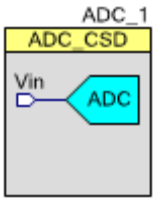
PSoC 4 10-Bit ADC (CapSense®)

3.10



Features

- Selectable 8- or 10-bit resolution
- Sample rates of up to 11.6 ksps with 10-bit resolution
- Input measurement range from VSSA to VDDA on any GPIO pin

Limitations in v3.X

- The component is directly impacted by changing the high-frequency clock or the system clock in run-time and may not operate as expected.

General Description

The 10-bit ADC for PSoC 4 is a triggered analog to digital converter. The component includes a customizer to configure the initial state and APIs to control the component from application firmware.

This datasheet includes the following sections:

- *Component Configuration Parameters* – Contains descriptions of the component's parameters in the configuration wizard.
- *Application Programming Interface* – Provides descriptions of all APIs in the firmware library, as well as descriptions of all data structures (Register map) used by the firmware library.
- *DC and AC Electrical Characteristics* – Provides the component performance specifications and other details such as certification specifications.

Input / Output Connections

This section describes the various input and output connections for the 10-bit ADC component. These are not exposed as connectable terminals on the component symbol but these terminals can be assigned to the port pins in the **Pins** tab of the Design-Wide Resources setting of PSoC Creator. The **Pin Editor** provides the guidelines on the recommended pins for each terminal and does not allow an invalid pin assignment.

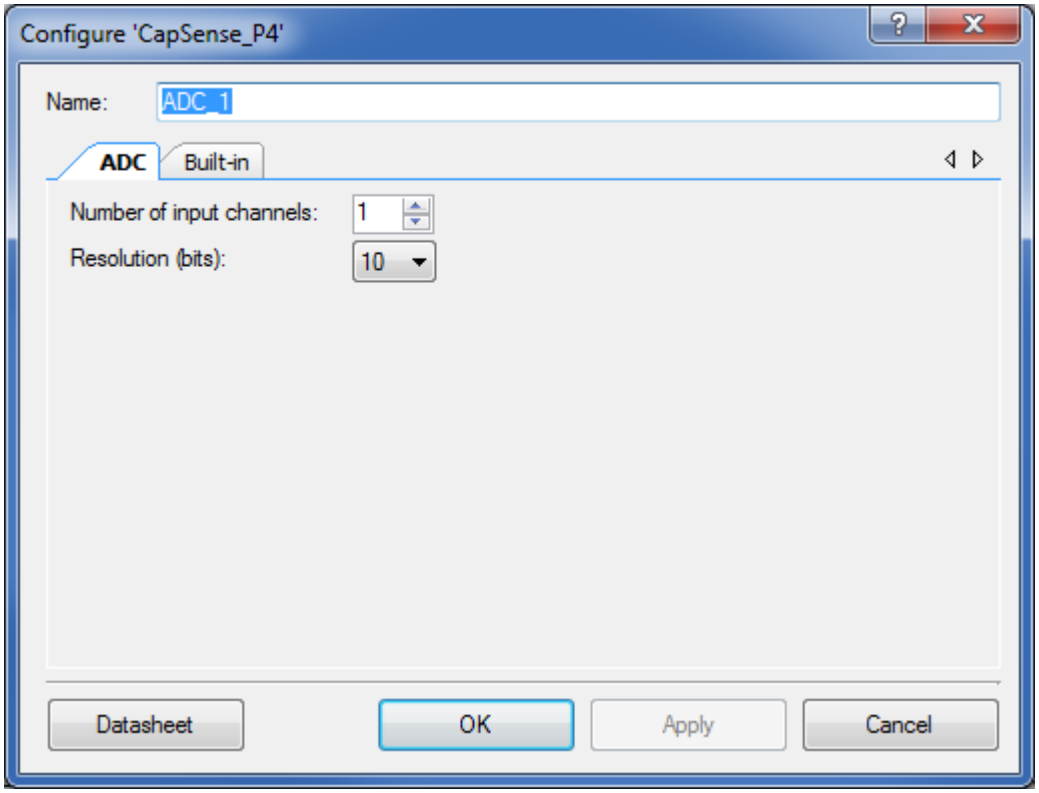
Name [1]	I/O Type	Description
AdcInput	Analog	ADC voltage inputs. The number of inputs is set by the component parameter.

1 No input/output terminals described in the table are shown on the component symbol in the Schematic Editor.

Component Configuration Parameters

Drag a component onto the design canvas and double-click to open the dialog.

ADC Tab



The parameters in this tab apply to the ADC functionality.

Name	Description
Number of input channels	Increment/decrement this value to specify the total input channels for the ADC. The range of valid values is 1-10.
Resolution (bits)	This drop-down is used to select the ADC resolution. The possible options are: ▪ 8 bits ▪ 10 bits

Application Programming Interface

Application Programming Interface (API) routines allow you to control and execute specific tasks using the component firmware. The following sections list and describe each function and dependency.

The CapSense firmware library supports the following compilers:

- ARM GCC compiler
- ARM MDK compiler
- IAR C/C++ compiler

In order to use the IAR Embedded Workbench refer to:

- PSoC Creator menu Help / Documentation / PSoC Creator User Guide
  Section: Export a Design to a 3rd Party IDE > Exporting a Design to IAR IDE

Note When using the IAR Embedded Workbench, set the path to the static library. This library is located in the following PSoC Creator installation directory:

PSoC Creator\psoc\content\CyComponentLibrary\CyComponentLibrary.cylib\CortexM0\IAR

By default, the instance name of the component is “ADC_1” for the first instance of a component in a given design. It can be renamed to any unique text that follows the syntactic rules for identifiers. The instance name is prefixed to every API function, variable, and constant name. For readability, this section assumes “ADC” as the instance name.

ADC Application Public Interface

Description

The ADC application public interface represents the abstraction layer of the ADC function. The ADC public interface is exposed to the user to implement the ADC function.

Functions

- void ADC_Start(void)
  Configures the hardware and performs a calibration.
- void ADC_Sleep(void)
  Prepares the component to deep sleep.
- void ADC_Wakeup(void)
  This function resumes the component after sleep.
- cystatus ADC_StartConvert(uint8 chId)
  Initializes an analog-to-digital conversion on the selected channel.
- uint8 ADC_IsBusy(void)
  The function returns the status of ADC's operation.
- uint16 ADC_ReadResult_mVolts(uint8 chId)
  The blocking function that starts a conversion, waits for the end of the conversion and returs the result.
- uint16 ADC_GetResult_mVolts(uint8 chId)
  Returns the last valid result for the given channel.
- cystatus ADC_Calibrate(void)
  Performs built-in calibration.
- void ADC_Stop(void)
  Disables the CSD sub-blocks that are in use while in the ADC mode, and frees the routing.
- void ADC_Resume(void)
  Resumes the ADC Component after a Stop call.

Function Documentation

void ADC_Start (void)

Configures the hardware and performs a calibration.

Go to the top of the ADC Application Public Interface section.

void ADC_Sleep (void)

Currently this function is empty and exists as a place for future updates, this function shall be used to prepare the component to enter deep sleep.

Go to the top of the ADC Application Public Interface section.

void ADC_Wakeup (void)

Currently this function is empty and exists as a place for future updates, this function shall be used to resume the component after exiting deep sleep.

Go to the top of the ADC Application Public Interface section.

cystatus ADC_StartConvert (uint8 *chId*)

Initializes an analog-to-digital conversion on the selected channel.

Parameters:

chId	The ID of the channel to be converted.

Returns:

The function returns cystatus of its operation.

- CYRET_LOCKED - The CSD hardware is in-use by CapSense. No conversion started.
- CYRET_BAD_PARAM - The chId was out of bounds. No conversion started.
- CYRET_STARTED - The ADC is already converting. No conversion started.
- CYRET_SUCCESS - A conversion has started.

Go to the top of the ADC Application Public Interface section.

uint8 ADC_IsBusy (void)

The function returns the status of ADC's operation.

Returns:

The function returns status of the ADC's operation.

- ADC_STATUS_IDLE - The ADC is not in use.
- ADC_STATUS_CONVERTING - A conversion is in progress.
- ADC_STATUS_CALIBPH1 - The ADC is in the first phase (of 3) of calibration.
- ADC_STATUS_CALIBPH2 - The ADC is in the second phase (of 3) of calibration.
- ADC_STATUS_CALIBPH3 - The ADC is in the third phase (of 3) of calibration.
- ADC_STATUS_OVERFLOW - The most recent measurement caused an overflow.

Go to the top of the ADC Application Public Interface section.

uint16 ADC_ReadResult_mVolts (uint8 *chId*)

The blocking function that starts a conversion, waits for the end of the conversion and returs the result.

Parameters:

chId	The ID of the channel to be measured

Returns:

The function returns voltage in millivolts or ADC_VALUE_BADCHANID if chId is invalid.

Go to the top of the ADC Application Public Interface section.

uint16 ADC_GetResult_mVolts (uint8 *chId*)

Returns the last valid result for the given channel.

Parameters:

chId	The ID of the channel to be measured

Returns:

The function returns voltage in mV or ADC_VALUE_BADCHANID if chId is invalid.

Go to the top of the ADC Application Public Interface section.

cystatus ADC_Calibrate (void)

Performs built-in calibration.

Returns:

The function returns cystatus of its operation.

- CYRET_LOCKED - The CSD hardware is in-use by CapSense, and could not be released.
- CYRET_SUCCESS - The block is configured for ADC use.
- CYRET_STARTED - Another ADC operation is in progress; this one was not completed.

Go to the top of the ADC Application Public Interface section.

void ADC_Stop (void)

Disables the CSD sub-blocks that are in use while in the ADC mode, and frees the routing.

Go to the top of the ADC Application Public Interface section.

void ADC_Resume (void)

Resumes the ADC Component after a Stop call.

Go to the top of the ADC Application Public Interface section.

Interrupt Service Routine

Description

The ADC component uses an interrupt that triggers after the end of each sensor scan.

After scanning is complete, the ISR copies the measured sensor raw data to the Data Structure. If the scanning queue is not empty, the ISR starts the next sensor scanning.

Component implementation avoids using critical sections in the code. In an unavoidable situation, the critical section is used and the code is optimized for the shortest execution time.

The ADC component does not alter or affect the priority of other interrupts in the system.

These API should not be used in the application layer.

Functions

- CY_ISR(ADC_IntrHandler)
  This is an internal ISR function for ADC implementation.

Function Documentation

CY_ISR (ADC_IntrHandler)

This ISR is triggered after a measurement completes or during calibration phases.

To use the entry or exit callbacks, define ADC_ADC_[ENTRY|EXIT]_CALLBACK and define the corresponding function, ADC_[Entry|Exit]Callback().

Go to the top of the Interrupt Service Routine section.

Macro Callbacks

Macro callbacks allow the user to execute code from the API files automatically generated by PSoC Creator. Refer to the PSoC Creator Help and Component Author Guide for the more details.

In order to add code to the macro callback present in the component's generated source files, perform the following:

- Define a macro to signal the presence of a callback (in cyapicallbacks.h). This will "uncomment" the function call from the component's source code.
- Write the function declaration using provided in the table name (in cyapicallbacks.h). This will make this function visible by all the project files.
- Write the function implementation (in any user file).

ADC Macro Callbacks

Macro Callback Function Name	Associated Macro	Description
ADC_EntryCallback	ADC_ENTRY_CALLBACK	Used at the beginning of the ADC interrupt handler to perform additional application-specific actions
ADC_ExitCallback	ADC_EXIT_CALLBACK	Used at the end of the ADC interrupt handler to perform additional application-specific actions

Global Variables

Description

The section documents the ADC component related global Variables.

The ADC component stores the component configuration and scanning data in the data structure. Refer to the Data Structure section for details of organization of the data structure.

Variables

- ADC_RAM_STRUCT ADC_dsRam

Variable Documentation

ADC_RAM_STRUCT ADC_dsRam

Variable that contains ADC configuration, settings and scanning results. ADC_dsRam represents RAM Data Structure.

API Constants

Description

The section documents the ADC component related API Constants.

Variables

- const ADC_FLASH_IO_STRUCT ADC_adcIoList[ADC_ADC_TOTAL_CHANNELS]

Variable Documentation

const ADC_FLASH_IO_STRUCT ADC_adcIoList[ADC_ADC_TOTAL_CHANNELS]

Array of pointers to the ADC input channels specific register

Data Structure

Description

This section provides the list of structures/registers available in the component.

Data Structures

- struct ADC_RAM_STRUCT
  Declares the top-level RAM Data Structure.
- struct ADC_FLASH_IO_STRUCT
  Declares the Flash IO object.

Data Structure Documentation

struct ADC_RAM_STRUCT

Go to the top of the Data Structures section.

Data Fields:

uint16	adcResult[ADC_ADC_TOTAL_CHANNELS]	Stores the latest ADC result for the channel. The array size is equal to the number of ADC channels used in the project.
uint8	adcStatus	Stores the status of ADC.
uint8	adcIdac	ADC IDAC
uint8	adcResolution	Stores the ADC resolution.
uint8	adcAzTime	Stores the AZ time used for ADC conversion.

struct ADC_FLASH_IO_STRUCT

Go to the top of the Data Structures section.

Data Fields:

reg32 *	hsiomPtr	Pointer to the HSIOM configuration register of the IO.
reg32 *	pcPtr	Pointer to the port configuration register of the IO.
reg32 *	drPtr	Pointer to the port data register of the IO.
reg32 *	psPtr	Pointer to the pin state data register of the IO.
uint32	hsiomMask	IO mask in the HSIOM configuration register.
uint32	mask	IO mask in the DR and PS registers.
uint8	hsiomShift	Position of the IO configuration bits in the HSIOM register.
uint8	drShift	Position of the IO configuration bits in the DR and PS registers.
uint8	shift	Position of the IO configuration bits in the PC register.

Memory Usage

The component Flash and RAM memory usage varies significantly depending on the compiler, device, number of APIs called by the application program and component configuration. The table below provides the total memory usage of firmware for given component configuration.

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

PSoC 4 (GCC)

The following component configuration is used to represent the memory usage:

Configuration	Memory Consumption	
	Flash	SRAM
ADC only: *Resolution (bits)* = 10-bit / *Number of input channels* = 10	<2500	<100

MISRA Compliance Report

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

- Project deviations – applicable for all PSoC Creator components
- Specific deviations –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 10-bit ADC component has the following specific deviations:

MISRA-C:2004 Rule	Rule Class (Required/ Advisory)	Rule Description	Description of Deviation(s)
8.8	R	An external object or function shall be declared in only one file.	Some arrays are generated based on the component configuration and these arrays are declared locally in the .c source files where they are used instead of in .h include files.
12.13	A	The increment (++) and decrement (--) operators should not be mixed with other operators in an expression.	These violations are reported for the GCC ARM optimized form of the “for” loop that have the following syntax: for(index = COUNT; index --> 0u;) It is used to improve performance.

MISRA-C:2004 Rule	Rule Class (Required/ Advisory)	Rule Description	Description of Deviation(s)
14.2	R	All non-null statements shall either have at least one side effect however executed, or cause the control flow to change.	These violations are caused by expressions suppressing the C-compiler warnings about the unused function parameters. The CapSense component has manydifferent configurations. Some of them do not use specific function parameters. To avoid the complier's warning, the following code is used: (void)paramName.
16.7	A	A pointer parameter in a function prototype should be declared as the pointer to const if the pointer is not used to modify the addressed object.	Mostly all data processing for variety configuration, widgets and data types is required to pass the pointers as an argument. The architecture and design are intended for this casting.
18.4	R	Unions shall not be used.	There are two general cases in the code where this rule is violated. 1. CapSense_PTR_FILTER_VARIANT definition and usage. This union is used to simplify the pointer arithmetic with the Filter History Objects. Widgets may have two kinds of Filter History: Regular History Object and Proximity History Object. The mentioned union defines three different pointers: void, RegularObjPtr, and ProximityObjPtr. 2. APIs use unions to simplify operation with pointers on the parameters. The union defines four pointers: void*, uint8*, uint16*, and uint32*. In all cases, the pointers are verified for proper alignment before usage.

Component Debug Window

PSoC Creator allows you to view debug information about components in your design. Each component window lists the memory and registers for the instance. For detailed hardware registers descriptions, refer to the appropriate device technical reference manual.

To open the Component Debug window:

1. Make sure the debugger is running or in the break mode.
2. Choose Windows > Components… from the Debug menu.
3. In the Component Window Selector dialog, select the component instances to view and click OK.

The selected Component Debug window(s) will open within the debugger framework. Refer to the "Component Debug Window" topic in the PSoC Creator Help for more information.

Resources

The 10-bit ADC component always consumes one CSD (CapSense Sigma-Delta) block, two 7-bit IDACs, one Analog Mux bus B, and one port-pin for each input.

References

General References

- *Cypress Semiconductor web site*
- *PSoC 4 Device datasheets*

Application Notes

Cypress provides a number of application notes describing how PSoC can be integrated into your design. You can access them at the *Cypress Application Notes web page*.

Code Examples

PSoC Creator provides access to code examples in the Code Example dialog. For component-specific examples, open the dialog from the Component Catalog or an instance of the component in a schematic. For general examples, open the dialog from the Start Page or **File** menu. As needed, use the **Filter Options** in the dialog to narrow the list of projects available to select.

Refer to the "Code Example" topic in the PSoC Creator Help for more information.

There are also numerous code examples that include schematics and code examples available online at the *Cypress Code Examples web page*.

Development Kit Boards

Cypress provides a number of development kits. You can access them at the *Cypress Development Kit web page*. Mentioned Code Examples uses the following development kits:

- *CY8CKIT-041 PSoC® 4 S-Series Pioneer Kit*
- *CY8CKIT-048 PSoC® Analog Coprocessor Pioneer Kit*

DC and AC Electrical Characteristics

Specifications are valid for +25° C, VDD 3.3v, Cmod = 2.2nF, Csh = 10nF, and CintA = CintB = 470 pF except where noted.

Note Final characterization data for PSoC 4100S and PSoC Analog Coprocessor devices is not available at this time. Once the data is available, the component datasheet will be updated on the Cypress web site.

ADC Performance Characteristics

Parameter	Min	Typ	Max	Units	Details/ Conditions
Resolution	-	-	10	bits	Auto-zeroing is required every millisecond
Number of channels - single ended	-	-	16		Defined by AMUX Bus
Monotonicity	-	-	-	Yes	Yes
Gain error	-	-	±2	%	In V_{REF} (2.4 V) mode with V_{DDA} bypass capacitance of 10 µF
Input offset voltage	-	-	3	mV	In V_{REF} (2.4 V) mode with V_{DDA} bypass capacitance of 10 µF
Current consumption	-	-	0.25	mA	
Input voltage range - single ended	V_{SSA}	-	V_{DDA}	V	
Input resistance	-	2.2	-	KΩ	
Input capacitance	-	20	-	pF	
Power supply rejection ratio	-	60	-	dB	In V_{REF} (2.4 V) mode with V_{DDA} bypass capacitance of 10 µF
Sample acquisition time	-	1	-	µs	
Conversion time for 8-bit resolution at conversion rate = Fhclk/(2^(N+2)). Clock frequency = 48 MHz.	-	-	21.3	µs	Does not include acquisition time. Equivalent to 44.8 ksps including acquisition time.
Conversion time for 10-bit resolution at conversion rate = Fhclk/(2^(N+2)). Clock frequency = 48 MHz.	-	-	85.3	µs	Does not include acquisition time. Equivalent to 11.6 ksps including acquisition time.

Parameter	Min	Typ	Max	Units	Details/ Conditions
Signal-to-noise and Distortion ratio (SINAD)	-	61	-	dB	With 10Hz input sine wave, external 2.4V reference, V_{REF} (2.4 V) mode
Input bandwidth without aliasing	-	-	22.4	KHz	8-bit resolution
Integral Non Linearity. 1 KSPS	-	-	2	LSB	V_{REF} = 2.4 V or greater
Differential Non Linearity. 1 KSPS	-	-	1	LSB	

DC/AC Specifications

Refer to devices specific datasheet *PSoC 4 Device datasheets* for more details.

Component Errata

This section lists the problems known with this Component.

Cypress ID	Component Version	Problem	Workaround
261817	3.10	ADC_CSD v3.10 Component consumes two IDACs of CSDv2 IP instead of one IDAC.	No workaround. This will be addressed in a future release.

Component Changes

This section lists the major changes in the component from the previous version.

Version	Description of Changes	Reason for Changes / Impact
3.10.a	Updated datasheet.	Added errata item 261817.
3.10	Added the following features: ▪ CSX Touchpad support ▪ Self-test library ▪ Multi-frequency scan feature ▪ IDAC sinking mode in Fourth generation CapSense ▪ Standalone ADC	Expanded functionality. Fixed potential issue with Auto mode. Documented potential issue with Inactive sensor connection to shield.
3.0.c	Edited datasheet.	Revised to correct omission of the APIs.

Version	Description of Changes	Reason for Changes / Impact
3.0.b	Edited datasheet.	Added Component Errata section to document potential issue with Auto mode.
3.0.a	Removed empty CapSense_SaveConfig() and CapSense_RestoreConfig() APIs	No usage of these API is expected in future.
	Renamed CapSense_IsProximityTouchActive() to CapSense_IsProximitySensorActive() without functionality change	Providing a meaningful name and being consistent with other APIs
	Changed Sensitivity parameter to Finger Capacitance	Providing a meaningful parameter with intuitive usage
	Added IDAC sensing configuration parameter with IDAC sinking mode	Expanded functionality
	Edited datasheet.	Final characterization data for PSoC 4000S, PSoC 4100S and PSoC Analog Coprocessor devices is not available at this time. Once the data is available, the component datasheet will be updated on the Cypress web site.
3.0 (Early Access Release)	The initial version of new component implementation. This version is not backward compatible with the previous versions.	Improved implementation of the CapSense component with PSoC 4 devices.

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