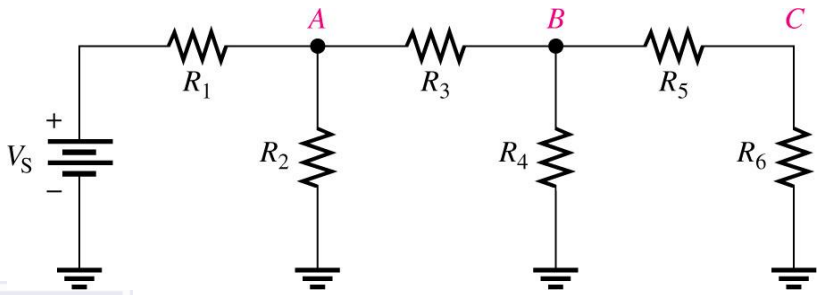
FACULTY OF ENGINEERING & TECHNOLOGY

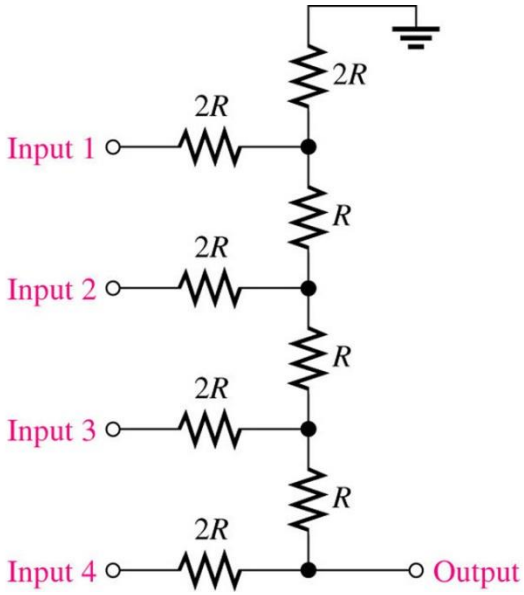
Digital to Analog (D/A, DAC, or D-to-A) Conversion

- Converting discrete signals into discrete analog values that represent the magnitude of the input signal compared to a standard or reference voltage
  - The output of the DAC is discrete analog steps.
  - By increasing the resolution (number of bits), the step size is reduced, and the output approximates a continuous analog signal.

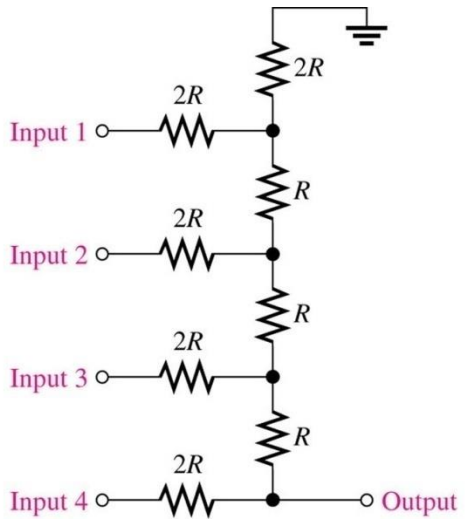
Analysis of a Ladder Network

- A resistive ladder network is a special type of series-parallel circuit.
- One form of ladder network is commonly used to scale down voltages to certain weighted values for digital-to-analog conversion
  - Called R/2R Ladder Network
- To find total resistance of a ladder network, start at the point farthest from the source and reduce the resistance in steps.

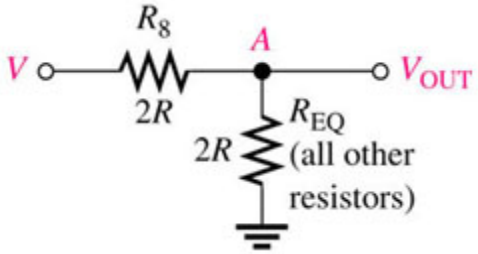




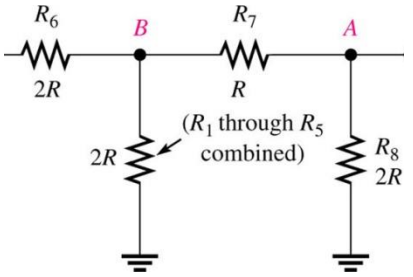
The R/R2 Ladder Network



Only Input 4 is HIGH

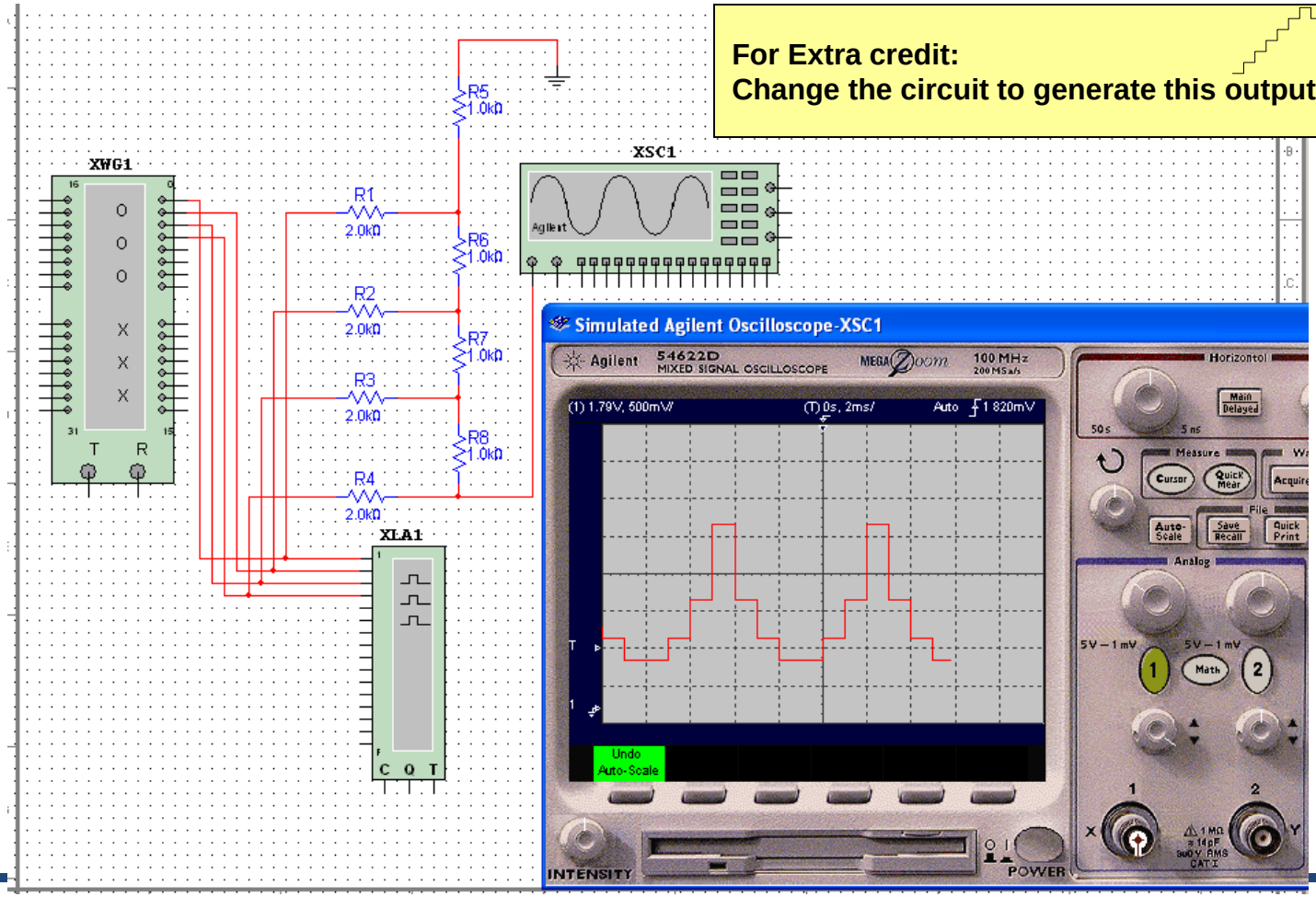


Only Input 3 is HIGH

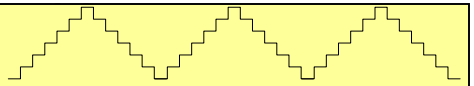


Used for Digital-to-analog converter!

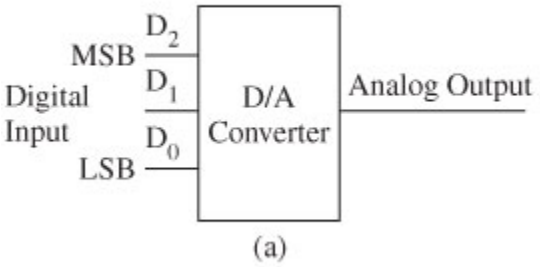
Examining Digital-to-Analog Conversion



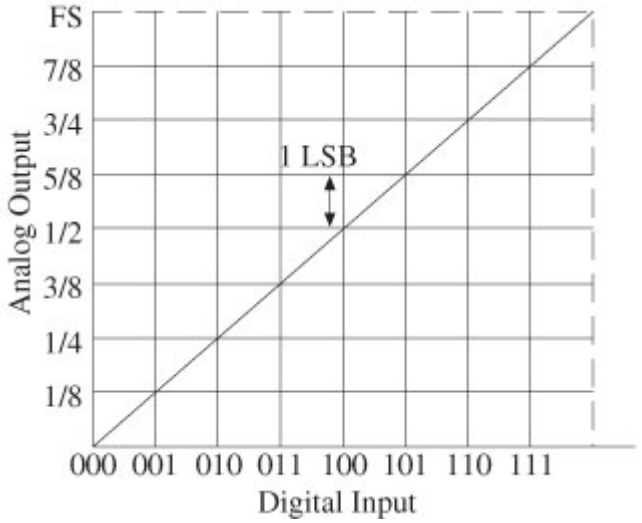
For Extra credit:
Change the circuit to generate this output:



- The resolution of a DAC is defined in terms of bits—the same way as in ADC.
- The values of LSB, MSB, and full-scale voltages calculated the same way as in the ADC.
- The largest input signal 111 is equivalent of 7/8 of the full-scale analog value.

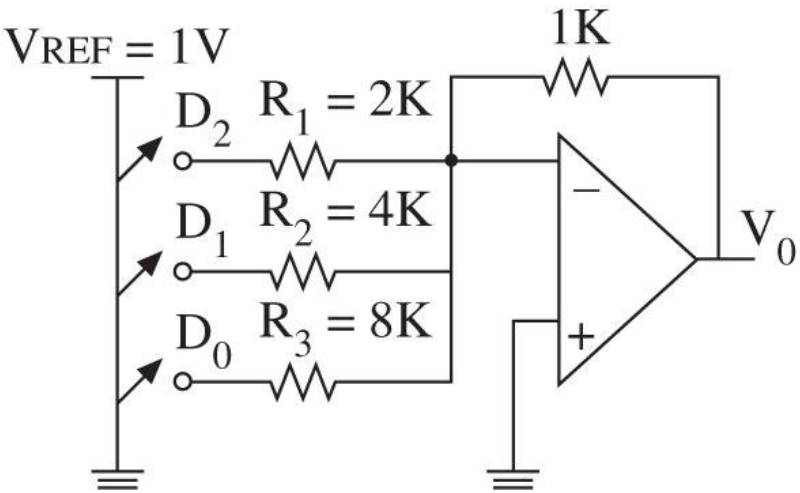


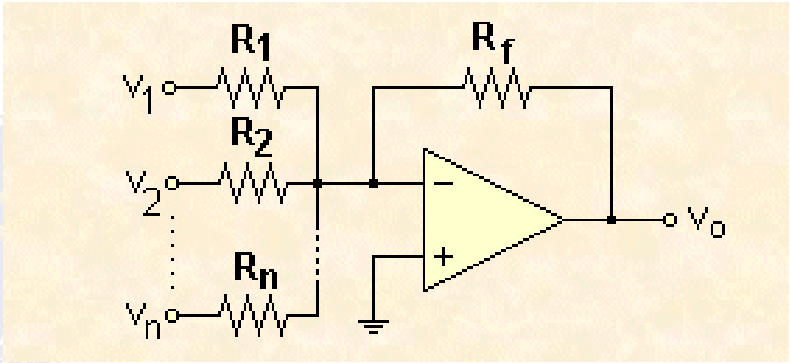
(a)



- Can be designed using an operational amplifier and appropriate combination of resistors
- Resistors connected to data bits are in binary weighted proportion, and each is twice the value of the previous one.
- Each input signal can be connected to the op amp by turning on its switch to the reference voltage that represents logic 1.
  - If the switch is off, the input signal is logic 0.

- 3-bit D/A Converter Circuit





The transfer function of the summing amplifier :

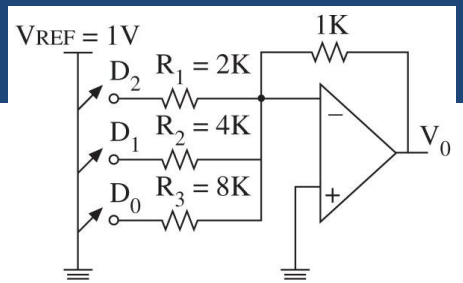
vo = -(v1/R1 + v2/R2 + … + vn/Rn)Rf

Thus if all input resistors are equal, the output is a scaled sum of all inputs.

If they are different, the output is a weighted linear sum of all inputs.

Summing amplifier

- R/2R Ladder Network for D/A Converter



- If the reference voltage is 1 V, and if all switches are connected, the output current can be calculated as follows:

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

- Output voltage

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

D/A Converters as Integrated Circuits

- D/A converters are available commercially as integrated circuits
- Can be classified in three categories.
  - Current output, voltage output, and multiplying type
    - Current output DAC provides the current I_O as output signal
    - Voltage output D/A converts I_O into voltage internally by using an op amp and provides the voltage as output signal
    - In multiplying DAC, the output is product of the input voltage and the reference source V_{REF}.
  - Conceptually, all three types are similar