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Welcome to the electrical aspect of building the SumoBot. In our lectures we have discussed how the three sub projects of building the SumoBot ultimately combine to produce a programmable robot. I will briefly outline the three sub projects below.

- Mechanical – provides the physical backbone of the robot
- Electrical – build a programmable circuit which is comprised of a microcontroller, a motor driver, and other supporting electronic devices
- Embedded – write an algorithm which utilizes the attached sensors and takes advantage of its mechanical and electrical design

In this document you will learn about the electrical connections which you will need to build in your circuit. There are three components of the electrical aspect you will need to build in order to complete the electrical circuits required for the SumoBot. Here is the general approach – first build a **power supply** and choose what source of power you're going to be using. There are options of regular non-rechargeable AA batteries, rechargeable AA, or lithium. Lithium is the most compact option however they are a bit more costly. These battery costs are inferred to your team.

Then you will build the programmable circuit using the **ATmega328p**. This is what gives you programming capabilities to control 19 different types of signals (13 digital and 6 analog signals).

Then we need to extend the capabilities of the microcontroller by using an **Integrated Circuit (IC)** called a motor driver, which allows the microcontroller to control more powerful signals that are to be delivered to the motors. This IC chip is called L293D. This device has built in diode protection, which eliminates the harmful **back EMF** produced by the motors. L293D allows the ATmega328p to control two motors independently. For more reading on these components there are datasheets that can be found online.

Next we add sensors to give the robot the ability to read data about its surrounding environment. There is no limit on the number of sensors on your SumoBot and no restrictions on the type of sensors you use. In a simple robot there are typically one proximity sensor in the front and two color sensors on the bottom. Again, we may be providing one sensor however should you need more, you can purchase them on your own accord.

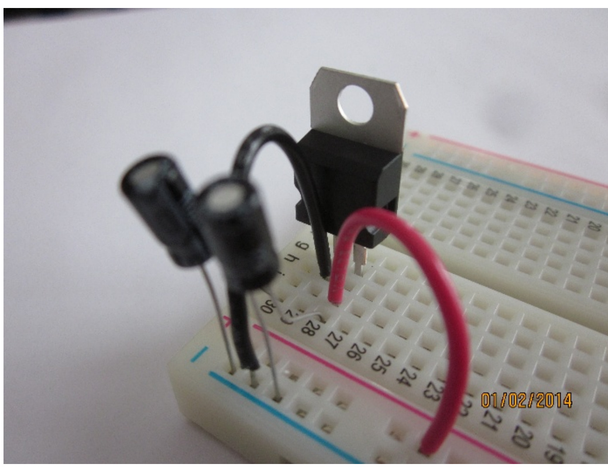
Lastly, I should point out it is extremely useful knowledge to know how to use a digital multimeter to be able to test for connections and measure voltages throughout the circuit building process. Now we will begin the fun. You may attempt to build the circuit alongside reading this document. Please use the breadboard as we will be hosting a soldering workshop to guide you through this process.

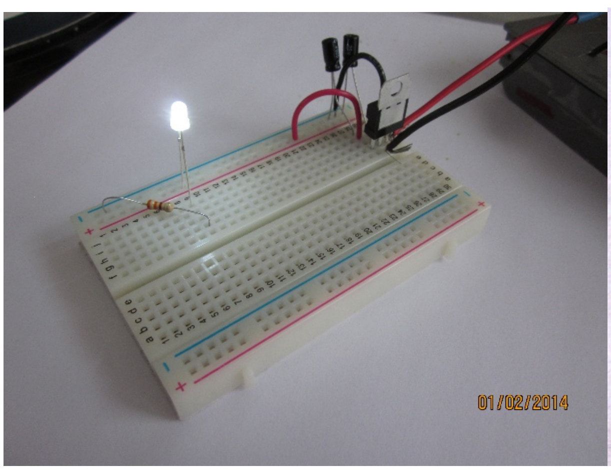
The Power Supply

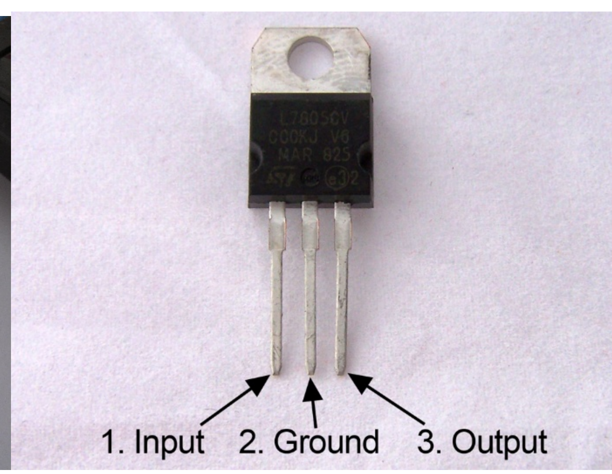
The power supply circuit is comprised of a few components. A 5V power regulator and some filtering capacitors. Capacitors are electronic components that act like a buffer before current flows through to the load. The 5V regulator is the L7805. What it does is reduce a range of voltages down to 5V. This is necessary as the microcontroller ATmega328p runs on 5V as specified by its datasheet. The regulator has 3 pins. Please refer to the following diagram.

The input pin allows a range of voltages 7V to 36V. This input signal must be grounded to the middle pin and consequently at the output we will see a 5V signal. From here we must connect two 10uF capacitors from the input to ground as well at the output to ground. Please see the diagram below for more clarity.

Finally ensure your power supply utilizes the rails of the breadboard as shown.





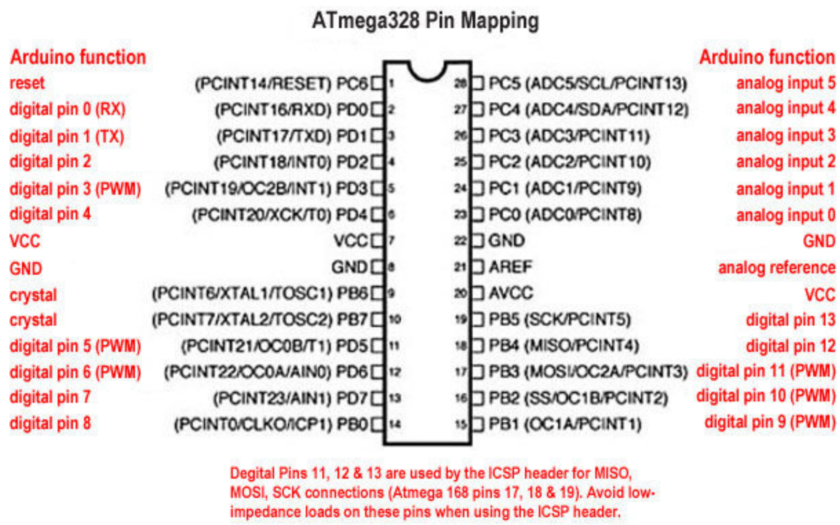


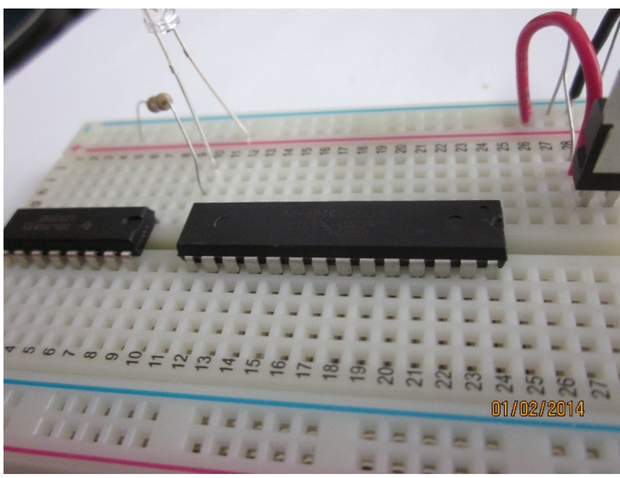
The Microcontroller

The table below maps out all the necessary connections for the microcontroller and the recommended connections to utilize the L293D motor driver and sensors.

Pin 1 – Reset, this pin is optionally connected to a toggle switch to reset the microcontroller	Pin 28 – Analog Input Pin 5 – your engineering decision on how you want to connect the sensors
Pin 2 – Digital In/Out 0, not in use.	Pin 27 – Analog Input Pin 4 – your engineering decision on how you want to connect the sensors
Pin 3 - Digital In/Out 1, not in use.	Pin 26 – Analog Input Pin 3 – your engineering decision on how you want to connect the sensors
Pin 4 - Digital In/Out 2, not in use.	Pin 25 – Analog Input Pin 2 – your engineering decision on how you want to connect the sensors
Pin 5 - Digital In/Out 3 + PWM Capable, not in use.	Pin 24 – Analog Input Pin 1 – your engineering decision on how you want to connect the sensors
Pin 6 - Digital In/Out 4, not in use.	Pin 23 – Analog Input Pin 0 – your engineering decision on how you want to connect the sensors
Pin 7 – VCC, connect this pin to the 5V source produced by the power supply.	Pin 22 – GND, connect this to the ground produced from the power supply
Pin 8 – GND, connect this to the ground produced from the power supply	Pin 21 – AREF, analog reference pin sets the reference voltage of the analog signals. Must be connected to 5V from the power supply.
Pin 9 – Crystal, the 16 MHz crystal is connected across both pin 9 and pin 10 where a 22pF capacitor connects pin 9 and 10 to ground. See figure X.	Pin 20 – AVCC, analog power source. Must be connected to 5V from the power supply.
Pin 10 - Crystal, the 16 MHz crystal is connected across both pin 9 and pin 10 where a 22pF capacitor connects pin 9 and 10 to ground. See figure X.	Pin 19 - Digital In/Out 13. **Recommended connection to Input 4, pin 15 on the L293D motor driver.**
Pin 11 - Digital In/Out 5 + PWM Capable, not in use.	Pin 18 - Digital In/Out 12. **Recommended connection to Input 3, pin 10 on the L293D motor driver.**
Pin 12 - Digital In/Out 6 + PWM Capable. **Recommended connection to Enable 1, pin 1 on the L293D motor driver.**	Pin 17 - Digital In/Out 11 + PWM Capable. **Recommended connection to Enable 2, pin 9 on the L293D motor driver.**
Pin 13 - Digital In/Out 7. **Recommended connection to Input 1, pin 2 of the L293D motor driver.**	Pin 16 - Digital In/Out 10 + PWM Capable, not in use.
Pin 14 - Digital In/Out 8. **Recommended connection to Input 2, pin 7 of the L293D motor driver.**	Pin 15 - Digital In/Out 9 + PWM Capable, not in use.

You can see why most connections are placed in specific places by looking at the diagram below. It is important to have the chosen pin out written down so that you can pass on this information to the embedded lead of your team. This is important for the embedded lead as they must know these pinouts to be able to control/program your SumoBot properly.


ATmega328 Pin Mapping
Arduino function
reset (PCINT14/RESET) PC6 1
digital pin 0 (RX) (PCINT16/RXD) PD0 2
digital pin 1 (TX) (PCINT17/TXD) PD1 3
digital pin 2 (PCINT18/INT0) PD2 4
digital pin 3 (PWM) (PCINT19/OC2B/INT1) PD3 5
digital pin 4 (PCINT20/XCK/T0) PD4 6
VCC VCC 7
GND GND 8
crystal (PCINT6/XTAL1/TOSC1) PB6 9
crystal (PCINT7/XTAL2/TOSC2) PB7 10
digital pin 5 (PWM) (PCINT21/OC0B/T1) PD5 11
digital pin 6 (PWM) (PCINT22/OC0A/AIN0) PD6 12
digital pin 7 (PCINT23/AIN1) PD7 13
digital pin 8 (PCINT0/CLKO/ICP1) PB0 14
Arduino function
28 PC5 (ADC5/SCL/PCINT13) analog input 5
27 PC4 (ADC4/SDA/PCINT12) analog input 4
26 PC3 (ADC3/PCINT11) analog input 3
25 PC2 (ADC2/PCINT10) analog input 2
24 PC1 (ADC1/PCINT9) analog input 1
23 PC0 (ADC0/PCINT8) analog input 0
22 GND GND
21 AREF analog reference
20 AVCC VCC
19 PB5 (SCK/PCINT5) digital pin 13
18 PB4 (MISO/PCINT4) digital pin 12
17 PB3 (MOSI/OC2A/PCINT3) digital pin 11 (PWM)
16 PB2 (SS/OC1B/PCINT2) digital pin 10 (PWM)
15 PB1 (OC1A/PCINT1) digital pin 9 (PWM)
Degital Pins 11, 12 & 13 are used by the ICSP header for MISO, MOSI, SCK connections (Atmega 168 pins 17, 18 & 19). Avoid low-impedance loads on these pins when using the ICSP header.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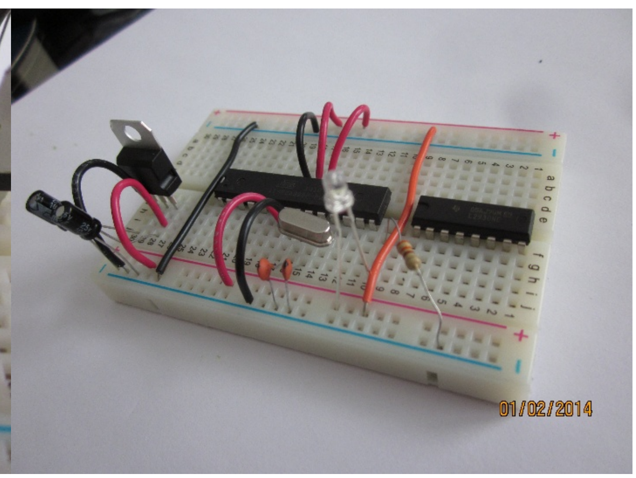
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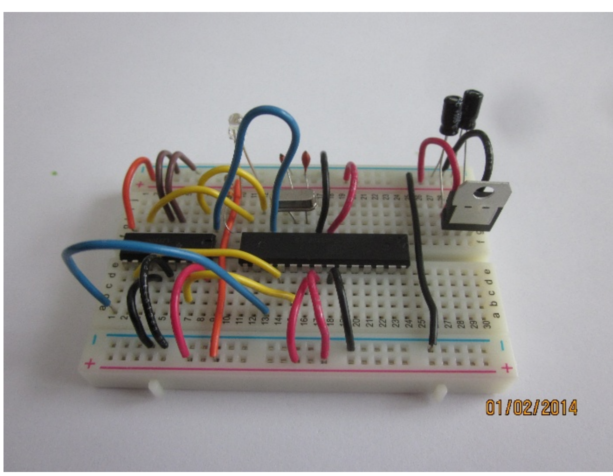
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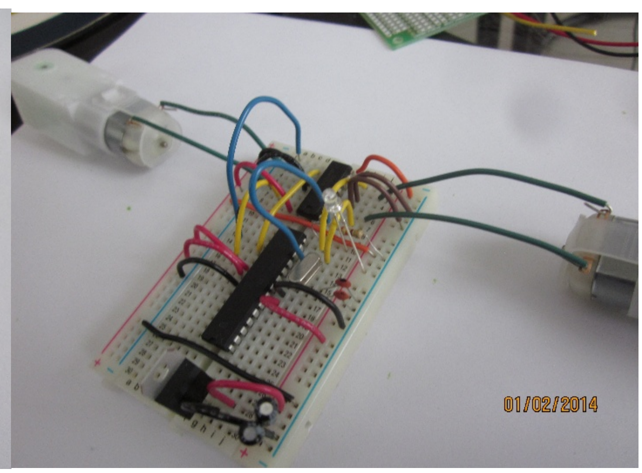
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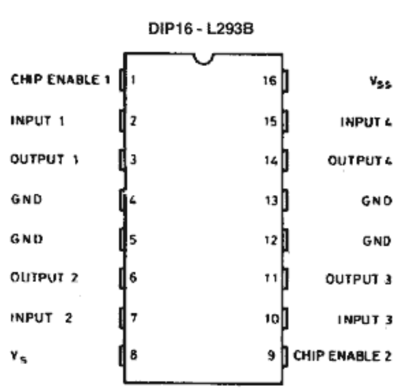
The Motor Driver

I will take a similar approach to explain the logical connections made on the motor driver, L293D. This IC chip is a simple chip that consists of 16 pins used for controlling the direction of the motors as well as its speed.

Pin 1 is an input signal that is received from the microcontroller. If this pin receives a LOW signal, it will cut off power being delivered to output 1 and 2, pins 3 and 6 respectively. If this pin receives a HIGH signal, the chip will deliver the signals to pins 2 and 7. **Recommended connection to Digital Pin 6.**	Pin 16 this pin receives the voltage signal necessary to power the IC chip. Usually we use 5V delivered from the power supply or microcontroller.
Pin 2, receives a signal from the microcontroller. This input pin acts synchronously with pin 7. To activate the **left** motor in one direction send this pin a HIGH signal and pin 7 a LOW signal. **Recommended connection to Digital Pin 7.**	Pin 15, receives a signal from the microcontroller. This input pin acts synchronously with pin 10. To activate the **right** motor in one direction send this pin a HIGH signal and pin 10 a LOW signal. **Recommended connection to Digital Pin 13.**
Pin 3, connect this to one of the leads on the left motor	Pin 14, connect this to one of the leads on the right motor
Pin 4 is connected directly to ground.	Pin 13 is connected directly to ground.
Pin 5 is connected directly to ground.	Pin 12 is connected directly to ground.
Pin 6, connect this to the other lead on the left motor	Pin 11, connect this to the other lead on the right motor
Pin 7, receives a signal from the microcontroller. This input pin acts synchronously with pin 2. To activate the **left** motor in the other direction send this pin a HIGH signal and pin 2 a LOW signal. **Recommended connection to Digital Pin 8**	Pin 10, receives a signal from the microcontroller. This input pin acts synchronously with pin 15. To activate the **right** motor in the other direction send this pin a HIGH signal and pin 15 a LOW signal. **Recommended connection - Digital Pin 12**
Pin 8, the Vs pin receives a voltage power signal which gets transmitted to the motors depending on the respective input signals. This voltage signal can be higher than 5V which will be used to power the microcontroller and the motor driver.	Pin 9 is an input signal which is received from the microcontroller. If this pin receives a LOW signal, it will cut off power being delivered to output 3 and 4, pins 11 and 14 respectively. **Recommended connection to Digital Pin 11.**



Debugging Your Circuit

The secret to debugging your circuit is by using the digital multimeter to test connections and measure voltages that you predict beforehand. If the predicted connections aren't present then your circuit has not been properly connected. These predictions come from our circuit design as well the voltages that should be output based on the programs you write. You should be using the least amount of solder possible. This is something we will go over a soldering workshop where we will build basic circuits with solder.

Adding Sensors

When you have completed your circuits and you have shown that you have full control over the motors, the next task is to add sensors. This step is pretty easy as most sensors you will be using will be analog and can connect directly to pins 23 through pins 28 and of course you will need to power the sensors which is provided by the power supply you built in earlier stages.

The types of sensors you use and the number of sensors are your decision. Your only constraint is the microcontroller provided. There are about 6 available digital in/out pins and 6 available analog sensors. It is your team's decision to use analog or digital sensors. That being said, analog proximity sensors from Sharp are the easiest to use and program for.

NOTE: I highly recommend building the SumoBot on the breadboard and from there test that it actually works. Once completed the circuitry the next step is to hand off the project to the Embedded Lead where they will make a slight modification to add on the programming interface to the robot.

Note 2: If you have any questions please contact me via email: sumo@utra.ca