PMA71xx/PMA51xx

SmartLEWIS^{TM} MCU

RF Transmitter FSK/ASK 315/434/868/915 MHz
Embedded 8051 Microcontroller with 10 bit ADC
Embedded 125 kHz ASK LF Receiver

Application Note

ADC Examples

Revision 1.0, 2010-03-03

Wireless Control

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1 Introduction

This document is a description of the Analog to Digital Converter (ADC) software examples for applications on the PMA71xx/PMA51xx. The available software examples show how to use the single ended input, the differential input and the differential high sensitivity input of the ADC.

The source code examples include inline documentation and are utilizing the PMA71xx/PMA51xx Software Framework and extend it with ADC functionality.

The PMA71xx/PMA51xx Software Framework is used in Version 2.0. For detailed information please refer to http://www.infineon.com/PMA (Documents -> Application Notes -> PMAx1xx - Software Framework).

2 PMA ADC Basics

The PMA71xx/PMA51xx offers a 10 bit successive approximation Analog to Digital Converter. It offers two differential high sensitivity input channels and one input channel configurable as single ended or differential input. Regardless of the conversion mode, input voltages on any channel must stay between GND and V_{Reg}. V_{Reg} depends on V_{Bat} and is approx. 2.5V as long as V_{Bat} is higher than 2.5V.

Several internal signals are available as reference voltages. For the differential high sensitivity input channel also the single ended input can be used to apply an external reference voltage.

2.1 Single Ended Input Measurement

When using the single ended mode on the standard sensor interface (channel 2), the voltage applied to the pin AMUX1 relative to GND is converted to a digital value. It is recommended to connect the unused AMUX2 to GND.

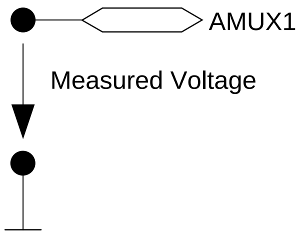


Figure 1 Schematic of a single ended measurement

To setup the standard sensor interface set ADCM.0-2[CS] to 010_b in order to set channel 2 as input channel and set the ADCC1.7[SeDC] to 0 for single ended conversion.

An appropriate reference signal source has to be selected to decide the conversion range. A list of available reference signals can be found in Table 1 on page 10.

As an example, when using the internal reference voltage source (channel 3) the conversion range is between 0V and 1210mV. A larger voltage than 1210mV applied to AMUX1 will be truncated to a digital ADC value of 1023 while negative voltage will result in a digital ADC value of zero. With the provided 10 bit resolution of the ADC, the least significant bit is representing 1.18mV.

The result of a single ended conversion can be calculated with the formula shown in Figure 2.

$$result_{code} = trunc\left(2^{10}\frac{U_{Channel} + U_{Offset}}{U_{Reference}}\right)$$

$U_{Channel}$ is the voltage applied to the standard sensor input AMUX 1,
U_{Offset} is the offset compensation value ADCOFF.5-0 [OFF5_0] and
$U_{Refereance}$ is the selected reference voltage ADCM.6-4[RV]

Figure 2 Formula to calculate a single ended conversion result

2.2 Differential Input Measurement

When the differential conversion on the standard sensor interface (channel 2) is used, the voltage between AMUX1 and AMUX2 is converted to a digital value. AMUX1 is connected to the positive input signal, AMUX2 to the negative. The voltage applied to AMUX1 and AMUX2 must not exceed V_{Reg}.

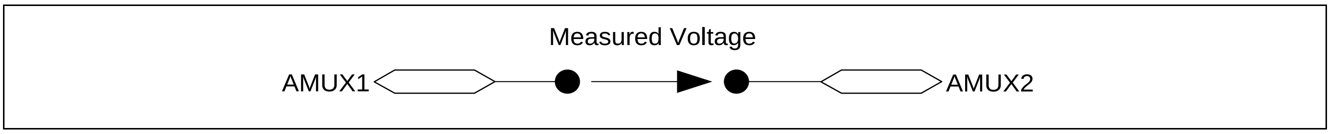


Figure 3 Schematic of a differential measurement

To setup the standard sensor interface set ADCM.0-2[CS] to 010_b in order to select channel 2 as input channel and set the ADCC1.7 [SeDC] to 1 for differential conversion. Also an appropriate reference signal source has to be selected.

As an example, when using the internal reference voltage source (channel 3) the conversion range is between -1210mV and 1210mV. Higher voltages between AMUX1 and AMUX2 than 1210mV will be truncated to a digital ADC value of 1023 while smaller values than-1210mV will result in a digital ADC value of zero. A voltage of zero between AMUX1 and AMUX2 will result in a digital ADC value of 512. With the provided 10 bit resolution of the ADC, the least significant bit is representing 2.36mV as the conversion range is twice the range of a single ended conversion.

The result of a differential conversion can be calculated with the formula shown in Figure 4.

$$result_{code} = 2^9 + trunc\left(2^9 \frac{U_{Channel} + U_{Offset}}{U_{Reference}}\right)$$

$\mathbf{U_{Channel}}$ is the voltage applied to the standard sensor input AMUX 1,
$\mathbf{U_{Offset}}$ is the offset compensation value ADCOFF.5-0 [OFF5-0] and
$\mathbf{U_{Reference}}$ is the selected reference voltage ADCM.6-4[RV]

Figure 4 Formula to calculate a differential conversion result

2.3 Differential High Sensitivity Input Measurement

There are two high gain input sources available, the differential high sensitivity input 1 (channel 6) and the differential high sensitivity input 2 (channel 7).

For the differential high sensitivity input 1 (channel 6), the positive input signal has to be connected to V1P and the negative input signal to V1N. V1M is a separate ground pin in order to reduce noise on the ADC measurement.

When using the differential high sensitivity input 2 (channel 7), the positive input signal has to be connected to V2P, the negative input signal to V2N and the ground signal to V1M.

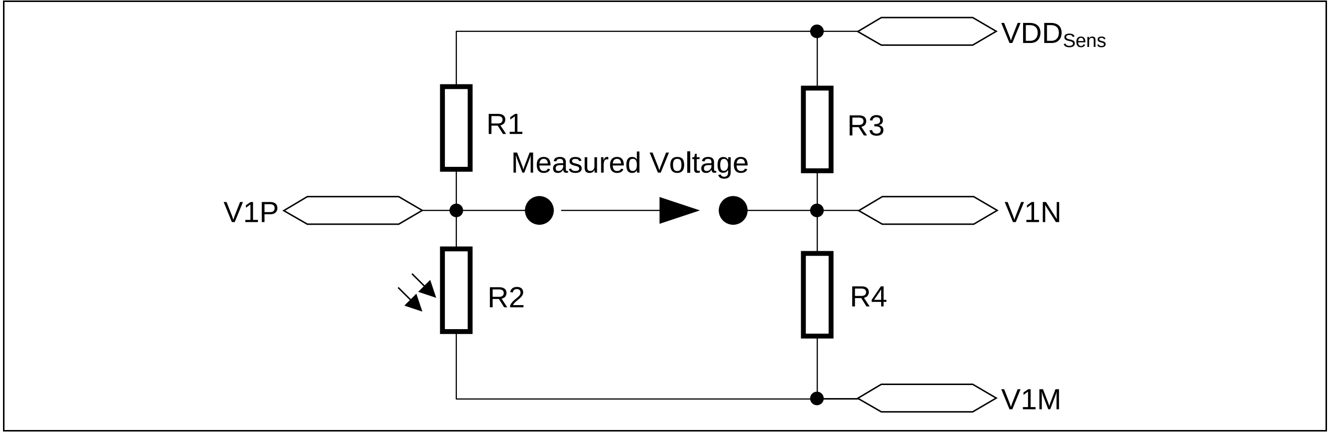


Figure 5 Schematic of a high sensitivity differential measurement

Furthermore there is a switchable supply available for the two differential high sensitivity inputs. In case of using the Wheatstone bridge supply, VDD_{Sens} is used as the positive end of the power supply and can be enabled by software during ADC measurement. For best measurement results the reference voltage channel 5 “Wheatstone bridge supply” should be used in this setup. To minimize the energy consumption “Wheatstone bridge supply” is automatically switched off when the measurement is finished.

When channel 6 or 7 is selected as input to the ADC, the reference voltage should be identical to the supply voltage of the sensor bridge, in order to get correct ratiometric operation. If the sensor bridge is connected between VDD_{Sens} and VM1 (or VM2) channel 5 will provide the correct reference voltage.

If the sensor is supplied by external power, the positive and negative supply voltages of the sensor bridge should be connected to channel 2 (AMUX1, AMUX2), and this channel should be used as a reference (see Figure 6). The supply voltage of the sensor must always be within the range GND to V_{Reg}.

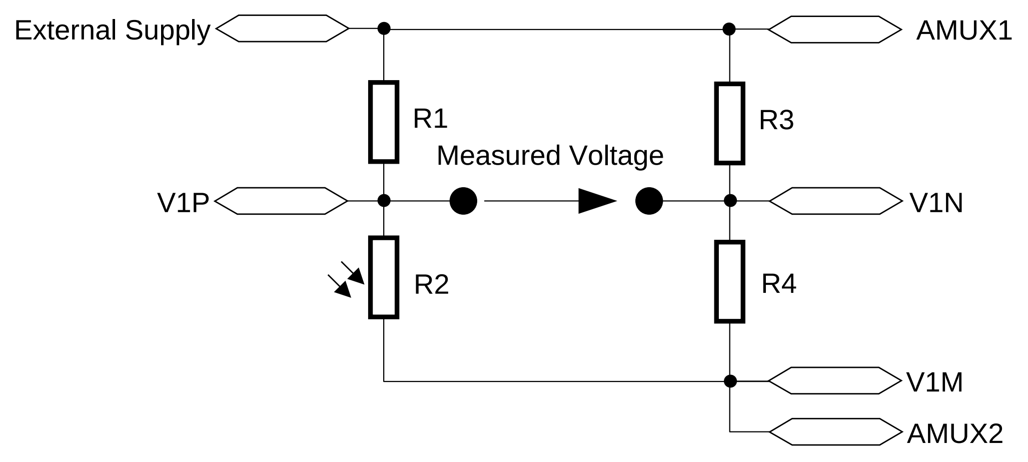


Figure 6 Schematic of a differential high sensitivity measurement with external supply

The result of a differential high sensitivity conversion can be calculated with the formula shown in Figure 7.

$$result_{code} = 2^9 + trunc\left(2^9 gain \frac{U_{Channel} + U_{Offset}}{U_{Reference}}\right)$$

$\mathbf{U}_{\mathbf{Channel}}$ is the voltage applied to the differential high sensitivity input
$\mathbf{U}_{\mathbf{Offset}}$ is the offset compensation value ADCOFF.5-0 [OFF5-0] and
$\mathbf{U}_{\mathbf{Reference}}$ is the selected reference voltage ADCM.6-4[RV].
The **gain** factor can be set to 38, 50, 60, 76 in register ADCC1.5-4[GAIN] for channel 6 & 7

Figure 7 Formula to calculate a differential high sensitivity conversion result (channels 6 & 7)

2.4 Reference Sources

The ADC of the PMA71xx/PMA51xx has multiple reference sources available. Basically all input sources can be used as reference source as well with the exception of the differential high sensitivity input channels.

Beside the technical possibility, not all combinations do make sense. For example using V_{Reg} as input source and the internal reference voltage as reference source will always result in 1023 as the V_{Reg} provides 2.5V but the internal reference voltage is 1.21V. This case does not have any practical relevance.

Table 1 provides an overview of the feasible combinations.

Table 1 Reference Voltage and Input Channel Matrix

Input **Reference**	Battery Sensor Signal	Temperature Sensor Signal	Standard-Sensor Interface	Internal Reference Voltage	V_{reg} Sensor Signal	Wheatstone Bridge Supply	Differential High Sensitivity Input 1 & 2
Battery Sensor Signal	**n.a.**	**X**	**X**	**X**	**X**	**X**	**X**
Temperature Sensor Signal	**X**	**n.a.**	**X**	**X**	**X**	**X**	**X**
Standard-Sensor Interface	**X**	**X**	**n.a.**	**X**	**X**	**X**	**X**
Internal Reference Voltage	**X**	**X**	**X**	**n.a.**	**n.a.**	**n.a.**	**X**
V_{reg} Sensor Signal	**X**	**X**	**X**	**n.a.**	**n.a.**	**n.a.**	**X**
Wheatstone Bridge Supply	**n.a.**	**n.a.**	**n.a.**	**n.a.**	**n.a.**	**n.a.**	**X**

3 Application Examples

This chapter describes the software examples provided with this application note. The ADC measurement results are transmitted by PMA51xx/PMA71xx to Infineon RF Receiver TDA5230. The installation of the PMA ADC Examples and the configuration of the Transmitter and Receiver is described in chapter 4.Tooling on Page 14.

3.1 Example Basics

The ADC Examples are based on the PMA Software Framework (Download more information from http://www.infineon.com/PMA). It extends the framework by two additional files, ADC_functions.h and ADC_functions.c, with two additional functions, *ADCInit()* and *ADCMeasure()*.

Inline documentation of the ADC software example is provided as HTML. To view the function descriptions of the ADC software example please open **index.html**, which is located in the ADC example folder, with a web browser.

3.1.1 ADCInit()

The PMA ADC registers are initialized according to a configuration provided as structure. All available options are described in the ADC_functions.h file as well as in the Function Documentation in the ADC examples folder.

3.1.2 ADCMeasure()

The ADCMeasure() function executes the measurement. The ADC is powered up, the bridge power supply is enabled, if selected in ADCInit(), the measurement is executed and the ADC is powered down again. The function returns 0 in case of a successful measurement, 1 if an underflow is detected and 2 for an overflow. The parameter of this function provides an integer pointer where the measurement result is stored.
When using differential conversion, the result can be positive or negative and is between -512 and 511. A single input conversion is always positive in a range between 0 and 1023.

3.2 Internal Voltage Sensor Example

The internal voltage sensor example just shows how to use the ADC functions. It does not require any external components and is executable on all PMA devices and Starter Kits providing the ADC functionality.

To measure the battery voltage in productive code the library function *MeasureSupplyVoltage(),* described in the PMA Function Library Guide, should be used. The library function includes factory trimming and temperature compensation.

3.3 Single Ended Input Measurement Example

All further examples are based on a light dependent resistor (LDR) as a signal source. The device used in these examples is a VT935G from PerkinElmer Optoelectronics with a resistance of typically 18.5kOhm at 10lux ambient light. This device should be easily available at a component distributor.

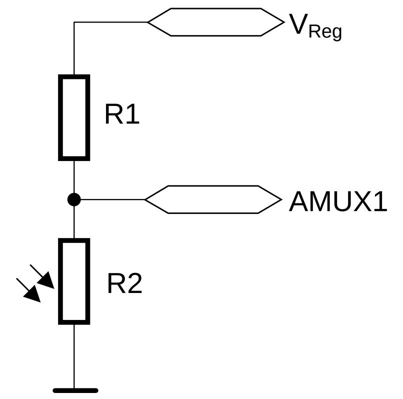


Figure 8 **Schematic of the single ended input LDR measurement example**

For the single ended input measurements the LDR is used as R2. The value of R1 is 18k. The V_{Reg} voltage (2.5V) is used as supply and as reference voltage.

Therefore an ADC result of about 520 is expected at 10lux ambient light (which basically is a candle light) as the proportion R1 to R2 is 18kOhm to 18.5kOhm. In a well-lit office an ADC result of about 100 can be expected, depending on the illumination level of the room.

To calculate the intensity of ambient light based on the measurement results, as a first step the resistance of the LDR is calculated based on the formula shown in Figure 9.

$$R_{LDR} = \frac{R_1 * \ Result_{code}}{1024 - Result_{code}}$$

R_1 is 18kOhm

Figure 9 Calculation of the LDR resistance in the single ended input measurement

Based on the LDR value the ambient light is calculated based on the formula shown in Figure 10. As the resistance of the LDR is not a linear function, a power with about 1.1 is necessary.

$$Ambient\ Light = 10 * \left(\frac{R_{LDR\_10Lux}}{R_{LDR}}\right)^{\frac{1}{0.9}}$$

R_{LDR_10Lux} is 18.5kOhm

Figure 10 Calculation of the LDR ambient light

3.4 Differential Input Measurement Example

The differential input measurement example is using a Wheatstone resistor bridge. The resistors R1 to R3 are all 18kOhm. This results in a measured voltage close to zero between AMUX1 and AMUX2 on 10lux ambient light (ADC conversion result is about 512). In a well-lit office where the ambient light is expected to be more than 10lux, the measured value will be negative (ADC conversion result below 512 is expected). The ADC function *ADCMeasure(..)* of the source code examples automatically converts this to a negative value.

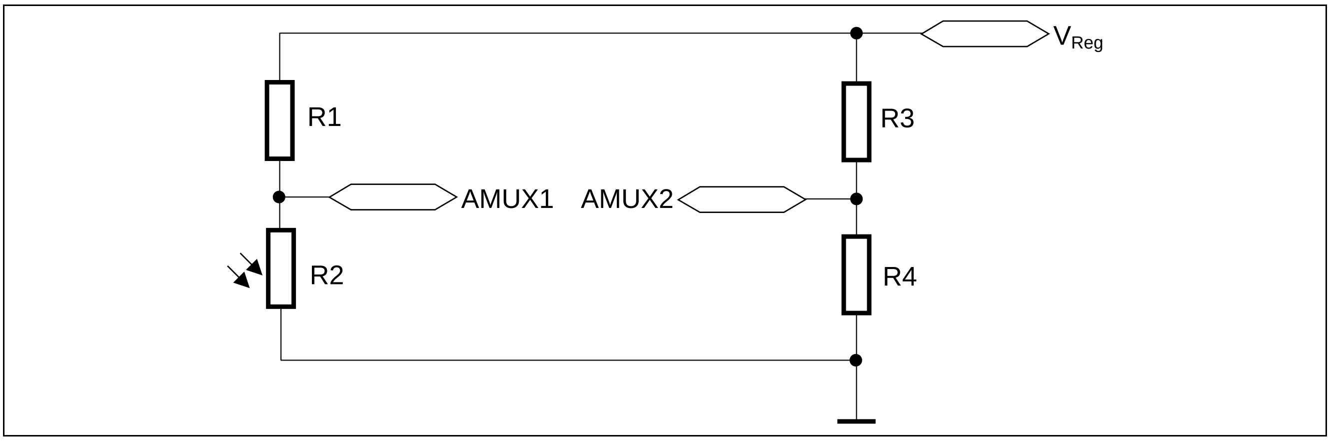


Figure 11 Schematic of the differential input LDR measurement example

The resistance of the LDR is calculated based on the formula shown in Figure 12.

$$R_{LDR} = \frac{R_1 * \ Result_{code} \ * (R_3 + R_4) + R_4 * 1024}{R_3 * 1024 - Result_{code} \ * (R_3 + R_4)}$$

R_1, R_2, R_3 are 18kOhm

Figure 12 Calculation of the LDR resistance in the differential input measurement

Note: The ambient light calculation is the same as in Figure 10 on page 12.

3.5 Differential High Sensitivity Input Measurement Example

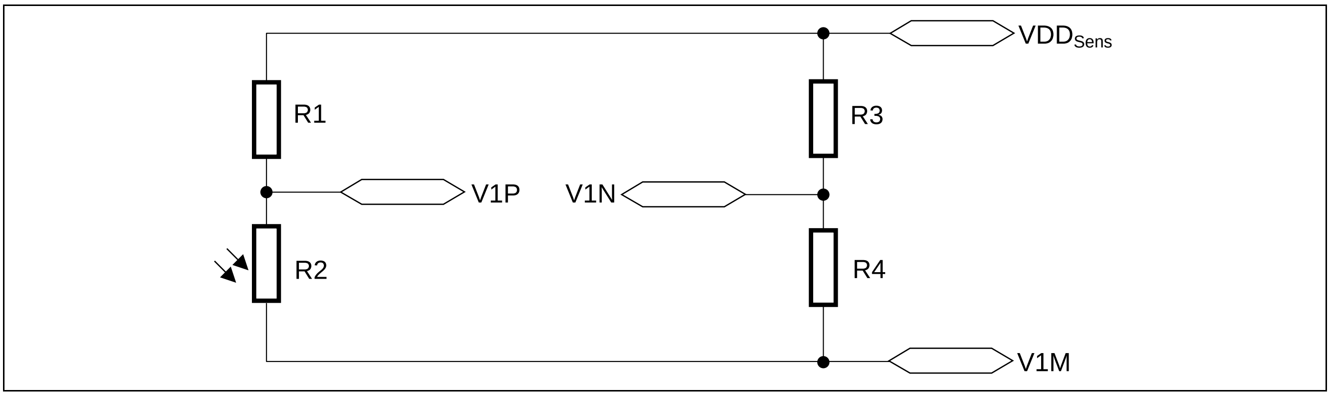


Figure 13 Schematic of the differential high sensitivity LDR measurement example with bridge power supply

Using the high sensitivity inputs the steps are similar to the differential input measurements but the gain has to be considered when calculating the resistance of the LDR. The formula with consideration of the gain is shown in Figure 14.

$$R_{LDR} = \frac{R_1 * \ Result_{code} \ * (R_3 + R_4) + R_4 * 1024 * Gain}{R_3 * 1024 * Gain - Result_{code} \ * (R_3 + R_4)}$$

Gain in the example code is set to 38

R_1, R_2, R_3 are 18kOhm

Figure 14 Calculation of the LDR resistance in the differential high sensitivity input measurement

4 Tooling

To get the shown examples properly running, Infineon provides a toolset which helps the developer to verify his work and that both transmitter and receiver are correctly configured. The provided quick start guides will give more details and also the steps to get the tools and boards running.

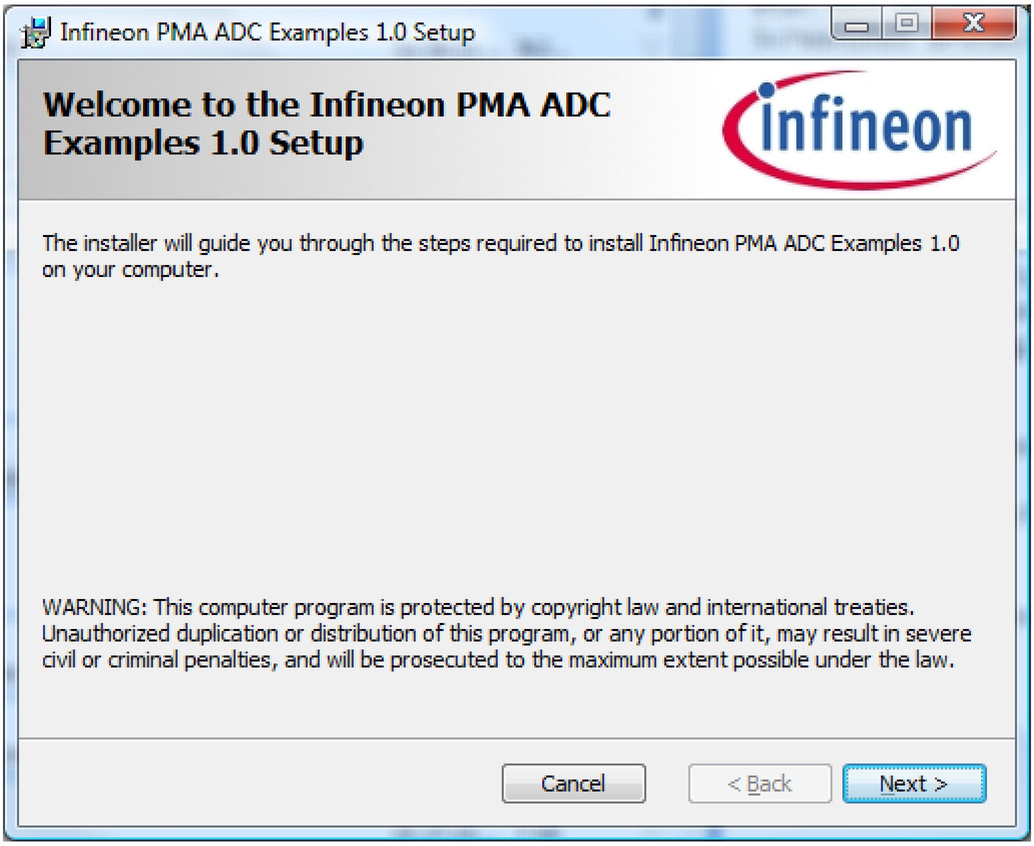
- Transmitter - PMA71xx/PMA51xx (Download more information from http://www.infineon.com/PMA_tooling)
- (Optional) Receiver - TDA523x (Download more information from http://www.infineon.com/TDA5230)

4.1 Transmitter

The Internal Voltage Sensor Example is fully functional on both development boards, the PMA Evaluation Kit and the PMA Starter Kit. Examples 3.3 to 3.5 should be used with the PMA Evaluation Kit which provides full access to all ADC pins.
Note: Please ensure that the matching network of the transmitter board corresponds to the selected protocol example frequency.

4.1.1 How to download ADC Examples to the PMA71xx/PMA51xx

1) Download and unzip PMA_ADC_Examples_Vx.x.zip from http://www.infineon.com/PMA.
2) Install PMA_ADC_Examples_Vx.x.msi to your preferred location on your hard or network drive.



Infineon PMA ADC Examples 1.0 Setup

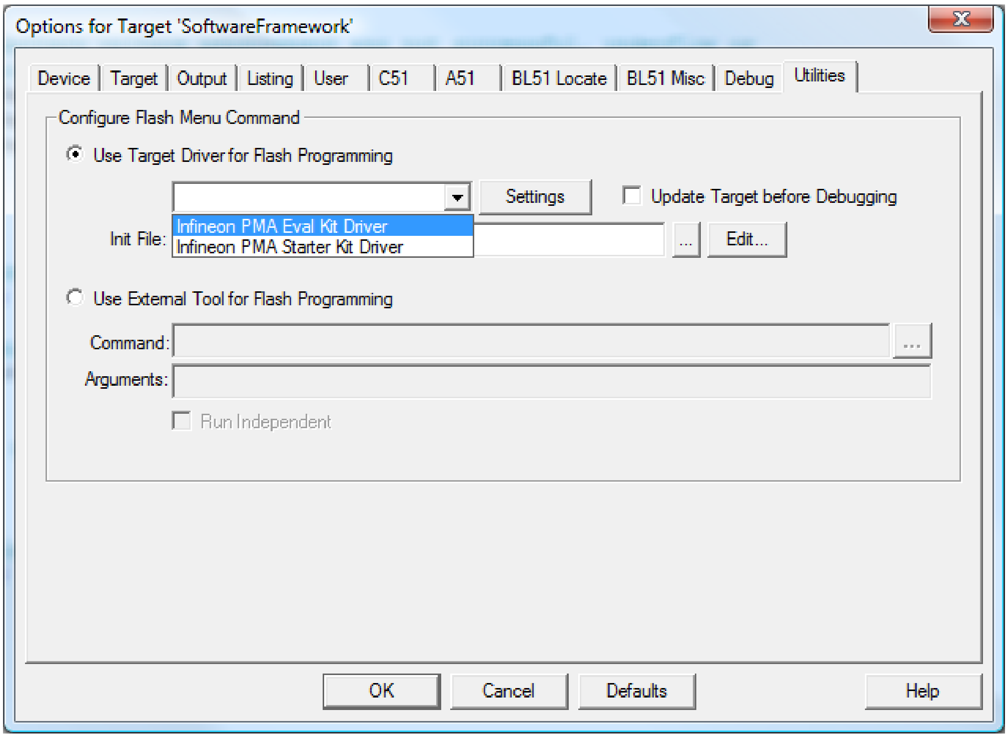
Welcome to the Infineon PMA ADC Examples 1.0 Setup

The installer will guide you through the steps required to install Infineon PMA ADC Examples 1.0 on your computer.

WARNING: This computer program is protected by copyright law and international treaties. Unauthorized duplication or distribution of this program, or any portion of it, may result in severe civil or criminal penalties, and will be prosecuted to the maximum extent possible under the law.

Figure 15 PMA ADC Examples Installer

3) Connect PMA Starter Kit or PMA Evaluation Kit to the PC or Notebook (ensure that you have installed the software environment for your development boards)
4) Start KEIL µVision
5) Compile the PMA_ADC_Examples_Vx.x project
6) Chose your development environment (PMA Starter Kit or PMA Evaluation Kit)



Options for Target 'SoftwareFramework'

Device | Target | Output | Listing | User | C51 | A51 | BL51 Locate | BL51 Misc | Debug | Utilities

Configure Flash Menu Command

● Use Target Driver for Flash Programming

Infineon PMA Eval Kit Driver
Infineon PMA Starter Kit Driver

☐ Update Target before Debugging

Init File:

○ Use External Tool for Flash Programming

Command:

Arguments:

☐ Run Independent

Figure 16 Development Board selection in KEIL µVision

7) Press the “LOAD” button to download the code example to your development board

4.1.2 PMA Evaluation Kit

The PMA Evaluation Kit consists of a PMA RF Evaluation Board. This kit is tailored for concrete application development based on PMA giving the developer highest flexibility and design freedom. Furthermore, the evaluation kit is required to be able to use all examples shown in this application note.

The PMA RF Evaluation Board has been designed to be connected to the PC via the SmartLEWIS™ System Interface Board (SIB v2.0). Alternatively a PMA Starter Kit may be used as interface to the PC. Both interface boards, SIB v2.0 or PMA Starter Kit, have to be ordered separately.

Note: The PMA Starter Kit is not sufficient for all examples as it does not offer external access to the ADC pins.

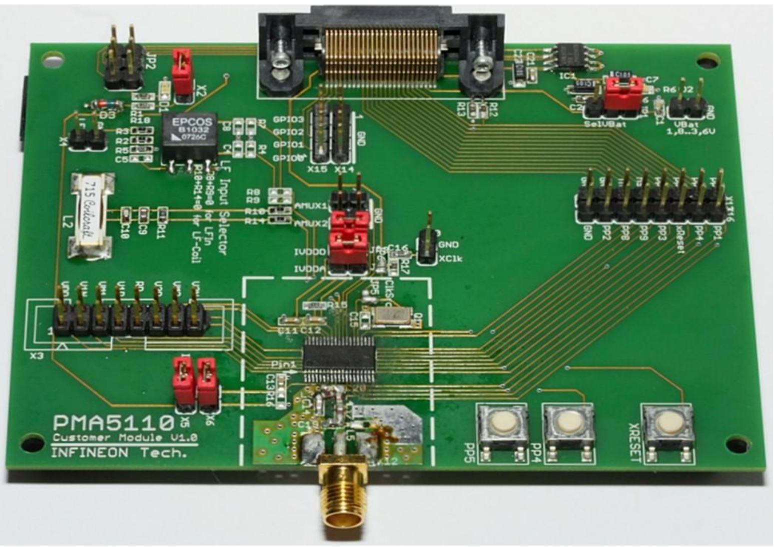


Figure 17 PMA Evaluation Kit

4.1.3 PMA Starter Kit

The PMA Starter Kit is an easy to use development tool coming along in a small form factor size, which can be directly connected to the PC via the USB interface.

This kit is tailored for first evaluation and software programming covering all products of the PMA71xx/51xx family.

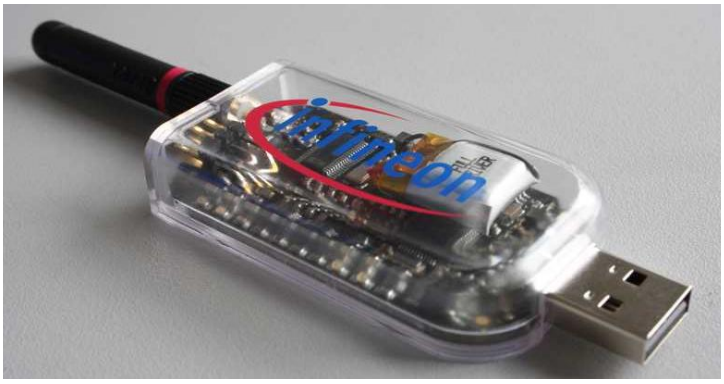
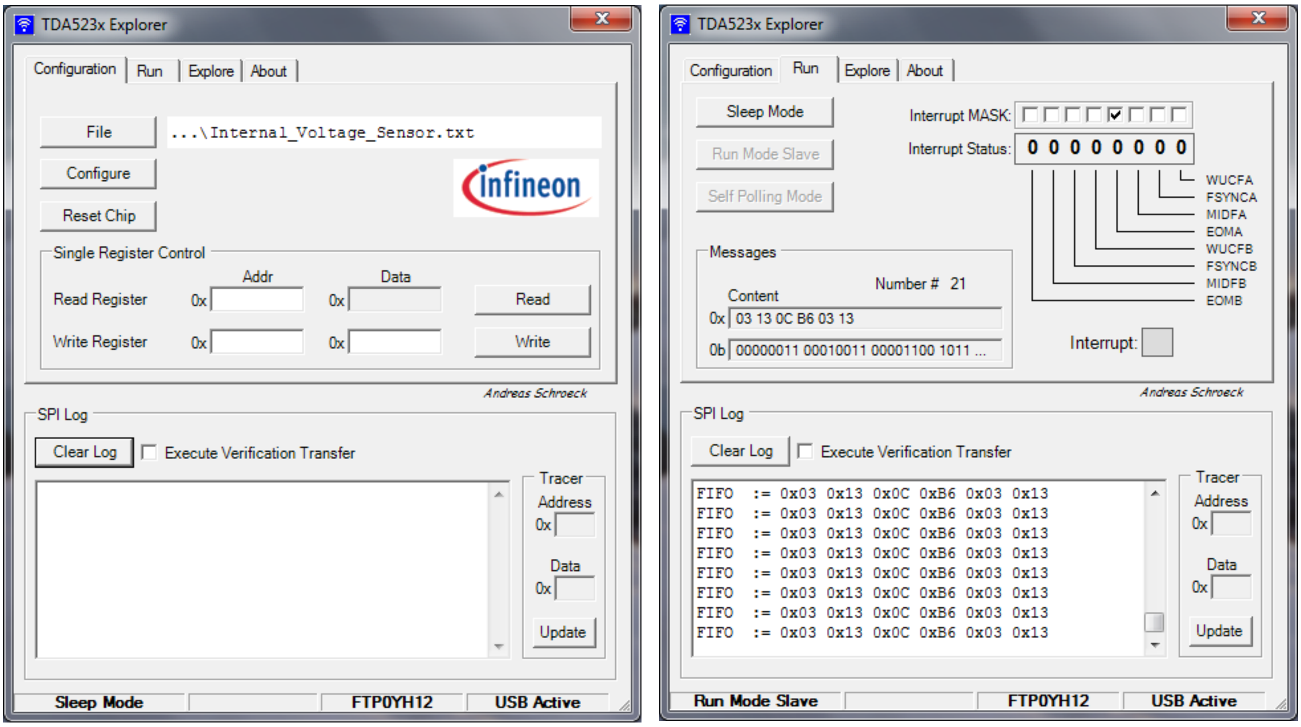


Figure 18 PMA Starter Kit

4.2 Receiver

Infineon TDA5230 is used as receiver. The TDA523x Eval Board is shown in Figure 19. For the configuration of the TDA523x Eval Board and the visualization of the received user data the TDA523x Explorer is used (see Figure 20). Every source code example includes a configuration file for TDA5230 receiver which can be found in folder **TDA523x_Receiver_Config_File**. More information about the configuration of TDA5230 and the handling of the TDA523x Explorer can be downloaded from http://www.infineon.com/tda5230.

Figure 19 TDA523x Eval Board



File: ...\Internal_Voltage_Sensor.txt

Status bar: Sleep Mode | FTP0YH12 | USB Active

Interrupt Status: 0 0 0 0 0 0 0 0

Number # 21

0x 03 13 0C B6 03 13

0b 00000011 00010011 00001100 1011 ...

```
FIFO  := 0x03 0x13 0x0C 0xB6 0x03 0x13
FIFO  := 0x03 0x13 0x0C 0xB6 0x03 0x13
FIFO  := 0x03 0x13 0x0C 0xB6 0x03 0x13
FIFO  := 0x03 0x13 0x0C 0xB6 0x03 0x13
FIFO  := 0x03 0x13 0x0C 0xB6 0x03 0x13
FIFO  := 0x03 0x13 0x0C 0xB6 0x03 0x13
FIFO  := 0x03 0x13 0x0C 0xB6 0x03 0x13
FIFO  := 0x03 0x13 0x0C 0xB6 0x03 0x13
```

Status bar: Run Mode Slave | FTP0YH12 | USB Active

Figure 20 TDA523x Explorer in configuration and run mode

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