TRAINING MANUAL

Getting Started with the SAM4L-EK Demo

AN-4553

Prerequisites

- **Hardware Prerequisites**
  - Atmel® SAM4L-EK Evaluation Kit
- **Software Prerequisites**
  - Atmel Studio 6.2
  - Atmel Software Framework 3.17.0 or higher
  - Latest J-Link/SAM-ICE™ Software and Documentation Pack
  - Atmel SAM4L-EK Board Monitor firmware v1.3 or higher
- **Estimated Completion Time:** 45min

Introduction

The goal of this hands-on is to:

- Become familiar with the Atmel SAM4L-EK Evaluation Kit
- Run and test the SAM4L-EK Demo
- Compare the measured current consumption values with the datasheet figures

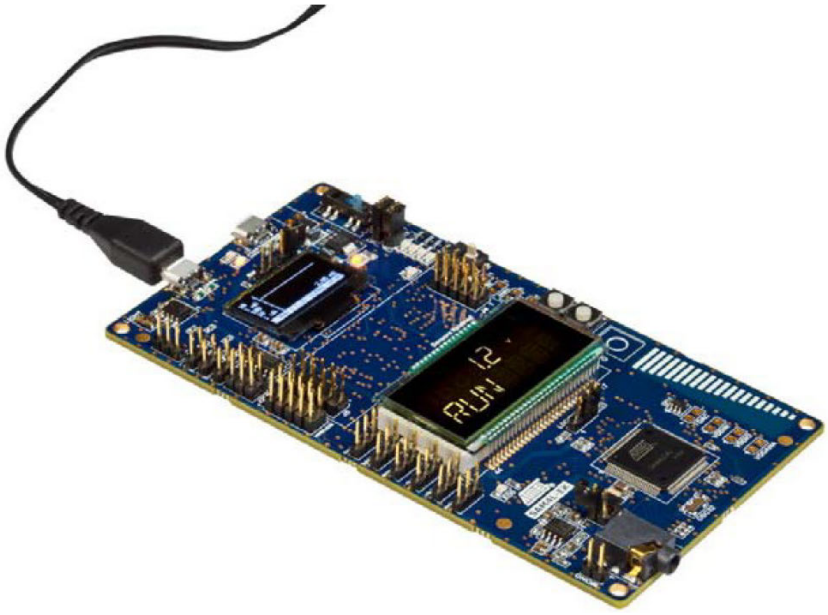


Table of Contents

Icon Key Identifiers

INFO	Delivers contextual information about a specific topic.
TIPS	Highlights useful tips and techniques.
TO DO	Highlights objectives to be completed.
RESULT	Highlights the expected result of an assignment step.
WARNING	Indicates important information.
EXECUTE	Highlights actions to be executed out of the target when necessary.

1. Training Module Architecture

This training material can be retrieved through different Atmel deliveries:

- As an Atmel Studio Extension (**.vsix** file), which can be found on the Atmel Gallery web site (http://gallery.atmel.com/) or using the Atmel Studio Extension manager
- As an Atmel Training Executable (**.exe** file) usually provided during Atmel Training sessions

Depending on the delivery type, the different resources needed to complete this training (hands-on documentation, datasheets, application notes, software, and tools) will be found on different locations.

1.1 Atmel Studio Extension (.vsix)

Once the extension has been installed, you can open and create the different projects associated with the training using the *"New Example Project from ASF..."* menu in Atmel Studio.

INFO The example projects installed through an extension are usually under "*Atmel Training > Atmel Corp. Extension Name*".

There are different projects which can be available depending on the extension:

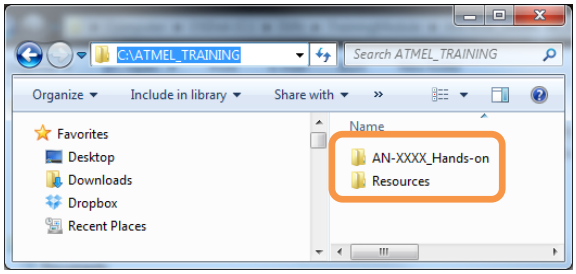
- **Hands-on Documentation**: contains the documentation as required resources
- **Hands-on Assignment**: contains the initial project that may be required to start
- **Hands-on Solution**: contains the final application, which is a solution project for this hands-on

INFO Each time a reference is made to some resources in the following pages, the user must refer to the **Hands-on Documentation** project folder.

1.2 Atmel Training Executable (.exe)

Depending on where the executable has been installed, you will find the following architecture which is comprised of two main folders:

- AN-XXXX_Hands-on: contains the initial project that may be required to start and a solution
- **Resources**: contains required resources (datasheets, software, and tools…)

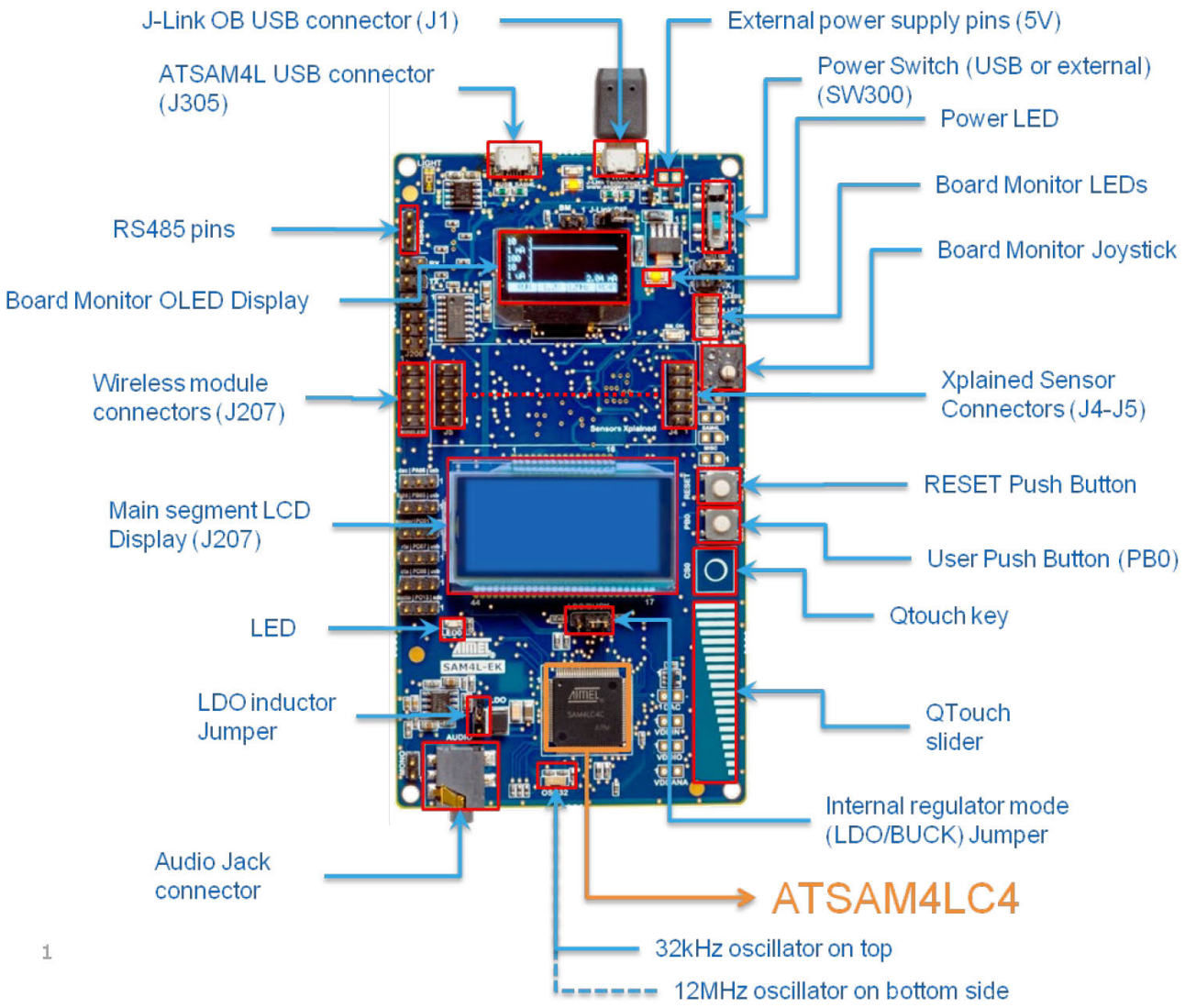


INFO Unless a specific location is specified, each time a reference is made to some resources in the following pages, the user must refer to this **Resources** folder.

2. Introduction to the Atmel SAM4L-EK

2.1 Atmel SAM4L-EK Description

Figure 2-1. ATSAM4L-EK Board Overview



INFO The JTAG ICE interface is on-board. It has the exact same features as a standard J-Link/SAM-ICE JTAG probe.

2.2 Powering the Board

The ATSAM4L-EK offers three interfaces to power the board:

- USB embedded debugger Segger J-Link OB (J1)
- USB ATSAM4LC4C (J305)
- External 5V (DC) source connected to the J303 2-pin header

To select the USB or the external power supply, a mechanical switch is used (SW300).

The default kit configuration is using ATSAM4LC4C BUCK regulator configuration, where ATSAM4LC4C is powered at 3.3V (VDDIN, VDDIO, VDDANA).

WARNING For this hands-on, the power is supplied through the USB embedded debugger Segger J-Link OB connector (J1). **Take care to use it** to get the measured values in the correct range.

2.3 Atmel SAM4L-EK Board Monitor

The Board monitor is an on board tool which makes possible the chip current consumption real time tracing.

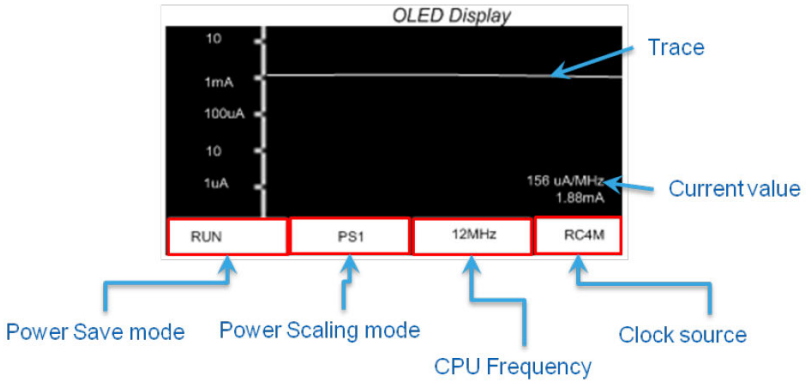
The Board Monitor features:

- 1x OLED display (128x64)
- 5x LEDs
- 1x joystick
- 1x USART connected to the ATSAM4LC4C MCU
- 1x TWI connected to the ATSAM4LC4C MCU

INFO The board monitor feature is implemented by an on board ATSAM3N4A MCU. The SAM4LC4C sends commands to update the board monitor status through the UART.

The SAM4L current consumption is directly displayed thanks to the on board OLED screen where the on running specifications are also specified as:

- The Power Save mode: RUN, WAIT, RET, or BCKUP
- The Power Scaling mode: PS0 or PS1 (PS2 mode not supported for now)
- The CPU frequency: 12MHz in the Demo
- The Clock Source as described by the picture below: RC4M, the RC Oscillator 12MHz in the Demo



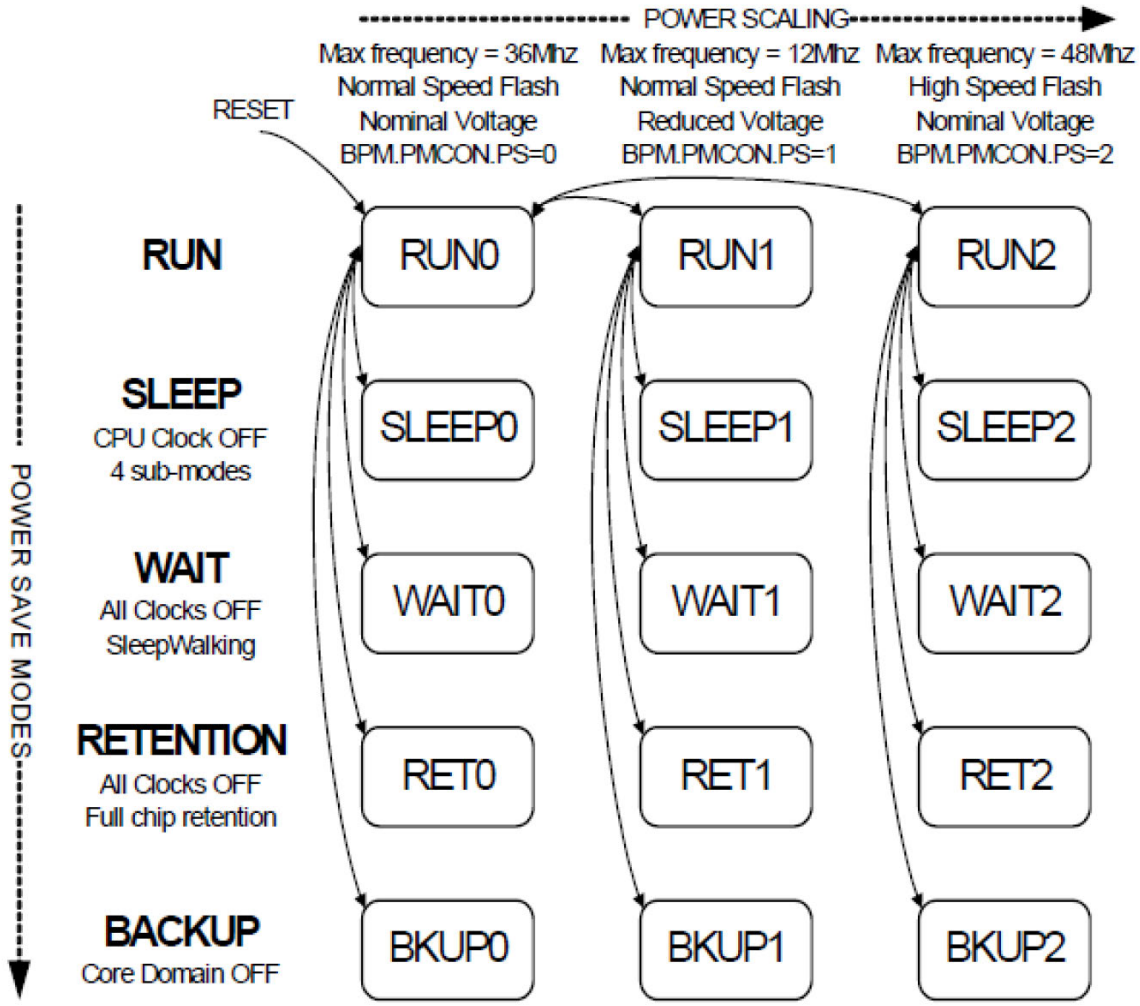
3. Introduction to SAM4L Power Management Features

3.1 Low Power Techniques

The ATSAM4L4/L2 supports multiple power configurations to allow the user to optimize its power consumption in different use cases. The Backup Power Manager (BPM) implements different solutions to reduce the power consumption:

- The Power Save modes intended to reduce the logic activity and to adapt the power configuration. See Section 3.1.1 Power Save Modes.
- The Power Scaling intended to scale the power configuration (voltage scaling of the regulator). See Section 3.1.2 Power Scaling.

These two techniques can be combined together to reach the lowest consumption according to the application performance requirement, as explained by the following picture:



3.1.1 Power Save Modes

At power-up or after a reset, the ATSAM4L4/L2 is in the RUN0 mode. Only the necessary clocks are enabled allowing software execution. The Power Manager (PM) can be used to adjust the clock frequencies and to enable and disable the peripheral clocks. When the CPU is entering a Power Save Mode, the CPU stops executing code. The user can choose between four Power Save Modes to optimize power consumption:

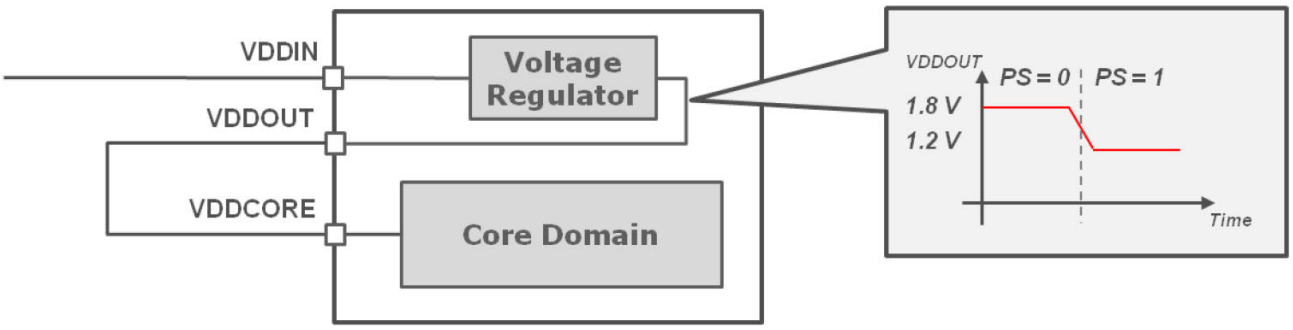
- **SLEEP mode**
  The Cortex®-M4 core is stopped, optionally some clocks are stopped, and peripherals are kept running if enabled by the user.
- **WAIT mode**
  All clock sources are stopped; the core and all the peripherals are stopped except the modules running with the 32kHz clock if enabled. This is the lowest power configuration where SleepWalking is supported.
- **RETENTION mode**
  Similar to the WAIT mode in terms of clock activity. This is the lowest power configuration where the logic is retained.
- **BACKUP mode**
  The Core domain is powered off, the Backup domain is kept powered. A wake up source exits the system to the RUN mode from which the Power Save Mode was entered.

INFO A reset source always exits the system from the Power Save Mode to the RUN0 mode. The configurations of the I/O lines are maintained in all Power Save Modes. Refer to the BPM chapter: “I/O lines pin muxing”.

TIPS For more information, refer to the Atmel AT01777: SAM4L Schematic Checklist document available on Atmel web site.

3.1.2 Power Scaling

The Power Scaling technique consists of adjusting the internal regulator output voltage (voltage scaling) to reduce the power consumption. According to the requirements in terms of performance, operating modes, and current consumption, the user can select the Power Scaling configuration that fits the best with its application.



3.2 Internal Voltage Regulator Modes

The ATSAM4L internal voltage regulator has two modes; **switching** or **linear** mode depending of BUCK/LDOn pin value.

- **When this pin is low**, the regulator is in **linear** mode and VDDOUT must be connected to VDDCORE externally
- **When this pin is high**, it **behaves as a switching regulator** and an inductor must be placed between VDDOUT and VDDCORE

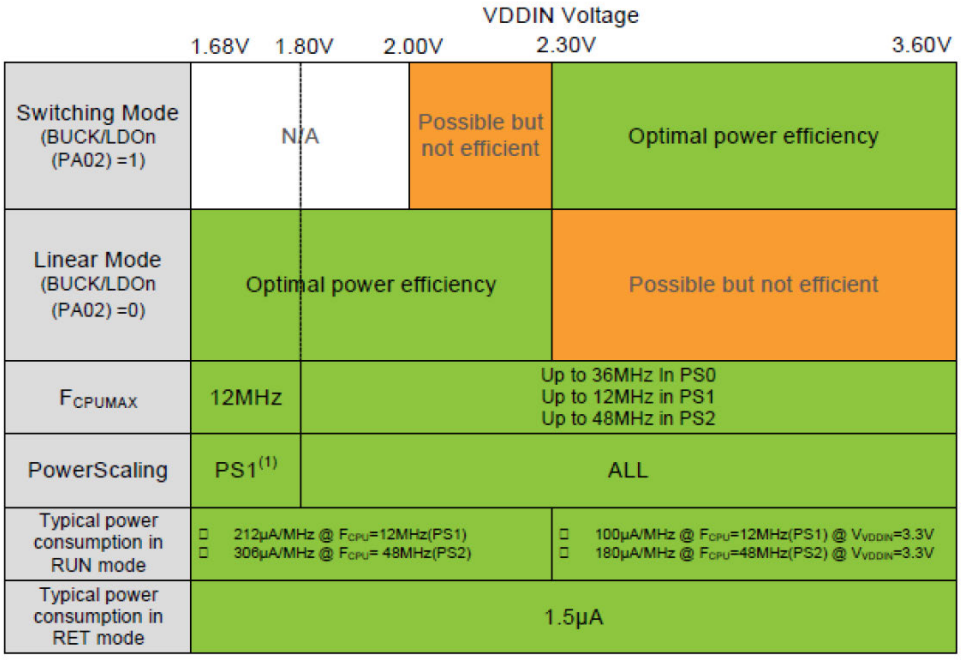
Internal regulator modes are chosen depending on the VDDIN application's value as described in the on the next page.

- If the VDDIN range is **2.3V<VDDIN<3.6V**, the switching mode is advised to have the optimal power efficiency
- If the VDDIN range is **1.68V<VDDIN<2.3V**, the linear mode is advised

This voltage regulator configuration has to be set once for all when designing the schematic by using a pull up or a pull down on the BUCK/LDO pin depending on the chosen mode.
The BUCK/LDO is sampled on power on reset and remains available for the application after reset.

Figure 3-1 shows the mandatory requirements for the power supply in the two modes.

Figure 3-1. Internal Voltage Regulator Configuration Choice versus VDDIN



Note 1. The SAM4L boots in PS0 on RCSYS(115kHz), then the application must switch to PS1 before running on higher frequency (<12MHz)

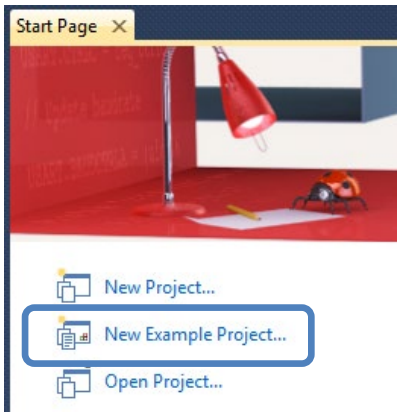
TIPS For more information, refer to the Atmel AT01777: SAM4L Schematic Checklist document or on Atmel web site.

INFO The SAM4L-EK board is configured in BUCK mode by default.

4. Assignment 1: Configure and Build the SAM4L-EK Low Power and QTouch Demo Application

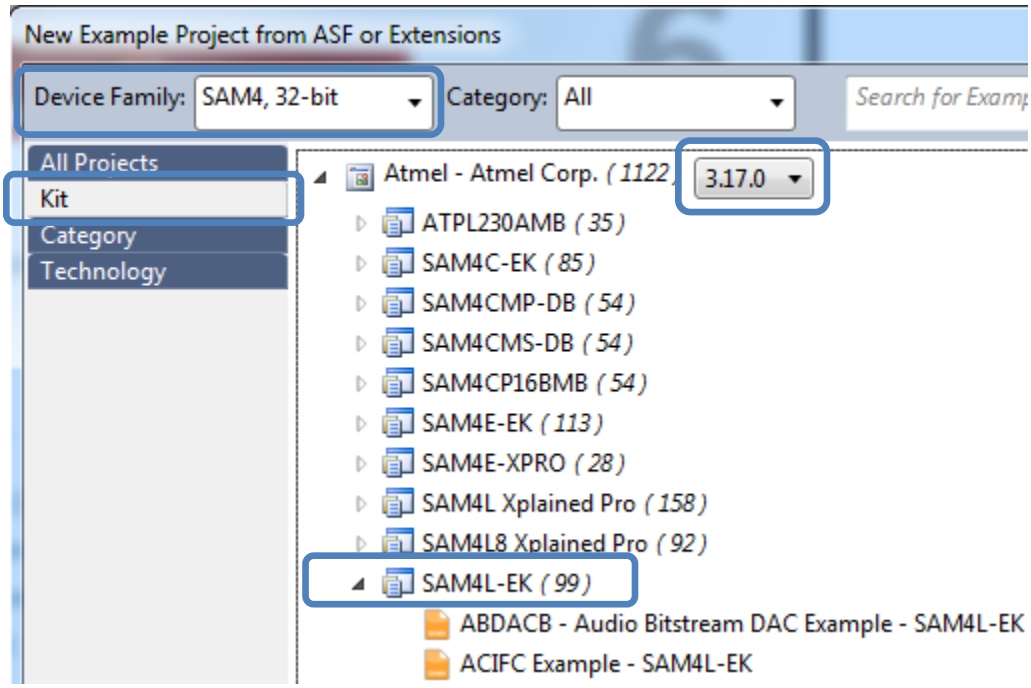
TO DO Open the SAM4L Low Power and QTouch® Demo project from ASF.

- Open Atmel Studio and click on *New Example Project…:*



In the New Example Project window, select:

- Device Family: SAM4, 32-bit
- ASF latest version
- Kit section then SAM4L-EK as Kit



- Then select *SAM4L Low Power and QTouch Demo - SAM4L-EK* in the example list

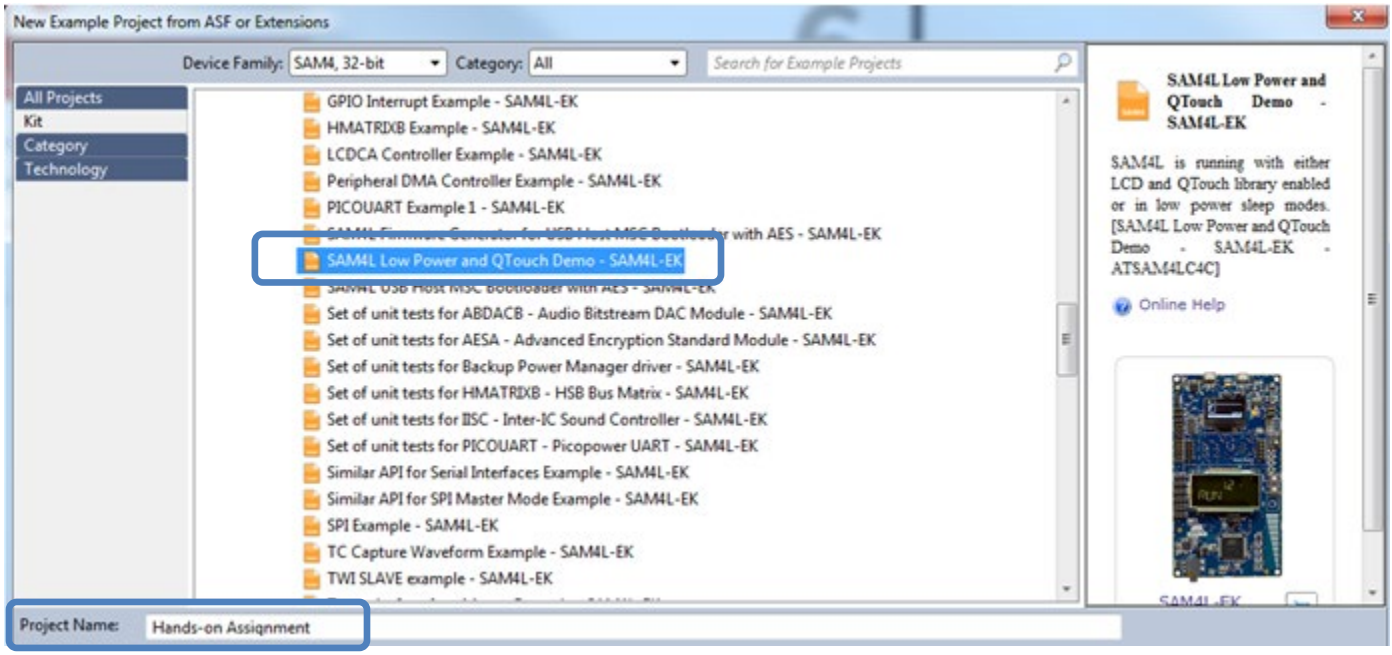
- Fill-in New Project fields according to following use cases:

Atmel Training Executable Case

- **Name**: Hands-On Assignment
- **Location**: “AN-4553_SAM4L-EK_Getting_Started_w_Demo\assignments” (relative path in the ATMEL_TRAINING installation folder)
- **Solution name**: Hands-On Assignment
- Click OK

Atmel Extension Case (downloaded from Atmel Gallery or Studio Extension Manager)

- **Name**: Hands-On Assignment
- **Location**: existing Hands-on Documentation solution path
- **Solution name**: Hands-On Documentation
- Click OK



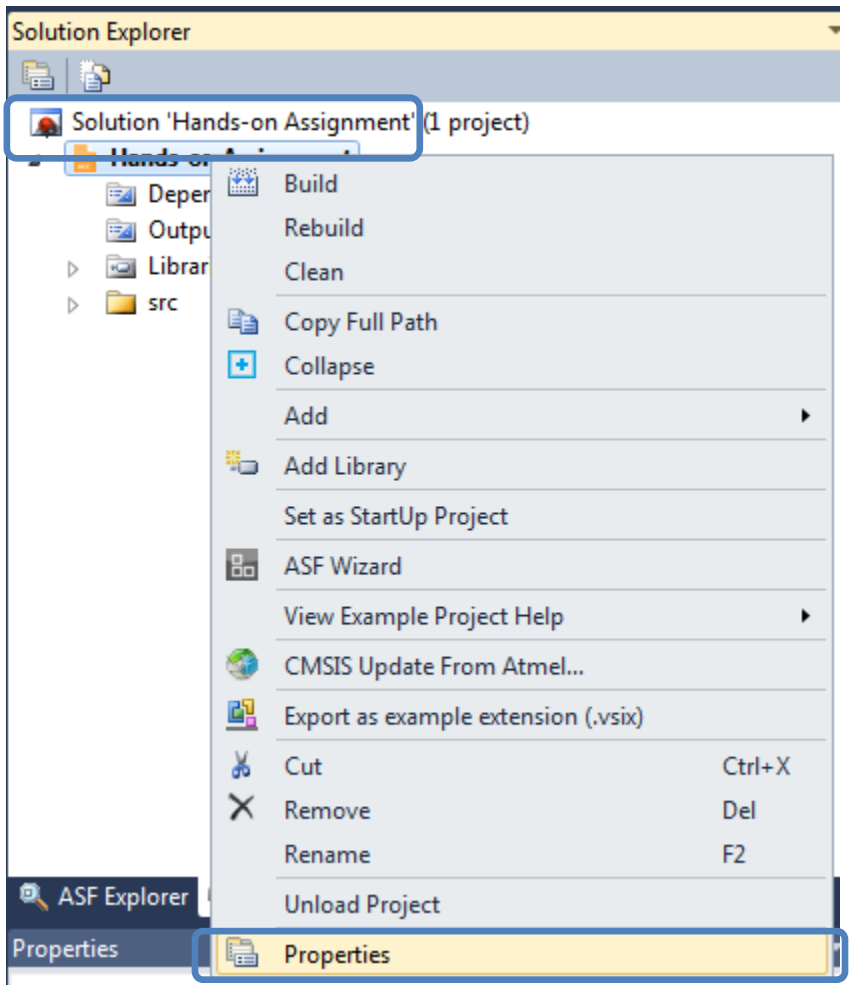
- Accept the different license agreements and click on *Finish*

RESULT The SAM4L Low Power and QTouch Demo project is now copied and loaded, and then Atmel Studio 6 Solution should appear.

WARNING By default, each Studio project is configured to connect to the target using JTAG interface. However, the SAM4L-EK board is designed to use the Serial Wire Debug protocol (**SWD**) instead of standard JTAG. Thus, the project has to be correctly configured to use the SWD interface in order to be able to program the chip.

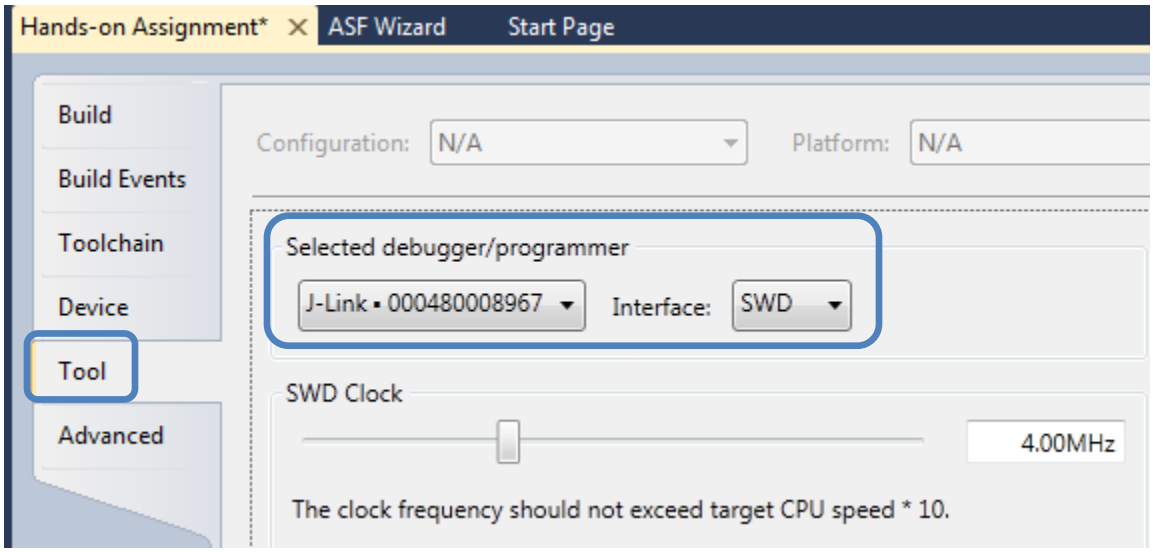
TO DO Configure the project to use the SWD protocol instead of JTAG.

- From the solution explorer window, right click on the **Hands-on Assignment** project file and select "Properties"



- Connect the SAM4L-EK to the computer using J-Link USB connector (J1)

- Now select:
    - Tool tab
    - Then, J-Link debugger/programmer
    - Finally the Serial Wire Interface (SWD)

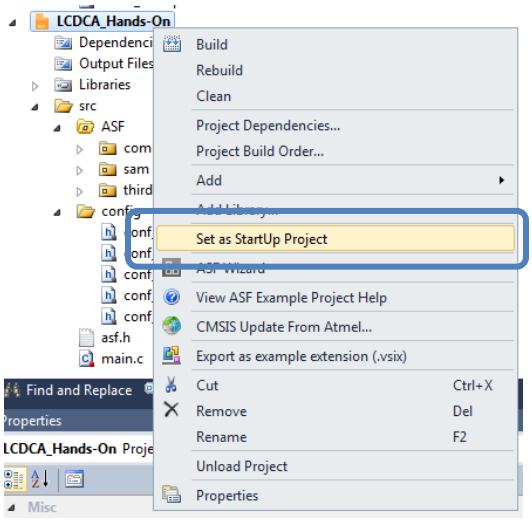


- Save the new project properties to apply them, by clicking on the save button:

RESULT Your project is now configured to use the SWD interface to correctly program your SAM4LC4 chip.

TO DO Build, program, and run the SAM4L Low Power and QTouch Demo project.

- Check that your working project is the one that will be compiled by right clicking on it from the Solution Explorer view and click on “Set as StartUp Project”



- In order to build the project, click on the Build button: 

WARNING Make sure the SAM4L-EK board is connected to your PC with a Micro-USB cable through the J-Link connector (J1) and not the USB SAM4L one.

- Then download the program in the internal flash of the SAM4L by clicking on the Start Debugging and break button: 
- Once programmed, start the code execution by clicking on the green arrow: 

RESULT The SAM4L Low Power and QTouch Demo Project is being executed and you should see the main LCD displays that the demo is running.

TIPS When the debug session is running, the Stop button  stops program execution and exits the debug session. If you want to stop the program but keep the debug session active, simply click on the Pause button  .

5. Assignment 2: Play with the SAM4L-EK Low Power and QTouch Demo

The goal of this assignment is to let you play with the Demo and understand its different features.

Current consumption that will be measured and displayed on the OLED screen will be explained later in a dedicated assignment.

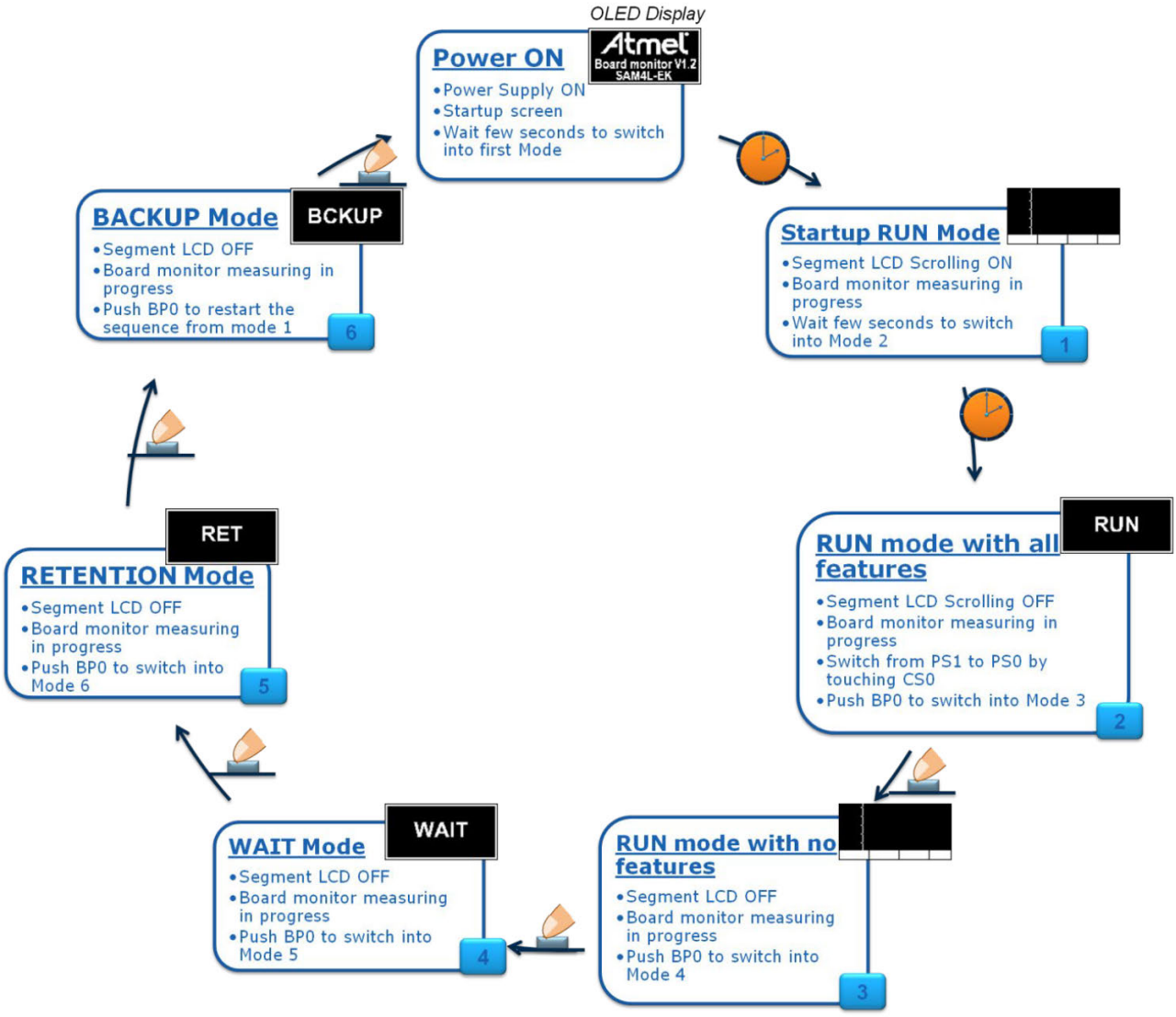
The SAM4L Low Power and QTouch demo implements different features:

- Low Power:
  - Display ATSAM4LC4C power consumption on the board monitor OLED display
  - Use of the Power Saving Modes
  - Use of the Power Scaling Modes (PS0 and PS1)
- Segment LCD Controller support:
  - Display text and text scrolling
  - Hardware automatic animations
- Hardware touch (QTouch) support:
  - One capacitive button
  - One slider

In this assignment, you will demonstrate most of them by playing with the demo application.

WARNING SAM4L-EK Board Monitor firmware version must be at least **v1.3** or higher or wrong info could be displayed on the OLED display. If the firmware is strictly lower than v1.3, refer to the ATSAM4L-EK User Guide on the web to understand how to reprogram its latest version.

Here is the sequential flow chart of the SAM4L-EK by running the Low Power and QTouch demonstration application:



Several modes are implemented in the SAM4L Low Power and QTouch Demo application:

- Mode 1: “startup, RUN mode” (after power-on reset)
- Mode 2: “RUN mode with **all** features”
- Mode 3: “RUN mode with **no** features”
- Mode 4: “WAIT mode”
- Mode 5: “RETENTION mode”
- Mode 6: “BACKUP mode”

In the following assignments you will switch between both of these modes in order to see the impact on the consumption directly from the board monitor OLED display.

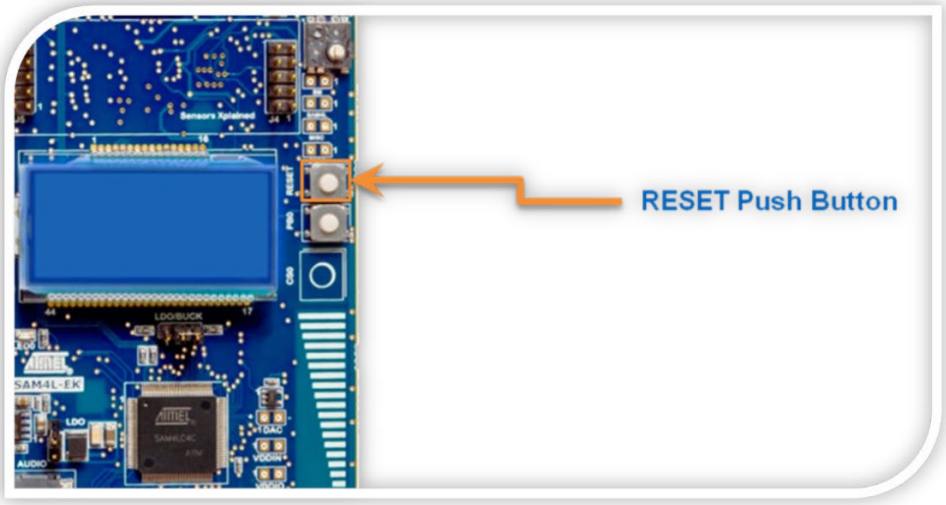
5.1 Mode 1: “startup, RUN mode” (after power-on reset)

From this mode:

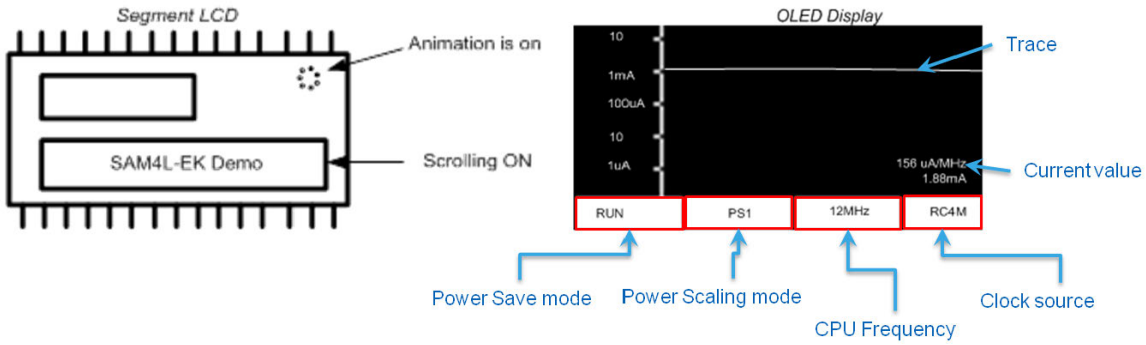
- ATSAM4LC4C is in active mode (12MHz on RC4M) with segment LCD and QTouch enabled
- ATSAM4LC4C displays on the segment LCD:
  - A scrolling text message “*SAM4L-EK Demo*”
  - Scrolling animation to show SAM4L is in active mode
- ATSAM4LC4C sends trough the USART its internal status to the board monitor (power save mode, voltage scaling, CPU frequency and clock source)
- The board monitor displays on the OLED display the current power consumption, power save mode, power scaling mode, CPU frequency, and clock source of ATSAM4LC4C

TO DO Execute the “startup RUN mode” (after power-on reset).

- If not already done, stop the debug session once the SAM4L is programmed by clicking on the stop button , to run the demo in standalone without the AS6 Debugger running
- Push the onboard RESET button:



- Check the demo status from the Segment LCD and from the Board monitor OLED displays during the “startup, RUN mode”. The scrolling on the main segment LCD display must be ON during few seconds.



INFO The “startup, RUN mode” (after power-on reset) will run only during five seconds before automatically switching to the “RUN mode with all features”. The main difference between these two modes is the main segment LCD scrolling, which is ON in the “startup RUN mode”.

RESULT The demo application is running well on the SAM4L-EK board.

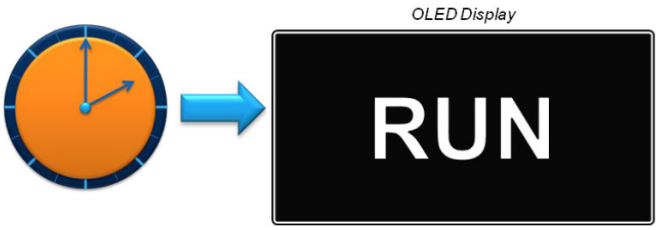
5.2 Mode 2: “RUN mode with all features”

From this mode:

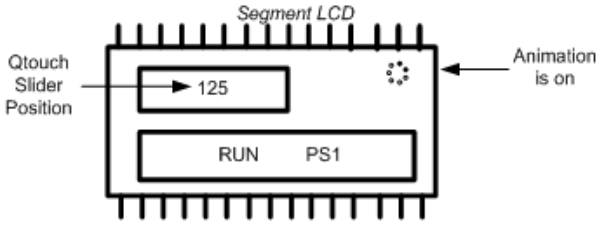
- The ATSAM4LC4C is in RUN mode. ATSAM4LC4C displays the voltage scaling mode (PS1 or PS0) on the segment LCD and its active mode (RUN)
- Using QTouch capacitive button CS0 will change voltage scaling configuration (PS1 or PS0)
- The QTouch slider position will be displayed (0 … 255) if a QTouch slider event is detected
- The ATSAM4LC4C sends its internal status trough USART to the board monitor (power save mode, voltage scaling, CPU frequency, and clock source) each time it changes
- Using PB0 button will disable QTouch and segment LCD, the demo move to Mode 3

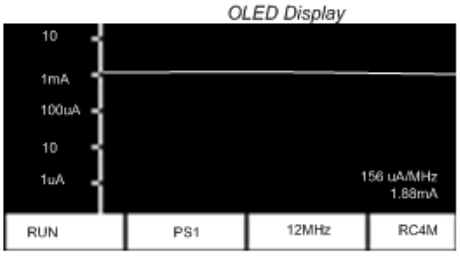
TO DO Demonstrate the “RUN mode with all features”.

- **Wait** a few seconds till the OLED screen displays *“RUN”* as soon as the mode switches to the *“RUN mode with all features”*:

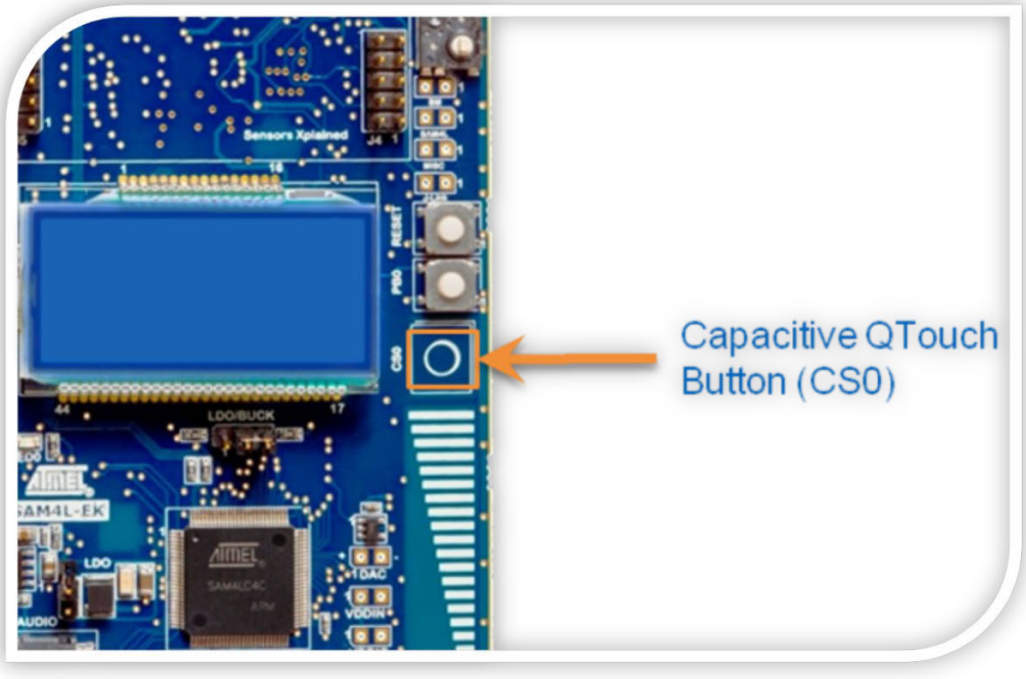


- **Check** the demo status from the Segment LCD and from the Board monitor OLED displays during the *“RUN mode with all features”*: The scrolling on the main segment LCD display must be OFF in this mode:

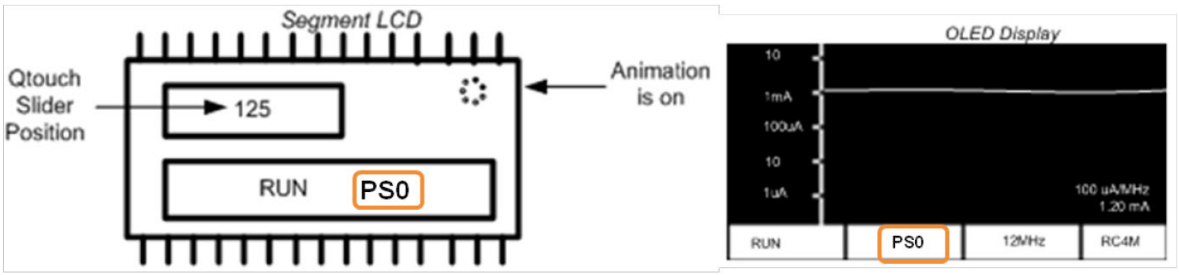




- **Switch** the power scaling mode from PS1 to PS0 by **touching** the QTouch capacitive button CS0 to change voltage scaling configuration:



- **Check** the demo status from the Segment LCD and from the Board monitor OLED displays during the *"RUN mode with all features"*: The scrolling on the main segment LCD display must be OFF and the power scaling segments should display *"PS0"* instead of *"PS1"*. A significant impact on the consumption should be observed (this will be explained later in the next assignment):



RESULT Your board is running well the "RUN mode with all features".

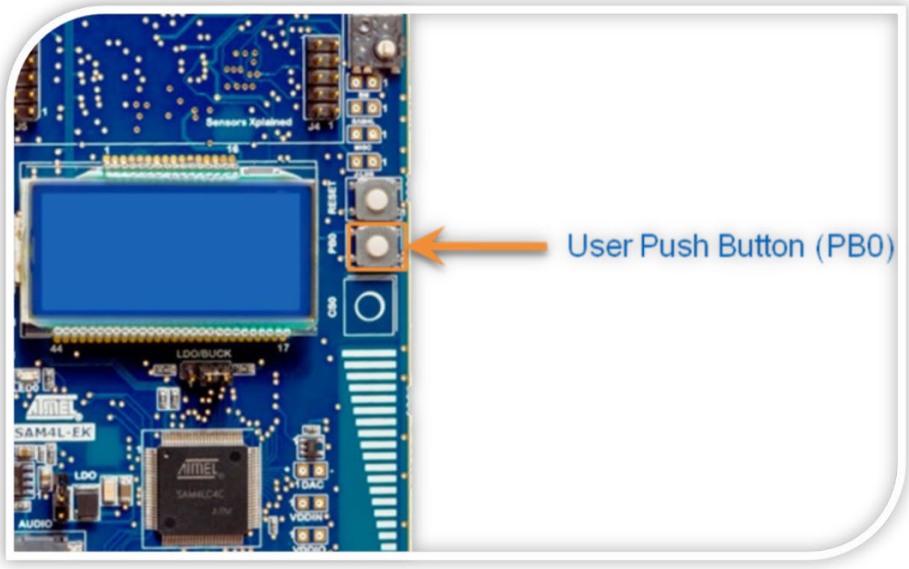
5.3 Mode 3 “RUN mode with no features”

From this mode:

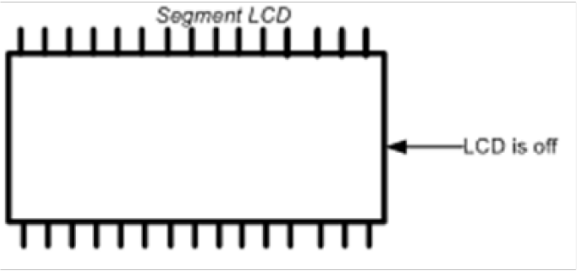
- The ATSAM4LC4C in active mode (12MHz on RC4M) with power scaling mode PS1. QTouch and Segment LCD are disabled
- The ATSAM4LC4C is executing the Fibonacci algorithm
- Using PB0 button will enter the *WAIT Power Save Mode* and move the demo to Mode 4

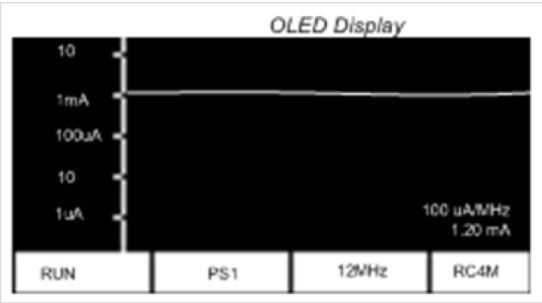
TO DO Demonstrate the *“RUN mode with no features”*:

- **Push** the User button PB0 to enter in the Mode 3: *“RUN mode with no features”*



- **Check** the demo status from the Segment LCD and from the Board monitor OLED displays during the *“RUN mode with no features”*: the segment LCD should be OFF in this mode:





RESULT Your board is running well the *“RUN mode with all features”.*

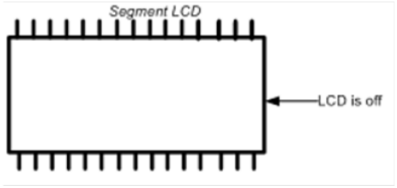
5.4 Mode 4: “WAIT mode”

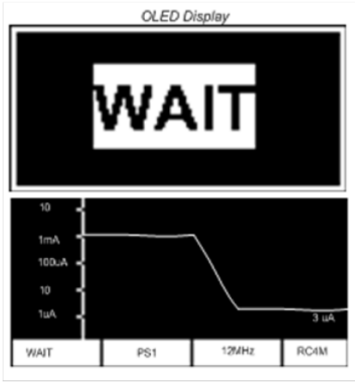
From this mode:

- The ATSAM4LC4C is in WAIT mode with power scaling mode PS1
- The ATSAM4LC4C sends its new internal status through the USART to the board monitor (power save mode, voltage scaling, CPU frequency and clock source). The Board monitors displays a splash screen indicating the new Power Save Mode (WAIT here).
- Using PB0 button will enter the RETENTION Power Save Mode and move the demo to Mode 5

TO DO Demonstrate the *“WAIT mode”*:

- As done previously, **Push** the User button PB0 to enter in the Mode 4: *“WAIT mode”*
- **Check** the demo status from the Segment LCD and from the Board monitor OLED displays during the *“WAIT mode”*: the segment LCD should be OFF in this mode and the consumption variation slope must be observable once the word *“WAIT”* has been displayed on the OLED screen:





RESULT Your board is running well the *“WAIT mode”*, and you can see the impact on the consumption directly from the board monitor.

5.5 Mode 5: “RETENTION mode”

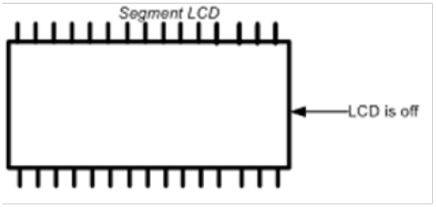
From this mode:

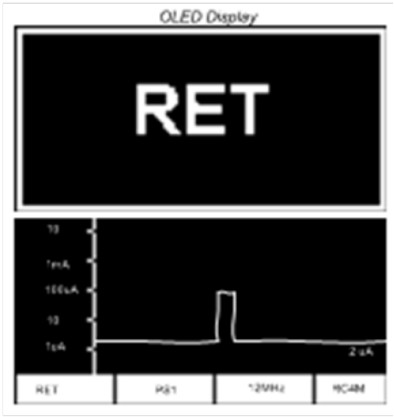
- The ATSAM4LC4C in RET mode with power scaling configuration PS1
- The ATSAM4LC4C sends its new internal status through USART to the board monitor (power save mode, voltage scaling, CPU frequency and clock source)
- Using PB0 button will enter the BACK-UP Power Save Mode and move the demo to Mode 6

TO DO Demonstrate the *“RETENTION mode”:*

- As done previously, **Push** the User button PB0 to enter in the mode 5: *“RETENTION mode”*
- **Check** the demo status from the Segment LCD and from the Board monitor OLED displays during the *“RETENTION mode”*: the segment LCD should be OFF in this mode and the consumption variation spike must be observable once the word *“RET”* has been displayed on the OLED screen.

WARNING The spike appearing is very brief, therefore, prepare pushing the BP0 and then keep your eyes focused on the OLED screen to see the spike.





RESULT Your board is running well the *“RETENTION mode”*, and you can see the impact on the consumption directly from the board monitor.

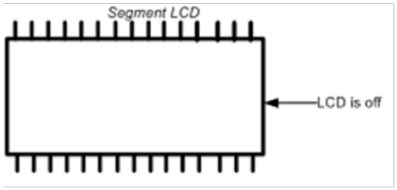
5.6 Mode 6: “BACKUP mode”

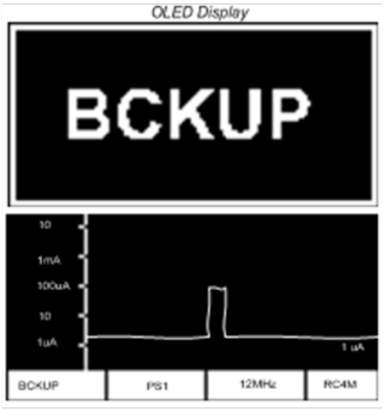
From this mode:

- The ATSAM4LC4C is in backup mode with power scaling mode PS1
- The ATSAM4LC4C sends its new internal status through USART to the board monitor (power save mode, voltage scaling, CPU frequency and clock source)
- Using PB0 button will go back to mode 1 in *“startup RUN mode”.*

TO DO Demonstrate the *“BACKUP mode”:*

- As done previously, **Push** the User button PB0 to enter in the mode 6: *“BACKUP mode”:*
- **Check** the demo status from the Segment LCD and from the Board monitor OLED displays during the “*BACKUP mode”*: the segment LCD should be OFF in this mode and the consumption variation spike must be observable once the word *“BCKUP”* has been displayed on the OLED screen:





RESULT Your board is running well the “BACKUP mode”, and you can see the impact on the consumption directly from the board monitor.

RESULT You are familiar with the Low Power Demo application; you can now make measurements to evaluate the SAM4L power management.

6. Assignment 3: Board Monitor Measurements Versus Datasheet Values in Switching Mode (BUCK)

In this assignment, you will make a comparison between values measured on the board monitor during the last assignments and the values specified in the datasheet **in switching mode**.

6.1 Find Power Consumption Values According to the SAM4L-EK Low Power and QTouch Demo Application

TO DO **Open** the product datasheet:

- To make this assignment, you need the SAM4L product datasheet:

Atmel Training Executable Delivery Case

- Open it from the *Resources\Datasheet* folder
  (folder located in the ATMEL_TRAINING installation folder).

Atmel Studio Extension Delivery Case

- Download it directly from the Atmel Web site:
  http://www.atmel.com/images/atmel-42023-arm-microcontroller-atsam4l-low-power-lcd_datasheet.pdf.

The device datasheet contains block diagrams of the peripherals and details about implementing firmware for the device. It also contains the electrical characteristics of the device.

- **Go to** the *"Electrical Characteristics"* section and **look for** the *"Power Consumption"* sub-section

- **Find** the configuration table which is the closest to our application configuration described below

INFO Application configuration:

- Power Scaling Mode 1
- VDDIN = 3.3V
- Oscillators
  - OSC0 (crystal oscillator) and OSC32K (32kHz crystal oscillator) stopped
  - RCFAST Running at 12MHz
- Clocks
  - RCFAST used as main clock source
  - CPU, AHB clocks undivided
  - APBC and APBD clocks divided by 4
  - APBA and APBB bridges off
  - The following peripheral clocks running
  - PM, SCIF, AST, FLASHCALW, APBC and APBD bridges
  - All other peripheral clocks stopped
- CPU is running on flash with 1 wait state

6.2 Perform Measurements using SAM4L-EK Board Monitor

TO DO **Fill in** the consumption comparison table below.

WARNING A power OFF/power ON sequence has to be performed in order to make the measurements. Stop the debugger and use the SW300 switch to power the board.

INFO RUN mode typical consumption is expressed in µA/MHz. The Power Saving Modes are in µA.

Power scaling mode 1 (PS1)	Datasheet Values	SAM4L-EK Demo Values (from board monitor)
Regulator mode	**BUCK**	**BUCK**
RUN mode with all features	N/A	
RUN mode with no features (Fibonacci)		
WAIT mode (OSC32K/AST running)		
RETENTION Mode (OSC32K running)		
BACKUP Mode (OSC32K running)		

RESULT You can see that the measured values from the application's board monitor are coherent with datasheet values.

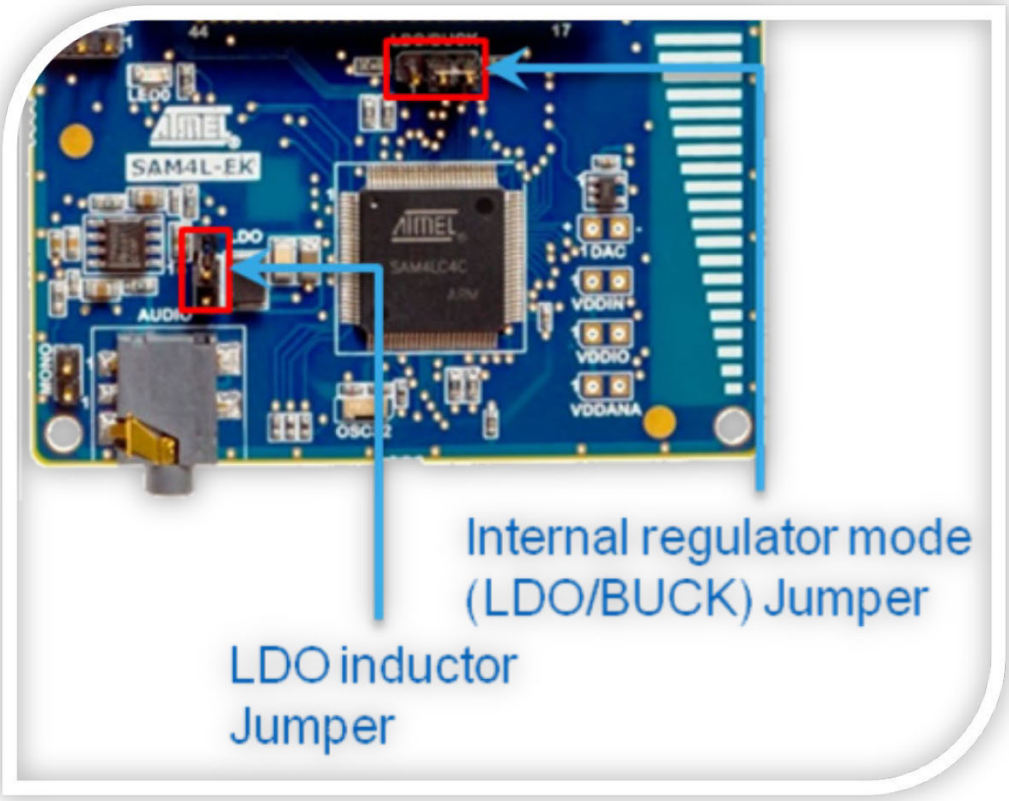
7. Assignment 4: Compare Power Consumption Values Between Switching and Linear Modes

In this assignment you will make the same measurements as in the previous assignments.

But this time, the internal voltage regulator has to be configured in linear mode.

TO DO **Set** your board according to the internal voltage regulator **LDO** mode configuration.

- **Switch off** the board power supply
- **Put** the LDO/BUCK jumper in the correct position
- **Close** the LDO inductor jumper to short the inductor used for the switching mode (BUCK)



RESULT Your board is now configured to run in LDO mode.

TO DO **Complete** the consumption comparison table below

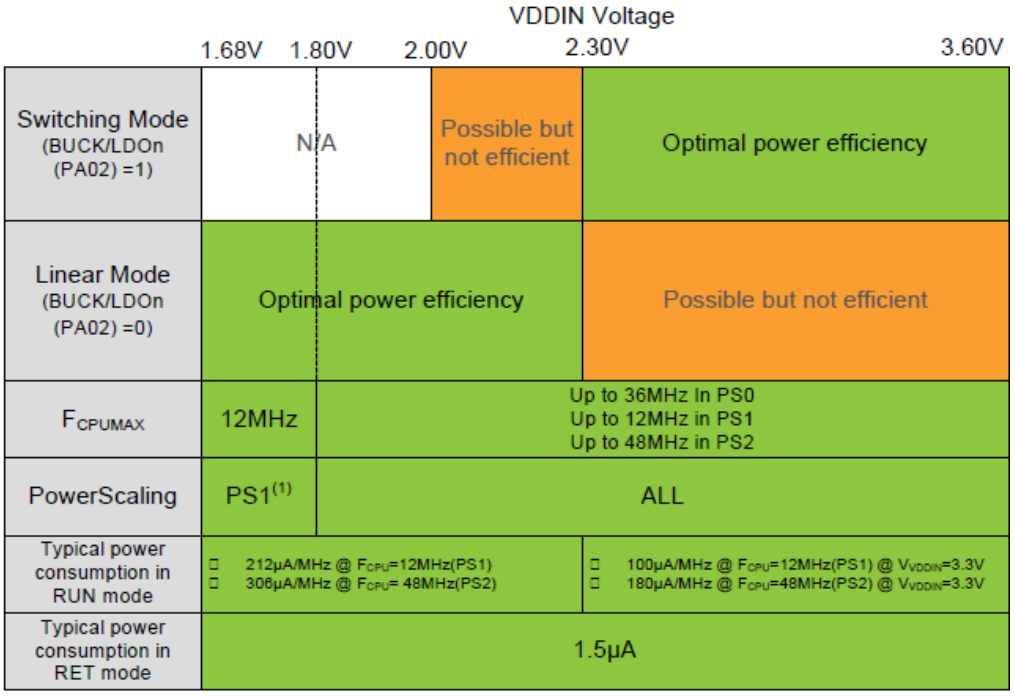
- Power On the board
- Report measured values for the BUCK mode and measure their equivalent for the linear mode:

Power scaling Mode 1 (PS1)	SAM4L-EK demo values (from the board monitor)	
Regulator mode	**LDO**	**BUCK**
Run mode with all features		
RUN mode with no features (Fibonacci)		
WAIT mode (OSC32K/AST running)		
RETENTION Mode (OSC32K running)		
BACKUP Mode (OSC32K running)		

RESULT You should higher values for the Linear mode for each RUN mode, but not for the low power modes: WAIT, RETENTION and BACKUP.

This conclusion follows Figure 7-1 from SA4L datasheet: as VDDIN = 3.3V, the Linear Mode is then recommended to get optimal power efficiency.

Figure 7-1. Efficient Power Strategy



Note 1. The SAM4L boots in PS0 on RCSYS(115kHz), then the application must switch to PS1 before running on higher frequency (<12MHz)

8. Conclusion

In this Hands-on, you have discovered the SAM4L main power management features.

You are now familiar with the SAM4L-EK evaluation Kit to design your own application starting from the SAM4L-EK Low Power and QTouch demonstration application as a first example code supplied from the Atmel Software Framework (ASF).

The board monitor has been introduced as a new design feature. Thanks to it, you performed a comparison between values specified in the datasheet versus the ones provided by the board monitor measurements.

And finally, you performed a quick comparison between the two different modes of the internal voltage regulator, linear versus switching mode.

9. Revision History

Doc. Rev.	Date	Comments
42244B	07/2014	Porting to Atmel Studio 6.2/ASF 3.17.0.
42244A	02/2014	Initial document release.

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