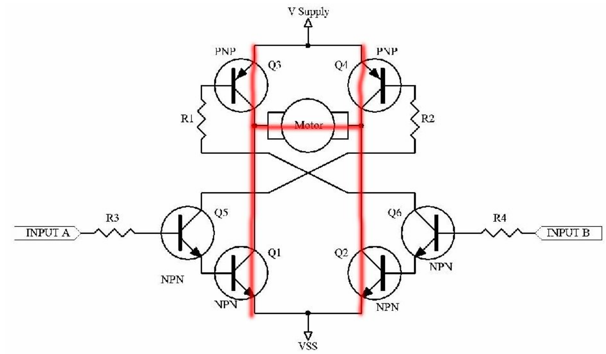
H-Bridge Primer

What is an H-Bridge anyway? An H-Bridge is usually used to control the direction of a motor but that is not necessarily the sole purpose. The “H” term comes from the arrangement of the drive transistors in relationship to the motor.



This article will describe what is important when designing an H-Bridge. The key is working backwards through your design and understanding the various current paths. First determine what the current demands of your motor are. If you don’t know the current rating, that’s ok, you should at least be able to determine what the operating voltage of the motor is either by the package that it came in, or the device such as a toy that it was removed from. If you’re lucky, there will be a label on the motor that tells you exactly what you need to know.

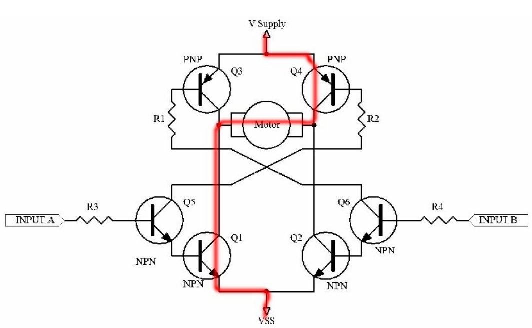
To determine the current demand of the motor we need to use an Ohmmeter to measure the resistance across the motor terminals. Make sure that you are only measuring across the motor terminals and that it is not connected to any other part of the circuit. Knowing Ohm’s law and dividing the operating voltage of the motor by the motor resistance we can determine the “stall” or start current of the motor.

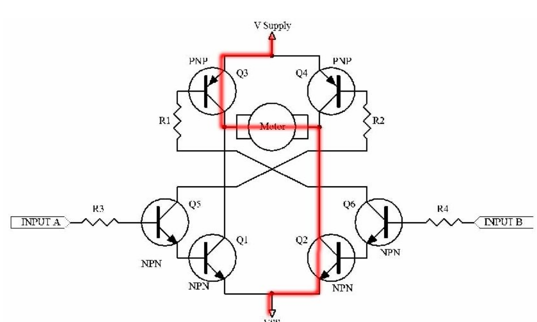
I = {Operating Voltage} / {Motor Resistance}

For the remainder of this example we will assume that the Operating voltage is 6V, and our measured resistance is 6 Ohms. Using the formula above we get 1 Amp of current required to drive the motor.
It is always a good design practice to give yourself a little bit of headroom. In this case, I usually double the current requirement, simply so that the transistors that I select won’t be stressed and have to work as hard. So, now the search is on to find transistors capable of delivering 2 Amps.

It is not an absolute requirement, but when searching for NPN and PNP transistors that will work together in a design such as an H-Bridge, complementary transistors are the way to go. This just means that the both of the transistor types will have the same electrical characteristics and that they will be well balanced.

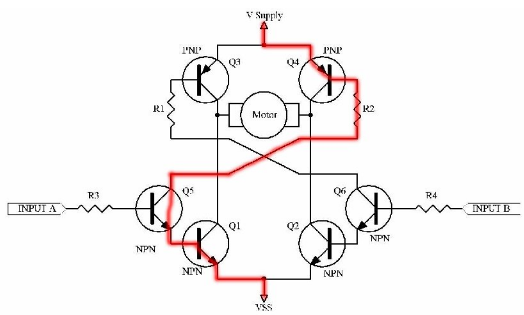
Ok, so now what? We have our transistors that can handle 2 or more Amps, what do we do now? It is important to know where this current needs to flow…

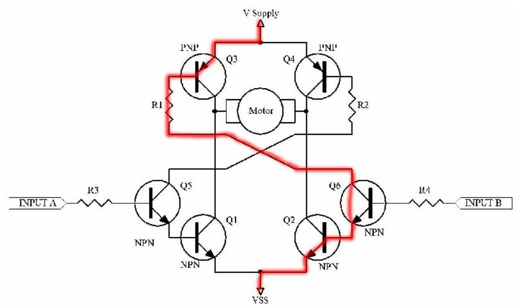




Depending on the direction you tell the motor to turn there are two paths for the drive current to flow. Understand that the drive current not only goes through the motor but is also present through at least two transistors at a time. (see images above) In order to adequately deliver the correct amount of drive current, Another important aspect of the transistor to look at is the Hfe or the Gain that the transistor has. This value can vary widely from transistor to transistor, manufacturer to manufacturer. Depending on the circuit design you might want to even go so far as to hand pick the transistors by measuring the Hfe. We won't do that here, instead we will use the minimum value listed from the datasheet. Ok, so in most cases, the lowest Hfe is about 10 to 20… we'll use 15 to continue with this example.

If the current through the drive transistors is 2 Amps, and we have an Hfe of 15, then we need to supply 133mA to the Base of the transistor. (2 Amps / 15 Hfe = 133.3mA) …. Better make that transistor**S**. Both the NPN and the PNP need to be supplied with 133mA. Depending on the motor direction, take a look at the two current paths below.





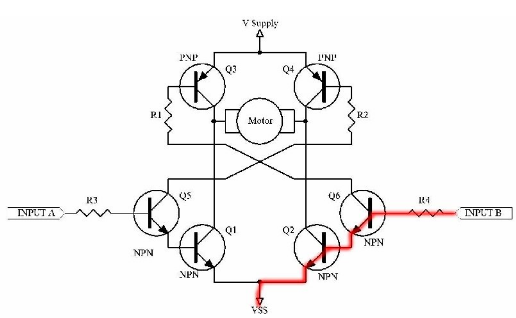
Now, something that I didn't mention earlier, only because it ends up error-ing in our favor adding to the rule of thumb of doubling the amount of required current. There is a diode drop across each transistor of about 0.6V due to the PN junction within the transistor. This means that with a 6V supply, your motor would actually see 4.8V across the terminals because of a 1.2V diode drop within the drive transistors. The reason that I say this now is because of the 133mA current requirement above. Here there are 3 transistors each contributing a 0.6V drop or a total of 1.8V. Eliminating the diode drop here in the equation would error against our favor. To determine the correct resistor value for R1 and R2, you need to take the Supply voltage minus the 1.8 Volt diode drop divided by the current requirement.

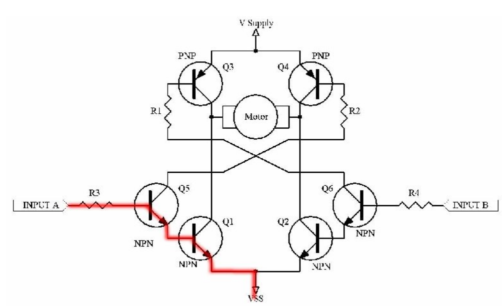
R1 = R2 = [{Voltage Supply} – {1.8Vdiode drop}] / {Current requirement}

R1 = R2 = [6V – 1.8V] / 133mA = 31.6 Ohms

It is ok to use the closest standard resistor value here…. Instead of 31.6 Ohms, a 33Ohm resistor would be fine.

Now there is only one more current path that needs to be considered, and this is where the H-Bridge inputs meet the Propeller or Stamp. Depending on the motor direction, take a look at the two current paths below.





Notice in the schematic above that there are only 2 transistors in the current path. This means that there is only a 1.2V diode drop. Using the lowest Hfe of 15 and remembering the current of 133mA, we can determine how much current is required for the input drives of the H-Bridge. 133mA / 15 Hfe = 8.8mA

{Input Drive Resistor} = [{I/O Voltage} – {1.2V diode drop}] / {Current requirement}

In the case with a Propeller, the I/O voltage would be 3.3V with any of the Stamp, or SX's it would be 5V

Propeller:
R3=R4= [3.3V – 1.2V] / 8.8mA = 238 Ohms or…. 240 Ohms closest standard value

Stamp, SX:
R3=R4= [5V – 1.2V] / 8.8mA = 431 Ohms or…. 470 Ohms closest standard value

That's about it!

Note: This H-Bridge design allows for different power supplies (motor vs. microcontroller) to be used.

Truth Table:

Input A	Input B	Motor
0	0	OFF
0	1	Forward
1	0	Reverse
1	1	**Not Allowed**