

PV198 - Analog to Digital Conversion

One-chip Controllers

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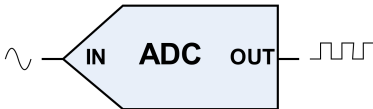
Homework

Intro

- Switch the branch to *Week_05!*
- Discussion of HW4

What is ADC

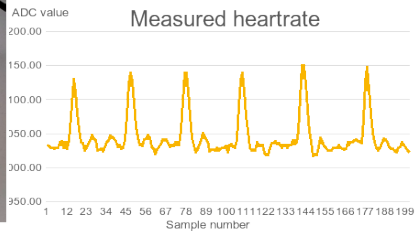
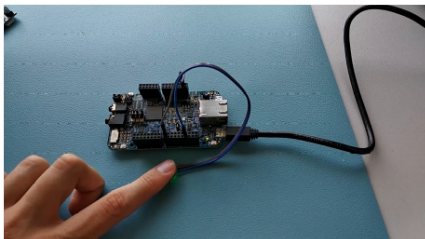
- **ADC** - Analog to **D**igital **C**onverter
- Convert analog signal into digital values



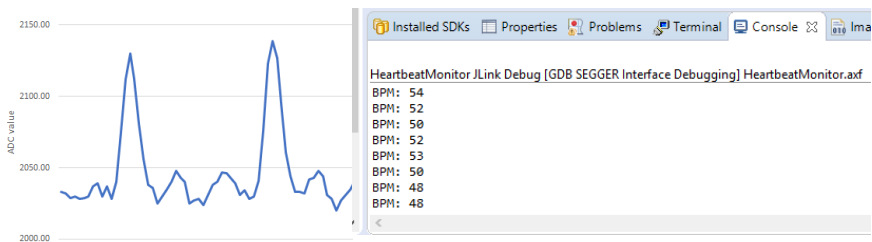
What is it used for

- Everything that needs to transfer analog values into digital values
- Audio
- Sensors
- Video

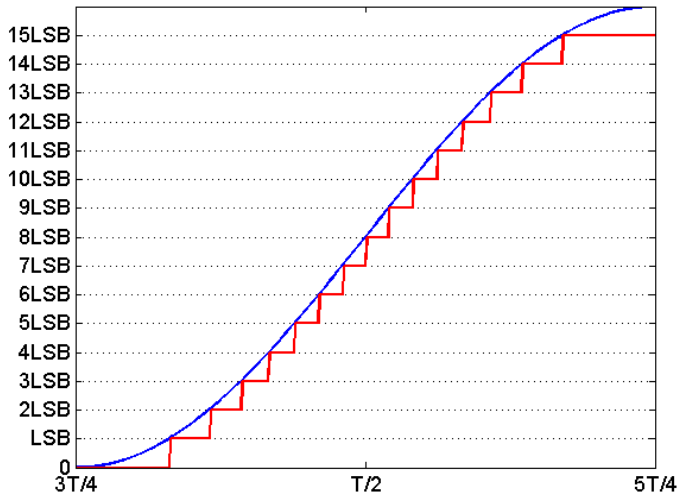
Demo - Heartbeat sensor



Demo - Heartbeat sensor

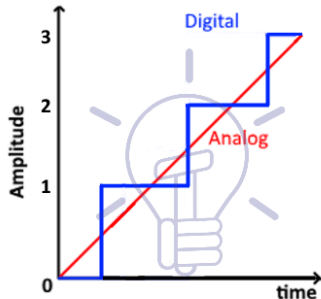


How does it work

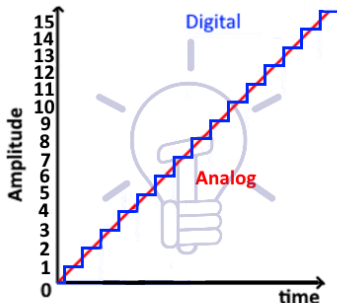


Sampling resolution

- 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



2-bit Resolution



4-bit Resolution

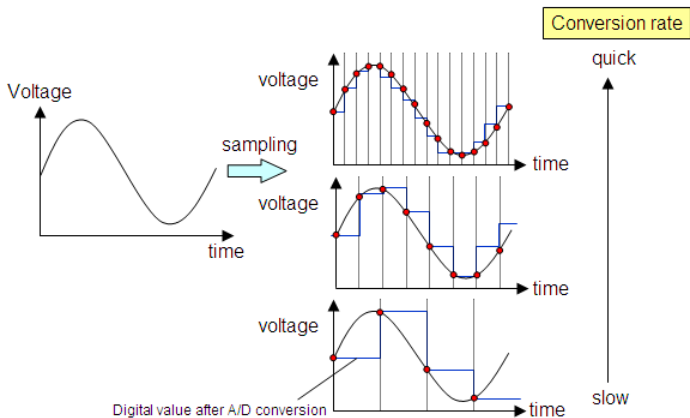
<https://www.electricaltechnology.org/2019/02/analog-to-digital-converter-adc.html>

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 least significant bit for the ADC

Sampling Rate

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



Dynamic Range

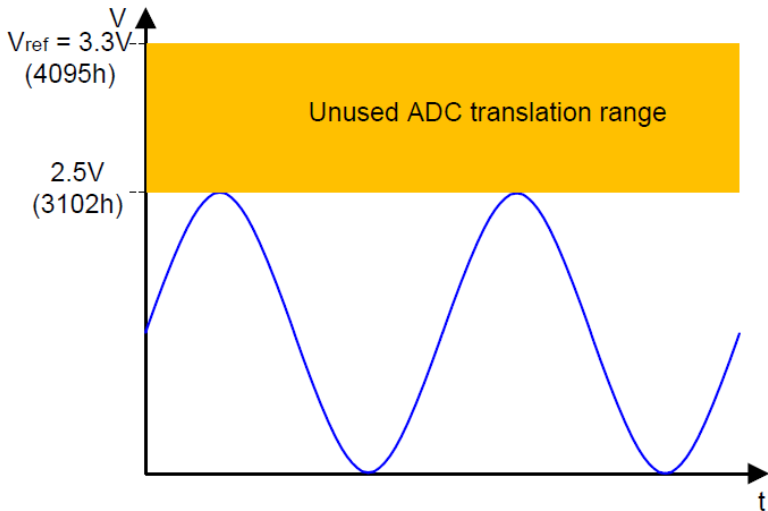
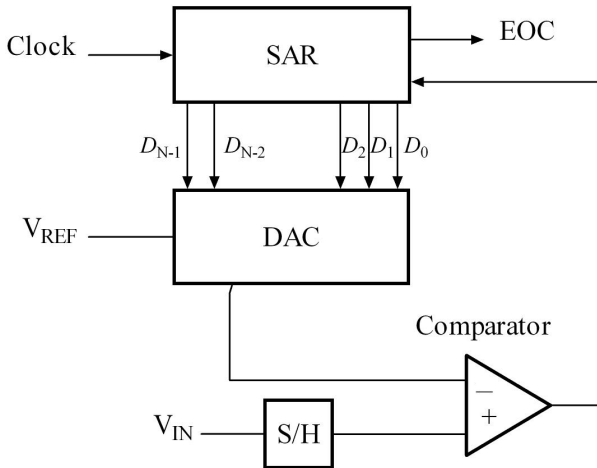


Figure 9. ADC dynamic range

Linear Successive Approximation Algorithm



Linear Successive Approximation Algorithm

- $V_{in} = 2.1V$
- $V_{ref} = 3.3V$
- 3-bit resolution

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

Linear Successive Approximation Algorithm

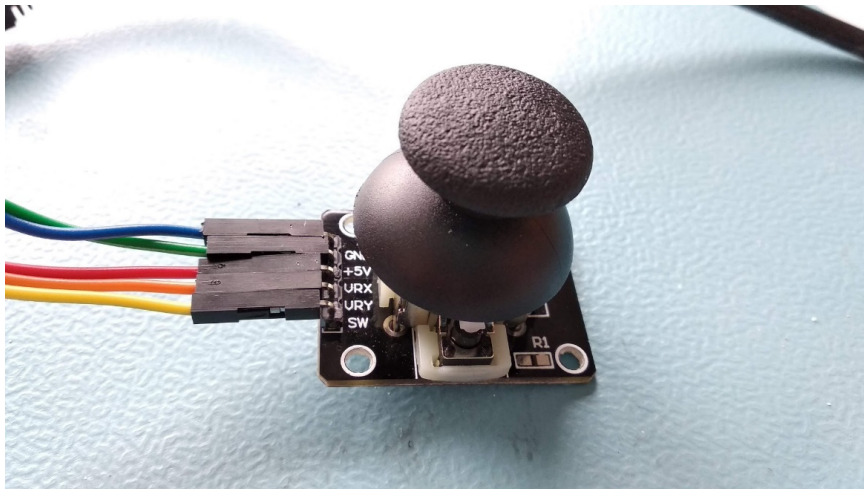
- $V_{in} = 1.16V$
- $V_{ref} = 3.3V$
- 5-bit resolution

| Step | Digital code | DAC output | Output Comparator | Digital output |
|------|--------------|------------|-------------------|----------------|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |

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
- [ADC16 - MCUXpresso SDK API Reference Manual](#)

Joystick



Joystick

■ 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 | <ul style="list-style-type: none"> 16-bit differential mode All other modes | V_{REFL} | — | $\frac{31}{32} \cdot V_{REFH}$ V_{REFH} | V | — |

Joystick - Connection (2 ADCs)

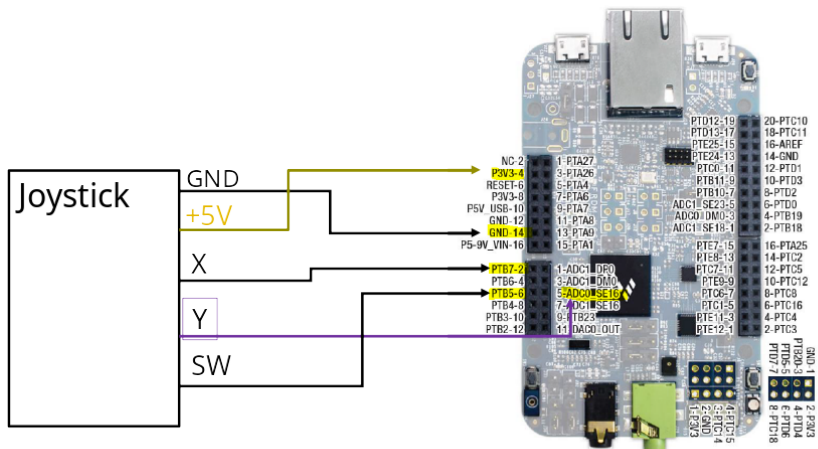


Figure 26. FRDM-K66F I/O header pinout

Joystick - Connection (1 ADC, 2 channels)

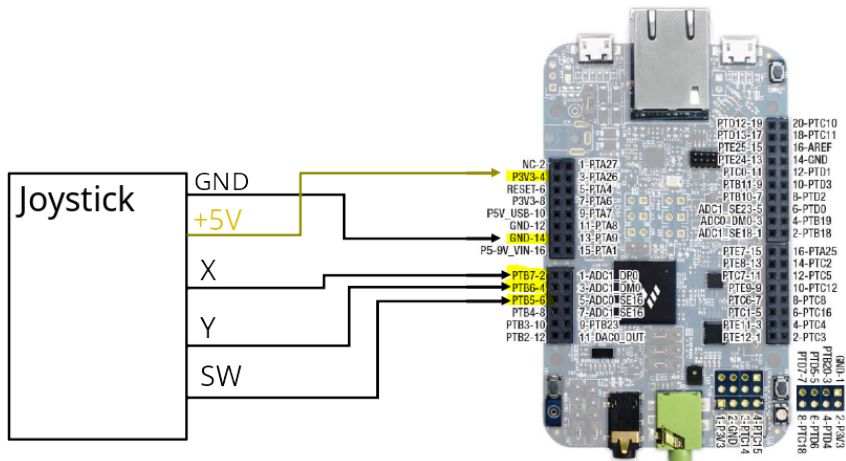


Figure 26. FRDM-K66F I/O header pinout

Application

Task

- Create an application that reads position of the joystick (both axes) using ADC0 and ADC1
- Print position to terminal
- Initialize read only once a second
- Use periodic check in main while loop to detect finished measurement
- When finished:
 - Read ADC using interrupts
 - React to joystick button press

Warning

ADC16_SetChannelConfig triggers a conversion.

Steps

1. Initialize (*MCUXpresso Configuration Tools*)
 - 1.1 Pins
 - 1.2 (Clocks)
 - 1.3 Peripherals (ADC0, ADC1)
2. Write application code

Homework

Use joystick to control LED's brightness

- Only use ADC1 peripheral with multiple channels
- Use the *1 ADC, 2 channels* connection
- X-axis (PTB7) controls green LED
- Y-axis (PTB6) controls red LED
- ADC value 0 = 0 % duty cycle (= LED OFF)
- ADC value MAX = 100 % duty cycle (= LED fully ON)

Warning

ADC has special handling of interrupt flags!

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