

Smart Electric Energy Meter

Key Features

- Accurate electric meter readings for billing
- Display for meter reading
- Two-way communication
- Real-time remote monitoring and diagnostics
- Consumption and load trends
- In-built safety and tamper proof design
- Design compliant to various safety standards

A **Smart Electric Energy Meter** is a modern digital energy meter that measures the amount of electrical energy consumed by a residence, business, or an electrically powered device. The energy is measured in kWh, which is also the standard billing unit for electricity usage. It measures electricity usage in real-time or near real-time and enables two-way communication between the consumer's meter and the utility company. It allows real-time monitoring, remote reading, dynamic pricing, and remote disconnection and load control. A typical Advanced Metering Infrastructure (AMI) comprises an energy meter, a communication network and a control center. The smart energy meter collects detailed usage data and transmits it to the utility's control center via a communication network. The transmitted data is further analyzed by the data management tool for usage trends and billing.

The smart energy meters can be further classified by phase type:

Single-Phase Energy Meter

- Used in homes, apartments, and small businesses where supply is single-phase ($\approx 110V/230V/240V$).
- Measure household energy usage, enable prepaid/postpaid billing, and alert utilities about outages or tampering.

Three-Phase Energy Meter

- Used in industrial, hospitals, IT parks, and large commercial complexes running on 3-phase supply ($\approx 208V/240V/415V$).
- Monitors higher loads, detects unbalanced phases, and measures total energy consumption.

Split Phase Energy Meter

A split-phase supply is a residential or light commercial power system delivering 120V and 240V from two 120V lines, 180 degrees out of phase with a common neutral. It is common in North America. A split-phase energy meter is a device that accurately measures real-time energy usage in a split-phase system.

Smart Energy Meters enable accurate billing, real-time monitoring, and grid-interactive operation across residential, commercial, and industrial applications. Modern 3-phase meters measure voltage, current, power, and energy parameters with Class 0.2S-1 accuracy (IEC 62053/IS 16444), supporting 240 to 415V AC and currents up to 60 A+.



Key Features:

- Dynamic tariffs, demand response, load control, remote disconnect via latching relays
- **Communication:** RF, GPRS/4G, PLC, LPWAN (LoRa/ NB-IoT) for Advanced Metering Infrastructure (AMR)/ Automated Meter Reading (AMI)
- Tamper detection, Time-of-use (TOU) metering, event logging, LCD display
- Precision metrology ICs + secure MCUs

Standards Compliance: IEC 62052/62053 (metering equipment), IEC 62056/Device Language Message Specification (DLMS)/ Companion Specification for Energy Metering (COSEM) (communication), IS 16444 (Indian Standard).

Power Supply

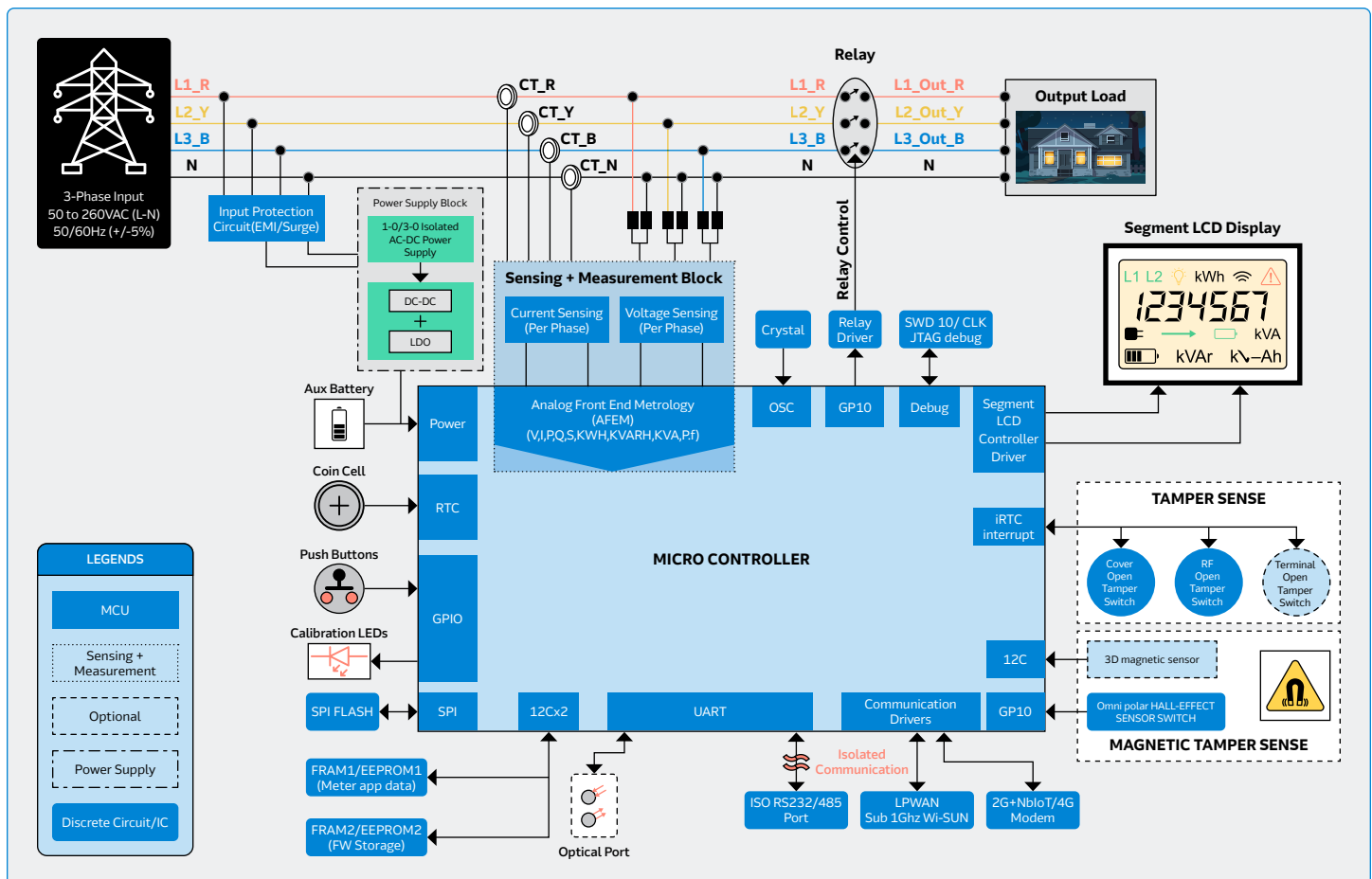
The smart energy meter integrates a robust power supply architecture designed to operate reliably under diverse grid conditions. The system is primarily powered from the AC mains via a high-efficiency isolated AC-DC

converter, a wide input voltage range (85V – 265V AC for single-phase or $3 \times 230\text{V}/415\text{V}$ AC for three-phase meters) into stable low-voltage DC rails.

These rails are further regulated by isolated and non-isolated DC-DC converters/LDOs to provide the multiple voltage levels required by the metering SoC, communication modules, discrete circuits/ICs, and the latching relay.

To ensure safety and compliance, the power supply incorporates input protection features, including overvoltage protection (OVP), undervoltage protection (UVP), overcurrent protection (OCP), and surge suppression in accordance with IEC 62052 and IEC 61000 standards for metering devices. For uninterrupted operation during power failures, the system incorporates auxiliary energy storage via a supercapacitor or rechargeable battery, supporting essential functions such as data retention, RTC operation, and tamper log preservation.

Figure 1: Electrical Energy Meter
Smart meters modernize grid efficiency through integrated subsystems for sensing, processing, secure communication, and control.



Sensing & Measurement

Voltage measurement is typically implemented through resistive divider networks or potential transformers (PTs), while current is sensed using current transformers (CTs), Rogowski coils, or precision shunt resistors, depending on the meter's accuracy class, load range and cost considerations.

A high-performance metrology IC/MCU with integrated sigma-delta ADCs and digital signal processing ensures precise waveform capture and real-time computation of electrical parameters. These ICs enable precise calculation of active, reactive, and apparent energy (kWh, kVARh, kVAh), power factor, harmonics, frequency, and phase angle — essential for both billing and power quality analysis. To meet regulatory accuracy classes (Class 0.2s, 0.5s, 1.0, or 2.0, as per IEC 62053 and IS 16444), smart meters use factory-calibration routines with temperature and drift compensation to ensure long-term stability.

In three-phase meters, multi-channel sampling ensures all phases are measured together, maintaining alignment and reducing errors.

Microcontroller Unit

The smart energy meter is powered by a high-performance MCU, which manages metering algorithms, handles sensor and communication interfaces, and ensures compliance with regulatory protocols. An integrated RTC provides accurate time stamping, which is critical for billing cycles, load profile management, and tariff synchronization with utility servers. Integrated memory (typically 256 KB – 512 KB Flash with additional EEPROM/ FRAM) stores consumption history, event logs, and calibration constants.

Communication Interfaces

Smart energy meters feature multiprotocol communication interfaces that enable seamless data exchange between the meter and utility back-end systems. Depending on deployment requirements, the meter supports RF, PLC, and cellular (GPRS/4G), and LPWAN technologies (LoRa, NBIoT), ensuring flexibility across urban, semi-urban, and rural networks. The communication module ensures reliable

data transmission over both short-range (RF/ PLC) and wide-area (cellular/ LPWAN) networks. Security and interoperability are maintained through industry standards such as DLMS/COSEM and compliance with IEC 62056 communication protocols.

These interfaces enable AMR for the periodic collection of consumption data, and AMI, which supports real-time monitoring, demand response, tariff management, remote connect/disconnect, and tamper/event reporting.

Display & User Interface

The User Interface of a smart energy meter is the primary interaction medium between the device and its users, including consumers, technicians, and utility operators. It typically consists of a segmented LCD or an LED display that provides real-time electrical parameters such as voltage, current, power factor, active and reactive energy, and tariff information. Visual indicators, such as load-status icons, tamper alerts, and communication activity, provide quick diagnostics. In addition to the display, the UI incorporates LED indicators, including a calibration-pulse LED for energy-measurement verification and status LEDs for communication activity and alarms.

Security & Tamper Detection

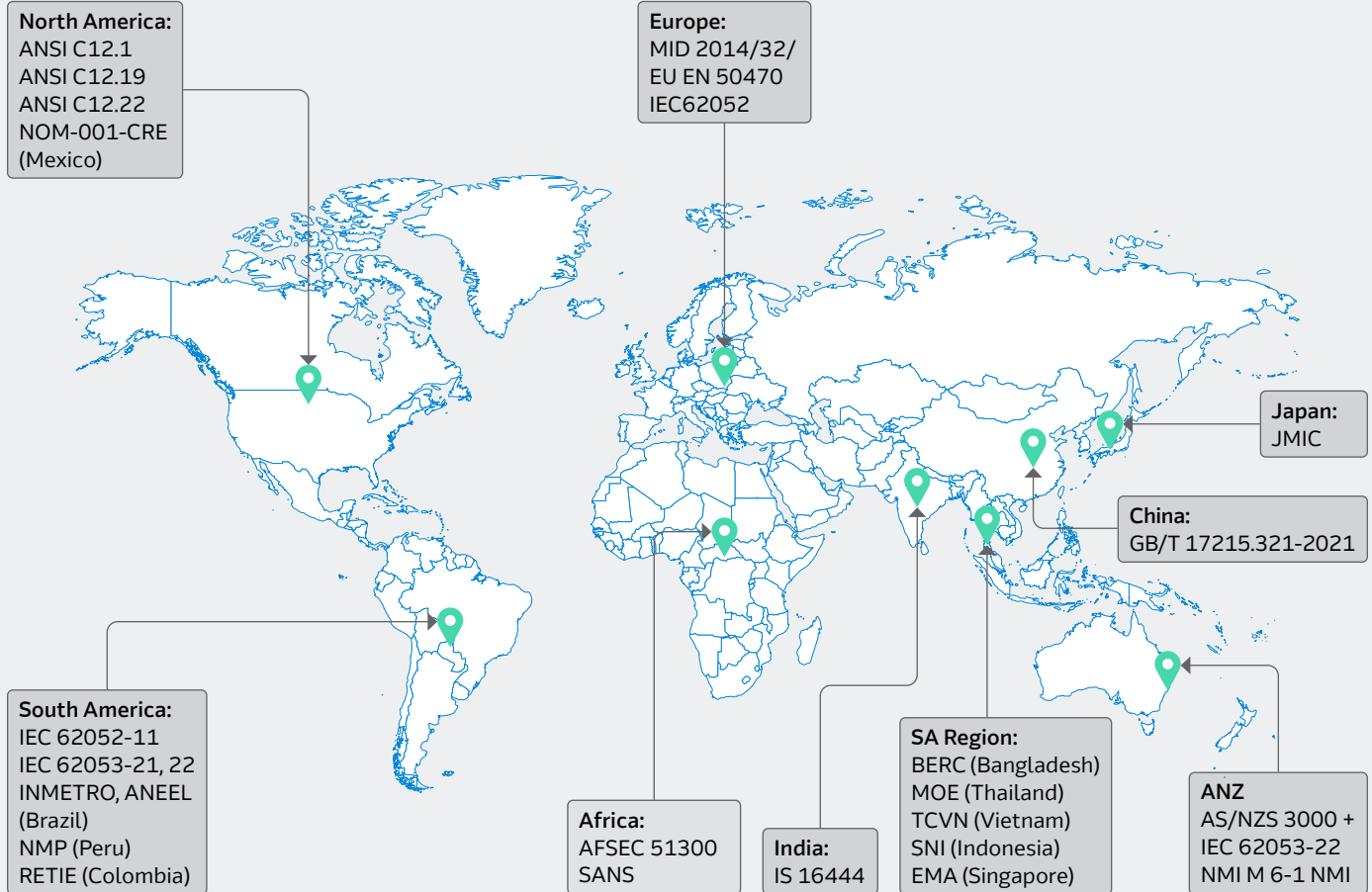
The smart energy meter uses built-in hardware and software security to prevent fraud and unauthorized access. Encryption standards such as AES-128/256 and secure authentication mechanisms ensure that all meter data is safe and accurate during storage and transmission.

DLMS Security Suites 0, 1, and 2 define different levels of security for smart meter communication, with Suite 0 being the most basic, Suite 1 using public-key cryptography for digital signing, and Suite 2 offering more advanced protection that can incorporate public-key cryptography with symmetric encryption.

The choice of a security suite depends on the communication security requirements and the specific algorithms supported by the smart meters and head-end systems.

In three-phase meters, multichannel sampling ensures all phases are measured together, maintaining alignment and reducing errors.

Safety & Security Standards



For tamper detection, the meter continuously monitors abnormal operating conditions, including:

- **Neutral Disturbance/ Earth Tamper** – detection of bypassing or missing neutral connections.
- **Magnetic Tamper** – identification of external magnetic interference attempts.
- **Reverse Current Flow** – detection of energy theft by reversing connections.
- **Cover Open/ Terminal Cover Tamper** – mechanical sensors log and report unauthorized meter access.
- **Voltage/ Current Imbalance** – identification of partial load bypass.

Events are logged in non-volatile memory with accurate timestamping and reported to the utility back-end via DLMS/COSEM event notification.

This enables utilities to take preventive actions, such as issuing alerts, implementing demand response, or remotely disconnecting, through the integrated latching relay.

Relay Control

The smart energy meter uses a latching relay, for remote power connect/disconnect. Utilities can manage service for nonpayment, overload, or safety events without manual intervention. The relay consumes power only during switching, ensuring energy efficiency and reliable long-term operation for single- and three-phase loads up to the full meter capacity.

Smart Energy Meter Line Card

Technology	Manufacturer	Part Number	Arrow Link	Data Sheet
POWER SUPPLY				
Protection	Littelfuse TDK	V20E510EP B72220S2681K101	Arrow link	Datasheet
DC-DC 12V to 5V Conversion	ST Microelectronics Microchip	L6983C50 MCP16301	Arrow link Arrow link	Datasheet Datasheet
Voltage References	onsemi	NCP431ACSNT1G	Arrow link	Datasheet
AC-DC Converter	ST Microelectronics Infineon Diodes Incorporated	VIPER267KDTR ICE5BR3995CZ AP3190	Arrow link Arrow link Arrow link	Datasheet Datasheet Datasheet
MEASUREMENT				
Signal Conditioning	Vishay ST Microelectronics	MMA02040C4703FB300 LMV324IDT	Arrow link Arrow link	Datasheet Datasheet
Current Sense	Infineon	TLI4971-A1205T5-E0001	Arrow link	Datasheet
Processing MCU	NXP Silabs Microchip	MKM35Z512VLL7 EFM32FG28 PIC32CXMT-SH	Arrow link Arrow link Arrow link	Datasheet Datasheet Datasheet
HMI				
Switches	Same Sky C&K Switches (Littelfuse)	TS04 Series, TS21-34-035-BK-160-SMT-TR PTS645x	Arrow link Arrow link	Datasheet Datasheet
LCD	NXP Tianma	PCF8553 C216x05 series	Arrow link Arrow link	Datasheet Datasheet
Tamper Sense	C&K Switches (Littelfuse)	PVA20AH53.5N	Arrow link	Datasheet
Buzzers	Same Sky	CPT-1203-03-SMT-TR	Arrow link	Datasheet
Secure Element	Infineon	OPTIGA TRUST B SLE 95250	Arrow link	Datasheet
MEMORY				
EEPROM	ST Microelectronics ROHM	M24M02DR BR24G-5A	Arrow link Arrow link	Datasheet Datasheet
Flash Memory	Winbond	W25Q80RVSSJQ	Arrow link	Datasheet
FRAM	Infineon	FM24V05	Arrow link	Datasheet
COMMUNICATION				
Optical Port (TX)	Everlight	IR333-3C	Arrow link	Datasheet
Optical Port (RX)	Everlight	PT334-6B	Arrow link	Datasheet
IR Receiver	Vishay	TSOP34838	Arrow link	Datasheet
Remote NiC (GPRS)	Neoway Quectel	N58 EC200N	Arrow link Arrow link	Datasheet Datasheet
Remote NiC (WiSUN)	Silicon Labs	EFR32FG28A120F1024 GM48-A	Arrow link	Datasheet
Remote NiC (Wirepass)	Silicon Labs	EFR32FG23A020F512G M40-B	Arrow link	Datasheet
Remote NiC (BLE)	Silicon Labs	EFR32BG22C224F512G M32-CR	Arrow link	Datasheet

For any questions regarding component selection for smart energy meters, please contact Arrow engineering.

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Technology	Manufacturer	Part Number	Arrow Link	Data Sheet
Remote NiC (Wi-Fi, Bluetooth, 802.15.4)	NXP	RW612	Arrow link	Datasheet
Remote NiC (Super Cap)	Cornell Dubilier Knowles	Eaton HV10302R7106-R	Arrow link	Datasheet
Remote NiC (DC-DC)	ST Microelectronics	STBB1AUPR	Arrow link	Datasheet
NFC (Near Field Communication)	NXP	PN7462AUHN	Arrow link	Datasheet
Ethernet Controllers	NXP	TJA1103	Arrow link	Datasheet
RS232/485 (Protection)	Littelfuse	SC1205-01ETG	Arrow link	Datasheet
Digital Isolators	Skyworks	Si88x2x	Arrow link	Datasheet
LOAD CONTROL				
Relay (Single Phase)	Golden Relay Panasonic FCL Components	ZC75N-2B-12SKWFTY DK1A-12V- F FTR-F1L	Arrow link Arrow link	Datasheet Datasheet Datasheet
Relay (Three Phase)	Golden Relay	ZC88N-90A-6V		Datasheet
Full Bridge Relay Driver	Allegro Rohm	A3908; A5989 BD69730FV-GE2	Arrow link	Datasheet Datasheet
TAMPER SENSE				
Open-Lid-Detection	C&K Switches (Littelfuse)	PS-221605-L NS, SDS	Arrow link	Datasheet
Magnetic 3D Hall Sensor	Allegro Diodes Incorporated Infineon	A31301 AH4930 TLV493	Arrow link Arrow link Arrow link	Datasheet Datasheet Datasheet
Hall Switch	Allegro Diodes Incorporated	CT813X; APS11753 AH180	Arrow link Arrow link	Datasheet Datasheet
TIMING				
Crystal	Abracon	Abracon ABS07 TXC 7XZ-32.768KBA-T	Arrow link Arrow link	Datasheet Datasheet
CONNECTORS				
SIM Card connector	Same Sky Molex	NSIM-15-C 047553-0001	Arrow link Arrow link	Datasheet Datasheet
Board to board connectors	Same Sky	CPG-03-SMT-TR	Arrow link	Datasheet
Ethernet connectors	Molex	44144-0005	Arrow link	Datasheet
THERMAL MGMT.				
Heat sinks	Same Sky	HSE-B20254-035H	Arrow link	Datasheet