

# ADC\_Filtering\_1

## for KIT\_AURIX\_TC297\_TFT

### ADC filtering

AURIX™ TC2xx Microcontroller Training  
V1.0.1



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## Scope of work

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**Four VADC channels are used to convert the same analog signal with different filters enabled.**

The Versatile Analog-to-Digital Converter (VADC) module is configured to convert four channels in background scan mode. The data resulting from the conversions of three channels is automatically modified: one channel computes an average on 4 results, another channel applies a 3<sup>rd</sup> order Finite Impulse Response (FIR) filter and another channel applies a 1<sup>st</sup> order Infinite Impulse Response (IIR) filter. Finally, the last channel measures the same signal without Data Modification. The channels are continuously converted and, for each of them, the maximum and minimum values are stored, which are then sent through UART in order to be compared.

# Introduction

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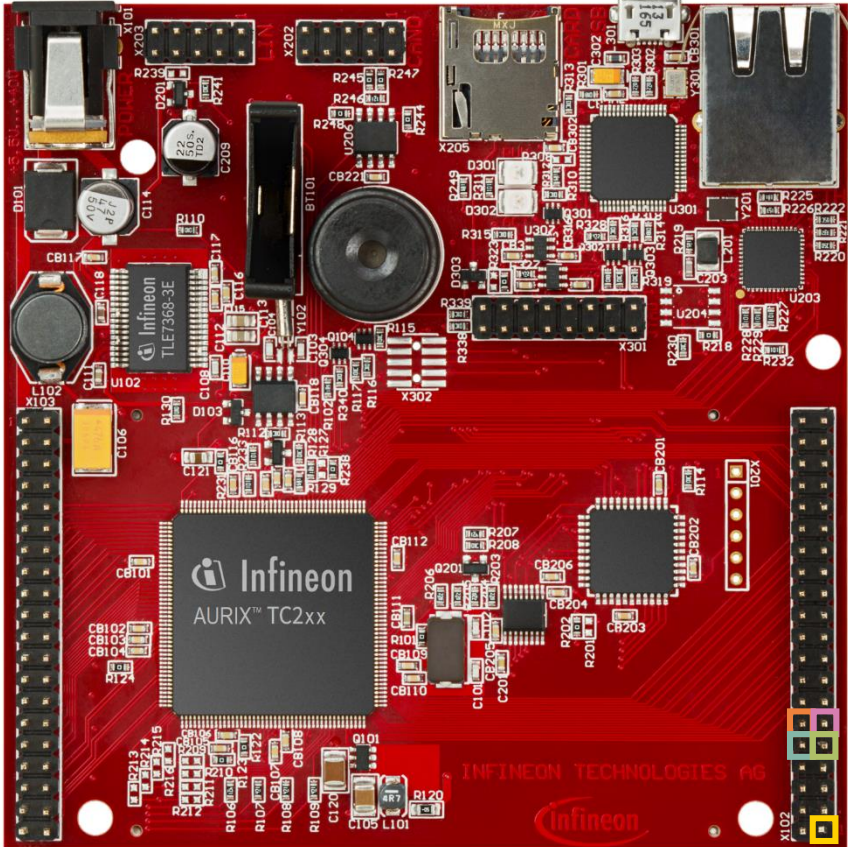
- › The Versatile Analog-to-Digital Converter module (VADC) of the AURIX™ TC29x comprises 11 independent analog to digital converters (VADC groups) with up to 8 analog input channels each.
- › Each channel can convert analog inputs with a resolution of up to 12-bit.
- › Analog/Digital conversions can be requested by several request sources:
  - **Queued request source**, specific to a single group
  - Channel scan request source, which comprises:
    - **Group scan source**, specific to a single group
    - **Background scan source**, which can request all channels of all groups
- › The Channel scan request source issues conversion requests for a coherent sequence of input channels, starting with the highest enabled channel number.
- › In background scan source (Channel scan request source), each channel is converted once per sequence. A conversion can be requested to be done once or repeatedly.
- › A background scan source can access all analog input channels that are not assigned to any group request source. These conversions are executed with low priority.

# Introduction

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- › The data resulting from conversions can be automatically modified before being used by an application to reduce the required CPU/DMA load to process the conversion.
  
- › Three types of data modification are supported:
  - **Standard Data Reduction Mode**
  - **Result Filtering Mode**
  - **Difference Mode**
  
- › With **Standard Data Reduction Mode**, the VADC accumulates up to 4 values before generating a result interrupt. This mode can be used on any result register of any group GxRES0..GxRES15, where x is the number of the group.
  
- › When **Result Filtering Mode** is enabled, depending on the configuration, the VADC can apply either a 3<sup>rd</sup> order Finite Impulse Response (FIR) filter with selectable coefficients, or a 1<sup>st</sup> order Infinite Impulse Response (IIR) filter with selectable coefficients to the conversion results. This mode can be applied on the result registers GxRES7 and GxRES15 of any group, where x is the number of the group.
  
- › The **Difference Mode** subtracts the contents of the result register GxRES0 from the conversion results. This mode can be used on the result registers GxRES1..GxRES15 of any group, where x is the number of the group.

# Hardware setup



This code example has been developed for the board `KIT_AURIX_TC297_TFT_BC-Step`. In this example, the port pins `AN0`, `AN2`, `AN3` and `AN8` are used, connected to `VCC_IN`.

	X102		
P14.5	40	39	P14.4
P20.10	38	37	P20.9
P15.7	36	35	P15.6
P15.5	34	33	P15.4
P15.3	32	31	P15.2
P22.3	30	29	P22.2
P22.1	28	27	P22.0
P33.11	26	25	P23.4
P23.3	24	23	P23.2
P23.1	22	21	P23.0
P33.6	20	19	P33.8
P33.12	18	17	P33.1
P33.2	16	15	P33.3
P33.4	14	13	P33.5
AN0	12	11	AN8
AN2	10	9	AN3
AN32	8	7	AN33
AN20	6	5	AN21
GND	4	3	GND
V_UC(+5V)	2	1	VCC_IN

**Note:** `VCC_IN` supplies the power provided to the board. If the board is supplied via the USB port, `VCC_IN` supplies ~3,3V, if the board is supplied with an external power supply, `VCC_IN` can reach 40V, thus connect the 4 analog pins to a DC signal between 0 and 5V instead.

# Implementation

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## Configuration of the VADC

The configuration of the VADC is done in the ***initADC()*** function in four different steps:

- › Configuration of the **VADC module**
- › Configuration of the **VADC groups**
- › Configuration of the **VADC channels**
- › Configuration of the **data modification**

## Configuration of the VADC module

The default configuration of the VADC module, given by the iLLDs, can be used for this example.

This is done by initializing an instance of the ***IfxVadc\_Adc\_Config*** structure and applying default values to its fields through the function ***IfxVadc\_Adc\_initModuleConfig()***.

Then, the configuration can be applied to the VADC module with the function ***IfxVadc\_Adc\_initModule()***.

# Implementation

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## Configuration of the VADC groups

The configuration of the VADC groups is done by initializing an instance of the *IfxVadc\_Adc\_GroupConfig* structure with default values through the function *IfxVadc\_Adc\_initGroupConfig()* and modifying the following fields:

- › **arbiter** – a structure that represents the enabled request sources, which can be Group scan, Queue and/or Background sources. In this example, **arbiter.requestSlotBackgroundScanEnabled** is set to **TRUE**, thus enabling the Background scan source.
- › **backgroundScanRequest** – a structure that allows to configure the Background Scan Request Source by setting:
  - **autoBackgroundScanEnabled** – a parameter to set the autoscan mode (conversions are requested continuously)
  - **triggerConfig** – a parameter that specifies the trigger configuration
- › **master** – to indicate which converter is the master
- › **groupId** – to select which converter to configure

While using multiple converters, they can have the same or different settings. In this example, the same configuration is applied to all the used converters by changing the **groupId** parameter in the **for** loop.

The configuration is applied through the function *IfxVadc\_Adc\_initGroup()* inside the **for** loop.

# Implementation

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## Configuration of the VADC channels

The configuration of each channel is done by initializing an instance of the *IfxVadc\_Adc\_ChannelConfig* structure with default values through the function *IfxVadc\_Adc\_initChannelConfig()* and modifying the following fields:

- › ***channelId*** – to select the channel to configure
- › ***resultRegister*** – to indicate the register where the A/D conversion value is stored
- › ***backgroundChannel*** – to specify that the selected channel is used as a background channel

Then, the configuration is applied with the function *IfxVadc\_Adc\_initChannel()* and the channel is added to the background scan sequence through the function *IfxVadc\_Adc\_setBackgroundScan()*.

Finally, the result registers used for storing the conversion results can be configured to use data modification, in order to enable the filtering.

## Configuration of the data modification

The data modification is configured in the *applyFiltering()* function.

The iLLDs for AURIX™ TC2xx do not support the VADC data modification, thus it is needed to directly modify the Group Result Control Registers (GxRCRy, with x indicating the Group number and y indicating the result register where to apply the filtering).



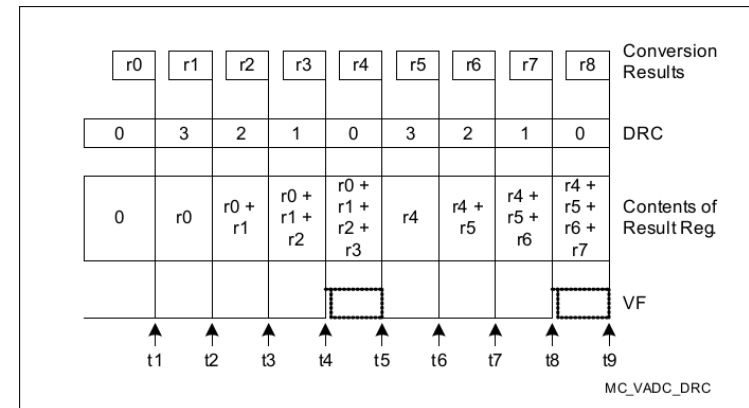
# Implementation

## Configuration of the data modification

To enable the **Standard Data Reduction Mode** on a specific result register, the Data Modification Mode (DMM) bit field of the associated GxRCRy register must be set to  $00_B$  and the Data Reduction Control (DRCTR) bit field of the same can be set to one of the following values:

**Table 1**

DMM	DRCTR	Mode
$00_B$	$0000_B = 0x0$	Data Reduction disabled
$00_B$	$0001_B = 0x1$	Accumulate 2 result values
$00_B$	$0010_B = 0x2$	Accumulate 3 result values
$00_B$	$0011_B = 0x3$	Accumulate 4 result values



When the conversion is ready, depending on the configuration of the DRCTR bit field, the result register contains the sum of up to 4 result values, thus it is needed to divide the content of the result register GxRESy by the number of the accumulated values in order to obtain an average of the measurements.

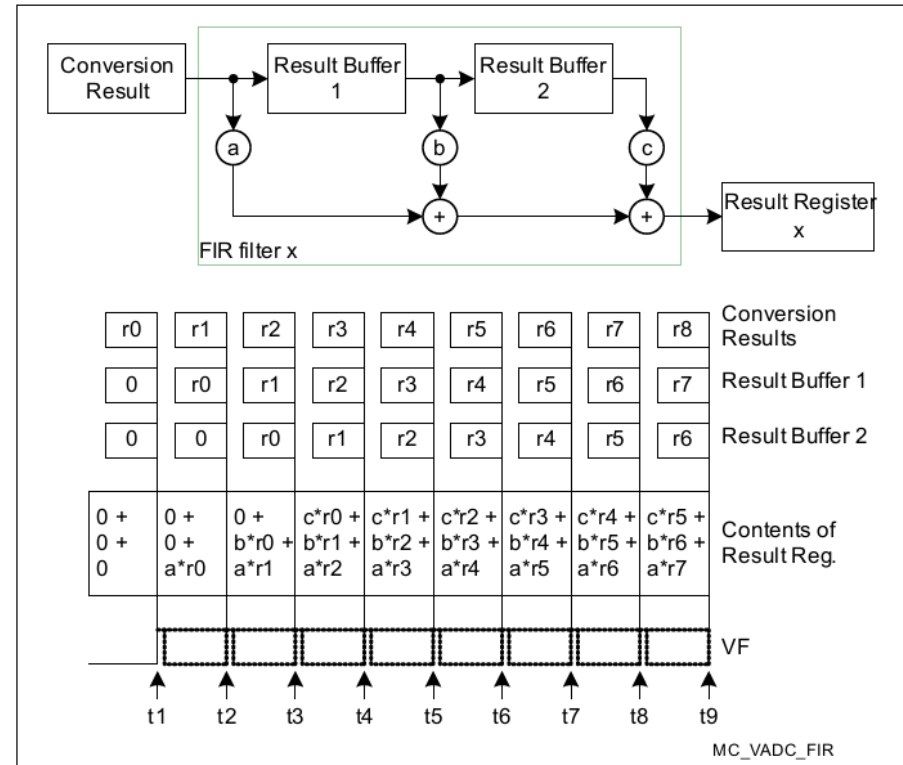
**Note:** Using Standard Data Reduction Mode, the final result must be read before the next data reduction sequence starts (before t5 or t9 in the example), otherwise the Valid Flag (VF) bitfield **will not be cleared**. In order to read a correct measurement, VF must be 1 and Data Reduction Counter (DRC) bitfield must be 0.

# Implementation

## Configuration of the data modification

To enable the **Result Filtering Mode** on a specific result register, the Data Modification Mode (DMM) bit field of the associated GxRCRY register must be set to  $01_B$  and the Data Reduction Control (DRCTR) bit field of the same register can be set to enable either a 3<sup>rd</sup> order Finite Impulse Response (FIR) filter or a 1<sup>st</sup> order Infinite Impulse Response (IIR) filter, both with selectable coefficients, according to the values in [Table 3](#).

When a **FIR filter** is enabled, depending on the selected coefficients, a gain of 3 or 4 (the DC gain of a FIR filter is equal to the sum of its coefficients) is applied to the ADC result, producing a 14-bit value. Therefore, in order to obtain the filtered measurement, it is needed to divide the content of the result register by the sum of the selected coefficients.



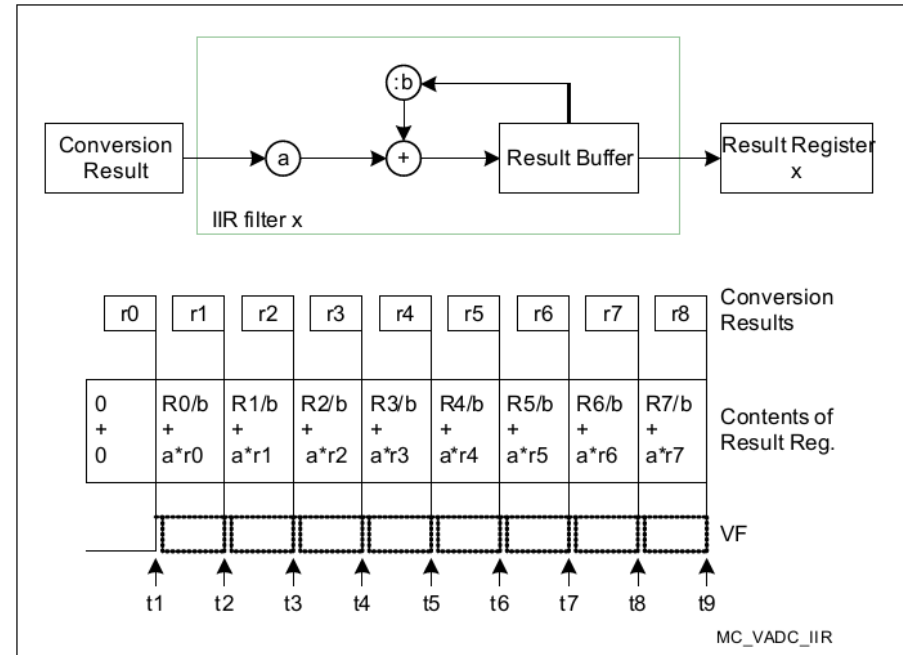
# Implementation

## Configuration of the data modification

The selectable coefficients for an **IIR filter** lead to a gain of 4 to the ADC result, producing a 14-bit value. Consequently, in order to obtain the filtered measurement, the content of the result register needs to be divided by 4.

All the measurement's divisions are carried out in the **Cpu0\_main.c** file, after reading the conversion result from the result register.

The FIR and IIR filters need to be initialized, otherwise the first values are incorrect (see the figures for the two filters).



**Note:** In this example, a delay before starting to read the conversion results is needed. This ensures that reading spikes in the VCC\_IN supply due to the initialization of the device are avoided and that incorrect values are not read due to the filters not being yet at full speed.

# Implementation

## Configuration of the data modification

**Result Filtering Mode:** Available coefficients for FIR and IIR filters are listed in Table 3.

In this example, the converted channels are configured as it follows:

**Table 2**

Channel	Data Modification Mode enabled
AN0	Standard Data Reduction Mode
AN2	Result Filtering Mode: FIR filter
AN3	Result Filtering Mode: IIR filter
AN8	No Data Modification Mode enabled

The channel AN8 has no data modification enabled in order to use it as a comparison.

**Table 3**

DMM	DRCTR	Filter coefficients
01 <sub>B</sub>	0000 <sub>B</sub> = 0x0	FIR filter: a=2, b=1, c=0
01 <sub>B</sub>	0001 <sub>B</sub> = 0x1	FIR filter: a=1, b=2, c=0
01 <sub>B</sub>	0010 <sub>B</sub> = 0x2	FIR filter: a=2, b=0, c=1
01 <sub>B</sub>	0011 <sub>B</sub> = 0x3	FIR filter: a=1, b=1, c=1
01 <sub>B</sub>	0100 <sub>B</sub> = 0x4	FIR filter: a=1, b=0, c=2
01 <sub>B</sub>	0101 <sub>B</sub> = 0x5	FIR filter: a=3, b=1, c=0
01 <sub>B</sub>	0110 <sub>B</sub> = 0x6	FIR filter: a=2, b=2, c=0
01 <sub>B</sub>	0111 <sub>B</sub> = 0x7	FIR filter: a=1, b=3, c=0
01 <sub>B</sub>	1000 <sub>B</sub> = 0x8	FIR filter: a=3, b=0, c=1
01 <sub>B</sub>	1001 <sub>B</sub> = 0x9	FIR filter: a=2, b=1, c=1
01 <sub>B</sub>	1010 <sub>B</sub> = 0xA	FIR filter: a=1, b=2, c=1
01 <sub>B</sub>	1011 <sub>B</sub> = 0xB	FIR filter: a=2, b=0, c=2
01 <sub>B</sub>	1100 <sub>B</sub> = 0xC	FIR filter: a=1, b=1, c=2
01 <sub>B</sub>	1101 <sub>B</sub> = 0xD	FIR filter: a=1, b=0, c=3
01 <sub>B</sub>	1110 <sub>B</sub> = 0xE	IIR filter: a=2, b=2
01 <sub>B</sub>	1111 <sub>B</sub> = 0xF	IIR filter: a=3, b=4

# Implementation

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## Configuration of the VADC

When the VADC module and its groups and channels are configured and the Data Modification registers are correctly configured, the scan sequence is started with the function ***IfxVadc\_Adc\_startBackgroundScan()***.

## Read the VADC measurements

Finally, to read a conversion, the function ***readADCValue()*** is used, which calls the ***IfxVadc\_Adc\_getResult()*** function from iLLDs until a new measurement is returned (a new measurement is considered correct only when both the Valid Flag and the Data Reduction Counter bitfield are set to 1 and respectively 0, the latter is needed because the Standard Data Reduction Mode is enabled on the AN0 pin).

All the functions used to get a conversion and configuring the VADC module, its group and channels can be found in the iLLD header ***IfxVadc\_Adc.h***.

# Implementation

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## Configuration of the UART

In this example, the UART connection is used to make the debugging more convenient and easier to understand. The configured VADC channels are continuously read, but the maximum and minimum values, together with the computed  $V_{pp}$  are printed using UART communication only when the user requests them.

The ***initUART()*** function initializes the UART communication.

The iLLD function ***IfxAsclin\_Asc\_initModuleConfig()*** fills the configuration structure ***ascConf*** with default values. Then, the parameters used to configure the module are set, depending on the needed connection: baudrate, Tx and Rx buffers, Tx and Rx pin configuration etc.

Finally, ***IfxAsclin\_Asc\_initModule()*** initializes the module with the user configuration and ***IfxAsclin\_Asc\_stdIfDPipeInit()*** initializes the standard interface to use the ASCLIN module.

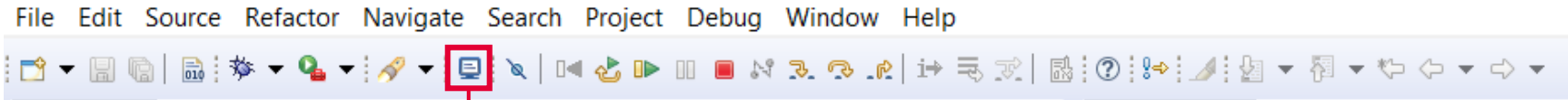
The functions ***isDataAvailable()*** and ***receiveData()*** are used to interface with the ASCLIN module to check if new data is available through the function ***IfxAsclin\_Asc\_getReadCount()*** and, respectively, to receive data over the UART communication through the function ***IfxAsclin\_Asc\_read()***.

The function ***IfxStdIf\_DPipe\_print()*** is used to print the stored processed values.

The functions used to interface and initialize the ASCLIN module can be found in the iLLD header ***IfxAsclin\_Asc.h***, while the latter can be found in the iLLD header ***IfxStdIf\_DPipe.h***.

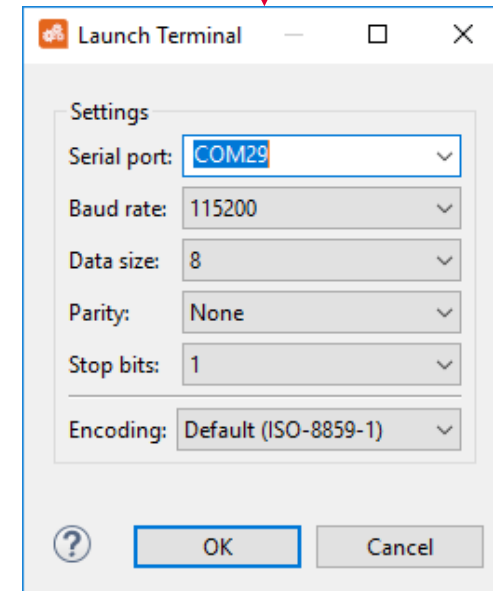
# Run and Test

- › For this training, a serial monitor is required for visualizing the values. The monitor can be opened inside the AURIX™ Development Studio using the following icon:



- › The serial monitor must be configured with the following parameters to enable the communication between the board and the PC:

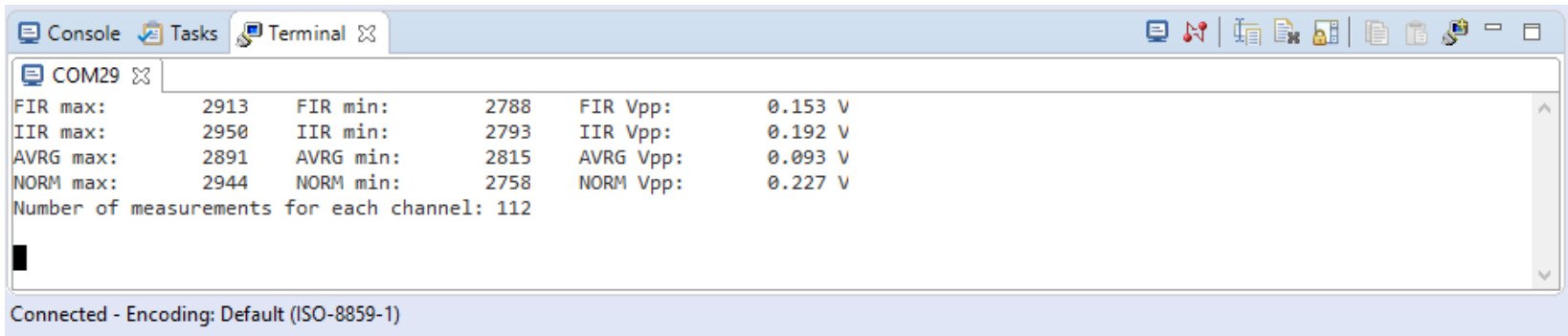
- Speed (baud): 115200
- Data bits: 8
- Stop bit: 1



# Run and Test

After code compilation and flashing the device, perform the following steps:

- > Connect the channels AN0, AN2, AN3 and AN8 to the VCC\_IN pin (~3.3V), or to any DC signal between 0 and 5V
- > Open the serial monitor and start the serial communication, linked with the appropriate COMx port (this can be checked in the Device Manager)
- > After a few seconds, send the character “1” to print the maximum and minimum values read by the channels, together with the computed  $V_{pp}$



```

COM29
FIR max:      2913    FIR min:      2788    FIR Vpp:      0.153 V
IIR max:      2950    IIR min:      2793    IIR Vpp:      0.192 V
AVRG max:     2891    AVRG min:     2815    AVRG Vpp:     0.093 V
NORM max:     2944    NORM min:     2758    NORM Vpp:     0.227 V
Number of measurements for each channel: 112
  
```

Connected - Encoding: Default (ISO-8859-1)

The maximum and minimum values are expressed as a 12-bits integer value, in decimal format (0 - 4095 range), while the  $V_{pp}$  is expressed in Volts

It can be noticed that for this signal, the filter applying an average is the most effective one to reduce the  $V_{pp}$  range



# References



- › AURIX™ Development Studio is available online:
- › <https://www.infineon.com/aurixdevelopmentstudio>
- › Use the „*Import...*“ function to get access to more code examples.



- › More code examples can be found on the GIT repository:
- › [https://github.com/Infineon/AURIX\\_code\\_examples](https://github.com/Infineon/AURIX_code_examples)



- › For additional trainings, visit our webpage:
- › <https://www.infineon.com/aurix-expert-training>



- › For questions and support, use the AURIX™ Forum:
- › <https://www.infineonforums.com/forums/13-Aurix-Forum>

# Revision history

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Revision	Description of change
V1.0.1	Update of version to be in line with the code example's version
V1.0.0	Initial version

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### Document reference

**ADC\_Filtering\_1\_KIT\_TC297\_TFT**

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