BME3321:Introduction to Microcontroller Programming

Introduction

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The Definitive Guide to ARM® Cortex®-M0 and Cortex-M0+ Processors (ch1,2,3,4,7)

Course overview

What is a Microcontroller?

- A microcontroller is a small computer which has
  - processor,
  - memory,
  - programmable peripherals (i.e., input/output)

Atmel AVR

AVR


ATX Mega


ATmega 328P

PIC 18F877A


8051

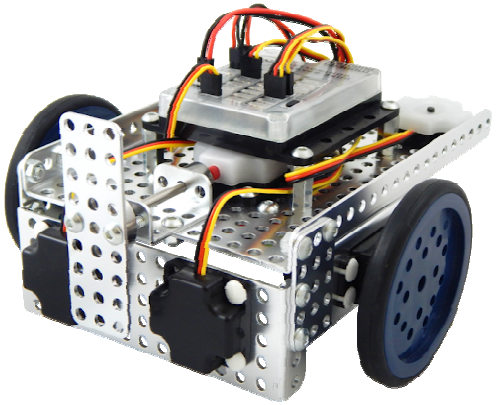

Arduino

ARM

Course overview

What is a Microcontroller?

- Used for specific (embedded) applications like...



Course overview

- We are going to learn about ARM- Cortex Microcontrollers

  Architecture, peripherials (General purpose I/O (GPIO), Interrupts, Timers, USART...), and programming

- References:

  1. The Definitive Guide to ARM® Cortex®-M0 and Cortex-M0+ Processors, Joseph Yiu, Second edition- 2015 (Ch 1,2,3,4,7,8)

  2. Mastering STM32, Carmine Noviello, 2016 (II Diving into the HAL)

  3. C How to Program, Paul Deitel - Harvey Deitel, Sixth edition (Ch 2-10, Especially program control, pointers, structures)

  4. STM32F407-reference manual and user manual

  5. https://www.st.com/en/microcontrollers-microprocessors/stm32-32-bit-arm-cortex-mcus.html

- Grading policy
  - 5 Labs → 25%
  - 2 HWs → 10%
  - 1 Midterm→25%
  - Final → 40%

Revision of some fundamental concepts- Logic gates

AND

$A \cdot B$

INPUT		OUTPUT
A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

OR

$A + B$

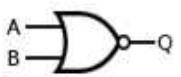
INPUT		OUTPUT
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

NAND

$\overline{A \cdot B}$

INPUT		OUTPUT
A	B	Q
0	0	1
0	1	1
1	0	1
1	1	0

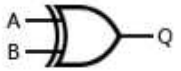
NOR



$\overline{A + B}$

INPUT		OUTPUT
A	B	Q
0	0	1
0	1	0
1	0	0
1	1	0

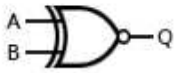
XOR



$A \oplus B$

INPUT		OUTPUT
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	0

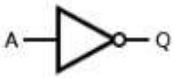
XNOR



$\overline{A \oplus B}$

INPUT		OUTPUT
A	B	Q
0	0	1
0	1	0
1	0	0
1	1	1

NOT (inverter)



$\overline{A}$

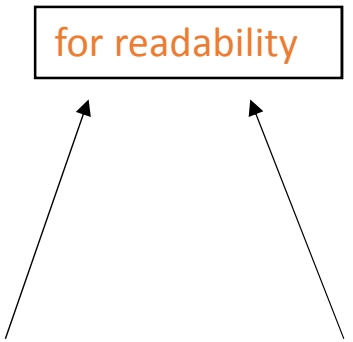
INPUT	OUTPUT
A	Q
0	1
1	0

Source:Wikipedia

Number systems

- Digital systems are binary based
  - Each data is represented using bits
  - A bit can be 1 or 0 (on or off)

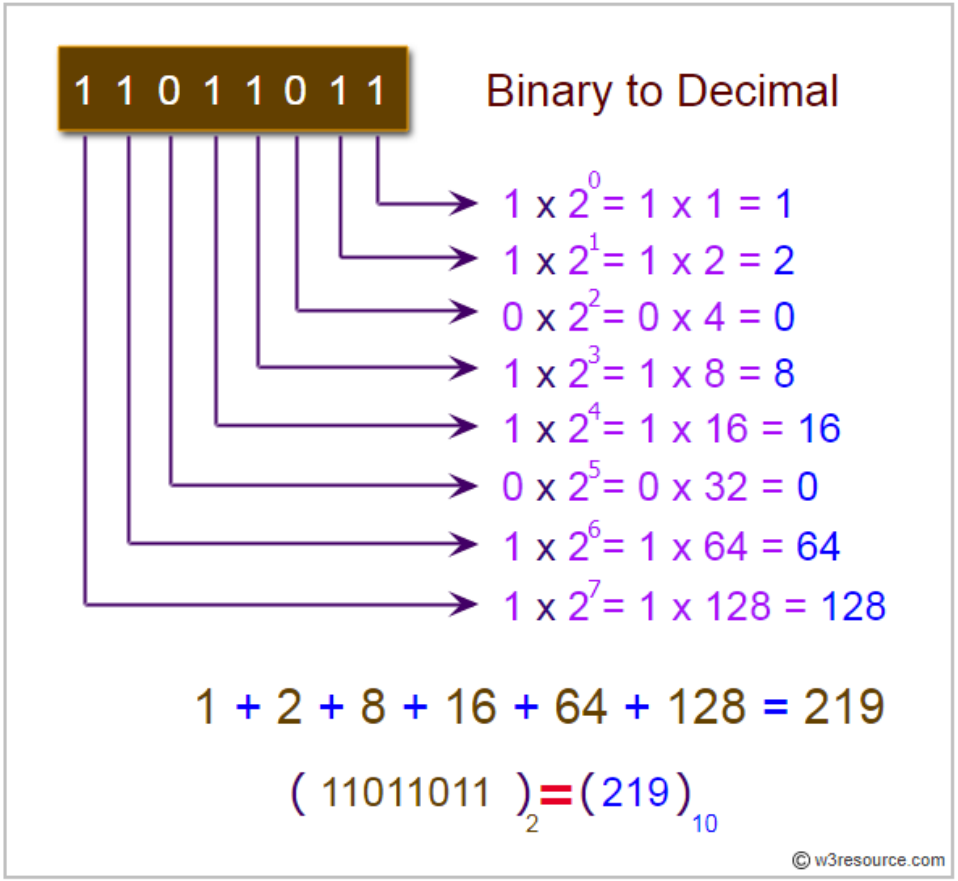
- Digital data can also be represented in: Binary (base 2), Decimal (base 10), Hex (base 16)



Decimal	Binary	Hex
0	0000	0x0
1	0001	0x1
2	0010	0x2
3	0011	0x3
4	0100	0x4
5	0101	0x5
6	0110	0x6
7	0111	0x7
8	1000	0x8
9	1001	0x9
10	1010	0xA
11	1011	0xB
12	1100	0xC
13	1101	0xD
14	1110	0xE
15	1111	0xF

Mostly used ones in microcontroller programming

Binary to decimal conversions



General formula for decimal conversions:

$$(n_{N-1}n_{N-2}\dots n_2 n_1 n_0)_b \rightarrow$$

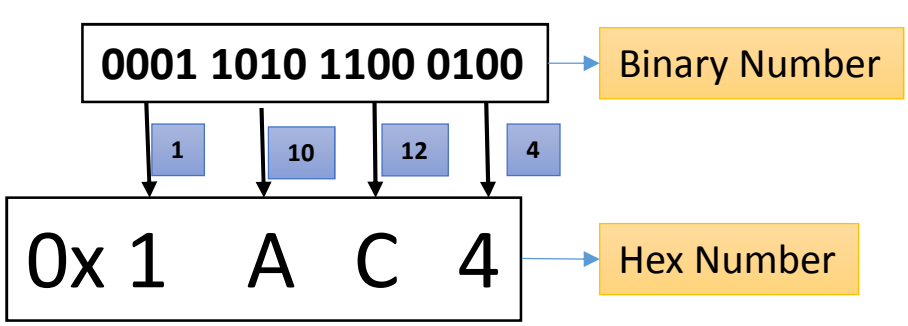
$$n_0 x b^0 + n_1 x b^1 + n_2 x b^2 + \cdots + n_{N-1} x b^{N-1}$$

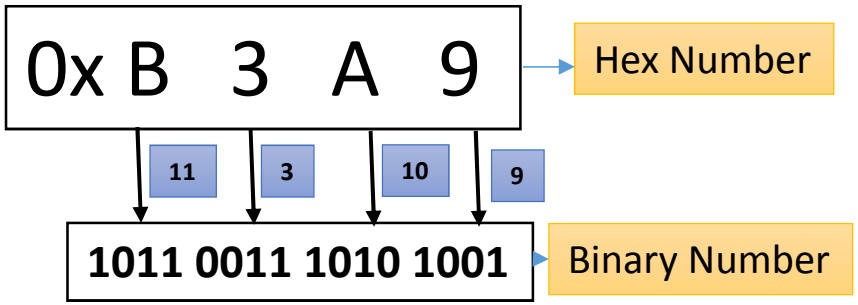
b: base (for binary 2, for hex 16)

Hex to Binary - Binary to Hex conversions

- Hex numbers are denoted with 0x... → To not confuse with other numbering systems
- Each hex value* is represented with 4 binary bits.

Examples:



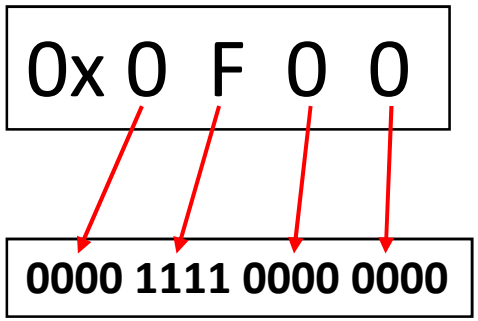


- Decimal numbering system can be used as a tool for binary to hex and hex to binary conversions.

Microcontroller programming with Hex numbering system

```
...
GPIOD->ODR=0x0F00
...
```

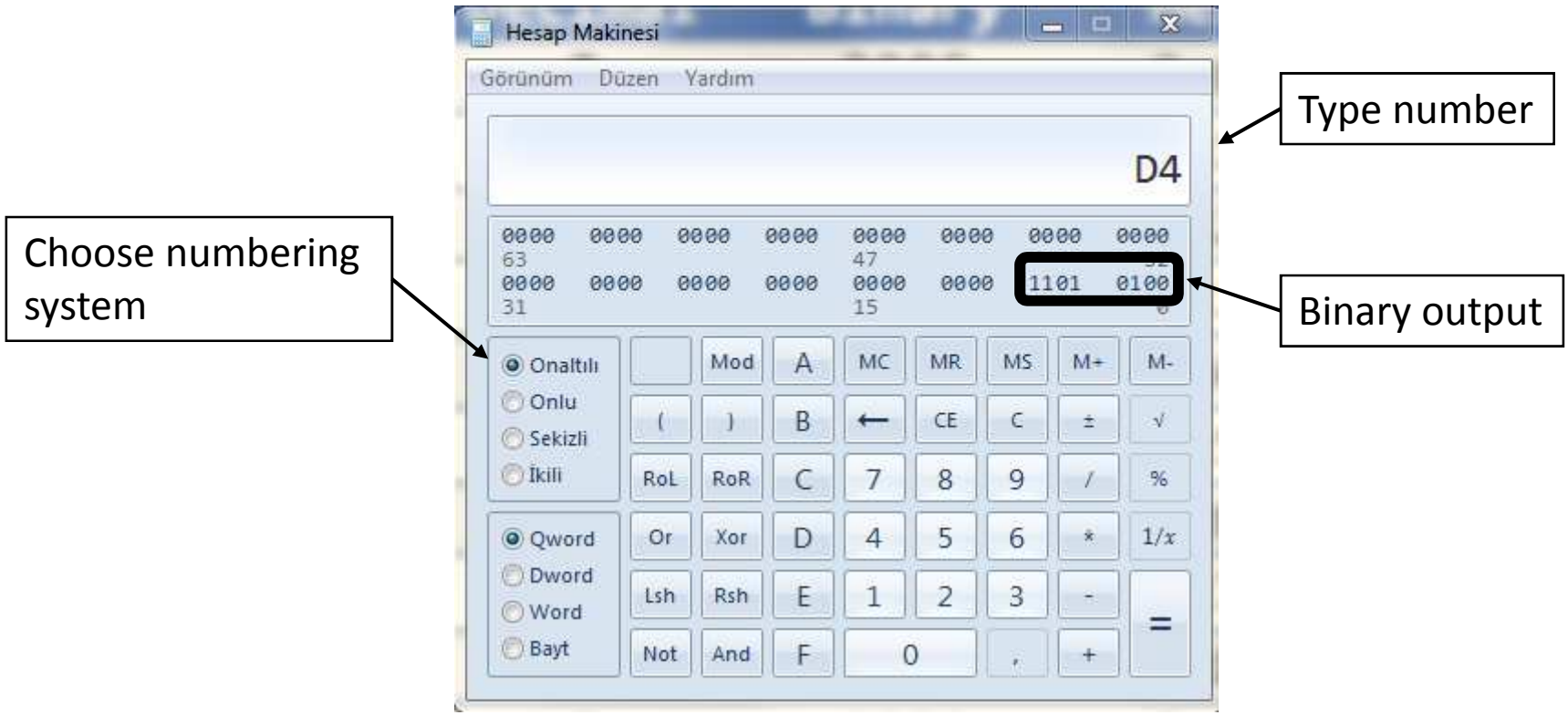
Some code



Use conversion table

Decimal	Binary	Hex
0	0000	0x0
1	0001	0x1
2	0010	0x2
3	0011	0x3
4	0100	0x4
5	0101	0x5
6	0110	0x6
7	0111	0x7
8	1000	0x8
9	1001	0x9
10	1010	0xA
11	1011	0xB
12	1100	0xC
13	1101	0xD
14	1110	0xE
15	1111	0xF

Windows calculator for conversions



- After typing the number, conversion can be done by selecting desired numbering system

Counting in different numbering systems

- Decimal

  0,1,2,3,4,5,6,7,8,9,10,11,12…,19,20,21,…,29,30,…,39….

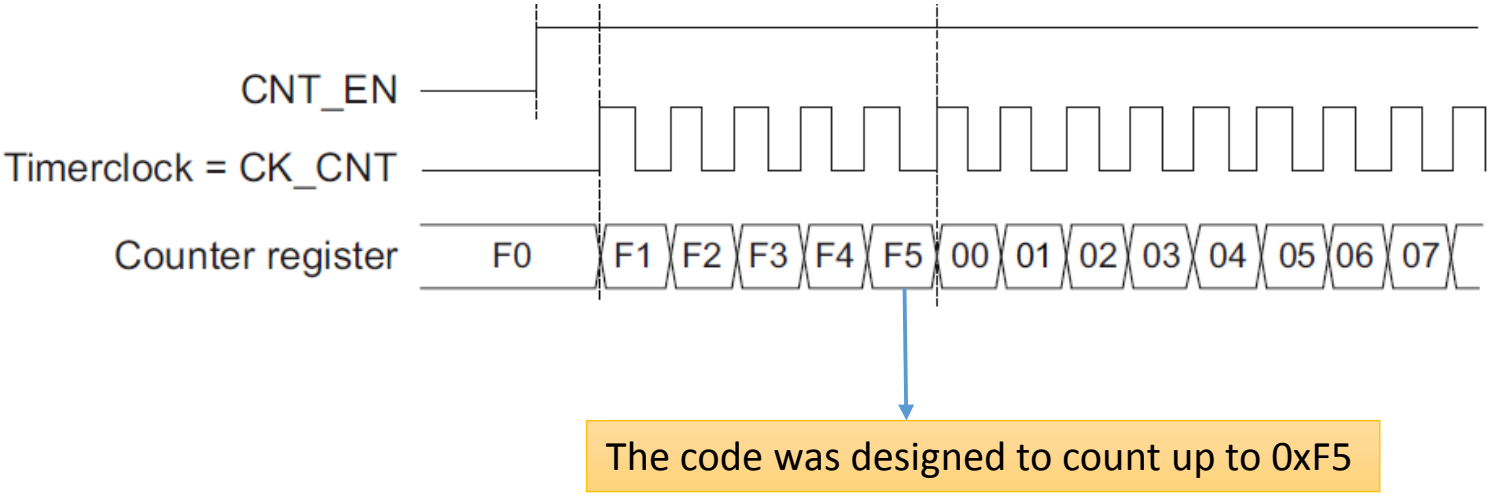
- Binary

  0,1,10,11,100,101,110,111,1000,….

- Hexadecimal

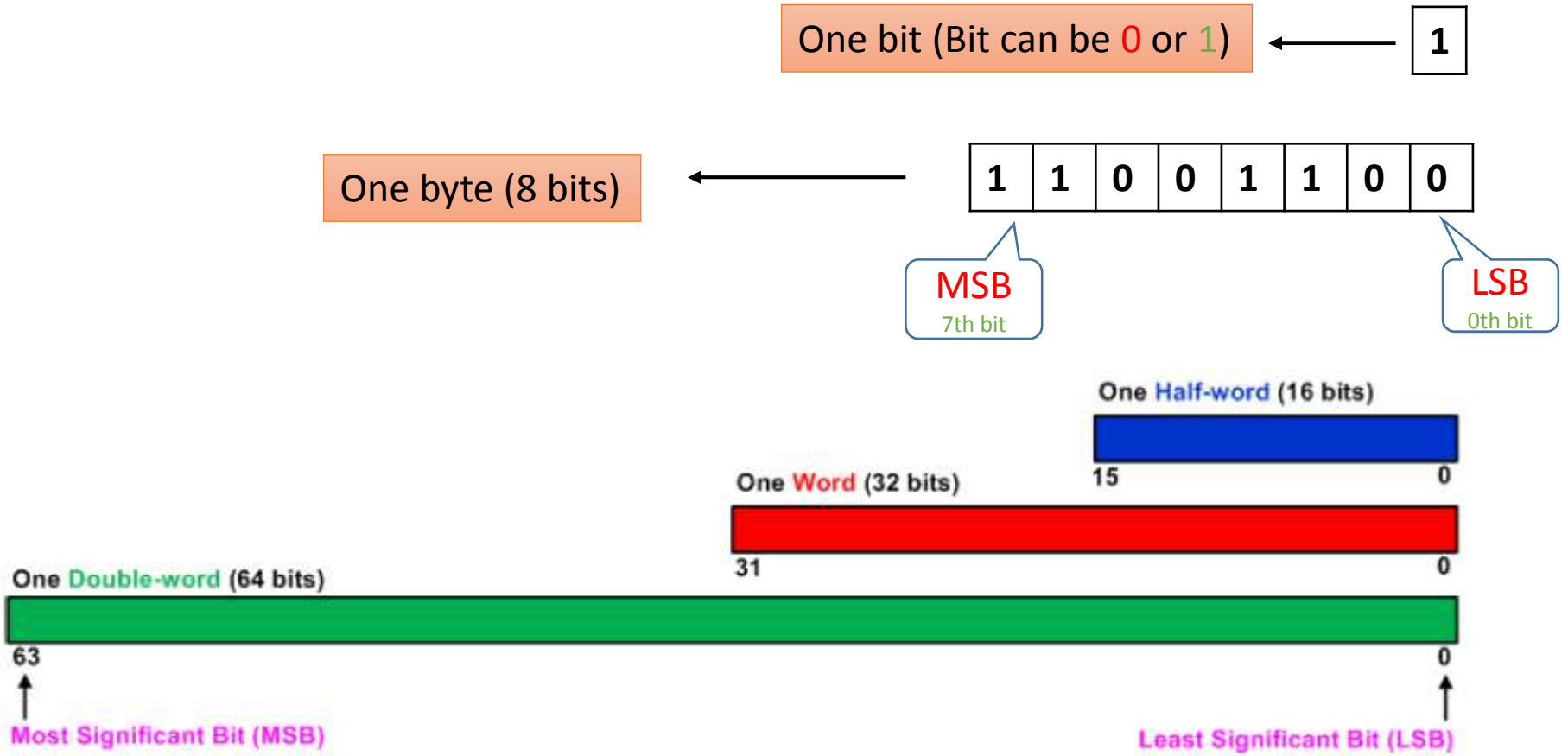
  0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F,10,11,…,1F,20,…,2F,30,.....

Counting in microcontrollers



- Generally, hex numbering is used in debug menu and reference manuals.

Terminologies



Prefixes

Prefixes	Value	Standard form	Symbol
Tera	1 000 000 000 000	10^{12}	T
Giga	1 000 000 000	10^{9}	G
Mega	1 000 000	10^{6}	M
Kilo	1 000	10^{3}	k
deci	0.1	10^{-1}	d
centi	0.01	10^{-2}	c
milli	0.001	10^{-3}	m
micro	0.000 001	10^{-6}	μ
nano	0.000 000 001	10^{-9}	n
pico	0.000 000 000 001	10^{-12}	p

Example:
4 GigaByte memory
$=4 * 10^{9} * 8$ bits

$=32 * 10^{9}$ bits

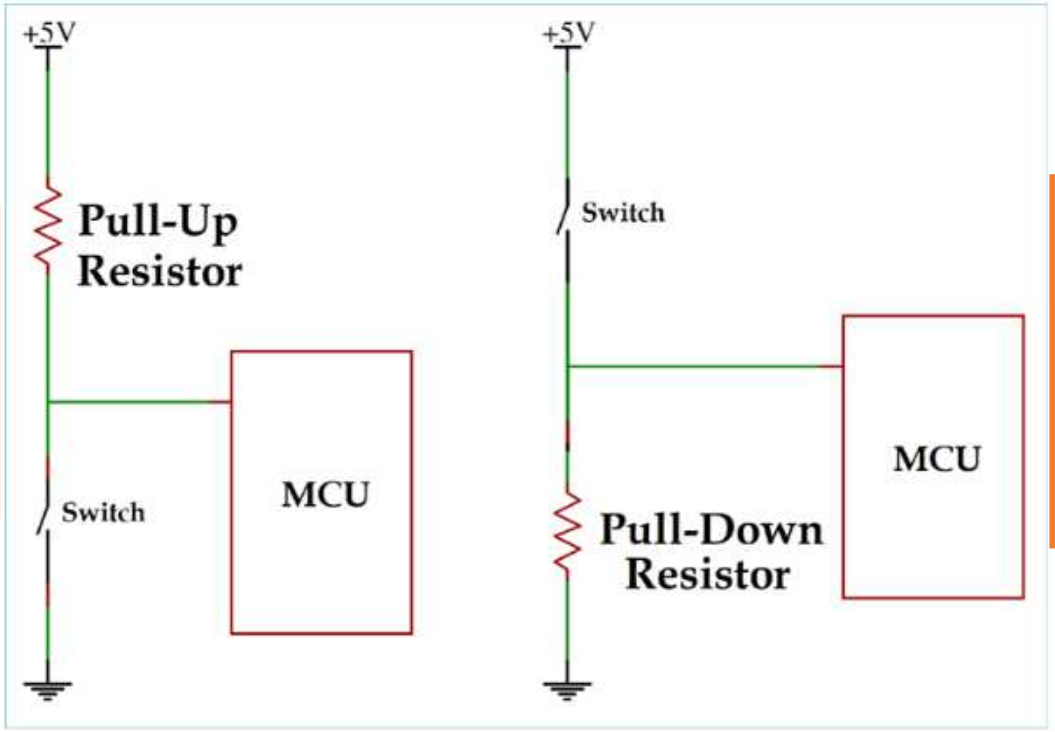
Data types

- char, short, integer...
- signed, unsigned

TYPE	BITS	MINIMUM	MAXIMUM	DECIMAL FORMAT
Unsigned char	8	0	255	Integer
Signed char	8	-128	127	Integer
Unsigned short	16	0	65535	Integer
Signed short	16	-32768	32767	Integer
Unsigned int	32	0	4294967295	Integer
Signed int	32	-2147483648	2147483647	Integer
Float (IEEE754)	32	-3.4028E+38	3.4028E+38	Real number
Double (IEEE754)	64	-1.7977E+308	1.7977E+308	Real number

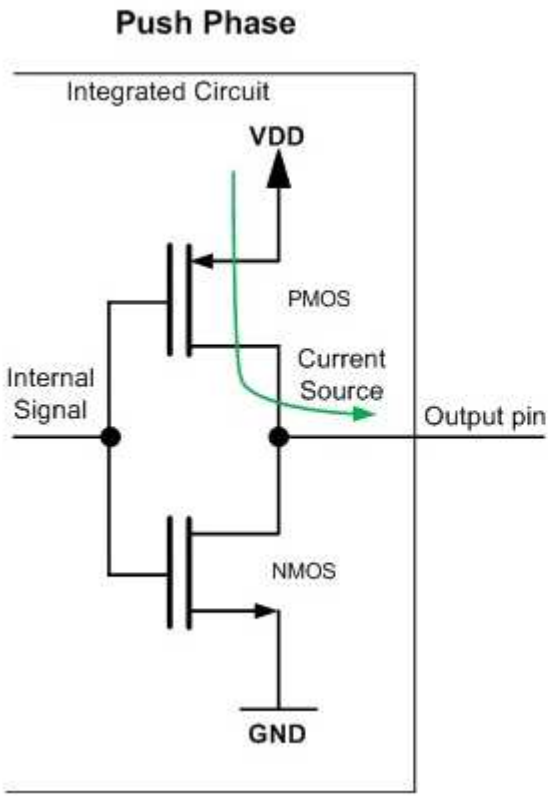
Some analog electronic terminologies

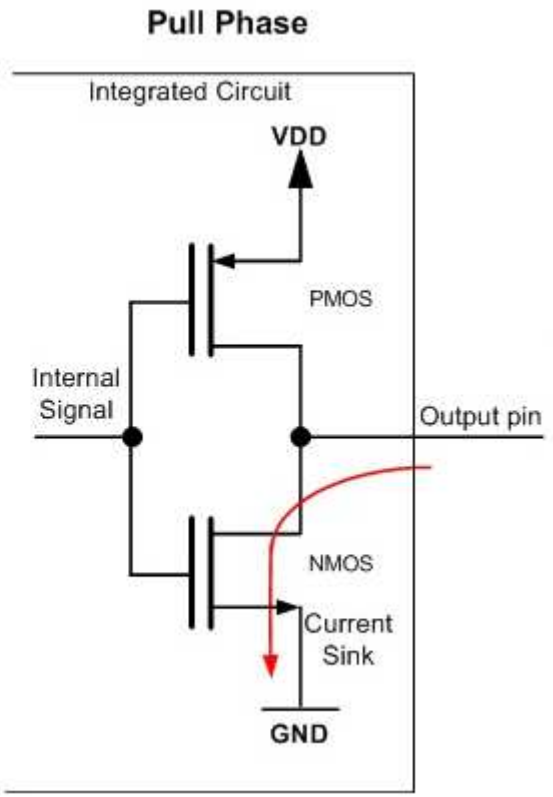
Pull-up connection
@MCU input pin:
Switch open 5V
Switch closed 0V



Pull-down connection
@MCU input pin:
Switch open 0V
Switch closed 5V

Push-Pull



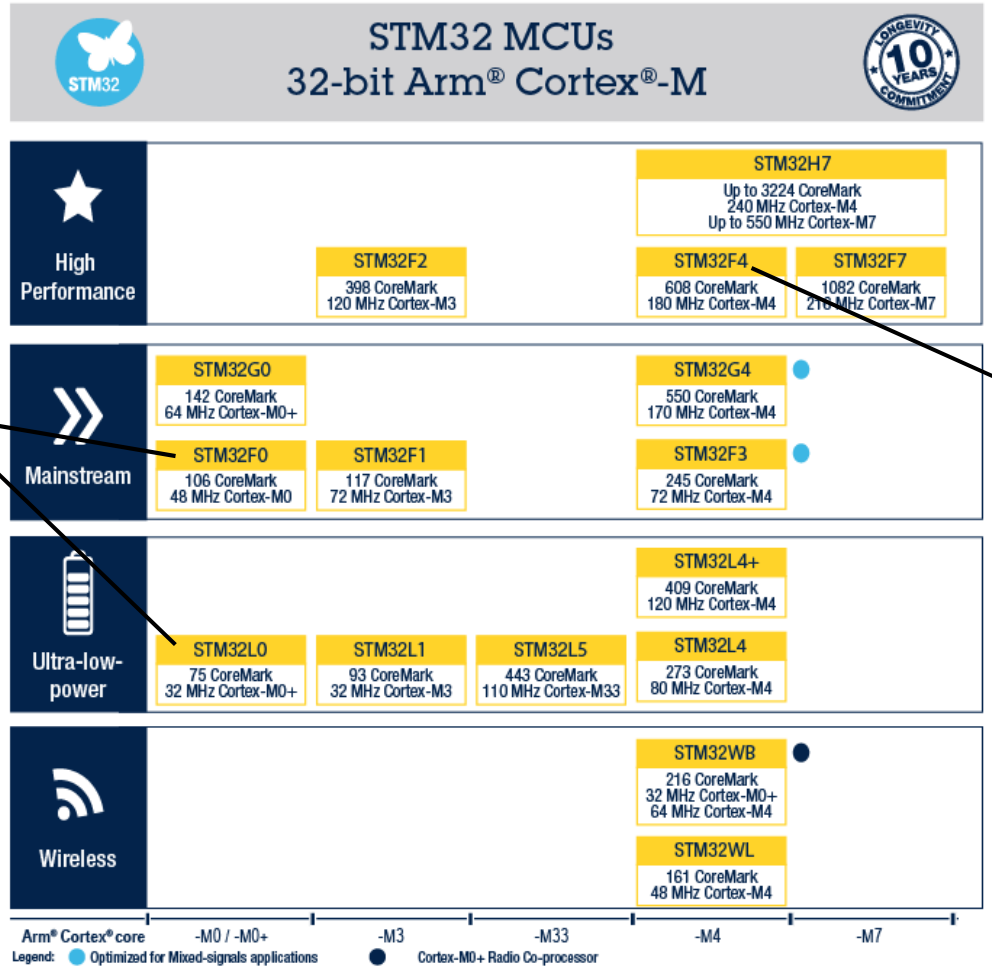


Push phase
Internal signal is low
NMOS OFF, PMOS ON

Pull phase
Internal signal is high
NMOS ON, PMOS OFF

STM32 microcontroller family

- ST microelectronics produces different types of 32-bit microcontrollers based on the Arm® Cortex®-M processor.



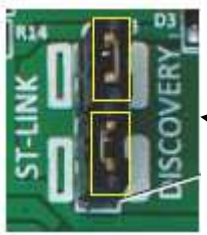
You can have any of these discovery cards (cost effective MCUs)

We have this one for the labs.

Check this website:
https://www.st.com/en/microcontrollers-microprocessors/stm32-32-bit-arm-cortex-mcus.html

- The obtained discovery card should have user button and user leds

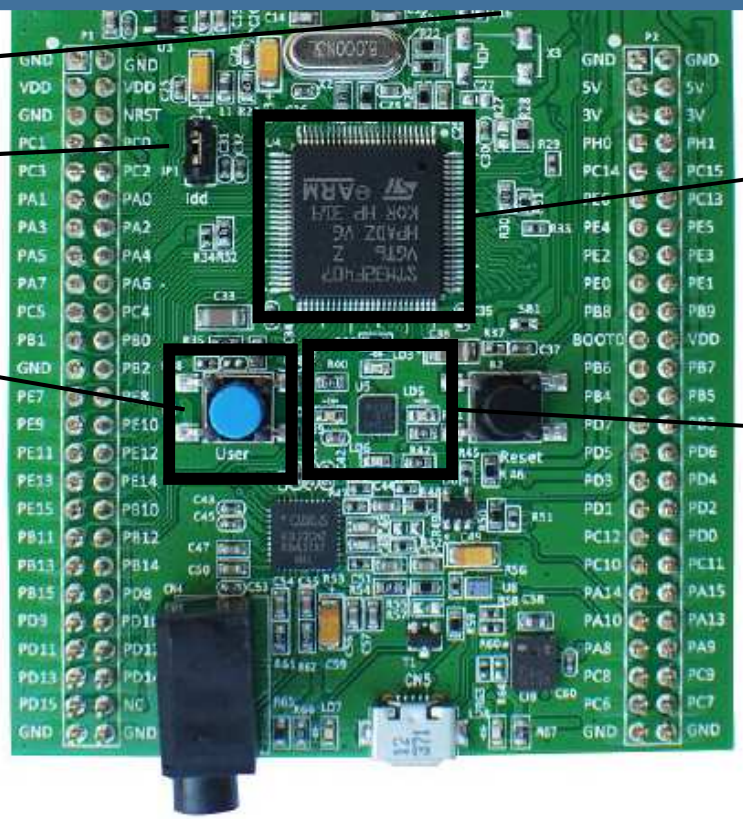
STM32F4 discovery card



USB-mini USB cable

ST-Link part to program/debug MCU

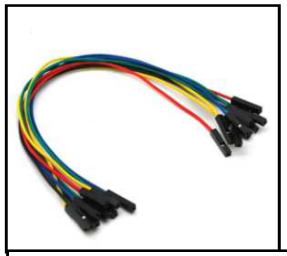
These jumpers must be on
CN3: to program MCU
JP1: for power



MCU

User button

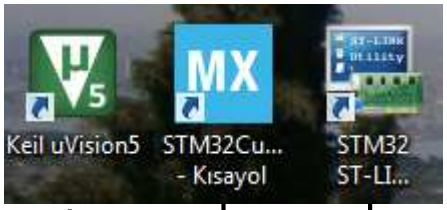
Green, orange, red, blue user leds are in this region



Female-female jumpers
for interconnection between pins

- Check out STMF4 user manual

Development toolchains and driver



STM32 ST-link Utility

Available at:
https://www.st.com/content/st_com/en/products/development-tools/software-development-tools/stm32-software-development-tools/stm32-programmers/stsw-link004.html

STM32CubeMX

Available at:
https://www.st.com/en/development-tools/stm32cubemx.html

Keil uVision (MDK-ARM)

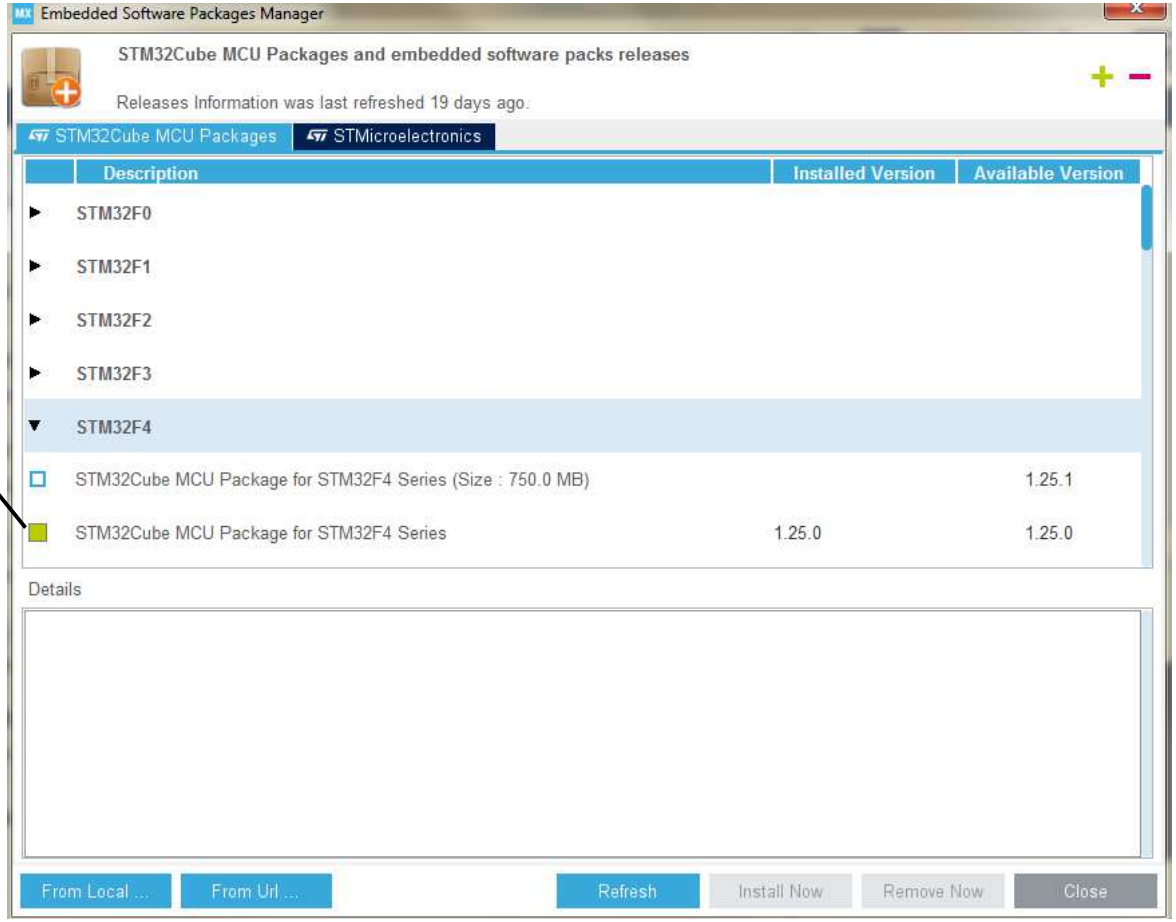
Available at:
https://www.keil.com/download/product/
(download MDK-ARM)

- STM32 ST-link Utility is driver so that computer recognize ST-Link
- STM32CubeMX is for initialization and code generation as template
- Keil uVision (MDK-ARM) is development environment for ARM- Cortex MCU

Development toolchains and driver

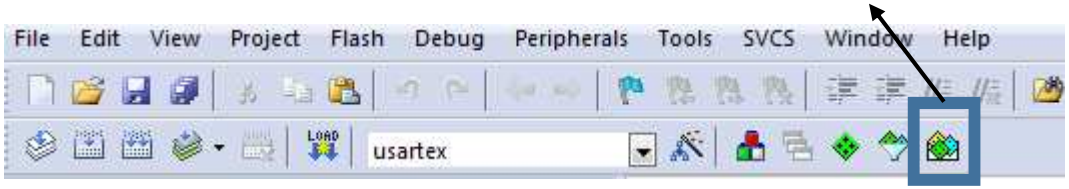
- While installing STM32CubeMX, you may be prompted to install java
- After installation, Help-> Manage embedded software packages

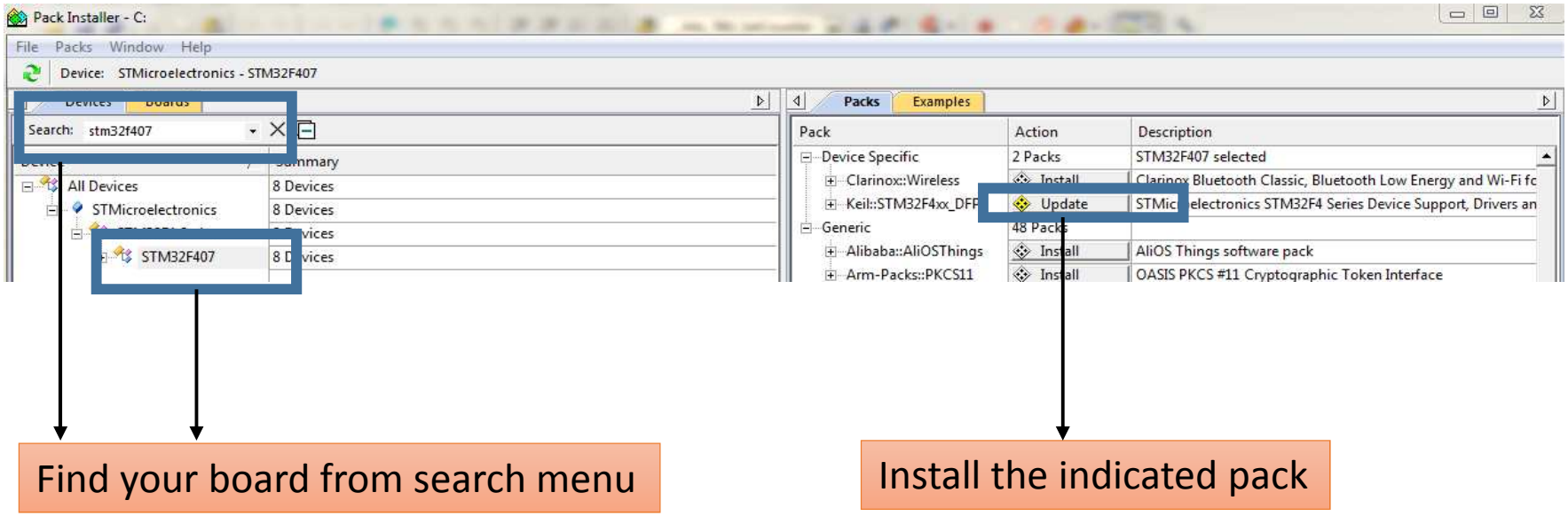
Install package for your MCU. Green color confirms that package is intalled



Development toolchains and driver

- After installation MDK-ARM, click on pack installer



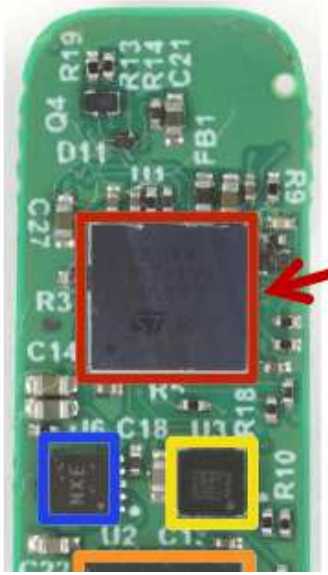


Find your board from search menu

Install the indicated pack

STM32 MCUs in industry

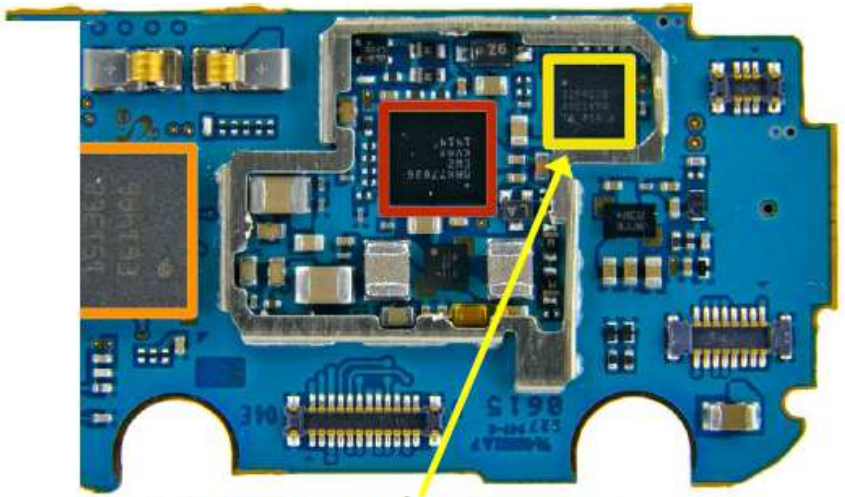
Fitbit Flex Teardown



STMicroelectronics 32L151C6 Ultra Low Power ARM Cortex M3 Microcontroller

STM32 MCUs in industry

Samsung Galaxy Gear



- STMicroelectronics STM32F401B **ARM-Cortex M4** MCU with 128KB Flash

source: ifixit.com