ARM

Practical project for STM32H7 embedded system (informative, additional content)

Sum of two numbers and LED diode blinking

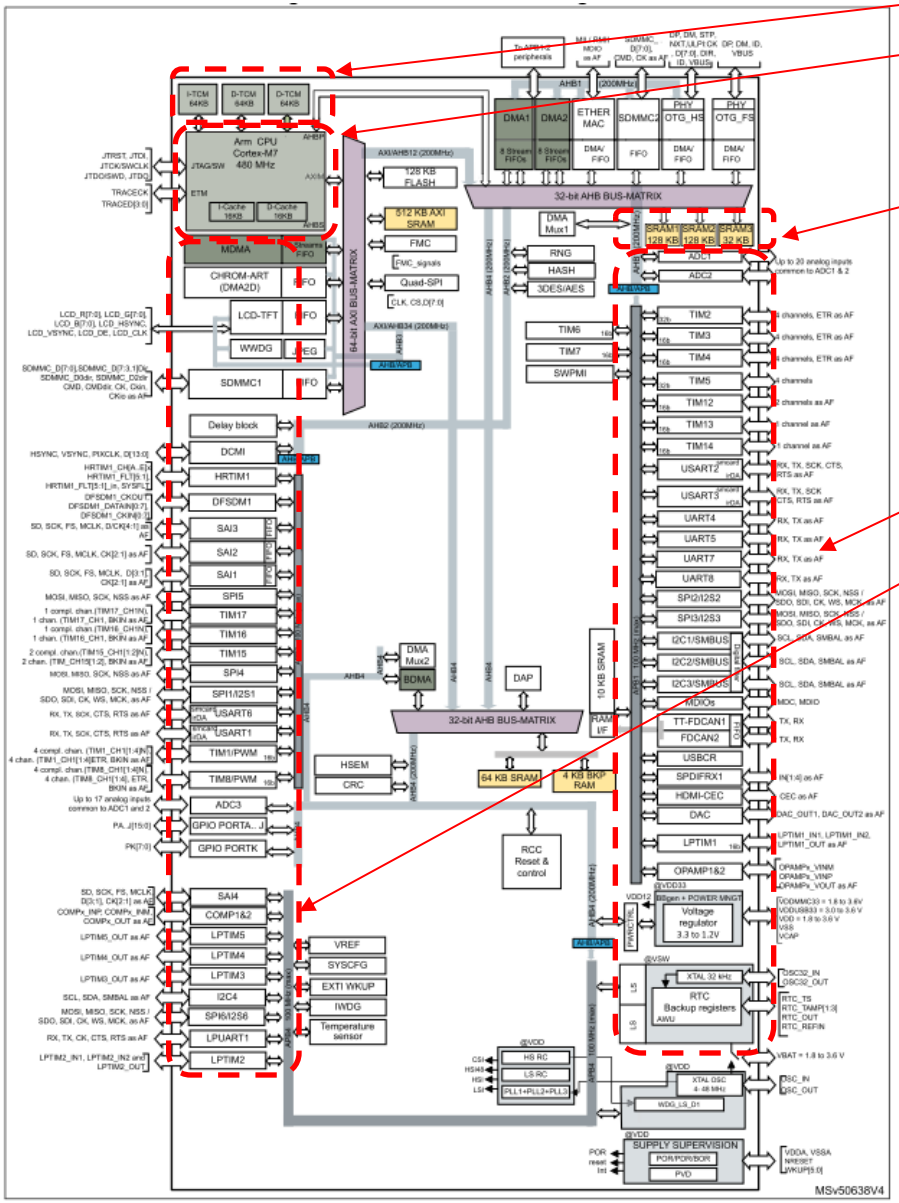
CubeIDE (VSCode)

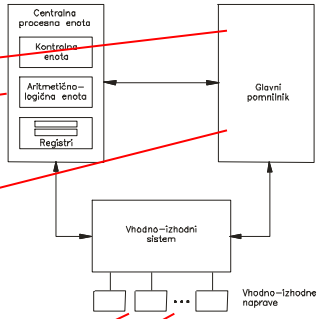
STM32H750B-DK Discovery development system

- Arm® Cortex® core-based microcontroller with 128 Kbytes (STM32H750XBH6) of Flash memory and 1 Mbyte of RAM, in TFBGA240+25 package
- 4.3” RGB interface LCD with touch panel connector
- Ethernet compliant with IEEE-802.3-2002, and POE
- USB OTG FS with Micro-AB connector
- SAI audio codec
- One ST-MEMS digital microphone
- 2 x 512-Mbit Quad-SPI NOR Flash memory
- 128-Mbit SDRAM
- 4-Gbyte on-board eMMC
- 1 user and reset push-button
- Fanout daughterboard
- 2 x FDCANs
- Board connectors:
  - USB FS Micro-AB connectors
  - ST-LINK Micro-B USB connector
  - USB power Micro-B connector
  - Ethernet RJ45
  - Stereo headset jack including analog microphone input
  - Audio header for external speakers
  - Arduino™ Uno V3 expansion connectors
  - STMod+

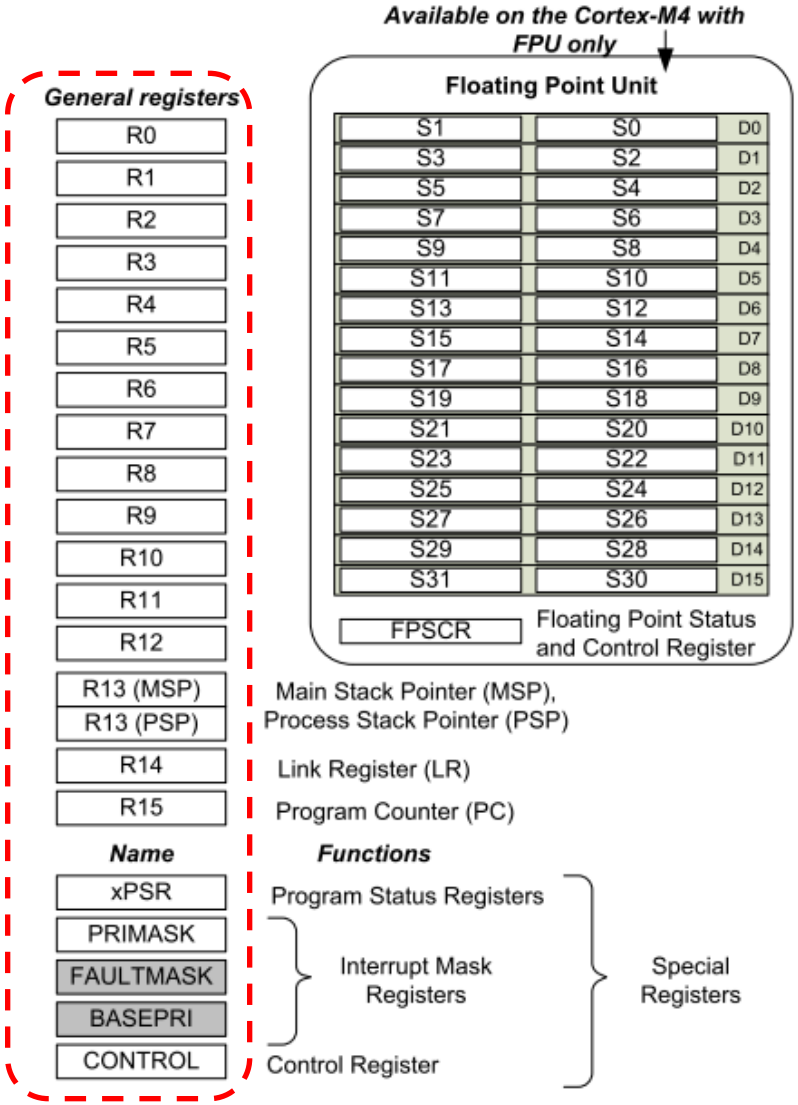
https://www.st.com/en/evaluation-tools/stm32h750b-dk.html

STM32H750XB MCU



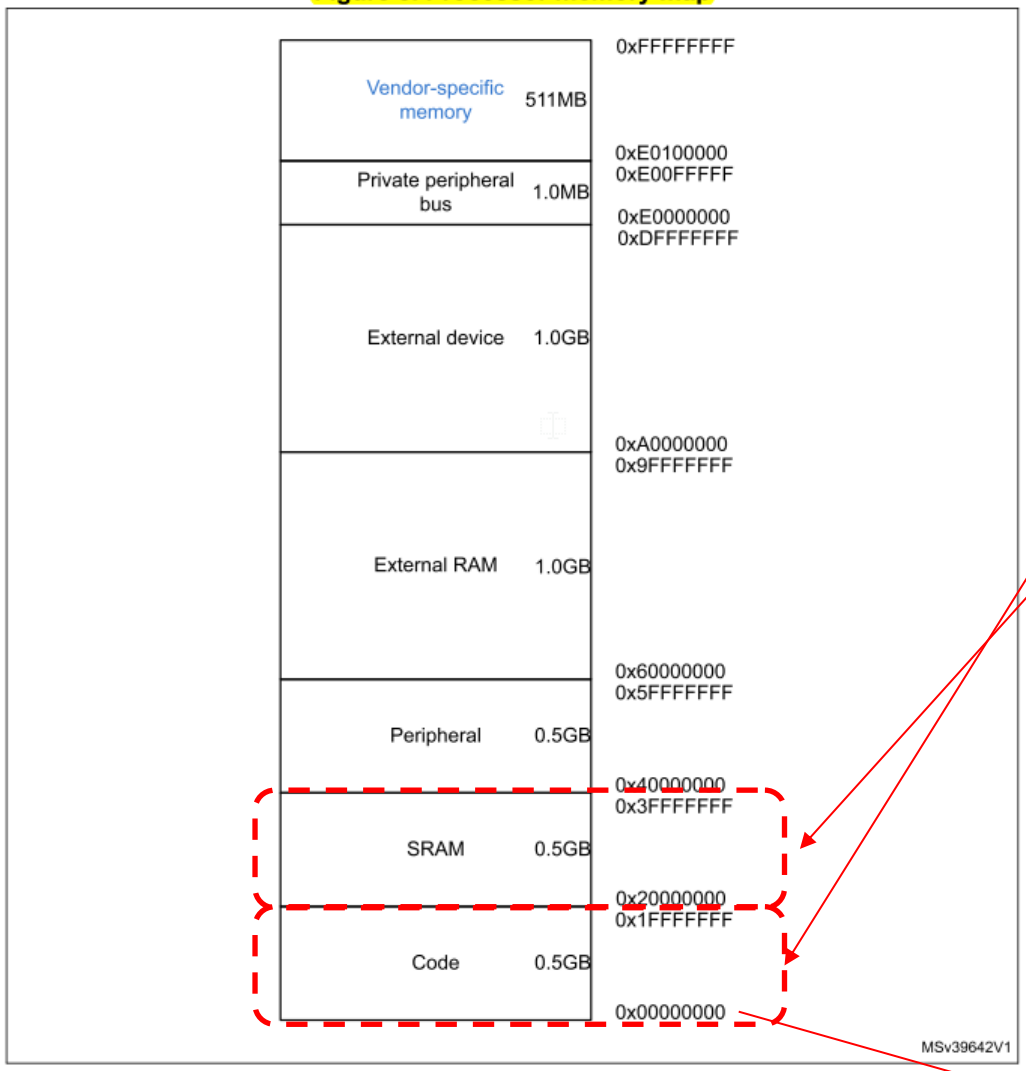


ARM Cortex M – Program model



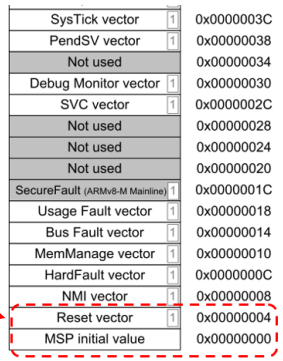
ARM Cortex M – Memory (address) space

Figure 8. Processor memory map



Memory mapping description – linker

```
MEMORY
{
  FLASH (rx)     : ORIGIN = 0x08000000, LENGTH = 128K
  DTCMRAM (xrw)  : ORIGIN = 0x20000000, LENGTH = 128K
  RAM_D1 (xrw)   : ORIGIN = 0x24000000, LENGTH = 512K
  RAM_D2 (xrw)   : ORIGIN = 0x30000000, LENGTH = 288K
  RAM_D3 (xrw)   : ORIGIN = 0x38000000, LENGTH = 64K
  ITCMRAM (xrw)  : ORIGIN = 0x00000000, LENGTH = 64K
}
```



ARM Cortex M – Vector table – Initial start

Vector Table	Vector address (initial)
Interrupt#239 vector	0x000003FC
Interrupt#31 vector	0x000000BC
Interrupt#1 vector	0x00000044
Interrupt#0 vector	0x00000040
SysTick vector	0x0000003C
PendSV vector	0x00000038
Not used	0x00000034
Debug Monitor vector	0x00000030
SVC vector	0x0000002C
Not used	0x00000028
Not used	0x00000024
Not used	0x00000020
SecureFault (ARMv8-M Mainline)	0x0000001C
Usage Fault vector	0x00000018
Bus Fault vector	0x00000014
MemManage vector	0x00000010
HardFault vector	0x0000000C
NMI vector	0x00000008
Reset vector	0x00000004
MSP initial value	0x00000000

Address 4 („Reset vector“) contains the address of the 1st instruction of the „initialization“ part, i.e. the initial code is located in the Reset_Handler subroutine.

```
.section  .text.Reset_Handler
 .weak   Reset_Handler
 .type   Reset_Handler, %function

Reset_Handler:

  …

  ldr   sp, =_estack      /* set stack pointer */

/* Call the application's entry point.*/

  bl   main

  bx   lr
```

Work on STM32H750B-DK board

Connection :

- **Micro USB** connector above the screen (arrow!), screen lights up.

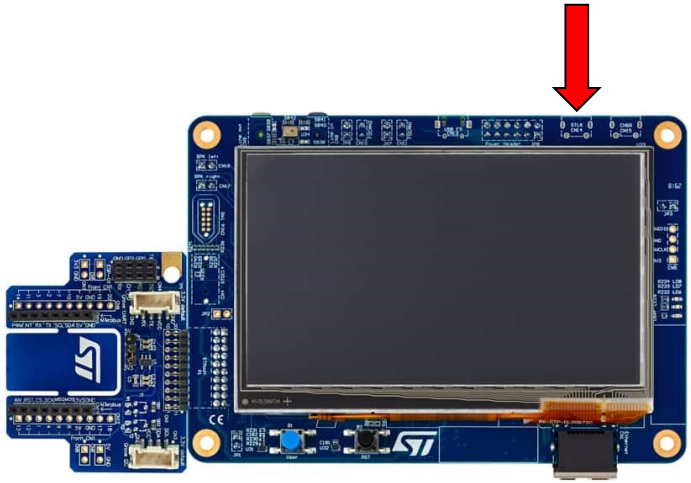
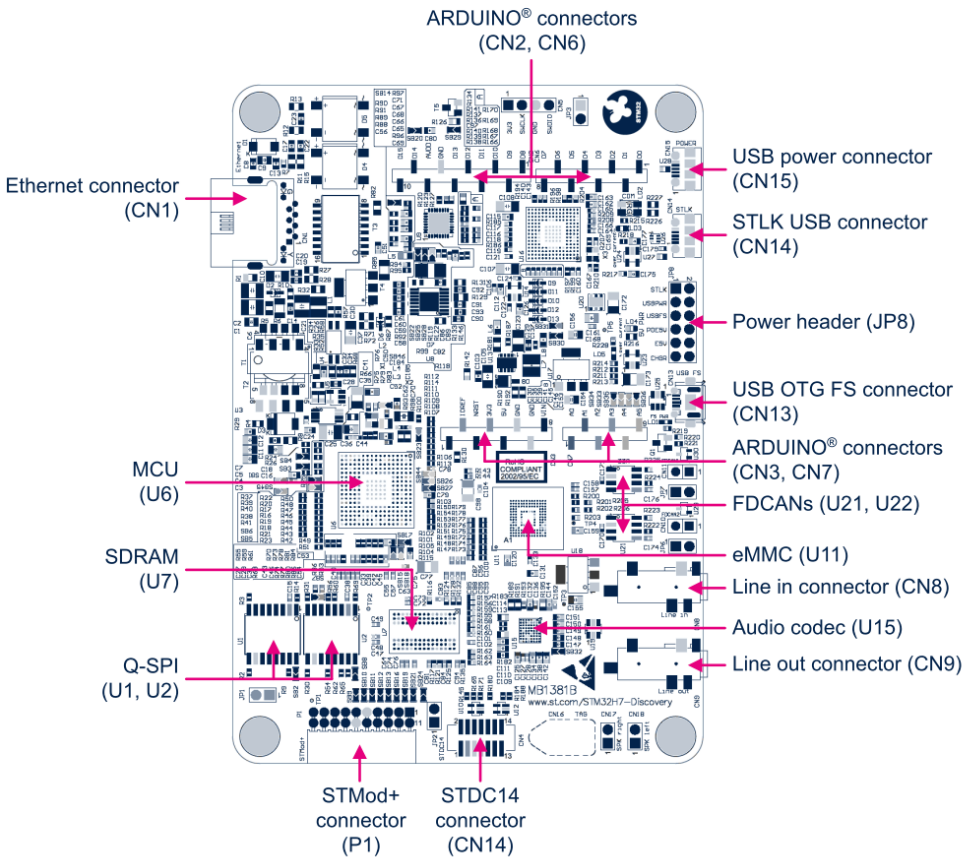
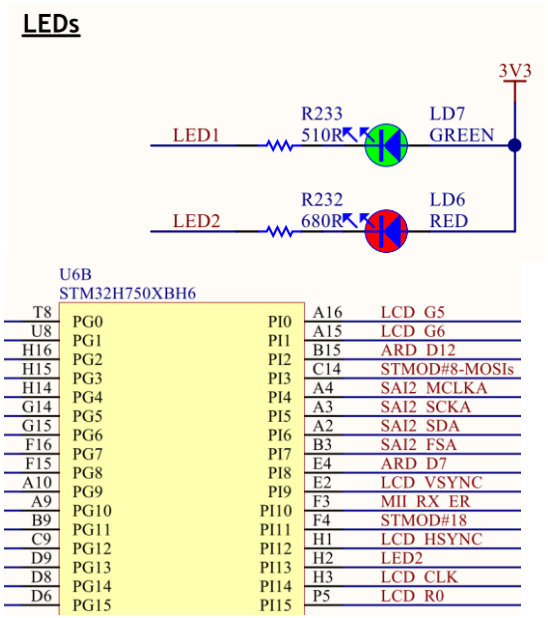


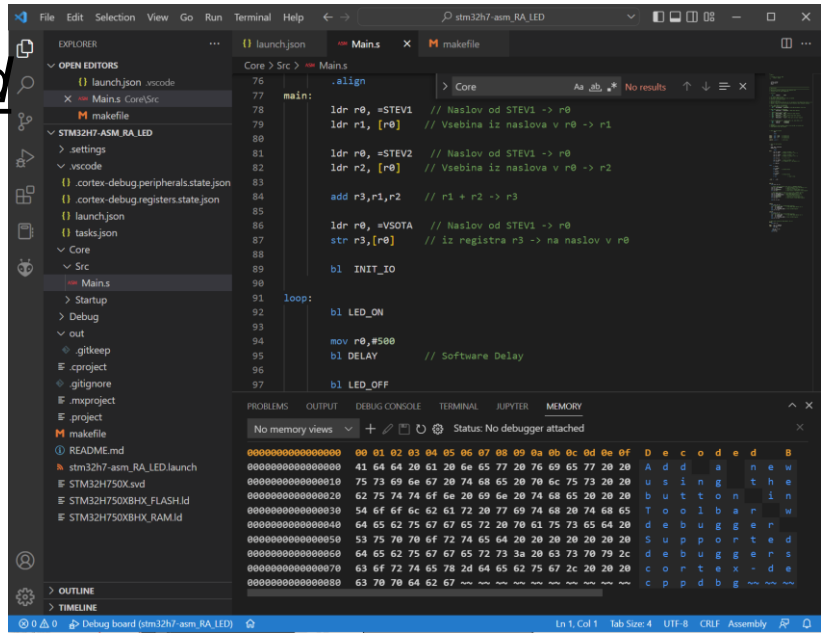
Figure 5. **STM32H745I-DISCO and STM32H750B-DK Discovery board bottom layout**





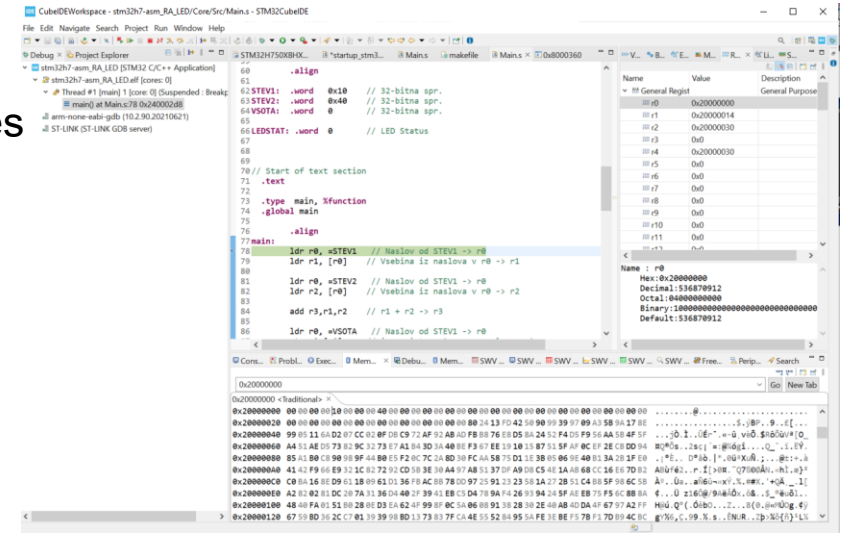
LED: red PI13, green PJ2

Work on STM32H750B-DK board



Special project for STM32H750B-DK (e-učilnica) :

- ***2 IDE environments (both „cross-platform“)***
  - ***VSCode (MS)***:
    - Also usefull for other languages, projects
    - Relies on external compilers
    - All configurable (configurations)
    - Install plugin „STM32 VS Code Extension “
  - ***CubeIDE (ST):***
    - Customized za ST boards
    - Tools for code generation, libraries setup - CubeMX
    - Based on Eclipse IDE
    - Easier installation



Specification of variables

Main.s :

```
// Start of data section
 .data                    // začetek sekcije s spremenljivkami    (v RAM pomnilnik)

 .align

STEV1: .word 0x10    // 32-bitna spr.
STEV2: .word 0x40    // 32-bitna spr.
VSOTA: .word 0       // 32-bitna spr.
```

Differences real board vs. CPULator simulator :

- Simulator (CPULator):
  - *Variables together with program*
  - *No special .data section*
  - *Simple instruction can be used to set the address in the register, e.g.:*
    - ***adr r0, STEV1***
- Board (STM32H750):
  - *Variables more distant from program*
    - *Variables in RAM memory, program in FLASH memory*
  - *Different instruction needed to set the address or any 32 bit value in the register, e.g.:*
    - ***ldr r0, =STEV1***

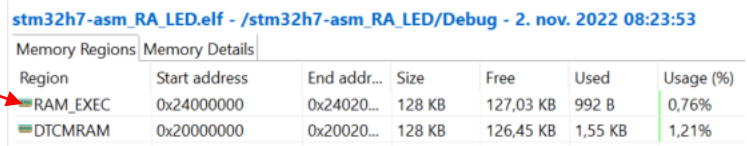
Program code

Differences real board vs. CPULator simulator :

- Simulator (CPULator):
  - *We write pure program only, no „initialization“ part*
- Board (STM32H750):
  - *Main program is actually a subroutine:*
    - *Called from initialization part (startup_stm32h750xbhx.s)*
    - *„initialization“ part of the project is always started first when the system is powered up or reset key is pressed*
  - *During intensive development, we often store the program also in RAM memory (to save erase cycles in FLASH)*
  - *At the end, program is stored in FLASH memory to stay permanent.*

Main.s :

```
// Start of text section
  .text                    // začetek sekcije s
programom (v FLASH pomnilnik)
  .type  main, %function
  .global main

  .align

main:
  ldr r0, =STEV1    // Naslov od STEV1 -> r0
  ldr r1, [r0]     // Vsebina iz naslova v r0 -> r1

  ldr r0, =STEV2    // Naslov od STEV1 -> r0
  ldr r2, [r0]// Vsebina iz naslova v r0 -> r2

  add r3,r1,r2     // r1 + r2 -> r3

  ldr r0, =VSOTA    // Naslov od STEV1 -> r0
  str r3,[r0]// iz registra r3 -> na naslov v r0
```

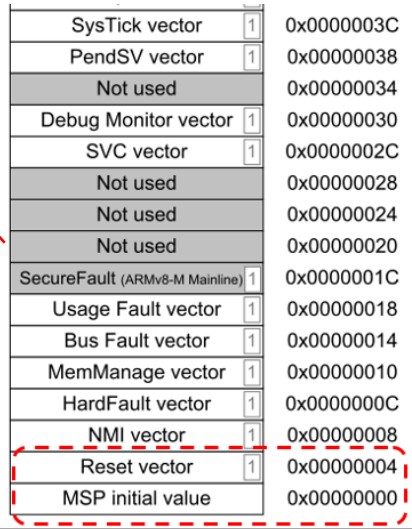


Initializaton part

startup_stm32h750xbhx.s:

```
g_pfnVectors:
  .word  _estack
  .word  Reset_Handler

  .word  NMI_Handler
  .word  HardFault_Handler
  .word  MemManage_Handler
  .word  BusFault_Handler
  .word  UsageFault_Handler
  .word  0
  .word  0
  .word  0
  .word  0
  .word  SVC_Handler
  .word  DebugMon_Handler
  .word  0
  .word  PendSV_Handler
  .word  SysTick_Handler
```

```
  .section  .text.Reset_Handler
   .weak   Reset_Handler
   .type   Reset_Handler, %function

Reset_Handler:

   ldr   sp, =_estack      /* set stack pointer */

/* Call the application's entry point.*/

   bl  main

   bx  lr
```



Main program – sum of two numbers

Main.s :

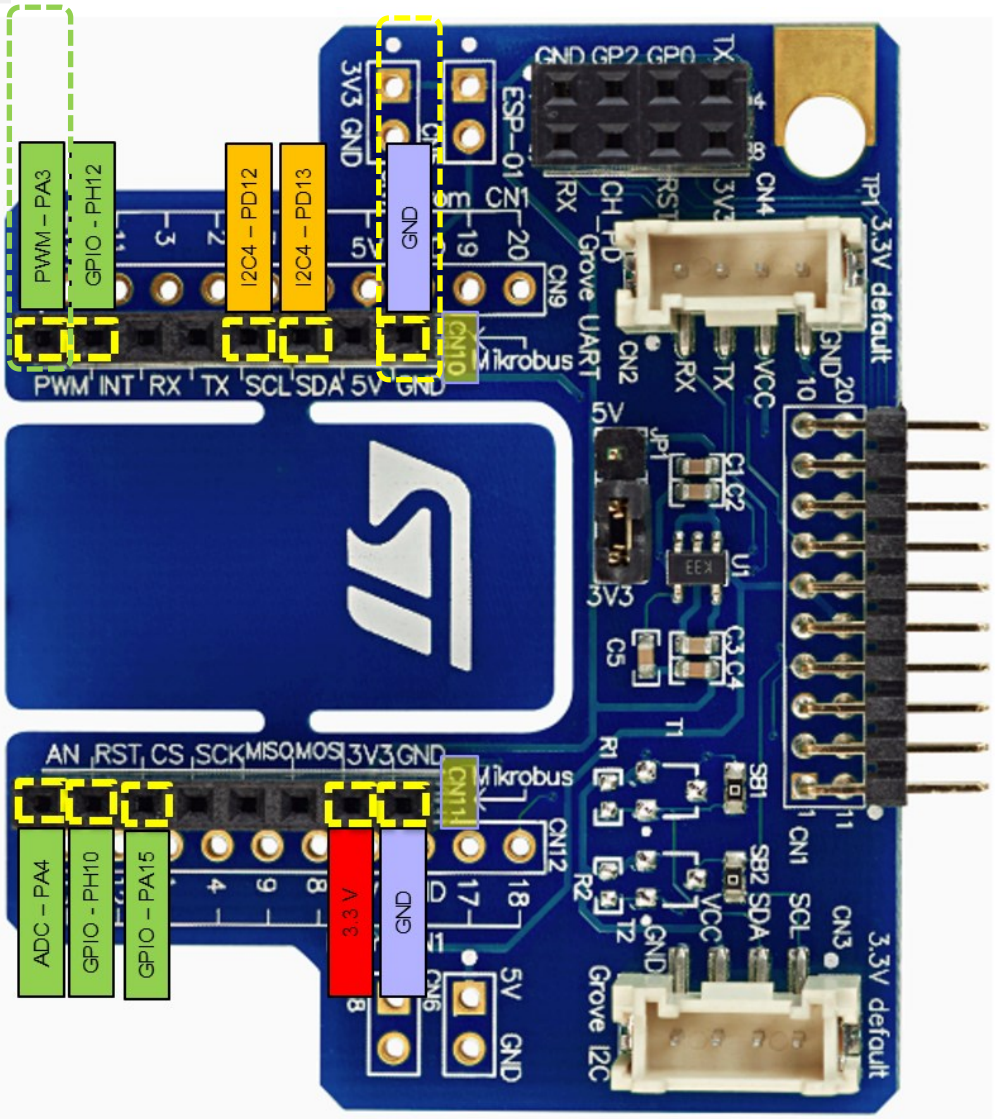
```
main:
        ldr r0, =STEV1    // Naslov od STEV1 -> r0 (simulator: adr r0,STEV1)
        ldr r1, [r0]      // Vsebina iz naslova v r0 -> r1

        ldr r0, =STEV2    // Naslov od STEV1 -> r0  (simulator: adr r0,STEV2)
        ldr r2, [r0]   // Vsebina iz naslova v r0 -> r2

        add r3,r1,r2      // r1 + r2 -> r3

        ldr r0, =VSOTA    // Naslov od STEV1 -> r0  (simulator: adr r0,VSOTA)
        str r3,[r0]    // iz registra r3 -> na naslov v r0
```

Main program –LEDs and PA3 blinking

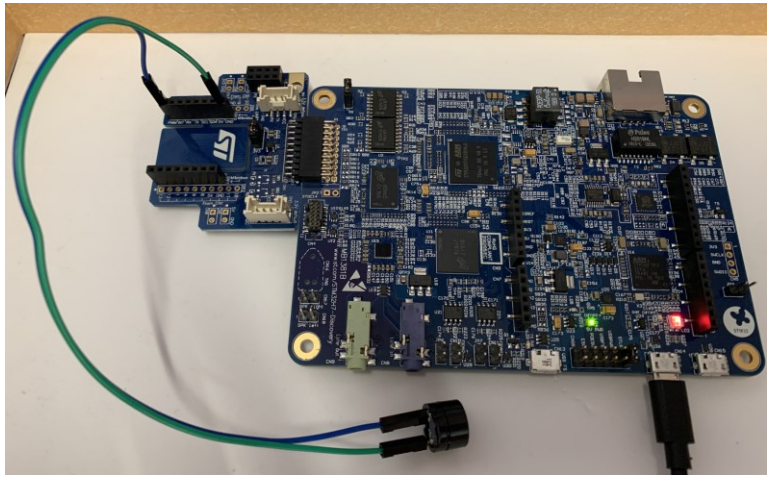
Main.s :

```
                bl INIT // Priprava V/I in sistemskih naprav za kontrolo LED diod in PA3

                ldr r1,=LED1
                ldr r2,=LED2
                ldr r3,=PA3

                mov r4,#0xff // LED(Pin) On value
                mov r5,#0 // LED(Pin) Off value

        loop:
                str r4,[r1] // Vklop LED1 diode
                str r5,[r2] // Izklop LED2 diode
                str r4,[r3] // Vklop PA3
                bl WRITEOUT // Prenesi na prikljucke

                @ delay half cycle

                str r5,[r1] // Izklop LED1 diode
                str r4,[r2] // Vklop LED2 diode
                str r5,[r3] // Izklop PA3
                bl WRITEOUT // Prenesi na prikljucke

                @ delay half cycle

                b loop // skok na vrstico loop:

        __end:   b __end
```

STM32H7 – Extension board



Proper connection



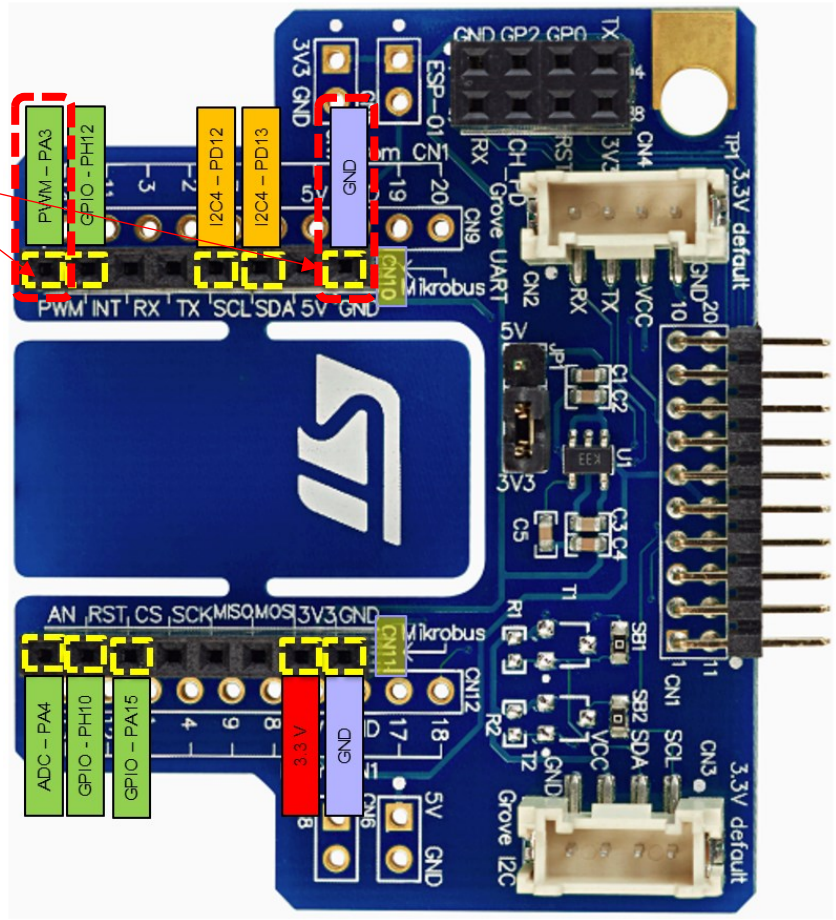
Incorrect connection !!!

https://www.st.com/en/evaluation-tools/stm32h750b-dk.html

Extension board (we will use PA3 pin as digital output)

Connection to STM32H7 : PA3 pin as digital output (we connect buzzer or LED diode with resistor)

GPIO	Type	Connector
PA3	Buzzer	+
GND	Buzzer	-



Informative, additional content

Branch instruction (further explanation)

Branch is an instruction of the GOTO label type. Address of the instruction at the line with label is written to PC register.

b (Branch)

```
zanka:      …
            sub r1, r1, #1
            b zanka @ GOTO zanka
```

Informative, additional content

Subroutines (further explanation)

When calling subroutines, we need to remember the return address !

Solution on ARM CPUs:

- **On subroutine call :**
  - return address (in pc) is stored in register r14 (link register = lr)
  - address of the 1st instruction of subroutine is put into pc
- **On return from subroutine**
  - return address restored from r14 (lr) to r15 (pc)
  - Made by push&pop instructions at the start and end of subroutine ->

Instruction to call subroutine:

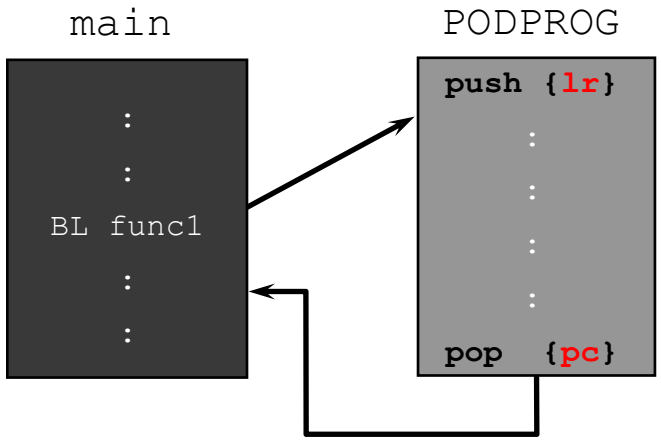
```
BL   SUBPROGR
```

- Branch with Link (L = 1) – store return address in r14.

Subroutines

Examples of subroutine calls

```
Case:

          bl   PODPROG
          ..
__end:    b __end

PODPROG: push {r1, ..., lr}
          ..


          pop  {r1, ..., pc}
```



Stack can be temporary storage also for used registers in subroutines, that change the content. After the return, their content can be restored from the stack.

```
LED_ON:
    push {r5, r6, lr}
// Set GPIOx Pins to 1 (through BSSR register)
ldr    r6, =GPIOI_BASE       // Load GPIOI BASE address to r6
mov    r5, #LEDs_ON
str    r5, [r6,#GPIOx_BSSR] // Write to BSRR register
  pop {r5, r6, pc}

LED_OFF:
    push {r5, r6, lr}
// Set GPIOx Pins to 0 (through BSSR register)
ldr    r6, =GPIOI_BASE       // Load GPIOI BASE address to r6
mov    r5, #LEDs_OFF
str    r5, [r6,#GPIOx_BSSR] // Write to BSRR register
  pop {r5, r6, pc}
```

```
// Delay with internal SW loop approx. r0 x ms
DELAY:
    push {r1, lr}

MSEC: ldr r1,=LEDDELAY
LOOP:   subs r1, r1, #1
        bne LOOP

      subs r0, r0, #1
      bne MSEC
    pop {r1, pc}
```

Challenges

- **Shorten time of on/off LED state**
  - Internal delay counter to usec (64000->64)

- **Change proportion of on/off LED state**
  - LED -> Dimmer

    Vklop:izklop (10:90 - LED „temna“, 90:10 - LED „svetla“)
    @ LED dimming (0-100% demo in 10% steps
    TABLECNT: .hword 9
    @ half blink period in microsecs
    TABLE: .hword 90,80,70,60,50,40,30,20,10

- **Change period (50% duty cycle)**
  - Buzzer -> melodies

    @ Kuza Pazi Melody on buzzer demo
    TABLECNT: .hword 15
    @ Kuza pazi c-d-e-d-c (C=262Hz, D=290Hz, E=330Hz)
    @ half note period in microsecs
    TABLE: .hword
    1908,1908,1908,1908,1700,1700,1700,1700,1515,1515,1700,1700,1908,1908,1908
    .equ REPEAT,100
    *.equ PAUSE,48000*20*
    @ first&second cycle counter is from TABLE, only period is varied at 50% duty cycle