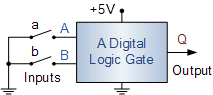
PULL UP AND PULL DOWN RESISTORS

Modern digital logic gates, IC’s and micro-controllers contain many inputs, called “pins” as well as one or more outputs, and these inputs and outputs need to be correctly set, either HIGH or LOW for the digital circuit to function correctly.

We know that logic gates are the most basic building block of any digital logic circuit and that by using combinations of the three basic gates, the AND gate, the OR gate and NOT gate, we can construct quite complex combinational circuits. But being digital, these circuits can only have one of two logic states, called the logic “0” state or the logic “1” state.

These logic states are represented by two different voltage levels with any voltage below one level regarded as a logic “0”, and any voltage above another level regarded as logic “1”. So for example, if the two voltage levels are 0V and +5V, then the 0V represents a logic “0” and the +5V represents a logic “1”.

If the inputs to a digital logic gate or circuit are not within the range by which it can be sensed as either a logic “0” or a logic “1” input, then the digital circuit may false trigger as the gate or circuit does not recognise the correct input value, as the HIGH may not be high enough or the LOW may not be low enough.



For example, consider the digital circuit on the left. The two switches, “a” and “b”, represent the inputs to a generic logic gate. When switch “a” is closed (on), input “A” is connected to ground, (0v) or logic level “0” (low) and likewise, when switch “b” is closed (on), input “B” is also connected to ground, logic level “0” (low) and this is the correct condition we require.

However, when switch “a” is opened (off), what will be the value of the voltage applied to input “A”, high or low. We assume it will be +5V (high) as switch “a” is open-circuited and therefore input “A” is not shorted to ground, but this may not be the case. As the input is now effectively unconnected from either a defined HIGH or LOW condition, it has the potential to “float” about between 0V and +5V (Vcc) allowing the input to self–bias at any voltage level whether that represents a HIGH or a LOW condition.

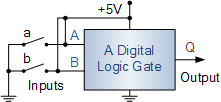
This uncertain situation may cause the digital input at “A” to stay at a logic level “0” (low) with the switch open, when we actually need a logic “1”, (high) causing the logic gate to falsely switch the output at “Q”. Also once there, this floating and weak input signal could easily change value at the slightest of interference or noise from its neighbouring inputs or could even cause it to go into oscillation, rendering the gate practically unusable. The same situation is also true with regards to the switching of input “B”.

Then to prevent accidental switching of digital circuits, any unconnected inputs called “floating inputs” should be tied to a logic “1” or logic “0” as appropriate for the circuit. We can easily do this by using what are commonly called **Pull-up Resistors** and **Pull-down Resistors** to give the input pin a defined default state, even if the switch is open, closed or there is nothing is connected to it.

When building digital electronic circuits, generally you will have some spare gates or latches within a single IC package left over, or the design of the circuit results in not all of a multi-input gates inputs being used. These unused logic inputs can be tied together or connected to a fixed voltage, using a high value resistor to either the Vcc voltage, known as pull-up or via a low value resistor to 0V (GND), known as pull-down. These unused inputs should never be left just floating about.

**Pull-up Resistors**

The most common method of ensuring that the inputs of digital logic gates and circuits can not self-bias and float about is to either connect the unused pins directly to ground (0V) for a constant low “0” input, (OR and NOR gates) or directly to Vcc (+5V) for a constant high “1” input (AND and NAND gates). Ok, lets look again at our two switched inputs from above.

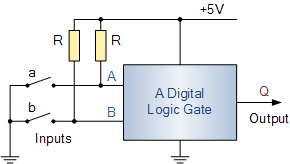


This time, to stop the two inputs, A and B, from “floating” about when the corresponding switches, “a” and “b” are open (off), the two inputs are connected to +5V supply.

You may think that this would work fine as when switch “a” is open (off), the input is connected to Vcc (+5V) and when the switch is closed (on), the input is connected to ground as before, then inputs “A” or “B” always have a default state regardless of the position of the switch.

However, this is a bad condition because when either of the switches are closed (on), there will be a direct short circuit between the +5V supply and ground, resulting in excessive current flow either blowing a fuse or damaging the circuit which is not good news. One way to overcome this issue is to use a pull-up resistor connected between the input pin and the +5V supply rail as shown.

**Pull-up Resistor Application**



By using these two pull-up resistors, one for each input, when switch “A” or “B” is open (off), the input is effectively connected to the +5V supply rail via the pull-up resistor. The result is that as there is very little input current into the input of the logic gate, very little voltage is dropped across the pull-up resistor so nearly all the +5V supply voltage is applied to the input pin creating a HIGH, logic “1” condition.

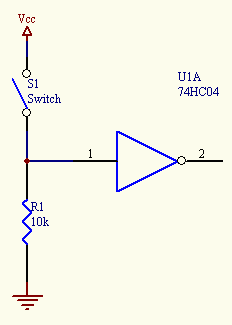
When switches “A”, or “B” are closed, (off) the input is shorted to ground (low) creating a logic “0” condition as before at the input. However, this time we are not shorting out the supply rail as the pull-up resistor only passes a small current (as determined by Ohms law) through the closed switch to ground.

By using a *pull-up resistor* in this way, the input always has a default logic state, either “1” or “0”, high or low, depending on the position of the switch, thus achieving the proper output function of the gate at “Q” and therefore preventing the input from floating about or self-biasing giving us exactly the switching condition we require.

While the connection between Vcc and an input (or output) is the preferred method for using a pull-up resistor.

**Pull Down Resistors**

Pull down resistor is just that, a resistor that pulls the voltage down, most commonly to ground. It is very useful whenever you have a net that in a certain state could be undefined or floating. 



Here is a typical example:  
**Open Switch:**  
Without the pull-down the input on this component would be undefined. The resistor pulls down the voltage on pin 1 of the component to 0/GND. This is useful because with an undefined input, you could get all kinds of weird stuff on the output pin, depending on the component, its supply voltage, noise etc. Most likely, when the switch is open you don't want anything on the output, so you define the input to 0 with a pull-down.   
  
  
**Closed Switch:**  
Now you have connected something on the input, and you probably want something to happen on the output. Since the resistor is of high value, the "leak" current is usually minimal, and the switch has virtually zero resistance, you get the desired voltage on pin 1 of the component, and the resistor can be ignored.  
  
The switch in this example does not have to be a manual switch, it can be pins on a microcontroller, fpga, FETs, relays, connectors, etc.   
  
The opposite of the pull-down resistor is the pull-up. It does exactly the same thing, but pulls the net up, normally to a Vcc of some value.