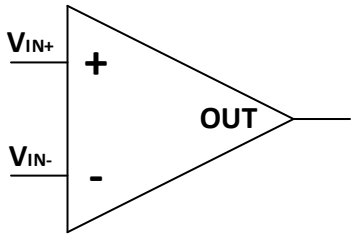
Analog

Microcontrollers only know two level on inputs and outputs; high and low, but the world is analog that is continuous variable signals like sound, light and temperature. Sensors that measure analog values can be accelerometer, gyroscopes, microphone, and temperature and light sensors. To allow a microcontroller to use the signals for decisions and calculations they have to be converted to something the controller understand. There are two ways to do this.

Analog comparator (AC)
An analog comparator compares two analog voltages and changes its output based on the input; if the + input is higher than minus input, the output is high and otherwise low. The comparator cannot tell anything about how much higher or lower one input is than the other.



ATmega328P has an inbuilt comparator with inputs on AINO (positive input) and AIN1 (negative input). An internal reference can be connected to the positive input and the negative to an ADC-input pin if the ADC is not in use. The comparator has interrupt control and can trigger input capture on Timer/Counter1.

Analog to digital converter (ADC).
Many microcontrollers have one or more inbuilt ADCs that can convert an analog input voltage to a digital number that can be used for calculations and decisions. This represents a quantization, which will introduce a small error depending on the range and resolution.

Resolution is measured in number of bits (M).
Range is maximum to minimum voltage (E_{RANGE}).
Speed is number of samples per second. E.g. 1 Msps (Mega samples per second).
Oversampling can be used for increasing resolution, doubling the number of samples can increase the resolution by one bit.

The quantization steps (Q) are determined by resolution and range. E.g. 0-5,12V range and 8-bits will give:

$$Q = \frac{E_{RANGE}}{2^M} = \frac{5{,}12V - 0V}{2^8\, steps} = \frac{5120mV}{256\, steps} = 20mV / step$$

Measurement of 1,24V will give:
1240mV / 20mV/step = 62

Errors in ADC converter:

- Offset
- Gain
- Linearity,

Some sensors doesn’t output analog voltages and instead have an inbuilt ADC and are accessed with a serial interface like I2C, SPI or UART.

ATmega328P has an inbuilt successive approximation ADC:
- 10-bit resolution, i.e.1024 levels.
- Configured in control and status registers.
- Needs power on AVCC pin to operate.
- Conversion time is 65µs to 260µs per sample for maximum resolution. Prescaler adjusts clock to ADC. 13µs per sample is 1MHz ADC-clock.
- Reference is AVCC, AREF-pin or internal 1.1V reference from bandgap.
- 6 _multiplexed_ inputs to ADC
- Result can be left or right adjusted.

Some AVRs have differential inputs and gain on some pins.

Digital to analog converter (DAC)
Some microcontrollers have one or more DACs built in, which can convert a digital value to an analog output voltage. More often we use the digital output pins with pulse-width modulation (PWM), which will be described with timers.