

# Embedded and Ambient Systems

2022.09.13.

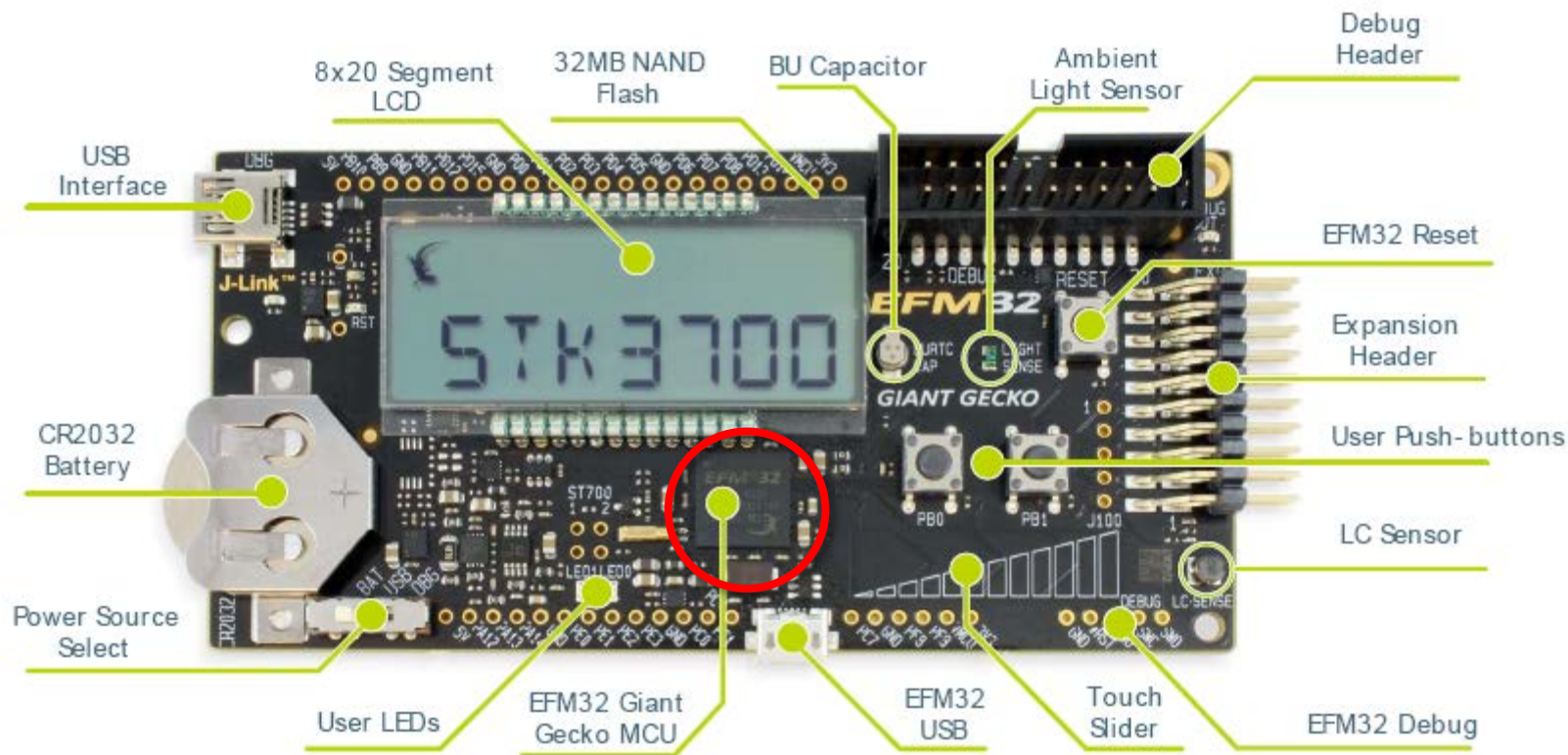
## Development Board



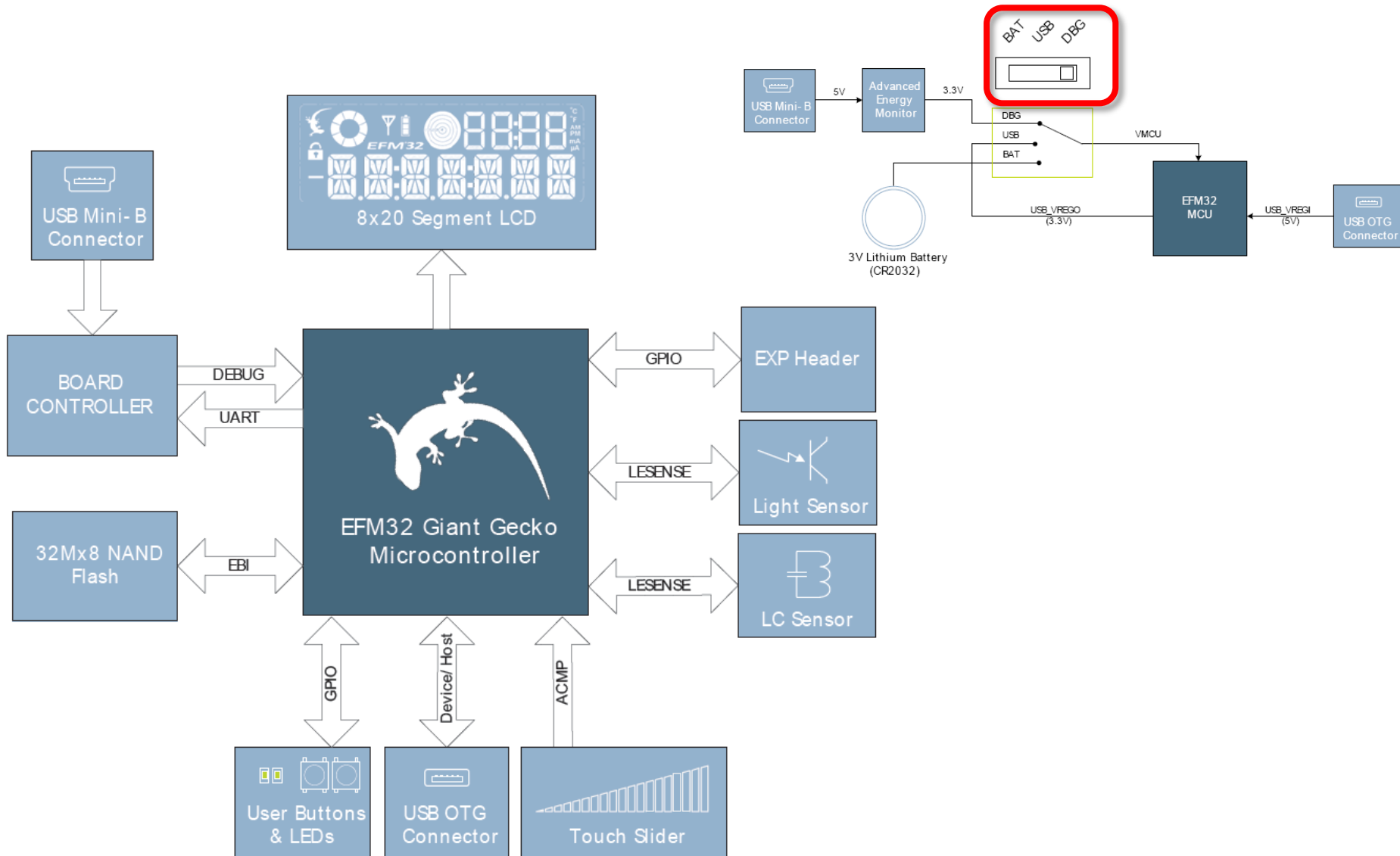
Méréstechnika és  
Információs Rendszerek  
Tanszék

# Main parts of the development board

## ■ EFM32GG-STK3700

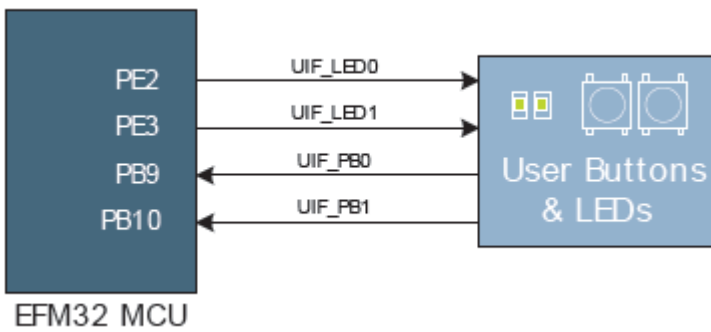


# Main parts of the development board



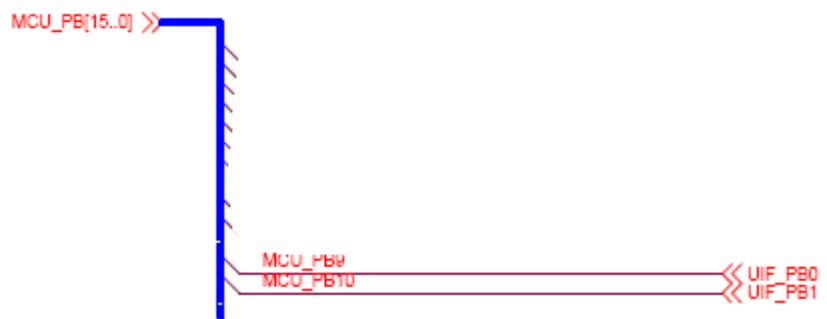
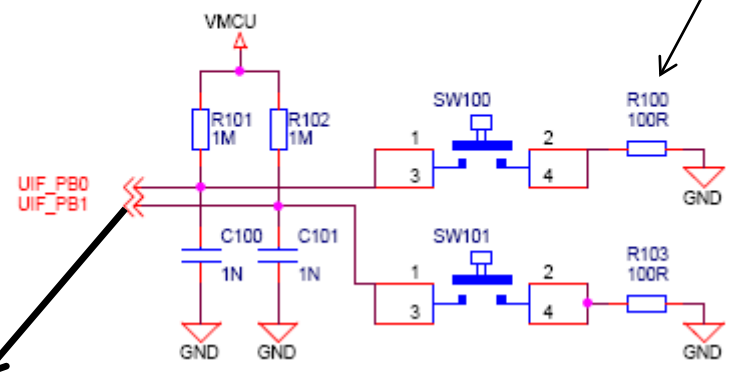
# Main parts of the development board

## ■ Push buttons and LEDs

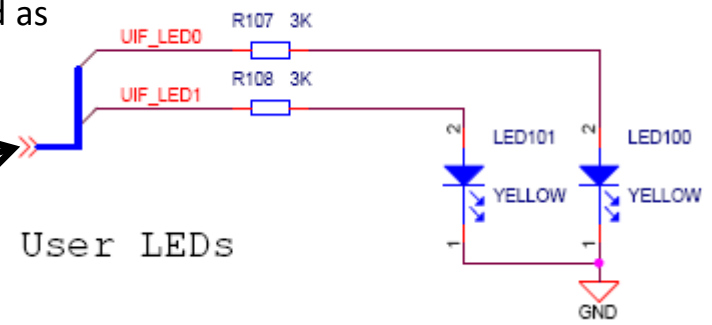


Current limiting protection resistance if pin is set as output

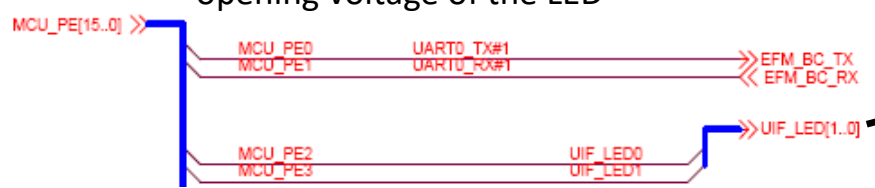
### 1 User pushbuttons



LED shunt resistance:  $(3.3V-2V)/3k\Omega \approx 0.4mA$   
~1mA...10mA current, and 1.5...2V voltage is expected as opening voltage of the LED

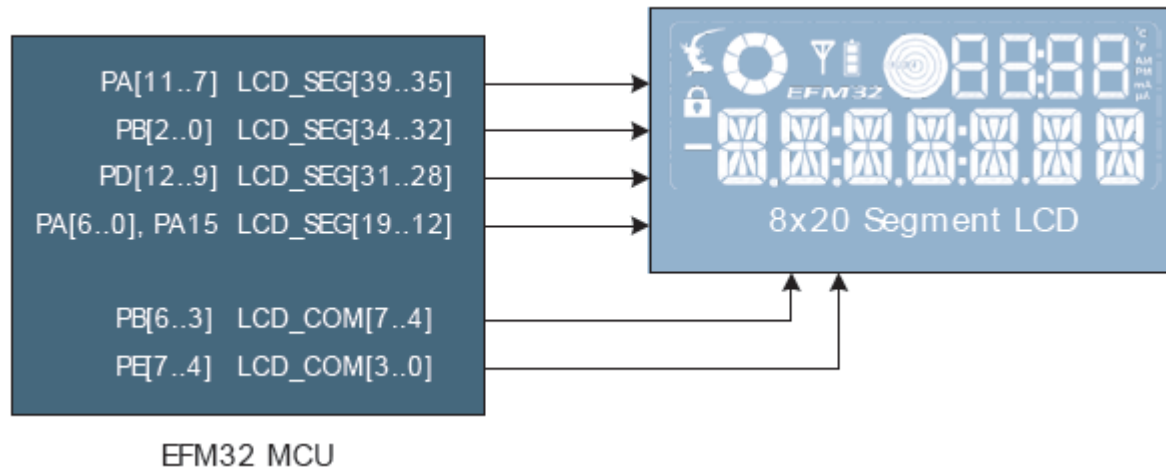


### User LEDs



# LCD display

- LCD display
  - Controller has integrated driver for the LCD as a dedicated peripheral
  - Alphanumerical and special characters and symbols



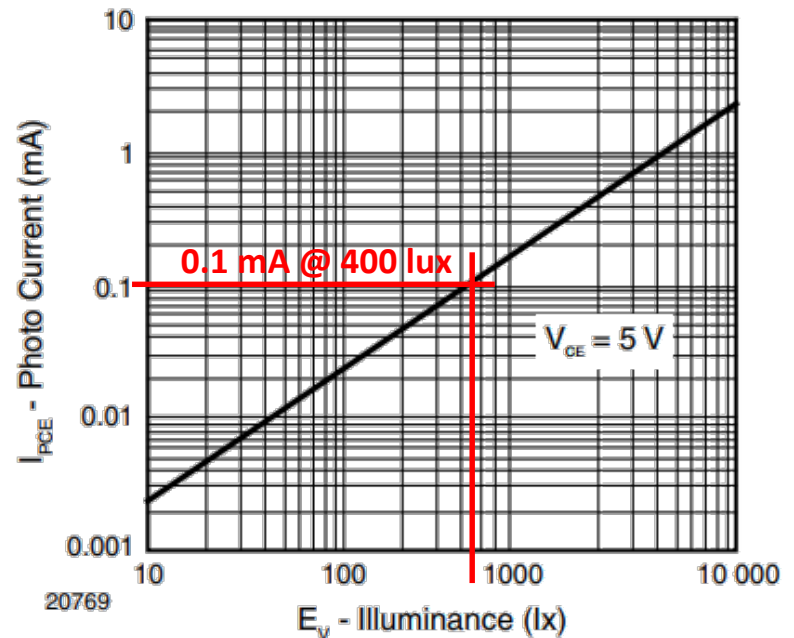
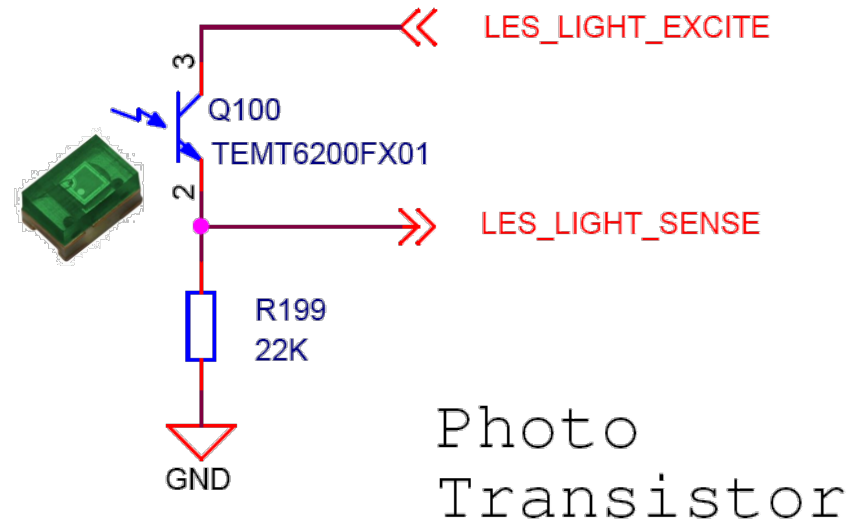
# Photosensor

- Implemented by a phototransistor
  - Light: „basis current”
- Luminance in an office: approx. 400 lux →

0.1mA →

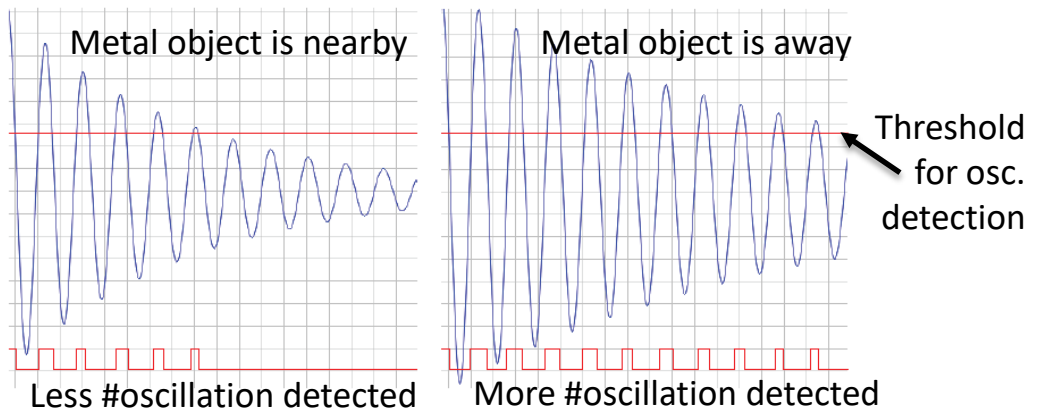
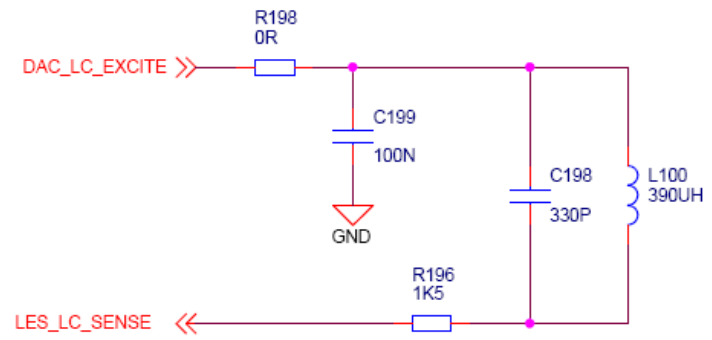
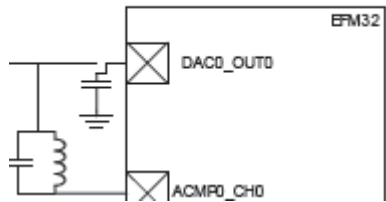
$$U_{\text{sense}} = 22 \text{ k}\Omega * 0.1 \text{ mA} = 2.2 \text{ V} :$$

Ok, for the ADC?



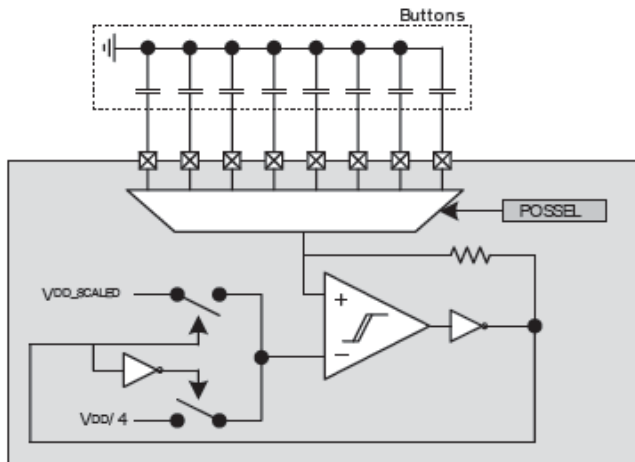
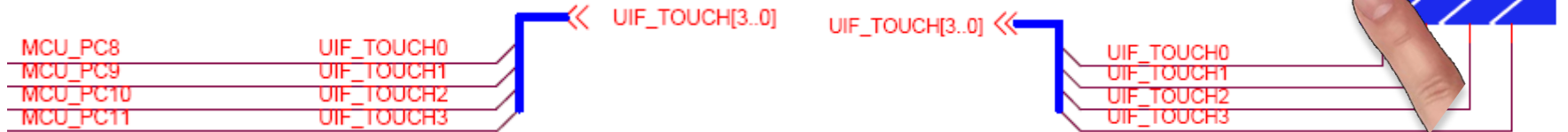
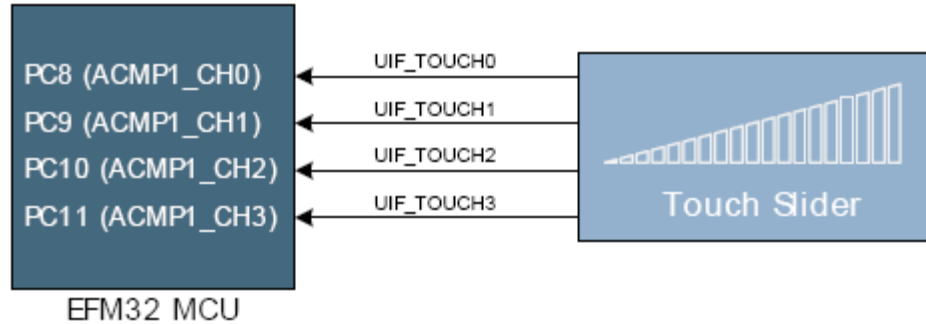
# LC metal sensor – operation principle

- External LC circuit is excited
- Oscillation time is measured
- The larger the decay time, the larger the quality factor of LC resonant circuit, i.e., the smaller the energy loss of the inductor
- If a metal object is in the vicinity of the inductor its energy loss gets larger, i.e., the decay time of the oscillation is reduced
- The effective range is a few millimeters



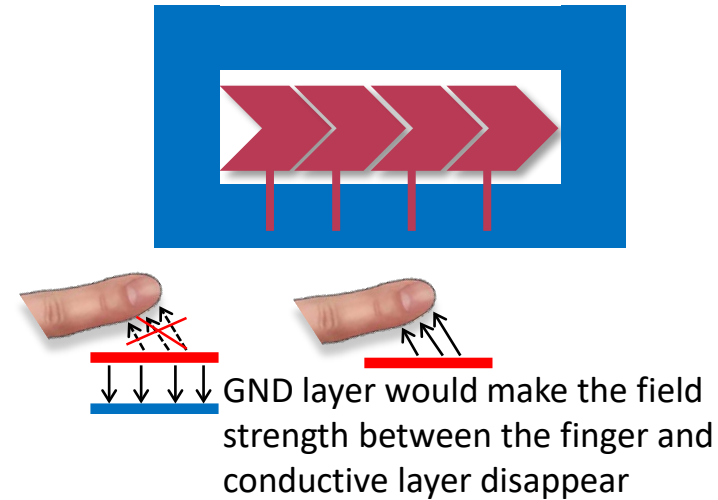
# Touch sensor

## ■ Touch slider



RC oscillator on the PCB.  
Approaching finger towards copper foil increases its capacity that detunes frequency. The larger the touched area the larger the capacity → frequency decreased

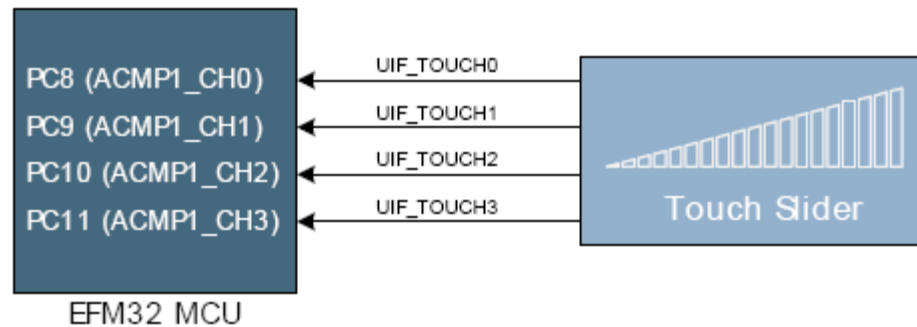
Sensor segments on the PCB.  
GND layer is not allowed to be placed underneath.





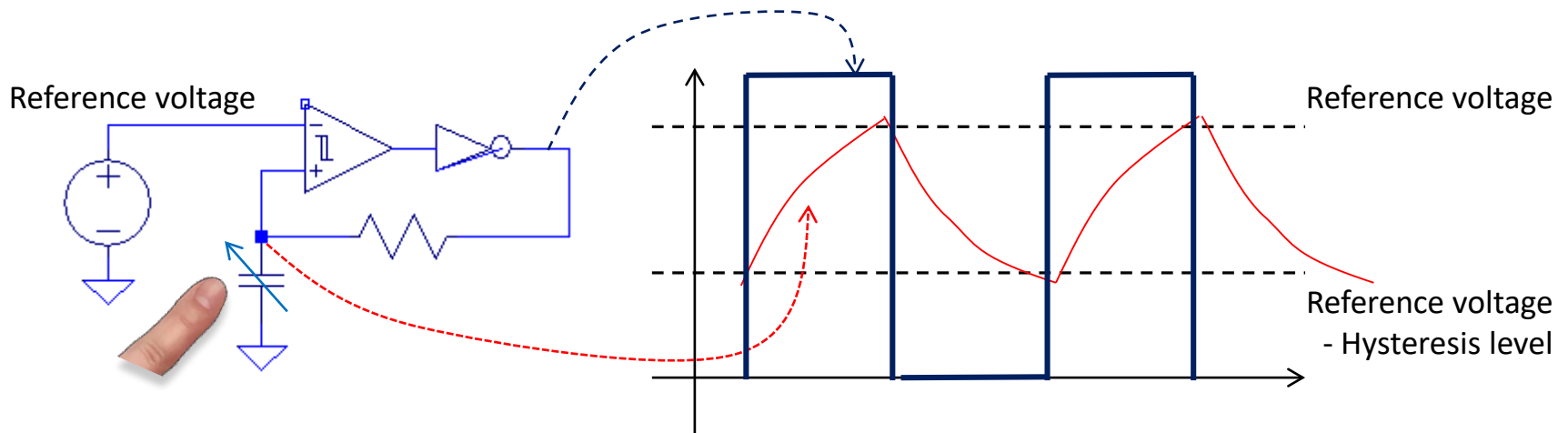
# Touch sensor

## ■ Touch slider



Excited by reference voltage the output of the comparator is Low  $\rightarrow$  output of inverter is High, i.e., capacitor is being charged

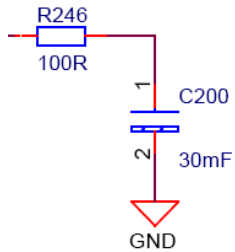
Exceeding the reference voltage output of the comparator gets High  $\rightarrow$  output of inverter is Low, i.e., capacitor is being discharged until lower hysteresis level is reached.



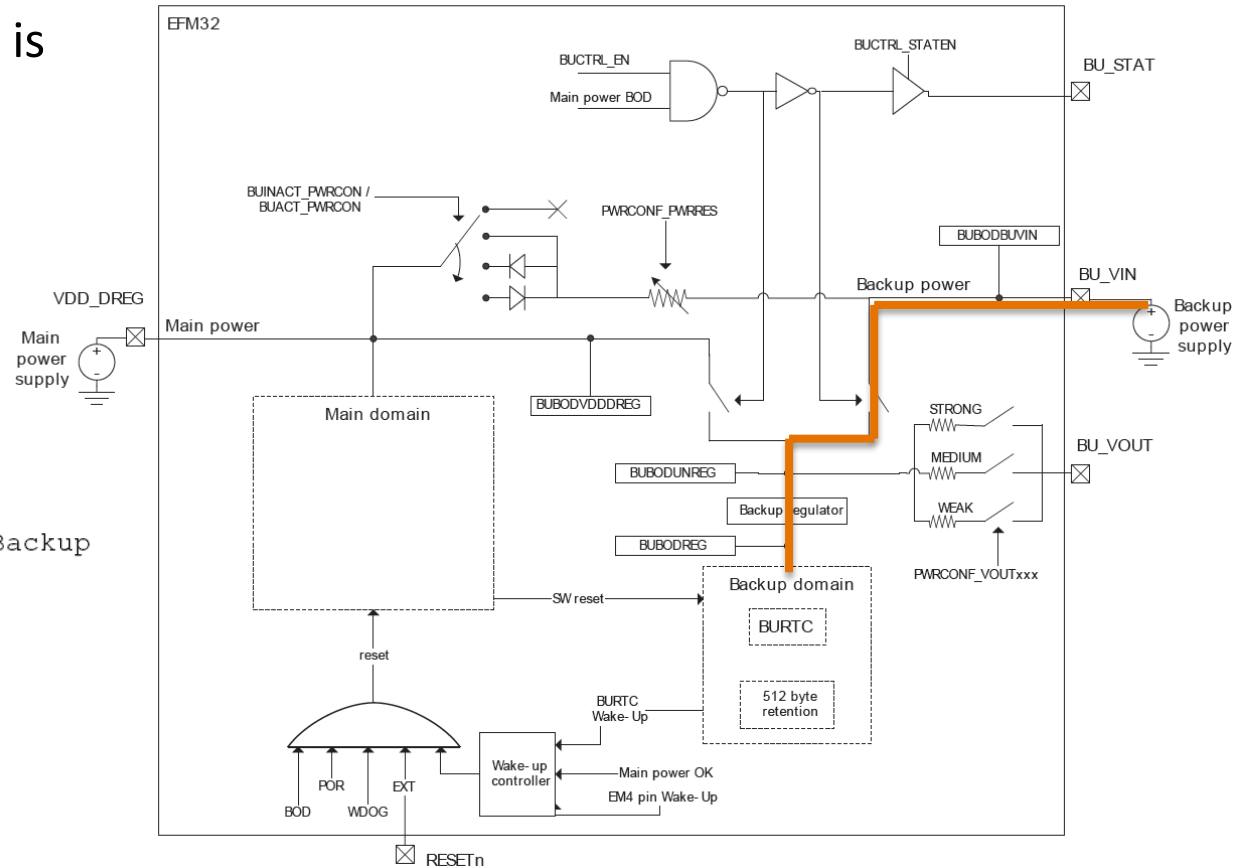
When the finger is close the capacity gets higher  $\rightarrow$  takes more time for charging/discharging  $\rightarrow$  freq. changed  $\rightarrow$  position sensed

# Backup power

- Backup power
  - Dedicated power supply
  - When normal power is off some units are powered by backup power

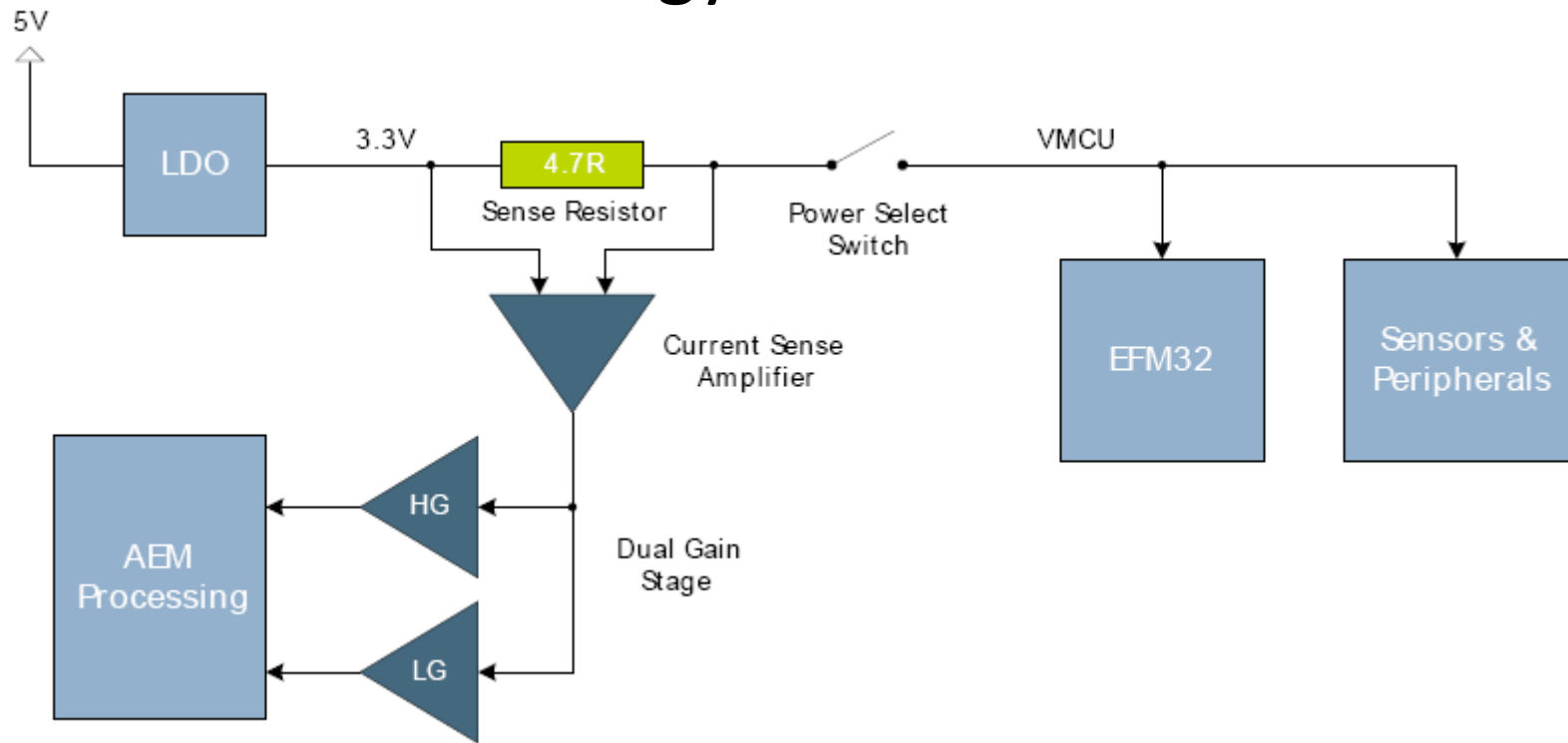


Capacitor for Backup Power Domain



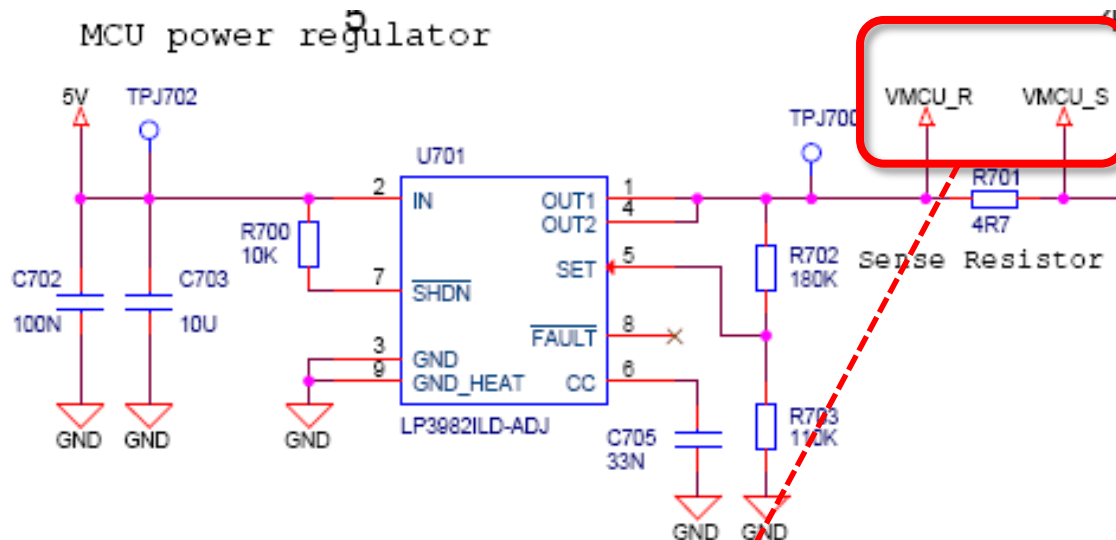
# Measurement of current consumption

- Voltage of a small value resistance is measured (see  $4.7\Omega$  resistance)
- AEM: Advanced Energy Monitor

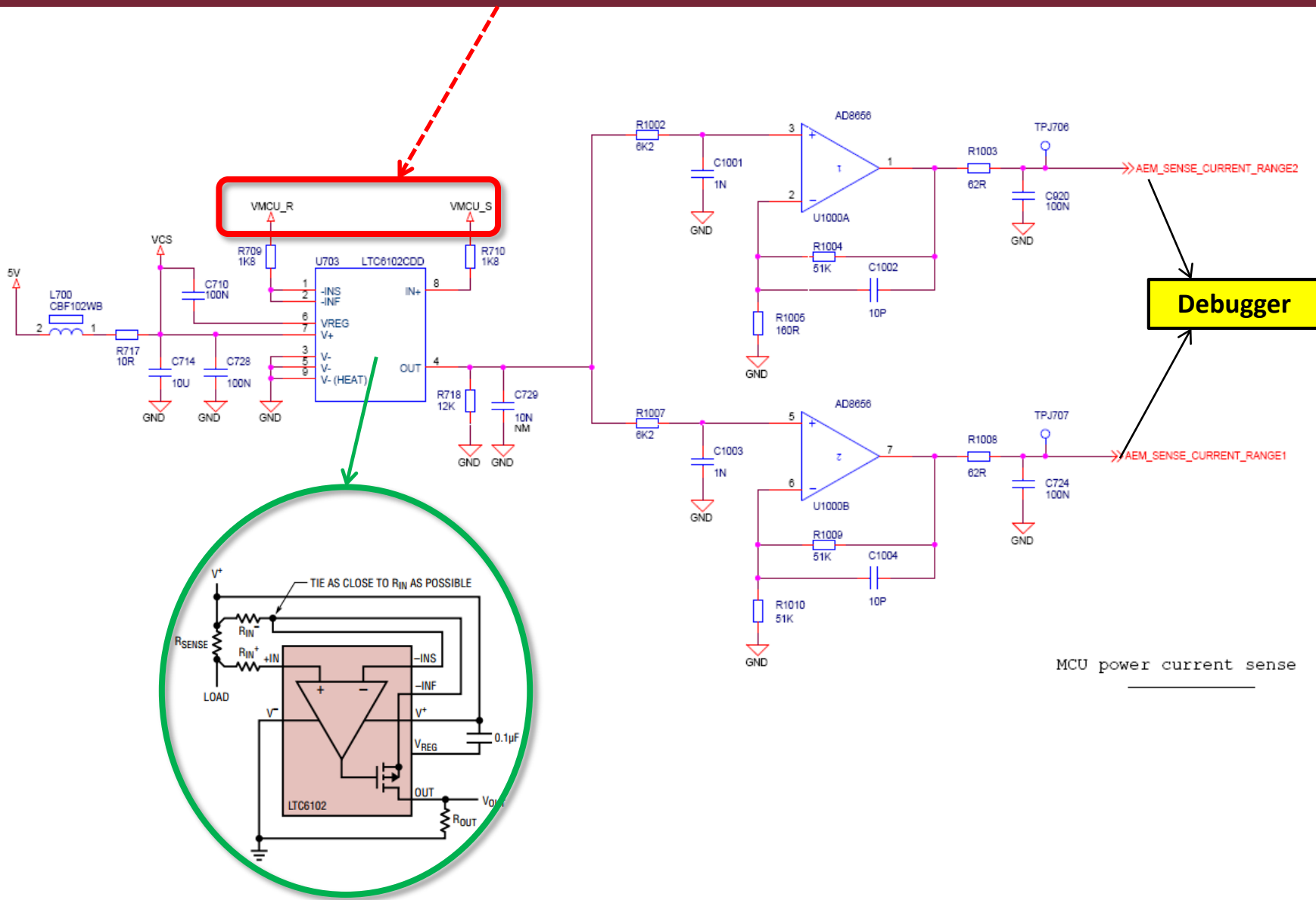


# Measurement of current consumption

- Voltage of a small value resistance is measured (see  $4.7\Omega$  resistance)



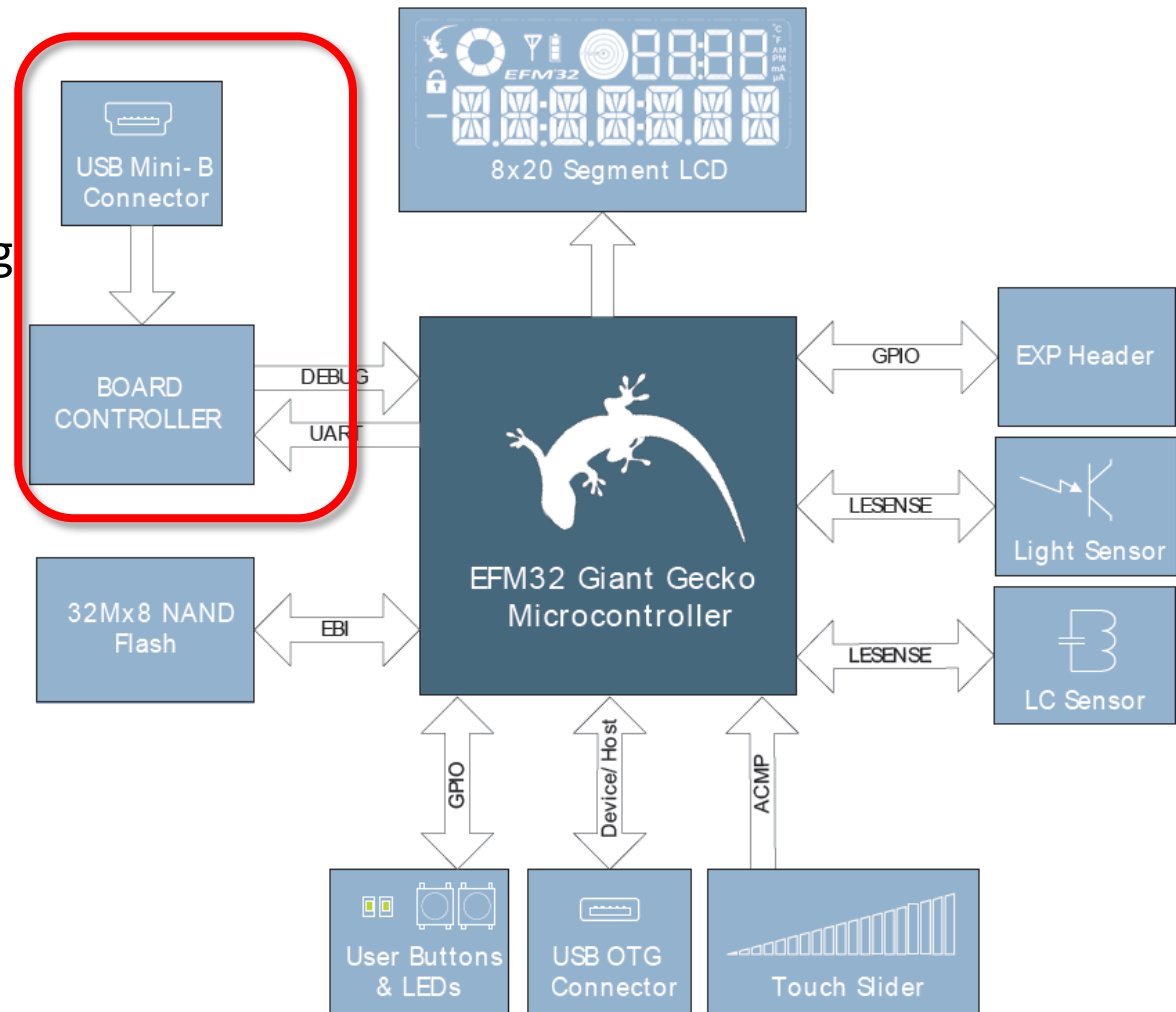
# Measurement of current consumption



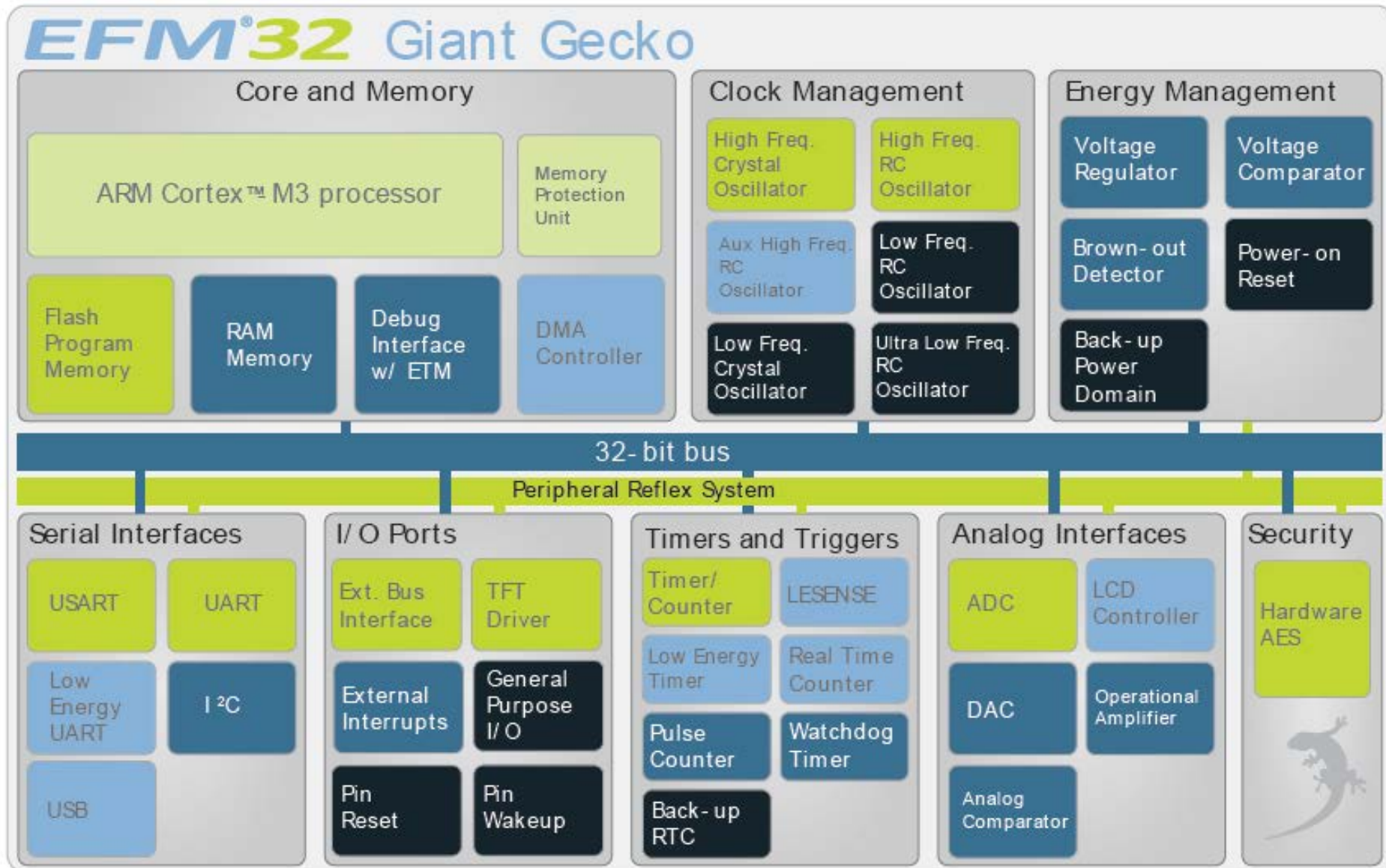
MCU power current sense

# Debug interface

- Connection between: Development environment and uC
- Debugger has access to internal registers and memory of uC via its debug port
- A debugger is a separated circuitry, an other uC-based unit connected to the dedicated interface of the main uC
- UART communication is possible



# Block diagram of the uC



# Block diagram of the uC

- Core: ARM Cortex-M3
- 32-bit bus is used to connect peripherals:
  - Clock management
  - Energy management
  - Serial comm lines
  - GPIO lines
  - Timer
  - Analog units (ADC, DAC, comparator, op. amplifier)
  - HW-based security features (Advanced Encryption Standard (AES))



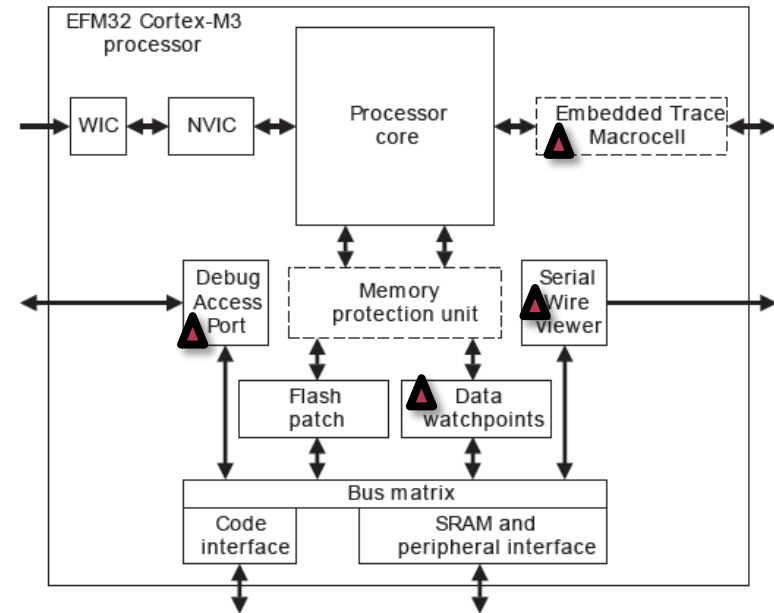


# Blocks of uC - core

- Core: ARM Cortex-M3
- Maximum 48 MHz clock frequency
  - Internal oscillator:
    - Max. 28 MHz,
    - Autonomous operation, even without external clock source
    - Implemented by RC oscillator: inaccurate, where accuracy is needed external crystal oscillator as clock source is better
- Internal peripherals
  - Interrupt control (Nested Vector Interrupt: NVIC)
  - State controller (System Control Block: SCB)
  - System timer: SysTick timer (24 bit) (safe timer for op. system)
  - Memory Protection Unit (MPU): to protect certain memory blocks (i.e. operation system)

# Blocks of uC - core

▲ : Can be used for debugging



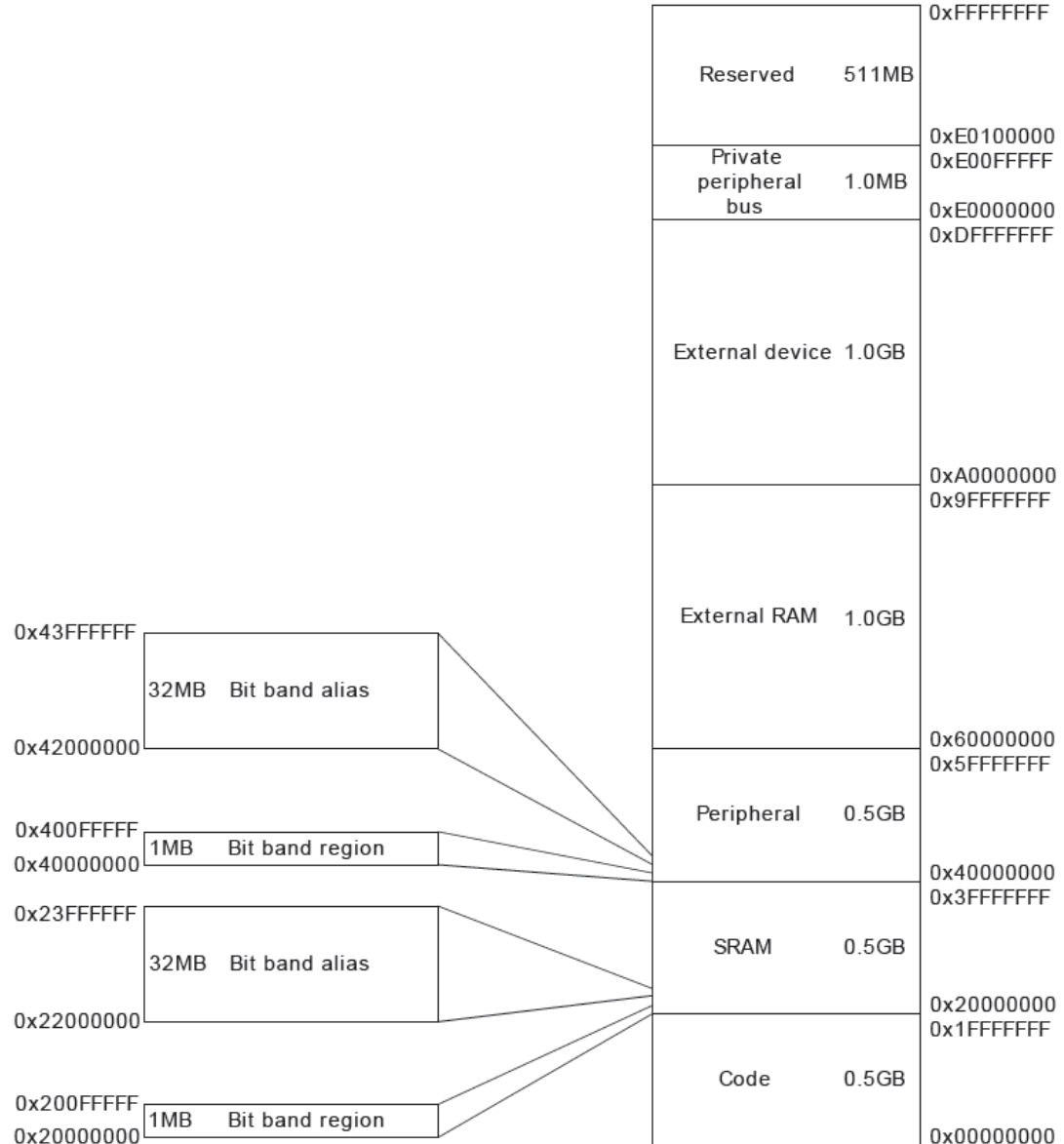
## ■ Internal blocks

- Interrupt control (Nested Vector Interrupt: NVIC)
  - WIC: wakeup interrupt controller: to save energy
- State Control (System Control Block: SCB)
- System timer: SysTick timer (24 bit)
- Memory Protection Unit (MPU): to protect certain memory blocks (i.e. operation system)
- Serial Wire Viewer, DAP: debug ports

## ■ Instruction set: 32-bit, but 16-bit (Thumb) mode is also possible

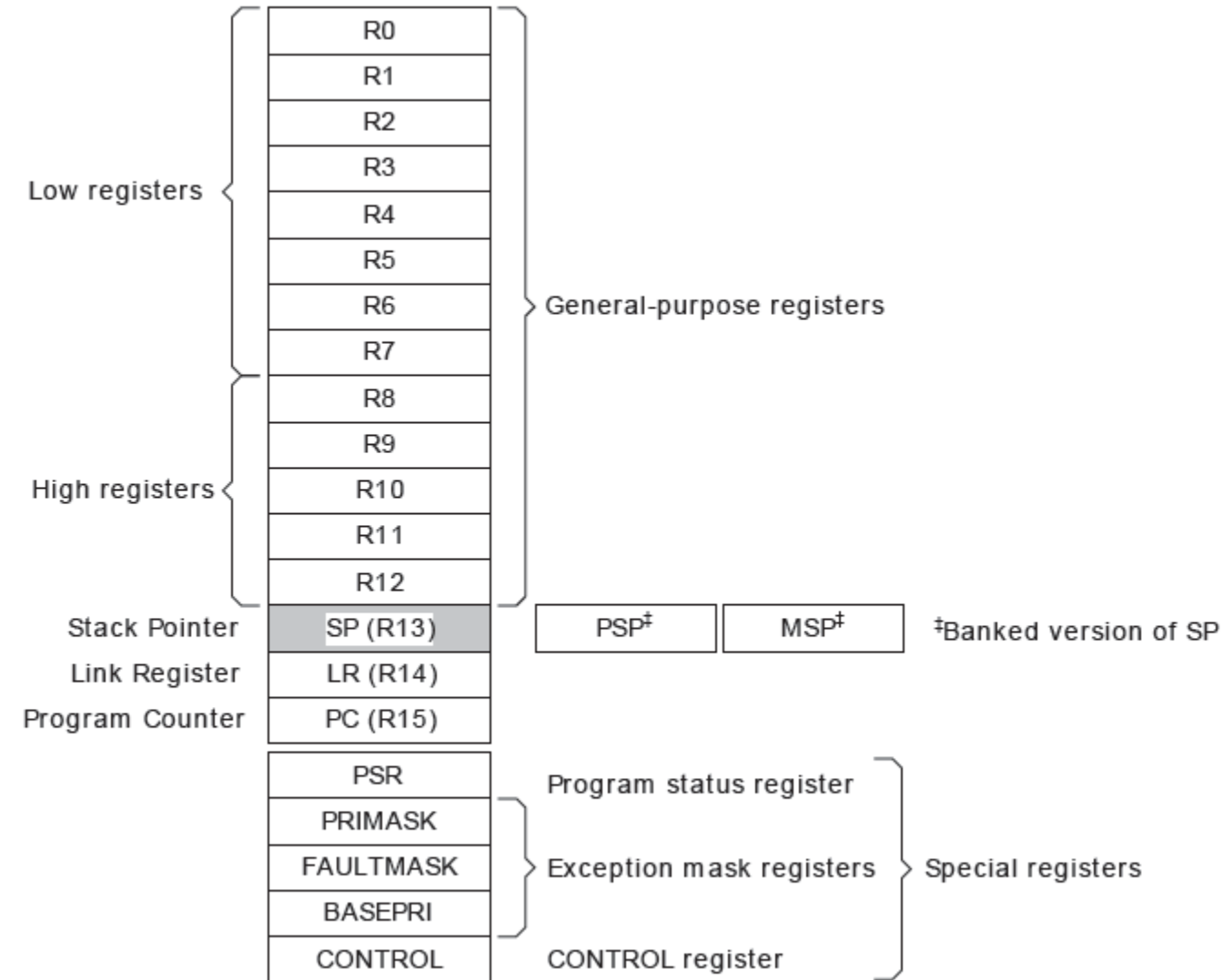
# Memory map

- 4 GB addressable memory (since 32-bit uC, but that amount of memory is not present → use of external memory is possible)
- Main memory blocks:
  - Code memory: Flash
  - Data memory: SRAM
  - Registers for peripherals (registers nested into the memory)
    - Used to configure peripherals
    - Bit band: certain bits of the registers are mapped into other registers for simpler access



# Registers

The processor core registers are:



# Energy friendly operation

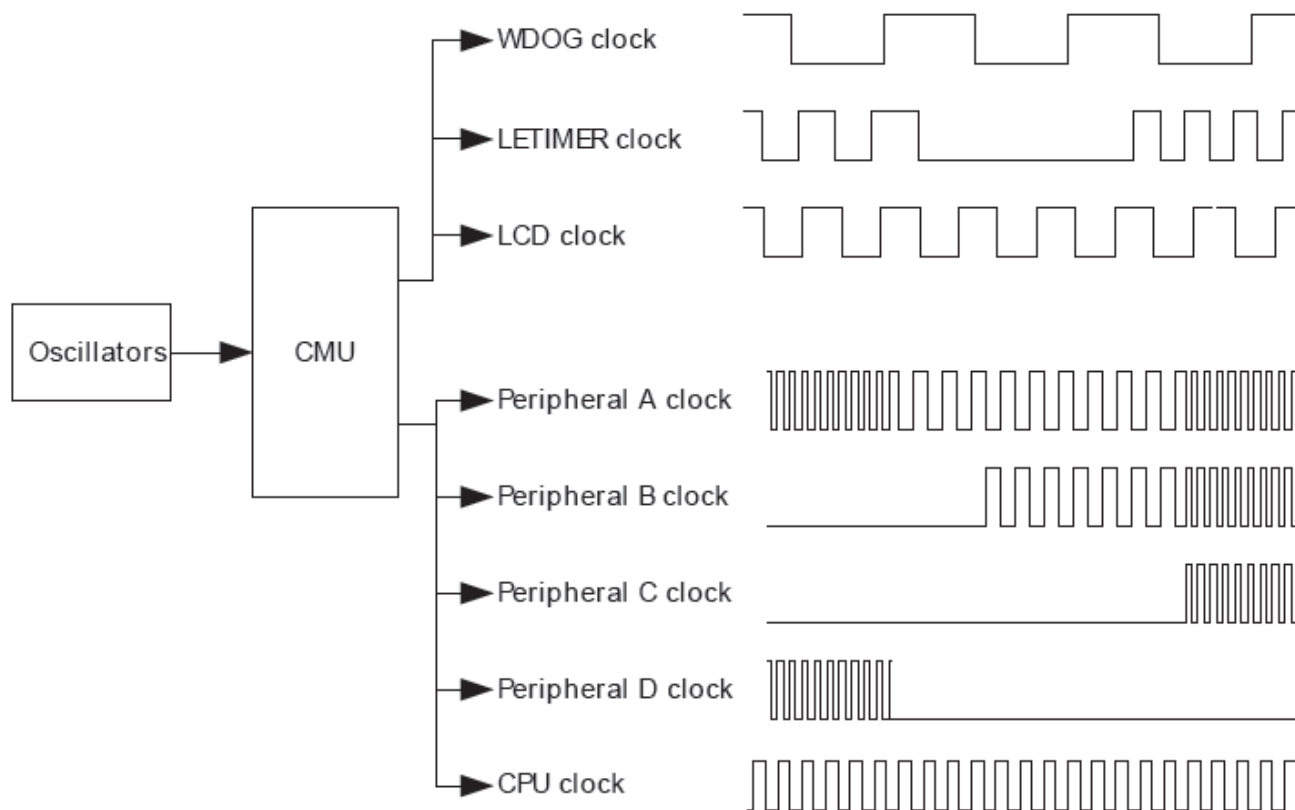
- EFM32: Energy Friendly Microcontroller, 32 bit
- EM0: CPU and all peripherals are in operation → 219  $\mu\text{A}/\text{MHz}$
- EM1: CPU in sleep mode and all peripherals are in operation → 80  $\mu\text{A}/\text{MHz}$
- EM2: only those peripherals are in operation that run on low frequency oscillator → approx. 1  $\mu\text{A}$
- EM3: low frequency oscillator is off; only some kind of interrupt can wake up the uC → approx. 0.8  $\mu\text{A}$
- EM4: pins are in reset state; only some kind of interrupt can wake up the uC → approx. 20 nA
- System level consideration: the appropriate EMx mode has to be chosen during system design phase:
  - What peripherals can be used in that EMx mode?
  - How the uC be waken up from that EMx mode?

# Clock management

- CMU: Clock Management Unit
- Current consumption is proportional to the clock frequency
  - In CMOS technology static current consumption is negligible, only dynamic behavior (when switching) consumes current
  - CMOS input can be well described by its capacity
  - Charge stored in a capacitor:  $Q=C*U$
  - If clock frequency is  $f$ , then the maximum number of switching in one second is  $f$ , i.e., charge flown  $\rightarrow$  current consumption:  $I=f*Q=f*C*U$
- Current consumption depends on the voltage
  - In general voltage is a design constraint, but when consumption matters the lower voltage is the better (e.g. in modern processors the core and the peripherals are operated at different voltage levels)
- Clock for non used peripherals can be disabled not to consume energy
- Actual frequency is set by division of source clock frequency
  - Remark: in case of certain processors clock frequency can be scaled up (multiplied) by a PLL
- Internal RC oscillator is also available but that its frequency is inaccurate

# Clock management

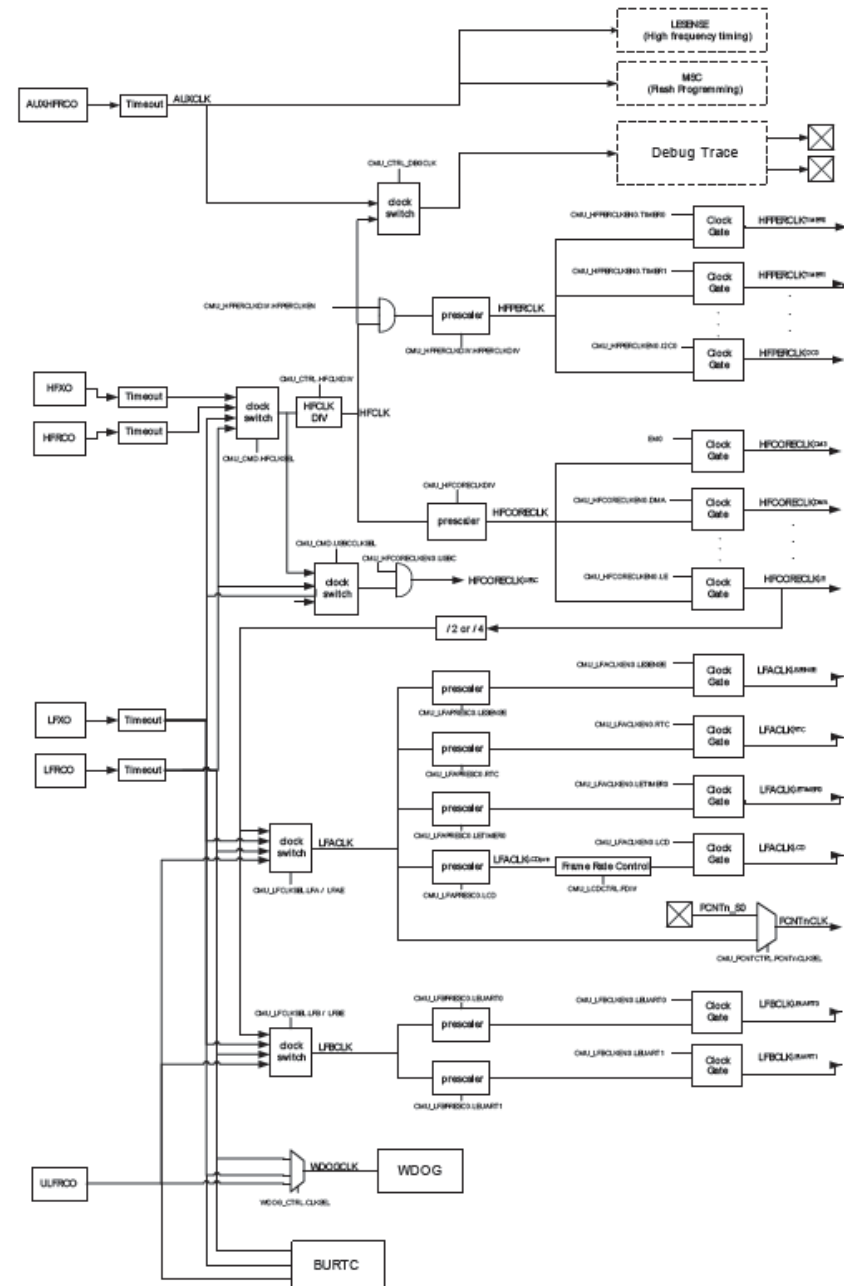
- Different peripherals can be operated at different clock frequencies



# Clock management

## ■ Configuration:

- The clock source to be used has to be enabled (NOTE: enabling must be first and initialize second, otherwise the processor will stop the operation since no clock will appear)
- The clock source has to be set
  - High frequency CLK
    - Internal RC osc. (1MHz...28MHz)
    - External crystal osc. (max. 48 MHz)
  - Low frequency CLK
    - Internal RC osc.(~32.768 kHz)
    - External crystal osc. (generally 32.768 kHz)
  - Some units are supported by supplementary internal RC oscillator
- Division ratio has to be set
- Clock has to be enabled at the certain peripheral





# Current consumption

- GPIO: 0.1 mA, 1 mA, 6 mA, 20 mA max current (programmable)



DRIVEMODE 0x0 RW Drive Mode Select  
Select drive mode for all pins on port configured with alternate drive strength.

Value	Mode	Description
0	STANDARD	6 mA drive current
1	LOWEST	0.1 mA drive current
2	HIGH	20 mA drive current
3	LOW	1 mA drive current

- ER14505: 3.6 V, 2700 mAh
- 1 mA current consumption  
→ 2700 h (~100day) operation
- 0.1 mA current cons. : ~3years
- 10 mA current cons. : ~10days
- See temperature dependence

### 3. CAPACITY VS. CURRENT

