Lily delta printer
Assembly and commissioning instructions.

References

https://github.com/Prouzeau/HXM-delta-printer

https://github.com/PRouzeau/3D-printer-spool-on-top

https://github.com/PRouzeau/Geared-Extruder

http://rouzeau.net/Print3D/Lily

http://rouzeau.net/twg/index.php?twg_album=3DPrint%2FLily
Photos Gallery

Duet control board information

http://reprap.org/wiki/Duet

https://github.com/dc42/RepRapFirmware/tree/dev/Release
Firmware DC42

https://github.com/chrishamm/DuetWebControl Web interface

Fisher documents.

http://forums.reprap.org/list.php?409 forum about Fisher

https://github.com/reprappro/RepRapFirmware/tree/master/SD-image

Table of content

1. Preparatory work

a) Preparatory work

Read and look carefully the instructions, BOM, drawings, templates, photos. It shall also be interesting to look at the Fisher documents.
Choose your options (fan voltage, flanged/non flanged tensioner bearings, printer dimensions: HXMF 131/500, HXMF 139/500: from Fisher kit or HXMS 140/530:standard printer built from scratch).
There is an additive BOM list to Fisher kit.
BOM is not yet published for a 'from scratch' build except there is another design for feet in two parts, with rods down the bottom plate, which will be stiffer. The hotend used will probably be the 'Hexagon', for its compactness and low cost.
The only critical element is the Fisher hotend, and its parts are not yet available as separate parts. Others specific parts are the extruder hobbed insert and the brass bowden end, but there are suppliers for them, see next chapter.
The duet board is available at Think3DPrint3D (Genuine V. 0.8.5) or Replikeo (Clone, yet 0.6 A – only).

b) Supplying stuff

Order stuff on internet early, that may takes time to arrive (up to 5 weeks if it came from China). That shall be your first task, but you may start printing in the same time.
Screws are better supplied to an internet specialist. Except for hotend attach screw which shall be in stainless steel (on the Fisher version), other bolts and nuts could be carbon steel, but buy quality (class 8.8), it does not cost more.
It is advisable to buy spare and think to other projects.
Wood screw shall be of the best quality to not split panels. I recommend the 'Rocket'.

Suppliers :

Think3DPrint3D https://www.think3dprint3d.com The Duet board designer	Duet board, cables, hobbed insert, misc. parts
Emaker shop http://www.emakershop.com/ Managed by Fisher designer -	Miscellaneous stock of Fisher parts
Robofun.ch https://www.robofun.ch/en/	hobbed insert, brass end, Duet board, heater block, nut
Replikeo www.replikeo.com	Duet board clone

RepRapPro China www.reprappro.com.cn	May supply to the world after RepRapPro closure

c) Printing

For printing, follow the recommendations indicated in the OpenScad files. Do respect them, and notably the infill. Depending your printer hotend ability, you may prefer use 0.25mm layers instead of 0.3mm as commonly required. Note that this are engineered parts and there is no benefit with smaller layers. Dimensional accuracy is not better. On the contrary, parts with larger layers tend to be stronger.
You could print while you are preparing the wood panels and your supply. You may print first the tensioners and their thumbwheels as they are the first parts to be assembled. - The tensioners prints are not the same for flanged or not flanged bearings (not flanged bearing tensioner is untested).
It is wise to print one carriage first to check the ball socket clearance. The ball insertion shall be quite firm, it will makes its place with time.
Note that the carriage and sockets are printed for 5.95mm balls. If your balls diameter is different, you shall regenerate the STL files with OpenScad before printing.
It is preferable to print feet, motor supports, carriages and effector base on the same printer with same parameters and filament, in the same X/Y angle to have the same defaults and maintain good sliding.
For the effector base, it is important that the X/Y dimensions are equal as the ball sockets are printed.
Use X/Y scaling parameters if needed. With RepRap firmare, use M579 for X/Y scaling
DC42 and Chrishamm fork implement this (from 1.09m version for DC42 fork).
To print the duct of the HXM Standard, use the special Slic3R profile supplied.

2. Manufacturing

a) Drilling top/bottom wood panels

Prepare panel and drill them according templates (DXF or PDF files). Side panel shall be marked to recognize internal and external faces (as they will have recesses for screw heads).

b) Cleaning printed parts

- While your parts are printed, clean them and check holes. Of importance are:
*holes for guiding rods in the foot and top support and in the tensioners. It may not be needed to clean the M3 screw holes except for the following :
* filament hole in extruder lever (2mm) ; tongue passage and bowden start hole shall be cleaned. Lever entering filament hole shall be threaded with a M4 screw.
* Motor support holes, Extruder base motor holes
* Tensioning wire holes in effector and carriages

c) Belt tensioners assembly

- Install screw in tensioners (screw M4x80, countersunk head+ 1 washer medium). Use two nuts for tensioning manoeuver, you may add the mini thumbwheel (the inserted nut is on tensioner side) or left just nut/counternut. There shall be minimum play between thumbwheel and tensioner. Nuts shall be locked with screw and well tightened. Note: this is very difficult to dissassemble, so be cautious.

Install the bearings according photos, using toothpick as a temporary maintainer for the two bearings. If you are using flanged bearings, it is imperative to add a washer (thickness ~0.8mm) between the bearings to limit belt friction on bearing flanges.

Plain bearings shall be pushed sideways as the belts guide hinder top entering. Installing the screw will push away the toothpick.

d) Carriage assembly

Assemble bearings on the carriage. Beware, this is not symmetric. Long bearing is on the left while looking the carriage with arms articulation facing you. Screw rubber stops. You may not need a nut and could screw directly in the plastic. M3x20+medium washer.

Somewhat grease the internal of the bearing. Use lithium bearing grease. White grease in spray is useful.

e) Pre-assembly of one column

- Pre-assemble one column and use it to drill the side panels holes. There are positioning holes diam 3mm in motor and bottom support. Beware of good perpendicularity between the rods and supports.
- End to end supports shall be exactly the same length as your panels (in principle 500mm).
- Install the carriage in this pre-assembly to check the sliding is good and your printed dimensions are accurate.

f) Drilling wood side panels

- use the preassembled column
- Motor holes in panel shall have a recess on the outside face for screw head of 4mm. It shall not be too deep, as the thread is blind in the motor.
- there shall be a hole diam 10, depth 5mm facing the motor shaft
- The clearance between tensioner and panel is minimal. So you could either grind the end of the bearing screw in the tensioner or make a 2mm recess in the wood panels facing the tensioner bearing. (the movement of the tensioner may not exceed 5mm)
- Disassemble the column

3. Assembly

a) Frame assembly

- Install the tensioners nuts in the column feet. A vise may help.
- Assemble top and bottom triangles. There is a calibrated stick you could print, or if your printer is too small, cut in any material. For the shown dimensions (internal radius 131mm), this stick is 172 mm. Look photos to see how to position them
- Make the positioning hole in your top plates sufficiently large (diam 6mm) as they shall not

force on the triangle, to have it remain with accurate dimensions
- Check carefully that the belt tensioners are easily sliding on the rods. You may use paraffin to help
- Before installing the bottom triangle, check your tensioning nuts are still there.
- Clamp the bottom triangle on the plate
- Punch precisely the bottom fixation holes
- Use wood screw for bottom triangle assembly. Alternatively, you may do larger holes (diam 6) and use M4 bolts with washers, which may limit the side forces on the column foot for good accuracy
- If not already done, check the foot rod hole are cleaned and of appropriate diameter. Insert the rods in foot while hammer gently with a mallet to not destroy feet.
- Introduce carriage in appropriate position
- It is better to install the belts now, as installing them later (from the top plate hole) may be a bit more difficult. You need to make a 1mm hole at the end of the belt to pull it with a rigid wire around tensioner bearing. Note that as on the fisher, this is the back of the belt which run on bearings and the belt is twisted on return path.

- slide motor support on limited length and check that the sliding is ok then slide it to final position.

- Bolt the side panel on the feet with rod tightening screws (M4x50, domed headin diam 6 holes). Tight moderately.

- Set the frame upside/down. Beware, not completely assembled, it is a bit fragile.
- Install clamps to prevent panel splitting while tightening wood screws. Set wood screw (4x40) and tighten firmly. Remove clamps.
- Return your frame in normal position and tighten the side panel attach M4 screw
- Punch holes in the feet support and install wood screws.
- Check your motor supports are flush with side panels (use top plate)
- Prepare motor screws M3x40, flat head. They may be a bit difficult to install, so slightly grinding their end conically may help. Pre-install them in panel with Medium washer. Don't use hex head screw as I have done, because you can't push them in place (I set spring in my socket spanner to push the screws). I ended to install M3 rods then cutting them to replace some screws.
- Make a loop with the end of your belt and position your motor inside the belt loop
- Screw the motor in place
- Install top panel and attch with wood screw 4x40. Use clamps as before
- Install three rubber pads as feet and two pads on the back of the base plate.

b) Arms assembly

Balls shall be glued to rods.

Make a mark on rods before screwing them, to avoir overscrew, which destroy the link part.

All rods shall have the same length. If you cannot measure the arm length, make a template to check all arm length are identical. You will be able to evaluate the arm length by printing calibration parts.

The arm length is axis to axis, so the measured length does include ball diameter, e.g. for 190mm, with 6mm balls, you shall measure 196mm. Measure your ball diameters.

c) Effector support assembly

Screw the standoff with domed head screws M3*12.
Wire the three pair of standoff to make a continuous circuit done by the balls, as on the Fisher Bed with two links and the cable connected on the remaining pair. The eyed terminals shall be installed inside, with bulge turned on the outside (look photos). These terminals shall have a sufficient clearance to have their bulge just above the effector. This is not the case of the original eyed terminals which unfortunately cannot be reused.
Instead of what is done on prototype, you may wire only one pair of standoff. For this to work properly, you shall have a weaker rubber on the side of the wired standoff pair, which is delicate and then not recommended.

d) Hotend assembly

The hotend itself shall be assembled per RRP instructions, and if you get it from a Fisher, this is already done and left unmodified.

Hotend attach to support. Support shall be in ABS or PETG or other heat resistant plastic, as temperatures may go up to 60°C on hotend fins. The fin block is not in contact with the support (there is an insulating gasket) but the screw do conduct heat and is ~10°C below fin temperature.

4 bolts Bolt M3x35, countersunk head, STAINLESS STEEL A2 or A4 , 8 washers M3 medium.

The hotend support part shall be well cleaned, preferably with a sharp cutter to have good airflow. This is a bit critical. There are some flats parts set for bridging which shall be cut to enter the hotend in its place. The hotend fan bottom part shall but cut internally reclined to the hotend (the gasket will maintain tigthness), which is also needed because the bridging make this not very nice.

The bridging area at at outlet of the hotend duct probably need to be filed. A slight chamfer (0.5 mm) may be cut at the outlet. (part thickness ~1.2 mm).

1 plumbing fiber gasket 20/27 (3/4") thickness 1.5mm. Shall be cut internally to a diameter of 17mm (hotend fin diameter). Passage for screws are drilled in place while cleaning the holes in the hotend support.
Bolts on fan side are installed with head on gasket (with a washer), bolts near center will have the nuts on gasket (also with a washer). You will have to rotate the hotend to allow passage of screwdriver. Do it gently and tighten later with the nuts.

You will have to install the balls of the kinematic support. Glue them on their screws.

Fan holes shall be drilled to 3mm. Attach to the support with wood screws 3x15.

e) Extruder assembly

See the instruction for the geared extruder in dedicated documents.

The extruder is installed on a plate attached to side panels. It is inclined by 22.5° from vertical.

There is a template for HXM131 (with the board top panel drilling template), the width will be larger for the HXM 139 – to be defined how much.

There are printed brackets which will give you the proper inclination. Use the bracket assembled on the plate as a template for marking holes to be done on the side panels.

For HXM 131, the top of the extruder plate support shall be at 68mm from the bottom of top plate.

f) Bowden tube assembly.

For HXM 131, Bowden tube length shall be at least 420mm (this is the original length on the Fisher)

It may be sufficient for the HXM139, but you may have to lower somewhat the extruder plate (by ~ ~10mm, this shall be checked).

Follow closely RRP instructions. You may experience filament blockage if Bowden tube is tightened too firmly in the hotend, so I always unscrew by ½ turn after assembly on the hotend.

g) Tensioning wire installation

Use Nylon wire 10kg. Use [['8' type knots→http://www.animatedknots.com/fig8_/#ScrollPoint]] on looped wire as they are bigger knots and less prone to break.
- Install effector in place (without hotend), the socket ball grip shall be sufficient to maintain it without the wires.

Cut 3 time 1m length of nylon wire.
- Makes a loop with a return branch of 100mm, Tape the return branch.
- Make at least three 8 knots with the loop on the end to block passage in holes. Pass the wire in wire hole in carriage from top to bottom, then in same side effector hole, then make a turn around the side of the effector (to avoid conflicting with the hotend support), then pass in the other arm side of the effector (top to bottom), then in the other side of the carriage. Mark color with a marker 30mm after the outlet of the wire.
- Remove arms to be able to pull the wire and make knots.
- Make a loop folded at the mark, Tape the loop. Make at least three '8' knots, with the loop end at ~ 15mm from the knots.
- Reinstall arms and check tension. Shall be between 500g and 1 kg, but that is a bit difficult to evaluate.
- Remove arms and add knots to increase tension if needed.
- Repeat for other sides

h) Wiring the fans

Fan is supplied in 5V and the current is sunk by a MOSFET on the negative side of the fan. However, on the Duet, there is a LED to indicate fan operation, which means that sunk pin could be supplied in 19V through the LED when fan is not in operation. So a protecting diode is installed, but in 5V, the forward voltage reduce significantly the fan power and a low forward voltage diode shall be used. I choose SB340.

If you are practicing electronics and are handy, you may remove the fan LED instead of adding a protecting diode.

VERY IMPORTANT: On the Duet 0.6, The sunk pin is the pin inside, the outside pin is supplied in

19V and a mistake will send 19V on the 5V supply and will burn the board. Check the photo, my board is still alive (...). The Molex connector will orient the plug.
Beware of boards which are supplied with simple pins instead of Molex connectors (this is the case of my Duet 0.8.5 on The D-Box), that is very dangerous and a mistake take only one second to smoke your board.

i) Other wiring

Look at the Fisher installation procedure. If using Fisher kit, one motor cable shall be lengthened. Be cautious, a contact fault in the wiring may burn a driver, hence your whole board. Beware of the original RRP power supply plug, if the cable pull sideways, you could have a short in the plug. Bending plug tabs may help. Hopefully, in case of a short there is a protection in the power supply block which make clicking noises. This is why the plug have been replaced by a cable.
The effector cables shall be poreferably groupes in a textile sleeve. This is better for maintenance than zip-ties.
The effector cables shall be braced to the effector to maintain it vertically and avoid conflicts with the carriage. See photo.

All motor cables shall be attached to the top structure and shall not move. Best is to use zip-ties. The effector cable shall be alone in the top hole through to not move other cables. A retainer shall be installed to avoid any cable movement atop the board.

j) Hotend support installation

Look photos.
I use slices of old bike tire tubes as rubber 'springs'.
Depending your tube size, there may be two rubber turns on the hotend support arm, but the attach to effector shall be with one turn only. Use rigid wires to pull the rubber on effector attach, this makes installation easy.

4. Commissioning

a) Updating software and firmware

UPDATE the firmware to the last version of DC42 fork. See page on RepRap Wiki for the update.
UPDATE the web interface (all content of www directory) if you have a recent version of DC42 fork. Web interface as found in the Fisher image won't work. Edge/IE have issues with the web interface
Take the image of the HXM, or, if not available, the image of the Fisher.

Update the image with the following HXM files :

- Configuration file (sys/config.g)
- Homing file (sys/homedelta.g) for operation without end switches
- Calibration file (sys/bed.g) – shall be adapted to your machine (see calibration paragraph)
- Interface file (www/js/interface.js)
- Miscellaneous macros

b) Commissioning

Mechanical commissioning. Make a general control of the printer mechanics, check all screw tightening, plays and especially cable clearance while moving the effector. It is especially

important that the cable didn't go in carriage way while homing the printer. For full diameter use, you shall cut (with a saw, not with disk) the bottom rod located on the fan duct side, as the part fan duct will conflict with the rod at maximum printing diameter.

Use RRP commissioning procedure for Fisher except:
- enter http://HXM in your browser to access to the machine web interface.
- Without switches, the available height defined in M665 is not used, you shall define the height in the 'homedelta.g' macro. Start with a height smaller than expected, so when the effector goes to 0, it is above the real 0.

Note: during automatic calibration, if the sensor is triggered before the hotend is lowered down, this is because the bowden tube traction is lifting the hotend support of the effector, triggering the contact. IN that case, you shall reinforce your rubbers, see the paragraph below 'Checking sensor triggering force'.

After doing the RRP commissioning, you shall do :
- Calibrate your extruder. Bowden tube disconnected, make a mark on your filament, cold extrude 1000mm of filament, make another mark, measure, and correct the value steps/mm (its G-code M92 in config.g file).
New step/mm = Old Step/mm * 1000/measured length (in mm).
Code 'T0' , then 'M302 P1' (allow cold extrusion), then 'G1 E1000 F2000' (extrude 1000mm)
To retract 'G1 E-1000 F2000' then 'M302 P0' to prevent cold extrusion.
Nota: code 'M84' shut down all motors

- Thermistor ADC checking (look RepRap Wiki duet page links)

- Sensor offset adjustment (H parameter in bed and bed_report macro)
There is more offset on the side than in center (this is reverse of the Fisher, where the offset is larger at the center).
Bed, bed_report and P0 to P6 macros shall have same coordinates and be adjusted while you displace probing points, which may notably be needed if your bed surface is weraed (as could occurred easily with BuildTak) or for a different usable diameter.
To test the offset, you shall :
Do at least 3 calibrations till you get consistent results.
Execute M665 and note the reported parameters to modify your configuration file.
Please note that if you use the homing macro without end switches, the height in M665 will not be used and the height shall be modified in the homedelta.g

Move to the calibration points with the P0 to P6 macros and lower the head manually atop a paper sheet till the paper sheet began to have difficulties to slide.
Repeat for all the probe points, note the values on a paper.
You shall then modify the H parameters in the bed.g file and reload this file on the SD card. I find the FTP the easiest method for that.
Values found shall be substracted to the already defined offset, meaning that if you find +0,1 and the offset is already -0,22, you shall do -0,22-(+0,1) = -0,32
If using a 'BuildTak' surface, you shall not 'crush' the filament on the surface and the resulting value while paper began not to slide shall be within – 0.1~0,12 mm , so you shall substract 0,12 to lift up the hotend, say if offset is -0,25 while paper is sliding at exactly 0, you shall set -0,36.
After adjustment of H parameters in bed.g, modify the bed_report.g with same values, then

reload bed_report.g on the SD card and run the macro.
If your paper report is neat, but the results of the calibration and bed_reports shows differences, that means that your bed is not flat. What count is the paper measure, not the calibration result, so do not cheat by modifying the H parameter to obtain a very low calibration value.

Note that all macros could be run after being loaded on the SD card by FTP, without rebooting or restarting.

c) Checking sensor triggering force

Shall be from 800g to 1200g. Note that the Z offset of calibration points depends from this force, so if you change the rubbers, you may do a new test of calibration.
Use a kitchen scale (on support to clear the triangle rods), and lower the effector with the manual commands till triggering the sensor (web interface shall be parametered for 0.05 mm displacements). You shall home your printer before installing the scale if you want to avoid heavy impact on the scale !
Adjust your rubbers if load is excessive or insufficient (you may play with their width). The rubber shall be well inserted behind their retaining bars.

d) Miscellaneous

There are very few modifications between the prototype and the documents supplied. One of those is that the back panel is now full width. This is for:
* Installing a fume recycler on activated carbon pad (like on the D-Box) on the left. See new photos
* Having place to install tools on the right of the back panel, which will be more elegant than on one of the front panel (and more roomy also). A door have been added. See photos
End switch holder is not finalized, as there is no switch on prototype, for simplicity and reliability. However, the design was started and could be found in the OpenScad file.

Acronyms :
RRP : RepRapPro company, Fisher designer and supplier, closed its doors mid January 2016.
TBD: To be done