Texas Instruments

White Paper

SLAA835B–May 2018–Revised August 2018

Smart Analog Combo Enables Tomorrow's MCU-Based Sensing and Measurement Applications

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More and more applications are emerging that require intelligent sensing capabilities on end nodes. These applications cross industry segments including building automation, factory automation and control, and medical health and fitness. For new product development teams, designing each new product or system individually without capitalizing on previous design work will surely tax the engineering resources of any organization.

A new generation of microcontrollers (MCUs) is quickly and efficiently adaptable to different types of sensing and measurement applications, such as those involving the sensing of light, humidity, temperature, power current, carbon monoxide, and many other conditions or parameters. The most prominent example of this new type of MCU is the MSP430FR23xx MCU family, which integrates ferroelectric random access memory (FRAM) technology and a smart analog combo (SAC) with ultra-low-power consumption.

The smart analog combo includes configurable analog signal chain elements including operational amplifiers (Op-Amps) and 12-bit digital-to-analog converters (DACs). The smart analog combo supports flexible configuration of the input path [for example, Op-Amp or programmable gain amplifier (PGA)] and the output path (for example, a 12-bit DAC) on the signal conditioning chain of a unified single IP. Additionally, the MSP430FR23xx MCUs integrate a 12-bit analog-to-digital converter (ADC) and two enhanced comparators.

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1 Introduction

The smart analog combo (SAC) enables a configurable signal-conditioning chain for the sensing and measurement market. Customers can flexibly configure the Op-Amp or PGA of a signal amplifier or 12-bit DAC for internal IPs and external voltage references.

Advantages of the smart analog combo include:

- Flexibility
  - Configurable input and output paths
  - Adaptable analog conditioning circuit
  - Programmable configuration
  - Consistent user interface on all levels
- Economics
  - Optimized bill-of-materials cost
  - Few to no external components required
  - Smaller printed circuit board (PCB) outline

The smart analog combo is available on several MSP430™ MCUs in the MSP430FR23xx family. Table 1 defines the different smart analog combo (SAC) configurations. Table 2 lists the configurations available on MSP430 MCUs.

Table 1. Smart Analog Combo Options

SAC Configuration	Op Amp	PGA	12-Bit DAC
SAC-L1	✓		
SAC-L2	✓	✓	
SAC-L3	✓	✓	✓

Table 2. Summary of the Smart Analog Combo Configurations and How Many Modules are Integrated on Each Device Family

Device	SAC Configuration
MSP430FR231x	1 SAC-L1
MSP430FR235x	4 SAC-L3

2 Smart Analog Combo Applications

The application areas appropriate to the smart analog combo are quite broad, but three in particular stand out: building automation, factory automation and control, and medical health and fitness. Specific applications include smoke detection, gas detection, current-loop transmission, blood glucose meters (BGM) or oximeter, small form-factor pluggables (SFPs), and audio systems.

2.1 Smoke Detection

There are two methods for smoke detection using AC measurement or DC measurement.

For AC measurement, a general voltage signal conditioner measures the photodiode current, through a DC blocker (usually a large capacitor) before analog-to-digital conversion. Figure 1 shows an AC measurement-based smoke detector implemented using two smart analog combo SAC-L3 configurations.

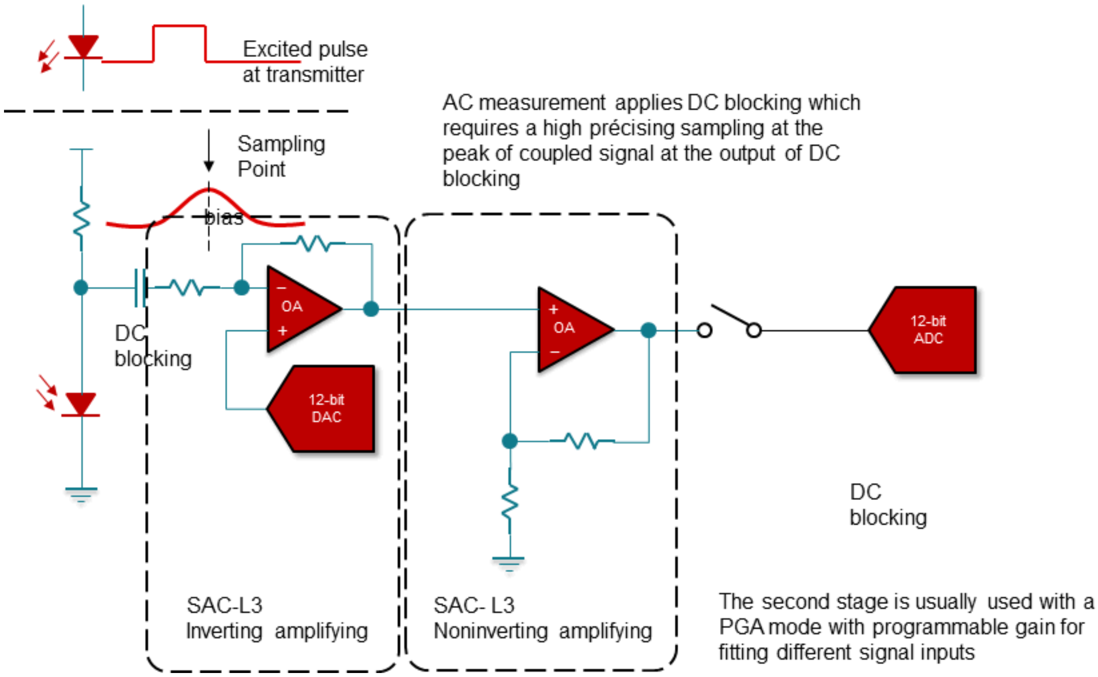

Figure 1. Block Diagram Showing AC Measurement in a Smoke Detector Application Using the MSP430 Smart Analog Combo

For DC measurement, a current-to-voltage converter (usually a transimpedance amplifier (TIA) with low-leakage input) measures the photodiode current, with an optional second-stage voltage signal conditioner before analog-to-digital conversion. By replacing the feedback circuit with a diode or transistor, the application can include a logarithmic amplifier in parallel to extend the measurable dynamic range by compressing the large signal outputs The smart analog combo can act as a TIA, and internal connections with the ADC and a paired SAC can save more GPIOs. Figure 2 shows a DC measurement-based smoke detector implemented using the smart analog combo SAC-L3 configuration.

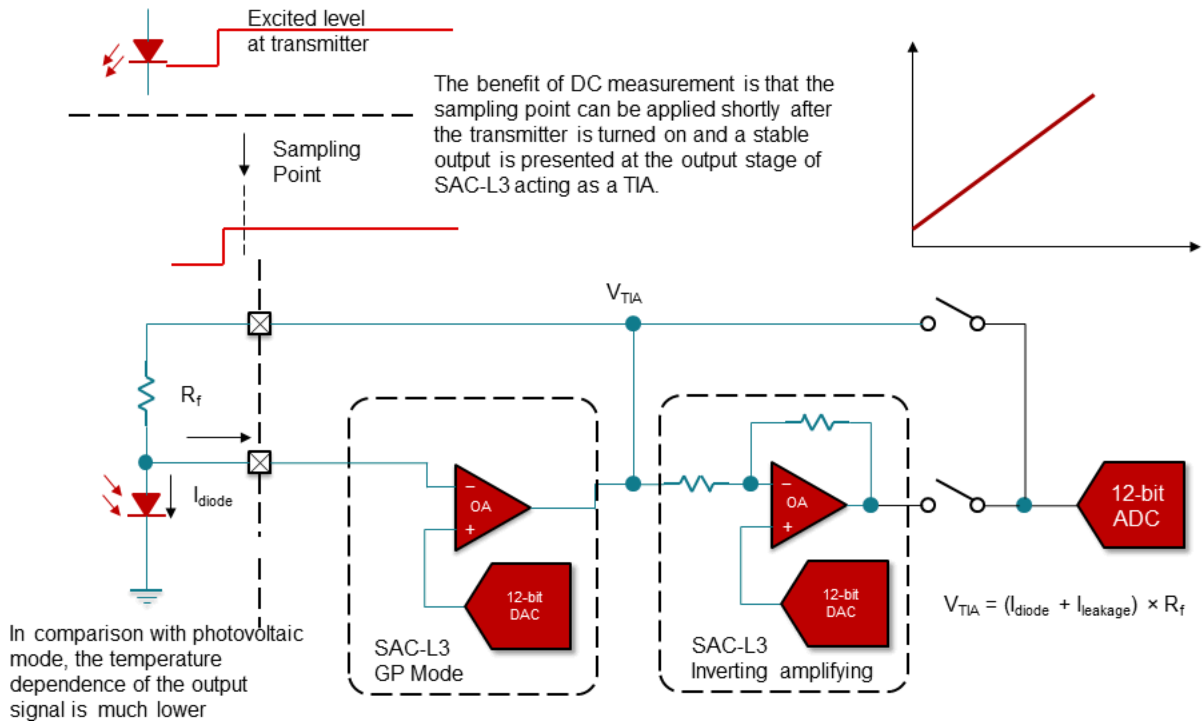

Figure 2. Block Diagram Showing DC Measurement in a Smoke Detector Application Using the MSP430 Smart Analog Combo

2.2 Gas or PM2.5 Detector

A current-to-voltage converter (usually a trans-impedance amplifier with low-leakage input) measures the photodiode current, with an optional second-stage voltage signal conditioner before analog-to-digital conversion.

This application typically uses a battery supply; the ultra-low-power MCU and its related analog modules contribute most to power consumption. This is especially true in a gas sensor node that must continuously monitor carbon dioxide gas concentration and generate an alarm if the concentration exceeds a given limit for a certain amount of time. The ultra-low power smart analog combos within lower-power FRAM MCUs benefits applications requiring continuous signal monitoring, such as gas detectors. Figure 3 shows a block diagram of a gas detector using the smart analog combo SAC-L3 configuration.

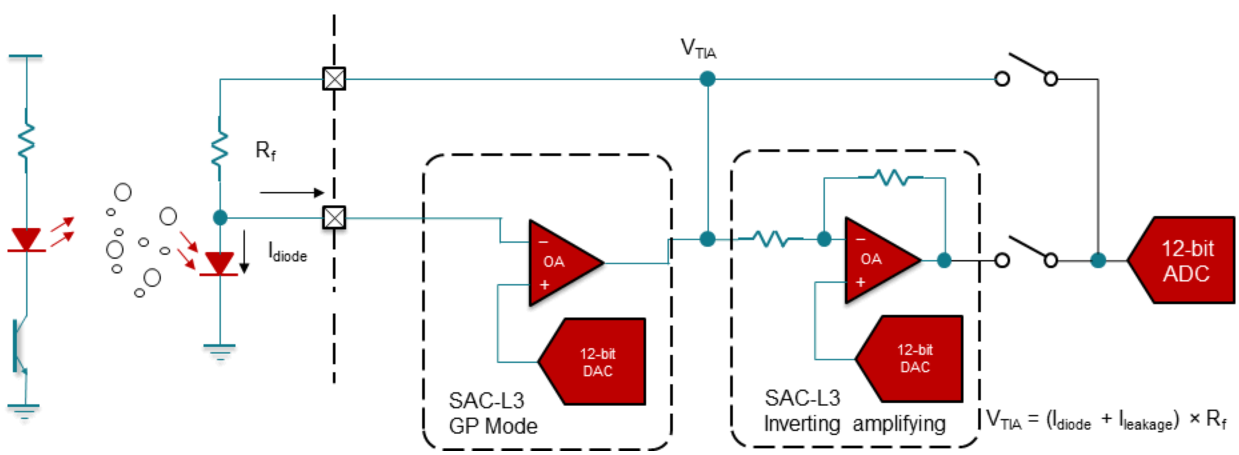

Figure 3. Block Diagram of a Gas Detector Using the MSP430 Smart Analog Combo

2.3 Blood Glucose Meter or Oximeter

A current-to-voltage converter (usually a trans-impedance amplifier with low-leakage input) measures the test strip current, with an optional second-stage voltage signal conditioner before analog-to-digital conversion.This application uses two 12-bit DAC modules: one for the test-strip-driven voltage and the other for audio source generation. Figure 4 shows a BGM application block diagram using three smart analog combo SAC-L3 configurations.

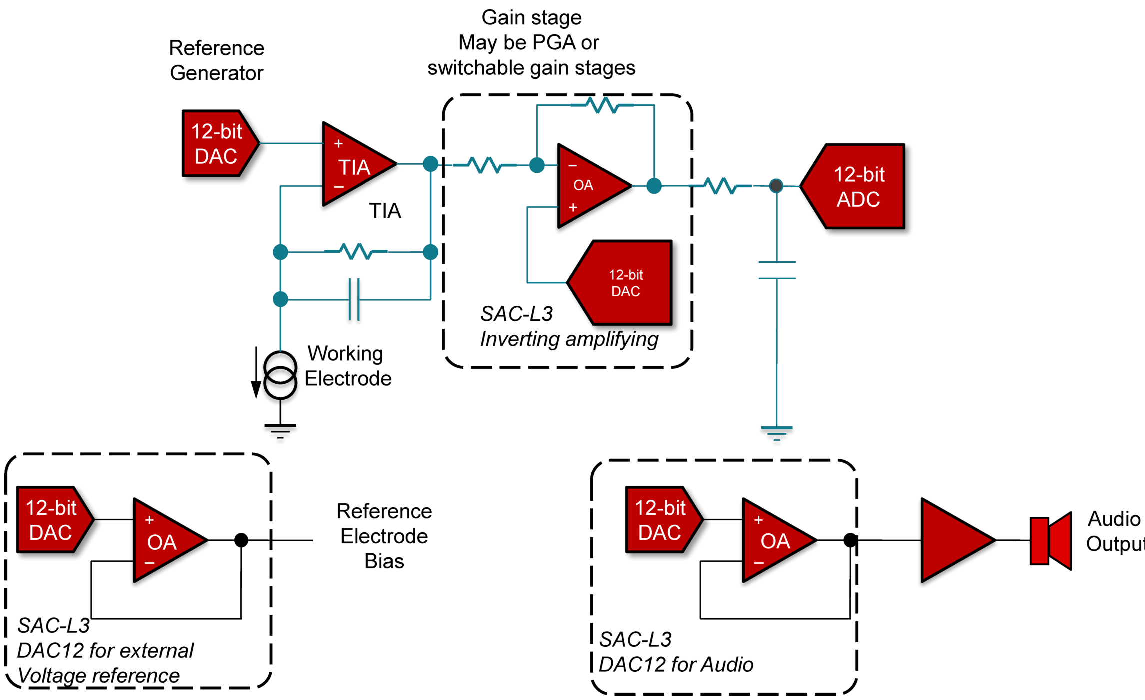

Figure 4. Block Diagram of a Blood Glucose Meter Using the MSP430 Smart Analog Combo

2.4 Current-Loop Transmitter

One 12-bit DAC loads a lookup table of a sine wave, with the other smart analog combo is used as a low-pass filter and a voltage-to-current converter with an external bipolar-junction-transistor (BJT) amplifier. Figure 5 shows a current-loop transmitter application using two smart analog combo SAC-L3 configurations. TI offers a 4- to 20-mA loop-powered resistance temperature detector (RTD) temperature transmitter reference design based on the MSP430FR2355 MCU using two SAC-L3 modules.

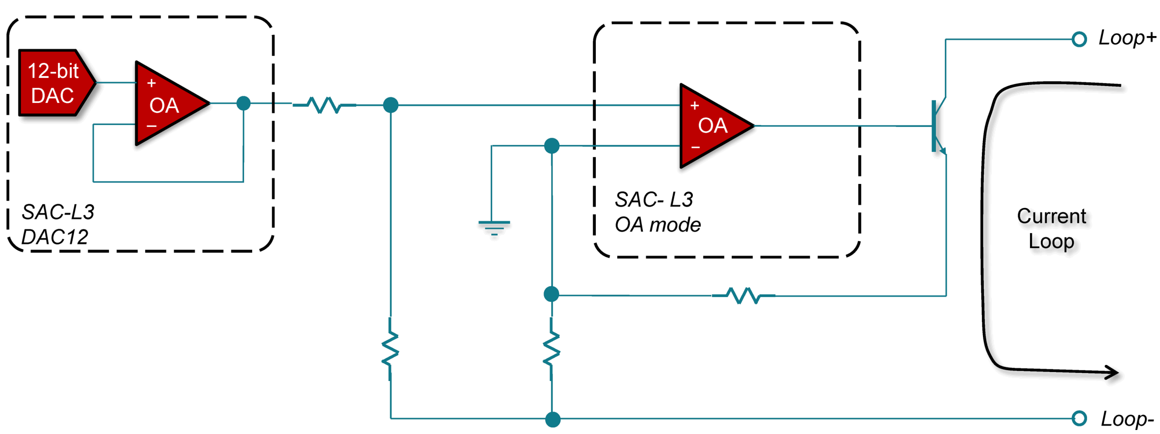

Figure 5. Block Diagram of a Current-Loop Transmitter Using the MSP430 Smart Analog Combo

2.5 Small Form-factor Pluggable (SFP) optical transceivers

This application uses at least three DACs: two for receiver and transmitter power monitors and one for transmitter-mode configuration. The integrated DACs are more easily programmed up to a 12-bit resolution using minimal PCB size, which is especially important in SFP applications. Figure 6 shows an SFP optical transceiver board using three smart analog combo SAC-L3 configurations.

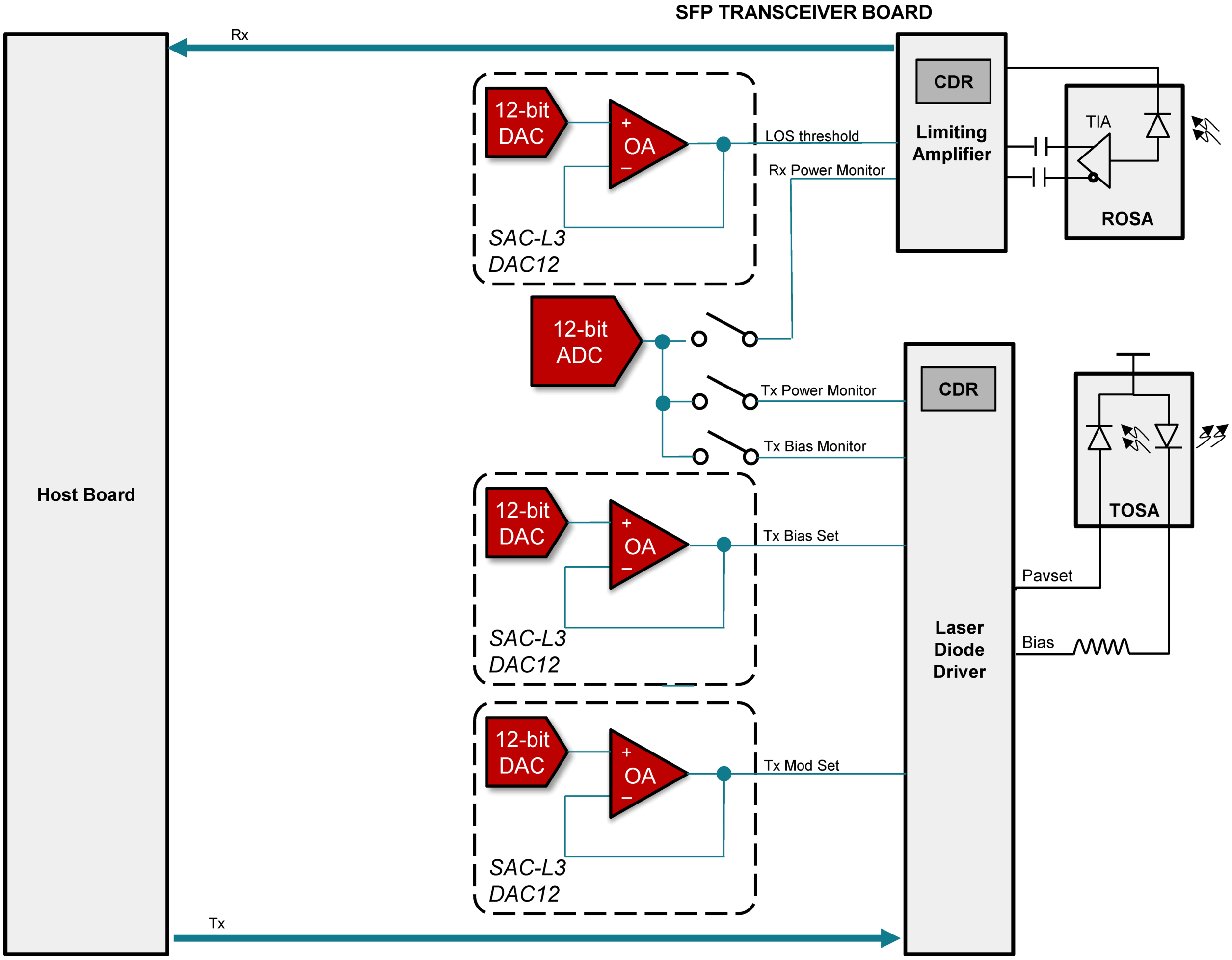

Figure 6. Block Diagram of a SFP Transceiver Board Using the MSP430 Smart Analog Combo

2.6 Audio Applications

A 12-bit DAC followed by a bandpass filter drives an external audio amplifier, which can achieve a 10-bit effective number of bits (ENOB). 12-bit DAC leverages the cost and performance for many audio requirements, such as in a smoke detector. Figure 7 shows an audio application using one smart analog combo SAC-L3 configuration.

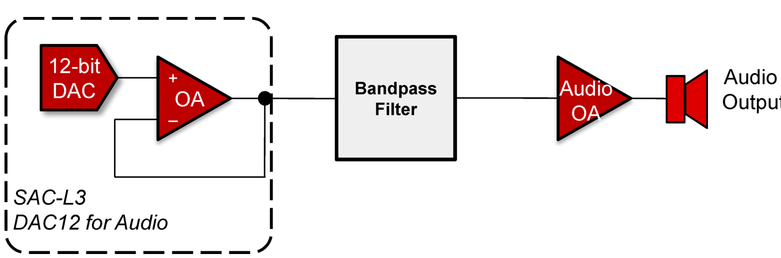

Figure 7. Block Diagram of an Audio Application Using the MSP430 Smart Analog Combo

3 Conclusion

The integrated smart analog combo in the MSP430FR23xx family of MCUs provides flexibility to configure the integrated signal chain elements as well as BOM and PCB reduction for industrial systems. With several configurations to choose from, developers are able to meet the needs of their individual applications.

4 References

1. MSP430FR4xx and MSP430FR2xx Family User's Guide
2. MSP430FR231x Mixed-Signal Microcontrollers data sheet
3. MSP430FR235x, MSP430FR215x Mixed-Signal Microcontrollers data sheet
4. How to Use the Smart Analog Combo in MSP430™ MCUs

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from May 25, 2018 to August 22, 2018	Page
• Updated Figure 1, Figure 2, and Figure 3 (corrected direction of diodes)	3

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