USING THE CT43X TMR CURRENT SENSOR IN POWER DISTRIBUTION UNITS (PDUS)

By Allegro MicroSystems

ABSTRACT

The CT43x is a series of very-high-accuracy contact current sensors with an integrated current-carrying conductor (CCC) that handles up to 50 A. It has very high sensitivity and a wide dynamic range with excellent accuracy (very low total output error) across frequency. It integrates two Allegro XtremeSense™ tunneling magnetoresistance (TMR) full bridges in a parallel orientation along with a U-shaped internal conductor to reduce the effects of stray external magnetic fields on the current measurement.

RELEVANT PRODUCTS

CT430, CT431

RELEVANT RESOURCES

CT430 power distribution unit (PDU) evaluation board

INTRODUCTION

The cost of electricity for servers is one of the largest operating costs for data centers. Managing energy consumption is critical to controlling operating costs, and energy management requires accurate energy measurement.

There are multiple locations at which data center consumption can be measured, each of which provides a different level of detail about where power is being consumed.

At the center level, power metering can provide an aggregate measurement of power consumption for the data center. Although this may be necessary, it is not useful for fine control of the power consumption.

Metering at the equipment rack level provides an aggregate measurement of all power delivered to the rack, but it does not allow separation of consumption by servers and cooling equipment.

Measuring the energy and power at each outlet of a PDU provides granularity at the power supply level, allowing specific actions to be taken to improve efficiency.

This application note describes an architecture for a metered PDU with energy measurement at each outlet.

CURRENT SENSORS FOR ENERGY MEASUREMENT

Measuring power and energy requires measurement of both voltage and current. In power distribution units, the AC line voltage to be measured can be scaled to levels that the measurement analog-to-digital converter (ADC) can tolerate with a voltage divider or, if galvanic isolation is required, with a voltage transformer.

Current cannot be measured directly with an ADC. A current sensor is required to generate a voltage that is proportional to the current to be measured. The most prevalently used current sensors have been current-sense resistors or current transformers. This report describes the use of Allegro CT43x TMR current sensors in a PDU. A brief comparison of these three technologies is shown in Table 1.

Table 1: Current Sensor Comparison

Sensor Technology	Advantages	Disadvantages
Current-sense resistor	Very low cost Small physical size	No voltage isolation—sensor must be at line voltage
Current Transformer	Good linearity Voltage isolation	Large physical size High manufacturing cost High cost
TMR Sensor	Small physical size Great linearity Voltage isolation	Cost

CT430 PDU EVALUATION BOARD

The PDU incorporates an Atmel M90E26 energy-metering IC for data acquisition and metering calculations. The M90E26 is a single-phase metering IC comprising multiple ADCs for measuring voltage and current, a digital signal processor (DSP) module for power and energy calculations, and a serial interface for communicating with a microcontroller.

A block diagram of one channel of the PDU is shown in Figure 1.

The voltage transformer scales the AC line voltage to the input range of the metering IC and provides galvanic isolation between the AC line and the PDU circuitry. The voltage transformer is a 1:1 transformer. Resistors between the AC line and the primary side limit the primary current to ~2 mA. The burden resistor on the secondary side scales the secondary voltage to within the approximately ±850 mV input range of the M90E26 ADC. In a single-phase PDU, only one voltage measurement is needed; therefore, the voltage transformer circuit provides the voltage measurement signal for all the channels in the unit.

The CT430 has an in-package current-carrying conductor that is connected in series with the load. The CT430 output is connected to the line-current measurement inputs of the M90E26. The CT430 output signal is buffered with an operational-amplifier (op-amp) circuit to scale the 2.5 V ± 2.0 V output CT430 to the 1.65 V ± 0.85 V input range of the M90E26. It also provides a low-impedance source for the ADC inputs. The M90E26 analog inputs for current measurement have a typical 1 kΩ input impedance because they are designed to be driven by low-impedance sensors, such as current-sense resistors or current transformers.

The SPI interface allows the microcontroller to control the metering IC to perform calibration and to read the voltage, current, power, and energy registers.

The design is modular, and the number of metered outlets can be expanded by replicating the CT430 and M90E26 circuitry for each outlet.

A block diagram of the PDU evaluation board is shown in Figure 2. General purpose I/O (GPIO) lines from the microcontroller are used as SPI chip-select pins for each M90E24 metering IC to select the channel to/from which the microcontroller writes/reads.

The PDU evaluation board is designed for 120 V_{AC} line voltage and 15 A per socket, limited by the use of NEMA 5-15 sockets and 20 A variants of the CT430 sensors. The design can easily be scaled for higher line voltages by changing the current-limiting resistors in series with the voltage transformer primary, and by replacing the outlet sockets. Increasing the current rating requires replacement of the 20 A sensors with sensors calibrated for a higher current range, as well as replacement of the outlet sockets with sockets rated for higher current.

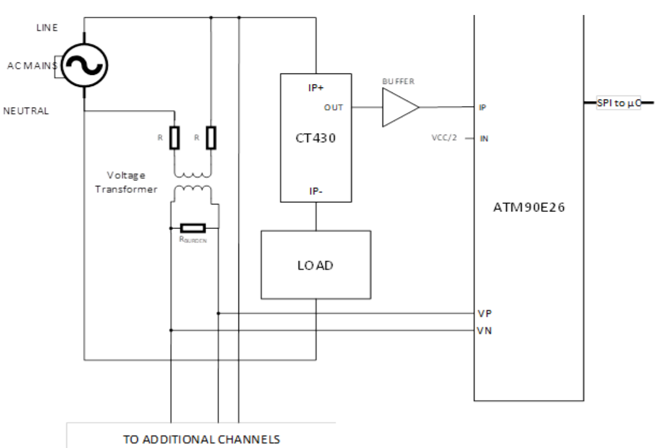

Figure 1: PDU Channel Architecture

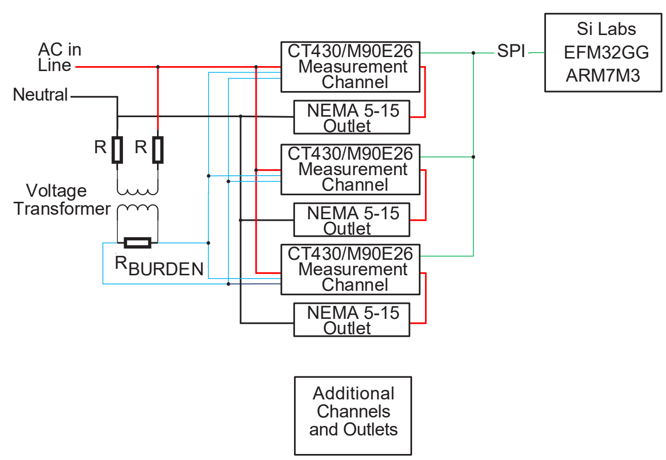

Figure 2: PDU Evaluation Board Block Diagram

TEST RESULTS

A test board was built to evaluate and demonstrate the applicability of the CT430 in PDU applications. The test board comprised two metering circuits using the Microchip ATM90E26 energy metering IC. The board was built so that both metering ICs would experience the same voltage and current; that is, the current sensors are connected in series, while the voltage-sense inputs are in parallel. For one circuit, the current sensor function was served with a 20 A, 1000:1 current transformer (CT) that could be used in a typical PDU design. The other circuit replaced the 20 A CT with a 20 A variant of the CT430 and signal conditioning circuitry to bring the CT430 output into the input range of the analog input of the M90E26. A Silicon Labs ARM M3-based micro-controller was used to configure the metering chips and to read the measurement data via a serial peripheral interface (SPI) connection.

Testing showed that the current and power measurements using the CT430 were essentially the same as the measurements using the current transformer. Test results follow.

The power measurements reported by the two metering chips vs. the test current, as well as the difference between the measurements, are shown in Figure 3. The scale for the difference is shown in the secondary vertical axis on the right side of the chart.

The RMS current reported by the metering chips plotted against the test current, with the difference between the two measurements on the secondary vertical scale, is shown in Figure 4.

The difference between the test current and the current measurement from the metering chips is shown in Figure 5.

The test data shows that the measurement performance of the CT430 is equivalent to the measurement performance using the current transformer, indicating that the CT430 is a viable replacement for the current transformer in metered PDUs.

Figure 4: Current Measurement Comparison

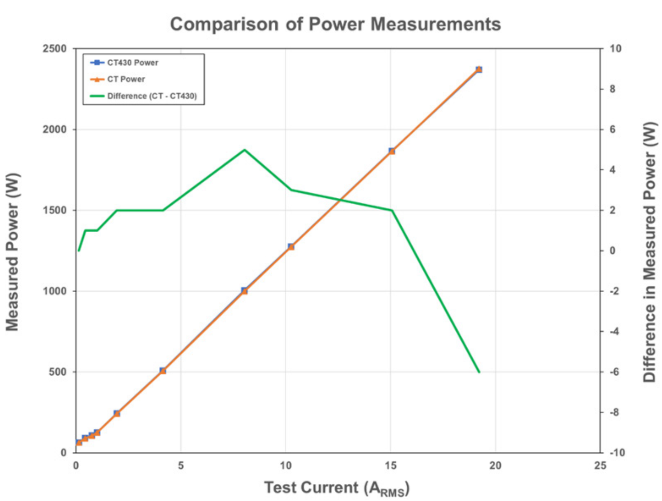

Figure 3: Power Measurement Comparison

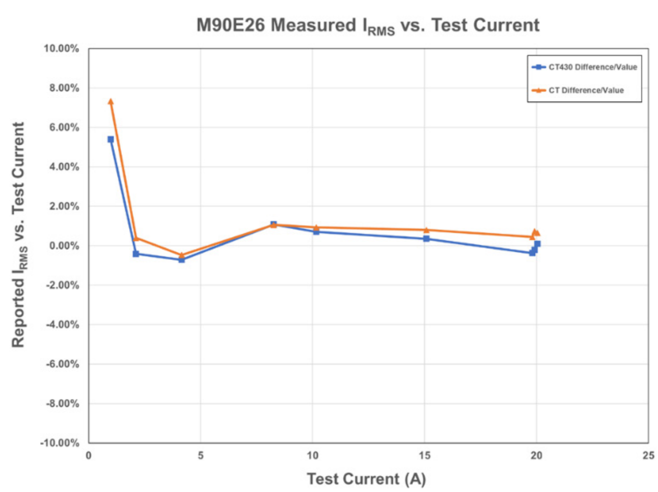

Figure 5: Current Measurement Difference

SCHEMATICS

A schematic for the CT430 PDU outlet metering module is shown in Figure 6. The CT430 is connected via an op-amp circuit to the I1 inputs of the M90E26 metering chip. The circuit scales and level-shifts the CT430 output voltage from its single-ended 2.5 V ± 2.0 V range to the 1.65 V ± 0.85 V input expected by the metering chip. Because the metering chip inputs are differential, a voltage divider provides a 1.65 V input to I1N, and the CT430 signal is applied to I1P.

The voltage reference for the metering chip is provided via a voltage transformer. The ZMPT101B is a 2 mA current, 1:1 transformer. The four 25.5 kΩ resistors in series between the AC line input and the primary of the voltage transformer limit the primary current to 1.6 mA peak at 120 V_{AC} line-input voltage. The 174 Ω burden resistor on the secondary winding of the transformer provides a 289 mV peak input to the metering chip.

The line current passes through the in-package current conductor of the CT430 to the load.

A four-wire SPI connection between the microcontroller and the M90E26 allow the microcontroller to configure and calibrate the metering chip and read the voltage, current, power, and energy registers.

NOTE: If metering is provided for each outlet of the PDU, the voltage transformer circuit is not replicated for each outlet, because all of the loads experience the same line voltage.

OTHER INFORMATION

For additional documentation, visit www.allegromicro.com.

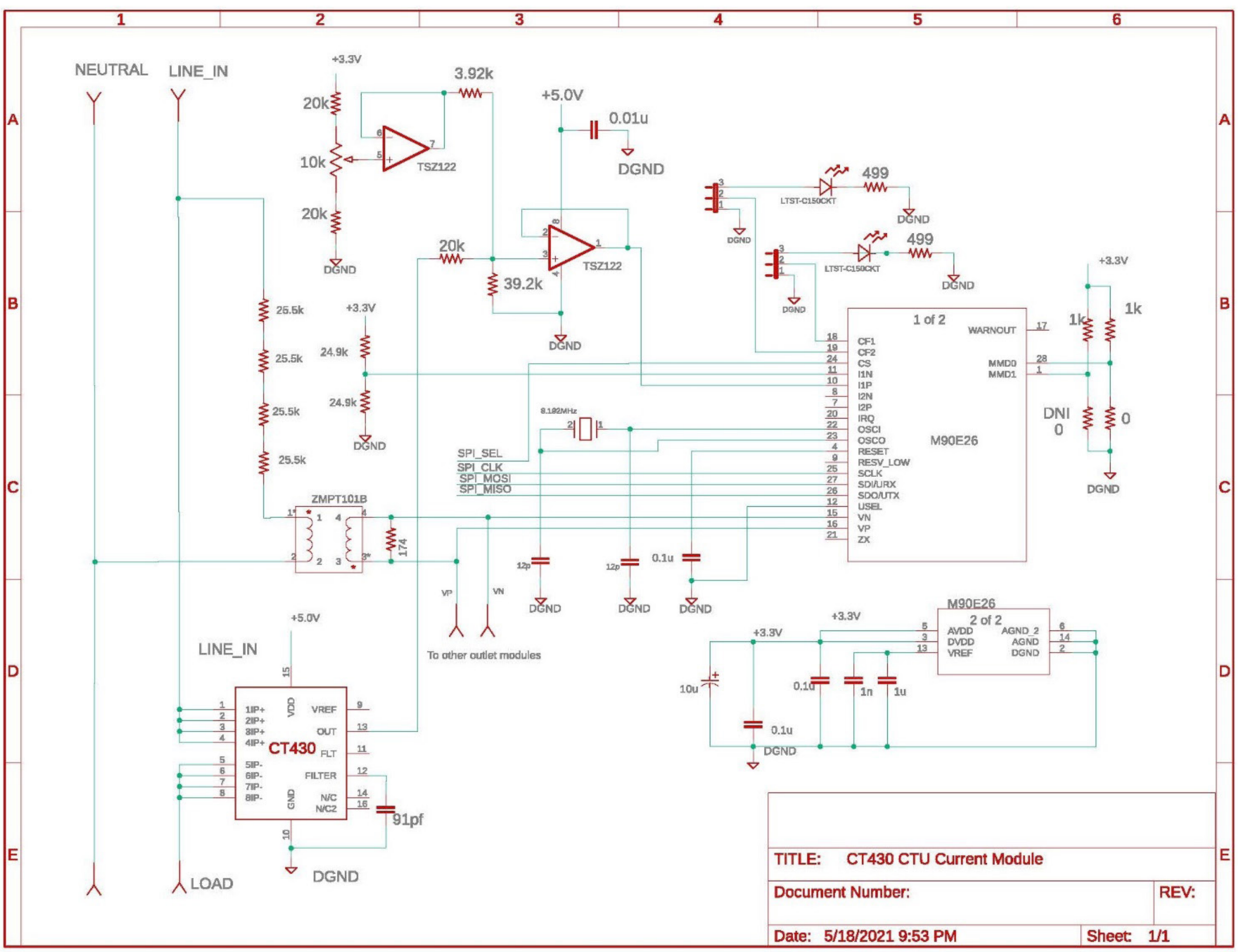

Figure 6: CT430 PDU Outlet Module

Revision History

Number	Date	Description	Responsibility
1	November 17, 2023	Document rebrand and minor editorial corrections	J. Henry

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