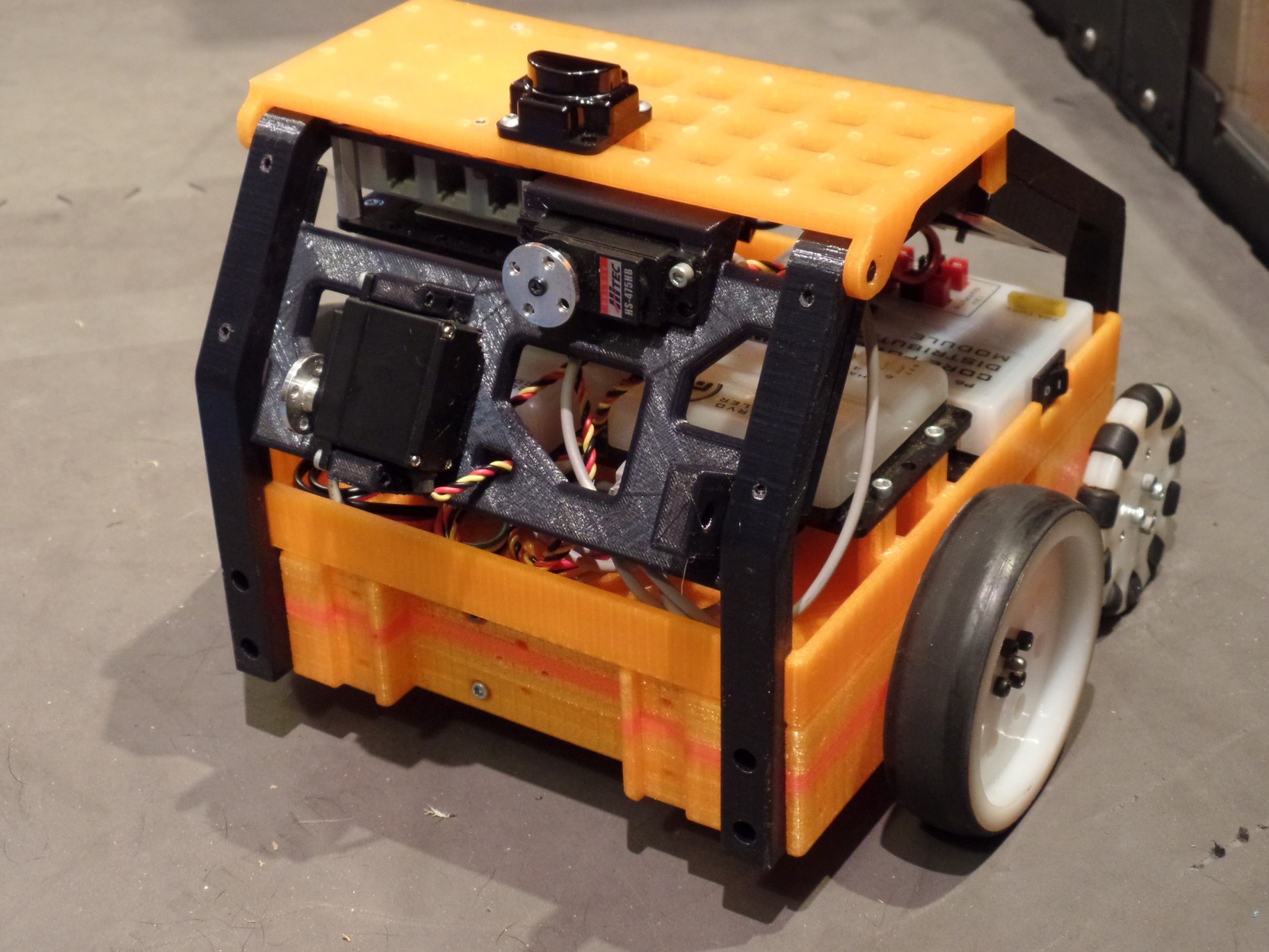
Scrambler Robot

*Dale Jordan*

*August 14, 2017*



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# Introduction

The Scrambler Robot is a low cost robot designed to support machine learning research, especially for reinforcement learning.

The choice to go with a 3D printed robot was to minimize mechanical costs. An advantage is that new features can easily be created as the need arises.

This document describes the procedure necessary to print and construct the robot.

Inquires or questions about this robot can be directed to Dale Jordan at [dale.a.jordan@gmail.com](mailto:dale.a.jordan@gmail.com).

# Before You Start

This robot has only been printed with an Ultimaker2 printer using the Cura slicer software. All settings and comments refer to this environment. Other printers should work fine as there are only a few critical capabilities needed.

The platform build area should be at least 220mm x 220mm to handle the various parts. The printing height only requires about 45mm. Most of the parts are made with PLA, which is inexpensive and easy to use. Any similar type material could be substituted. In addition, there are a few components that need to be of higher strength. For these, colorFabb XT was used. Again other similar strength materials could also be used.

# Assembly Tools

The following table lists some necessary and/or useful tools for constructing the robot.

|  |  |  |
| --- | --- | --- |
| **Tool** | **Description** | **Comments** |
| PowerPoleCrimper.png | TRIcrimp Power Pole Crimping Tool | Used for building power cables and attaching power pole connectors the motors. |
| PowerwerxInsertionExtractionTool.png | **Anderson Powerpole Removal, Insertion/Extraction Tool** |
| Wire Stripper.png | Wire Stripper |
| BallEndHexDriver.png | Ball End Hex Drivers:  1/16, 5/64, 3/32, 7/64 | Allows for tightening hex head Tetrix screws at an angle. |
| Drill Bit.png | Drill Bits:  4.7 mm, 6 mm, 8 mm | * 8 mm to round out bushing holes * 6 mm to round out motor gears * 4.7 mm to round out wheel gears |
| tap.png | 6-32 tap | Most holes to be tapped are through-hole so any tap should work. A few holes are relatively shallow, so if a bottom tap is handy, it can be used to get more threads cut. |
| Phillips Screwdriver.png | #1 Philips Screw Driver | Used to connect the servo horn to the servo. |
| SnapoffKnife.png | Snap-off Utility Knife | Used to remove PLA Flex parts from the buildplate |

# Materials and Parts List

|  |  |  |  |
| --- | --- | --- | --- |
| Picture | Part Number | Quantity | Description |
| PLA Spool.png |  | ≈600g | PLA Filament. The number of spools needed is based on the number of colors used in the robot. |
| ColorFabbSpool.png |  | ≈70g | colorFabb XT or similar high strength material. |
| PLA_FlexSpool.png |  | ≈30g | PLA Flex or other similar material. Slicer parameters were set for PLA Flex, but tuning these for other material is possible. |
| ZTE Speed Phone.png |  | 1 | ZTE Speed Phone for the robot. In addition, an additional phone, OTG cable and F310 joystick are needed for the driver station.  The brackets on the robot are currently designed to only hold the ZTE. |
| OTG Cable.png |  | 1 | OTG (On the Go) cable |
| CorePowerDistModule.png | AUP3010 | 1 | Modern Robotics Core Power Distribution Module |
| CoreMotorController.png | **AUM3020** | 1 | Modern Robotics Core Motor Controller |
| CoreServoController.png | **AUS3015** | 1 | Modern Robotics Core Servo Controller |
| CoreDeviceInterfaceModule.png | **AUA3030** | 1 | Modern Robotics Core Device Interface Module |
| CoreLegacyModule.png | **AUL3025** | 1 | Modern Robotics Core Legacy Module |
| http://cdn3.volusion.com/vyfsn.knvgw/v/vspfiles/photos/am-2964-2S.jpg?1420269442 | **am-2964** | 2 | AndyMark Neverest 40 Motor |
| http://cdn3.volusion.com/vyfsn.knvgw/v/vspfiles/photos/am-2992-2S.jpg?1420269442 | Am-2992 | 2 | AndyMark **Encoder Cable with 4-pin Connector** |
| PowerPoleConnectors.png | WP15-xx  WP30-xx |  | Power Pole Connectors 15 Amp  (30 Amp optional, for converting battery and power distribution connectors) |
| ZipCord.png |  |  | Red/Black Zip Cord (18 gauge) |
| USB_Cable.png |  | 4 | USB Type A to Mini-B, 1 foot  Ex: StarTech 1-Feet Mini USB 2.0 Cable - A to Mini B (USB2HABM1) from Amazon |
| USB_Cable.png |  | 1 | USB Type A to Mini-B, 6 inch |
| TetrixServo.png | W39197 | 2 | 180° Standard-Scale HS-485HB Servo Motor |
| TetrixBattery.png | W39067 | 1 | TETRIX 12-Volt Rechargeable NiMH Battery Pack |
| TetrixWheel4inch.png | W39055 | 2 | Tetrix 4” wheels |
| TetrixOMNI_3inch.png | W31132 | 2 | Tetrix 3” OMNI Wheels |
| TetrixAxle.png | W39088 | 3 | Tetrix 100 mm Axles  Note: one axle is cut in half and used to mount the OMNI wheels. |
| TetrixAxleHub.png | W39172 | 6 | Tetrix Axle Hubs |
| TetrixAxleHub.png | W39079 | 2 | Tetrix Motor Hubs |
| AxleSpacer.png | W39101 | 3 | 3/8” Tetrix Axle Spacer |
| TetrixBushing.png | W39091 | 8 | Tetrix Bushing |
| TetrixCollar.png | W39092 | 2 | Tetrix Axle Collar |
| StandoffPosts.png | W39102 | 4 | Tetrix Stand-off Posts 1” |
| ButtonHeadCapScrew.png | W39111 | 27+ | Button Head Cap Screw 6-32 x 3/8”.  At least this many are needed. |
| SocketHeadCapScrew_5-16.png | W39098 | 35+ | Socket Head Cap Screw 5/16”.  At least this many are needed. |
| SocketHeadCapScrew_1-2.png | W39097 | 38+ | Socket Head Cap Screw 1/2”.  At least this many are needed. |
| Super Glue.png |  |  | Super Glue. Either liquid or the gel. The gel is a little easier to work with as it doesn’t easily run all over. It also takes a little longer to dry. |
| Loctite.png |  |  | Loctite Blue |

# Printing the Robot

The specifications and comments below are for using the Ultimaker2 printer and Cura 15.02.1 software. Most parameters are typical for printing the various materials. Full settings mode was used for these prints as it gives finer control over printing parameters. As a starting point the “Normal print” mode in the “Quick print” settings were instantiated as the parameters for the “Full settings” mode. Highlighted parameters indicate which values were changed from these defaults.

## Ultimaker2 Default Parameters

### Parameters set in Cura

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Basic** | | | | | |
|  | **Quality** | | | | |
|  | Layer height (mm) | | | 0.2  Parts don’t generally have a lot of detail, so increasing the layer height reduces the printing time considerably. |
| Shell thickness (mm) | | | 0.8 |
| Enable retraction | | | true |
| **Retraction (expert config)** | | | |
|  | | Minimum travel (mm) | 20  When printing the fill pattern, there are many small movements that don’t require lifting the head, so this parameter is made large so that only the lift happens for long moves of the head. |
| Enable combing | On |
| Minimum extrusion before retracting (mm) | 0.02 |
| Z hop when retracting (mm) | 0.2  This gets us high enough to not contact material that has already been printed on this layer. |
| **Fill** | | | | |
|  | Bottom/Top thickness (mm) | | | 0.6 |
| Fill density (%) | | | 20 |
| **Infill (expert config)** | | | |
|  | | Solid infill top | True |
| Solid infill bottom | True |
| Infill overlap (%) | 15 |
| **Speed and Temperature** | | | | |
|  | Print speed (mm/s) | | | 50 |
| **Support** | | | | |
|  | Support type | | | None |
| Platform adhesion type | | | None |
| Skirt **(expert config)** | | | |
|  | | Line count | 1 |
| Start distance (mm) | 5.0 |
| Minimal length (mm) | 150 |
| **Advanced** | | | | | |
|  | **Machine** | | | | |
|  | Nozzle size (mm) | | | 0.4 |
| **Quality** | | | | |
|  | Initial layer thickness (mm) | | | 0.3 |
| Initial layer line width (%) | | | 100 |
| Cut off object at bottom (mm) | | | 0 |
| **Speed** | | | | |
|  | Travel speed (mm/s) | | | 180.0  Takes advantage of the fact that the printer is capable of moving faster. It results in a small saving in print time. |
| Bottom layer speed (mm/s) | | | 30  PLA will typically adhere to the build plate at this speed. This greatly helps the first layer print time. |
| Infill speed (mm/s) | | | 0 |
| Top/bottom speed (mm/s) | | | 0 |
| Outer shell speed (mm/s) | | | 0 |
| Inner shell speed (mm/s) | | | 0 |
| **Cool** | | | | |
|  | Minimum layer time (sec) | | | 5 |
| Enable cooling fan | | | True |
| **Cool (expert config)** | | | |
|  | Fan full on at height (mm) | | 0.5 |
| Fan speed min (%) | | 100 |
| Fan speed max (%) | | 100 |
| Minimum speed (mm/s) | | 10 |
| Cool head lift | | False |

### Ultimaker2 Settings

The parameters on the printer are mostly determined by the material selection. The only apparent difference is the retraction parameters. These parameters can all be adjusted on the fly from the “tune” menu. For printing with different materials, it is helpful to get the parameters for these stored in the printer. Information on how to do this can be found at: <http://support.3dverkstan.se/article/36-creating-custom-material-profiles>. The following table lists the parameters for the different materials used for this robot.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **PLA** | **colorFabb XT** | **PLA Flex** |
| Speed | 100% | 100% | 100% |
| Temperature | 210C | 240C | 210C |
| Buildplate Temp | 60C | 70C | 100C |
| Fan Speed | 100% | 50% | 100% |
| Material flow | 100% | 100% | 110% |
| Retraction length | 5.50 mm | 5.50 mm | 2 mm |
| Retraction speed | 35 mm/s | 35 mm/s | 15 mm/s |

## Printed Materials

Before printing components, check for special printing notes below for hints and optimizations in printing. The modified parameters given in the table are variances from the default settings for the material type listed above.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Item** | **Modified Print Parameters** | **Print Time (hh:mm)** | **Length (m)** | **Weight (g)** |
| DriveTrain.png  Chassis.stl | Material: PLA  Print Speed: 70 mm/s  Temperature: 220C  Bed Temp: 70C | 16:39 | 29.04 | 230 |
| Battery Cover.png  Battery Cover.stl | Material: PLA | 2:06 | 3.11 | 25 |
| Layer Mounting Studs.png  Layer Mounting Studs.stl | Material: PLA  Print 4 copies | :05  :24 | .05  .21 | <1  2 |
| Drive Gears.png  Motor Gear.stl | Material: ColorFabb XT  Shell Thickness: 1.6mm  Print 2 copies | :53  1:51 | 1.16  2.32 | 9  18 |
| Wheel Gear.png  Wheel Gear.stl | Material: ColorFabb XT  Shell Thickness: 1.6mm  Print 2 copies | :53  1:52 | 1.17  2.34 | 9  19 |
| Battery Latch.png  Battery Latch.stl | Material: ColorFabb XT | 0:07 | 0.20 | 2 |
| MotorClampXT.png  Motor Clamp.stl | Material: ColorFabb XT  Shell Thickness: 1.6mm  Print 2 copies | 0:35  1:13 | .84  1.69 | 7  13 |
| Control Platform.png  Control Platform.stl | Material: PLA  Solid infill bottom: False  Print Speed: 60 mm/s | 6:50 | 11.55 | 91 |
| Wire Clamp.png  Wire Clamp.stl | Material: PLA  Print 2 copies. May want extra copies for controlling sensor wires. | 0:04  0:09 | 0.09  0.19 | 1  1 |
| Wire Clamp Extended.png  Wire Clamp Extended.stl | Material: PLA  Print 4 copies | 0:04  0:16 | 0.10  0.40 | 1  4 |
| Wire Clamp Dual.png  Wire Clamp Dual.stl | Material: PLA  Currently not used, but may be useful for other clamping purposes. | 0:07 | 0.18 | 1 |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
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|  |  |  |  |  |
|  |  |  |  |  |

# Printing Notes

## Multiple Items

For cases where multiple parts are needed, many of these can be printed at the same time by multiplying the part in Cura. For best results, in the Tools Menu, select “Print one at a time”.

* Layer Mounting Studs – can easily be printed four at a time
* Motor and Wheel Gears – all four (two of each) can be printed at once
* Motor Clamps – can easily be printed at once
* Wire Clamps – all three varieties can be printed at once

Items that can’t or shouldn’t be printed at once are:

* Phone Mount Flex – flex material takes special care to print, so handling them separately is best.
* Roll Bar Back – these parts are too big to fit more than one the build platform at once.

## Chassis

The chassis has a long printing time, so various parameters can be adjusted to reduce this as much as possible. There is not a lot of detail in the chassis so printing speeds can be increased. Along with this, the nozzle and bed temperature were increased to keep the quality up. The material flow rate could also be increased to insure enough plastic is extruded, especially when printing flat top areas. There is a good deal of stress on this part, so you want to guard against under-printing as that leads to a weaker part.

There is a lot of surface area in contact with the build plate, so only apply glue stick (from your standard office supply store) or other adhesive to the corner areas (about 2” square on each corner) to keep them from curling. Don’t glue middle unless necessary. If glue is applied everywhere it can be difficult to remove the print from the build plate. The use of adhesive is important at the corners, as they tend to curl up otherwise.

## Battery Cover

The battery cover has a moveable hinge printed in place. A spacing of 0.5 mm is maintained between the moveable parts. Typically, during printing there will be some plastic crossing this gap, so when the print is completed it will require carefully bending of the components to break these plastic bridges. Rotating the hinge several times is usually sufficient to get the hinge to work freely.

## Control Platform

As with the Chassis, just need to glue down the corners.

Solid infill for the bottom is turned off. This print sits directly on top the chassis which has ample structural support.

# Assembling Robot

## Chassis

The chassis is the most complicated and sturdiest piece in the robot. The heavy items, motors and battery mount to it. It needs to withstand the rigors of driving and the inevitable contact with other objects. Although not as strong as metal, the walls are thick enough to withstand normal driving with the occasional run-in with other objects. It wasn’t designed to withstand battle-bot activities.

### Preparation

Some preparation is needed on a newly printed chassis before parts can be mounted. Screws are used to attach many parts. Holes for these needs to be tapped with a 6-32 tap (Figure 1). Bushing holes for axle mounting are not completely round or may have plastic irregularities in them. Carefully rounding out these with an 8 mm bit facilitates assembly.

|  |
| --- |
| **Chassis Front View for tapped holes**  Chassis Prep Front.png  Blue – through hole tapped holes |
| **Chassis Side View for tapped holes and bushing mounts (both sides are symmetric)**  Chassis Prep Side.png  Blue – through hole tapped holes  Yellow – bushing holes |
| **Chassis Rear View for tapped holes**  Chassis Prep Rear.png  Blue – through hole tapped holes |

Figure -- Chassis views showing tapped hole locations

### Control Platform Mounting Studs

The mounting studs are used to align and help secure the Control Platform to the chassis (Figure 2). These studs should be secured to the chassis with Super Glue or similar adhesive for use on PLA. The studs should fit snuggly in the holes. Depending on how much the holes shrink during printing, it may be necessary to clear out the holes with an 8 mm bit.

|  |
| --- |
| Chassis Assembly Studs 1.png |

Figure -- Attaching Mounting Studs

### Drive Gears

The gears in the drive train are attached to aluminum hubs for strength in connecting to the motor shaft and axles. The only difference in the gears is the size of the center hole (6mm for motor shaft and 4.7mm for the axle).

|  |  |  |
| --- | --- | --- |
| **Parts for Motor Gear Assembly** | | |
|  | 2 | Motor Gear |
|  | 2 | Tetrix Motor Hubs |
|  | 8 | Socket Head Cap Screw 1/2” |
| **Parts for Wheel Gear Assembly** | | |
|  | 2 | Wheel Gear |
|  | 2 | Tetrix Axle Hubs |
|  | 8 | Socket Head Cap Screw 1/2” |

For each gear:

1. Assemble the gears by attaching to the appropriate hub with four screws (Figure 3). The Gears can be identified by a small M (motor) or W (wheel) printed on the gear.
2. To insure that shaft holes in the gears are round and match the hub holes, pass a drill bit through the shaft holes to clear out any imperfections. Use a 6 mm bit for the Motor Gear Assembly and a 4.7 mm bit for the Wheel Gear Assembly.
3. Remove the set screw from each hub and apply Loctite to the threads, then reinsert it.

|  |  |
| --- | --- |
| Gear Hub Assembly 1.png | Gear Hub Assembly 2.png |

Figure -- Drive Gear Assembly

### Motor Clamp Preparation

Each motor mount needs three holes tapped (Figure 4).

|  |
| --- |
| MotorClampTappedHoles.png |

Figure -- Motor Clamp Tapped Hole Locations

### Mounting Motors

|  |  |
| --- | --- |
| **Parts for Mounting Motors in Chassis** | |
| 1 | Chassis |
| 2 | Motors |
| 2 | Motor Clamps |
| 6 | Socket Head Cap Screw 1/2” |
| 2 | Motor Gear Assemblies |

For each motor:

1. Install Power Pole Connectors on the motor wires. The wires are left long in case you want to repurpose the motors later.
2. Plug the encoder cable into the motor.
3. Orient the motor as it will be placed in the chassis (Figure 5), but don’t insert it yet.
4. Slide a motor clamp over the back end of the motor with the gap facing up (this will be to the bottom of the robot when assembled).
5. Slide a motor gear assembly over the shaft and tighten the set screw at the inside edge of the flat on the shaft.
6. Insert the motor into the motor mount on the chassis.
7. Line up the motor clamp with the mounting holes and secure with two ½” socket cap screws. Note: for the motor in the middle of the chassis, there are two tool feed-through holes to insert the hex driver to tighten the clamp.
8. On the motor clamp, loosely insert a ½” socket cap screw into the gap hole. It will be tightened later after the wheels are inserted.
9. Rotate the motor so that the gear is well away from the wheel axle holes.

|  |
| --- |
| Blue – holes to allow tool insertion to tighten motor clamp.  Red – wheel axle holes.  Chassis Motor Assembly.png |

Figure -- Connecting Motors and Gears in the Chassis

### Drive Wheels

|  |  |
| --- | --- |
| **Parts for Mounting Motors in Chassis** | |
| 1 | Chassis |
| 2 | 4” Wheels |
| 2 | 100 mm axles |
| 2 | Axle Hubs |
| 2 | 3/8” Axle Spacer |
| 4 | Bushings |
| 8 | Socket Head Cap Screw 1/2” |
| 2 | Wheel Gear Assembly |

For each wheel:

1. Make a drive wheel assembly (Figure 6). Before attaching the wheel hub, remove the set screw and apply loctite to the threads.
2. Insert bushing into appropriate holes in the chassis (Figure 7).
3. Insert Wheel Gear Assembly (Figure 8) into place in the chassis, then slide axle from the drive wheel assembly through the wheel gear until the spacer is snug against the outside of the chassis.
4. Tighten the set screw on the wheel gear assembly on the flat of the axle.
5. Rotate the motor until the gears are fully meshed, then tighten the screw on the motor clamp to secure everything.

|  |
| --- |
| **Exploded view**  Wheel Assembly 1.png |
| **Final**  Wheel Assembly 2.png |

Figure -- Drive Wheel Assembly

|  |
| --- |
| ChassisWheelBushingAssembly.png |

Figure -- Bushing Insertion

|  |
| --- |
| **Exploded view**  ChassisWheelAssembly1.png |
| **Final**  ChassisWheelAssembly.png |

Figure -- Drive Wheel Mount

### OMNI Wheel Mount

Assemble two OMNI wheels, one for each side of the robot (Figure 9). Before mounting the axle hubs, apply loctite to the threads of the set screws.

|  |  |  |
| --- | --- | --- |
| **Parts** | | |
|  | 1 | Chassis |
|  | 2 | Tetrix 3” OMNI Wheels |
|  | 2 | 50 mm axle (one 100mm axle cut in half) |
|  | 2 | Tetrix Axle Hubs |
|  | 2 | Tetrix Axle Collar |
|  | 4 | Tetrix Bushing |
|  | 8 | Socket Head Cap Screw 1/2” |

|  |
| --- |
| **Exploded View**  Front Wheel Mount.png |
| **Final**  Front Wheel Mount2.png |

Figure -- OMNI Wheel Mount

### Battery Latch

Attach Battery Latch (Figure 10).

|  |  |  |
| --- | --- | --- |
| **Parts** | | |
|  | 1 | Chassis |
|  | 1 | Battery Latch |
|  | 2 | Button Head Cap Screw 6-32 x 3/8” |

|  |
| --- |
| Yellow – Battery Latch  Red – Button Head Cap Screws  Blue – Tool feed-through holes for tightening screws  ChassisBatteryLatch.png |

Figure -- Attach Battery Latch

### Battery Cover

Install Battery Cover (Figure 11).

|  |  |  |
| --- | --- | --- |
| **Parts** | | |
|  | 1 | Chassis |
|  | 1 | Battery Cover |
|  | 3 | Button Head Cap Screw 6-32 x 3/8” |

|  |
| --- |
| Blue – screw mounting locations  ChassisBatteryCover.png |

Figure -- Attach Battery Cover

This completes the assembly of the chassis. The Control Platform sits directly on top of the chassis and must be built next.

## Control Platform Assembly

The Control Platform houses the power distribution module, motor and servo controllers. Most of the electrical interconnections take place on this platform, so proper cable routing is handled here. This is a very compact design and given the layout of the Modern Robotics Controllers, the routing becomes 3-dimensional in nature.

The servo controller is raised well off the platform so that the USB cables can be routed and excess lengths stored under it. Similarly, the motor controller is raised enough to allow the motor and encoder wires to be routed under it.

Lengths and sizes of the USB and power wires shipped with the Modern Robotics Controllers, while well suited for FTC robot design, are too long and bulky for this design, so smaller USB cables were purchased and custom power cables made.

### Preparation

Mounting holes for the control modules and wire clamps need to be tapped with a 6-32 tap (Figure 12).

|  |
| --- |
| Control Platform Tapped Holes.png |

Figure -- Tapped Hole locations for Control Platform

### Mount Control Platform

The Control Platform sits directly on top the chassis over the mounting pins (Figure 13). Feed the motor power and encoder cables through the holes of the Control Platform before sliding it over the pins.

|  |
| --- |
| Control Layer Mounted with wires.jpg |

Figure -- Control Platform Mount

### Motor Wire Routing

The motor wires have been left long as there is room under the motor controller to contain these. Also, some slack needs to be left in these wires in case the motors and gears need adjustment from the underside of the chassis. Mount the wires as shown (Figure 14)

1. Separate the power wires from the encoder wires.
2. Ends of the power wire connectors should just reach the form of the chassis (proper length for connecting to the motor controller later).
3. Fan-fold the power wires to take up the excess slack and secure to the chassis with a printed wire clamps (Wire Clamp Extended).
4. Connectors on the encoder cables should extend just past the front of the chassis.
5. Fan-fold the encoder wires to take up the excess slack and secure to the chassis with a printed wire clamps.

|  |
| --- |
| ––––Motor Wires Routed and Clamped.JPG |

Figure -- Motor Wire Mounting

### Mounting Core Power Distribution Module and Motor Controller

Mount the Core power Distribution Module with five screws as shown (Figure 15). Similarly mount the Motor Controller with four screws as shown.

|  |  |  |
| --- | --- | --- |
| **Parts** | | |
|  | 1 | Core Power Distribution Module |
|  | 1 | Motor Controller |
|  | 9 | Button Head Cap Screw 6-32 x 3/8” |

|  |
| --- |
| PowerMotorControllerMount.JPG |

Figure -- Power Distribution and Motor Controller Mount

### Installing USB Cables and Connecting the Motor Controller

Figure 16 shows the USB Cables attached and the wire connections for the motor controller.

1. Attach four 12” USB Cables as shown in ports P1 through P4 on the Power Distribution Module.
2. Connect Cable from P1 to the Motor Controller. Place a small service loop in the cable to take up the slack.
3. Connect the motor encoder wires to the Motor Controller. The left motor encoder cable attaches to the ENC 1 connector and the right motor encoder cable to the ENC 2 connector.
4. Connect the motor power wires with the left motor going to the motor 1 connector and the right to the motor 2 connector.

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| USB CAble Routing.JPG |

Figure -- USB Cable and Motor Controller Wiring

### Motor and Servo Controller Power Cable

Construct the power cable for the motor controller with a 10 ½” length of zip cord and 15 Amp Anderson Power Pole connectors (Figure 17). Similarly, construct the servo controller power cable with 5 ½” length of zip cord.

|  |  |  |
| --- | --- | --- |
| **Parts** | | |
|  | 1 | 10 ½” Zip Cord |
| 1 | 5 ½” Zip Cord |
| 8 | 15 Amp Power Pole Connectors |
| 4 | Power Housing WP15 |

|  |
| --- |
| Power Cables.JPG |

Figure -- Motor and Servo Controller Power Cables

### Mounting Servo Controller

Attach the Servo Controller and wiring as shown (Figure 18).

1. Mount the servo using four 5/16” Socket Head Cap Screws.
2. Attach the servo power cable between the Power Distribution Module and the Servo Controller. Place a small service loop in the cable and tuck under the servo.
3. Connect the USB cable from port P2 to the servo.
4. Connect the motor power cable between the Power Distribution Module and the Motor Controller. Secure with two Wire Clamps and two 5/16” Socket Head Cap Screws.

|  |
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| Servo Install.JPG |

Figure -- Servo Controller Attachment

### Battery and Phone Cable Attachments

1. Insert the battery in the battery compartment from underneath the robot. The cable should extend through the opening in the left rear corner of the robot (Figure 19).
2. Connect this cable the Power Distribution Module Cable. Place a small service loop in the distribution module cable to take up the slack.
3. Connect a 6” USB cable to the mini USB connector on the Power Distribution Module. The other end will be connected to the phone later.

Note: For more reliable power connections, the Tamiya Connectors as shipped with the battery and Power Distribution Module can be replaced with 30 Amp Anderson Power Pole Connectors. Pictures shown here, all have this modification done.

|  |
| --- |
| Battery Connection.JPG |

Figure -- Battery and Phone Cable Connections

## ZTE Phone Mount Assembly

The phone is held in-place by two soft brackets made from flexible PLA. These are mounted on a carrier that gets attached to the robot.

|  |  |  |
| --- | --- | --- |
| **Parts** | | |
|  | 1 | Android Mount Bracket |
| 2 | Phone Mount Flex |
| 4 | Button Head Cap Screw 6-32 x 3/8” |

1. Prepare the printed Phone Carrier by tapped the holes for mounting the phone brackets (Figure 20).
2. Mount the two phone brackets with four Button Head Cap Screws (Figure 20)

|  |
| --- |
| Android Mount Bracket Prep.png |

Figure -- Phone Carrier Preparation

|  |
| --- |
| **Exploded View**  AssemblePhoneMount1.jpg |
| **Finished Mounting Bracket**  AssemblePhoneMount2.jpg |

Figure -- Mounting Phone Brackets

## Sensor Platform Assembly

The Core Legacy Module and Core Device Interface Module are mounted to the underside of the Sensor Platform. This platform is hinged and mounted on top of the robot. It rotates up to easily attach sensors to the modules.

|  |  |  |
| --- | --- | --- |
| **Parts** | | |
|  | 1 | Core Legacy Module |
|  | 1 | Core Device Interface Module |
|  | 4 | Stand-off Posts 1” |
|  | 12 | Button Head Cap Screw |
|  | 1 | Sensor Platform |

1. Attach the Legacy and Device Interface Modules with stand-off posts and button head cap screws (Figure 22).
2. Attach this assembly to the underside of the Sensor Platform (Figure 23).

|  |  |
| --- | --- |
| **Exploded View**  **Sensor Block.png** | **Assembled View**  Sensor Block Final.png |

Figure -- Sensor Module Assembly

|  |
| --- |
| **Exploded View**  Sensor Platform Exploded.png |
| **Assembled View**  Sensor Platform Assembled.png |

Figure – Sensor Platform Assembly

## Tool Platform Assembly

This assembly is easily constructed by mounting two servos to the platform (Figure 24). Later a manipulator will get attached to the servos.

|  |  |  |
| --- | --- | --- |
| **Parts** | | |
|  | 1 | Tool Platform |
|  | 2 | Servo |
|  | 8 | Socket Head Cap Screw 1/2” |

|  |
| --- |
| **Tool Platform Exploded**  **ToolPlatformExploded.png** |
| **Tool Platform Assembled**  **ToolPlatformAssembled.png** |

Figure -- Tool Platform Assembly

## Roll Bar Assembly

The roll bars are used to mount the phone, sensor and tool platforms.

### Assemble Roll Bars

|  |  |  |
| --- | --- | --- |
| **Parts** | | |
|  | 1 | Roll Bar Front Left |
| 1 | Roll Bar Front Right |
| 2 | Roll Bar Back |
| 4 | Socket Head Cap Screw 6-32 x 5/16” |

1. Prepare the roll bars for assembly by tapping the mounting holes (Figure 25)
2. Assemble the back half to the front half with two Socket Head Cap Screws (Figure 26).

|  |  |
| --- | --- |
| **Roll Bar Back Tap.png** | Roll Bar Front.png |

Figure -- Roll Bar Preparation

|  |
| --- |
| RollBarAssembly.png |

Figure -- Roll Bar Assembly

### Attach Platforms to Roll Bars

|  |  |  |
| --- | --- | --- |
| **Parts** | | |
|  | 1 | Roll Bar Left Assembly |
| 1 | Roll Bar Right Assembly |
| 1 | Phone Mount Assembly |
| 1 | Tool Platform Assembly |
| 1 | Sensor Platform Assembly |
| 8 | Socket Head Cap Screw 6-32 x 1/2” |

1. Using the left Roll Bar Assembly, attach the Tool Platform Assembly with two screws (Figure 27).
2. Similarly attach the Phone Mount Assembly as shown (Figure 27).
3. Attach the Sensor Platform to the hinge stud on the roll bar (Figure 28).
4. Connect right Roll Bar Assembly to the other side. Insure the Sensor Platform Hinge point gets inserted before attaching the other platforms with screws (Figure 29).
5. Insert a ZTE phone into the phone brackets (Figure 30).

|  |
| --- |
| RollBarPhoneTool.png |

Figure -- Attach Phone and Tool Assemblies to left Roll Bar

|  |
| --- |
| RollBarPhoneToolSensor.png |

Figure -- Attaching Sensor Platform

|  |
| --- |
| RollBarCompleteExploded.png |

Figure -- Connect Right Roll Bar to Assembly

|  |
| --- |
| **Roll Bar Phone.png** |

Figure -- Attaching the Phone

### Mount Roll Bars

1. Attach the Roll Bar Assembly to the front and back of the chassis eight ½” Socket Head Cap Screws.
2. Connect the phone to the 6” USB cable to the Power Distribution Module with an OTG (On-The-Go) cable.

This completes the assembly of the robot.

|  |
| --- |
| Servo and USB Connections.JPG |

|  |  |
| --- | --- |
| Assembled Front View.JPG | Assembled Back View.JPG |