NBD
"Nothing But Dewalts"

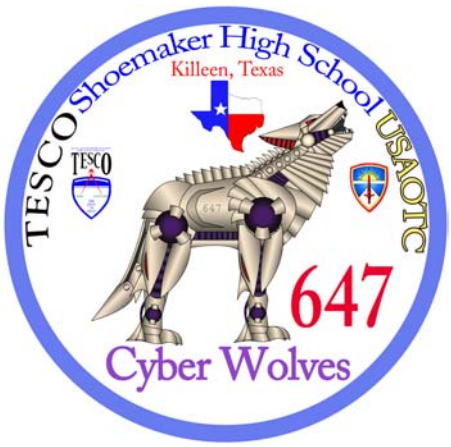
Author: Joseph Pavliga, Team 647 Shoemaker HS Cyber Wolves
Co-Author: Joseph Johnson, Team 47 Chief Delphi
December 30, 2004

Table of Contents

Tables

Figures

Drawings



Author: Joseph Pavliga, Team 647 Shoemaker HS Cyber Wolves
Co-Author: Joseph Johnson, Team 47 Chief Delphi

Dedication and Acknowledgments

I would like to thank Joe Johnson for sharing his information with me so I could write this paper and share it with the FIRST community. I would like to thank Mike Owens, High School Teacher and founder of the Shoemaker Cyber Wolves Robotics Team, for pointing me to the Delphi Booth during 2004 Nationals, which was my introduction to the Dewalt XRP transmissions. Also, thanks to Bruce Coons, fellow mentor, and all the contributors for starting an R & D fund this year so that prototype projects like this are possible for the Shoemaker HS Cyber Wolves team. Also, thanks to Lou Oudin, long time FIRST supporter and owner of Capital Die, a tool shop in suburban Detroit, who has graciously agreed to support teams in areas without local machine shop by providing competitive costs to make some of the parts discussed in this paper. Also, thanks to George Niebler, our local machinist who has graciously supported the Cyber Wolves through many seasons of FIRST robotics.

Foreword

By Dr. Joe

I am listed as a “Co-author” of this paper. I think perhaps “Editor” or “Advisor” would have been a better word. I almost struck out the term and changed it to one of these others when I decided against it.

Before I explain, let me say that this is Joe Pavliga’s paper. He wrote the entire paper with only the briefest of outlines as to what the content should be. I essentially sent him the actual gearboxes Chief Delphi made for the 2004 season along with some spare parts. After one or two quickly dashed off e-mails and a phone conversation, Joe P. has come up with this wonderful Whitepaper. I believe it will quickly become known as one of the most important robot construction How To’s FIRSTers have access to. For this, we have Joe P to thank. He pushed me and pushed me to get the data he needed. When I wasn’t able to write it up, HE DID IT. Well done Joe P.

Now back to this idea of Co-Authorship, I was about to strike "Co-author" in deference to all the hard work that Joe P. has put into this paper. But in the end, I selfishly decided against it. If Joe P. is willing to let me share part of the credit, I am willing to let him. After all, I was more than an editor and advisor in that the idea to set out to find a FIRST friendly transmission was a very deliberate quest of mine in the summer of 2003. I purchased and evaluated many gearboxes & transmissions that summer. I even designed several simple gearboxes that I thought could be easily made by FIRST teams. Then I saw the 3 speed Dewalt XRP Drill with its metal housing and its made-for-FIRST handle attachment. I almost heard angel choirs singing. Taking the transmission apart, I felt an emotion akin to love well up in my heart. Chief Delphi built a prototype chassis using the Dewalts in the late fall of '03. When it shifted on the fly reliably using mere servos, climbed shear walls like Gollum and pushed our prior year's robot around like a rag doll, I knew this transmission was going to change FIRST robots for the years to come.

The 2004 FIRST Season confirmed our prototype's performance under competition conditions. Chief Delphi 9 had NBD: "Nothing But Dewalts." Nine of these Bad Dads drove our wheels, gathered balls, powered arms & fingers, climbed stairs and, oh yeah, hung from the bar and held us there after power was cut. With 3 Regionals, the Championships, and 2 post-season competitions under our belt, not to mention hours of practice time and a practice robot, we have not had a transmission failure yet. Many of them have never been off the machine after we tighten them down the first time. After 8 years of wallowing, WALLOWING in addendems, dedendems, DP's, and Center Distances Enlargements, after custom gearboxes wrecking havoc on my team resources and, yes, on my family life, I have become a Charter Member of the NBDA (Nothing But Dewalts Anonymous). I am helpless before a higher power. Even though I design gearboxes for a living, I cannot design a smaller, better, lighter, cheaper, easier to use transmission for FIRST robots.

I am clearly sold on this transmission. But perhaps I have not closed the deal with you. Below are some of reasons to consider using the NBD strategy:

- Robust, Light, Compact
- Easy to mount to your robot
- Easy to interface to #35 Chain
- 3 Gear Ratios: 47:1, 15:1, 12:1
- Can be RELIABLY shifted "on the fly" using standard servo
- Transmission does not "pop out of gear" Set it and forget it.
- No-backdrive option (useful for hanging for example)
- Built in Slip Clutch can be used to limit torque output but does not slip when locked out.

So there you have it, my best case for using Nothing But Dewalts on your next FIRST robot. How to accomplish this? Joe P. tells all in the following instant classic. Read on…

Dr. Joe Johnson, Ph.D., P.E., Co-Author

How to interface FIRST legal motors with Dewalt XRP 3-Speed Transmissions.

In this paper I will cover how to interface the Chiaphua, Fisher Price and Globe motors to the commercial off the shelf Dewalt XRP 3-speed transmission. The Keyang seat motor and Bosch Drill motor can be adapted very easily too and were done for the 2004 season. This may be considered for a future improvement if they are in the 2005 kit and beyond. This transmission is by far one of the easiest and cheapest ways I have seen to get into a multi-speed drive train. This lightweight transmission assembly is rugged, with all metal gears, and can be shifted on the fly. FIRST legal motors can be interfaced to the Dewalt XRP transmission with minimal machining capabilities, which means you can spend more time on other appendages. The Dewalt XRP transmission assembly for the Fisher Price weighed in at 1.57 pounds with the eight-tooth sprocket on the end. The Fisher Price motor and motor plate weighed in at .63 pounds. The total weight for the Fisher Price motor and transmission assembly equals 2.2 pounds. The Globe motor/transmission interface is similar in weight to the Fisher Price motor/transmission interface. The shifter is designed such that a servo can easily and reliably shifts the Dewalt XRP transmission.

Interfacing the Chiaphua motor and the Dewalt XRP Transmission.

The Chiaphua is the hardest of the three motors to interface to the Dewalt XRP transmission. However, it is relatively easy compared to trying to machine your own multi-speed transmission. When you add up all the costs, it ends up being less than half the cost of any of the multi-speed transmissions using the Chiaphua motor that I have seen so far. For the Fisher Price motor and Globe motor the costs are even less than for the Chiaphua motor. The gear ratio for the Chiaphua conversion is 12:1, 4:1, 3:1, because you throw away the first stage of the Dewalt transmission.

The Dewalt DC980KA parts that need to be ordered from the reference web site http://www.dewaltservicenet.com/ for one Chiaphua/Dewalt XRP transmission are listed below.

Table 1 - Dewalt Chiaphua Bill of Material

Parts from DC980KA						
605256-01	screw	2	$0.63	$1.26		
620711-00	clamshell set	1	$7.73	$7.73		
.397892-05	transmission	1	$22.61	$22.61		
395666-01	gear case assy	1	$33.71	$33.71		
682211-00	screw,torx	1	$0.63	$0.63		
				Total:	$65.94	

Also needed are four 4-40 x .25 inch pan head screws, four 6-32 x 2 inch socket head cap screws and two 10-32 x .5 inch flat head screws. There is a list of parts that can be fabricated in the following drawing package.

Lou Oudin will sell the kit of parts for the Chiaphua/Dewalt interface for $80 per motor. You will need to send him the Carrier Gear to be modified. Lou is still working on a quote for an "a la cart" order form, if you want this but not that.
Also, a quote to get the pinion gears modified for the Globe and Fisher Price motors.
Program, Setup, and delivery $ 40.00 per lot
Wire cut for hole per req. $ 25.00 each for 1 - 10 pieces.
$ 20.00 each for 11 or more pieces.

The Address is Capital Die and Manufacturing Co., 10150 Capital Avenue, Oak Park, Michigan 48237
The Telephone number is (248) 542-9200. Mention FIRST. Capital Die accepts Mastercard. The easiest way to pay him is a credit card.

Detailed Assembly Instructions.

1. From the Dewalt transmission, take out the clutch rod, spring, pall, back plate, first stage ring gear, and the four first stage planet gears and set them aside. They are of no use in this assembly. See Figure 1. Also take out the anti-backdrive pins located at the top of the transmission under the black plastic cap, unless you want to keep them in to prevent back driving. See Figure 2.

Figure 1 - Spare Parts

Figure 2 - Anti-Backdrive Pins

2. Take the Carrier Sun gear that is located behind the four planet gears and clean it good with solvent. This is Top Hat Carrier that needs to be machined to specifications in Drawing 3. See Figure 3.

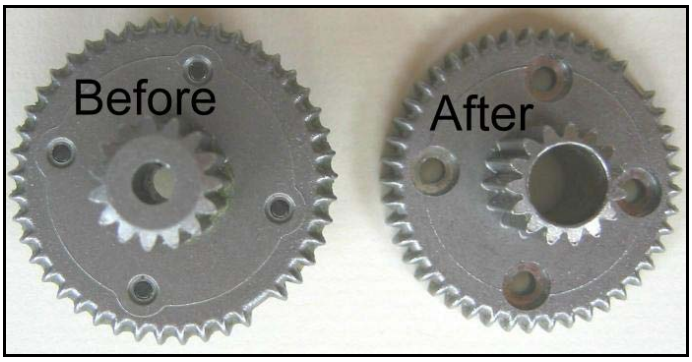


Figure 3 - Carrier Sun Gear

3. Assemble the Plastic Top Hat shown in Drawing 2 to the Top Hat Carrier with four pan head 4-40 x .25inch screws. See Figure 4.

Figure 4 - Top Hat Carrier Assembly

4. Assemble the Chiaphua Plate shown in Drawing 1 onto the Chiaphua motor using two flat head 10-32 X .5 inch screws. Press the Top Hat Carrier assembly onto the Chiaphua shaft per the specifications in Drawing 4. **Important ** The back of the motor needs to be supported when you press on the Top Hat Carrier assembly or the shaft could get pressed through the back of the motor. I took the back plate off of the Chiaphua motor so that force from the press was being transferred to the back of the solid Chiaphua shaft. I did this to avoid any pressure on the back bearing. The only thing that was hard when putting the back plate on was the bolts that go through the housing are hard to line up with the holes because the magnets are pulling them inward. It took a few tries to get the bolts aligned properly.

Final Chiaphua motor assembly should look like the Figure 5.

Figure 5 - Chiaphua Motor Assembly

5. Cut the yellow clamshell along the outside of raised molded line and across the top of the handle with a band saw or hack saw. This will leave the needed piece of remaining yellow clamshell a bit long, but can be sanded down to size by hand. This part of the clamshell set is not needed. See Figure 6. The length of the remaining clamshell set should be about 1.040 inches if measured from the rim by the square tab. Drill out the four screw holes with a 9/64 drill. This will allow clearance holes for the 6-32 socket head cap screws. See Figure 7.

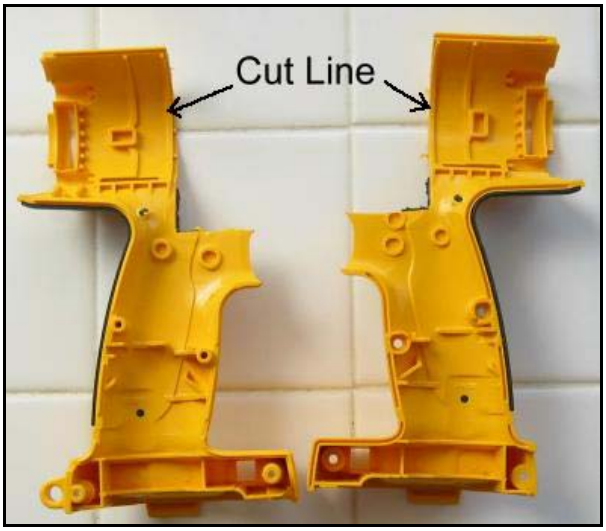


Figure 6 - Clamshell Pieces not needed

Figure 7 - Clamshell with 9/64" holes

6. Shave or cut the white plastic off the bottom end of the transmission housing .190 inches. I used a sanding wheel to get close to the desired measurement and did the rest by hand sanding. See Figure 8. The measurement taken from the top edge of the white transmission housing should be 2.180 inches. See Figure 9.

Figure 8 - Cutting Transmission to Size

Figure 9 - Transmission Measurement

7. If using the Servo Plate, as shown in Drawing 5, cut two of the 6-32 socket head cap screws down to 1.65 inches and two down to 1.57 inches. If your not using the Servo Plate then all four 6-32 socket head cap screws go down to 1.57 inches. Then unscrew the three torx screws and take off the black plastic clutch ring on the magnesium housing. This ring is not needed and gets in the way of tightening down the 6-32 socket head cap screws.

8. Take the magnesium housing and insert the transmission. See Figure 10. Insert the two yellow plastic clamshell pieces over the transmission and screw the yellow plastic pieces together. See Figure 11.

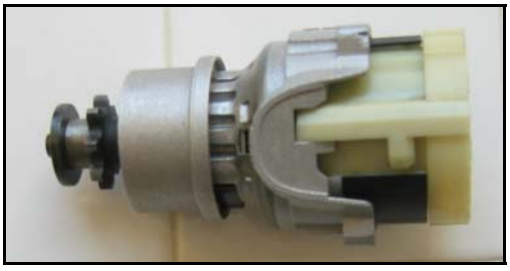


Figure 10 - Magnesium Housing and Transmission

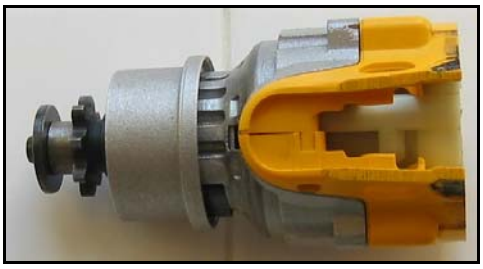


Figure 11 - Dewalt Transmission Assembly

9. Insert the sun gear and Chiaphua assembly into the planetary gears of the transmission. Take the Servo Plate as shown in drawing 5, Servo, and use the two 6-32 x 1.65 inch socket head cap screws for tightening down this part. The servo plate gets mounted on the "3" side of the housing. The longer 6-32 socket head cap screws are used because of the thickness of the servo plate. Use the two 6-32x1.57 inch socket head cap screws for the other side to hold the whole assembly together. See Figure 12

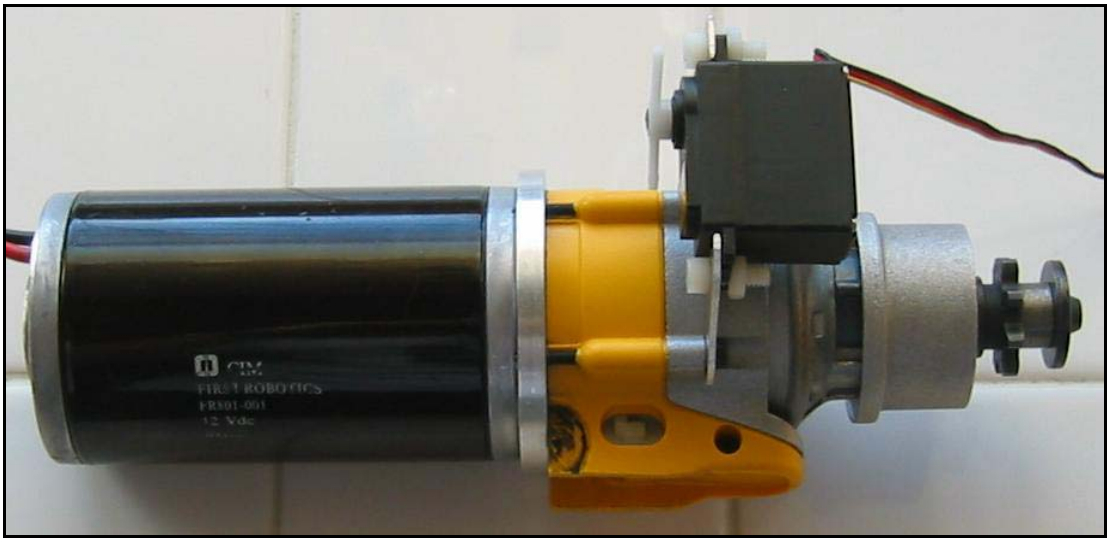


Figure 12 - Chiaphua/Dewalt Assembly with Servo

10. Line up the Servo arm with the black plastic shifter knob on the transmission and drill a 1/16 inch hole straight through. See Figure 13. You will drill through the black plastic skin and the white plastic shifter tube (not visible underneath). The white plastic shifter tube is not symmetric so when drilling a 1/16 inch hole on top of the black plastic skin, drill biased toward the "3" side of the transmission. See Figure 14 and 15. This lets the shifting linkage get the best grip on the actual shifter tube. The shifting linkage can only be snaked though the holes by first attaching to the transmission side, then attached to the servo horn (while the horn is disconnected from the servo), then the servo horn is attached. It is recommended to install the servo horn while the transmission is in 2nd gear and the servo is in mid-travel (PWM=127). This will allow the servo to move and shift to 1st and 3rd. In any case, the PWM values for 1st, 2nd and 3rd should be adjusted in software to match the actual values. If shifted slowly, the transmissions will actually shift into "neutral" between each gear. This feature together with sensors on the wheels can be used to help the software provide smoother shifting via "software synchronization" but that is a topic for another whitepaper.

The assembly is now complete.

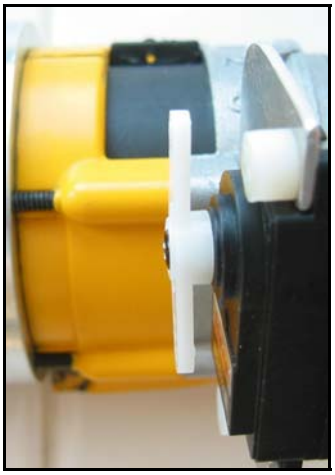
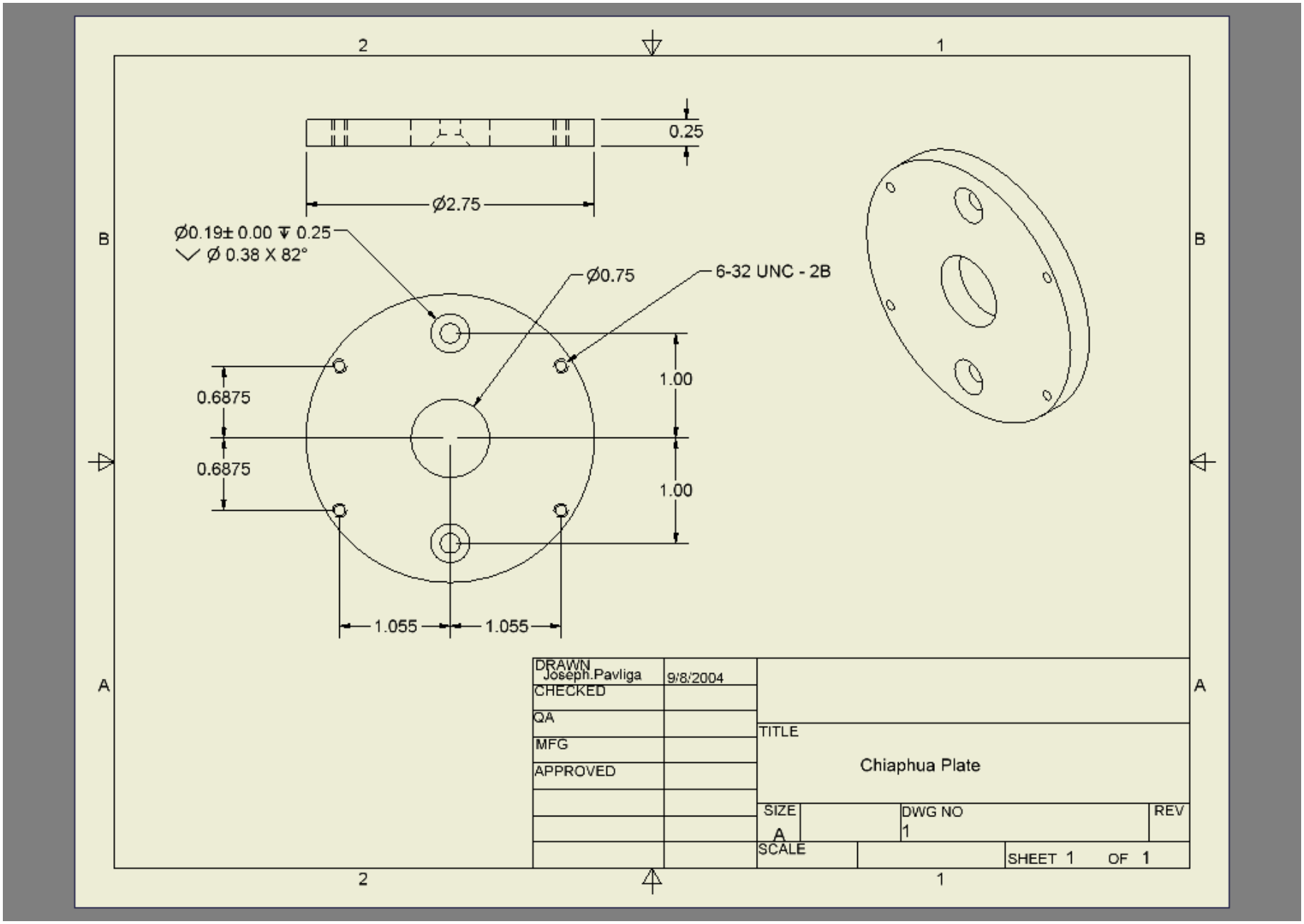


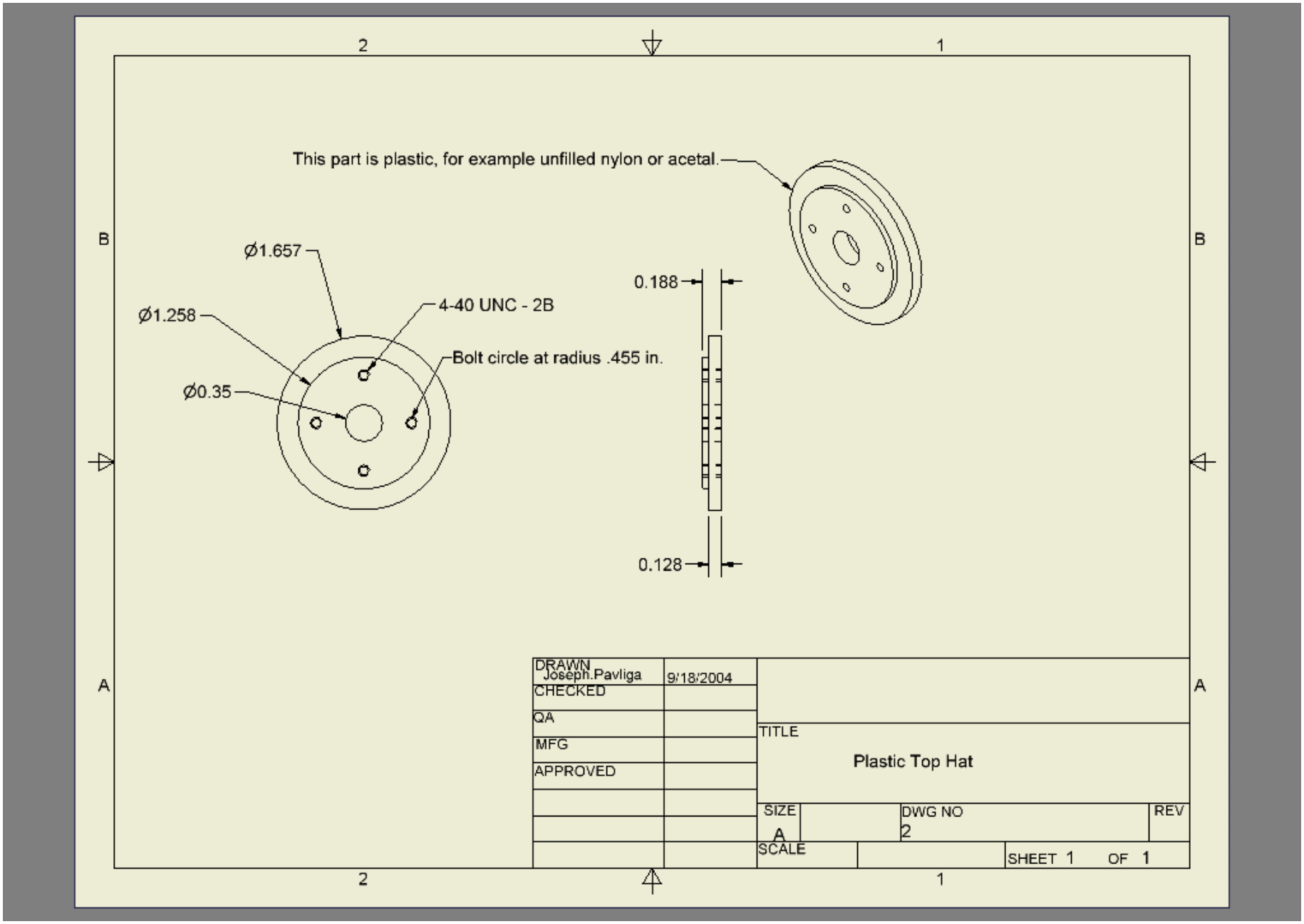
Figure 13 - Black Plastic Shifter Skin

Figure 14 - White Plastic Shifter Tube

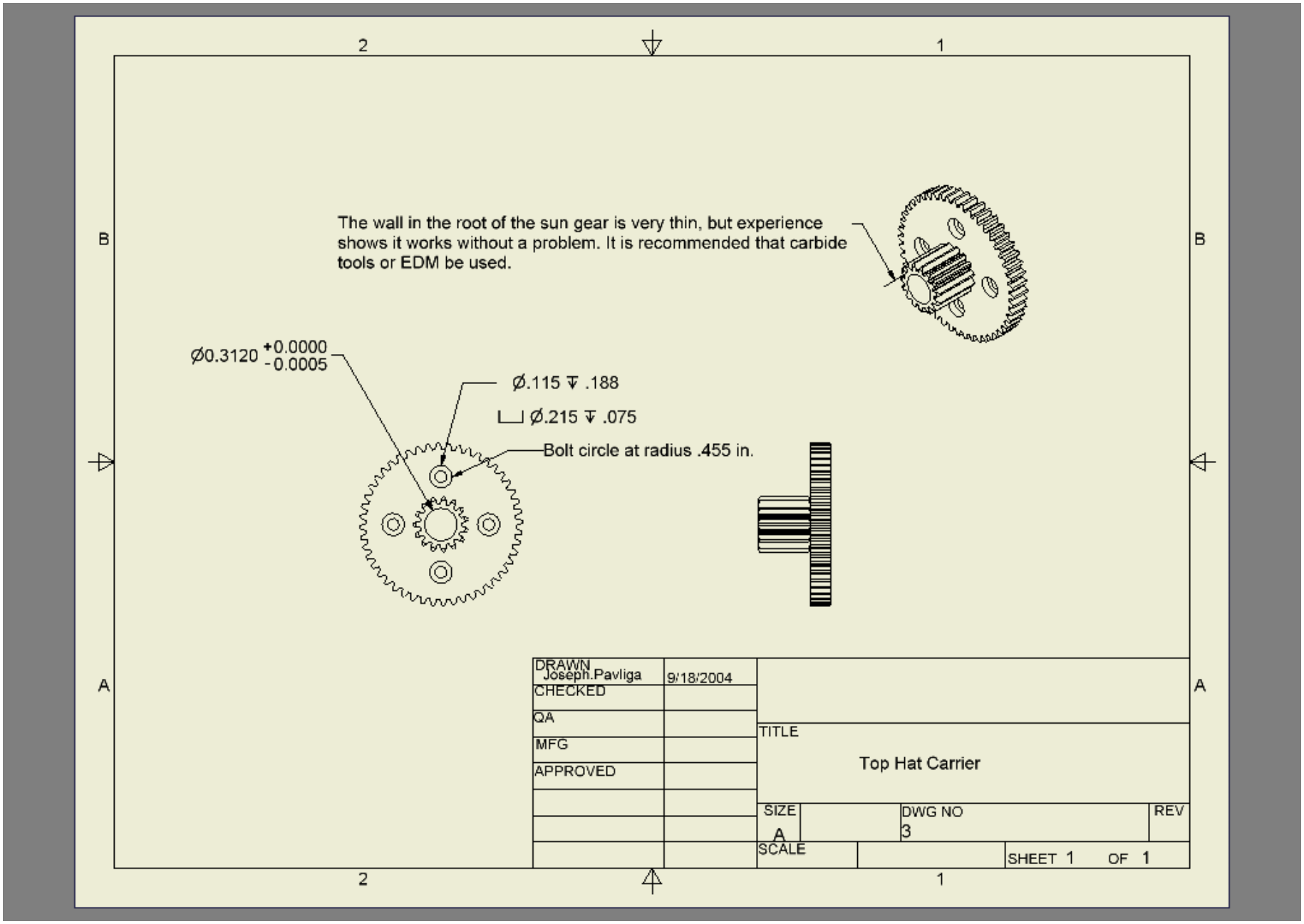
Figure 15 - Final Chiaphua/Dewalt Assembly.



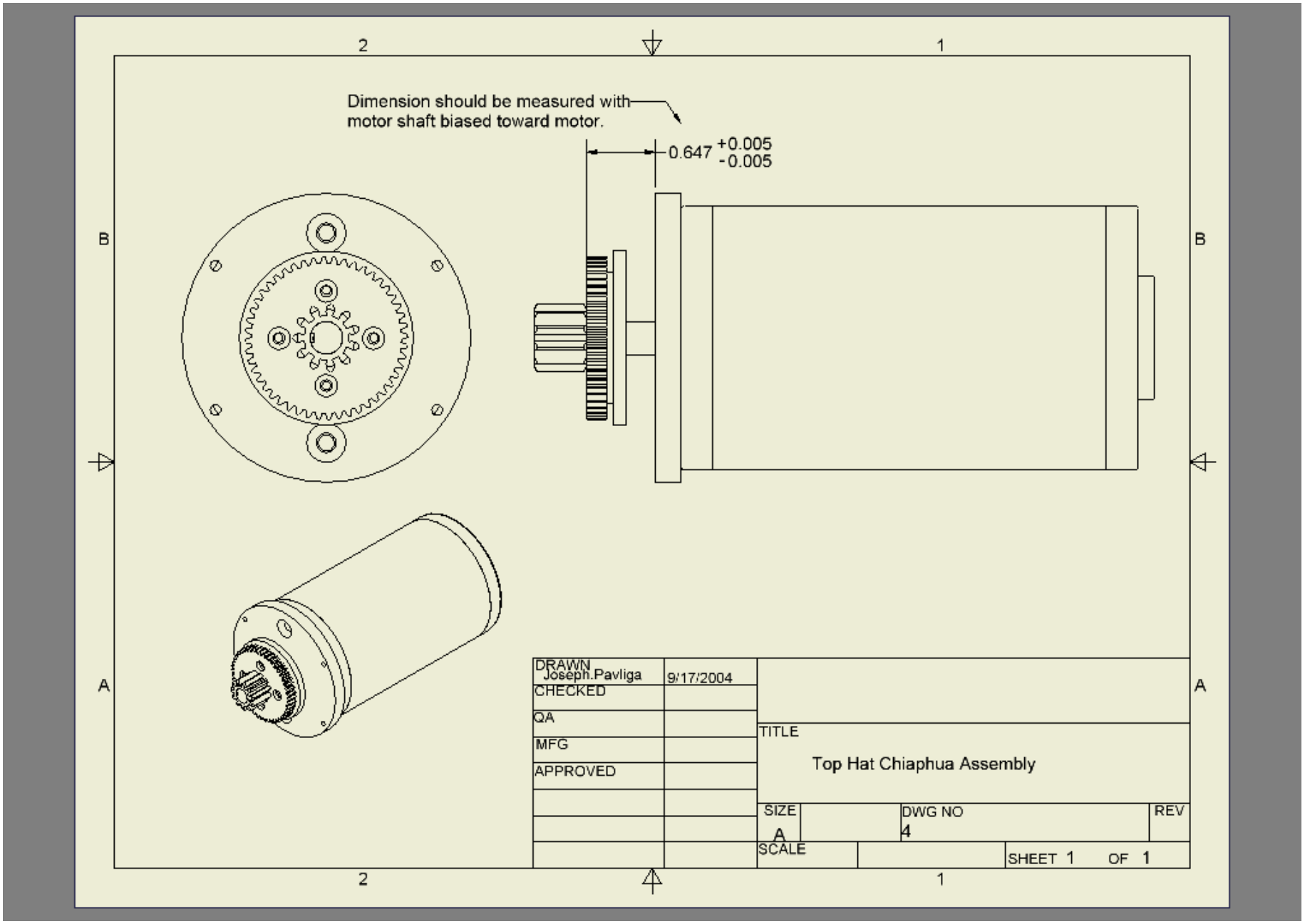
Drawing 1 - Chiaphua Plate



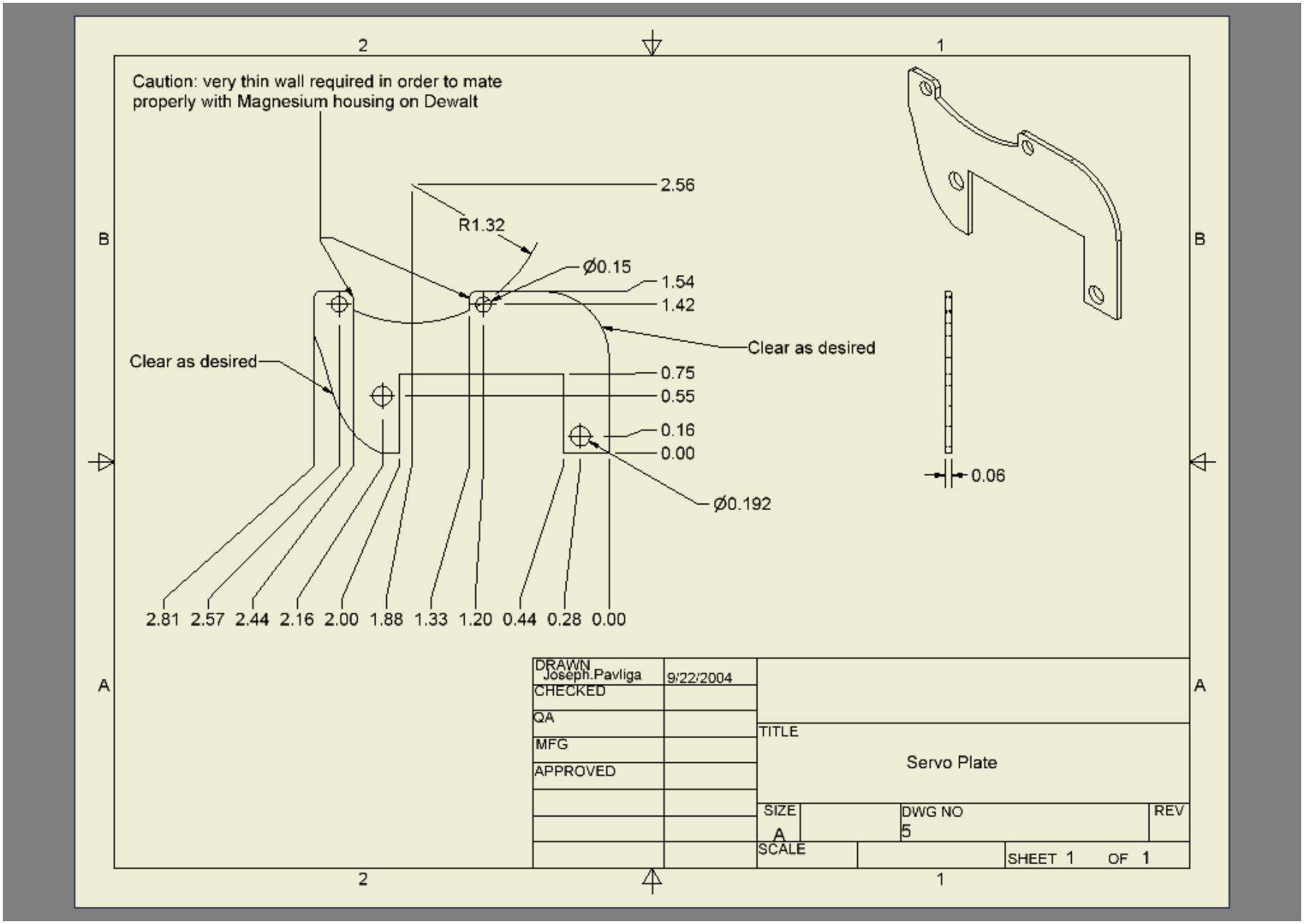
Drawing 2 - Plastic Top Hat



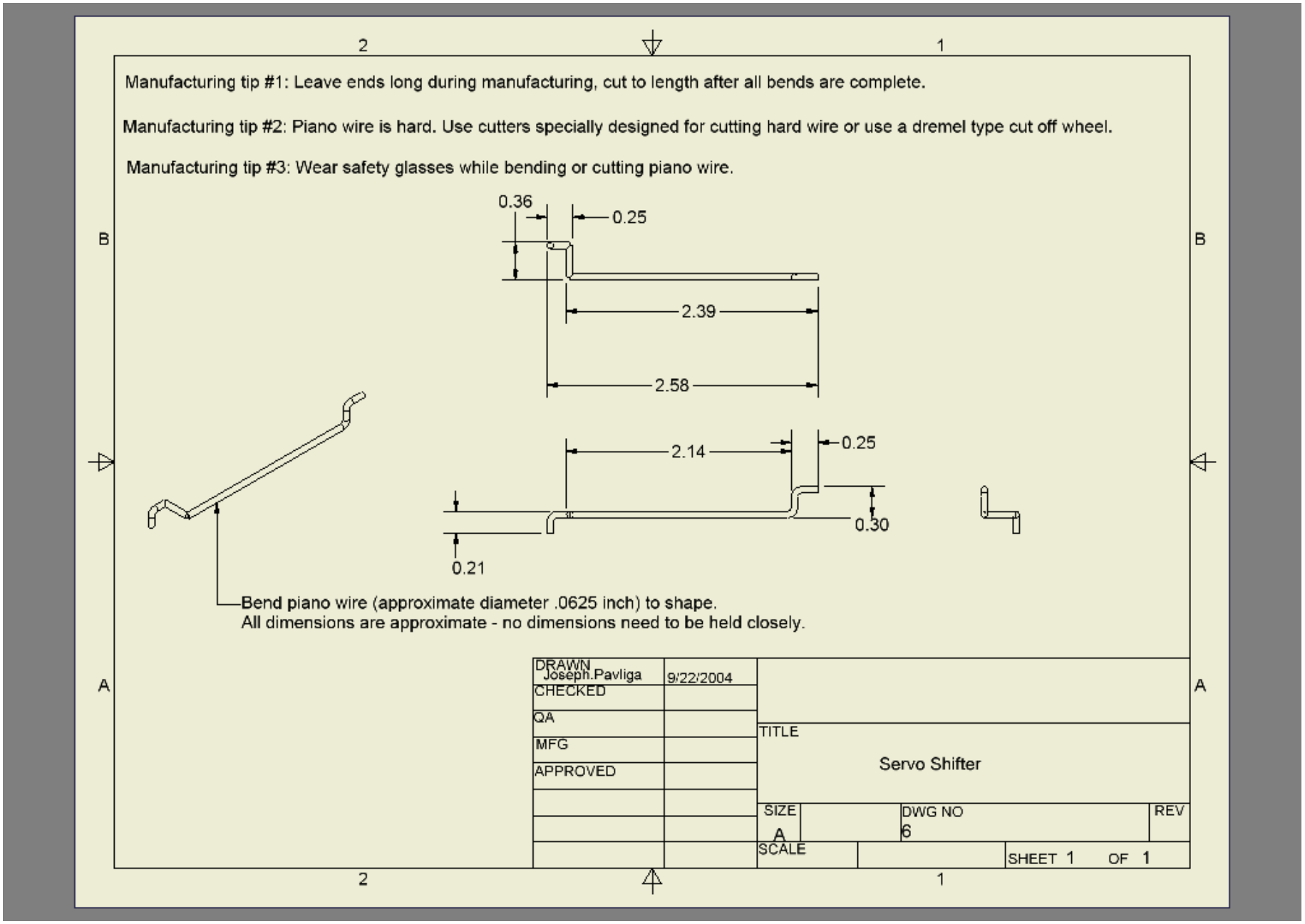
Drawing 3 - Top Hat Carrier



Drawing 4 - Top Hat Chiaphua Assembly



Drawing 5 - Servo Plate



Drawing 6 - Servo Shifter

Interfacing the Fisher Price motor and the Dewalt XRP Transmission.

For the Fisher Price and the Globe motor interface you will need pinion gears for Sun1. The Dewalt transmission will provide us a ready source of gears for Sun1. If you buy one extra transmission, you get four Sun1s for modification from the Planet2 stage. If you make several Dewalt transmissions that require this sun gear (2 Fisher Price and 2 Globe for example), you only need to purchase 1 extra transmission for every 4 assemblies. So, in this Dewalt Bill of Material, I will add an extra transmission.

Table 2 - Dewalt Fisher Price Bill of Material

Parts from DC980KA					
605256-01	screw	1	$0.63	$0.63	
620711-00	clamshell set	1	$7.73	$7.73	
397892-05	transmission	2	$22.61	$45.22	
395666-01	gear case assy	1	$33.71	$33.71	
394514-00	motor adaptor	1	$1.75	$1.75	
398978-00	lead wire	1	$1.07	$1.07	
682211-00	screw, torx	5	$0.63	$3.15	
330019-49	screw, plastic	4	$0.63	$2.52	
620747-00	end cap	1	$2.58	$2.58	
				Total:	$98.36

1. Make a plate that fits on the front of the Fisher Price motor and goes inside the black plastic Dewalt motor adaptor, as shown in Drawing 7.

2. Use a boring bar or grinding wheel and remove the tabs in the bottom and ridge on the inside of the motor adapter. The inside diameter of the motor adaptor is 1.905 inches. Drill 1/8 inch holes to match the ones in the Fisher Price motor plate. See Figure 16.

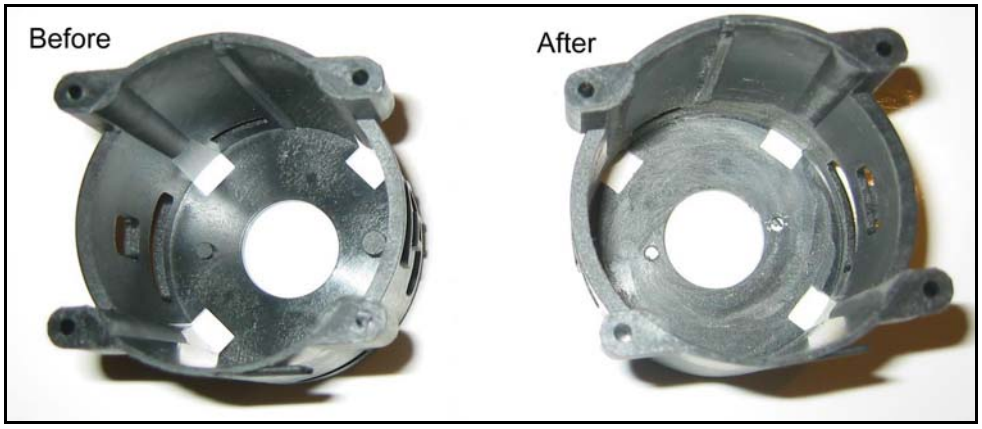


Figure 16 - Fisher Price Motor Adapter

3. Press the modified pinion gear (.125 inch +0.0000" -0.0005 " hole) on the shaft. The distance from the top of the pinion gear to the front of the motor case is .072 inches, measured with the motor shaft biased towards the motor. Be careful not to bend this motor shaft. Make sure the shaft is square as you press on the gear.

4. Use two button head M3x.5x10mm screws and screw on the adapter plate and black plastic motor adapter to the Fisher Price motor. Button head screws are important because they will fit inside the standard transmission without causing any difficulty. Be sure the screws are not too long or they will seize the motor.

5. Cut the handle off of the clamshell set. Insert the Fisher Price motor assembly into the transmission and assemble the yellow clamshell set over the transmission and motor assembly. See Figure 17.

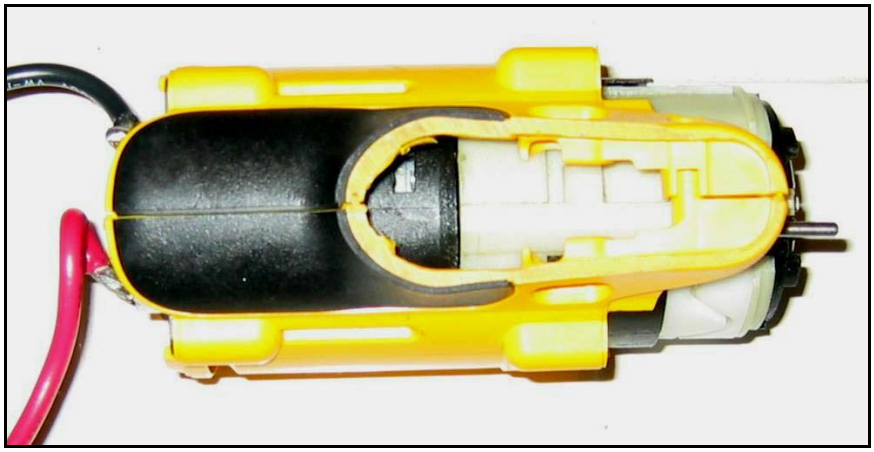
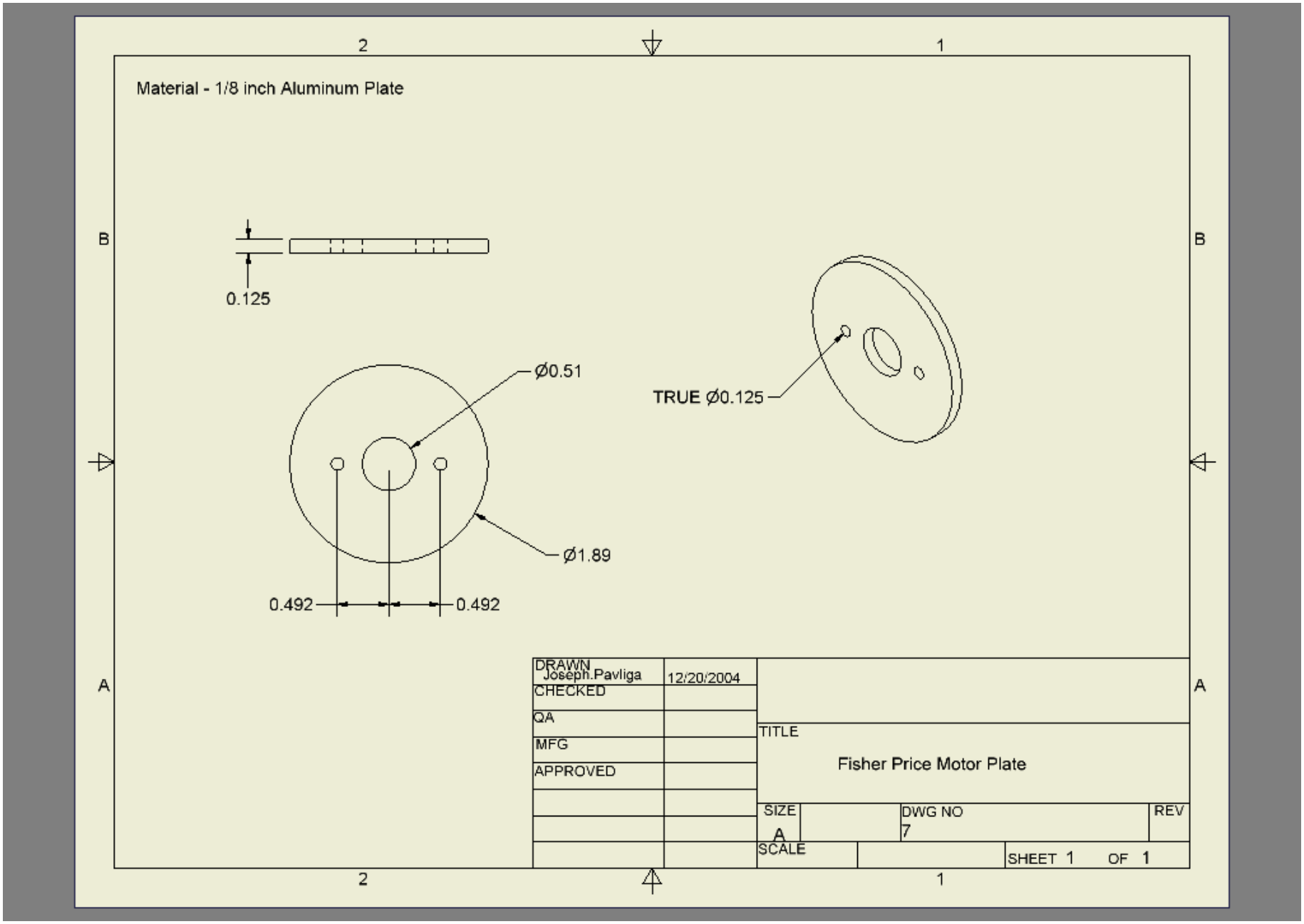


Figure 17 - Fisher Price/Dewalt Sub-assembly

6. Screw the magnesium housing to the top of the yellow clamshell set with four screws. Cut holes in the end cap so the wires from the motor will fit through the end cap. Screw the end cap to the bottom of the clamshell set with four screws. See Figure 18.

Figure 18 - Fisher Price/Dewalt Assembly



Drawing 7 - Fisher Price Motor Plate

Interfacing the Globe motor and the Dewalt XRP Transmission.

Table 3 - Dewalt Globe Bill of Material

Parts from DC980KA					
605256-01	screw	1	$0.63	$0.63	
620711-00	clamshell set	1	$7.73	$7.73	
397892-05	transmission	1	$22.61	$22.61	
395666-01	gear case assy	1	$33.71	$33.71	
394514-00	motor adaptor	1	$1.75	$1.75	
398978-00	lead wire	1	$1.07	$1.07	
682211-00	screw,torx	5	$0.63	$3.15	
330019-49	screw,plastic	4	$0.63	$2.52	
620747-00	end cap	1	$2.58	$2.58	
				Total:	$75.75

1. The transmission steel housing on the Globe motors can be easily removed with a small punch. You can punch the 3 pins inside of the housing. See Figure 19. Once you push them in enough, you can remove the housing from the globe motor. Remove the "Cast teeth" on the front face of the motor either by using a lathe or by careful use of a hacksaw or Dremel with a file used to clean things up. See Figure 20.

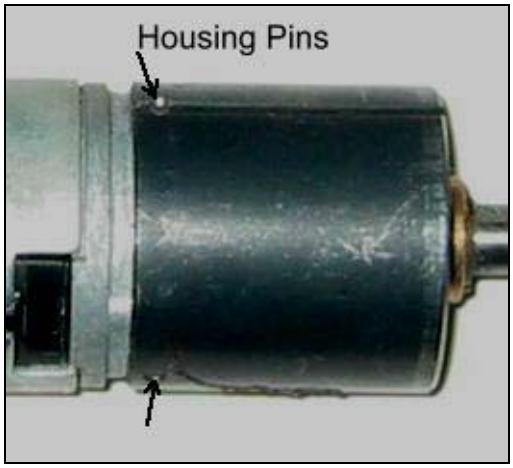


Figure 19 - Transmission Housing Pins

Figure 20 - Globe Motor Cast Teeth

2. Press off the gear on the Globe motor.

3. Press the modified pinion gear from the extra transmission (.138 inch +0.0000" -0.0005" hole) on to the shaft of the Globe motor. The distance from the top of the pinion gear to the front of the motor case is .515 inches, measured with the motor shaft biased towards the motor.

4. Chuck up the black plastic motor adaptor and use a boring bar to remove the two tabs on the bottom and to open up the hole in the bottom to the outside diameter of the step in the casting on the motor (measured away from the screw bosses). The large hole in the motor adapter should measure 1.42 inches. The large 1.42 inch hole should fit tight around the motor step. A loose fit risks the motor fitting poorly. Use a rat tail file to open up room for the screw hole bosses. They will serve as anti-rotation devices in this assembly. See Figure 21 and 22.

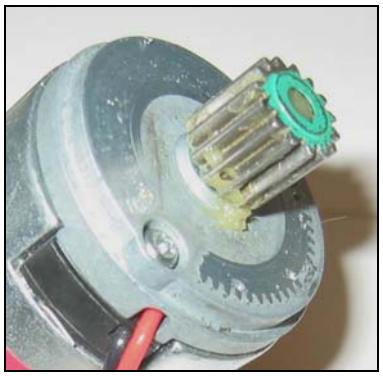


Figure 21 - Globe Motor Step in Casting

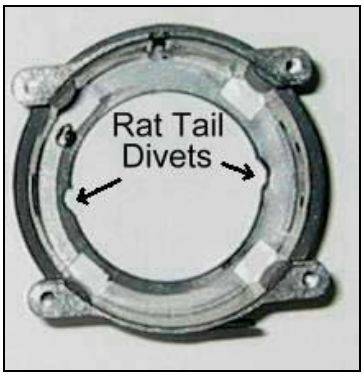


Figure 22 - Globe Motor Adaptor

5. Cut a 0.5 inch ring from schedule 40 pipe. Glue it to the outside of the motor. The top edge of the ring is approximately 1.54 inches from the step in the casting on the motor. See Figure 23. The schedule 40 pipe will fit between the motor housing and the motor adaptor and allow the wiring to flow freely past the schedule 40 ring. See Figure 24.

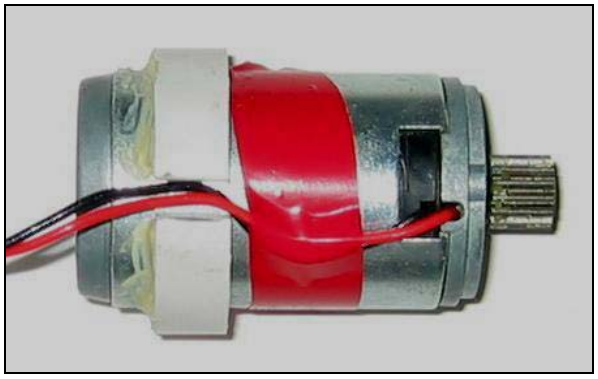


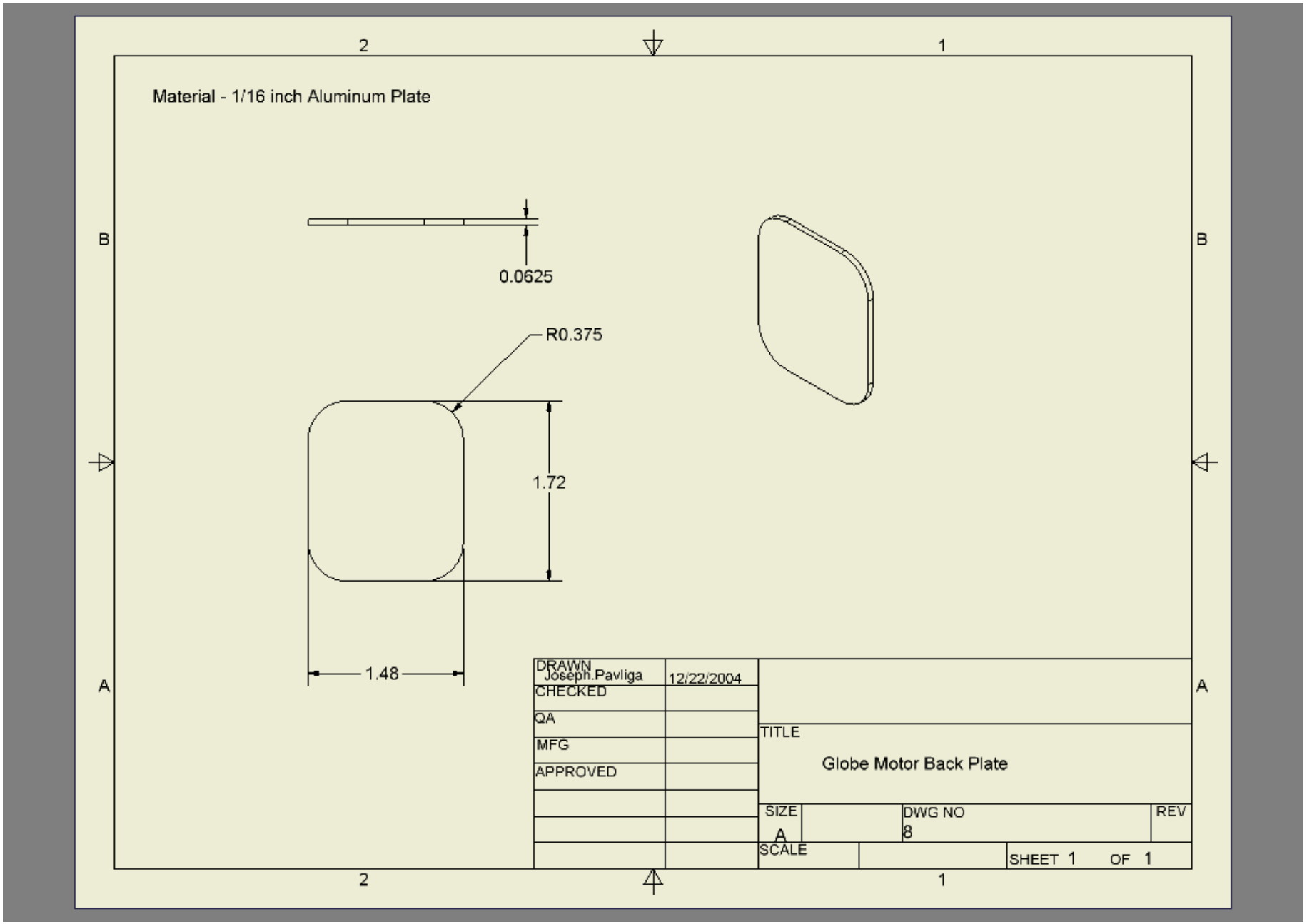
Figure 23 - Globe Motor with Schedule 40 Pipe

Figure 24 - Globe Motor Assembly

6. Assembly is done similar to the Fisher Price interface except a plate, as shown in Drawing 8, is needed that fits behind the motor to keep it from working out of the motor adaptor. See Figure 25 and 26.

Figure 25 - Globe Motor Back Plate

Figure 26 - Globe Motor/Dewalt Assembly



Drawing 8 - Globe Motor Back Plat

Mounting of the FIRST Legal Motors/Dewalt Transmission

The Dewalt XRP transmission assembly is designed to take a side load which comes with a handle so a construction worker can lean on it. Because it is designed for a clamp on handle, a simple standard aluminum clamp collar (1 11/16" 2 piece collar (McMaster.com #6436K151) for about $17 can be used. All you have left to do is weld or bolt the clamp collar to a bracket on your robot. See Figure 27.

Figure 27 - Dewalt Transmission Mount

You can also make your own clamp collar with tubes, bolts and a hole saw.

- Aluminum Rectangular tube ¾" X 1½", .125" wall (McMaster.com #88935K53)
- ¼ -20, 4" Length Bolts – harder is better (McMaster.com #91257A558)
- 1 11/16" hole saw (McMaster.com #41005A31)

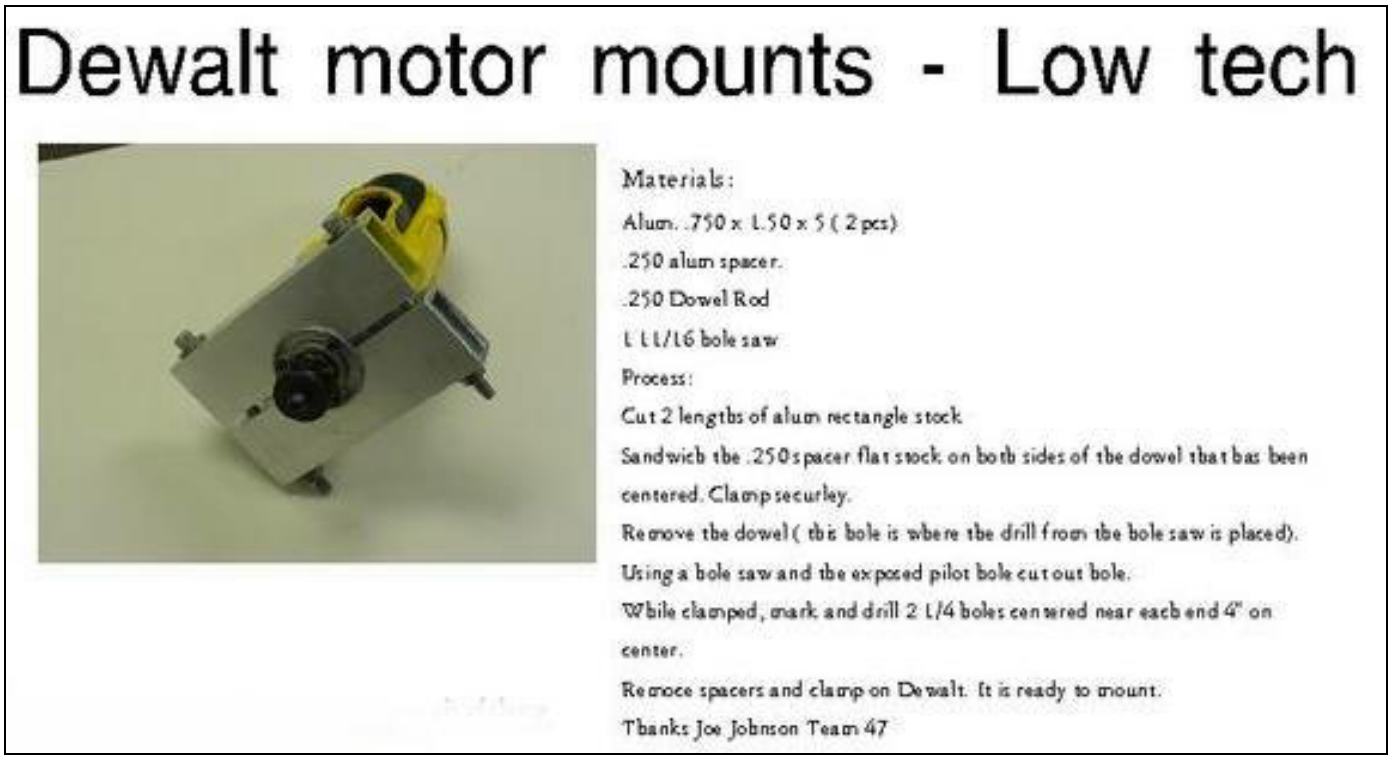


Figure 28 - Low Tech Dewalt Mount

Picture & instructions are courtesy of Mike Martus & OCCRA. The hyperlink to the website is http://www.chiefdelphi.com/forums/pictures.php?s=&action=single&picid=8751&direction=ASC&sort=title&perrow=10&trows=10&quiet=Verbose

Interfacing the Dewalt XRP Transmission to #35 Chain

The output shaft is 1/2 inch and easy to interface to with a eight tooth #35 sprocket. Just drill and tap through with ½ -20 threads. Screw the sprocket on to the drill output shaft, make a small 1/2 inch spacer, put a Case-Hardened Steel Extra-Thick Flat Washer 1/4" Screw Size, 9/32" ID, 5/8" OD (McMaster.com #98099A029) on the end, and put in the Standard Left Hand Chuck Screw (Dewaltservicenet.com #605256-01) to keep the sprocket from unscrewing. See Figure 28.

Figure 29 - #35 Sprocket Assembly

This was a Rev. 1 design. It turned out to work but there were issues with the design. We would use a 9T sprocket in the future unless the application really could not afford the 12% loss in torque and/or 12% increase in speed. The Rev. 1 design was very worried about side loading the Dewalt output shaft, so it struggled to keep the sprocket as close to the drill housing as possible. As it turned out, the extra 1/8 of an inch towards the drill housing that this design gained was not worth the bother. This was confirmed by use in OCCRA (an 18 team FIRST-light Fall robotics league in Oakland County, Michigan) where they had no problems with the extra distance. In the Rev. 1 design, everything was designed to be driven using an 8T sprocket before it was realized just how tricky using an 8T sprocket was going to be. Chief Delphi's experience in 2004 shows that an 8T sprocket can be made to work, but a 9T gives more margin for error. With an 8T, you will have to make more complex modifications to the standard sprocket (reducing the length in addition to drill and tapping the center bore) and you will have to make a very thin walled, very strong tube/spacer (For high torque applications, Chief Delphi had to make theirs from .5 OD ChromeMoly tube -- which was not very easy to work with). Finally, the large washer had to be monitored in high torque applications because it was prone to "coning" which sometimes became bad enough that the washer had to be replaced.

Recommended practice: use a standard 9T sprocket, drilled and tapped thru with 1/2-20 thread and use the thick washer (McMaster.com #98099A029) in combination with a slightly shortened standard Dewalt left hand screw (Dewaltservicenet.com #605256-01). Again, the robustness of this solution was confirmed with its use in the Fall 2004 season of OCCRA (Oakland County Competitive Robotics Competition).