Microcontroller to Sensor Interfacing Techniques

Document Revision: 1.01
Date: 3rd February, 2006

BiPOM Electronics, Inc.

16301 Blue Ridge Road, Missouri City, Texas 77489
Telephone: 1-713-283-9970 Fax: 1-281-416-2806
E-mail: info@bipom.com
Web: www.bipom.com

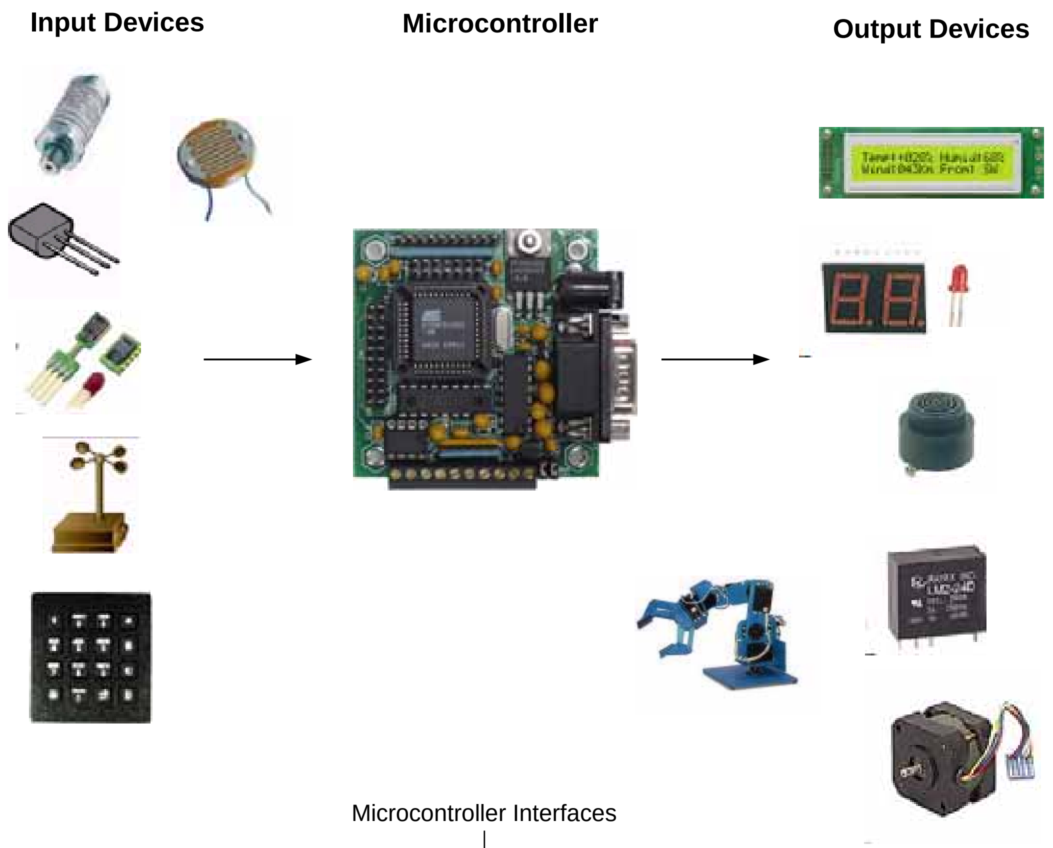
This document is available for download from www.bipom.com

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.



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.

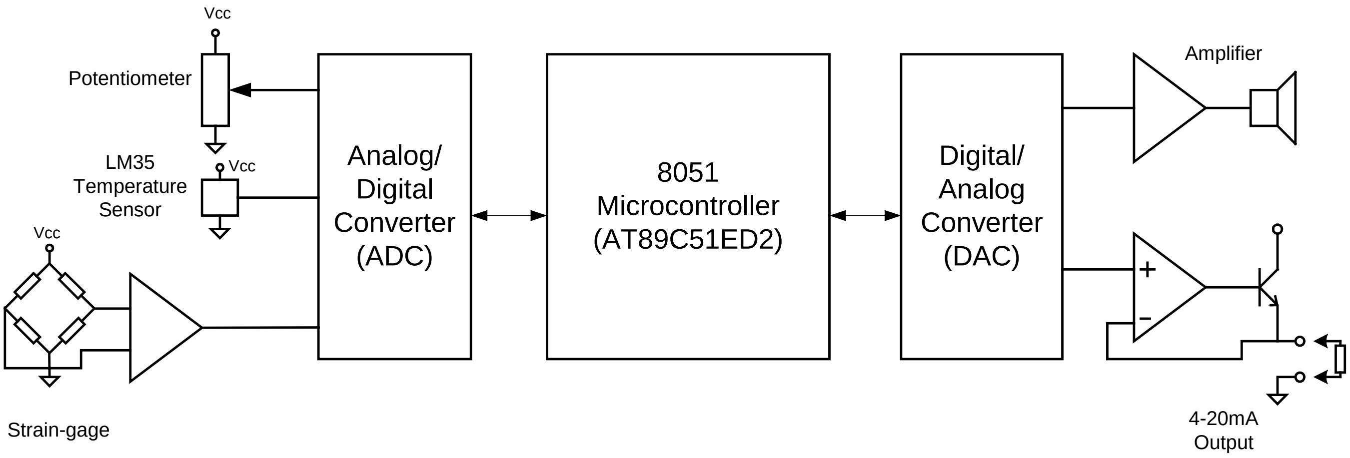
Voltage type: Typical ranges

- 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

Temperature Sensors

- RTD
- Thermistor
- Thermocouple
- Semiconductor Temperature Sensors

Criteria	Thermocouple	RTD	Thermistor	Semiconductor
Temperature Range	Very wide -450°F +4200°F	Wide -400°F +1200°F	narrow -100°F +500°F	narrow -60°F to 250°F
Interchangeability	Good	Excellent	Poor to fair	Good
Long-term Stability	Poor to fair	Good	Poor	Good
Accuracy	Medium	High	Medium	High
Repeatability	Fair	Excellent	Fair to good	Good
Sensitivity (output)	Low	Medium	Very high	High
Response	Medium to fast	Medium	Medium to fast	Medium to fast
Linearity	Fair	Good	Poor	Good
Self Heating	No	Very low to low	High	High
Point (end) Sensitive	Excellent	Fair	Good	Good
Lead Effect	High	Medium	Low	Low
Size/Packaging	Small to large	Medium to small	Small to medium	Small to medium

RTD’s

Also called Platinum RTD because it is typically made of platinum. A change in temperature causes a change in resistance of platinum. This change can be measured with an ohmmeter.

Within a limited range, the resistance of metals increases in proportion to the temperature as defined by the formula:

$$R_t = R_0\left[1 + \alpha\left(t - t_0\right)\right]$$

where:

R_t = resistance at temperature t

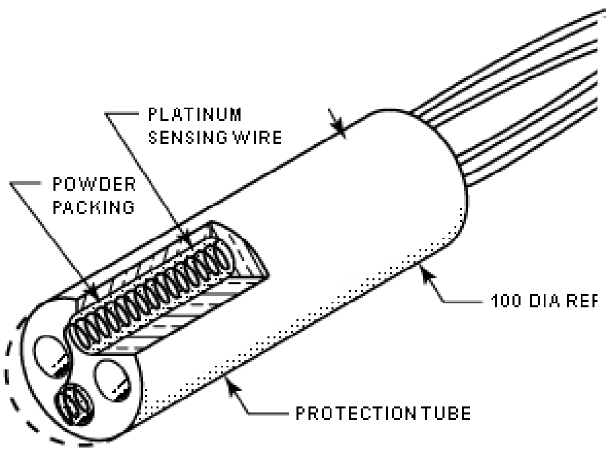
R_0 = resistance at a standard temperature t_0

α = temperature coefficient of resistance ($^{\circ}C^{-1}$)

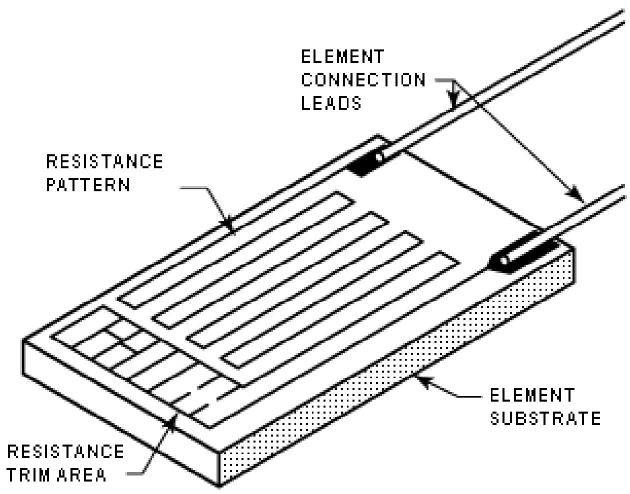
In theory, any metal could be used to measure temperature. The metal selected should have a high melting point and an ability to withstand the effects of corrosion. Platinum has therefore become the metal of choice for RTD's. Its desirable characteristics include chemical stability, availability in a pure form, and electrical properties that are highly reproducible.

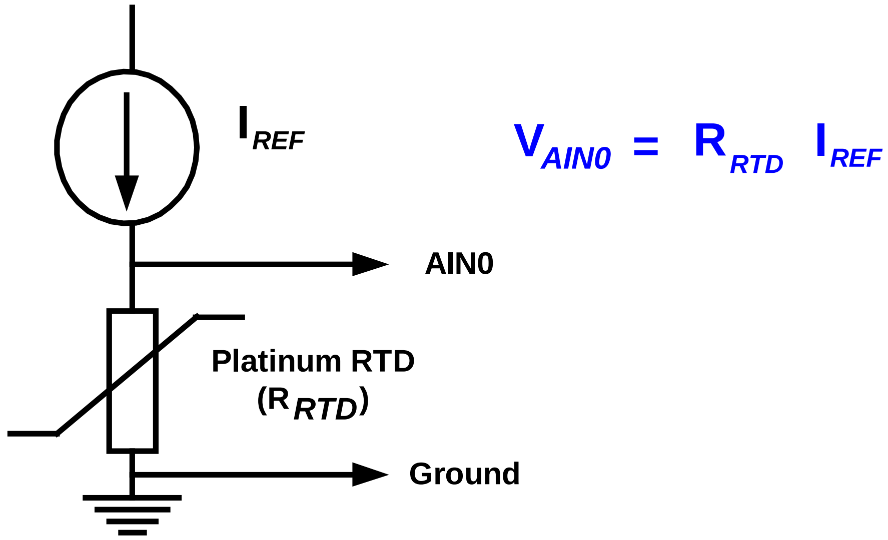
Typical readings for platinum are 100 ohms at 0 Celsius and 139 ohms at 100.

Wire-wound type

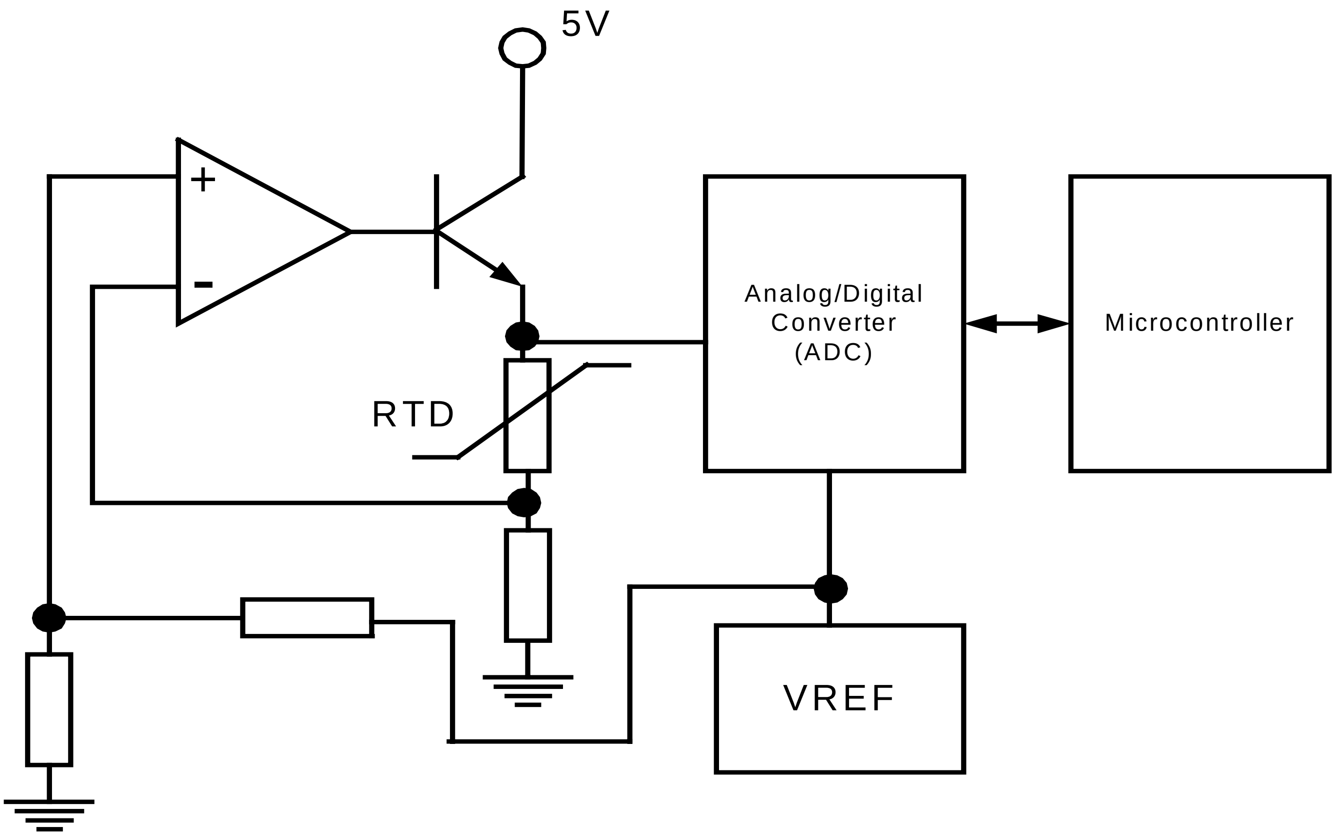


Thin film type





RTD’s require a constant current source, such as 1mA. Such a low current keeps the self heating to a minimum.



Thermistors

Thermistors are thermally sensitive resistors and have, according to type, a negative (NTC), or positive (PTC) resistance/temperature coefficient.

Manufactured from the oxides of the transition metals - manganese, cobalt, copper and nickel, NTC thermistors are temperature dependant semiconductor resistors. Operating over a range of -200°C to + 1000°C, they are supplied in glass bead, disc, chips and probe formats.

Thermistors are typically very low cost devices (under $1).

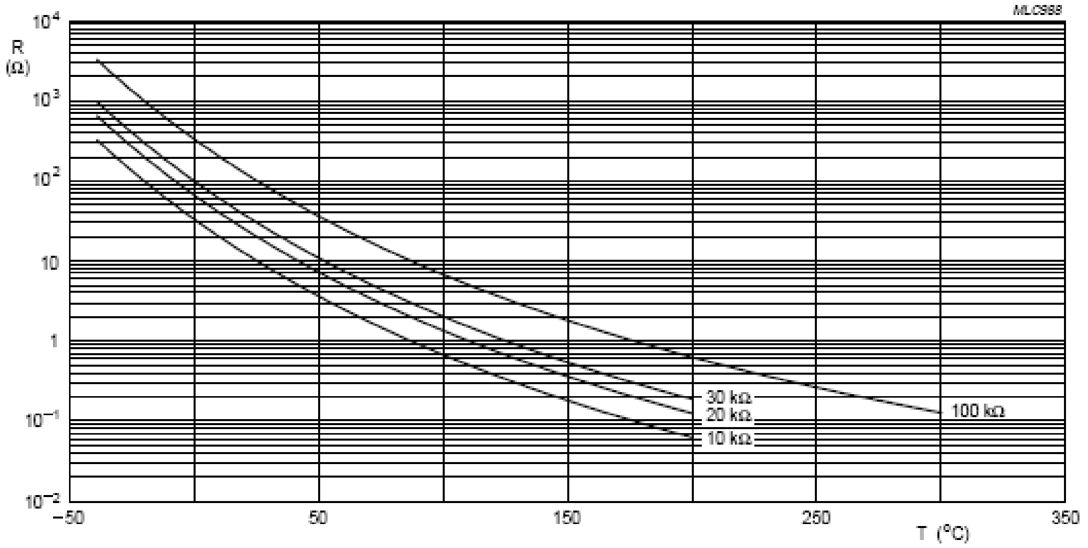
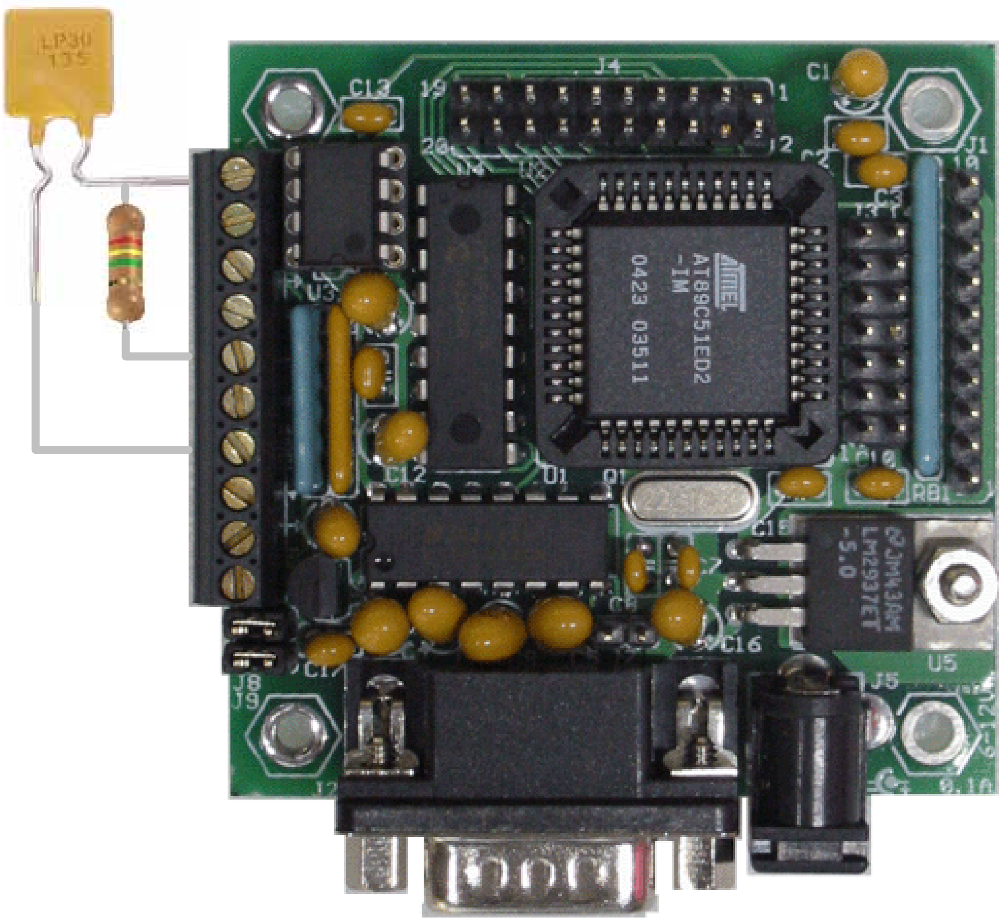
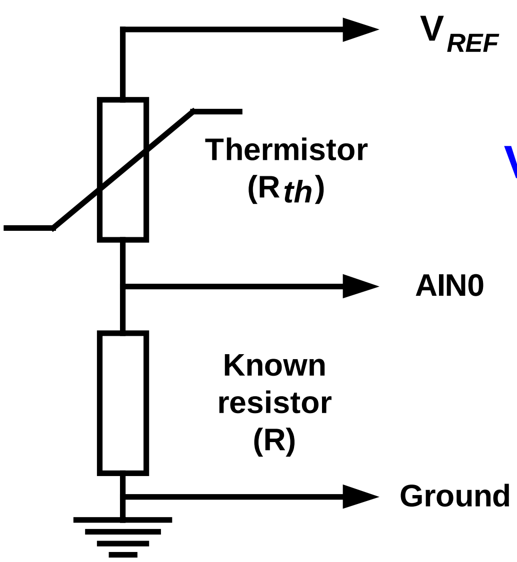


Fig.6 Typical R-T characteristics for the 2322 633 5/8.... series.





$$V_{AIN0} = \frac{R}{R + R_{th}} V_{REF}$$

Thermocouples

Thermocouples convert temperature to voltage. They rely on Seebeck effect which states that a junction of different metals will generate a voltage that is proportional to the temperature of the metals. Thermocouples are low cost temperature sensors, they are readily available from multiple sources and they can measure a wide range of temperatures that can not be measured with semiconductor type temperature sensor. For example, they can be used to measure the temperature of the inside of a ceramics kiln which can reach 1200 Celsius.

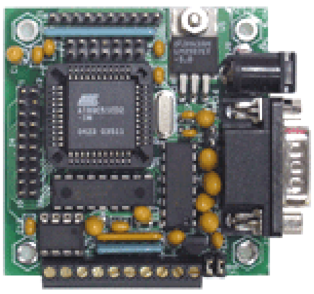
The temperature range of a thermocouple depends on the type of metals that make up the thermocouple. There are some industry standard types as shown in the table:

Type	Range (Celsius)	Range (Fahrenheit)	Features
E	95-900°C	200-1650°F	Highest Output
J	95-760°C	200-1400°F	
K	95-1260°C	200-2300°F	
T	0-350°C	32-660°F	

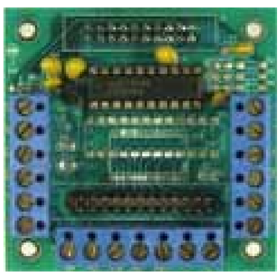
Thermocouples give out voltages in the range of micro volts so the output of a thermocouple must be amplified before it can be converted into a digital value.

BiPOM offers a dedicated thermocouple board **THERMOCOUPLE-1** that supports all the popular thermocouple types (jumper selectable) and accepts up to 4 thermocouples simultaneously.

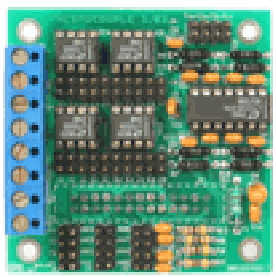
MINI-MAX/51-C2



DAQ-2543



THERMOCOUPLE-1



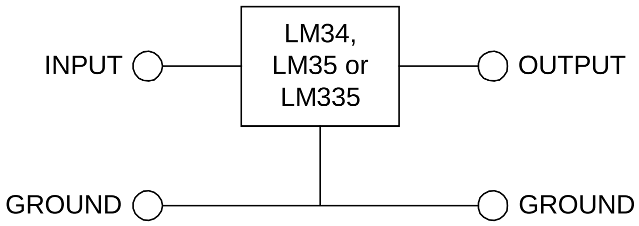
THERMOCOUPLES

Semiconductor Temperature Sensors

Analog

<u>Voltage Output</u>

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

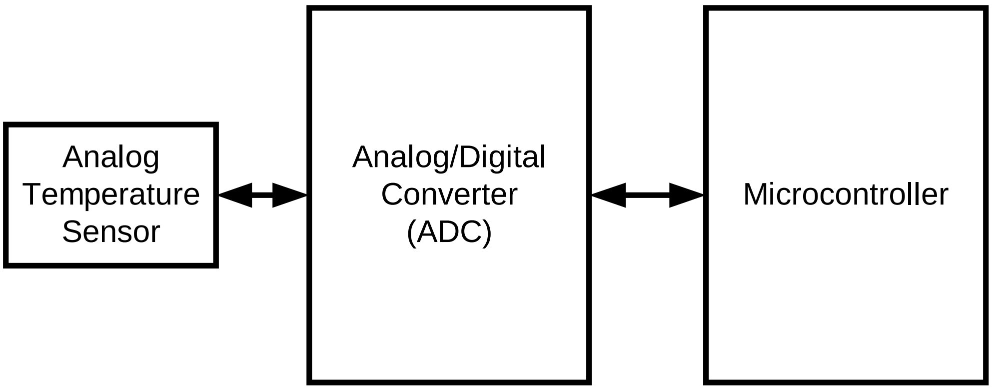


LM34: Fahrenheit sensor (10 millivolts/Fahrenheit)
LM35: Celsius sensor (10 millivolts/Celsius)
LM335: Kelvin sensor (10 millivolts/Kelvin)

<u>Current Output</u>

Typically 2-pin devices.

AD590: Kelvin sensor (1uA/Kelvin)



Digital

<u>Frequency Output</u>

MAX6576

<u>1-wire</u>

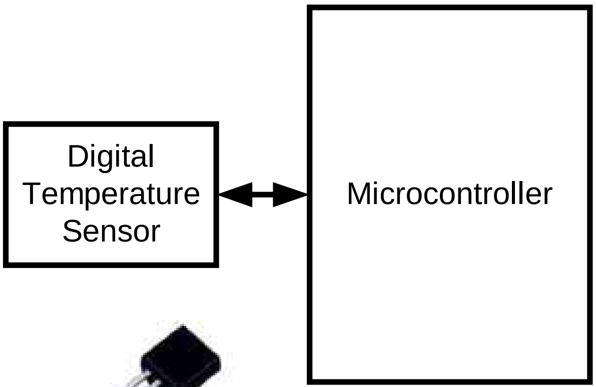
DS18B20

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

DS1621

<u>3-wire</u>

DS1620



Analog Digital Conversion

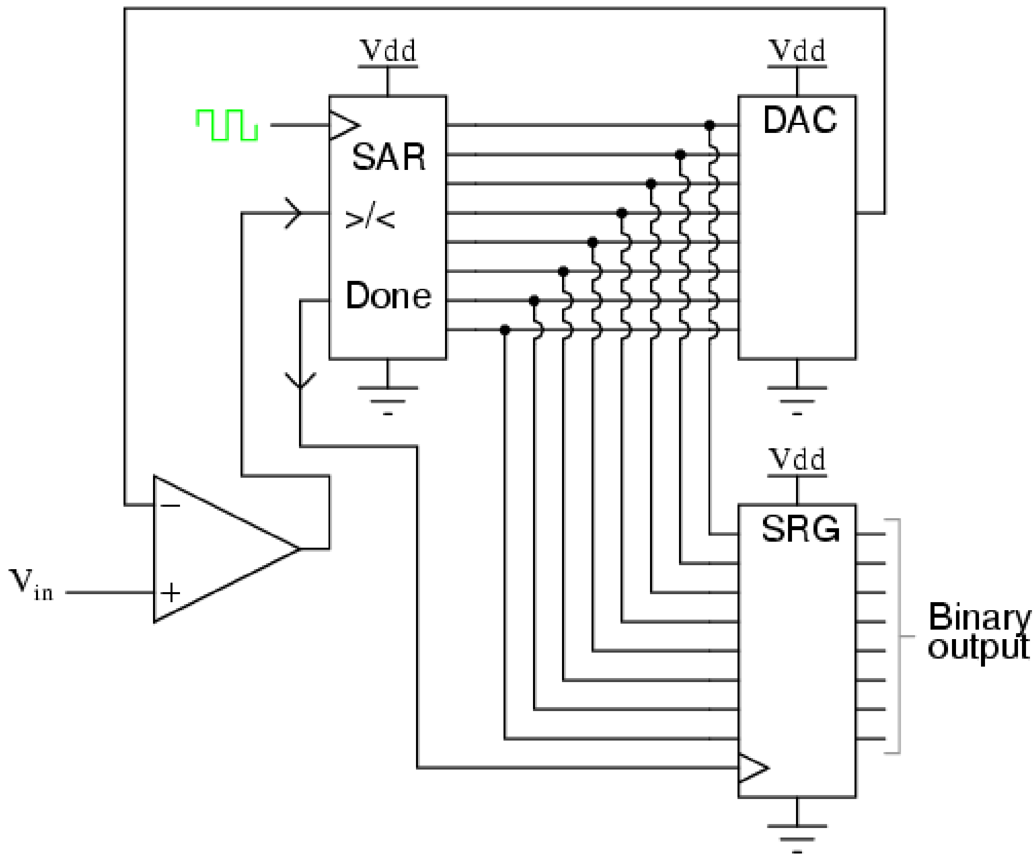
- Voltage to Frequency
- Flash ADC
- Successive Approximation
- Dual-Slope Integration
- Delta-Sigma

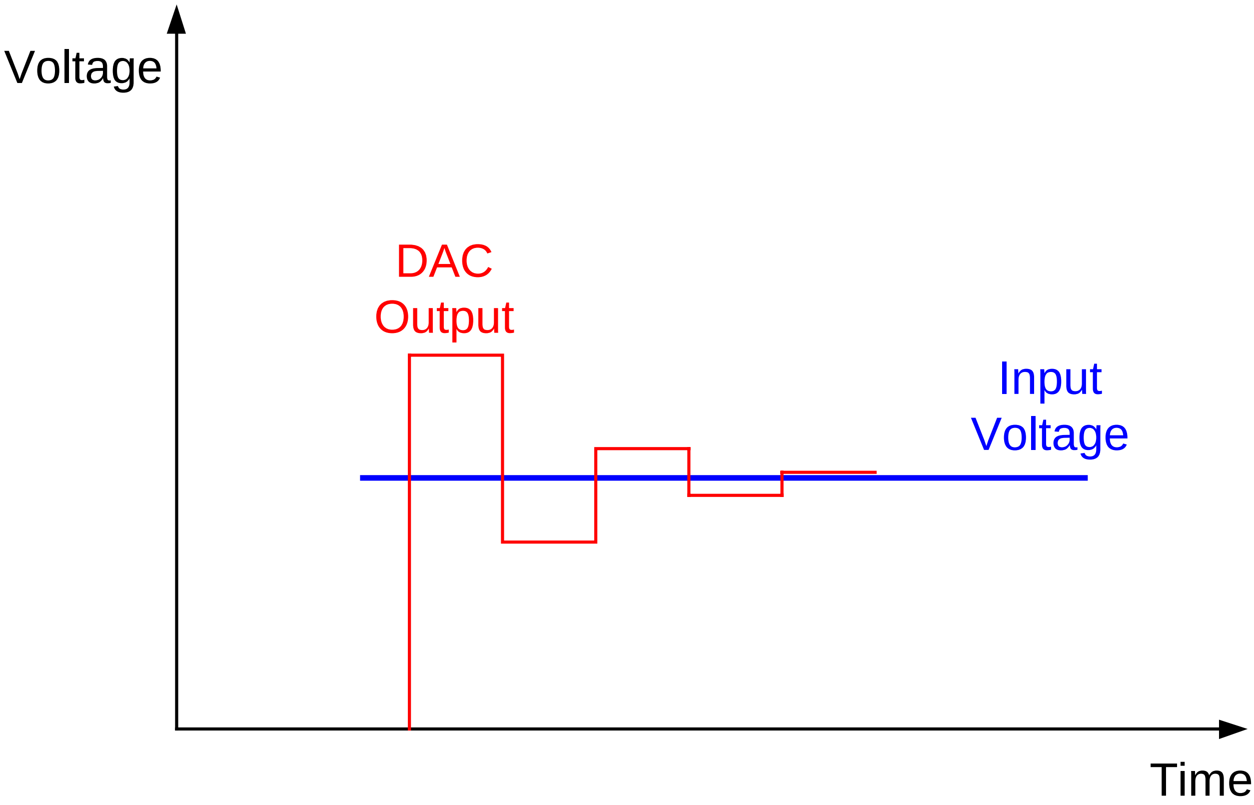
Successive approximation ADC

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

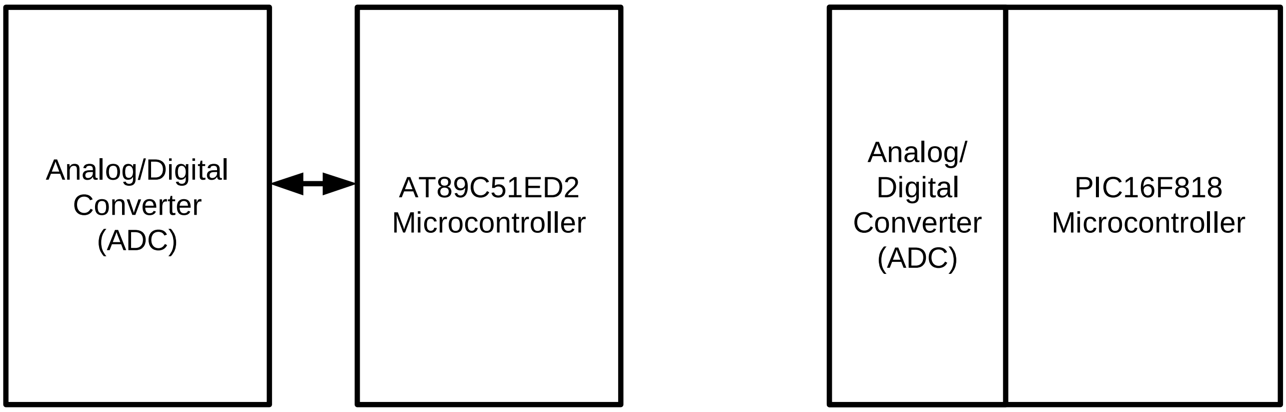
- Successive Approximation Register
- Result Register
- DAC
- Comparator

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.