\circ C$ accuracy depending on temperature range, features SMBus and two-wire interface	Temp. Sensor
LM57	Resistor-Programmable Temperature Switch and Analog Temperature Sensor. The trip temperature (TTRIP) is programmable (256 points) by using two external 1% resistors	Temp. Sensor
Touch Pad/Key Pad		
TSC3060	Capacitive touch up to 3.2"	Touch/Key Pad
TSC2046E	Resistive Touch	Touch/Key Pad

Grid Infrastructure

Other Recommended Products

Power

Isolated AC/DC		
Device	Description and Benefits	Type
UCC28710/700	PWM controller with/without Integrated 700V startup switch. Constant-Voltage, Constant-Current Controller with Primary-Side Regulation, QR Green mode, Optocoupler less feedback, very low no-load power, High efficiency	AC/DC Supply
Cap Drop Type		
Device	Description and Benefits	Type
TPS5401	Cost-optimized 42-V, 0.5-A step-down DC/DC converter; Cap-drop off-line power supplies	Step-Down Regulator
TPS54060/160/260	DC/DC switching power supply: 60-V, 0.5-A/1.5-A/2.5-A step-down DC/DC converters with ECOMode for light load efficiency and very low Iq	Step-Down Regulator
DC/DC		
Device	Description and Benefits	Type
TPS54478	2.95V to 6V Input, 4A Output, DC/DC switching power supply: 2MHz, Synchronous Step Down	Step-Down Regulator
TPS5432	2.95V to 6V Input, 3A Output, Value conscious, 700kHz Synchronous Step Down Converter	Step-Down Regulator
TLV62084	2.7V to 5.5V input, 2-A output, 2x2mm SON, synchronous DC/DC step-down converter, DCS-Control for fast transient response	Step-Down Regulator
LM3671	2.7V to 5.5V Input, 600mA output, 2MHz, Step-Down DC/DC Converter optimized for powering low voltage circuits	Step-Down Regulator
TLV62080	2.5V to 5.5V Input, 1.2A step down converter in 2x2mm package and high efficiency over wide output current range	Step-Down Regulator
TPS62560	2.5V to 5.5V input with up to 600mA output, Synchronous step down converter, optimized for low power or battery applications	Step-Down Regulator
TPS62175	28Vin, 500mA output, 2x3mm SON, synchronous DC/DC step-down converter with Sleep Mode	Step-Down Regulator
TPS562200/2210/3200/3210	4.5V to 17-V input 2-A and 3-A output respectively; DC/DC Step-Down Converter, adaptive on-time D-CAP2™ with Advanced Eco-mode enabling high efficiency over load range, fast transient response, allows use of low ESR caps, SOT-23 package	Step-Down Regulator
LMR12010	20VIN 1A Buck regulator.30nA low shutdown Iq and switching up to 3MHz. Offers internal softstart, Current-mode PWM control	Step-Down Regulator
TPS61230/51/91	High Efficiency Synchronous Boost Converter with integrated 5-A Switch	Buck-Boost Regulator
TPS63060/1	DC/DC buck-boost regulators: 2.5- to 12-V input voltage with 93% efficiency and 2.25-A switch-current limit	Buck-Boost Regulator
LM2733	0.6/1.6MHz Boost Converter, Has 40V integrated FET switch with low RDSon. Offers cycle-by-cycle current limiting	Step-Up/Boost Regulator
LM5001	75V integrated MOSFET with a 1 Amp peak current limit for Boost & SEPIC implementation	Step-Up/Boost Regulator
LM5160	65V, 1.5A Constant On-Time Synchronous Buck Regulator. Can also be configured in flyback mode	Step-Down Regulator
LM25011	42V, 2A Constant On-Time Buck Regulator with Adjustable Current Limit	Step-Down Regulator
LMZ30604	4A SIMPLE SWITCHER® Power Module with 2.95V to 6V Input in QFN package	Step-Down Regulator
Linear Regulators		
Device	Description and Benefits	Type
LP38691	500mA, low dropout, CMOS linear regulator with tight output tolerance and excellent AC performance	LDO
TLV707xx	200mA LDO with low Iq and tight output regulation (2% typ). Offers excellent line and load transient performance	LDO
PMICs		
Device	Description and Benefits	Type
TPS65290	Power Management IC for smart grid space	PMU
TPS650250	Low-cost PMU for AM335x	PMU
TPS65250	Power Management IC for smart grid space with "last gasp" storage and release circuit	PMU
Voltage Supervisor and Reset		
Device	Description and Benefits	Type
TPS3700	UV, OV window voltage monitor with wide operating voltage range	Voltage Supervisor
TLV803/809/810	Industry-standard Voltage Supervisor with 200ms reset delay	Voltage Supervisor
TPS3808	Highly accurate (0.5% typ) supervisor with low Iq and adjustable reset delay	Voltage Supervisor
Chargers		
Device	Description and Benefits	Type
BQ24171	Highly integrated 1 to 3 cell Li-ion/Li-polymer charger with battery detection, pre-conditioning, charge monitoring and termination	Battery Charger
BQ25504	Ultra-low-power boost converter with battery management for energy-harvester applications	Boost controller, Battery charger, MPPT controller

Smart Grid Communications

Data Concentrators

Advanced Metering Infrastructure (AMI) networks are the foundation for Smart Grid deployments around the world. AMI provides the two-way communications necessary for utilities to automate billing, remote connect/disconnect of individual meters, and implement demand response programs. AMI networks also provide the ability for real-time monitoring of grid operations and immediate notification of outages to speed utilities' ability to respond and restore power to energy consumers quickly and efficiently.

Data concentrators play a key role in AMI networks as they are the point of interaction between the utility's central operations network and individual end points. The data concentrator nodes securely aggregate data from a network of meters sends it to utility servers.

TI AMI data concentrator solution provides a secure, high performance reference that maximizes the number of end points serviced and therefore reduces the utility's overall cost of deployment. The data concentrator solution supports both wired AMI networks such as PLC and wireless AMI networks using low-power RF mesh or star topologies.

For PLC networks using the PRIME or G3-PLC standards, TI offers a complete software solution which separates the real-time functions into the F28PLC91 processor while keeping the upper levels of the stack on the AM3359 host MPU running Linux. This allows developers to write applications in a familiar environment quickly and easily.

Evaluate TI's solutions for data concentrator based on ARM™ technology. Support up to 2000 nodes G3-PLC standard, PRIME standard, IEEE-1901.2 standard

Supports control and data communications: 2x Ethernet, 3-phase PLC interface, sub-1-GHz and 2.4-GHz RF, 2x RS-232, 3x RS-485

Designed to best practices for high-speed systems: Good reference for design passing ESD system tests; BOM and schematics available

Hardware Features

- Isolation to prevent damage from high-voltage currents
- Three-phase PLC module support
- On-board 120-/240-V power supply
- AM335x processor:
 - Sitara™ processor for upper-level data concentrator stack and communications
 - Full Linux BSP supported by TI
- Temperature sensor
- Sub-1-GHz and 2.4-GHz RF
- Infrared receiver and transmitter
- 2x USB
- 2x Ethernet
- 2x RS-232
- 3x RS-485

Data Converter Reference Design

TIDEP-0006	Reference Design	
TMDSDC3359	Evaluation Module	\$699

Data Concentrator Devices

Product	Benefits
AM3359 ARM-Cortex A8 MPU	<ul style="list-style-type: none"> • Up to 1GHz performance • Extensive peripheral set with 2x G-bit Ethernet, USB • Linux SDK
F28PLC91S	PLC processor supports PRIME, G3-PLC, IEEE-1901.2 across FCC frequency band
AFE032	PLC Analog front end for FCC frequency band
TPS65910A	Power Management IC with 4 DC/DCs, 8 LDOs, and RTC
TPS54620	4.5V to 17V input, 6A Synchronous Step-Down SWIFT™ Converter
UCC28710/22	Constant-Voltage, Constant-Current Controller with Primary-Side Regulation for Bipolar Power Devices
UCC28740	Constant-Voltage, Constant-Current Flyback Controller using Opto-Coupler Feedback

View more information at www.ti.com/smartgrid

Smart Grid Communications

Power Line Communications (PLC)

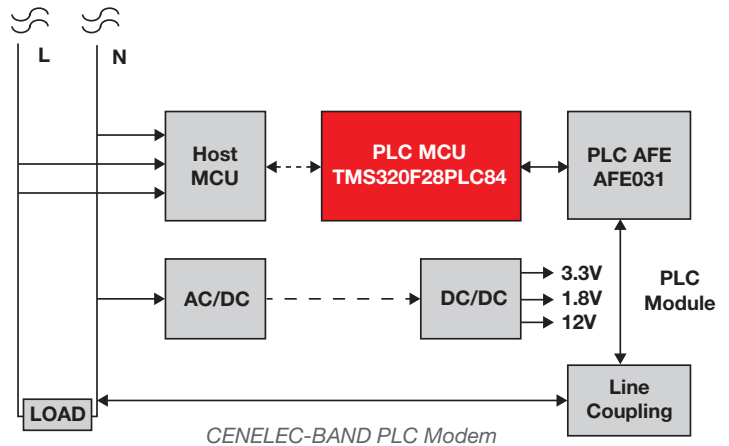
TI's Power Line Communication modem systems provide the best performing communication platform for today's Smart Grid networks around the world. These PLC solutions provide the flexibility of a single hardware and software design that can support multiple standards and therefore a single global platform, which reduce R&D costs and speed time to market.

TI's PLC reference designs have achieved official certification from the G3-PLC Alliance for the CENELEC and ARIB frequency bands and from the PRIME Alliance for the CENELEC frequency band.

TI's proprietary PLC Lite technology offers a compelling option for low-cost communications in industrial systems where compliance to industry standards is not required. PLC Lite is based upon modern OFDM modulations techniques and therefore provides a robust solution in noise-filled environments.



Complete information about TI's PLC solutions is available at www.ti.com/plc



TMDSPLCKITV4 Power Line Communications Developer Kits

- Choice of chipset optimized for CENELEC, ARIB, or FCC frequency band
- Two PLC modems based upon a small System on Module (SOM) form factor
- PLC SOMs may be purchased separately for rapid prototypes.
- TI's Zero-configuration GUI diagnostic tool
- Downloadable software development kit for PRIME, G3-PLC, IEEE-1901.2, or PLC-Lite standards.



TMDSPLCKITV4-CEN



SOMPLC-F28PLC83

Reference Designs for PLC

PLC Standard	Frequency Band	Chipset	Reference Design
PRIME™ or G3-PLC	CENELEC (10kHz-90kHz)	TMS320F28PLC84 + AFE031	TIDM-SOMPLC-F28PLC83
G3-PLC™	ARIB (154kHz – 453kHz)	F28M35 + AFE032	TIDM-SOMPLC-F28M35
G3-PLC™ or IEEE-1901.2	FCC (154kHz-490kHz)	F28PLC90 + AFE032	TIDM- SOMPLC-F28PLC90
PLC Lite	CENELEC (10kHz-90kHz)	TMS320F28035 + AFE031	TIDM-SOMPLC-INDUSTRIAL-CENELEC
PRIME, G3-PLC, IEEE-1901.2, PLC Lite	CENELEC, ARIB, FCC	Docking station for all PLC designs. Supplies power and line coupling to AC mains.	TIDA-00192
PRIME, G3-PLC, IEEE-1901.2	CENELEC, ARIB, FCC	AM3359 ARM Cortex-A8 MPU	TIDEP0006

PLC Development Tools

CENELEC Frequency Band	TMDSPLCKITV4-CEN	\$499
CENELEC Frequency Band SOM only	SOMPLC-F28PLC83	\$79
ARIB Frequency Band	TMDSPLCKITV4-ARIB	\$499
FCC Frequency Band	TMDSPLCKITV4-FCC	Contact TI
PLC Data Concentrator	TMDSDC3359	\$699

View more information at www.ti.com/smartgrid

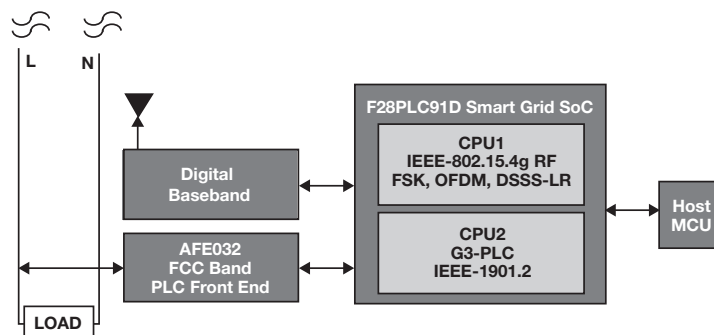
Smart Grid Communications

Wireless Communications

Sub-1GHz

TI's SimpleLink™ CC11xx, CC12xx Smart RF Transceivers and the next generation SimpleLink™ Sub-1GHz Wireless MCUs offer high performance, best-in-class range and co-existence and leading low power consumption. Our Sub-1GHz portfolio has a broad range of options to meet the design needs for large AMI networks in regions across the world.

TI's Sub-1GHz RF solutions support the IEEE-802.15.4g standard FSK modulation. The optional OFDM and DSSS modulations are also supported with a high-performance software defined radio solution.



The hybrid network offers compatibility with legacy systems through 802.154g FSK, high data rates with 15.4g OFDM, and extreme sensitivity with 15.4g DSSS modulations. IEEE-1901.2 PLC adds connectivity to end points difficult to reach with RF.



Sub-1GHz Devices

Device	Benefits	Reference Design and Development Tool
CC1200 Transceiver	Data rates up to 1Mbps, +16dBm output power.	CC120XEM-868-930-RD CC120XEM-420-470-RD
CC1120/1125	Narrowband Transceiver with channels down to 6.25kHz. Receive sensitivity of -129dBm.	CC1120EM-868-915-RD
F28PLC91D	Dual-core 32-bit MCU optimized for 802.15.4g RF and narrowband PLC processing.	Contact TI

ZigBee®

A longstanding promoter of the ZigBee Alliance, TI is a leading supplier of IEEE 802.15.4 ZigBee solutions. Certified by the ZigBee Alliance to meet all conformance and interoperability standards, TI's ZigBee solutions provide both the superior performance and low power consumption that make them ideal choices for wirelessly connecting electric meters, flow meters, and home energy gateways.

Complete solutions are available either standalone with TI's Wireless Microcontroller (MCU) devices, such as the CC2538, which execute all layers of the ZigBee stack plus application profiles; or as Wireless Network Processors that allow a central host processor to combine multiple protocols and applications.



Key Products for ZigBee Communications

Device	Key Benefits	Reference Designs and Development Tools
CC2538	Highest performance ZigBee Wireless MCU with ARM® Cortex®-M3, 512KB flash. Single-chip solution for ZigBee Smart Energy Profile 1.x coordinators and end points	CC2538-CC2592EM-RD
CC2533	Optimized system-on-chip (SoC) solution for IEEE 802.15.4 based systems. Wireless Network Processor for ZigBee Smart Energy Profile 1.x coordinators and end points.	CC2533EMK
CC2592	2.4GHz range extender. Increase range by 7x with +22dBm output power, low RX/TX current consumption, and small 4x4mm package.	CC2538-CC2592EM-RD

View more information at www.ti.com/smartgrid

Smart Grid Communications

Wireless Communications

Wi-Fi

Wi-Fi® is a key technology in driving the Internet of Things (IoT) by enabling devices to connect directly to each other or to broader networks. With generations of RF and Wi-Fi IP expertise, TI is the world's leading supplier of embedded Wi-Fi products for portable, battery-powered devices.



Start your design with the industry's first single-chip MCU with built-in Wi-Fi connectivity. Created for the Internet of Things (IoT), the SimpleLink CC3200 device is a wireless MCU that integrates a high-performance ARM Cortex-M4 MCU, allowing customers to develop an entire application with a single IC. With on-chip Wi-Fi, Internet, and robust security protocols, no prior Wi-Fi experience is required for faster development.

View more information at www.ti.com/smartgrid

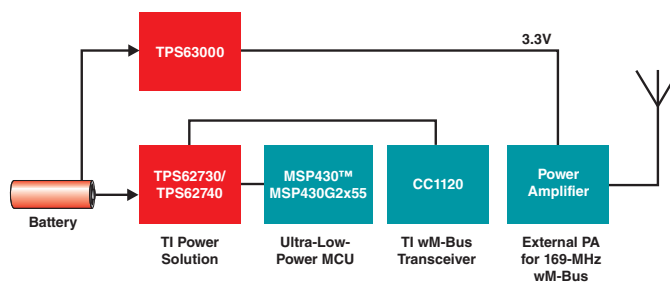
Key Products for Wi-Fi Communications

Device	Benefits	Reference Design and Development Tool
CC3200	SimpleLink Wi-Fi Wireless MCU with ARM Cortex®-M4 , integrated Wi-Fi connectivity, security.	TIDC-SMARTPLUG-WIFI
CC3100	SimpleLink Wi-Fi Wireless Network Processor provides easy connectivity for Smart Grid applications. Fully integrated 802.11 b/g/n radio, baseband, and MAC. Serial interface to any 8, 16, or 32-bit MCU	CC3100BOOST-RD

Wireless M-Bus

The Wireless M-Bus protocol has become the choice for many Smart Grid deployments due to its simple star network topology using either the ISM 868MHz band or the 169.4MHz sub-band.

TI's complete Wireless M-Bus solutions support both frequency bands with a combination of ultra-low power MCUs, CC11xx and CC12xx SmartRF transceivers, robust and field-proven software stack, and high-efficiency, RF-friendly DC/DC power supplies. The Wireless M-Bus solution is fully compliant with EN 13757-4 modes N,C S, and T.



Key Products for Wireless M-Bus Communications

Device	Benefits	Reference Design and Development Tool
CC1120	Narrowband Transceiver with channels down to 6.25kHz	CC1120EM-868-915-RD CC1120EMK-169
MSP430F5438A	Ultra-low power MCU with 256KB flash.	MSP-EXP430F5438
CC1310	Ultra-low power Wireless MCU with ARM® Cortex®-M3, 128KB flash. +14dBm output power. Package as small as 4x4mm and consumption less than 6mA.	Contact TI
TPS62730	Step-down buck converter for Ultra-low power wireless applications	TPS62730EVM-726

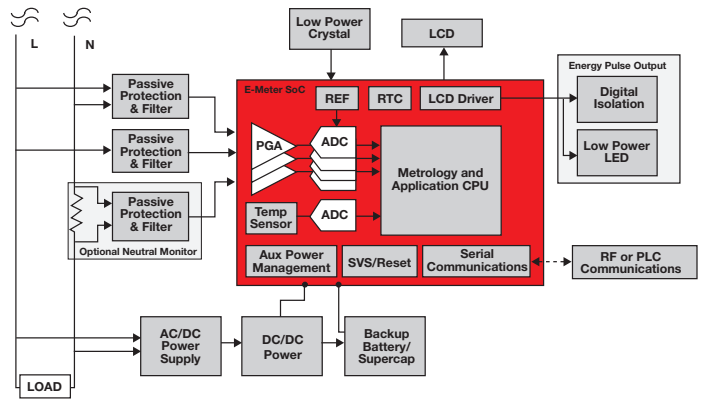
View more information at www.ti.com/smartgrid

Industrial Energy Measurement

Utility Meters

Utility-grade electric meters demand great reliability, security, and integration to provide the best value to consumers. Texas Instruments' solutions meet the industry's needs for efficient energy measurement in utility-grade meters. TI's utility meter SoCs are designed to meet all requirements of the ANSI C12.20 and IEC 62053 standards. TI's utility meter metrology solutions include sophisticated anti-tampering protection to protect meter integrity and reduce non-technical losses in the field.

View more information at www.ti.com/metering



Single-Phase Utility Meter

Smart Utility Meters Reference Designs and Development Tools

Name	Description and Benefits	TI Design or Tool
Class 0.2 Single-Phase Meter	Better than Class 0.2 accuracy across 2000:1 dynamic range. Calculates all energy measurement parameters. Expandable with communications interface.	TIDM-SINGLEPHASEMETER EVM430-F6736
Class 0.5 Single-Phase Meter	Class 0.5 accuracy with universal input voltage range. Calculates all energy measurement parameters.	TIDM-SINGLEPHASEMETER FE427A, EVM430-FE427A
Low-Cost Two-Phase Electric Meter	Class 1.0 accuracy with universal input voltage range. Calculates all energy measurement parameters.	TIDM-TWOPHASEMETER-I2040
Class 0.2 Three-Phase Meter	Better than Class 0.2 accuracy across 2000:1 dynamic range. Up to 512KB flash and expandable with communications interface.	TIDM-THREEPHASEMETER-F6779 EVM430-F6779
Class 0.5 Three-Phase Meter	Better than Class 0.5 accuracy across 2000:1 dynamic range. Up to 128KB flash and expandable with communications interface.	TIDM-THREEPHASEMETER-F67641 EVM430-F67641
Implementation of a 3-Phase Rogowski Coil Based Electric Meter	Class 0.5 accuracy using low cost Rogowski coils. Efficient software integration of Rogowski coil output.	TIDM-3PHMETER-ROGOWSKI
Three-Phase Meter with WiFi connectivity	SimpleLink™ Wi-Fi connectivity is added to Class 0.2 three-phase meter.	TIDC-3PHMTR-WIFXR

Power Supply Reference Designs for Smart Utility Meters

Name	Description and Benefits	TI Design or Tool
Primary-Side Regulated Flyback Supply	Wide V_{IN} capability (85V _{AC} to 265V _{AC}) with 5V/0.3A output. Integrated MOSFET and low component count.	PMP9689
Primary-Side Regulated Isolated Flyback Supply	Universal mains supply with 24V @ 25mA output. Quasi-resonant controller with integrated MOSFET. 82% full load efficiency.	PMP8590
Non-Isolated Flyback Supply	Quasi-resonant controller with 184V _{AC} -707V _{AC} input. Outputs 12V@1A and 3.3V@100mA. 84% efficiency at full load.	PMP8678
Primary-Side Regulated Flyback Supply for meters with Power-Line Communications	Universal mains supply with 15V/20W output followed by optional DC/DC and LDO stages for 5V, 3.3V, 1.8V, and 1.2V.	PMP9185.4

Power Supply Products for Smart Utility Meters

Device	Key Benefits
UCC28710/22	Constant-Voltage, Constant-Current Controller with Primary-Side Regulation for Bipolar Power Devices
UCC28740	Constant-Voltage, Constant-Current Flyback Controller Using Opto-Coupler Feedback
UCC28910	700V Flyback Switcher with Constant-Voltage Constant-Current and Primary-side Control
LM5017	100V, 600mA synchronous step-down regulator with integrated high side and low side MOSFETs.
TPS54060A	60V, 0.5A, step down regulator with an integrated high side MOSFET.



EVM430-F6736



EVM430-F6779



EVM430-F67641

Firmware for Energy Measurement and Utility Meters

The TI Energy Library provides proven firmware for all energy measurement parameters needed in utility meters and industrial applications. The Energy Library is provided without charge in source code format with each development tool.

The TI DLMS/COSEM Library is available for the MSP430™ MCU products. All COSEM classes are supported along with the Public Client, Meter Reader, and Utility Setting associations. The DLMS library is downloadable in object code format via part number DLMSOBJ-EVAL.

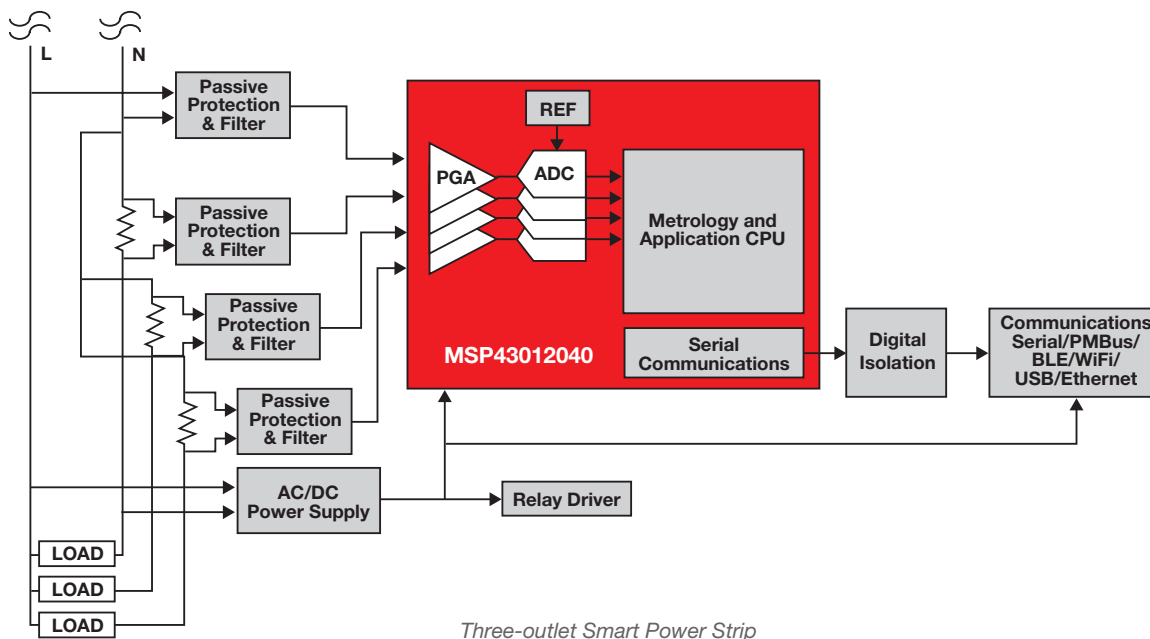
Industrial Energy Measurement

Industrial Energy Measurement

Accurate energy consumption measurement is becoming more important for businesses and consumers as they work to control their energy costs. Data center operators seek to measure the power consumed by individual servers in order to monitor efficiency and accurately bill customers for web or cloud hosting services. Consumers wish to monitor the energy consumed by major home appliances in an integrated home automation system with easy access to their data.

TI's industrial energy measurement solutions provide OEMs with rapid development time, flexibility, and low cost of ownership. The AFEs for embedded energy measurement are complemented by complete, ready-to-use firmware packages which provide all required energy and power consumption results.

TI's Industrial Energy Measurement reference designs include energy measurement and communications options such as WiFi .



Reference Designs for Industrial Energy Measurement

Name	Description and Benefits	TI Design or Tool
Class 0.2 Single-Phase Meter	Better than Class 0.2 accuracy across 2000:1 dynamic range. Calculates all energy measurement parameters. Expandable with communications interface.	TIDM-SINGLEPHASEMETER EVM430-F6736
Server Power Monitor	Single-phase energy measurement with Class 0.5 accuracy. Measures active, reactive, and apparent power along with power factor. Automatic switching between AC and DC input.	TIDM-SERVER-PWR-MON
Two Phase Embedded Meter	Measures active, reactive, and apparent power along with power factor on each of two phases independently. Achieves better than Class 0.2 over 30mA to 30A range.	TIDM-2PHASE-SUBMTR
Wi-Fi-enabled Smart Plug	Class 0.5 measurement accuracy with SimpleLink™ Wi-Fi connectivity. Compact design with minimal component count to minimize BOM cost.	TIDC-SMARTPLUG-WIFI

Industrial Energy Measurement Devices

Product	Benefits
MSP430I2040	<ul style="list-style-type: none"> Low-cost energy measurement MCU Flexible configuration of four sensor inputs for voltage and current Small package size for small form factor products
UCC28910D	<ul style="list-style-type: none"> 700V Flyback Switcher with Constant-Voltage Constant-Current and Primary-side Control
TPS77033	<ul style="list-style-type: none"> Single-output 50mA LDO, low quiescent current
ULN2003LV	<ul style="list-style-type: none"> Low-power relay driver

View more information at www.ti.com/metering

Flow Metering

Smart Metering for Gas/Water/Heat/Heat Cost Allocator

TI provides complete system design solutions for flow meters that are optimized, to provide extended battery life and long-term reliability.

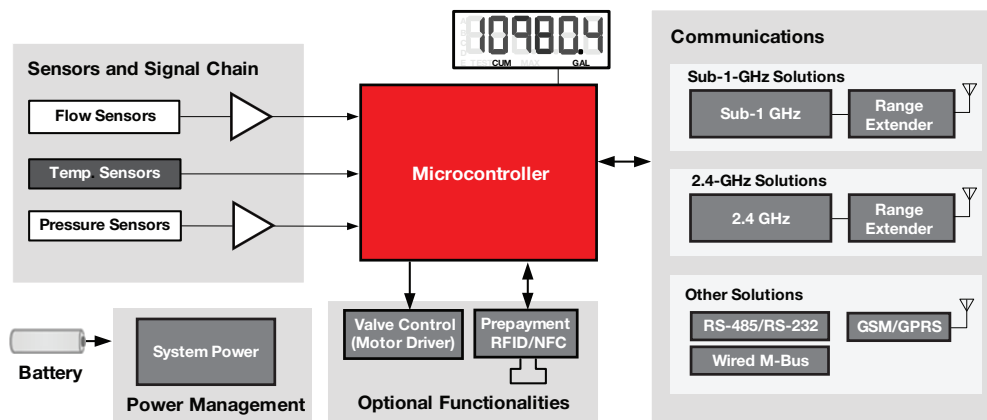
TI features the world's lowest power MCU to provide extended battery life and long-term reliability. The new FRAM-based ultra-low-power MSP430™ microcontroller brings faster writes as well as unmatched endurance and flexibility to enable constant on-the-fly data logging and faster, simpler wireless firmware updates. TI's new FlowESI GUI eases sensor setup in software and EnergyTrace++™ technology enables developers to debug power consumption down to the peripheral-level like never before while maintaining high dynamic range from nA to mA.

TI's DC/DC converters and LDOs with dynamic voltage scaling (usually implemented with a V-Select logic pin) can further increase battery life. As part of maximizing battery life, the correct selection of an ultra-low quiescent current power management device is a key to optimizing the low power of the MCU. While running the MCU directly from the battery may work (within the specified MCU operating range) and seem to save the cost of power management components, the lack of voltage regulation means much higher MCU stand-by power consumption and lower battery life.

TI delivers a broad portfolio of devices in the analog signal chain such as ADC and DAC converters, low-noise amplifiers, precision AFE for Time-of-flights (TOF) and Time-to-Digital Converter (TDC). High-performance data converters include 12- to 18-bit SAR ADC, 16- to 24-bit delta-sigma ADC, 10- to 16-bit pipeline ADC, and 8- to 20-bit DACs. Usually the voltage is digitized with precision ADCs. The mechanical forces in meters can be measured/detected by various types of sensors. Because voltages are very low, precise low-noise amplifiers (for flow and temperature), and instrumentation amps (for pressure) such as the OPA2209 and INA10x, respectively, are needed at the front end. The Time-of-Flights (TOF) and Time-to-Digital Converter (TDC) are intended for ultrasonic sensing applications.

TI provides the Low Power RF portfolio (both sub-1GHz and 2.4GHz solutions) that interface with a TI MCU. This type of communication enables features such as early leak detection in the water meter solutions as well as monitoring and customer awareness.

TI solutions also support optional functionalities such as remote valve control using DRV family of motor drive control devices and NFC prepayment using TI's RFID/NFC transceiver ICs.



TI Flow Sensing Solutions

Sensing Techniques	Sensor Types	TI Solution	Benefits	Actions
Rotation Detection	<ul style="list-style-type: none"> LC sensors Magnetic sensors (Resistor ladder, GMR sensors) Optical sensors 	Flexible solution based on ESI + MCU + SW optimized combo	<ul style="list-style-type: none"> Continuous flow measurement in low power mode 5X less power consumption compared to equivalent software implementation 	
Ultrasonic Time of Flight (TOF)	Piezzo ceramic PMUT, CMUT	Flexible solution based on TDC + MCU + SW optimized combo	<p>Ultra-low-noise signal chain:</p> <ul style="list-style-type: none"> Offers customizable system to meet various system requirement Enables system differentiation for developers Provides optimized combination for accuracy and low power 	

View more information at www.ti.com/flowmeter

Flow Metering

TI Reference Designs

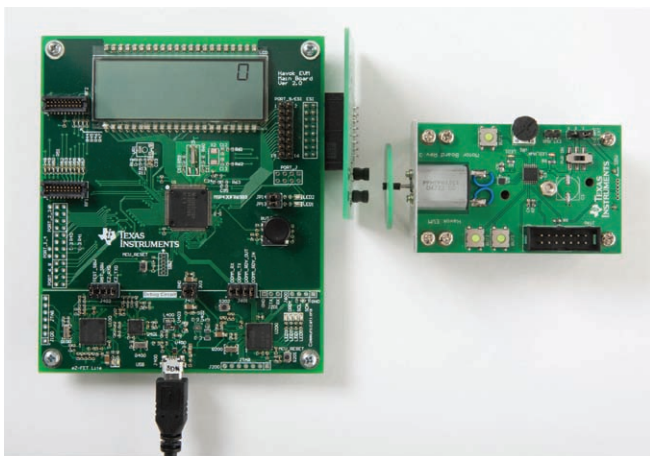
Water Meter Reference Design for two LC Sensors, Using Extended Scan Interface (ESI)

TIDM-LC-WATERMTR

One of the challenges in battery operated water meters is to continuously measure the water flow information while consuming as little energy as possible. TIDM-LC-WATERMTR design features a MSP430™ FRAM-based microcontroller with 100uA/MHz active-mode current, 450nA standby-mode current with the real-time clock enabled, and integrated low-power analog and digital peripherals. Additionally, the MCU offers for near infinite write endurance, quick/low-power writes, and data flexibility. This reference design demonstrates a usage example of the integrated Extended Scan Interface (ESI) on the microcontroller to achieve ultra-low power consumption compared with the same detecting methodology using an external circuit. In water meter designs, coupled to LC rotation detection sensor (provided), the ESI is continuously detecting the rotation of the propeller while the rest of the microcontroller is in a low-power mode. By using the ESI integrated in the MSP430 MCU, this design automates the measurement process and reduces CPU involvement, which helps to reduce overall power consumption.

Key Features

- Supports 2 LC sensors for detecting rotation movement including rotating direction
- Ultra-low power consumption compared with external hardware solution
- GUI for setting up and calibrating the ESI
- Easy to install daughter sensor board for MCU target board
- Motor control board with variable speed to simulate flow using metal plate
- RF socket available to enable low power RF extension (Sub 1GHz or 2.4GHz ZigBee)



Get more information: www.ti.com/tool/TIDM-LC-WATERMTR

Reference Designs

Name	Description	TI Design
Water meter reference design for two/three LC sensors, using Extended Scan Interface (ESI)	MSP430FR689 based on FRAM device uses two/three LC based sensors, enhanced scan interface to measure flow, motor control board to simulate flow rate with real-time update to LCD and RF modules	TIDM-LC-WATERMTR TIDM-3LC-METER-CONV
Water meter reference design for optical sensors, using Extended Scan Interface (ESI)	MSP430FR689 based on FRAM device uses optical sensors and enhanced scan interface to measure flow, motor control board to simulate flow rate, and real-time update to LCD and RF modules	TIDM-OPTICALWATERMTR
Water meter reference design for two GRM sensors, using Extended Scan Interface (ESI)	MSP430FR689 based on FRAM device uses GMR sensors and enhanced scan interface to measure flow, motor control board to simulate flow rate and real-time update to LCD and RF modules	TIDM-GMR-WATERMTR
Flow meter host MCU board with segment LCD and prepayment or dual RF option	Very quick implementation of a pre-payment function for flow meter application or any other ultra-low power application requiring segment LCD as well	TIDM-FLOWMETER-DUALRF
ETSI Cat. 1 receiver capable wM-Bus 169MHz RF subsystem for Smart gas and water meters	Very low-power, ETSI Cat. 1 Receiver capable RF subsystem for wM-Bus enabled Smart gas and water meters at 169MHz	TIDC-WMBUS-169MHZ
ETSI Cat. 2 receiver capable wM-Bus 868MHz RF subsystem for Smart gas and water meters	This reference design describes an ETSI Cat. 2 receiver capable RF subsystem for Smart meters, fully compliant with the most popular wM-Bus S, T and C-modes at 868MHz as per EN13757-4:2014	TIDC-WMBUS-868MHZ
TDC-based ultrasonic water meter	Achieves time resolution needed for gas and water ultrasonic time-of-flight measurements. Host can enter shutdown (power-saving) mode once measurement is initiated (until interrupt is received)	Contact TI representative

Flow Metering

Smart Metering for Gas/Water/Heat/Heat Cost Allocator

Smart Gas/Water/Heat Meter Products

Function	Part Number	Key Features	Category
Ultra-Low-Power Microcontrollers			
MSP430F448/F449 (48/60-KB Flash)	MSP430F417	32KB flash, 96-seg LCD	General Purpose
	MSP430F448	48/60KB flash, 160-seg LCD, hardware multiplier, temp sensor	
	MSP430FW429	60KB flash, LCD, scan interface peripheral for rotation detection in low-power mode (supports multiple types of sensors)	Scan Interface for Rotary Flow Meters
	MSP430FR5969	64KB ultra low power FRAM, RTC, ADC12 - 16ch, AES256	Embedded FRAM
	MSP430FR6989	128 KB ultra-low-power FRAM, RTC, ADC12 - 16 channel, AES256, ESI for rotation detection in low-power mode	ESI for Rotary Flow Meters
Apps Processor	MSP430F6736	128 KB flash, 320-seg LCD, RTC with battery backup, power management	High Performance
	MSP430F6638	256KB flash, 160-seg LCD, RTC with battery backup	
	MSP430F6779	512KB flash, 320 segment LCD, RTC with battery back-up power management	
MCU + RF System-on-Chip (SoC)	CC430F6147	Sub-1-GHz SoC, LCD; CC1101 transceiver, MSP430™ MCU	MCU + RF SoC
Connectivity			
Sub-1GHz	SimpleLink™ CC1101	Transceiver; low cost, low power; -116-dBm sensitivity	Proprietary RF wM-Bus
	SimpleLink CC1120	Transceiver; high performance, narrowband, -123-dBm sensitivity	
	SimpleLink CC1175	Transmitter; high performance, narrowband, 16-dBm TX power	
	SimpleLink CC110L	Transceiver; cost-optimized, -116-dBm sensitivity	Range Extender
	SimpleLink CC1190	RF front end; 27-dBm (0.5-W) TX power	
2.4GHz	SimpleLink CC2510	Low-cost SoC; 8051 MCU (up to 32KB flash), -103-dBm sensitivity	Proprietary RF
	SimpleLink CC2520	Transceiver; 8051 MCU (up to 256KB flash), -98-dBm sensitivity	ZigBee®/IEEE 802.15.4
	SimpleLink CC2530	SoC; 8051 MCU (up to 256KB flash), -97-dBm sensitivity	
	SimpleLink CC2538	SoC; Cortex™-M3 MCU (up to 512K flash, 32K RAM)	
	SimpleLink CC2590	RF front end; cost-effective, for low-power apps, 14-dBm TX power	Range Extender
	SimpleLink CC2591	RF front end; cost-effective, for low-power apps, 22-dBm TX power	
	WL18xx	Transceiver module, integrated Wi-Fi® + dual-mode Bluetooth®, MIMO, extended range, Wi-Fi direct concurrent operation	Wi-Fi
	SimpleLink CC3100	Self contained Wi-Fi network processor, easy to use security and integrated internet protocols	
	SimpleLink CC3200	Contains CC3100 network processor + ARM Cortex M4 MCU which is fully programmable	
Wired M-Bus	TSS721A	Meter-Bus (M-Bus) transceiver; meets EN1434-3 standard	Wired M-Bus
Prepayment (RFID/NFC)	TRF7960A	RFID/NFC reader/writer IC; fully integrated protocol handling	RFID/NFC
	TRF7970A	RFID/NFC transceiver IC (supports reader/writer, peer-to-peer and card-emulation modes); fully integrated protocol handling; compliant to NFC standards NFCIP-1 and NFCIP-2	
Power Management			
PMIC	TPS65290	Power management IC for gas/water meters	Ultra-Low PMU
	TPS65250	Power management IC with "last gasp" storage and release circuit	PMU with 3 DC/DC Converters and Charge and Pump
Step-Down Regulator	TPS62730	Step-down converter with Bypass Mode for ultra-low-power wireless connectivity	Step Down Converter with Bypass Mode for Ultra Low Power Wireless Applications
	TPS62740	Ultra-low Iq, step-up converter with Bypass Mode for extended battery operation	
	TPS61291	Ultra-low Iq, step-up converter with Bypass Mode for extended battery operation	Low Iq Boost Converter
Additional Smart Functionalities			
Valve Control (Motor Driver)	DRV8830	Secure I ² C control interface; up to 1-A continuous current with inrush protection	Brushed
	DRV8832	Speed regulation: Constant speed over lifetime of battery	
	DRV8833	Up to 3-A continuous current with inrush protection	Brushed/Stepper
	DRV8835	Up to 3-A continuous current in a 2x3-mm package; split V _M /V _{CC} supplies	
	DRV8836	Tiny 2x3-mm package; dedicated sleep pin; 40-nA sleep current	Brushed
	DRV8837	Up to 1.8-A continuous current in a 2x2-mm package; split V _M /V _{CC} supplies	
Analog Front-End	TDC1000	Precision AFE for Time-of-Flights (TOF)	Ultrasonic AFE
Time to Digital Converter	TDC7200	Time-to-Digital Converter (TDC)	Ultrasonic TDC

Renewable Energy

Solar Power

Solar Grid Tie

A worldwide concern for future access to affordable, sustainable energy is driving the development of more efficient solar power generation. In any photovoltaic (PV) based system, the inverter is a critical component responsible for the control of electricity flow between the module, battery, loads, and power grid. The challenge is how to do this in an efficient, reliable and cost effective manner.

Solutions from TI

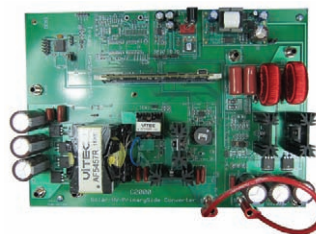
TI's grid-tied solar power solutions meet the technical demands of the smart grid. They enable reactive power handling, all necessary functions such as control of power stages, phase and frequency locking, and maximum power point tracking (MPPT) are implemented. All of these combine to create more robust and efficient grid-tied solar energy harvesting systems.

All of these functions require optimized intelligent control that can occur in real time or near-real time. Performance processors, such as the Texas Instrument's TMS320C2000™ family of microcontrollers, provide the high level of computational performance and programming flexibility needed for the real-time signal processing in solar power inverters. Highly integrated digital signal controllers help inverter manufacturers create more efficient, cost-effective and reliable products that can support the growing demand for solar energy. Combined with great analog products such as the SM72295 full bridge driver and the LM5017 flyback regulator TI provides complete reference designs for high performance, cost efficient solutions.

TI's Solar Micro Inverter Development Kit & Reference Design showcases the usage of a C2000™ MCU in a typical grid-tied micro inverter application. All necessary functions such as control of DC/DC boost stage via an active clamped flyback stage, control of DC/AC inverter, accurate grid phase and frequency locking, maximum power point tracking (MPPT),

and state machine control are implemented and full source code is available through controlSUITE. Key algorithms such as software phase locked loops, MPPT implementation, and PIDs are provided as optimized library blocks which can enable faster time to market for customers. TI Design: www.ti.com/ww/en/more/solutions/solar.shtml

Together, the **TIDM-SOLAR-DCDC** and the **TIDM-SOLAR-ONEPHINV** comprise a complete solar inverter for central or string topologies. TI's **C2000™ Solar MPPT DC/DC converter** is a digitally-controlled solar converter for use in central or string solar inverters. It is a companion to the C2000™ Solar DC/AC Single Phase Inverter (TIDM-SOLAR-ONEPHINV), a grid-tied, single phase, DC/AC inverter.



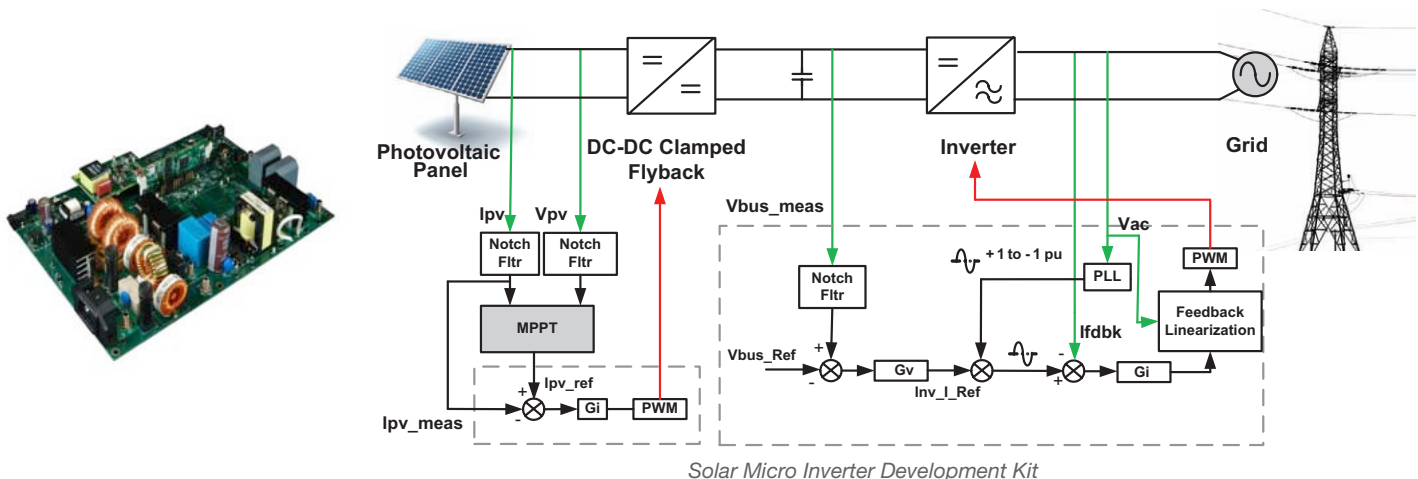
TIDM-SOLAR-DCDC



TIDM-SOLAR-ONEPHINV

TI's Power Line Communications (PLC) Lite™ Reference Design for Industrial Applications is a new option for adding communications to industrial equipment such as solar arrays. PLC Lite™ offers higher data throughput than earlier forms of PLC and greater robustness for transmission across noisy electric lines by using OFDM PHY technology. This design is based upon a C2000™ controlCARD and an analog front end for PLC.

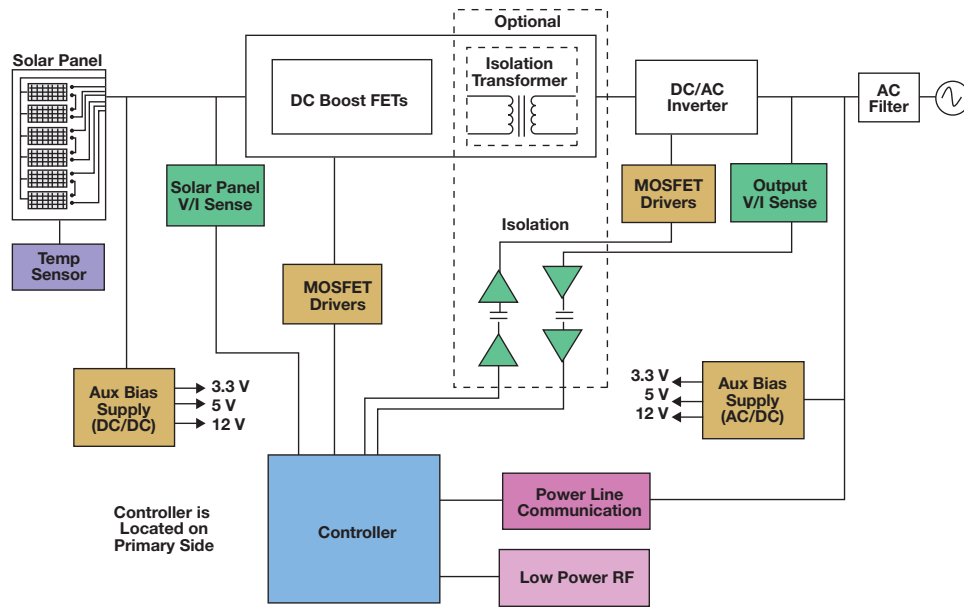
More information about PLC Lite is available as part of this TI Design: www.ti.com/tool/TIDM-INDUSTRIAL-PLC



View more at www.ti.com/solarpower

Renewable Energy

Solar Power



Solar Power Inverter Reference Design with PLC

Solar Power

Device	Description and Benefits	Type
TMS320F28035	Real-Time 32-Bit Microcontroller with programmable Control Law Accelerator, High-Resolution PWMs, and high-speed on-chip ADCs	C2000™ Real-Time Microcontroller
SM72295	3A, 100V Full bridge MOSFET gate driver with integrated current sense amplifier	MOSFET gate driver for DC/DC stage of the inverter
LM5017	600mA, 100V wide vin synchronous buck regulator	Integrated switch step-down DC/DC regulator for bias power
SM72482	Dual 5A low side MOSFET gate driver	MOSFET gate driver for DC/AC stage of the inverter
SM74101	7A low side MOSFET gate driver	MOSFET gate driver for DC/AC stage of the inverter
SM72238	Low Iq, 100mA, 30V Low Dropout linear regulator	Low dropout linear regulator for bias power

Solar Solutions

Name	Description	TI Design
C2000™ Solar DC/DC Converter with Maximum Power Point Tracking (MPPT)	This design is a digitally-controlled, solar DC/DC converter with maximum power point tracking (MPPT), for use in central or string solar inverters	TIDM-SOLAR-DCDC
C2000™ Solar DC/AC Single Phase Inverter	This design is a digitally controlled, grid-tied, single phase, full-bridge DC/AC inverter stage for use in central or string solar inverters	TIDM-SOLAR-ONEPHINV
Grid-tied Solar Micro Inverter with MPPT	This design is a digitally-controlled, grid-tied, solar micro inverter with maximum power point tracking (MPPT), which lends itself to many benefits, including elimination of partial shading conditions, increased system efficiency, improved reliability and greater modularity	TIDM-SOLARUINV
Solar Power Energy Harvester Reference Design Using a Super Cap	This design is a Solar charger and energy harvester using a highly integrated power management solution that is well-suited for ultra-low power applications from the microwatts (μ W) to milliwatts (mW)	TIDA-00242
Solar MPPT Charge Controller	This design is a 20A Maximum Power Point Tracking (MPPT) solar charge controller created for solar panel inputs corresponding to 12V and 24V panels. The design is targeted for small and medium power solar charger solutions.	TIDA-00120

View more at www.ti.com/solarpower

Renewable Energy

Solar Power

Solar Charge Controllers

As the reserves of non-renewable sources of energy (like coal, petrol etc) are depleting, there is an ever increasing demand for 'cleaner' sources of energy such as solar energy, wind energy, geothermal energy etc. to generate electric power. Solar Energy is a good choice for electric power generation, and it refers to the utilization of the radiant energy from the sun. The challenge to large scale solar power generation is to be able to cost effectively extract the solar power and have an effective storage mechanism

Solutions from TI

Photovoltaic (PV) cells are a good source to generate electrical energy directly from solar energy. Photovoltaic cells have mostly been used to power small and medium-sized applications. Since solar energy generation is not continuous in nature, most of these applications will also need a battery as a

storage mechanism. The solar energy from the PV array is fed to the battery using a charger circuit. Traditional chargers are deficient in extracting the full energy from the array. Because of the current-voltage characteristics of the solar cells, it will require an intelligent circuit between the panel and battery to utilize the maximum power available from the PV array, called a maximum power point tracker (MPPT).

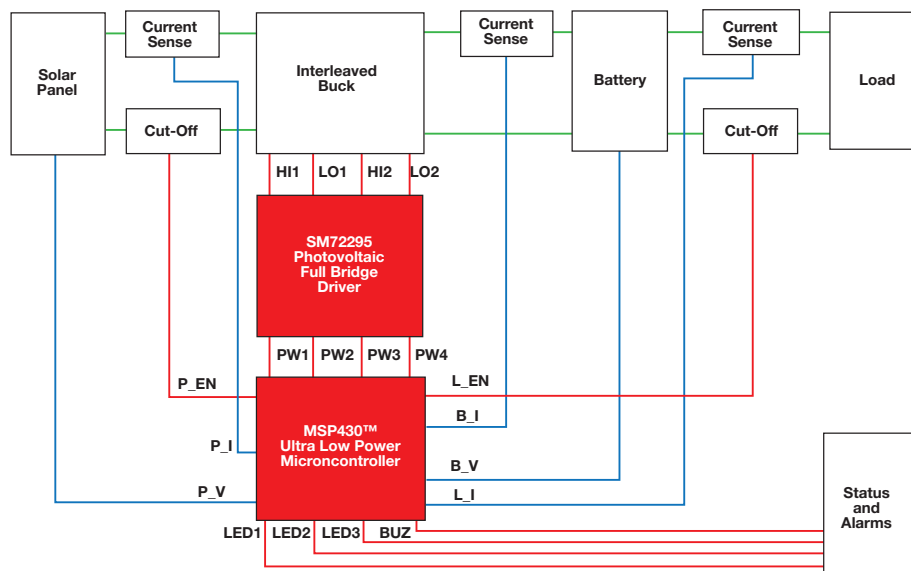
We present **TIDA-00120**, the hardware and software implementation of a maximum power point tracker using the ultra-low power MSP430™ microcontroller and highly integrated SM72295 gate driver. While MPPT implementation using a microcontroller is not new, the uniqueness of this solution is its high Integration, low standby power consumption and low cost, which extends the use of MPPT into the cost sensitive low power applications.

Solar Charge Controllers

Device	Description and Benefits	Type
MSP430F5152	The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency	MSP430™ Microcontroller
SM72295	3A, 100V Full bridge MOSFET gate driver with integrated current sense amplifier	MOSFET gate driver for DC/DC stage of the inverter
LM5019	100mA, 100V wide vin synchronous buck regulator	Integrated Switch step-down DC/DC regulator for bias power



Solar MPPT Charge Controller Evaluation Board
www.ti.com/tool/TIDA-00120



View more at www.ti.com/solarpower

Smart Grid & Energy Solutions

External Representation

TI maintains an active presence in global regulatory bodies:

- Bluetooth® Special Interest Group (SIG)
- ECHONET Consortium European Telecommunications Standards Institute (ETSI)
- G3-PLC™ Alliance
- HomePlug® Alliance
- IEEE 1901.2 narrowband PLC standard
- IEEE 802.15.4/IEEE 802.15.4g Smart Utility Network (SUN) wireless standard
- IPSO Alliance
- ITU-T G.9901, G.9902, G.9903, G.9904 narrowband PLC standard
- PRIME Alliance
- Wi-Fi Alliance®
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