Complete Build Package

Information Regarding Focus SLS Build package

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Table of content

Introduction

In this document, I will try and explain everything on how to build a focus SLS printer. This document is not yet complete. Like focus, it will be updated bit by bit until all of the necessary information is complete.

Focus started October 2012 as a how hard can it be. After half a year the answer is clear: Very hard. Designing the printer took slightly over a month. Building it took another month. It was at electronics where I met my first real hurdle. I am a mechanical engineer, not a software or electrical engineer. Getting the printer to make its first real movement took 2 months. Getting it to print from a SD card took another month. Even now the firmware has a lot of bugs and points of improvement. After this point was when I first decided to share my progress.

Important notes

The firmware is basic, full of bugs and only functioning on a basic level. There practically no safeties, The buffer is basic and has little protection from unexpected problems. Also the buffer has no protection from overflowing. When the buffer overtakes itself, it will repeat some bits, without powering the laser (the laser target is below the current). Gcode can only be sent on a SD card and must be put in the top folder in the form of a .txt called "print.txt". There is no acceleration and the movement uses the micros() timer to determine when to make a step. This timer overflows every 71 minutes causing the motors to lose steps in some cases, depending on when the timer overflows.

When this project started there was too much difference with FDM technology to convert existing firmware. Now that the printer has become RAMPS compatible, a new driver is needed. I however lack proper programming skills to convert a driver. More work by exterior parties is needed on this front. The firmware CAN print and deposit new layers, just not in an elegant, finely controlled way.

Expect parts, firmware, schematics and designs to change, Focus is a work in progress.

I am not responsible for any harm or damage caused to people, pets and the surroundings by Focus. This project uses high power lasers that can damage eyes in a matter of milliseconds. You were born with a brain, you can think for yourself, so do it.

What is focus

Focus is a powder printer designed to print in various powdered materials using various techniques. These techniques include SLS (selective laser sintering), SLM (selective laser melting) and 3DP (printing with binder in powder). Focus can also be outfitted to use a basic FDM (fused deposition modeling) extruder and can be used as a laser engraver, but those are just capabilities. Focus is designed to be cheap to build and be very versatile. When right parts are sourced, focus can be built for under €600,-, As much as a normal reprap printer.

Focus is built around easily obtainable parts that are already very common in reprap printers. This included NEMA17 stepper motors, RAMPS 1.4 electronics 624 bearings and LM8UU bearings.

Because SLS and 3DP printing is still very experimental in the 3D printer community, more research of materials and techniques is needed. Focus offers a cheap platform for a lot of experiments. Expensive things like vacuum and heated buildbox have been left out of the design.

What will you need

To build a focus, there are several parts and materials that you will need. These are split in to several categories.

Printed parts

Name	Quantity	Description
Carriage belt clamp	2	
Carriage carrier	1	
Carriage hookup	1	
Carriage Laser Mount	1	
Carriage LM8UU holder	9	
Piston bearing plate	24	
Piston Endstop Holder	2	
Piston Motor cover	2	
Piston Motor Mount NEMA17	2	
Piston Nut trap	2	
Piston Screw holder	2	
Piston wallguide	4	
Roller V3 pivot block driver	1	
Roller Holder V2	2	
Roller Hookup V2	1	
Roller V3 pivot block	1	
Roller V3 pivot block mirror	1	
Roller Maglock	2	
Tray Handle	1	
X Bar Clamp Endstop	1	
X Bar Clamp	5	
X belt Clamp	2	
X Driven Clamp	2	
X Driver Guide	2	
X Idler Clamp Mirror	1	
X Idler clamp	1	
X Maglock	2	
X Motor Mount mirror	1	
X motor Mount	1	
Y Axis Idler	1	
Y Axis motor holder	1	

Parts

Name	Quantity	Description
Laser safety glasses	More than 1	NOT OPTIONAL!
15mm MDF 1100x1200mm	1	For all of the wooden parts. See Cut List
NEMA 17 stepper motor	5	

Vitamins

Name	Quantity	Description
LM8UU	9	Linear 8mm bearing
624	35	Radial 4x13x5mm bearing
M4 self-locking nut	125	
M4 nut	93	
M4 washer	333	
M4 Cil. Head screw 20mm	58	
M4 Cil. Head screw 25mm	2	
M4 Cil. Head screw 30mm	27	
M4 Cil. Head screw 40mm	82	
270mm M4 threaded rod	2	Depositer frame
130mm M4 threaded rod	2	Piston lead screw
M5 Fender washer	16	
M4 Hex. Bolt 40mm	3	
M3 self-locking nut	16	
M3 washer	66	
M3 Cil. Head screw 12mm	20	
M3 Cil. Head screw 16mm	8	
M3 Cil. Head screw 25mm	8	
M8 nut	24	
M8 washer	24	
M8 hex bolt 100mm	4	
M8 Threaded rod 340mm	3	
M6 threaded Rod 200mm	4	
M6 nut	24	
M6 washer	24	
Spring	16	6x30mm
500mm Ø8mm smooth rod	2	For the X-Axis
315mm Ø8mm smooth rod	2	For the Y-axis
Assorted wood screws	-	For joining all the MDF parts
Corner brace	4	For attaching the hopper to the frame
Small magnets max Ø10 by 3mm	4	For the maglocks

*All values are can differ in small quantities

Electronics

control

Name	Quantity	Description
Arduino Mega 2560	1	Main driver board
RAMPS 1.4	1	
Pololu Stepper motor driver	4	
Opto endstop	4	
4x20 HD44780 LCD screen	1	Used for displaying information
SD ramps sd card reader	1	Used for reading Gcode
Ramps keyboard	1	Used for controlling Focus
12V 4A+ power supply	1	For powering the printer
A way of powering an Arduino	1	The Arduino needs juice too

Laser driver

Name	Quantity	Description
LM317	2	
0.39Ω resistor 3W	2	
220Ω resistor	1	
50Ω 3W+ potmeter	1	
5kΩ potmeter	1	
1N4007 diode	1	
100nf capacitor	1	
47µF electrolytic capacitor	1	
10µF electrolytic capacitor	1	
PCB terminal block double	1	
Header male 3 pins	1	
Header female 3 pins	1	
TO220 heat sink	2	
60mm fan	1	

Electronics

Hardware

control

The electronics are RAMPS, a standard for diy 3D printers. Attached to this electronics are: 5 Motors, 3 separate and two wired in a group, 4 Endstops, 1 20x4 LCD screen, 1 keypad with at least 8 buttons and 1 74HC165 shift register and one SD card reader. The laser driver is attached to the mosfet that heats nozzle number one.

Wiring

Wiring Focus is similar to wiring a normal printer with ramps. The X motor attaches to the X motor driver, the Y motor attaches to the Y motor driver. The Build piston motor attaches to the E0 driver and the Feed piston motor attaches to the E1 driver. Special care is needed for the X motors, there are two stepper motors and they need to be mirrored. This can be done by inverting the coils and the coil polarity. This essentially means that wire 1 of X-motor one needs to be attached to wire 4 of X-motor two, wire 2 to wire 3 and so on.

The laser driver needs to be attached to the E0 mosfet.

Laser driver

The laser driver uses a double lm317 to control both current and voltage. This happens in two stages. The first lm317 is wired as a voltage regulator. The 5k potentiometer is used to set the voltage. The second lm317 is wired as a constant current regulator, controlling the current sent to the laser. The 50Ω potentiometer controls the current.

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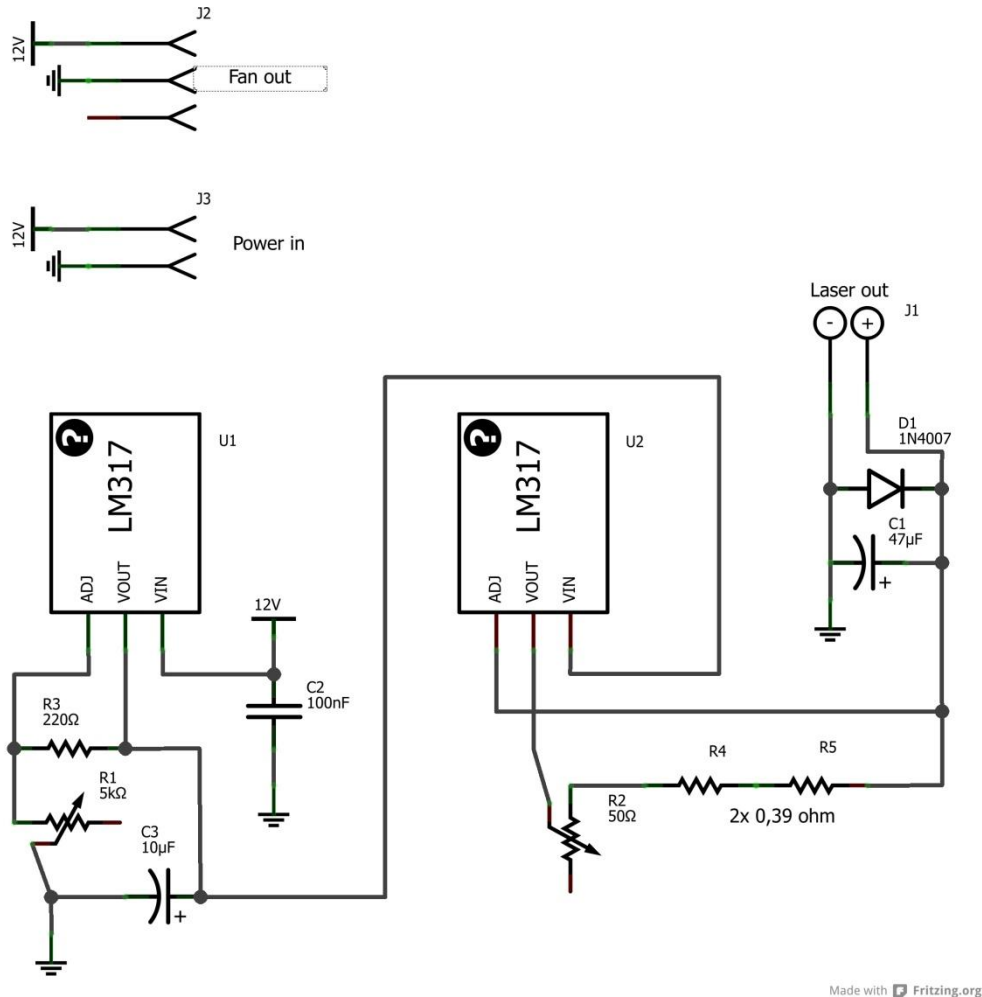
The minimum input voltage is 12V. With this, the laser driver can supply up to 2V and 1,6A. A higher input voltage is necessary if a higher drive voltage is needed. The double lm317 use dissipate a lot of energy and the practical voltage drop is around 10V. An ammeter can be put between the second lm317 and the laser output to measure the current through the laser.

Firmware

Most recent version: Beta_0_02_RAMPS

The firmware is a built from scratch program that reads and converts Gcode to movement. When the extruder moves in a printing (forward) direction, the laser will turn on. If there is no material printed in the Gcode, the laser will turn off again. The laser wont reverse. If a reverse target is set, the firmware will simply ignore it. A G92 E0 will set the E-Axis to 0 to keep moving forward.

The firmware cannot receive controls directly from the computer. It uses an SD card. The firmware looks for a txt file in the top folder called "print.txt". This is the only file that the printer will read from the SD card.

The firmware currently has a buffer of 10 steps. If not all buffers are filled, after each step of either the X- or the Y-Axis and when there is enough time left, another character form the SD card's Gcode will be read and processed. If a full line has been read and is usable code, it will be added to the buffer. To keep the buffer filled, at least 40 steps are needed per target. With 64 steps/mm, this is around 0,5mm. If there are too many targets smaller than 0,5mm, the buffer will overtake itself and redo parts of the print without turning on the laser. G92 and Z-Axis movements will completely fill the buffer before proceeding to the next required steps.

If all of the Gcode has been from the SD card, the buffers are empty and the target is reached, the firmware should stop printing and turn of the laser. This is however <u>NOT</u> always the case. Sometimes the firmware will end before the buffer is empty, sometimes at the end the firmware will jam and sometimes the firmware will <u>NOT TURN OFF THE LASER</u>. Leaving the printer unattended is at your own risk. You have been warned.

Software

The electronics and the firmware are made so that they are capable of using FDM Gcode. This removes the need for special software to turn the 3D files in to printer files. The laser turns on whenever the extruder moves in a forward position. There is no software to control the printer directly. Gcode is uploaded using a SD card. All off the other functions are controlled on the printer using the LCD screen and the keyboard.

Specs

General printer specs

- Build box: 115*130*≈100m,
- Max X feedrate: ≈30mm/s
- Max Y feedrate: ≈50mm/s
- Max Z feedrate: Unknown

Points of improvement

Focus is a first generation 3D powder printing platform. There are still a lot of problems that need to be fixed. Most of the problems won't affect the basic function of the printer. The printer will however run smoother, more reliable and generally better when these points are improved.

Firmware

The biggest problems is the firmware. As stated before, I am no software engineer. I have stretched my skills to the limit to produce a functioning piece of firmware. The firmware still has plenty of bugs and necessary additions.

There is no connection written between the arduino and the computer. All of the gcode is send via an SD card. For easier control it would be better if focus could be controlled by the computer. This will however not only require firmware, but also software to be written.

The firmware is written around the Micros() timers in arduino. This gives a real time control of movement that can easily be programmed. Problems with this is that the timer overflows every 71 minutes. It is not known what will happen in the milliseconds right before and after the timer overflows, but the printer might lose steps.

Pistons

The pistons are not design to be completely powdertight. Some powder can leak past the pistons. The Tray is below everywhere there is powder so any spill is caught. A system with less leakage might make for a more efficient print.

The piston is guided at the walls of the buildbox with bearings. This system is chosen because it was the simplest way. The original design didn't even have any guidance of the pistons. A more reliable system with linear guides needs to be made if more accurate piston movement is needed.

Roller

(Nearly) all commercial powder printers have roller. The original design also had a roller, but it was replaced with a simpler depositer to make the design easier to make. In the long run it might be better if a roller was added. Rollers don't just distribute the powder, they also compact it, lowering shrink. Also the rolling motion distributes the powder more even.

SLS

SLS has many features to aid smooth printing. Focus has none. SLS printing in nylon gives huge amounts of shrink in even tiny parts. No solutions are yet found to successfully print with the hardware available. It might be better to use Focus as a 3DP printer.

Future plans

Focus doesn't have the laser power to melt serious powders, doesn't have the wavelength to print in pure white materials and doesn't have the speed to handle a CO2 laser. This gives problems for all SLS and SLM applications.

3DP nozzles are being developed and converted to help print in different materials. Some of these materials are: Zcorp powder, gypsum, casting sand, stainless steel powder and ceramics. This will however not happen for at least another 2 months*.

An aluminum buildbox is going to be developed. An aluminum buildbox can be manually heated and cooled. Also an aluminum buildbox is more heat resistant, so metal powders can be printed too.

*(Sorry, I've got school business to attend to. If you want it sooner, you'll have to do it yourself)

SLS specific changes

Focus is an experimental platform. It is therefore not optimized for SLS printing. Focus lacks basics needed for SLS printing, such as a nitrogen chamber, a heated buildbox or a high wavelength (CO2) laser.

The used lasers (808nm) can't print in white materials or clear materials. To give the laser some grip, 1% carbon is added to the powder mixture to help transfer the heat to the printing material. With this minute impurity, all materials can be printed while only minimally impacting the material performance. Without a CO2 laser, anything that is clear or perfectly white can't be printed without adding additional materials.

Sintering happens in an oxygen free environment, such as CO2, N2 or H2 (H2 doesn't really seem safe). Focus currently has no way of creating this oxygen free environment. A gastight chamber that can hold preferably N2 needs to be added if any sintering is ever to happen.

Laser melting only benefits from oxygen free environments, against oxidation, but is not mandatory to my knowledge. Laser melting metals does however need a buildbox upgrade. The MDF used for the current buildbox can't handle the heat generated from melting metals. An aluminum or steel buildbox is needed for high heat applications. An added bonus with a heat resistant buildbox is that it can be manually heated to create a heated buildbox.