Cross Section Creative Technology

Operational Amplifiers

Sensors and Actuators

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What are Amplifiers?

From www.gadgetuniverse.com

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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?

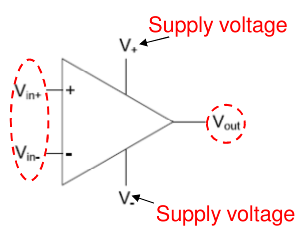

Figure 10.1: *Schematic symbol for an operational amplifier.*

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

- 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

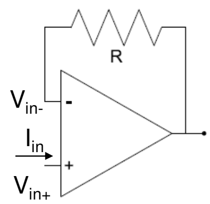

Figure 10.2: *Operational amplifier with in a negative feedback configuration using a resistor.*

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

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Closed-loop Model of Opamp

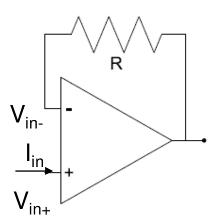

Figure 10.2: *Operational amplifier with in a negative feedback configuration using a resistor.*

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

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

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Op amps and Inverting Amplifiers

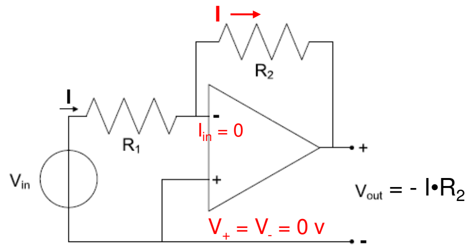

Figure 10.3: *Operational amplifier used in an inverting amplifier circuit.*

$I = V_{in} / R_1$

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

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Op amps and Inverting Amplifiers

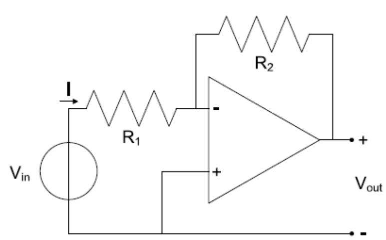

Figure 10.3: *Operational amplifier used in an inverting amplifier circuit.*

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

$G = - R_2 / R_1$

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

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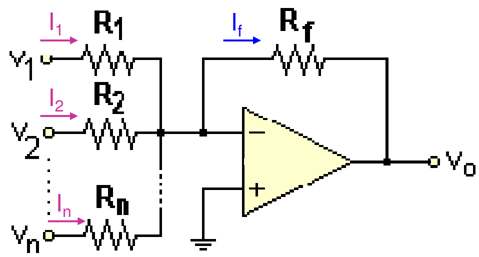
Op amps and Summing Amplifiers



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

Op amps and Non-inverting Amplifiers

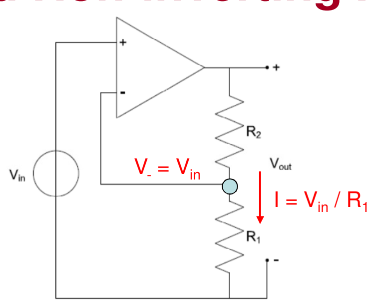


Figure 10.4: *Operational amplifier used in a non-inverting amplifier circuit.*

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

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

Op amps and Non-inverting Amplifiers

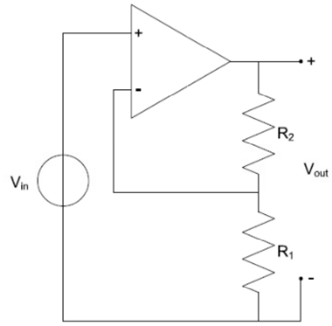


Figure 10.4: *Operational amplifier used in a non-inverting amplifier circuit.*

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

G = 1 + R2 / R1

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Operational Amplifiers

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

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Amplifying AC Signal

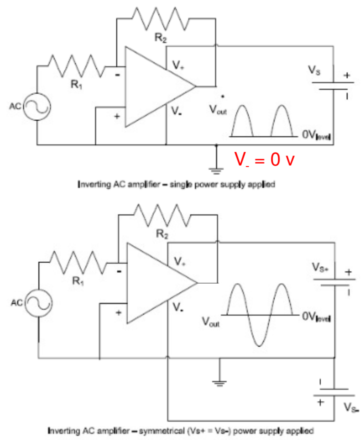

Figure 10.5: *Operational amplifier used as AC amplifier.*

Op amps and Comparators

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

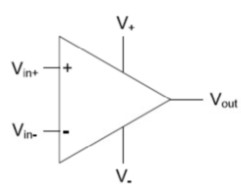

Figure 10.1: *Schematic symbol for an operational amplifier.*

$V_{in+} > V_{in-}$, $V_{out} = V_+$
$V_{in+} < V_{in-}$, $V_{out} = V_-$

Op amps and Comparators

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

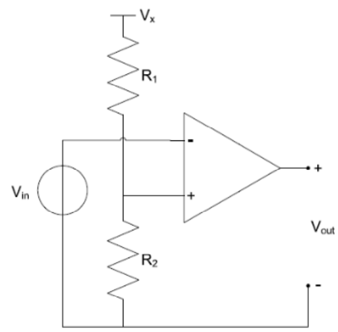

Figure 10.6: *Operational amplifier used in a comparator circuit with static comparison.*

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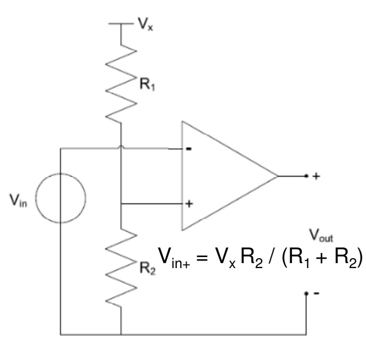
Op amps and Comparators

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



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

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

How to obtain the following?

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

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

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

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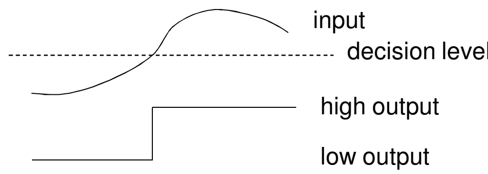
Op amps and Comparators



Output of a comparator when the input is clean.

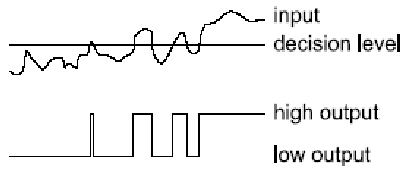


Figure 10.7: *The output of a comparator toggles when the input is noisy.*

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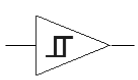
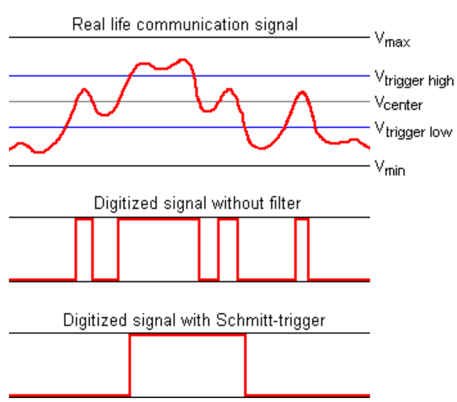
Op amps and Comparators

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

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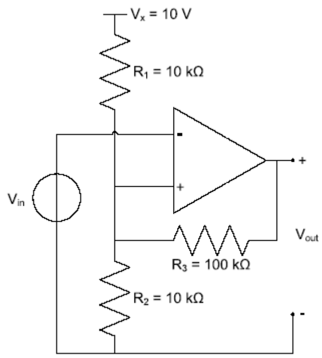
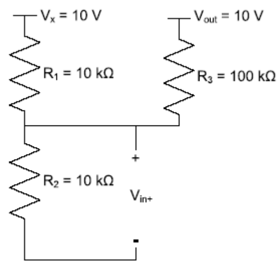
Op amps and Comparators

$V_{out, high} = 10$ V





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

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

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

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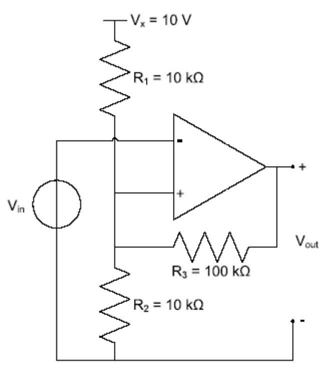
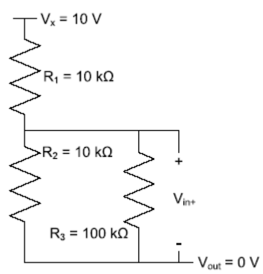
Op amps and Comparators

$V_{out, low} = 0$ V





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

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

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

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Op amps and Comparators

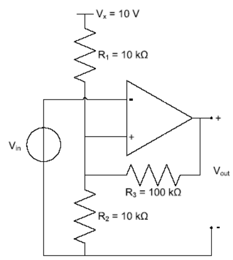
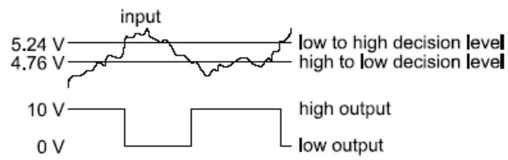


Figure 10.9: *An opamp with feedforward in a static comparator circuit.*



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

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Sensors and Actuators

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Human Senses

from http://www.phoenixmasonry.org/masonicmuseum/glossary/images/slide_77_the_five_senses.jpg

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What are Sensors and Actuators?

- Electronic sensors and actuators are components that enable interaction between the physical world and electrical circuits.
- A sensor converts a physical phenomenon into an electrical signal for processing.
- An actuator converts a processed electrical signal to a physical phenomenon.

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Why Sensors and Actuators?

- Design intelligent products
- Extend the sensing beyond our human senses
  - Standard frequency range of human hearing: 20 Hz - 20 kHz
  - Limited temperature range a human being can feel
  - etc.
- Benefit our life
  - Health
  - Security
  - Entertainment
  - etc.

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Sensing the Environment

- Sensors have been used to explore the changes in the environment.
- Provide direct information on physical parameters:
  - Lightness
  - Pressure
  - Temperature
  - Magnetic field
  - etc.
- Give indirect indication on emotion of human:
  - comfortable
  - excited
  - angry
  - etc.

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Actuators

- An actuator converts a processed electrical signal to a physical phenomenon.
- Actuators can have both continuous and discrete values. - switch light on / off or use a dimmer
- Actuators are all around us:
  - speakers
  - electric motors
  - heating elements
  - light sources
  - etc.

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A Central Heating System

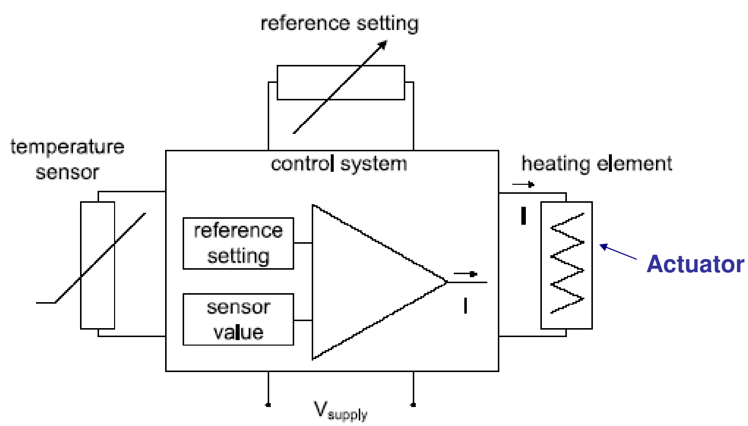

Figure 11.1: *Closed-loop temperature control system.*

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Example Design Project

Light Dependent Sensors

Green street, B1.1 project, designed by Ivo Wouters, Bart van Oorschot, Jasper Blom, Maarten Woudstra, Rick Paffen and Rik Hermans
http://www.youtube.com/watch?v=rOWoT-PJPiI

Light Dependent Resistor (LDR)

The resistance of a LDR depends on the lightness:
- When the lightness increases, the value of the resistance decreases.
- Typical resistance values: 5.5 kΩ in dark, 55 Ω in a light environment

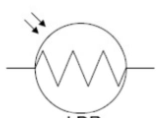

Figure 11.3: *Schematic symbol for an LDR*

Light Dependent Resistor (LDR)

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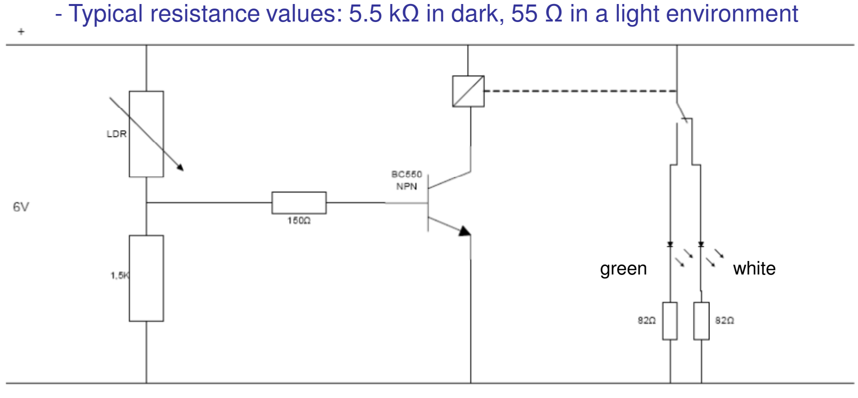
- Typical resistance values: 5.5 kΩ in dark, 55 Ω in a light environment



LDR for light color switching control - Student project "Green Street"
designed by Ivo Wouters, Bart van Oorschot, Jasper Blom, Maarten Woudstra, Rick Paffen and Rik Hermans
http://www.youtube.com/watch?v=rOWoT-PJPiI

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Temperature - sensitive: NTC and PTC

- NTC: Resistance value decreases when temperature increases.
- PTC: Resistance value increases when temperature increases.

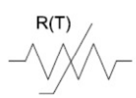

Figure 11.8: *Schematic symbol for NTCs and PTCs.*

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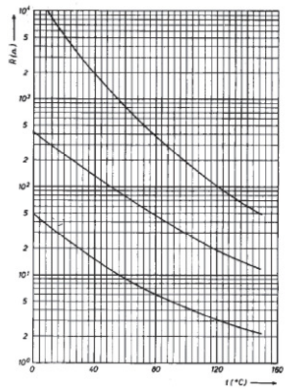
Temperature - sensitive: NTC and PTC

- NTC: Resistance value decreases when temperature increases.
- PTC: Resistance value increases when temperature increases.



Resistance vs. temperature for three different NTCs.

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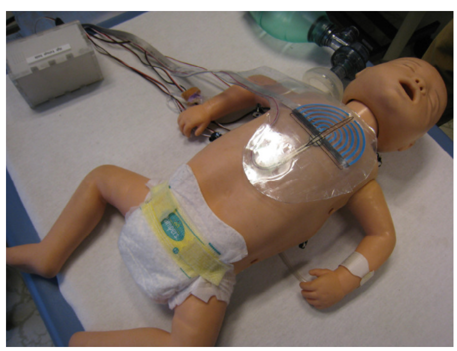
Example Design Project

Pressure Sensors



Rhythm of life (I&II), M1.1 and B2.1 project, designed by Floris Kimman, Maarten Geraets, Yening Jin, Nicolas Nelson, Mark Thielen, Yi Xue
http://www.idemployee.id.tue.nl/w.chen/papers/wchen-TITB-Journal10.pdf

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Smart Textile

- Health monitoring

Textile sensor in a belt to monitor child's ECG and respiration.
- Ghent University, Belgium

- Protection for special tasks, e.g. Jackets for fire fighter

from: bensguide.gpo.gov/images/ben/ben_fireman.jpg

- Emotion reflection (e.g. body motion monitoring, color changing T-shirt)

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Example Design Project

Smart Textile Sensors

Smart jacket for NICU, M2.2 project, designed by Sibrecht Bouwstra
http://www.smartjacket.id.tue.nl/

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E-atelier

- http://www.eatelier.nl/
- http://www.eatelier.nl/components
- http://www.eatelier.nl/example-circuits/blog

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