MOSFET H-Bridge Schematic & Theory of Operation

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Newsgroups: comp.robotics.misc
Subject: MOSFET H bridge - h-bridge.gif [1/1]
Date: 19 Dec 1995 07:58:06 GMT

This H-bridge uses MOSFETs for one main reason - to improve the efficiency of the bridge. When BJT transistors (normal transistors) were used, they had a saturation voltage of approximately 1V across the collector emitter junction when turned on. My power supply was 10V and I was consuming 2V across the two transistor required to control the direction of the motor. 20% of my power was eaten up by the transistors. I tried darlingtons etc... nothing worked. The transistors also would get quite hot - no room for heatsinks.

I chose MOSFETs because when they turn on they have an ON resistance called RDS(on). This is the resistance between the Drain and Source when turned on. It is quite easy to buy MOSFETs that have very low RDS(on) ratings of less than 0.1 ohm. At 4 amps, this would mean that the voltage drop would be 0.4V per MOSFET, a definite improvement. The MOSFETs I chose had an RDS(on) rating of 0.04 ohms which greatly improved my efficiency.

Now, when a MOSFET has a low RDS(on) rating, it usually has quite a high current rating typically in the 10s of amps. I needed 4 amps continous and the MOSFET I chose offered 25 amps. Naturally, the lower the RDS(on) rating, the more expensive the MOSFET. BTW, both types of MOSFETs are available in TO220 packages.

Low RDS(on) P channel MOSFETs are more difficult to find than N channel. I had to resign myself to a higher rated P channel MOSFET. There are quite a few MOSFET manufacturers:
MOTOROLA, International Rectifier, National Semiconductor to name a few.

MOSFETs work by applying a voltage to the Gate. They call this transconductance. When a positive voltage greater than the Gate threshold voltage is applied, the MOSFET turns on (Q4 & Q6 - N Channel only). The P channel works in reverse (See Q3 & Q5).

IMPORTANT: MOSFETs are extremely static sensitive but more important is that if the Gate is left open (no connection), the MOSFET can self-destruct. The Gate is a very high impedance device (10+ megohms) and noise can trigger the MOSFET. Resistors R3, R4, R6 & R8 have been added specifically to stop the MOSFET from self destructing. It is very important to install these resistors FIRST before installing the MOSFETs. You will find that after these resistors are installed that the MOSFETs are quite stable devices. The resistors pull-down the Gates and turn off the MOSFETs, not to mention add some static protection.

D1 to D4 route back EMF from the motor back to the power supply. Some MOSFETs (actually most) have these diodes built-in, so they may not be necessary.

Q1 & Q2 are NPN transistors that control the DC motor action.

STOP Mode

When A=0 and B=0, the motor is stopped. R3 and R4 pull up the Gates of

Q3 and Q5 respectively and turn off the MOSFETs.

REVERSE Mode

When A=0 and B=1 (+5V), the motor is in reverse. Q1 is turned off and Q3 is turned off due to R3. Q2 is turned on by the voltage at B. Q2's collector pulls Q5's Gate to ground. This turns on Q5 (P channel needs more -ve voltage than Source to turn on). The -ve side of the motor is raised to +12V. R5 raises Q4's Gate to +11V or so which turns on Q4. Q4's Drain goes to ground which makes the +ve side of the motor go to ground. R7 is also connected to the +ve side of the motor which pulls down Q6's Gate and makes sure that it is turned off.

The current path for the motor is from +12V to Q5 to -ve contact to +ve contact to Q4 to ground.

FORWARD Mode

When A=1 and B=0, the motor is in forward. Q2 is turned off and Q5 is turned off due to R4. Q1 is turned on due to the voltage at A and Q1's collector goes to ground. This turns on Q3 which raises the motor's +ve side to +12V. R7 raises Q6's Gate voltage and turns it on. When Q6 turns on, R5 makes sure that Q4 remains off.

The current path for the motor is from +12V to Q3 to +ve contact to -ve contact to Q6 to ground.

NOT ALLOWED Mode (or only once mode)

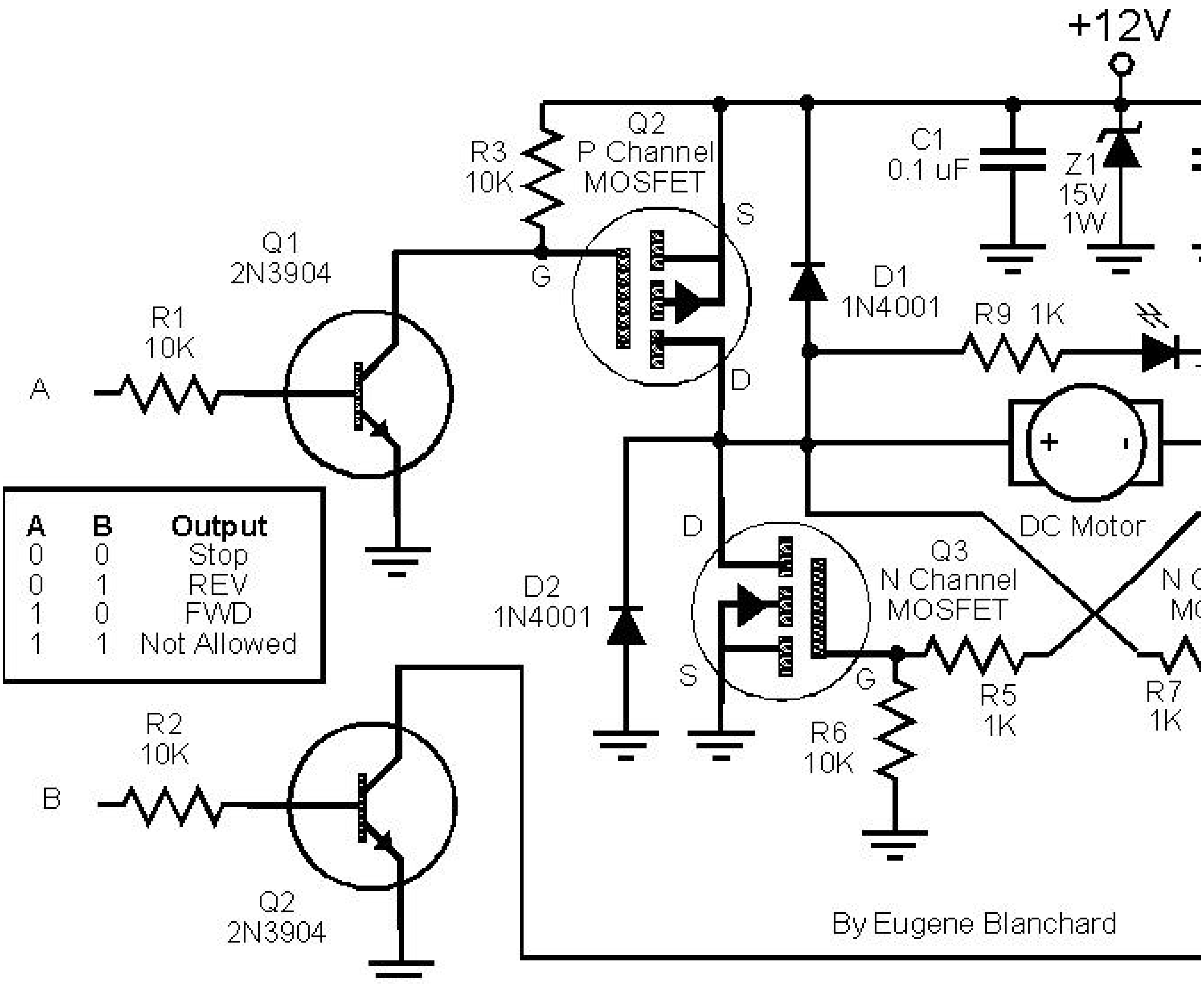
IF A=1 and B=1 then all MOSFETs turn on which shorts out the power supply among other things - Not recommended.

The tricolor LED allows you to test the circuit without connecting the motor. The LED will be green for one direction and red for the other. Handy test.

Motors make a lot of electrical noise from the brushes when running and huge electrical spikes when stopping, starting and especially changing direction. C1 and C2 try to suppress the noise spikes. Negative spikes are shorted to either ground or the power supply by D1 to D4. Z1 tries to clip the positive spikes.

Try to keep the motor supply separate from the logic supply if possible or go to extreme filtering techniques using coils, diodes and capacitors to filter out the motor noise.

Attached is the schematic as a GIF file


+12V
Q2
P Channel
MOSFET
R3
10K
C1
0.1 uF
Z1
15V
1W
S
G
D
D1
1N4001
R9 1K
Q1
2N3904
R1
10K
A
DC Motor
A B Output
0 0 Stop
0 1 REV
1 0 FWD
1 1 Not Allowed
D
D2
1N4001
Q3
N Channel
MOSFET
S
G
R5
1K
R7
1K
R6
10K
R2
10K
B
Q2
2N3904
By Eugene Blanchard