Faculty of Engineering
Department of Electronics and Communications

GEE336
Electronic Circuits II

Lecture #10
ADC & DAC

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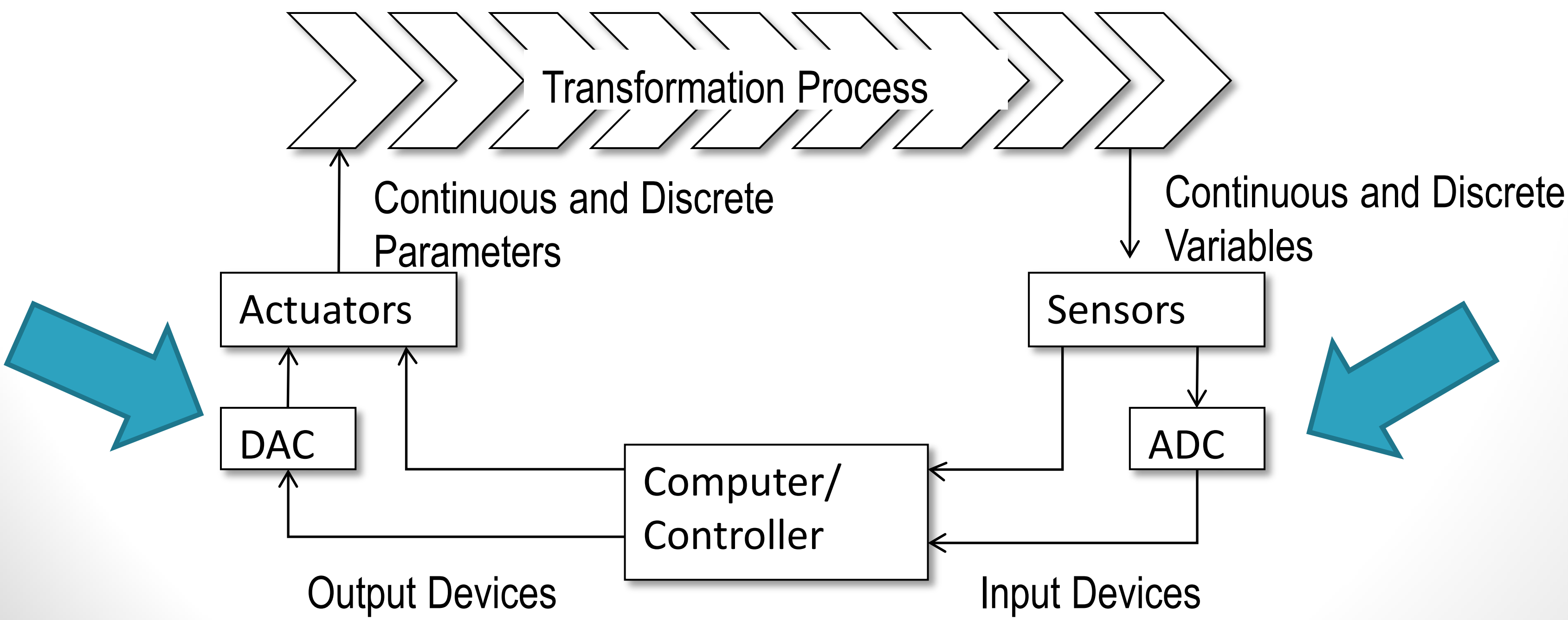
Agenda

- Introduction
- Analog-to-Digital Converter
- Digital-to-Analog Converter

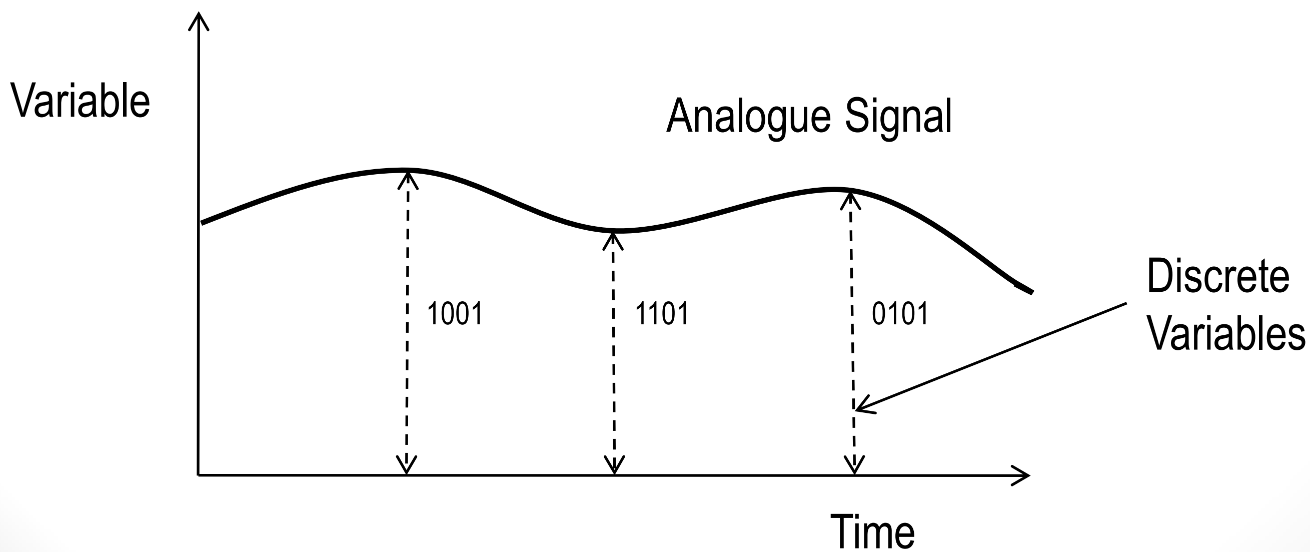
Computer Process Control System

- To implement process control, the computer must collect data and transmit signals to the production process.
- Components required to implement the interface:
  - Sensors to measure continuous and discrete process variables
  - Actuators to drive continuous and discrete process parameters
  - Devices for ADC and DAC
  - I/O devices for discrete data



Analog-to-Digital Conversion (ADC)

- **Sampling** – converts the continuous signal into a series of discrete analog signals at periodic intervals
- **Quantization** – each discrete analog is converted into one of a finite number of (previously defined) discrete amplitude levels
- **Encoding** – discrete amplitude levels are converted into digital code



Features of an ADC

- Sampling rate – rate at which continuous analog signal is polled e.g. 1000 samples/sec
- Quantization – divide analog signal into discrete levels $N_q = 2^n$
  - where N_q = quantisation levels; and n is the number of bits.
- Resolution – depends on number of quantization levels

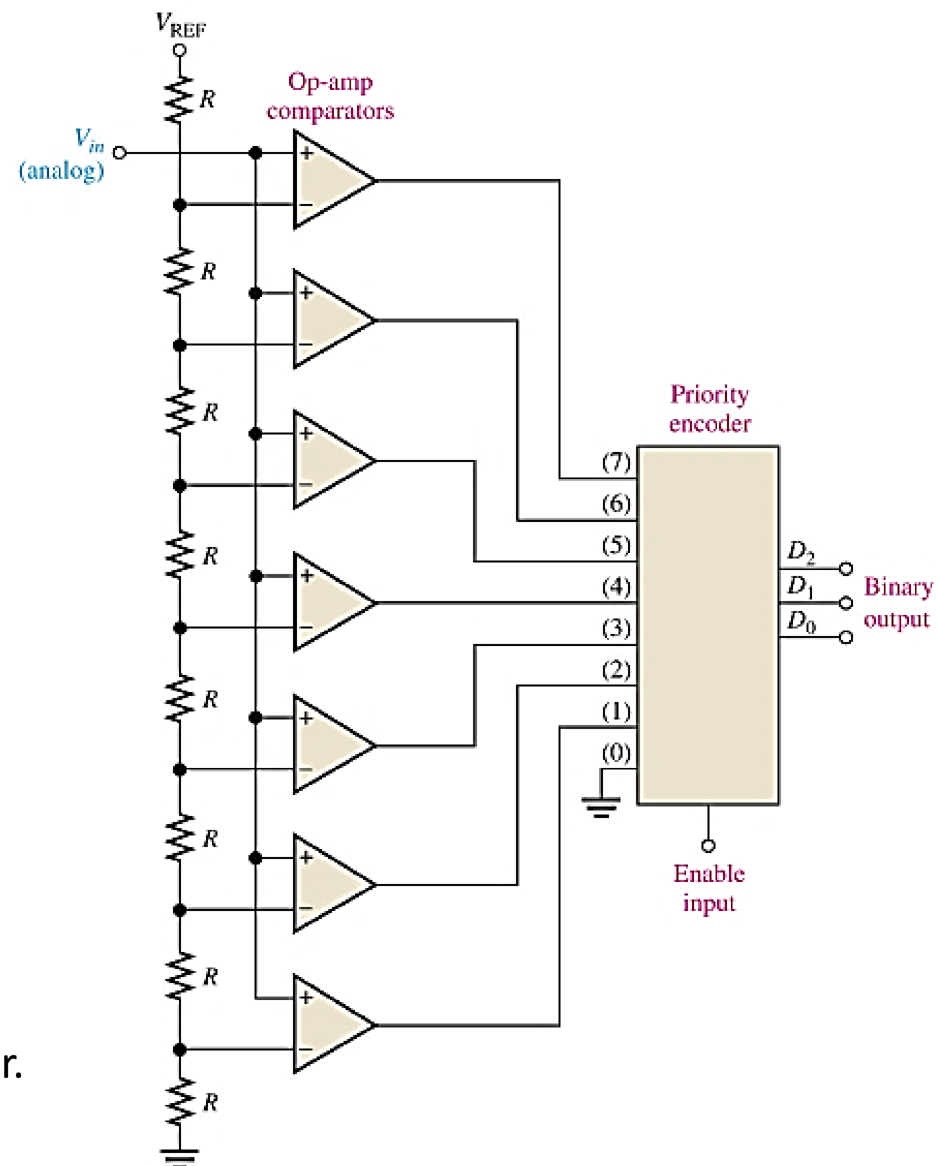
$$R_{ADC} = \frac{L}{N_q - 1} = \frac{L}{2^n - 1}$$

  - where R_{ADC} is the resolution of the ADC; L is the full-scale range of the ADC
- Conversion time – how long it takes to convert the sampled signal to digital code
- Conversion method – means by which analog signal is encoded into digital equivalent
  - Example – Successive approximation method & Flash

Flash ADC

- The **simultaneous**, or **flash**, method of A/D conversion uses **parallel comparators** to compare the linear input signal with **various reference** voltages developed by a voltage divider.
- When the **input** voltage **exceeds the reference** voltage for a given comparator, a **high level is produced** on that comparator's output.

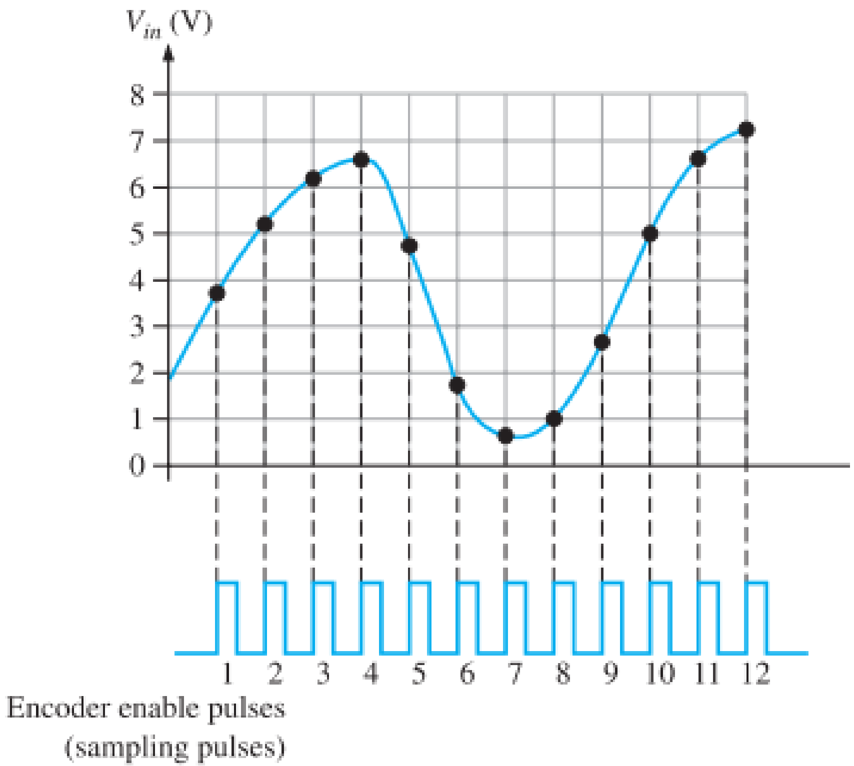
→**2^n- 1** comparators are required for conversion to an **n-digit** binary number.

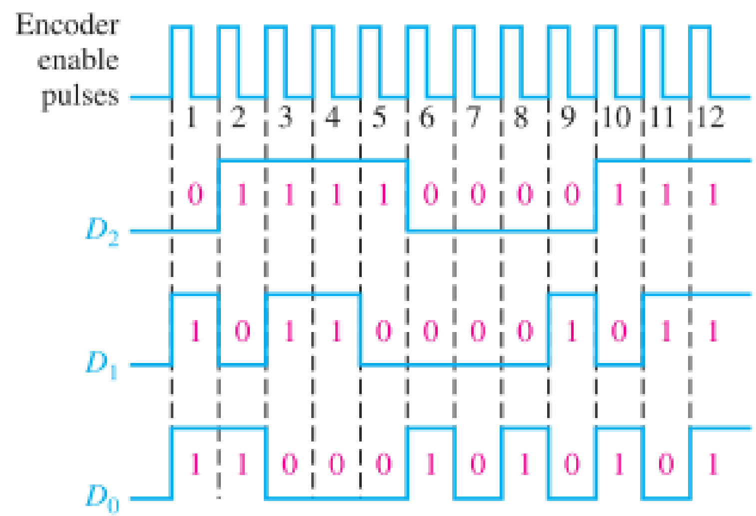


Example

EXAMPLE 13–4

Determine the binary number sequence of the three-digit simultaneous ADC in Figure 13–16 for the input signal in Figure 13–17 and the sampling pulses (encoder enable) shown. Draw the resulting digital output waveforms.





The resulting binary output sequence is listed as follows and is shown in the waveform diagram of Figure 13–18 in relation to the sampling pulses.

011, 101, 110, 110, 100, 001, 000, 001, 010, 101, 110, 111

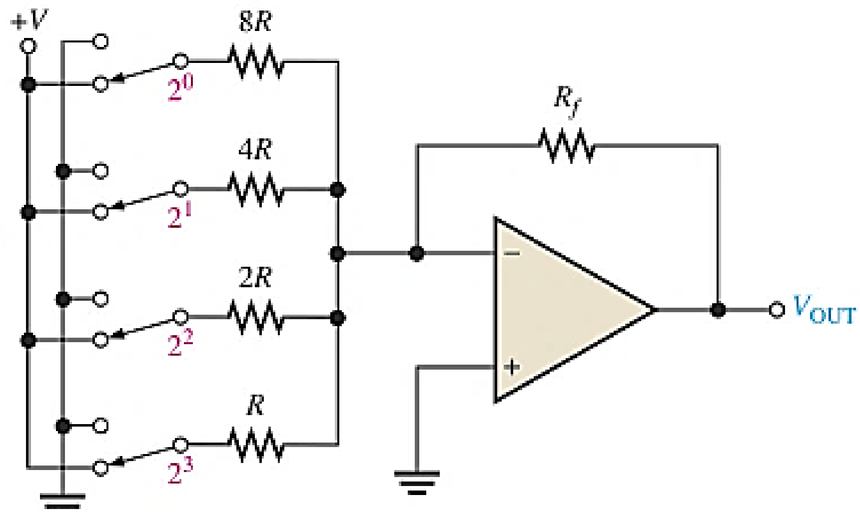
DAC

- Convert digital values into continuous analogue signal
  - Decoding digital value to an analogue value at discrete moments in time based on value within register

$$E_0 = E_{ref}\left\{0.5B_1 + 0.25B_2 + \cdots + \left(2^n\right)^{-1} B_n\right\}$$

Where E_0 is output voltage; E_{ref} is reference voltage; B_n is status of successive bits in the binary register

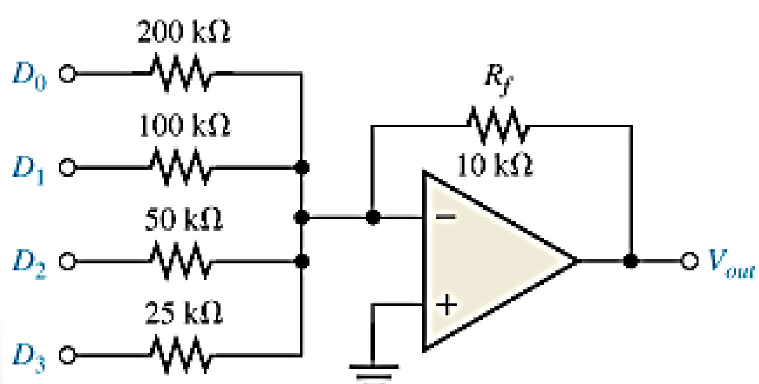
Scaling Adder as a four-digit DAC

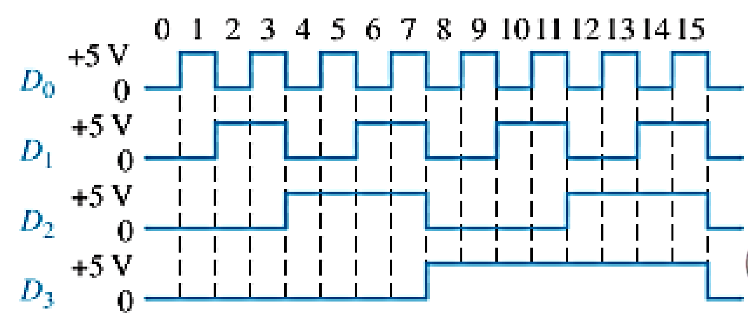


I_0=+V/8R
I_1=+V/4R
I_2=+V/2R
I_3=+V/R

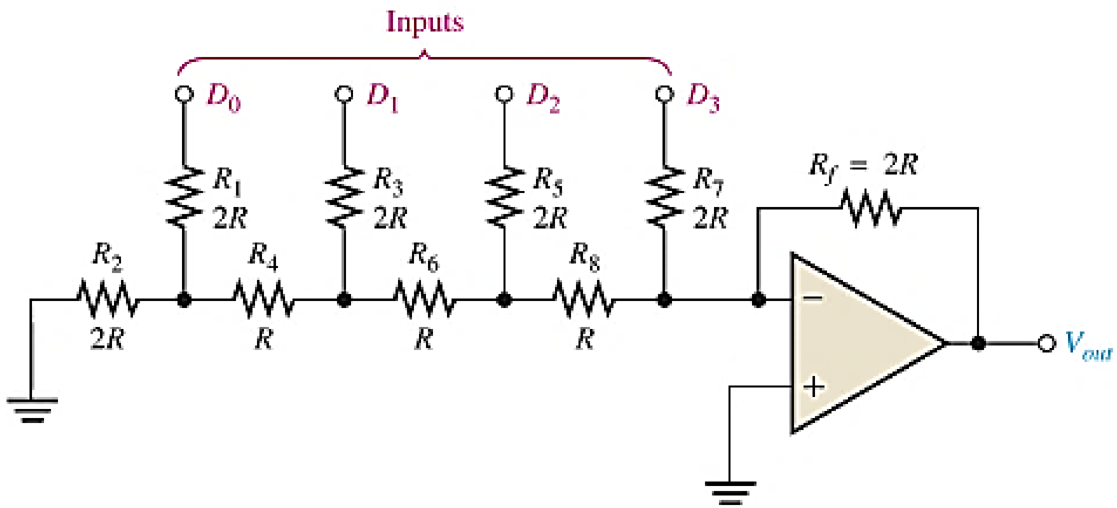
$V_{out(D0)}$=-R_f I_0
$V_{out(D1)}$=-R_f I_1
$V_{out(D2)}$=-R_f I_2
$V_{out(D3)}$=-R_f I_3

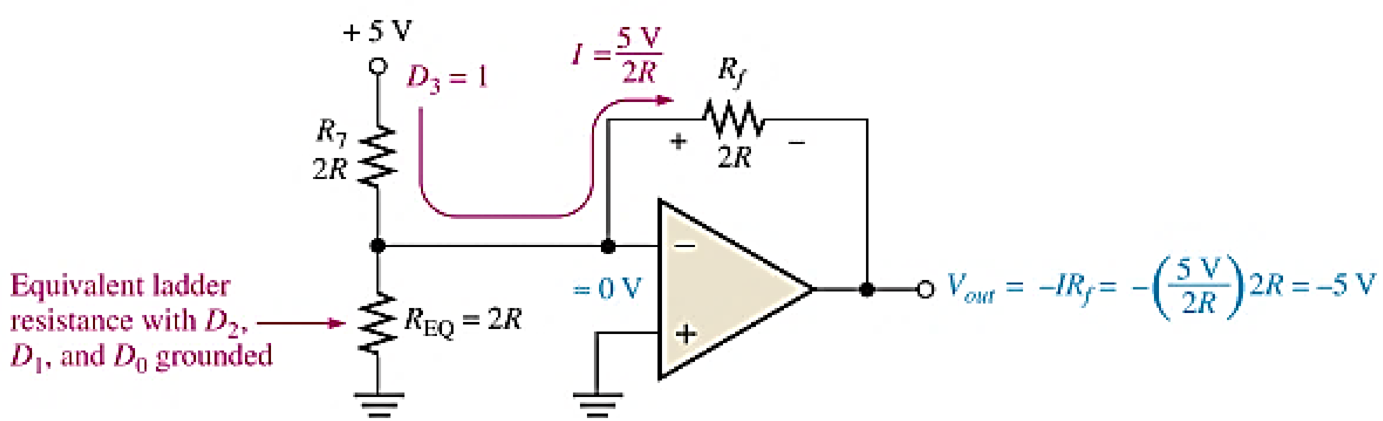
- Example 13-9





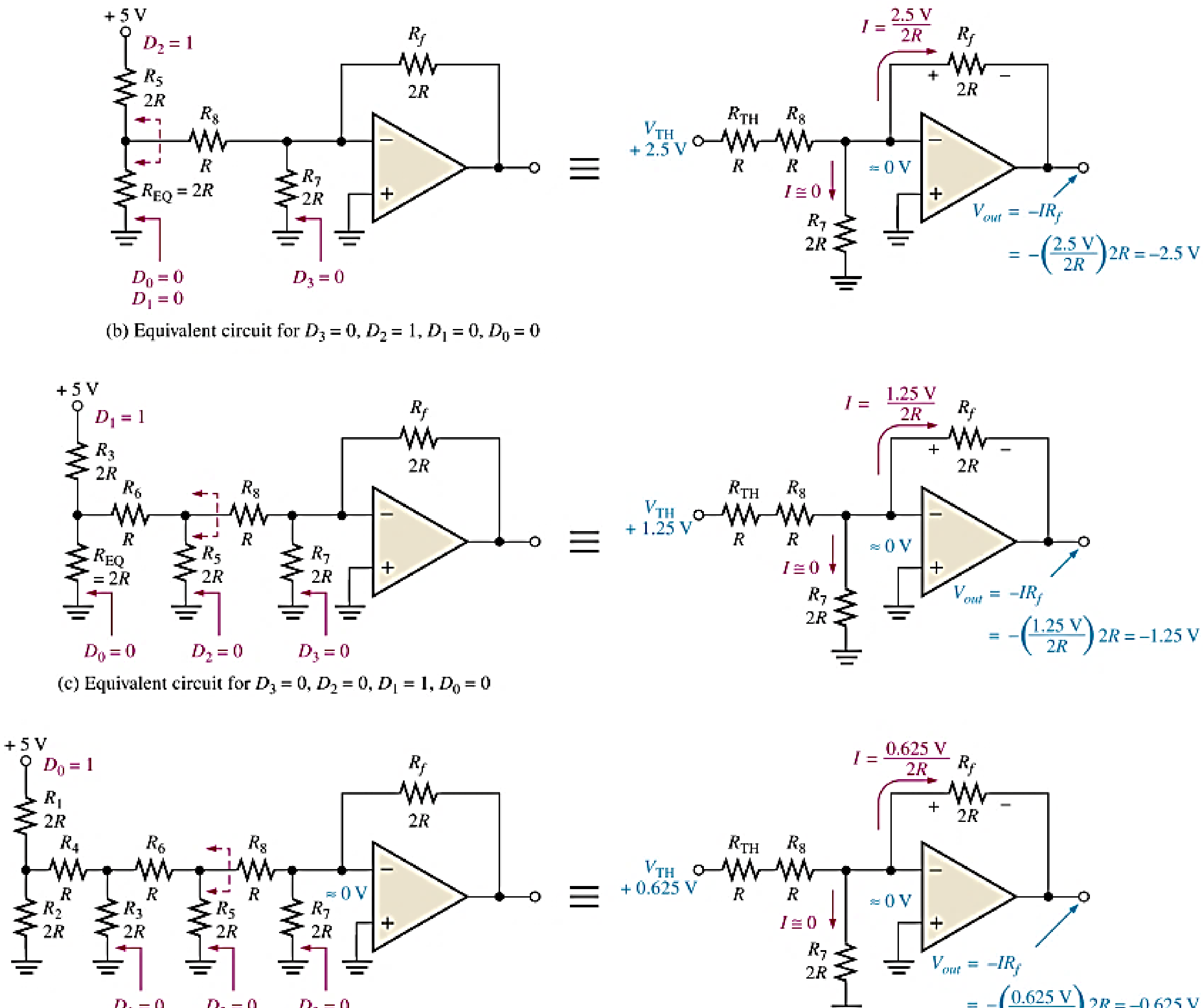
R/2R ladder DAC





(a) Equivalent circuit for $D_3 = 1, D_2 = 0, D_1 = 0, D_0 = 0$

An R/2R ladder DAC ..



(b) Equivalent circuit for $D_3 = 0, D_2 = 1, D_1 = 0, D_0 = 0$

(c) Equivalent circuit for $D_3 = 0, D_2 = 0, D_1 = 1, D_0 = 0$

(d) Equivalent circuit for $D_3 = 0, D_2 = 0, D_1 = 0, D_0 = 1$

▲ **FIGURE 13–30**

Analysis of the *R*/2*R* ladder DAC.

- For more details, refer to:
  - Chapter 13 at T. Floyd, **Electronic Devices**,9th edition.
- The lecture is available online at:
  - http://bu.edu.eg/staff/ahmad.elbanna-courses/12884
- For inquires, send to:
  - ahmad.elbanna@feng.bu.edu.eg