

What's the Big Deal about Circuit Breakers?



Prasanna Rajagopal97

A [circuit breaker](#) is one of the most essential components of an electrical power system, used in electrical transmission and distribution networks to protect equipment or circuits during fault conditions such as a short circuit or overload by interrupting the circuit. Industrial breakers are generally three- and four-pole designs, with current-interrupting capability ranging from few hundreds of amps up to 6.3kA. For one- or two-pole residential breakers, miniature circuit breakers (MCBs) offering only overcurrent protection are very common. Arc fault current interrupters (AFCIs) and ground fault current interrupters (GFCIs) are special-function breakers that interrupt during arc faults and ground faults, respectively.



Interrupting a high current and/or voltage during fault conditions results in an arc. The length of the arc depends on the voltage levels and intensity of the interrupting current. Different mechanisms and mediums like vacuum, air, insulating gas, sulfur hexafluoride or oil contain, cool and extinguish the arc to control the intensity. Residential applications use MCBs <100A, with thermal or thermal magnetic-type breaking mechanisms. Low- and medium-voltage systems use molded-case circuit breakers (MCCBs), which are available for up to 2.5kA-4kA of current, and offer additional features like an adjustable trip mechanism. Air circuit breakers (ACBs) are available in a range from 630A up to 6.4kA. During a short circuit, ACBs open the circuit within 40ms to 60ms, allowing more than two cycles of fault current through before opening. Loads protected by an ACB (for example, transformers and bus bars) must be rated to withstand fault current for a short duration.

A circuit breaker consists of current and voltage sensing, analog signal conditioning, a microcontroller (MCU), a power-management block, and an actuation driver/tripping unit. It may also include an analog-to-digital converter (ADC), either external or as a peripheral internal to the MCU. One important subsystem in a modern MCCB or ACB is the electronic trip unit (ETU), which performs tasks like true root-mean-square (RMS) current sensing, adjustable trip time, zone-selective interlocking, and self-powering and communications. Current transformers (CTs) or Rogowski coils sense and measure a wide range of input current.

MCCBs are a high-volume market, where the cost of the system needs to be as low as possible. This is possible by sensing current using a 12-bit successive-approximation-register (SAR) ADC that is built into TI's MSP430™ MCU, as demonstrated in the [Signal Processing Subsystem and Current Input-Based Self Power for Breaker Applications \(ACB/MCCB\)](#) reference design. [Figure 1](#) shows the block diagram of the signal-processing

front end for the ETU. This system provides a fast startup time of <30ms and includes one-cycle true RMS calculation, with an accuracy of $\pm 3\%$. Amplifiers with two gains measure a wide range of current, with higher accuracy for both protection and metering. The reference design also demonstrates self-powering of the system by using power from CTs.

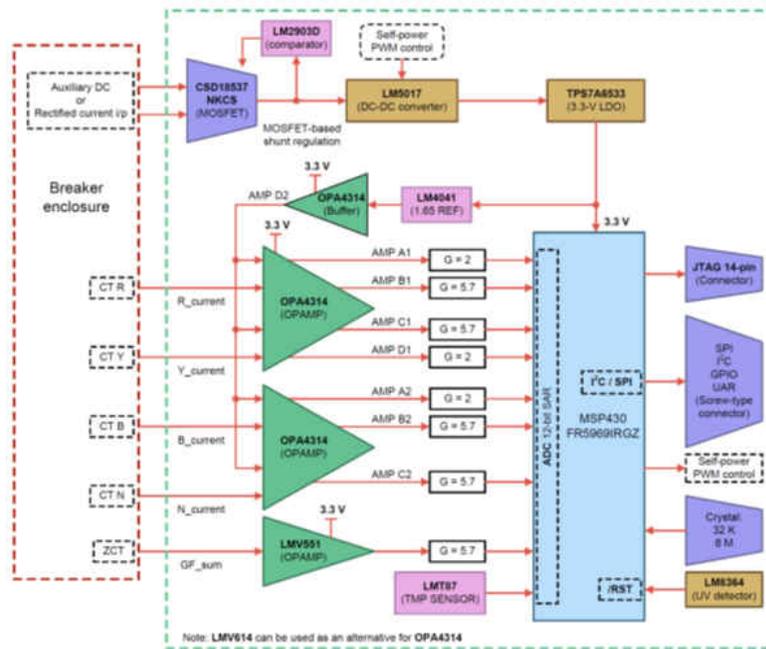


Figure 1. Signal Processing Subsystem and Current Input-Based Self Power for Breaker Applications Reference Design Block Diagram

Unlike MCCBs, ACBs need high performance and accurate analog signal processing at the front end for wider input-current ranges; the resolution of the ADC built into the MCU may not be sufficient for this application. The [High Resolution, Fast Startup Analog Front End for Air Circuit Breakers reference design](#) demonstrates higher measurement accuracy at the lowest possible cost by using the ADS131E08S external ADC, a 24-bit delta-sigma data converter with eight-channel simultaneous sampling capability, as shown in [Figure 2](#). ACBs are specified to trip within 35ms to 40ms while powered under a fault condition. This trip time includes system power up, AC current measurement and breaking the fault current. The ADS131E08S starts up in <3ms, contributing to a reduced overall startup time. The ADC's programmable gain amplifier (PGA) reduces the need for external components, improving temperature performance and reliability. A 24-bit data converter provides accurate input AC voltages and currents for a dynamic range of 1000V/500A.

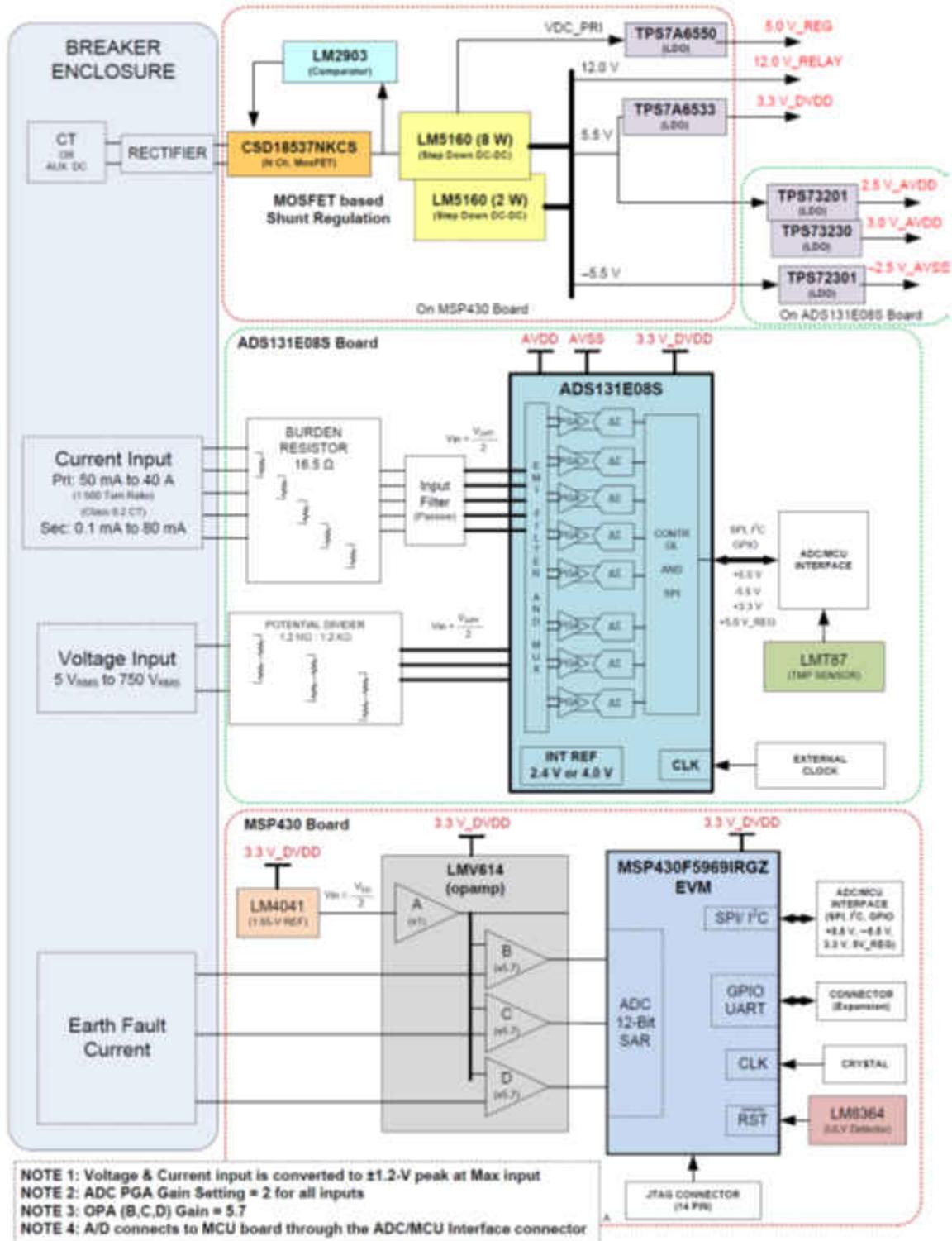


Figure 2. Analog Front End for ACB Block Diagram

TI provides analog, digital, power and MCU solution required for designing of ETU in circuit breakers. TI products and system solutions enable faster development of subsystems within the circuit breaker with optimized cost and excellent performance.

Additional Resources

- Learn more about simplifying circuit breakers using [delta-sigma ADCs](#).
- [Download the data sheet](#) for the ADS131E08S data converter.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2023, Texas Instruments Incorporated