Analog/Digital Conversion with Microcontrollers

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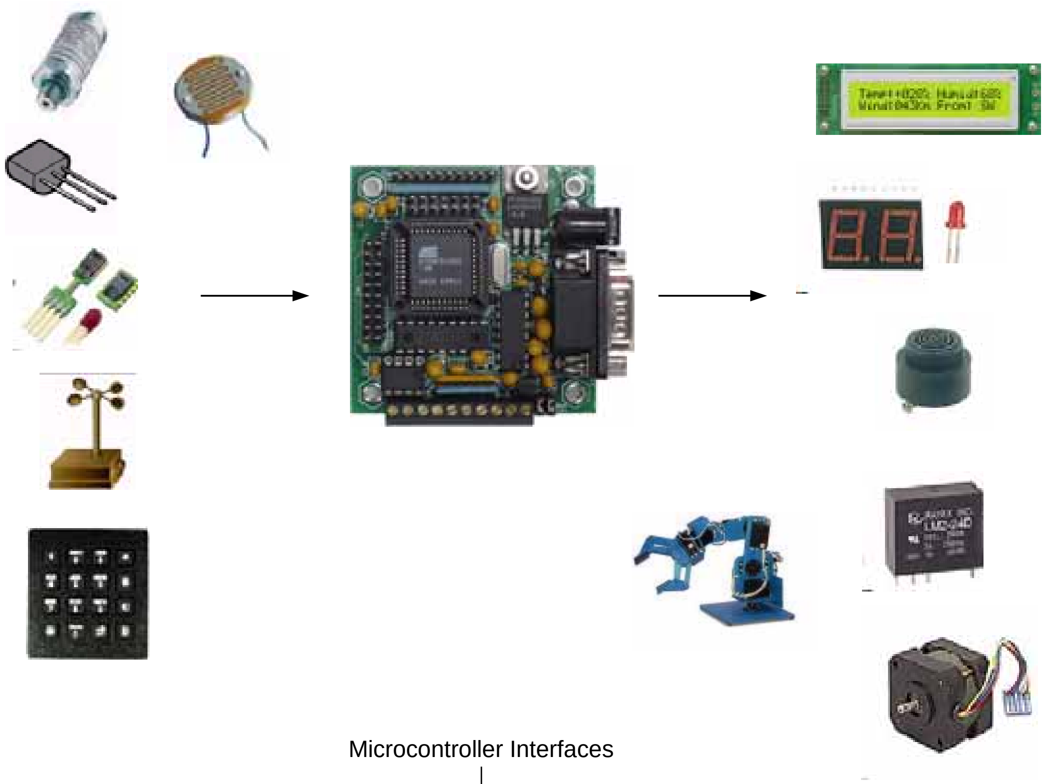
Overview

Micro-controllers are useful to the extent that they communicate with other devices, such as sensors, motors, switches, keypads, displays, memory and even other micro-controllers.

Many interface methods have been developed over the years to solve the complex problem of balancing circuit design criteria such as features, cost, size, weight, power consumption, reliability, availability, manufacturability.

Many microcontroller designs typically mix multiple interfacing methods. In a very simplistic form, a micro-controller system can be viewed as a system that reads from (monitors) inputs, performs processing and writes to (controls) outputs.

Input Devices **Microcontroller** **Output Devices**



Microcontroller Interfaces

- Digital
  - On/Off
  - Parallel
  - Serial
    - Asynchronous
      - 1-wire
      - RS232/RS485
      - Ethernet
    - Synchronous
      - 2-wire (I2C)
      - 4-wire (SPI, Microwire)
- Analog
  - Voltage
  - Current

Analog Inputs/Outputs

Voltage-based control and monitoring.

Advantages

- Simple interface
- Low cost for low-resolutions
- High speed
- Low programming overhead

Disadvantages

- High cost for higher resolutions
- Not all microcontrollers have analog inputs/outputs built-in
- Complicates the circuit design when external ADC or DAC are needed.
- Short distance, few feet maximum.

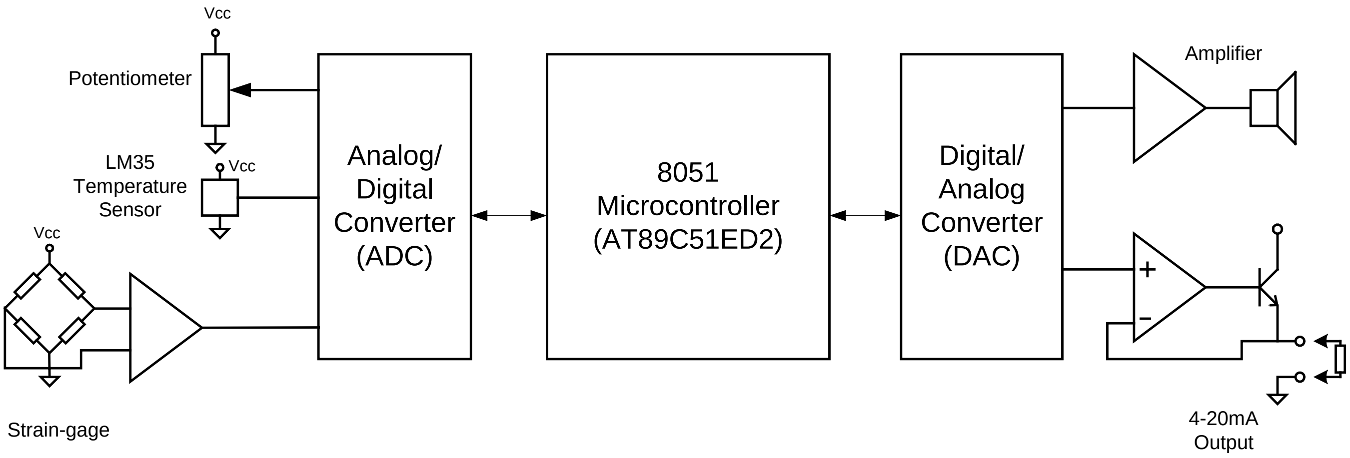
Voltage type: Typical ranges

- 0 to 2.5V
- 0 to 4V
- 0 to 5V
- +/- 2.5V
- +/- 4V
- +/- 5V

Current type: Typical ranges

- 0-20mA
- 4-20mA

Analog Interface



Sensor Types

- Temperature
- Humidity
- Light
- Acceleration
- Force
- Frequency
- Flow
- Pressure
- Torque
- Proximity
- Displacement

Analog Digital Conversion

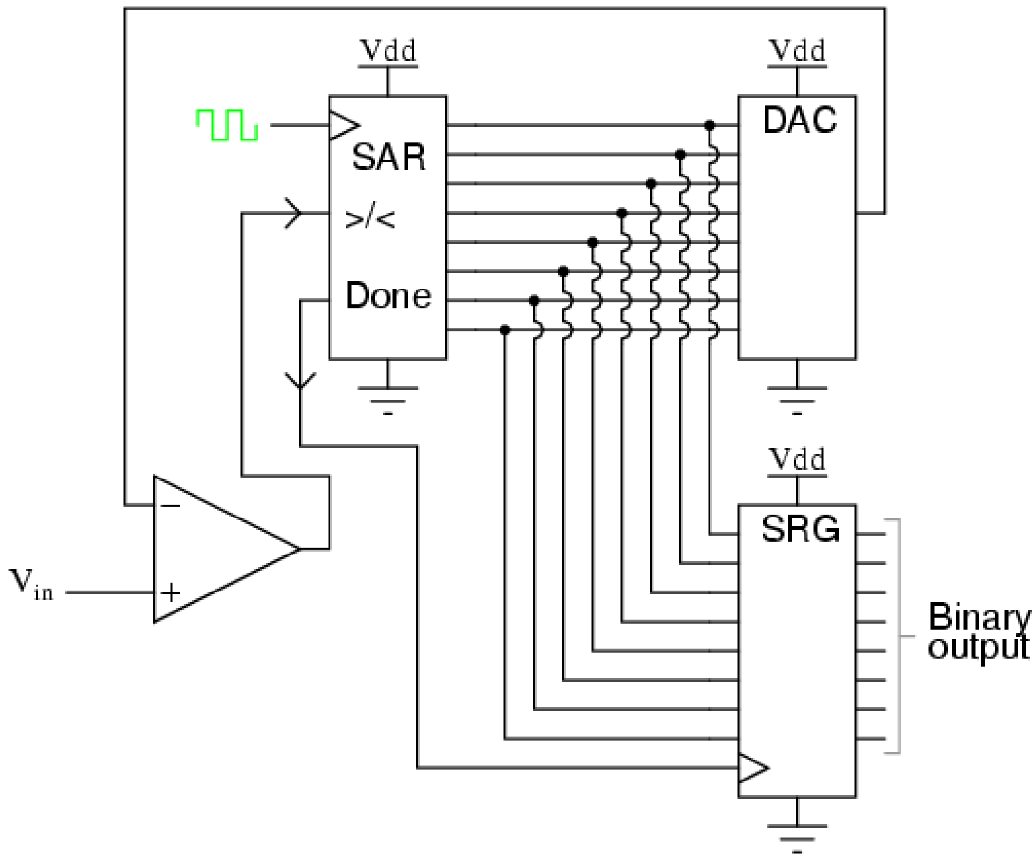
- Voltage to Frequency
- Flash ADC
- Successive Approximation
- Dual-Slope Integration
- Delta-Sigma

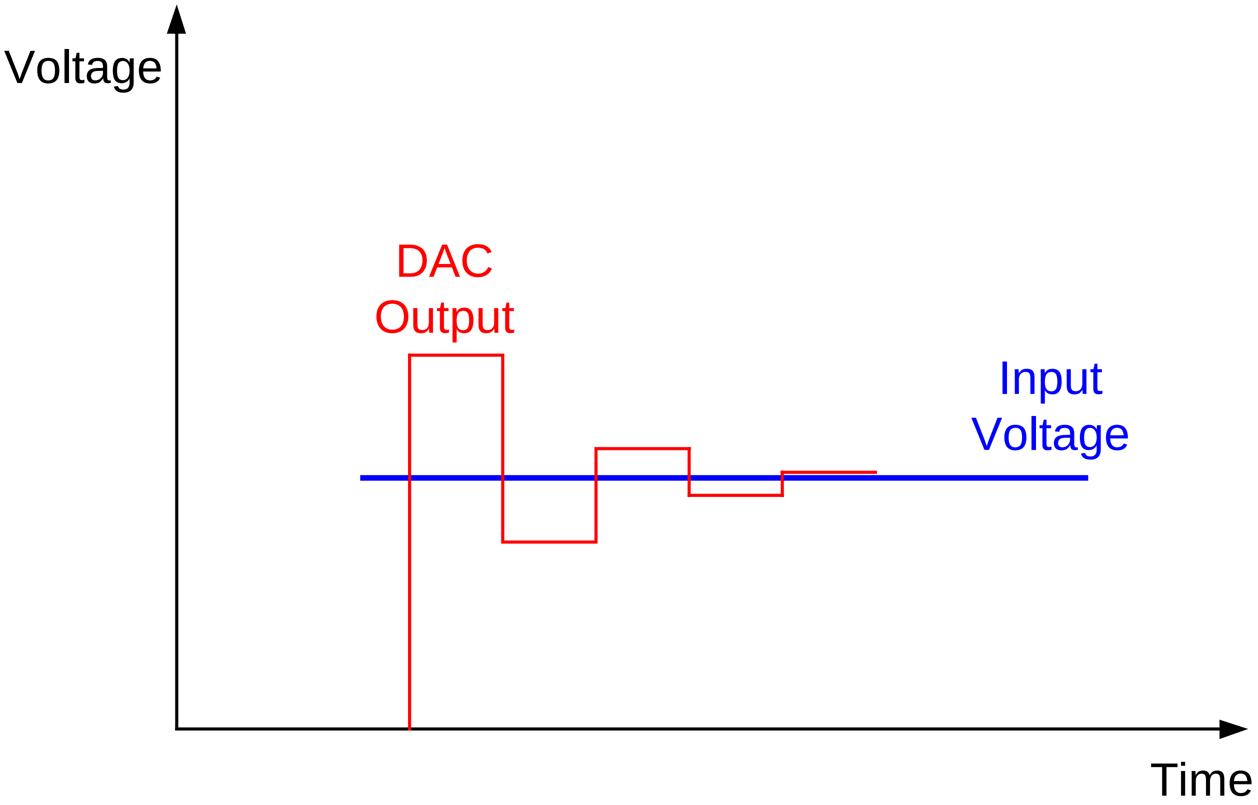
Successive approximation ADC

Successive Approximation ADC’s are popular for use with microcontrollers due to low-cost and ease of interfacing. A successive approximation ADC consists of:

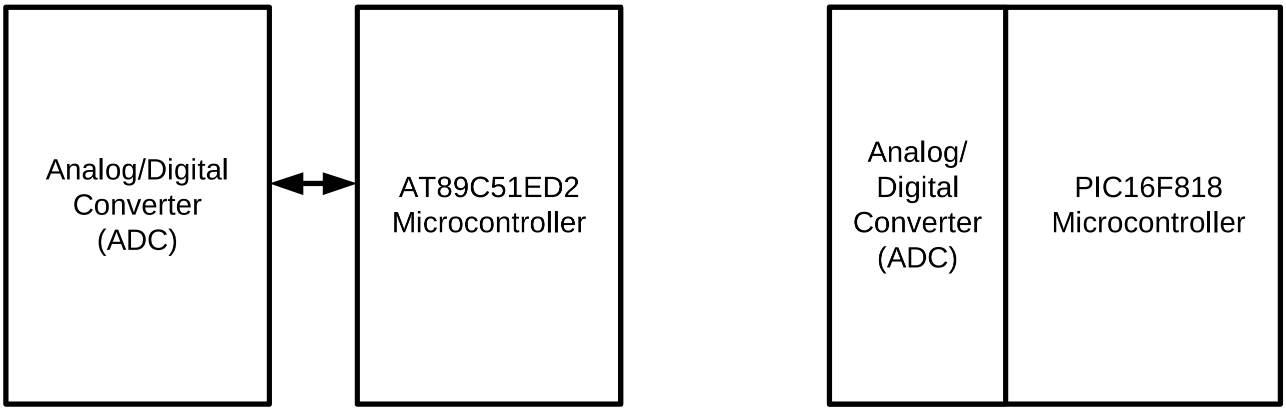
- Successive Approximation Register
- Result Register
- DAC
- Comparator

Successive-approximation register counts by trying all values of bits starting with the most-significant bit and finishing at the least-significant bit. Throughout the count process, the register monitors the comparator's output to see if the binary count is less than or greater than the analog signal input, adjusting the bit values accordingly. This way, the DAC output eventually converges on the analog input signal and the result is presented in the Result register.





ADC can be external to the microcontroller or built-in:



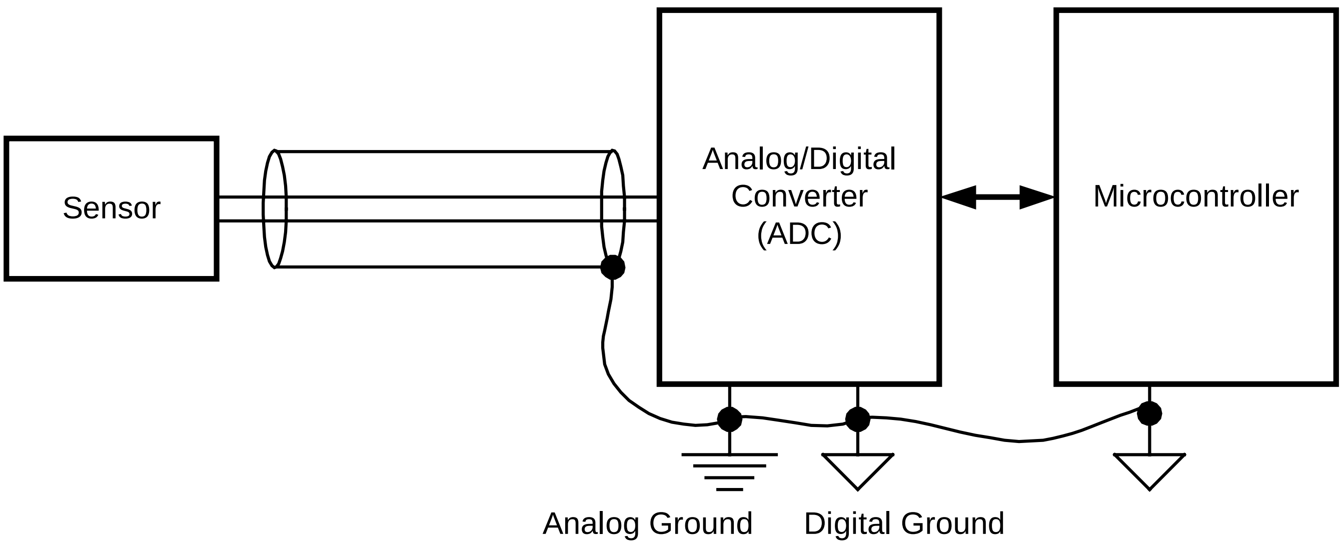
Noise considerations

Many sensors, such as thermocouples, generate a relatively small voltage so noise is always an issue. The most common source of noise is the utility power lines (50 Hz or 60 Hz).

Typically, the bandwidth for temperature sensors is much lower than 50 or 60 Hz so a simple low-pass filter will work well in many cases.

Other measures to keep noise away:

- Keep the sensor wires short.
- Use shielded sensor cables with twisted pair wires.
- Use a dedicated precision voltage reference, not the microcontroller supply.
- Use 4-20mA loop or even better, a digital signal for long cable runs.
- Provide low impedance paths to ground at the ADC inputs if possible.
- Average readings in software.
- Analog ground and digital ground should connect at the ADC.
- Analog ground should not carry large currents.
- Ground planes should not carry any currents.

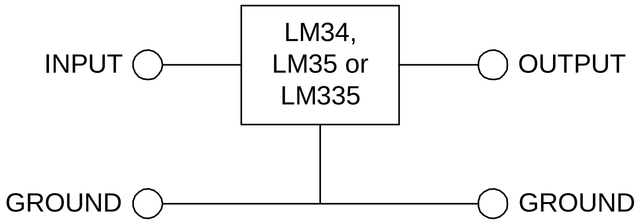


Semiconductor Temperature Sensors

Analog

<u>Voltage Output</u>

Typically three-pin devices: Power, ground and output.

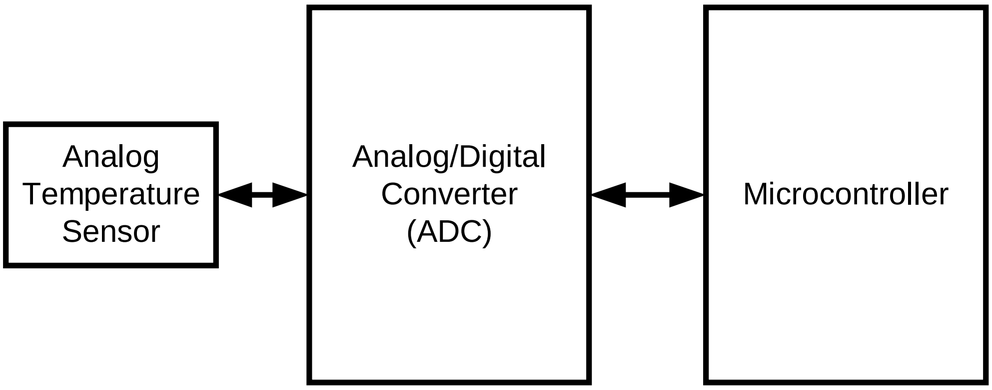


LM34: Fahrenheit sensor (10 millivolts/Fahrenheit)
LM35: Celsius sensor (10 millivolts/Celsius)
LM335: Kelvin sensor (10 millivolts/Kelvin)

<u>Current Output</u>

Typically 2-pin devices.

AD590: Kelvin sensor (1uA/Kelvin)



Digital

<u>Frequency Output</u>

MAX6576

<u>1-wire</u>

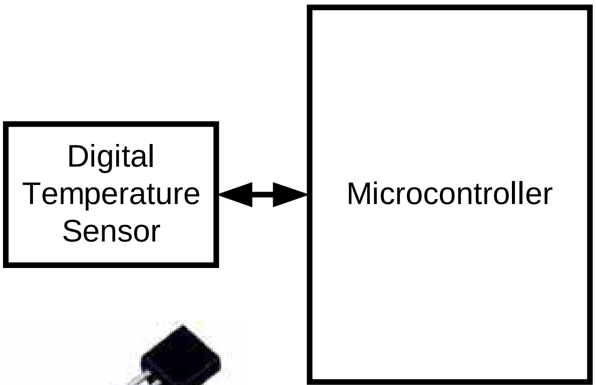
DS18B20

<u>2-wire/SMBUS</u>

DS1621

<u>3-wire</u>

DS1620



Analog/Digital Converter Application Examples

Digital Scale
Voice Recorder
Voice Recognition
Sprinkler control system
Engine controller
Power Supply controller
Factory automation
Medical (EEG, ECG, etc.)
Instrumentation – voltmeters, digital oscilloscopes, ohmmeters