# Wheatstone bridge coffeemaker

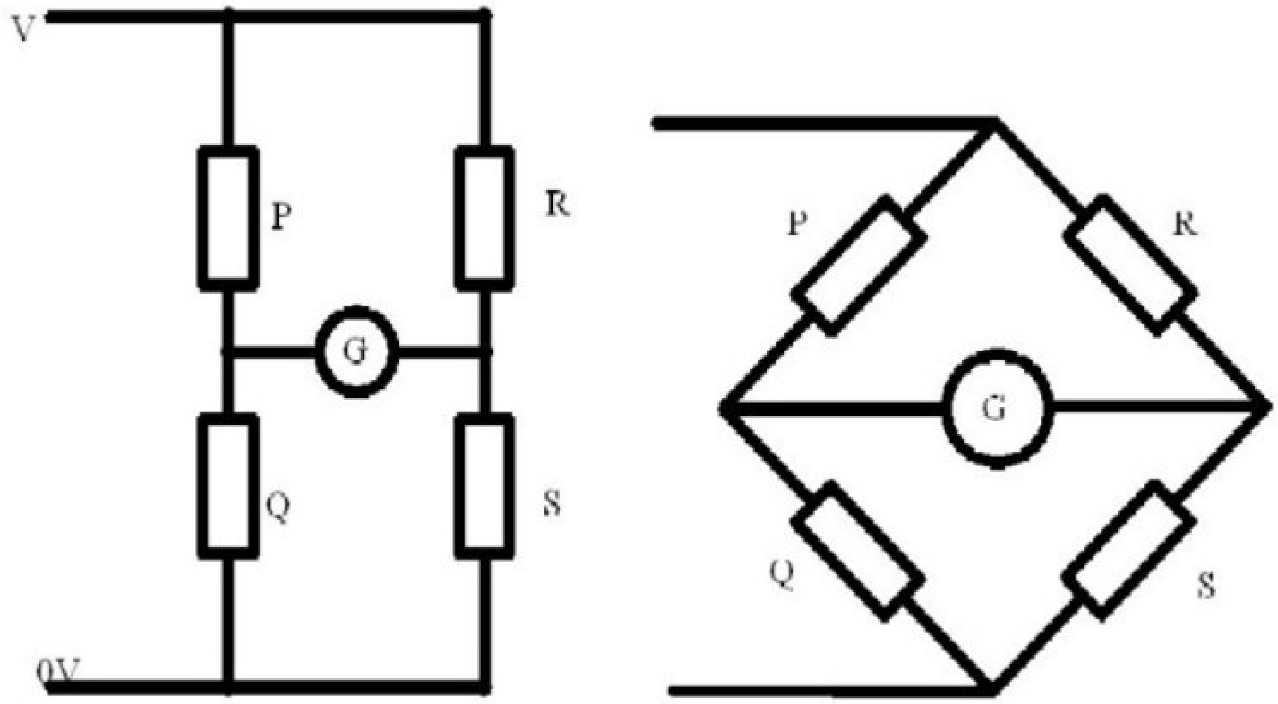
Jan Bollen

# Agenda

- Wheatstone bridge
- Opamp Component
- Opamp Comparator
- Hysteresis

# Principle

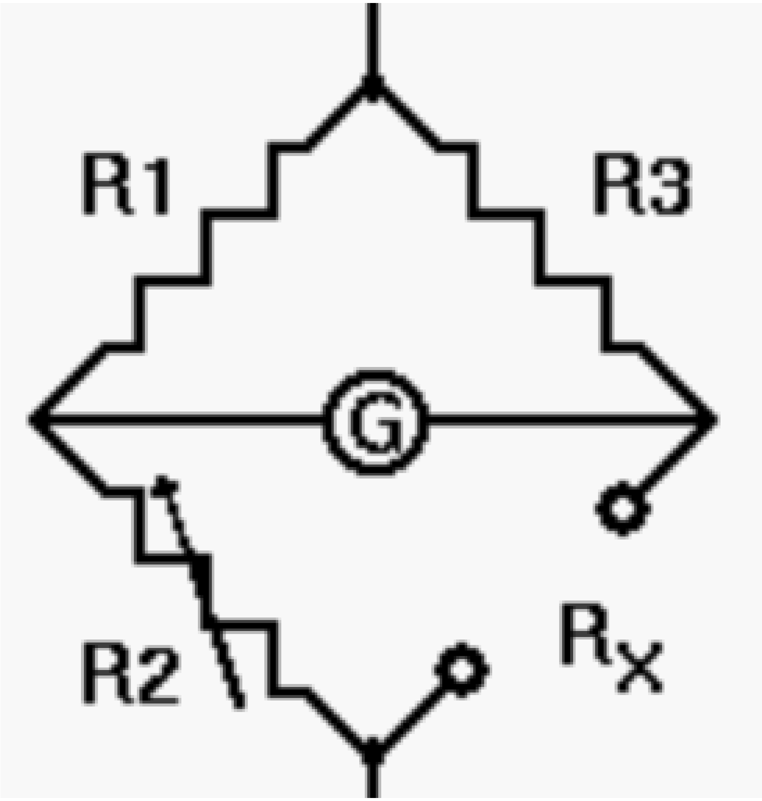
A Wheatstone Bridge consists of **two voltage-dividers**.




At **balance** there is no current that flows through a Galvanometer G ( G = a sensitive ampere meter).

# Working

Resistor $R_X$ is connected as the fourth side of the circuit




R2 is adjusted until the galvanometer G reads **zero**.

At this point,

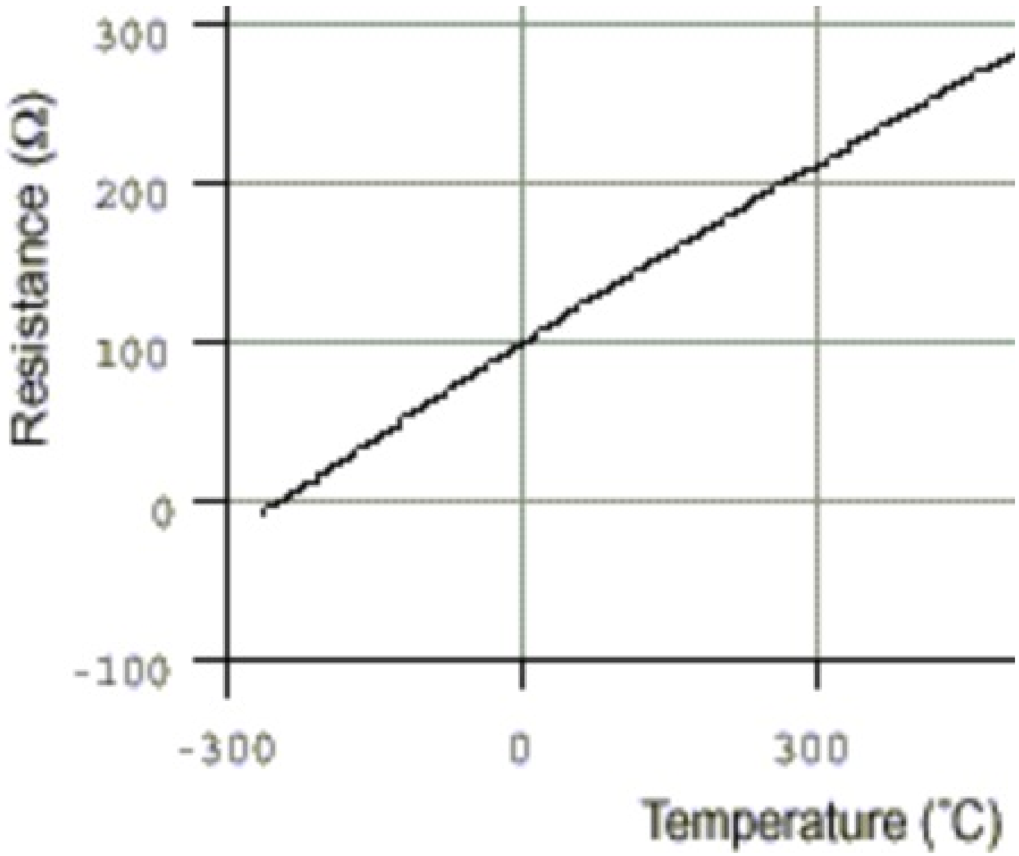
$$\mathbf{R_X/R2 = R3/R1}$$

**or**

$$\mathbf{R_X = R2 \times R3/R1}.$$

# PT-100

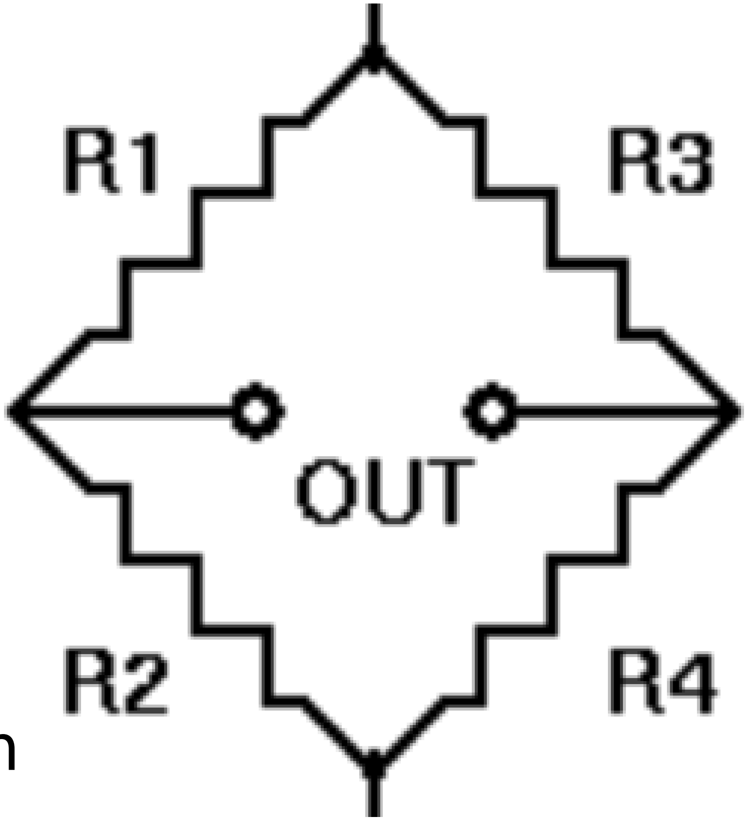
**Platinum resistance temperature detect**




Pt-100
typical resistance
of 100 Ω at 0°C

Resistance increases lineair
when temperature is increasing

# Sensitivity




R2 = PT-100 = 100 Ohm

R1 = R3 = R4 = Rx

Simulate with

Rx = 1 Ohm, Rx = 10 Ohm

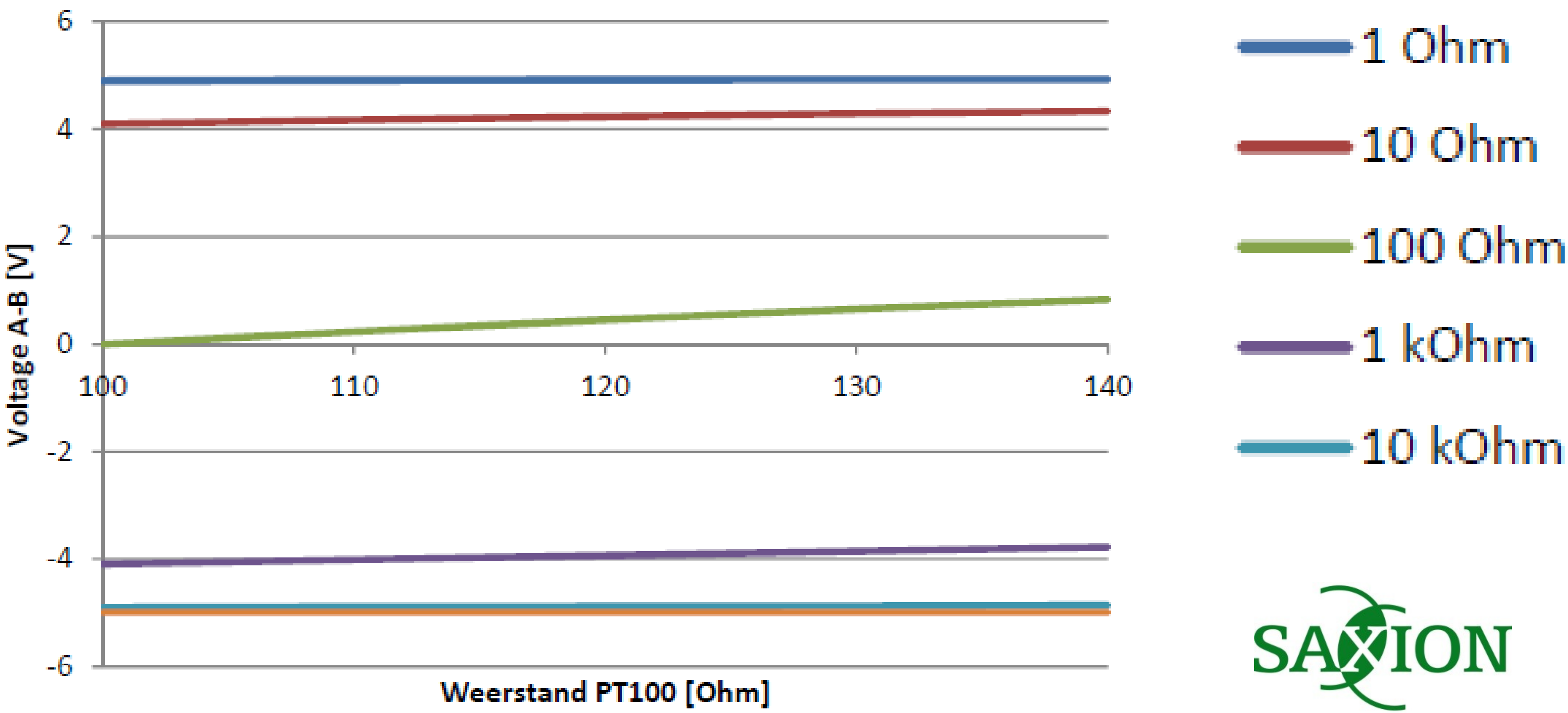
Rx = 100 Ohm, Rx = 1k Ohm

Rx = 10 K Ohm

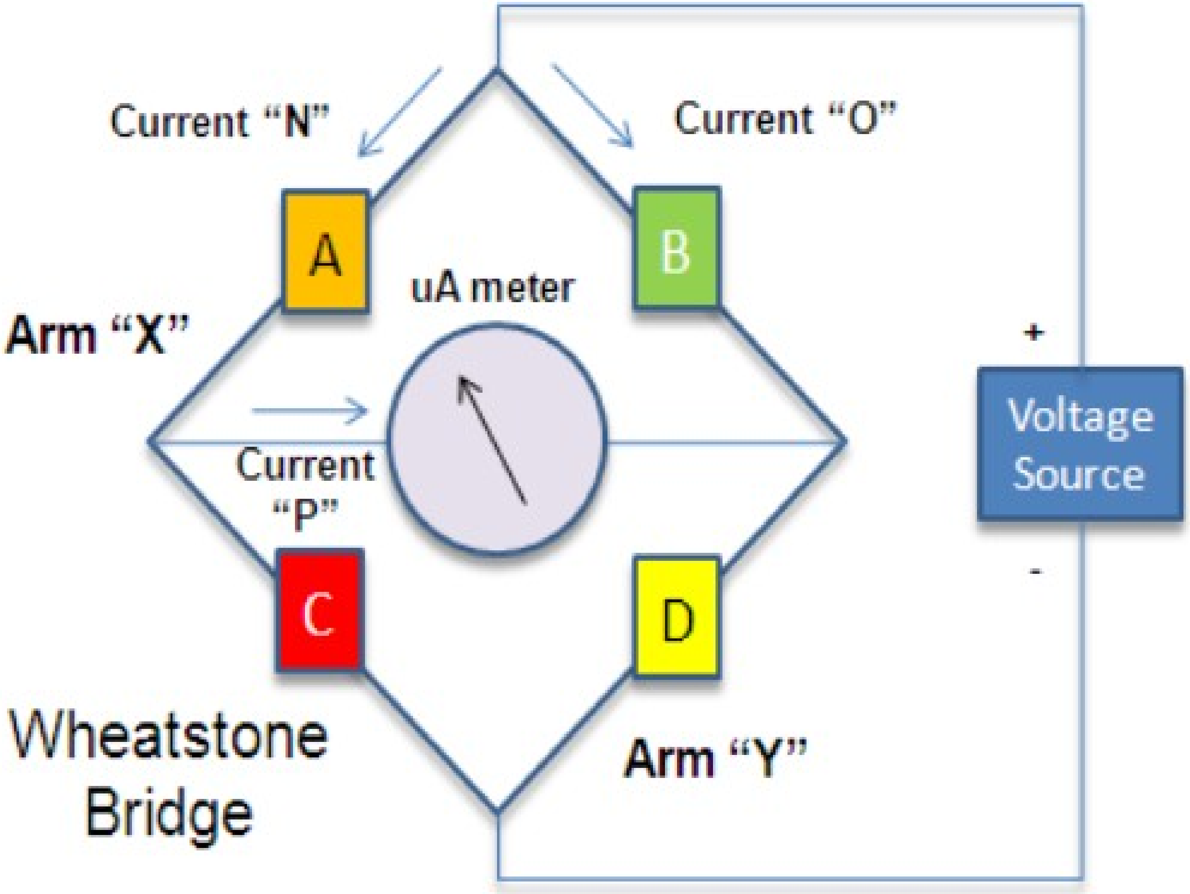
Find the resistor Rx for maximum sensitivity in Uout signal, conclusion?

# Simulation graph

Bridge Voltage = f (resistance PT-100)



# Balance idea for coffeemaker




2 arms;

One for Reference

One for Measuring

**In balance A.D = B.C**

# Opamp Component coffeemaker

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# **OP**erational **AMP**lifier
# **OPAMP** as
# **Comparator**

How does an OpAmp work open loop?

What is compare?

What is hysteresis?

# OPAMP, symbol and package

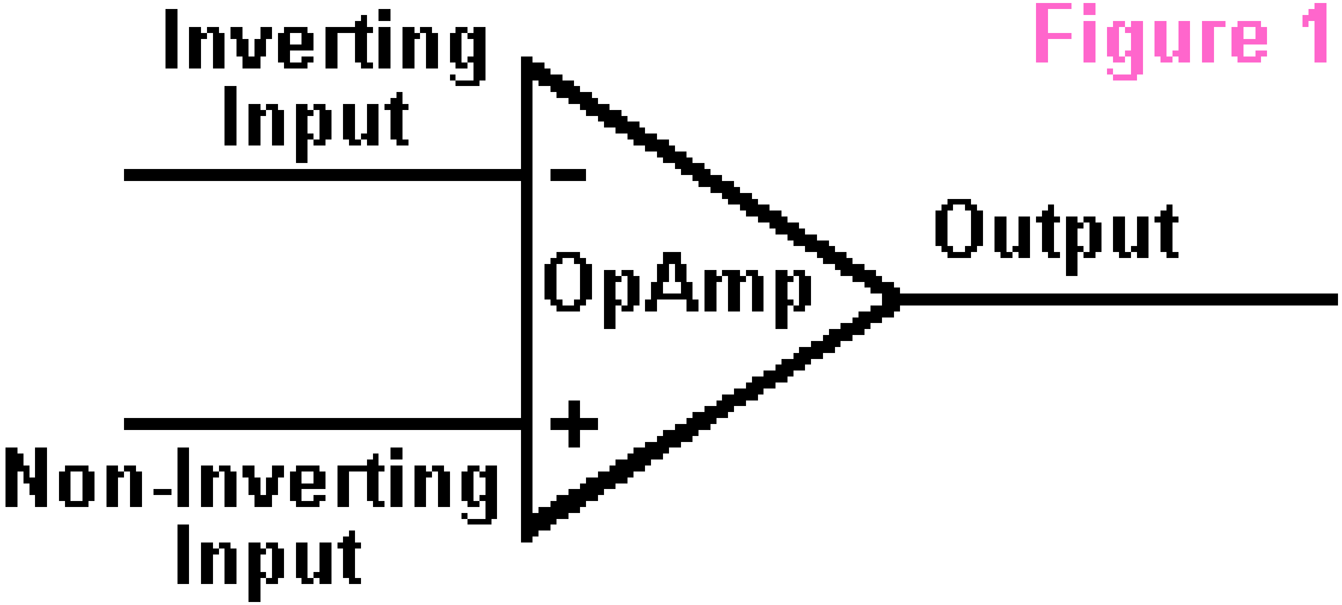
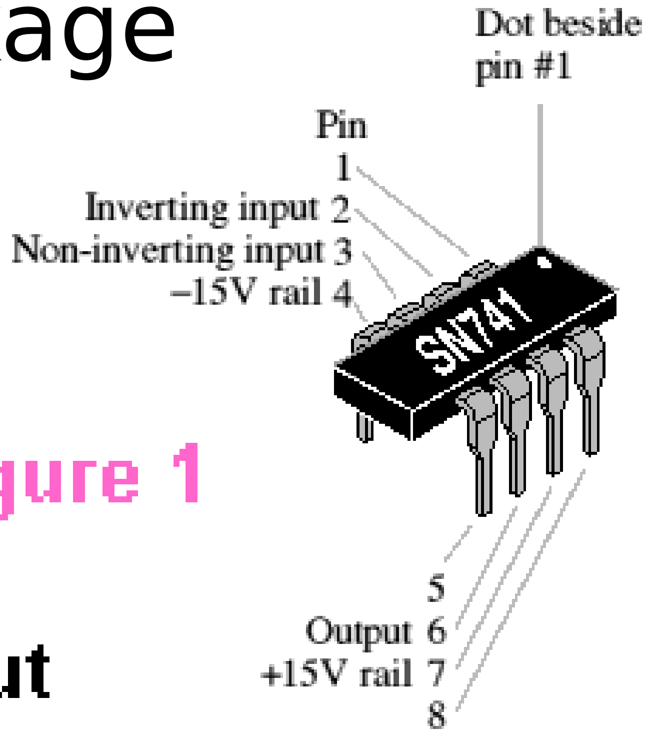



Figure 1



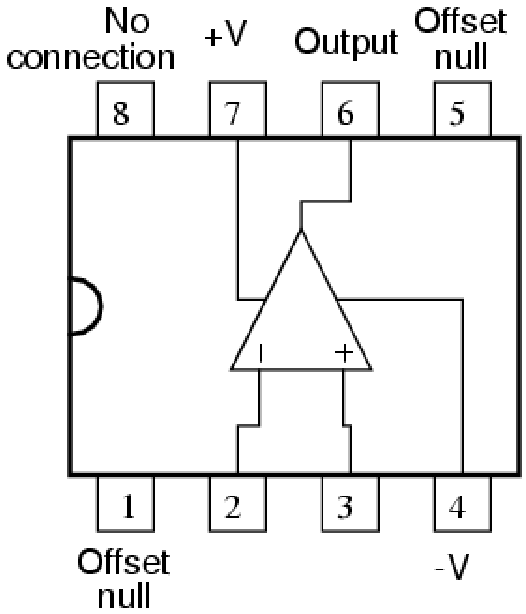
# OPAMP, connections

**+V** = **Vcc**
= *most positive*
power supply
**-V** = **Vee**
= *most negative*
power supply

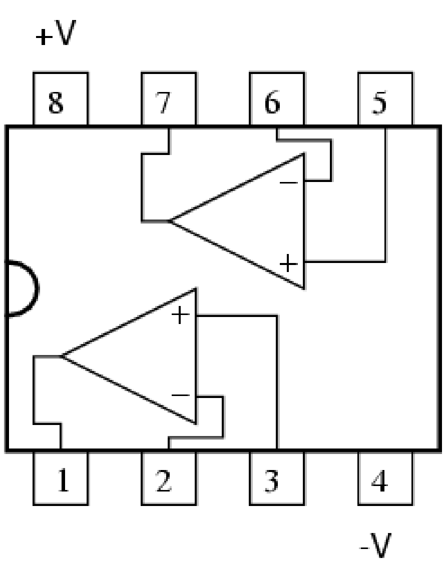
**V+** = non-inverting input
**V-** = inverting input

**Output** = output

*Typical 8-pin "DIP" op-amp integrated circuit*




Dual op-amp in 8-pin DIP



# OPAMP, internal

**+V** = **Vcc**

**-V** = **Vee**

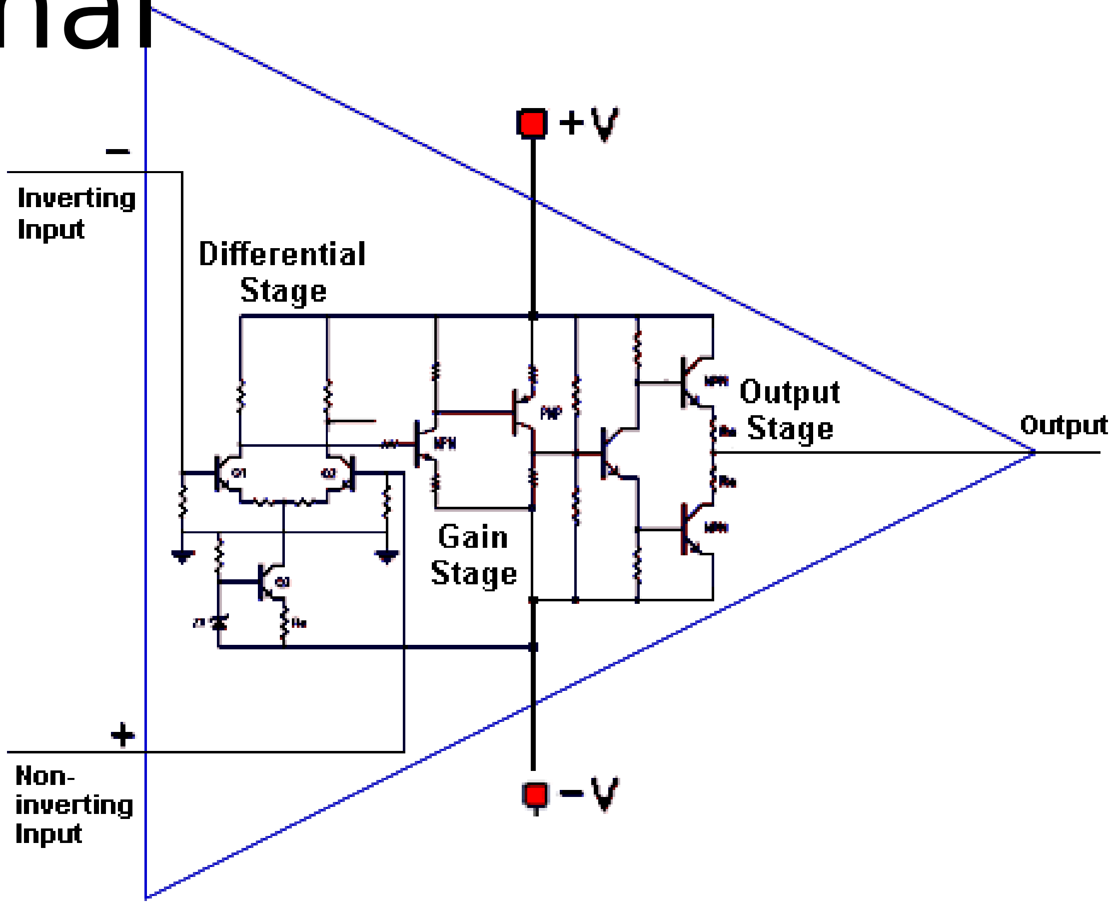
**V+** =

non-inverting input

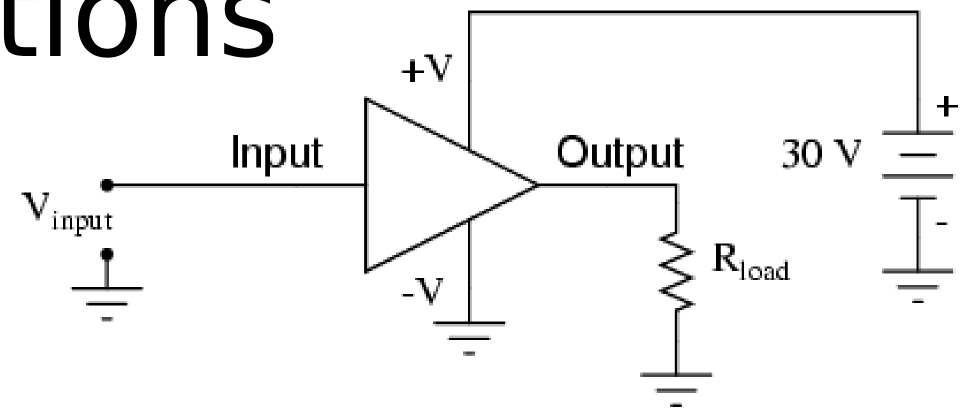
**V-** =

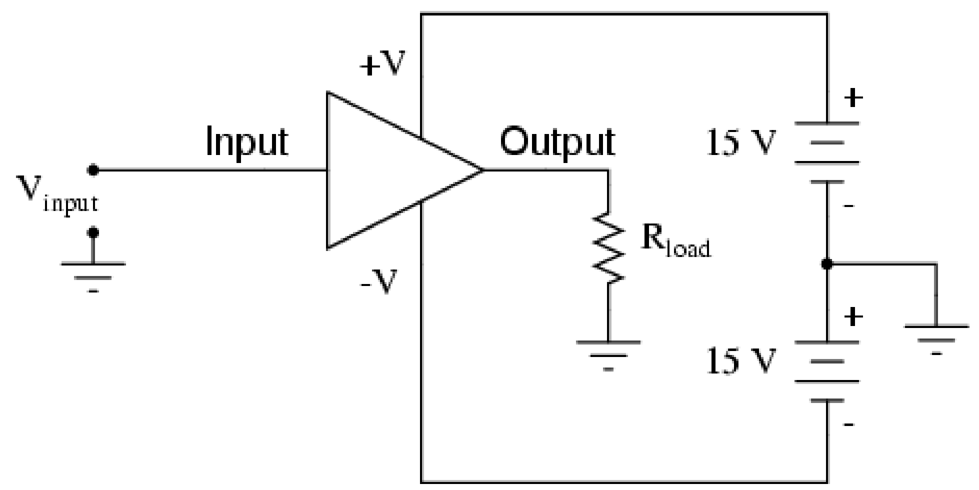
inverting input

**Output** = output

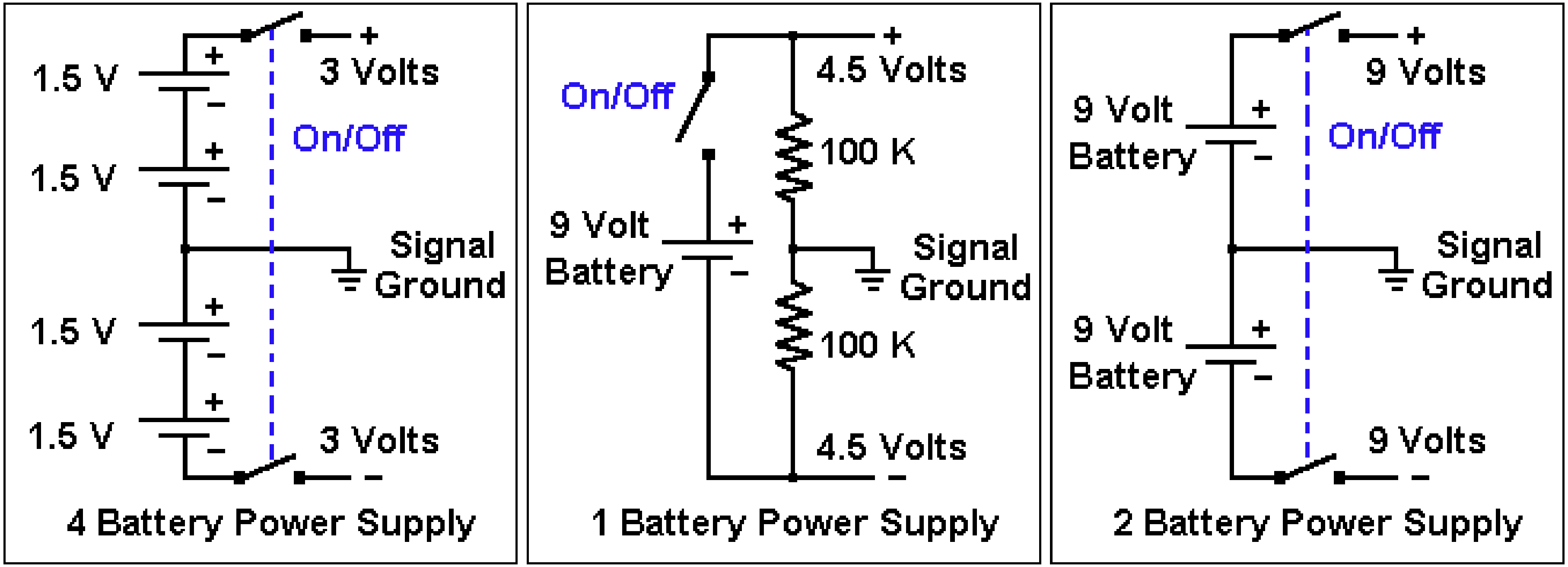


# Power connections

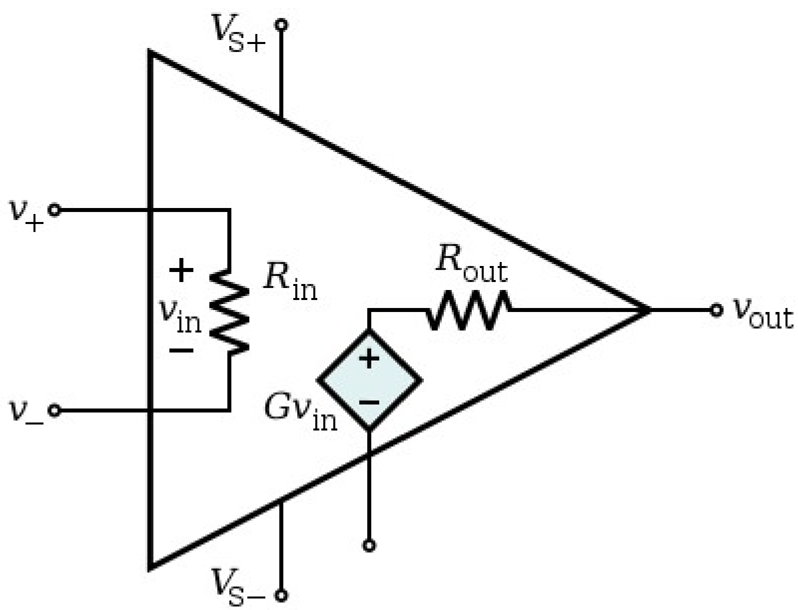


# OPAMP, Vcc and Vee, examples



# OPAMP, remember **GOLDEN RULES**




1) The input impedance is infinite - i.e. no current ever flows into either input of the op-amp.

2) The output impedance is zero - i.e. the op-amp can drive any load impedance to any voltage.

3) The open-loop gain (A) is infinte.

4) The bandwidth is infinite.

5) The output voltage is zero when the input voltage difference is zero.

# OPAMP, in real

| What You WANT | What You GET |
| --- | --- |
| 1) The input impedance is infinite - i.e. no current ever flows into either input of the op-amp. | NO, but it is often GIGA or TERA Ω! |
| 2) The output impedance is zero - i.e. the op-amp can drive any load impedance to any voltage. | NO, but is can be a few ohms in many cases! |
| 3) The open-loop gain (A) is infinte. | NO, but it is usually several million! |
| 4) The bandwidth is infinite. | NO, usually several MHz. |
| 5) The output voltage is zero when the input voltage difference is zero. | NO, offset voltages exist, but can be trimmed. |

# Opamp Comparator coffeemaker

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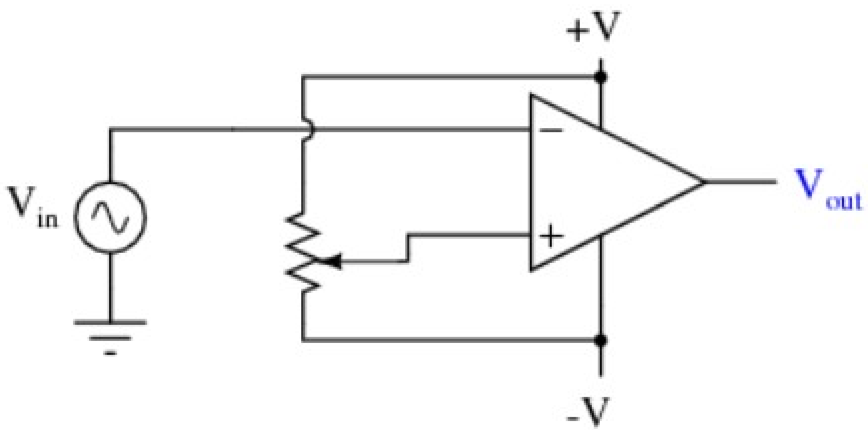
# Comparator




**+V** = **Vcc** = + 5 Volt

**-V** = **Vee** = - 5 Volt

R = voltage divider adjusted at + 1 Volt

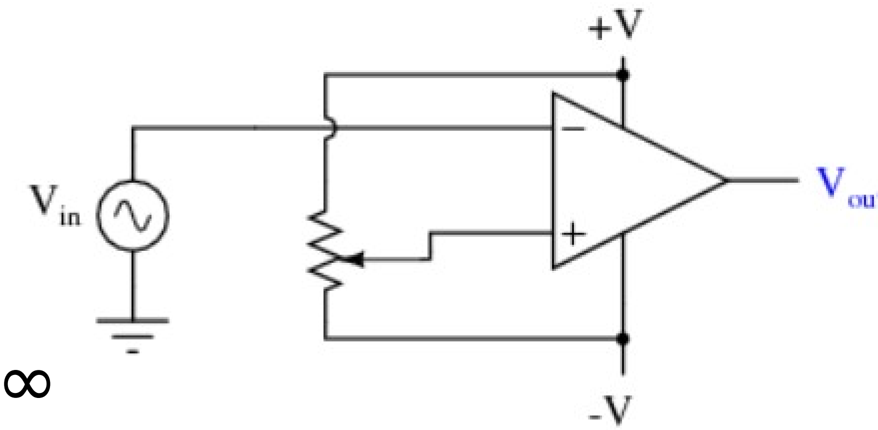
**V+** = + 1 Volt

**V-** = sine wave of + 5 Volt top

sine wave of 10 Volt top-top

Question; what will be the **output voltage?**

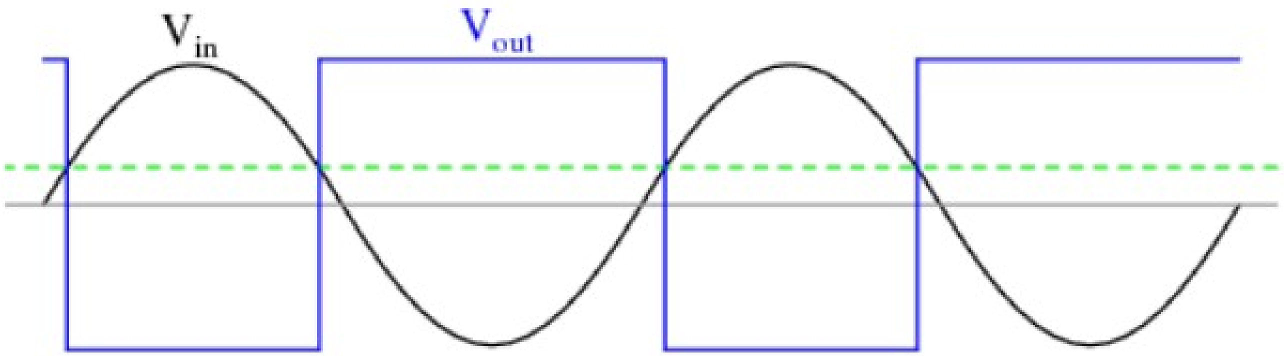
# Comparator



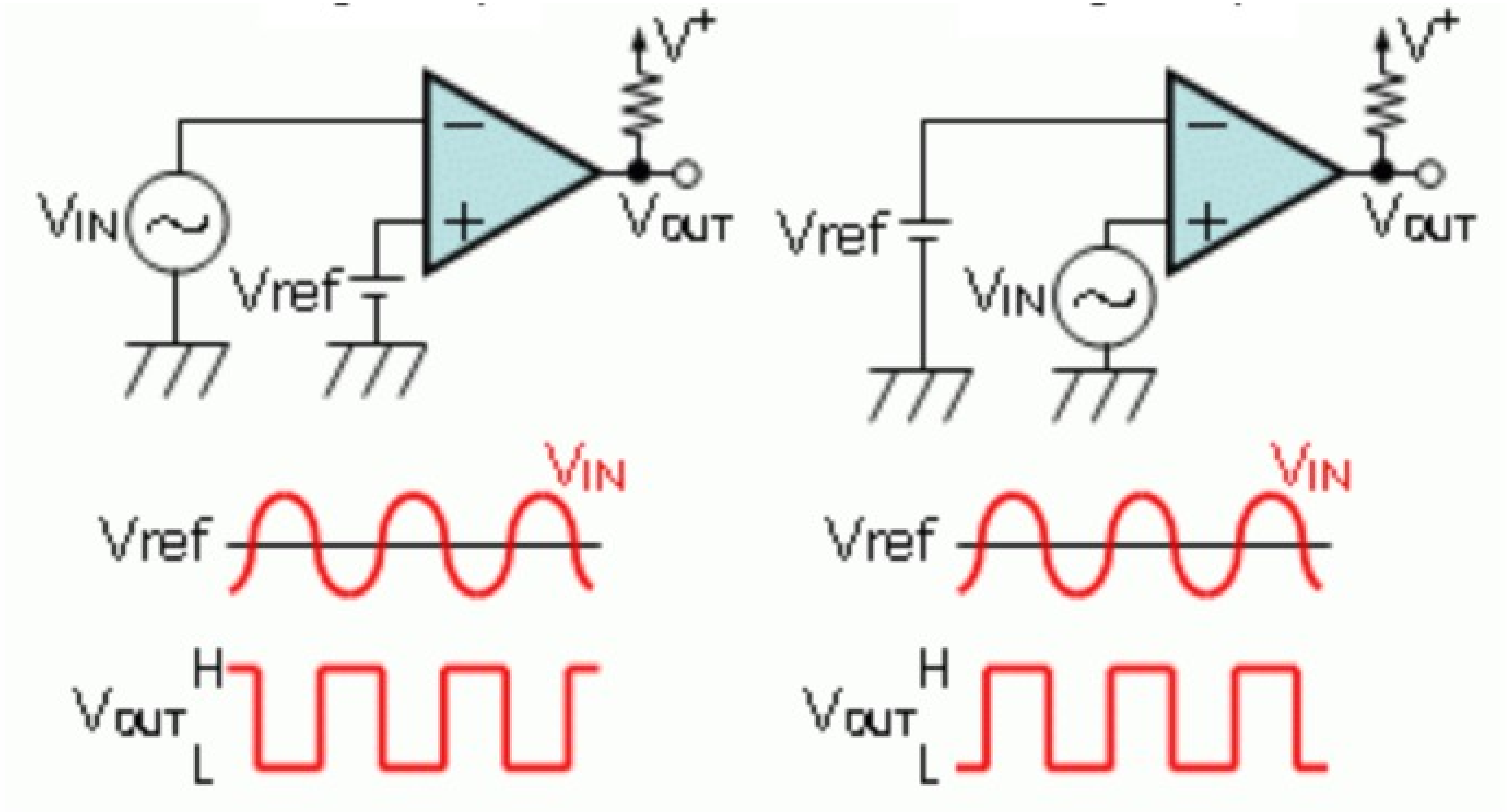

**Uout** = A **(V+** - **V-**)

A = open-loop gain = ∞

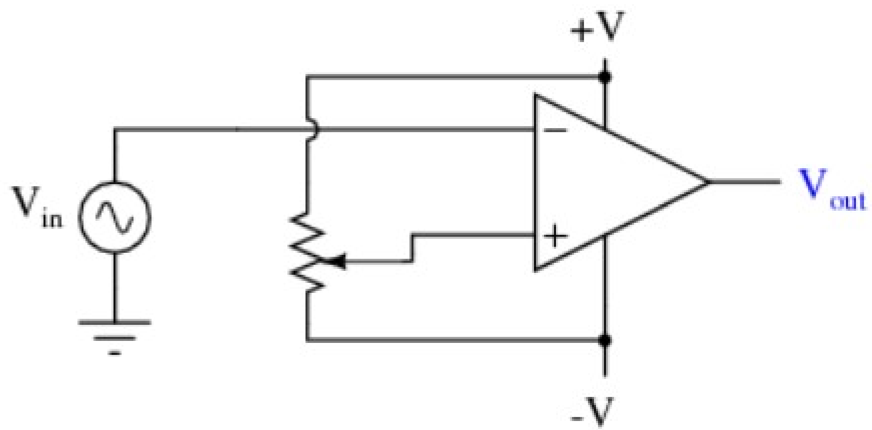
Question; what will be the signals if we change the connections of V+ and V-



# What is the difference?



# Case




+V = +15 Volt

-V = -15 Volt

Question;

1 Is this an inverting comparator or
an non-inverting comparator?

2 Can the output voltage be equal to 0 (zero) volt?

3 Conclusion?

# Summary

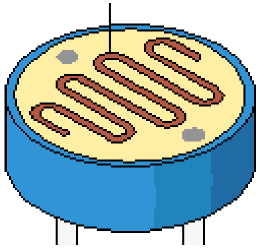
A comparator compares 2 values, in our case

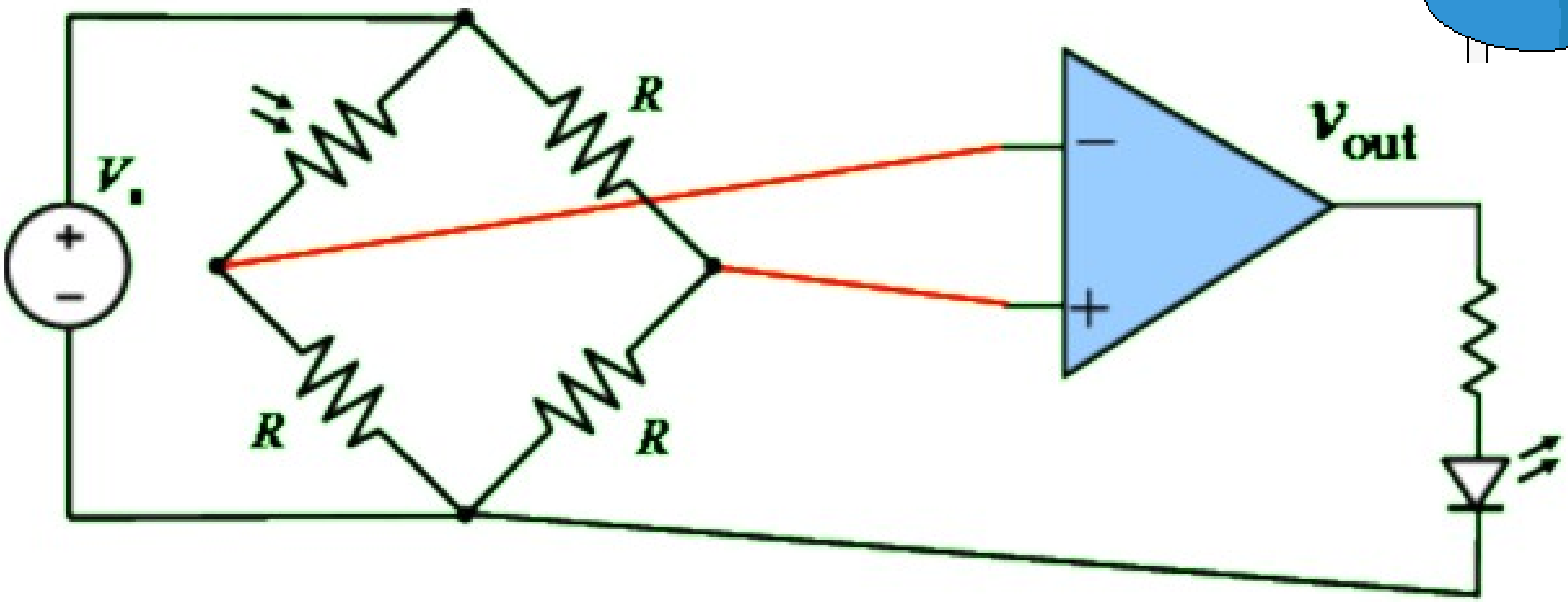
1 a reference value
(desired temperature / set point)

2 a measured value
(actual temperature)

And gives a logical output signal, indicating
too hot (no heating, heating **off**) or
too low (heating **on**)

# Light switch, example



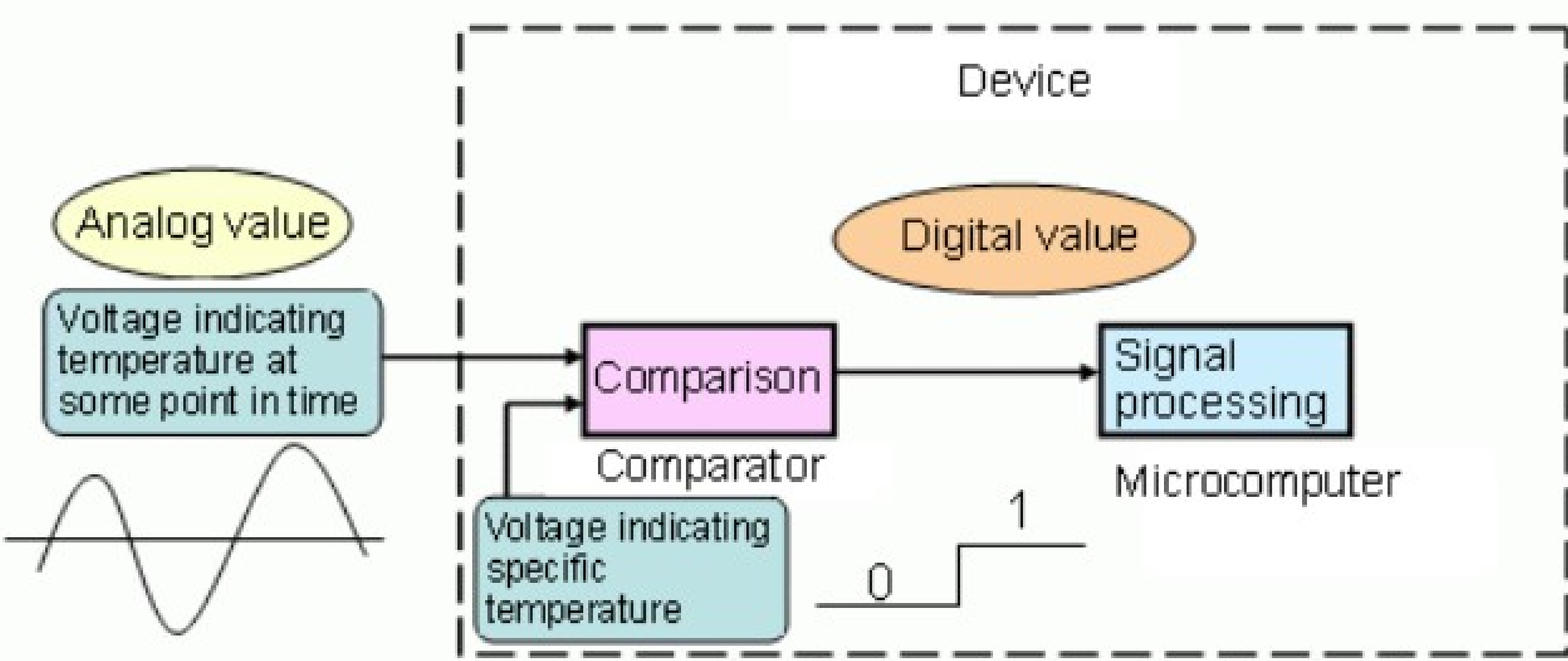



Explain how this circuit works.

If it is light is the value of LDR high or low

If it is dark is the value of LDR high or low

# Block diagram



# Opamp Hysteresis coffeemaker

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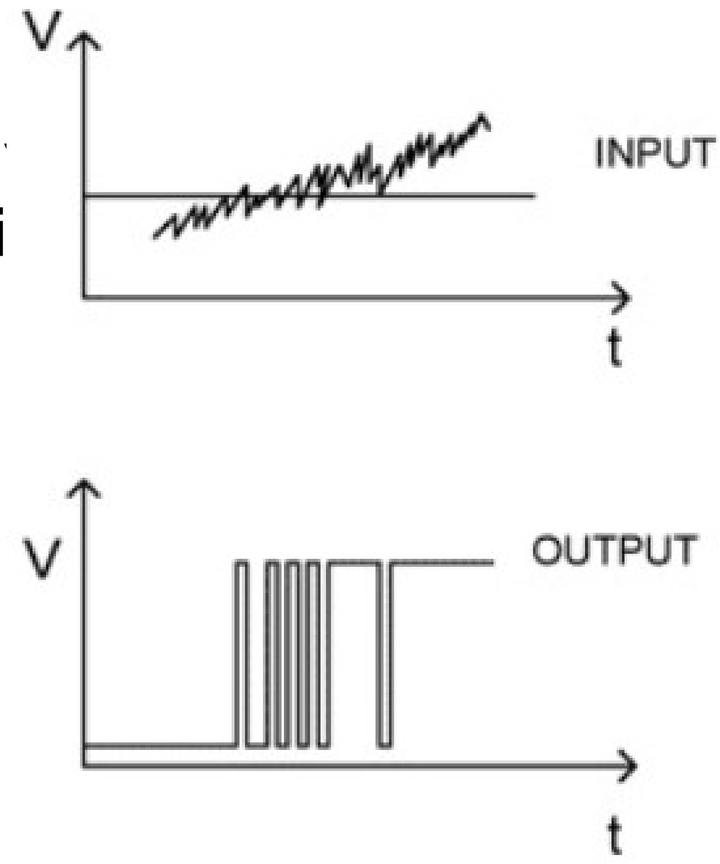
# On-Off-On-Off

If temperature changes slightl
around set point the heater wi

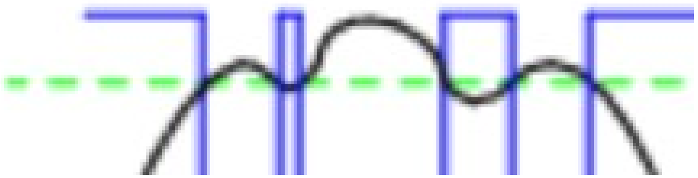


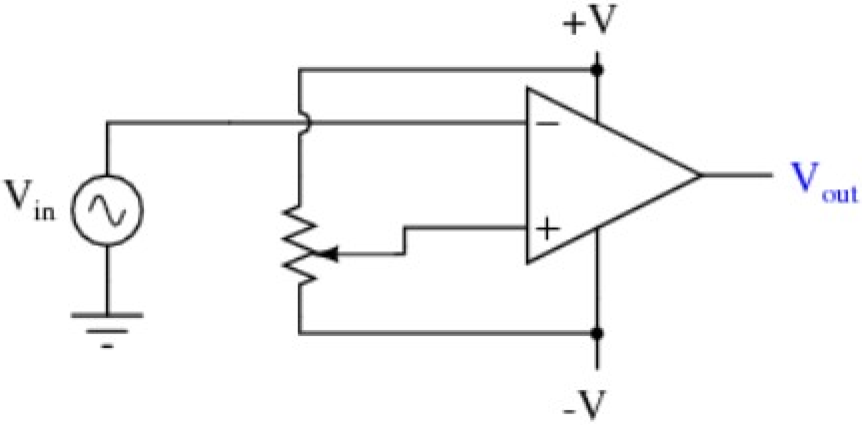

on-off-on-off-on-off-on-off

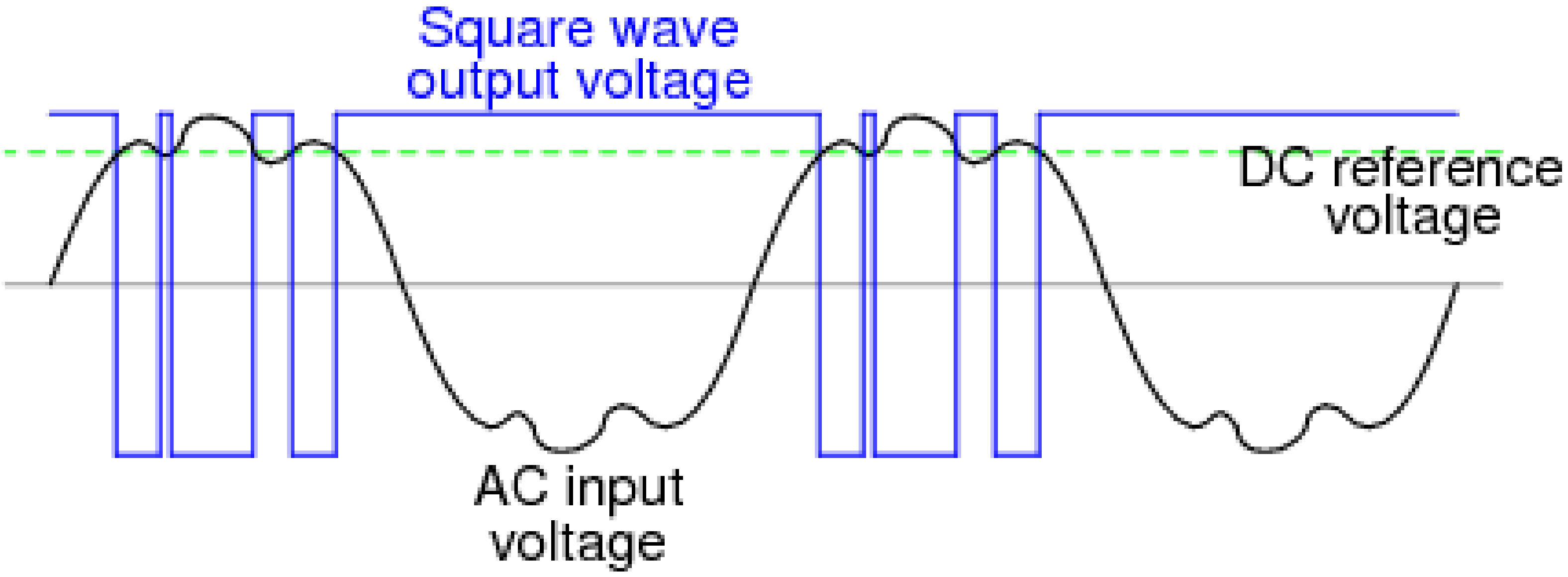
This is unwanted,

then we use a hysteresis.

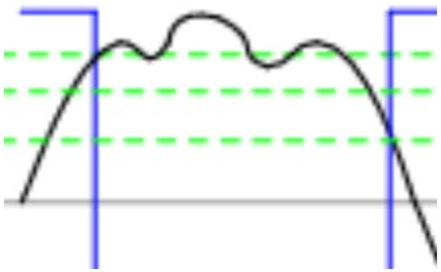
# On-Off-On-Off

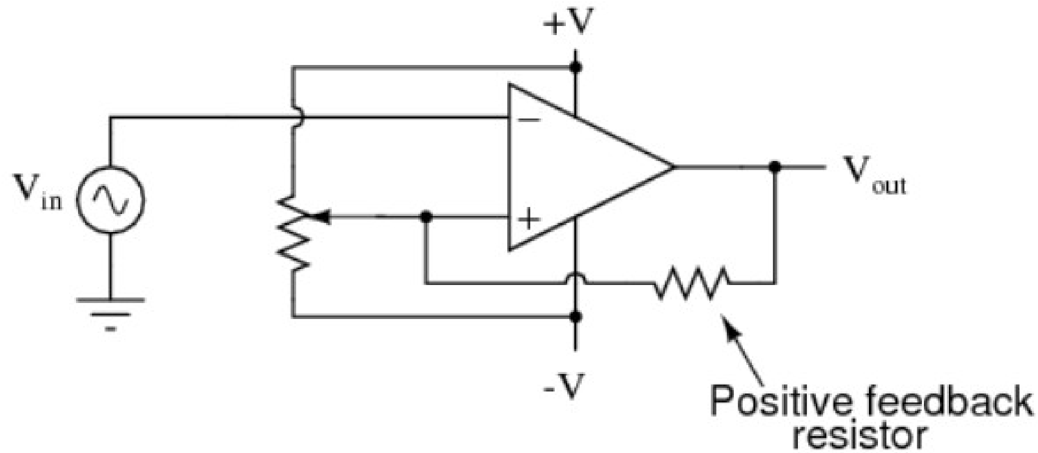



+V
-V
Vin
Vout
−
+

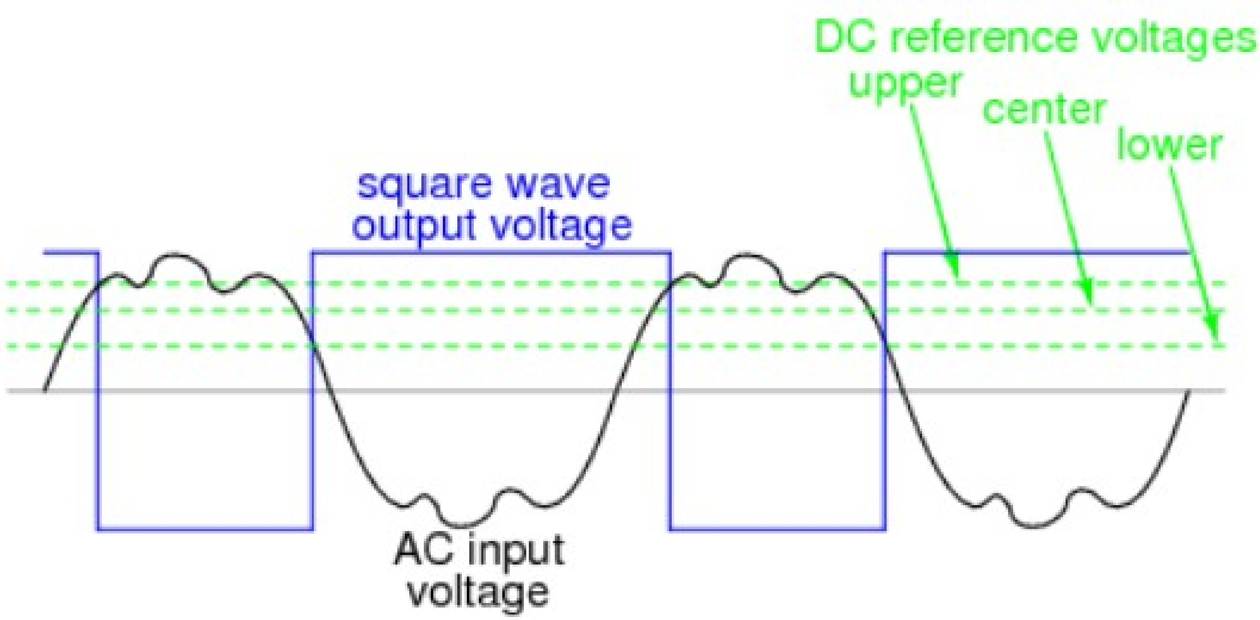

Square wave output voltage
DC reference voltage
AC input voltage

# Hysteresis






**Changing reference level !!**

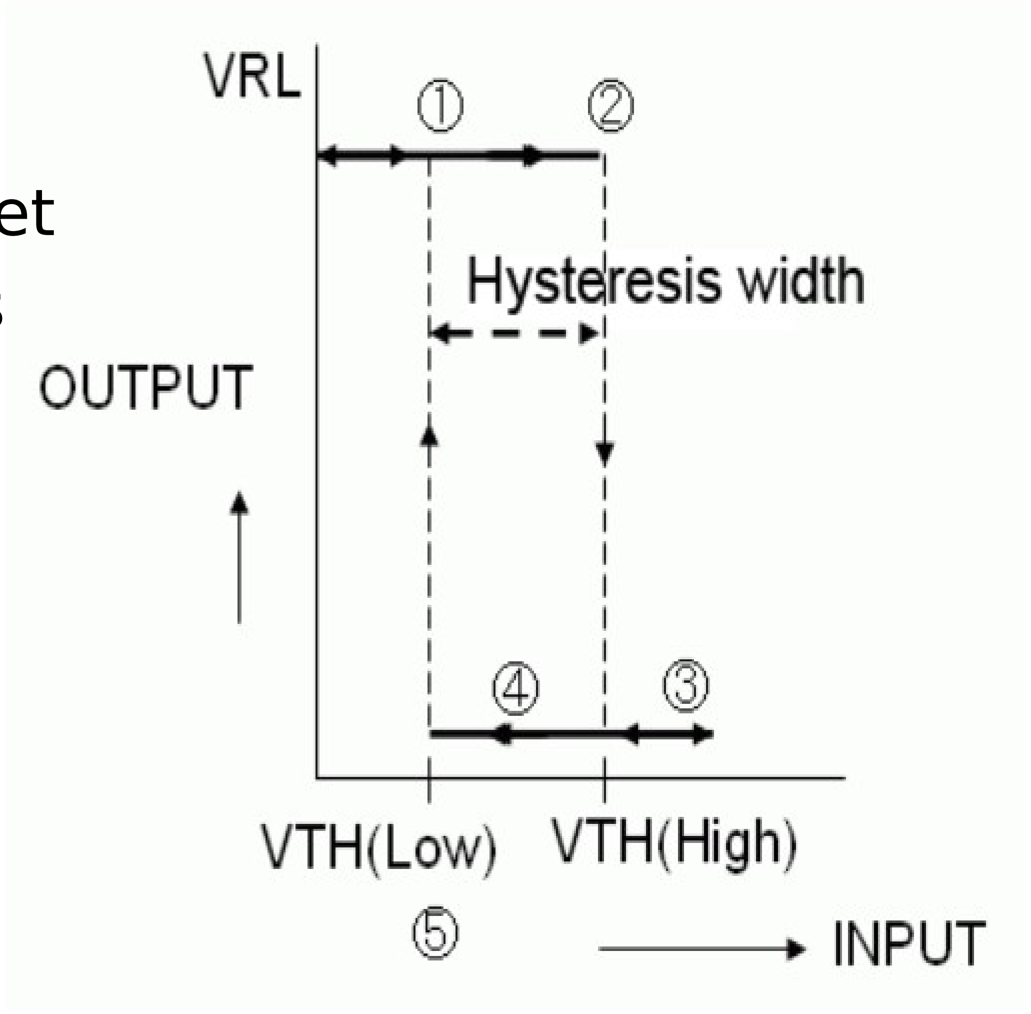


# Hysteresis

By using hysteresis we get
2 new threshold voltages

V TH high
V TH low

In between is the
Hysteresis width
or dead zone,
Noise is permitted here



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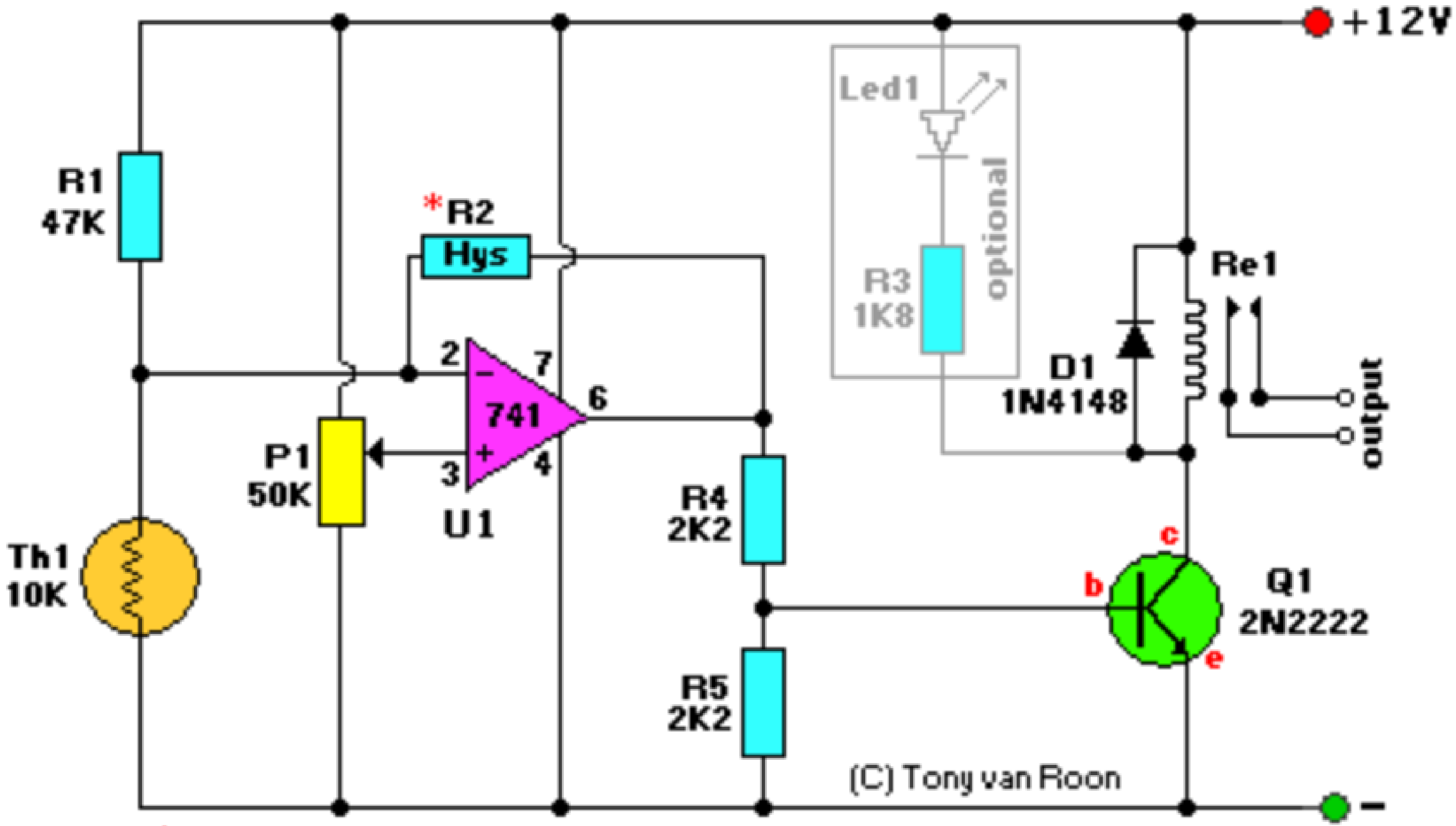
# Heat Sensor




*R2 = Hysteresis. If relay 'chatters' make value approx. 150 - 390 K

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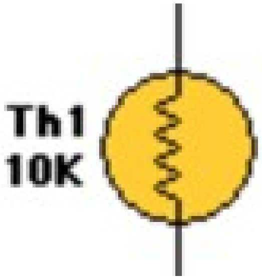


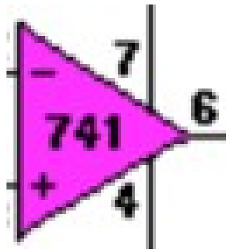


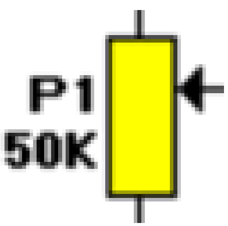


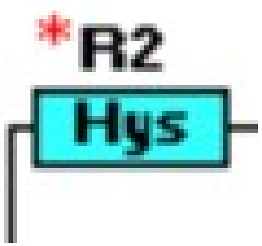


The Thermistor **NTC (Negative Temperature Coefficient)** is 10K. The resistance lowers as the surrounding temperature increases which affects the output (pin 6) and energizes the small relay and Led1.

**P1** is a regular trimmer potentiometer and adjusts a certain **range of temperatures.**

**R2** is optional in case your relays tends to 'chatter' a bit. It provides **hysteresis** when the set temperature of the thermistor reaches its threshold point.