Electronics
Logic Gates: Measuring Current Limits

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Current convention

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By convention, current into a chip is positive, so current out of a chip is negative.

Operating current limits

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In addition, there is some current required by the chip itself, as long as power is applied.

Floating inputs

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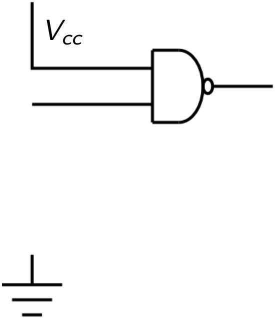

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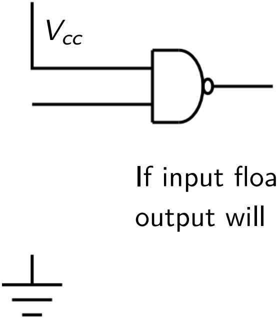

If input floats HIGH,
output will be LOW.

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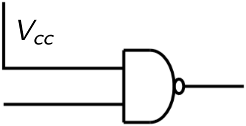
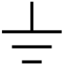


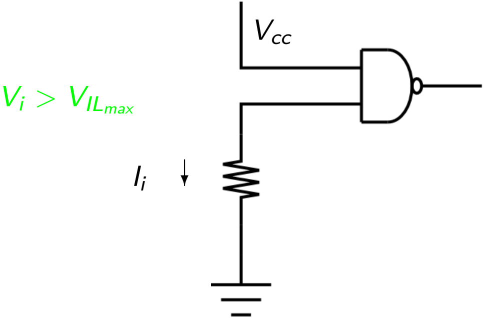
If input floats HIGH,
output will be LOW.



If input floats LOW,
output will be HIGH.

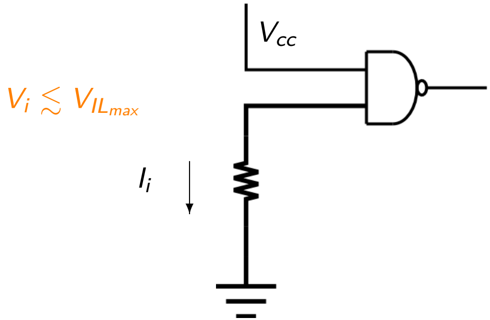
If the input floats HIGH, then current will need to be drawn *to* ground to make it LOW.

Input floating HIGH



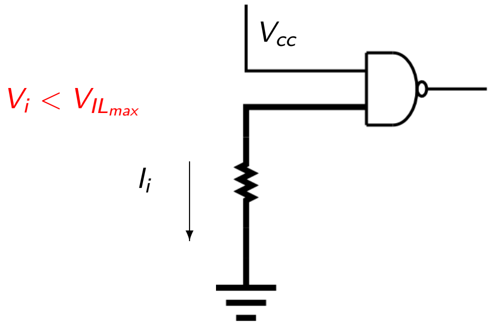
A large resistor won't allow enough current to make the input LOW.

Input floating HIGH



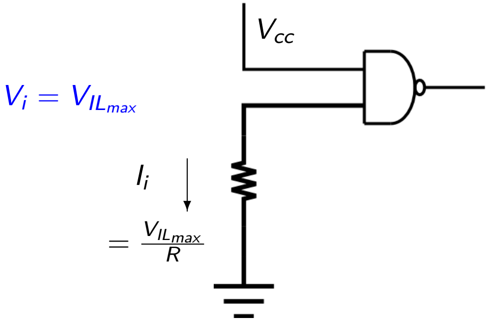
Some resistance will allow enough current to make the input $V_{IL_{max}}$.

Input floating HIGH



A low enough resistance will allow enough current to make the input below $V_{IL_{max}}$; i.e. LOW.

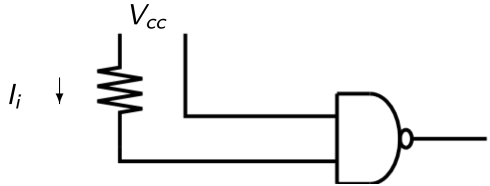
Input floating HIGH



The current *limit* is when $V_i = V_{IL_{max}}$.

If the input floats LOW, then current will need to be drawn *from* V_{cc} to make it HIGH.

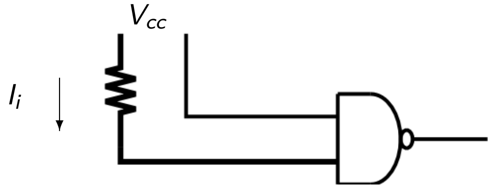
Input floating LOW



$V_i < V_{IH_{min}}$

A large resistor won't allow enough current to make the input HIGH.

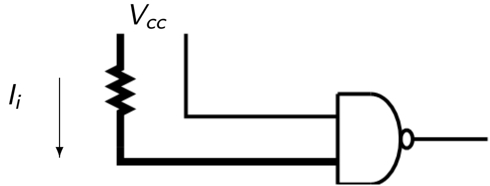
Input floating LOW



$V_i \gtrsim V_{IH_{min}}$

Some resistance will allow enough current to make the input $V_{IH_{min}}$.

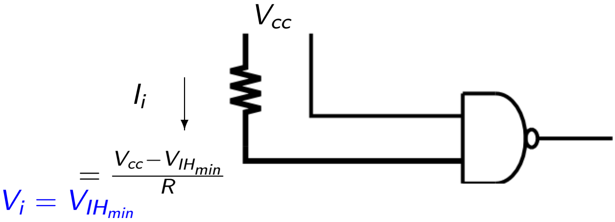
Input floating LOW



$V_i > V_{IH_{min}}$

A low enough resistance will allow enough current to make the input above $V_{IH_{min}}$; i.e. HIGH.

Input floating LOW



The current *limit* is when $V_i = V_{IH_{min}}$.

In order to measure the input requirements for a gate, you could wire up the first circuit of the previous figure.

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An oscilloscope could be used to measure $\mathrm{V_{in}}$ and $\mathrm{V_{out}}$.

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An oscilloscope could be used to measure $\mathrm{V_{in}}$ and $\mathrm{V_{out}}$.

Since one end of R is tied to a known voltage, and the other end is connected to the oscilloscope, then the voltage across R is known, and thus the current through R can be calculated using Ohm's Law.

With nothing connected to the inputs of a gate, so there is no current in, you may observe its output.

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If the inputs of a device "float" so that they appear to be in a particular state with nothing connected, then by definition you don't need to supply *any* current to keep them in that state!

Actually it can be more complicated than that.

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Sometimes the inputs float to voltage which is in the indeterminate region, so that sometimes they will appear to be high and other times they will appear to be low.

Starting with the lowest current possible, in the first circuit above, if you monitor the value of $\mathrm{V_{out}}$ as current is increased, you can determine when the output voltage just reaches the specified value of $\mathrm{V_{OL_{max}}}$ and thus determine $\mathrm{I_{IH_{min}}}$

Keep in mind the earlier note about whether a limit is called a "maximum" or a "minimum", it will be referred to here as a minimum.

If you wire up the second circuit above and starting with the lowest possible current, monitor the value of $\mathrm{V_{out}}$ as current is increased, you can observe when the output voltage just falls below the specified value of $\mathrm{V_{OH_{min}}}$. and thus determine $\mathrm{I_{IL_{min}}}$.

Fan–out

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When one gate feeds into *many* gates, as in the figure below, the the first gate must be able to source (or sink) enough current for *all* of the gates it feeds.

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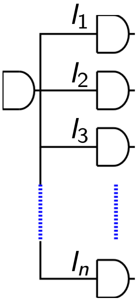

The **fan-out** of a gate is *the number of gates of that family which can be fed by a single gate*.

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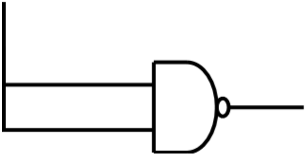
Keep in mind that the fan-out will be limited by the *lower* of the number for sourcing and sinking, since both must be possible.

CMOS fan–out

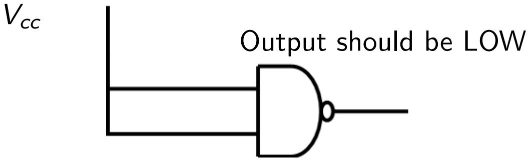
CMOS fan–out

For CMOS, adding more gates will change the speed limit of the circuit.

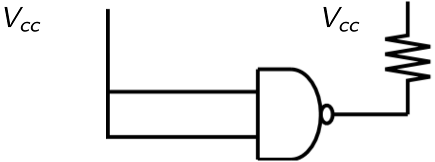
Output low



Output low

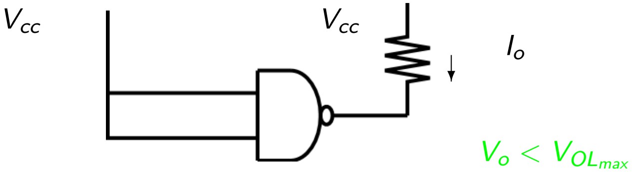


Output low



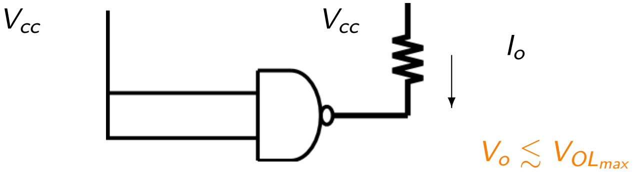
Suppose we tie it HIGH

Output low



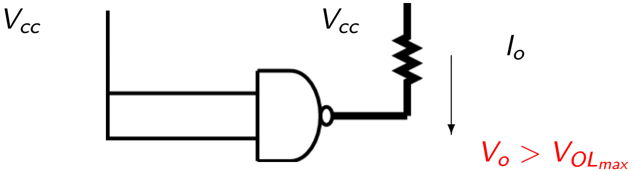
A large resistor won't allow enough current to keep the output from being a valid LOW.

Output low



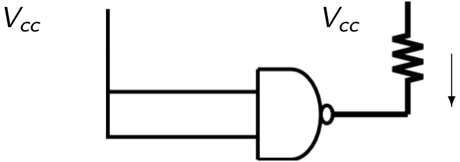
Some resistance will allow enough current to make the output $V_{OL_{max}}$.

Output low



A low enough resistance will allow enough current to make the output above $V_{OL_{max}}$; i.e. invalid as a LOW.

Output low

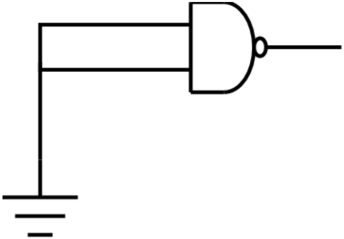


$$I_o = I_{OL_{max}}$$
$$= \frac{V_{cc} - V_{OL_{max}}}{R}$$

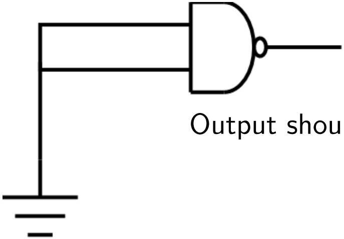
$$V_o = V_{OL_{max}}$$

The current *limit* is when $V_o = V_{OL_{max}}$.

Output High



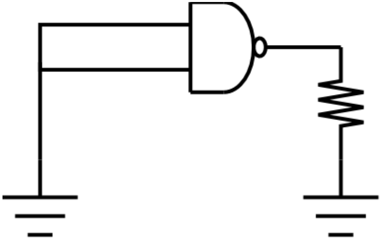
Output High



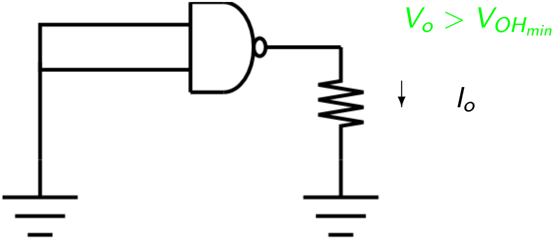
Output should be HIGH

Output High

Suppose we tie the output LOW



Output High



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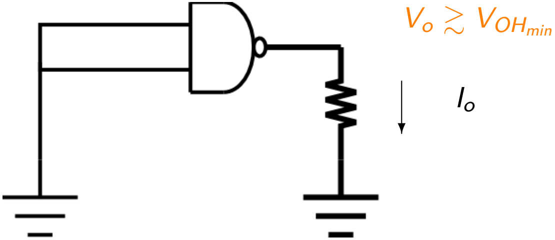
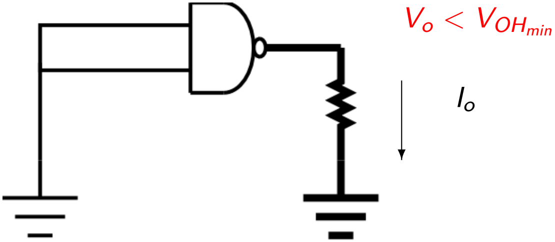
Output High



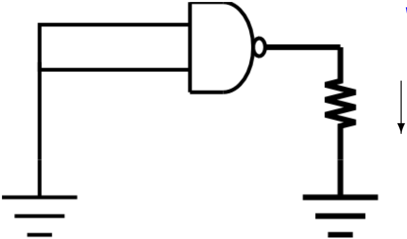
Some resistance will allow enough current to make the output $V_{OH_{min}}$.

Output High



A low enough resistance will allow enough current to make the output below $V_{OH_{min}}$; i.e. invalid as a HIGH.

Output High



$V_o = V_{OH_{min}}$

$I_o = I_{OH_{max}}$

$= \frac{V_{OH_{min}}}{R}$

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Using the value of the *output* ***sinking*** *current* $\mathrm{I_{OL_{max}}}$ from the data sheets, you can determine the maximum value of current which keeps the output in the low state and thus $\mathrm{I_{OL_{max}}}$.

If you set up the second circuit above, and obtain the value of the *output* ***sourcing*** *current* $\mathrm{I}_{\mathrm{OH}_{\max}}$ from the data sheets, then you can determine the maximum value of current which keeps the output in the high state and thus $\mathrm{I}_{\mathrm{OH}_{\max}}$ in a manner similar to the one previously described.