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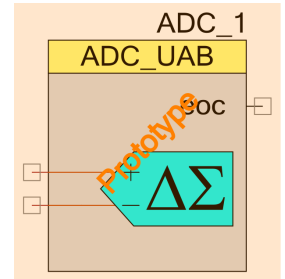
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# Incremental ADC (ADC\_UAB)

## 1.20

## Features

- Single sample incremental ADC
- Rail to rail input voltage capability
- Differential or single-ended input
- Full scale ranges from  $\pm V_{dda}$  down to  $\pm 150$  mV
- Data scaling, saturation, and calibration managed by API functions



## General Description

The Incremental ADC (ADC\_UAB) Component is a general purpose retriggerable ADC that can provide results with a resolution of 14 bits and a conversion time of 1 ms.

Results are returned through API function calls that perform scaling, saturation, and calibration tasks.

## When to Use an Incremental ADC

The ADC\_UAB is useful for making slow, irregular, or asynchronous measurements of system voltages.

## Input/Output Connections

This section describes the various input and output connections for the ADC\_UAB Component. An asterisk (\*) near the terminal name indicates that the terminal may not be shown on the Component symbol for the conditions listed in the description of that I/O terminal.

Terminal Name	I/O Type	Description
eoc	Digital Output	This output can be used to trigger the transfer of data once the conversion is complete. This terminal is always present.
+Input	Analog Input	This input (not marked; it is always the upper terminal of the differential input pair on the symbol) is the 'positive' (also called non-inverting) analog signal input to the ADC.
-Input *	Analog Input	This input (not marked; it is always the lower terminal of the differential input pair on the symbol) is the 'negative' (also called inverting) analog signal input to the ADC. When the ADC_UAB is in single-ended mode, the inverting input of the ADC is connected internally to the reference.

## Component Parameters

This section covers the various parameters that can be altered or inspected through the Component Configure Dialog, grouped within a series of tabs. To explore this, drag an Incremental ADC onto your design and double-click it to open the Configure dialog.

**PRELIMINARY**

For any selectable parameter, the option shown here in **bold** is the default.

## Basic Tab

Configure 'ADC\_1'

Name:

**Basic** Built-in

Input

☒ Differential

☐ Single-ended

Reference

Input range:

Timing

Conversion time: 0.95 ms

Max source impedance: 27 k

Transfer Function

	Code	Vdiff
Max	8191	1.200 V
Mid	0	0.000 V
Min	-8192	-1.200 V

Datasheet OK Apply Cancel

### Input

Select single-ended or differential. In single-ended mode, the voltage at the input terminal is converted with respect to its reference voltage. The returned code is zero when the single-ended input is equal to the reference voltage, negative when below the reference voltage and positive when above it.

- **Differential**
- Single-ended

### Input range

The selection available in the pull-down depends on whether differential or single-ended input mode has been selected.

Some input ranges are expressed as absolute voltages, and are referenced to the internal bandgap voltage of 1.2 V. Others depend on the actual value of the Vdda supply voltage (not the numeric value entered in the Design-Wide Resources (DWR)), through the use of a Vdda/2 reference voltage. In single-ended operation, the Vneg terminal of the ADC is always connected to its reference voltage, of either 1.2 V or Vdda/2.

**Note** Range selections that don't cover the complete code range will be marked below with *italics*.

**Differential mode**

- $\pm 2.4\text{ V}$
- $\pm 1.2\text{ V}$
- $\pm 0.6\text{ V}$
- $\pm 0.3\text{ V}$
- $\pm 0.15\text{ V}$
- $\pm V_{dda}$
- $\pm V_{dda}/2$
- $\pm V_{dda}/4$
- $\pm V_{dda}/8$
- $\pm V_{dda}/16$

**Single-ended mode**

- $-0.15\text{ V to } 3.6\text{ V}$
- $0\text{ V to } 2.4\text{ V}$
- $0.6\text{ V to } 1.8\text{ V}$
- $0.9\text{ V to } 1.5\text{ V}$
- $1.05\text{ V to } 1.35\text{ V}$
- $-0.15\text{ V to } V_{dda}$
- $0\text{ V to } V_{dda}$
- $0.25\text{ V}_{dda}\text{ to } 0.75\text{ V}_{dda}$
- $0.375\text{ V}_{dda}\text{ to } 0.625\text{ V}_{dda}$
- $0.4375\text{ V}_{dda}\text{ to } 0.5625\text{ V}_{dda}$

In differential operation, full code range can be obtained if the voltage difference between the inputs meets the range criterion and both input voltages are between  $-0.15\text{ V}$  and  $V_{dda}$ .

**Conversion time (display only)**

This field displays the total conversion time in milliseconds. This is the time from calling the StarConvert() function to returning a calibrated value from the GetResult16() function in the ISR.

**Maximum source impedance (display only)**

This field displays the maximum resistive source impedance to ensure specified accuracy.

**Transfer Function (display only)**

This section displays the converter transfer functions relating output data to input voltage (for data returned by the API function call, not the raw data).

## Application Programming Interface

By default, PSoC Creator assigns the instance name **ADC\_1** to the first instance of the ADC\_UAB in a given design. You can rename it to any unique value that follows the syntactic rules for identifiers. The instance name becomes the prefix of every global function name, variable, and constant symbol. For readability, the instance name used in the following section is **ADC**.

This Component's API contains the following sections:

- [Initialization](#)
- [General](#)
- [Interrupt Service Routine](#)
- [Power](#)
- [Global Variables](#)
- [Global Constants](#)
- [API Memory Usage](#)

## Initialization

Functions that are used for starting and stopping the Component.

### Functions

- void [ADC\\_Start](#) (void)
- uint32 [ADC\\_StartConvert](#) (void)
- void [ADC\\_Stop](#) (void)
- void [ADC\\_Init](#) (void)
- void [ADC\\_Enable](#) (void)

### Function Documentation

*void ADC\_Start ( void )*

Performs all required initialization for this component, and enables the power. The power is set to the appropriate level based on the clock frequency. Does not start a conversion.

*uint32 ADC\_StartConvert ( void )*

Begins a conversion.

#### Returns

- CYRET\_STARTED: The ADC is already converting. No new conversion started.
- CYRET\_SUCCESS: A new conversion has started.

*void ADC\_Stop ( void )*

Disables underlying hardware. Terminates conversion if there is a conversion in progress.

*void ADC\_Init ( void )*

Configures hardware and data structures according to component parameters. Does not power hardware. Called from [ADC\\_Start\(\)](#). [ADC\\_Start\(\)](#) is the preferred method for initializing the component. The ISR is set to the [ADC\\_ConversionInt\(\)](#) here. During calibration, the ISR is temporarily set to the [ADC\\_CalibrateInt\(\)](#) and then restored to [ADC\\_ConversionInt\(\)](#).

*void ADC\_Enable ( void )*

Enables underlying hardware. Does not start a conversion. Called from [ADC\\_Start\(\)](#). [ADC\\_Start\(\)](#) is the preferred method for initializing the component.

## General

General APIs that are used for run-time configuration of the Component during active power mode. These include reading from registers, and writing to registers.

### Functions

- uint32 [ADC\\_IsEndConversion](#) (ADC\_eoc\_enum retMode)
- uint32 [ADC\\_Calibrate](#) (ADC\_calibrate\_mode\_enum calibrateMode)

- int16 [ADC\\_RawToResult16](#) (int32 raw)
- int16 [ADC\\_CountsTo\\_mVolts](#) (int32 counts)
- int32 [ADC\\_CountsTo\\_uVolts](#) (int32 counts)
- float32 [ADC\\_CountsTo\\_Volts](#) (int32 counts)
- int32 [ADC\\_GetRaw](#) (void)
- int16 [ADC\\_GetResult16](#) (void)

## Function Documentation

*uint32* [ADC\\_IsEndConversion](#) ( *ADC\_eoc\_enum* retMode )

Immediately returns the status of the conversion or does not return (blocking) until the conversion completes, depending on the retMode parameter.

### Parameters

- retMode: Check conversion return mode. The options for this parameter are:
  - [ADC\\_RETURN\\_STATUS](#): Immediately returns the conversion or calibrate status. If the value returned is non-zero, the conversion is not complete, and this function should be retried until a result of zero is returned.
  - [ADC\\_WAIT\\_FOR\\_RESULT](#): Does not return a result until the ADC conversion is complete.

### Returns

- 0: The ADC is still calculating the last result.
- nonzero: The last conversion is complete.

*uint32* [ADC\\_Calibrate](#) ( *ADC\_calibrate\_mode\_enum* calibrateMode )

Configures hardware for calibration. The status of the calibration is either returned immediately or is blocked until the calibration completes, depending on the calibrateMode input.

### Parameters

- calibrateMode: Check calibration return mode. The options for this parameter are:
  - [ADC\\_USE\\_INTERRUPT](#): Calibration will be interrupt-driven. Will enter calibration interrupt twice, then set [ADC\\_calStatus](#) to IDLE. Other tasks may be performed while waiting for calibration to complete.
  - [ADC\\_WAIT\\_FOR\\_CALIBRATE](#): Does not return a result until the ADC calibration is complete

### Returns

- nonzero: calibration was successful.

### Side Effects

- Sets the UAB interrupt vector to [ADC\\_CalibrateInt](#) during calibration. Sets it back to [ADC\\_ConversionInt](#) when finished.

***int16 ADC\_RawToResult16 ( int32 raw )***

For a given raw input, returns the calibrated ADC result. This result is saturated at the lower and upper limits of the operating resolution. The calibration formula is:

$$\frac{(raw - calibrateHigh) \times (MAX\_HIGH - MAX\_LOW)}{calibrateHigh - calibrateLow} + MAX\_LOW$$

**Parameters**

- raw: The direct output of the decimator register.

**Returns**

- int16: Saturated and calibrated ADC result.

***int16 ADC\_CountsTo\_mVolts ( int32 counts )***

For given counts input, returns the voltage relative to Vneg. For example, if the input voltage to the ADC was 0.534 volts, the return value would be 534. The equation for the result is:

$$result(mV) = \frac{counts \times gain \times 2 \times reference}{Resolution} + Vneg$$

In Differential Mode, Vneg is zero. In Single-Ended Mode, Vneg is the reference. Resolution is 14-bit.

**Note** The multiplication of counts (14-bit max), reference (14-bit max) and gain (2 max) results in a maximum of 29-bits. An increase in any of these parameters will cause the result to overflow 32 bits.

**Parameters**

- counts: A calibrated ADC result.

**Returns**

- int16: The voltage relative to Vneg in units of millivolts.

***int32 ADC\_CountsTo\_uVolts ( int32 counts )***

For given counts input, returns the voltage relative to Vneg. For example, if the ADC measured 0.534 volts, the return value would be 534000. The equation for the result is:

$$result(uV) = \frac{counts \times gain \times 2 \times reference}{Resolution} + Vneg$$

In Differential Mode, Vneg is zero. In Single-Ended Mode, Vneg is reference. Resolution is 14-bit.

**Parameters**

- counts: A calibrated ADC result.

**Returns**

- int32: The voltage relative to Vneg in units of microvolts.

*float32* **ADC\_CountsTo\_Volts** ( *int32* counts )

For given counts input, returns the voltage relative to Vneg. For example, if the ADC measured 0.534 volts, the return value would be 0.534. The equation for the result is:

$$result(V) = \frac{counts \times gain \times 2 \times reference}{Resolution} + Vneg$$

In Differential Mode, Vneg is zero. In Single-Ended Mode, Vneg is the reference. Resolution is 14-bit.

### Parameters

- counts: A calibrated ADC result.

### Returns

- float32: The voltage relative to Vneg in units of volts.

*int32* **ADC\_GetRaw** ( void )

Get a raw result value from the ADC's decimator output register.

### Returns

- int32: Uncalibrated contents of decimator's result register.

*int16* **ADC\_GetResult16** ( void )

Returns the calibrated ADC result. This result is saturated at the lower and upper limits of the 14-bit operating resolution.

### Returns

- int16: Saturated, calibrated ADC result.

## Interrupt Service Routine

The ADC generates an interrupt before and after calibration and conversion. Call [ADC\\_EnableIRQ\(\)](#) to enable Component interrupts.

### Functions

- void [ADC\\_EnableIRQ](#) (void)
- void [ADC\\_DisableIRQ](#) (void)
- void [ADC\\_ConversionInt\\_EntryCallback](#) (void)
- void [ADC\\_ConversionInt\\_ExitCallback](#) (void)
- void [ADC\\_CalibrateInt\\_EntryCallback](#) (void)
- void [ADC\\_CalibrateInt\\_ExitCallback](#) (void)
- void [ADC\\_ClearInterrupt](#) (void)



## Function Documentation

***void ADC\_EnableIRQ ( void )***

Enables interrupt after a conversion finishes. Conversion entry and exit callbacks should be defined in *cyapicallbacks.h*.

***void ADC\_DisableIRQ ( void )***

Disables interrupt after a conversion finishes.

***void ADC\_ConversionInt\_EntryCallback ( void )***

Conversion interrupt entry callback. Perform a task before [ADC\\_StartConvert\(\)](#) takes place.

Enabled by defining **ADC\_CONVERSIONINT\_ENTRY\_CALLBACK** in the automatically generated *cyapicallbacks.h* file, and defining this function.

Conversion interrupts are only called when interrupts are enabled (see [ADC\\_EnableIRQ\(\)](#)).

***void ADC\_ConversionInt\_ExitCallback ( void )***

Conversion interrupt exit callback. Perform a task after [ADC\\_StartConvert\(\)](#) completes.

Enabled by defining **ADC\_CONVERSIONINT\_EXIT\_CALLBACK** in the automatically generated *cyapicallbacks.h* file, and defining this function.

Conversion interrupts are only called when interrupts are enabled (see [ADC\\_EnableIRQ\(\)](#)).

***void ADC\_CalibrateInt\_EntryCallback ( void )***

Calibrate interrupt entry callback. Perform a task before **each** calibration phase ([ADC\\_Calibrate\(\)](#) has two phases).

Enabled by defining **ADC\_CALIBRATEINT\_ENTRY\_CALLBACK** in the automatically generated *cyapicallbacks.h* file, and defining this function.

Calibrate interrupts are called every time [ADC\\_Calibrate\(\)](#) is called, even if [ADC\\_EnableIRQ\(\)](#) hasn't been called.

***void ADC\_CalibrateInt\_ExitCallback ( void )***

Calibrate interrupt exit callback. Perform a task after **each** calibration phase ([ADC\\_Calibrate\(\)](#) has two phases).

Enabled by defining **ADC\_CALIBRATEINT\_EXIT\_CALLBACK** in the automatically generated *cyapicallbacks.h* file, and defining this function.

Calibrate interrupts are called every time [ADC\\_Calibrate\(\)](#) is called, even if [ADC\\_EnableIRQ\(\)](#) hasn't been called.

***void ADC\_ClearInterrupt ( void )***

Clear a pending interrupt. A pending interrupt must be cleared for subsequent interrupts to be handled.

## Power

Functions used to control power consumption of the ADC.

### Functions

- void [ADC\\_Sleep](#) (void)
- void [ADC\\_Wakeup](#) (void)

### Function Documentation

*void ADC\_Sleep ( void )*

Prepare the component for entering deep sleep. The underlying hardware requires a high speed clock, so it will not run in deep sleep. Do not call this function before normal sleep (cpu off). For normal sleep, a conversion will continue operating as normal.

*void ADC\_Wakeup ( void )*

Restore the component to its pre-deep sleep condition. Should be called just after awaking from deep sleep.

## Global Variables

Global variables used in the Component.

Globals are noted in the description of the functions that use globals.

### Variables

- uint8 [ADC\\_initVar](#)
- uint8 [ADC\\_irqEnabled](#)

### Variable Documentation

*uint8 ADC\_initVar*

Indicates whether the ADC has been initialized. Set by [ADC\\_Start\(\)](#).

*uint8 ADC\_irqEnabled*

Indicates whether the ADC uses interrupts. Set by [ADC\\_EnableIRQ\(\)](#), cleared by [ADC\\_DisableIRQ\(\)](#).

## Global Constants

Global constants used in the Component.

### Variables

- [ADC\\_PARAM\\_VREF\\_VOLTAGE\\_MV](#)
- [ADC\\_PARAM\\_VREF\\_VOLTAGE\\_UV\\_SCALEDOWN](#)
- [ADC\\_PARAM\\_VREF\\_VOLTAGE\\_V](#)

## Variable Documentation

### *ADC\_PARAM\_VREF\_VOLTAGE\_MV*

Full-scale center voltage, in millivolts.

### *ADC\_PARAM\_VREF\_VOLTAGE\_UV\_SCALEDOWN*

Full-scale center voltage, in microvolts.

### *ADC\_PARAM\_VREF\_VOLTAGE\_V*

Full-scale center voltage, in volts.

## API Memory Usage

The Component memory usage varies significantly, depending on the compiler, device, number of APIs used and Component configuration. The following table provides the memory usage for all APIs available in the given Component configuration.

The measurements have been done with the associated compiler configured in the Release mode with an optimization set for size. For a specific design, the map file generated by the compiler can be analyzed to determine the memory usage.

### PSoC Analog Coprocessor (GCC)

Configuration	Flash Usage (Bytes)	SRAM Usage (Bytes)
Typical	1976	318
All APIs	2202	318

### PSoC Analog Coprocessor Resources

The Incremental ADC Component uses the following device resources:

Resource Type	Used	Free
Interrupts	1	25
IO	3	35
Decimator	1	1
UAB Channels	2	0
Voltage References	1	3

## Functional Description

The ADC has two unbuffered switched-capacitor inputs that connect to the pair of voltage signals to be sampled differentially. In single-ended operation, one of these inputs is pre-connected to the potential with which single-ended measurements are defined. This is an internal reference voltage of either 1.2 V or  $V_{dda}/2$ .

Both inputs to the ADC can be taken up to 150 mV more positive than  $V_{dda}$  or 150 mV more negative than  $V_{ssa}$ .

The ADC's modulator uses a two-phase clock. On phase 1, the  $V_{in}$  terminal is sampled in a non-inverting mode. On phase 2, the  $V_{neg}$  terminal is sampled in an inverting mode. The modulator's output therefore represents the difference between the two input voltages. There is a small time offset (1  $\mu$ s) between the sampling of the two inputs. This causes a slight deterioration of AC CMRR at high input frequencies.

The 1-bit output of the modulator is decimated by a dedicated filter. The result of that process is further adjusted for scale factor and offset, shifted and saturated in the supplied API functions in order to deliver a final result.

The ADC hardware makes one complete conversion and then stops.

Raw digital output from the ADC hardware can be accessed through DMA. It does not have any direct use since it has not been calibrated and may have saturated the 14-bit resolution. Fitting of the data into the chosen resolution, including calibration and saturation management, is achieved in the function [ADC\\_RawToResult16\(\)](#), which returns the desired result in a signed 16-bit integer variable. [ADC\\_RawToResult16\(\)](#) can also post-process blocks of data stored in SRAM.

## Capacitor values affect source impedance

The capacitor values and the clock rate are used to determine the maximum permissible source resistance. This is communicated in the customizer.

Each input connection to the ADC has an apparent resistive input impedance of approximately 1M $\Omega$  (under the default clocking arrangements), terminated at the reference potential.

Mismatches in the source impedance in differential mode can cause degradation of CMRR.

## Calibration procedure

[ADC\\_Calibrate\(\)](#) triggers a two-point calibration, which results in two calibration constants that are used to correct the offset and scale factor of the conversion results.

The final output is a valid (i.e. not wrapped) signed 14-bit representation of the input voltage, as long as the input voltage is within the input range of the ADC.

Calibration is done at the base 'unity gain' configuration, using differential input voltage of +reference and -reference. The modulator capacitors are then returned to the target values as set by the user's gain requirement, and the results are scaled appropriately.

This form of calibration does not correct for any error in the reference voltage itself, only in the transfer function that relates digital code to the input voltage as a fraction of the reference voltage.

## Industry Standards

This section lists the industry standard compliance of the ADC\_UAB Component.

## MISRA Compliance

This section describes the MISRA-C:2004 compliance and deviations for the Component. There are two types of deviations defined:

Deviation Type	Description
Project deviations	Deviations that are applicable for all PSoC Creator Components
Specific deviations	Deviations that are applicable only for this Component

This section provides information on the Component-specific deviations. The project deviations are described in the MISRA Compliance section of the System Reference Guide along with information on the MISRA compliance verification environment.

The ADC\_UAB Component has the following specific deviations:

Rule	Class	Description	Description of Deviation(s)
3.1	R	All usage of implementation-defined behaviour shall be documented.	Embedded Component, UABPRIM, source code has comments containing one of the following characters: '\$', '@', or ''.
19.7	A	A function should be used in preference to a function-like macro.	UABPRIM source code uses function-like macros to take generic functions and rename them for specific use cases and use pre-defined parameters making the API easier to use. Also, there are read-modify-write macros that are in most UABPRIM API functions and are used to improve readability of the code so that the intent is clearly understood. The macros have proper parenthesis shielding the parameters as well as the whole macro.

## DC and AC Electrical Characteristics

Characterization data of the ADC Component is pending.

## Component Errata

This section lists known problems with the ADC Component.

Cypress ID	Component Version	Problem	Workaround
254437	All	For parts marked ES (Engineering Sample), when SYSCLK is divided from HFCLK, the Component will not function as expected.	Use a SYSCLK divider value of 1 in the Design-Wide Resources Configure System Clocks -> High Frequency Clocks tab.

## Component Changes

This section lists the changes in the ADC\_UAB Component from the previous versions.

Version	Description of Changes	Reason for Changes / Impact
1.20	Update UABPRIM version to 1.30. Add a build warning about a divided SYSCLK on ES parts. Fix transfer function in GUI for differential mode.	Update UABPRIM to latest version. Inform customer of known problem on ES parts. Transfer function was incorrect for differential mode.
1.10	Update UABPRIM version to 1.20	Update UABPRIM to latest version
1.0.b	Added link to Component web page from Symbol	Link missing in prior versions
1.0.a	Edited datasheet	Updated Component symbol to show as Prototype
1.0	Initial Version	

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