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PV198 – One-chip Controllers

ADC

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Content

1. What is ADC
2. What is it used for
3. How does it work
4. FRDM-K66F ADC
5. Joystick
6. Application

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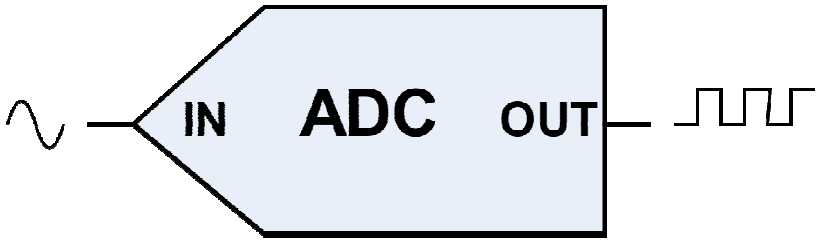
What is ADC

- **ADC** – **A**nalog to **D**igital **C**onverter

- Converting analog signal into digital values



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What is it used for

- Everything that needs to transfer analog values into digital values

- Audio
- Sensors
- Video
- …

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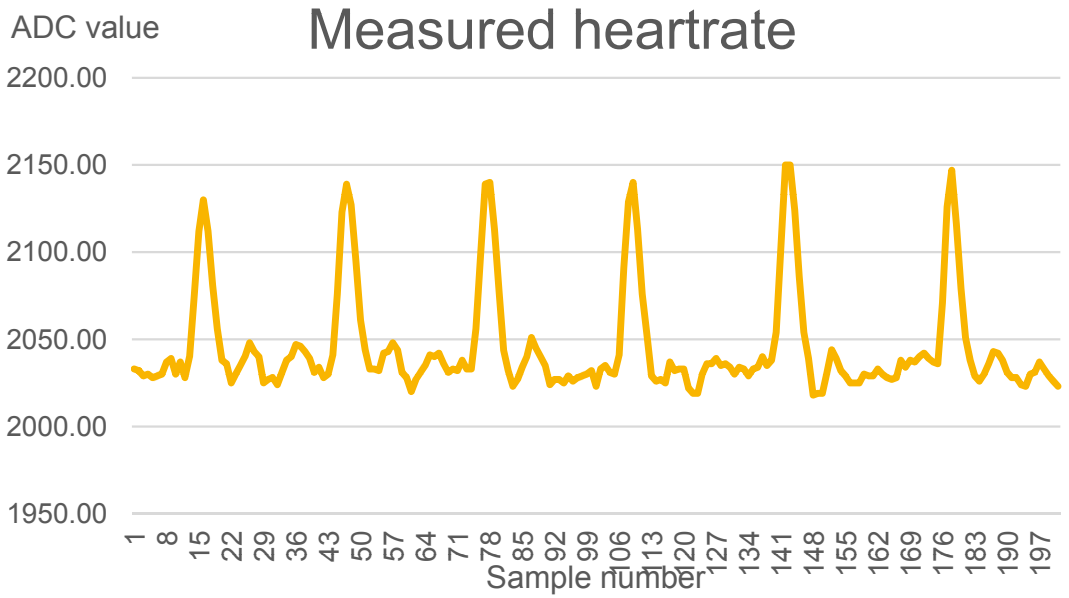
Demo – Heartbeat sensor



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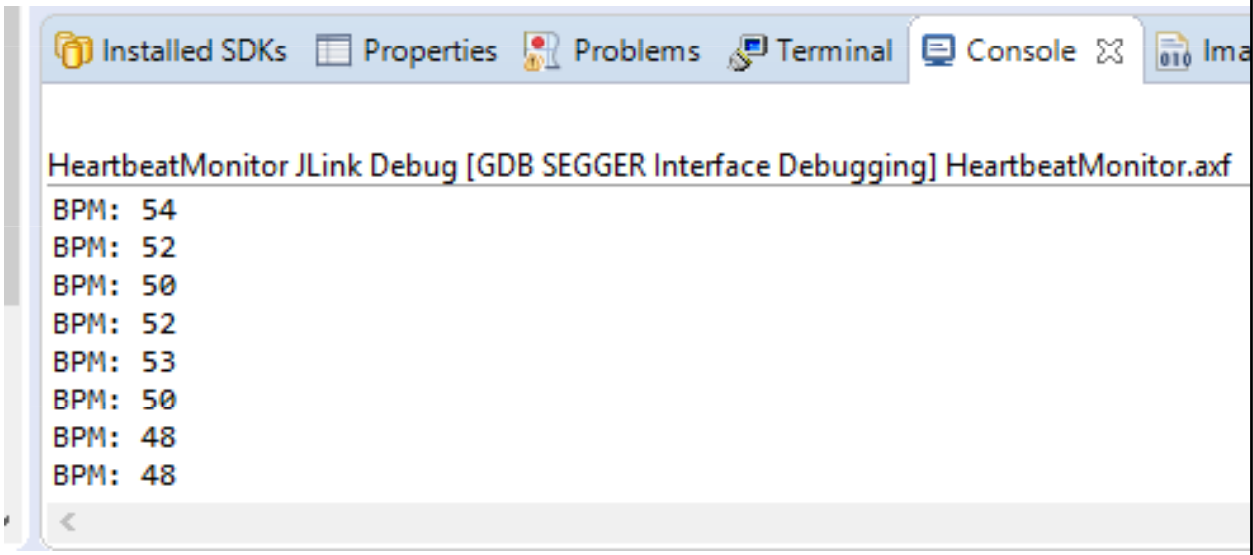
Demo – Heartbeat sensor



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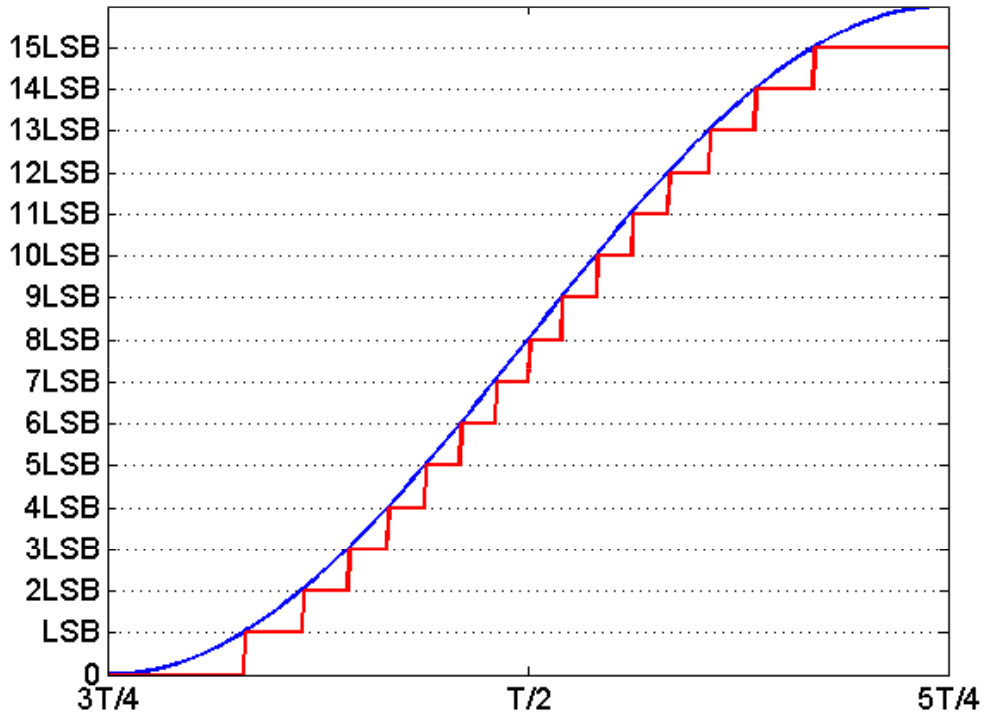
How does it work



https://www.allaboutcircuits.com/technical-articles/understanding-the-dynamic-range-specification-of-an-ADC/

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How does it work – Resolution

- Smallest incremental voltage that can be recognized and thus causes a change in the digital output
- Expressed as the number of bits output by the ADC

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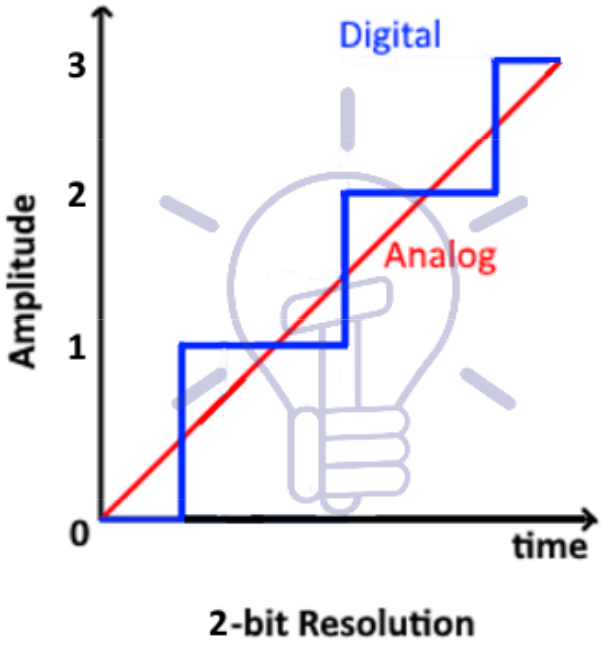
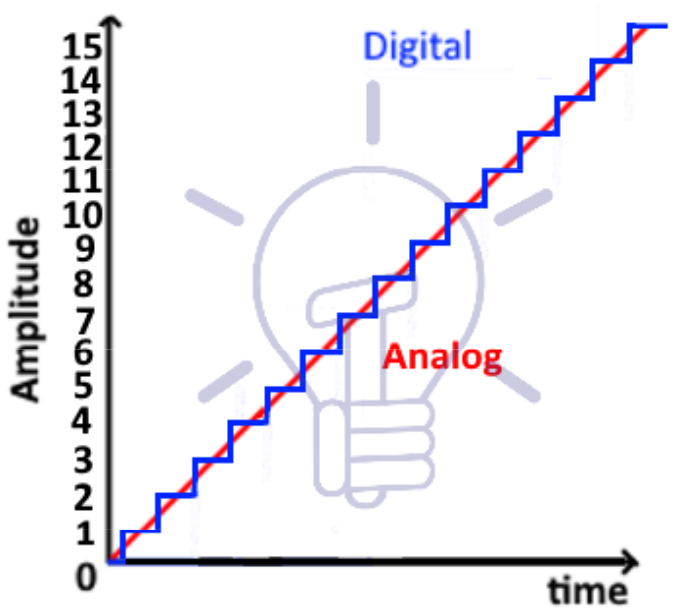
How does it work – Resolution



2-bit Resolution



4-bit Resolution

https://www.electricaltechnology.org/2019/02/analog-to-digital-converter-adc.html

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How does it work – Quantization error

- Difference between analog value and rounded digital value (rounding error)
  - Change in analog value smaller than the step of the digital value is ignored
  - The quantization error is 0.5 LSB for the ADC

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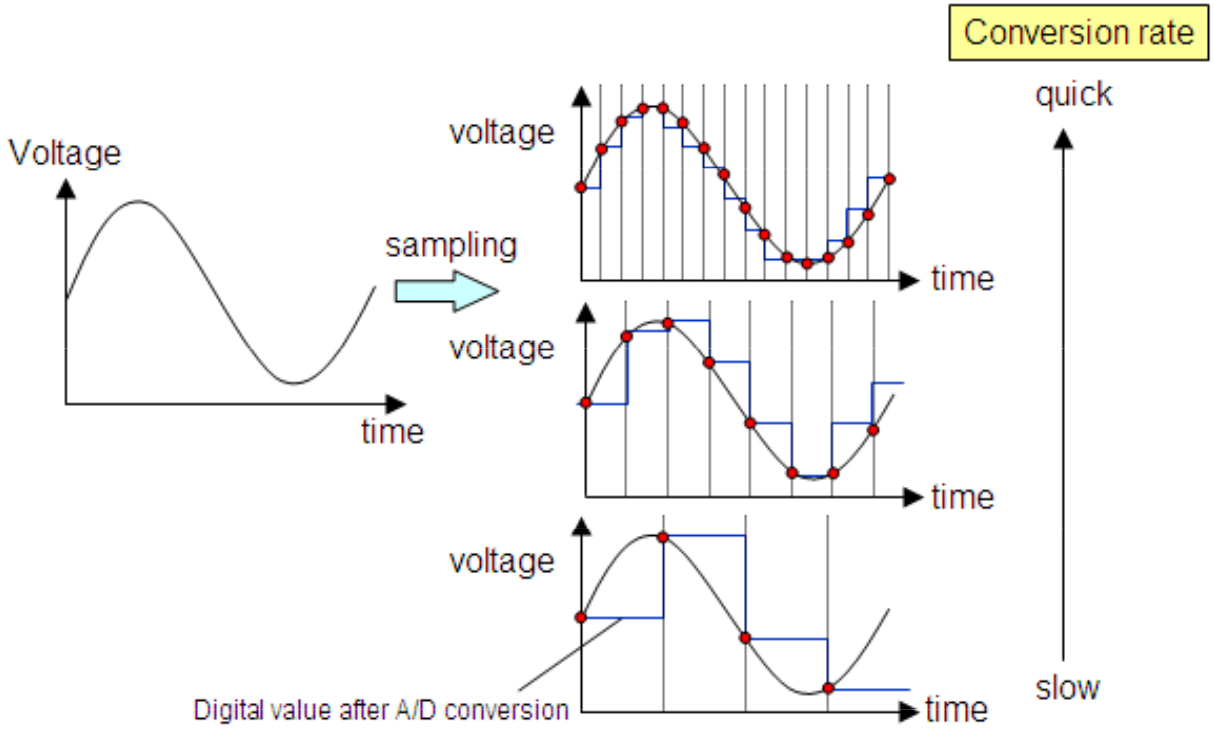
How does it work – Sampling rate

- Nyquist–Shannon theorem
  - ADC sampling frequency must be at least twice the analog signal frequency



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How does it work – Dynamic range

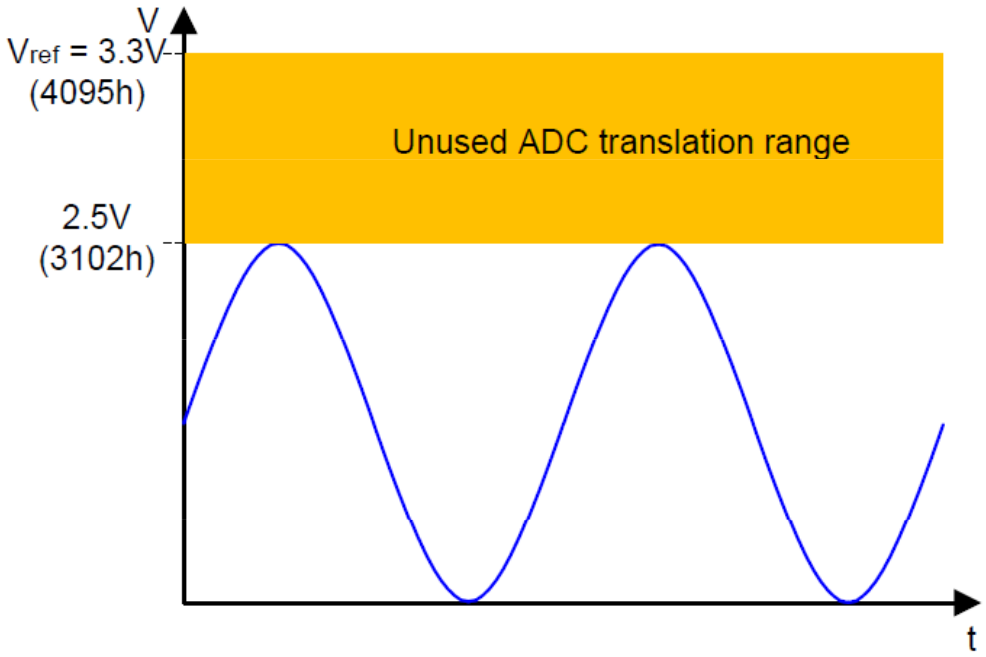

Figure 9. ADC dynamic range

https://www.nxp.com/docs/en/application-note/AN5250.pdf

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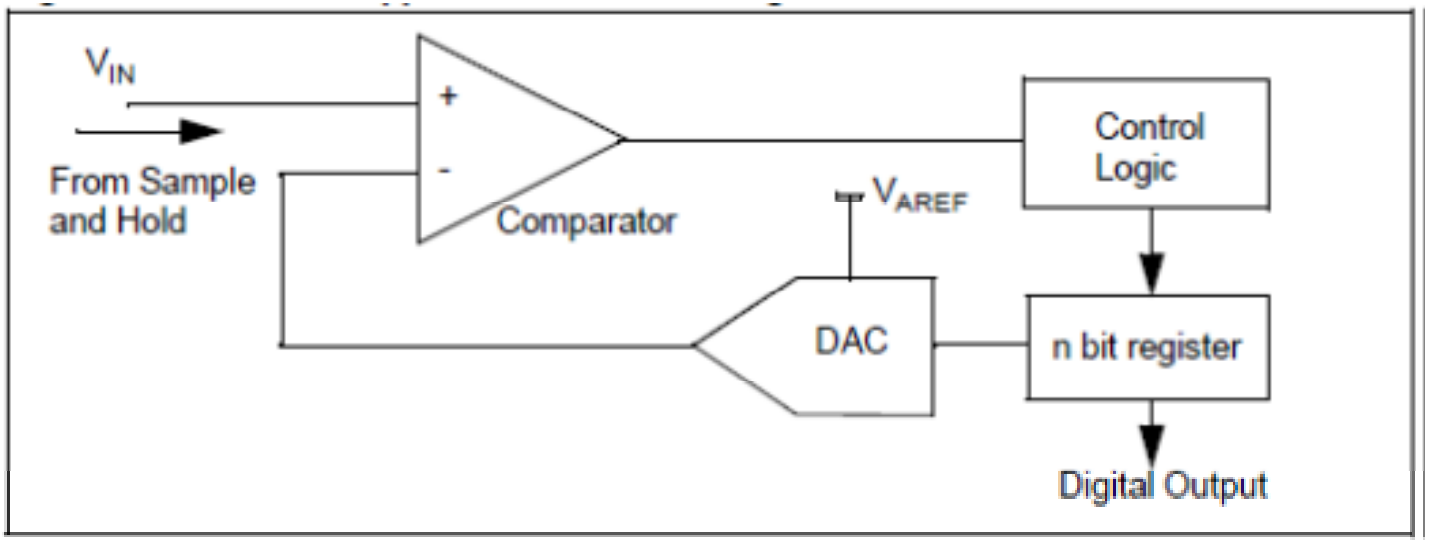
Linear successive approximation algorithm



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Linear successive approximation algorithm

Example:
Vin = 2.1 V
Vref = 3.3 V
3-bit resolution

Step	Digital code	DAC output	Comparator output	Digital output
1	100	1.65 V	1	1|00
2	110	2.475 V	0	10|0
3	101	2.0625	1	**101**

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Linear successive approximation algorithm

Example:
Vin = 1.16 V
Vref = 3.3 V
5-bit resolution

Step	Digital code	Bit voltage	DAC output	Comparator output	Digital output
1					
2					
3					
4					
5					

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FRDM-K66F ADC

- **Linear successive approximation algorithm with up to 16-bit resolution**
- Single or continuous conversion
- Can work in low-power modes
- HW trigger to start conversion
- HW average function
- Conversion complete interrupt
- DMA support

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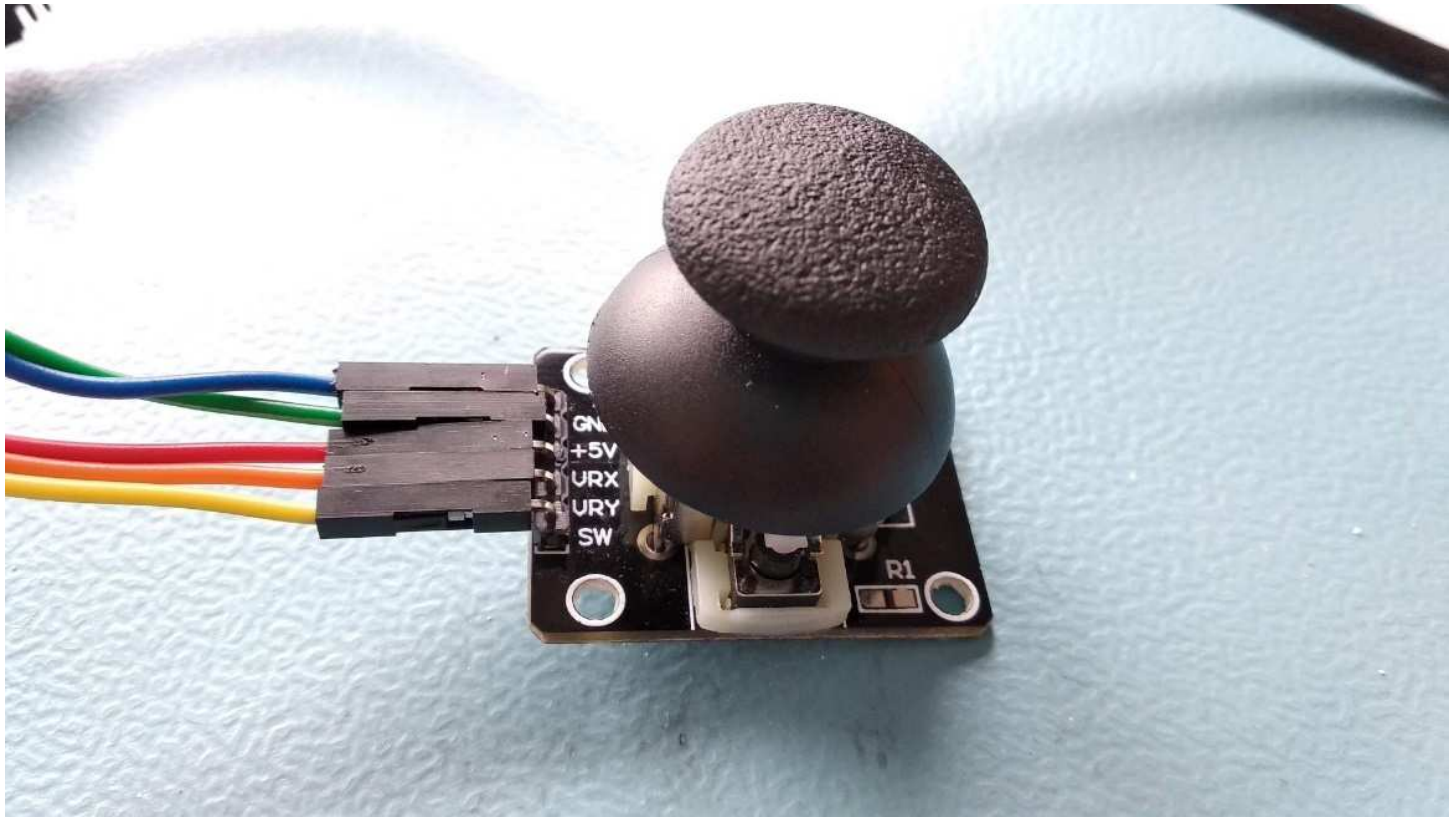
Joystick



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Joystick

- Connection to board **(do not use 5V!!!)**

3.6.1.1 16-bit ADC operating conditions

Table 31. 16-bit ADC operating conditions

Symbol	Description	Conditions	Min.	Typ.[1]	Max.	Unit	Notes
V_{DDA}	Supply voltage	Absolute	1.71	—	3.6	V	—
ΔV_{DDA}	Supply voltage	Delta to V_{DD} ($V_{DD} - V_{DDA}$)	-100	0	+100	mV	2
ΔV_{SSA}	Ground voltage	Delta to V_{SS} ($V_{SS} - V_{SSA}$)	-100	0	+100	mV	2
V_{REFH}	ADC reference voltage high		1.13	V_{DDA}	V_{DDA}	V	
V_{REFL}	ADC reference voltage low		V_{SSA}	V_{SSA}	V_{SSA}	V	
V_{ADIN}	Input voltage	• 16-bit differential mode • All other modes	VREFL VREFL	— —	31/32 * VREFH VREFH	V	—

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Joystick – Easy (2 ADCs)

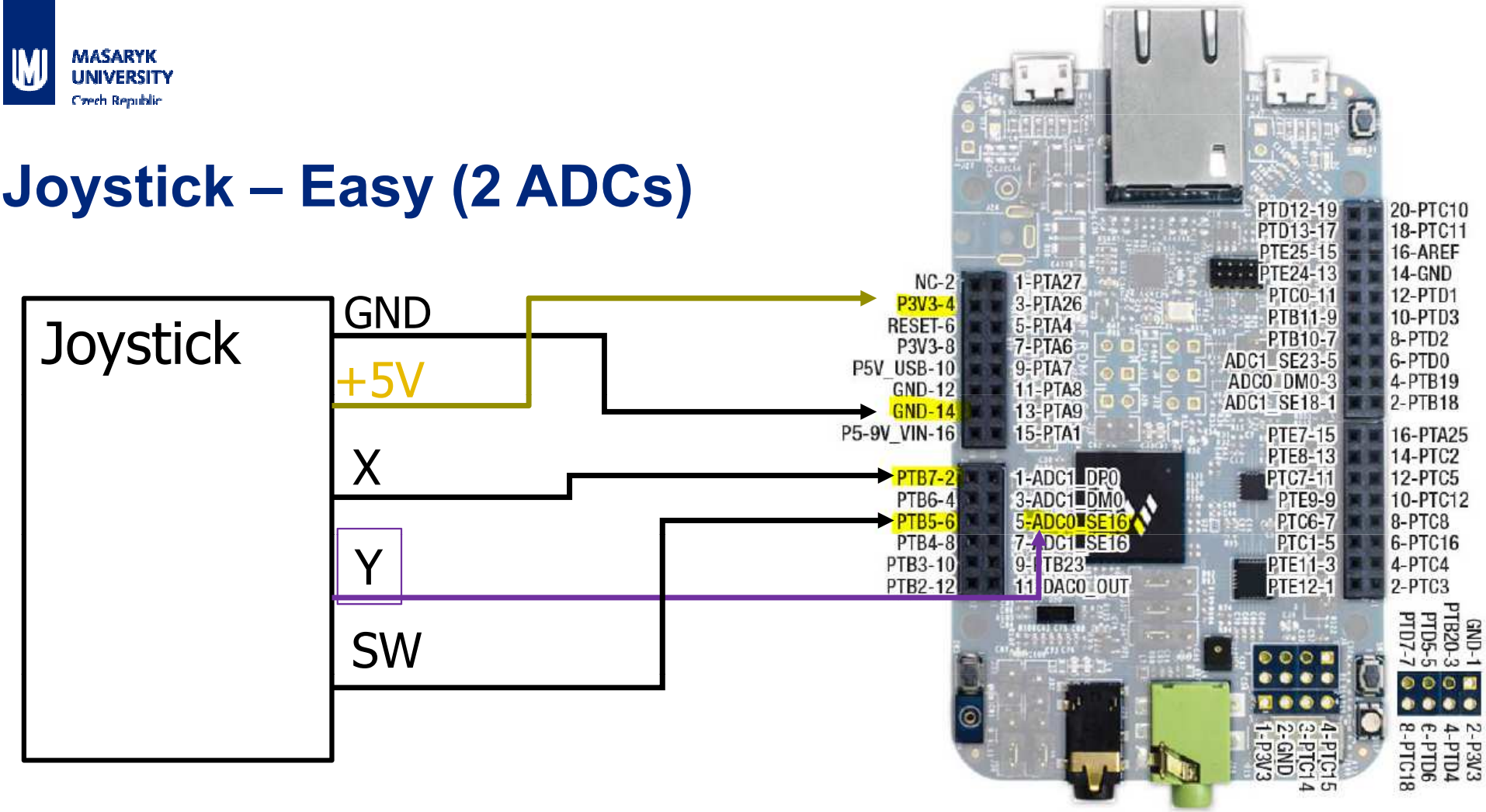

Figure 26. FRDM-K66F I/O header pinout

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Joystick – Difficult (only 1 ADC)

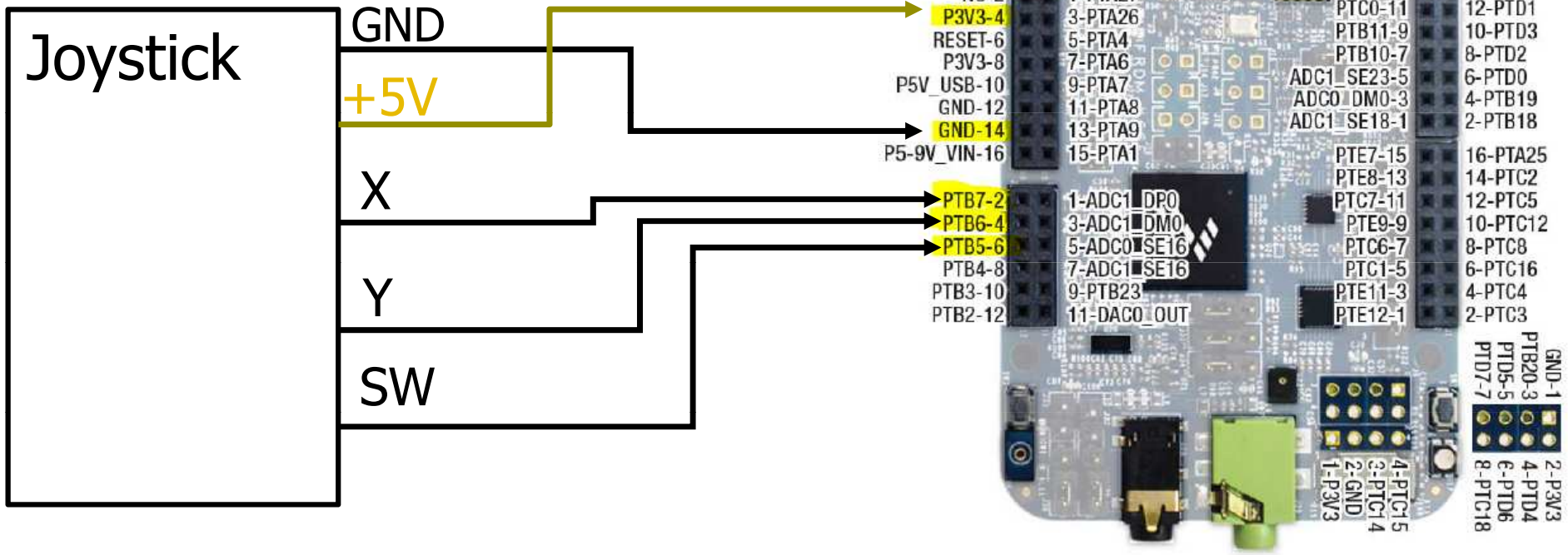

Figure 26. FRDM-K66F I/O header pinout

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Application

- Create an application that reads position of the joystick (both axes) using ADC0 and ADC1
- Print position to terminal

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Application

- Write periodic check into while loop to test if measurement is finished
- Use PIT to initialize read only once a second
- Either:
  - Write ADC read only using Interrupts
  - React to joystick button press

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Steps

- Initialize *(MCUXpresso Configuration Tools help here)*
  - Pins (route ADC channels to pins)
  - Clocks
  - Peripherals (configure ADC0 and ADC1)
- Write application code (print position of the joystick)

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Homework

- Use joystick to control LEDs (change intensity when joystick moves – use PWM)
- Use only ADC1 peripheral, with multiple channels
- Warning: ADC has special handling of interrupt flags