

LYMAN / MULIER FILAMENT EXTRUDER V5

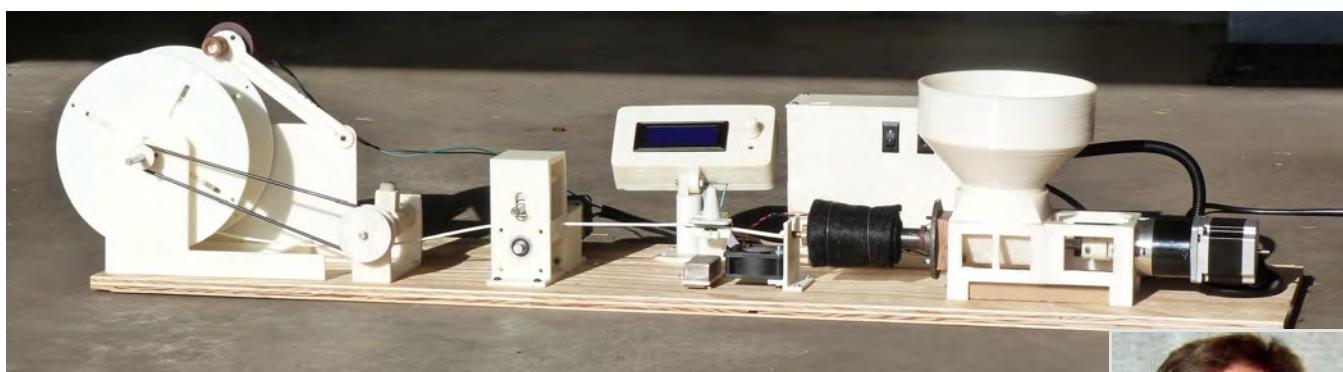
Construction and Operating Manual



HUGH LYMAN Lyman's Filament Extruder V5
INVENTOR

The Extruder is patterned after the V4.1 Extruder with many changes which you will see in the following pages of this manual.

No liability is accepted for errors, omissions and the use of this manual. Users use at their own risk.



Mulier's Filament Extruder V5



This picture is a 3D printed part with filament extruded with Ex-truder V5. It is the Cone for the Filament Sensor as designed by Filip Mulier.

It is 30mm high, 18mm at the base and 9mm at the top. The top rim is 1mm thick. It was printed on a TAZ printer with a 0.35mm nozzle. This shows the quality of prints made with V5 filament.

FILIP MULIER
CO-INVENTOR



Filip Mulier is an Electronic Engineer that has developed the Filament Sensor and the Mackerel coding for the V5 Extruder. Also he is responsible for the selection of the motors, electronics and the Setup & Operating section of this manual.

You are going to love the LCD display and functions.

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The Ultimate Desktop 3D Printer Filament Extruder



The **LYMAN / MULIER FILAMENT EXTRUDER V5** is a complete desktop extruder system that produces filament for use in 3D printers. It can extrude 1.75mm to 3mm diameter filament without changing the nozzle. Once set up it can be left unattended and in about 4 hours it will extrude and level wind 2 lbs of filament on a spool.

Watch the video on YouTube for the setup procedure.

Video link: <http://youtu.be/vL9zDOdRqBo>

If it is a desktop extruder it ought to be able to run on a desktop. You can tell how quiet it is by watching the video. You will only hear it when the camera is close to the machine. OK, so if you are watching the LCD display you will see the thickness of the filament diameter as it changes by the second. The quality is going to be around +/- 0.10mm for 3mm filament, with occasional blips over or under that. Hallelujah, the average is also displayed, so when done I mark the average on the spool and I don't have to measure it before slicing. My machine is extruding around 11mm per sec (25 inches/min). This is not smoke and mirrors, wherein others give info that doesn't hold up. I know, I bought one.

Two folks have contributed to the design and success of Version 5 Extruder:

Filip Mulier designed the firmware Mackerel and furnished the filament sensor along with the LCD control system. Also he has done the debugging of the system and written the manual part for operating the extruding system. He has the same extruder as mine. We have worked hand in hand developing this extruder. As Filip commented: "Marlin eat Mackerel, 3D printers eat filament".

Mehmet Sutas design of a printed worm gear for the level wind assembly led me to the new level wind assembly as shown.

Some of the new features of V5:

1. Stepper motors for the extruder and the puller assemblies.
2. LCD display for controlling a Ramps 1.4 with a Mega 2560 R3 with Mackerel firmware.
3. Redesigned the level winding assembly with printed worm gear.
4. LCD with menus that control all extruder functions.
5. Filament sensor that shows the diameter of the filament as it extrudes, also shows the average diameter.
6. After reaching a preset length of filament the extruder automatically shuts off.

All the functions controlled by the LCD are listed in the section titled "Setting up and Operating the Extruder with a RAMPS-based LCD controller"

CONSTRUCTION COMMENTS:

The following is an explanation of each part shown on sheets A01 through A08. All cyan colored parts in the drawings are 3D printed. All white parts in photos are 3D printed.

I suggest 3D printing all the printed parts first and assembling the sub assemblies before mounting any of them to the Base Plate. Do this while you wait for part shipments to arrive.

What I am showing is how I constructed the extruder. I am sure there are better ways and hopefully my notes will help. Many parts I used only because I had them on hand. Better parts (like fasteners) may be available.

STARTING ON SHEET A01

The extruder consists of (8) sub assemblies.

1. Extruder Assembly
2. Sensor & Fan Assembly
3. Electronics Case Assembly
4. LCD Pedestal Assembly
5. Puller Roller Assembly
6. Level Wind Assembly
7. Spool Filament Wind Assembly
8. Base Plate

SHEET A02: EXTRUDER ASSEMBLY PARTS:

Part # 1 - Brass Nozzle:

A brass 1/2" NPT plug with a serrated 1/4" serrated hose tip. This type of nozzle needs no machining, just mount it to the coupler. This nozzle plug has a hollow core. No tape is used on threads.

The filament exits the nozzle at around 5mm, the Puller Roller assembly stretches the filament to the set diameter anywhere from 1 to 3mm depending on the speed of the rollers. I have even extruded to thread size.



Part # 2 - Heat Band:

The heat band is 1" ID. It fits over the coupler snug, wherein it needs no clamp. It will need a little prying open as the coupler it fits on is 1.0625" OD.

Part # 3 - Pipe Coupler:

Black Iron 1/2" NPT pipe coupler. Different brands of couplers will vary in OD dimension. Check the diameter before using one other than listed in BOM.

Part # 4 - Pipe Nipple: ("Barrel")

Black Iron 1/2" pipe nipple is 4" long. I like this length the best of several I have tried, as the heat starts dissipating about half way back toward the hopper. I tried an aluminum nipple and found the it got too hot near the hopper and started melting the pellets before they had a chance to hit the high heat, thus they gummed up as semi molten plastic near the hopper and jammed the auger. I drilled two small holes in the nipple 1-1/4" from hopper end to allow air to escape as the pellets compress. Some pellet dust will also escape.



Part # 5 - Insulating Washer:

This washer is to help stop heat transmission from the bolts to the ABS plastic hopper. Here is shown one made from a sheet of 1/8" phenolic panel which is what I had. Use anything you think is good.

**Part # 6 - Floor Flange 1/2" NPT black iron:**

This part needs 4 holes drilled to match the holes in the hopper. See drawing sheet P08 for details.

**Part # 7 - Oak Insulation Block:**

See drawing sheet P08 for details.

**Part # 8 - Flanged Brass Bushing 5/8" ID:**

This bushing will hold the Oak Block away from the hopper the thickness of the flange. I trimmed the neck to be flush with the inside of the hopper wall.

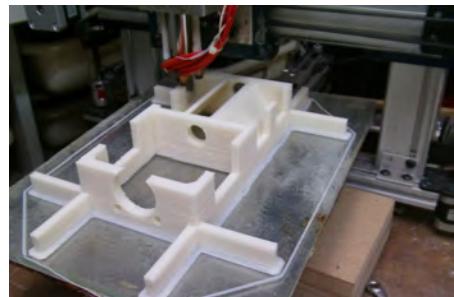
Part #9 - Auger Bit 5/8" x 17":

The bit I am now using is a Bosch I got on eBay. It has a hex driver end which made it easy to attach the coupler to. It only needs one end cut off for sizing. There is just enough a lip at the transition of the hex to round that will accept a 1/2" ID thrust bearing.

See drawing sheet P07 for details.

**Part # 10 - Thrust Bearing 1/2":**

No comment, see picture.

**Part # 11 - Hopper Motor Mount 3D Printed:**

The design of this part was created with outriggers to control warping. The print was on a 9"x12" heated bed. I use a 3/16" tempered glass plate and I coat it with a sugar water solution which grips the ABS plastic. It is sliced with a brim, 85% infill, 2 perimeters, and printed slow. The part will not come off the plate until it cools. Then I cut off the outriggers and dress the part. Two stl files are included, one with and one without outriggers.

Parts #'s 12,13,16,17 & 20: Fasteners:

No comments.

**Part # 14 - Motor to Auger Coupler 3D printed:**

This coupler was an experiment that worked. It is one piece where one end has a hex shaped hole to receive the auger and the other end with a round hole with a keyway to receive the motor shaft. It takes a little dressing to make the fit. I heated the auger hex end and pressed it into the hex hole to make a good fit. There is no bushing in the center wall of the hopper.

See drawing sheet A10 for a section view of the extruder.

Part # 15 - M1 Extruder Gear Motor:

This is a Nema 23 stepper gear motor, 1:15 gear ratio, 2.8A, 150 kg-cm torque. It will do 116 rpm, however it runs about 20 rpm max for extruding filament. Any faster and the filament is not cool enough before it enters the rollers which is 11.75" from center of the rollers to the tip of the nozzle. . The RPM's are adjustable in the LCD menu. I run mine at 18 to 19 rpm which extrudes about 25" per minute. If you use a different gear motor ratio the steps are adjustable in the menu. Lengthen the 11.75" distance and I would assume you can run it faster, however the A4988 drivers only puts out 2A which limits the torque and speed of the motor, therefore a stronger driver is required.

**Part # 18 - Pellet Funnel, 3D Printed:**

The funnel fits into the funnel base and is removable. It is 6.75" in diameter. The funnel and hopper will hold 2 lbs of pellets.

**Part # 19 - Funnel Base, 3D Printed:**

The funnel base is a transition from square to round. It holds the funnel or will hold a thin wall 3" shipping tube as shown in the picture. The base is cemented to the hopper base using a ABS solvent cement.

**Part # 21 - Thermistor**

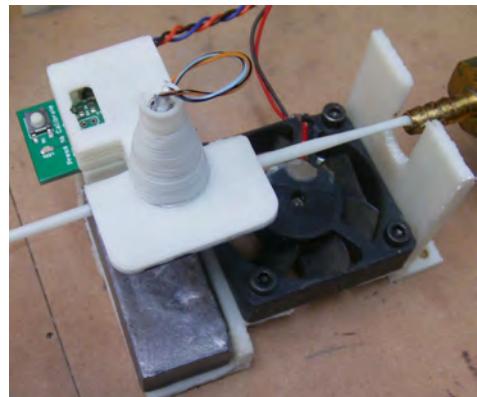
The Thermistor is an Epcos 100k ohm. It is taped to the black iron coupler with Kapton tape. Note the thermistor is laid at the gap of the heat band and is applied before the heat band is installed. If you use a different thermistor , you can adjust for it in the Mackerel code the same as in Marlin.



A03 - SENSOR / FAN ASSEMBLY:

This photo shows the Sensor / Fan assembly not attached to the base plate, wherein I am using a lead weight to hold it in place during work in progress. I may not even attach it to the Base Plate. As the fan and sensor brackets are separate mounting the fan to each completes the full assembly.

The sensor itself is optional. Without it the extruder can be operated in the same way as version V4, but you will have to measure the diameter by hand.

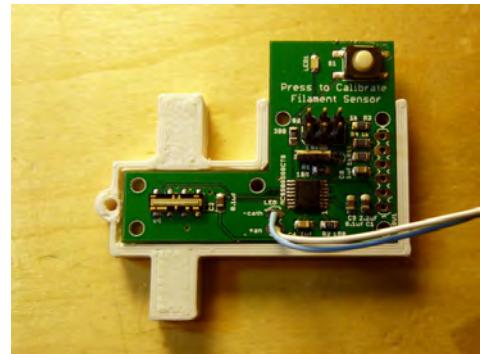


Part # 1 - PCB Sensor Circuit Board:

See Filip Mulier's upload on Thingiverse:

<http://www.thingiverse.com/thing:89044>

The 3D printed parts are custom for this extruder. The electronic components are listed in the BOM.



Part # 2 - Sensor Bottom Base Plate, 3D printed:

There is a groove in the plate that the filament will travel. The design allows for placing the filament in the sensor without having to thread it through a hole.



Part # 3 - Sensor Top Plate, 3D printed:

The top plate has part painted using black acrylic craft paint.

Part #4 - Light Cone, 3D printed:

I printed 4 of these at one time with a 0.35mm nozzle and slowly. The cone is very delicate and printing 4 gives enough time for the filament to cool going from one to the other. I got 3 good ones out of 4. Paint the inside of the cone with black acrylic craft paint. The cone is cemented to the top plate.

Part # 4 - Fan:

The fan is 50 x 50 x 10mm , 12V brushless.

Part # 5 - Sensor Mounting Bracket, 3D printed:

When the sensor is mounted to the bracket the groove in the sensor's bottom plate will be about 1/8" higher the filament nozzle, thus it stays in place with the tension on the filament from the puller rollers. This is critical for getting consistent sensor readings.

Part # 6 - Fan Mounting Bracket, 3D printed:

The windshield portion of the bracket keeps air from the fan cooling the nozzle.

Part # 7 & 8 - Fasteners:

No comment:

ELECTRONIC CASE ASSEMBLY:

This assembly consists of 21 components, 35 pieces total.

Dimensions: 250W x 160H x 55D mm.

The case can be any size you wish as long as the components fit. It can include the LCD display with a larger case. The design is the way I liked it with LCD mounted separately.

I like to attach as many of the electronic components that I can to the panels before I cement the front, ends and bottom together. The standoffs for mounting the Power Supply and the ramps do not have holes, therefore you will have to position the components, mark and drill the holes.

Parts #'s 1,2,3,4,5 & 6 - Case 3D printed Parts:

Some of the parts are printed with filament extruded from V4.1 extruder.

Some have been printed with filament extruded for V5 extruder.

I printed these parts with 2 perimeters, 2 solid top and bottom layers, 40% infill, at a medium speed.

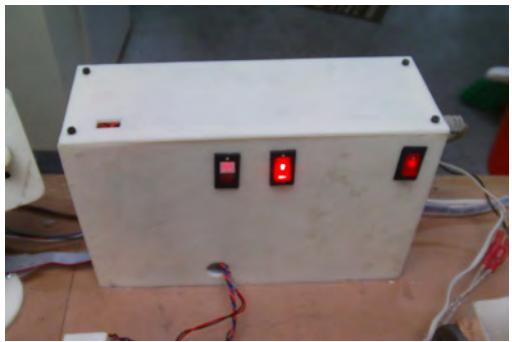
The front face and end panels are cemented to the bottom frame using ABS solvent cement. The back and top panels are loose and attached with M3 x 10mm cap screws. The ends have brass heat inserts to receive the cap screws.

Part # 7 - Brass Heat M3 Insert:

I made a soldering iron tip with a 3mm screw attached to an old soldering iron for heating and inserting the brass inserts.

Part #'s 8,9 & 19 - Fasteners:

No comment.



See drawing sheet P02 for part illustrations.



Part # 10 - 120V Power Switch Illuminated:

This switch as others has to be grounded for the light to work. So it is grounded to the 120V ground on the Power Supply unit.



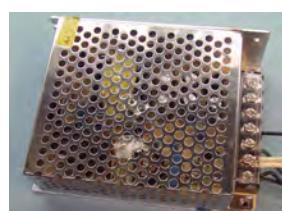
Part # 11 - 12V Switches Illuminated:

The middle switch turns on the Ramps and does not illuminate till the heat is turned on by the LCD controller. The left switch turns on the M3 motor of the Spool Winder. Both switches are grounded to 12V supply from the Ramps.



Part #12 - Power Receptacle

No comment



Part # 13 - Power Supply 120V AC to 12V DCs, 10A:

This power supply is the smallest one I could find at 140x100x40mm.

The Front Face Panel is configured for this one. If a larger one is used the Electronic Case has to be modified.



Part # 14 - Solid State Relay:

The picture shows the one I use. Get a good one as I have had several fail while extruding.

Part # 15 - Arduino Mega 2560 R3:

Get an original not a China copy.

**Part # 16 - Ramps 1.4:**

Get a good one not a China copy.

**Part # 17 - LCD Adapter:**

This part comes with the LCD module and is priced on drawing sheet A05. It attaches to the Ramp 1.4 at the bottom. Make sure your Ramps has the mounting pins.

**Part # 18 - Cooling Fan:**

If you use the heat sinks on the motor drivers this may not be necessary. I keep knocking the heat sinks off so I replaced them with the fan. Size is 40x40x10mm.

**Part # 20 - Motor Drivers:**

This is a A4988 standard driver. I have tried several different ones and they have not worked as good or any better. We are still working on something that will produce more amps than the 2A they supply. In my clumsy self I have fried at least a dozen of these. Their pots stink.

**Part # 21 - Power Cord:**

Just has to fit the receptacle.



LCD PEDESTAL ASSEMBLY:

This assembly is actually optional. The display can be mounted in the Electronic Case if you make it bigger. I have the stl files for a larger case and if you want it I will send them to you. I really like this pedestal as when I am working on the back side I can swivel it around and see what is happening and the viewing angle is also adjustable.



Part #1 - Pedestal Base:

The post on the base will need a little dressing to fit snuggly into the PVC pipe.



Part #2 - Pedestal Swivel Post:

The swivel post also will need dressing to fit the PVC pipe. Mine fits just so it will swivel with a small effort. I attached the 1/4" hex nut to a long bolt and heated it, then pressed it into the hex receiving hole in the post.



Part #3 - Control Knob:

This is printed with a D shaped hole to fit the LCD control post.



Part #4 - Front Pedestal Case:

There are two stl files for this part. One with outriggers to control warping and one without. If you use PLA you probably can use the one without. The only part that needs to be ABS is the Extruder Hopper. Some dressing of the part is needed for fitting the LCD board.

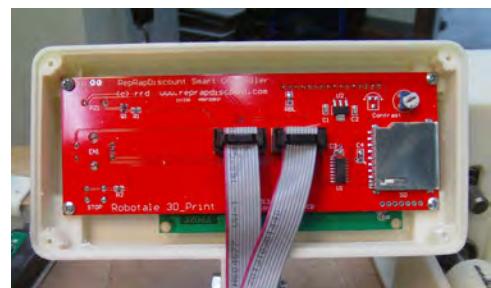
Part #5 - Back Pedestal Lid:

The lid is printed with a standoff shroud with a notched out section at the bottom for the wires to exit from the LCD board. As it is printed with a brim some dressing is required.



Part #6 - LCD Smart Controller with Adapter:

The adapter is shown on the Electronic Case page.



Part #7 - PVC Schedule 40 Pipe - 60mm long:

This is the transition part from the Base Post and the Swivel Post. It is a thin wall pipe. It is visible at the bottom of the first picture.

Part #'s 8,9,10,11 & 12 - Fasteners:

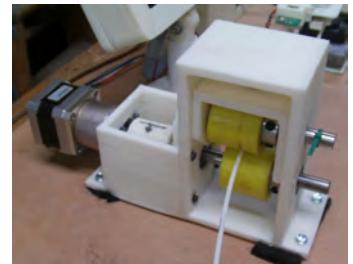
No comment.

SHEET A06: PULLER ROLLER ASSEMBLY

The assembly is printed with 4 parts. The Base bracket holds the drive roller and the idler roller bracket which holds the idler roller. The separate motor mount hold the gear motor M2. The black pads under the assembly is scrap welding blanket I used for the hot end nozzle wrap. Worked good for noise control.

Part #1 - Roller Mount Bracket Base:

Place the spring on the Idler roller bracket and place it in the top of the Base bracket, holding it here with a clamp. Feed the shaft through the slots in the Base bracket through the roller and on through the idler bracket and Base slot. Hold it there with a clamp while the drive roller is installed in a similar way. Note that I used ball bearings in lieu of bushings.



Part #2 - Motor Mount Bracket:

First install the heated plastic M3 in the four 5mm holes. The Base bracket has four matching holes in the end so a long hex wrench can be used to attached the Motor Mount to the Base with the 3mm cap screws. Leave the screws loose till the motor, coupler and shaft are well aligned.

Part #3 - Motor to Shaft Coupler:

The motor Coupler is designed with D shaped holes, 8mm for the motor shaft and 3/8" for the roller shaft. Some dressing of the holes is needed. I heated the shaft end and pressed it in the hole for sizing and wobbled it a little so it would flex. The 3/8" shaft needs the end ground to the hole shape.

Part #4 - Idler Roller Bracket:

The Bracket and the Base each have a centered knob to hold the spring in place. Place the spring on the Bracket knob and fit it in the Base with the spring top in the knob on the Base. Hold it up to the top with a clamp while installing the drive roller. Install the flanged bushings with the flange on the inside.. Here again I used ball bearings in the bracket.

Part #5 - Geared Stepper Motor, Nema 17:

This is the same gear motor I use on my 3D printers self built extruders. It has a 1:14 gear ratio and the Psteps in the firmware need to be 373.3. this is adjusted with LCD if it is different. The only problem with buying direct from Kysan is the minimum \$200 order requirement. I used it as I had it. Any similar gear motor should work. Note the wire colors are different than the M1 extruder motor.

Part #6 - Urethane Rollers:

These are 35A durometers, 1.5" in diameter.

Part #'s 7 & 8 - Shafts:

These are 3/8" diameter to fit the Urethane rollers.

See drawing sheet P10 for dimensions. The drive shaft has the end ground to fit the coupler.

Part #9 - Spring:

The spring is 0.5" ID and is 1" long and wire size is 0.055" diameter. I wish everything was in mm. Millimeters = 25.4mm per inch.

Part #'s - 10, 11,12,13 & 14 - Fasteners:

No comments. See prior note on part 10.

Part #15 - Ball Bearing 3/8" ID—7/8" OD

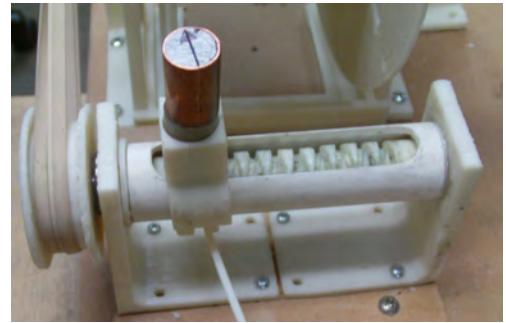
The stl files are designed for this bearing. You can use a flanged brass bushing in lieu of this, however the hole in the roller brackets would have to be changed.

SHEET A07: LEVEL WIND FILAMENT ASSEMBLY

I can't even remember how many hours this took to complete. The worm gear design was inspired from **Mehment Suta's** gear design shown on Thingiverse. Once this worked the rest was easy. I must have printed a dozen worm gears before it worked. This is one of the best assemblies I have done. Oh, it works so good. Sorry for the bragging. The second one I made for **Filip Mulier** was easier. A simpler design is work in progress.

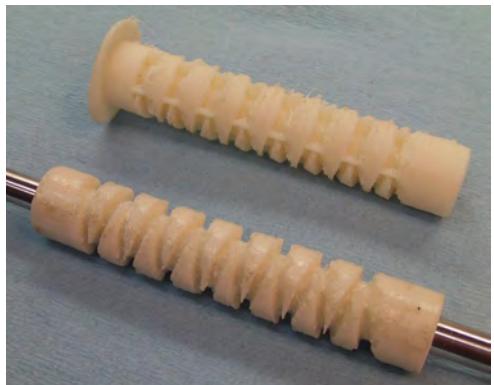
Part #1 - Mounting Brackets:

There are two of these as they are necessary for assembly. They are attached to a base plate and the base plate is attached to the base panel after it is adjusted so as to align with the rubber bands that drive the gear.



Part #2 - Filament Guide:

The guide holds the Pawl and the forks at the bottom guide the filament. With the forks it is easy to hand set the filament in them after the filament is attached to the spool. This part fits over the 3/4" pvc pipe housing.



Part #3 - Worm Gear:

This is the toughest part. Be patient. I had to add to the design supports positioned to print the gears. These have to be removed and the gear needs considerable dressing by filling the gears and the core smooth. I cut them down vertical and then broke them off before filling. When done the part was coated with ABS solvent cement which made it hard and smooth. Also the stl file has a disc base included for printer support and this has to be remove. The shaft hole is drilled out with a 8mm drill bit and the shaft is pressed through so it is tight. The top picture of the gear shows the supports as printed.

Part #4 - Pulley:

The gear pulley here is larger than the spool pulley, wherein the rpm's are correct to turn the worm gear proper for level winding on the spool.

I also sliced the worm gear in half and printed the two halves then glued them together. Some machining is needed to perfect the end travel points to rotate the pawl and it still requires plenty of clean up.



Part #5 - Shaft:

The shaft is 8mm in diameter and the length is 155mm.

Part #6 - Ball Bearings:

No comment.



Part #7 - Pawl:

This part I machined on a mill out of 5/8" peek. The hole was drilled out on a lathe. The length I found was too short to hold enough lead weight, thus I added a piece to add more weight. The stl file is longer and lead filled it should work fine.

Part #8 - Lead:

For this part I melted lead and poured it in to the Pawl cavity.

Part #9 - PVC Pipe Shroud:

This part is schedule 80 PVC 3/4" pipe. The slot was cutout on a mill. It is exactly 109mm long. After assembly the pipe is glued to the brackets.

Part #10 - Fasteners:

No comment.

Part #11 - Mounting Block:

This is 1/2" MDF board, 4.875" x 2.375" to mount the assembly to. The assembly is attached to Base Plate. This block is optional.

SHEET A08 - SPOOL WIND ASSEMBLY:

This assembly consists of ten printed parts. This is my latest design. There are many options on how to make this assembly, so anyway it works if fine. I now have 16 spools made and 6 of them are filled of filament extruded from V5 extruder. You can make these spools out of cardboard, using a 3" shipping tube for the core. I have made several.

Part #1 & 2 - Spool Support Stands:

These part must be attached to the Base Plate spaced 115mm apart. Take care in alignment. Part #1 is printed with two gussets for rigidity.

**Part #3 - Shaft Collars:**

The collars will need drilling out for the size shaft that is used. They need to fit tight on steel shaft and can be glued to a wood dowel shaft. After assembly glue the collars to the spool disc.

**Part #4 - Pulley:**

The pulley also will be need drilling out for the shaft size. Fit it the same as the collars.

**Part #5 - Spool Core:**

No comment.

**Part #6 - Spool Discs:**

The discs are 8" in diameter and the spool will hold 1 kg of filament. There is a round shroud in the print that is for aligning the core to the center of the disc. The discs and core are cemented together with solvent.

**Part #7 - Motor Arm:**

In the stl files are two Arms, one with holes for mounting the shown gear motor and one without holes so it can be machined for any other motor.

Part #8 - Motor Shaft Cog:

This is printed with a D shaped hole to be pressed onto the gear motor shaft.

Part #9 - Gear Motor:

This motor is 70 rpm. The speed can be adjusted in the LCD menu

Part #10 - Spool Shaft:

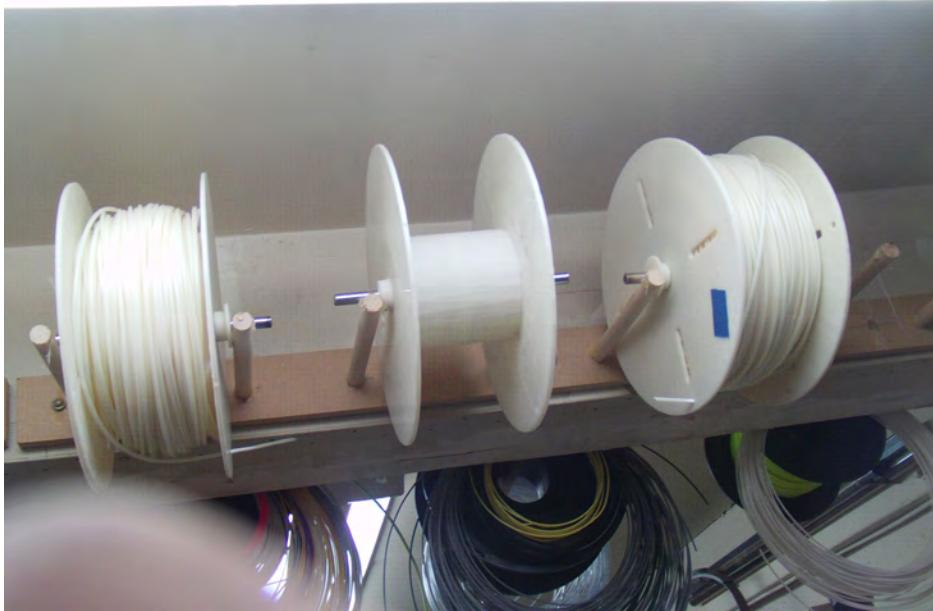
Again, I used what I had which is 8mm. Other diameters and other material can be used. A wood dowel will work also.

**Part #11 - Latex Tubing**

The latex tube is the friction grip that turns the spool. It fits snug over the shaft cog. This will wear out in time and has to be replaced. This should be cleaned off after each spool extruded. Mine wore a slot in the tube after a dozen uses, so I wrapped a rubber band around it to fill the slot. I plan on trying just a rubber band wrapped around the cog.

Part #'s - 12,13,14,15,16, & 17: Fasteners:

No comment



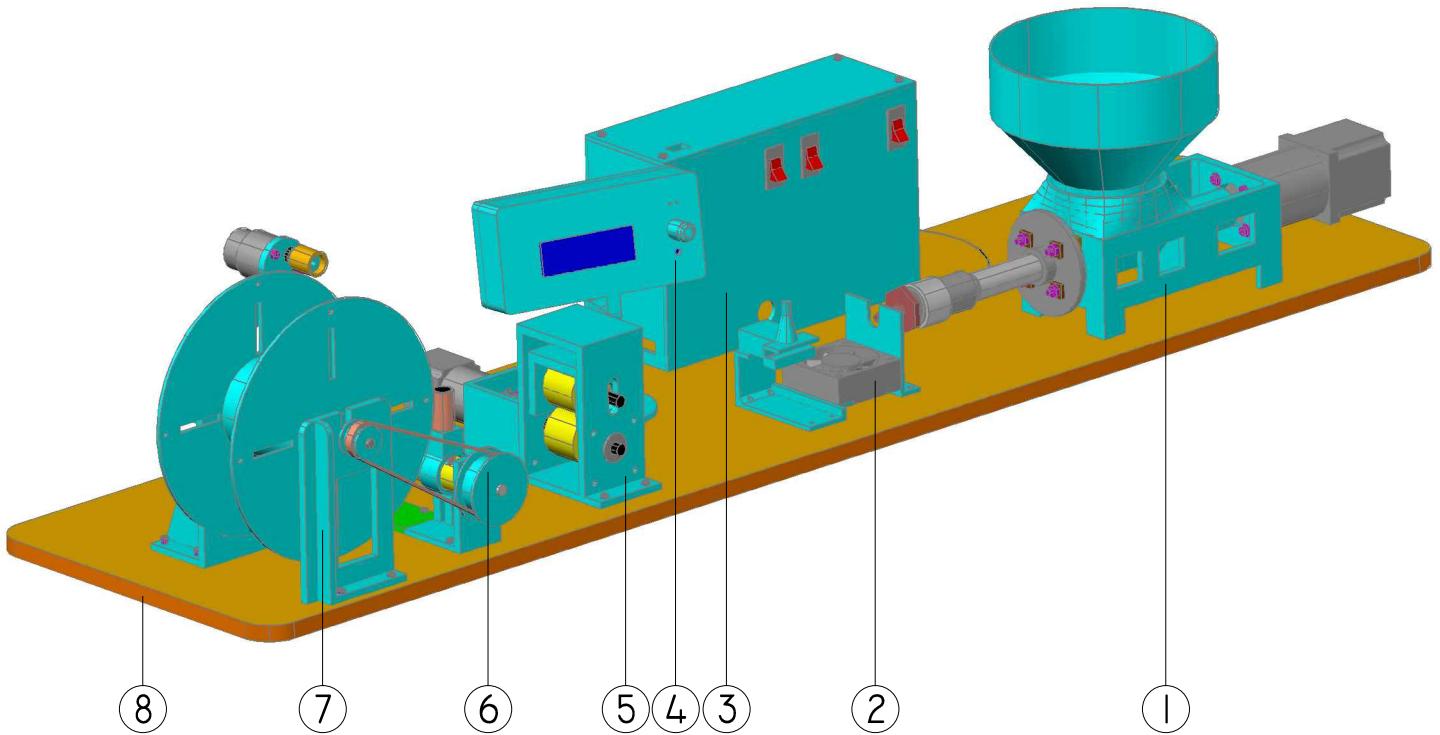
Spool storage rack

This is my spool system which is unique in its self. Use your own imagination and design one that fits your system and equipment. The rubber band around the shaft keeps the spool from free wheeling.

Spool on TAZ printer

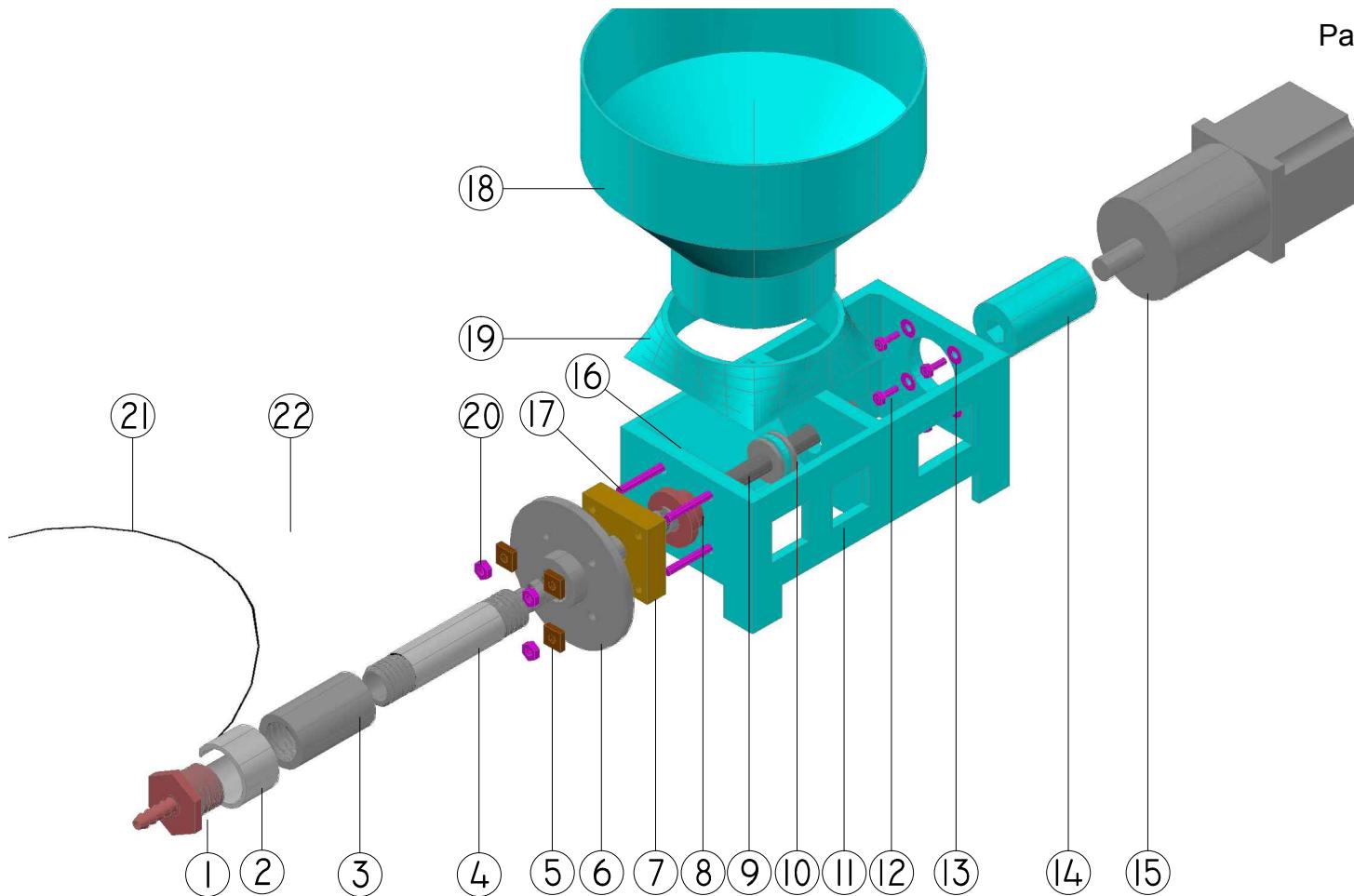


Spool on ORD printer



SUB-ASSEMBLIES

1. EXTRUDER ASSEMBLY
2. SENSOR / FAN ASSEMBLY
3. ELECTRONICS CASE ASSEMBLY
4. LCD PEDESTAL ASSEMBLY
5. PULLER ROLLER ASSEMBLY
6. LEVEL WIND ASSEMBLY
7. SPOOL FILAMENT WIND ASSEMBLY
8. BASE PLATE



BILL OF MATERIAL

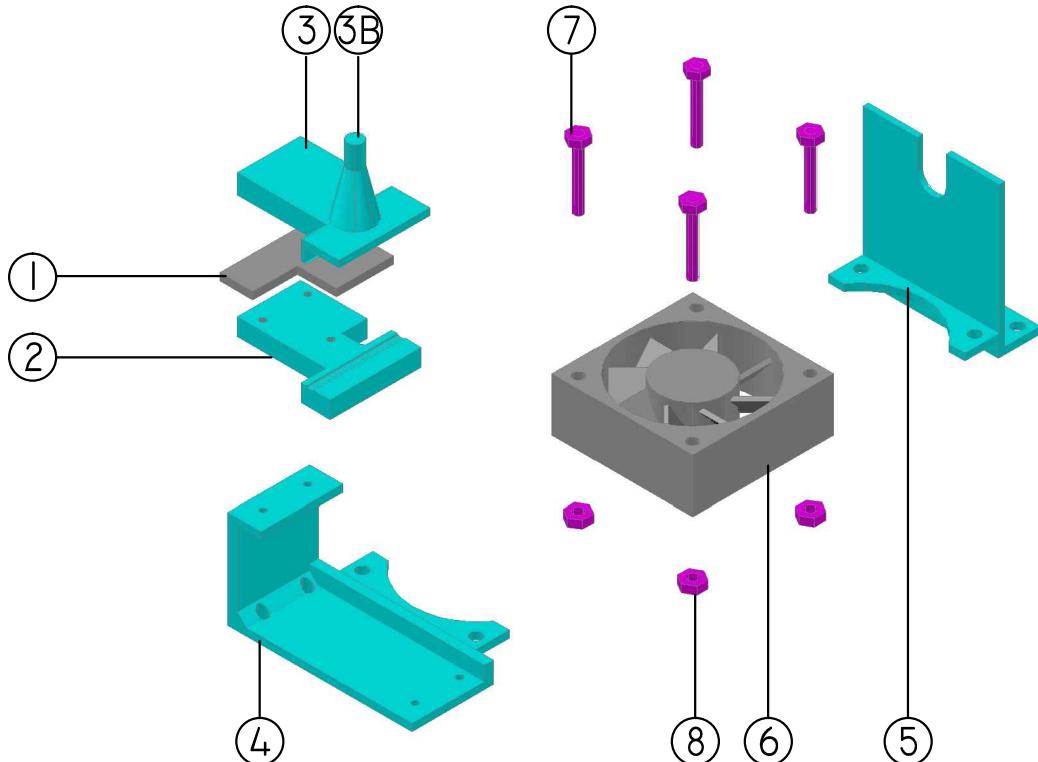
PART#	DESCRIPTION	QTY	PRICE	TOTAL	PART #	SOURCE	NOTE
1	BRASS PLUG NOZZLE 1/2" NPT W/1/4" HOSE CONNECTION	1	\$3.00	\$3.00	FL225	ACE HARDWARE	PRICE ESTIMATED
2	HEAT BAND 1" ID - 120V	1	\$23.00	\$23.00	G472516	ZORO TOOLS	I DIDN'T USE CLAMP
3	COUPLER 1/2" NPT BLACK IRON	1	\$2.56	\$2.56	46685K264	MCMATER CARR	
4	NIPPLE 4"x 1/2" NPT BLACK IRON	1	\$1.28	\$1.28	44615K464	MCMATER CARR	
5	WASHER INSULATING - PHENOLIC OR OAK	4	\$0.50	\$2.00			CUSTOM MAKE
6	FLANGE FLOOR 1/2" NPT Malleable IRON	1	\$2.09	\$2.09	G1596061	ZORO TOOLS	
7	INSULATOR BLOCK - 1/2" OAK WOOD	1	\$1.00	\$1.00			CUSTOM MAKE
8	BRASS FLANGED BUSHING 5/8" ID	1	\$1.24	\$1.24	6391K241	MCMATER CARR	TRIM TO FIT BASE WALL THICKNESS
9	AUGER BIT 5/8" OD	1	\$20.00	\$20.00	BOSH	EBAY	HEX DRIVE END - SEARCH
10	THRUST BEARING 1/2" ID	1	\$2.72	\$2.72	6655K17	MCMATER CARR	
11	3D PRINTED EXTRUDER BASE FILAMENT	1	\$12.00	\$12.00	STL-1	PRINT	FILAMENT COST ESTIMATED
12	CAP SCREW M5 x 15mm	4	\$0.17	\$0.68	154262	FASTENAL	
13	WASHER 5mm	4	\$0.30	\$1.20	40354	FASTENAL	
14	3D PRINTED MOTOR COUPLER	1	\$1.50	\$1.50	STL-2	PRINT	FILAMENT COST ESTIMATED
15	MOTOR GEARED NEMA 23 15:1 GEAR	1	\$74.00	\$74.00	3333_0	PHIDGETS	
16	WASHER 4mm	4	\$0.03	\$0.12	40353	FASTENAL	
17	CAP SCREW 4 x 45mm	4	\$0.35	\$1.40	11103318	FASTENAL	
18	3D PRINTED FUNNEL OR 3" ID TUBE	1	\$8.00	\$8.00	STL-3	PRINT	FILAMENT COST ESTIMATED
19	3D PRINTED FUNNEL BASE	1	\$2.00	\$2.00	STL-4	PRINT	CEMENT TO EXTRUDER BASE
20	NUT NYLOK 4mm	4	\$0.11	\$0.44	40147	FASTENAL	
21	THERMISTOR 100K & WIRING	1	\$4.00	\$4.00	UMTHR100	ULTIMACHINE	W/ PTFE SLEEVING
22	WELDING BLANKET HOT END WRAP 3" x 12"	1	\$2.25	\$2.25		EBAY	NOT SHOWN
TOTAL COST excluding shipping, wires & supplies			\$166.48				

HUGH LYMAN
FILIP MULIER
INVENTORS

EXTRUDER ASSEMBLY
LYMAN / MULIER FILAMENT EXTRUDER V5

SCALE: NONE
DRW: H.LYMAN
DATE: 6/12/14

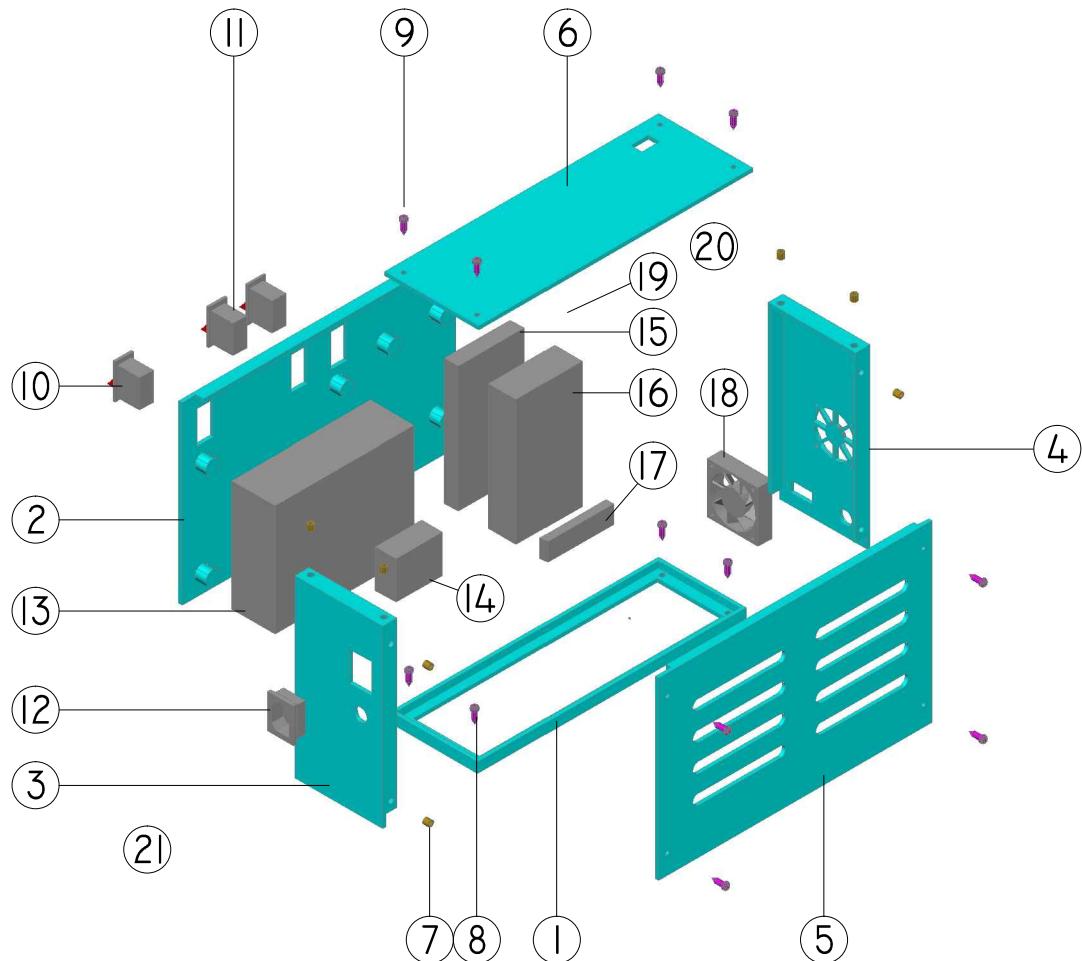
A02

**BILL OF MATERIAL**

PART#	DESCRIPTION	QTY	PRICE	TOTAL	PART #	SOURCE	NOTE
1	PC BOARD - SEE PCB BOM BELOW	1	\$11.94	\$11.94		SEE BELOW	
2	3D PRINTED SENSOR BASE PLATE	1	\$1.00	\$1.00	STL-5	PRINTED	
3	3D PRINTED SENSOR TOP PLATE	1	\$1.00	\$1.00	STL-6	PRINTED	
3B	3D PRINTED SENSOR CONE	1	\$0.50	\$0.50	STL-6B	PRINTED	
4	3D PRINTED SENSOR BRACKET	1	\$1.00	\$2.50	CF-429	PRINTED	
5	3D PRINTED FAN BRACKET	1	\$1.00	\$1.00	STL-7	PRINTED	
6	FAN 12V 50x50x25mm	1	\$2.50	\$1.00	STL-8	ALL ELECTRONICS	
7	NUT M4	4	\$0.11	\$0.44	TBD	FASTENAL	
8	CAP SCREW M4x30mm	4	\$0.30	\$1.20	TBD	FASTENAL	
TOTAL COST excluding shipping, wires & supplies				\$19.38			

PCB BILL OF MATERIAL

PART#	VALUE	DESCRIPTION	QTY	PRICE	TOTAL	PART #	SOURCE	NOTE
C1	2.2uF	0805 2.2uF 16volts Y5V 20%	1	\$0.06	\$0.06	77-VJ0805V225MXJTBC	www.mouser.com	Vishay
C2, C9	0.1uf	.1uF 25volts X7R 20%	2	\$0.06	\$0.12	77-VJ0805Y104MXXAC	www.mouser.com	Vishay
C4, C8	1uf	0805 1uF 10volts X7R 10%	2	\$0.05	\$0.10	77-VJ0805Y105KXQTBC	www.mouser.com	Vishay
LED		Standard LEDs - Through Hole Red Round LED	1	\$0.15	\$0.15	941-C503BRBNCW0Z0AA	www.mouser.com	Cree, Inc.
LED1		20mA	1	\$0.10	\$0.10	720-LSR976-NR-1	www.mouser.com	Osram Opto Semiconductor
R2	150	100ppm	1	\$0.08	\$0.08	71-CRCW0805-150-E3	www.mouser.com	Vishay
R3, R4, R1	1k	100ppm	3	\$0.08	\$0.24	71-CRCW0805-1.0K-E3	www.mouser.com	Vishay
R6	300	Thick Film Resistors - SMD 1/8watt 300ohms 5%	1	\$0.08	\$0.08	71-CRCW0805300RJNEA	www.mouser.com	Vishay
S1		SMD	1	\$0.39	\$0.39	667-EVQ-Q2F03W	www.mouser.com	Panasonic
U\$1	MC9S08SG8CTG	SGF	1	\$2.12	\$2.12	841-S9S08SG8E2CTG	www.mouser.com	Freescale Semiconductor
U\$3	BIG_TSL1401CL	Sensor Array 400dpi 128 pixel	1	\$6.34	\$6.34	856-TSL1401CL	www.mouser.com	ams
		Screws & Fasteners 1/2 2-56 STEEL PAN	4	\$0.16	\$0.64	534-9356	www.mouser.com	Keystone Electronics
		PC Board	1	\$1.52	\$1.52		www.seeedstudio.com	See note in wiring diagram
TOTAL COST excluding shipping, wires & supplies				\$11.94				



BILL OF MATERIAL

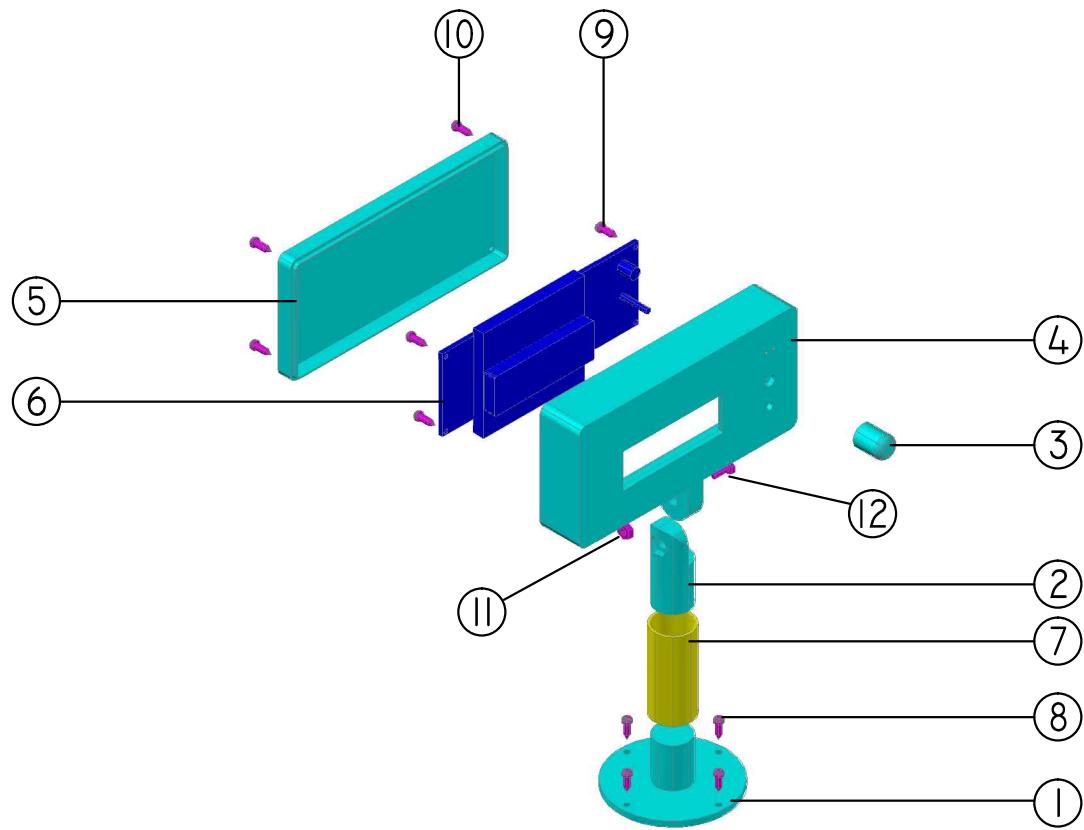
PART#	DESCRIPTION	QTY	PRICE	TOTAL	PART #	SOURCE	NOTE
1	3D PRINTED CASE BOTTOM	1	\$1.60	\$1.60	STL-9	PRINTER	
2	3D PRINTED CASE FRONT	1	\$5.00	\$5.00	STL-10	PRINTER	
3	3D PRINTED CASE RIGHT END	1	\$2.50	\$2.50	STL-11	PRINTER	
4	3D PRINTED CASE LEFT END	1	\$2.50	\$2.50	STL-12	PRINTER	
5	3D PRINTED CASE BACK	1	\$5.00	\$5.00	SRL-13	PRINTER	
6	3D PRINTED CASE TOP	1	\$2.50	\$2.50	STL-14	PRINTER	
7	BRASS PLASTIC HEAT INSERT 3mm - 5mm OD	8	\$0.13	\$1.04	94180A331	McMASTER CARR	
8	SCREW #4x1/2" PHSM	4	\$0.05	\$0.20		HARDWARE STORE	
9	CAP SCREW M3x6	8	\$0.16	\$1.28	11103295	FASTENAL	
10	SWITCH 120V ILLUMINATED	1	\$1.25	\$1.25	30183-SW	MPJA	
11	SWITCH 12V ILLUMINATED	2	\$1.25	\$2.50	30184-SW	MPJA	
12	CONNECTOR 120V POWER INLET	1	\$0.49	\$0.49	17371-PL	MPJA	
13	POWER SUPPLY 12V 10A - 140x100x40mm	1	\$15.00	\$15.00		EBAY	
14	SOLID STATE RELAY	1	\$6.00	\$6.00		EBAY	
15	MEGA 2560 R3 CONTROLLER	1	\$20.00	\$20.00		EBAY	
16	RAMPS 1.4 CONTROLLER	1	\$27.00	\$27.00		EBAY	
17	WIRE ADAPTER FOR LCD					EBAY	SEE A05 FOR LCD PRICE
18	FAN 40x40x10mm 12V	1	\$1.00	\$1.00		EBAY	
19	SCREW #4x3/8" PHSM	6	\$0.04	\$0.24		HARDWARE STORE	NOT SHOWN IN DRAWING
20	MOTOR DRIVERS A4988	2	\$9.95	\$19.90	2128	POLOLU	NOT SHOWN IN DRAWING
21	POWER CORD 120V	1	\$4.25	\$4.25		EBAY	NOT SHOWN IN DRAWING
TOTAL COST	excluding shipping, wires & supplies			\$119.25			

HUGH LYMAN
FILIP MULIER
INVENTORS

ELECTRONIC CASE ASSEMBLY
LYMAN / MULIER FILAMENT EXTRUDER V5

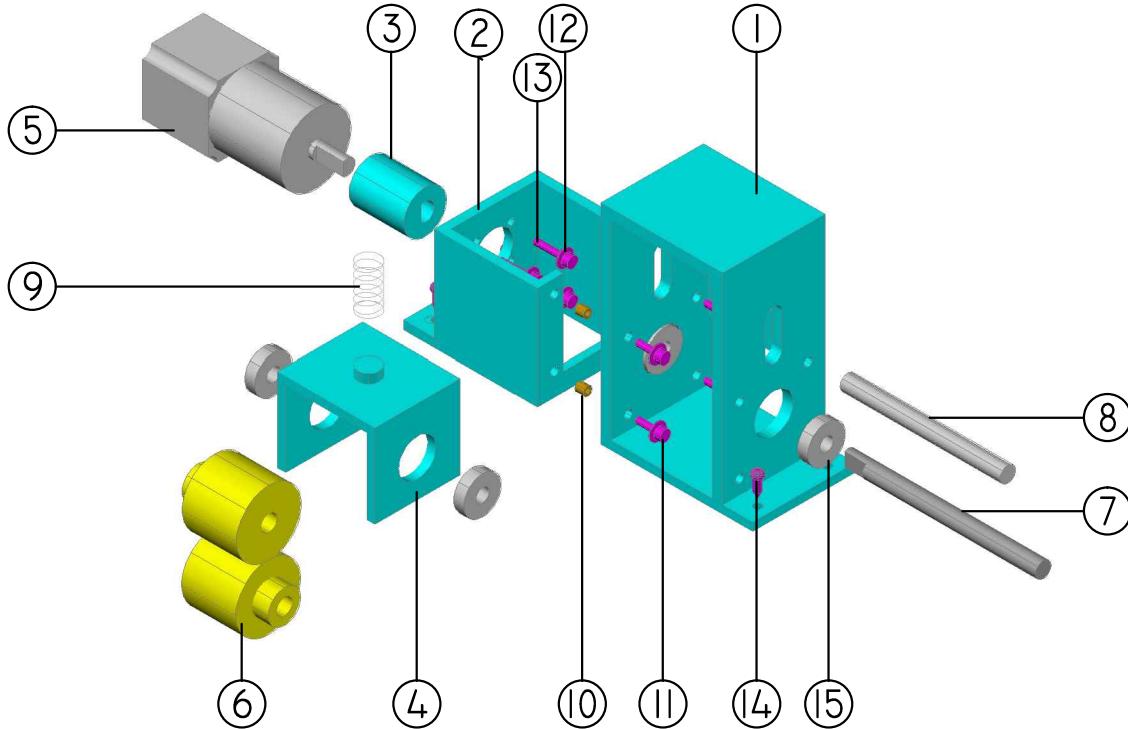
SCALE: NONE
DRW: H.LYMAN
DATE: 6/12/14

A04



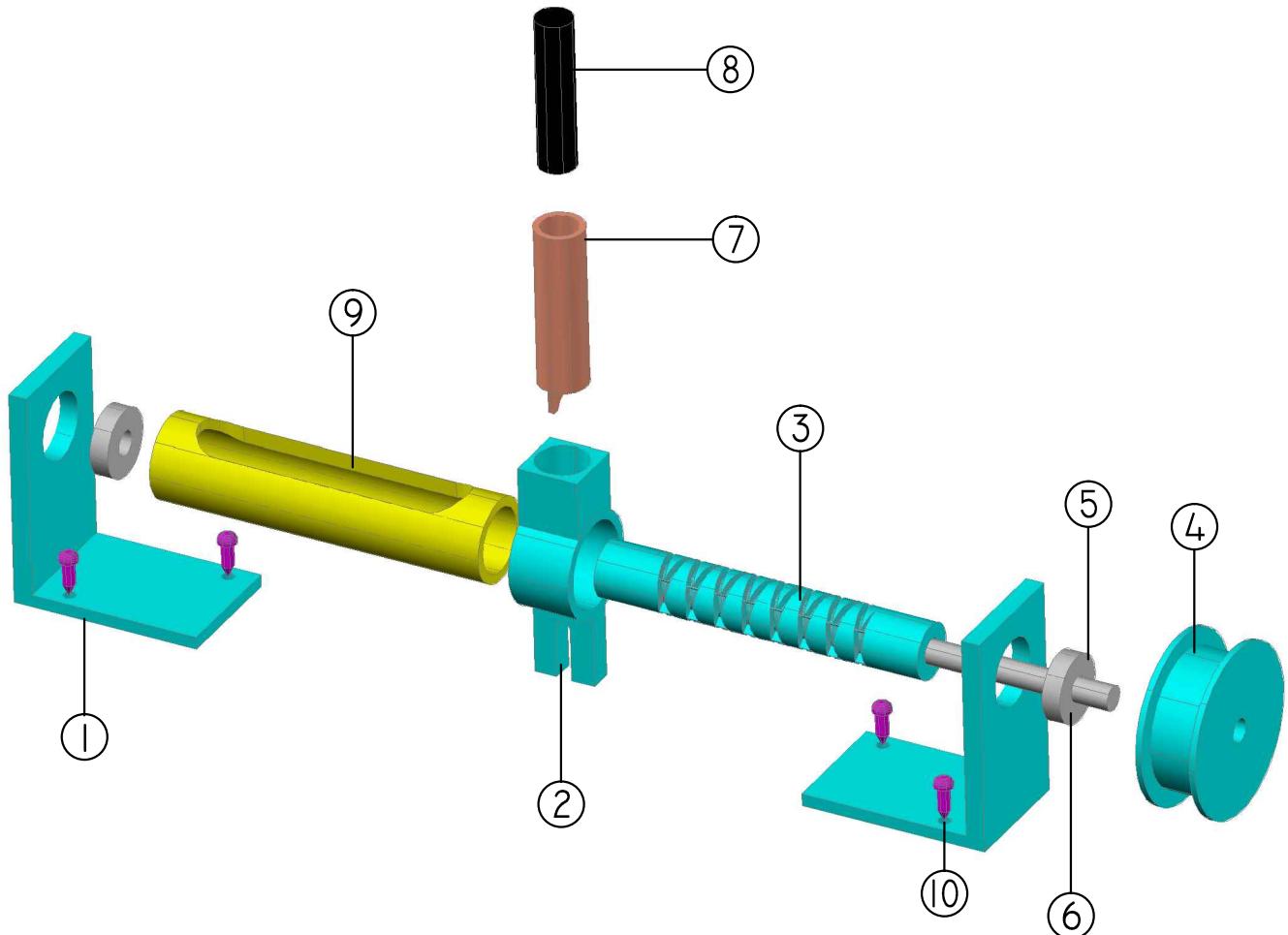
BILL OF MATERIAL

PART#	DESCRIPTION	QTY	PRICE	TOTAL	PART #	SOURCE	NOTE
1	3D PRINTED BASE	1	\$1.40	\$1.40	STL-15	PRINT	
2	3D PRINT SWIVEL POST	1	\$0.70	\$0.70	STL-16	PRINT	
3	3D PRINTED KNOB	1	\$0.15	\$0.15	STL-17	PRINT	
4	3D PRINTED CASE FRONT	1	\$5.00	\$5.00	STL-18	PRINT	
5	3D PRINTED CASE BACK	1	\$2.80	\$2.80	STL-19	PRINT	
6	LCD SMART 2004 CONTROLLER WITH ADAPTER	1	\$26.00	\$26.00	2004	EBAY	
7	PVC PIPE - 3/4" SCHEDUAL 40 - 60mm LONG	1	\$0.25	\$0.25		HARDWARE STORE	
8	SCREW #4x1/2" PHSM	4	\$0.04	\$0.16		HARDWARE STORE	
9	SCREW #4x3/8" PHSM	4	\$0.04	\$0.16		HARDWARE STORE	
10	SCREW #4x3/4" PHSM	4	\$0.04	\$0.16		HARDWARE STORE	
11	NUT NEX 1/4"	1	\$0.10	\$0.10		HARDWARE STORE	
12	BOLT 1/4" x 1" HEX HEAD	1	\$0.20	\$0.20		HARDWARE STORE	
TOTAL COST excluding shipping, wires & supplies				\$37.08			



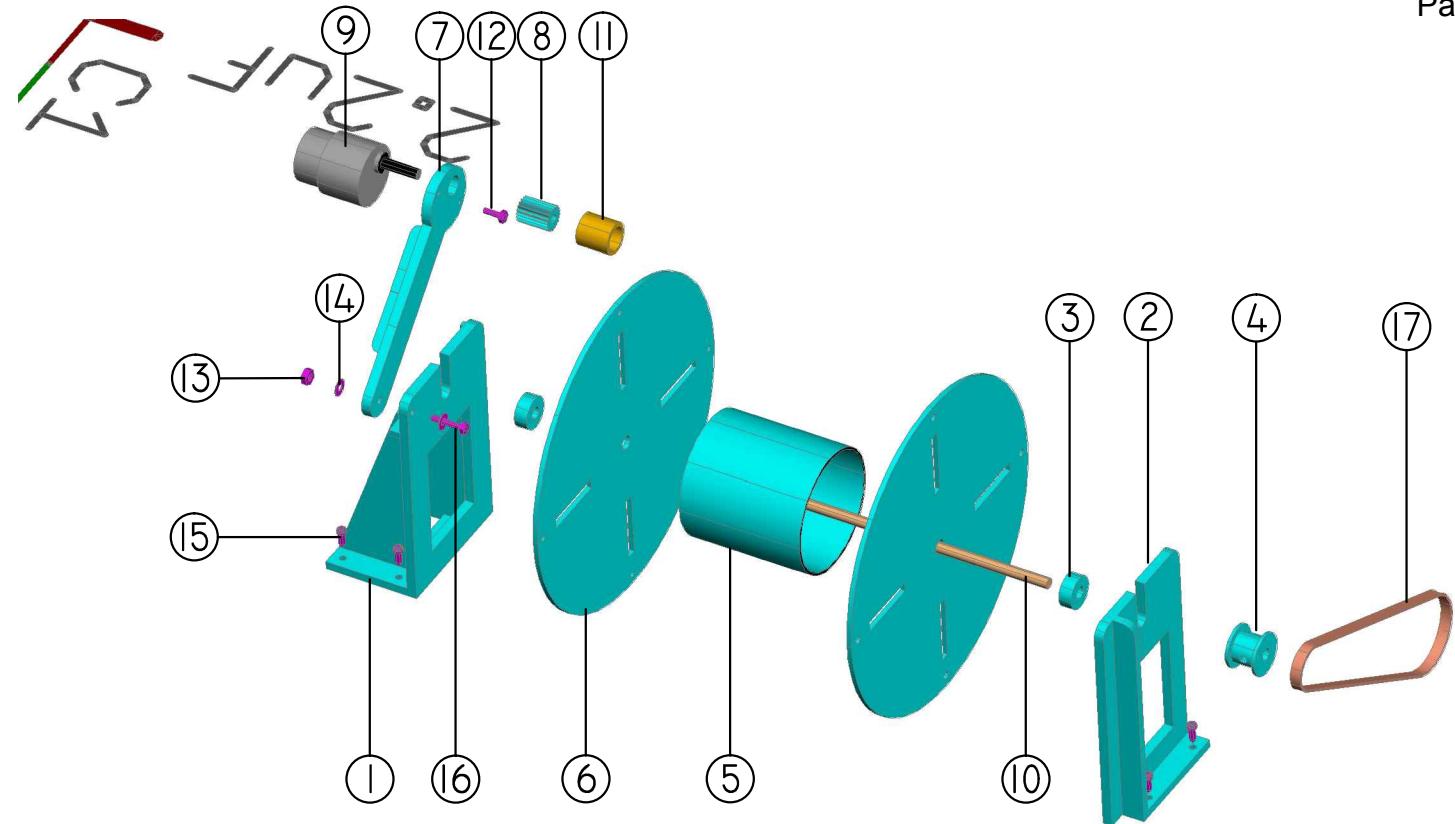
BILL OF MATERIAL

PART#	DESCRIPTION	QTY	PRICE	TOTAL	PART #	SOURCE	NOTE
1	3D PRINTED ROLLER BLOCK BASE	1	\$4.20	\$4.20	STL-20	PRINT	
2	3D PRINTED MOTOR BRACKET	1	\$2.00	\$2.00	STL-21	PRINT	
3	3D PRINTED MOTOR COUPLER	1	\$0.50	\$0.50	STL-22	PRINT	
4	3D PRINTED ROLLER BRACKET	1	\$1.50	\$1.50	STL-23	PRINT	
5	MOTOR GEARED STEPPER NEMA 17	1	\$29.00	\$29.00	1040220	KAYSAN	
6	URETHANE DRIVE ROLLERS 3/8" ID 35A	2	\$29.32	\$58.64	2475K61	McMASTER CARR	
7	SHAFT 3/8" x 4-1/2"	0.5	\$2.65	\$1.33	6061K108	McMASTER CARR	
8	SHAFT 3/8" x 4"	0.5	\$2.65	\$1.33	6061K108	McMASTER CARR	
9	SPRING 1/2" x 1"	1	\$1.50	\$1.50		HARDWARE STORE	
10	BRASS PLASTEC HEAT INSERTS 3mm	4	\$0.13	\$0.52	94180A331	McMASTER CARR	
11	CAP SCREW 3mm x 14	4	\$0.20	\$0.80	1139518	FASTENAL	
12	WASHER 3mm	8	\$0.03	\$0.24	1140352	FASTENAL	
13	CAP SCREW 3mm x 12	4	\$0.19	\$0.76	1134505	FASTENAL	
14	SCREW #4x 1/2" PHSM	4	\$0.04	\$0.16		HARDWARE STORE	
15	BEARING BALL 3/8" ID	4	\$4.80	\$19.20	Kit2052	VXB	
TOTAL COST excluding shipping, wires & supplies				\$121.67			



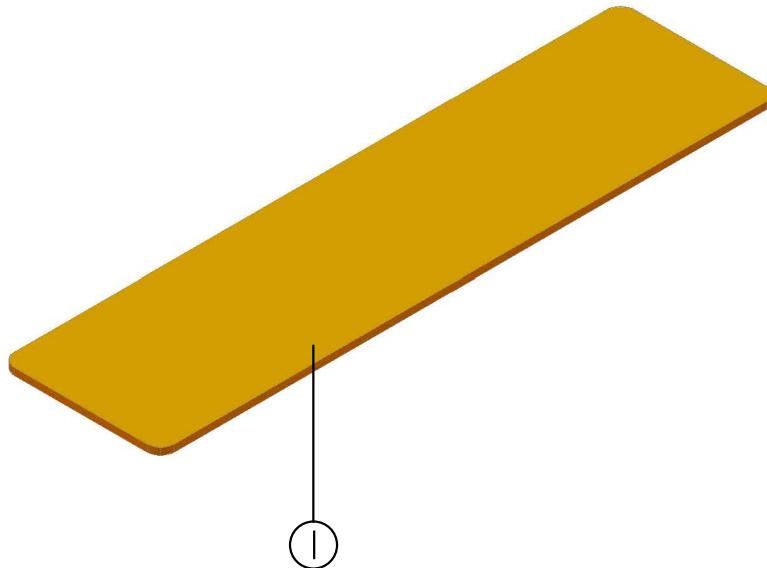
BILL OF MATERIAL

PART #	DESCRIPTION	QTY	PRICE	TOTAL	PART #	SOURCE	NOTE
1	3D PRINTED BRACKET	2	\$1.00	\$2.00	STL-24	PRINTED	
2	3D PRINTED GUIDE	1	\$0.50	\$0.50	STL-25	PRINTED	
3	3D PRINTED WORM GEAR	1	\$0.90	\$0.90	STL-26	PRINTED	
4	3D PRINTED PULLEY	1	\$1.60	\$1.60	STL-27	PRINTED	
5	SHAFT 8mm x 155mm	1	\$5.78	\$5.78	6112K44	McMASTER CARR	
6	BEARING BALL 8mm ID	2	\$4.37	\$8.74	MR608-2R5	VXB	OPTION: USE BRASS BUSHING
7	PAWL - PEAK 5/8" OD x 65mm	1	\$4.36	\$4.36	8503K232	McMASTER CARR	DRILL OUT FOR FILLING WITH LEAD
8	LEAD TO FILL PAWL	1	\$1.00	\$1.00		EBAY	NEED A LEAD MELTER
9	PVC PIPE - 3/4" SCHD 80 x 109mm	1	\$1.00	\$1.00		HARDWARE STORE	
10	SCREW #4 x 1/2"	4	\$0.04	\$0.16		HARDWARE STORE	
TOTAL COST excluding shipping, wires & supplies			\$26.04				



BILL OF MATERIAL

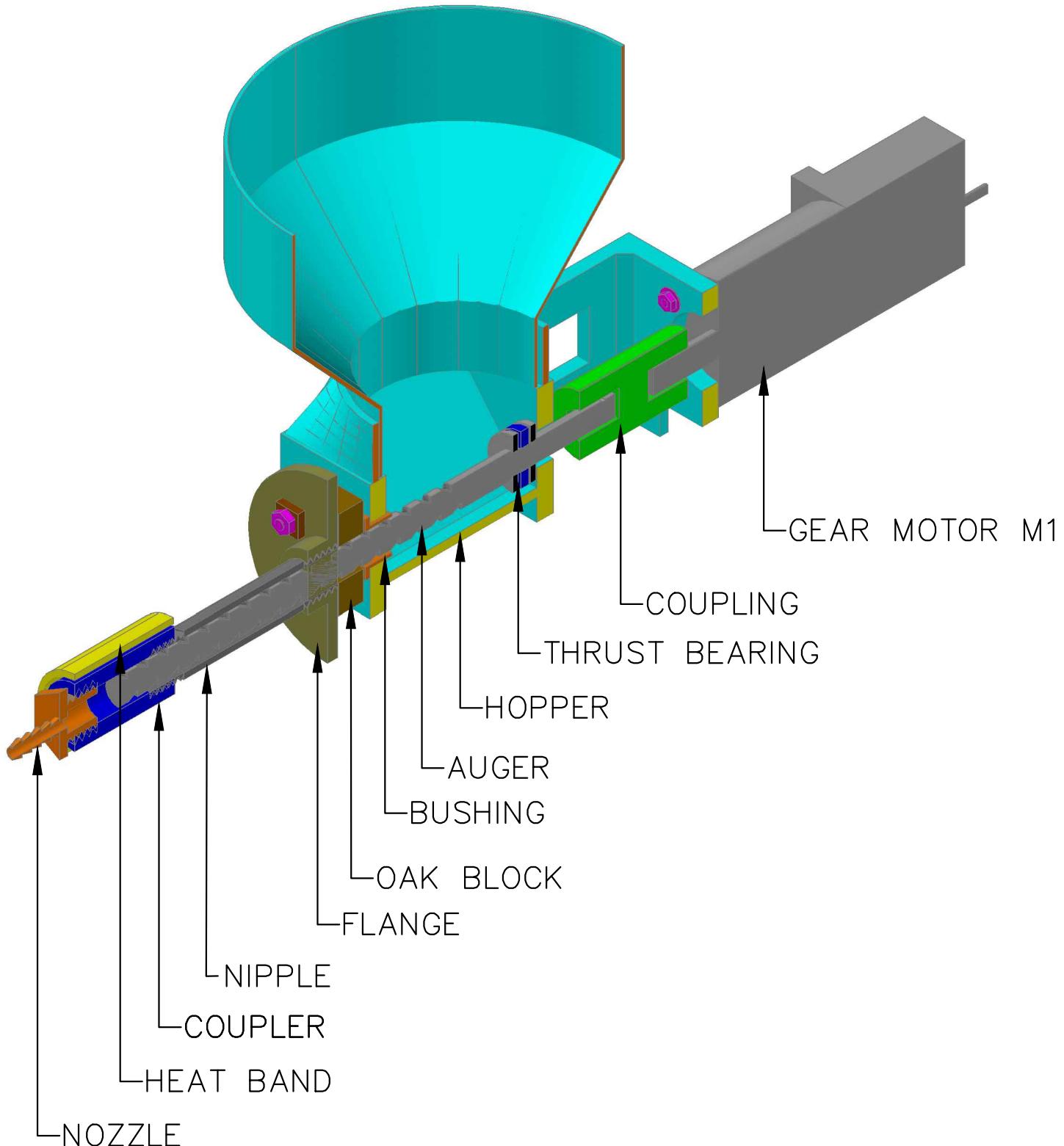
PART#	DESCRIPTION	QTY	PRICE	TOTAL	PART #	SOURCE	NOTE
1	3D PRINTED LEFT BRACKET STAND	1	\$4.00	\$4.00	STL-28	PRINTED	
2	3D PRINTED RIGHT BRACKET STAND	1	\$3.20	\$3.20	STL28	PRINTED	
3	3D PRNTED COLLAR	2	\$0.50	\$1.00	STL30	PRINTED	
4	3D PRINTED PULLEY	1	\$0.75	\$0.75	STL-31	PRINTED	
5	3D PRINTED SPOOL CORE	1	\$2.20	\$2.20	STL-32	PRINTED	
6	3D PRINTEED SPOOL DISC	2	\$3.50	\$7.00	STL-33	PRINTED	
7	3D PRINTED MOTOR ARM	1	\$0.75	\$0.75	STL-34	PRINTED	
8	3D PRINTED MOTOR SHAFT COG	1	\$0.50	\$0.50	STL-35	PRINTED	
9	MOTOR GEARED SMALL 12V +/- 70 RPM	1	\$10.00	\$10.00		EBAY	
10	SPOOL SHAFT, 3/8" x 6.5" WOOK DOWEL	1	\$0.50	\$0.50			
11	TUBE LATEX 1/2" ID 25mm LONG	1	\$0.43	\$0.43		EBAY	SOLD BY THE FOOT
12	CAP SCREW M3 x 10mm	2	\$0.10	\$0.20	11103297	FASTEN ALL	
13	NUT M4 NYLOCK	1	\$0.11	\$0.11	40147	FASTEN ALL	
14	WASHER M4	2	\$0.03	\$0.06	40353	FASTEN ALL	
15	SCREW #4x 1/2" PHSM	4	\$0.04	\$0.16		HARDWARE STORE	
16	CAP SCREW M4 x 20mm	1	\$0.28	\$0.28	1139507	FASTEN ALL	
17	RUBBER BAND	3	\$0.05	\$0.15			
TOTAL COST excluding shipping, wires & supplies				\$31.29			

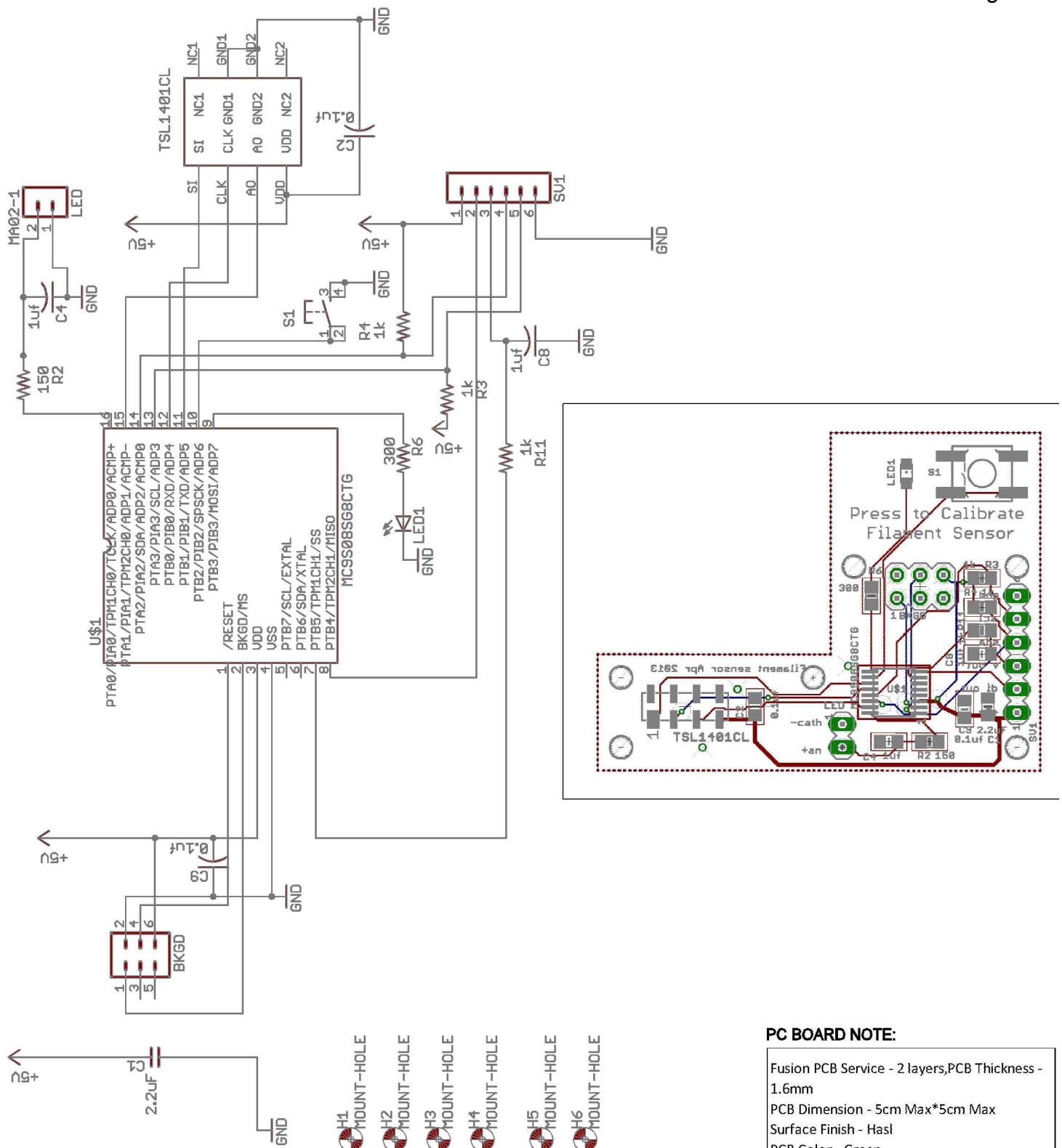


**PART # 8
BASE PLATE
DRAWING A01**

SZE: 46" x 12" x $\frac{1}{2}$ " MDF BOARD
NOT SHOWN IN PART DRAWINGS

BILL OF MATERIAL							
PART#	DESCRIPTION	QTY	PRICE	TOTAL	PART #	SOURCE	NOTE
1	BASE PLATE - 46 x 12 x 1/2" MDF BOARD	1	\$5.00	\$5.00		HOME DEPOT	PRICE ESTIMATED
TOTAL COST excluding shipping, wires & supplies				\$5.00			



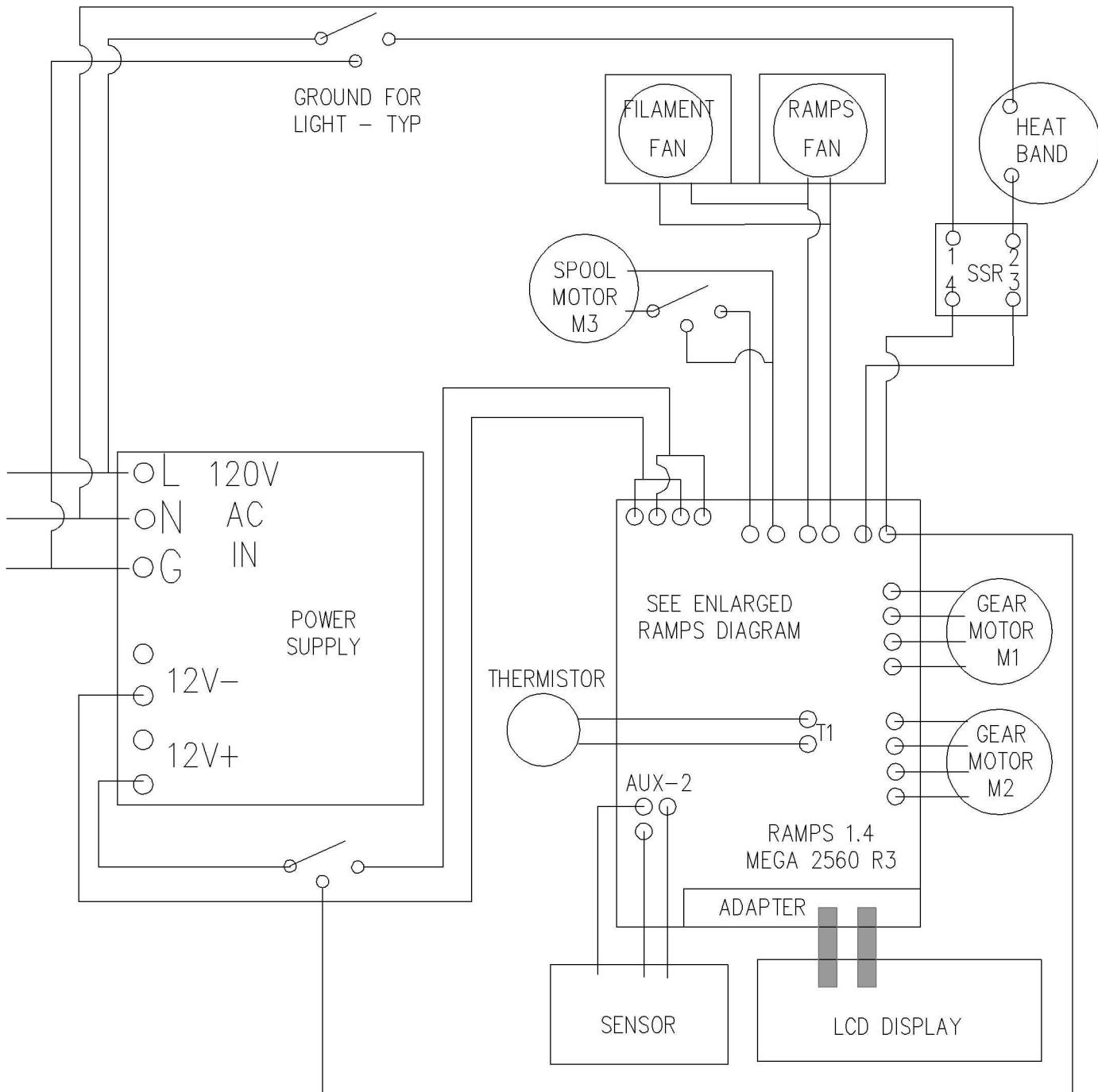


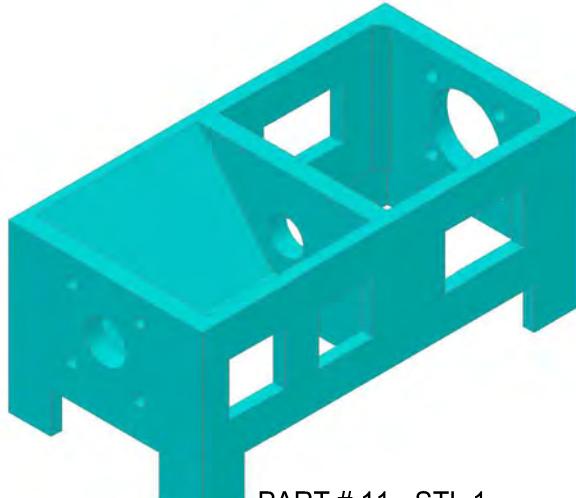
HUGH LYMAN
FILIP MULIER
INVENTORS

SENSOR SCHEMATICS & PCB
LYMAN / MULIER FILAMENT EXTRUDER V5

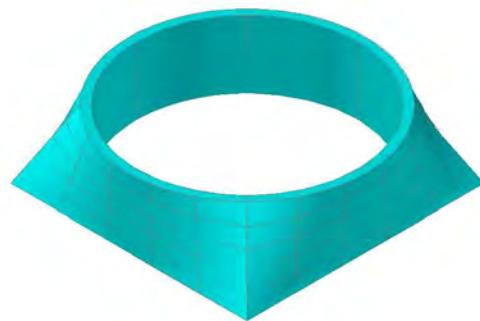
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DRW: F.MULIER
DATE: 6/12/14

A11

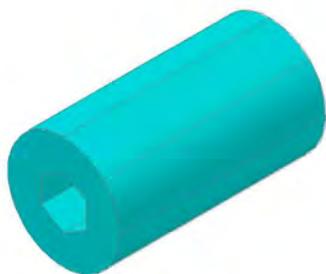




PART # 11 - STL 1
M1 MOTOR & HOPPER BASE
DRAWING A02



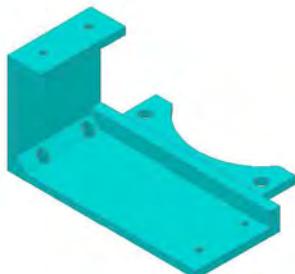
PART # 19 - STL 4
FUNNEL BASE
DRAWING A02



PART # 14 - STL 2
MOTOR - AUGER COUPLER
DRAWING A02

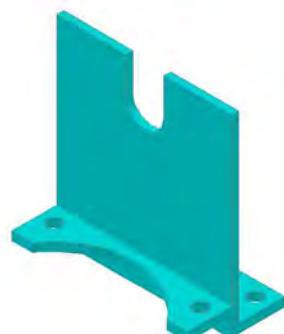


PART # 18 - STL 3
FUNNEL
DRAWING A02

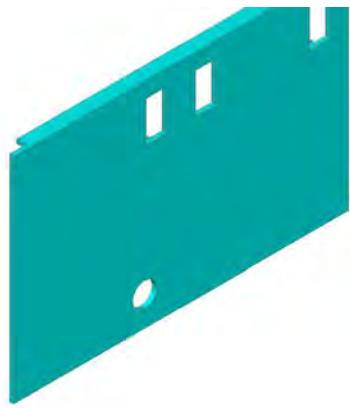


PART # 6 - STL 7
SENSOR BRACKET
DRAWING A03

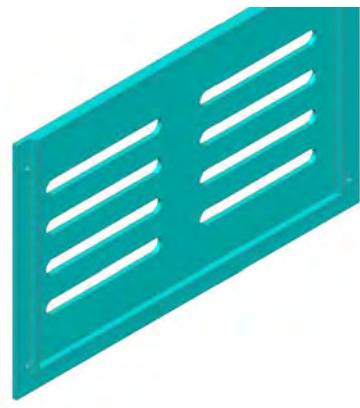
STL FILES ARE ORIENTED
FOR 3D PRINTING



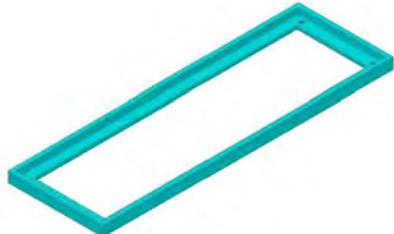
PART # 8 - STL 8
FAN BRACKET
DRAWING A03



PART # 2 - STL 10
FRONT FACE PANEL
ELECTRONICS BOX
DRAWING A04



PART # 5 - STL 13
BACK PANEL
ELECTRONICS BOX
DRAWING A04



PART # 1 - STL 9
BOTTOM PANEL
ELECTRONICS BOX
DRAWING A04



PART # 6 - STL 14
TOP PANEL
ELECTRONICS BOX
DRAWING A04



PART # 4 - STL 12
LEFT END PANEL
ELECTRONICS BOX
DRAWING A04

FRONT, ENDS & BOTTOM
ARE CEMENTED
TOGETHER



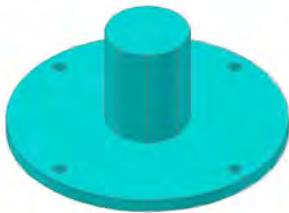
PART # 3 - STL 11
RIGHT END PANEL
ELECTRONICS BOX
DRAWING A04



PART # 4 - STL 18
LCD FRONT ENCLOSURE
DRAWING A05



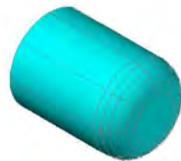
PART # 5 - STL 19
LCD BACK ENCLOSURE
DRAWING A05



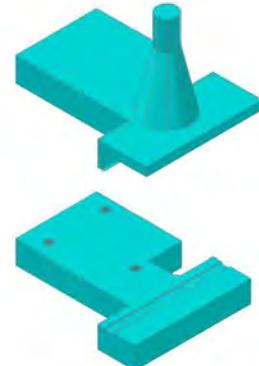
PART # 1 - STL 15
BASE
DRAWING A05



PART # 2 - STL 16
LCD BACK PART
DRAWING A05



PART # 3 - STL 17
CONTROL KNOB
DRAWING A05



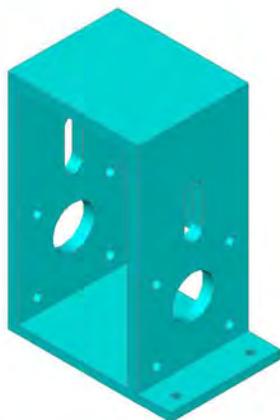
PART # 1 & 2 - NO STL YET
PCB BOARD ENCLOSURES
DRAWING A03

HUGH LYMAN
FILIP MULIER
INVENTORS

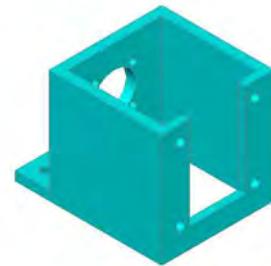
3D PRINTED PARTS
LYMAN / MULIER FILAMENT EXTRUDER V5

SCALE: NONE
DRAW: H.LYMAN
DATE: 6/12/14

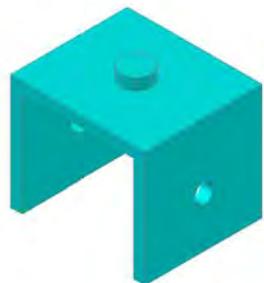
P03



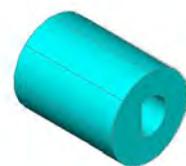
PART # 1 - STL 20
ROLLER BASE BLOCK
DRAWING A06



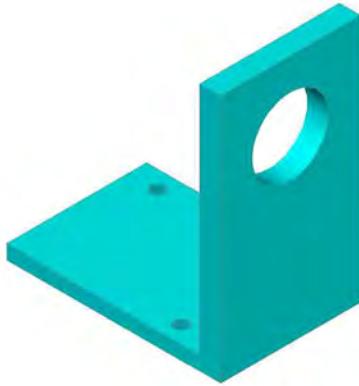
PART # 2 - STL 21
MOTOR BASE BLOCK
DRAWING A06



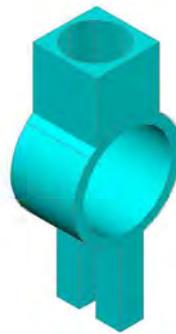
PART # 4 - STL 23
ROLLER BRACKET
DRAWING A06



PART # 3 - STL 22
MOTOR - SHAFT COUPLER
DRAWING A06



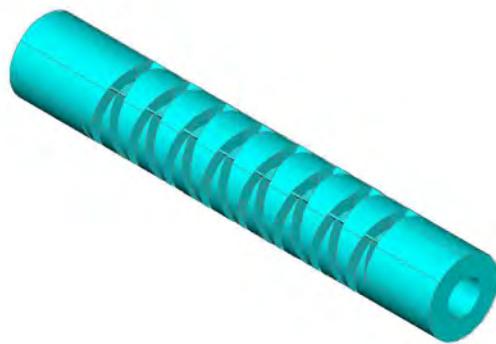
PART # 1 - STL 24
LEVEL WIND BRACKET
DRAWING A07
2 REQUIRED



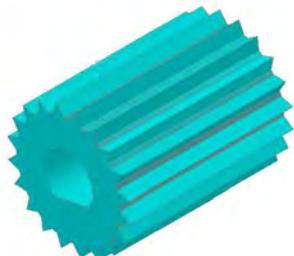
PART # 2 - STL 25
PAWL GUIDE
DRAWING A07



PART #4 - STL 27
PULLEY
DRAWING A07



PART # 3 - STL 26
WORM GEAR
DRAWING A07



PART # 8 - STL 35
MOTOR COG
DRAWING A08



PART # 3 - STL 35
SHAFT COLLAR
DRAWING A08
2 REQUIRED



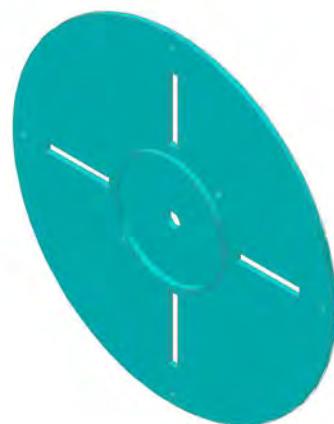
PART # 1 - STL 28
FRONT BRACKET STAND
DRAWING A08



PART # 2 - STL 29
BACK BRACKET STAND
DRAWING A08



PART # 7 - STL 34
MOTOR ARM
DRAWING A08



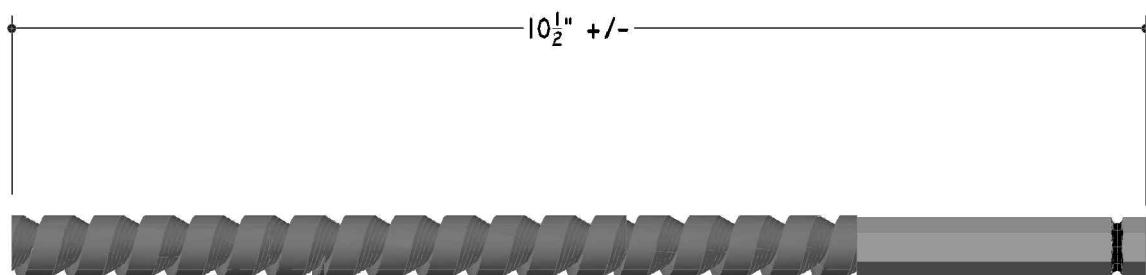
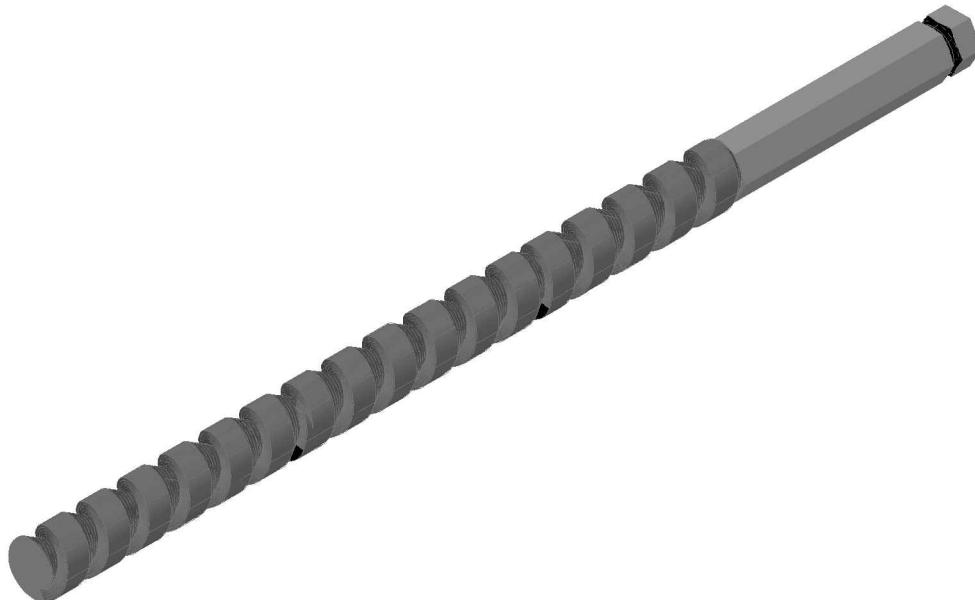
PART # 6 - STL 33
SPOOL DISC
DRAWING A08
2 REQUIRED



PART # 5 - STL 32
SPOOL CORE
DRAWING A08



PART # 4 - STL 31
PULLEY
DRAWING A08



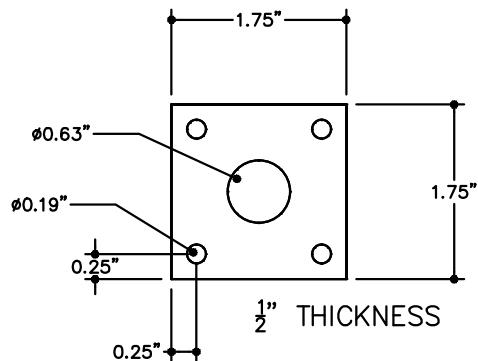
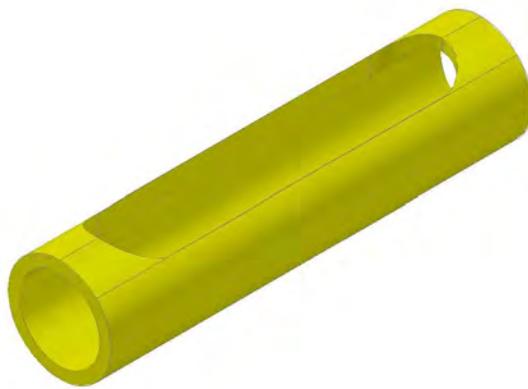
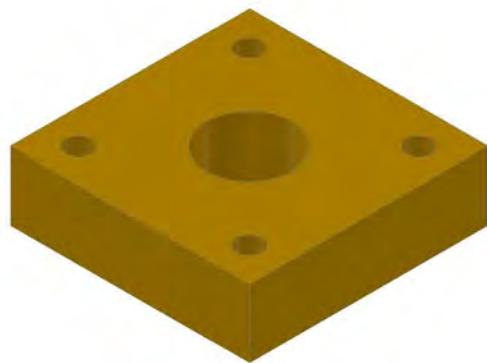
PART # 9
AUGER BIT
DRAWING A02

HUGH LYMAN
FILIP MULIER
INVENTORS

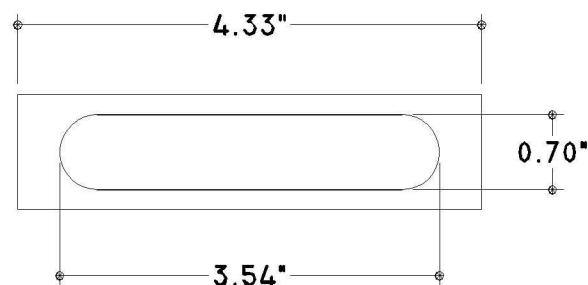
CUSTOM PARTS
LYMAN / MULIER FILAMENT EXTRUDER V5

SCALE: NONE
DRW: H.LYMAN
DATE: 6/12/14

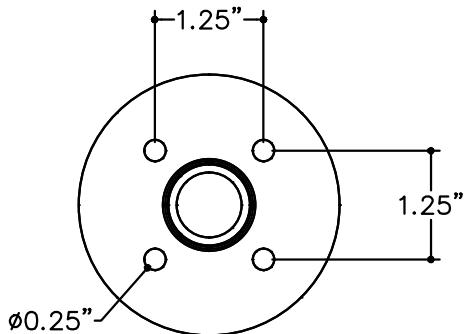
P07



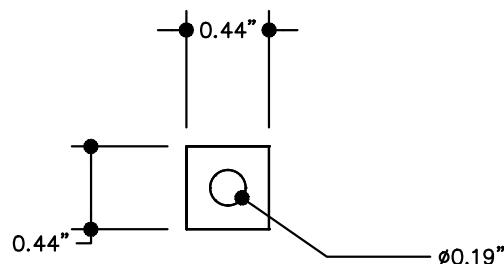
PART # 7
OAK INSULATING BLOCK
DRAWING A02



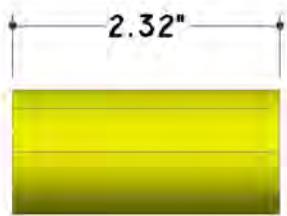
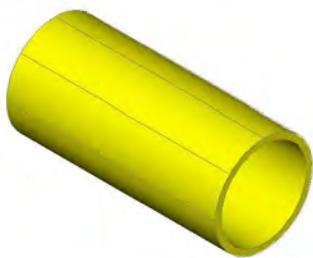
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DRAWING A02



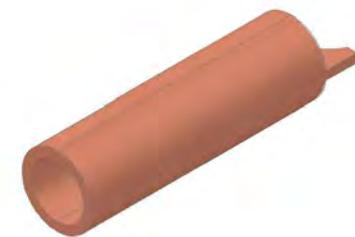
PART # 6
FLOOR FLANGE $\frac{1}{2}$ " NPT
DRAWING A02



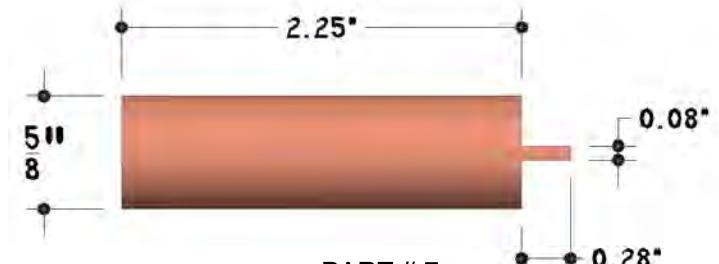
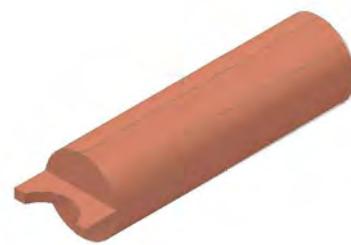
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INSULATION WASHER
DRAWING A02



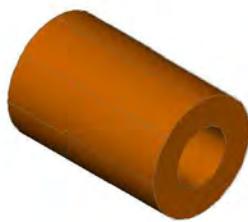
PART # 7
PVC PIPE
DRAWING A05



DRILLED OUT AND
FILLED WITH LEAD

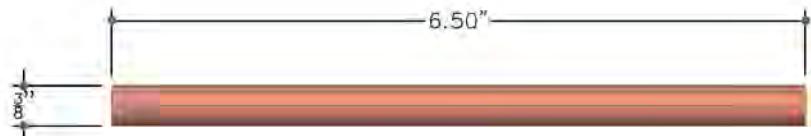


PART # 7
PEEK PAWL
DRAWING A07

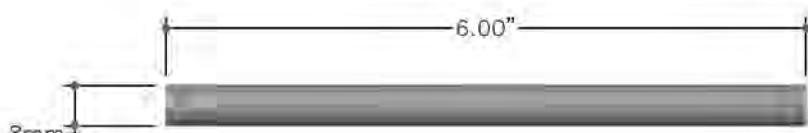


PART 11
LATEX TUBE
DRAWING A08
+/- 1" LONG

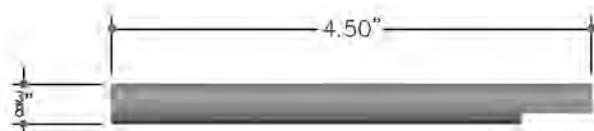




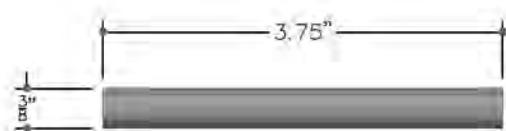
PART # 10
DOWEL SHAFT
DRAWING A08



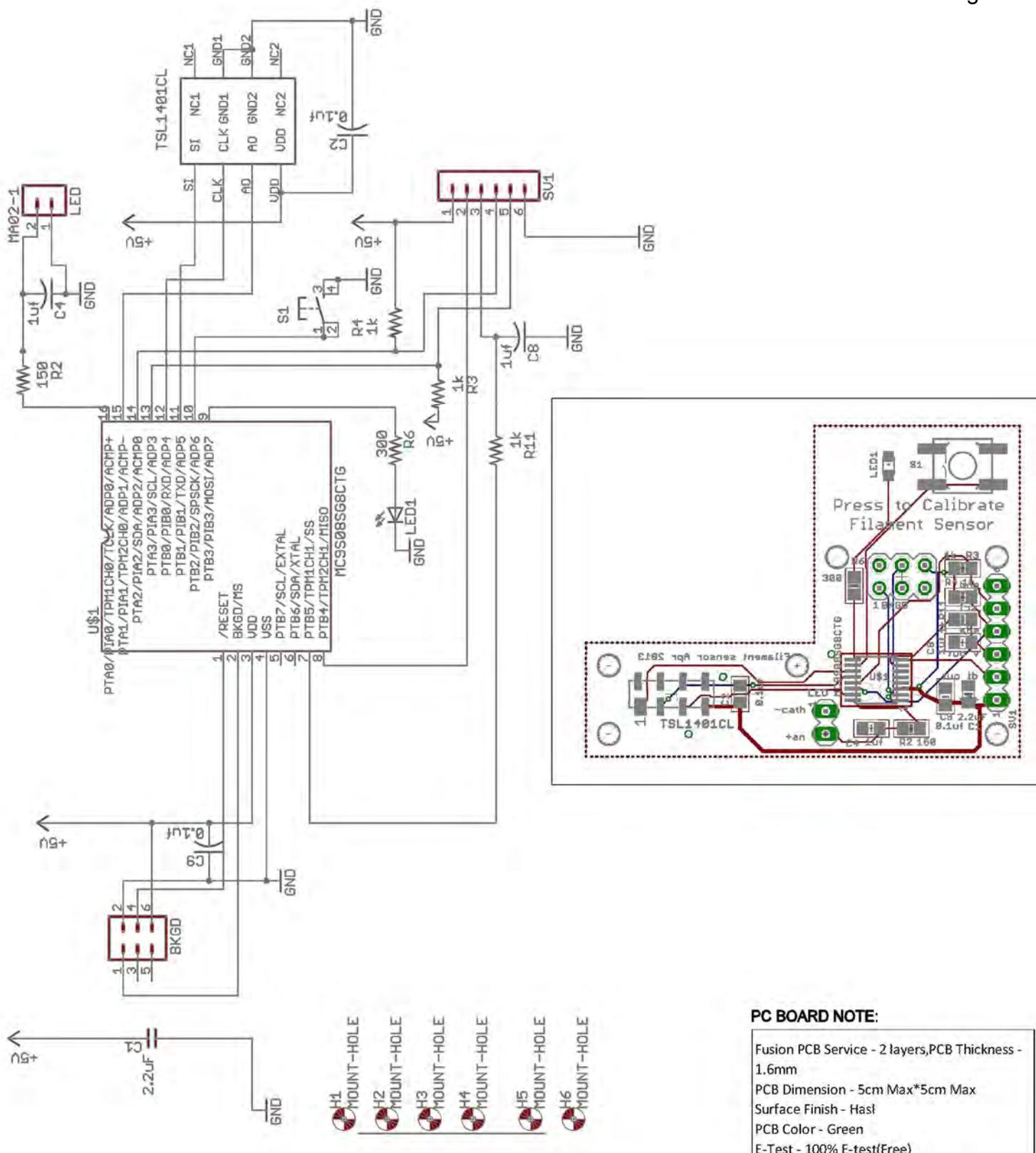
PART # 5
LEVEL WIND SHAFT
DRAWING A07



PART # 7
ROLLER DRIVE SHAFT
DRAWING A06



PART # 8
IDLER ROLLER SHAFT
DRAWING A06

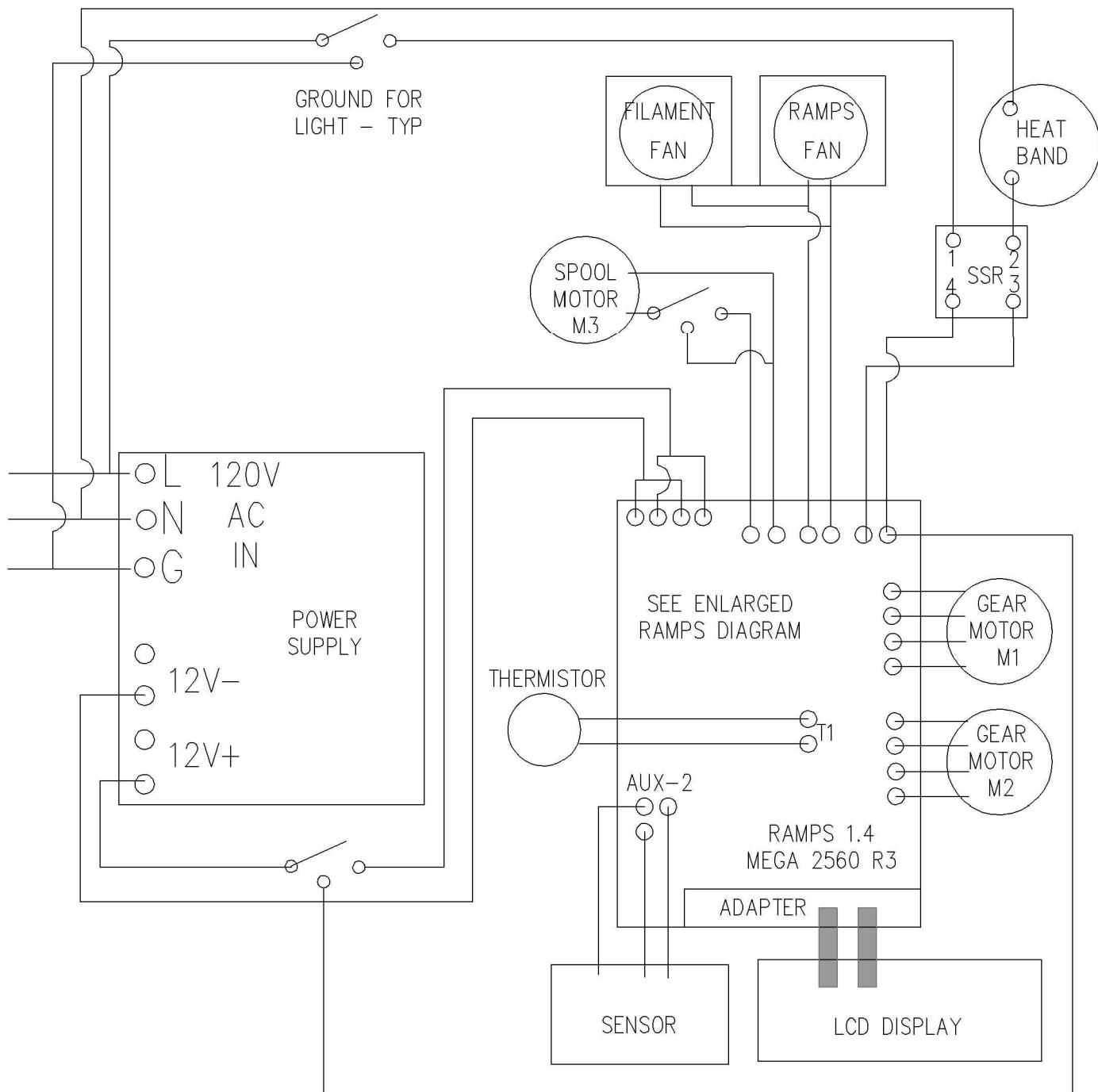


HUGH LYMAN
FILIP MULIER
INVENTORS

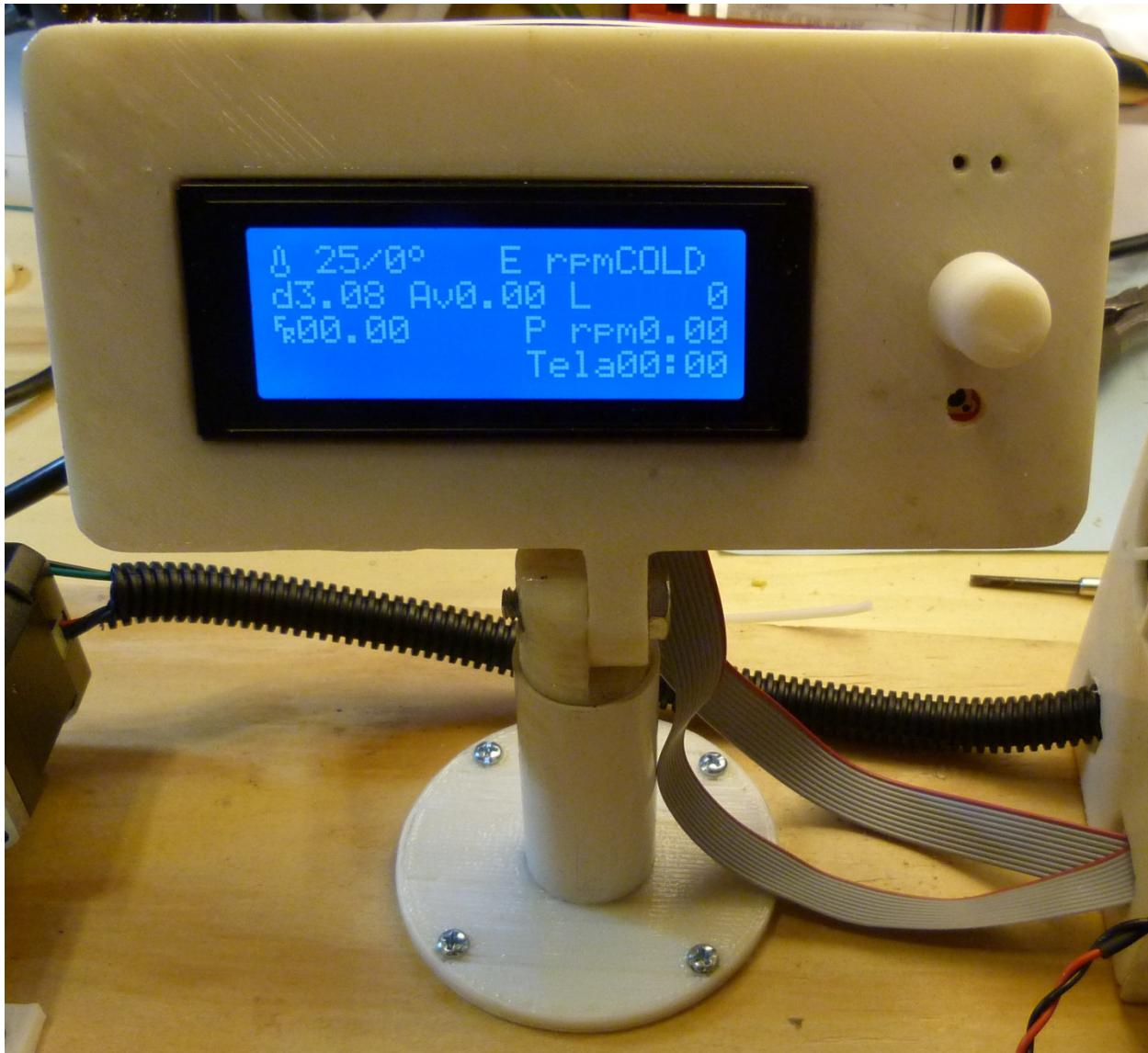
SENSOR SCHEMATICS & PCB
LYMAN / MULIER FILAMENT EXTRUDER V5

SCALE: NONE
DRW: F.MULIER
DATE: 6/12/14

A11



Setting up and Operating the Extruder with a RAMPS-based LCD controller



This manual should be used in conjunction with the Lyman – Mulier Extruder V5.

No Liability is accepted for errors, omissions and the use of this manual or the hardware or software referenced. Users use it at their own risk.

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Description

This controller was designed in conjunction with Hugh Lyman to control a Lyman filament extruder with geared stepper motors. It is currently designed to support the RAMPS 1.4 with Smart LCD 2004 and works with a prototype filament width sensor. It replaces much of the control electronics in a typical filament extruder with one controller. It can control the extruder motor, puller motor, Extruder heater (PID) with thermistor, winder motor, filament cooling fan and has input for a filament width sensor. The processes and menus have been adapted to control a filament extruder.

This firmware, called Mackerel¹, is based on Marlin 3D Printer Firmware but also has many original parts. The firmware can be compiled and uploaded to the Mega 2650 with the Arduino development environment. The latest firmware can be found at:

<https://github.com/filipmu/Marlin-Mackerel>

Features:

- Allows complete control of a Lyman Filament Extruder via LCD menus.
- Controls an extruder screw motor (geared stepper motor) so that it runs at a fixed RPM that can be set with the LCD.
- Controls a Puller motors (geared stepper motor) calibrated in mm/sec. This motor can also be quickly adjusted with the LCD.
- Accurate temperature control of extruder barrel (Uses temperature PID control and allows for auto-tuning)
- With the filament diameter sensor, accurate real time filament diameter display and control.
- Displays statistics (average diameter, length) of the extruded filament.
- Shuts off once desired length of filament is extruded.
- Allows selection of different thermistors (like Marlin)
- Can connect with Pronterface or Repetier Host to view the extruder temperature trending curves.
- Smooth motion control of extruder and puller geared stepper motors.
- Has an input for mechanical switch to allow quick control of the extruder motor.
- Parameters saved in EEPROM.
- Ability to control speed of the brushed DC winder motor.

¹ Marlins eat Mackerel, 3D printers consume filament.

- ON/OFF control of the filament cooling fan.

Background

This new controller concept was born out of collaboration between Hugh Lyman, creator of the first and also a series of open source low cost filament extruders, and Filip Mulier, the creator of a prototype filament sensor. The mutual goal was to create a controller that could improve on the existing controls of the Lyman Extruder V4.1 in a number of areas:

- Consolidate the separate control units used in V4.1 into one overall controller to simplify the design.
- Continue to leverage off-the-shelf components as much as possible.
- Reduce costs where possible, which lead to the concept of repurposing the controllers currently used 3D printers.
- Provide more real-time information and control using a liquid crystal display.
- Improve the extruder torque capability and speed control.
- Incorporate measurement and feedback control over filament diameter.
- Build know-how into the controller logic to simplify and automate extruder operation.

The pair started work on the controller in early March 2014 developing and refining the controller and extruder s with prototypes at each of their respective locations. Each collaborator brought complementary skills to the project. Hugh brought years of experience designing and building filament extruders, along with a mechanical engineering aptitude. He is a thought leader in this area and coordinated the mechanical and overall design. Filip contributed electronic, sensor, control, and embedded software engineering know-how . By the end of June the new design, V5 of the filament extruder was complete.

Setup

This section describes how to set up the controller, in terms of identifying compatible hardware, reviewing the wiring diagram, and describing how to install the firmware.

Compatible Controller Hardware

The controller is based on the following electronic hardware components, assembled to make the extruder controller. Please note the proper versions of the hardware to ensure compatibility with the firmware.

1. RAMPS 1.4 - http://reprap.org/wiki/RAMPS_1.4
2. Mega 2560 R3 - <http://arduino.cc/en/Main/ArduinoBoardMega2560>
3. A4988 stepper motor driver boards with heatsink x2 – here is one example (w/o heatsink)
<http://www.pololu.com/product/1182/>
4. SMART 2004 LCD Controller - http://www.reprap.org/wiki/RepRapDiscount_Smart_Controller

5. Filament Sensor prototype (optional) - <http://www.thingiverse.com/thing:89044>

6. 12 v power supply – A power supply of at least 5A and 12 volts. -
http://reprap.org/wiki/Power_Supply#OEM_type_PSU

Default Extruder Hardware

The Mackerel firmware assumes the following default hardware is used for the extruder:

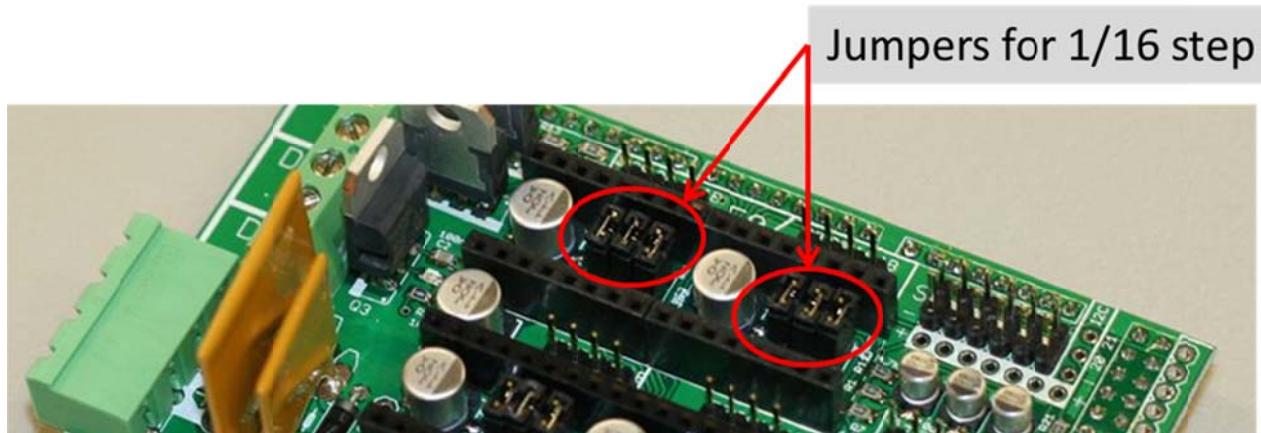
- M1 Extruder Motor: a stepper motor with 200 steps/rev and a 15.3:1 gearbox.
- M2 Puller Motor: a stepper motor with 200 steps/rev and a 100:1 gearbox.
- M3 Winder Motor: a geared DC motor that spins at 70RPM with 12 volt supply
- Puller driven roller: 120mm circumference (38mm/1.5 in diameter).
- Thermistor: 100K EPCOS.

If there are any differences, the defaults can be changed either using the LCD menus or changing the firmware configuration file.

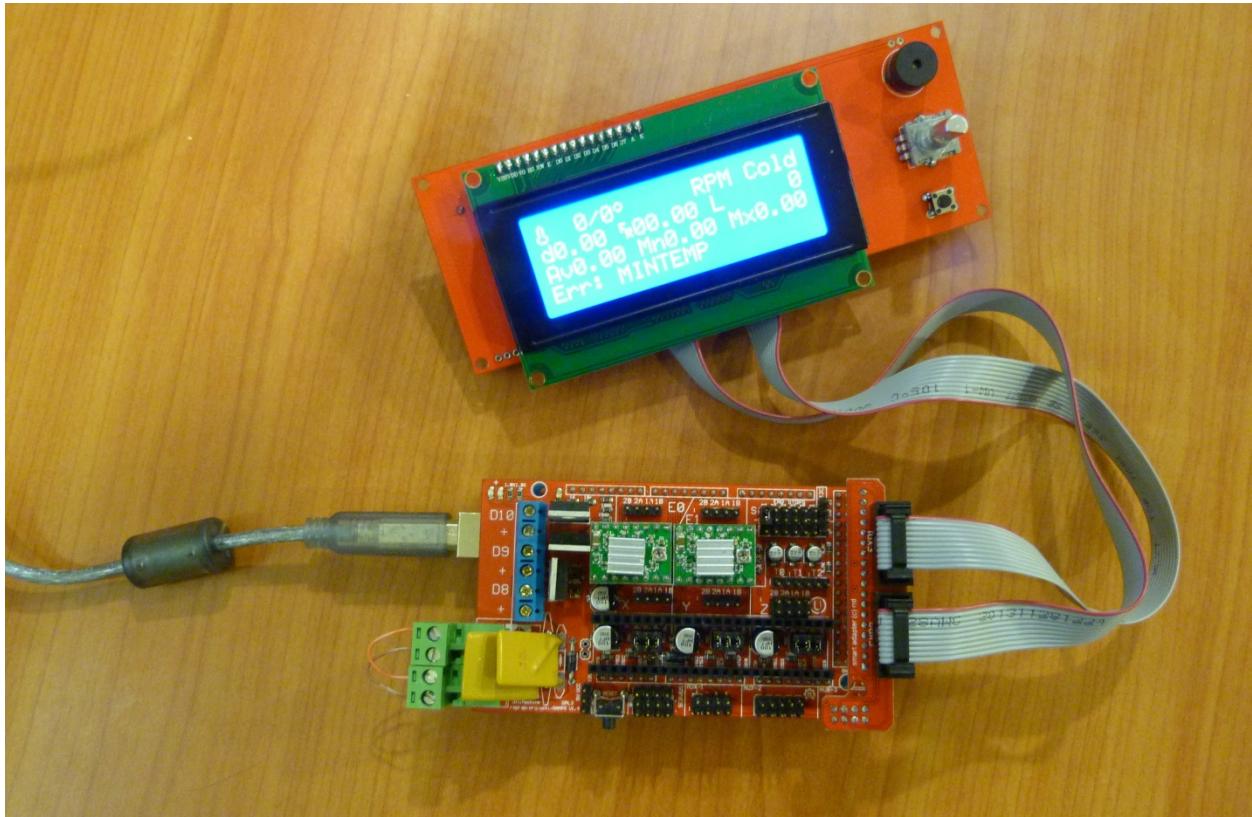
Assembly of RAMPS, Mega 2560, A4988 driver boards, SMART 2004 LCD Controller

1. The electronic hardware components are assembled together to make the extruder controller. The RAMPS is a daughter board (also known as a shield) for the Mega 2560. It has headers that mate with pins on the Mega.

2. The RAMPS has a set of jumpers for each stepper output to control the type of step output (full, half, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$). Ensure this is set to $\frac{1}{16}$ step output for E0 and E1 by placing 3 jumpers as shown in the picture below. Jumpers are not needed for X, Y, or Z outputs since these are not used.



3. The A4988 stepper motor driver boards should be placed over the jumpers oriented as shown in the picture below.



4. LCD Connection – The SMART 2004 LCD Controller is connected to the RAMPS 1.4 using with an adaptor board and two ribbon cables. The adaptor board is plugged into the Aux3 and Aux 4 connectors on the RAMPS.

Firmware Installation

The firmware is installed into the Mega 2560 using the Arduino toolset and a USB cable. The Arduino toolset can be obtained from <http://www.arduino.cc/en/Main/Software>.

The latest version of the firmware can be obtained from github: <https://github.com/filipmu/Marlin-Mackerel>. Click the ‘download Zip’ button to obtain it.

1. Extract the Zip file.
2. Start Arduino software
3. From the top menu select tools->board->Arduino Mega 2650
4. Click open select \Marlin-Mackerel\Mackerel\mackerel.ino

5. If configuration changes are needed to support non-default hardware (like no filament sensor, alternative stepper motors), the configuration.h file needs to be edited. Select the configure.h tab and edit the file (see Appendix, Configuration Changes for further details on possible changes)

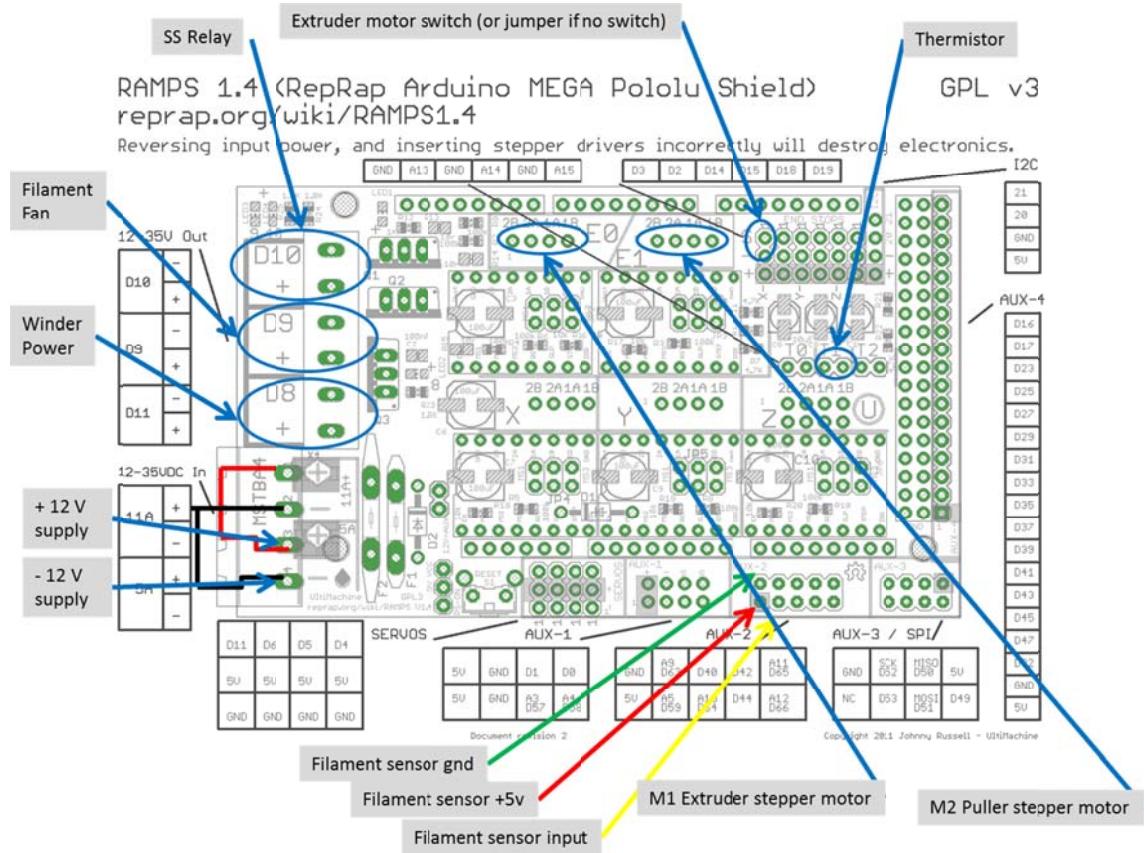
6. Click upload. After a minute or two you will see “Upload Done” message

After the firmware is installed, you should see the LCD display starting to show the settings, and it will start to beep, indicating that the temperature is too low (thermistor failure). This is expected, since no thermistor is connected. At this point you are ready to power down and wire up the controller.

Note: Firmware updates may be available from the github site and the same approach is used to install updates. The controller can remain wired with the main power off during firmware updates. The usb cord will power the controller for the update.

Wiring connections

Please see the diagram below for wiring connections to the RAMPS 1.4.



+12V supply – The positive terminal of the 12 v supply should be connected to both positive power screw terminals on the RAMPS board.

-12V supply – The negative terminal of the 12 v supply should be connected to both negative power screw terminals on the RAMPS board.

Winder Power – The terminal block labelled D8 will provide power for the geared DC spool motor M3. Note the + indicating the positive terminal. Voltage will range from 0-12v depending on speed setting.

Filament Fan – The terminal block labelled D9 will provide 12 v power for the brushless filament fan. Again, note the + indicating the positive terminal.

SS Relay – Terminal block labelled D10 provides the control signal to the solid state relay for controlling the heater current. Again, note the polarity indicated by the +. Provides a 12v signal to the SS relay.

Extruder motor switch (or jumper if no switch) – These pins on the RAMPS are an input to allow an external switch to control the extruder motor. This allows the user to quickly turn on and off the extruder without having to go through the LCD menu. If no switch is desired, place a jumper across these pins.

Thermistor – The thermistor is connected to the pins labelled T1. The default thermistor is an Epcos 100K, but this can be changed in the firmware configuration.

M1 Extruder Stepper Motor – The 4 wire extruder stepper motor is attached to the E0 stepper motor output of the RAMPS. Connect one phase of the stepper motors to the pins 1A, 2A. The other phase of the stepper motor goes to pins 1B, 2B. If the stepper motors rotate the wrong way, switch the phases. If a connector is used, simply rotate the connector 180 degrees and reconnect.

M2 Puller Stepper Motor – The Puller stepper motor is connected to the E1 stepper motor output of the RAMPS. Each phase is connected in a manner similar to M1.

Optional Filament Sensor

Filament Sensor gnd – This pin provides the ground connection to the filament sensor board.

Filament Sensor +5v – This pin provides the +5v supply to the filament sensor board.

Filament Sensor input – This pin is an input for the filament sensor's analog output voltage.

Controller Operation

This section describes how to interpret the main status display and get around the controller menus. It also details what is available on each menu.

LCD Display

The following picture shows the main status display of the controller and indicates what parameters are displayed.



- ① Actual Extruder barrel temp in deg C
- ② Setpoint Extruder barrel temp in deg C
- ③ RPM of the Extruder motor (also displays 'COLD' for cold extruder and 'OFF' when external extruder switch is off)
- ④ Measured diameter of filament in mm
- ⑤ Average measured filament diameter
- ⑥ Length of filament produced in mm
- ⑦ Filament Feed rate at Puller in mm/sec
- ⑧ RPM of the Puller motor
- ⑨ Time remaining in hh:mm to reach Length Cutoff
- ⑩ Time elapsed in hh:mm in current run

Last row – also shows status or warning message

Turning the rotary knob on the status display will let you increase or decrease the filament feed rate during extruder operation.

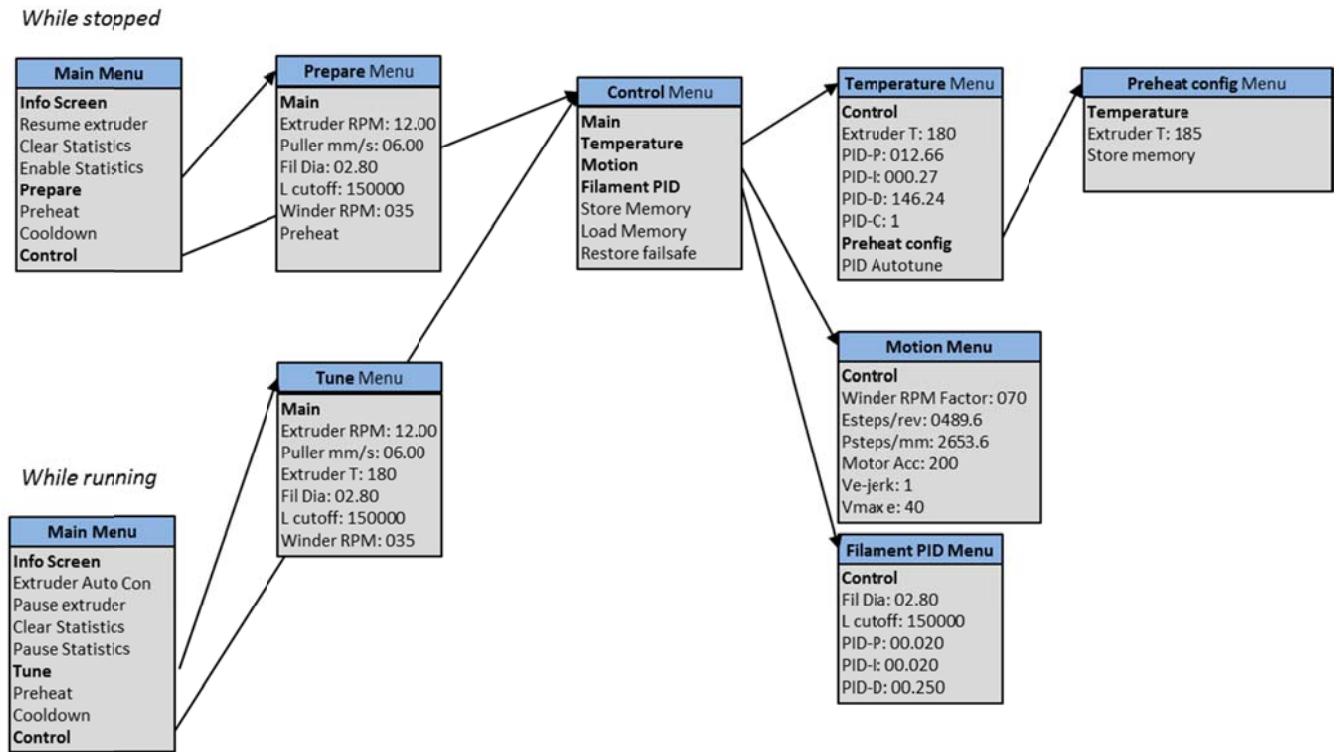
Accessing the Menus

Menus are accessed by pressing the rotary knob from the main status display. When on a menu, the rotary knob is used to either highlight the next menu, or make a numerical parameter adjustment.

Pressing the rotary knob selects the next menu or sets the numerical parameter.

Menus

This diagram shows the available menus of the controller.



The Main menu, Prepare menu, and Tune menu are those that are most commonly used while operating the extruder. Note that the ‘Prepare’ Menus shows up when the extruder is stopped and the ‘Tune’ menu shows up when the extruder is running. The Control menu and those following are used to set the control parameters of the extruder, and used less frequently.

Main Menu – While motors are Idle

Info Screen: – Returns to the info screen.

Resume extruder: – Will turn on the Puller motor, extruder motor (if warmed up), Winder motor, and fan (if warmed up). The extruder motor will be disabled if the extruder is not 170 deg C or greater to protect the motor and gearbox.

Clear Statistics: – Clears the Filament average diameter, extruded length, and elapsed time statistics. This lets you clear the stats if you have enabled the statistics while the extruder is not running – see next menu item.

Enable Statistics: – turns on the gathering of statistics while extruder is not running. This is useful if want to test the filament sensor without running the extruder.

Prepare: – Go to the Prepare menu. This menu lets you enter the parameters needed to start the run.

Preheat: – This will turn on the heater to the configured temp setting. The system will beep when it is at the desired temperature so that you know the extruder is ready to operate. Pressing the knob will stop the beep.

Cooldown: – This will turn off the heater to allow the extruder to cool.

Control – Go to the Control menu, which is used to set the parameters for motion, temperature, and filament control.

Main Menu – While motors are running

Info Screen: – Returns to the status info screen.

Extruder Auto Con: – Turns on the PID loop that controls the puller motor speed based on the filament diameter. This control scheme will attempt to hold the measured filament diameter to the desired setpoint.

Pause extruder: – Turns off all motors.

Clear Statistics: – Clears the Filament average diameter, extruded length, and elapsed time statistics. In most runs of the extruder, it takes some time and tuning to get the extruder to produce the desired filament diameter. This lets you clear the stats after the initial startup and tuning of the extruder.

Pause Statistics: – Pauses collection of statistics. Freezes the current values of the stats on the status screen.

Tune: – Goes to menu used to tune settings such as motor speeds while running the extruder.

Preheat: - This will turn on the heater to the configured temp setting. The system will beep when it is at the desired temperature so that you know the extruder is ready to operate. Pressing the knob will stop the beep.

Cooldown: – This will turn off the heater to allow the extruder to cool.

Control: – Go to the Control menu, which is used to set parameters for motion, temperature, and filament control.

Prepare Menu

Main: – Returns to the Main Menu.

Extruder RPM: - Enter the desired extruder RPM achieved when the extruder is enabled. Default is 12 RPM .

Puller mm/s: - Enter the desired default puller mm/second. Default is 6 mm/sec

Fil Dia: - Enter the desired filament diameter when using Extruder Auto Control. Default is **2.8mm**

L cutoff: - Enter the length of filament desired before the machine is automatically halted. Default is 150,000mm.

Winder RPM: - Enter the desired winder RPM. Default is 35 RPM. Note that this is only an approximate RPM and depends on the motor load.

Preheat: - Turn on the heater to the configured temp setting. System will beep when at temperature. Can press the knob to stop the beep.

Tune Menu

Main: – Returns to the Main Menu

Extruder RPM: - Enter the desired extruder RPM. Default is 12. This will change the extruder RPM while the extruder is operating.

Puller mm/s: - Enter the desired default puller mm/second. Default is 6 mm/sec. Alternatively, turn the knob on the main status screen.

Extruder T: - Enter the desired setpoint extruder temperature in deg C. Default is 185 deg. Changing the setpoint here will change the temperature of the extruder while running. It does not update the preheat setting. To update the preheat setting, see the Preheat Config Menu.

Fil Dia: - Enter the desired filament diameter when using filament PID control. Default is 2.8mm

L cutoff: - Enter the length of filament desired before the machine is automatically halted. Default is 150,000mm. This can be changed while the extruder is running. The Time remaining display will change based on the length entered.

Winder RPM: - Enter the desired winder RPM. Default is 35. Note that this is only an approximate RPM and depends on the motor load.

Control Menu

Main: – Return the Main Menu

Temperature: – Select the Temperature control menu (Heater settings)

Motion: – Select the Motion control menu (Motor settings)

Filament PID: – Select the Filament PID control menu (Filament PID settings)

Store Memory: – Save settings in EEPROM

Load Memory: – Load EEPROM settings

Restore failsafe: – Revert back to firmware initial default settings for all parameters.

Temperature Menu

Control: – Return back to the Control Menu

Extruder T: - Enter the desired extruder temperature in deg C. Default is 185 deg.

PID-P: - Enter the desired P value for the heater PID loop. Default is 12.66. See Autotune to automatically tune this. For some explanation, see the Appendix.

PID-I: - Enter the desired I value for the heater PID loop. Default is 0.27. See Autotune to automatically tune this. For some explanation, see the Appendix.

PID-D: - Enter the desired D value for the heater PID loop. Default is 146.24. See Autotune to automatically tune this. For some explanation, see the Appendix.

PID-C: - Enter the desired C value for the heater PID loop. Default is 1. This is usually not adjusted.

Preheat Config: – Menu to configure settings for the standard preheat.

PID Autotune: – Brings the extruder to the configured preheat temperature and cycle the temperature 5 times to automatically tune the Temperature PID parameters above. Beeps when the process is complete, which may take 15-20 minutes. Use Store Memory to save parameters for future runs.

Motion Menu

Control: – Return back to the Control Menu

Winder RPM Factor: - Enter the 12 volt rated RPM of the spool winder motor. Default is 70 RPM. This is used by the firmware to control the output duty cycle for the winder output based on desired RPM. This approach for motor control is only approximate, so the actual shaft RPM may differ depending on load and other factors.

Esteps/rev: Enter the number of steps per 1/100th of a revolution of the extruder, taking into account the gearbox and fractional steps. Default is 489.6. for a 200 step/rev stepper motor with 15.3:1 gears. See Appendix on how to determine value for different stepper motors or gear ratios.

Psteps/mm: Enter the number of steps per 1mm of motion of the puller motor, taking into account the gearbox and fractional steps. Default is 2653.6 for a stepper with 100:1 gears. See Appendix on how to determine value for different stepper motors or gear ratios and a means to measure and calibrate.

Motor Acc: Enter the acceleration for the steppers in mm/sec². Default is 200. This setting limits the acceleration asked of the stepper motors. It should be reduced if at motor startup the stepper motors are not able to keep up with the acceleration. This is indicated by the steppers losing steps (not turning, but making a buzzing sound).

Ve-jerk: Default is 1.0. Advanced setting that does not normally need to be changed.

Vmax e: Default is 40 1/100ths revolutions per second, or 24RPM.

Filament PID Menu

Control: – Return back to the Control Menu

Fil Dia: - Enter the desired filament diameter when using filament PID control. Default is 2.8mm

L cutoff: - Enter the length of filament desired before the machine is automatically halted. Default is 150,000mm.

PID-P: - Enter the desired P value for the filament diameter PID loop. Default is 0.020. This parameter is adjusted based on behavior of control. See appendix for general tips on tuning a PID loop.

PID-I: - Enter the desired I value for the filament diameter PID loop. Default is 0.020. This parameter is adjusted based on behavior of control. See appendix for general tips on tuning a PID loop.

PID-D: - Enter the desired D value for the filament diameter PID loop. Default is 0.250. This parameter is adjusted based on behavior of control. See appendix for general tips on tuning a PID loop.

Preheat config Menu

Temperature: Return back to the Temperature Menu.

Extruder T: - Enter the desired extruder temperature in deg C that will be used for the setpoint when ‘Preheat’ is selected in the Main Menu or Prepare Menu . Default is 185 deg.

Store memory: – Save all the current settings in EEPROM.

Control Setup

In this section we will go through the various control settings in the menus. These settings only need to be changed if using motors with a gear ratio that are different than the default, or if heater temperature control is not tuned.

Motor Setup

The motor setup involves computing the factors that relate the number of steps sent to the motor controller with the menu input (RPM or mm/sec). Each motor (Extruder and Puller motors) has its own factor. The firmware uses these factors to calculate the number of steps/sec to send the stepper controller based on the users input (RPM or mm/sec), ensuring that the actual motion of the motors matches the user input exactly. These factors need to be changed if you change any of the following:

- Change the gear ratio of the motor. For the Extruder, the specified gear ratio is 15.3:1 and for the puller it is 99 and 1044/2057 : 1 (approx. 100:1).
- Change the stepper motor. The firmware is defaulted to 200 steps per revolution of the stepper motor.
- Change the step fraction of the stepper controller boards. The firmware assumes 1/16 stepper fraction, (16 pulses rotates the motor 1 mechanical step).

If any of these are changed, please see the next two sections for how to enter new Esteps/Rev or Psteps/mm parameters.

Setting Esteps/Rev for the Extruder motor

The following chart shows how to calculate the Esteps/rev based on the motor, gearbox, and stepper controller parameters. The Scaling Factor of 1/100 is expected by the firmware and is used to keep the numbers to within a reasonable magnitude (<9999).

Motor steps/rev	Step fraction	Gear Ratio	Scaling Factor	Esteps/rev
200	1/16	15.3:1	1/100	
200 * 16 * 15.3 * 1/100				= 489.6

Setting Psteps/mm for the Puller motor

The following charts shows how to calculate the Psteps/mm setting based on the motor, gearbox, stepper controller, and puller drive roller parameters .

Motor steps/rev	Step fraction	Gear Ratio	Puller Driven Roller Diameter (mm)	Psteps/mm
200	1/16	99 1044/2057:1	38	
200 * 16 * 99.507 / (38 * 3.1415)				= 2653.6

Motor steps/rev	Step fraction	Gear Ratio	Puller Driven Roller Diameter (mm)	Psteps/mm
200	1/16	14:1	38	
200 * 16 * 14 / (38 * 3.1415)				= 375.3

Motor steps/rev	Step fraction	Gear Ratio	Puller Driven Roller Diameter (mm)	Psteps/mm
200	1/16	5:1	38	
200 * 16 * 5 / (38 * 3.1415)				= 134.0

The above works fine, but since the puller driven roller is usually urethane, it is indented by the filament, and so the effective diameter is less than the diameter measured with a ruler. After setting the value calculated above, more accuracy can be achieved by the following calibration approach:

1. Run the puller motor at a set mm/s (like 10 mm/sec) in the controller and run a fixed length of filament through it while timing how long it takes. Can use some scrap filament and make 2 marks on it with a permanent marker a known distance apart (300mm say). You would expect it to take $300/10=30$ sec for the known length of filament to pass, but in reality it may be different.

2. Based on the actual time you would adjust the Psteps/mm using:

$$(\text{New Psteps/mm}) = (\text{Old Psteps/mm}) * (\text{Actual time in seconds}) / (\text{Expected time in seconds})$$

Heater Setup

In this section we describe how to adjust the PID parameter settings for the heater. This is only required if the heater temperature significantly overshoots the target setting when heating up, oscillates, or seems to take a long time to get to temperature. These may be signs that the PID parameters are not correct for the extruder heater.

1. Go to the Temperature Menu and note the P, I , and D parameter values for later reference.
2. Go to the Preheat Config Menu and ensure that the Extruder T is at a typical value for normal extruder operation (185 – 230).
3. Select Autotune on the Temperature Menu.
4. The extruder will begin to heat up, as shown on the status screen. You will see the measured temperature go up slightly past the Extruder T of step 2, and then cool off below the Extruder T.
5. The Autotune routine will repeat this 4 more times to optimize the temperature PID parameters.
6. The controller will beep indicating Autotune is complete. Press the knob to stop the beeping.
7. Go to the Temperature Menu and note the new P, I, and D values as compared to the ones noted in step 1.
8. Go to the Control Menu and select Store Memory to save the settings to EEPROM so that they become the new default at power up.

Running the Extruder

This section describes the basic approach for starting, running, and shutting down the extruder.

Starting the Run

1. Turn on the heater by selecting Preheat from the Main Menu.
2. Wait until the temperature hits the set point (default is 185 deg). The beeper will go. Can press the knob to shut off.

3. Turn on the motors and fan by selecting Resume Extruder from the Main Menu. Both the extruder and puller motors should be rotating. Extruder default is 12 RPM and the Puller is 6mm/s. The winder motor will start up as well, assuming the winder motor switch is on.

During the Run

At this point you can turn the knob and change the speed of the puller motor to any desired speed. At this time you should be able to thread the extruder, by pulling the extruded plastic with a pliers to create a thinner filament and feeding it into the sensor and puller Rolls.

1. Adjust the Puller motor speed via the knob to achieve close to the filament diameter desired (for example, 2.8mm). Can use the Tune menu or Control menu to make adjustments to motor speeds, target filament diameter etc.
2. Switch to Extruder Auto Con from the Main Menu to go to automatic control of the puller motor. Puller motor is then controlled by the sensor to hold the selected filament diameter. You will notice the puller motor speed increase or decrease as needed to maintain a more stable filament diameter.
3. Go to the Tune menu and set the desired length of filament to extrude. (150,000mm is the default)
4. You can Clear Statistics on the Main Menu to start collecting data now that filament is under control. At this point it may make sense to discard the filament produced so far, and begin spooling the filament produced while under control.

Shutdown

The machine will enter cooldown and stop the motors automatically when the selected length of filament is produced (default 150,000mm). Alternatively you can select Pause Extruder on the Main Menu at any time to turn off the motors. Then select Cooldown on the Main Menu to shut off heater.

Appendix

Tuning the A4988 stepper motor driver boards

Tuning the A4988 stepper motor driver boards is critical to achieve adequate torque, especially for the extruder motor M1. Each of the A4988 stepper motor driver boards has a small potentiometer control on it that can be rotated with a screwdriver. This potentiometer controls the current going to the motor, and therefore the amount of torque provided by the motor shaft. At one end of the range, the current will be low, and the motor may stop turning and lose steps. At the other end of the range, the stepper driver overheats, and cuts out, causing clicking and erratic operation of the motor. The goal is to find a setting that produces enough torque to drive the motor in all conditions, but not cut out due to overheating. Sometimes it takes a bit of time for the overheating to occur (20-30 sec) so it may work fine for a while at

a setting, but then fail. The potentiometer needs to be adjusted while the motor is under load. If you use a metal screwdriver you may introduce interference which can cause the controllers to cut out as well. Sometimes it stops working and you need to cycle the power to the controller. This can be a tricky step since these controller boards are just acceptable at producing the current required to turn the extruder shaft and there is not much extra torque available.

PID operation and PID Tuning (from Wikipedia)

The PID controller algorithm involves three separate constant parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted P, I, and D. Simply put, these values can be interpreted in terms of time: P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change.[1] The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve, a damper, or the power supplied to a heating element.

By tuning the three parameters in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the setpoint, and the degree of system oscillation. Note that the use of the PID algorithm for control does not guarantee optimal control of the system or system stability.

PID Manual Tuning

If the system must remain online, one tuning method is to first set I and D values to zero. Increase the P until the output of the loop oscillates, then the P should be set to approximately half of that value for a "quarter amplitude decay" type response. Then increase I until any offset is corrected in sufficient time for the process. However, too much I will cause instability. Finally, increase D , if required, until the loop is acceptably quick to reach its reference after a load disturbance. However, too much D will cause excessive response and overshoot. A fast PID loop tuning usually overshoots slightly to reach the setpoint more quickly; however, some systems cannot accept overshoot, in which case an overdamped closed-loop system is required, which will require a P setting significantly less than half that of the P setting that was causing oscillation.

Effects of *increasing* a parameter independently

Parameter	Rise time	Overshoot	Settling time	Steady-state error	Stability
P	Decrease	Increase	Small change	Decrease	Degrade
I	Decrease	Increase	Increase	Eliminate	Degrade
D	Minor change	Decrease	Decrease	No effect in theory	Improve if D small

For more info, see: https://en.wikipedia.org/wiki/PID_controller,
<https://hennulat.wordpress.com/2011/01/12/pid-loop-tuning-101/>, <http://www.expertune.com/tutor.aspx>

Tips for Tuning the Filament Diameter PID

Tuning the PID parameters for the filament diameter control is generally trial and error on the running extruder, but here are some tips that might help.

- Minimize distance between the filament sensor and extruder nozzle. Keep the filament sensor as close as physically possible to the filament cooling fan, and the filament cooling fan close to the extruder nozzle. Also make sure that this distance stays fixed. Long distances results in poorer control performance.
- The time period of the PID depends on the feedrate. It is easier to tune when the feedrate is high because the system will respond and stabilize faster when parameters are changed.
- The PID control has a long time period, so it takes a while to stabilize. In other words, when you make changes to the PID parameters, you need to observe the results for a number of minutes to see if control is better or worse.
- Start with small values of P and I (around .010 to .020) and then increase, observing the trend of the filament diameter. If you notice that the filament diameter is oscillating over long time periods, the P and I values are too large.
- Only small values are required. When $P > .030$ the oscillation is noticeable. Also making $I > .050$ causes oscillation. Your mileage may vary.
- The D parameter is not crucial – adjust P and I first and then fine tune to see if improvements occur.
-

Technical note: The PID control is not time-based, it is feedrate-based. Most PID loops have a fixed time interval that is used to update the control (dt is a time unit in seconds). For the filament control, the update interval is distance-based (dt is a distance unit in mm). PID updates are done every time a fixed length of filament passes the puller rollers. This approach was chosen because the filament sensor is a fixed distance away from the extruder nozzle, causing a feedback time delay that varies with feedrate. This ensures the same PID parameter settings work for any filament feed rate.

Configuration Changes

This section describes some of the more common changes that can be made to the firmware configuration file **Configuration.h** to effect extruder operation. For some settings, modifying the configuration file is the only way to make changes to these settings. These changes can then be uploaded as described earlier in the manual. The configuration borrows many additional settings from its Marlin roots not mentioned here. Note that changing the Configuration.h file in ways not mentioned below requires understanding the code, or at a minimum understanding Marlin, and may or may not give the intended results.

Thermistor Selection

The type of thermistor used needs to be defined in the firmware, so that the right calibration curves are employed. Below is the section of the Configuration.h file that pertains to this setting. The line in the file that affects the change in setting is highlighted in green:

```

//=====
//===== Thermal Settings =====
//=====

//--NORMAL IS 4.7kohm PULLUP!-- 1kohm pullup can be used on hotend sensor, using correct resistor and table
//

//// Temperature sensor settings:
// -2 is thermocouple with MAX6675 (only for sensor 0)
// -1 is thermocouple with AD595
// 0 is not used
// 1 is 100k thermistor - best choice for EPCOS 100k (4.7k pullup)
// 2 is 200k thermistor - ATC Semitec 204GT-2 (4.7k pullup)
// 3 is Mendel-parts thermistor (4.7k pullup)
// 4 is 10k thermistor !! do not use it for a hotend. It gives bad resolution at high temp. !!
// 5 is 100K thermistor - ATC Semitec 104GT-2 (Used in ParCan & J-Head) (4.7k pullup)
// 6 is 100k EPCOS - Not as accurate as table 1 (created using a fluke thermocouple) (4.7k pullup)
// 7 is 100k Honeywell thermistor 135-104LAG-J01 (4.7k pullup)
// 71 is 100k Honeywell thermistor 135-104LAF-J01 (4.7k pullup)
// 8 is 100k 0603 SMD Vishay NTCS0603E3104FXT (4.7k pullup)
// 9 is 100k GE Sensing AL03006-58.2K-97-G1 (4.7k pullup)
// 10 is 100k RS thermistor 198-961 (4.7k pullup)
// 20 is the PT100 circuit found in the Ultimainboard V2.x
// 60 is 100k Maker's Tool Works Kapton Bed Thermistor
//
// 1k ohm pullup tables - This is not normal, you would have to have changed out your 4.7k for 1k
// (but gives greater accuracy and more stable PID)
// 51 is 100k thermistor - EPCOS (1k pullup)
// 52 is 200k thermistor - ATC Semitec 204GT-2 (1k pullup)
// 55 is 100k thermistor - ATC Semitec 104GT-2 (Used in ParCan & J-Head) (1k pullup)
//
// 1047 is Pt1000 with 4k7 pullup
// 1010 is Pt1000 with 1k pullup (non standard)
// 147 is Pt100 with 4k7 pullup
// 110 is Pt100 with 1k pullup (non standard)

#define TEMP_SENSOR_0 1

```

In the highlighted line, the default thermistor is indicated as 1, which is the EPCOS 100K. If another thermistor is being used, then the 1 should be replaced by the number for that thermistor in the comments.

Default Temperature PID Settings

The PID settings for the heater can be set directly in the Configuration.h file. This will make them the default settings that return when selecting Restore Failsafe from the Control Menu in the LCD.

```

// PID settings:
// Comment the following line to disable PID and enable bang-bang.
#define PIDTEMP
#define BANG_MAX 255 // limits current to nozzle while in bang-bang mode; 255=full current
#define PID_MAX 255 // limits current to nozzle while PID is active (see PID_FUNCTIONAL_RANGE below); 255=full current
#ifndef PIDTEMP
    //#define PID_DEBUG // Sends debug data to the serial port.
    //#define PID_OPENLOOP 1 // Puts PID in open loop. M104/M140 sets the output power from 0 to PID_MAX
    #define PID_FUNCTIONAL_RANGE 10 // If the temperature difference between the target temperature and the actual temperature
        // is more than PID_FUNCTIONAL_RANGE then the PID will be shut off and the heater will be set to min/max.
    #define PID_INTEGRAL_DRIVE_MAX 255 //limit for the integral term
    #define K1 0.95 //smoothing factor within the PID
    #define PID_dT ((OVERSAMPLENR * 8.0)/(F_CPU / 64.0 / 256.0)) //sampling period of the temperature routine

    // If you are using a pre-configured hotend then you can use one of the value sets by uncommenting it
    //Lyman Filament Extruder
        #define DEFAULT_Kp 12.66
        #define DEFAULT_Ki 0.27
        #define DEFAULT_Kd 146.24

```

The highlighted line shows where to change the default P, I, and D parameters.

Remaining Extruder Settings

The next section of the Configuration.h file identifies all the remaining settings that should be changed to affect the extruder operation. We will go into each row in detail.

```

/*****\

* Lyman Filament Extruder
* Settings
*****\

#define LYMAN_EXTRUDER

//comment the next line out if there is no filament sensor
#define FILAMENT_SENSOR

#define DEFAULT_EXTRUDER_RPM 12 //define default extruder RPM
#define EXTRUDER_RPM_MAX 50
#define EXTRUDER_RPM_MIN 1
#define DEFAULT_PULLER_FEEDRATE 6.0 //default puller feedrate when turned on
#define PULLER_FEEDRATE_MIN 1.0 // min feedrate in manual control, 1 mm/sec min feed - limited by max pulse rate of 50,000
#define PULLER_FEEDRATE_MAX 15.0 // max feedrate in manual control 12mm/sec max feed - limited by max pulse rate of 50,000
#define PULLER_WHEEL_CIRC 120 //circumference of urethane puller wheel in mm

#define DEFAULT_WINDER_RPM_FACTOR 70 //factor for converting winder PW to rpm - reflects rpm of motor at 12v
#define DEFAULT_WINDER_SPEED 35 //default winder speed (0-DEFAULT_WINDER_RPM_FACTOR)

#define DESIRED_FILAMENT_DIA 2.8 //define the default desired Filament diameter
#define PREHEAT_EXTRUDER_TEMP 185 //Set to 185 deg C based on Hugh's suggestion

#define DEFAULT_fwidthKp 0.020
#define DEFAULT_fwidthKi 0.020
#define DEFAULT_fwidthKd 0.250

#define PULLER_PID_MIN_LIMIT 1.0 //min output limit of filament dia control in mm/sec
#define PULLER_PID_MAX_LIMIT 24.0 //max output limit of filament dia control in mm/sec
#define PULLER_PID_INTEGRATOR_WIND_LIMIT 1000000 //absolute value of integrator windup max value

#define DEFAULT_LENGTH_CUTOFF 150000 //length in mm where extruder will shut down

#define EXTRUDE_MINTEMP 170 //min temp that extruder motor will run
//this prevents dangerous Extruder moves, i.e. if the temperature is under the limit
//can be software-disabled for whatever purposes by
#define PREVENT_DANGEROUS_EXTRUDE

#define DEFAULT_ESTEP_PER_REV 489.6 //default setting for the extruder step calibration
#define DEFAULT_PSTEP_PER_MM 2653.6 //default setting for the puller motor step calibration

//The next two defines have arrays of 5 values which correspond to the 5 axis X,Y,Z,E,P
//For the Lyman Extruder, only E = Extruder Motor and P = Puller Motor settings are utilized
#define DEFAULT_AXIS_STEPS_PER_UNIT {78.7402,78.7402,200.0*8/3,DEFAULT_ESTEP_PER_REV,DEFAULT_PSTEP_PER_MM}
#define DEFAULT_MAX_FEEDRATE {500, 500, 5, 50, 50} // (mm/sec)

#define DEFAULT_MOTOR_ACCELERATION 200 // E and P max acceleration in mm/s^2 - controls extruder acceleration
#define DEFAULT_EJERK 1.0 // (mm/sec)
#define DEFAULT_PJERK 1.0 // (mm/sec)

#define FILAMENT_SENSOR

```

This row indicates to the firmware whether a filament sensor is attached. If you do not have a filament sensor then this should be commented out by placing two // in front of the line. The controller will then hide anything that depends on a filament diameter reading. It will still allow full control of the extruder motors and heater.

```
#define DEFAULT_EXTRUDER_RPM 12 //define default extruder RPM
```

This row sets the default extruder RPM. This will make it the default setting that returns when selecting Restore Failsafe from the Control Menu in the LCD.

```
#define EXTRUDER_RPM_MAX 50  
#define EXTRUDER_RPM_MIN 1
```

These rows set the range of extruder RPM that can be selected in the LCD menus. The maximum can be set based on the capability of the extruder motor and stepper controller.

```
#define DEFAULT_PULLER_FEEDRATE 6.0 //default puller feedrate when turned on
```

This row sets the default puller federate in mm/sec . This will make it the default setting that returns when selecting Restore Failsafe from the Control Menu in the LCD.

```
#define PULLER_FEEDRATE_MIN 1.0 // min feedrate in manual control, 1 mm/sec min feed - limited by max pulse rate of 50,000  
#define PULLER_FEEDRATE_MAX 15.0 // max feedrate in manual control 12mm/sec max feed - limited by max pulse rate of 50,000
```

These rows set the range of puller federate (mm/s) that can be selected in the LCD menus. The maximum can be set based on the capability of the puller motor and stepper controller. When using a puller motor with a high gear ratio, the maximum federate is limited by the firmware's 50,000 steps/sec limitation.

```
#define PULLER_WHEEL_CIRC 120 //circumference of urethane puller wheel in mm
```

The firmware takes into account the puller driven roller's circumference to determine the RPM of the puller motor. If the extruder has a roller that is not 1.5in diameter (38mm) then this should be changed. The circumference = $3.1415 \times$ diameter of the driven roller.

```
#define DEFAULT_WINDER_RPM_FACTOR 70 //factor for converting winder PW to rpm - reflects rpm of motor at 12v
```

This factor should represent the RPM the geared winder motor achieves when powered by 12 volts. If the geared winder motor is not 70 RPM @ 12V then this factor should be changed to give more accurate speed settings.

```
#define DEFAULT_WINDER_SPEED 35 //default winder speed (0-DEFAULT_WINDER_RPM_FACTOR)
```

This is the default geared winder motor speed in RPM. Note that the actual speed of the geared motor may differ depending on the load.

```
#define DESIRED_FILAMENT_DIA 2.8 //define the default desired Filament diameter
```

This is the default set point for the filament diameter in mm when using a filament sensor.

```
#define PREHEAT_EXTRUDER_TEMP 185 //Set to 185 deg C based on Hugh's suggestion
```

This is the default extruder temp used in the preheat menu.

```
#define DEFAULT_fwidthKp 0.020  
#define DEFAULT_fwidthKi 0.020  
#define DEFAULT_fwidthKd 0.250
```

These settings affect the PID for the filament diameter control. They are largely set using trial and error. See the Appendix for general tips on tuning a PID.

```
#define PULLER_PID_MIN_LIMIT 1.0 //min output limit of filament dia control in mm/sec
#define PULLER_PID_MAX_LIMIT 24.0 //max output limit of filament dia control in mm/sec
#define PULLER_PID_INTEGRATOR_WIND_LIMIT 1000000 //absolute value of integrator windup max value
```

These settings affect the PID loop for the filament diameter control. They define the allowable output range of the PID and Integrator windup. These are advanced settings and would only need to be changed if the extruder machine design is radically different from the Lyman design.

```
#define DEFAULT_LENGTH_CUTOFF 150000 //length in mm where extruder will shut down
```

This is the default desired length in mm that defines a normal extruder run. After this much filament is produced, the extruder automatically shuts down.

```
#define EXTRUDE_MINTEMP 170 //min temp that extruder motor will run
//this prevents dangerous Extruder moves, i.e. if the temperature is under the limit
//can be software-disabled for whatever purposes by
#define PREVENT_DANGEROUS_EXTRUDE
```

These settings control the safety interlock between the extruder motor and the extruder temperature. Recommendation is to leave these as is.

```
#define DEFAULT_ESTEP_PER_REV 489.6 //default setting for the extruder step calibration
#define DEFAULT_PSTEP_PER_MM 2653.6 //default setting for the puller motor step calibration
```

These settings control the default Esteps/rev and Psteps/mm for the firmware. Changing them here will make them the default setting that returns when selecting Restore Failsafe from the Control Menu in the LCD. The settings were described in the section Motor Setup.

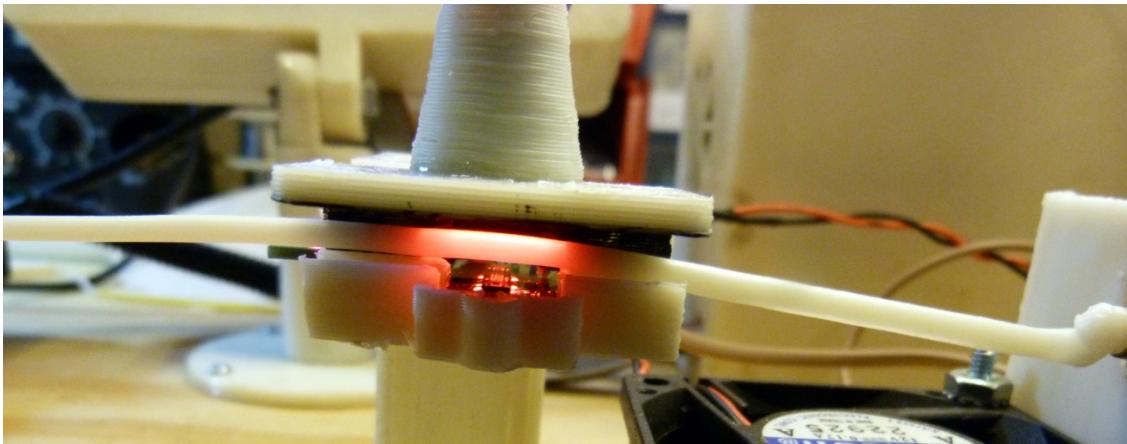
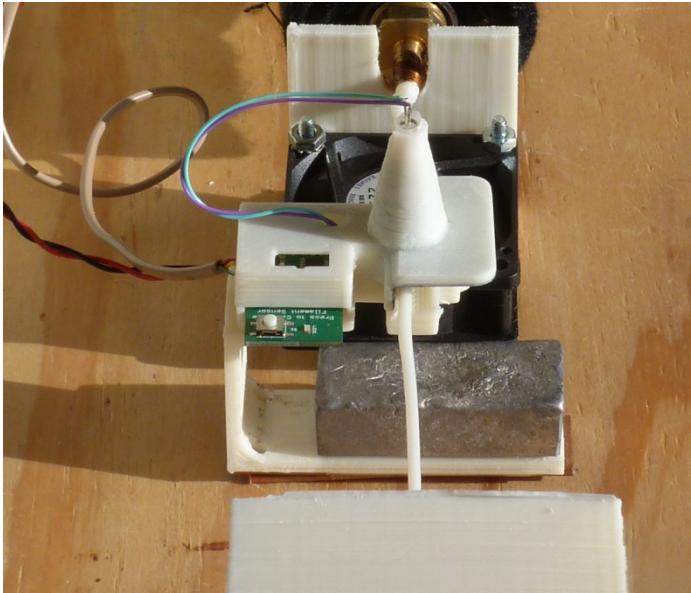
```
#define DEFAULT_MOTOR_ACCELERATION 200 // E and P max acceleration in mm/s^2 - controls extruder acceleration
#define DEFAULT_EJERK 1.0 // (mm/sec)
#define DEFAULT_PJERK 1.0 // (mm/sec)
```

These settings affect the stepper motor motion control. Users may want to adjust the Default Motor Acceleration in situations where the stepper motors are not able to accelerate as fast as demanded by the controller. The Ejerk and Pjerk settings are advanced settings and should not require adjustment for the standard Lyman extruder design.

Filament Sensor Input

This section describes the technical aspects of the filament sensor input. The filament sensor input is on the AUX2 input of the RAMPS board and is analog input A5 of the Mega 2560. The firmware expects an analog voltage that is proportional to the filament diameter in mm. When powered by exactly 5.00v at the supply, the filament sensor is expected to produce an output voltage of 1v per mm. To handle variations in supply and still provide accurate measurement, a ratiometric i/o approach is used. The A5 input of the Mega 2560 is ratiometric, and so it expects a ratiometric output from the filament sensor. Also, the Mega 2560 and the sensor are powered by the same supply. This ensures that if the supply voltage is not exactly 5.00, or varies over time, the firmware will still get an accurate reading from the sensor. The firmware expects the sensor to provide updates every 1 second or faster, to ensure good averaging and filament control.

Filament Sensor



1) Connect Power by opening the case

- a) Carefully remove the LED in the illumination tower by using a small screwdriver to gently pry it out leveraging the LED edge.
- b) Unscrew the 2-56 screws in the back of the case.
- c) LED will fit through hole in front case if you want to free the front case.
- d) Gently remove the PC board from the back case.
- e) Solder wires for +5.00v supply to the terminals marked "+5v" and "gnd". Sensor is calibrated for a 5.00v supply, but will also operate at 3.30v.

- f) Solder a wire for sensor output to the terminal marked "v out". The other terminals are currently not used.
- g) Reassemble – carefully press the PC board into the back part of the case. Insert the LED into the hole in the case and reassemble the case. Press the LED into the illumination tower, being careful not to allow the LED wires to short.

2) Test the sensor

- a) The sensor has two measurement modes, a ratio-metric mode (steady LED) or an absolute voltage mode (blinking LED). Pressing the calibration button briefly will switch modes. Last setting is saved in Flash.
- b) Apply power to the sensor. The sensor is calibrated for a 5.00v supply and will provide a voltage output of 1mm/1volt when the supply is exactly 5.00v in ratio-metric mode. In absolute mode, supply voltage does not impact the measurement.
- c) A precise calibration wire is provided, which has a dimension of 1.57mm. Carefully place this in the sensor and it should read close to 1.57 volts, or 31.4% of the actual supply voltage (in ratio-metric mode).
- d) The calibration button can be used to calibrate the sensor on the calibration wire. This should only be needed if the sensor is modified (different housing, LED, etc). Press the calibration button while the calibration wire is inside the sensor to calibrate. Hold the button for roughly 3 seconds, until the LED lights or flashes again. The sensor is then calibrated and settings will be saved in the flash.

3) Use the sensor – some options

- a) Sensor could be wired to a suitable digital panel meter to show real-time caliper. (use the absolute mode – flashing LED)
- b) Sensor output could be wired to the extruder control to influence extrusion rate. In this case it is best to supply the sensor from the same 5.0v supply as the control board so that the Sensor output and the A/D input have exactly the same input range and use the ratiometric mode (steady LED).

4) Troubleshooting

- a) Dust or debris on the sensor will lead to false readings. Sensor can be cleaned with a cotton swab if this occurs.
- b) Calibrating the sensor without the calibration wire inserted will lead to unpredictable behavior. To correct, recalibrate with the calibration wire correctly inserted in the sensor.
- c) For accurate readings, the filament must stay down against the sensor. Upward motion of the filament (away from the image sensor) will lead to inaccurate measurements.