Data Converters

ELEC 330

Digital Systems Engineering

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Images Courtesy of Ramesh Gaonkar and Delmar Learning

THE CITADEL

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

Basic Concepts

- Analog Signals
  - Continuous
  - Infinite values in a given range
  - Example
    - Clock face with hands
- Digital Signals
  - Discrete values
    - On/Off
    - 1/0
  - Example
    - Digital clock

Basic Concepts

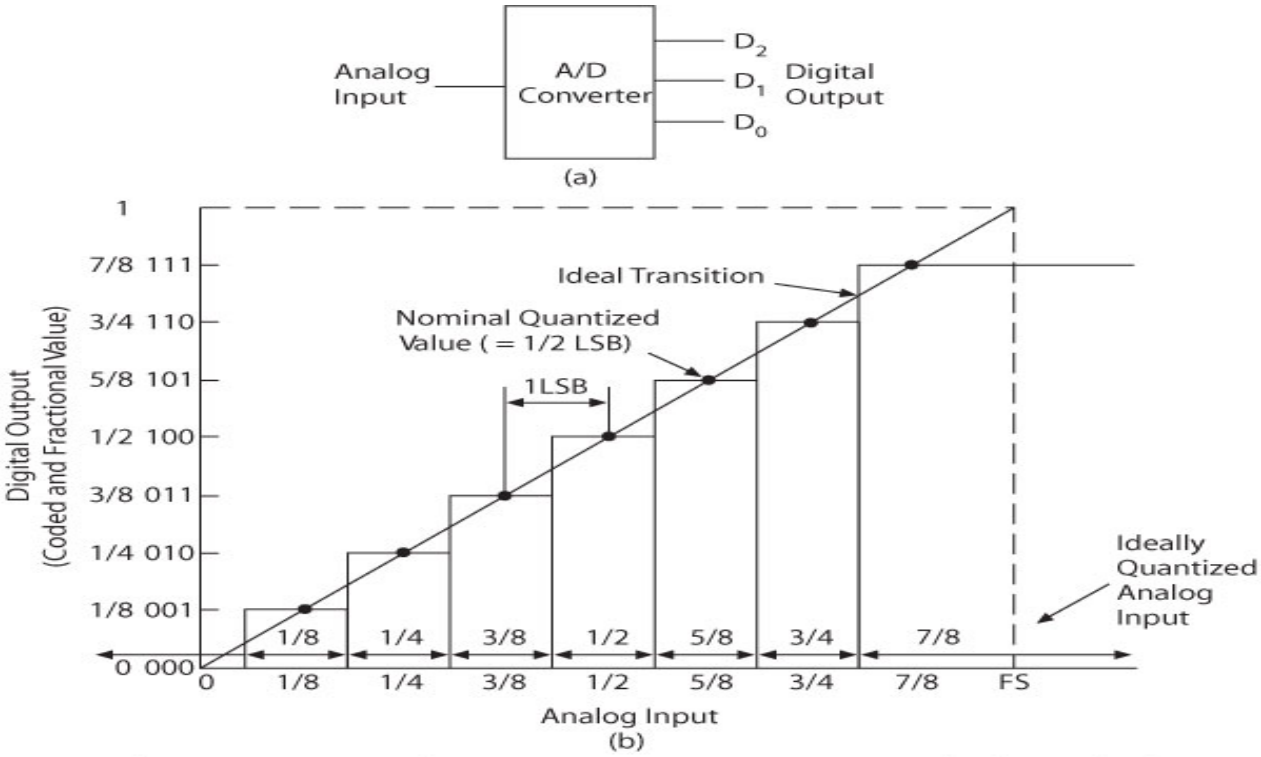
- Limitations of analog signals
  - Pick up noise as they are amplified
  - Difficult to store
- Advantages of digital signals
  - Noise margin
  - Easily stored in memory
- Limitations of digital signals
  - How accurately analog signals are represented
    - Quantization

Embedded System

- Typical analog/digital system
  - Transducer
    - Converts non-electrical signals into electrical signals
  - A/D converter
    - Converts analog signals into digital signals
  - Digital processor
    - Processes digital data
  - D/A converter
    - Converts digital signals into equivalent analog signals
  - Transducer
    - Converts electrical signals into non-electrical signals

Analog-to-Digital Conversion

- A/D, ADC, or A-to-D
  - Converting a continuous varying signal, such as voltage or current, into discrete digital quantities that represent the magnitude of the signal compared to standard or reference

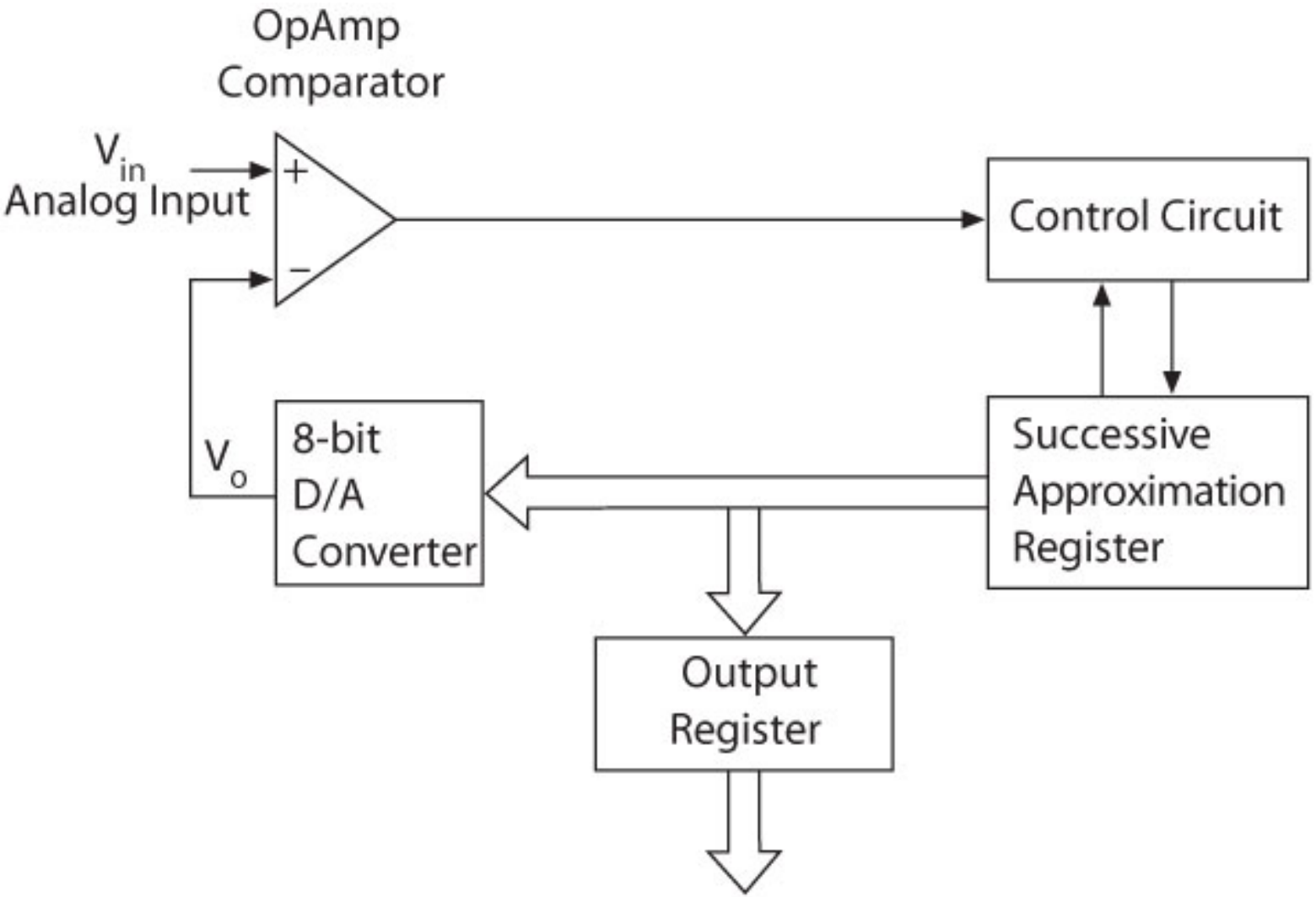


SOURCE: Analog Devices, Inc., Integrated Circuit Converters, Data Acquisition Systems, and Analog Signal Conditioning Components (Norwood, Mass.: Author, 1979), p. I–18.

A/D Conversion

- Flash
  - Uses multiple comparators in parallel
  - High-speed, high cost
- Integrator
  - Charges a capacitor for a given amount of time
  - Slow, but high accuracy and low noise
- Successive Approximation
  - Effective compromise among resolution, speed, and cost
- Counter
  - Similar to successive approximation circuit
  - Slower, with variable conversion times

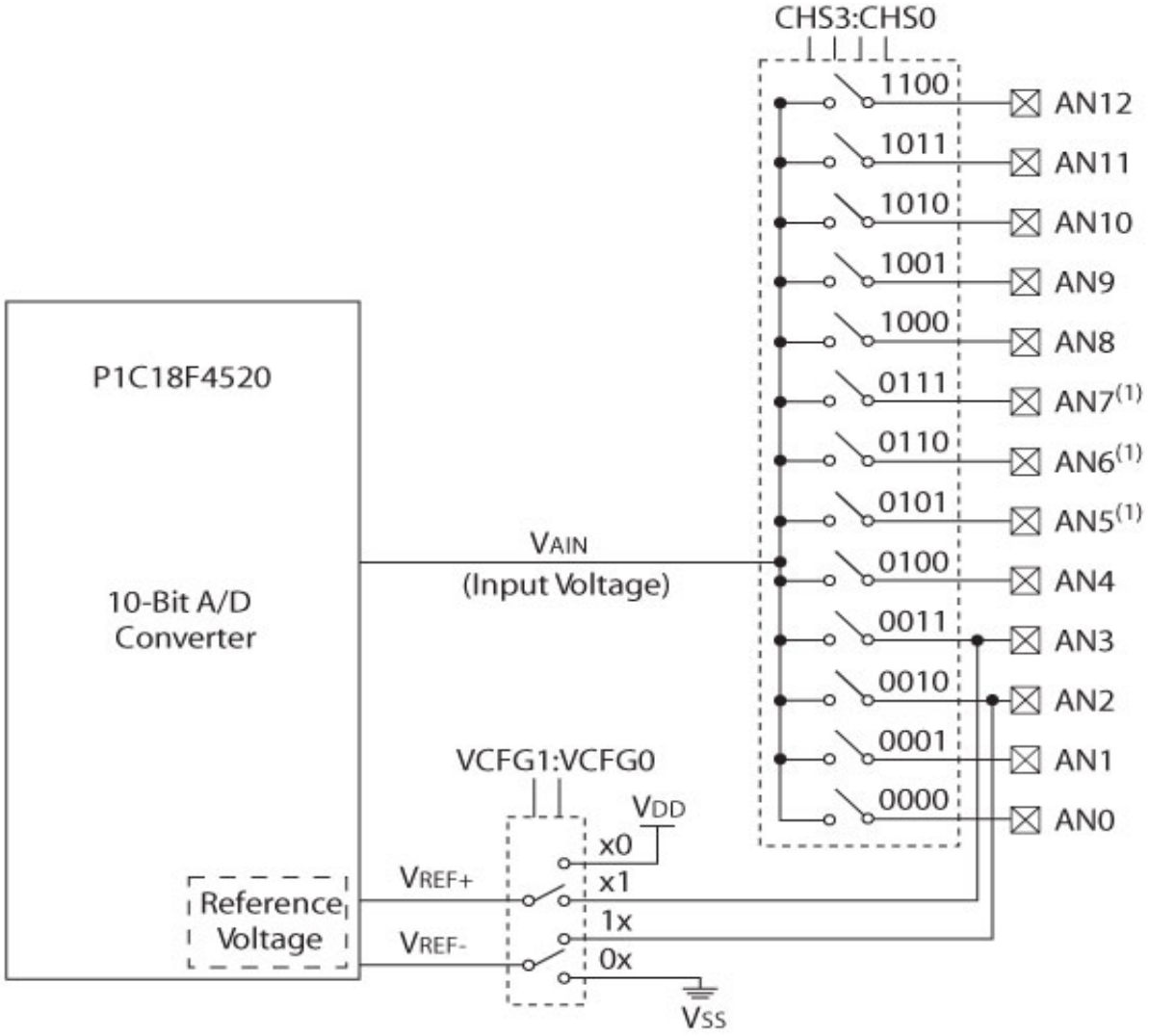
Successive Approximation



PIC18F A/D Converter Module

- The PIC18F4520
  - 10-bit A/D converter
  - 13 channels AN0 - AN12
  - Three control registers
    - ADCON0, ADCON1, and ADCON2
- The PIC18F452
  - 10-bit A/D converter
  - 8 channels AN0 - AN7
  - Two control registers
    - ADCON0 and ADCON1

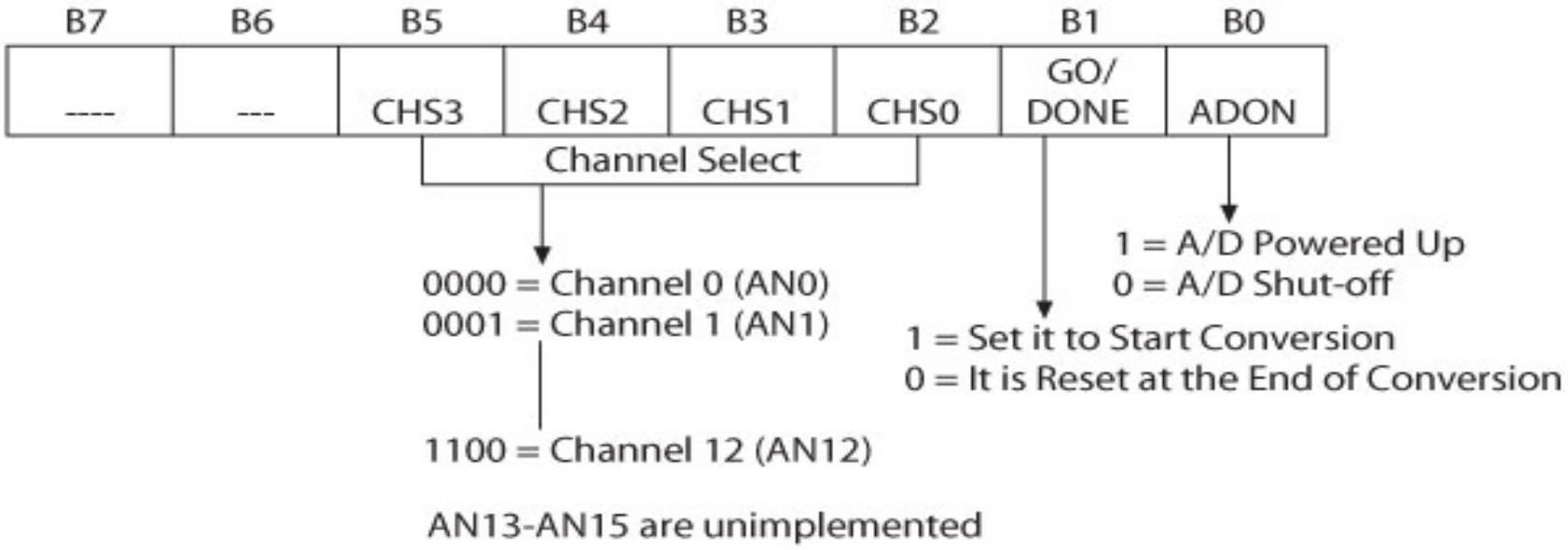
PIC18F4520 A/D Converter



Note 1: Channels AN5 through AN7 are not available on 28-pin devices.
2: I/O pins have diode protection to VDD and VSS.

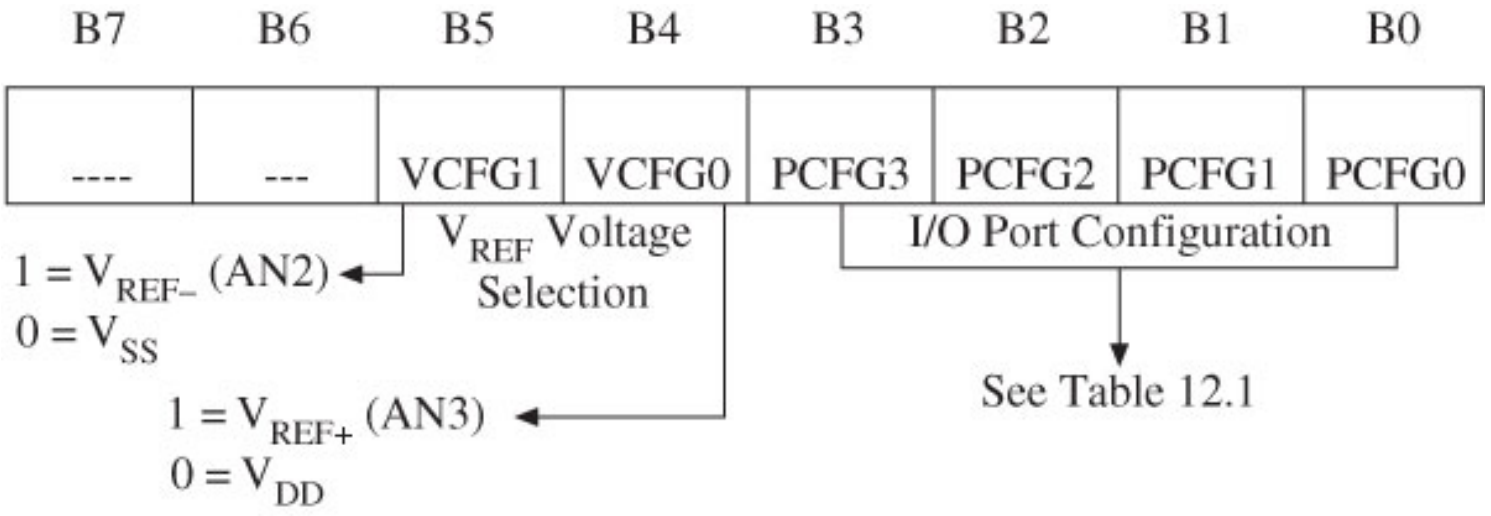
A/D Control Register0

- ADCON0 Register
  - Select channel for input analog signal
  - Start conversion
  - Indicate end of conversion



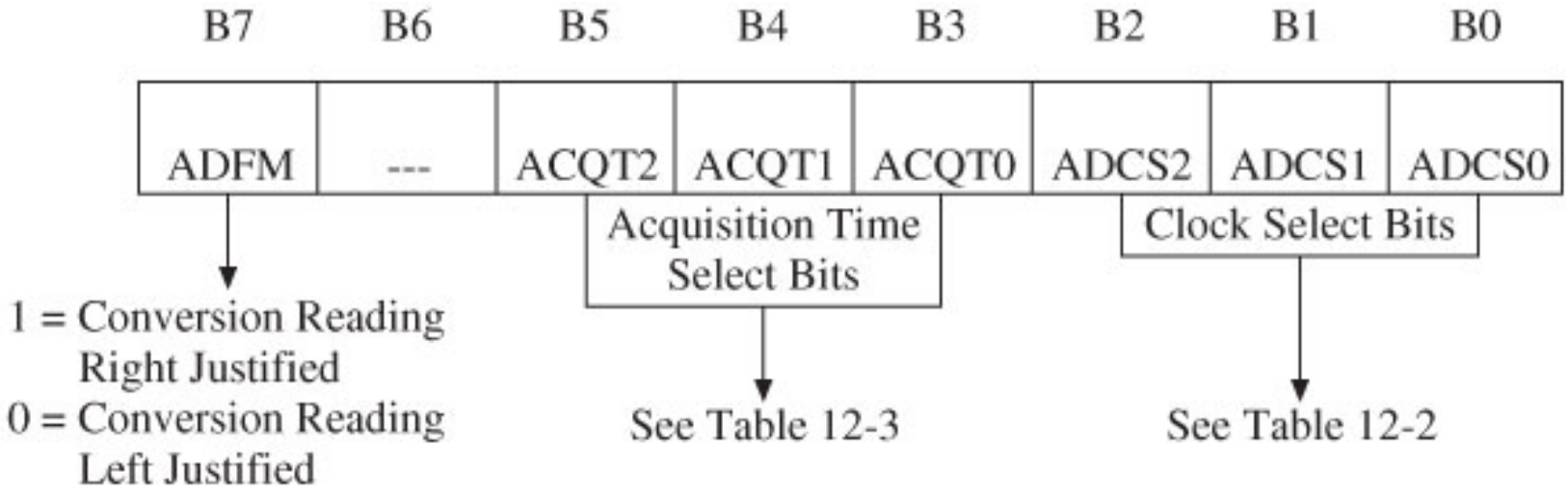
A/D Control Register1

- ADCON1 Register
  - Set up I/O pins
    - Analog signal or digital signals
  - Select V_{REF} voltages

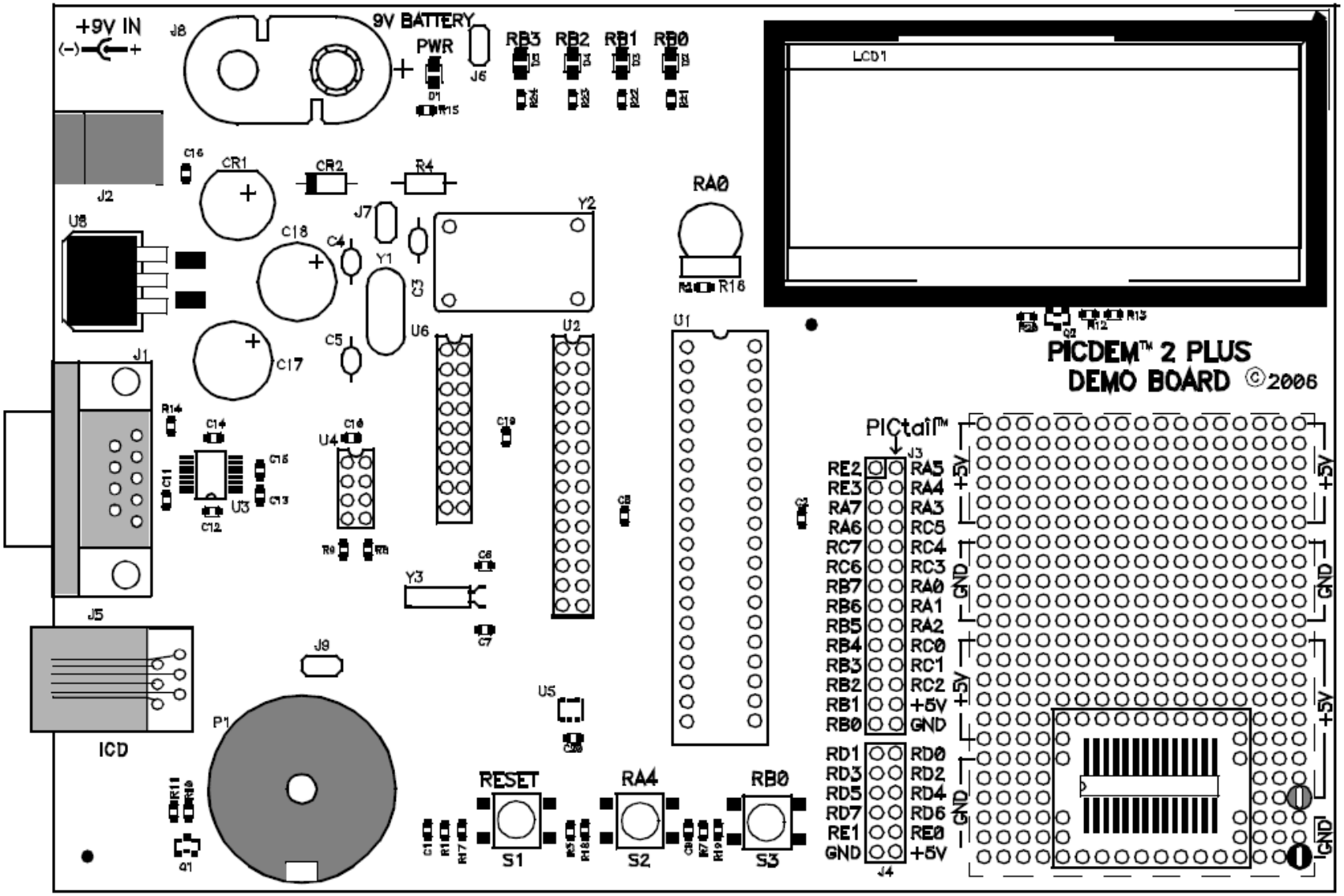


A/D Control Register2

- ADCON2 Register
  - Select acquisition time and clock frequency
  - Right or left justify output reading



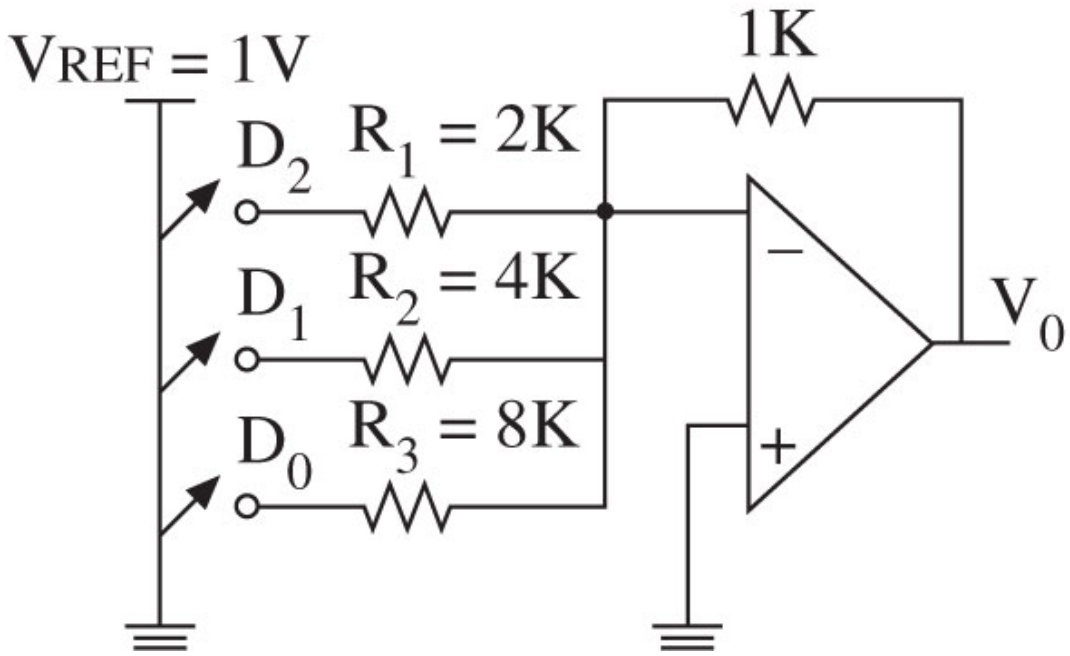
PICDEM 2 Plus



Digital to Analog Conversion

- D/A, DAC, or D-to-A
  - Converting discrete signals into analog values that represent the magnitude of the input signal compared to a standard or reference
    - Output is discrete analog steps
  - Increasing the resolution (number of bits)
    - Step size is reduced
    - Approximates a continuous analog signal

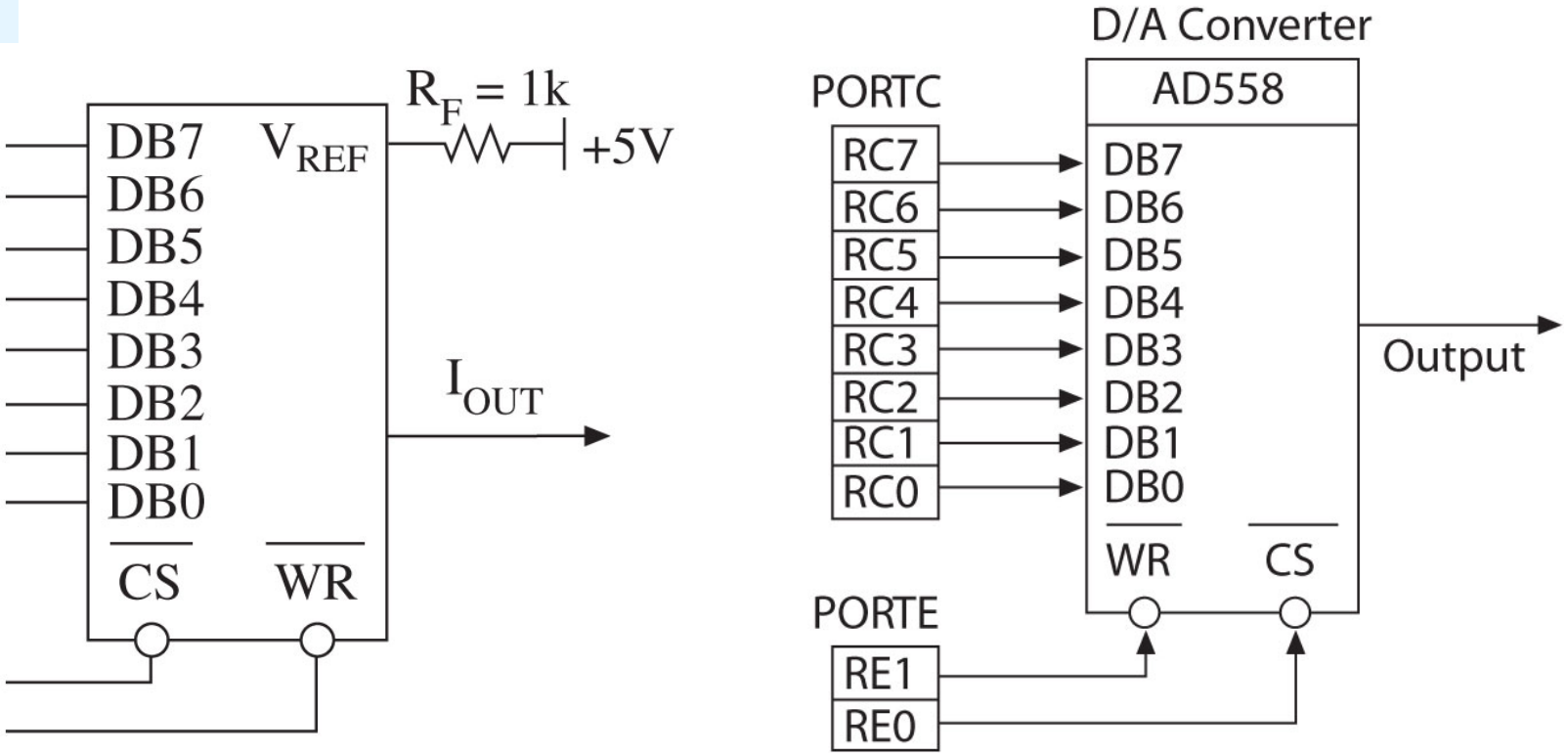
D/A Converter Circuits



$$I_o = I_T = I_1 + I_2 + I_3 = \frac{V_{REF}}{R_1} + \frac{V_{REF}}{R_2} + \frac{V_{REF}}{R_3} = \frac{V_{REF}}{1\,k}\left(\frac{1}{2} + \frac{1}{4} + \frac{1}{8}\right) = 0.875\,mA$$

$$V_O = -R_f I_T = -(1k)\times(0.875\ mA) = -0.875\ V = \left|\tfrac{7}{8}\ V\right|$$

IC D/A Converters



$$I_O = \frac{V_{REF}}{R_{REF}}\left(\frac{DB7}{2} + \frac{DB6}{4} + \frac{DB5}{8} + \ldots\ldots + \frac{DB0}{2^8}\right)$$

$$I_O = 5\text{ mA}\left(\frac{1}{2} + \frac{0}{4} + \frac{0}{8} + \frac{1}{16} + \frac{0}{32} + \frac{0}{64} + \frac{0}{128} + \frac{1}{256}\right) = 2.832\text{ mA}$$