

# E11: Autonomous Vehicles Fall 2014

# Lab 1: Mudduino Assembly

Arduino is a popular open-source system built around an Atmega328 microcontroller with analog and digital inputs and output ports to interface with the real world and a USB port to interface with a PC or Mac. The Mudduino is a custom version of the Arduino system developed at HMC for E11. It includes LEDs, a speaker, an H-bridge (for motor control), and an area for prototyping add-on circuitry.

In this lab you will assemble and test your Mudduino board. You will be using this board for the remainder of the semester, so it is important to assemble it properly. But don't worry! If you damage parts on your board, you may ask your instructor for spare parts.

# **Soldering Background**

Soldering is a process in which two metal items are fused together by melting an alloy between them. For this lab, you will be soldering together the pins of the electrical components in your kit to the electrical contacts on the board. There are two types of soldering: through-hole and surface-mount (surface-mount parts only attach to one side of the printed circuit board). You'll be responsible for soldering on the through-hole components.

Before beginning the board assembly, make sure to familiarize yourself with the components in the component dictionary starting on page 6. It might be helpful to also skim through the lab to get an idea of the steps involved. If you have any questions, feel free to ask for help. You may also find that borrowing an additional hand or two to hold components may save you some trouble.

# **Mudduino Overview**

The schematic and layout for the Mudduino board are shown on the following pages.

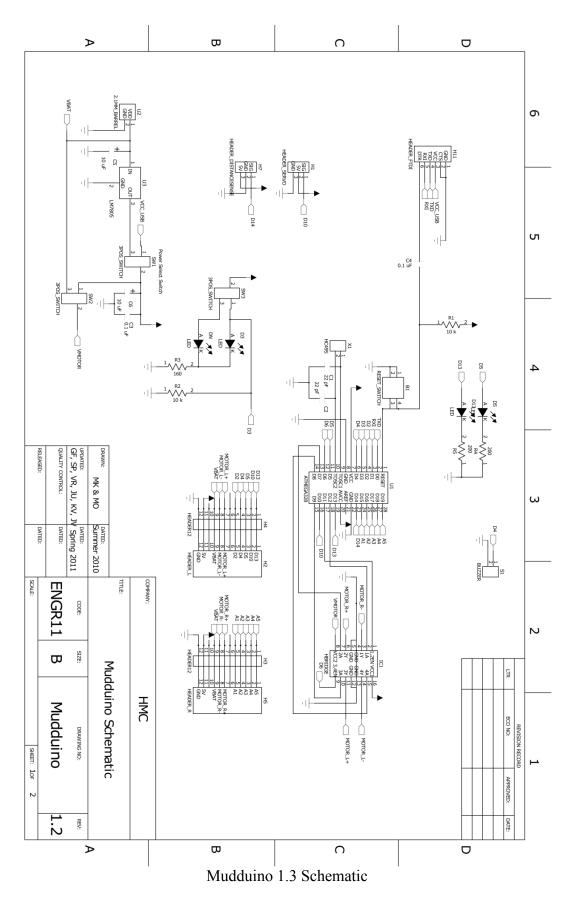
Take some time to learn to read the schematic and familiarize yourself with the contents of the board.

Digital Pin #	Analog Pin #	Notes
0		Serial TXD – don't use
1		Serial RXI – don't use
2		Header D2
3		Team ( $0 = \text{green} / 1 = \text{white}$ ) read only
4		Header D4, Buzzer
5		Header D5 / green LED / programming indicator
6		Left Motor Enable
7		Right Motor +
8		Left Motor -
9		Left Motor +
10		Header D10 / Servo (use servo.write)
11		Right Motor Enable
12		Right Motor -
13		Header D13 / red LED
14	0	Distance Sensor
15	1	Header A1
16	2	Header A2
17	3	Header A3
18	4	Header A4, Reflectance Sensor
19	5	Header A5, Phototransistor

As you work with your Mudduino in later labs, you'll find the following table of pins helpful.

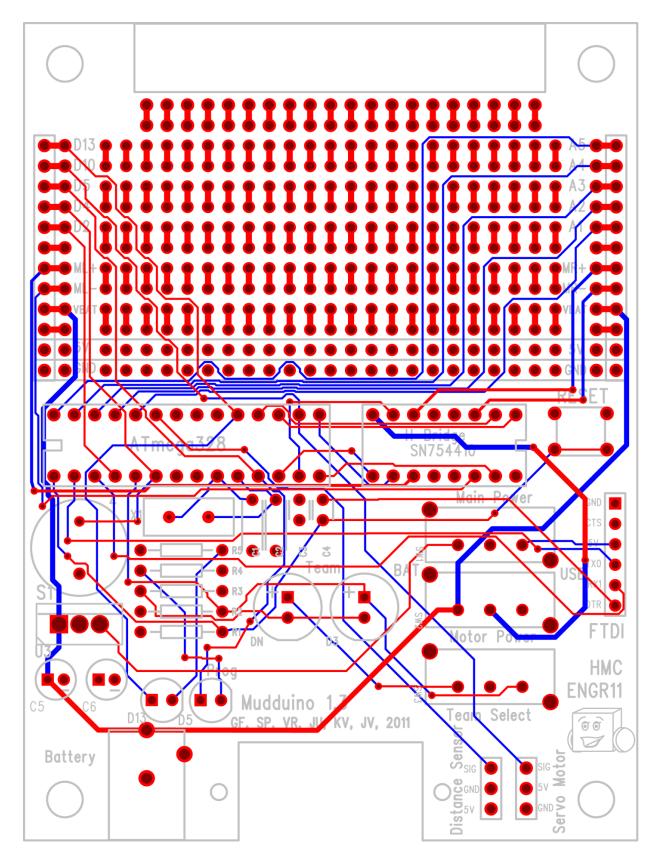
Notes:

- Atmega operating voltage: 5 V
- Maximum output current: 40 mA
  - A short circuit exceeding this current may destroy the Atmega output pin
- Digital pins 2 and 3 support external interrupts using attachInterrupt()
- Digital pins 3, 5, 6, 9, 10, and 11 may be operated as pulse-width modulated analog outputs using analogWrite(). Pins 6 and 11 are already devoted to adjustable motor power in this fashion.
- Pin 10 servo: servo.attach(10) then servo.write(angle);  $0 \le angle \le 180$
- Digital pins 14-19 / analog pins 0-5 may be operated as analog inputs or digital I/Os
- pinMode(), digitalRead(), digitalWrite(), and analogWrite() refer to the digital pin number
- analogRead() reads the voltage at the specified analog pin number

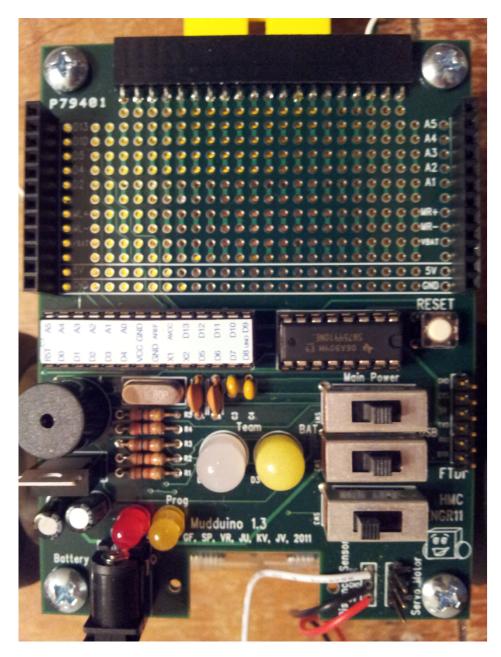


## Bill of Materials for Mudduino 1.3

Absolute     Description     Description     Description     Description       Maddum     1     Advanced Crunit     Fields 4     5.35     955       Diplo (Find) headed     1     Advanced Crunit     Fields 4     5.35     955       21 of protein     2     Diplow     Fields 4     5.35     955       23 of appetrix     2     Diplow     Fields 4     5.35     955       23 of appetrix     2     Diplow     Fields 4     5.33     955       31 of appetrix     2     Diplow     Fields 4     5.33     955       31 of appetrix     2     Diplow     Fields 4     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.33     955     5.35     5.33	Subsystem/Part	Quantity	Supplier	Part Number	Cost (bulk)	Total Cost	
Module1Monetal Cravit Board52.0352	Subsystem/Fait	Quantity	Supplier	Fart Number	COSt (Duik)	Total Cost	
12.pp. request header2Polo91009100910195029502.2 pr optordr2Digley424.PM50.01150.2150.212.3 pr optordr2Digley424.PM50.01650.010.4 spmth2Digley424.PM50.01650.010.4 spmth1Digley424.PM50.01750.0170.5 spm 10.01Digley75.111.14.9050.03750.0376 spm nach header1Digley55.111.14.9050.03750.0376 spm nach header1Digley54.011.00.9052.27751.015 spm nach header1Digley54.010.9052.27751.015 spm nach header1Digley54.01.00.9050.02750.025 spm nach header2DigleyC14170067-0050.00350.025 spm nach header1DigleyC14170067-0050.00350.025 spm nach header1DigleyC14170067-0050.00350.025 spm nach header1DigleyC14170067-0050.00350.025 spm nach header1DigleyC14170067-0050.00350.025 spm nach header1DigleyC14170067-0050.03750.035 spm nach header1DigleyC14170067-0050.0550.025 spm nach header1DigleyC14170067-0050.0550.025 spm nach header1DigleyC14170067-0050	Mudduino						
rest     Number     1     Digity     SMMD ND     S0.211							
22 pf capacitor     2     Digkery     14294HAD     50.111     50.21       3.01 of capacitor     2     Digkery     399-4268-400     50.117     50.21       6.111     Digkery     399-4268-400     50.117     50.21     50.21       6.111     Digkery     354.1114-40     50.217     50.22     50.20       6.111     Digkery     554.101.50-400     52.227     50.24       7.111     Digkery     554.101.50-400     52.227     50.24       8.111     Digkery     554.101     50.51-40     50.51-40     50.51-40     50.51-40     50.51-40     50.51-40     50.51-40     50.51-40     50.51-40     50.51-40     50.51-40     50.51-40     50.52     50.20     50							
10 if expectan     2     Digkery     P82-800     50.08     50.18       Ref Smm LD     1     Digkery     751.1141 ND     50.23     50.23       Ref Smm LD     1     Digkery     751.1141 ND     50.23     50.23       Spen mail Small     1     Digkery     751.1141 ND     50.23     50.23       Spen mail Small     1     Digkery     594.5440     50.23     50.53       Spen mail Small     1     Digkery     594.5440     50.23     50.53       Spen mail Small     1     Digkery     CF14/T100CT+M     50.23     50.50       Did Commendation     2     Digkery     CF14/T100CT+M     50.23     50.50       Did Commendation     1     Digkery     CF14/T100CT+M     50.23     50.50       Did Commendation     1     Digkery     CF14/T100CT+M     50.23     50.30       Did Commendation     1     Digkery     14.1110CT+M     50.23     50.33       Did Commendation     1     Digkery     14.110CT+M     50.23     50.50							
0.1 of engendrer     2     Digkey     399-066-ND     50.112 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td></t<>							
Ref Smn 10     Opjikry     75.11414.ND     50.37.3							
op in make header     1     Digikery     SMM1031-SOHD     52.272     50.28       Bigh make header (20 pol)     1     Digikery     SS66-840     51.276     51.28       San Franke header (20 pol)     1     Digikery     SS66-840     51.276     51.28       San Franke header (20 pol)     1     Digikery     CP12014     50.272     52.27       Data Mark (20 pol)     1     Digikery     CP14171596CF+80     60.022     50.02       Data Mark (20 pol)     1     Digikery     CP14171596CF+80     60.022     50.03       Data Mark (20 pol)     1     Digikery     A100216-80     50.03     50.03       Data Mark (20 pol)     1     Digikery     A100206-80     50.33     50.33       Data Mark (20 pol)     1     Digikery     CP1047400     50.46     50.05       Among 22 Add (portgrammed with (mol)     1     Superhead Mark (20 pol)     50.55     51.25       Mark (20 pol)     Superhead Mark (20 pol)     51.25     51.25     51.25     51.25       Mark (20 pol)     1     Superhead Mar	Red 5mm LED	1		751-1141-ND	\$0.373	\$0.37	
3 pin male hader     1     Digkey     5404(31-500)     52.272     52.276     52.278       3 pin framely handler hader     1     Digkey     356(4-80)     52.272     52.57     52.55     52.55     52.55     52.55     52.55     52.55     52.55     52.55     52.55     52.55     52.55     52.55     52.55     52.55     <							
Bight angele formule hander (20 poi)     512							
3 pin Fenden     1     Digkey     340514400     50.34     50.34       1280 H bridge     2     Digkey     CF1417100CT-N0     50.029     50.02       100 resistor     2     Digkey     CF1417100CT-N0     50.029     50.02       100 Ohm resistor     1     Digkey     CF1417100CT-N0     50.022     50.02       100 The resistor     1     Digkey     CF1417100CT-N0     50.022     50.03       100 Marce State (reprogrammed with the)     1     Digkey     CF1320A40     50.55       20mmer State (reprogrammed with the)     1     SuperforghteeLoom     R8.0711.03     51.29       100 Bigkey     CF1320A40     S1.29     S1.29     S1.29     S1.29       100 Bigkey     CF1420A40     S1.31     S1.31     S1.31     S1.							
1239 Hrvinge     1     Opjetery     497.2936-490     52.22     52.72       100 Christian     2     Digley     CF141T130CTA0     50.039     50.05       100 Christian     2     Digley     CF141T130CTA0     50.022     50.04       100 Christian     1     Digley     CF14T130CTA0     50.07     50.07       100 Christian     1     Digley     CF14D140     50.07     50.07       200 Christian     Startian     Digley     CF14D140     50.05     50.55       200 Christian     Startian     Startian     Startian     Startian     50.05     50.55       200 Christian     Startian     Startian     Startian     Startian     51.00     51.00     51.00     51.00     51.00     51.00     51.00 <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td></td<>							
Ibk resistor     2     Digkey     CF141T00RCTAD     50.027     50.02       D30 Dhn resistor     1     Digkey     CF141T08RCTAD     50.022     50.02       Bazzer     1     Digkey     CF141T08RCTAD     50.022     50.00       Bazzer     1     Digkey     CF141T08RCTAD     50.026     50.30       Bay DPI Hong at 28 socket     1     Digkey     AL00206 ND     50.26     50.30       Bay DPI Hong at 28 socket     1     Digkey     AL00206 ND     50.26     50.30       State Sta							
p200 0mr vestor     9     Opekvy     CF141700R74D     50.027     55.07       Bauzer     1     Opekvy     A100208-N00     50.268     55.03       Bap in DP httrings oxidet     1     Digkvy     A100208-N00     50.288     55.03       Stop in DP in three socies     1     Digkvy     A100208-N00     50.388     50.33       Stop in DP in three socies     1     Digkvy     CF1.32A-N00     50.375     50.38       Stop in three socies     1     Digkvy     CF1.32A-N00     50.568     50.568       Atting socies     1     Sparifultion     Digkvy     CF1.32A-N00     50.568     51.89       Stop in thr DD     1     Sparifultion     Digkvy     S1.138     51.89       Stop in thr DD     1     Sparifultion     Div Systap     S1.39							
Buzzer     1     Digkery     100-1153-100     50.77     55.77       Boyn DP Mindge socket     1     Digkery     A100210-ND     50.236     50.33       Boyn DP Mindge socket     1     Digkery     A100210-ND     50.236     50.33       Boyn DP Mindge socket     1     Digkery     G1.110-ND     50.348     50.47       Box Syst Side Segulator     1     Digkery     G1.110-ND     50.755     50.38       Sos syst Side switch     2     Digkery     G7.110-ND     50.755     50.38       Sos syst Side switch     1     Digkery     G7.110-ND     50.755     50.38       White Bonn LD     1     SuperforgiteScom     R.84 (10.36)     51.49     51.35       Sos Syst Side Side switch     1.0     Digkery     G7.110-ND     51.49     51.35     51.35       Sime GP2/MA2YMOF Anolgo Distance Sensor (20-50 cm)     1     Polok     117     53.89     50.89       Sim GP2/MA2YMOF Anolgo Distance Sensor (20-50 cm)     1     Polok     117     53.89     50.89      Sim GP2/MA2YMOF Anolgo Distance Senso	160 Ohm resistor	1			\$0.020	\$0.02	
22-pin DP Amega 228 socket     1     Digkey     AL0205 NUM     50.20     55.30       1     Digkey     AL0205 NUM     50.31     55.31       7805 Y Voltage Regulator     1     Digkey     651.116 NUM     50.33       7805 Y Voltage Regulator     1     Digkey     673.146 NUM     50.375     55.38       3005 spt1 side switch     3     Digkey     673.146 NUM     50.375     55.38       3005 spt1 side switch     1     Digkey     673.146 NUM     50.566     55.56       Attern processor     1     Sparkfun     DFV-052.14     54.90     54.95       Sensor TUT TO Cale     1     Sparkfun     DFV-072.18     51.135     51.25       Sensor GY20ANSCH And Distance Sensor (20-150 cm)     1     Poloi     133     51.25     91.25       Differ To Processor     1     Digkey     CP1.4172.00C TAM     50.08     50.08       Sony GY20ANOSCH And Distance Sensor (20-150 cm)     1     Poloi     131     51.35       Sony GY20ANOSCH And Distance Sensor (20-150 cm)     1     Poloi     11	p200 Ohm resistor	2	Digikey	CF14JT200RCT-ND			
16-bit DPH bridge socket     1     Digkey     AD302-bit     50.311     50.312     50.313     50.312     50.312     50.313     50.313     50.313     50.313     50.313     50.313     50.313     50.313     50.313     50.313     50.313     50.313     50.313     50.313     50.313     50.314     50.313     50.314							
7805 SV voltage Regulator     1     Digkey     LMRSAGCT-ND     50.468     59.47       3pos spit side switch     1     Digkey     673-1108-ND     50.375     50.38       3pos spit side switch     1     Digkey     CP-102A-ND     50.505     50.38       3pos spit side switch     1     Digkey     CP-102A-ND     50.505     50.55       Atmega 328 chig (preprogrammed with Uno)     1     Superfighthetics com     R8.87110-300     51.89     51.89       Green Rim LED     1     Superfighthetics com     R8.570-360     51.49     51.49       Sits to TTLFTID Cable     1     Digkey     751.102-ND     51.91     51.91       Sits to TTLFTID Cable     1     Pololu     1137     512.59     52.29       Sits TOTELTID Cable     1     Pololu     1137     512.59     50.30       Sits TOTELTID Cable     1     Digkey     CF1.102A-ND     51.91     51.91       QRD1114 Reflectance sensor     1     Digkey     CF1.102A-ND     50.08     50.08       Sit Sits TottETID     1							
16 MHz crystal     1     Digkey     631.108-ND     50.375     50.387       2.1mn power jack     1     Digkey     CP-1840-ND     50.750     52.25       2.1mn power jack     1     Digkey     CP-1840-ND     50.750     52.25       Minte Bam LED     1     3uperfrighteds.com     Rik 450-380     51.89     51.89       Green 8mn LED     1     superfrighteds.com     Rik 450-380     51.49     54.95       Sang GP270A02X0F Analog Distance Sensor (2D-150 cm)     1     Sparkfun     DEV.09718     51.25       Sang GP270A02X0F Analog Distance Sensor (2D-150 cm)     1     Digkey     CF111200-ND     51.91     51.91       Sang GP270A02X0F Analog Distance Sensor (2D-150 cm)     1     Digkey     CF111270-ND     50.88     50.88       Sang GP270A02X0F Analog Distance Sensor (2D-150 cm)     1     Digkey     CF111270-ND     50.88     50.88       Sang GP270A02X0F Analog Distance Sensor (2D-150 cm)     1     Digkey     CF111270-ND     50.88     50.88     50.88     50.88     50.88     50.88     50.88     50.88     50.88     50							
3 pos spat side switch     3 pike     0 pike     67 + 312A ND     50 / 750     52 / 75 / 75 / 75 / 75 / 75 / 75 / 75 /							
2.1mm power jack     1     Digkey     C = 102.4ND     50.560     50.560       Armega 232 (int) perpogrammed with Uno)     1     Sparkfun     DEV-1052.40     54.950							
Armega 328 chip (preprogrammed with Uno)     1     Sparkfurn     504-10524     \$4.495       White Simu LED     1     superfrightleds.com     RLW-VL10-60     \$1.49     \$1.49       Green Simu LED     1     superfrightleds.com     RLW-VL10-60     \$1.49     \$1.49       USB to TLI FTD ( Cable     1     Sparkfurn     DEV.09718     \$12.59     \$12.59       Sensor Sirvos     1     Pololu     1137     \$12.59     \$12.59       BWT7RA Fhortansistor     1     Digikey     751-1020-MD     \$51.31     \$13.13       ORD114 Areflectance sensor     1     Digikey     CF147300KCT-ND     \$50.08     \$50.08       20 ohn resistor     1     Digikey     CF147300KCT-ND     \$50.08     \$50.08       30 kOhn resistor     1     Digikey     CF14730KCT-ND     \$50.08     \$50.09       30 kOhn resistor     1     Digikey     CF14730KCT-ND     \$50.08     \$50.09       30 kOhn resistor     1     Digikey     CF14730KCT-ND     \$50.85     \$51.95       520 So Evo     1     NobulyFatt <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td></t<>							
White Brun LED     1     supertrighteds.com     Risk 9000     51.89     67.89       Creen Sam LED     1     Supertrighteds.com     Risk 50300     51.40     51.40     51.40     51.40     51.40     51.40     51.40     51.40     51.40     51.40     51.79     51.795     51.795     51.795     51.795     51.250     50.280     30.200     50.080     30.080     30.080     30.080     30.080     30.080     30.080     30.080     50.080     30.080     50.080     30.080     50.080	· · ·						
USB to TIL FIDI Cable     1     Sparkfun     DEV-09718     \$17.95     \$17.95       Sensor/Seroos     -							
sensor/Servos     Image: Control of the sensor (20-150 cm)     Stars of Control of the senson (20-150 cm)     Stars of Control of the	Green 8mm LED	1	superbrightleds.com	RL8-G50-360	\$1.49	\$1.49	
Sharg GP2Y0A0ZYK0F Analog Distance Sensor (20-150 cm)     1     Pololu     1137     S12.59     S12.59       GR01114 Reflectance sensor     1     Digikey     QR01114-ND     S1.31     S1.31       John ST HAFAge cable     1     Digikey     QR0114-ND     S0.88     S0.88       220 ohm resistor     1     Digikey     CF1417230KCT-ND     S0.08     S0.08       330 kOhm resistor     1     Digikey     CF1417330KCT-ND     S0.08     S0.08       330 kOhm resistor     1     Digikey     CF141710K0CT-ND     S0.028     S0.03       300 kOhm resistor     1     Digikey     CF141710K0CT-ND     S0.028     S0.03       300 kOhm resistor     1     Digikey     CF141710K0CT-ND     S0.028     S0.03       300 kOhm resistor     1     Digikey     CF141710K0CT-ND     S0.028     S0.03       S609 Servo     1     HobbyPartz     Servo TPro-S609     S2.77     S2.77       Drive Train     2     Pololu     1677     S7.85     S7.85     S7.85       Brushed DC Motor: 13-528, 04 <td< td=""><td>USB to TTL FTDI Cable</td><td>1</td><td>Sparkfun</td><td>DEV-09718</td><td>\$17.95</td><td>\$17.95</td></td<>	USB to TTL FTDI Cable	1	Sparkfun	DEV-09718	\$17.95	\$17.95	
Sharg GP2Y0A0ZYK0F Analog Distance Sensor (20-150 cm)     1     Pololu     1137     S12.59     S12.59       GR01114 Reflectance sensor     1     Digikey     QR01114-ND     S1.31     S1.31       John ST HAFAge cable     1     Digikey     QR0114-ND     S0.88     S0.88       220 ohm resistor     1     Digikey     CF1417230KCT-ND     S0.08     S0.08       330 kOhm resistor     1     Digikey     CF1417330KCT-ND     S0.08     S0.08       330 kOhm resistor     1     Digikey     CF141710K0CT-ND     S0.028     S0.03       300 kOhm resistor     1     Digikey     CF141710K0CT-ND     S0.028     S0.03       300 kOhm resistor     1     Digikey     CF141710K0CT-ND     S0.028     S0.03       300 kOhm resistor     1     Digikey     CF141710K0CT-ND     S0.028     S0.03       S609 Servo     1     HobbyPartz     Servo TPro-S609     S2.77     S2.77       Drive Train     2     Pololu     1677     S7.85     S7.85     S7.85       Brushed DC Motor: 13-528, 04 <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td></td<>							
BPW77NA Phototranstor     1     Digkey     751-1020-ND     51.91     51.91     51.91       3-pin JST PH-style cable     1     Pololu     117     \$0.88     \$0.88       20 Ohn resistor     1     Digkey     CF14/T220RCT-ND     \$0.08     \$0.08       20 Ohn resistor     1     Digkey     CF14/T330KCT-ND     \$0.08     \$0.08       210 Kohn resistor     1     Digkey     CF14/T330KCT-ND     \$0.08     \$0.08       20 Ohn resistor     1     Digkey     CF14/T330KCT-ND     \$0.09     \$0.09       20 Ohn resistor     1     Digkey     CF14/T380KCT-ND     \$0.09     \$0.09       0 mron Snap Action Switch     1     SparkFun     COM-00098     \$1.95     \$1.95       0 mron Snap Action Switch     1     HobyPartz     Servo     Servo     Serve     Serve<			Delelu	4407	612.50	ć12.50	
0R01114 Reflectance sensor     1     Digkey     0R0114-ND     \$1.31     \$1.31       9.jh JS PHAytle cable     1     Digkey     CF14IT220RCT-ND     \$0.08     \$0.08       220 ohm resistor     1     Digkey     CF14IT320RCT-ND     \$0.08     \$0.08       330 KDhm resistor     1     Digkey     CF14IT30XCT-ND     \$0.08     \$0.08       330 KDhm resistor     1     Digkey     CF14IT30XCT-ND     \$0.09     \$0.03       4-pin male header     1     Digkey     CF14IT30XCT-ND     \$0.09     \$0.30       5690 Servo     1     HobbyPartz     Servo_TPro-S690     \$2.77     \$2.77       Drive Train     1     Pololu     1677     \$7.78\$     \$5.78       Brushed DC Motor: 130-Size, 6V, 11.SkRPM, 800mA Stall     2     Pololu     1117     \$1.31     \$2.62       Tamiya 89918 Double Gearbox KIt - Clear     1     Pololu     163     \$6.75     \$6.75       Dolou Ball Caster, With 3/8' Metal Bal     1     Pololu     151.31     \$2.89     \$3.39       Tamiya Battery with 3/8' Metal Bal     1 <td></td> <td></td> <td></td> <td>-</td> <td></td> <td></td>				-			
3:pin 3T PH style cable     1     Pololu     117     \$0.89     \$0.89       320 ohm resistor     1     Digikey     CF1417230KT-ND     \$0.08     \$50.08       330 kOhm resistor     1     Digikey     CF141730KT-ND     \$0.023     \$0.03       4pin male header     1     Digikey     SM10315.0-ND     0.19     0.19       Omron Snap Action Switch     1     SparkFun     COM-00088     \$1.95     \$1.15       S690 Servo     1     HobyPartz     Servo TPro-S690     \$2.77     \$2.77       Drive Train     1     Pololu     1177     \$7.85     \$7.85       Brushed D Knotr: 130-Size, (X) LSARPM, 800m Stall     2     Pololu     113     \$2.62       Tamisa 3918 Double Gearbox Kit - Clear     1     Pololu     117     \$1.31     \$2.62       Tamisa 2014 DC Motor: 130-Size, (X) LSARPM, 800m Stall     2     Pololu     113     \$2.62       Towas and Utilities     1     Pololu     351     \$3.38     \$3.38       Mice cuter/striper, 10-30 AWG     1     Jameco     78992     \$3.49							
220 ohm resistor   1   Digikey   CF14JT220RCT-ND   \$0.08   \$50.08     330 kOhm resistor   1   Digikey   CF14JT330KCT-ND   \$0.029   \$0.03     330 kOhm resistor   1   Digikey   CF14JT330KCT-ND   \$0.029   \$0.03     4-pin male header   1   Digikey   CF14JT30KCT-ND   \$0.029   \$0.03     5590 Servo   1   Sparkfun   COM-0098   \$1.95   \$1.55     5590 Servo   1   HobbyPartz   Servo_TPro-\$690   \$2.77   \$2.77     Drive Train							
10 kOhm resistor     1     Digikey     CF14HTURKCT-ND     \$0.029     \$0.03       4-pin male header     1     Digikey     SAM1031-50-ND     0.19     1.19     1.19     1.19     1.19     1.19     1.19     1.19     1.19     1.19     1.19     1.19     1.19     1.19 <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td></td<>							
4-pin male header     1     Digkey     SAM1031-50-MD     0.19     0.19       Omron Snap Action Switch     1     SparkFun     COM-00098     \$1.95     \$51.95       Soglo Servo     1     HobpYpartz     Servo_TPro-SG90     \$2.77     \$2.77       Drive Train     1     Pololu     1677     \$7.85     \$7.85       Brushed DC Motor: 130-Size, Of, J1.SkRPM, 800mA Stall     2     Pololu     117     \$1.31     \$2.62       Tamiya 20145 Narrow Tire Set (2 tires)     1     Pololu     63     \$6.75     \$6.75       Pololu     Ball Caster with 3/8" Metal Ball     1     Pololu     951     \$2.38     \$2.39       Ordo-point Dreadboard     1     Janeco     179902     \$3.38     \$3.38       Diagonal cutter     1     Janeco     16838     \$1.49     \$3.49       Vire cuter/striper, 10-30 AWG     1     Janeco     16838     \$1.49     \$1.49       Vire 22AWG solid wire (100ft spool)     1     Janeco     36881     \$5.59     \$5.59       Colobox     1     BatterySpa	330 kOhm resistor	1		CF14JT330KCT-ND	\$0.08	\$0.08	
Ommon Snap Action Switch     1     SparkFun     COM-00088     \$1.95     \$1.95     \$5.95       SG90 Servo     1     HobyPartz     Servo_TPro-SG90     \$2.77     \$2.77       Drive Train	10 kOhm resistor	1	Digikey	CF14JT10K0CT-ND	\$0.029	\$0.03	
SG90 Servo     1     HobbyPartz     Servo_TPro-SG90     \$2.77     \$2.77       Drive Train     1     HobbyPartz     Servo_TPro-SG90     \$2.77     \$2.77       Drive Train     1     Pololu     1677     \$7.85     \$7.85       Brushed DC Motor: 130-Size, 0Y, 11.5kRPM, 800mA Stall     2     Pololu     1177     \$1.31     \$2.62       Tamiya 20145 Narrow Tire Set (2 tires)     1     Pololu     63     \$6.75     \$6.75       Pololu     Ball Caster with 3/8" Metal Ball     1     Pololu     951     \$2.39     \$2.39       Tools and Utilities     -     -     -     -     -     -       400-point breadboard     1     Jameco     179902     \$3.39     \$3.39       Wire cutter/stripper, 10-30 AWG     1     Jameco     16838     \$1.49       Precision screwdriver set     1     Jameco     26094     \$2.95     \$2.95       Toolson     1     Jameco     36881     \$5.59     \$5.59       Power System     -     -     -     -							
Drive Train     Pololu     1677     57.85     57.85       Brushed DC Motor: 130-Size, 6V, 11.5KPM, 800mA Stall     2     Pololu     1117     51.31     52.62       Brushed DC Motor: 130-Size, 6V, 11.5KPM, 800mA Stall     2     Pololu     1117     51.31     52.62       Tamiya 20145 Narrow Tire Set (2 tires)     1     Pololu     951     52.39     52.39       Tools and Utilities     1     Pololu     351     53.38     53.38       Diagonal cutter     1     Jameco     179902     53.59     53.59       Vire cutter/stripper, 10-30 AWG     1     Jameco     16838     51.49     53.49       Chip puller (yellow)     1     Jameco     16838     51.49     55.59       Toolbox     1     Jameco     26094     52.95     55.59       Nire 22KWG solid wire (100ft spool)     1     Jameco     36881     55.59     55.59       NiMH 7.2 V Battery     1     BatterySpace.com     RC-HAA6R1WR22     \$15.95     \$15.95       Tamiya Batter (Charger     1     BatterySpace.com <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td></t<>							
Tamiya 89918 Double Gearbox Kit - Clear   1   Pololu   1677   \$7.85   \$7.85     Brushed DC Motor: 130-Size, 6V, 11.5KRPM, 800mA Stall   2   Pololu   63   \$6.75     Tamiya 70145 Narrow Tirse Set (2 tires)   1   Pololu   63   \$6.75     Pololu Ball Caster with 3/8" Metal Ball   1   Pololu   951   \$2.39     Tools and Utilities   1   Pololu   351   \$3.38     Diagonal cutter   1   Jameco   179902   \$3.59   \$3.49     Chip puller (yellow)   1   Jameco   16838   \$1.49   \$1.49     Precision screwdriver set   1   Jameco   16838   \$1.49   \$2.495     Toolbox   1   Stockroom   1   Stockroom   1   \$1.49     Wire 22AWG solid wire (100ft spool)   1   Jameco   36881   \$5.59   \$5.59     Toolbox   1   BatterySpace.com   RC-HAA6R1WR22   \$15.95   \$5.19.95     Tamiya 814ery Charger   1   BatterySpace.com   CH-UN123   \$18.85   \$18.85     2.1 mp power cable   1   BatterySpace.com   CH-UN	SG90 Servo	1	HobbyPartz	Servo_IPro-SG90	\$2.77	\$2.77	
Tamiya 89918 Double Gearbox Kit - Clear   1   Pololu   1677   \$7.85   \$7.85     Brushed DC Motor: 130-Size, 6V, 11.5KRPM, 800mA Stall   2   Pololu   63   \$6.75     Tamiya 70145 Narrow Tirse Set (2 tires)   1   Pololu   63   \$6.75     Pololu Ball Caster with 3/8" Metal Ball   1   Pololu   951   \$2.39     Tools and Utilities   1   Pololu   351   \$3.38     Diagonal cutter   1   Jameco   179902   \$3.59   \$3.49     Chip puller (yellow)   1   Jameco   16838   \$1.49   \$1.49     Precision screwdriver set   1   Jameco   16838   \$1.49   \$2.495     Toolbox   1   Stockroom   1   Stockroom   1   \$1.49     Wire 22AWG solid wire (100ft spool)   1   Jameco   36881   \$5.59   \$5.59     Toolbox   1   BatterySpace.com   RC-HAA6R1WR22   \$15.95   \$5.19.95     Tamiya 814ery Charger   1   BatterySpace.com   CH-UN123   \$18.85   \$18.85     2.1 mp power cable   1   BatterySpace.com   CH-UN	Drive Train						
Brushed DC Motor: 130-Size, 6V, 11.5kRPM, 800mA Stall   2   Pololu   1117   \$1.31   \$2.62     Tamiya 70145 Narrow Tire Set (2 tires)   1   Pololu   63   \$6.75   \$6.75     Pololu Bil Caster with 3/8" Metal Ball   1   Pololu   951   \$2.39   \$2.39     Tools and Utilities   -   -   -   -   -   -     400-point breadboard   1   Pololu   351   \$3.38   \$3.38     Diagonal cutter   1   Jameco   179902   \$3.59   \$3.59     Wire cutter/stripper, 10-30 AWG   1   Jameco   16838   \$1.49   \$1.49     Precision screwdriver set   1   Jameco   16838   \$1.49   \$1.49     Toolbox   1   Jameco   36881   \$5.59   \$5.59     Power System   1   Jameco   36881   \$5.59   \$5.19.55     2.1 mm power cable   1   Digkey   CP-2213-ND   \$3.33   \$3.33     2.1 mm power cable   1   Digkey   CP-2213-ND   \$3.33   \$3.33     2.1 mm power cable   1   Mcmaster		1	Pololu	1677	\$7.85	\$7.85	
Pololu Ball Caster with 3/8" Metal Ball     1     Pololu     951     \$2.39     \$2.39       Tools and Utilities							
Tools and Utilities     Image: Constraint of the	Tamiya 70145 Narrow Tire Set (2 tires)	1	Pololu	63	\$6.75	\$6.75	
400-point breadboard   1   Pololu   351   \$3.38   \$3.38     Diagonal cutter   1   Jameco   179902   \$3.59   \$3.59     Wire cutter/stripper, 10-30 AWG   1   Jameco   78992   \$3.49   \$3.49     Chip puller (yellow)   1   Jameco   16838   \$1.49   \$1.49     Precision screwdriver set   1   Jameco   226094   \$2.95   \$2.95     Toolbox   1   Stockroom	Pololu Ball Caster with 3/8" Metal Ball	1	Pololu	951	\$2.39	\$2.39	
400-point breadboard   1   Pololu   351   \$3.38   \$3.38     Diagonal cutter   1   Jameco   179902   \$3.59   \$3.59     Wire cutter/stripper, 10-30 AWG   1   Jameco   78992   \$3.49   \$3.49     Chip puller (yellow)   1   Jameco   16838   \$1.49   \$1.49     Precision screwdriver set   1   Jameco   226094   \$2.95   \$2.95     Toolbox   1   Stockroom							
Diagonal cutter     1     Jameco     179902     \$3.59     \$3.59       Wire cutter/stripper, 10-30 AWG     1     Jameco     78992     \$3.49     \$\$3.49       Chip puller (yellow)     1     Jameco     16838     \$1.49     \$\$2.49       Precision screwdriver set     1     Jameco     226094     \$\$2.55     \$\$2.95       Toolbox     1     Jameco     36881     \$\$5.59     \$\$5.59       Wire 22AWG solid wire (100ft spool)     1     Jameco     36881     \$\$5.59     \$\$5.59       Power System     1     BatterySpace.com     RC-HAA6R1WR22     \$\$15.95     \$\$15.95       1 miya Battery Charger     1     BatterySpace.com     CH-UN122     \$\$15.95     \$\$13.33       2.1 mm power cable     1     Digikey     CP-2213-ND     \$\$3.33     \$\$3.33       Chassis     1     HMC     N/A     \$\$20.00     \$\$20.00       Aluminum Female Threaded Hex Standoff, 1/4" Hex, 1-1/2" Length, 8-32 Screw Size     4     Mcmaster     9008K23     \$15.08     \$0.30       21no-pitd Stl Pan Head Phillips Machine Screw, 8-32					40.00	40.00	
Wire cutter/stripper, 10-30 AWG     1     Jameco     78992     \$3.49     \$3.49       Chip puller (yellow)     1     Jameco     16838     \$1.49     \$1.49       Precision screwdriver set     1     Jameco     226094     \$2.95     \$2.95       Toolbox     1     Stockroom							
Chip puller (yellow)     1     Jameco     16838     \$1.49     \$1.49       Precision screwdriver set     1     Jameco     226094     \$2.95     \$2.95       Toolbox     1     Stockroom     -     -     -       Wire 22AWG solid wire (100ft spool)     1     Jameco     36881     \$5.59     \$5.59       NiWh 7.2 V Battery     1     BatterySpace.com     RC-HAA6R1WR22     \$15.95     \$15.95       2.1 mm power cable     1     BatterySpace.com     CH-UN123     \$18.95     \$18.95       2.1 mm power cable     1     Digikey     CP-2213·ND     \$3.33     \$3.33       Chassis     1     HMC     N/A     \$20.00     \$20.00       Aluminum Female Threaded Hex Standoff, 1/4" Hex, 1-1/2" Length, 8-32 Screw Size     4     Mcmaster     91780A202     \$0.71     \$2.84       Multipurpose Aluminum (alloy 6061), 1/2" Square, 6' Length     1     Mcmaster     9008K23     \$15.08     \$0.30       Zinc-ptld Stl Pan Head Philips Machine Screw, 8-32 Thread, 1/2" Length     9     Mcmaster     90272A194     \$2.85     \$0.26							
Precision screwdriver set     1     Jameco     226094     \$2.95     \$2.95       Toolbox     1     Stockroom							
Toolbox     1     Stockroom     1     Stockroom       Wire 22AWG solid wire (100ft spool)     1     Jameco     36881     \$5.59     \$5.59       Power System     1     BatterySpace.com     RC-HAAGR1WR22     \$15.95     \$15.95       Tamiya Battery Charger     1     BatterySpace.com     CH-UN123     \$18.95     \$18.95       2.1 mm power cable     1     Digikey     CP-2213-ND     \$3.33     \$3.33       Chassis     1     HMC     N/A     \$20.00     \$20.00       Aluminum Female Threaded Hex Standoff, 1/4" Hex, 1-1/2" Length, 8-32 Screw Size     4     Mcmaster     91780A202     \$0.71     \$2.84       Multipurpose Aluminum (alloy 6061), 1/2" Square, 6' Length     1     Mcmaster     9008K23     \$15.08     \$0.30       Zinc-pitd Stl Pan Head Phillips Machine Screw, 8-32 Thread, 1/2" Length     9     Mcmaster     90272A194     \$2.85     \$0.47       2-56 x %" Phillips pan head machine screw     2     Mcmaster     90272A107     2.28/100     0.05       2-56 nut     4     Mcmaster     91841A003     2.77/100     0.11 </td <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>							
Wire 22AWG solid wire (100ft spool)   1   Jameco   36881   \$5.59   \$5.59     Power System   1   BatterySpace.com   RC-HAAGR1WR22   \$15.95   \$15.95     Tamiya Battery Charger   1   BatterySpace.com   CH-UN123   \$18.95   \$18.95     2.1 mm power cable   1   Digikey   CP-2213-ND   \$3.33   \$3.33     Chassis   1   HMC   N/A   \$20.00   \$20.00     Aluminum Female Threaded Hex Standoff, 1/4" Hex, 1-1/2" Length, 8-32 Screw Size   4   Mcmaster   91780A202   \$0.71   \$2.84     Multipurpose Aluminum (alloy 6061), 1/2" Square, 6' Length   1   Mcmaster   9008K23   \$15.08   \$0.30     Zinc-pitd Stil Pan Head Phillips Machine Screw, 8-32 Thread, 1/2" Length   9   Mcmaster   900272A194   \$2.85   \$0.47     2-56 x %" Phillips pan head machine screw   2   Mcmaster   90272A106   1.30/100   0.03     2-56 nut   4   Mcmaster   91841A003   2.77/100   0.11     4-40 nut   2   Mcmaster   91841A003   2.77/100   0.11     4-40 nut   2   Mcmaster   918					7-100	,	
NiMH 7.2 V Battery     1     BatterySpace.com     RC-HAA6R1WR22     \$15.95     \$15.95       Tamiya Battery Charger     1     BatterySpace.com     CH-UN123     \$18.95     \$18.95       2.1 mm power cable     1     Digikey     CP-2213-ND     \$3.33     \$3.33       Chassis     1     Digikey     CP-2213-ND     \$3.33     \$3.33       3D printed chassis     1     HMC     N/A     \$20.00     \$20.00       Aluminum Female Threaded Hex Standoff, 1/4" Hex, 1-1/2" Length, 8-32 Screw Size     4     Mcmaster     91780A202     \$0.71     \$2.84       Multipurpose Aluminum (alloy 6061), 1/2" Square, 6' Length     1     Mcmaster     9008K23     \$15.08     \$0.30       Zinc-pltd StI Pan Head Phillips Machine Screw, 8-32 Thread, 1/2" Length     9     Mcmaster     90072A017     \$2.84       Multipurpose Aluminum (Alloy 6061).063" Thick, 12" X 12"     1     Mcmaster     90272A077     \$2.85     \$0.62       So.47     5.56 x ¼" Phillips pan head machine screw     2     Mcmaster     90272A077     \$2.8100     0.05       4-40 x ¼" Phillips pan head machine screw     2	Wire 22AWG solid wire (100ft spool)	1		36881	\$5.59	\$5.59	
NiMH 7.2 V Battery     1     BatterySpace.com     RC-HAA6R1WR22     \$15.95     \$15.95       Tamiya Battery Charger     1     BatterySpace.com     CH-UN123     \$18.95     \$18.95       2.1 mm power cable     1     Digikey     CP-2213-ND     \$3.33     \$3.33       Chassis     1     Digikey     CP-2213-ND     \$3.33     \$3.33       3D printed chassis     1     HMC     N/A     \$20.00     \$20.00       Aluminum Female Threaded Hex Standoff, 1/4" Hex, 1-1/2" Length, 8-32 Screw Size     4     Mcmaster     91780A202     \$0.71     \$2.84       Multipurpose Aluminum (alloy 6061), 1/2" Square, 6' Length     1     Mcmaster     9008K23     \$15.08     \$0.30       Zinc-pltd StI Pan Head Phillips Machine Screw, 8-32 Thread, 1/2" Length     9     Mcmaster     90072A017     \$2.84       Multipurpose Aluminum (Alloy 6061).063" Thick, 12" X 12"     1     Mcmaster     90272A077     \$2.85     \$0.62       So.47     5.56 x ¼" Phillips pan head machine screw     2     Mcmaster     90272A077     \$2.8100     0.05       4-40 x ¼" Phillips pan head machine screw     2							
Tamiya Battery Charger   1   BatterySpace.com   CH-UN123   \$18.95   \$18.95     2.1 mm power cable   1   Digikey   CP-2213-ND   \$3.33   \$3.33     Chassis   1   Digikey   CP-2213-ND   \$3.33   \$3.33     Chassis   1   HMC   N/A   \$20.00   \$20.00     Aluminum Female Threaded Hex Standoff, 1/4" Hex, 1-1/2" Length, 8-32 Screw Size   4   Mcmaster   91780A202   \$0.71   \$2.84     Multipurpose Aluminum (alloy 6061), 1/2" Square, 6' Length   1   Mcmaster   9008K23   \$15.08   \$0.30     Zinc-pitd Stl Pan Head Phillips Machine Screw, 8-32 Thread, 1/2" Length   9   Mcmaster   90272A194   \$2.85   \$0.42     Wultipurpose Aluminum (Alloy 6061).063" Thick, 12" X 12"   1   Mcmaster   89015K37   \$15.77   \$0.47     2-56 x ¼" Phillips pan head machine screw   2   Mcmaster   90272A077   2.28/100   0.05     4-40 x ¼" Phillips pan head machine screw   2   Mcmaster   91841A003   2.77/100   0.11     4-40 nut   2   Mcmaster   91841A003   2.77/100   0.11     4-40 nut   2 <td></td> <td></td> <td></td> <td></td> <td>A</td> <td>Ar</td>					A	Ar	
2.1 mm power cable     1     Digikey     CP-2213-ND     \$3.33     \$3.33       Chassis     Image: Chassis <th i<="" td=""><td></td><td></td><td></td><td></td><td></td><td></td></th>	<td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
Chassis     Image: Chassis							
3D printed chassis     1     HMC     N/A     \$20.00     \$20.00       Aluminum Female Threaded Hex Standoff, 1/4" Hex, 1-1/2" Length, 8-32 Screw Size     4     Mcmaster     91780A202     \$0.71     \$2.84       Multipurpose Aluminum (alloy 6061), 1/2" Square, 6' Length     1     Mcmaster     9008K23     \$15.08     \$0.30       Zinc-pltd Stl Pan Head Phillips Machine Screw, 8-32 Thread, 1/2" Length     9     Mcmaster     90072A194     \$2.85     \$0.26       Multipurpose Aluminum (Alloy 6061).063" Thick, 12" X 12"     1     Mcmaster     89015K37     \$15.77     \$0.47       2-56 x ¼" Phillips pan head machine screw     2     Mcmaster     90272A077     2.28/100     0.05       4-40 x ¼" Phillips pan head machine screw     2     Mcmaster     90272A106     1.30/100     0.03       2-56 nut     4     Mcmaster     91841A003     2.77/100     0.11       4-40 nut     2     Mcmaster     91841A005     2.75/100     0.05       2-56 x 1/4" pan-head straight slot black nylon machine screw     2     Mcmaster     91841A005     2.75/100     0.05       2-56 x 1/4" pan-head straight slo		-	- Signey	51 2213 ND	دد.دې	رو.رې	
Aluminum Female Threaded Hex Standoff, 1/4" Hex, 1-1/2" Length, 8-32 Screw Size     4     Mcmaster     91780A202     \$0.71     \$2.84       Multipurpose Aluminum (alloy 6061), 1/2" Square, 6' Length     1     Mcmaster     9008K23     \$15.08     \$0.30       Zinc-pitd Stl Pan Head Philips Machine Screw, 8-32 Thread, 1/2" Length     9     Mcmaster     90272A194     \$2.85     \$0.26       Multipurpose Aluminum (Alloy 6061).063" Thick, 12" X 12"     1     Mcmaster     89015K37     \$15.77     \$0.47       2-56 x X" Phillips pan head machine screw     2     Mcmaster     90272A106     1.30/100     0.03       2-56 nut     4     Mcmaster     91841A003     2.77/100     0.11       4-40 nut     2     Mcmaster     91841A005     2.75/100     0.05       2-56 x 1/4" pan-head straight slot black nylon machine screw     2     Mcmaster     91841A005     2.77/100     0.11	Chassis						
Multipurpose Aluminum (alloy 6061), 1/2" Square, 6' Length     1     Mcmaster     9008K23     \$15.08     \$0.30       Zinc-pltd Stl Pan Head Phillips Machine Screw, 8-32 Thread, 1/2" Length     9     Mcmaster     90272A194     \$2.85     \$0.47       Multipurpose Aluminum (Alloy 6061).063" Thick, 12" X 12"     1     Mcmaster     89015K37     \$15.77     \$0.47       2-56 x ¼" Phillips pan head machine screw     2     Mcmaster     90272A106     1.30/100     0.03       2-56 nut     4     Mcmaster     91841A003     2.77/100     0.11       4-40 nut     2     Mcmaster     91841A005     2.75/100     0.05       2-56 x 1/4" pan-head straight slot black nylon machine screw     2     Mcmaster     91841A005     2.75/100     0.05							
Zinc-pitd Sti Pan Head Phillips Machine Screw, 8-32 Thread, 1/2" Length     9     Mcmaster     90272A194     \$2.85     \$0.26       Multipurpose Aluminum (Alloy 6061).063" Thick, 12" X 12"     1     Mcmaster     89015K37     \$15.77     \$0.47       2-56 x X" Phillips pan head machine screw     2     Mcmaster     90272A077     2.28/100     0.05       4-40 x X" Phillips pan head machine screw     2     Mcmaster     90272A106     1.30/100     0.03       2-56 nut     4     Mcmaster     91841A003     2.77/100     0.11       4-40 nut     2     Mcmaster     91841A005     2.75/100     0.05       2-56 x 1/4" pan-head straight slot black nylon machine screw     2     Mcmaster     91841A005     2.75/100     0.05							
Multipurpose Aluminum (Alloy 6061) .063" Thick, 12" X 12"     1     Mcmaster     89015K37     \$15.77     \$0.47       2-56 x %" Phillips pan head machine screw     2     Mcmaster     90272A077     2.28/100     0.05       4-40 x %" Phillips pan head machine screw     2     Mcmaster     90272A106     1.30/100     0.03       2-56 nut     4     Mcmaster     91841A003     2.77/100     0.11       4-40 nut     2     Mcmaster     91841A005     2.75/100     0.05       2-56 x 1/4" pan-head straight slot black nylon machine screw     2     Mcmaster     91841A005     2.75/100     0.05							
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2-56 nut     4     Mcmaster     91841A003     2.77/100     0.11       4-40 nut     2     Mcmaster     91841A005     2.75/100     0.05       2-56 x 1/4" pan-head straight slot black nylon machine screw     2     Mcmaster     94735A177     4.96     0.10							
4-40 nut     2     Mcmaster     91841A005     2.75/100     0.05       2-56 x 1/4" pan-head straight slot black nylon machine screw     2     Mcmaster     94735A177     4.96     0.10							
2-56 x 1/4" pan-head straight slot black nylon machine screw 2 Mcmaster 94735A177 4.96 0.10							
<b>Total Cost =</b> \$162.22	- /						
					Total Cost =	\$162.22	



Mudduino Layout (component side wires red, solder side wires blue, silk screen gray)



Photograph of Assembled Mudduino Board

## **Component Dictionary**

This dictionary will help you identify the components that you will be using.

## Resistors

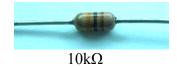
Resistors are identified with four colored bands. The first three indicate the value, in ohms ( $\Omega$ ). The fourth indicates the tolerance; it is typically gold, indicating +/- 5%.

The values are determined using the following color codes:

- 0 Black
- 1 Brown
- 2 Red
- 3 Orange
- 4 Yellow
- 5 Green
- 6 Blue
- 7 Violet
- 8 Grey
- 9 White

This can be remembered using the mnemonic "Bad beer rots our young guts but vodka goes well".

The first two bands are read as a two digit number, and the third is a power of ten multiplying the number. For example, red – black – brown – gold indicates 201, meaning 20 x  $10^1 = 200 \Omega$ , with a 5% tolerance. Brown – black – orange – gold indicates 103, meaning 10 x  $10^3 = 10,000 \Omega$  (written 10 k  $\Omega$ ).



## Capacitors

Capacitors are notoriously difficult to read. Usually large-valued electrolytic capacitors have their value written on the side. For example, a 10-microfarad ( $10^{-5}$  F) capacitor is labeled 10 µF. Small capacitors are sometimes labeled with a 3-digit code indicating their value in picofarads ( $10^{-12}$  F) in a fashion similar to resistors. For example, 104 means 10 x  $10^4$  pF =  $10^{-7}$  F = 0.1 µF. A 2-digit code just indicates the value in picofarads. For example, 22 means 22 pF.



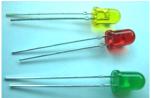
Ceramic - 22pF





## LEDs

Light-emitting diodes have two terminals. They long terminal is the *positive* side, called the *anode*. The short terminal, usually marked with a flat edge on the lens, is the *negative* side, called the *cathode*. It is important to solder LEDs in the correct orientation otherwise they will not work.







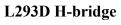




Slide Switch

2.1mm Power Jack

Atmega 328











## Assembling the Board

This section guides you through soldering your Mudduino board. The steps work from the thinnest components upward to make assembly easier. When you are all done, your board should look like the one on page 6.

## Identify the component side of your board

Your Mudduino board has two sides: the component side and the solder side. Through-hole components are placed on the component side with their legs extending through the holes to be soldered on the solder side. If you do not place all of your components on the component side, you will make your future self very unhappy. All the soldering should be done on the solder side of the board. The component side is the one with the text and component shape outlines. The solder side has additional traces but no component outlines.

## Make your board unique!

In order to keep your board from getting mixed up with other students' boards, write your name on the solder side. Sharpie will be the best for this.

## How to solder

Before you begin soldering, moisten the sponge. When the iron first heats up, tin the tip by applying a generous amount of solder all over the tip, then wiping off the excess on the sponge. Periodically re-tin the soldering iron as you work to keep the tip looking silvery rather than black and blistered. This preserves the life of the tip and allows for better heat conduction during soldering.

Place only a couple components in the board at a time. Bend the legs so that the component stays in place without having to be held; they should make a good mechanical connection without the solder. The solder serves to make a good electrical connection, but should not be necessary to hold the component. Some parts have polarity, meaning that they only work in one direction. Be sure to put them in the right direction or you'll have to cut them out and redo them later.

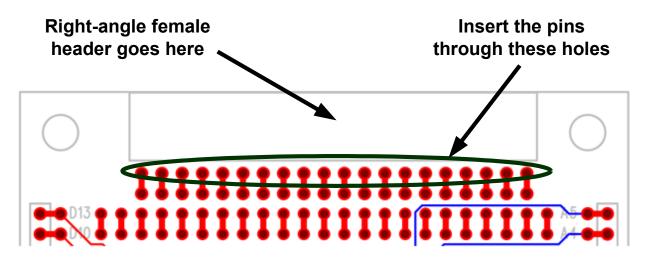
When you make a solder joint, touch the tip of the iron to the pad on the board at the same place it touches the lead of the component. Apply the solder to the junction of the lead and board that has been heated by the iron, not the iron itself. The solder should smoothly adhere to the pad and the component pin rather than balling up on the component or the iron. The connection should appear shiny; a gray color indicates a possible unreliable "cold solder" joint. A "cold solder" joint does not provide a good electrical connection.

When you have completed a set of joints, chop the leads off on the solder side with diagonal cutters. Hold the lead as you cut it so that the lead doesn't go flying into your lab-mate's eye.

If you are in doubt about the quality of your solder joints, ask early on rather than doing all of them first and discovering that your connections are intermittent or unreliable. Some of the components will be soldered close to vias (the small holes through the board used to connect between wiring layers on the printed circuit board). Be sure excess solder does not bridge to the via, creating a short circuit. When you are done, tin the iron one last time to protect the tip before turning it off.

## Place right-angle female headers

There is a long set of female headers that sit at a right angle to the leads. These are one of the shortest components in terms of height off of the board. They also have several joints perfect for warming up your soldering skills. These headers will serve to be the connection point for the off-board sensors: IR reflectance sensor and phototransistor. Place the part at the top of the board as shown below



You want the black plastic to be on the component side of the board. Turn the board upside down so you can access the leads on the solder side of the board. The weight of the board should help keep the pins in place while you are soldering.

## **Place the Resistors**

There are five resistors to place on the circuit board that limit current on the LEDs and set defaults on switches. Resistors also do not have polarity. Gently insert a resistor into the slot, turn the board over and bend the leads outward to hold the resistor in place; then, solder. Be sure to pull the leads all the way through the board so the resistor lies flat against the board. Note, the labeling on the board goes down, R5 to R1.

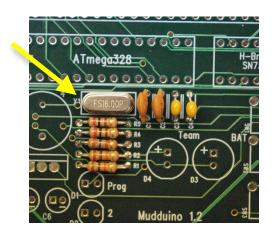


R1 and R2 are 10 kΩ resistors (Brown Black Orange) R3 is a 160 Ω resistor (Brown Blue Brown) R4 and R5 are 200 Ω resistors (Red Black Brown)

The characters R1, R2, etc., have been printed on the PCB to indicate the placement of the resistors.

## Place the clock crystal

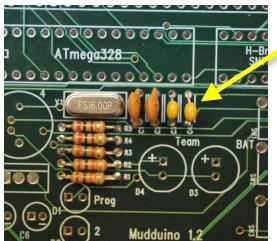
X1 is the 16 MHz quartz crystal. This is the means by which the Mudduino keeps time. It has no polarity, which means you can solder it in either way. Solder the clock crystal as done for the resistors.



## **Place ceramic capacitors**

The next step is to insert the four small ceramic disc capacitors. These are not polarized and can be inserted in either direction. Solder these on in the same way the resistors were. The two 0.1

 $\mu$ F capacitors are bypass capacitors that stabilize the power supply on the board. The 22 pF capacitors are used to store energy in conjunction with the clock crystal.



Bend the leads and insert in the diagram positions as shown below. We advise that you solder each component one by one. Be sure to pull the leads all the way through the board so the capacitors are as close to the board as possible.

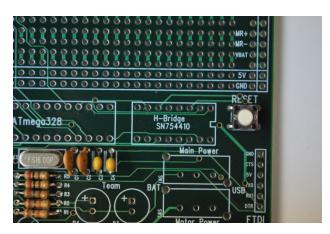
Clip the leads off when you are finished. Cut as much off as possible, as the board will need to lie flat in later labs. When you are done, the board should look like as the picture above

C1 and C2 are the larger brownish 22 pF capacitors.

C3 and C4 are the small yellow ceramic 0.1  $\mu F$  capacitors.

## Place the reset button

The reset button restarts the microcontroller when pushed. It will take a little extra pressure when pushing the leads through the circuit board. It has no polarity.



## **Place IC Sockets**

Integrated circuits (ICs, better known as chips) are sensitive to heat and other damage. It is prudent to place them in sockets so that you do not overheat them during soldering and can easily remove them in case of damage.

There are two sockets; one has 28 pins, the other has 16 pins. Make sure to match the socket's notch with the footprint's notch on the board. Again, bend the legs in the opposite corners of the sockets to hold them in place before you solder.

#### Place electrolytic capacitors

The voltage regulator supplies current sufficient to meet the average demand of circuits on the board. However, whenever there are spikes of current at high frequency, the voltage briefly droops in order to keep up with the current demand, just as the lights in Metropolis dim as the evil genius closes the switch on his giant antimatter ray gun. Electrolytic capacitors store charge and provide current to keep the voltage at the desired level during the spikes. They are called bypass capacitors because they provide another path for the current to flow.



Electrolytic capacitors, unlike the ceramic ones, are polarized. This means it **matters** what direction they are put in. There are two ways to determine the polarity. If the leads on your capacitors are uncut, the longer of the two leads is the positive (+) terminal and goes in the hole with square copper plating. The other way is to look at the capacitor and find the stripe going down one side. This points to the negative (-) lead. This lead then goes in the hole with circular copper plating. If you install an electrolytic with the incorrect polarity, it could leak or explode.

C5 and C6 are both 10 µF caps.

## Place the LEDs

The LEDs, like the electrolytic capacitors, are polarized. The positive terminal has a longer lead. The lens of the LED has a flat edge next to the negative terminal. Notice that the holes where the LEDS are placed are shaped differently. Insert the LEDs in the board with the positive terminal in the square hole. Insert all LEDs in the board <u>before</u> soldering one or else they may not lie flat on the board next to each other.

We have four LEDs that come in two different sizes.

5mm LEDs: D5 is green. D13 is red. 8mm LEDs: D3 is yellow-colored, (but glows white), and DN is translucent-white tinted (but glows green).

## Place the pins for the FTDI and servo

You will have to cut one set of three male header pins (for the servo) and one set of six male header pins (for the FTDI connector) from the long strip of headers using your diagonal cutters. The long side will be pointing up from the component side of the board, with the **short pins going through the hole**. The longer gold-plated pins and the black plastic strip should stay on the component side. Both are located to the bottom, right of the board.

## Place the remaining input/output female header pins

The female header pins provide convenient receptacles for the Mudduino input / output (I/O) ports. You should have two 12- pin female headers. They will be along the outer left and right edges of the board for ease of access.

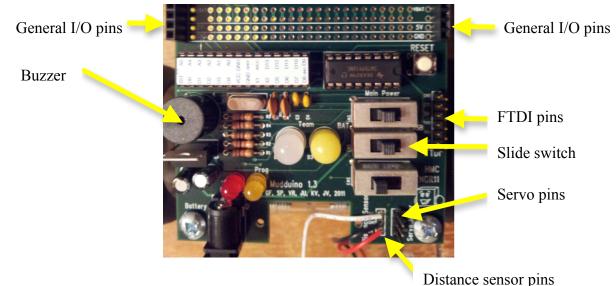
#### Place the buzzer

The buzzer or speaker, S1, will be useful for debugging and for amusing yourself by playing random tunes. You'll notice the speaker has polarization markings on the bottom. However, because the speakers are not of the best quality, the direction you put it in won't affect the sound. If you really care, the negative terminal points to ground (lower half of the board).

## Place the three 3-position switches

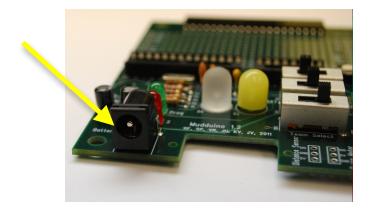
The switches govern three functions. The top switch will distinguish where the boards power supply is coming from (either USB or Battery). The middle switch will determine the source of motor power (either USB or Battery also). The bottom switch will select between two colors to distinguish the team color of the Mudduino. (More on this later!)

The switches (SW1-SW3) can only be inserted one way. We again recommend bending the leads of the switches in one direction such that the switch remains in the board while you solder. Note each switch has two thicker legs. You should still solder these as they are for structural support. It will be easier to solder one switch at a time.



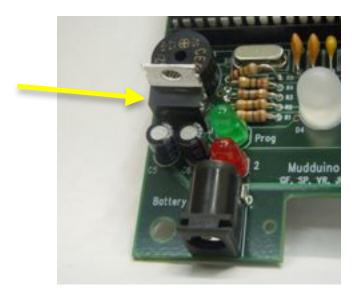
## Place the 2.1mm barrel jack

The barrel jack supplies external power to the board when you aren't connected to a computer via an FTDI cable. To solder this component a bit more easily, try bending the leads inwards on the solder side of the board before soldering.



## Place voltage regulator

The voltage regulator, U3, is the tallest component on the board. It drops the 7.2-8 V battery voltage down to a steady 5 V, which is the ideal operating voltage for the microprocessor and sensors. The component outline matches the top view of the part. This means the tall metal portion lines up with the skinny rectangle of the component's footprint. The regulator has polarity, so it must be oriented correctly.

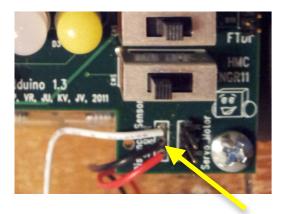


#### Attach the distance sensor cable

The distance sensor cable has three stranded wires and connector.

Strip <sup>1</sup>/<sub>4</sub>" of insulation off the end of each stranded wire. Insert the wires into the holes labeled Distance Sensor. The red wire is for 5V; the black is for GND, and the white is for signal (SIG). Solder and then cut off any excess wire.

Plug the connector into your black two-eyed distance sensor.



## Insert the ICs

Place the L293D H-Bridge motor driver in the smaller socket. The notch on the chip should be aligned with the notch at the right end of the socket (which should be aligned with the image on the PCB). You may need to carefully bend the legs of the chip slightly to fit it in the socket. One way is to press the legs against a flat surface such as a lab bench so that the legs all bend uniformly. Take care because the legs will break if you bend them more than about twice. Then place the ATMEGA328 microcontroller in the larger socket. Note that the notch is on the left side for this chip.

#### Woohoo! Your board is assembled!

# Testing

Once you're finished with the soldering, bring your Mudduino to the lab instructor. The instructor will visually inspect the board and check for shorts using a multimeter. Next, they will plug the board into a computer. If nothing starts smoking after a few seconds, the instructor will download a test program.

The instructor has two shields, which will plug into the left and right hand side of the board. These shields will allow us to quickly test continuity on the board. Once the board is programmed with lab1\_tester code, the instructor will attach the testing shields to your board and open a serial monitor on the computer. At this point, three LEDs should light up: the lower red LEDs on both shields, and the yellow team LED on the right shield. Press the reset button. If the board is working correctly, the following should take place:

- The board will print "Hello, world!" on the serial port.
- The speaker will play five tones.
- The digital pins will flash in order.
- The serial link will print whether the analog pins are working.

If all of these events take place, congratulations! Your board is complete! If not, the lab instructor will give you pointers on debugging your system.

# Clean Up

Clean up your lab station. Discard the refuse you accumulated while soldering. <u>Tin the iron and</u> <u>turn it off</u>. Please clear the benches and keep the lab clean. Wash your hands with soap and water because solder contains lead.