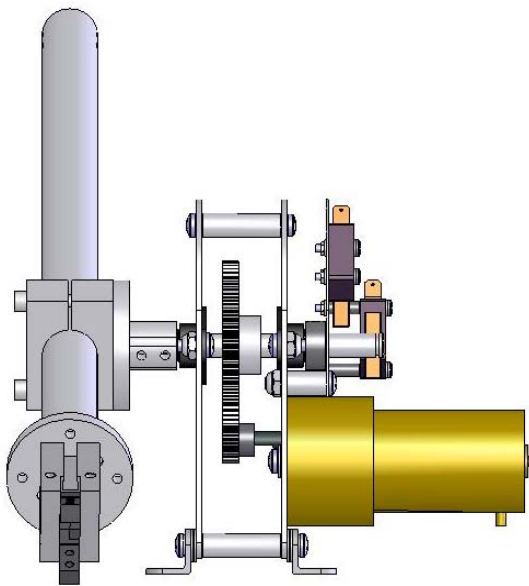


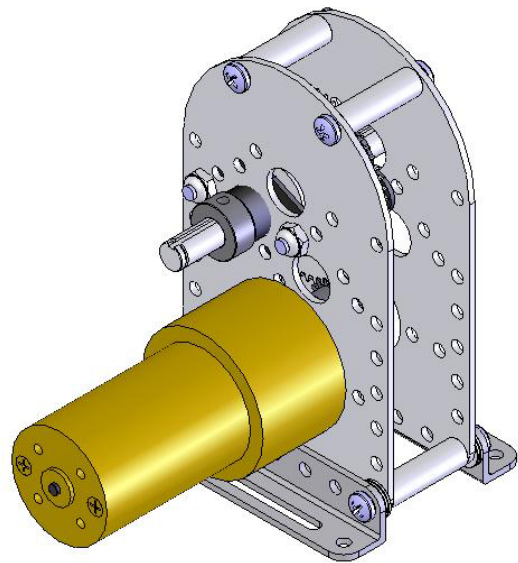
GEARS Transmission Module with *(Optional)* Pneumatic Gripper Arm and Limit Switch

Illustrated Assembly Manual

The GEARS Transmission and Pneumatic Gripper Arm Module can be used as a stand alone educational project or fitted to a mobile robot base.



**Transmission with
Arm and Limit
Switches**



Basic Transmission

**Transmission with
Arm and Limit
Switches Fitted to a
Mobile Robot**



Average Construction Time for 2 Students

Basic Transmission:	90 minutes +/-
Arm and Gripper with Pneumatics:	90 minutes +/-
Limit Switch Plate and Wiring:	90 minutes +/-

Required Tools and Supplies

Safety Glasses
 Phillips Head Screwdrivers (1 pt., 2pt.)
 Allen Wrench or Hex Key (sizes .050, 1/16, 5/64, 3/32, and 1/8)
 Box Wrench (sizes 3/8")
 File
 Dial Calipers

Materials

Structural

Qty.	
2	Transmission plates
2	3/8" Bore flanged sleeve bearing
1	4" x 3/8" Axle w 3/32" keyway
2	3/32" x 3/32" x 0.60" Steel key
1	3/8" Shaft collar
2	7-hole angles
1	24 Pitch-60T x 3/8" bore steel gear with 3/32" broached keyway
1	24 Pitch-15T x 1/4" bore x 3/8" face steel gear
2	3/8" Bore Keyed Aluminum Hubs
2	1/2" thick split bore arm clamps
2	GEARS Servo brackets
4	1.25" x 3/8" rd. alum. standoff
1	0.875" x 16" Arm Tube
1	Limit switch plate
2	Limit Switch Cams and set screws

Pneumatics

Qty.	
1	16mm bore angular gripper kit
1	4mm "Y" adapter
3	4mm tubing quick connects
1	Muffler
1	Plastic tubing plug
2	Feet 4mm Tubing
1	3/2 Solenoid valve
1	GEARS Pneumatic Kit (<i>Not included</i>)

Hardware and Supplies

Qty.	
16	#10-32 x 3/8" PH Machine screws (black)
4	#10-32 x 1/2" PH Machine screws (black)
2	#10-32 x 1-1/2" socket cap head screws
2	M4 x 0.7 x 8mm long PH screws
2	M4 Lock washers
4	M 2.5 x 6mm long ph Machine screws
4	M2.5 Lock washers
6	#10-32 Nylon lock nuts
15	#10 Lock washers
15	#10 Flat washers
2	4-40 x 1-1/4" PH machine screws
2	4-40 x 3/4" PH machine screws
2	4-40 x 7/8" PH machine screws
2	#4 x 3/8" long nylon spacers
8	4-40 flat washers
4	4-40 lock washers
4	4-40 hex nuts
2	#10-32 x 7/8" PH machine screws
2	#10 x 3/8".dia x 5/8" long nylon spacers
2	#10-32 Nylon locking nuts
2	#4 x 3/16 .dia x 0.3/8" long nylon spacers
1	3/8" Shaft Collar
1	3/4" x 3/32" key stock (60T gear)
1	1" x 3/32" key stock (Aluminum hub)
4	#8-32 x 1/8" set screws (gears)
4	#10-32 x 1/8" set screws (Alum. hubs)
2	#10-32 x 1/8" set screws (Cams)
4	1.25" rd. alum. Standoff
1	Small Tube Loctite™ 680
Electrical	
Qty.	
1	65:1 Gear Head Motor
1	5 Ampere speed controller (Not shown)
2	Limit Switches (Not shown)
2	Diodes (Not shown)
2	1/4" x 6" heat shrink
8	each M/F 1/4" quick disconnects

Assembly Instructions

(4:1 Gear Ratio)

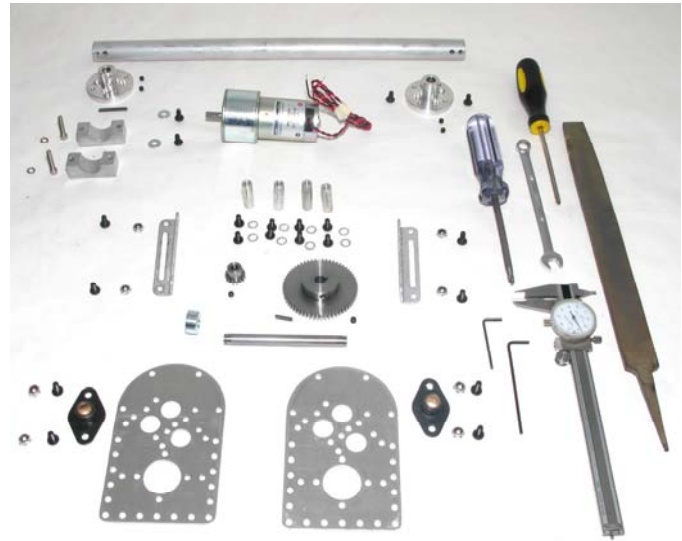
Step One: Inventory the Parts and Tools

Collect and layout the tools and components listed on the previous page.

Note: The kit includes extra fastener parts

Step Two: Transmission Plate Bearings

Attach the flanged sleeve bearings to the transmission plates

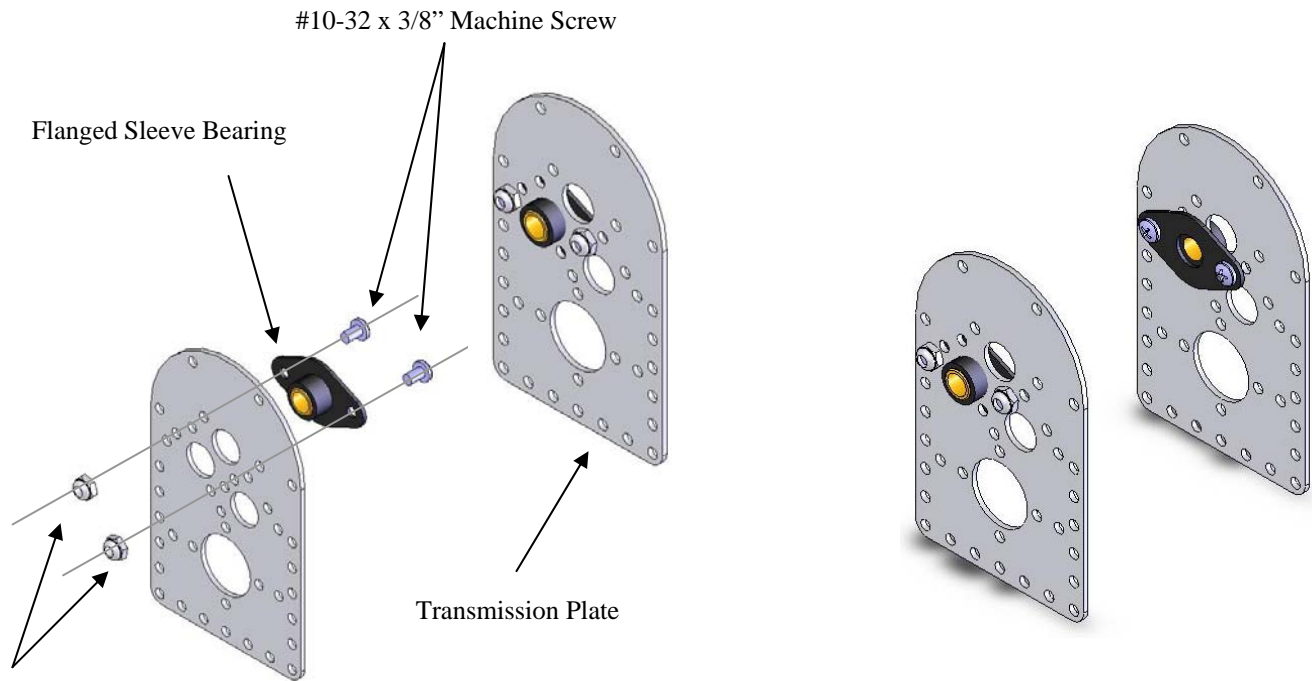


Necessary Components (1a)

Qty.	Description
2	Flange sleeve bearing
2	Transmission plates
4	#10-32 x 3/8" Machine screws
4	#10-32 Nylon lock nuts

Procedure

Attach the flanged sleeve bearing from the inside surface of transmission plates as shown below. Use two #10-32 x 3/8" PH machine screws and nylon lock nuts for each flanged bearing assembly. Position the flanged bearings and fasteners as shown in the photo



#10 Nylon Lock Nuts
below.

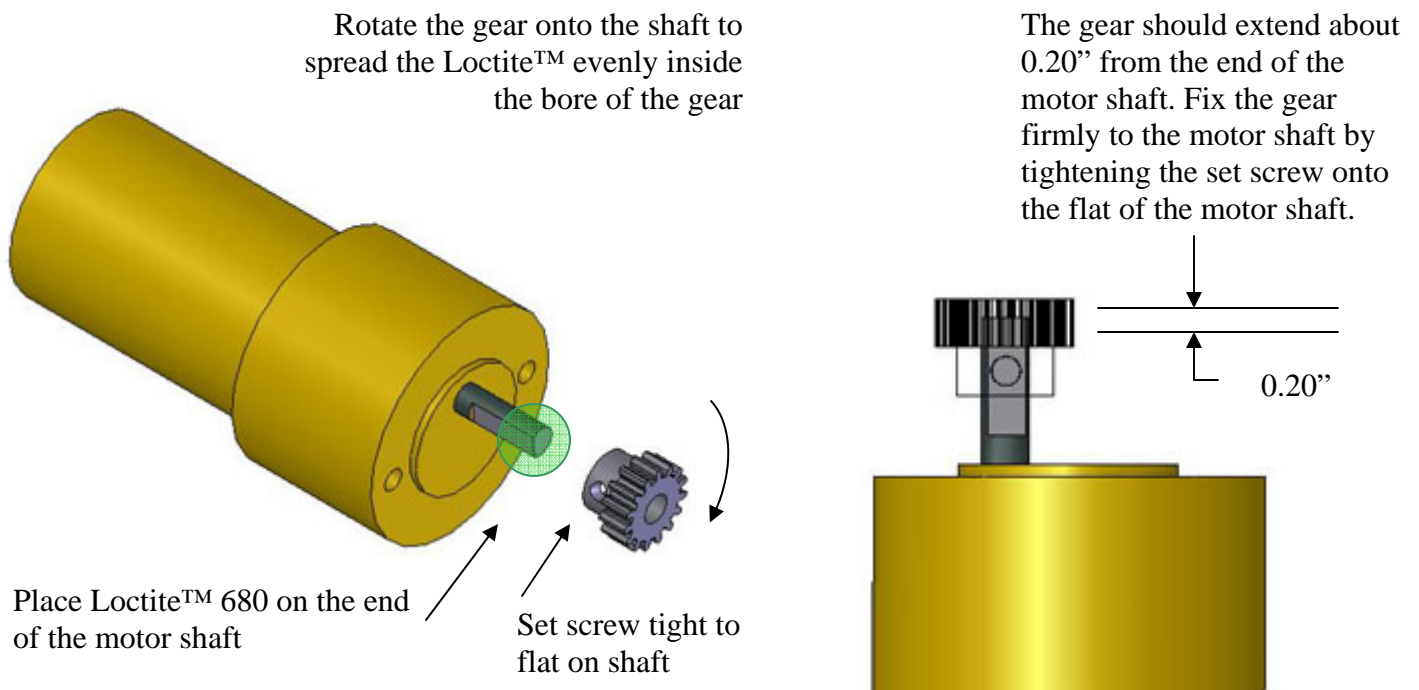
Step Three: Attach the 15 Tooth Spur Gear to the Motor Shaft

Necessary Components (1b)

Qty.	Description
1	Gear head motor assembly
1	15 Tooth steel spur gear with set screw
1	Small tube Loctite™ 680
	Denatured alcohol and paper towels
	Dial Calipers

Clean the motor shaft and gear thoroughly with denatured alcohol. Pay particular attention to cleaning the bore of the gear. Wipe the shaft and gear dry. Open the tube of Loctite™ and gently squeeze enough liquid from the tube to cover ¼” of the end of the motor shaft. Do not let the Loctite™ run down the motor shaft into the motor shaft bearing. If the Loctite™ seeps into the motor shaft bearing it will lock the bearing and shaft, cause permanent damage to the gearhead and void the motor warranty.

With the Loctite™ on the end of the shaft, twist the 15 tooth steel gear onto the shaft. Try to spread the Loctite™ inside the bore of the gear. Position the gear so that it protrudes 0.20” from the end of the shaft and secure the gear to the shaft by tightening the set screw firmly to the flat on the motor shaft. Wipe all excess Loctite™ from the shaft and gear. The Loctite™ will begin to set up within 10 minutes and cure in about an hour. Refer to the material data sheet at the end of this document for more specific information.



Step Four: Mount the Motor to the Transmission Plate

Use two #10-32 x 3/8" PH machine screws, washers and lock washers. Position the motor shaft as shown in the photo below.

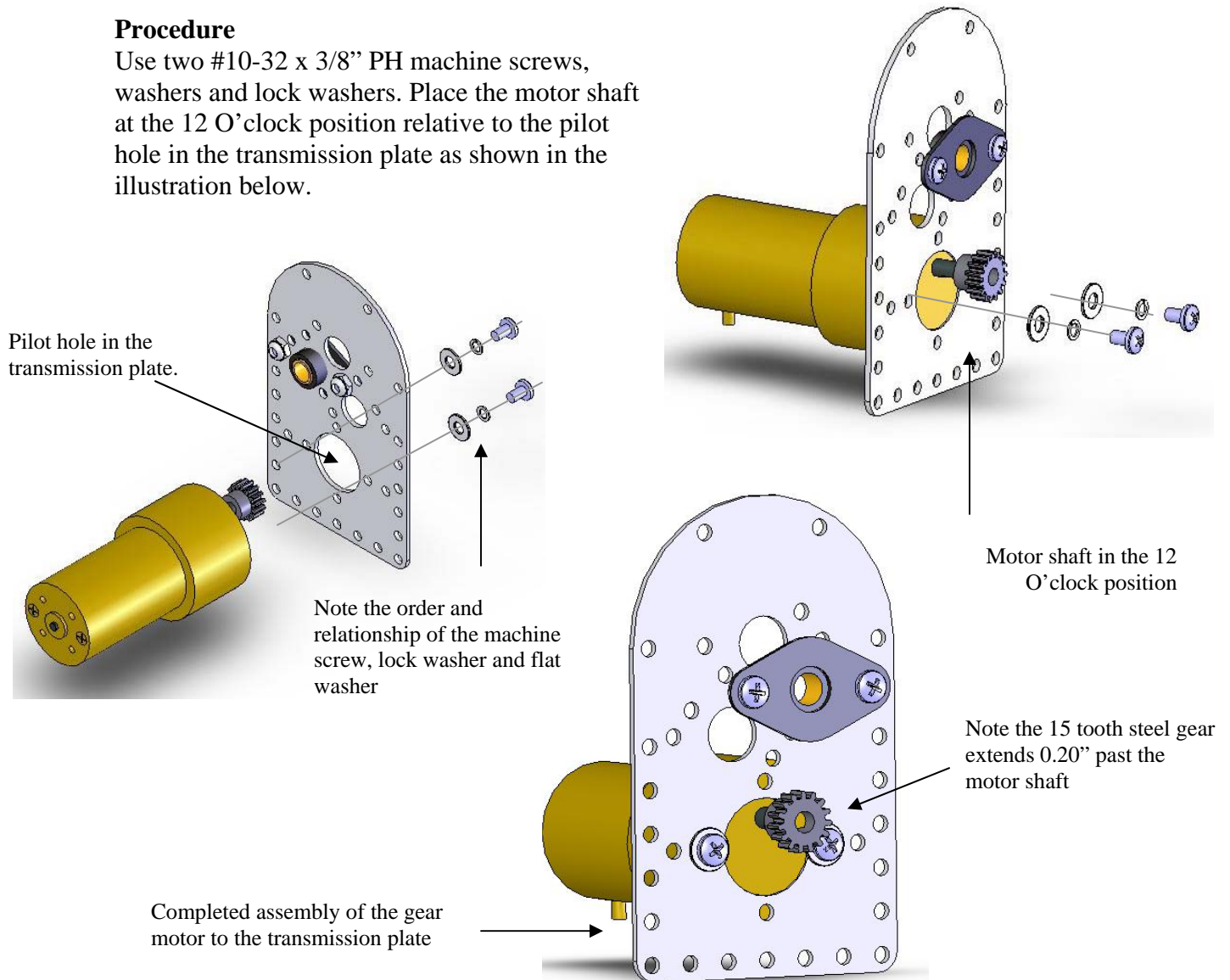
Necessary Components (1c)

Qty. Description

- 1 Gear head motor and spur gear assembly (*From step 3*)
- 2 #10-32 x 3/8" Machine screws
- 2 #10 Flat washers
- 2 #10 Lock washers

Procedure

Use two #10-32 x 3/8" PH machine screws, washers and lock washers. Place the motor shaft at the 12 O'clock position relative to the pilot hole in the transmission plate as shown in the illustration below.



Step Five: Add Standoffs and 7 Hole Angle

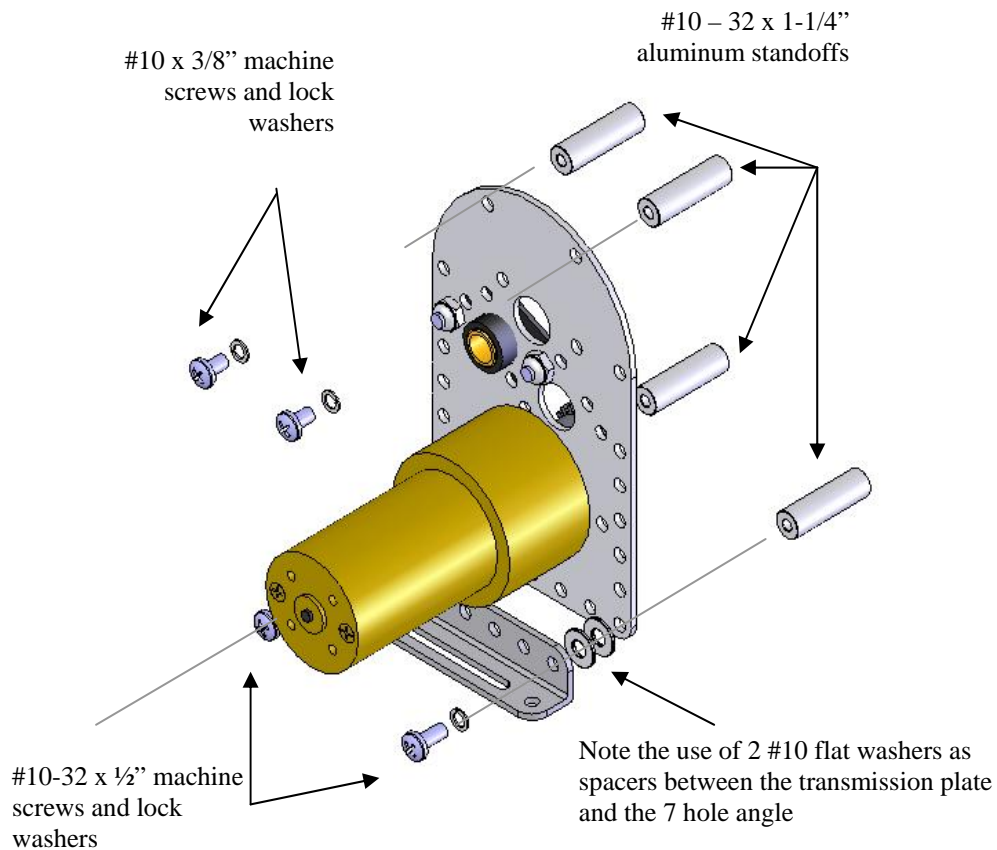
Necessary Components (1d)

Qty.	Description
4	1.25" Long aluminum standoffs
2	#10-32 x 3/8" PH machine screws
2	#10-32 x 1/2" PH machine screws
4	#10 Star or Lock washers
4	#10 Flat washers
1	7 Hole angle

Procedure

Screw the 1.25" standoffs to the transmission plate using #10-32 x 3/8" phillip head machine screws and lock washers as shown in the illustration below.

Secure the 7 hole angle to the transmission plate using #10-32 x 1/2" phillip head machine screws and lock washers. Use two #10 flat washers as spacers between the transmission plate and the 7 hole angle. This is necessary to ensure that the transmission will mount to the standard 1/2" pitch of the GEARS metal and hardware.



Step Four: Assemble 60 Tooth Gear and 3/8" Keyed Shaft

Necessary Components (1e)

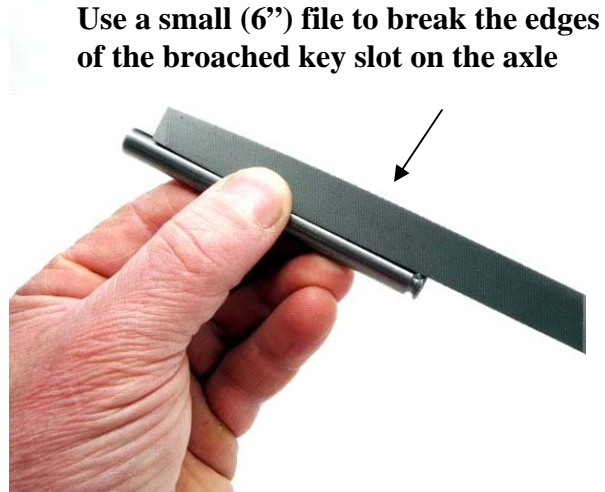
Qty. Description

- 1 60 Tooth gear with 3/32" broached key slot
- 2 #10 – 32 set screws
- 1 4" by 3/8" Steel shaft with 3/32" key slot
- 1 3/32" square x 0.6" keystock

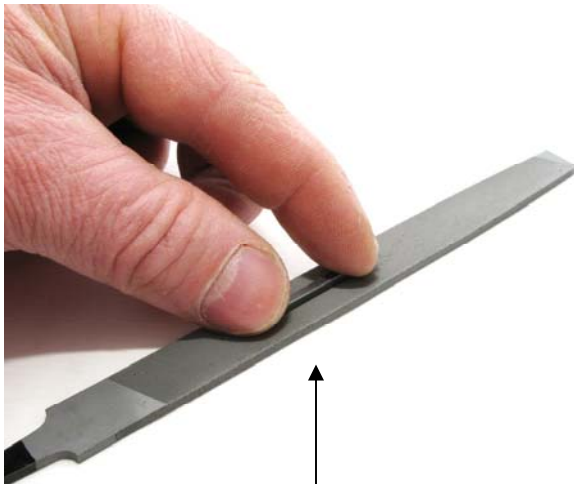
Procedure

Fitting the Key Stock

1. Check to see that the key stock slides easily along the broached key slot in the axle. If it does not, continue following steps 2-4
2. *Use the flat file to break the edges of the key slot along the entire length of the 3/8" dia. x 4" long machined axle. This will help ensure there are no burred metal edges on the axle key slot, and will allow the key stock to slide smoothly in the axle key slot.
3. Test to see if the key stock slides easily. If it still does not fit easily into the key slot continue to step 4.
4. File the key stock. See the picture below. This is easily accomplished by rubbing the key stock along the file to remove a few 0.0001" from the key, until it slides easily in the key slot.



Use a small (6") file to break the edges of the broached key slot on the axle



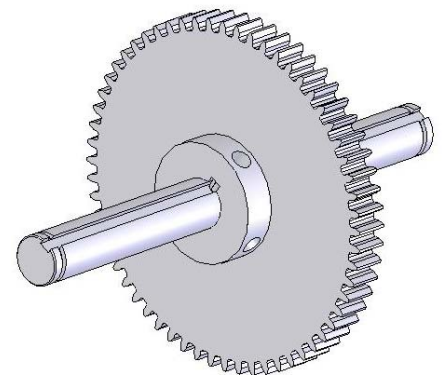
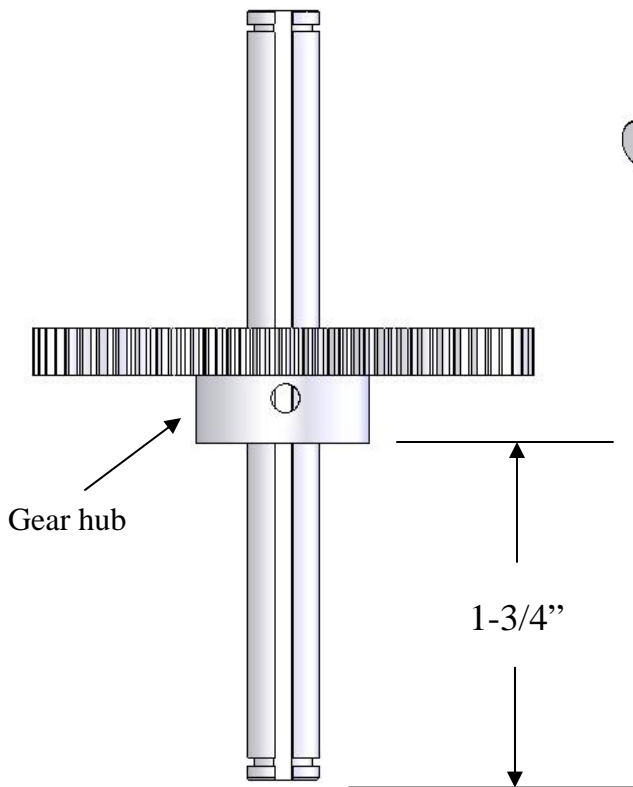
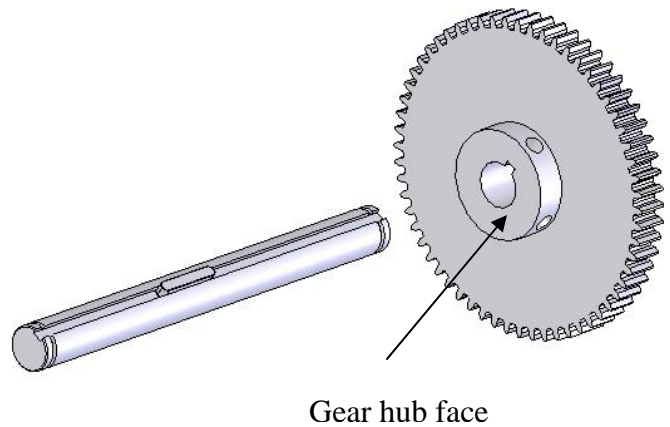
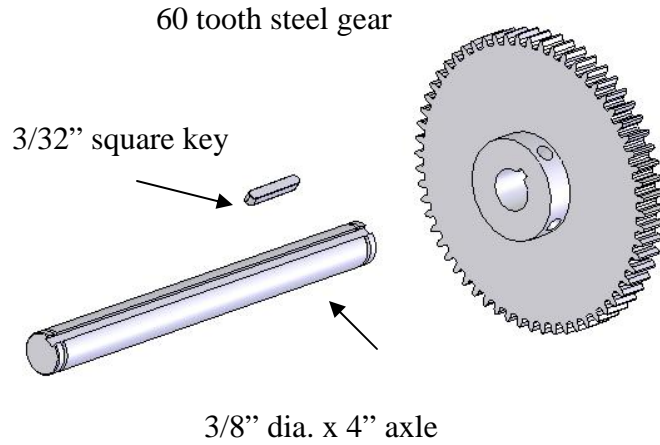
*Note: It may be necessary to "Fit" the keyway to the axle slot. This is easily accomplished by rubbing the key stock along the file to remove a few 0.0001" from the key, until it slides easily in the key slot. This only needs to be done once and it is a standard assembly procedure.

Use a small (6") file to smooth the key and fit it to the broached key slot on the axle

Fit the 60 Tooth Gear to the Axle

Prior to beginning this assembly, make certain the 3/32" x 0.6" key slides smoothly along the broached key slot in the axle. Refer to the procedure on the preceding page for detailed instructions on fitting the key.

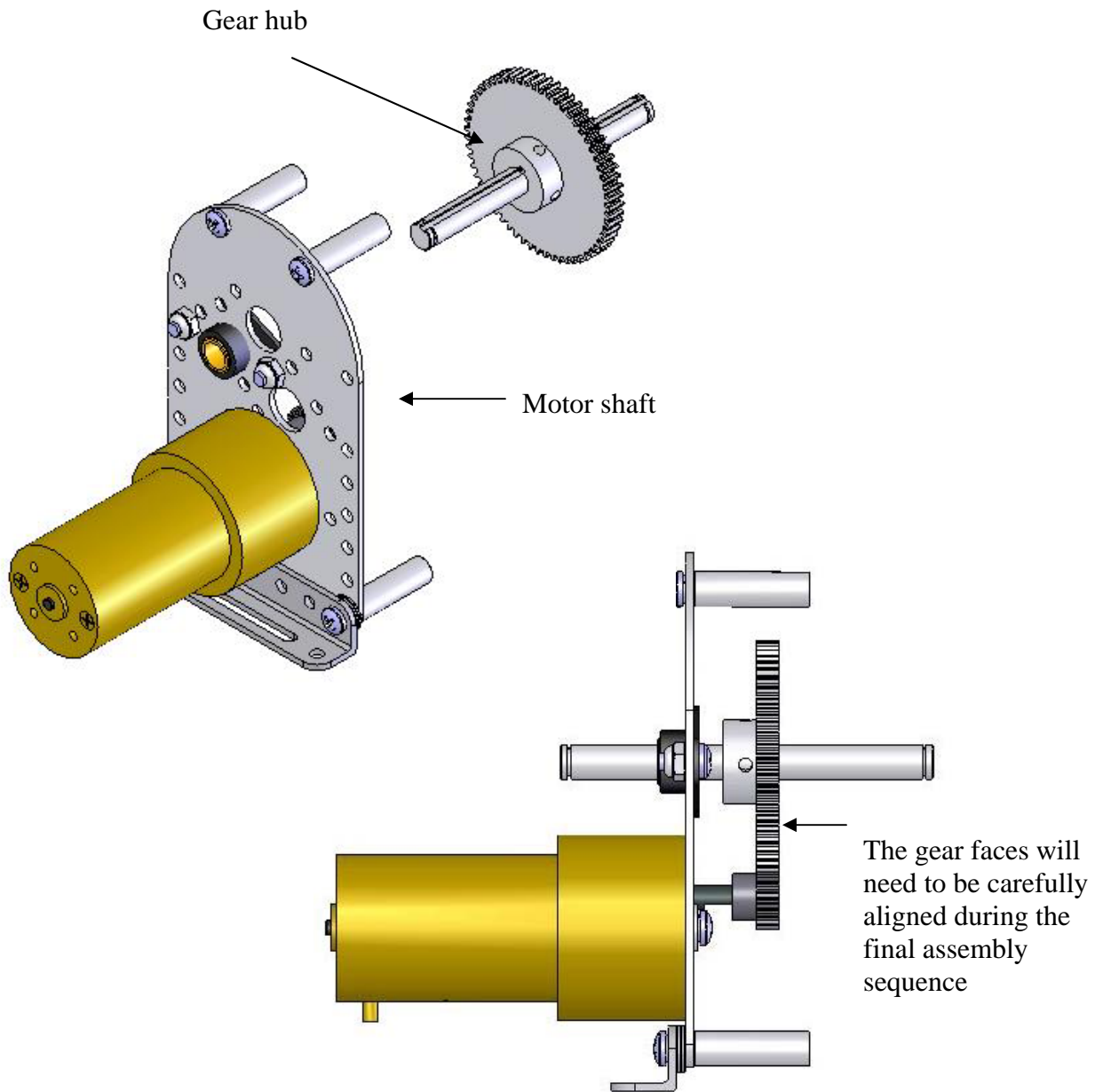
1. Slide the 0.60" keyway onto the shaft
2. Slide the 60 tooth gear onto the end of the 4" x 3/8" shaft.
3. Position the key flush with the outside face of the gear hub.
4. Slide the 60 tooth gear onto the shaft and key. Position the face of the gear hub approximately 1-3/4" from the end of the axle. Gently tighten the set screw onto the key. Do not tighten the second set screw at this time as it will be necessary to make final adjustments to the position of the gear later in the assembly.



Step Five: Fit the Gear and Axle Assembly to the Transmission Plate and Bearing

105 Webster St. Hanover Massachusetts 02339 Tel. 781 878 1512 Fax 781 878 6708 www.gearseds.com

1. Orient the gear and axle assembly as shown in the illustration below. The 60 tooth gear hub faces the motor shaft.
2. Slide the axle into the flanged bearing and align the 15 and 60 tooth gears as shown. Temporarily align the face of the gears.



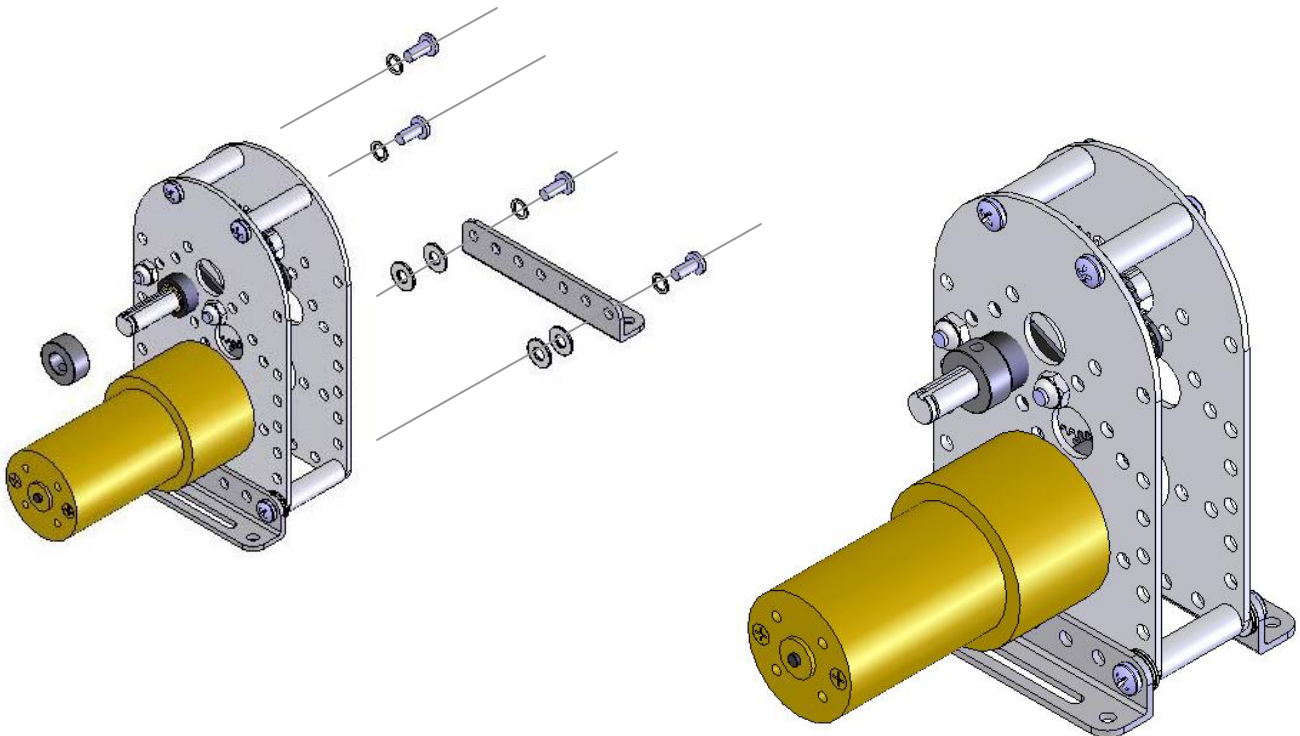
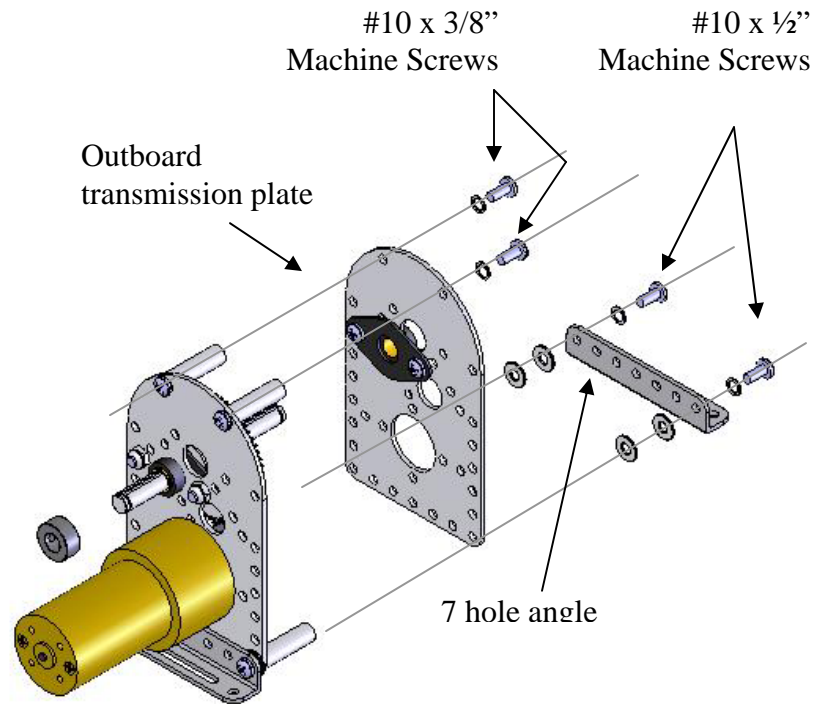
Step Five: Assemble the Outboard Transmission Plate

Necessary Components (1f)

Qty.	Description
2	#10-32 x 3/8" PH machine screws
2	#10-32 x 1/2" PH machine screws
4	#10 Star or Lock washers
4	#10 Flat washers
1	7 Hole angle
1	3/8" ID shaft collar

Procedure

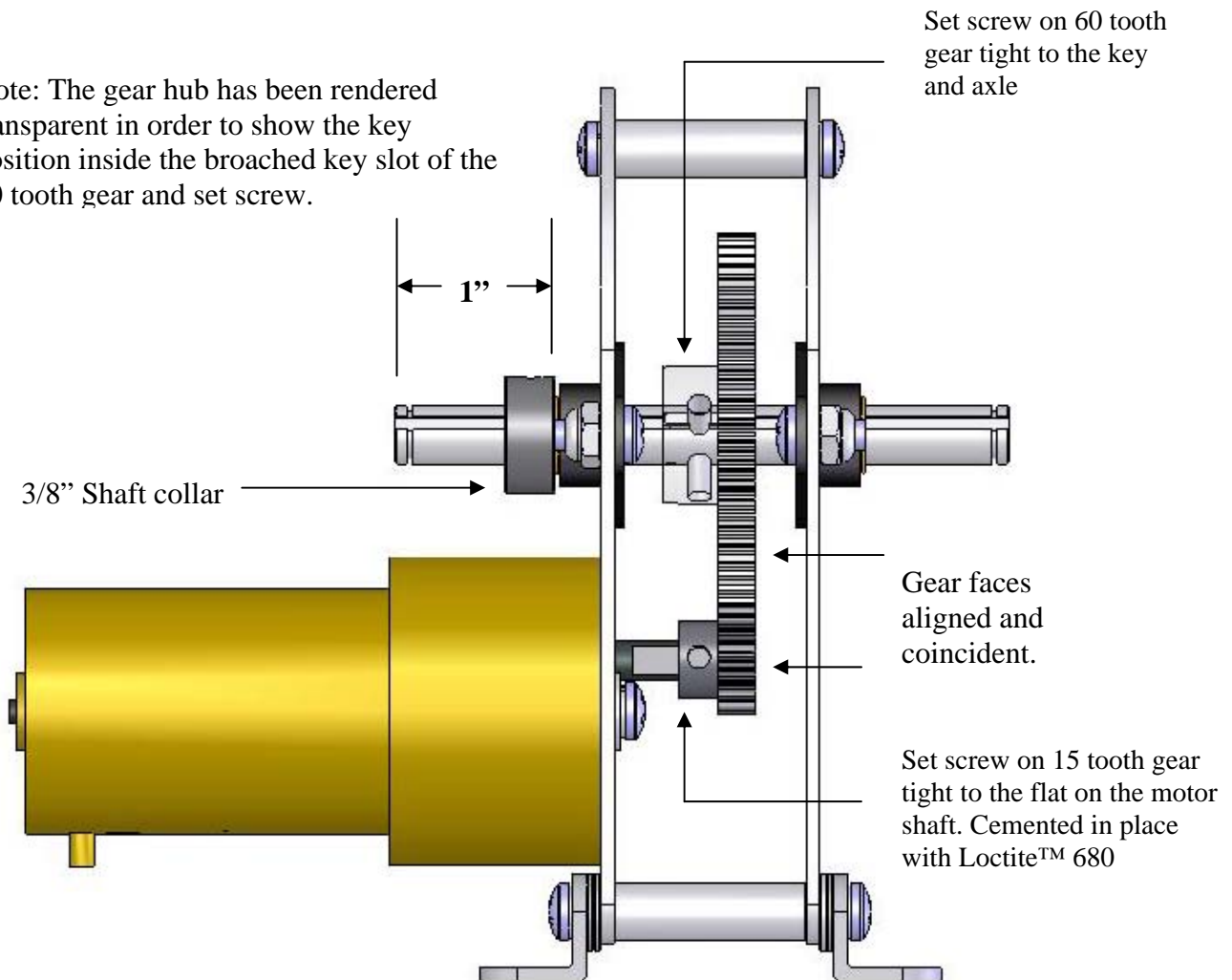
1. Attach the outboard transmission plate to the standoffs as shown



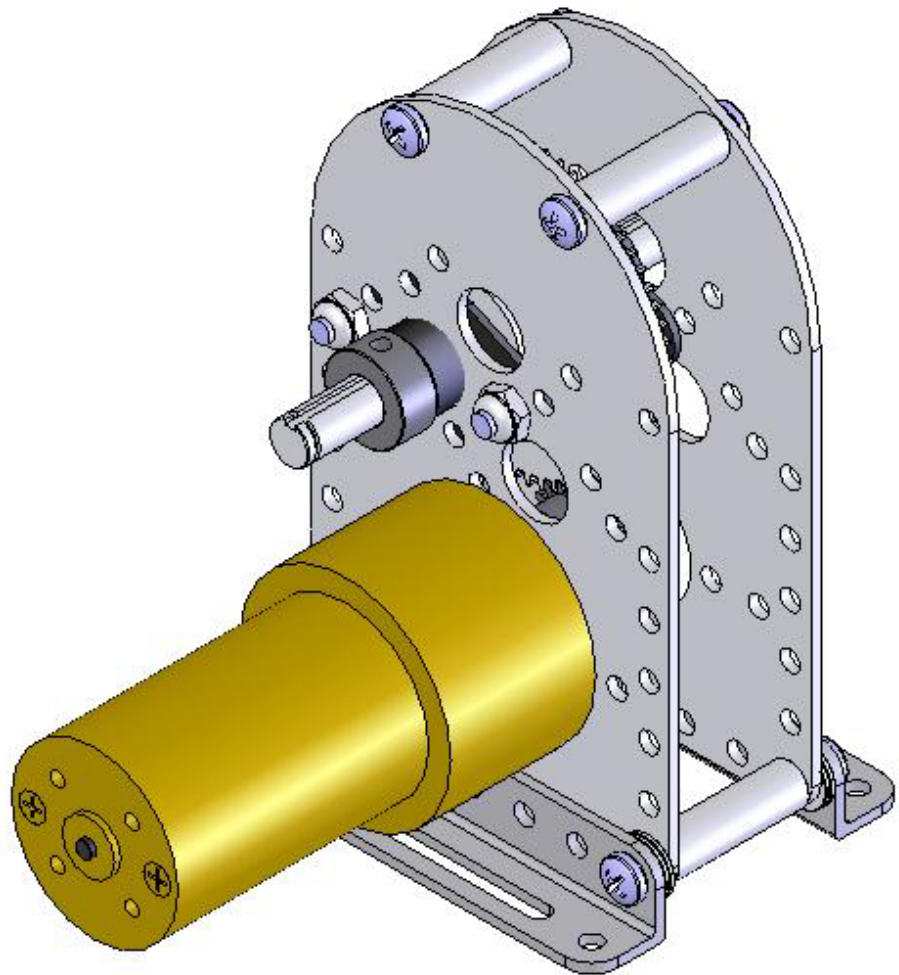
2. Loosen the set screws on the 60 tooth gear, and 3/8" shaft collar.

3. Slide the 3/8" x 4" axle into position as shown in the illustration below. The 3/8" axle should extend beyond the bearing of the outboard transmission plate, a distance of a 1" (minimum) to 1.1" (maximum).
4. With the axle positioned correctly, lock the shaft collar onto the axle by tightening the shaft collar set screw onto the axle. **Do not tighten the shaft collar set screw onto the broached key slot in the axle.** This will damage the key slot which will need to be repaired by careful and time consuming filing.
5. With the shaft collar secured to the axle and the inside face of the shaft collar tight to the bearing face, align the 60 tooth gear into alignment with the 15 tooth gear on the motor shaft. See the illustrations below.
6. Hold the axle, shaft collar and 60 tooth gear in position and tighten the set screws on the 60 tooth gear. Make certain that the set screw in the broached key slot, fully captures the gear, key and axle. This gear, key and axle assembly is a common and optimal method for affixing a component to a shaft.

Note: The gear hub has been rendered transparent in order to show the key position inside the broached key slot of the 60 tooth gear and set screw.



Completed Transmission Module



The GEARS
Transmission
Module can be used
as a stand alone

educational construction activity with which students and teachers can develop lessons that include some or all of the following STEM skills and concepts;

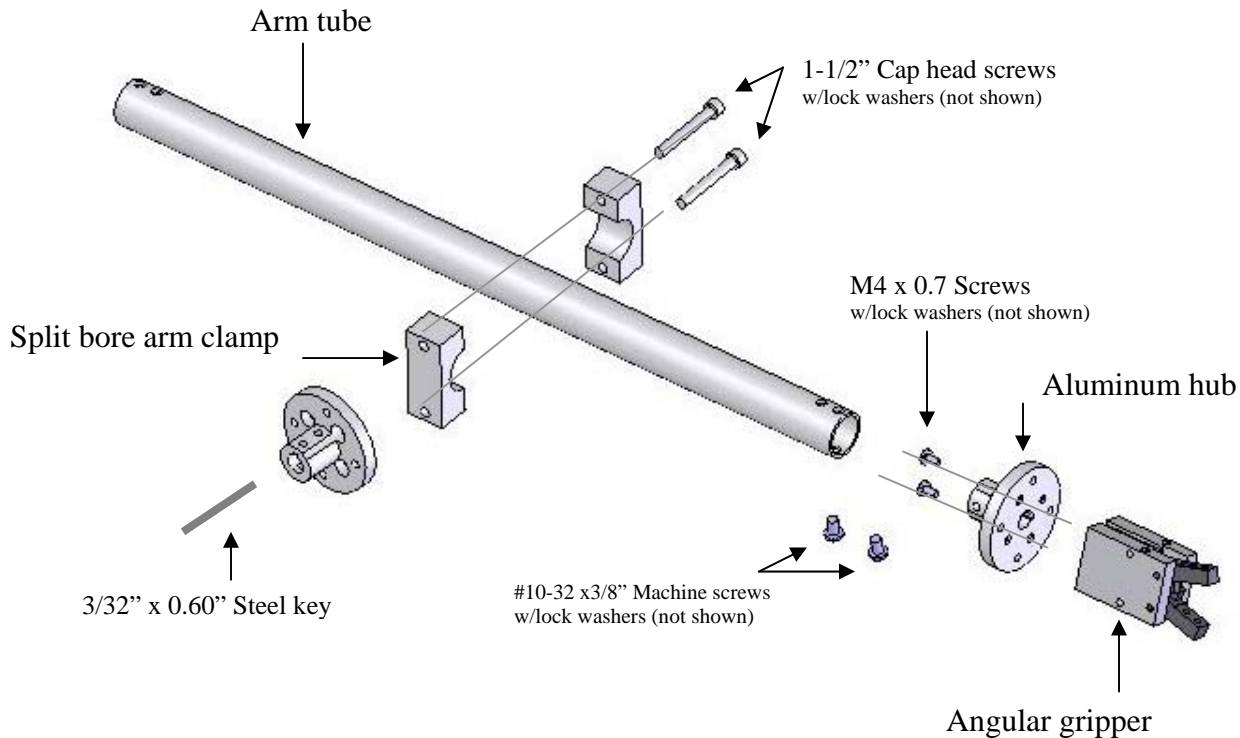
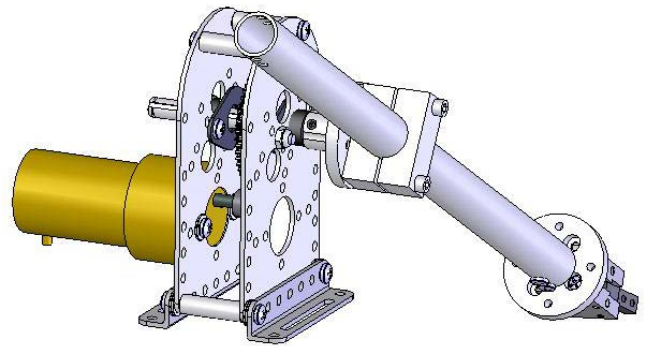
DC Motor Fundamentals
Generator Fundamentals
Machine Screw Fasteners
Bearings
Keyway Applications
Gear Pitch Math
Computing Gear Centers

Measure RPM
Measure Torque
Measure Voltage
Measure Current
Voltage/RPM relationship
Torque/Current Relationship
Calculate Efficiency

Read Specifications
Power and Energy
Design Gears in CAD
Create CAD Models
Calculate Surface Area
Measure plate Area and Volume
Measure plate Mass
Calculate Plate Density

Adding the Arm and Gripper Assembly to the Transmission

Step One: Inventory the Parts and Tools
Collect and layout the arm components listed and shown below.



Necessary Components (2a)

Qty.	Description
2	3/8" Bore keyed aluminum hubs
2	#10-32 x 3/16" Set screws (for hubs)
4	#10 lock washers
1	3/32" x 3/32" x 0.60" Steel key
2	1/2" thick split bore arm clamps
1	0.875" x 16" Arm Tube
2	#10-32 x 3/8" Machine screws (black)
2	#10-32 x 1-1/2" cap head machine screws
1	Pneumatic gripper kit (<i>see right panel</i>)

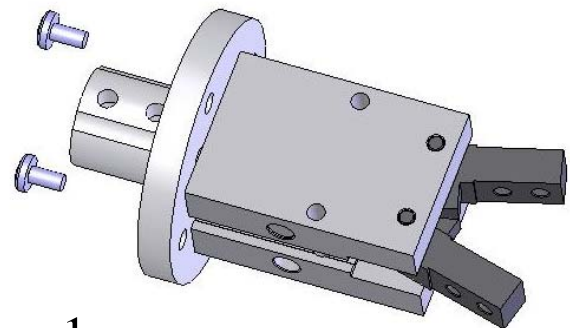
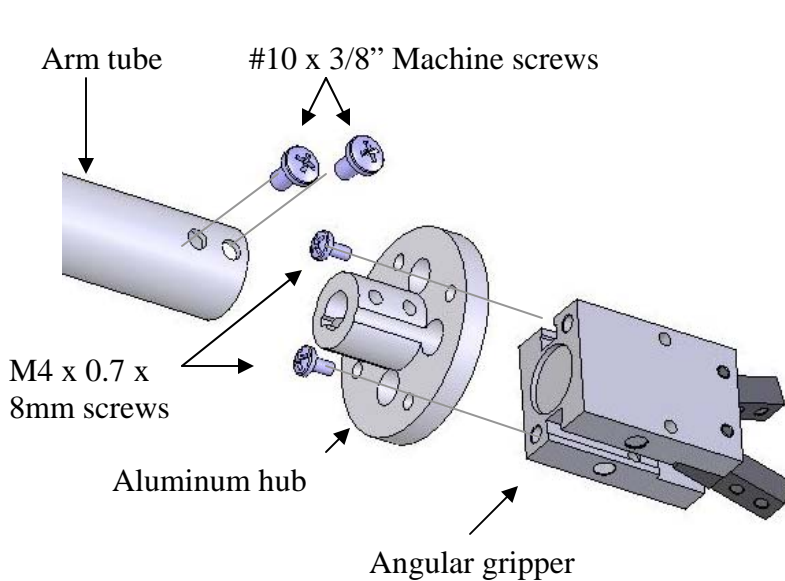
Pneumatic Gripper Kit

1	16mm Bore angular gripper
3	Quick disconnects for 4mm tube
1	4mm "Y" adapter
1	Muffler
1	Plastic tube plug
2	GEARS Servo brackets for gripper finger adapters
2	Feet 4mm tubing
1	3/2 Solenoid valve
4	M 2.5 x .45 x 6mm ph machine screws
4	2.5mm flat washers
4	2.5mm lock washers
2	M4 x 0.7 x 8mm long ph machine screws
2	M4 lock washers

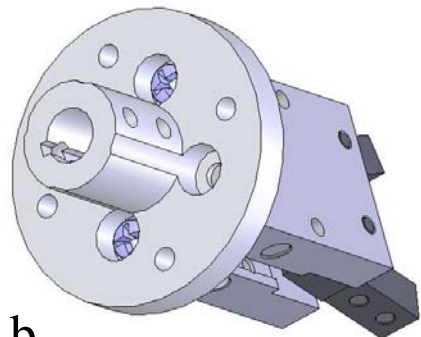
Step Two: Construct the Angular Gripper and Arm Assembly

Procedure

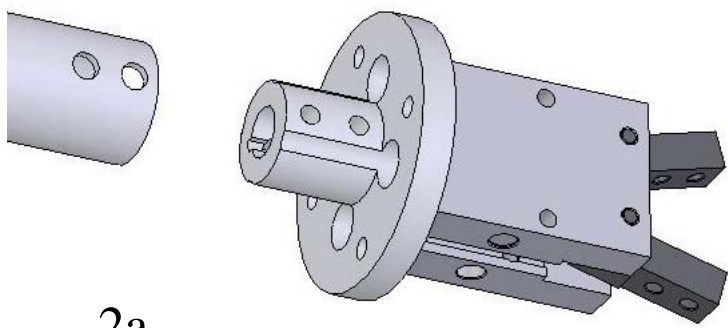
1. Fasten the aluminum hub to the angular gripper using (2) M4 x 0.7 x 8mm long PH screws and lock washers (*lock washers not shown in illustration*)
2. Fasten the Aluminum hub and gripper assembly to one end of the arm tube using (2) #10-32 x 3/8" Machine screws (black)



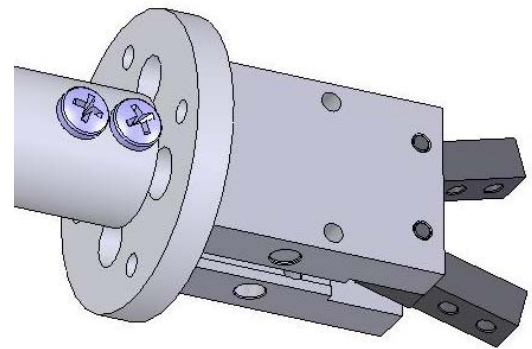
1a



1b



2a



2b

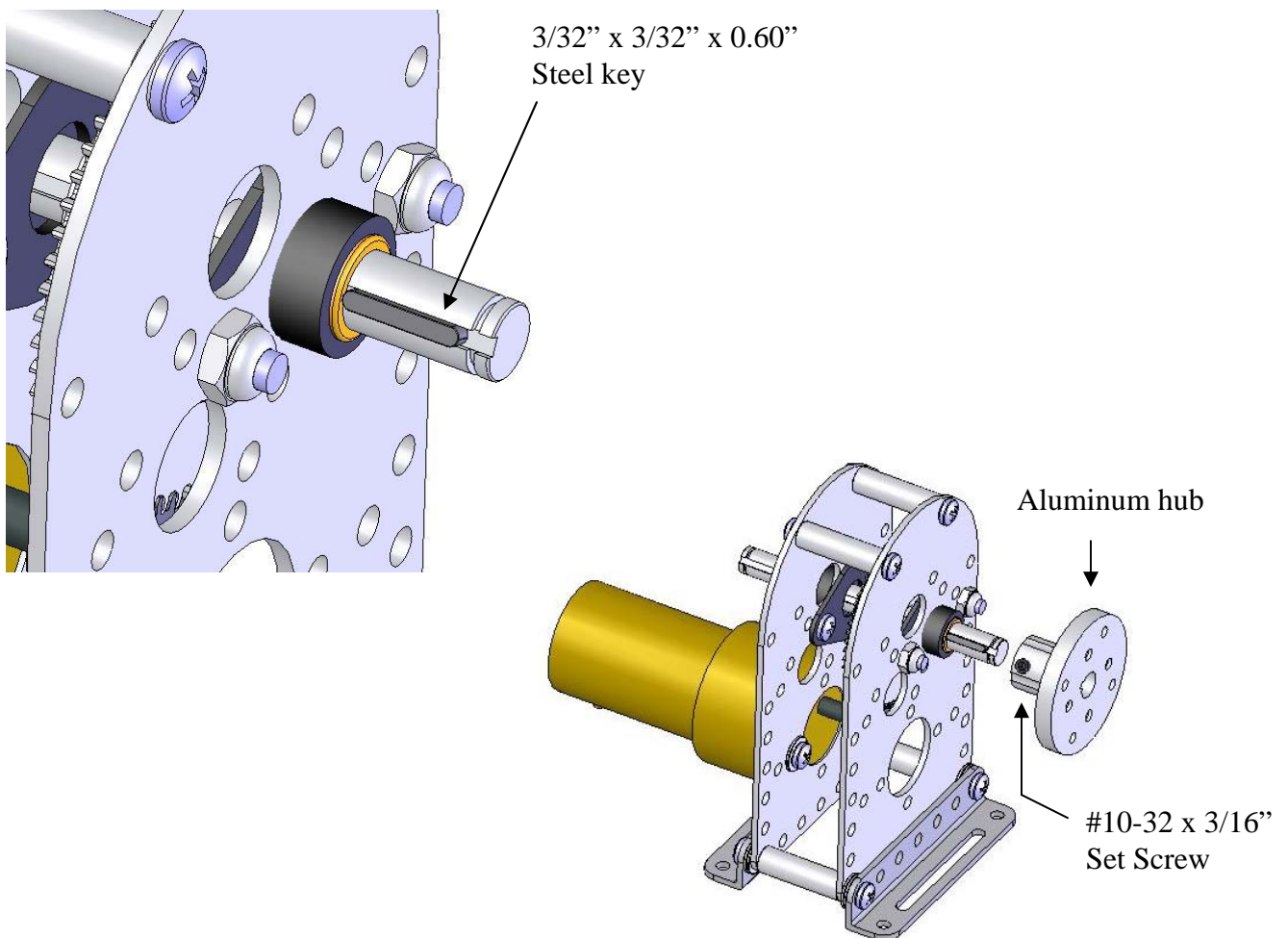
Step Three: Attach the Aluminum Hub to the Transmission

Necessary Components (from 2a)

Qty.	Description
1	3/32" x 3/32" x 0.60" Steel key
2	3/8" Bore keyed aluminum hubs
1	#10-32 x 3/16" Set screw

Procedure

1. Fasten the aluminum hub to the outboard end of the 3/8" axle.
2. Slide a 3/32" x 3/32" x 0.60" Steel key into the key slot on the axle.
3. Fit the aluminum hub to the axle and key.
4. Fix the aluminum hub to the axle by tightening the set screw onto the key and axle.



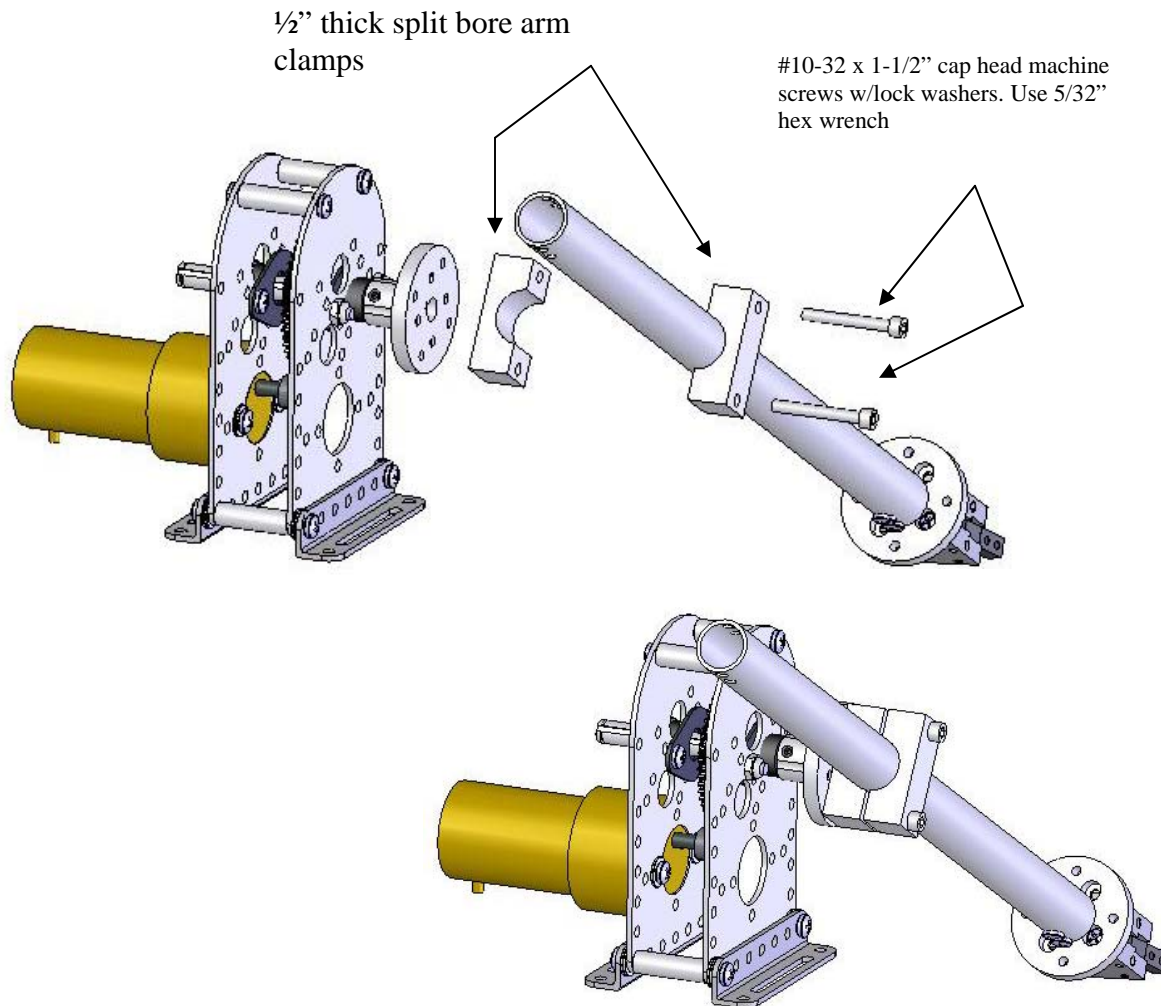
Step Three: Attach the Arm Assembly to the Aluminum Hub on the Transmission

Necessary Components (from 2a)

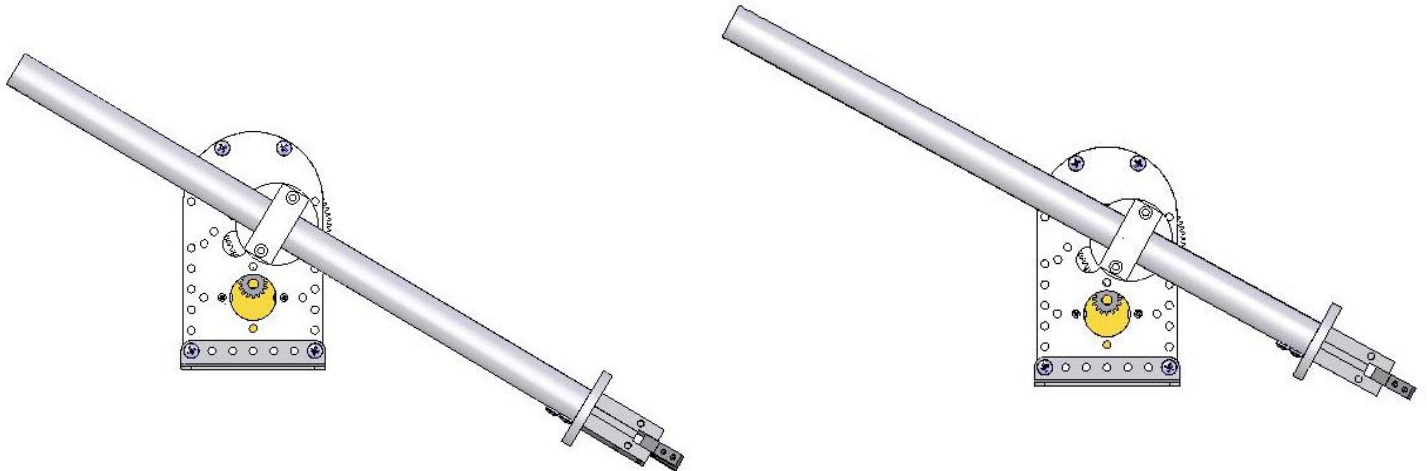
Qty.	Description
2	1/2" thick split bore arm clamps
2	#10-32 x 1-1/2" cap head machine screws
2	#10-32 lock washers

Procedure

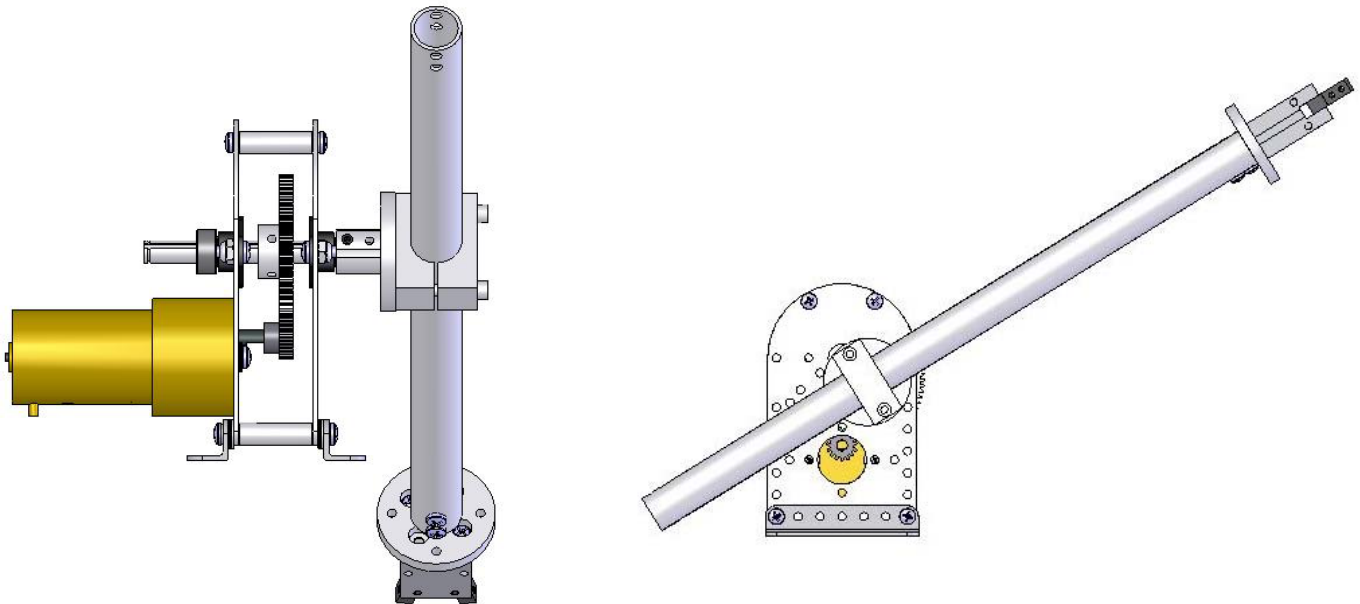
1. Fasten the arm and gripper assembly to the aluminum hub on the transmission using the 1/2" thick split bore arm clamps and the #10-32 x 1-1/2" cap head machine screws
2. Adjust the arm extension by loosening the #10-32 x 1-1/2" cap head machine screws and sliding the arm to the desired position.
3. Tighten the #10-32 x 1-1/2" cap head machine screws to secure the arm
Use a 5/32" hex wrench.



Multiple Views of the Arm and Transmission Assembly



Arm shown fixed in two different extensions



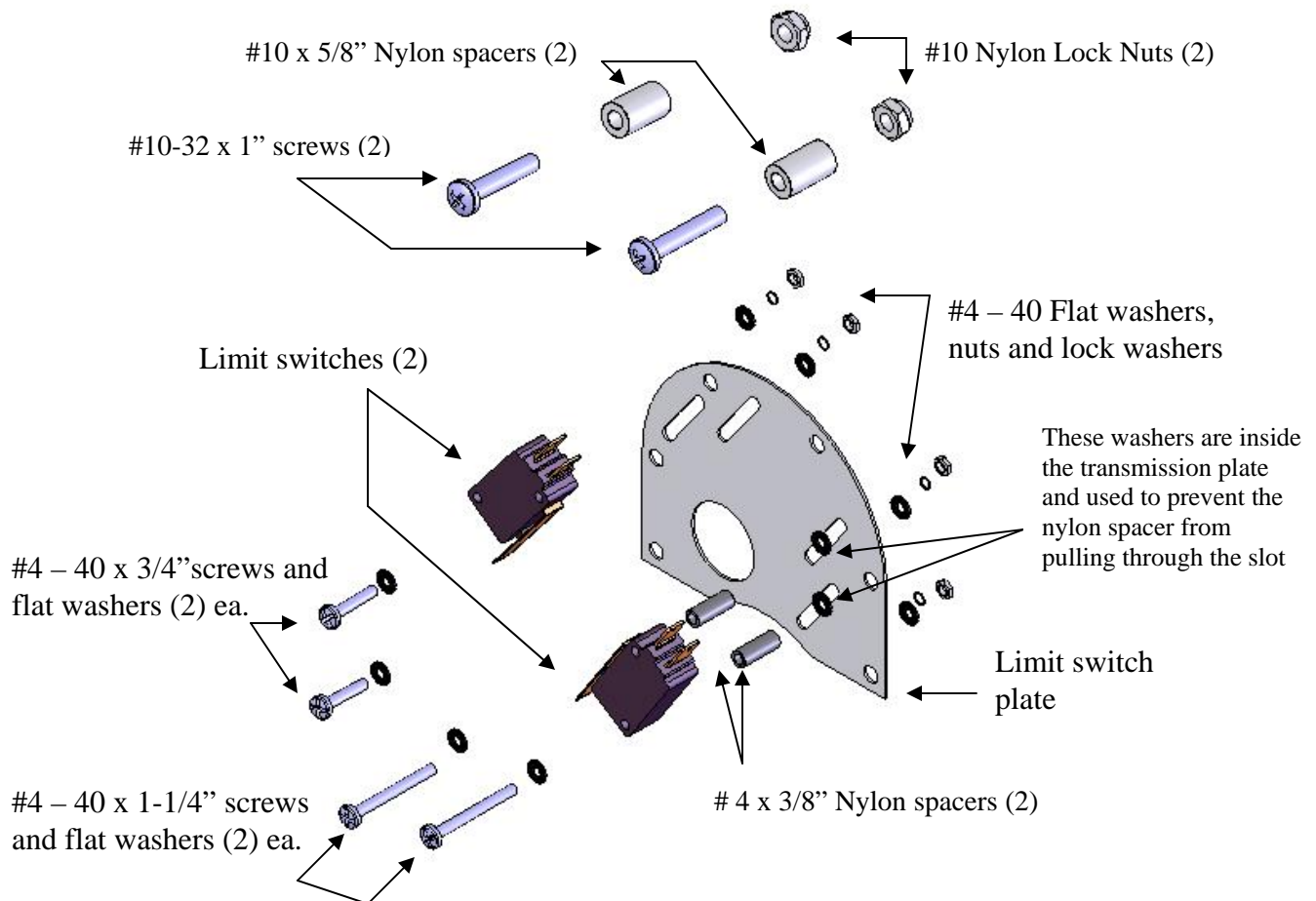
Rear view and side View

Assemble and Mount the Limit Switch Plate Assembly

Step One: Inventory the Parts and Tools Collect and layout the limit switch plate components listed below.

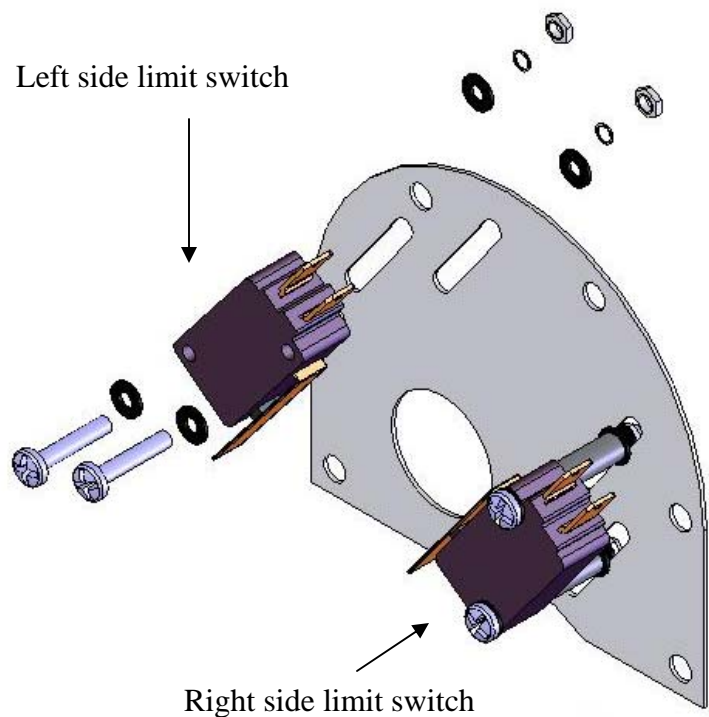
Necessary Components (3a)

Qty.	Description
1	Limit switch plate
2	Limit Switches
2	4-40 x 1-1/4" PH machine screws
2	4-40 x 3/4" PH machine screws
10	4-40 flat washers
4	4-40 lock washers
4	4-40 hex nuts
2	#10-32 x 1" PH machine screws
2	#10 x 3/8" dia x 5/8" long nylon spacers
2	#10-32 Nylon locking nuts
2	#4 x 0.190 dia x 3/8" long nylon spacers
2	Limit Switch Cams
2	#10-32 set screws (not shown)

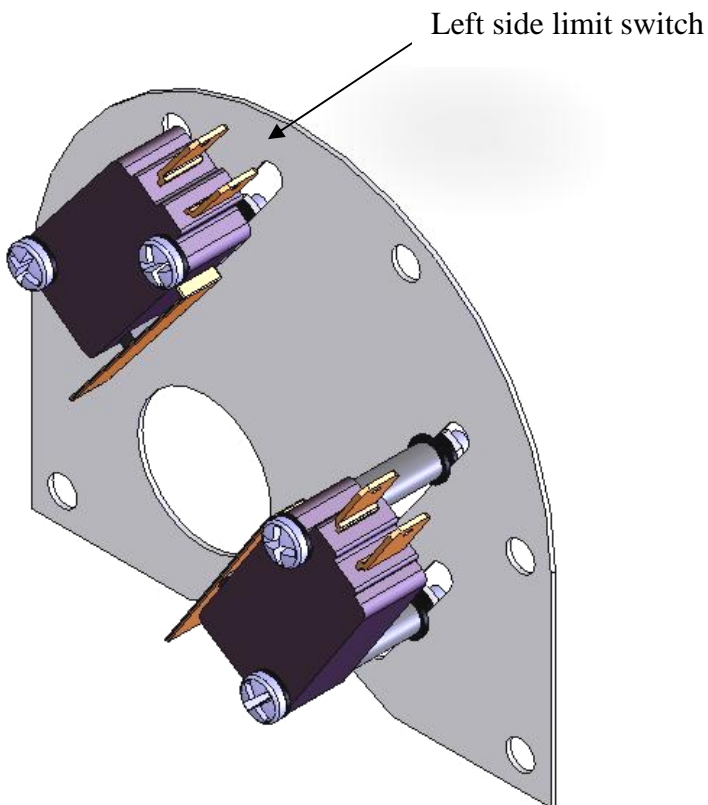


Step Two: Mount the Right Limit Switch to the Limit Switch Plate

1. Orient the right side limit switch and plate as shown in the illustration on the preceding page and on the right.
2. Fasten the right side limit switch to the plate using (2) #4-40 x 1-1/4" screws, flat washers, lock washers hex nuts and #4 x 0.190" dia. x 3/8" long nylon spacers as shown.
3. Hand tighten the limit switch fasteners for the moment, as they will need to be adjusted during final assembly.



Note: Nylon spacers are not needed for mounting the left side limit switch. Mount the limit switch directly to the plate as shown below.

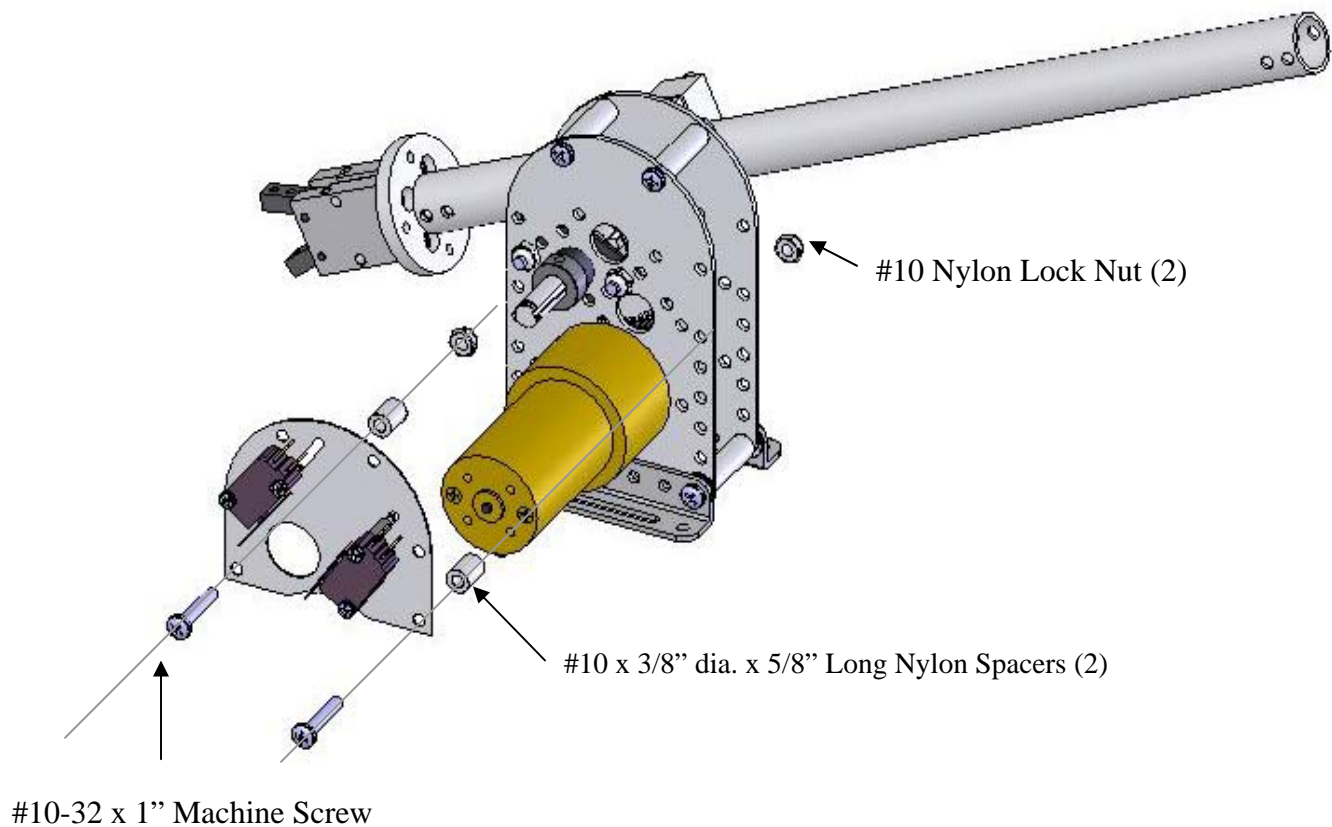


Step Three: Mount the Left Limit Switch to the Limit Switch Plate

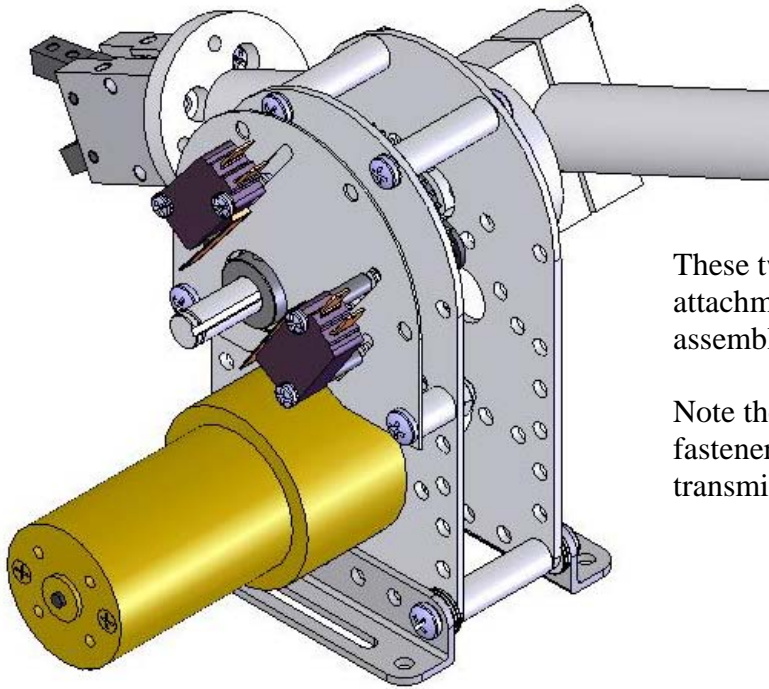
1. Orient the limit switch and plate as shown in the illustration on the left.
2. Fasten the limit switch to the plate using (2) #4-40 x 3/4" screws, flat washers, lock washers and hex nuts.
3. Hand tighten the limit switch fasteners as they will need to be adjusted during final assembly.

Step 4: Mount the Limit Switch Plate Assembly to the Transmission

1. Orient the limit switch plate assembly and transmission as shown below.
2. Fasten the limit switch plate assembly to the transmission to the plate using (2) #10-32 x 1" machine screws, #10 x 3/8" dia. x 5/8" long nylon spacers and #10 locking nuts.
3. Hand tighten the limit switch plate assembly fasteners as they will need to be adjusted during final assembly.

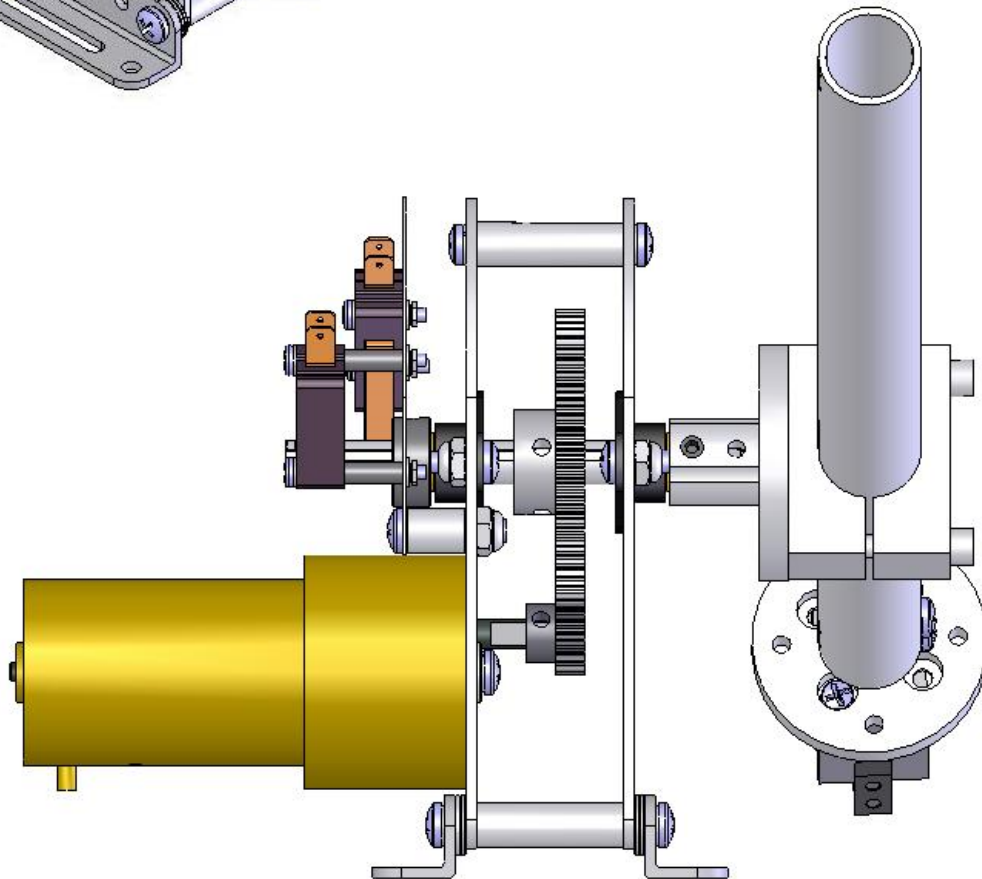


Step 4: Mount the Limit Switch Plate Assembly to the Transmission (cont'd)



These two graphic show the proper attachment of the limit switch plate assembly to the transmission plate

Note the attachment points of the fasteners and nylon spacers to the transmission plate.

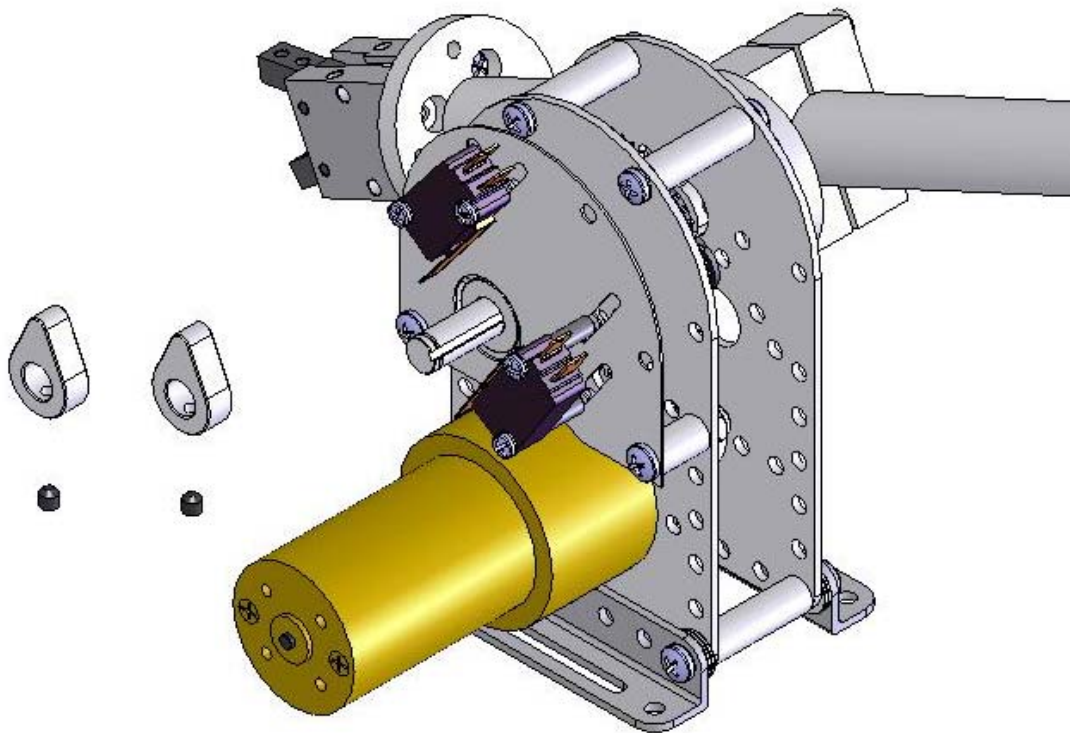


Step 5: Mount the Limit Switch Cams to the Axle

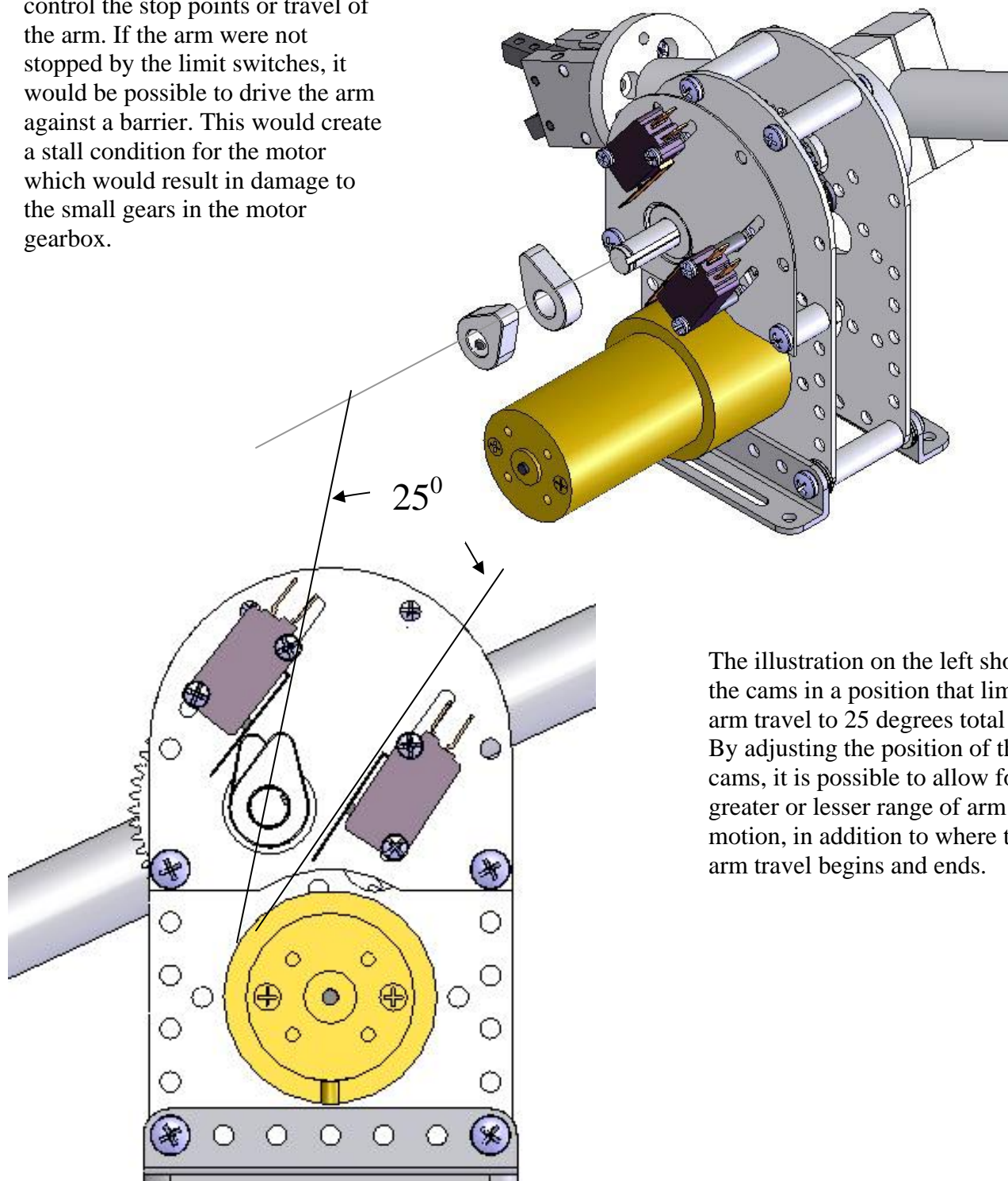
1. Thread the set screws (2) into the limit switch cams.
2. Using a battery to power the motor, position the arm in the desired (lowered or raised) position.
3. Slide one limit switch cam onto the axle and position the cam so that it just closes the innermost limit switch. Gently tighten the cam set screw to hold it in place.

Note: It will likely be necessary to readjust the cams to obtain optimum control of lowered or raised arm positions.

4. Using the battery set the arm to the other desired position.
5. Slide the remaining limit switch cam onto the axle and position the cam so that it just closes the outermost limit switch. Gently tighten the cam set screw to hold it in place.




The limit switches are used to control the stop points or travel of the arm. If the arm were not stopped by the limit switches, it would be possible to drive the arm against a barrier. This would create a stall condition for the motor which would result in damage to the small gears in the motor gearbox.



The illustration on the left shows the cams in a position that limits the arm travel to 25 degrees total range. By adjusting the position of the cams, it is possible to allow for greater or lesser range of arm motion, in addition to where the arm travel begins and ends.

How Limit Switches and Diodes Control Motor Direction

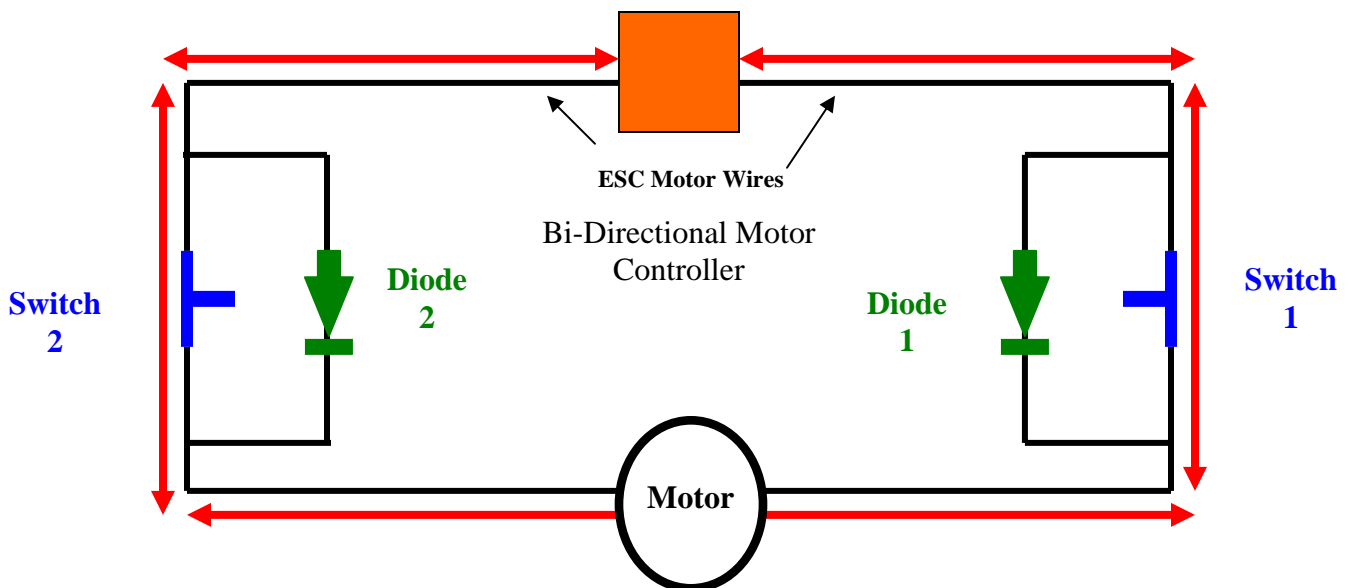
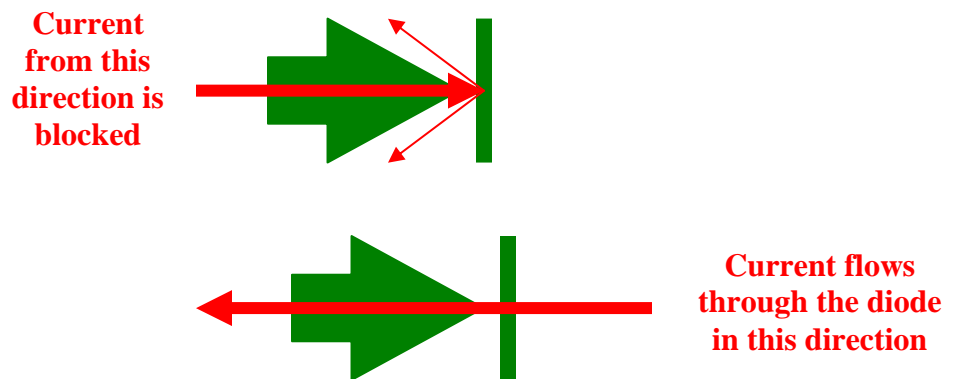
Study the electric circuit schematic at the bottom of the page.

The blue “T’s”  are schematic symbols for a (limit) switch.

The green arrows with a blocking line  are schematic symbols for a diode.

Diodes are one way valves for current.

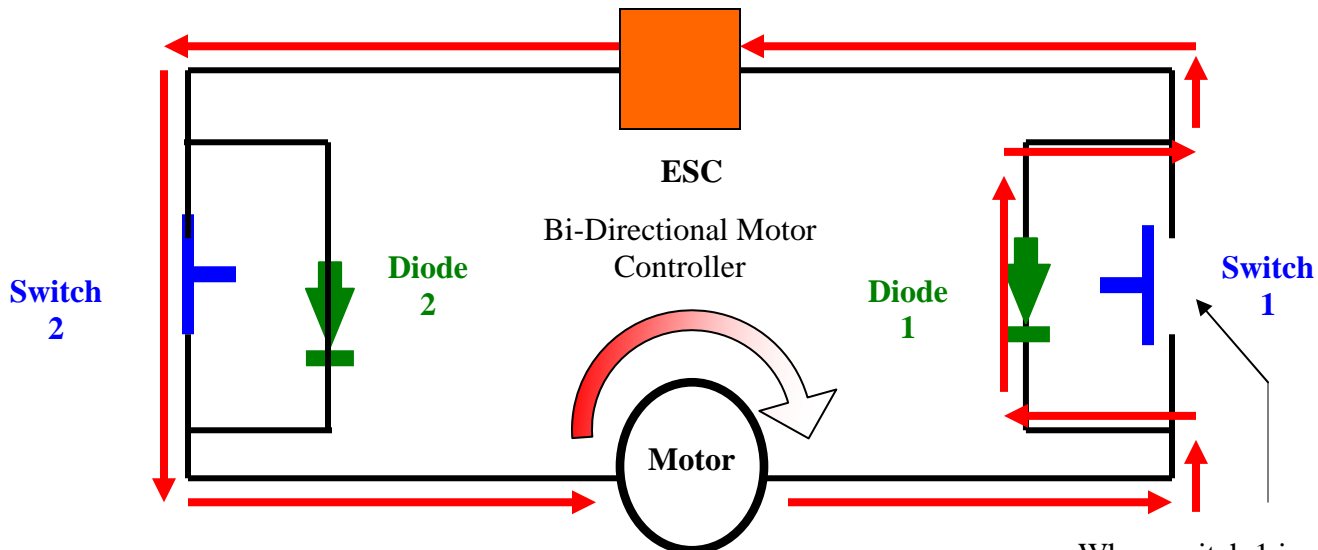
The arrow head hitting the blocking line illustrates the direction in which the current is blocked.



In the schematic diagram above, both **switches** are wired normally closed, and the current (Red arrows) can bypass the diodes and flow through the circuit in both directions

Current Direction Determines Motor Rotation

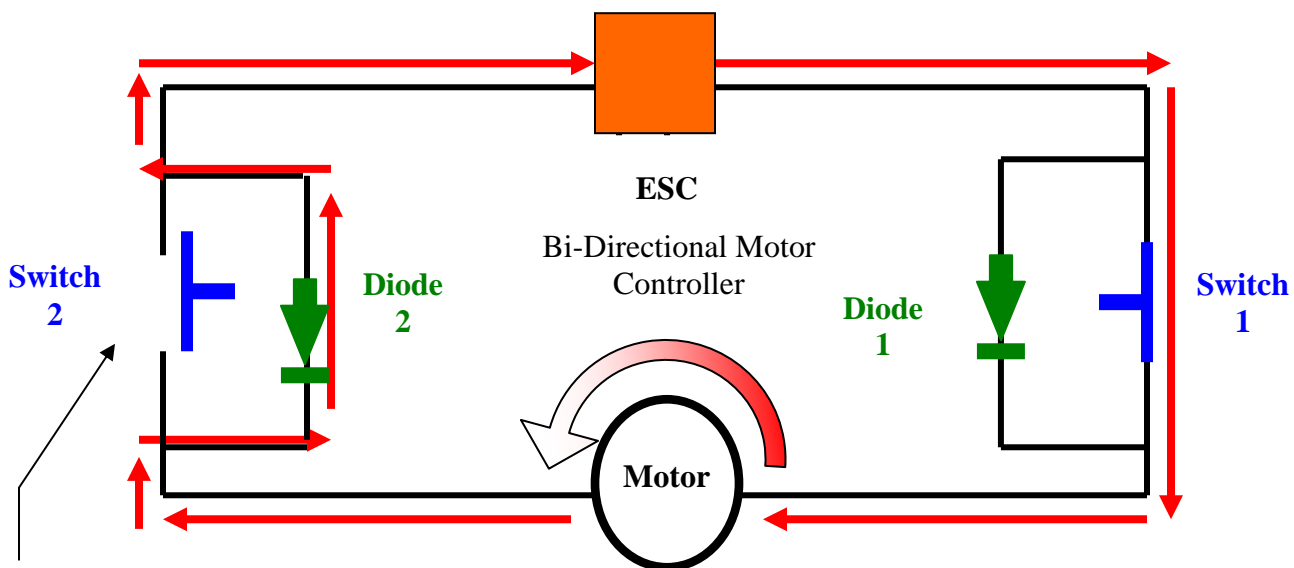
In the schematic diagram below, **Switch 1** is open, and the current (Red arrows) must pass through the **Diode 1**. With **Switch 1** open, current can flow through **Diode 1** and thus through the circuit only in the direction shown.



The motor rotation direction is determined by the current direction through the circuit.

When switch 1 is open the current can flow through diode 1 only in the direction shown.

In the schematic diagram below, **Switch 2** is open, and the current (Red arrows) must pass through the **Diode 2**. With **Switch 2** open, current can flow through **Diode 2** and thus through the circuit only in the direction shown.



When switch 2 is open the current can flow through diode 2 only in the direction shown

The motor rotation direction is determined by the current direction through the circuit.

Step 6: Wiring the Limit Switches and Diodes to Control the Stopping and Direction of a Motor

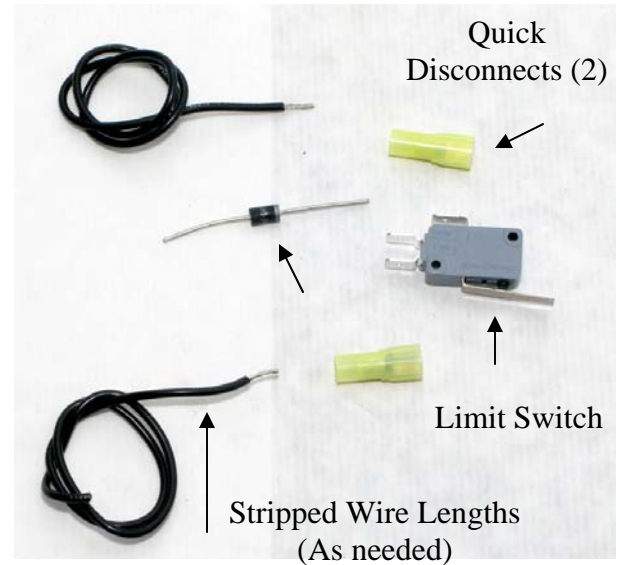
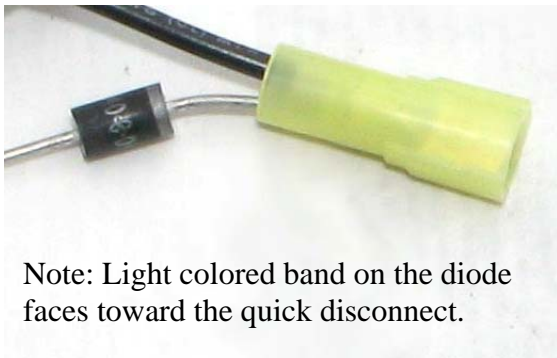
Necessary Components (3b)

Qty.	Description
4	12-14 gauge x 1/4" female insulated quick disconnects
2	Diode
2	Limit Switch
4	* Feet of 16 gauge wire
1	Motor Speed Controller

**(Note: Wire length is dependent on the placement of the completed transmission unit relative to the motor controller, batteries etc. and must be determined by the user)*

Procedure

1. Assemble the necessary components
2. Strip the ends of the 16 gauge wire back @ 3/8"
3. Twist the wire around the diode lead marked with a silver stripe. Insert the diode and wire pair into the quick disconnect.
4. Using a pair of wire crimps, crimp the diode, wire and quick connect assembly firmly in place. Test the crimped attachment by pulling on the wire and diode.

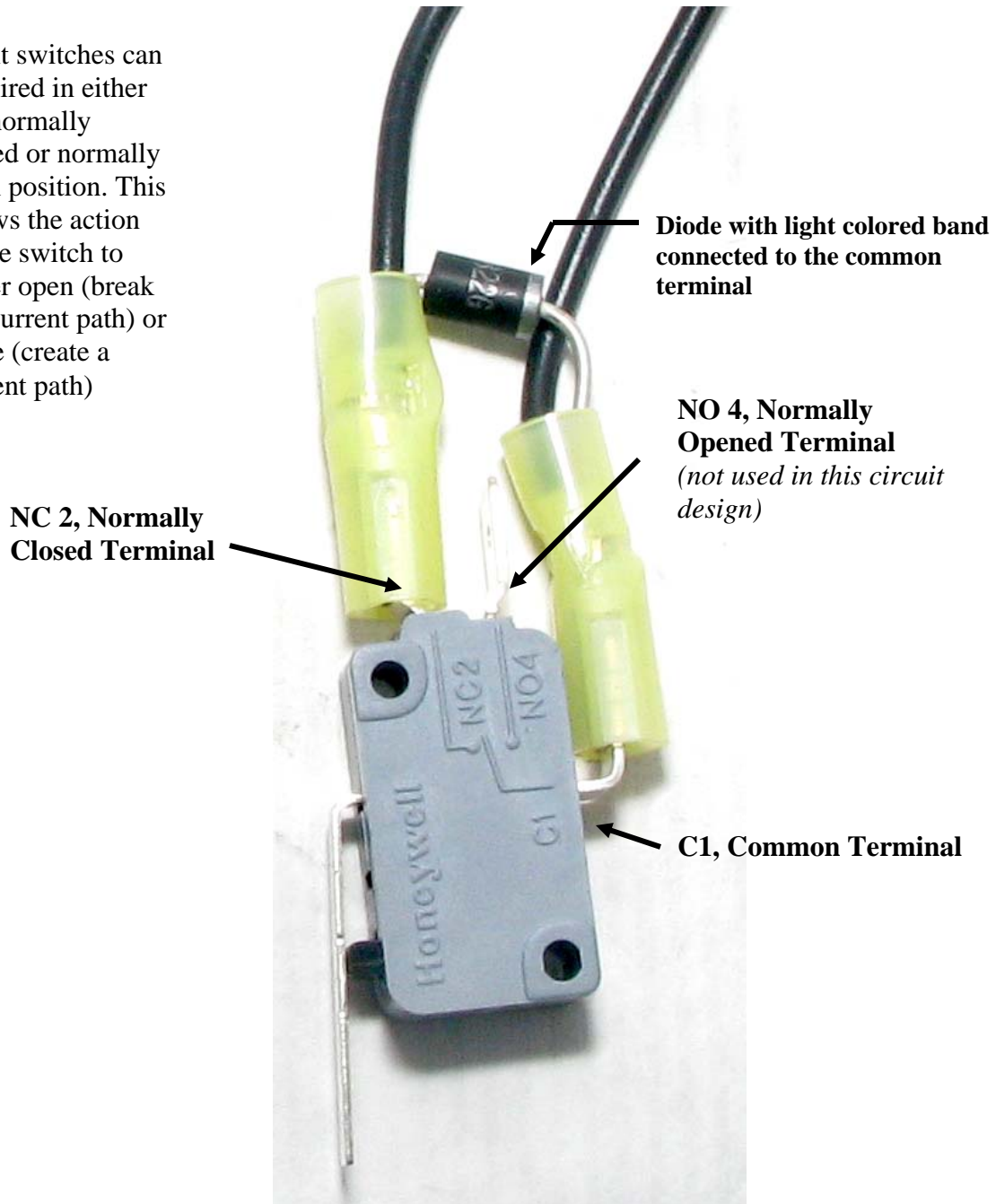


Use crimping tool to secure the wire and diode lead to the quick disconnect

Step 6: Wiring the Limit Switches and Diodes to Control the Stopping and Direction of a Motor *(Continued)*

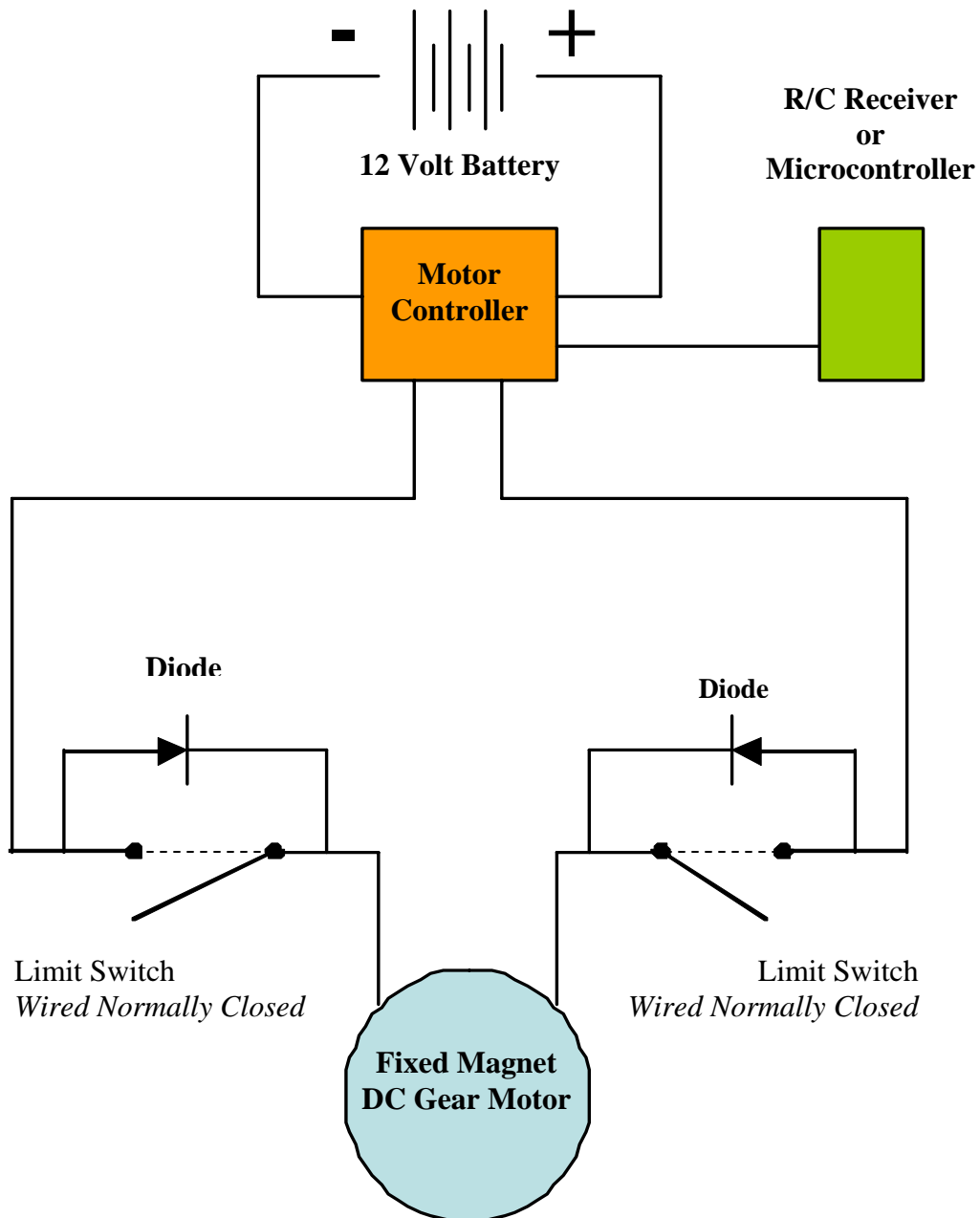
The illustration on the right shows the correct wiring of the completed limit switch and diode assembly.

Limit switches can be wired in either the normally closed or normally open position. This allows the action of the switch to either open (break the current path) or close (create a current path)



The Limit Switch Circuit Schematic

The symbolic representation of the limit switch control circuit is presented below. An actual photograph image of the completed circuit is presented on the following page. Study the circuit diagram (below) and compare it to the photographic image in order to best understand how the circuit works and how to construct it.



The Completed Circuit

The best way to both understand the operation of the limit switch and motor circuit is to

