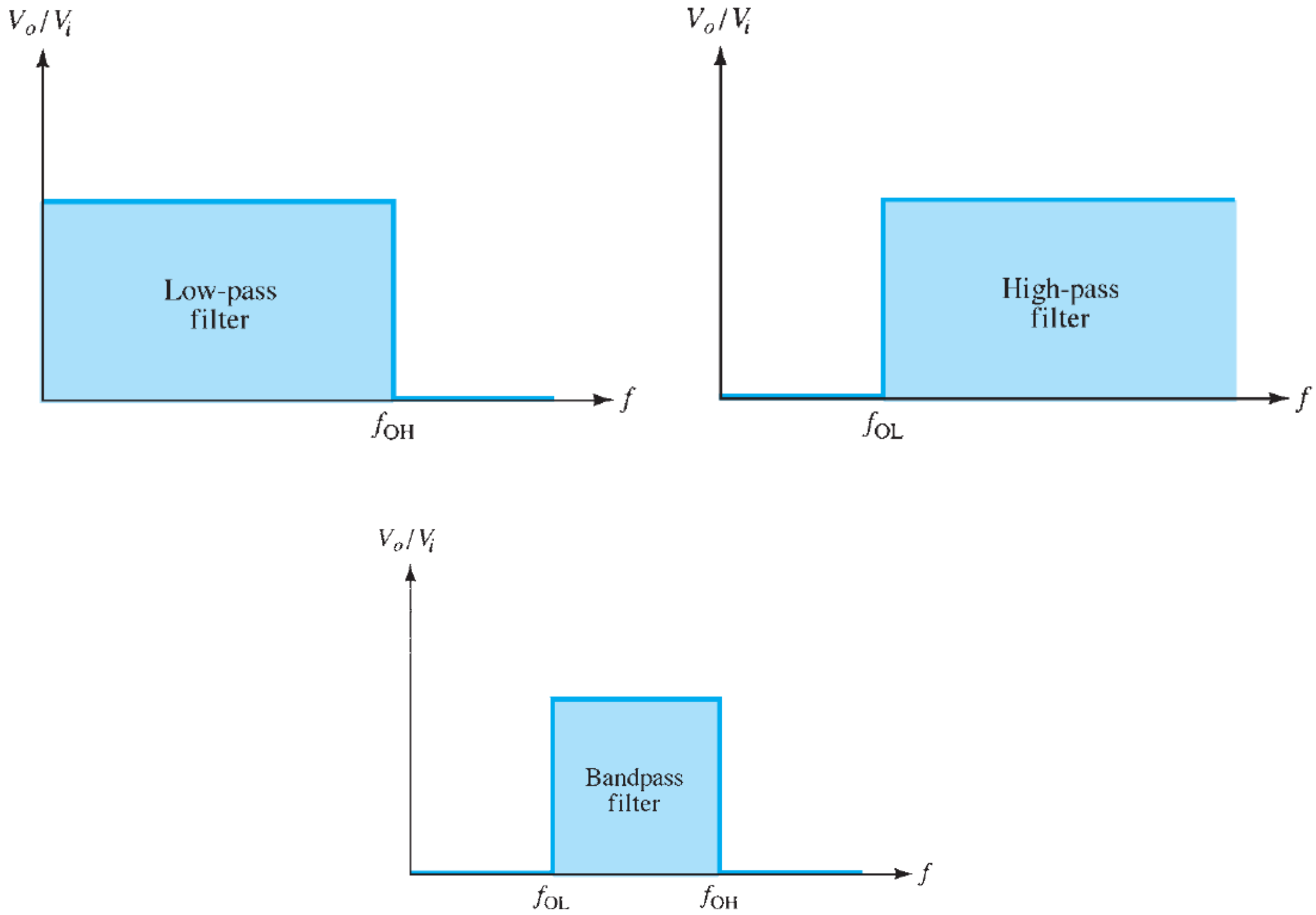
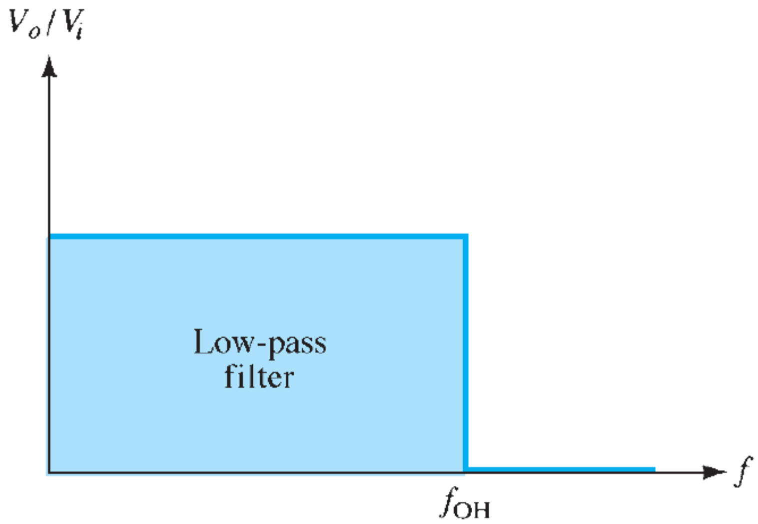
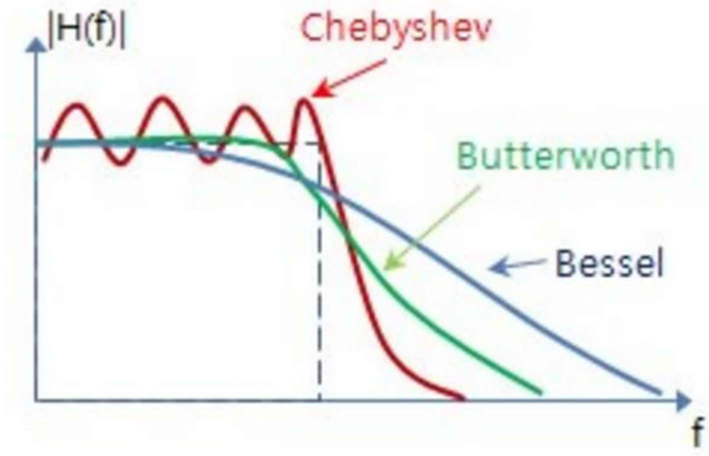
Active Filters

Active Filters

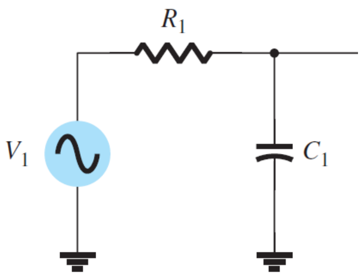


Ideal and Practical Filters

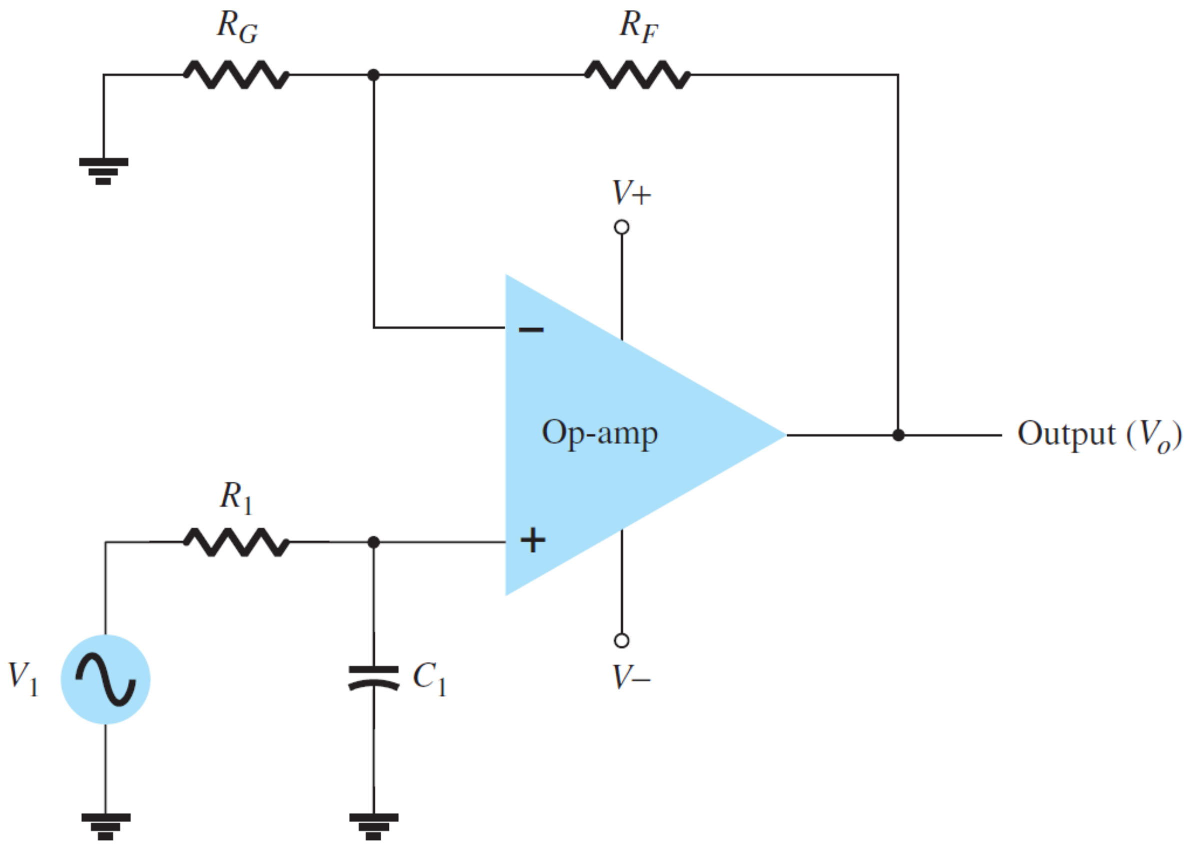




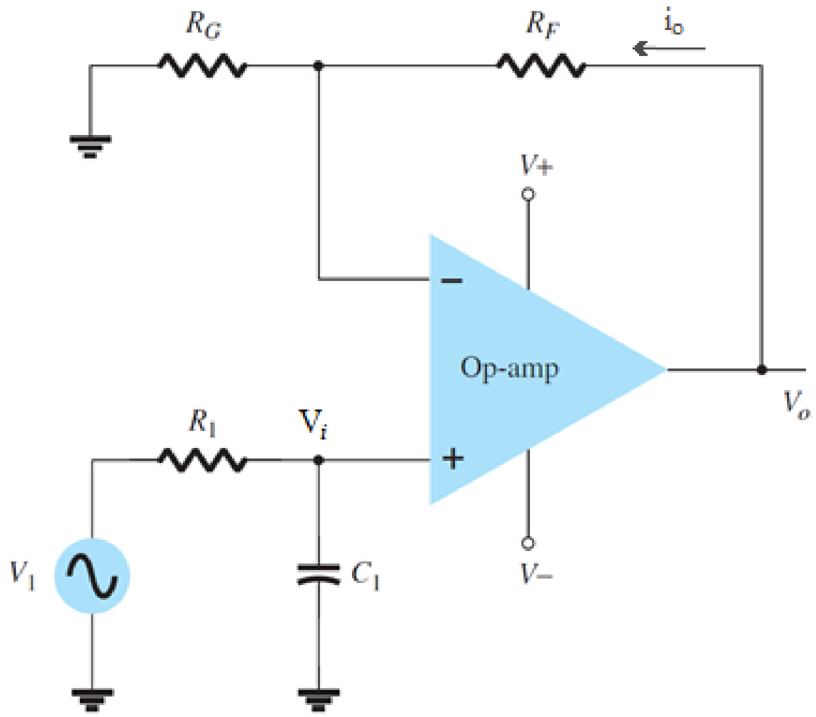
Active Filters



RC Low-pass filter



Active Filters



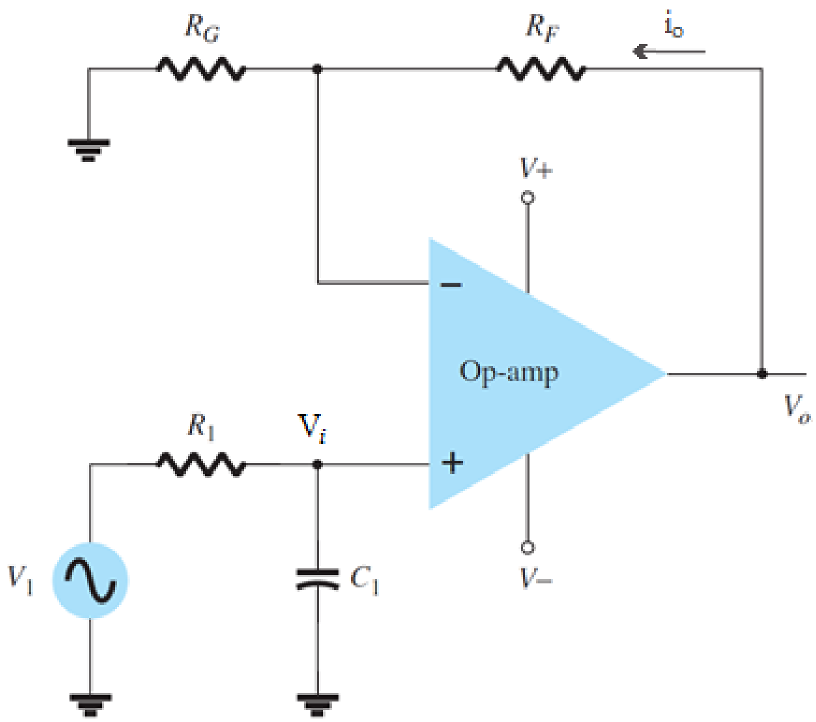
$$V_i = \frac{V_1}{R_1 + \frac{1}{j\omega C_1}} \cdot \frac{1}{j\,\omega C_1} \Rightarrow V_i = \frac{V_1}{1 + j\omega R_1 C_1}$$

$$i_o = \frac{V_o - V_i}{R_F} \approx \frac{V_i}{R_G} \Rightarrow V_o = \left(1 + \frac{R_F}{R_G}\right) V_i$$

Combining:

$$V_o = \left(1 + \frac{R_F}{R_G}\right)\left(\frac{1}{1 + j\omega R_1 C_1}\right) V_1$$

Active Filters



$$\frac{V_o}{V_1} = A_v = \left(1 + \frac{R_F}{R_G}\right)\left(\frac{1}{1 + j\omega R_1 C_1}\right)$$

Real number (gain)

>1 for a low-pass filter with voltage gain

Low-pass filter

$$f_{OL} = \frac{1}{2\,\pi R_1 C_1}$$

cut-off frequency

Active Filters

$$\frac{V_o}{V_1} = A_v = \left(1 + \frac{R_F}{R_G}\right)\left(\frac{1}{1 + j\omega R_1 C_1}\right)$$

Real number (gain)

Low-pass filter

>1 for a low-pass filter with voltage gain

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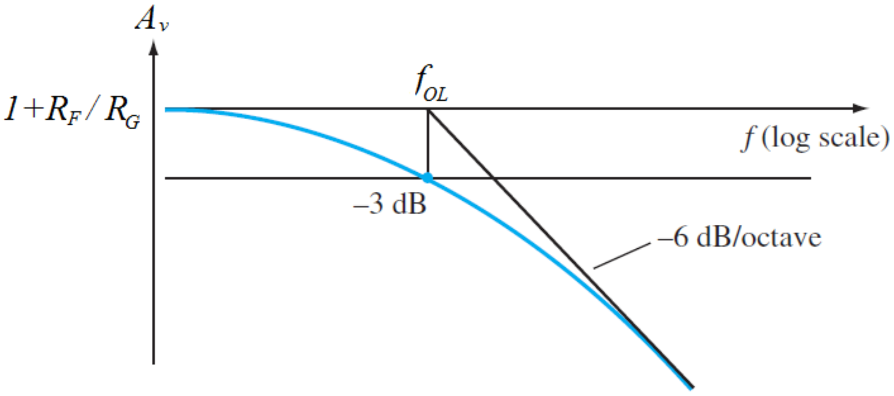
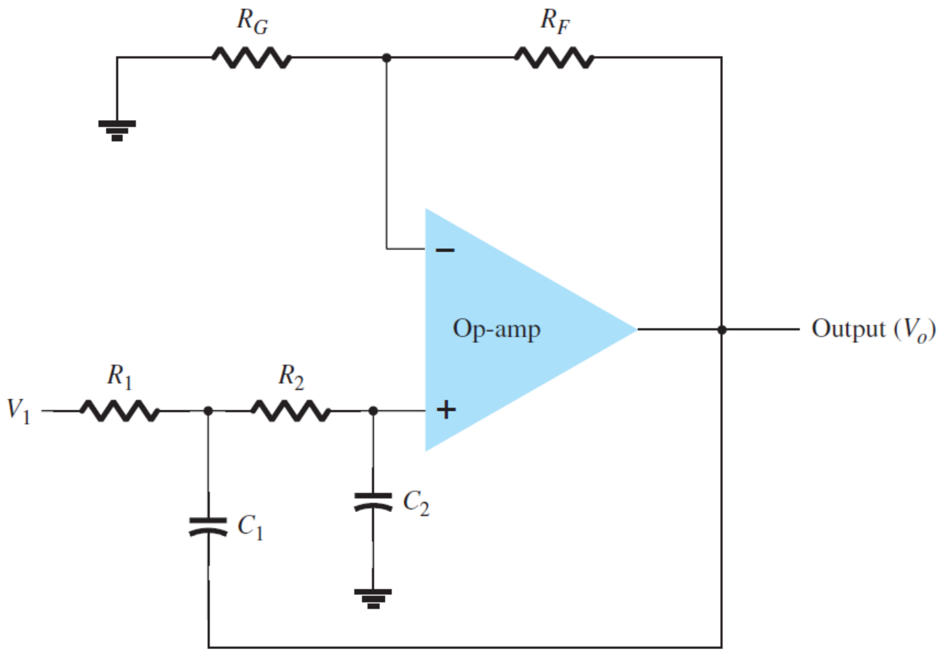
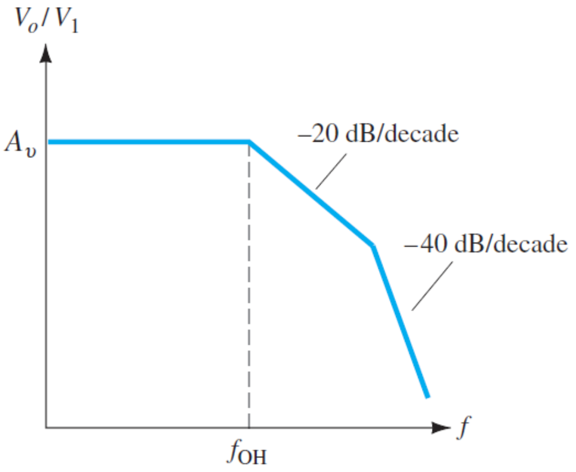
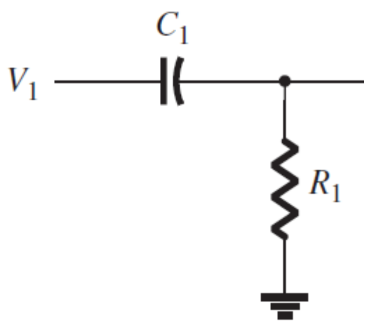


Active Filters

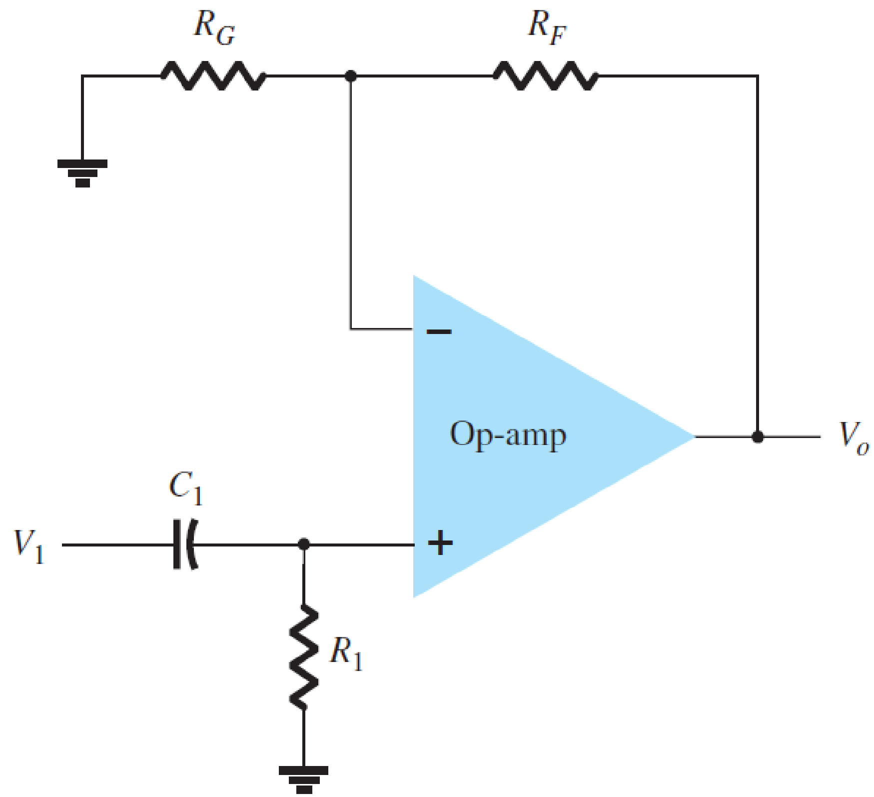




Active Filters



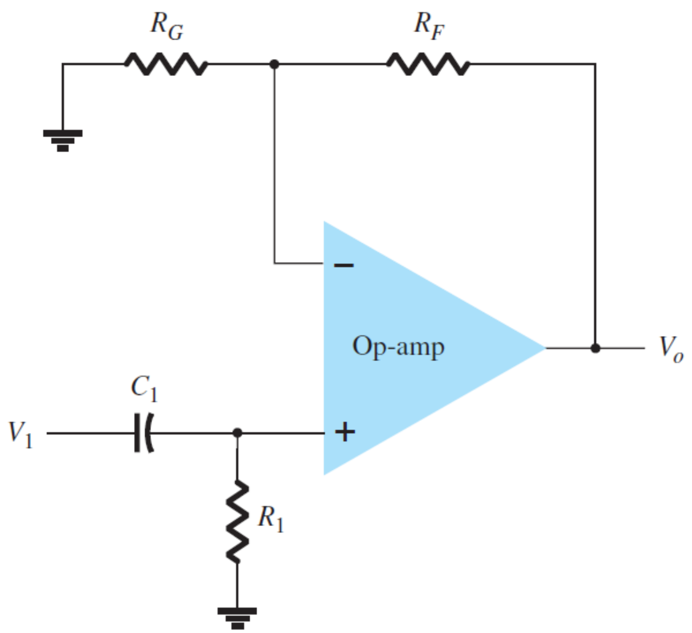
RC High-pass filter

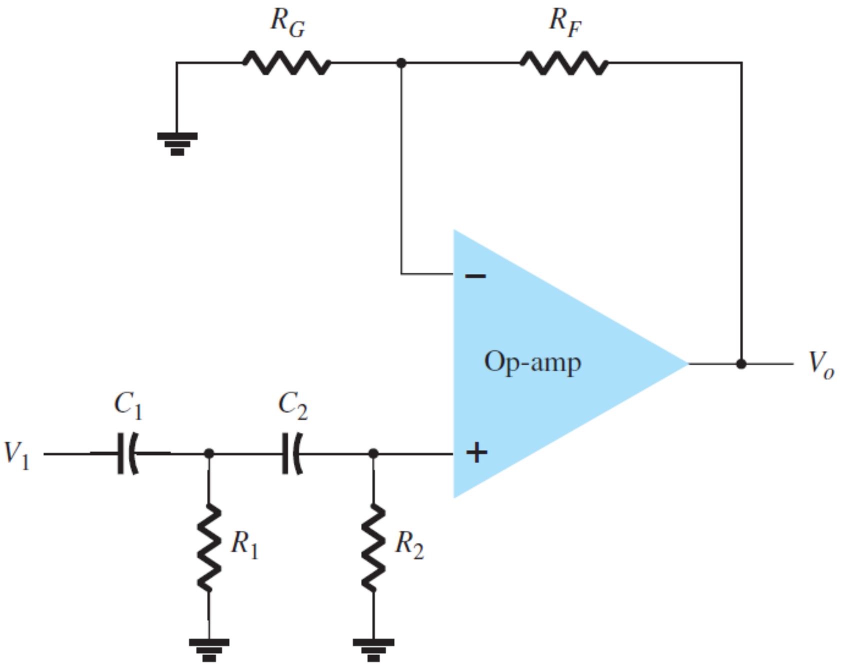


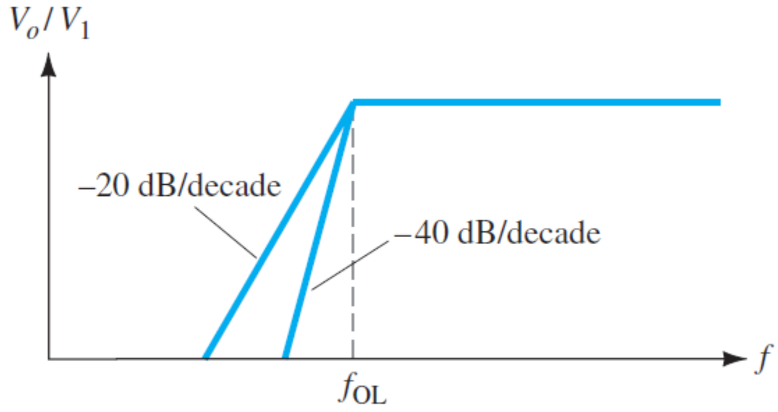
$$A_v = \left(1 + \frac{R_F}{R_G}\right)$$

$$f_{OH} = \frac{1}{2\,\pi R_1 C_1}$$

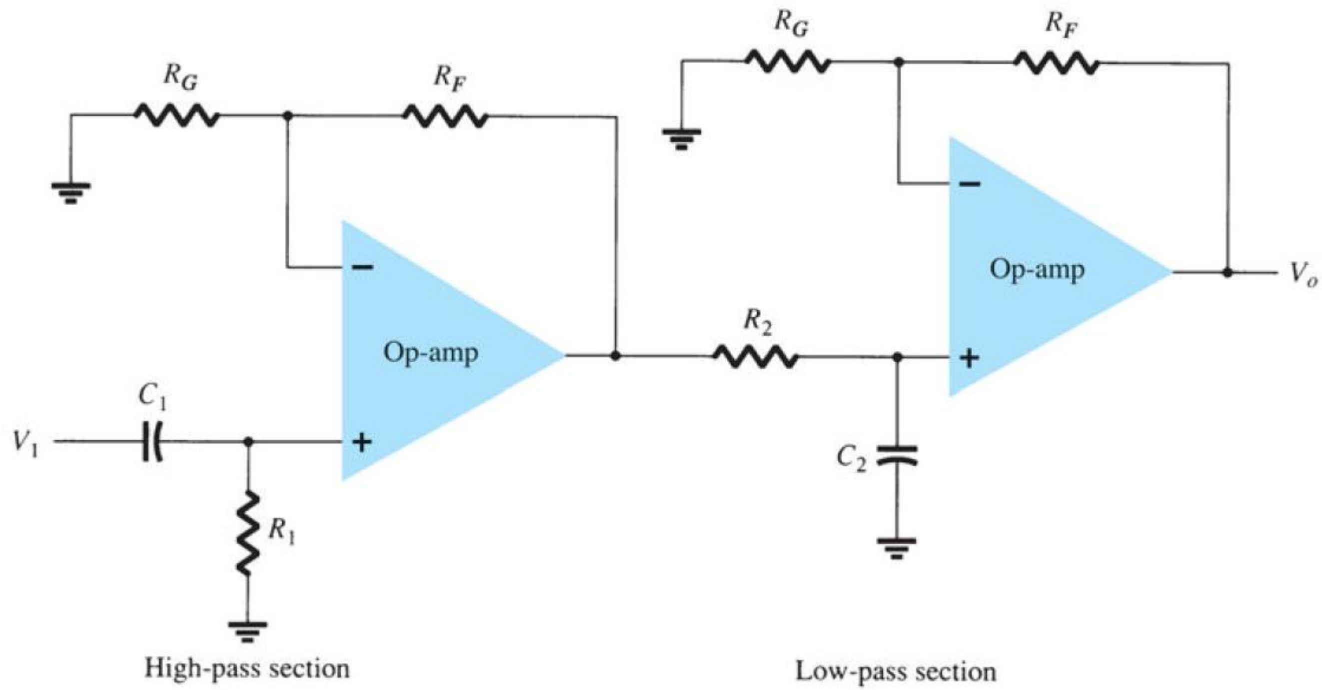
Active Filters

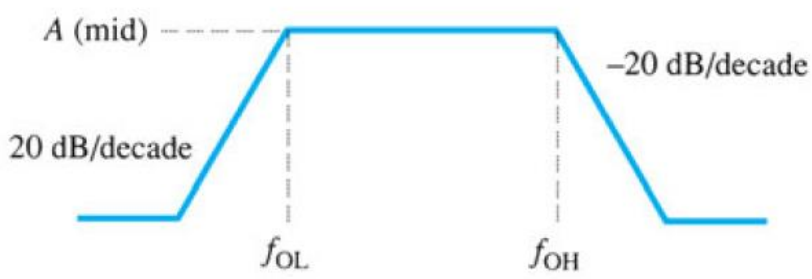




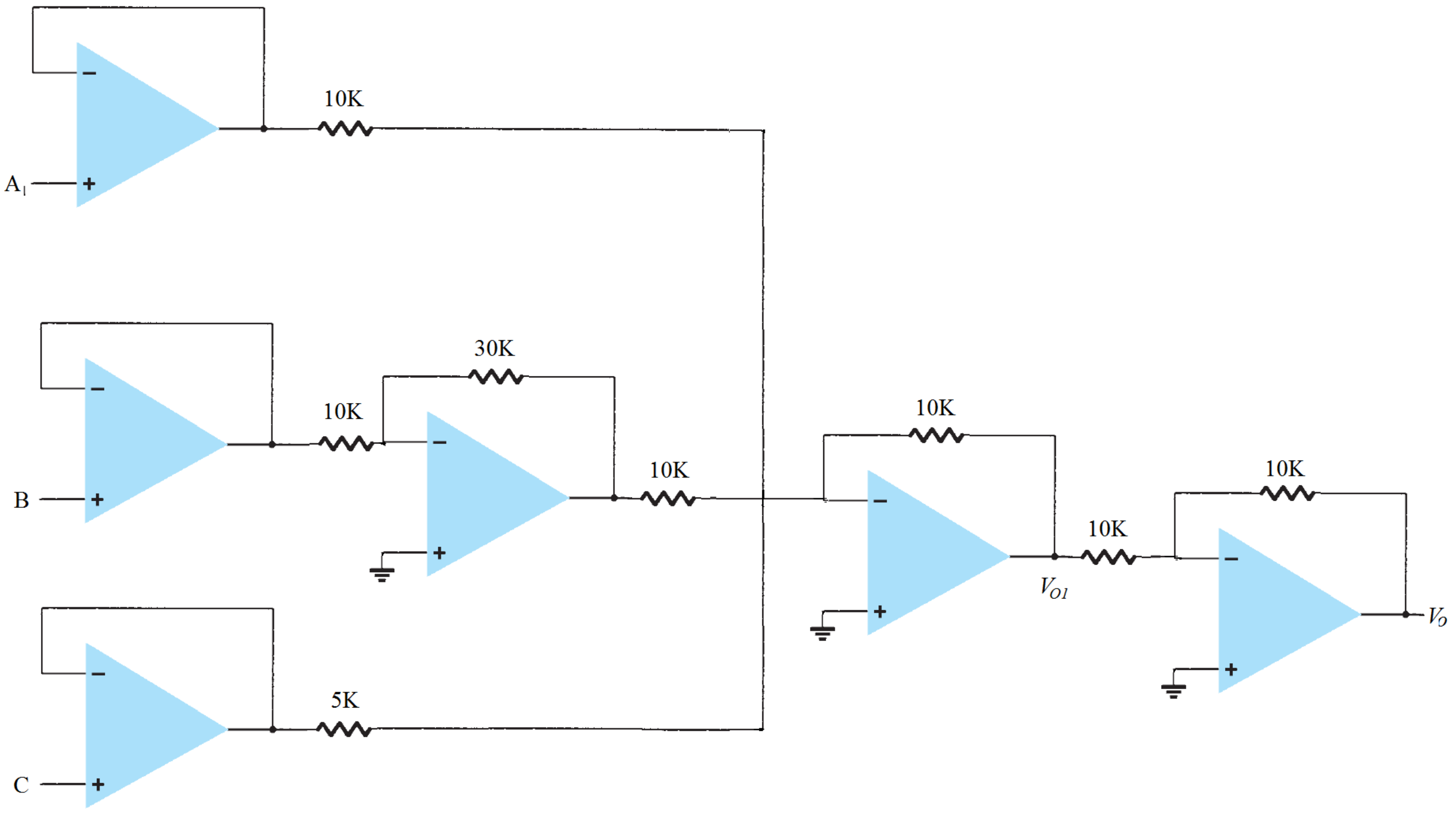


Active Filters

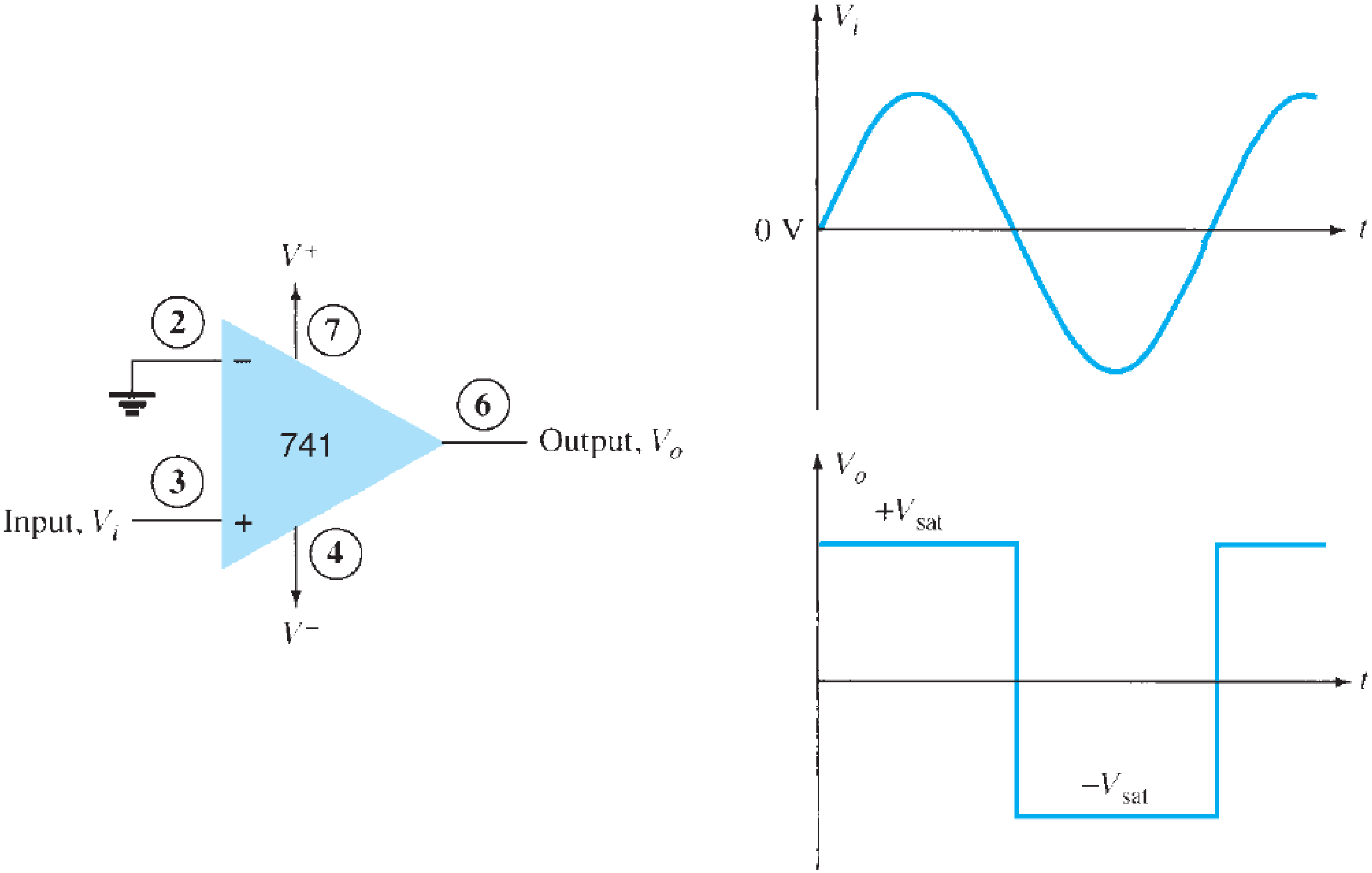




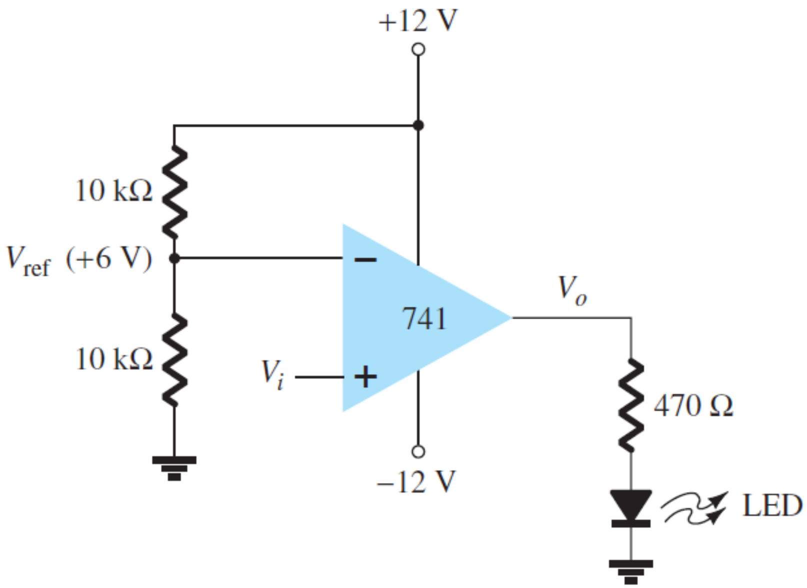
Example Applications



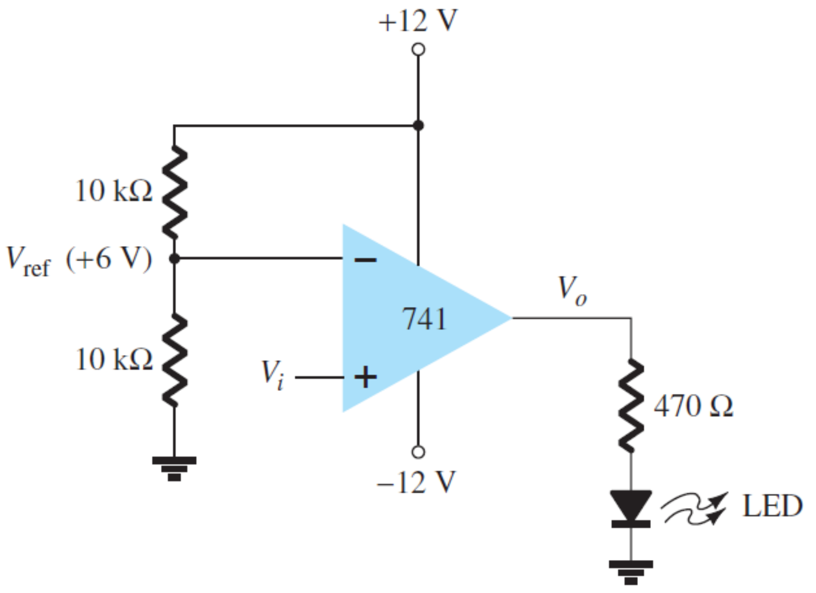
Linear Integrated Circuits



Linear Integrated Circuits

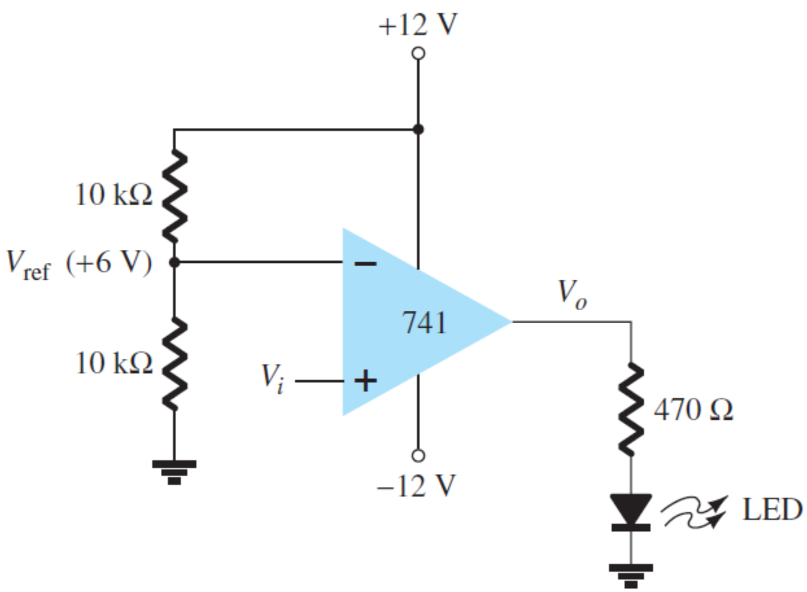


Linear Integrated Circuits

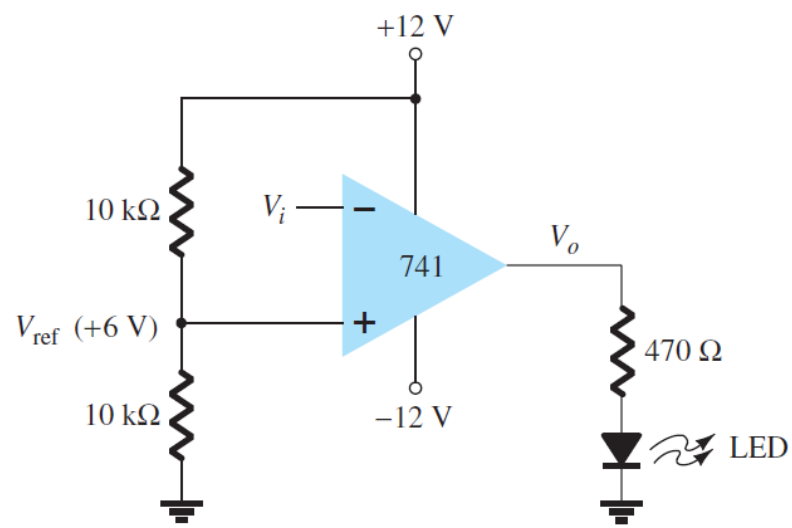


LED *on* when
V_i goes *above*
V_{ref} (= +6 V)

Linear Integrated Circuits

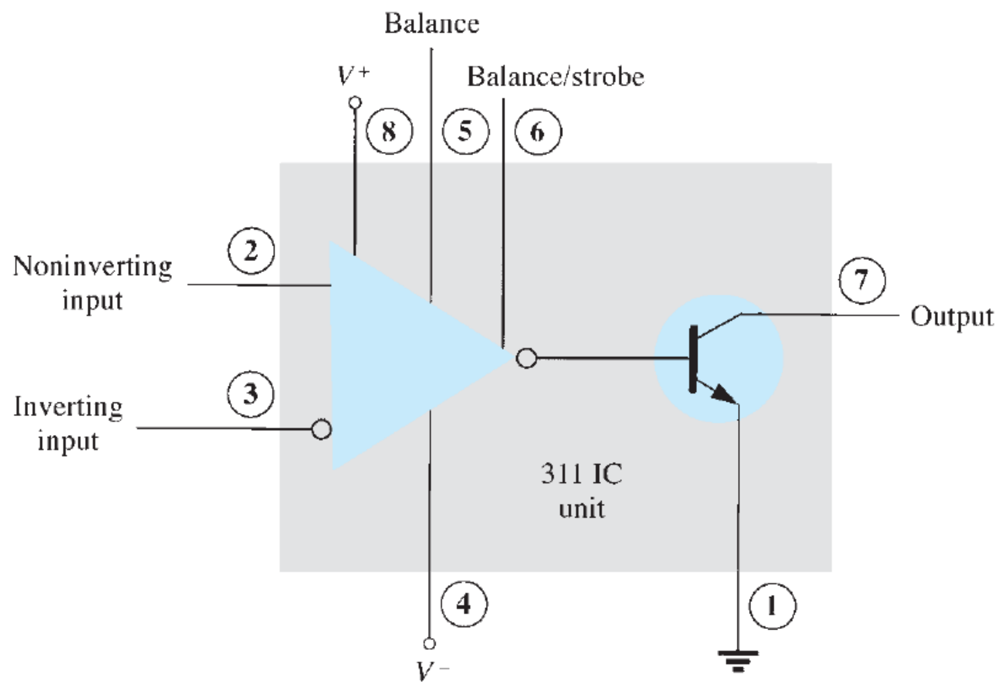


LED *on* when V_i goes *above* V_{ref} (= +6 V)

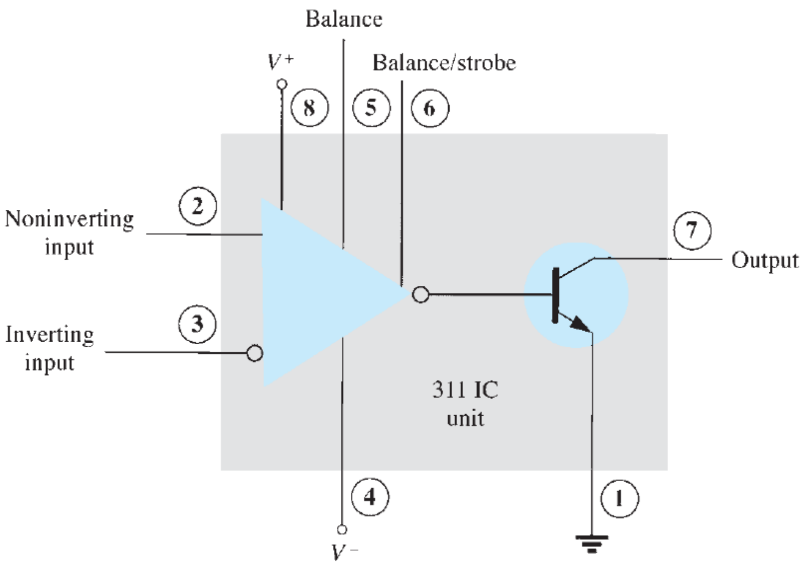


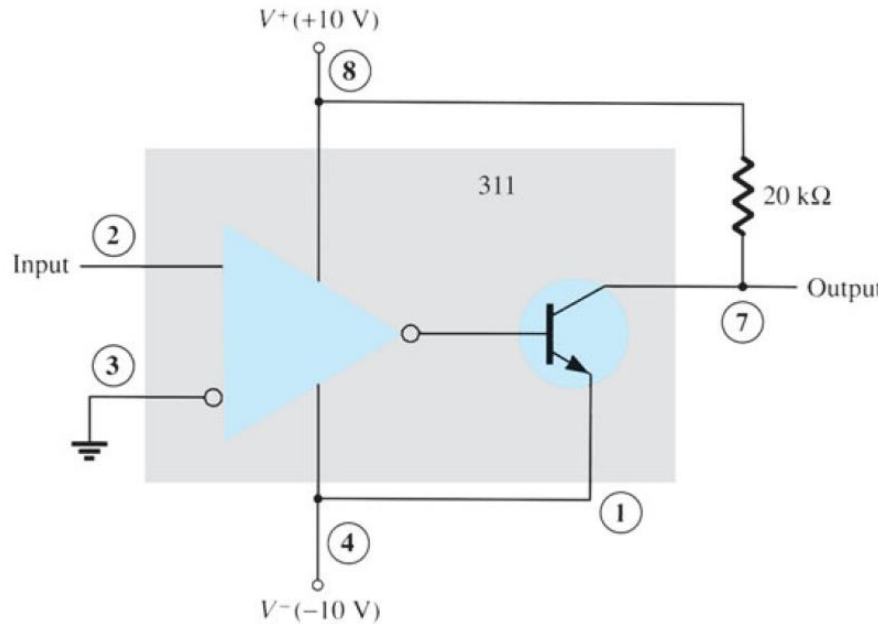
LED *on* when V_i goes *below* V_{ref} (= +6 V)

Linear Integrated Circuits – IC 311 Comparator

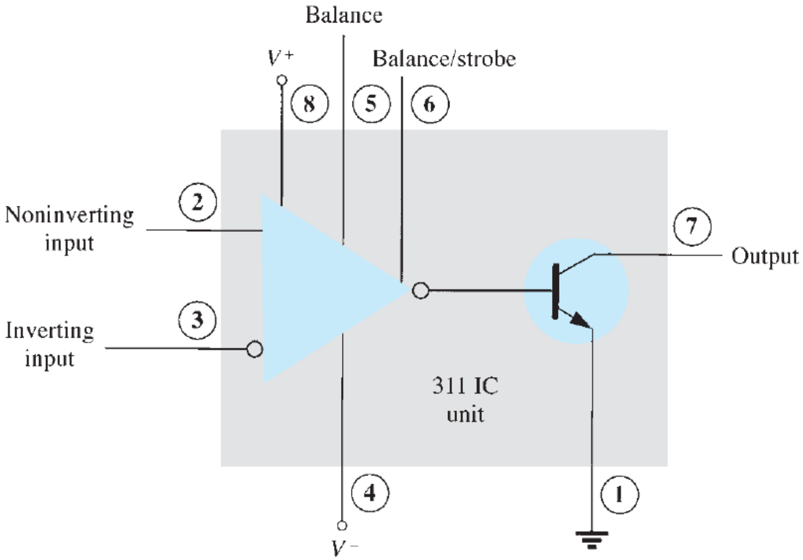


Linear Integrated Circuits – IC 311 Comparator

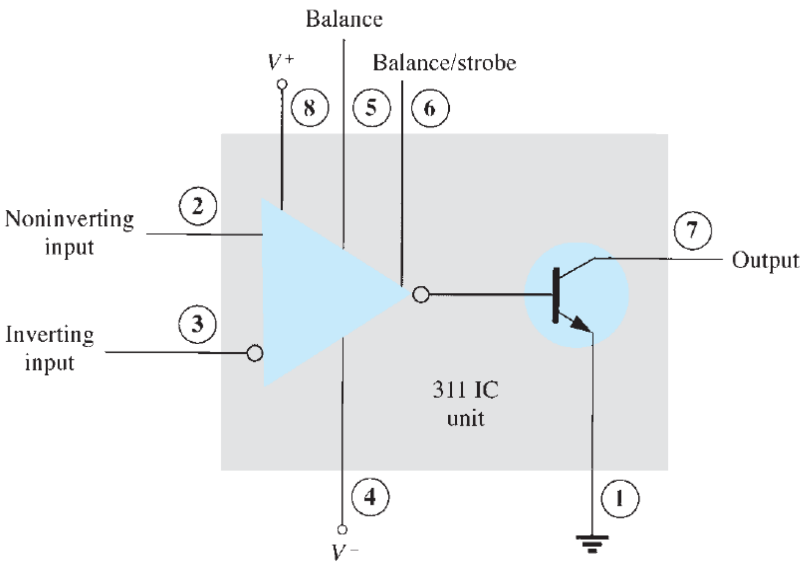


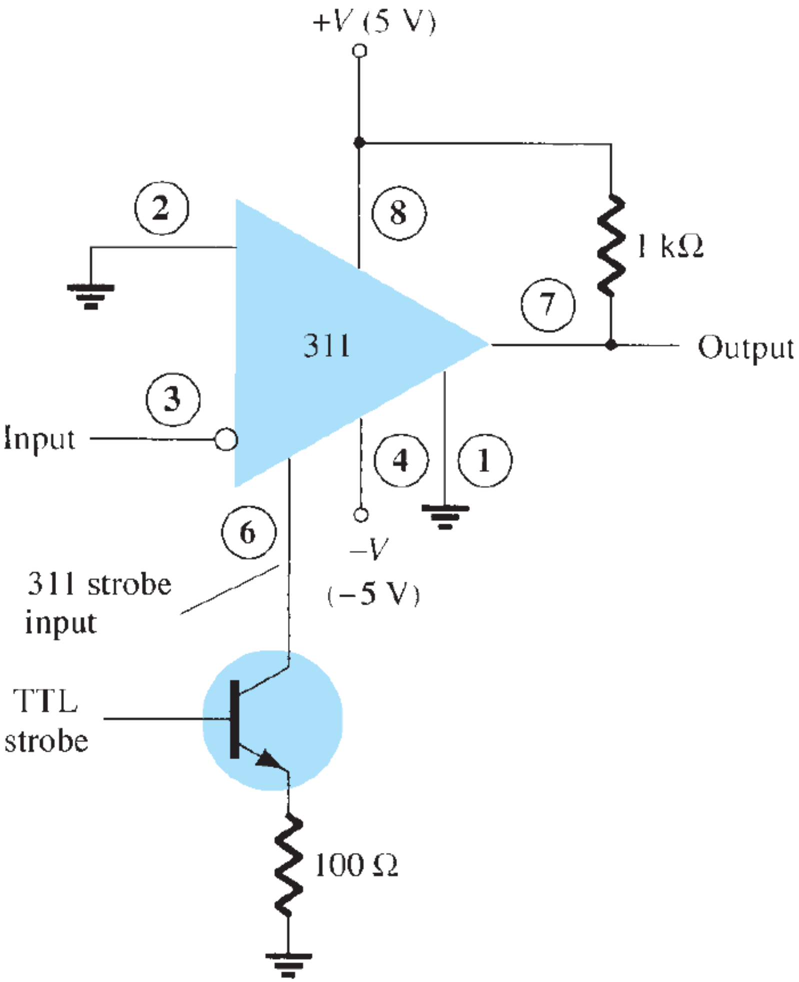


Linear Integrated Circuits – IC 311 Comparator



Linear Integrated Circuits – IC 311 Comparator

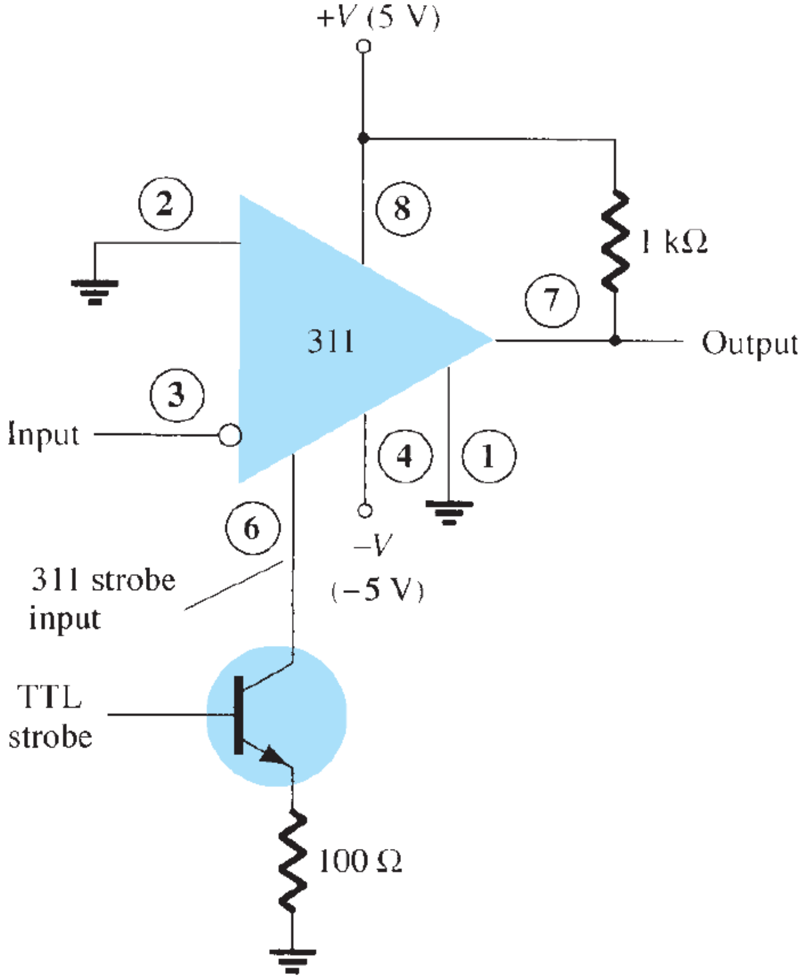




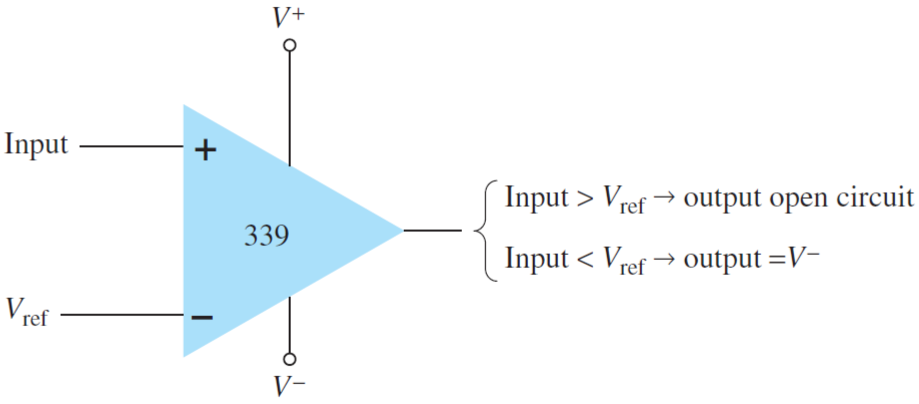
Linear Integrated Circuits – IC 311 Comparator

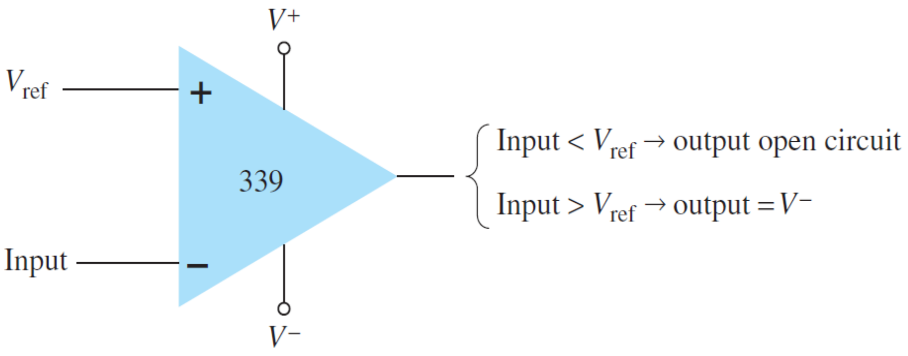
If $V_{in} > 0$ V (V_{ref}), V_o is HIGH if TTL Strobe is OFF

If TTL Strobe goes HIGH, V_o=HIGH regardless of input

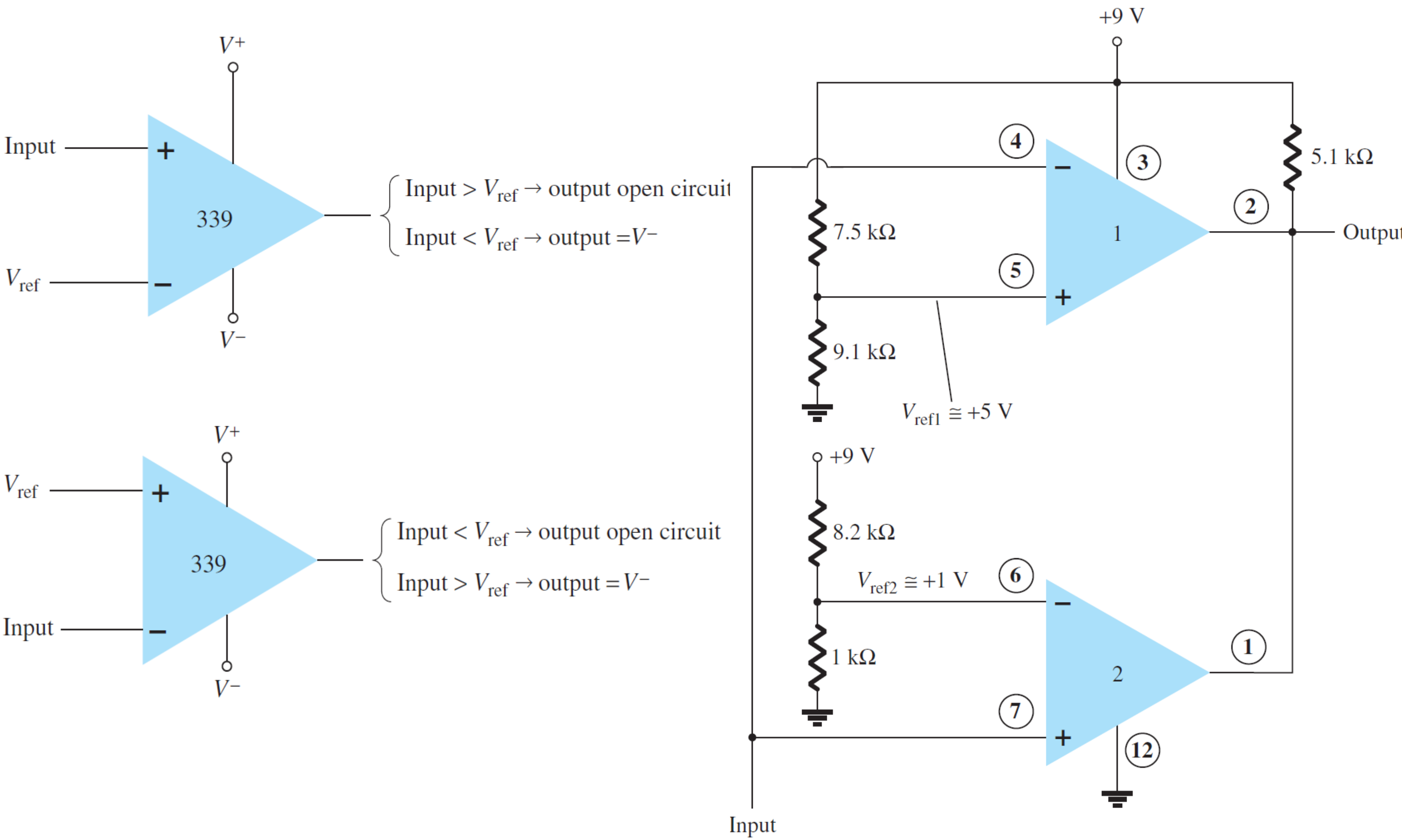


Linear Integrated Circuits – IC 339 Comparator



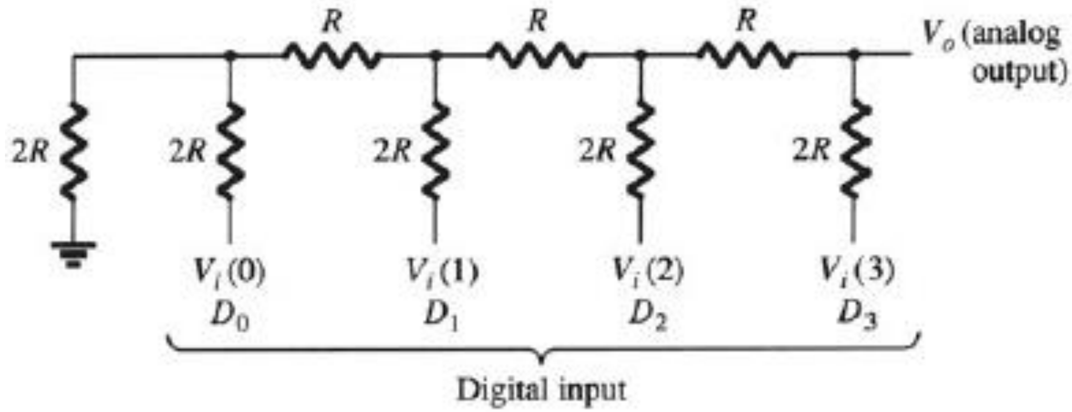


Linear Integrated Circuits – IC 339 Comparator



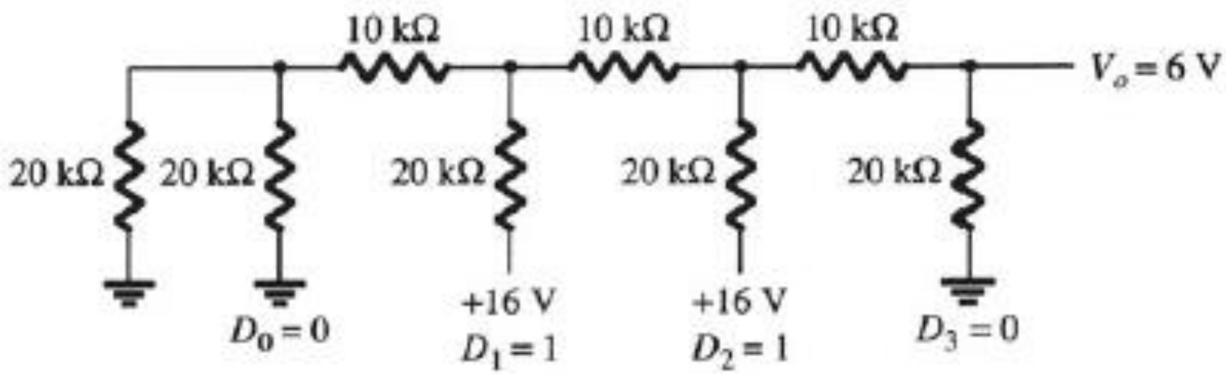
Linear Integrated Circuits –
Digital to Analog Converters (DAC)

Ladder Network Conversion



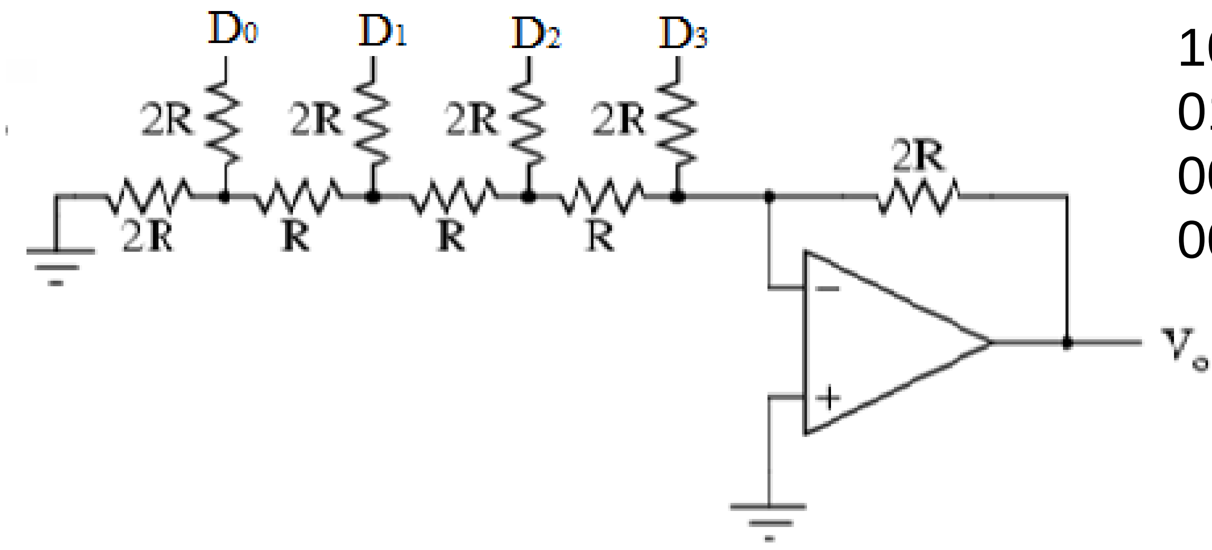
$$V_o = \frac{D_0 \times 2^0 + D_1 \times 2^1 \times D_2 \times 2^2 + D_3 \times 2^3}{2^4} V_{\text{ref}}$$

Linear Integrated Circuits – DAC



$$V_o = \frac{0 \times 1 + 1 \times 2 + 1 \times 4 + 0 \times 8}{16}(16\text{ V}) = 6\text{ V}$$

Linear Integrated Circuits – DAC



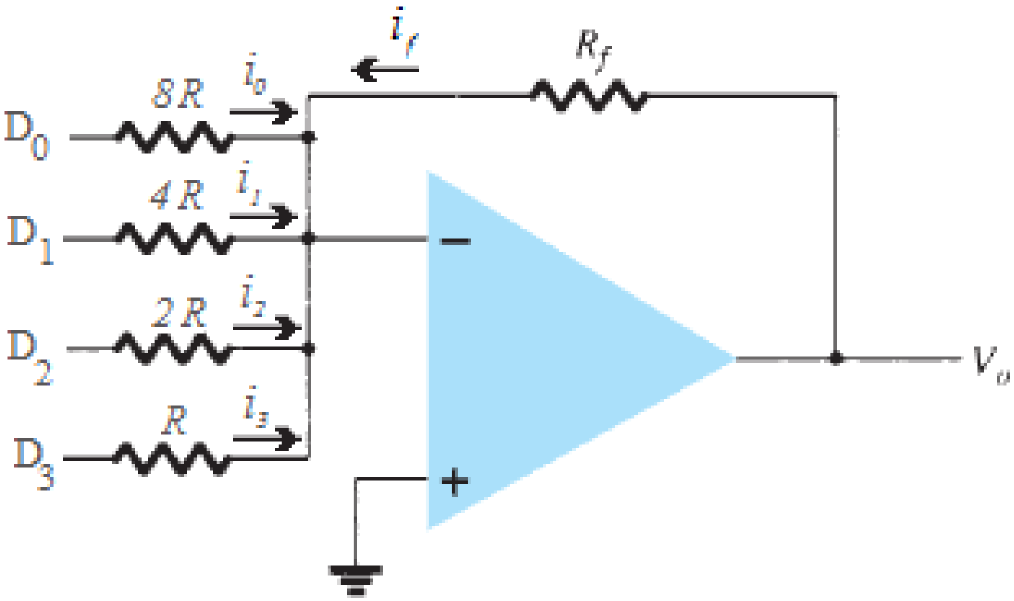
1000 -> V_o=-5V
0100 -> V_o=-2.5V
0010 -> V_o=-1.25V
0001 -> V_o=-0.625V

0 0000 -> V_o=0 V
1 0001 -> V_o=-0.625 V
2 0010 -> V_o=-1.25 V
3 0011 -> V_o=-1.85 V
.
.
.
15 1111 -> V_o=-9.375 V

$(0101)_2 = (5)_{10}$
=> V_o=-2.5-0.625=-3.125 V

Linear Integrated Circuits – DAC

Binary Weighted DAC



$$i_0 = \frac{V}{8R}$$

$$i_1 = \frac{V}{4R}$$

$$i_2 = \frac{V}{2R}$$

$$i_3 = \frac{V}{R}$$

$$i_f = \frac{V_o}{R_f}$$

$$i_f = -(i_0 + i_1 + i_2 + i_3)$$

$$V_o = -R_f V\left(\frac{1}{8R} + \frac{1}{4R} + \frac{1}{2R} + \frac{1}{R}\right)$$

Linear Integrated Circuits – DAC

Performance Characteristics:

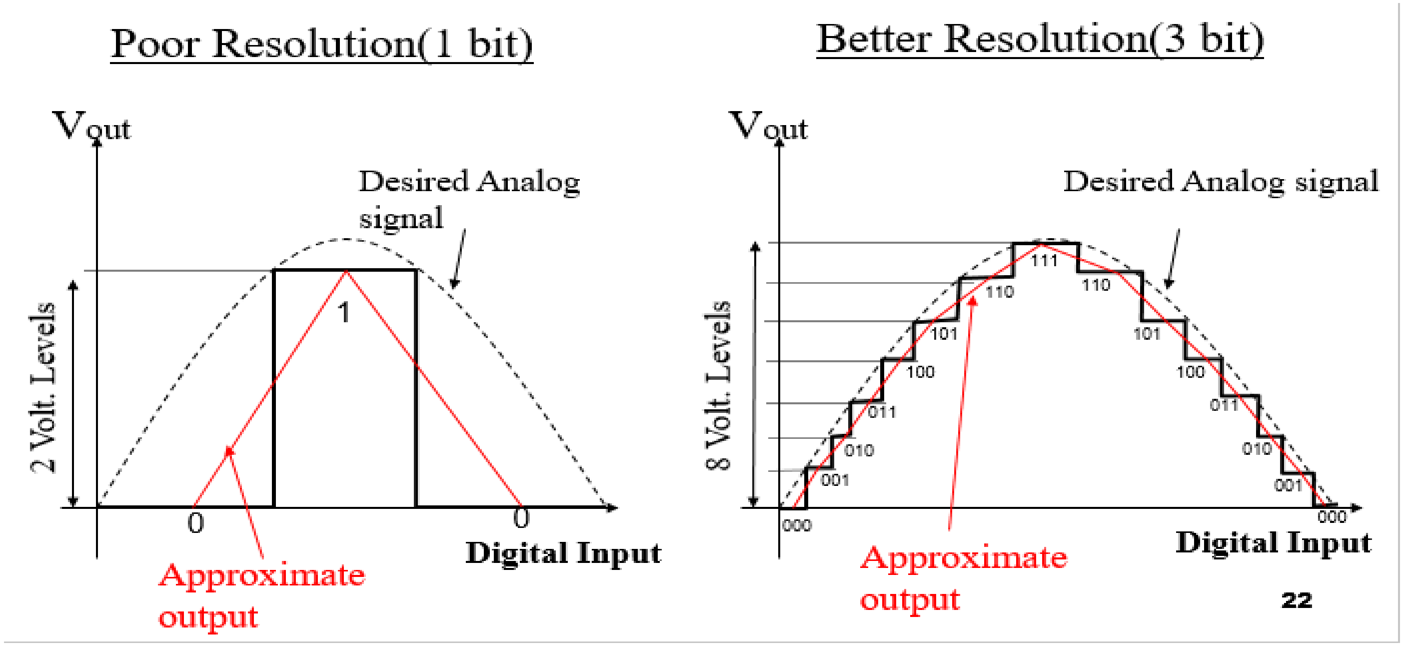
1. Resolution
2. Accuracy
3. Linearity
4. Monotonicity
5. Settling time

Linear Integrated Circuits – DAC

Resolution: Can be defined as

a. the of number of bits (i.e., n)
b. The number of steps (i.e., 2^n -1)

How closely can we approximate the desired output signal(Higher Res. = finer detail=smaller Voltage divisions)



Linear Integrated Circuits – DAC

Accuracy: A comparison of the actual output of a DAC with the expected output. At the worst case, accuracy is $V_{ref}/2^n$

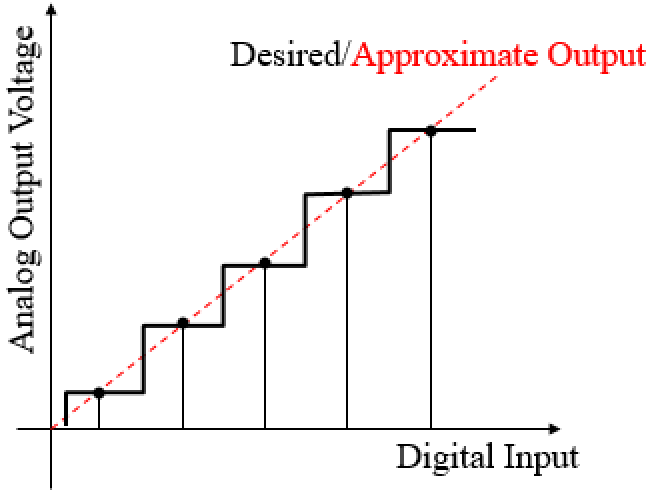
- Expressed as a percentage of a full-scale, or maximum, output voltage
- For example, if a converter has a full-scale output of 10V and the accuracy is ±0.1 %, then the maximum error for any output voltage is (10 V)(0.001) =10 mV
- For an 8-bit converter, 1 LSB is 1/256 = 0.0039 (0.39% of full scale). Accuracy is approximately ±0.2%

Linear Integrated Circuits – DAC

Linearity: the difference between the desired analog output and the actual output over the full range of expected values.

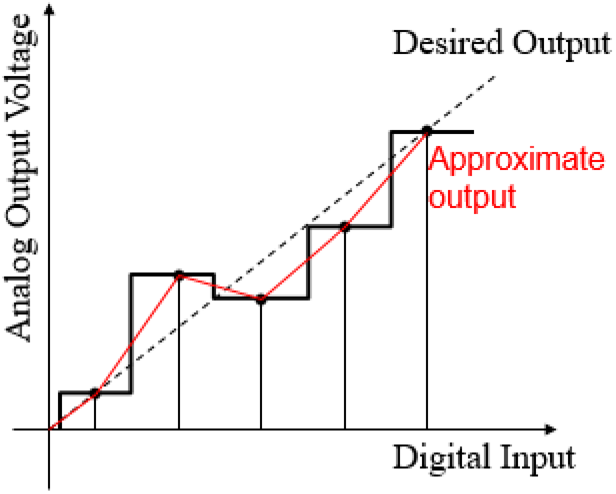
- Ideally, a DAC should produce a linear relationship between a digital input and the analog output, this is not always the case.
- Any change in the input state will not be reflected in the output state immediately. There is a time lag, between the two events

Linearity(Ideal Case)



Perfect Agreement

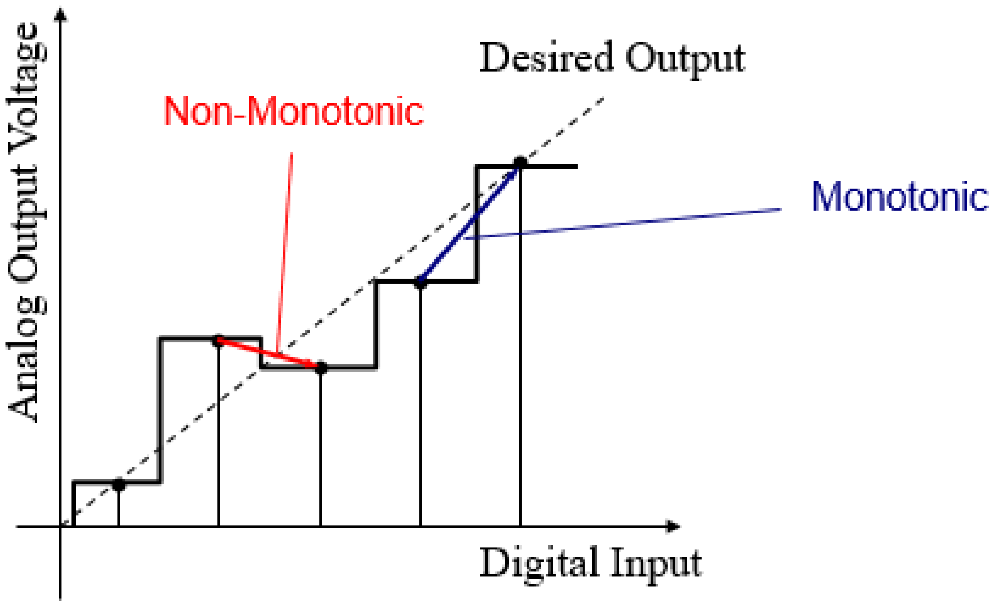
NON-Linearity(Real World)



Miss-alignment

Linear Integrated Circuits – DAC

Monotonicity: A DAC is monotonic if it does not take any reverse steps when it is sequenced over its entire range of input bits.



Linear Integrated Circuits – DAC

Settling Time

- The time required for the input signal voltage to settle to the expected output voltage(within +/- VLSB).
- Any change in the input state will not be reflected in the output state immediately. There is a time lag, between the two events