Electronics
Logic Gates: Open Collector Output

Terry Sturtevant

Wilfrid Laurier University

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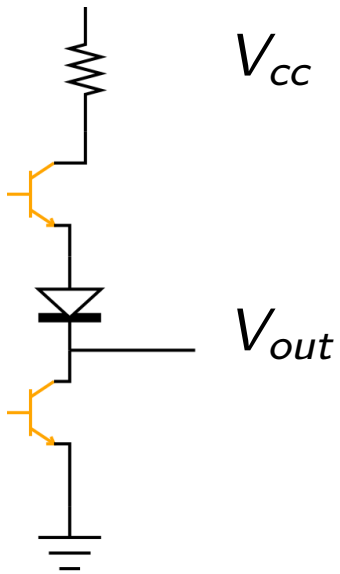
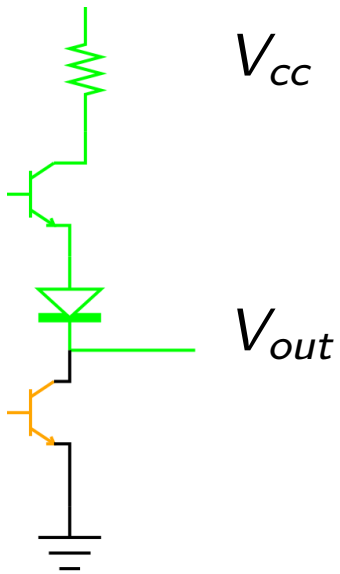
Totem pole outputs

Totem pole outputs



- Two transistors
- Only one on at one time

Totem pole outputs



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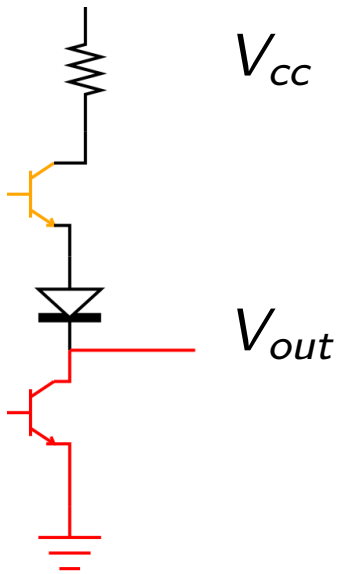

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TTL Totem Pole Output Equivalent Circuit

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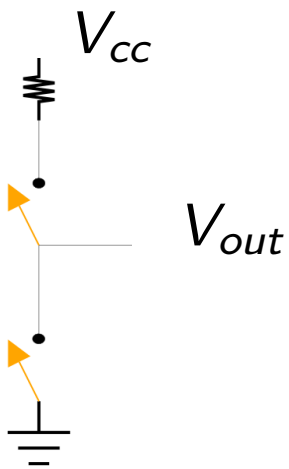

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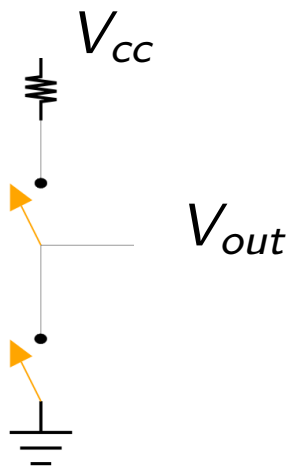
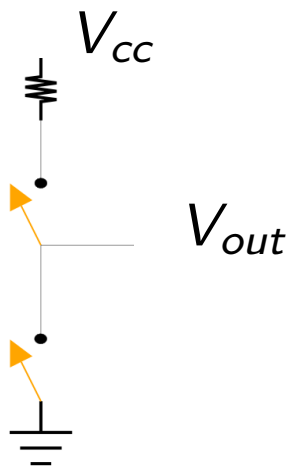


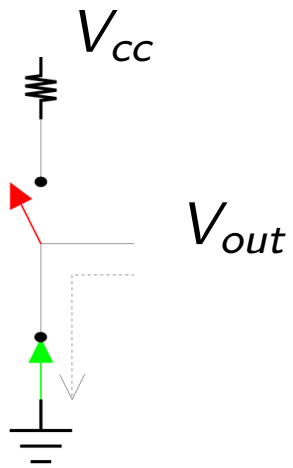
- Transistor acts like a switch

TTL Totem Pole Output Equivalent Circuit



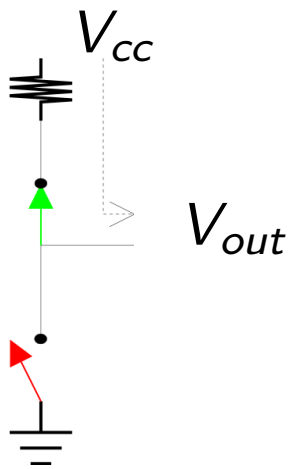
- Transistor acts like a switch
- Output is a voltage divider

Totem pole outputs; output low



- Upper transistor OFF (open switch)
- Lower transistor ON (closed switch)

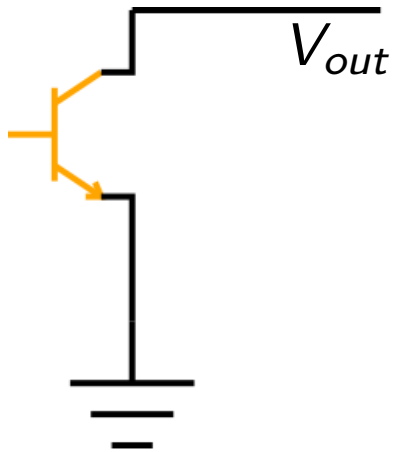
Totem pole outputs; output high



- Upper transistor ON (closed switch)
- Lower transistor OFF (open switch)
- *The voltage at the output will depend on the current drawn because of the resistor.*

Open collector outputs

Open collector outputs



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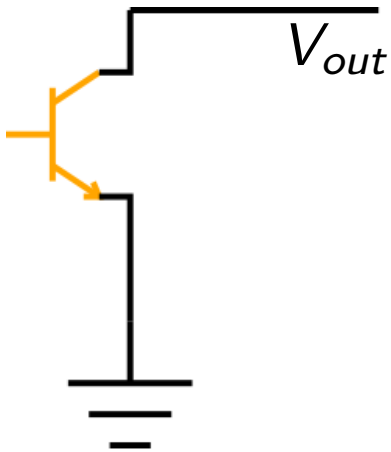
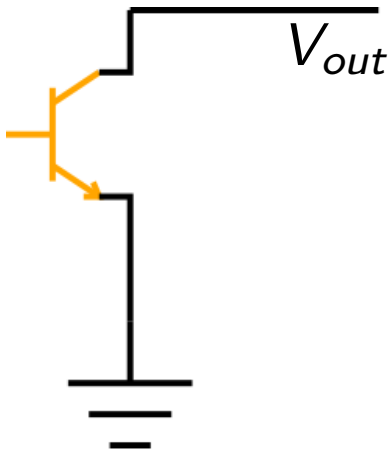


- Single transistor; ON or OFF

Open collector outputs



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Open collector output equivalent circuit

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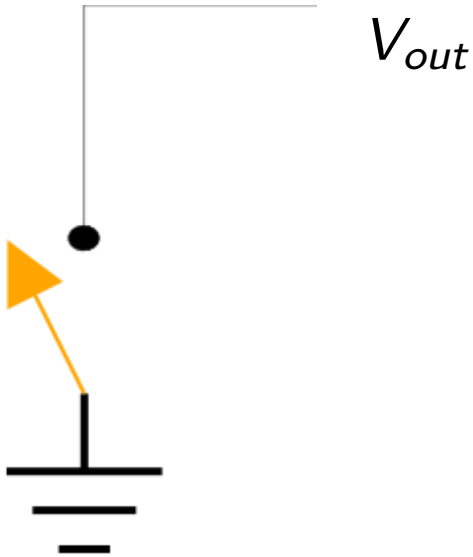

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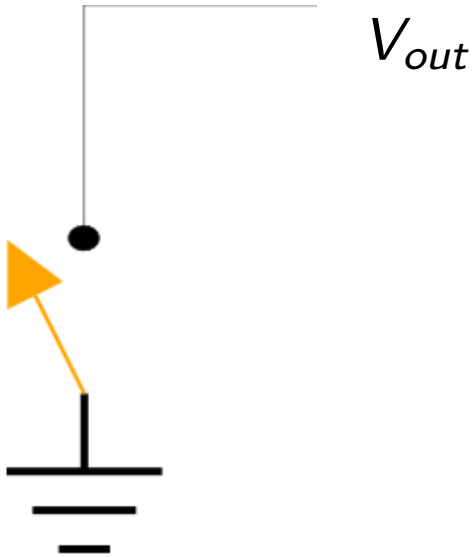

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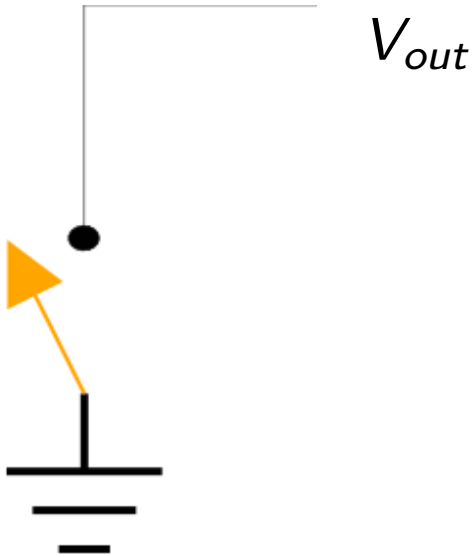
Open collector output equivalent circuit



- Output is either grounded or *floating*
- An external pull-up resistor is required to produce a high output

Open Collector Output Equivalent Circuit (Output Low)

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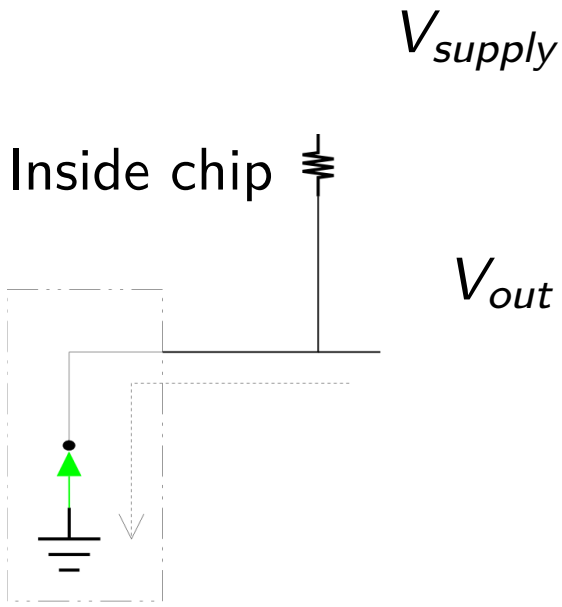

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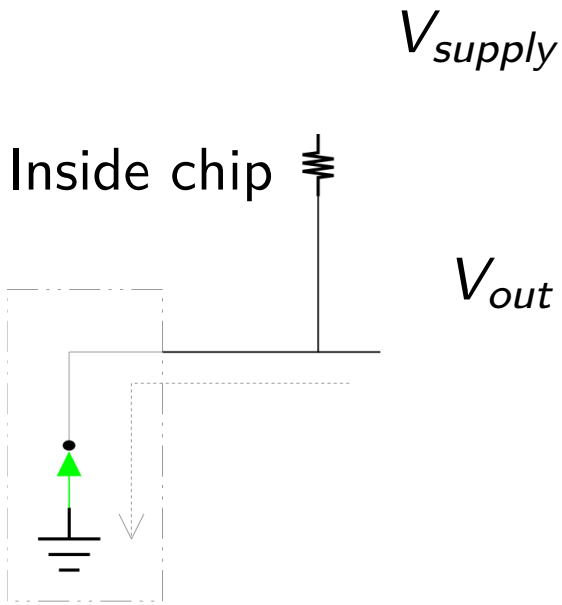
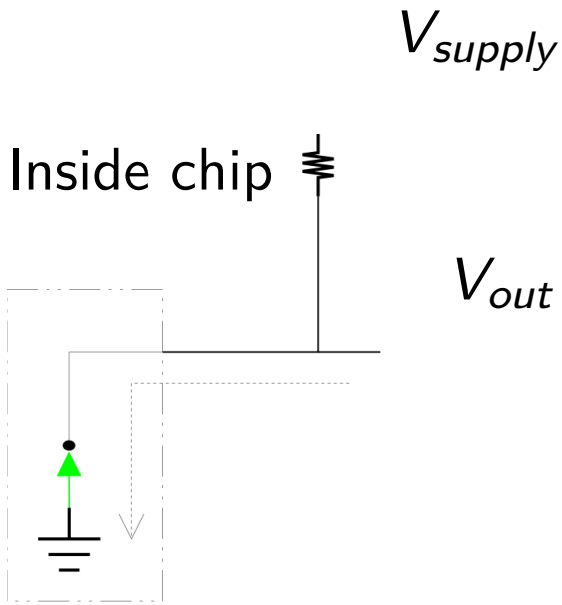


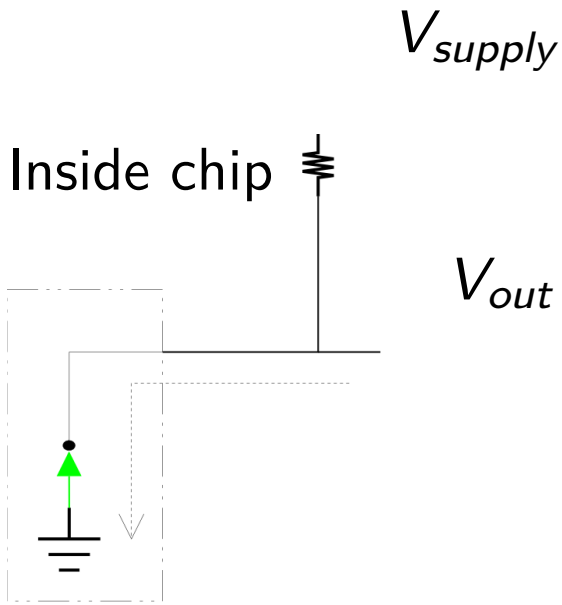
- Transistor ON (closed switch)

Open Collector Output Equivalent Circuit (Output Low)



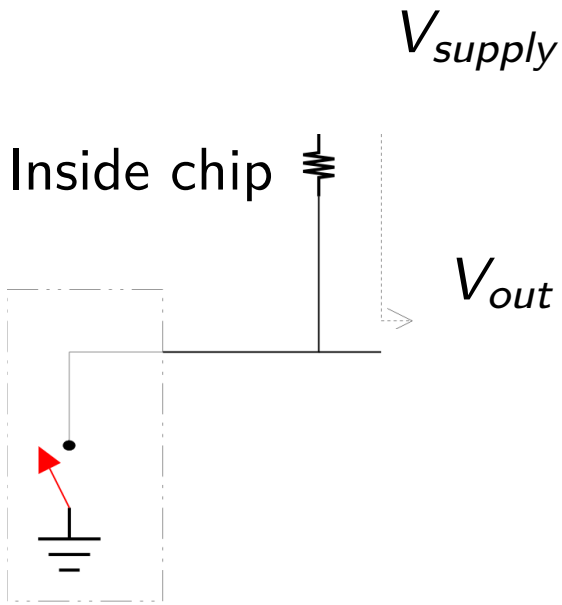
- Transistor ON (closed switch)
- V_{out} pulled to GROUND

Open Collector Output Equivalent Circuit (Output Low)



- Transistor ON (closed switch)
- V_{out} pulled to GROUND
- Current into gate

Open Collector Output Equivalent Circuit (Output High)



- Transistor OFF (open switch)
- V_{out} pulled to V_{supply}
- Current from supply

Why use open collector gates?

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- More current

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- Mixing logic families

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- Mixing logic families
- Wired ANDing of outputs

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Note: I_{OH} for open-collector gate?

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Note: I_{OH} for open-collector gate?

Look at the sign given for I_{OH}, and consider what that means.

Mixing logic families

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- V_{OH} for TTL is 2.4V.

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- V_{IH} for 5V CMOS is 3.5V.
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Examples

TTL open collector output can feed into 10V CMOS *if* the output is pulled up to 10V. (But V_{cc} is still 5V!)

Totem pole outputs tied together

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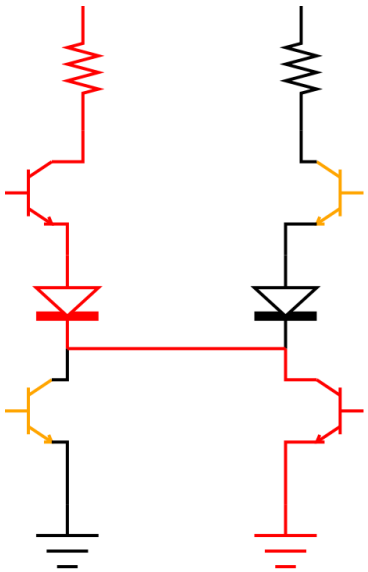

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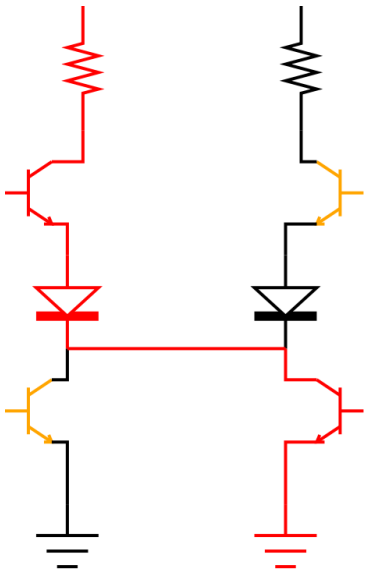
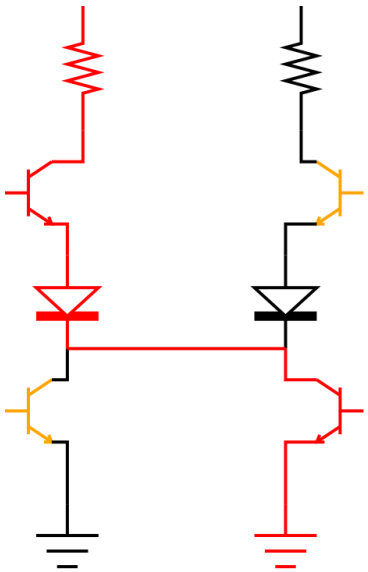


Which gate will win?

Totem pole outputs tied together



Which gate will win? (Think about current limits.)

Wire ANDing of outputs

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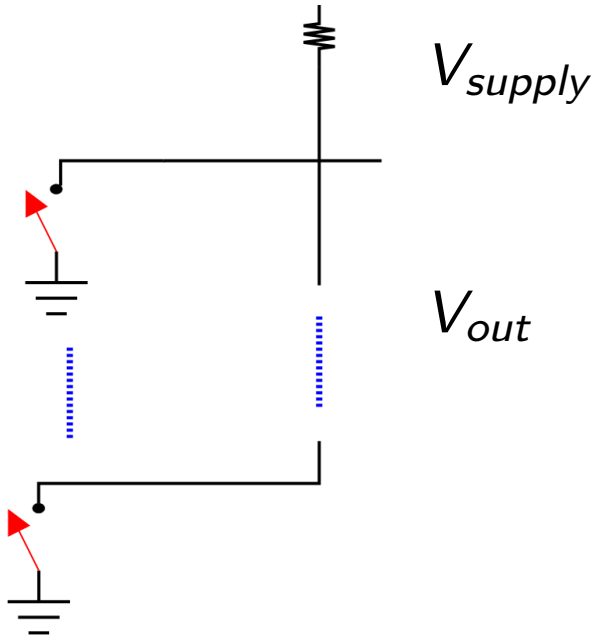

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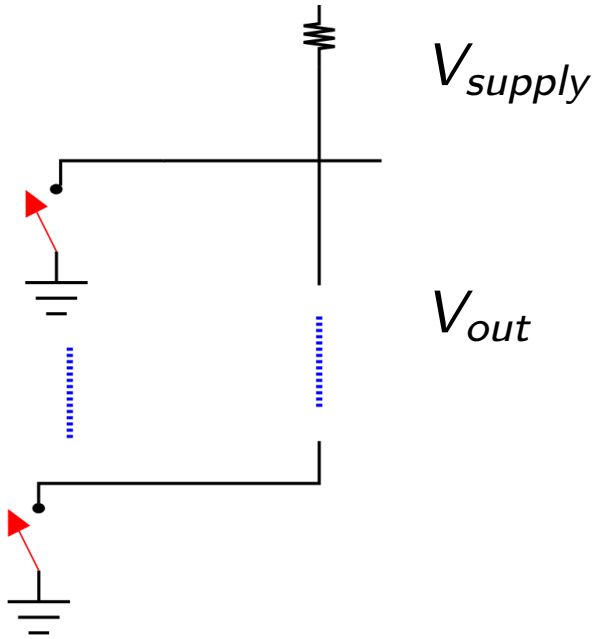
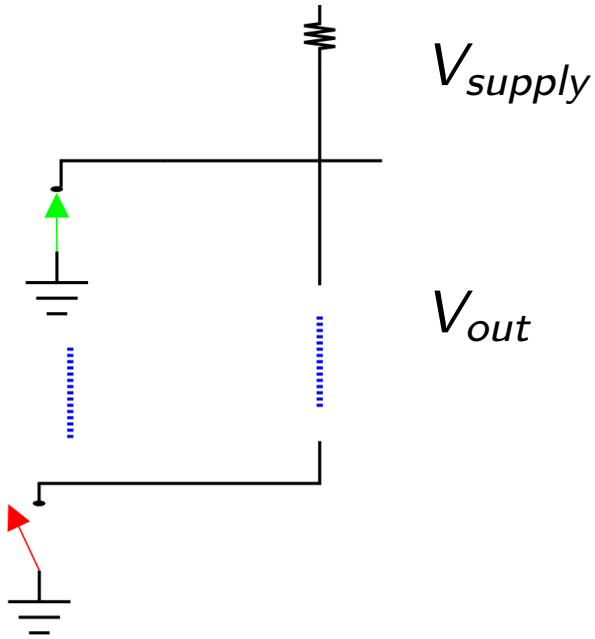


- No gate is grounded, so output is pulled high.

Wire ANDing of outputs



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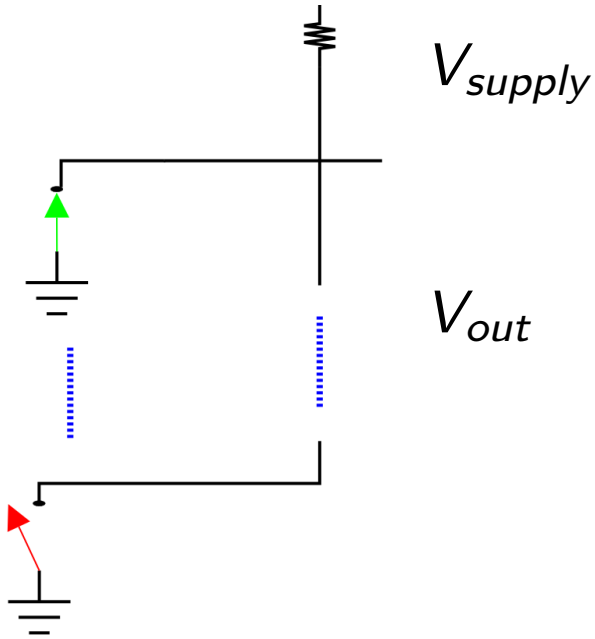

- One gate is grounded, so output is low.

Pull-up Resistor Calculations

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How do you calculate the pull-up resistor value?

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- When the output is low, the gate must be able to sink the current from the pull-up resistor *and* anything else connected. This will produce a *minimum* value for the resistor.

Pull-up Resistor Calculations

How do you calculate the pull-up resistor value?

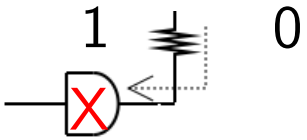
- When the output is low, the gate must be able to sink the current from the pull-up resistor *and* anything else connected. This will produce a *minimum* value for the resistor.
- When the output is high, the current through the pull-up resistor must be high enough for whatever is connected to it. This will produce a *maximum* value for the resistor.

Pull-up Resistor; output low

Calculating R_{min}

Pull-up Resistor; output low

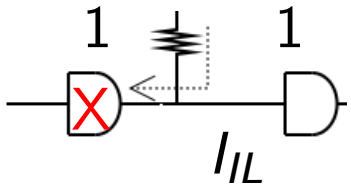
Calculating R_{min}



When the output is low, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL})$

Pull-up Resistor; output low

Calculating R_{min}

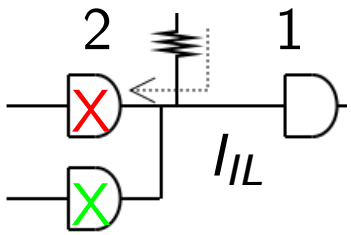


When the output is low, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL} - I_{IL})$

(Current through R is *reduced* by I_{IL}.)

Pull-up Resistor; output low

Calculating R_{min}



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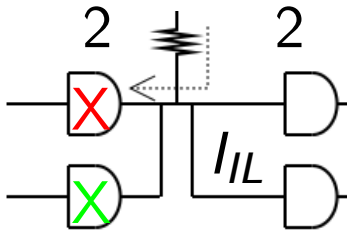
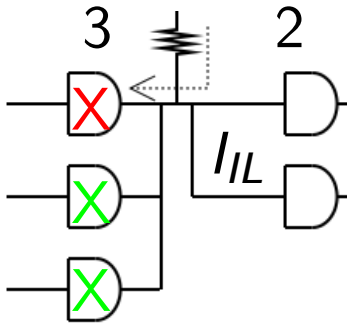


When the output is low, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL} - 2 \times I_{IL})$

Pull-up Resistor; output low

Calculating R_{min}



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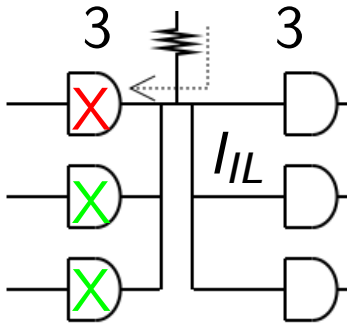

When the output is low, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL} - 3 \times I_{IL})$

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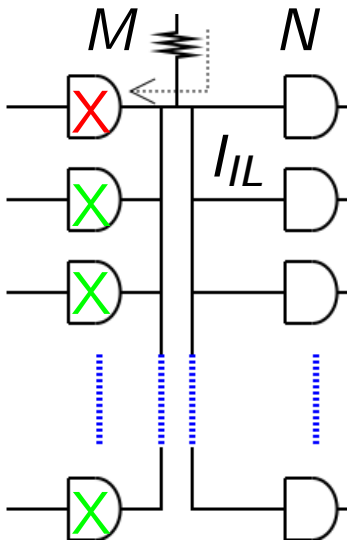

When the output is low, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL} - N \times I_{IL})$

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Calculating R_{max}

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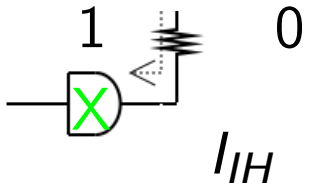
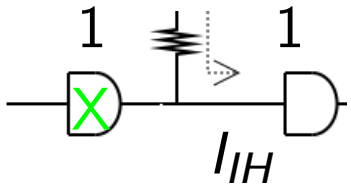


When the output is high, $R_{max} = (V_{cc} - V_{OH}) / (I_{OH})$

Pull-up Resistor; output high

Calculating R_{max}

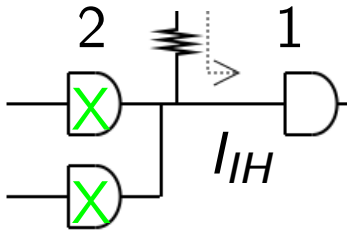


When the output is high, $R_{max} = (V_{cc} - V_{OH}) / (I_{OH} + I_{IH})$

(Current through R is *increased* by I_{IH}.)

Pull-up Resistor; output high

Calculating R_{max}



When the output is high,

$$R_{max} = (V_{cc} - V_{OH}) / (2 \times I_{OH} + I_{IH})$$

Pull-up Resistor; output high

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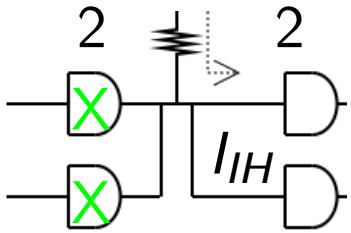

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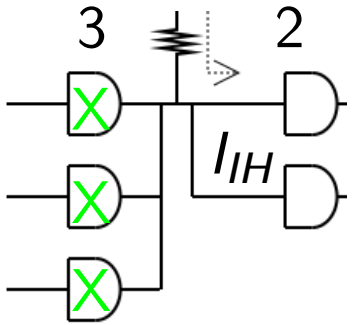

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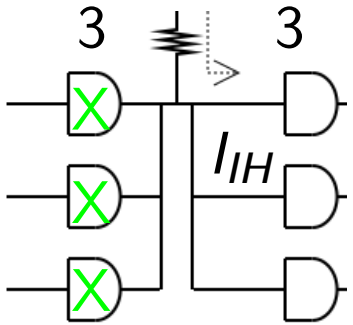

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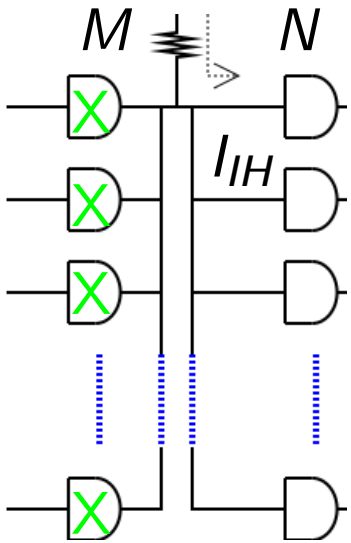

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CMOS output

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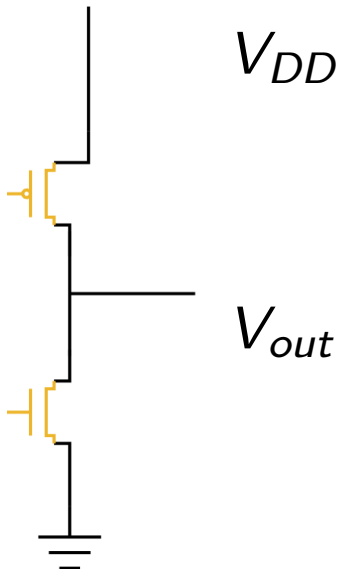

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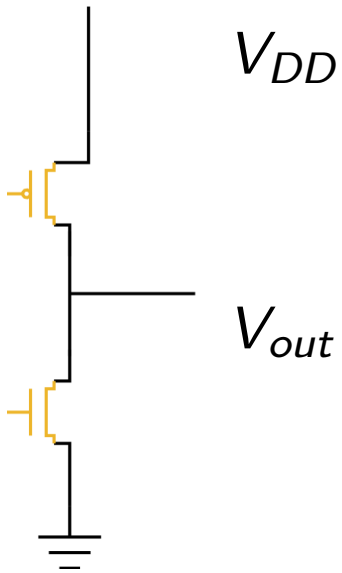

- Two transistors

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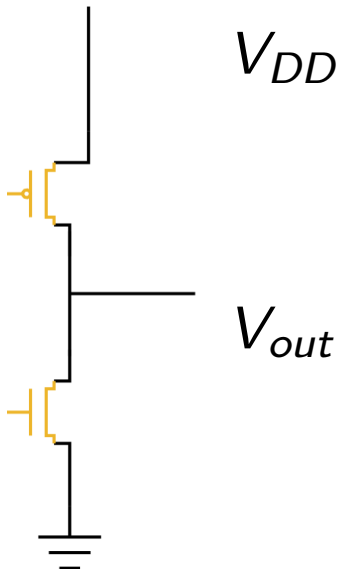

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