

Name/NetID:

Teammate:

Module 6C: Building Motor Drive Circuit (BJT)

Module Outline

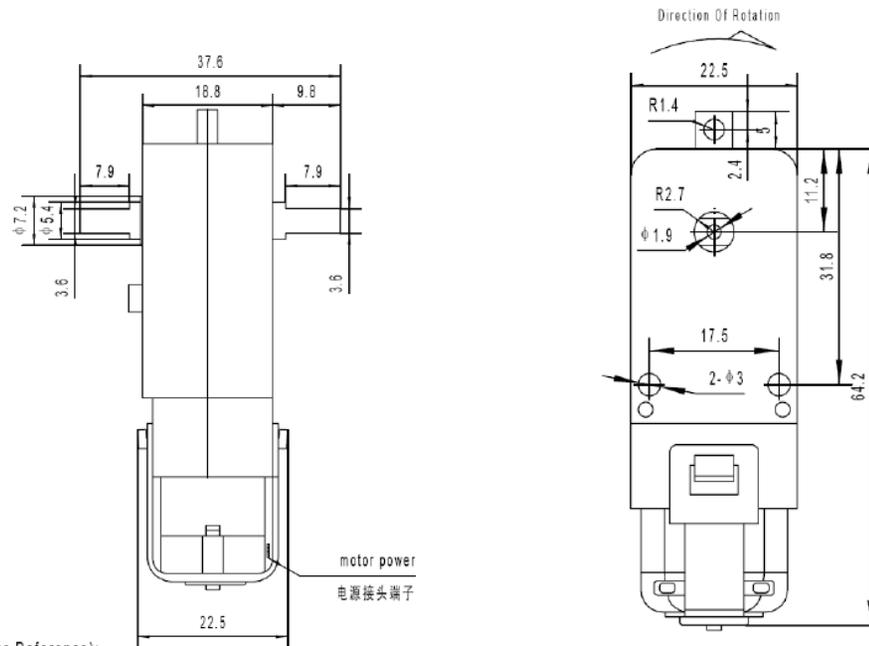
The vehicle connected to a battery with some resistors inserted – to keep the velocity slow enough that the car does not crash – is the first stage in building a fully autonomous car. As the design stands the vehicle can move in only one way, depending on how much resistance is inserted in series with the motor. To change how it moves you must manually change the arrangement and values of the resistors. Not very autonomous. The next step is to include a control circuit that can turn the motors on and off – for this task the Arduino is perfect. The digital I/O pins will be used to turn the motors on and off and control the speed of the motors as well. Only one problem needs to be overcome – an interface is needed between the relatively power hungry motors and the very small current sourcing capacity of most digital circuitry, and analog circuitry used to control them.

Procedures

The motors, as you will find out in a later lab, demand quite a lot of current. The current rating for the pins on the Arduino board – 40mA – suggests that the board cannot handle the current needed by the motor without damage. The datasheet for the motors on the Magician Chassis, shown in the figure below, indicates that when the motor is running freely at a voltage $\sim 5V$ it will draw $\sim 190mA$ and at most 250mA which is much greater than 40mA. You could try to limit the speed of the motors with resistors but the behavior will be unpredictable and there is a much better way.

This scenario is very common – how to drive a device or circuit that have high power needs but the control circuitry is not capable of providing that power. One solution is to use a transistor circuit as an interface between the two.

DG01D-A130GEARMOTOR



GEAR BOX Specification(For Reference):

Suggested Voltage: 4.5V DC

1、No Load Speed: 90 ± 10 rpm

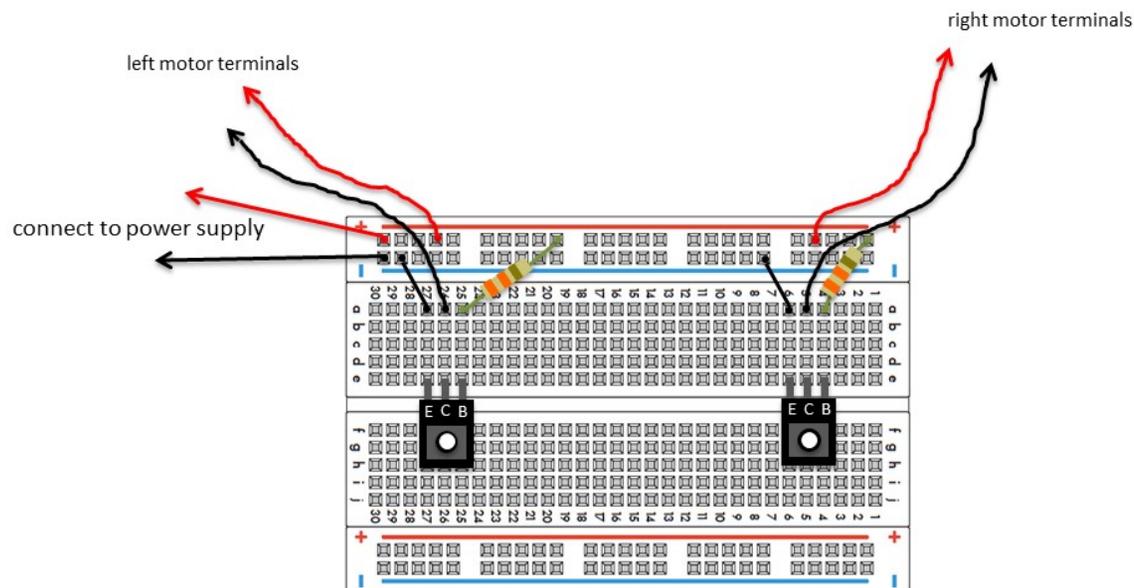
2、No Load Current: 190mA (250mA MAX)

3、Allowable max. Torque: 800gf.cm min

Simple Test of the Transistor

The following instructions, along with the figures on the following page, are an intermediate stage in building the full motor drive circuitry. By building this circuit first you will be sure that the connections to the transistor are correct before connecting it to the Arduino.

- ✓ Mount the protoboard on top of the chassis. It is not recommended to commit to a placement yet so don't use the adhesive on the bottom yet. A less permanent option is to use the Velcro available in the lab.
- ✓ Insert the transistors available in the lab into the protoboard as shown in the figure below.
- ✓ Connect the transistor pins labeled **E** to ground labeled **-** on the protoboard as shown in the figure below.
- ✓ Connect the motor terminals of each motor with the positive terminal of the motors to the **+** terminal of the power strip and the negative terminal to the transistor labeled **C**.
- ✓ Put the vehicle on a stand – the small wooden blocks or your partner holding it will work fine.
- ✓ Connect the power supply to the power strips on the protoboard setting the voltage to 5V keeping it in the OUTPUT OFF mode until you are finished wiring the transistors.
- ✓ Connect the pin labeled **B** on both transistors through a 330Ω resistor to the positive terminal on the power strip. (refer to the physical diagram below for help)



Notes:

Question 1: Turn the power supply on making sure it is set to 5V. Is the motor turning?

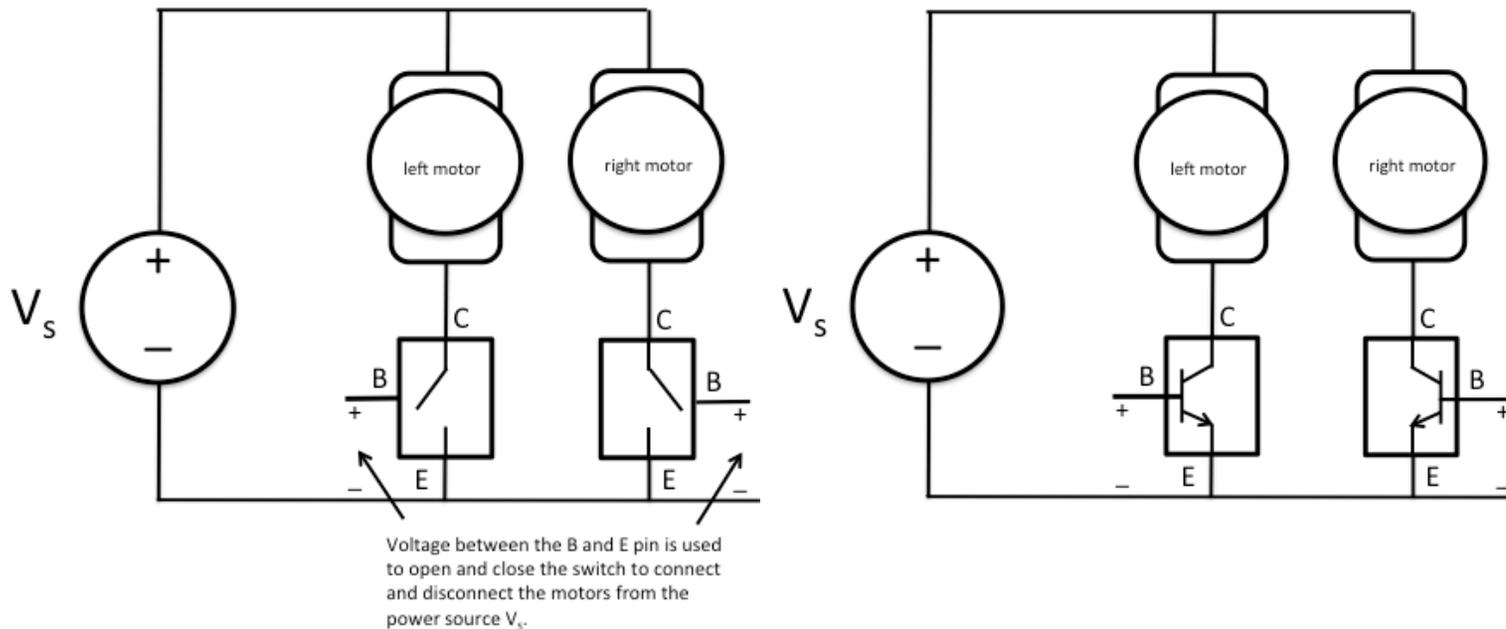
Question 2: If the answer to Question 1 was **no** then there is a wiring problem. Fix it – Is the motor turning?

Repeat until the answer is YES.

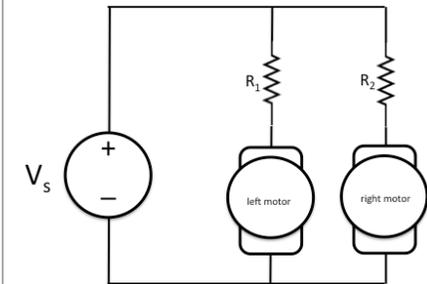
What is a Transistor

At this point you have put together the chassis and connected the motors to first the power supply and then a battery pack to get the vehicle body to start moving on a table. To slow down the speed of the vehicle you inserted resistors in series with the power supply. Because the motors demand $\sim 150\text{mA}$ of current it was difficult to find the right combination. Too little resistance and the resistor burns – too much and the motors will not be able to overcome the internal friction and will not turn. How to control the motors that demand more power than most circuits used to control them can handle?

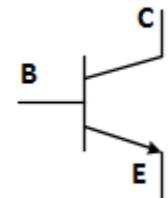
A special device is needed between the motor power source and the motors that acts as an electronic switch. The transistor is that special device – you will study it in class and characterize it in a later lab. There are many different types of transistors. The ones you will be using are Bipolar Junction Transistors (BJT) – a 2N5192 if you are looking for a datasheet. The pins of a BJT are named the Collector (**C**), the Emitter (**E**), and the Base (**B**). The desired current flows along a path between the collector and emitter. The signal that controls this current is applied to the base (see figure below).



Notes:



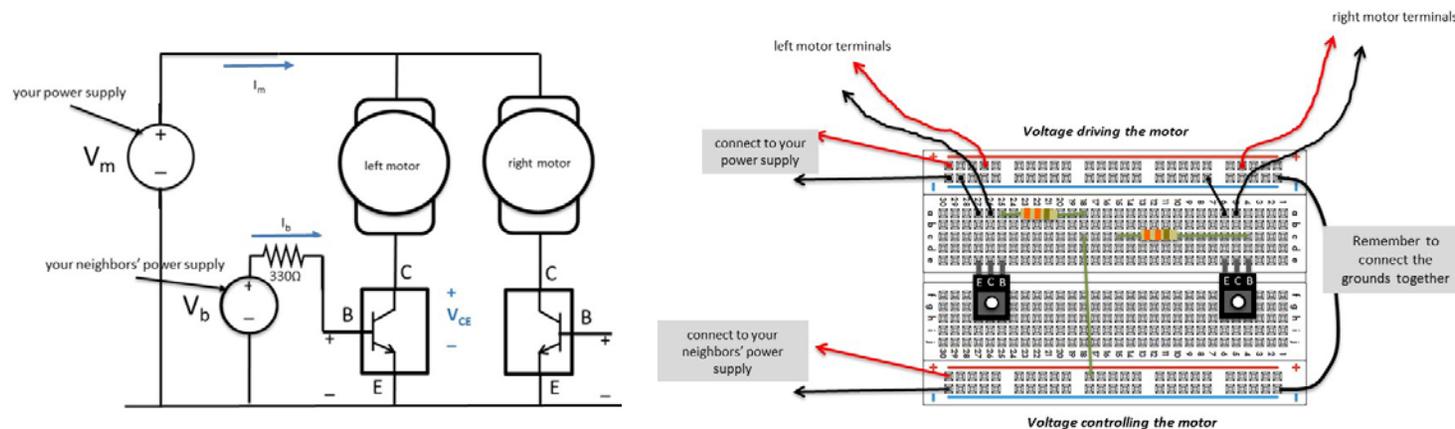
Circuit you built in Module 2



Circuit symbol for an NPN BJT – you will learn more about these devices and what NPN means during lecture and in future labs.

This next portion emphasizes that the transistor is a device that can control the flow of current through a power hungry device connected to beefy power source by using a signal that can be driven by a completely different much lower power source (sharing the same common or ground connection).

- ✓ Hook up the power supply from your neighbors' bench to the other power strip on the protoboard and **connect the grounds on both sides together**.
- ✓ Now connect the pin labeled **B** on **one** of the transistors through the 330Ω resistor to the positive terminal of the power strip you just connected to your neighbors' supply.
- ✓ Set the voltage of your neighbors' power supply to 5V – labeled V_b in the schematic below.
- ✓ Set the voltage of your power supply to 5V – labeled V_m in the schematic below.



Your supply is driving the motor while your neighbors' is controlling the state of one of the transistor keeping it in the ON state for now – the motor should be turning.

Question 3: For the motors that is connected to both supplies label on the physical diagram above I_m , I_b , and V_{CE} .

Notes:

Question 4: Change the small signal that is controlling the state of the transistor by changing the voltage of your *neighbors'* supply in .5V steps starting at 0V filling in the following table. Note the voltage where the motor first turns on and a qualitative description of the speed of rotation at each voltage once the motor starts moving. **YOU DO NOT NEED the DMM** to make the current measurements – you can read the current directly from the two power supplies.

| Voltage (V_{BE}) | I_b | I_m | V_{CE} | Comments |
|----------------------|-------|-------|----------|----------|
| .5 | | | | |
| 1 | | | | |
| 1.5 | | | | |
| 2 | | | | |
| 2.5 | | | | |
| 3 | | | | |
| 3.5 | | | | |
| 4 | | | | |
| 4.5 | | | | |
| 5 | | | | |

Question 5: Plot both I_b and I_m vs. the voltage that you varied using your neighbors' power supply.

Question 6: Plot V_{CE} vs. the same voltage.

Question 7: Using these two plots and/or the data explain the features of the data that indicate that by varying the voltage across the base and emitter (V_{BE}) you can control the motor. Things to look for are: i) the value of V_{BE} when the motor first starts turning, ii) how V_{CE} changes as V_{BE} is increased, iii) comparison of values of I_b and I_m after the motor starts turning. Do you see how the small current I_b is controlling the much larger current I_m by changing the voltage V_{BE} ?