# MAKING ELECTRICITY METERS SMARTER: WHY YOU SHOULD SWITCH TO A DISCRETE ARCHITECTURE USING PRECISION ADCS

New Product Update

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# Agenda

- What system level requirements are common across metering architectures?
- How does TI's new ADC and MCU products address those requirements?
- *Reference Designs using AMC131M03 and ADS131M08: 1ph and 3ph*
- How do energy metering architectures scale across these EEs?
- *Overview of Energy Metrology Library and Features*
- *Summary*

# Electricity meters: architectures

## Where do the energy calculations happen?

| | SoC (MSP430i20, MSP430F67) | ASSP | Discrete (ADS131M0x, AMC131M0x) |
|---|---|---|---|
| **Architecture** | All integrated in one SOC | ASSP + application processor | AFE + 1 controller (energy calculations + application processing) |
| **Number of output parameters** | Unlimited | Fixed | Unlimited |
| **Advanced metrology (such as load desegregation)** | Possible | Not Possible | Possible |
| **Measurement accuracy** | Low | Low | High |
| **Processor / controller BOM flexibility** | None | Flexible | Flexible |
| **Metrology firmware development** | *Depends | None | **Significant |
| **Silicon area (cost)** | High | Moderate | Low |

* Some metrology SoCs include some common metrology calculations which reduces the software development burden of the customer

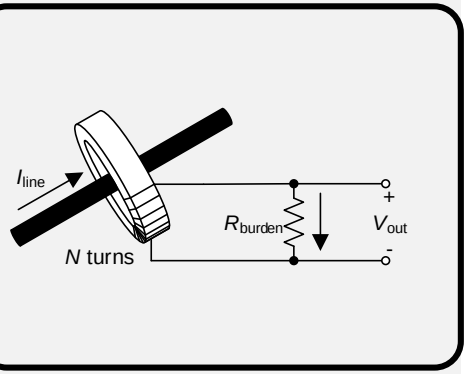
** We released a processor agnostic energy calculations firmware library to go with ADS131M0x, this will reduce the development effort for the customer - see backup slides at the end of this presentation

Link to Energy Library on ti.com

# Energy metering: sensor types

## Current sensor choice

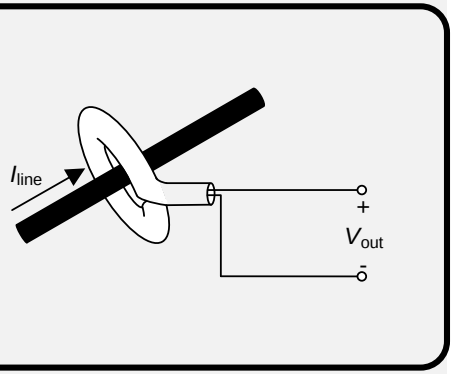
### Current transformer




$$V_{out} = \frac{I_{line} R_{burden}}{N_{turns}}$$

- **Provides isolation**
- Saturation possible
- Phase calibration required

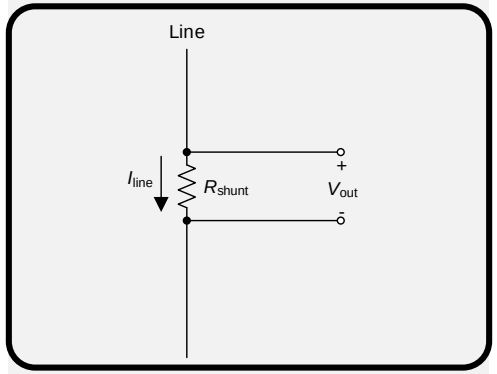
### Rogowski coil




$$V_{out} \propto \frac{dI_{line}}{dt}$$

- **Provides isolation**
- Saturation not possible
- Integration required
- Cannot measure DC

### Shunt




$$V_{out} = I_{line} R_{shunt}$$

- **Not isolated**
- Resistance may vary when self-heated
- Anti-magnetic
- Small form factor

| | Number of phases | |
|---|---|---|
| **Sensor** | **Single phase** | **Polyphase** |
| **CT** | **ADS131M0x** | **ADS131M0x** |
| **Rogowski** | **ADS131M0x** | **ADS131M0x** |
| **Shunt** | **ADS131M0x** | **AMC131M02/3** |

**!** Polyphase shunts require isolation between phases

Transmitting raw conversion data using SPI over digital isolation is too expensive

## Safety & standardization

| Norm | Specifications |
|---|---|
| IEC-61000-4-3/5/6 | EMC: radiated RF/surge |
| IEC-61000-4-2/4 | ESD 8kV contact-15kV air, EFT |
| IEC-61000-4-30 | Harmonic analysis |
| IEC-61010, UL2735 | Safety in e-meters |
| EN-50470 | requirements & test e-meter |
| IEC- 62051/52-21/23 | AC / DC testing for e-meter |
| CISPR11 / 32 / 25 | Radiated emission |
| ANSI C12 | Accuracy in e-meters |

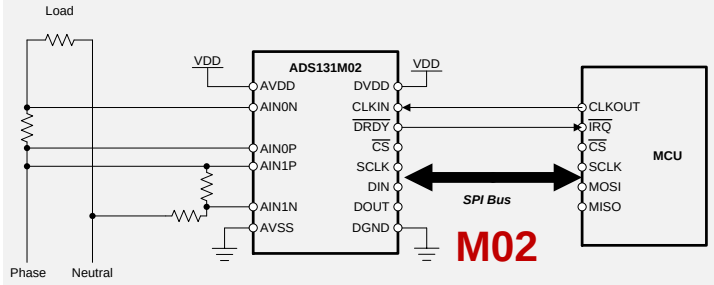
# How do TI's new ADCs + MCUs enable energy metering?

| EE requirement | TI ADC + MCU feature & benefit | CT | Shunt |
|---|---|---|---|
| **Measure 1 up to 3 phases - with or w/o neutral** | **Channel scalability when pairing TI ADC with TI MCU** | X | X |
| **RMS measurement of AC signal** | **ADC bipolar input range** | X | X |
| **Phase to phase synchronization** | **Ch to ch phase compensation** | X | |
| **Functional safety standards** | **Galvanic isolation (digital, power)** | X | X |
| **Wireless connectivity to cloud** | **Best in-class EMC performance** | | X |
| **Harmonic analysis (load desegregation)** | **ADC bandwidth** | X | X |

# Scalability: channel scaling to cover all combinations

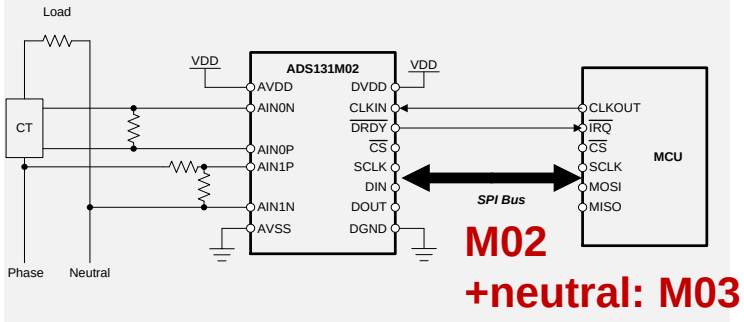
| | Number of phases | |
|---|---|---|
| **Sensor** | Single phase | Polyphase |
| **CT** | ADS131M0x | ADS131M0x |
| **Rog.** | ADS131M0x | ADS131M0x |
| **Shunt** | ADS131M0x | AMC131M0x |

## 1-phase shunt



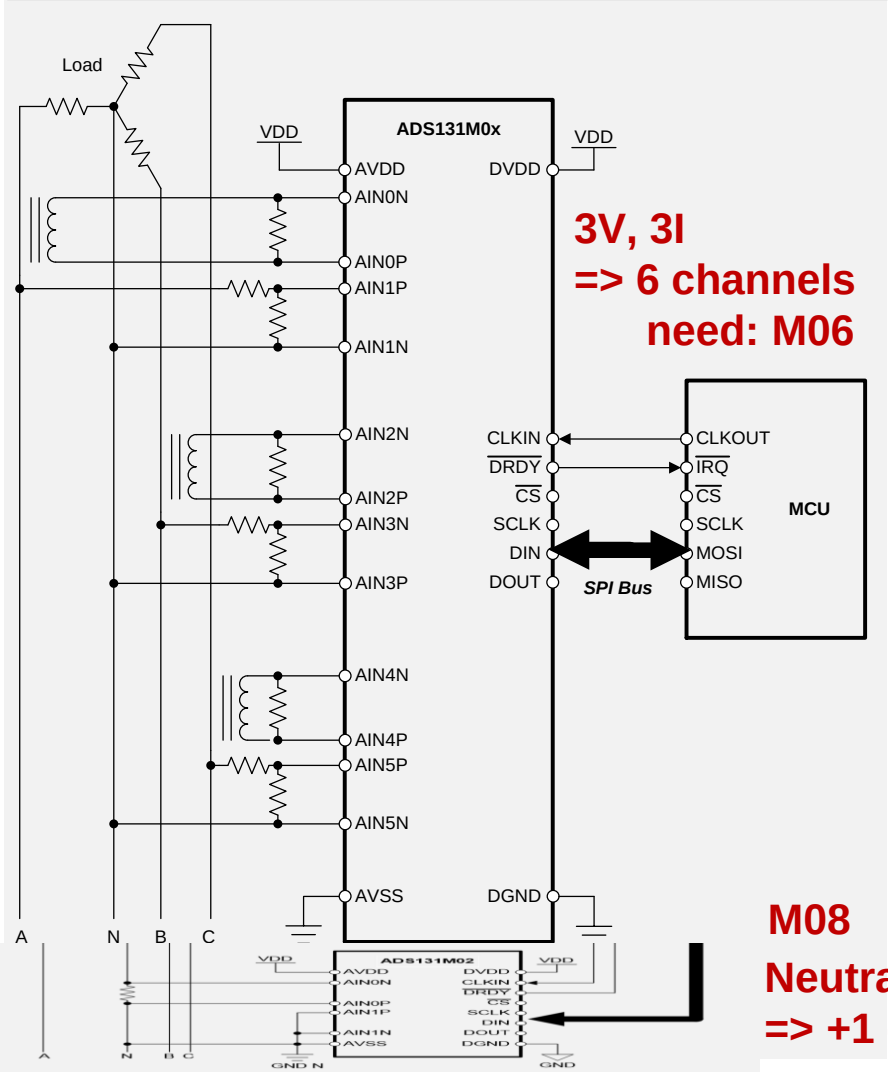

**M02**

## 1-phase current transformer




**M02**
**+neutral: M03**

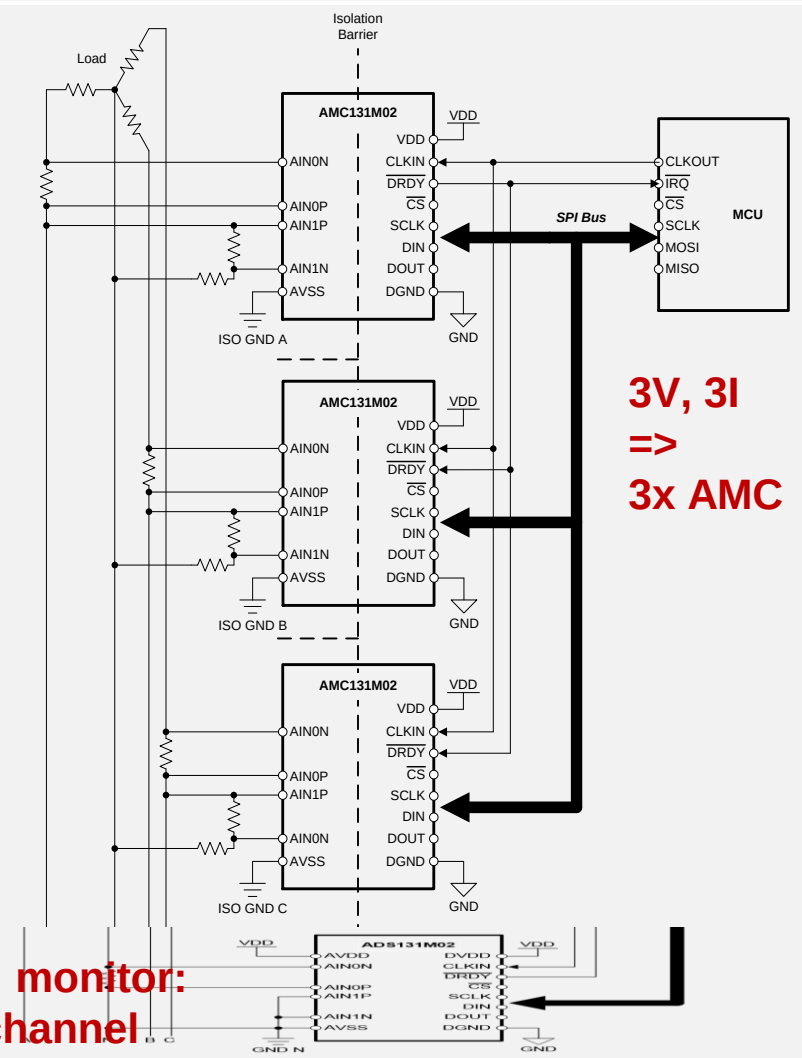
## 3-phase current transformer




**3V, 3I**
**=> 6 channels**
**need: M06**

**M08**
**Neutral monitor:**
**=> +1 channel**

## 3-phase shunt




**3V, 3I**
**=>**
**3x AMC**

# AMC131M02 / AMC131M03

Now APL'd

Multichannel **isolated** AFE for e-metering | 24-bit, 64 kSPS| **high accuracy** and **isolated power**

## Features

| | |
|---|---|
| **Resolution** | 24-bit |
| **# of Ch** | 2 / 3 |
| **Sample rate** | 64 kSPS |
| **Interface** | SPI |
| **DVDD** | 3 V to 5.5 V |
| **Input type** | Single-ended differential |
| **Temperature range** | -40°C to +125°C |
| **Package** | SOIC-20 |

**High dynamic range: 102-dB**

**Integrated data and power isolation**

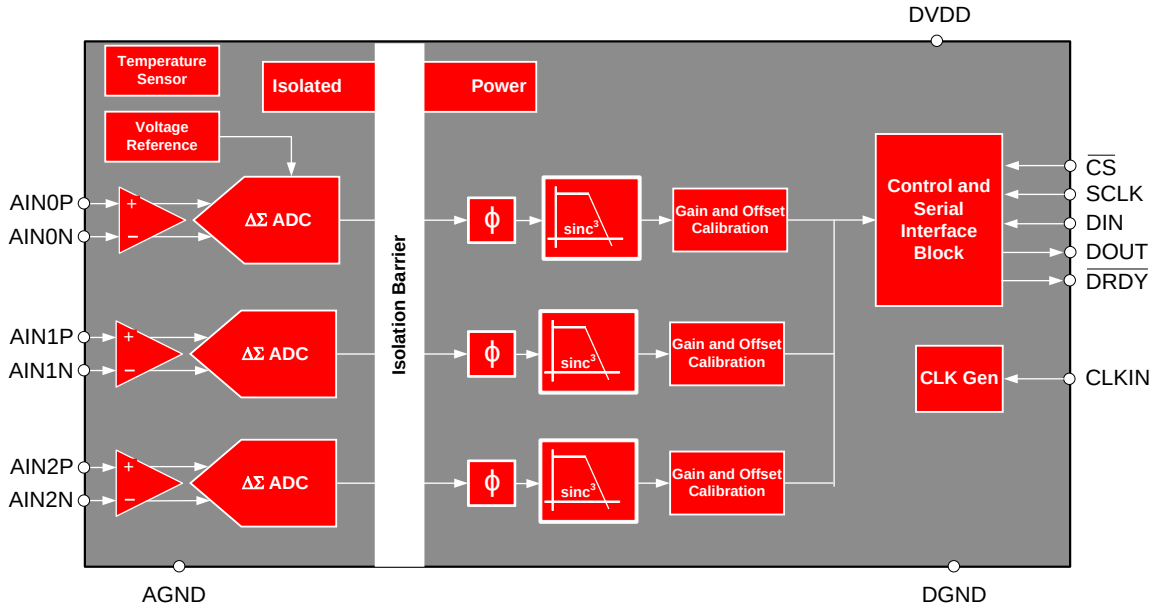
**Device features:**
Ch-to-ch phase delay
easy multi-device sync
high input impedance

## Applications

- Polyphase shunt energy measurement
- HEV/EV
- EV charging
- Power distribution unit (PDU)
- Energy storage unit
- Shunt current sensing

## Benefits

- Built in data and power isolation allows for phase-to-phase isolation for polyphase shunt metering applications
- Synchronization between devices allows high system accuracy
- Built in temperature sensor allows for easy temperature compensation

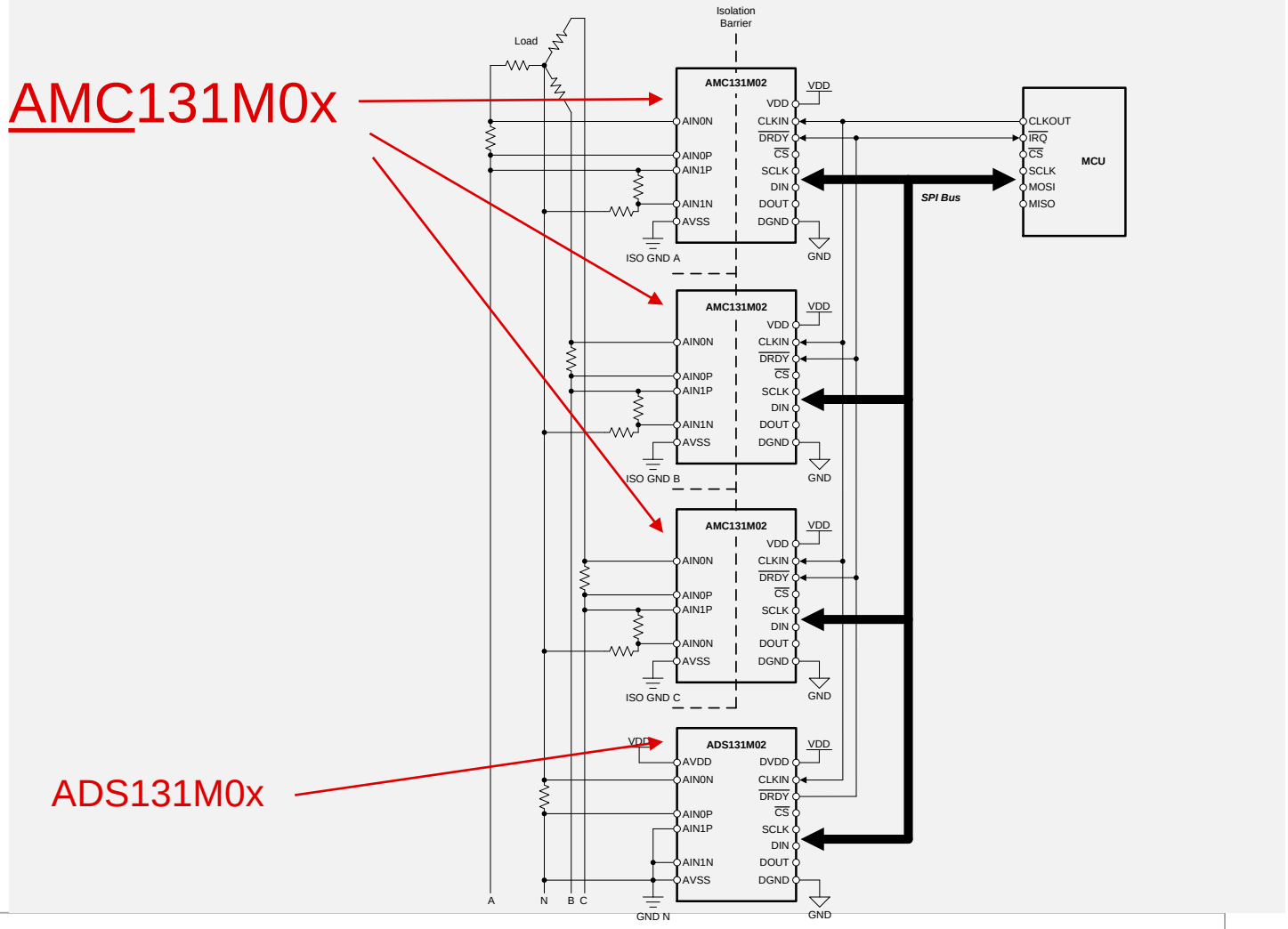


# PADC solution: poly phase shunt based e-meters

**New solution: AMC131M0x - Isolated Analog Front End for E-Metering**

- **Isolated data**
- **Isolated power**
- **Same performance and look/feel as ADS131M0x**
- **Smallest size isolated (power & data) E-meter frontend in industry (no stitching capacitor needed)**

## 3-phase current and voltage + shunt neutral



# Energy metering is not just in electricity meters?

## And what architectures are commonly used?

| End equipment | # of phases | CT | Shunt | Rogowski or other |
|---|---|---|---|---|
| Electricity meter (residential, commercial) | 1, 2, 3 | X | X | X |
| AC charging station (pile) | 3 | X | X | |
| DC charging station | 1 (DC) | X | X | |
| Power distribution unit (PDU) | 24 to 36 | X | X | |
| Energy storage unit (ESS) | 3 | X | X | |

# Upcoming reference designs featuring AMC131M03

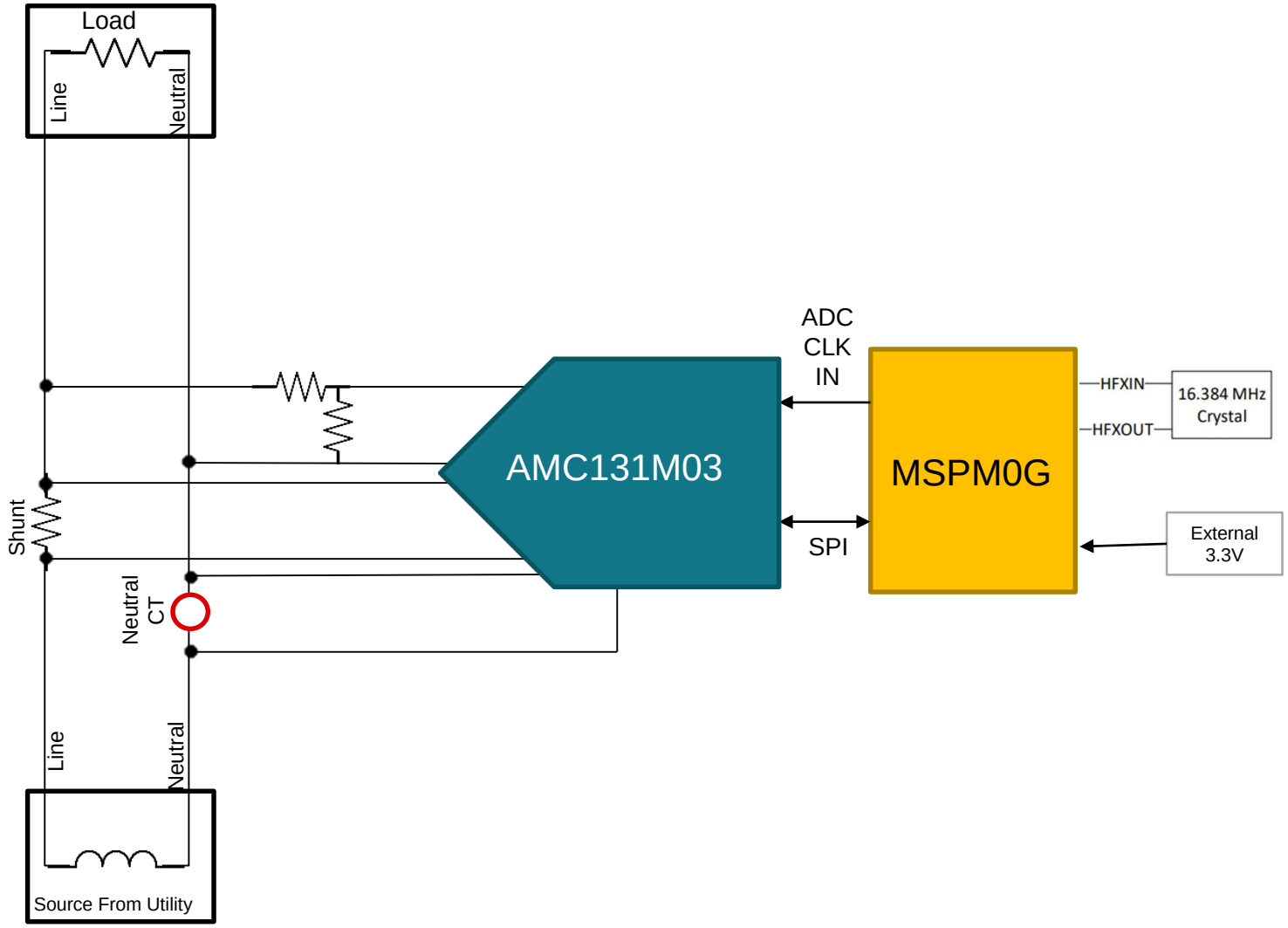
# AMC131M03 shunt e-meter reference design: 3 phase

## Features

- Class 0.2 single-phase metrology up to 100 A (200 µΩ shunts)
- High performance 24-bit SD ADC up to 32 kSPS sampling rate
- Integrated digital isolation and power
- ARM Cortex M0+ MCU supports metrology algorithms
- MCU agnostic energy library:
  - Active and reactive energy and power, root mean square(RMS) Current (live and neutral) and voltage, power factor, line frequency calculations, line-line voltage, V/I phase angle, sags, swells

## Benefits

- Same family ADC can be used for single phase shunt or poly phase CT
- Flexibility in combining Metrology MCU and ADC for various performance points



# AMC131M03 Shunt E-Meter Reference Design: 3 Phase

## Features

- Class 0.2 three-phase metrology up to 100 A (200 µΩ shunts)
- High performance 24-bit SD ADC up to 32 kSPS sampling rate
- Neutral line low power ADC for tampering detection
- Integrated digital isolation and power
- ARM Cortex M0+ MCU supports metrology algorithms
- MCU agnostic energy library:
  - Active and reactive energy and power, root mean square(RMS) current (live and neutral) and voltage, power factor, line frequency calculations, line-line voltage, V/I phase angle, sags, swells

## Benefits

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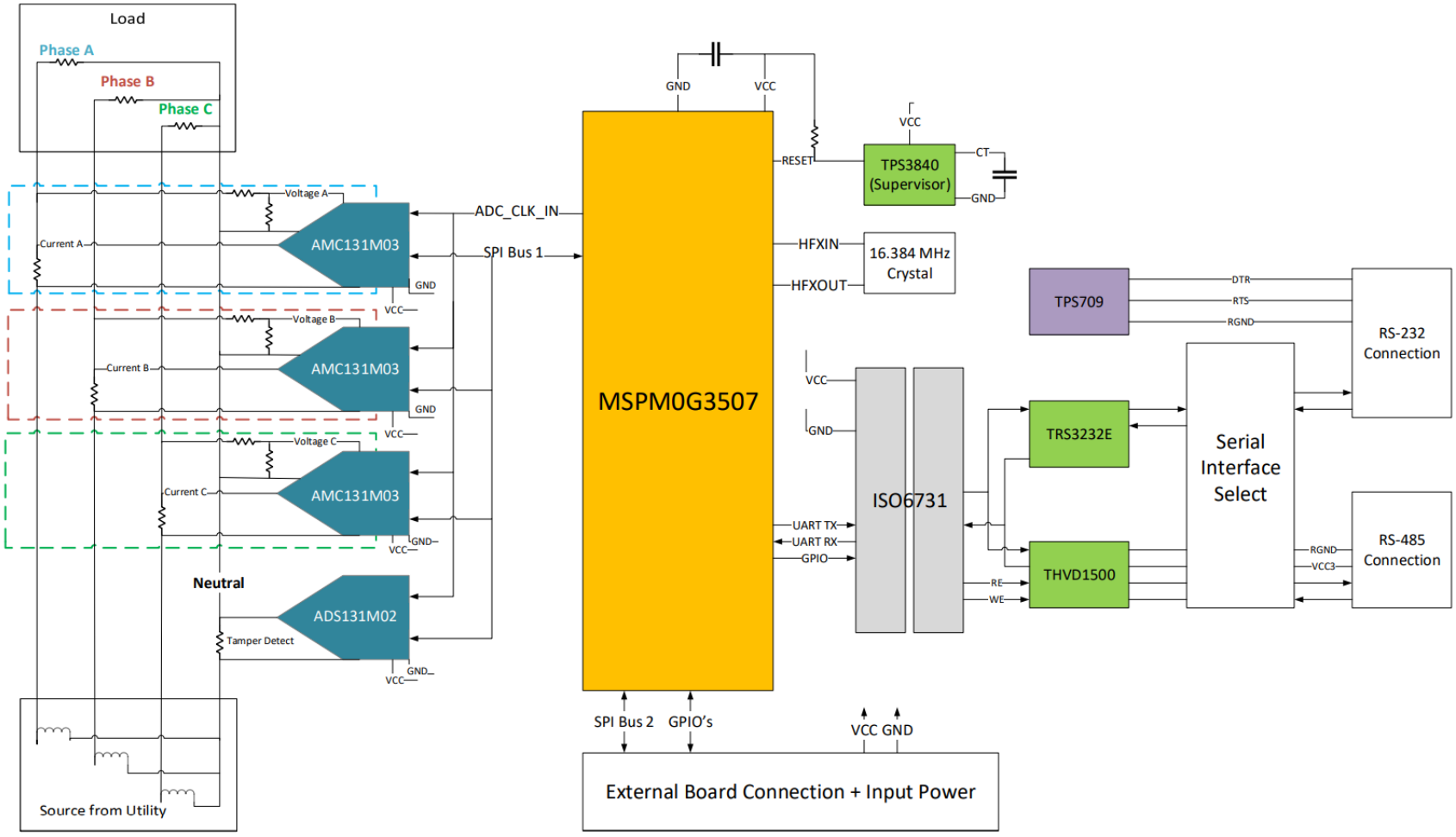

# Energy library: features

- **Rollouts for features**
  - Basic metrology power calculations on TIDA-010243 (CT-based 3-Phase metering) – DONE
  - V1.00 metrology power calculations + THD, dips/sags, zero crossing, phase to phase angle – In progress

| Features | TIDA-010243 | Energy Metrology Library V1.00 Released |
|---|---|---|
| Total and per phase active energy (kWh) | ● | ● |
| Total and per phase reactive energy (kvarh) | ● | ● |
| Total and per phase apparent energy (kVAh) | ● | ● |
| Total and per phase active power (kW) | ● | ● |
| Total and per phase reactive power (kvar) | ● | ● |
| Total and per phase apparent power (kVA) | ● | ● |
| Total and per phase fundamental active energy | | ● |
| Total and per phase fundamental active power | | ● |
| Total and per phase power factor | Per phase only | ● |
| Per phase voltage root mean square (RMS) | ● | ● |
| Per phase current root mean square (RMS) | ● | ● |
| Line frequency | ● | ● |
| Per Phase Voltage THD | | ● |
| Per Phase Current THD | | ● |
| Supply voltage dips/sags, swells, interruptions, under/over deviation | | ● |
| Voltage phase to phase angle | | ● |
| Per phase zero crossing | | ● |
| Button support for changing LCD displayed parameters | | |
| Support for multiple ADS131M0x in a single SPI bus | | |
| Line to Line Voltages | | |
| Fundamental Line to Line Voltages | | |
| Voltage to Current angle, per phase | | |
| Vector sum of all currents | | |
| Harmonic Calculation | | |

# Energy library: TI MCUs

- **Cost-effective 3-phase e-meters: MSPM0G with faster sampling rates (NEW)**
  - 8 ksps+ @ 30 bytes read-in @ SPI clock = 19.95 MHz (ADS/AMC131M0x + MSPM0G)
  - **Very cost-effective 3-phase e-meters: MSPM0L (NEW)**
    - 2 ksps @ 30 bytes read-in @ SPI clock = 16 MHz (ADS/AMC131M0x + MSPM0L)
    - 4 ksps @ 18 bytes read-in @ SPI clock = 16 MHz (split phase and 2-phase e-meters) - estimated
- **Smart 3-phase e-meters: CC13x2 / CC26x2 / CC13x4/26x4 (NEW)**
  - BLE-enabled 2.4 GHz or dual-band (sub1 G + 2.4 GHz) e-meters with HW security and encryption
  - 8 ksps @ 30 Bytes read-in @ SPI clock = 6 MHz (WiSUN, wMBus or Mioty enabled sub-1 GHz e-meters with HW security and encryption and energy library in a single chip!)

# Summary

- We offer a dual-chip approach
  - High precision ADC + TI MCU
- Have solution options for multiple cost points through MCUs
- Provide example application Library
  - Currently available on multiple TI Wired & Wireless MCUs
    - MSPM0
    - Cortex – M3, M4, M4F, & M33
- Energy metering architecture can be used in a variety of systems.

# Questions?

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