Analog-to-Digital Conversion

Acknowledgements: Developed by Ui Luu and Manny Griego, Faculty of Glendale Community College, Glendale, Arizona.

Time Required: 1 hour

Equipment & Tools

- Internet connection
- Standard browsing (web surfing) capabilities

Team or Individual: This is an individual activity.

Learning Objectives

1. Complete a table of specifications for an analog-to-digital converter.
2. Calculate digital value for varying voltages applied to an analog-to-digital converter.
3. Determine the ADC readings that correspond to varying temperatures when given temperature characteristics of a thermistor.

Performance and Task Procedures

- Review the information presented in the Introduction below.
- Obtain an analog-to-digital converter data sheet from the Internet or other source.
- Use the formula to calculate digital values and resistance for different input temperatures.

Deliverables

- Completed table for converter specifications
- Completed table for ADC digital output as a function of temperature

Scoring or Grading Criteria: The decision to grade students on their deliverables is left to the instructor.

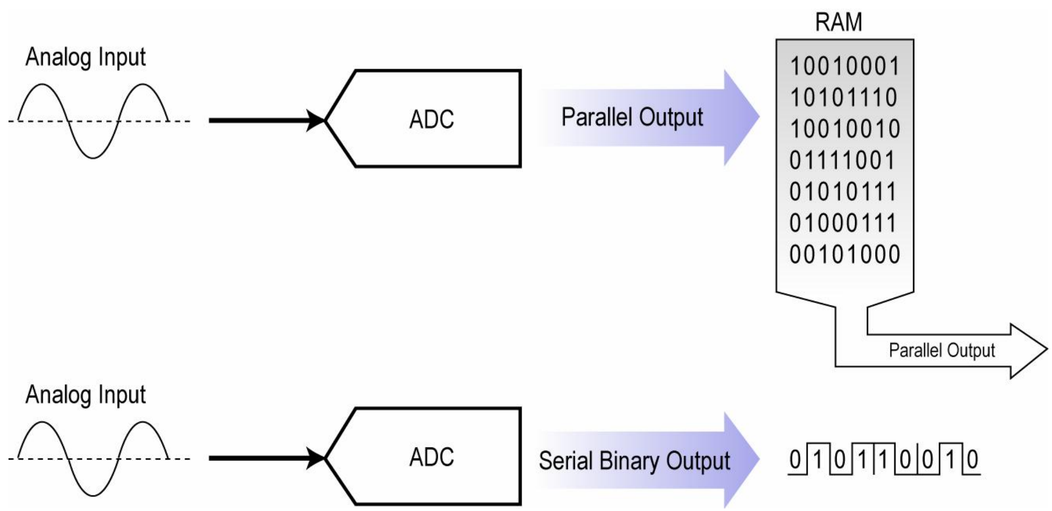
Introduction

Analog signals are voltages that vary smoothly and continuously over time. Examples include voice, music, video, and physical variations from sensors and transducers. A DC voltage is analog. In the past, analog signals were manipulated and processed with either analog or linear circuits like amplifiers, filters, mixers, or modulators/demodulators. Even though analog processing is still widely used, it has been largely replaced in electronic equipment.

Analog-to-digital conversion is carried out by a circuit called an analog-to-digital converter or A/D converter (ADC). The discovery and the low cost implementation of digital signal processing (DSP) has made digital processing both cheap and convenient. The availability of fast, very low cost microprocessors used in digital signal processing offers significant benefits over analog processing methods.

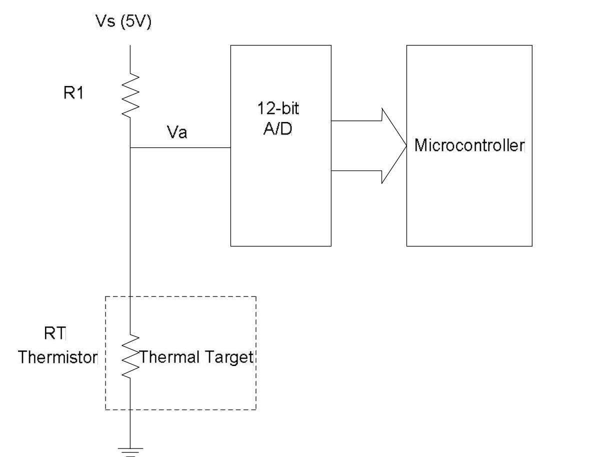
Some form of data conversion is necessary to put analog signals into digital form and then convert them back to analog after processing. Analog-to-digital conversion is the process of taking an analog signal and converting it into a sequence of fixed length and proportional binary numbers. The term digitize is often used to describe the ADC process. The binary numbers are processed, stored, and/or transmitted digitally.

The generic block shown here is used to represent an analog-to-digital converter (ADC). The input is an analog signal. The output is a sequence of parallel binary words. Some ADCs produce a serial binary output.



The two basic parts to ADC are sampling and quantization. Sampling means measuring the analog signal for a short instant at fixed time intervals. Quantization means converting the measured sample voltage into a proportional binary code.

In the example used for this drill down, a thermistor type sensor is used to monitor temperature. As illustrated by the temperature monitor system block diagram, temperature variation causes the thermistor resistance change and varies the analog input voltage.



Applying A/D in a Temperature Monitor system

In the temperature monitor system, the resistance of the thermistor (R_T) varies with temperature input. The thermistor has the following characteristics:

Temperature (° C)	R_T (Ohm)
25	1000
30	955
35	909
40	864
45	818
50	773
60	682
70	591
80	500

For example, at 60 degree C, $R_T = 682$ Ohm.

Recall Ohm's law: ($R_1 = 1000$ Ohm, $V_s = 5$ V)

$$V_a = [R_T/ (R_1+R_T)] \text{ x } V_s = [682/ (1000+682)] \text{ x } 5 = 2.027 \text{ V}$$

For a 12-bit system, the ADC digital output is:

$$\text{Digital Value} = (2.027/V_s) \text{ x } 4095 = 1660$$

As a result, when the microcontroller is reading the A/D input of 1660 counts, the system recognizes the thermal target temperature is 60 degree C.

Drill Down Procedure

1. Use Ohm's law and the formulas provided to calculate the digital values and input voltage for a 12 bit ADC with a 5 volt reference voltage and varying resistance values. Refer to the Temperature Monitor System diagram as needed. Record your answers in the table below.

   The formula for finding the voltage is: $V_a = (R_T / R_1 + R_T) \times V_s$

   The formula for finding the digital value is: Digital Value = (Analog Value/V_s) x 4095

   Given: $R_1 = 1000\ \Omega$

Temperature (° C)	RT (Ohm)	V_a	A/D Counts
25	1000		
30	955		
35	909		
40	864		
45	818		
50	773		
60	682		
70	591		
80	500		

2. Use a search engine such as Google or Yahoo or other technical magazines or books to locate a data sheet for a 12 bit analog-to-digital converter. The Web References section under Research and Resources lists some manufacturer's web sites as a starting point.
3. Copy or print out the data sheet to bring to class and share with other class members.
4. List the specifications for the ADC in the table on the next page.

Table 1

Manufacturer	
Web Site	
Part Number	
Conversion Method	
Dynamic Range	
Number Of Bits Of Resolution	
Signal to Noise Ratio (SNR)	
Effective Number of Bits (ENOB)	
Spurious Free Dynamic Range (SFDR)	
Cost	
Applications	