E7020e

HARDWARE

Switch
Potentiometer
Temperature
Pressure
Microphone
Accelerometer
Gyro
Magnetometer
Ultrasound
Chemical sensor
Camera
Humidity
Proximity
Hall
Variable Reluctance
Light sensor
Color sensor
Radar
Lidar
GPS
…

PROTECTION

POWER

INPUT

PROCESSING

OUTPUT

PROTECTION

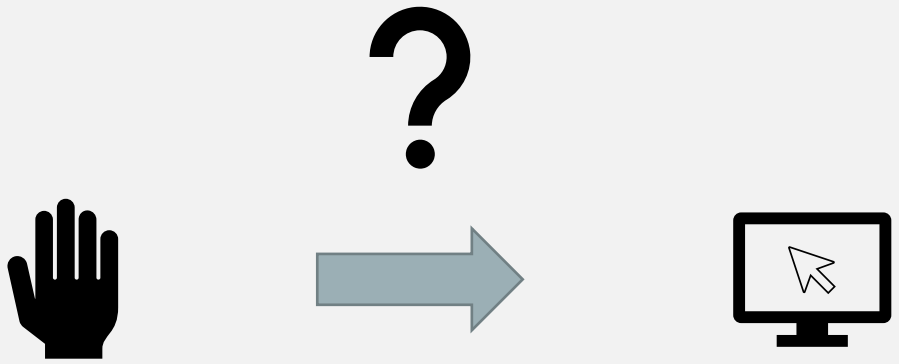
PROTECTION

LED
Lamp
Relay
Solenoid
Valve
Motor
Servo
Display
Loudspeaker
Laser
Ignition coil
Heater
Peltier
Piezoelectric element
…

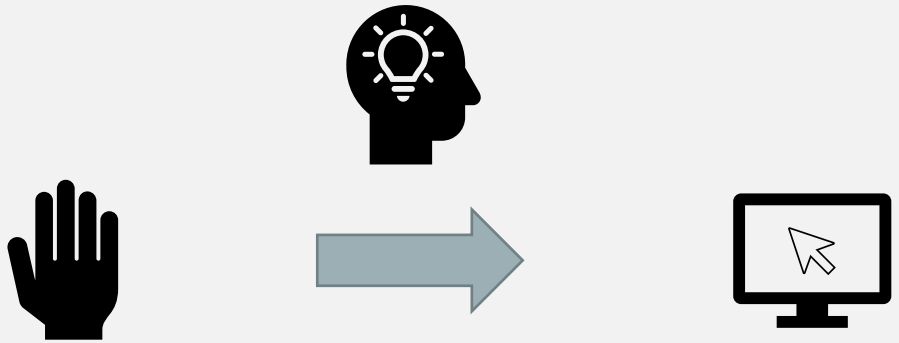
OTHER DEVICE

OTHER DEVICE

PROBLEM

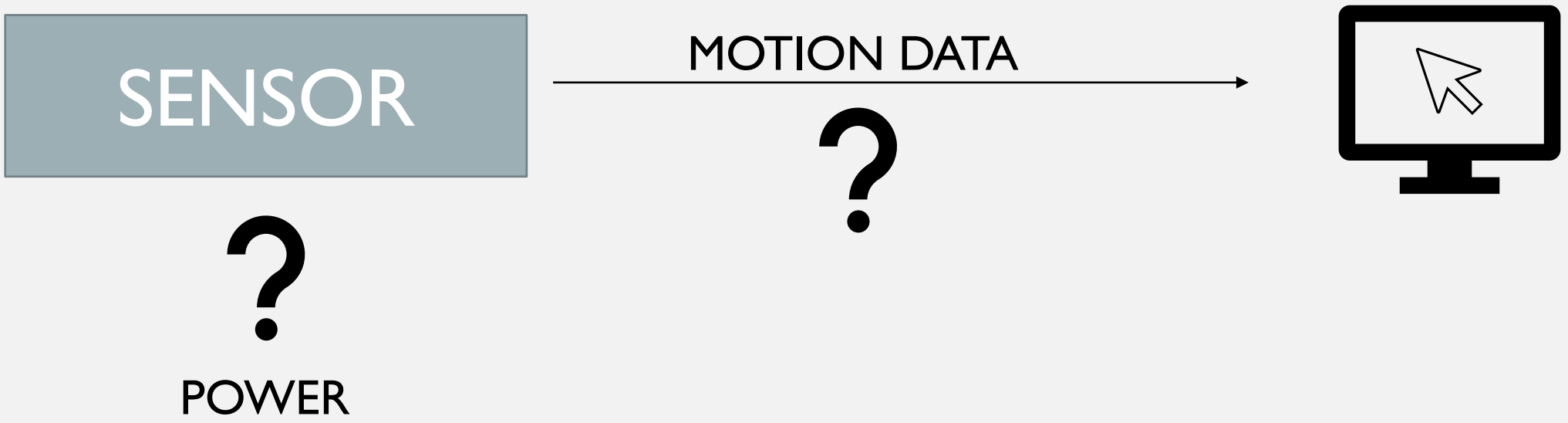


PROBLEM



MOTION SENSOR

BLOCK DIAGRAM



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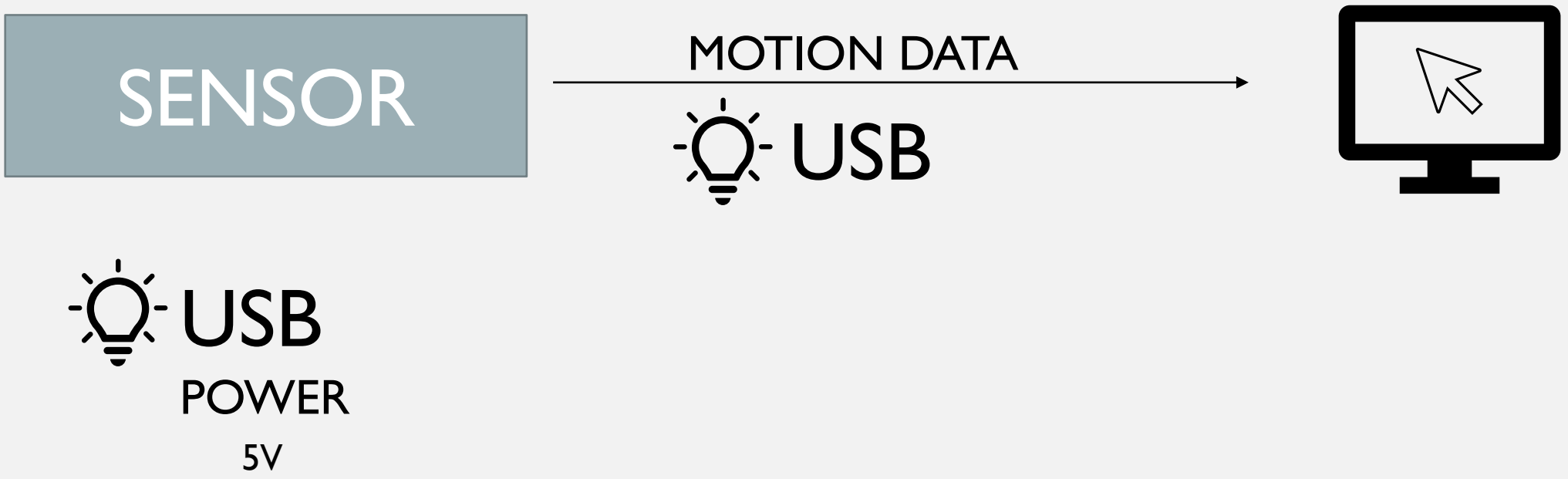


SENSOR

PMW3389

System-on-a-Chip (SoC)

IR LED + Camera + DSP

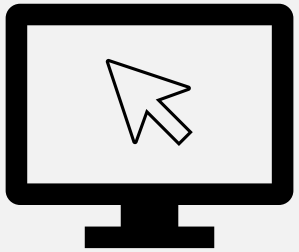
SPI communication

BLOCK DIAGRAM

SENSOR

MOTION DATA

⚠ USB



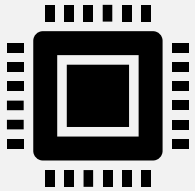
⚠ USB

POWER

5V

SPI → USB

MCU



MCU

”Single chip computer”
CPU
Memory
Peripherals
GPIO

GPIO

”General purpose input/output”

Voltage levels to represent bits/booleans

Tri-state: Low/Hi/Hi-Z (floating)

INPUTS:

Active low / active high

Pull up/down resistors (/internal)

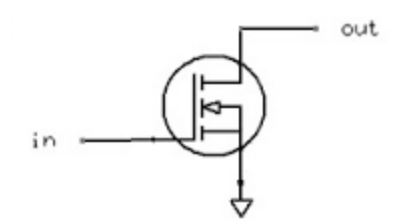
OUTPUTS:

Push-pull

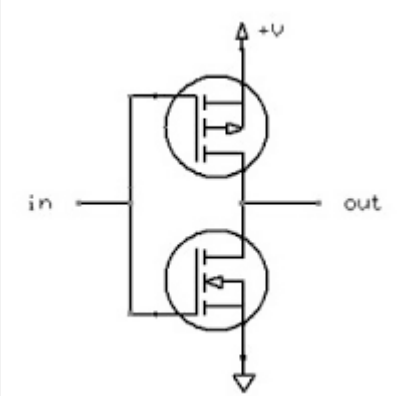
Open drain

Pull-up resistor

Open drain output



Push-pull output
(“totem-pole”)



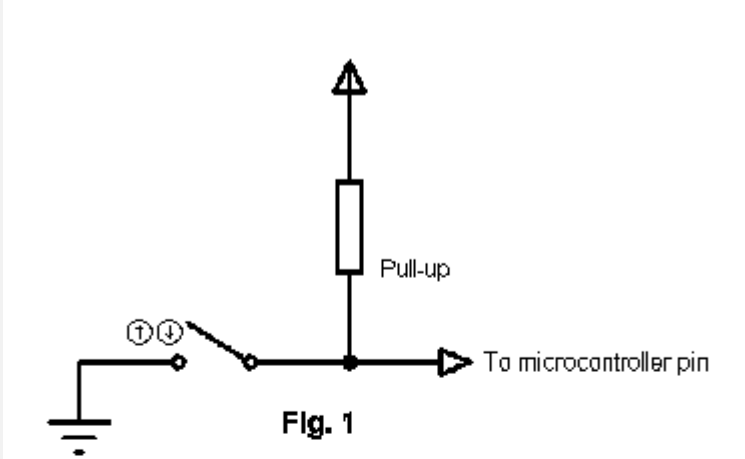


Fig. 1

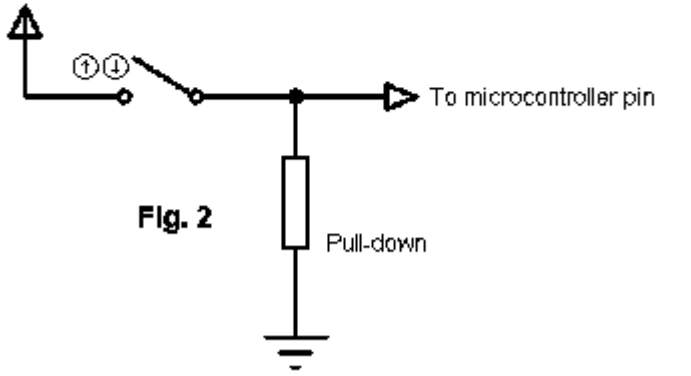
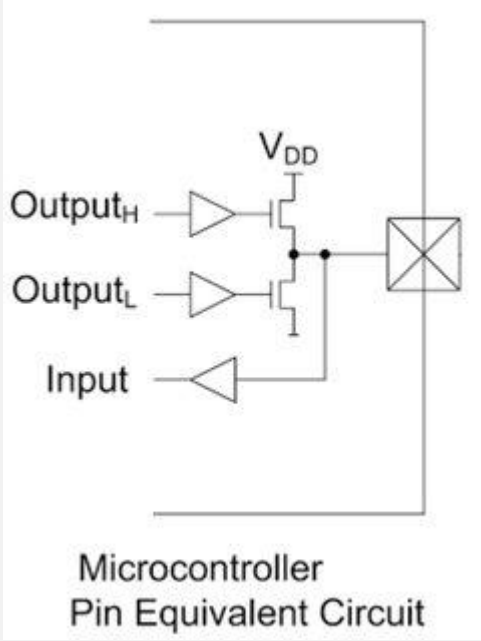


Fig. 2

GPIO

RATINGS

Max current (sink/source)
Max voltage (5v tolerant?)
Input/output resistance
Capacitance
Rise/fall time



Microcontroller
Pin Equivalent Circuit

GPIO

Associated special functionality Peripherals

”INTERFACES TO OUTSIDE WORLD”

UART / SERIAL
SPI
I2C
USB
TIMER
PWM
QUADRATURE DECODER
…

Table 9. Alternate function mapping

Port		AF00	AF01	AF02	AF03	AF04	AF05	AF06	AF07	AF08	AF09	AF10	AF11	AF12	AF13	AF14
		SYS_AF	TIM1/TIM2	TIM3/ TIM4/ TIM5	TIM9/ TIM10/ TIM11	I2C1/I2C2/ I2C3	SPI1/SPI2/ I2S2/SPI3/ I2S3/SPI4	SPI2/I2S2/ SPI3/ I2S3	SPI3/I2S3/ USART1/ USART2	USART6	I2C2/ I2C3	OTG1_FS		SDIO		
Port A	PA0	-	TIM2_CH1/ TIM2_ETR	TIM5_CH1	-	-	-	-	USART2_ CTS	-	-	-	-	-	-	-
	PA1	-	TIM2_CH2	TIM5_CH2	-	-	-	-	USART2_ RTS	-	-	-	-	-	-	-
	PA2	-	TIM2_CH3	TIM5_CH3	TIM9_CH1	-	-	-	USART2_ TX	-	-	-	-	-	-	-
	PA3	-	TIM2_CH4	TIM5_CH4	TIM9_CH2	-		-	USART2_ RX	-	-	-	-	-	-	-
	PA4	-	-	-	-	-	SPI1_NSS	SPI3_NSS/ I2S3_WS	USART2_ CK	-	-	-	-	-	-	-
	PA5	-	TIM2_CH1/ TIM2_ETR	-	-	-	SPI1_SCK	-	-	-	-	-	-	-	-	-
	PA6	-	TIM1_BKIN	TIM3_CH1	-	-	SPI1_ MISO	-	-	-	-	-	-	-	-	-
	PA7	-	TIM1_CH1N	TIM3_CH2	-	-	SPI1_ MOSI	-	-	-	-	-	-	-	-	-
	PA8	MCO_1	TIM1_CH1	-	-	I2C3_SCL	-	-	USART1_ CK	-	-	OTG_FS_ SOF	-	-	-	-
	PA9	-	TIM1_CH2	-	-	I2C3_ SMBA	-	-	USART1_ TX	-	-	OTG_FS_ VBUS	-	-	--	-
	PA10	-	TIM1_CH3	-	-	-	-	-	USART1_ RX	-	-	OTG_FS_I D	-	-	-	-
	PA11	-	TIM1_CH4	-	-	-	-	-	USART1_ CTS	USART6_ TX	-	OTG_FS_ DM	-	-	-	-
	PA12	-	TIM1_ETR	-	-	-	-	-	USART1_	USART6_	-	OTG_FS_	-	-	-	-

MCU

STM32F411

ARM Cortex M4F

SPI Peripheral

USB PHY

STM32F411

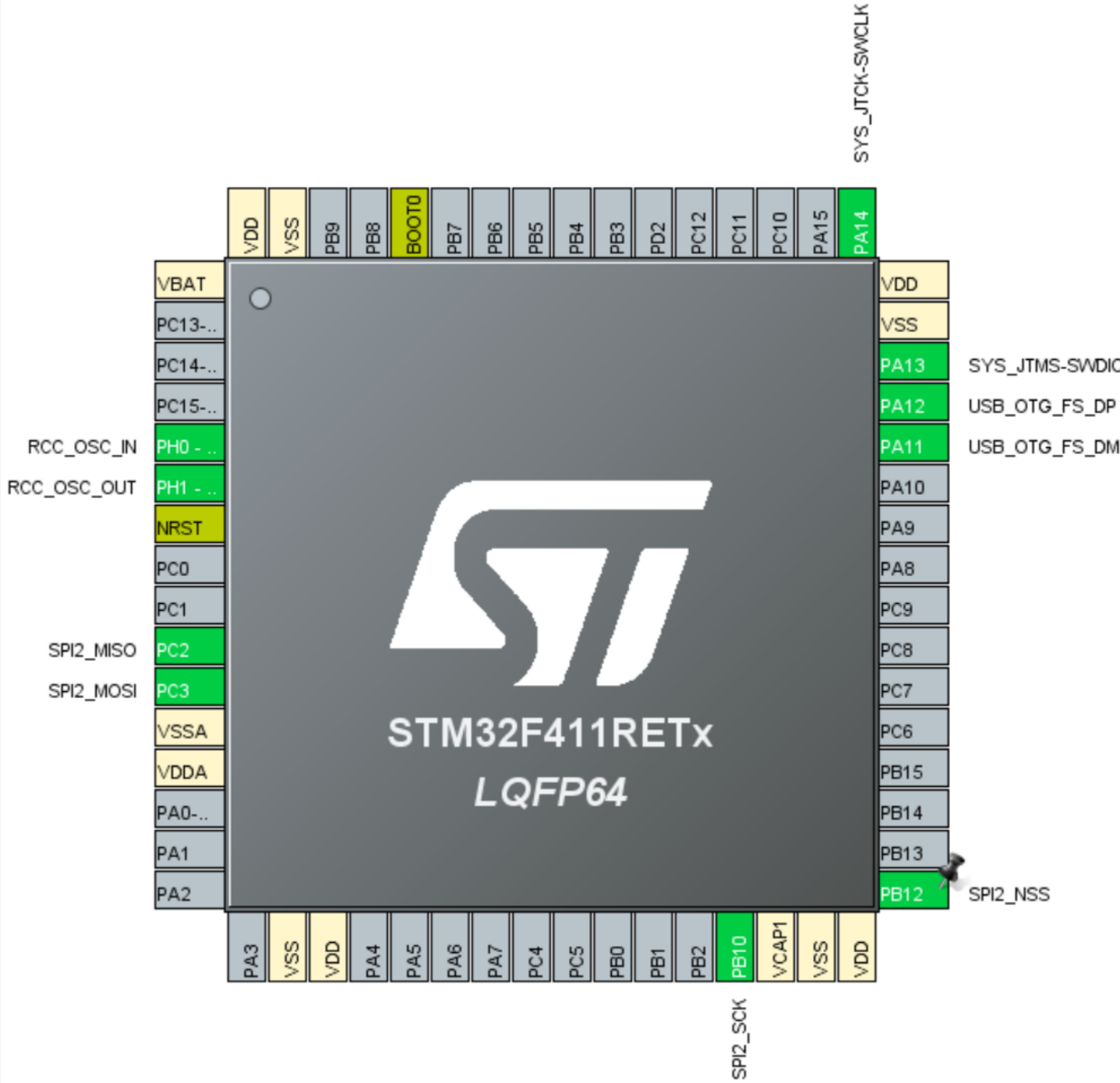
STM CubeMX Software

SPI

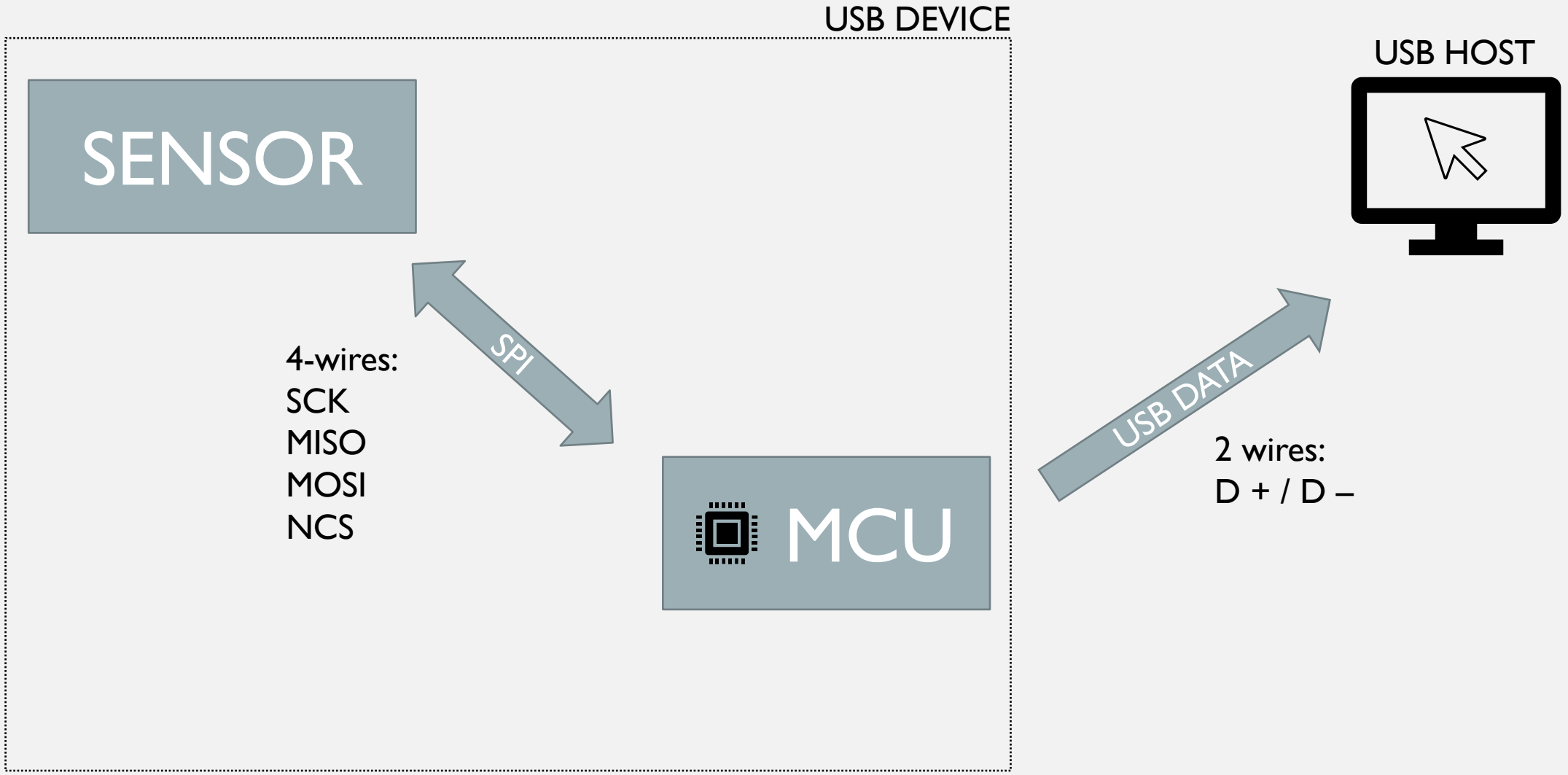
SCK
MISO
MOSI
NCS

USB

D+
D-



BLOCK DIAGRAM



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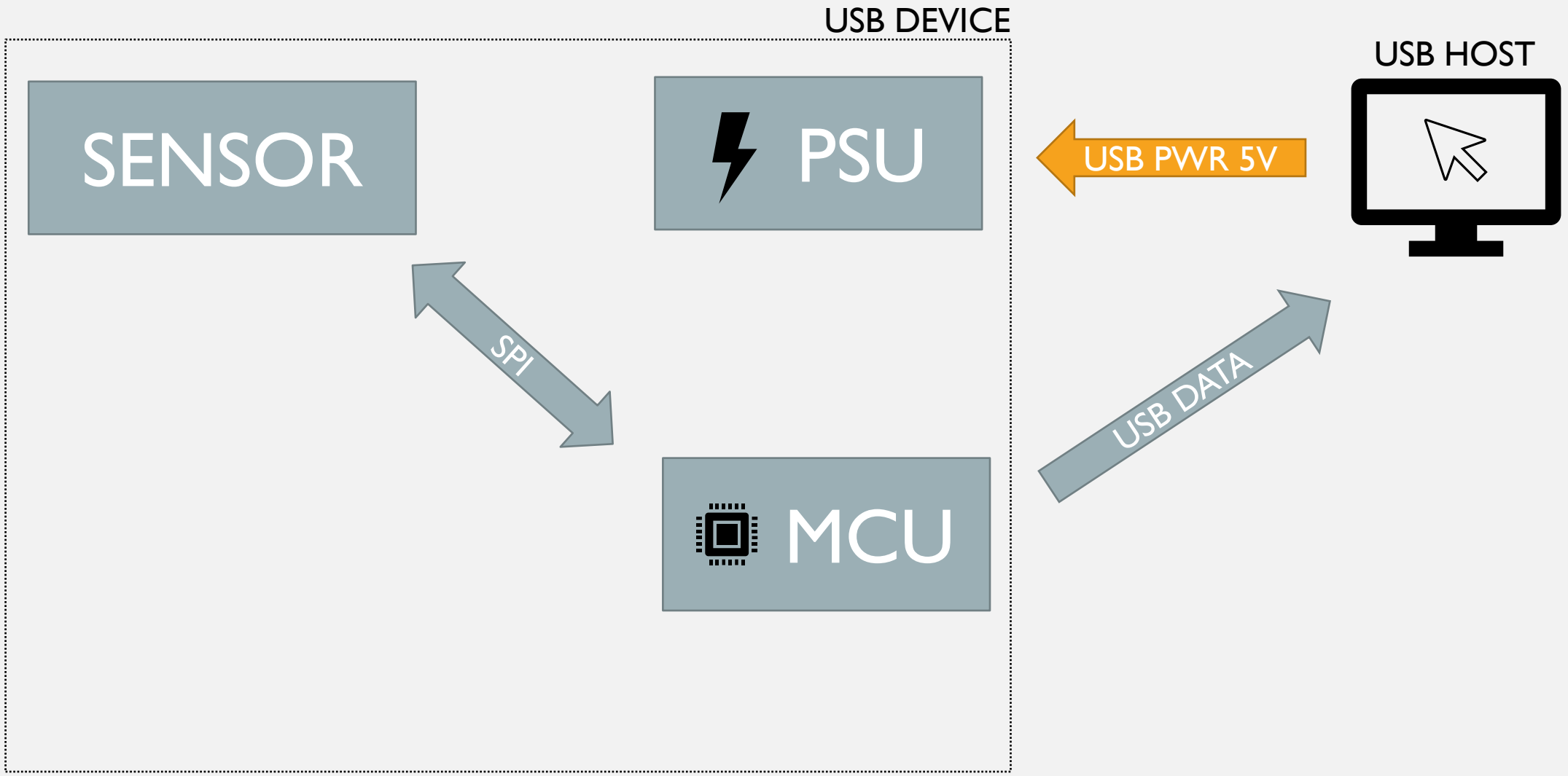


POWER SUPPLY UNIT (PSU)

SOURCE

AC/DC?
Voltage? (+/- tolerance?)
Current? (battery?)

DESTINATION

Voltage? (+/- tolerance?)
Current draw?
Noise?

Heat?
Efficiency?
Reliability?
Space constraints?
Cost?

POWER SUPPLY UNIT (PSU)

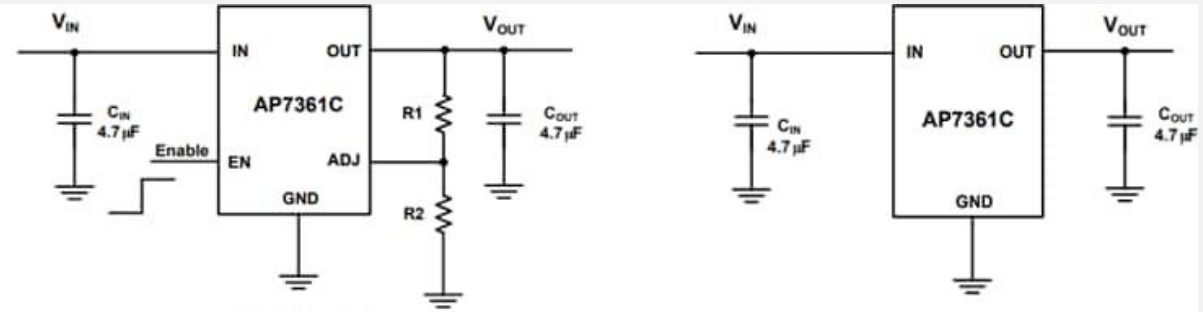
VOLTAGE REGULATORS

LINEAR REGULATOR
SWITCHING REGULATOR

POWER SUPPLY UNIT (PSU)
LINEAR REGULATOR

”3-terminal” device (in, out, ref)
Fixed/adjustable output voltage

Vin >= Vout + Vdropout
Low dropout regulator (LDO)



PROS:
Low noise
Good line/load regulation
Cheap

CONS:
Excess voltage → HEAT

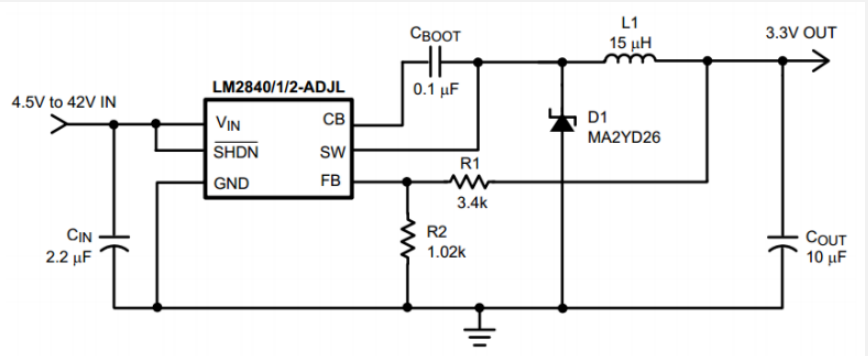
POWER SUPPLY UNIT (PSU)
SWITCHING REGULATOR

BUCK (higher voltage → lower voltage)

BOOST (lower voltage → higher voltage)

INVERTING

Transistor as switch → Low loss



PROS:

(Generally) higher efficiency

"trades voltage for current"

Can provide ISOLATION

Can generate INVERTED voltage

CONS:

More complicated

(ready-made on-board-modules available)

Higher ripple/noise (LC filtering)

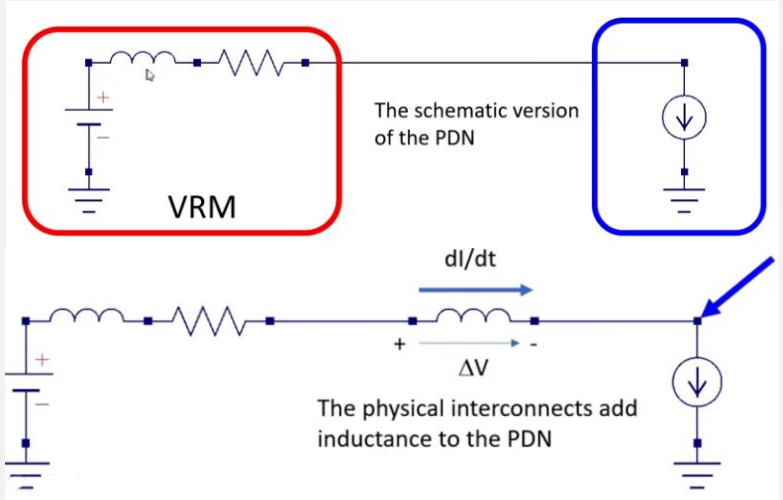
EMI

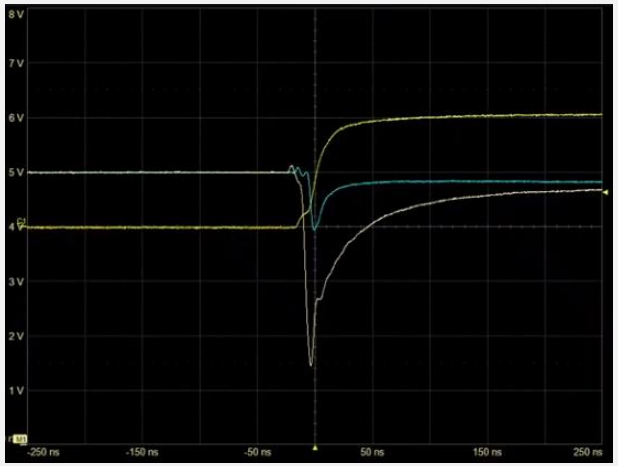
Load regulation

POWER DISTRIBUTION NETWORK

DECOUPLING

LOW INDUCTANCE POWER SOURCE
STABLE SUPPLY VOLTAGE
PREVENT UNDEFINED BEHAVIOUR

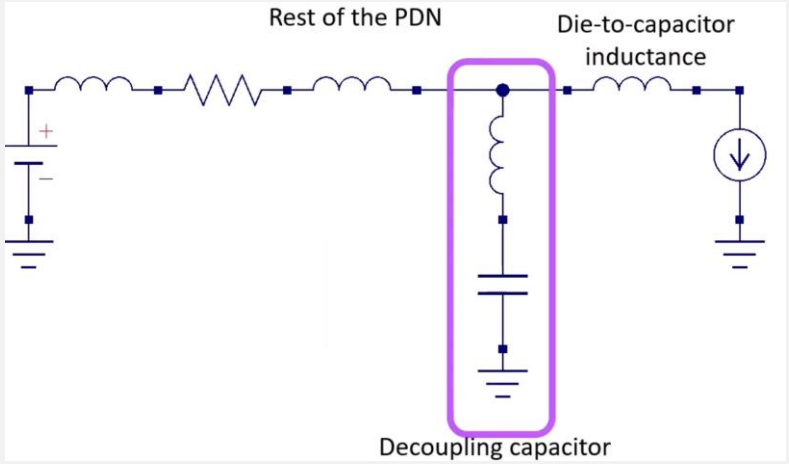


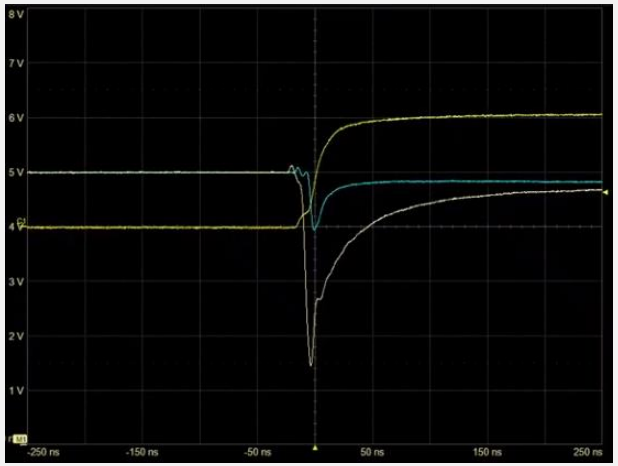


POWER DISTRIBUTION NETWORK

DECOUPLING

LOW INDUCTANCE POWER SOURCE
STABLE SUPPLY VOLTAGE
PREVENT UNDEFINED BEHAVIOUR



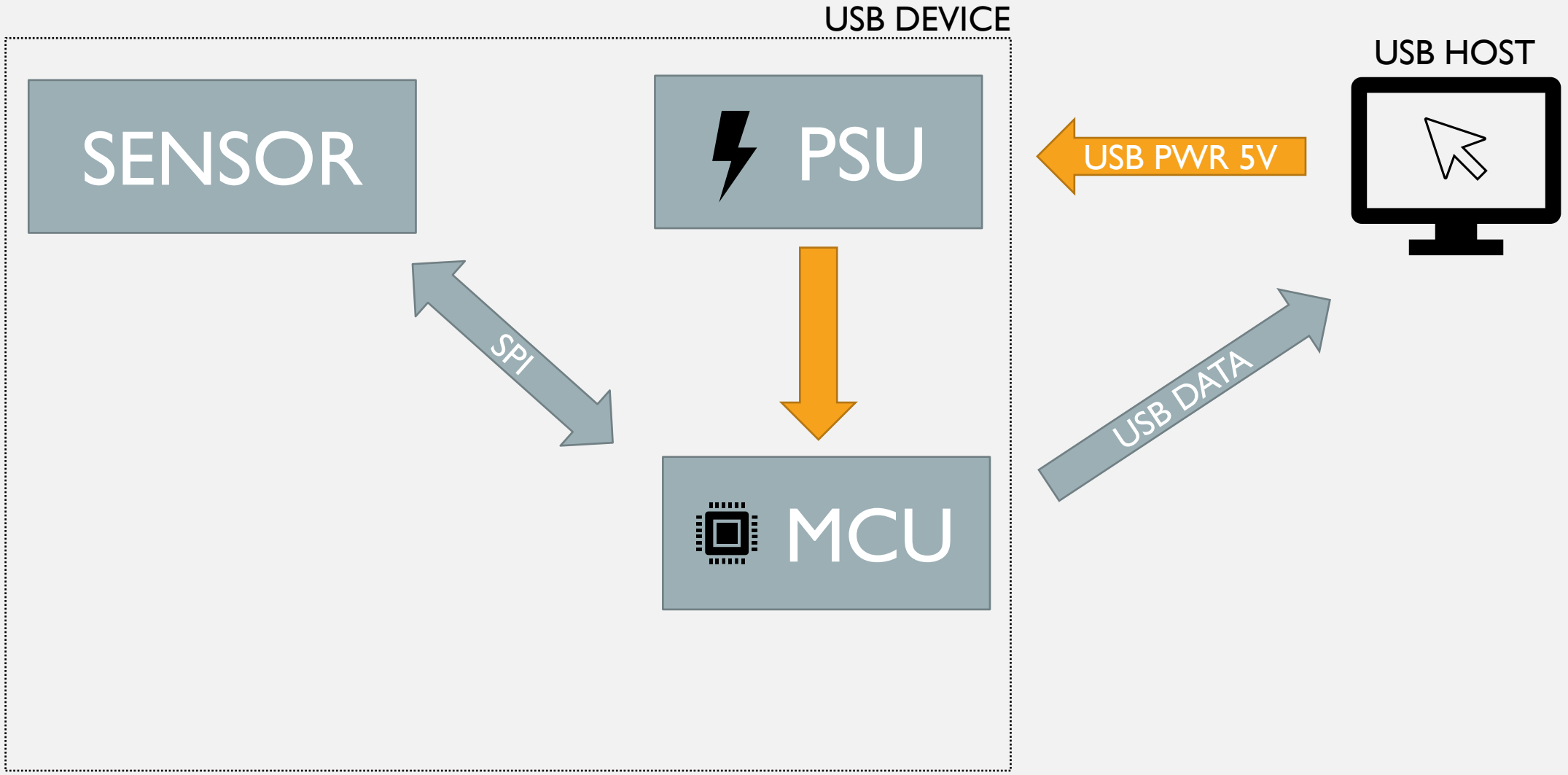


LOW INDUCTANCE

”Large enough” capacitance

$$C > \frac{\Delta Q}{\Delta V} = \frac{I\Delta t}{\Delta V}$$

BLOCK DIAGRAM



POWER SUPPLY UNIT (PSU)

DESTINATION 1: MCU

STM32F411

Vdd = 1.7 – 3.6V

I(max) = 160mA

= 3.3V

POWER SUPPLY UNIT (PSU)

SOURCE

AC/DC?
Voltage? (+/- tolerance?)
Current? (battery?)

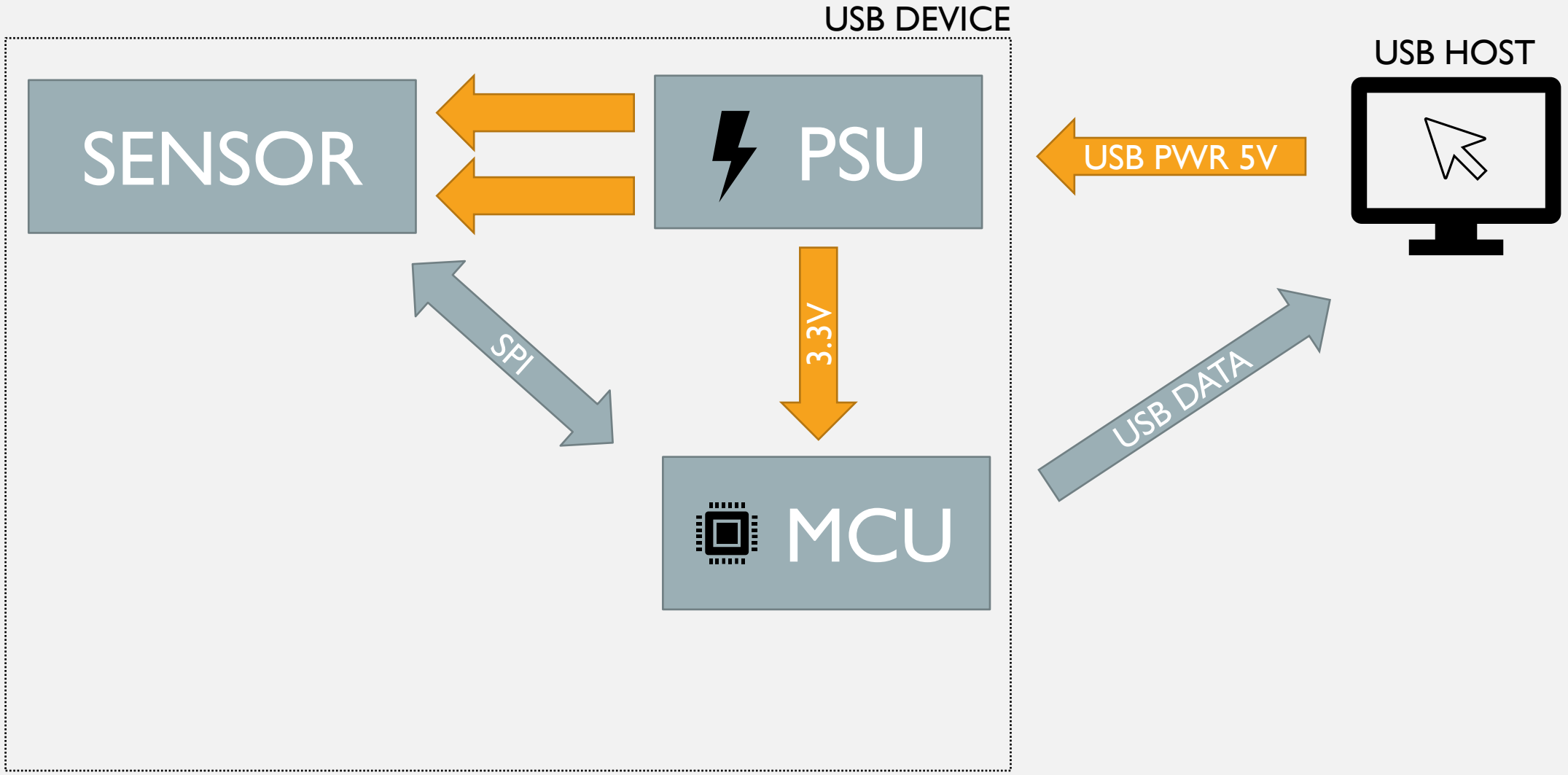
DESTINATION

Voltage? (+/- tolerance?)
Current draw?
Noise?

Heat?
Efficiency?
Reliability?
Space constraints?
Cost?

LDO

BLOCK DIAGRAM



POWER SUPPLY UNIT (PSU)

DESTINATION 2: SENSOR SoC

PMW3389

Vddio = 1.8 - 3.6V

= 3.3V

Vdd = 1.8 - 2.1V

I(max) = 21mA

= 1.9V

POWER SUPPLY UNIT (PSU)

SOURCE

AC/DC?
Voltage? (+/- tolerance?)
Current? (battery?)

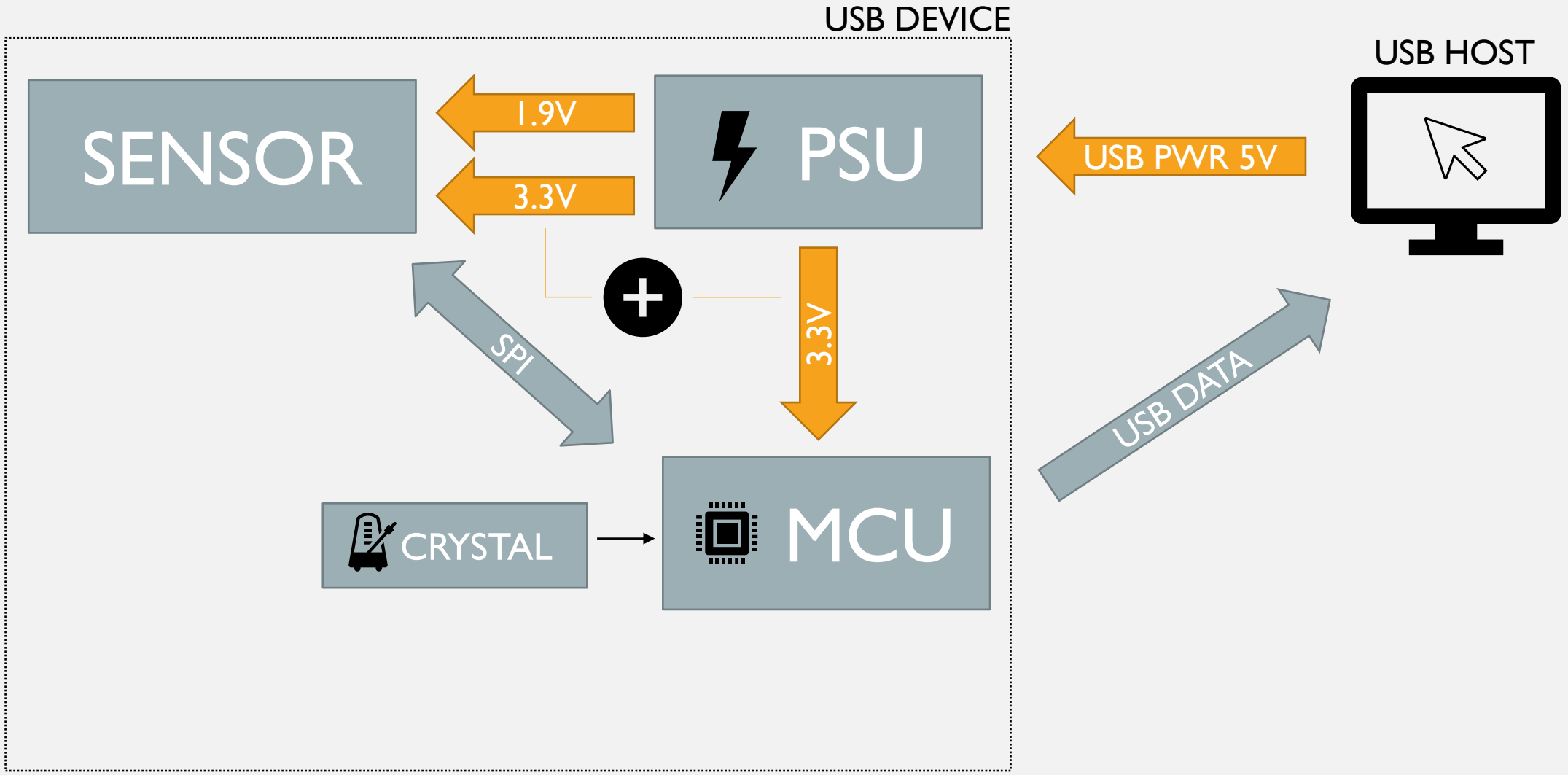
DESTINATION

Voltage? (+/- tolerance?)
Current draw?
Noise?

Heat?
Efficiency?
Reliability?
Space constraints?
Cost?

LDO

BLOCK DIAGRAM



OSCILLATORS

INTERNAL (HSI/LSI)

RC OSCILLATOR
LOW ACCURACY

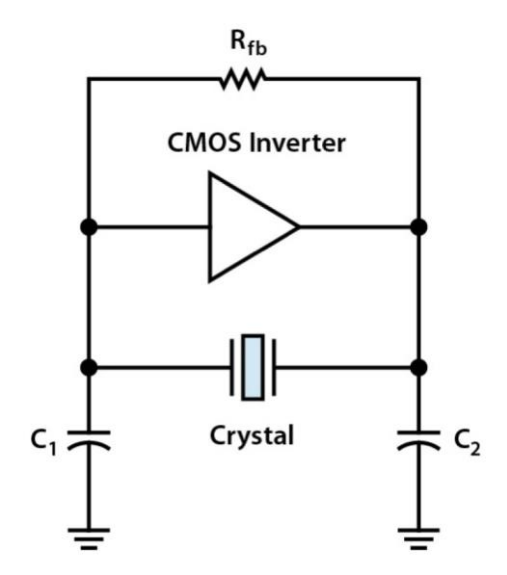
EXTERNAL (HSE/LSE)

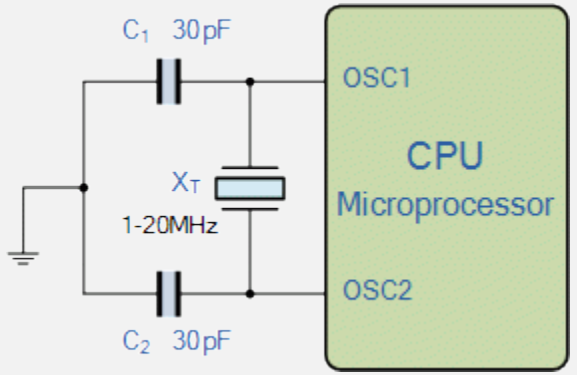
QUARTZ CRYSTAL
HIGH ACCURACY
TEMPERATURE STABILITY

CRYSTAL OSCILLATOR

QUARTZ CRYSTAL

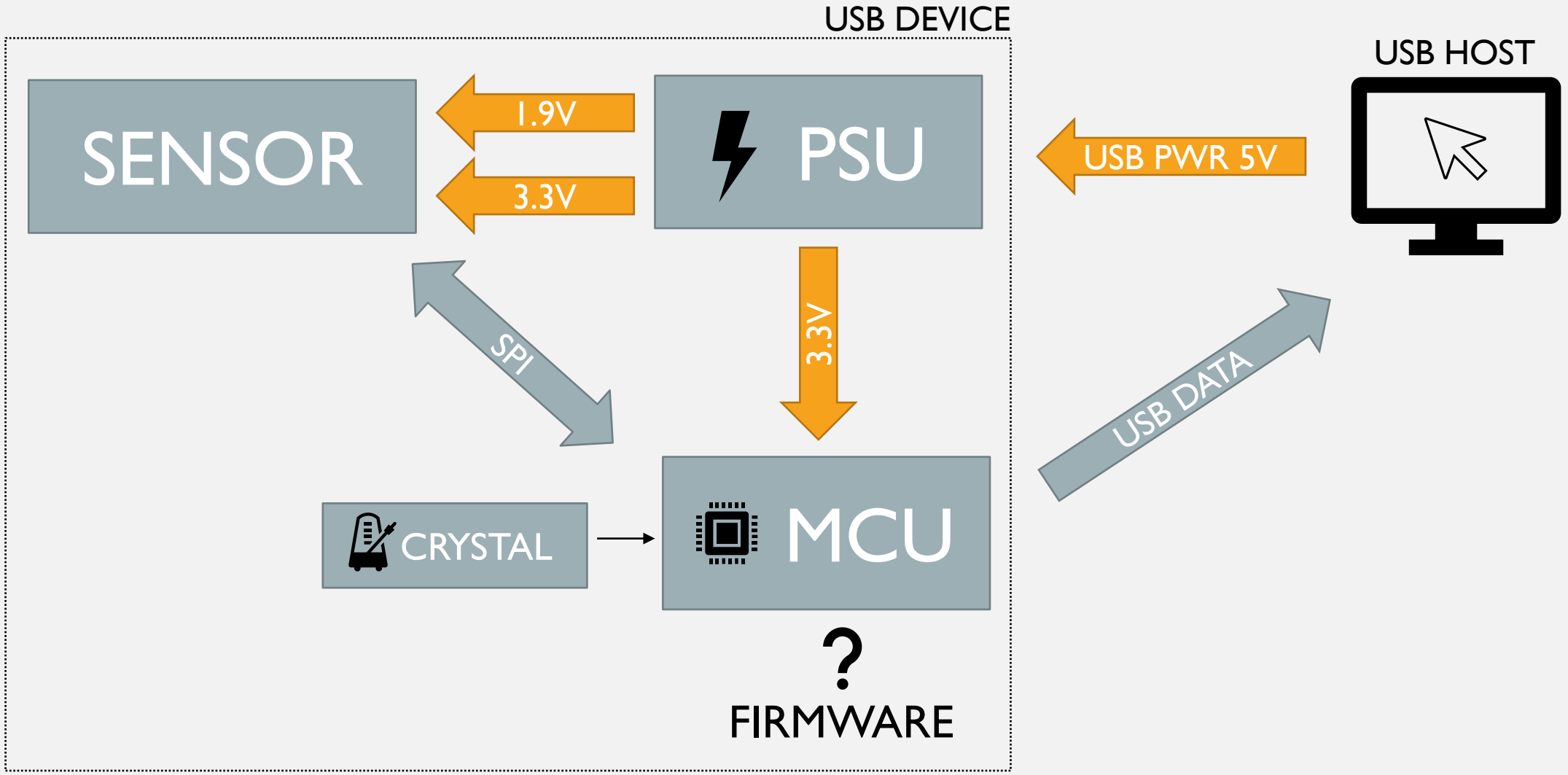
PIERCE OSCILLATOR





C1 = C2 = 2 x (Cload – Cstray)

BLOCK DIAGRAM



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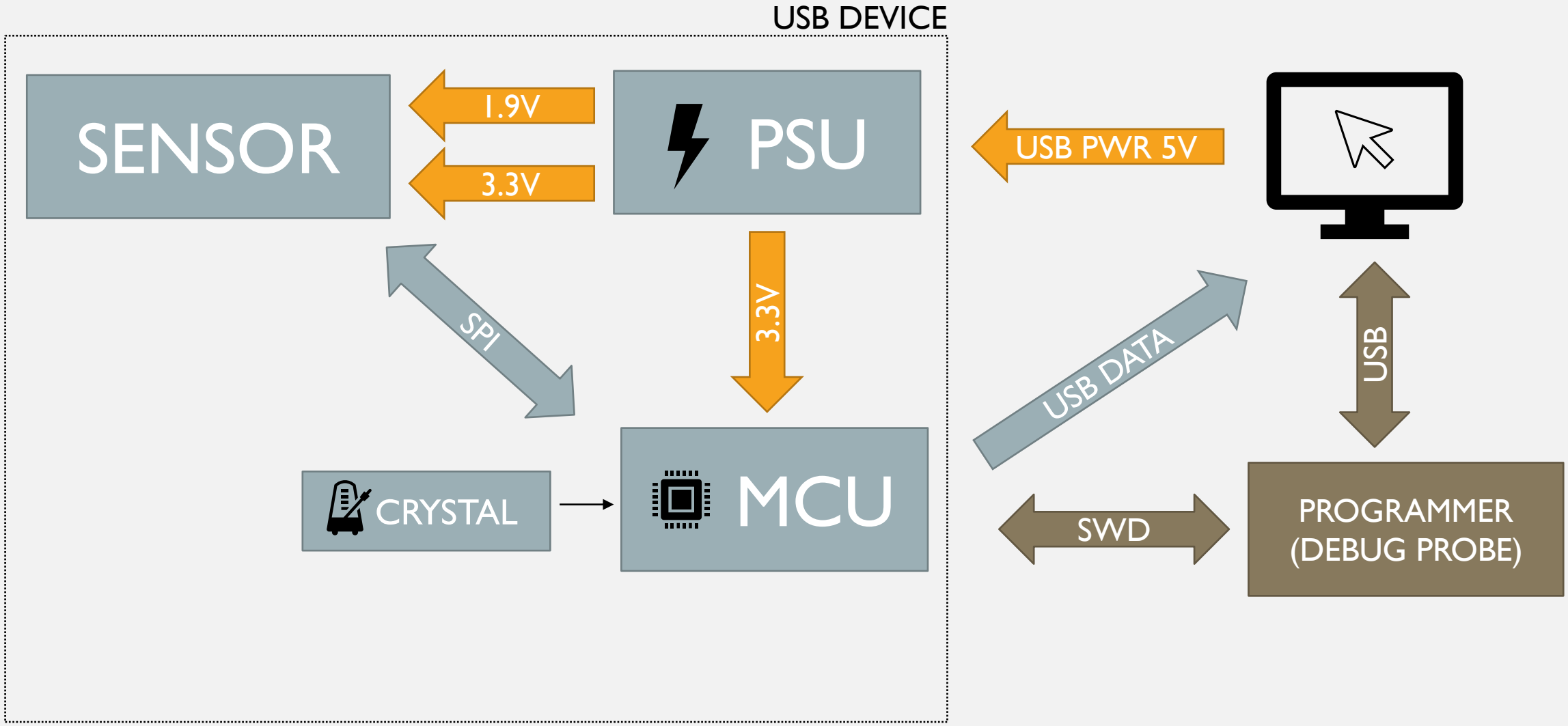

STM32F411

Additional connections

NRST

Reset pin
Active low
Internal pull-up
Button shorts to GND
Bypass capacitor

BOOT0

DFU mode
Jumper to Vdd

SWD

SWCLK
SWDIO