The Mech Motor Driver Circuit Board

Overview and Assembly Instructions

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The Handy Board Microcontroller motor output port can only deliver up to 600 mA of current, which is below the required level of the DC motors that are typically used for mechatronics robot projects. In order to provide more current to these motors, the bipolar push-pull motor driver circuit shown below in Figure 1 was designed.

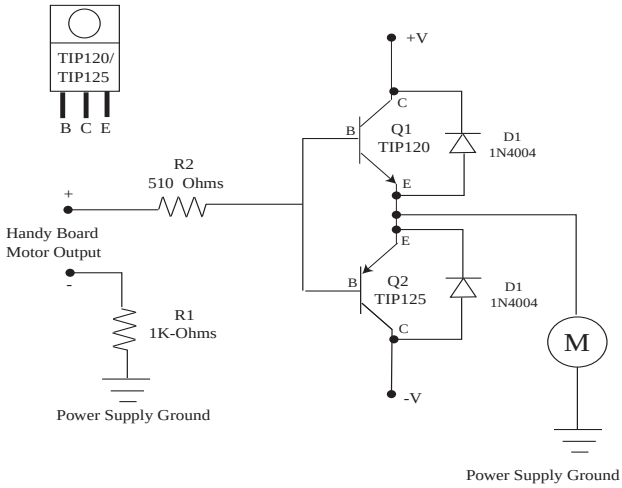

Figure 1: The bipolar push-pull motor driver circuit designed to provide larger current to DC motors.

The motor driver circuit was designed to (a) provide current to drive larger DC motors and (b) to isolate the Handy Board Microcontroller from potential damage caused by over current draw. To make life easier, a printed circuit board containing trace patterns for four driver circuits shown in Figure 2 was designed and manufactured for the mechatronics projects. Each team gets one printed circuit board along with enough components to construct two motor driver circuits. The assembly instructions are presented below in Section 3.

1 Theory of Operation

The theory of operation of the circuit is simple. The circuit consists of two Darlington power transistors (NPN and PNP), several resistors and diodes. The motor driver circuit requires a bipolar power supply ($\pm$3.6V from an R/C car battery), which allows it to control a motor in two directions. When the input voltage to the driver circuit (i.e. from the Handy Board) is zero volts, both transistors are cut off and the output voltage to the motor is zero volts. As the input voltage to the base of the transistors goes positive and exceeds about 0.5 volts, the NPN Darlington power transistor (Q1, TIP120) conducts and operates as an emitter follower, which supplies the load current to the motor. Meanwhile, the emitter-base junction of the PNP Darlington power transistor (Q2, TIP125) will be reversed-biased by the positive input from the Handy Board, thus turning the PNP transistor off. Conversely, when the output from the Handy Board motor port swings negative, the NPN shuts off and the PNP conducts and operates as an emitter follower supplying the load current to the motor in the opposite direction. Two flyback diodes are added to both transistors to dissipate voltage spikes caused by inductance effects from the motor during switching.

2 Features and Limitations

The Mech Driver Board has the following features:

1. Uses standard components such as a TIP120 (NPN) and a TIP125 (PNP) Darlington power transistor, 2 resistors (510Ω, 1$k\Omega$), and 2 rectifier diodes (1N4004).

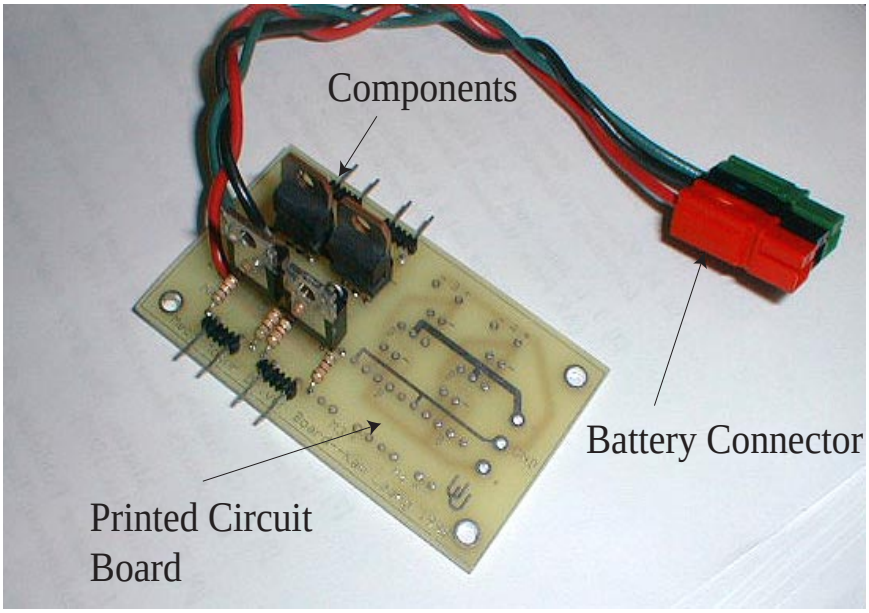

Figure 2: The push-pull motor driver circuit board assembled with battery power leads.

2. Can drive up to 4 DC motors.
3. Can be powered by two separate power supplies. Two driver circuits are powered by one power supply and the other two are powered by another power supply. Two different types of motors, which require two different supply voltages, can be used with the Mech Motor Board. In addition, the two separate power supplies provide power isolation between two sets of motors.
4. Contains 4 mounting holes with diameters large enough to fit 4-40 screws.
5. Transistor arrangement is compatible with heat sinks, which can be used to help dissipate heat during operation.
6. The printed circuit board (PCB) has labelled holes for easy assembly.

From experiments conducted in the lab, the bipolar push-pull motor driver circuit was rated up to 850mA of continuous current without the use of a heat sink. Using a proper heat sink for the Darlington power transistors, the motor driver circuit was rated up to 1.5A of continuous current. The absolute maximum current that the circuit can handle is 4.0A for approximately 2 seconds. Current draw beyond this limit can cause the transistors to overheat and fail.

3 Assembly Instructions

The layout of each circuit is as follows (Figure 3). All of the components for one circuit lies between "*Input 1*" and "*Output 1*", "*Input 2*" and "*Output 2*", etc., which is shown in Figure 3. *Input 1* is the input signal (from the Handy Board) to the circuit and *Output 1* is the output signal from the motor driver circuit, similarly for *Input 2* and *Output 2*, etc. The circuits *Input 1* and *Input 2* are powered by the left most power supply inputs (+, -, *GND*) and the circuits *Input 3* and *Input 4* are powered by the right most power supply inputs (+, -, *GND*).

Follow the instructions below to assemble the Mech Motor Driver Board. The order of instructions presented was determined to be the easiest approach to assembling the board. Refer to Figure 3 for component placement.

1. Decide on the number of circuits and power supplies required. For example, if two circuits are required, which can be powered by the same power supply, then *Input 1* and *Input 2* should be used. Otherwise, if two circuits are required and each require their own separate power supplies, then *Input 1* and *Input*

3 or *Input 2* and *Input 4* should be used. The maximum number of circuits that the Mech Motor Driver Board can accommodate is four!

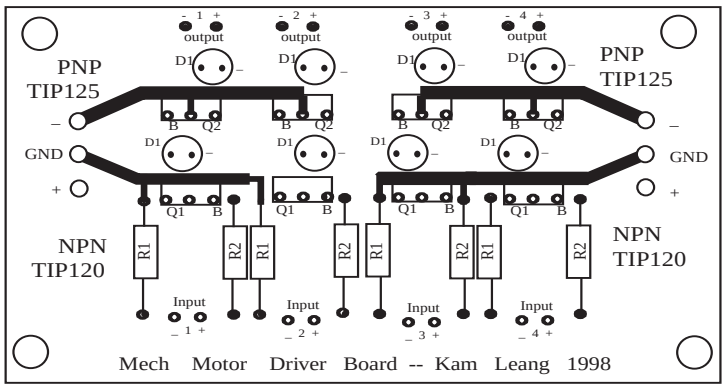

Figure 3: The Mech Motor Driver printed circuit board.

2. Solder resistors R1 ($1k\Omega$) and R2 (510Ω) in the proper location (see Figure 3). Be conservative with the solder. The board traces and plated through holes do not require much solder to hold the resistors or other components in place. Too much solder can create "short circuits" between adjacent holes or traces. Be very careful not to accidentally solder over other holes! If this happens, use solder wick to remove the excess solder.

3. Bend the diode D1 (1N4004) as shown below in Figure 4. Insert the diodes into the holes of the circuit board. Be sure that the cathode lead of the diode is inserted into the hole with the "-" mark. If the diode is not soldered properly, damage may result. Each circuit requires two diodes and there are a total of eight for four circuits. Double check again to make sure that the diodes are solder properly!

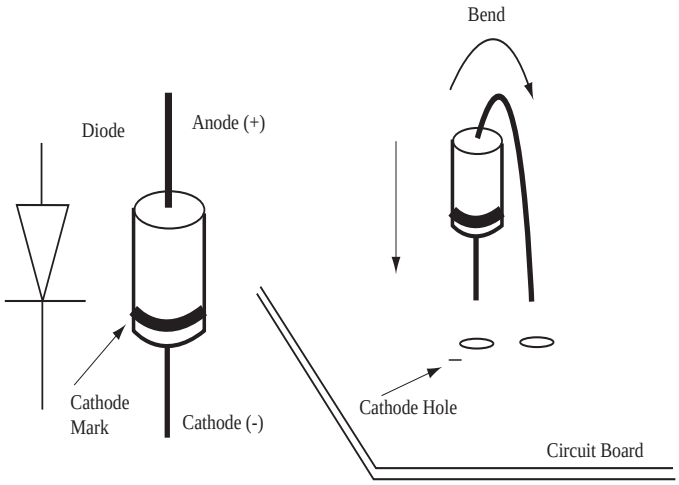

Figure 4: Installing the flyback diodes. It is important to match the cathode lead to the appropriate hole on the circuit board as shown.

4. Next, solder Q1 (TIP120) as shown below in Figure 5 (also refer to Figure 3 for transistor placement). Notice the "*B*" marking on the circuit board and how *Q1* should be placed. Arrange the transistor such that the "base" lead fits into this hole.

5. Solder *Q2* (TIP125) in the same manner as *Q1*. Refer to the previous step and Figure 3 and 5. Again, *Q2* can only be positioned one way to fit the hole with the "*B*" marking.

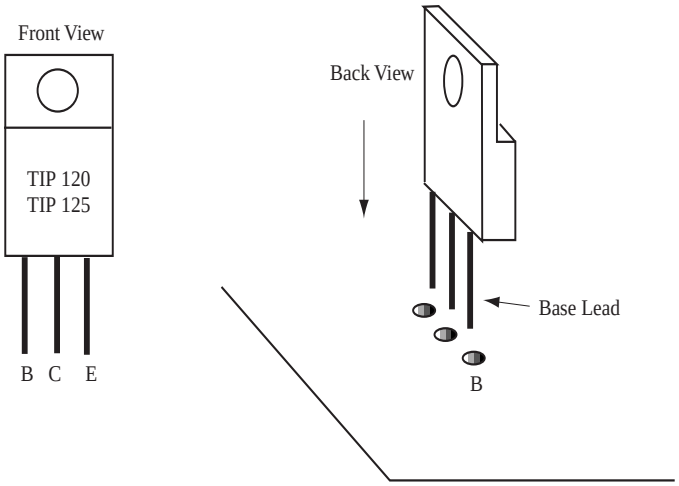

Figure 5: Positioning the Darlington power transistor in the circuit board.

6. Once all of the components have been properly soldered to the board, solder power wires to the appropriate holes. The standard colors for the power should be red (+), black (-), and green (*GND*). Solder to the end of these wires the appropriate battery power connectors (red, black, green, see Figure 2).
7. Solder input wires to *Input 1*, *Input 2*, etc., so that they can be connected to the Handy Board motor output ports. The "+" label next to *Input 1*, *Input 2*, etc., should be connected to the "+" terminal on the Handy Board motor output port and the "-" should be connected to the "-" terminal on the Handy Board motor output port. Refer to the Handy Board Reference Manual or ask your TA for help.
8. Finally, solder output wires from each circuit (i.e., "*Output 1*", "*Output 2*", etc.) and connect them to a DC motor(s). There are two wires per motor (i.e., "+" and "-").
9. Once the motor driver board has been properly assembled, secure it to a solid foundation via 4-40 or similar size screws. Make sure to keep all potential solder joints and conductive surfaces on the board away from other conductive materials such as bare wire, aluminum, etc. If the board is mounted to a robot that has an aluminum platform, be sure to properly isolate the motor driver board from the aluminum or other potentially hazardous conductive surfaces.

4 Testing

Follow the steps below to test the board.

1. Connect the Handy Board's motor *output* port to the motor driver circuit board's *inputs*.
2. Plug in your favorite DC motor to the *outputs* of the motor driver circuit board.
3. Connect the battery to the power wires on the circuit board, making sure you have the appropriate polarity. Touch the transistors to see if they are HOT. If they are, disconnect power immediately because the circuit is damaged. Go back and make sure all of the components were assembled correctly. Otherwise, continue to the next step.
4. Use the "*motor(int m,int p)*" command in Interactive C to power the motor and cross your fingers! If the motor turns in both directions when the appropriate command is given, then congrats! Otherwise, disconnect power, check all solder connections, and component placement for error. If a component feels hot to the touch, then the component may be damaged. Check for bad solder connections, short circuits, misplaced components, broken traces and connections, and appropriate application of power. Continue testing and ask your TA for help if you are stumped. If nothing works, email the author at kleang@eng.utah.edu for help.