

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

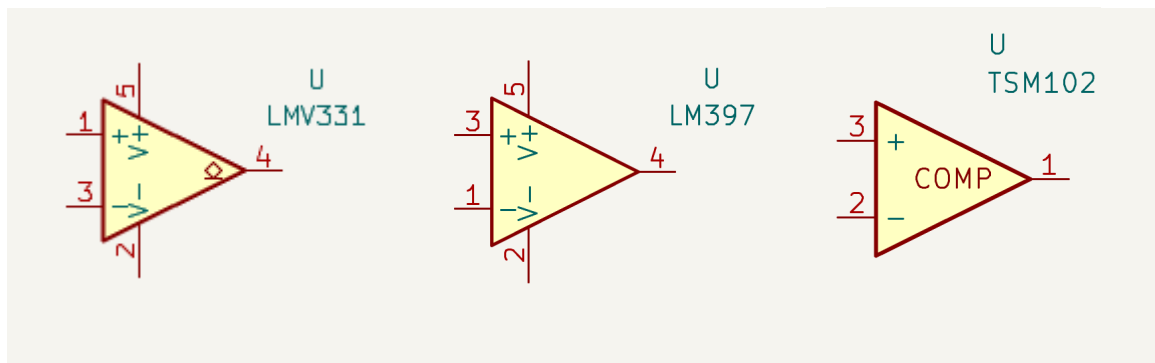
Up to now we focussed on operational amplifier, which is only usable in a closed-loop setup. However, it also as a “special brother”, the **comparator**.

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_{p} and the inverting input u_{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.

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

Similar to the operational amplifier, the situation $u_{\text{d}} = 0$ is important.

This time, $u_{\text{d}} = 0$ is not automatically reached, but it is the “turning point” for changing the output value.

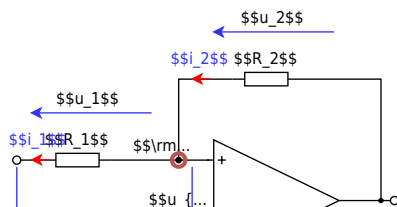
The values of the output voltages $U_{\text{sat, min}}$ (and $U_{\text{sat, max}}$, when defined) are given by the voltage supply of the comparator,

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** ($R_{\text{I}}=0$, $R_{\text{O}} \rightarrow \infty$, $A_{\text{D}} \rightarrow \infty$) also apply here.

Therefore, the currents through the resistors R_1 and R_2 are the same: $i_1 = i_2$ (given, that $R_{\text{O}} \rightarrow \infty$).

$u_{\text{D}}=0 \quad \rightarrow \quad u_{\text{O}} \text{ changes its state}$

At the “turning point” with $u_{\text{D}}=0$, the input and output voltages are equal to the voltages over the resistances.

However, the signs have to be considered (when u_{O} is positive, u_{i} has to be negative for $u_{\text{D}}=0$): $u_1 = -u_{\text{I}} \quad u_2 = u_{\text{O}}$

Then, the currents i_1 and i_2 are given by $i_1 = -\frac{u_{\text{I}}}{R_1} \quad i_2 = \frac{u_{\text{O}}}{R_2}$

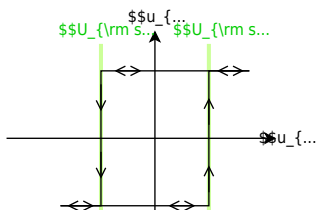
And therefore, this “turning point” is given by $u_{\text{I}} = -\frac{R_1}{R_2} \cdot u_{\text{O}}$

These “turning points” are called **threshold**.

The upper threshold $U_{\text{sh,u}}$ and the lower threshold $U_{\text{sh,l}}$ are given by $\boxed{U_{\text{sh,u}} = +\frac{R_1}{R_2} \cdot u_{\text{O}} \quad U_{\text{sh,l}} = -\frac{R_1}{R_2} \cdot u_{\text{O}}}$

The shown “switching effect” is called **hysteresis**.

The curve is called **hysteresis loop** and shows the switching at the upper and lower threshold.



Applications

Bang-Bang Control

De-Noise

Analog-to-Digital Converter (ADC)

Common pitfalls

- ...

Exercises

Worked examples

...

Embedded resources

Longer tutorial on Schmitt trigger



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