Electronics
Logic Gates: Open Collector Output

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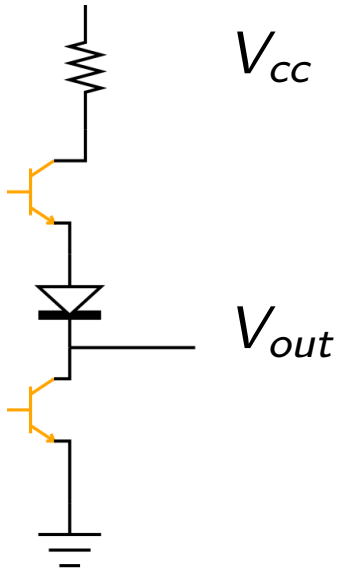
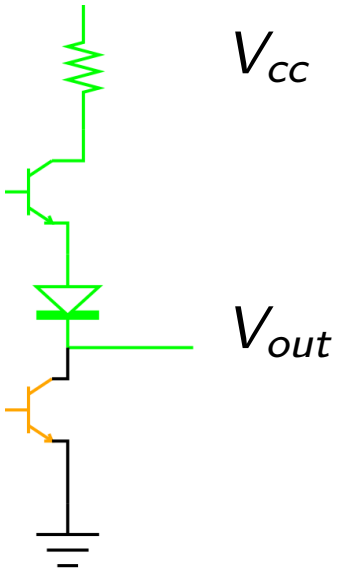
Totem pole outputs

Totem pole outputs



- Two transistors
- Only one on at one time

Totem pole outputs



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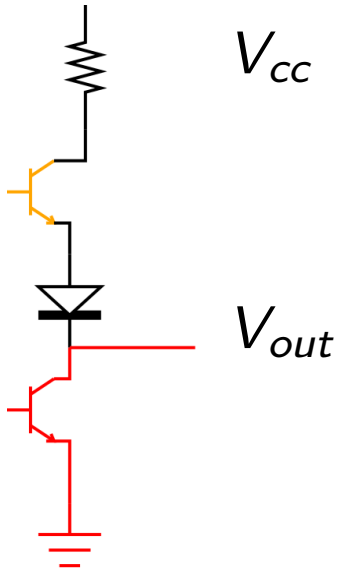

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TTL Totem Pole Output Equivalent Circuit

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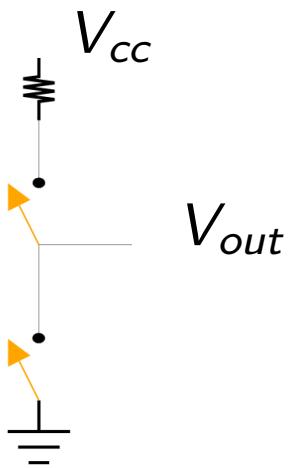
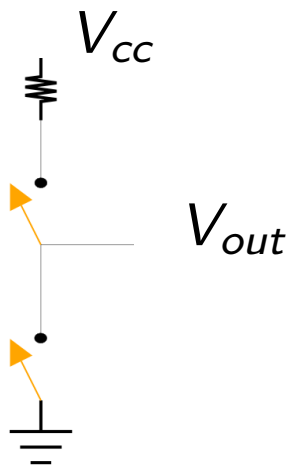
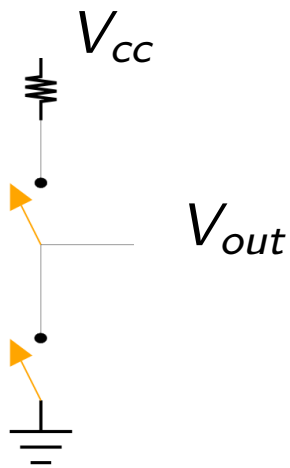


TTL Totem Pole Output Equivalent Circuit



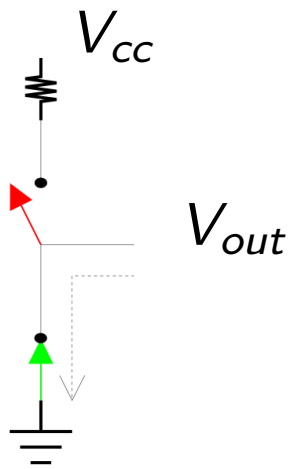
- Transistor acts like a switch

TTL Totem Pole Output Equivalent Circuit



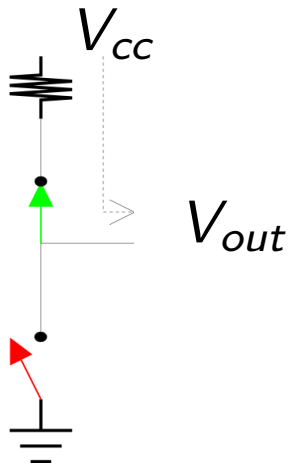
- Transistor acts like a switch
- Output is a voltage divider

Totem pole outputs; output low



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

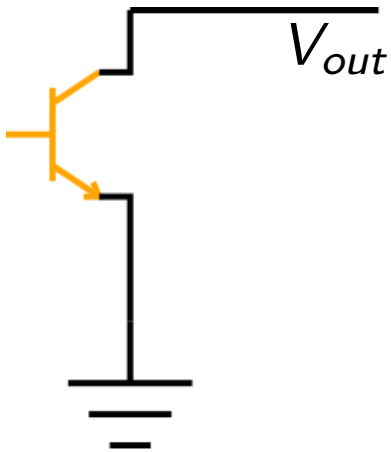
Totem pole outputs; output high



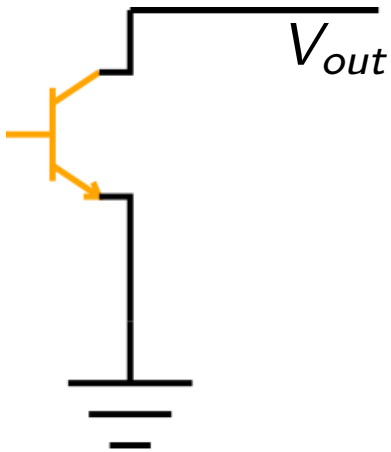
- Upper transistor ON (closed switch)
- Lower transistor OFF (open switch)
- *The voltage at the output will depend on the current drawn because of the resistor.*

Open collector outputs

Open collector outputs

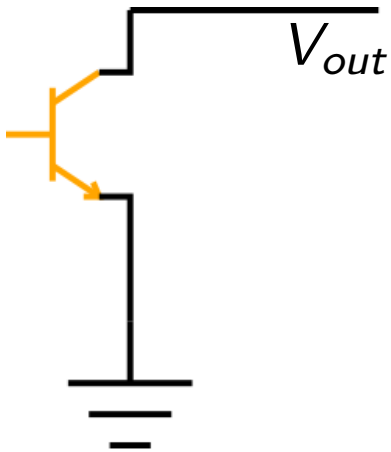


Open collector outputs



- Single transistor; ON or OFF

Open collector outputs



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Open collector output equivalent circuit

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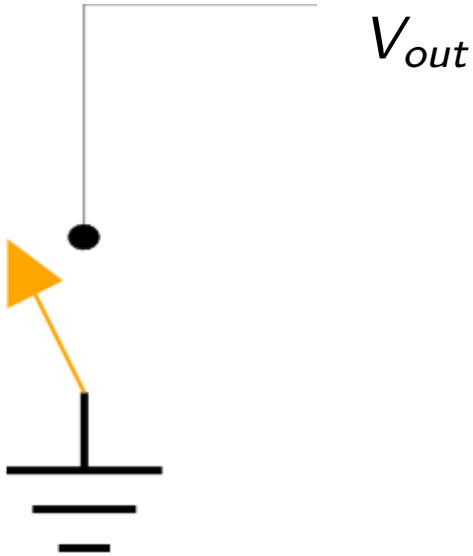
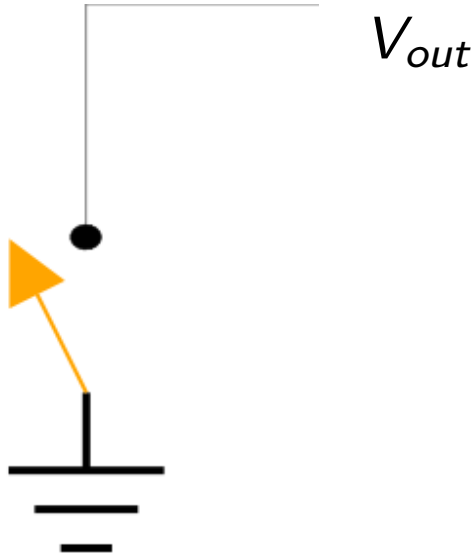
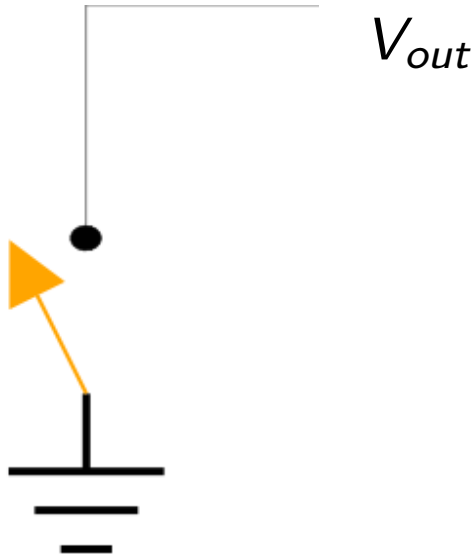


Open collector output equivalent circuit



- Output is either grounded or *floating*

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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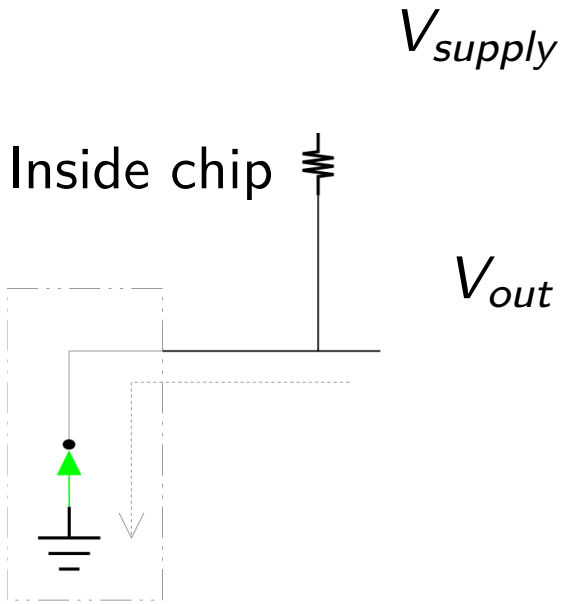
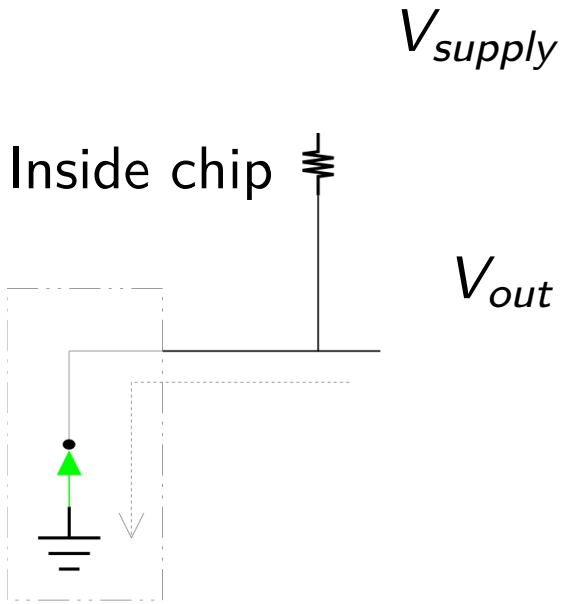
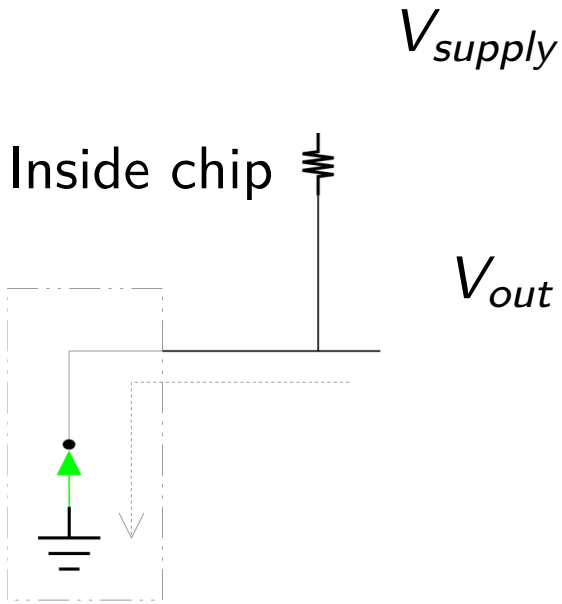


Open Collector Output Equivalent Circuit (Output Low)



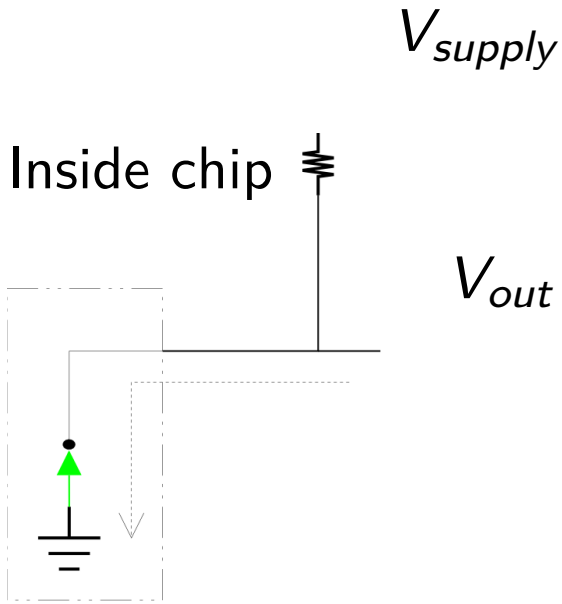
- Transistor ON (closed switch)

Open Collector Output Equivalent Circuit (Output Low)



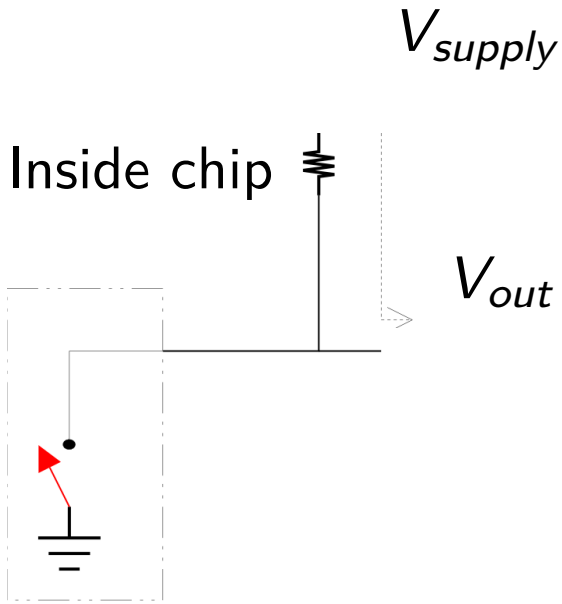
- Transistor ON (closed switch)
- V_{out} pulled to GROUND

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
- Wired ANDing of outputs
- Bidirectional communication

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

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- A TTL open collector gate can *source* ?
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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 4.5V HC(MOS) is 3.15V.

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- V_{OH} for TTL is 2.4V.
- V_{IH} for 4.5V HC(MOS) is 3.15V.
- V_{IH} for 6V HC(CMOS) is 4.20V.

Mixing logic families

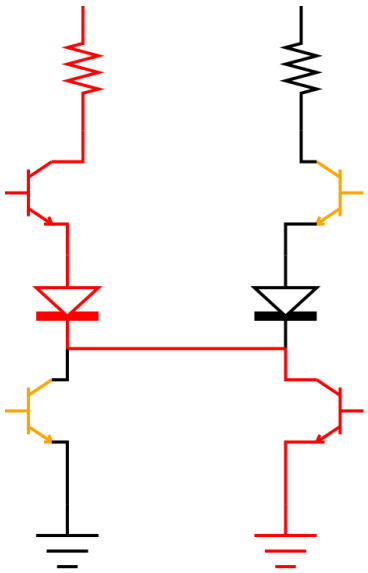
- V_{OH} for TTL is 2.4V.
- V_{IH} for 4.5V HC(MOS) is 3.15V.
- V_{IH} for 6V HC(CMOS) is 4.20V.

Examples

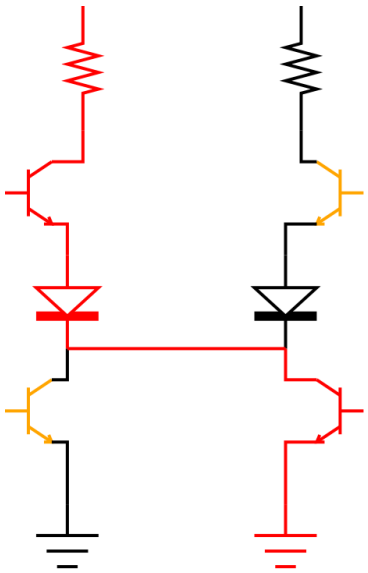
TTL open collector output can feed into 5V HC(CMOS) *if* the output is pulled up to 5V. (But V_{cc} is still 5V!)

Totem pole outputs tied together

Totem pole outputs tied together

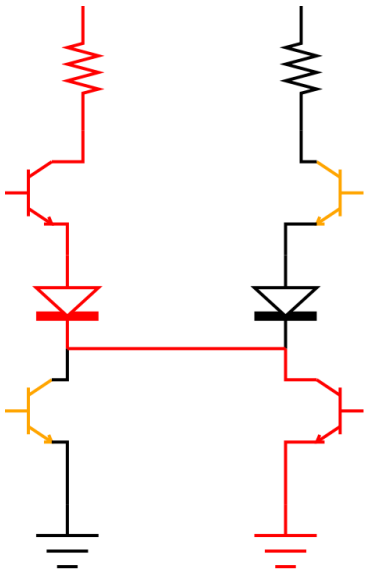


Totem pole outputs tied together



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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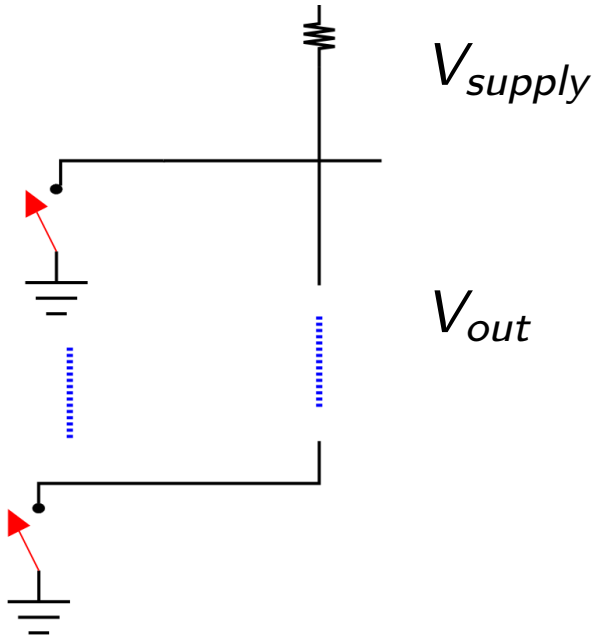

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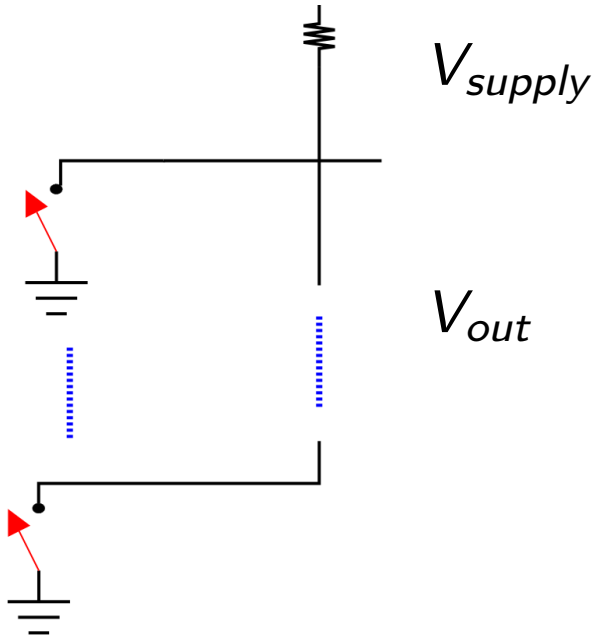
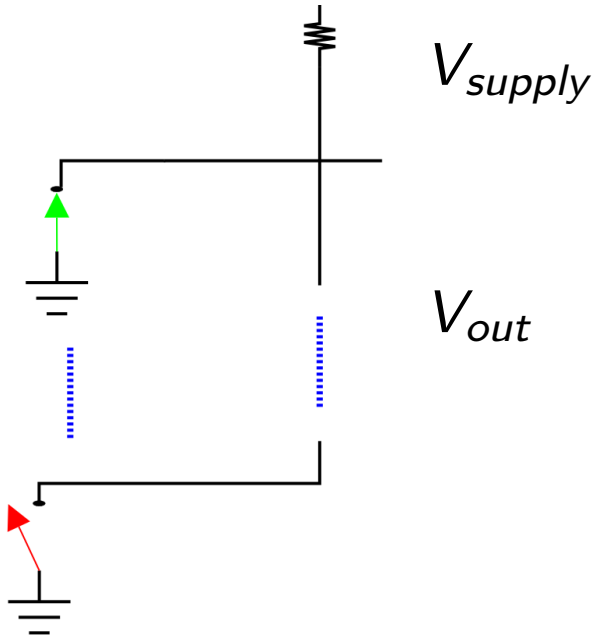
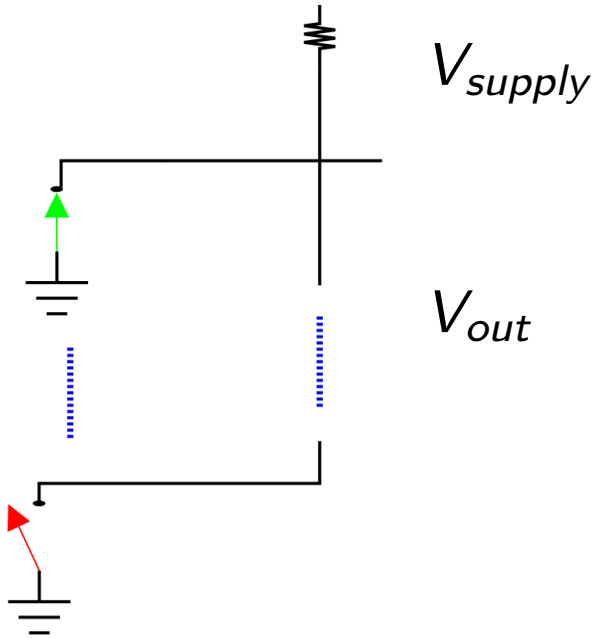


- No gate is grounded, so output is pulled high.

Wire ANDing of outputs



Wire ANDing of outputs



- One gate is grounded, so output is low.

Bidirectional communication

Bidirectional communication

If *two* (or more) devices are connected to the same open collector signal, then the signal can be an input *or* an output for both.

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?

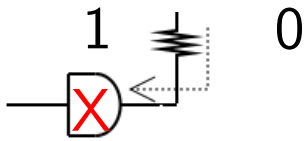
- When the output is low, the gate must be able to sink the current from the pull-up resistor *and* anything else connected. This will produce a *minimum* value for the resistor.
- When the output is high, the current through the pull-up resistor must be high enough for whatever is connected to it. This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

Pull-up Resistor; output low

Calculating R_{min}

Pull-up Resistor; output low

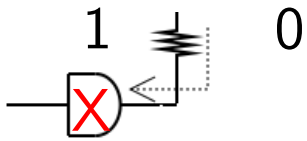
Calculating R_{min}



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

Pull-up Resistor; output low

Calculating R_{min}

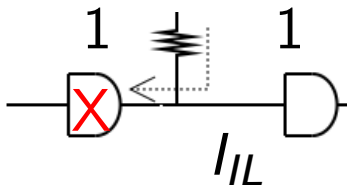


When the output is low, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL})$

(If R were smaller, the output couldn't be kept low.)

Pull-up Resistor; output low

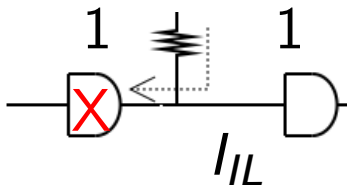
Calculating R_{min}



If another gate follows, then the output has to sink through *both* the resistor *and* the gate input, so the current through R must be **REDUCED**.

Pull-up Resistor; output low

Calculating R_{min}

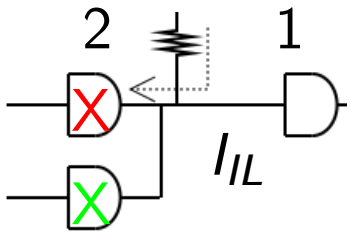


When the output is low, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL} - I_{IL})$

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

Pull-up Resistor; output low

Calculating R_{min}



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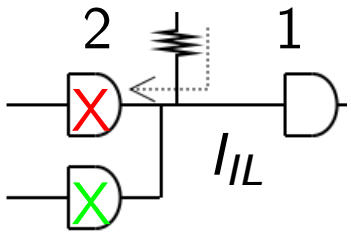
Pull-up Resistor; output low

Calculating R_{min}

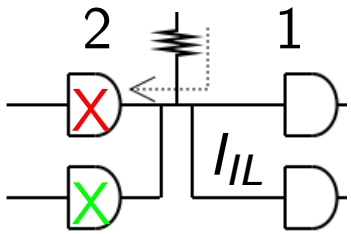


When the output is low, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL} - I_{IL})$

Another gate with a wired-OR output won't change the current through R, since its output is floating.

Pull-up Resistor; output low

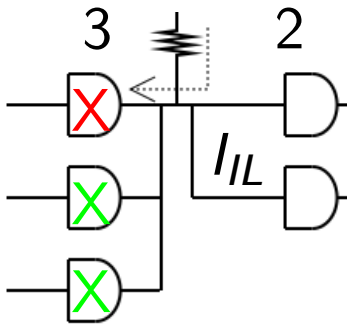
Calculating R_{min}



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}



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

Pull-up Resistor; output low

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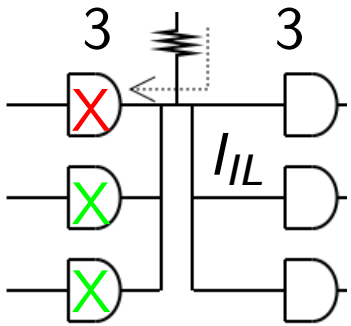
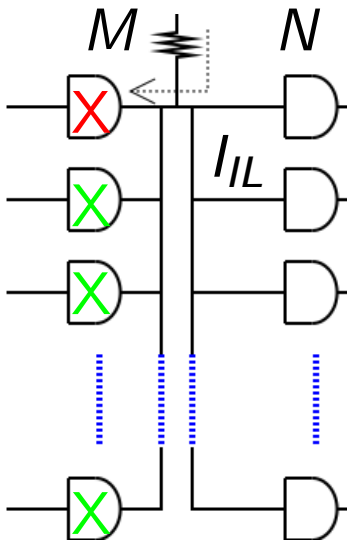


When the output is low, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL} - 3 \times I_{IL})$

Pull-up Resistor; output low

Calculating R_{min}



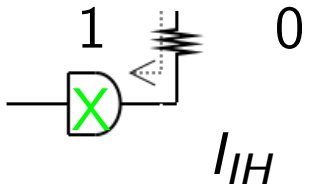
When the output is low, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL} - N \times I_{IL})$

Pull-up Resistor; output high

Calculating R_{max}

Pull-up Resistor; output high

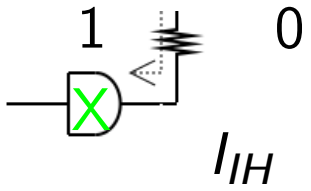
Calculating R_{max}



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

Pull-up Resistor; output high

Calculating R_{max}

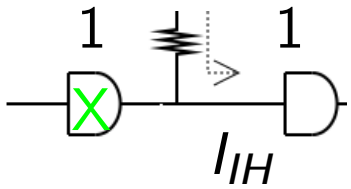


When the output is high, $R_{max} = (V_{cc} - V_{OH}) / (I_{OH})$

(If R were bigger, V_{OH} wouldn't be guaranteed.)

Pull-up Resistor; output high

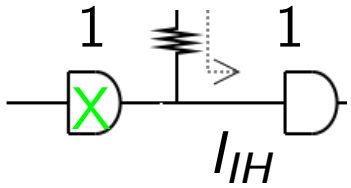
Calculating R_{max}



If another gate follows, then the current has to pull *both* the resistor *and* the gate input HIGH, so the current through R must be **INCREASED**.

Pull-up Resistor; output high

Calculating R_{max}

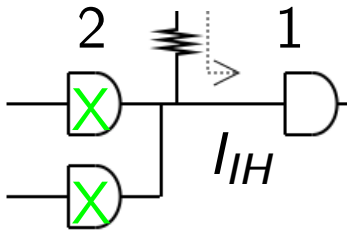


When the output is high, $R_{max} = (V_{cc} - V_{OH}) / (I_{OH} + I_{IH})$

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

Pull-up Resistor; output high

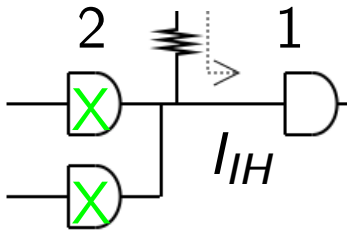
Calculating R_{max}



Another gate with a wired-OR output will *also* need to be pulled HIGH, so the current must be **INCREASED**.

Pull-up Resistor; output high

Calculating R_{max}

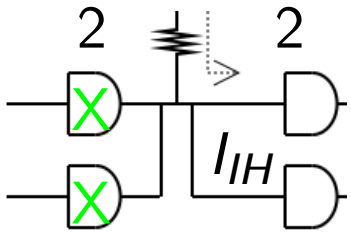


When the output is high,

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

Pull-up Resistor; output high

Calculating R_{max}

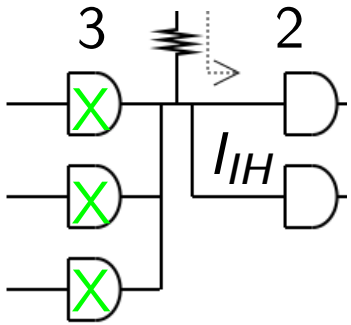


When the output is high,

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

Pull-up Resistor; output high

Calculating R_{max}

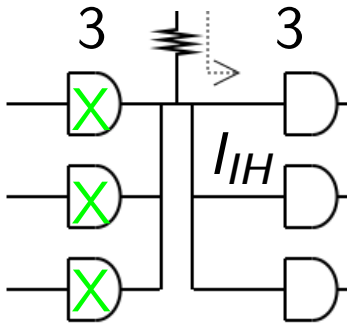


When the output is high,

$$R_{max} = (V_{cc} - V_{OH}) / (3 \times I_{OH} + 2 \times I_{IH})$$

Pull-up Resistor; output high

Calculating R_{max}

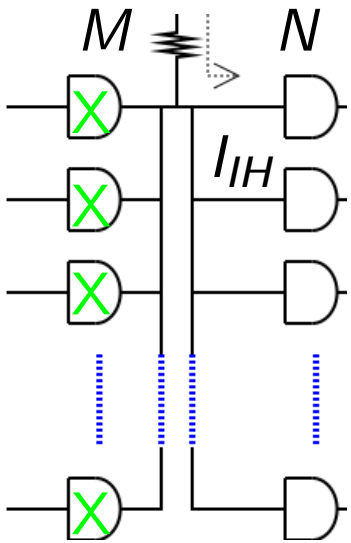


When the output is high,

$$R_{max} = (V_{cc} - V_{OH}) / (3 \times I_{OH} + 3 \times I_{IH})$$

Pull-up Resistor; output high

Calculating R_{max}



When the output is high,

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

So, to summarize:

So, to summarize:

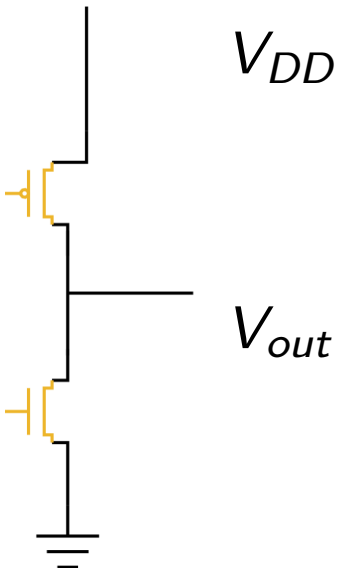
$$R_{min} = (V_{cc} - V_{OL}) / (I_{OL} - N \times I_{IL})$$

So, to summarize:

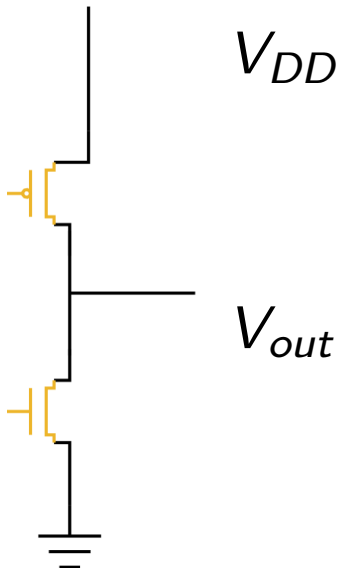
$$R_{min} = (V_{cc} - V_{OL}) / (I_{OL} - N \times I_{IL})$$
$$R_{max} = (V_{cc} - V_{OH}) / (M \times I_{OH} + N \times I_{IH})$$

CMOS output

CMOS output

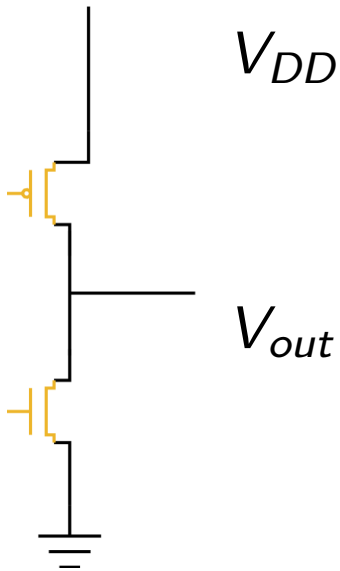


CMOS output



- Two transistors

CMOS output



- Two transistors
- Only one on at one time