

# Block 23 — Comparator Circuits

## Student Group

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# Block 23 — Comparator Circuits

## Learning objectives

After this 90-minute block, you can

- ...

## Preparation at Home

Well, again

- read through the present chapter and write down anything you did not understand.
- Also here, there are some clips for more clarification under 'Embedded resources' (check the text above/below, sometimes only part of the clip is interesting).

For checking your understanding please do the following exercises:

- ...

## 90-minute plan

1. Warm-up (x min):
  1. ....
2. Core concepts & derivations (x min):
  1. ...
3. Practice (x min): ...
4. Wrap-up (x min): Summary box; common pitfalls checklist.

## Conceptual overview

1. ...

## Core content

### Comparator

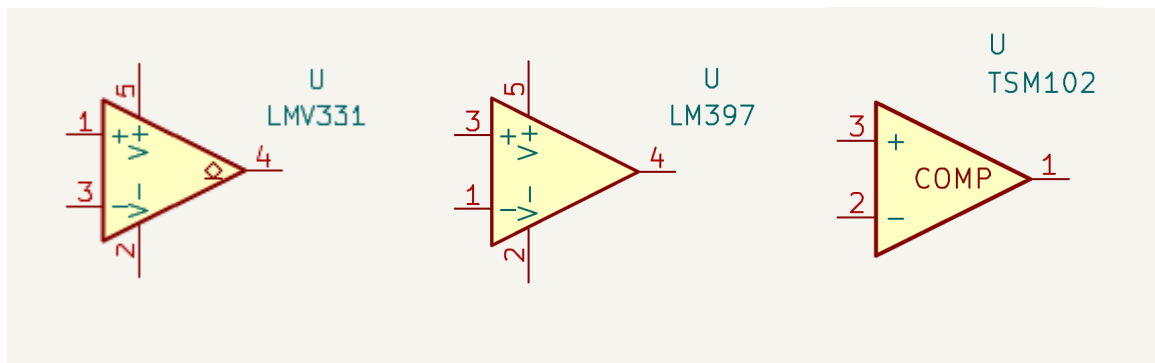
Up to now we focussed on operational amplifier, which is only usable in a closed-loop setup. However, it also as a “special brother”, the **comparator**.

The differences form the comparator in contrast to the operational amplifier are:

1. It is **only used in positive feedback**. It should never be used in negative feedback.
2. It is optimized for **fast switching**

3. It only outputs **in saturation**, which means it only has two possible outputs, see details below.

The symbol is related to the op-amps triangular shape - often the exact same symbol is used.



We again have two inputs: The non-inverting input  $u_{\text{p}}$  and the inverting input  $u_{\text{n}}$ . They result in the differential voltage  $u_{\text{d}} = u_{\text{p}} - u_{\text{n}}$ .

So, but what is the output, now? For this, it helps to have a look onto the simulation below.

There are two types of comparators:

#### 1. comparators with open-collector output:

This type outputs the minimum value, when the non-inverted input is bigger than the inverted one.

Otherwise, the output is **high-ohmic** or **undefined**.

This is sometimes shown by a diamond shape  $\diamond$  on the output.

For these type, a **pull-up resistor** is needed to have a readable output in case of  $u_{\text{d}} > 0$ .

$$u_{\text{O, OC}} = \begin{cases} \text{undefined} & \text{for } u_{\text{d}} > 0 \\ U_{\text{sat, min}} & \text{for } u_{\text{d}} < 0 \end{cases}$$

#### 2. comparators with push-pull output:

This type outputs the minimum value, when the non-inverted input is bigger than the inverted one.

Otherwise, it outputs the maximum value.

$$u_{\text{O, PP}} = \begin{cases} U_{\text{sat, max}} & \text{for } u_{\text{d}} > 0 \\ U_{\text{sat, min}} & \text{for } u_{\text{d}} < 0 \end{cases}$$

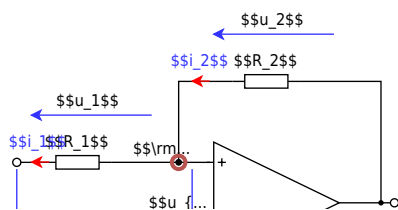
The values of the output voltages  $U_{\text{sat, min}}$  (and  $U_{\text{sat, max}}$ ), when defined) are given by the voltage supply of the comparator,

In the first simulation they are set unipolar to  $U_{\text{sat, min}} = 0 \text{ V}$  and  $U_{\text{sat, max}} = 5 \text{ V}$ .

## Non-inverting Schmitt Trigger

Based on the comparator, we can try to setup a “op-amp like” circuitry. However, we have to take care, that we use a positive feedback.

The most important circuit is similar to the inverting amplifier, but with positive feedback is it the **non-inverting Schmitt trigger**.



The **golden rules** ( $R_{in} = 0$ ,  $R_{out} \rightarrow \infty$ ,  $A_{D} \rightarrow \infty$ ) also apply here.

And similar to the operational amplifier the situation  $u_{in} = 0$  is important. This time, it is not automatically reached, but the turning point for changing the output value.

$$u_{in} \neq 0, u_{out} = \begin{cases} U_{sat, max} & \text{for } u_{in} > 0 \\ U_{sat, min} & \text{for } u_{in} < 0 \end{cases}$$

## Common pitfalls

- ...

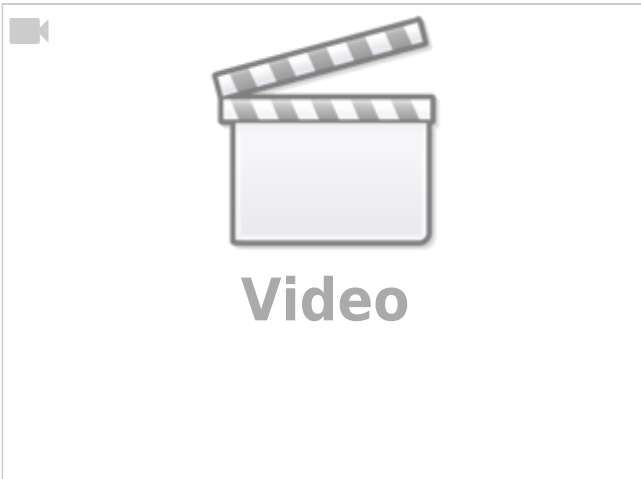
## Exercises

### Worked examples

...

## Embedded resources

Longer tutorial on Schmitt trigger



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