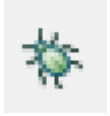
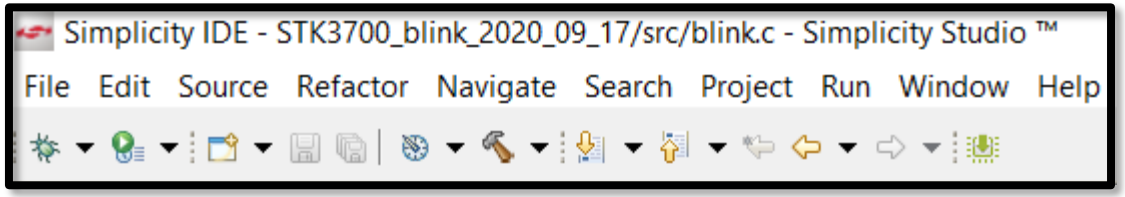
Embedded and ambient systems 2023.09.27.

Practice 2

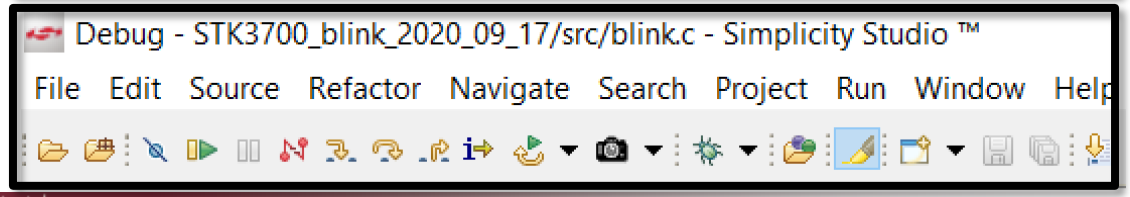
Méréstechnika és
Információs Rendszerek
Tanszék

Example: Blink project

- Review of Blink project at a source code level
- Note icon  : compiles and loads (Debug active)
- Note icon  : only compiles (IDE mode only)
  - Can my code be compiled?
  - Is there any syntactical error?
- Note icon  : starts the downloaded code
- Note icon  : disconnects and switches IDE mode



->IDE mode



->Debug mode

Example: Blink project

- Written in C programming language
- Entry point is the main function, this function is called and so the program starts here

```
int main(void)
{
  /* Chip errata */
  CHIP_Init();

  /* If first word of user data page is non-zero, enable Energy Profiler trace */
  BSP_TraceProfilerSetup();

  /* Setup SysTick Timer for 1 msec interrupts  */
  if (SysTick_Config(CMU_ClockFreqGet(cmuClock_CORE) / 1000)) {
    while (1) ;
  }

  /* Initialize LED driver */
  BSP_LedsInit();
  BSP_LedSet(0);

  /* Infinite blink loop */
  while (1) {
    BSP_LedToggle(0);
    BSP_LedToggle(1);
    Delay(1000);
  }
}
```

HW errors corrected in SW

Real-time data acquisiton

Initialize SysTick timer peripheral that calls SysTick_Handler interrupt function in every 1ms and increments msTicks variable in every 1ms

```
void SysTick_Handler(void)
{
  msTicks++;        /* incre
}
```

Initialize the LEDs

Set LED nr.0, i.e., turned on

In the while loop blinking LED algorithm is implemented

Change the state of LED nr.0

Change the state of LED nr.1

Wait 1000ms

Delay function

```
void Delay(uint32_t dlyTicks)
{
  uint32_t curTicks;

  curTicks = msTicks;
  while ((msTicks - curTicks) < dlyTicks) ;
}
```

One input parameter: how many ticks to wait-> 1tick=1ms in this program

Create variable curTicks

Value of msTicks is passed to curTicks

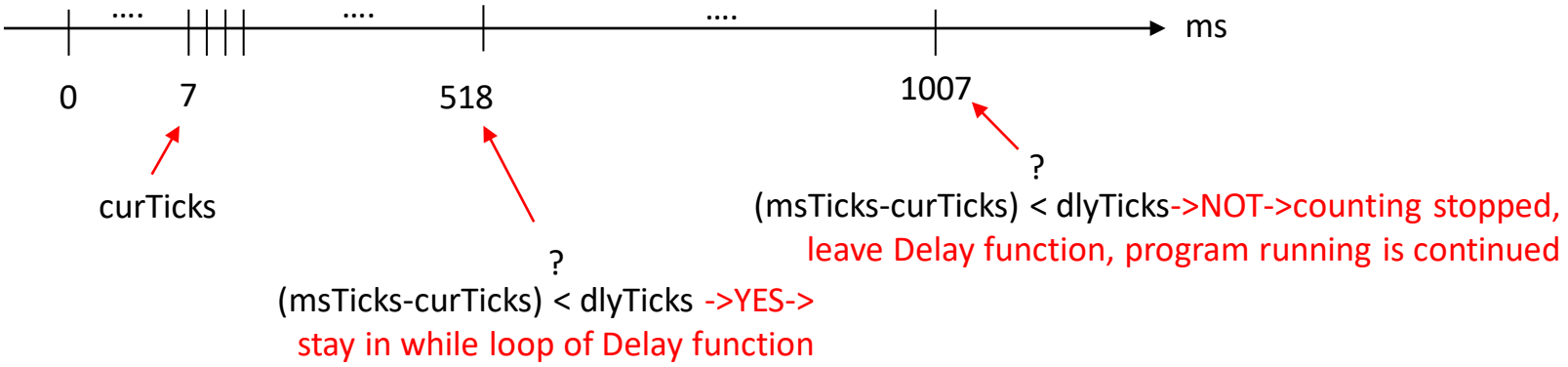
Wait until condition is met (program stucks in the while loop until condition is met)

msTicks: the current tick (time, keeps increasing by 1ms)

curTicks: equals msTick value when Delay function was called, constant value during the Delay function runs

dlyTicks: time of delay, now it is 1000ms: the time to toggle LEDs

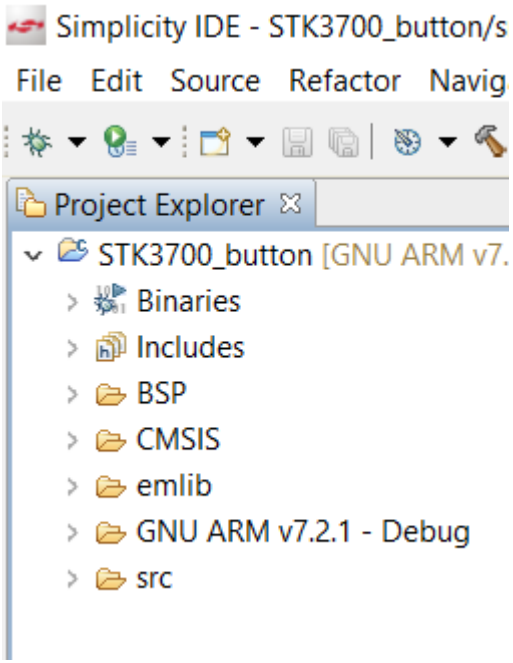
- Operation of Delay function:

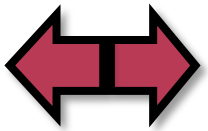


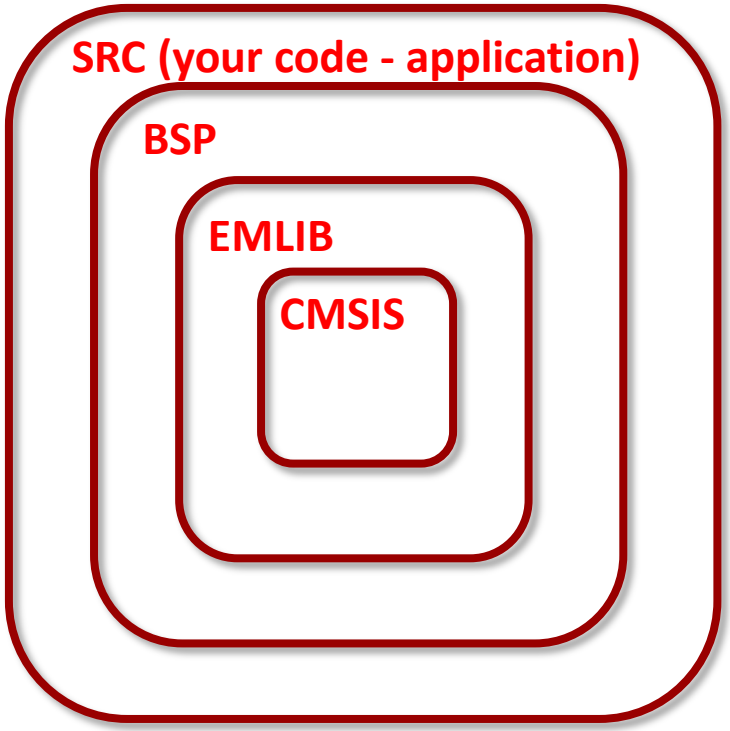
- This Delay function is a blocking wait->program cannot run until 1000ms is elapsed

Hierarchy of functions

- Project Explorer window and the hierarchy of functions gathered in libraries

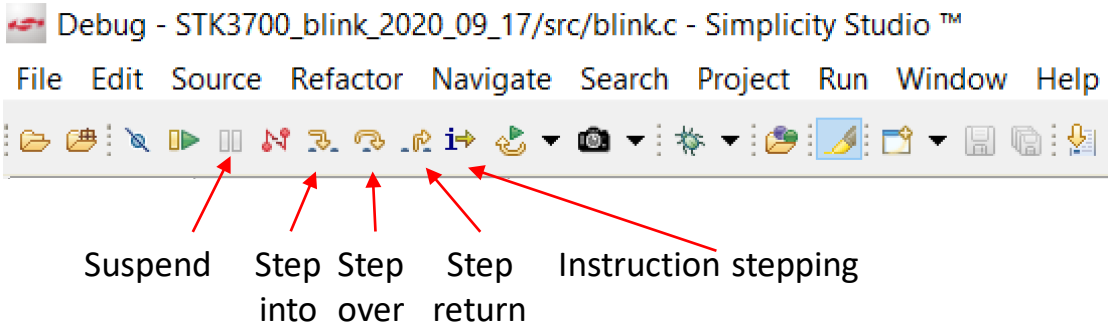






- All levels can be reached from SRC level directly

Examination of the Blink program



- When the program is suspended it runs most probably in the Delay function since LEDs changes quickly and uC runs the Delay function most of the time

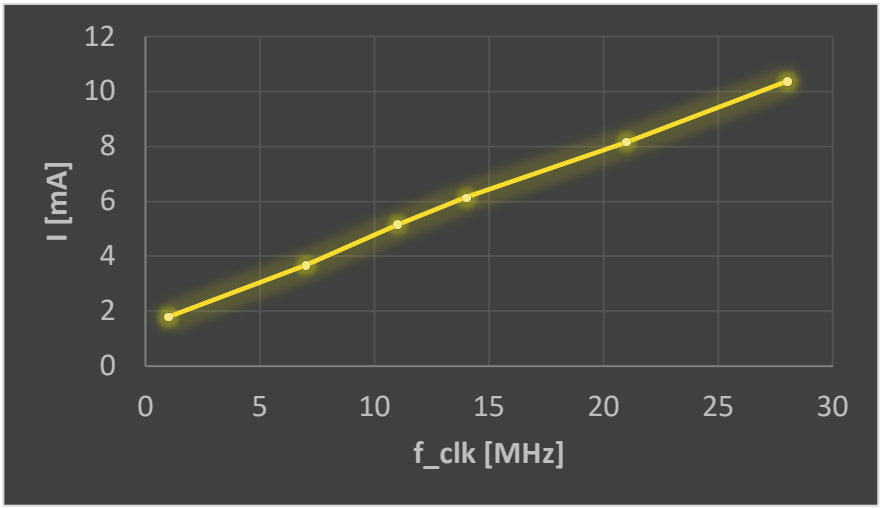
	Suspend	The [**Suspend**] button halts the MCU.
	Step Into	The [**Step Into**] button single steps into the first line of a function.
	Step Over	The [**Step Over**] button single steps over a function, executing the entire function.
	Step Return	The [**Step Return**] button steps out of a function, executing the rest of the function.
	Instruction Step-ping Mode	The [**Instruction Stepping Mode**] button toggles assembly single stepping. When enabled, single steps will execute a single assembly instruction at a time. See the [**Disassembly**] view for the assembly code corresponding to the source code at the current line of execution.

- Changes of variables and register content can be followed easily in Debug mode

Current consumption as a function of f_clk

- Modify the Blink program to measure current consumption as a function of uC clock frequency
- How the clock frequency can be accessed?
  - Insert the appropriate function:
  - CMU_HFRCOBandSet(cmuHFRCOBand_1MHz);
- Measure current consumption when clock frequency is set to 1, 7, 11, 14, 21 and 28MHz -> conclusion?

f_clk [MHz]	I [mA]
1	1.8
7	3.68
11	5.16
14	6.15
21	8.17
28	10.38



Hint for measurement of current consumption as a function of f_clk

```
int main(void)
{
  /* Chip errata */
  CHIP_Init();

  /* If first word of user data page is non-zero, enable Energy
  BSP_TraceProfilerSetup();

  CMU_HFRCOBandSet(cmuHFRCOBand_11MHz);


  /* Setup SysTick Timer for 1 msec interrupts  */
  if (SysTick_Config(CMU_ClockFreqGet(cmuClock_CORE) / 1000)) {
    while (1) ;
  }

  /* Initialize LED driver */
  BSP_LedsInit();
  BSP_LedSet(0);
  BSP_LedSet(1);


  /* Infinite blink loop */
  while (1) {
    //BSP_LedToggle(0);
    //BSP_LedToggle(1);
    Delay(1000);
  }
}
```

Buttons

- Certain version of SDK does not contain functions for the buttons in the BSP library, but they are available from the manufacturer (can be downloaded from the course web)
  - bsp_stk_buttons.c and bsp_stk_buttons.h
  - Copy bsp_stk_buttons.h and .c into the Includes lib. (see project explorer window->follow the path to be able to copy)
  - Copy bsp_stk_buttons.c into the BSP lib. (see project explorer window->drag and drop works)
- Check bsp_stk_buttons.h to find and use in the code these:
  - `BSP_ButtonsInit(void)` -> initialize buttons, e.g. BSP_ButtonsInit();
  - `BSP_ButtonGet(int btnNo)` -> read button, e.g. BSP_ButtonGet(0);
  - Do not forget to put in the code: `#include "bsp_stk_buttons.h"`
- Modify the program to light up LEDx if BTNx is pushed

Modified code for push buttons

```
/* Initialize LED driver */
BSP_LedsInit();
BSP_LedClear(0);
BSP_LedClear(1);

/* Initialize Buttons */
BSP_ButtonsInit();

/* Infinite button loop */
while (1) {
    if (BSP_ButtonGet(0)){
        BSP_LedClear(0);
    }else{
        BSP_LedSet(0);
    }
}
```

The building process (see console)

15:28:17 **** Build of configuration GNU ARM v7.2.1 - Debug for project STK3700_button ****
make -j4 all

Building file: ../src/button.c
Invoking: GNU ARM C Compiler
arm-none-eabi-gcc -g3 -gdwarf-2 -mcpu=cortex-m3 -mthumb -std=c99 '-DDEBUG_EFM=1' '-DEFM32GG990F1024=1' -I"I:/Simplicity_studio/developer/sdks/gecko_sdk_suite/v2.6//hardware/kit/EFM32GG_STK3700/config" -I"I:/Simplicity_studio/developer/sdks/gecko_sdk_suite/v2.6//platform/CMSIS/Include" -I"I:/Simplicity_studio/developer/sdks/gecko_sdk_suite/v2.6//platform/emlib/inc" -I"I:/Simplicity_studio/developer/sdks/gecko_sdk_suite/v2.6//hardware/kit/common/bsp" -I"I:/Simplicity_studio/developer/sdks/gecko_sdk_suite/v2.6//platform/Device/SiliconLabs/EFM32GG/Include" -O0 -Wall -c -fmessage-length=0 -mno-sched-prolog -fno-builtin -ffunction-sections -fdata-sections -MMD -MP -MF"src/button.d" -MT"src/button.o" -o "src/button.o" "../src/button.c“

Finished building: ../src/button.c

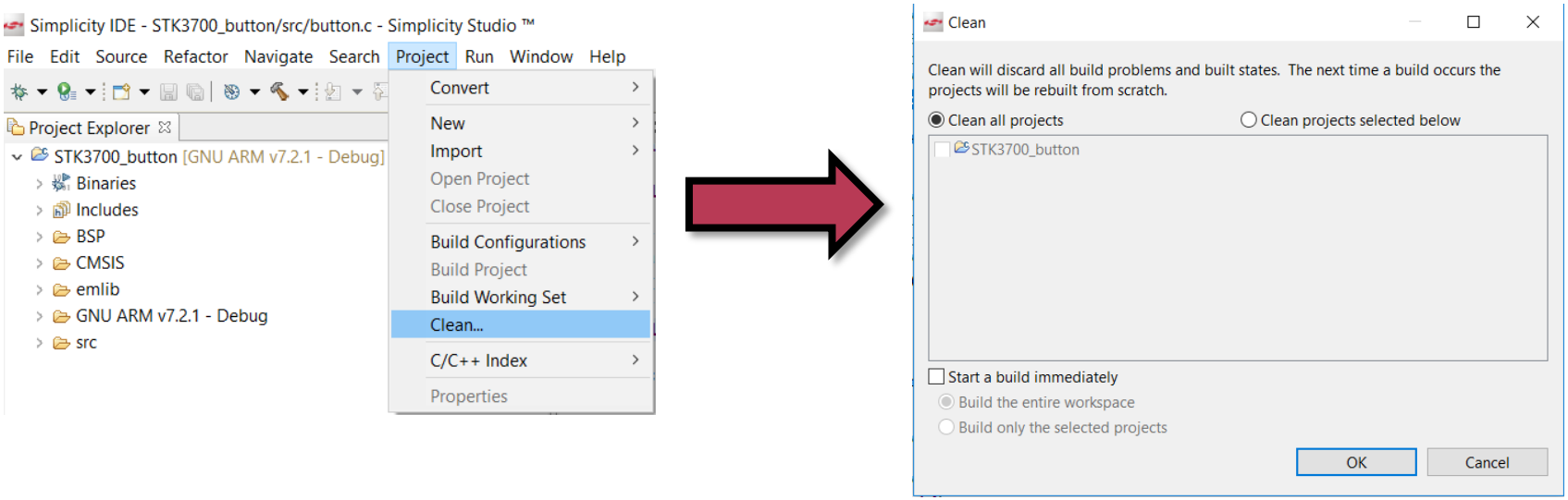
Building target: STK3700_button.axf
Invoking: GNU ARM C Linker
arm-none-eabi-gcc -g3 -gdwarf-2 -mcpu=cortex-m3 -mthumb -T "STK3700_button.ld" -Xlinker --gc-sections -Xlinker -Map="STK3700_button.map" --specs=nano.specs -o STK3700_button.axf "./BSP/bsp_bcc.o" "./BSP/bsp_stk.o" "./BSP/bsp_stk_buttons.o" "./BSP/bsp_stk_leds.o" "./BSP/bsp_trace.o" "./CMSIS/EFM32GG/startup_gcc_efm32gg.o" "./CMSIS/EFM32GG/system_efm32gg.o" "./emlib/em_assert.o" "./emlib/em_cmu.o" "./emlib/em_core.o" "./emlib/em_ebi.o" "./emlib/em_emu.o" "./emlib/em_gpio.o" "./emlib/em_system.o" "./emlib/em_usart.o" "./src/button.o" -Wl,--start-group -lgcc -lc -lnosys -Wl,--end-group

Finished building target: STK3700_button.axf

The building process (see console)

```
Building hex file: STK3700_button.hex
arm-none-eabi-objcopy -O ihex "STK3700_button.axf" "STK3700_button.hex"

Building bin file: STK3700_button.bin
arm-none-eabi-objcopy -O binary "STK3700_button.axf" "STK3700_button.bin"

Building s37 file: STK3700_button.s37
arm-none-eabi-objcopy -O srec "STK3700_button.axf" "STK3700_button.s37"

Running size tool
arm-none-eabi-size "STK3700_button.axf" -A
STK3700_button.axf  :
section          size      addr
.text            6612         0
.data             116   536870912
.bss               32   536871028
.heap            3072   536871064
.stack_dummy     1024   536871064
.comment          126         0
.debug_macro     7809         0

…….. Some more lines…….

.debug_frame     3764         0
Total          960914

15:28:26 Build Finished (took 8s.456ms)
```

The clean process (see console)



15:48:05 **** Clean-only build of configuration GNU ARM v7.2.1 - Debug for project STK3700_button ****

make -j4 clean

rm -rf ./src/button.o ./emlib/em_assert.o ./emlib/em_cmu.o ./emlib/em_core.o ./emlib/em_ebi.o ./emlib/em_emu.o ./emlib/em_gpio.o ./emlib/em_system.o ./emlib/em_usart.o ./CMSIS/EFM32GG/startup_gcc_efm32gg.o ./CMSIS/EFM32GG/system_efm32gg.o ./BSP/bsp_bcc.o ./BSP/bsp_stk.o ./BSP/bsp_stk_buttons.o ./BSP/bsp_stk_leds.o ./BSP/bsp_trace.o ./src/button.d ./emlib/em_assert.d ./emlib/em_cmu.d ./emlib/em_core.d ./emlib/em_ebi.d ./emlib/em_emu.d ./emlib/em_gpio.d ./emlib/em_system.d ./emlib/em_usart.d ./CMSIS/EFM32GG/system_efm32gg.d ./BSP/bsp_bcc.d ./BSP/bsp_stk.d ./BSP/bsp_stk_buttons.d ./BSP/bsp_stk_leds.d ./BSP/bsp_trace.d STK3700_button.axf

15:48:05 Build Finished (took 658ms)