Introducing Electronics

Ch 10

Operational Amplifiers,

What are Amplifiers?

From www.gadgetuniverse.com

What are Amplifiers?

• An amplifier is any device that use a small amount of energy to generate a larger amount of energy.
(e.g. amplification of a signal that your mobile phone received on its antenna, ECG measurement, ect.)

• Gain is a measure of amplification.
$G = V_{out} / V_{in}$ In specs, $G = 10*\log10 (P_{out}/P_{in})$, with a unit of dB.

Types of amplifiers:

• Electronic amplifiers
- Transistor amplifiers
- Operational amplifiers
- …

• Optical amplifiers

• …

What are Operational Amplifiers?

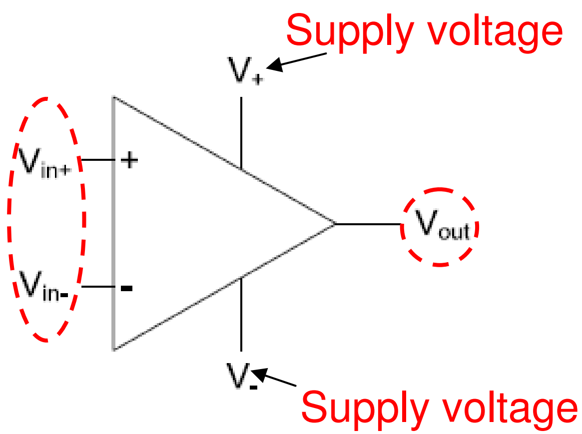


Figure 10.1: *Schematic symbol for an operational amplifier.*

$$V_{out} = G \cdot (V_{in+} - V_{in-}) \qquad (10.1)$$

- G is the gain.
- When no other components are connected, G is in the order of 10^5 to 10^7! (open-loop voltage gain)
- The output voltage is limited by the +/- supply voltages. (clipping)

Closed-loop Model of Opamp

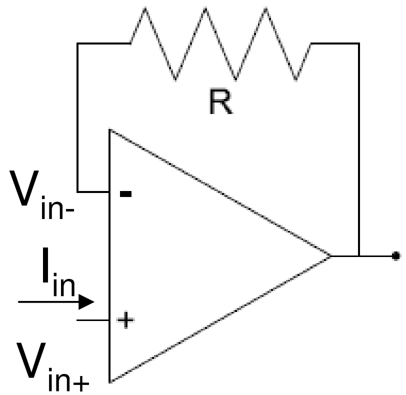


Figure 10.2: *Operational amplifier with in a negative feedback configuration using a resistor.*

- $I_{in} = 0$ (high input impedance)
- $V_{in+} = V_{in-}$

Closed-loop Model of Opamp

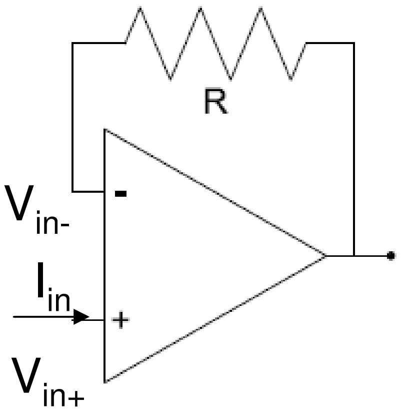


Figure 10.2: *Operational amplifier with in a negative feedback configuration using a resistor.*

- $V_{in+} > V_{in-}$: the output voltage increase V_{in-}
- $V_{in+} < V_{in-}$: the output voltage decrease V_{in-}

- $I_{in} = 0$
- $V_{in+} = V_{in-}$

Op amps and Inverting Amplifiers

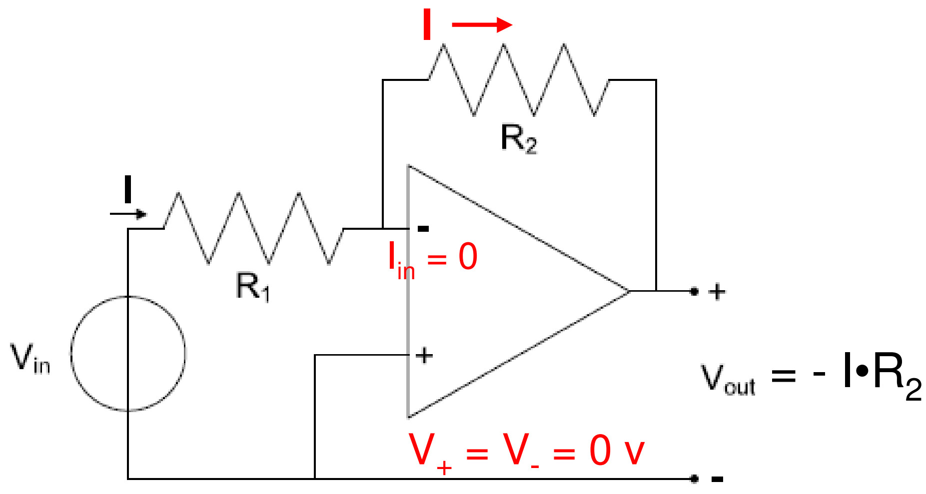


Figure 10.3: *Operational amplifier used in an inverting amplifier circuit.*

$$I = V_{in} / R_1$$

$$V_{out} = -\frac{R_2}{R_1} V_{in} \qquad (10.2)$$

Op amps and Inverting Amplifiers

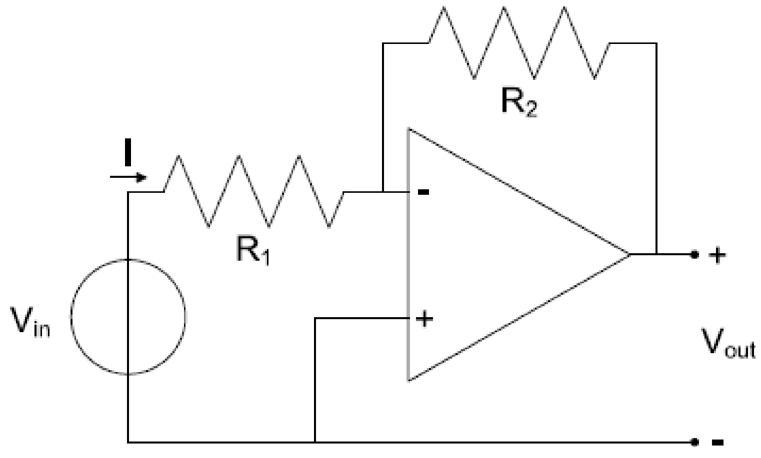


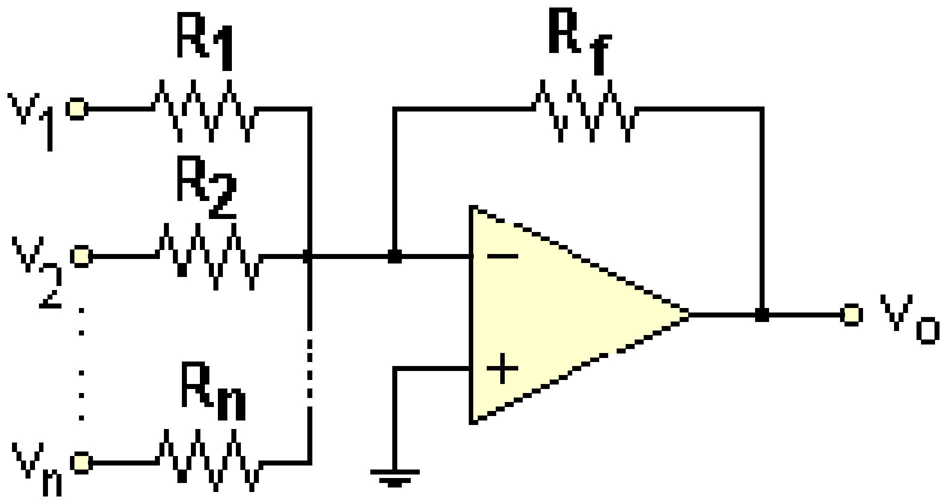
Figure 10.3: *Operational amplifier used in an inverting amplifier circuit.*

$$V_{out} = -\frac{R_2}{R_1} V_{in} \qquad (10.2)$$

$G = - R_2 / R_1$

- $R_2 > R_1$, Inverting amplifier
- $R_2 < R_1$, Inverting attenuator
- $R_2 = R_1$, Inverter

Op amps and Summing Amplifiers



$$V_o = -(V_1/R_1 + V_2/R_2 + \ldots + V_n/R_n)\cdot R_f$$

Op amps and Non-inverting Amplifiers

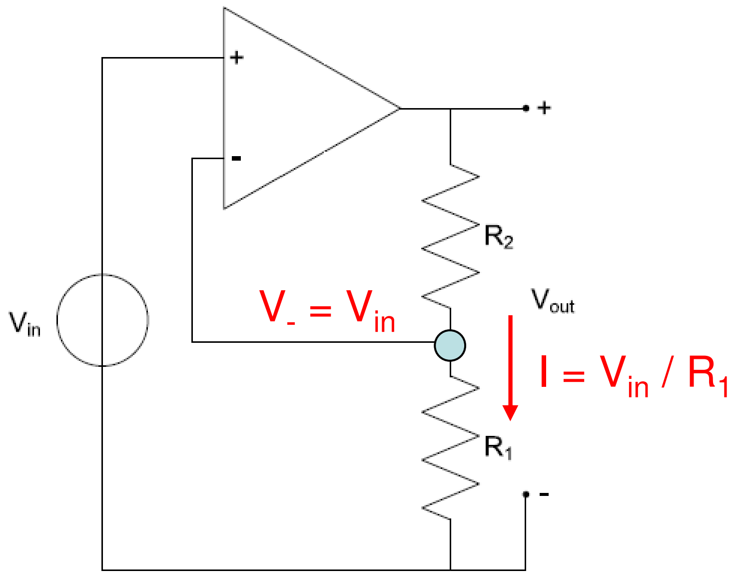


Figure 10.4: *Operational amplifier used in a non-inverting amplifier circuit.*

$$V_{out} = I\,(R_1 + R_2)$$

$$V_{out} = (1 + \frac{R_2}{R_1})V_{in} \qquad (10.3)$$

Op amps and Non-inverting Amplifiers

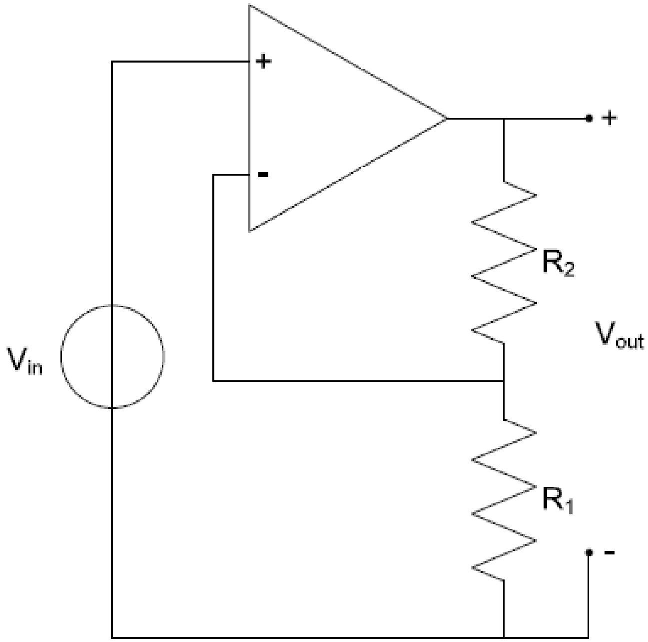


Figure 10.4: *Operational amplifier used in a non-inverting amplifier circuit.*

$$V_{out} = (1 + \frac{R_2}{R_1})V_{in} \qquad (10.3)$$

G = 1 + R2 / R1

Operational Amplifiers

Datasheet will provide you with the parameters needed to make a good choice of which opamp to use.

Amplifying AC Signal

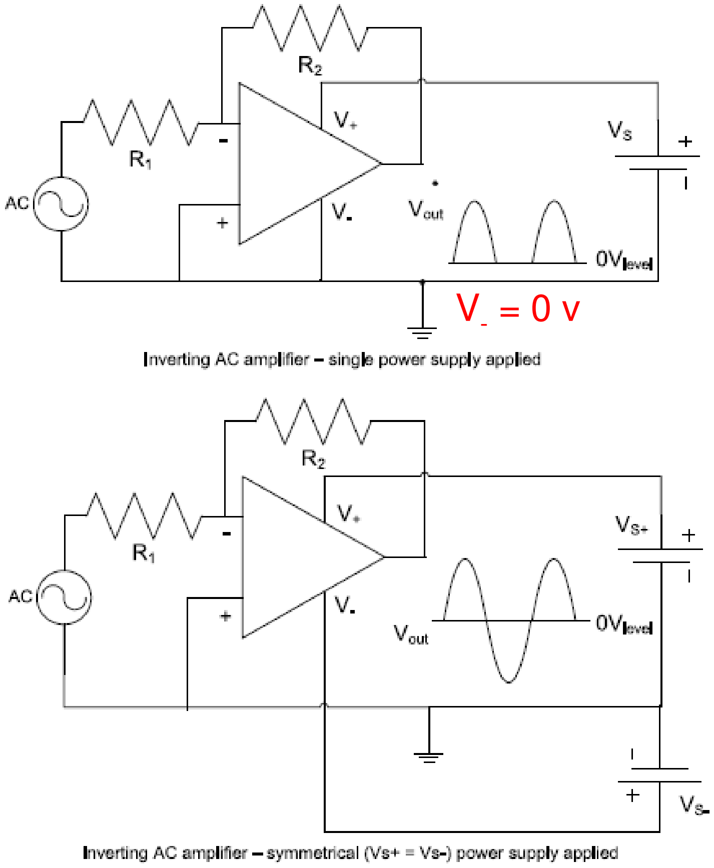


Figure 10.5: *Operational amplifier used as AC amplifier.*

Op amps and Comparators

- Circuits performing comparison are called comparators.
- Clipping amplifiers (open-loop) can be used for comparators.

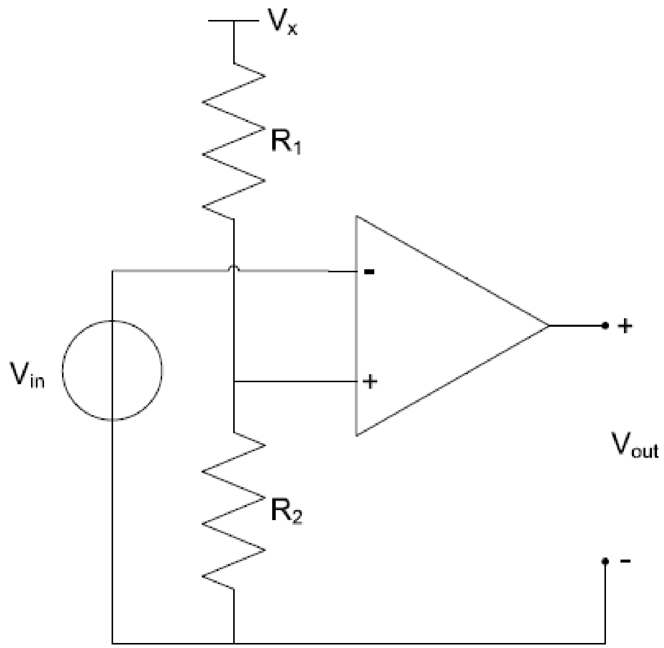
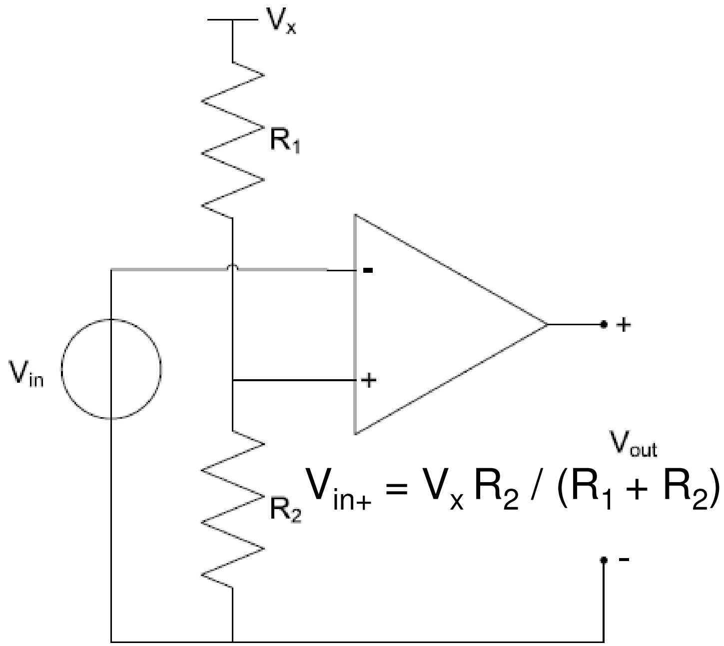


Figure 10.6: *Operational amplifier used in a comparator circuit with static comparison.*

Op amps and Comparators

$$V_{out} = G \cdot (V_{in+} - V_{in-}) \qquad (10.1)$$

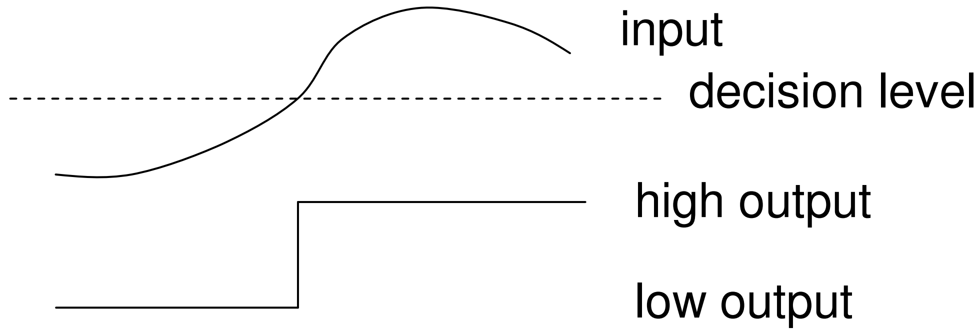


$$V_{in} < \frac{R_2}{R_1 + R_2} V_x \qquad V_{out} = V_{s+}$$

$$V_{in} > \frac{R_2}{R_1 + R_2} V_x \qquad V_{out} = V_{s-}$$

Figure 10.6: *Operational amplifier used in a comparator circuit with static comparison.*

Op amps and Comparators



Output of a comparator when the input is clean.

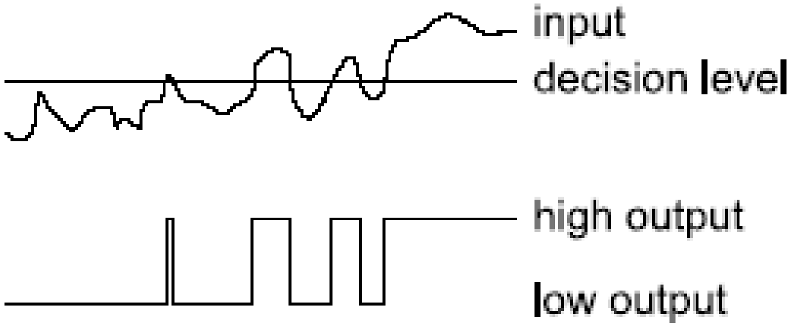
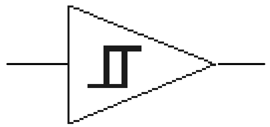


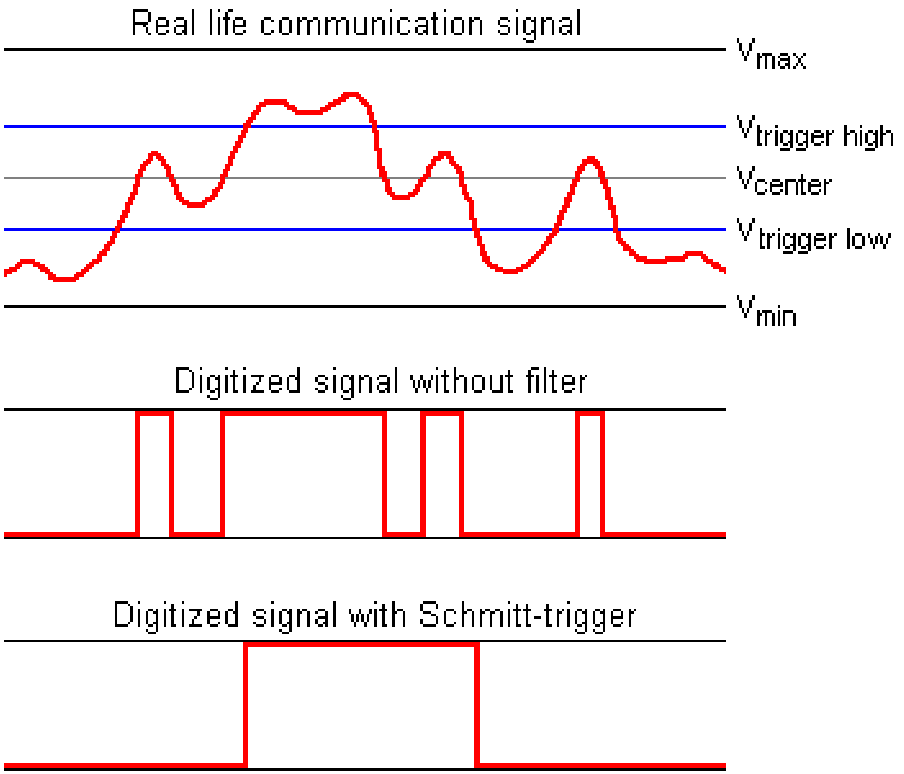
Figure 10.7: *The output of a comparator toggles when the input is noisy.*

Op amps and Comparators

A Schmitt trigger is a comparator circuit that incorporates positive feedback.



Schmitt trigger symbol



From **www.lammertbies.nl/comm/info/Schmitt-trigger.html**
http://en.wikipedia.org/wiki/Schmitt_trigger

Op amps and Comparators

$V_{out,\ high} = 10$ V

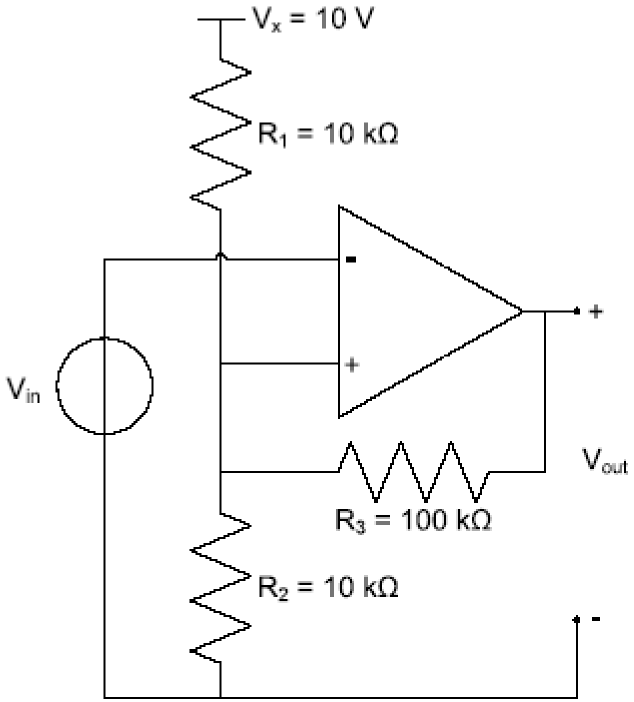
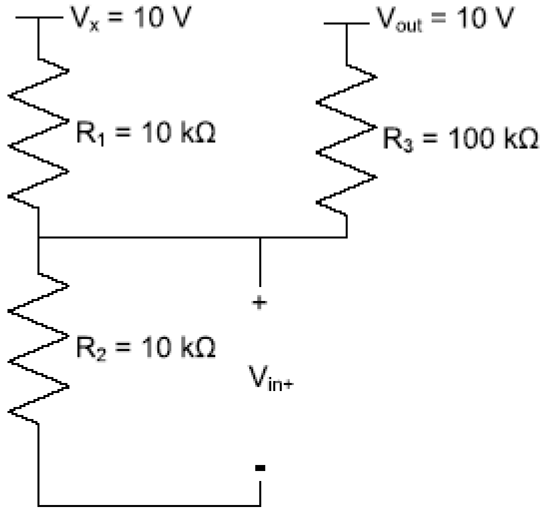


Figure 10.9: *An opamp with feedforward in a static comparator circuit.*



$$V_{in+} = \frac{R_2}{R_2 + \frac{R_1 \cdot R_3}{R_1 + R_3}} \cdot V_x = 5.24 \text{ V}$$

Output changes from high to low, when $V_{in} > V_{in+}$ (5.24 V).

Op amps and Comparators

$V_{out,\,low} = 0\ V$

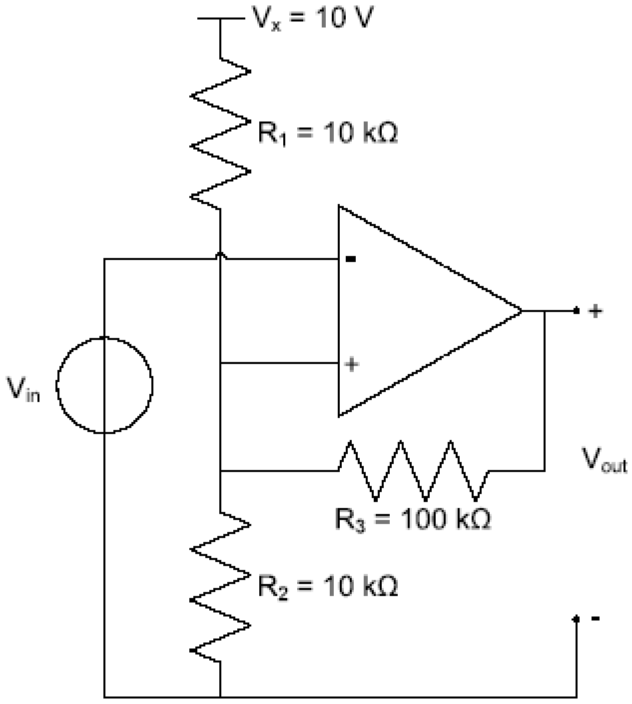
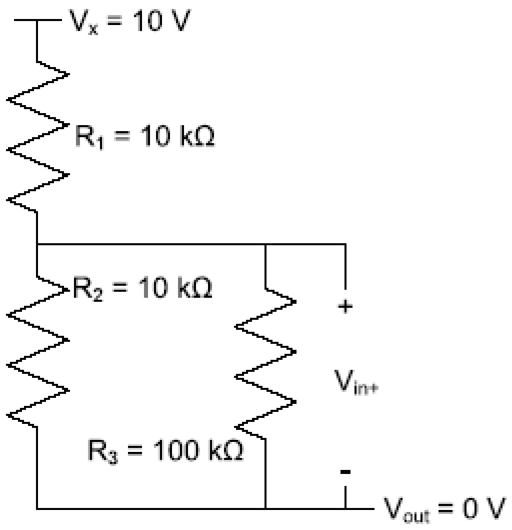


Figure 10.9: *An opamp with feedforward in a static comparator circuit.*



$$V_{in+} = \frac{\frac{R_2 \cdot R_3}{R_2+R_3}}{R_1+\frac{R_2 \cdot R_3}{R_2+R_3}} \cdot V_x = 4.76\ V$$

Output changes from low to high, when $V_{in} < V_{in+}$ (4.76 V).

Op amps and Comparators

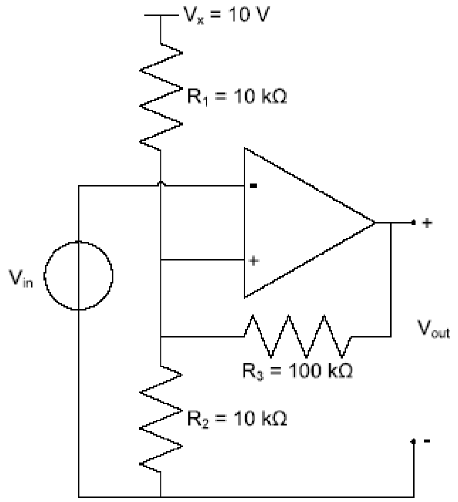
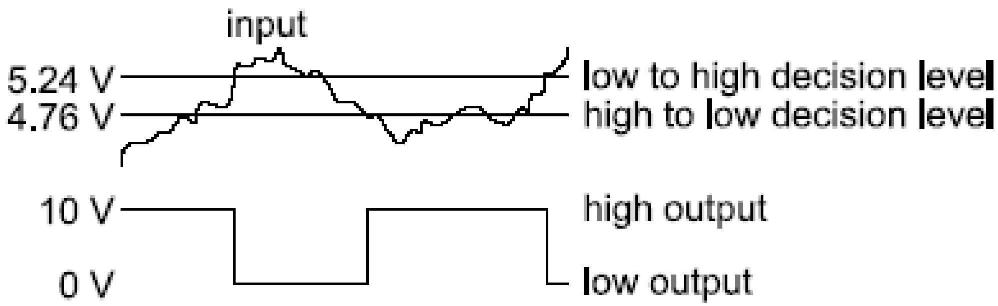


Figure 10.9: *An opamp with feedforward in a static comparator circuit.*



The output of a comparator with feedforward does not make the output toggle for noisy input signals.