Electronics Logic Gates: Open Collector Output

Terry Sturtevant

Wilfrid Laurier University

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Open collector outputs Open Collector Advantages CMOS outputs

Output circuit

Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Totem pole outputs

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Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Totem pole outputs



- Two transistors
- Only one on at one time

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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

TTL Totem Pole Output Equivalent Circuit

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TTL Totem Pole Output Equivalent Circuit



• Transistor acts like a switch

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TTL Totem Pole Output Equivalent Circuit



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

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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Totem pole outputs; output low



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

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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

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.

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Open collector outputs

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Open collector outputs



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Output circuit

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Open collector outputs



• Single transistor; ON or OFF

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Output circuit

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Open collector outputs



• Single transistor; ON or OFF

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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Open collector output equivalent circuit

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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Open collector output equivalent circuit



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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Open collector output equivalent circuit



• Output is either grounded or *floating*

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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Open collector output equivalent circuit



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

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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Open Collector Output Equivalent Circuit (Output Low)

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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Open Collector Output Equivalent Circuit (Output Low)



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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Open Collector Output Equivalent Circuit (Output Low)



• Transistor ON (closed switch)

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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Open Collector Output Equivalent Circuit (Output Low)



- Transistor ON (closed switch)
- Vout pulled to GROUND

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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Open Collector Output Equivalent Circuit (Output Low)



- Transistor ON (closed switch)
- Vout pulled to GROUND
- Current into gate

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Output circuit Output equivalent circuit Equivalent circuit;output low Equivalent circuit;output high

Open Collector Output Equivalent Circuit (Output High)



- Transistor OFF (open switch)
- Vout pulled to Vsupply
- Current from supply

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More current Mixing logic families Wire ANDing of outputs Pull-up Resistor Calculations

Why use open collector gates?

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Why use open collector gates?

More current

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Why use open collector gates?

- More current
- Mixing logic families

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Why use open collector gates?

- More current
- Mixing logic families
- Wired ANDing of outputs

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More current

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More current

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More current

• A TTL gate can *source* 0.4 mA.

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More current

- A TTL gate can *source* 0.4 mA.
- A TTL gate can *sink* 16 mA.

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More current

- A TTL gate can *source* 0.4 mA.
- A TTL gate can *sink* 16 mA.
- A TTL open collector gate can source ?

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More current

- A TTL gate can *source* 0.4 mA.
- A TTL gate can *sink* 16 mA.
- A TTL open collector gate can source ?
- A TTL open collector gate can *sink* 16 mA.

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More current

- A TTL gate can *source* 0.4 mA.
- A TTL gate can *sink* 16 mA.
- A TTL open collector gate can source ?
- A TTL open collector gate can *sink* 16 mA.

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

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More current

- A TTL gate can *source* 0.4 mA.
- A TTL gate can *sink* 16 mA.
- A TTL open collector gate can source ?
- A TTL open collector gate can *sink* 16 mA.

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

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

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Mixing logic families

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Mixing logic families

• V_{OH} for TTL is 2.4V.

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Mixing logic families

- V_{OH} for TTL is 2.4V.
- V_{IH} for 5V CMOS is 3.5V.

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Mixing logic families

- V_{OH} for TTL is 2.4V.
- V_{IH} for 5V CMOS is 3.5V.
- V_{IH} for 10V CMOS is 7V.

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Mixing logic families

- V_{OH} for TTL is 2.4V.
- V_{IH} for 5V CMOS is 3.5V.
- V_{IH} for 10V CMOS is 7V.

Examples

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

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Totem pole outputs tied together

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Totem pole outputs tied together



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Totem pole outputs tied together



Which gate will win?

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Totem pole outputs tied together



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

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Wire ANDing of outputs

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Wire ANDing of outputs



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Wire ANDing of outputs



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

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Wire ANDing of outputs



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Wire ANDing of outputs



• One gate is grounded, so output is low.

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Pull-up Resistor Calculations

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Pull-up Resistor Calculations

How do you calculate the pull-up resistor value?

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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.

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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.

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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, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL})$

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Pull-up Resistor; output low

Calculating R_{min}



When the output is low, $R_{min} = (V_{cc} - V_{OL}) / (I_{OL} - I_{IL})$ (Current through *R* is *reduced* by I_{IL} .)

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Pull-up Resistor; output low

Calculating R_{min}



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

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Pull-up Resistor; output low

Calculating R_{min}



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

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Pull-up Resistor; output low

Calculating R_{min}



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

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Pull-up Resistor; output low

Calculating R_{min}



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

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Pull-up Resistor; output low

Calculating R_{min}



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

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Pull-up Resistor; output high

Calculating R_{max}

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Pull-up Resistor; output high

Calculating R_{max}



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

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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} .)

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Pull-up Resistor; output high

Calculating R_{max}



When the output is high, $R_{max} = (V_{cc} - V_{OH}) / (2 \times I_{OH} + I_{IH})$

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Pull-up Resistor; output high

Calculating R_{max}



When the output is high, $R_{max} = \left(V_{cc} - V_{OH}\right) / \left(2 \times I_{OH} + 2 \times I_{IH}\right)$

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Pull-up Resistor; output high

Calculating R_{max}



When the output is high, $R_{max} = (V_{cc} - V_{OH}) / (3 \times I_{OH} + 2 \times I_{IH})$

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More current Mixing logic families Wire ANDing of outputs Pull-up Resistor Calculations

Pull-up Resistor; output high

Calculating R_{max}



When the output is high, $R_{max} = (V_{cc} - V_{OH}) / (3 \times I_{OH} + 3 \times I_{IH})$

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Pull-up Resistor; output high

Calculating R_{max}



When the output is high, $R_{max} = \left(V_{cc} - V_{OH}\right) / \left(M \times I_{OH} + N \times I_{IH}\right)$

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CMOS Output circuit

CMOS output

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CMOS Output circuit

CMOS output



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CMOS Output circuit

CMOS output



• Two transistors

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CMOS Output circuit

CMOS output



- Two transistors
- Only one on at one time

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