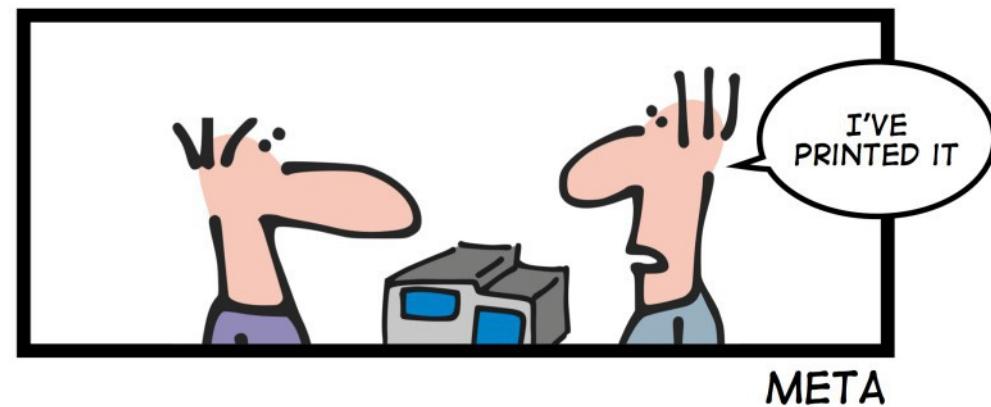
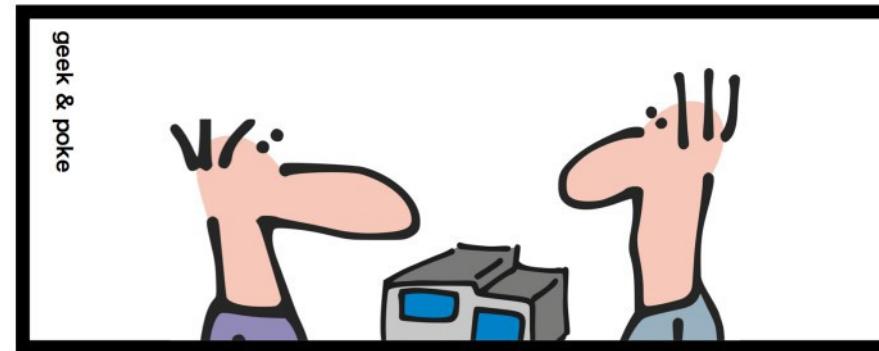
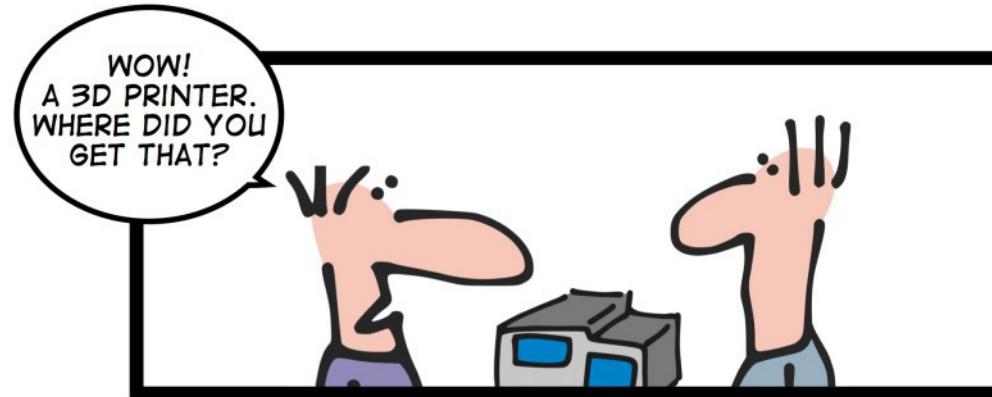


Reprap 3D Drucker

*OpenHardware &
OpenSoftware
in idealer Kombination*

Referent: Stefan Krister



Reprap 3D Drucker

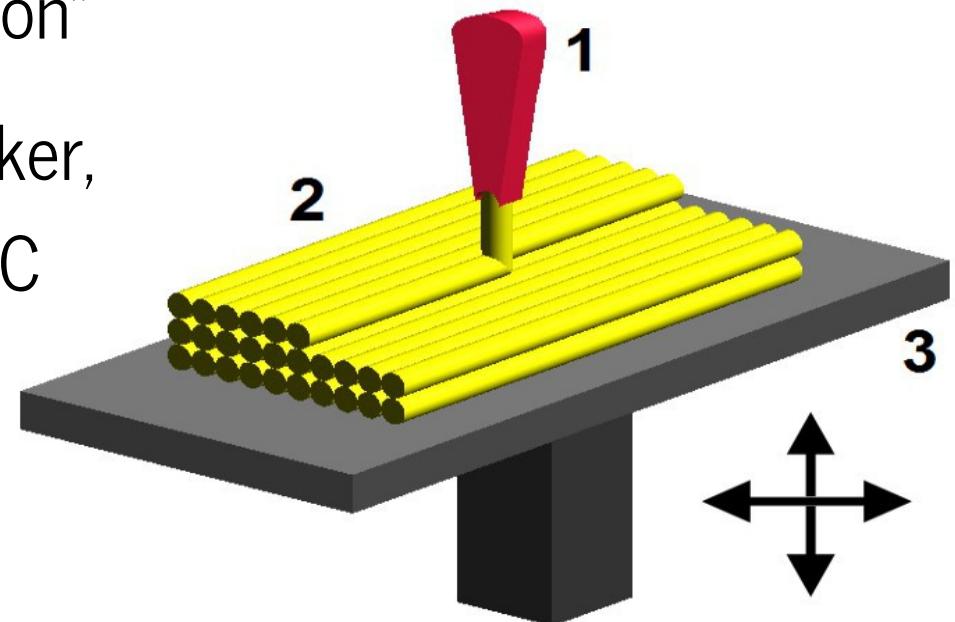
OpenHardware & OpenSoftware in idealer Kombination

- ⌚ Abgrenzung 3D Druck allgemein / Reprap
- ⌚ Bestandteile eines 3D Druckers
- ⌚ Software Workflow
- ⌚ Reprap Geschichte

Reprap 3D Drucker

⌚ Abgrenzung 3D Druck / Reprap

- ⌚ Replicating Rapid Prototyper
- ⌚ Verwendung von thermoplastischen Kunststoffen
- ⌚ „Fused filament fabrication“
- ⌚ Mikrocontroller am Drucker,
Druckaufbereitung am PC



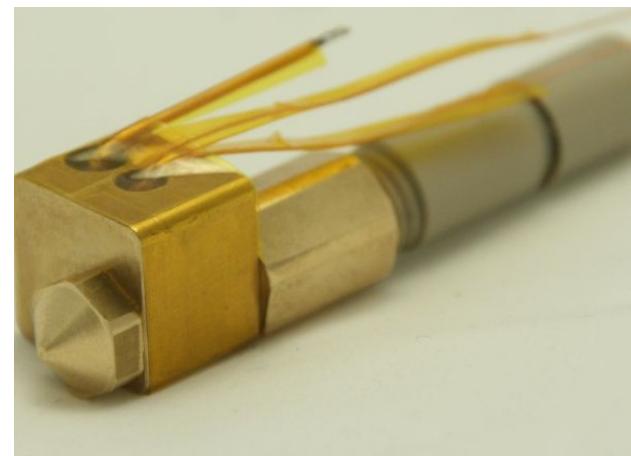
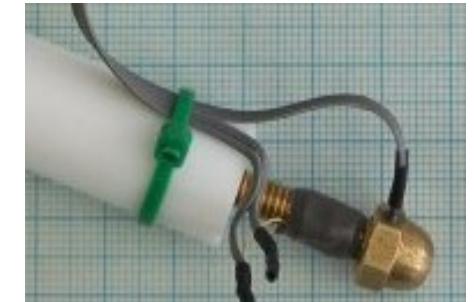
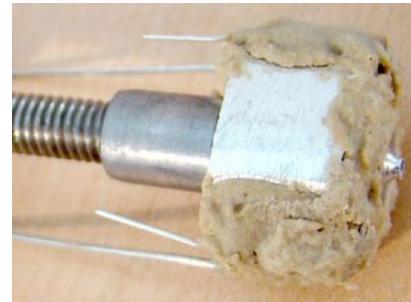
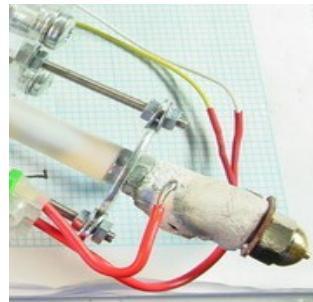
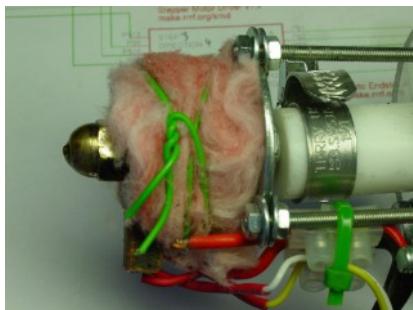
Reprap 3D Drucker

⌚ Abgrenzung 3D Druck / Reprap

- ⌚ Entwicklung unter Linux, muss aber auch mit Windows/MacOS laufen
- ⌚ Kartesische Achsenausrichtung
- ⌚ Genauigkeit $\leq 0,1\text{mm}$
- ⌚ Bauteile überall verfügbar (kaufen / drucken)

Reprap 3D Drucker

- beheizte Düse



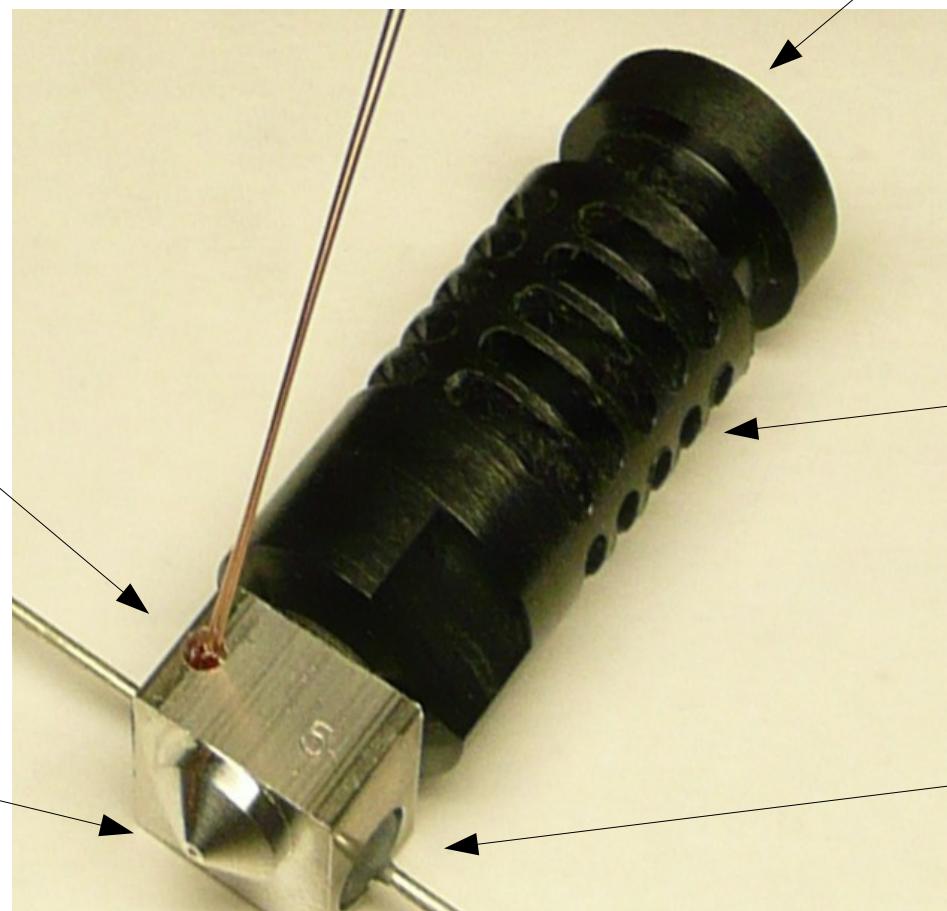
Reprap 3D Drucker

- beheizte Düse
 - J-Head MK5

Temperaturfühler
(Thermistor)

Düse aus
Aluminium

Hülse aus Polytetra-
fluorethylen (PTFE) /
Teflon (innen)

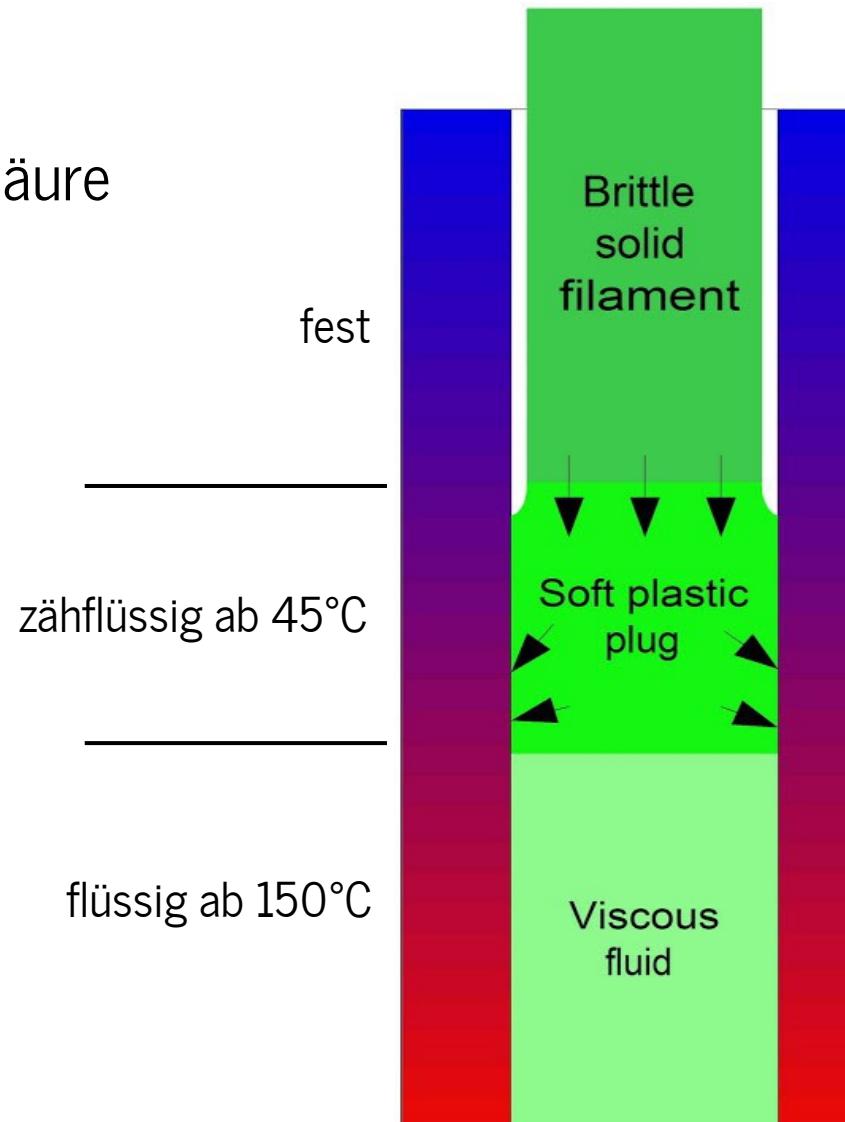


Halter aus
Polyether-
etherketon
(PEEK)

Heizwiderstand

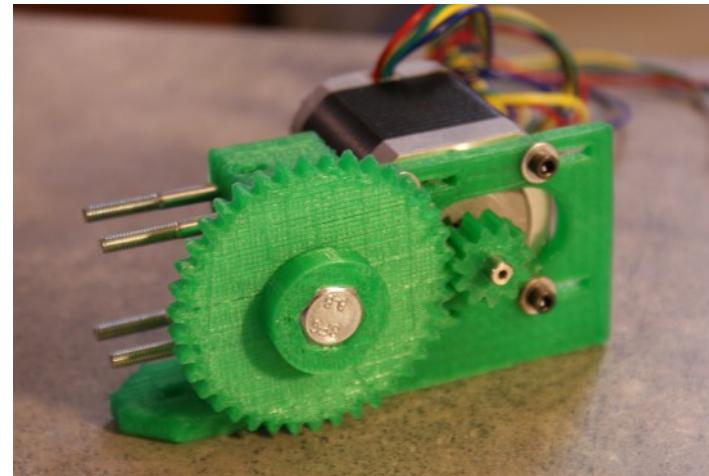
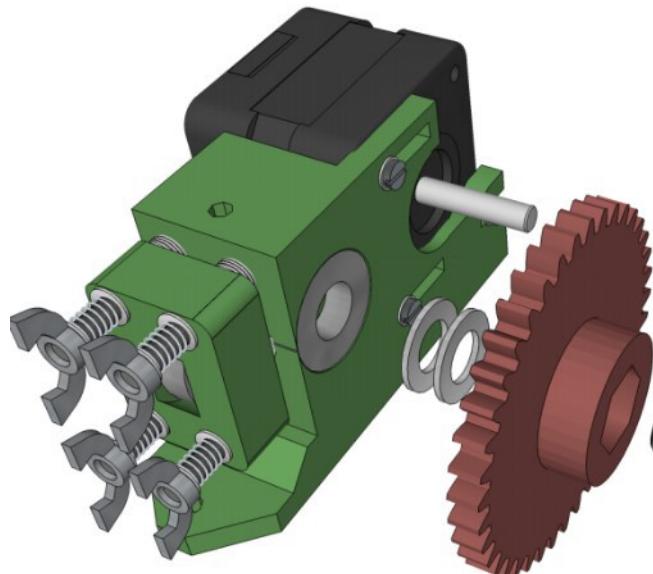
Reprap 3D Drucker

- beheizte Düse
 - Polylactide / Polymilchsäure (PLA)
 - Acrylnitril-Butadien-Styrol (ABS)Temperaturen je ca. 20°C höher



Reprap 3D Drucker

- steuerbarer Filamentvorschub



„Wade's Geared Extruder“
Übersetzung 11:39

M8x80 Sechskantschraube
„Hobbed Bolt“

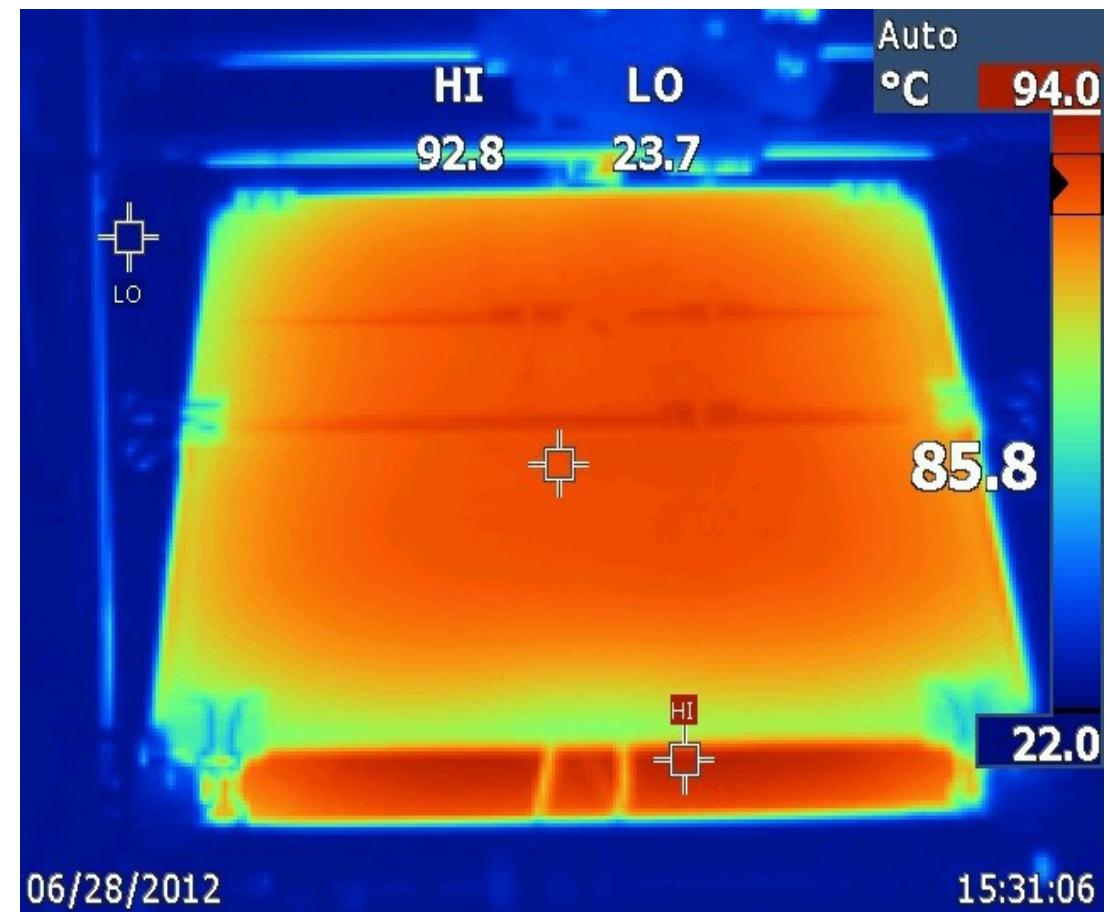
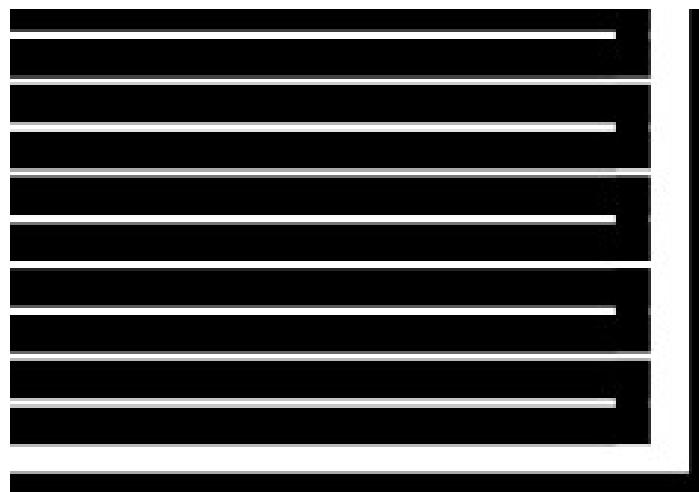
Reprap 3D Drucker

- (beheizbare) Unterlage auf der gedruckt wird



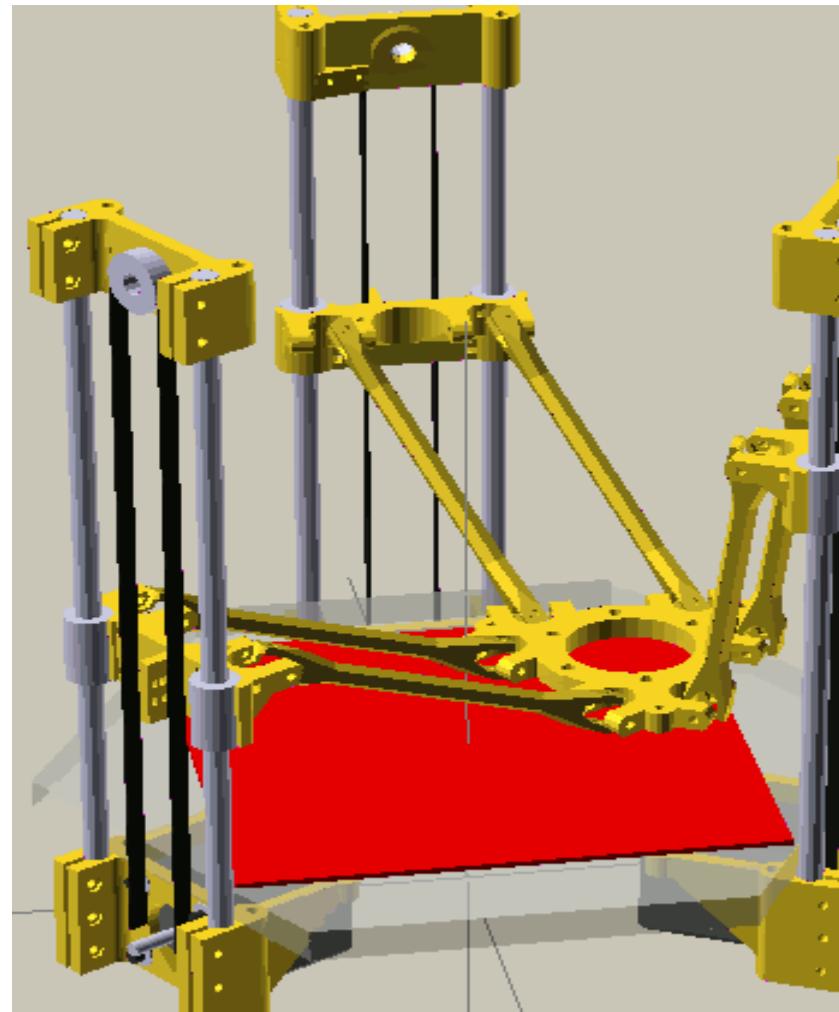
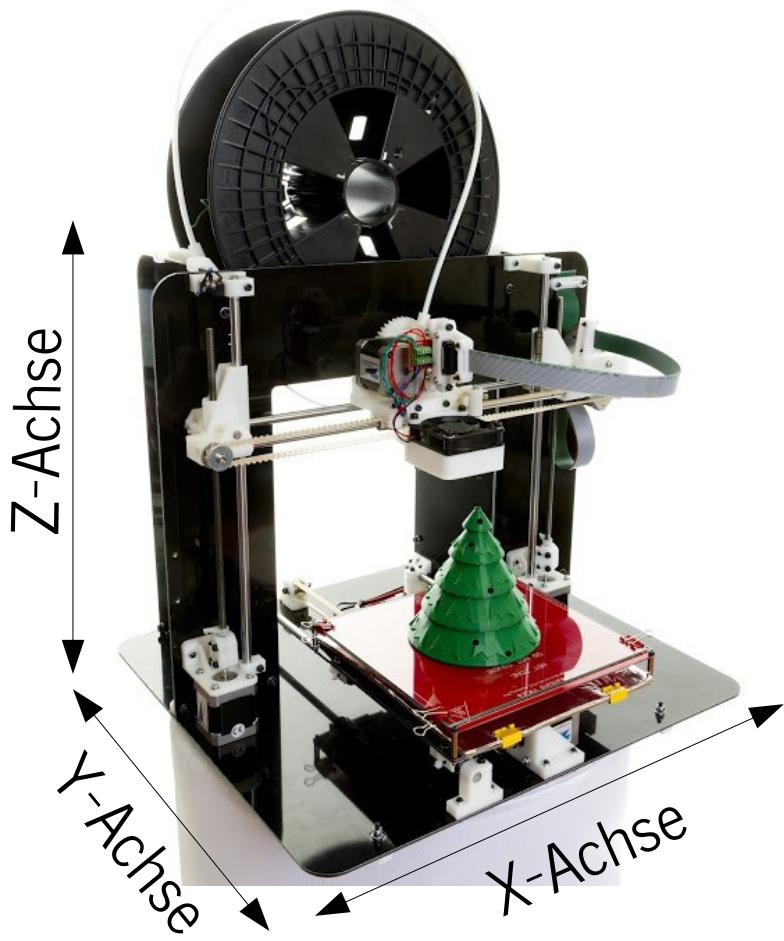
Reprap 3D Drucker

- (beheizbare) Unterlage auf der gedruckt wird



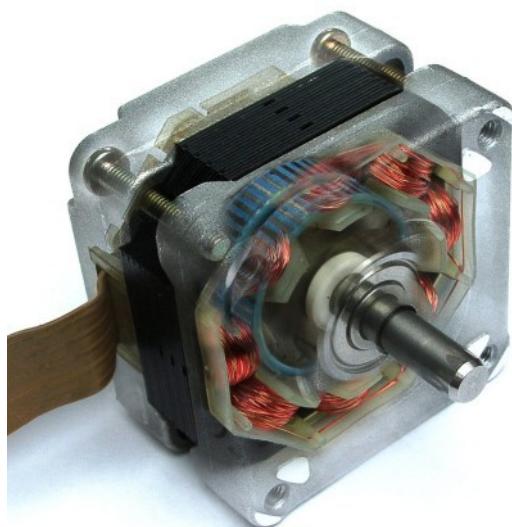
Reprap 3D Drucker

- kartesisch angeordnete X, Y und Z-Achsen



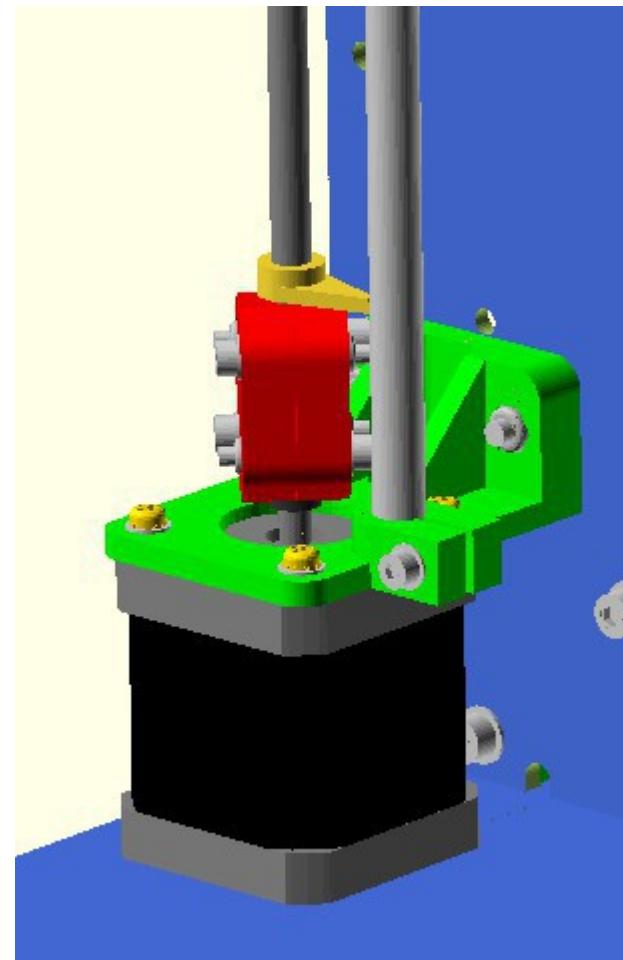
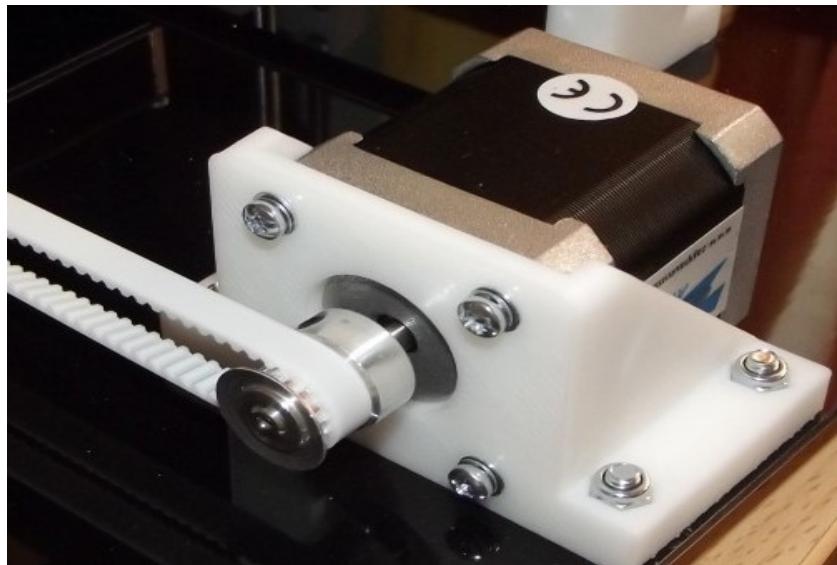
Reprap 3D Drucker

- Schrittmotor mit $1,8^\circ$ Schrittwinkel/Vollschritt
 - ≤ 200 Schritte/Umdrehung
- 16 Mikroschritte/Vollschritt
 - ≤ 3200 Schritte/Umdrehung



Reprap 3D Drucker

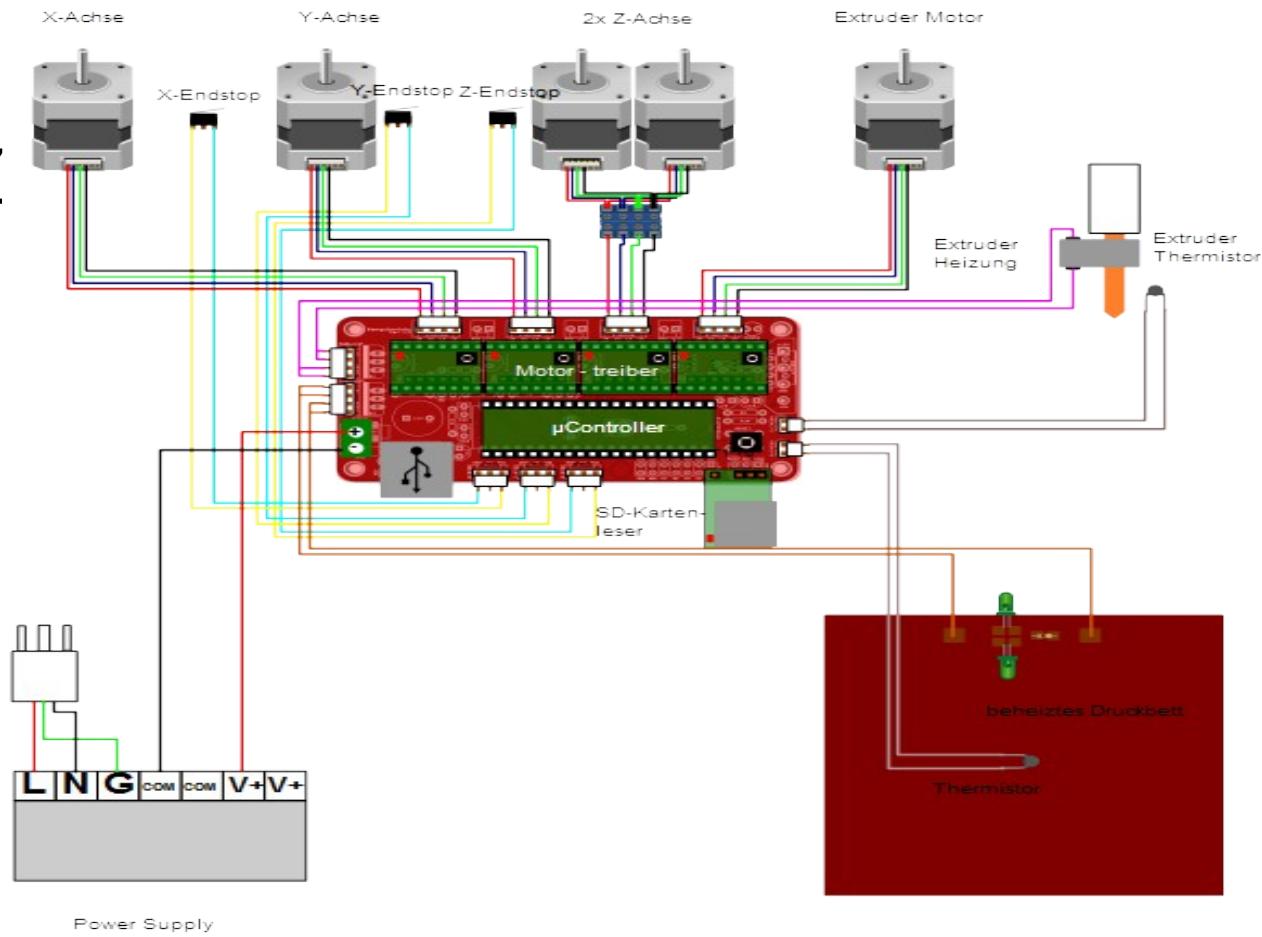
- Antrieb der Achsen
 - Zahnriemen / -räder
 - direkt / Gewindestange



- Mikrocontroller
- Motortreiber
- Endstop X, Y und Z
- USB-Schnittstelle
- (SD-Kartenleser,
Lüfter, LC-Display,
Tastatur ...)

Reprap 3D Drucker

Sanguinololu 1.2 Wiring Schematic



Reprap 3D Drucker

- Anforderungen an den Mikrocontroller
 - 2 analoge Eingänge (Thermistor)
 - 3 digitale Eingänge (Endstops)
 - 3 PWM-Ausgänge (Heizbett, Extruder, Lüfter)

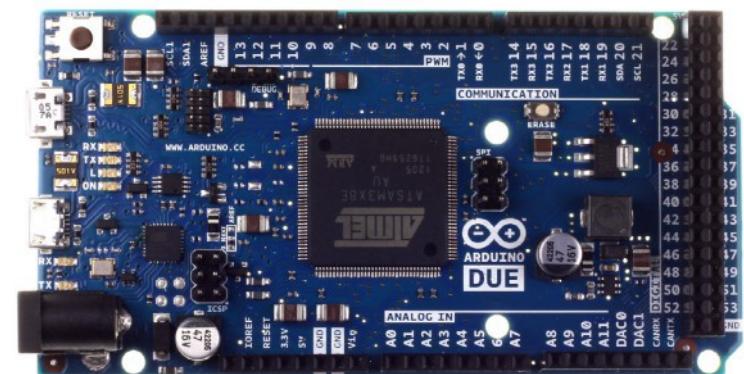
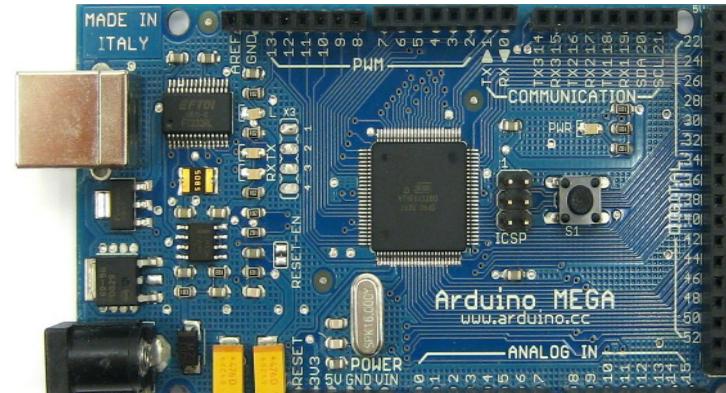
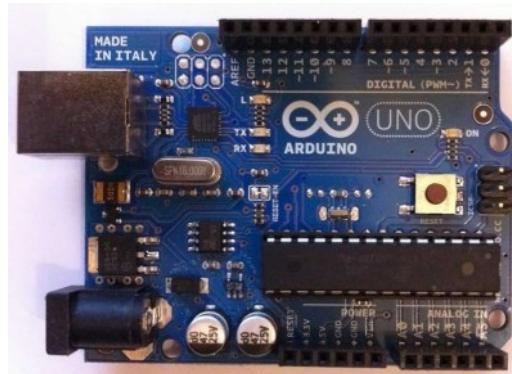
Reprap 3D Drucker

- Anforderungen an den Mikrocontroller
 - 4 digitale Ausgänge (Achsen, Filamentvorschub)
 - ausreichend schnell (PID-Software-Regler, PC-Kommunikation, LCD, Extras)
 - ausreichend Speicher (ROM, RAM, EEPROM)

Reprap 3D Drucker

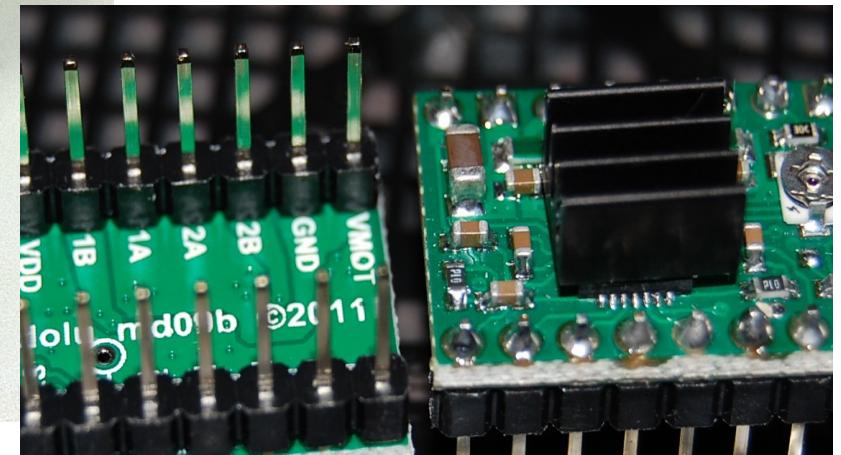
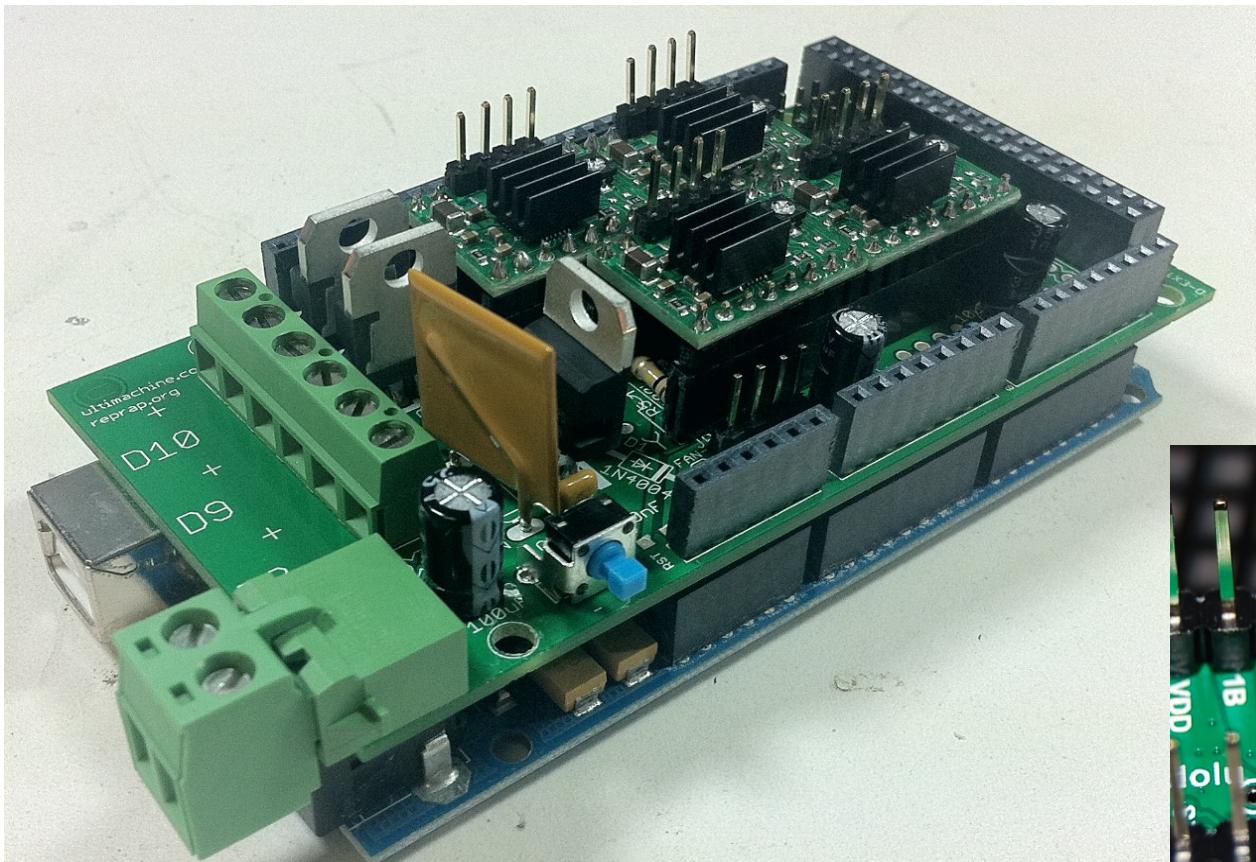
- Vergleich Arduino / Mega / Due

	µController	Flash	EEPROM	SDRAM	digitale Ein- / Ausgänge	analoge Eingänge
Arduino Uno	ATmega328	32 KiB	1 KiB	2 KiB	14	6
Arduino Mega	Atmega2560	256 KiB	4 KiB	8 KiB	54	16
Arduino Due	AT91SAM3X8E (32bit)	512 KiB	n.v.	96 KiB	54	12



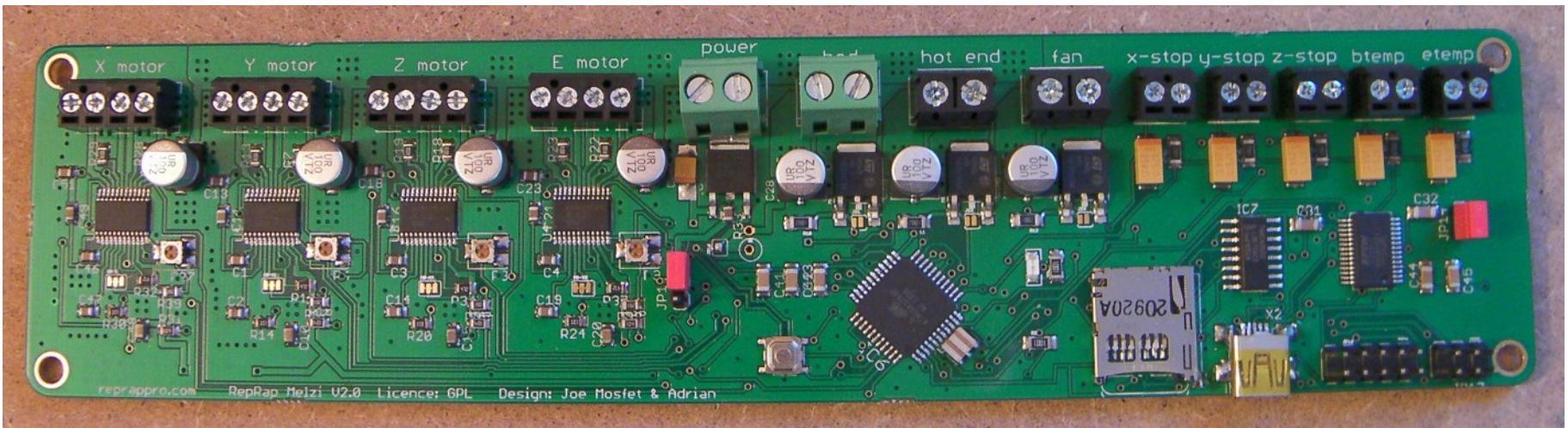
Reprap 3D Drucker

- Reprap Arduino Mega Pololu Shield (RAMPS)
 - ca. €50 + €30 + 4*10€ (Arduino, RAMPS, Pololus) = €120



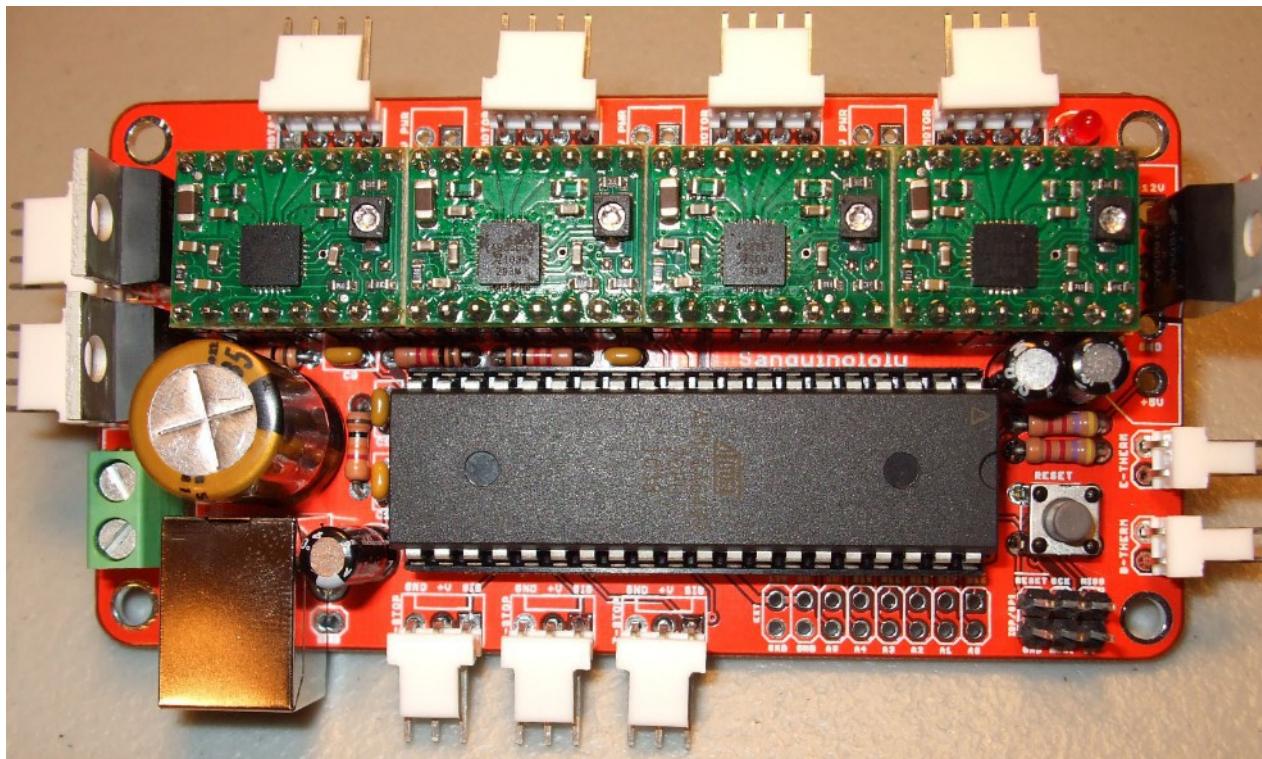
Reprap 3D Drucker

- Alternativen zum Arduino + RAMPS
 - Melzi-Board (ca. €120)



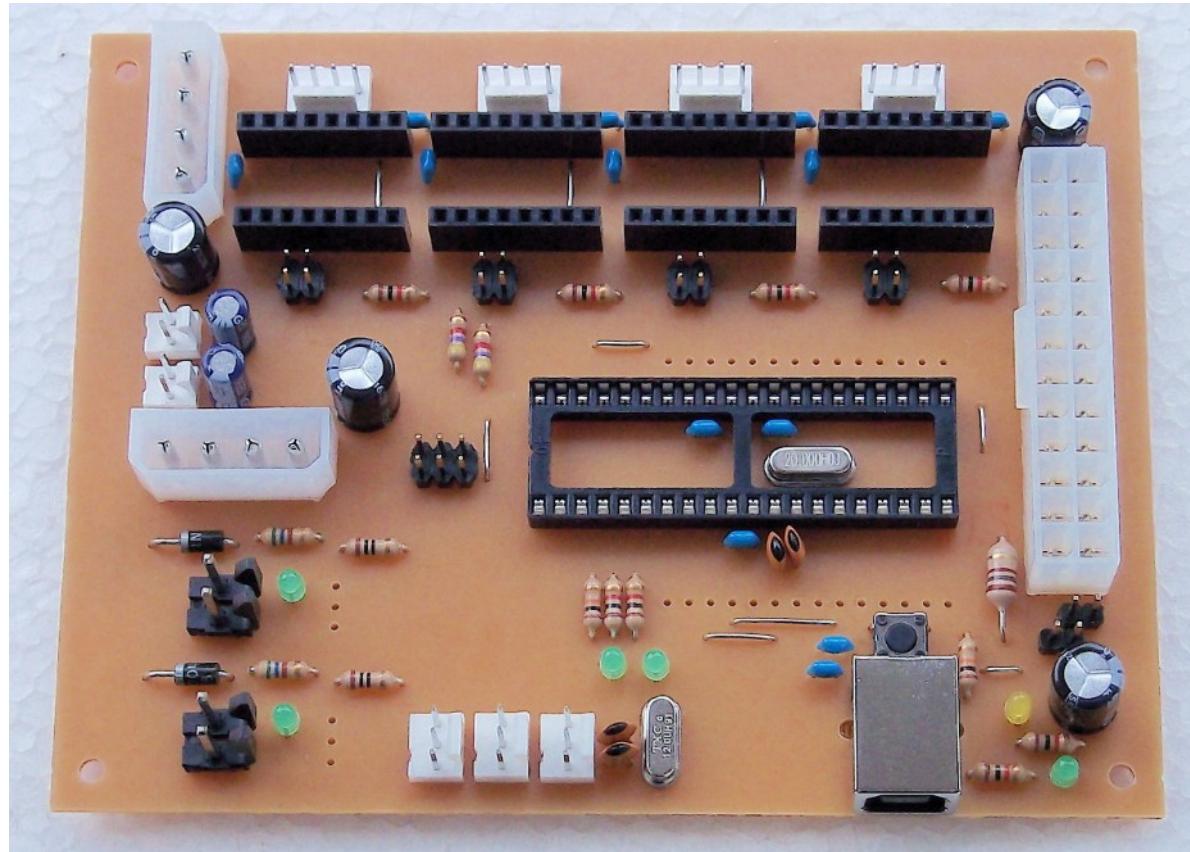
Reprap 3D Drucker

- Alternativen zum Arduino + RAMPS
 - Sanguinololu-Board (ca. €60 + 4x€10 = €100)



Reprap 3D Drucker

- Alternativen zum Arduino + RAMPS
 - Gen7-Board (Bausatz €60 + 4*€10 = €100)



Reprap 3D Drucker

- rechnerischer Stromverbrauch

- Elektrische Leistung (Gleichstrom) $P = \frac{U^2}{R}; P = U \cdot I$
- Heizbett $\frac{12^2 V}{1,2 \Omega} = 120W$

- Extruder $\frac{12^2 V}{5,8 \Omega} = 24,8 W$

- Schrittmotoren $4 \cdot 12V \cdot 1A = 48W$

- Elektronik ca. 5W max.

Σ ca. 200W max.

Reprap 3D Drucker

- tatsächlicher Stromverbrauch
 - Druckzeit: 6:45h
 - Anzeige am Wattmeter: 0,79 kWh
 - Ø Leistungsaufnahme:

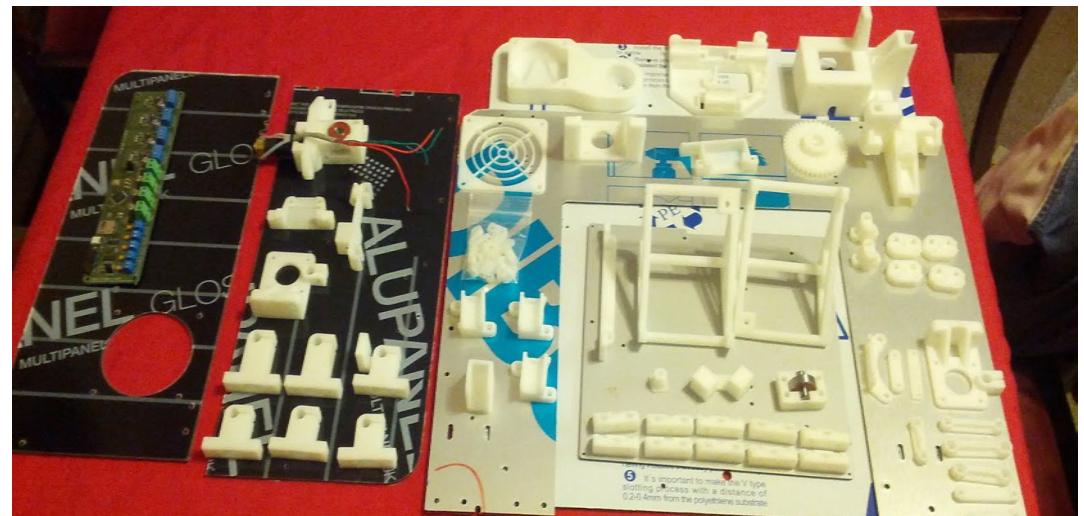
790Wh / 6,75h

$$= \underline{\underline{117 \text{ W}}}$$



Reprap 3D Drucker

- Kosten (Mendel90)
 - Bausatz € 499,00
 - Steuern € 99,80
 - Porto € 35,00
 - Summe € 781,25



Reprap 3D Drucker

- Weitere Materialien
 - diverse Werkzeuge (Schraubenschlüssel, -dreher, Innensechskant, Abisolierzange, Seitenschneider, Lötkolben)
 - Feinmechanik-Öl, Lithium-Fett
 - Aceton
 - Holzleim auf Polyvinylacetat-Basis, Klebestift, Malerkrepp

Reprap 3D Drucker

- Filament / Faberdashery.co.uk

- 10x10m 3mm PLA div. Farben € 30,00
- 4x100m 3mm PLA div. Farben € 111,00
- 2x50m 3mm PLA div. Farben € 30,50
- Porto € 14,00
- Summe € 229,97



Reprap 3D Drucker

⌚ Software Workflow

- ⌚ 3D-Zeichenprogramm
- ⌚ Umwandeln in .stl Datei
- ⌚ Erzeugen der Druckschichten und Druckwege (slicing), speichern der .gcode Datei

Reprap 3D Drucker

⌚ Software Workflow

- ⌚ Übertragen der .gcode Datei an den Drucker (seriell/USB oder SD-Karte)
- ⌚ Drucker-Firmware interpretiert Kommandos und führt aus

Reprap 3D Drucker

- 3D-Zeichenprogramm
 - geometrische Grundkörper
 - Anordnen und Kombinieren
 - Funktionen
 - Programmierung
 - Export als .stl Datei



Box



Pyramide



Pyramidenstumpf



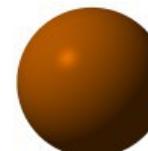
Zylinder



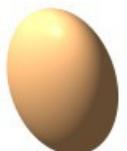
Kegel



Kegelstumpf



Kugel



Ellipsoid



Torus



Elliptischer Torus



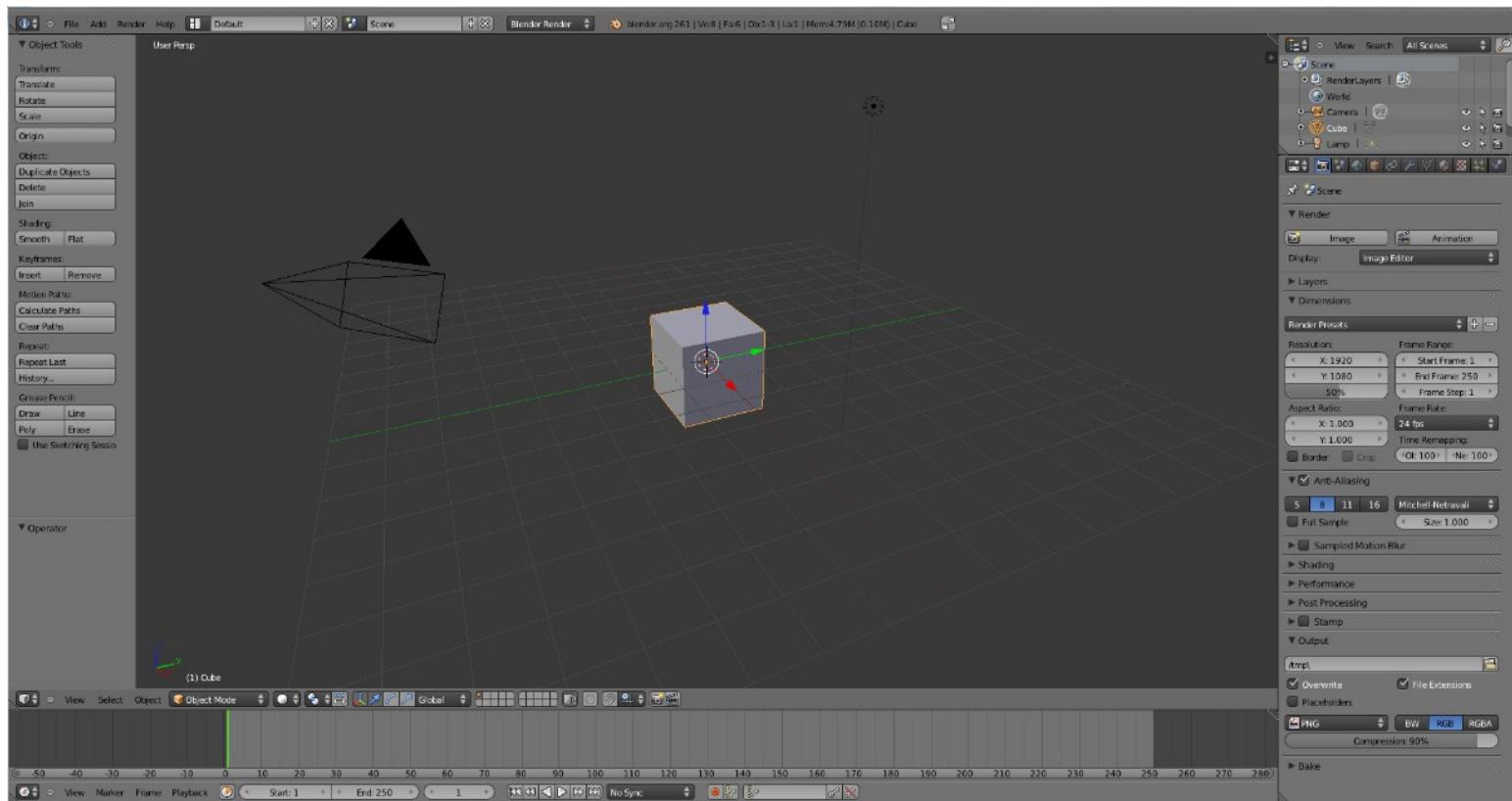
Helix



Schraube

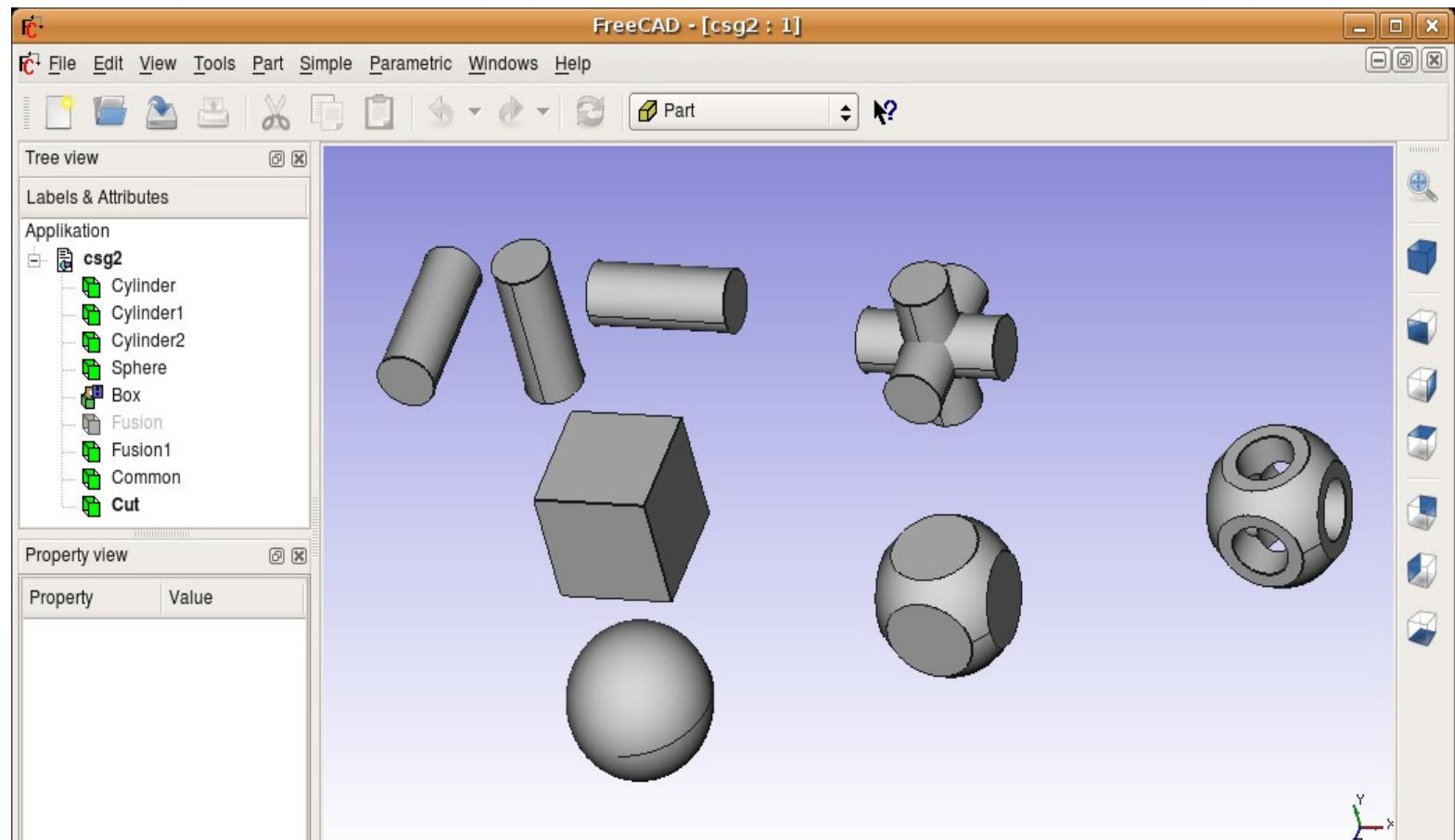
Reprap 3D Drucker

- 3D-Zeichenprogramm
 - Blender



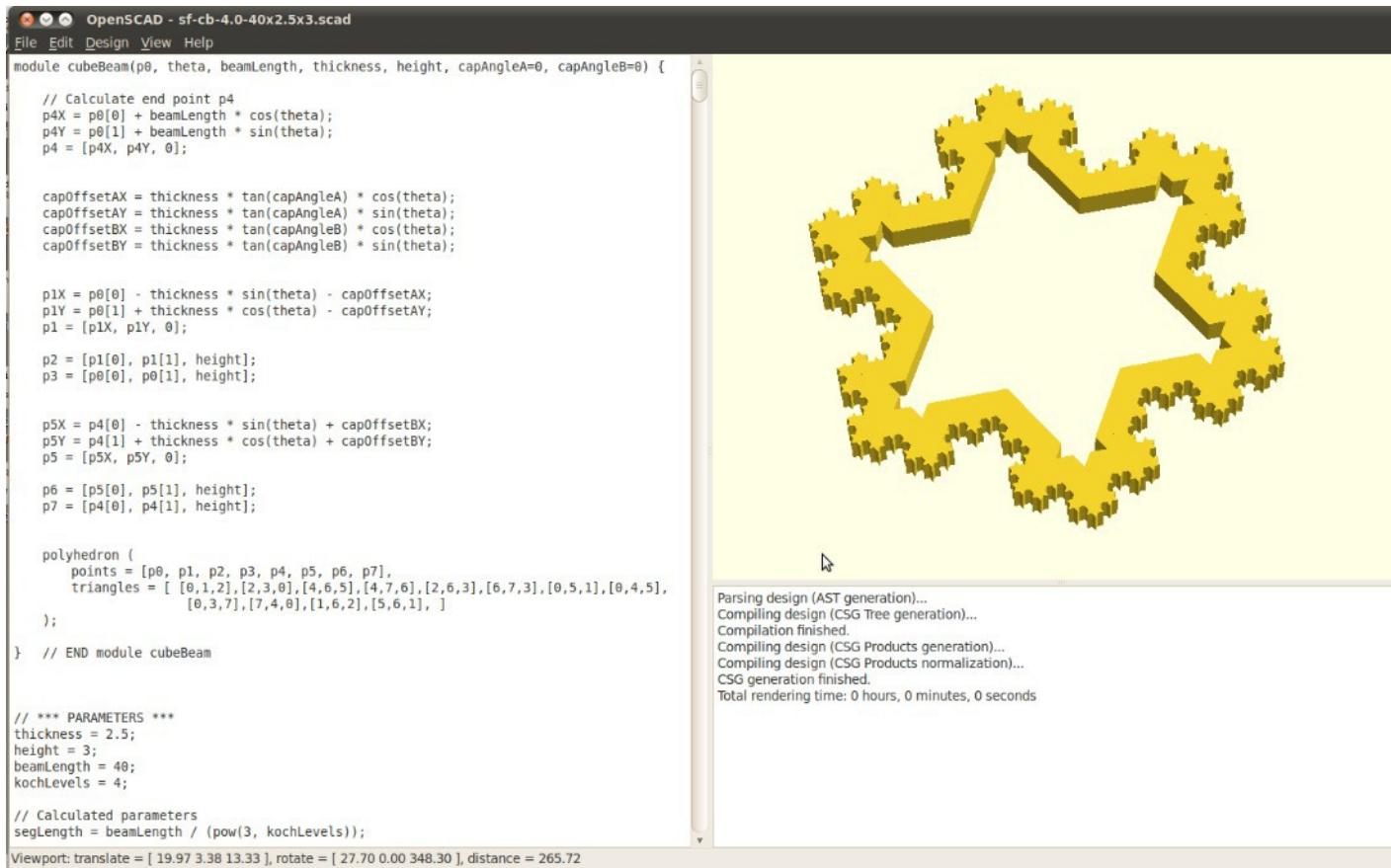
Reprap 3D Drucker

- 3D-Zeichenprogramm
 - FreeCAD



Reprap 3D Drucker

- 3D-Zeichenprogramm
 - OpenSCAD



The screenshot shows the OpenSCAD application window. On the left, the code editor displays the SCAD script for generating a fractal gear. On the right, the preview window shows a 3D rendering of the gear, which has a highly detailed, jagged, fractal-like texture. At the bottom of the preview window, there is a status bar with build-related messages.

```

File Edit Design View Help
module cubeBeam(p0, theta, beamLength, thickness, height, capAngleA=0, capAngleB=0) {
    // Calculate end point p4
    p4X = p0[0] + beamLength * cos(theta);
    p4Y = p0[1] + beamLength * sin(theta);
    p4 = [p4X, p4Y, 0];

    capOffsetAX = thickness * tan(capAngleA) * cos(theta);
    capOffsetAY = thickness * tan(capAngleA) * sin(theta);
    capOffsetBX = thickness * tan(capAngleB) * cos(theta);
    capOffsetBY = thickness * tan(capAngleB) * sin(theta);

    p1X = p0[0] - thickness * sin(theta) - capOffsetAX;
    p1Y = p0[1] + thickness * cos(theta) - capOffsetAY;
    p1 = [p1X, p1Y, 0];

    p2 = [p1[0], p1[1], height];
    p3 = [p0[0], p0[1], height];

    p5X = p4[0] - thickness * sin(theta) + capOffsetBX;
    p5Y = p4[1] + thickness * cos(theta) + capOffsetBY;
    p5 = [p5X, p5Y, 0];

    p6 = [p5[0], p5[1], height];
    p7 = [p4[0], p4[1], height];

    polyhedron (
        points = [p0, p1, p2, p3, p4, p5, p6, p7],
        triangles = [ [0,1,2],[2,3,0],[4,6,5],[4,7,6],[2,6,3],[6,7,3],[0,5,1],[0,4,5],
                      [0,3,7],[7,4,8],[1,6,2],[5,6,1], ]
    );
}

// END module cubeBeam

// *** PARAMETERS ***
thickness = 2.5;
height = 3;
beamLength = 40;
kochLevels = 4;

// Calculated parameters
segLength = beamLength / (pow(3, kochLevels));

```

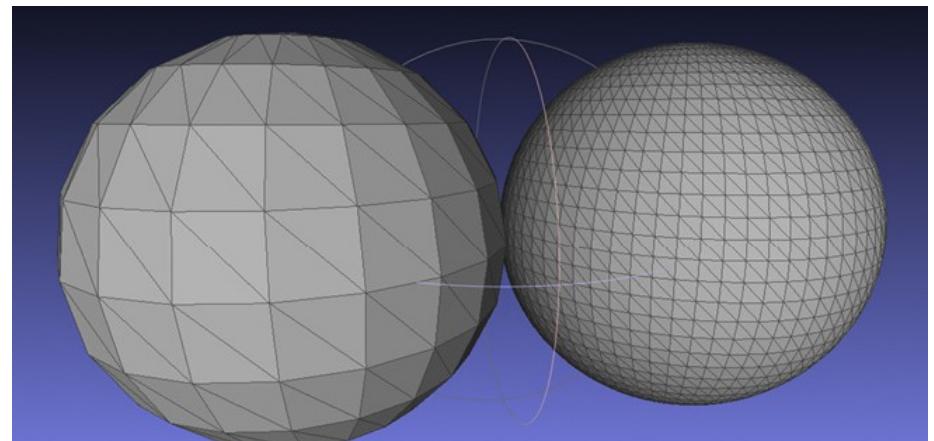
Parsing design (AST generation)...
 Compiling design (CSG Tree generation)...
 Compilation finished.
 Compiling design (CSG Products generation)...
 Compiling design (CSG Products normalization)...
 CSG generation finished.
 Total rendering time: 0 hours, 0 minutes, 0 seconds

Viewport: translate = [19.97 3.38 13.33], rotate = [27.70 0.00 348.30], distance = 265.7

Reprap 3D Drucker

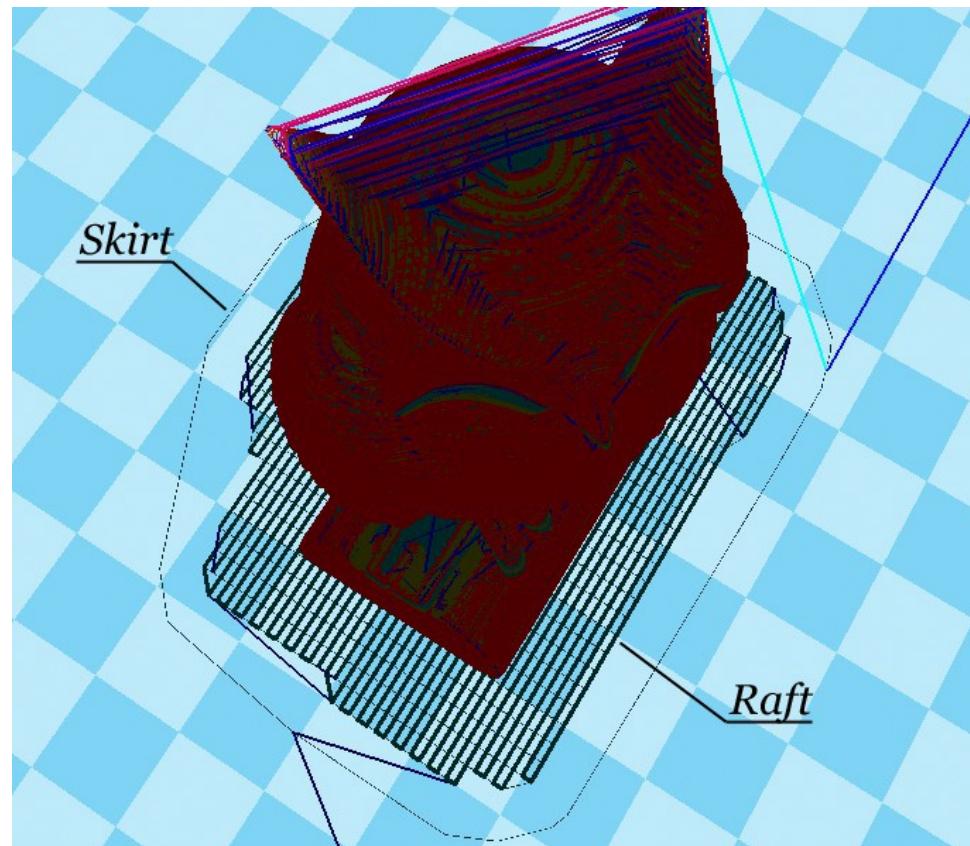
- .stl Dateiformat
 - Enthält Dreieck-Koordinaten

```
solid name
  facet normal n1 n2 n3
    outer loop
      vertex p1x p1y p1z
      vertex p2x p2y p2z
      vertex p3x p3y p3z
    endloop
  endface
endsolid name
```



Reprap 3D Drucker

- Erzeugen der Druckschichten (slicing)
 - Profil (Drucker, Genauigkeit, Material)
 - Objekte
 - Skirt (optional)
 - Raft (optional)



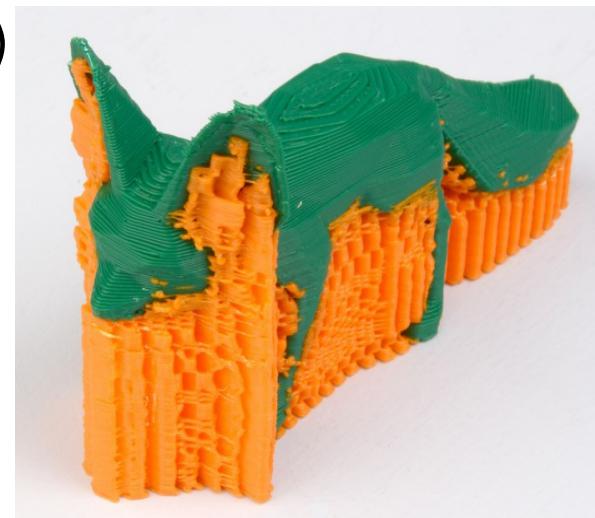
Reprap 3D Drucker

- Erzeugen der Druckschichten (slicing)

- Brim (optional)



- Support (je nach Objekt zwingend)



Reprap 3D Drucker

- Erzeugen der Druckschichten (slicing)
 - Infill (0-100%)
 - Perimeter
 - ... weitere 100 Parameter ...
 - Ausgabe .gcode-Datei



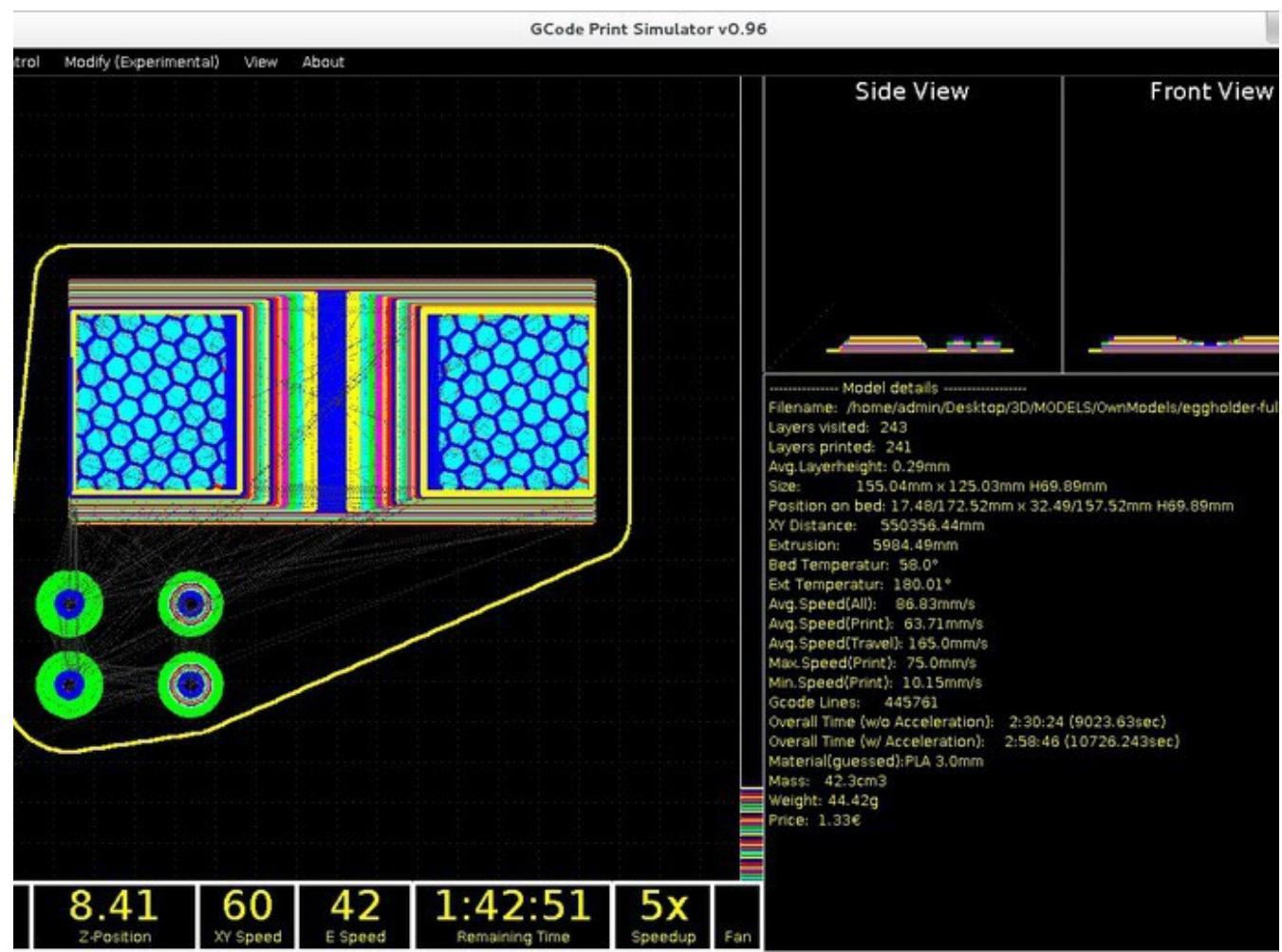
Reprap 3D Drucker

- Erzeugen der Druckschichten (slicing)
 - .gcode Dateiformat

```
M83 ; use relative distances for extrusion
G28 ; move to home position
G1 X5 Y99 F9000 ; Go to the middle of the front
G1 Z0.05 ; close to the bed
M104 S200 ; set extruder temp to 200°C
M190 S55 ; set bed temp to 55°C & wait
M109 S200 ; wait for extruder temp is 200°C
G1 E5 F50 ; extrude a blob
G1 X40 F4000 ; wipe 40mm along the edge of the bed
G1 Z0.3 ; lift Z
```

Reprap 3D Drucker

- Erzeugen der Druckschichten (slicing)
 - Kontrolle der .gcode Datei

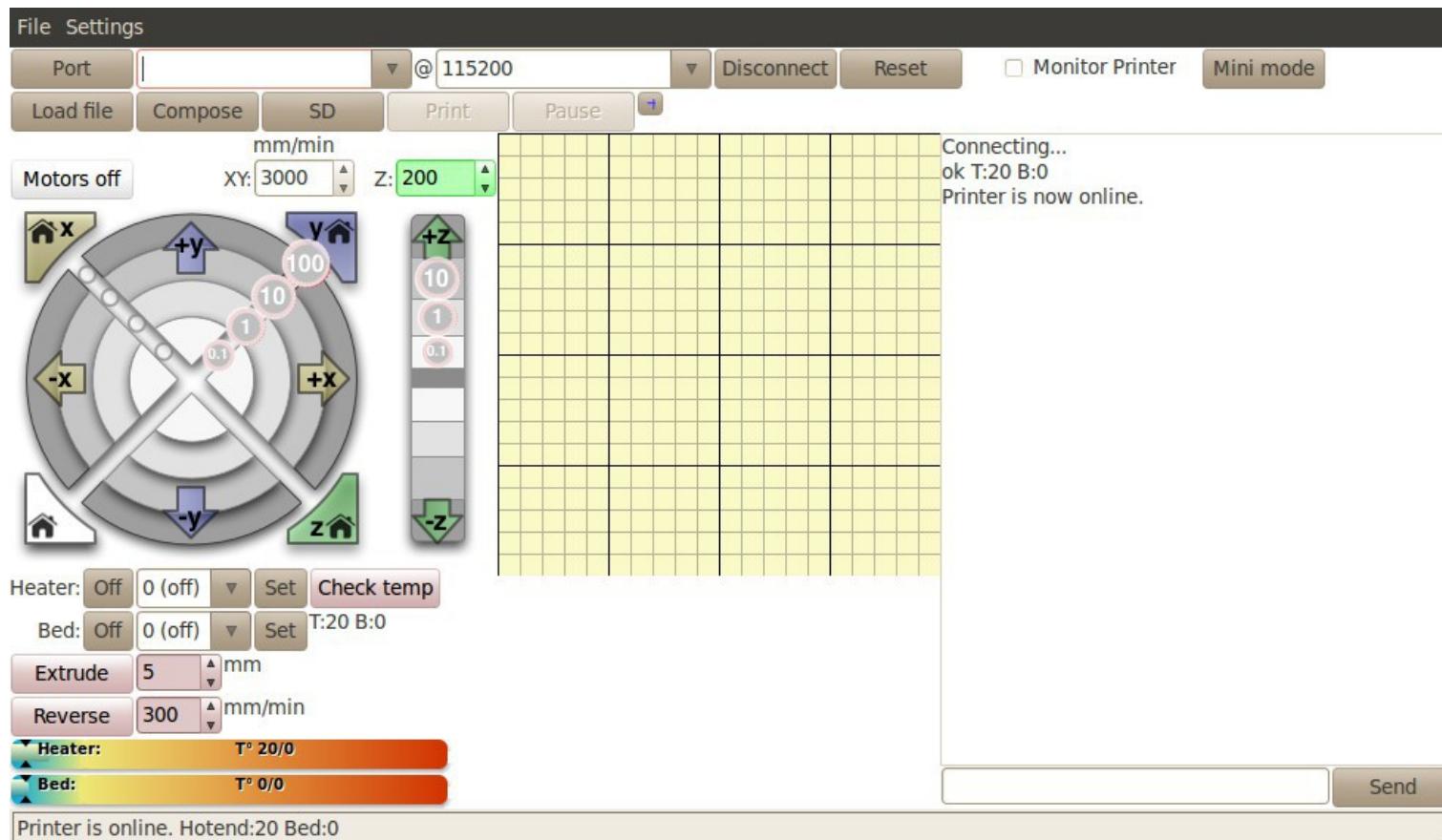


Reprap 3D Drucker

- Hostsoftware am PC
 - Steuerung / Bedienung des Druckers
 - Übertragung der .gcode Datei
 - Anordnen der Objekte auf dem Druckbett
 - Slicer und .gcode-Visualisierung
 - Kontrolle während dem Druck

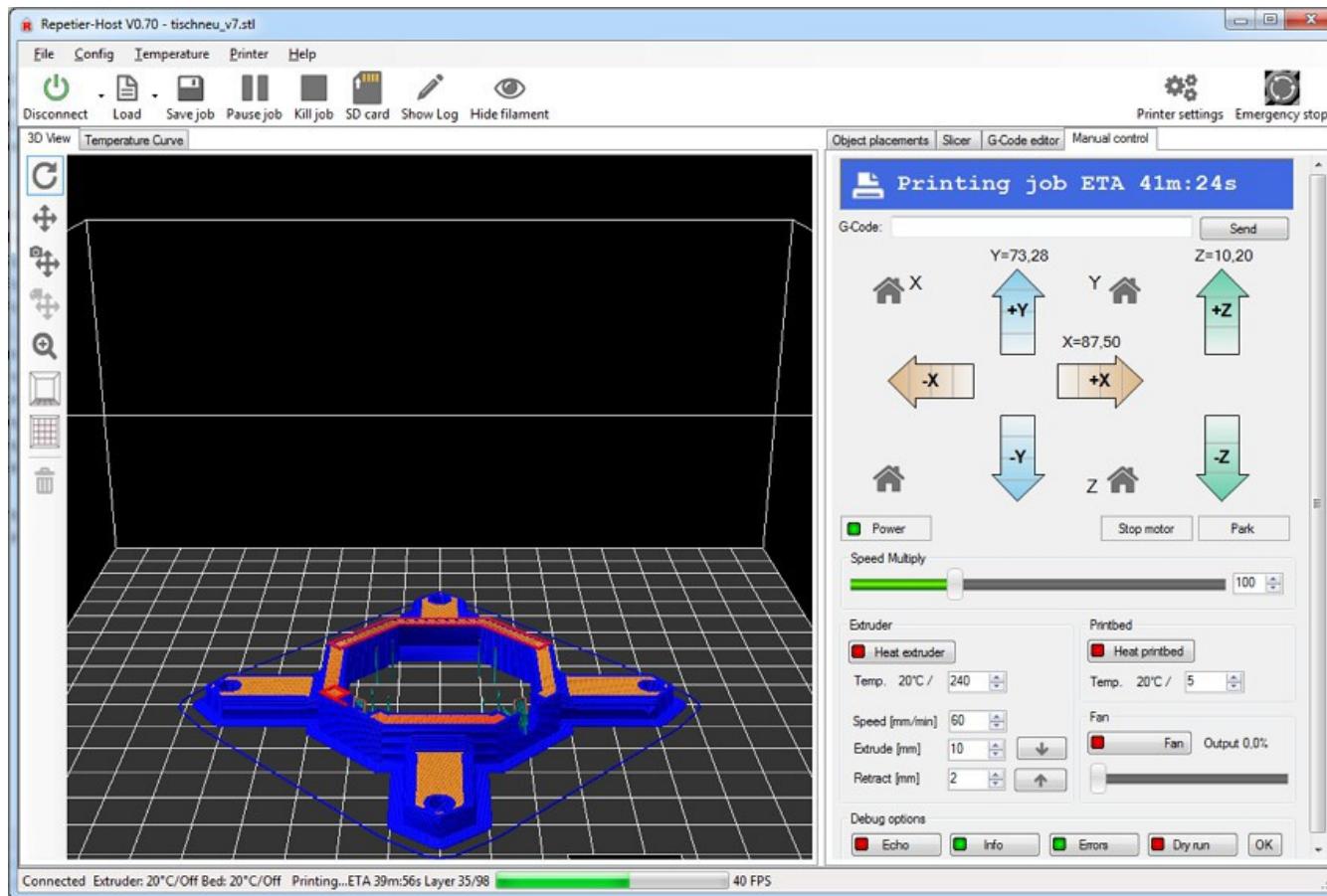
Reprap 3D Drucker

- Hostsoftware am PC
 - Pronterface



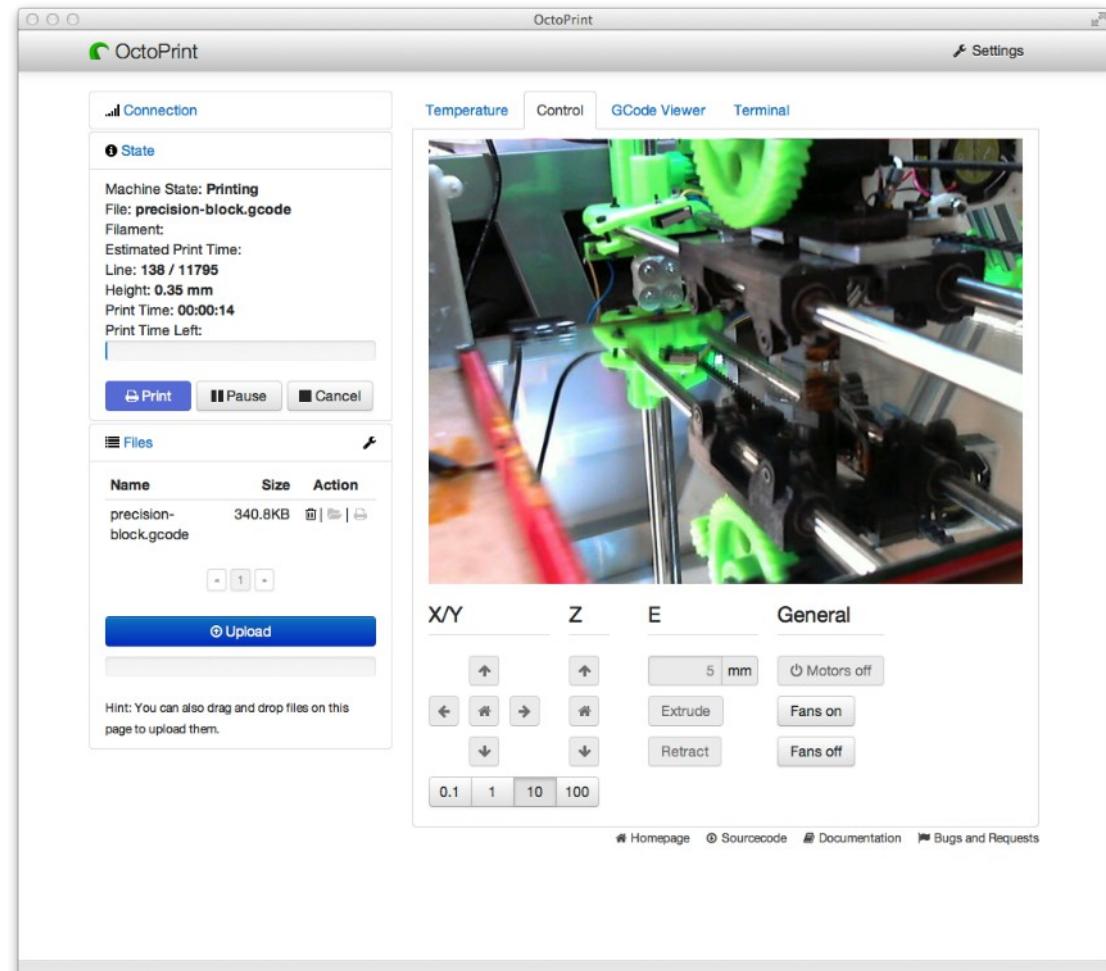
Reprap 3D Drucker

- Hostsoftware am PC
 - Repetier Host



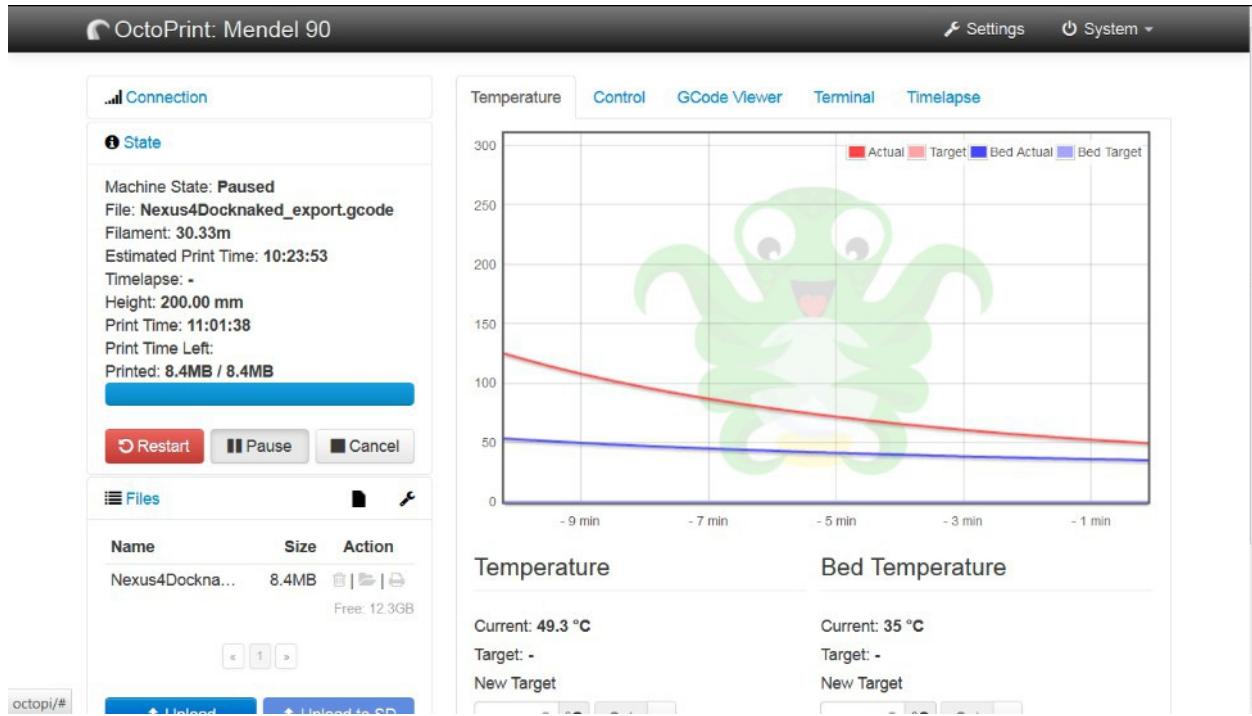
Reprap 3D Drucker

- Hostsoftware Spezialfall „OctoPrint“
 - Beobachten während dem Druck
 - Zeitrafferfilme
 - Netzwerk

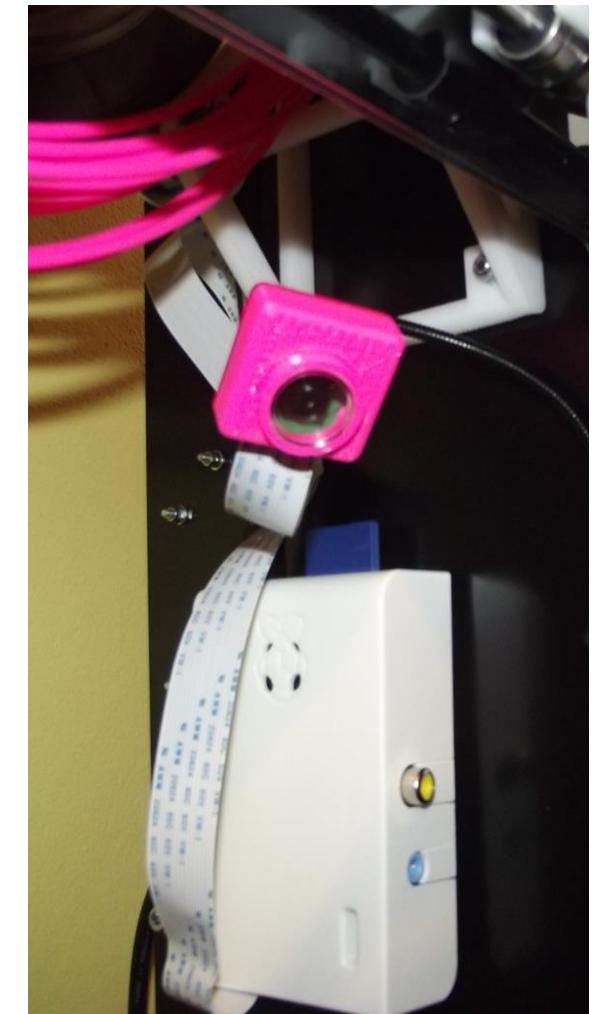


Reprap 3D Drucker

- Hostsoftware + Hardware Spezialfall „OctoPi“
 - Raspberry Pi (+ PiCam) + Linux + Octoprint

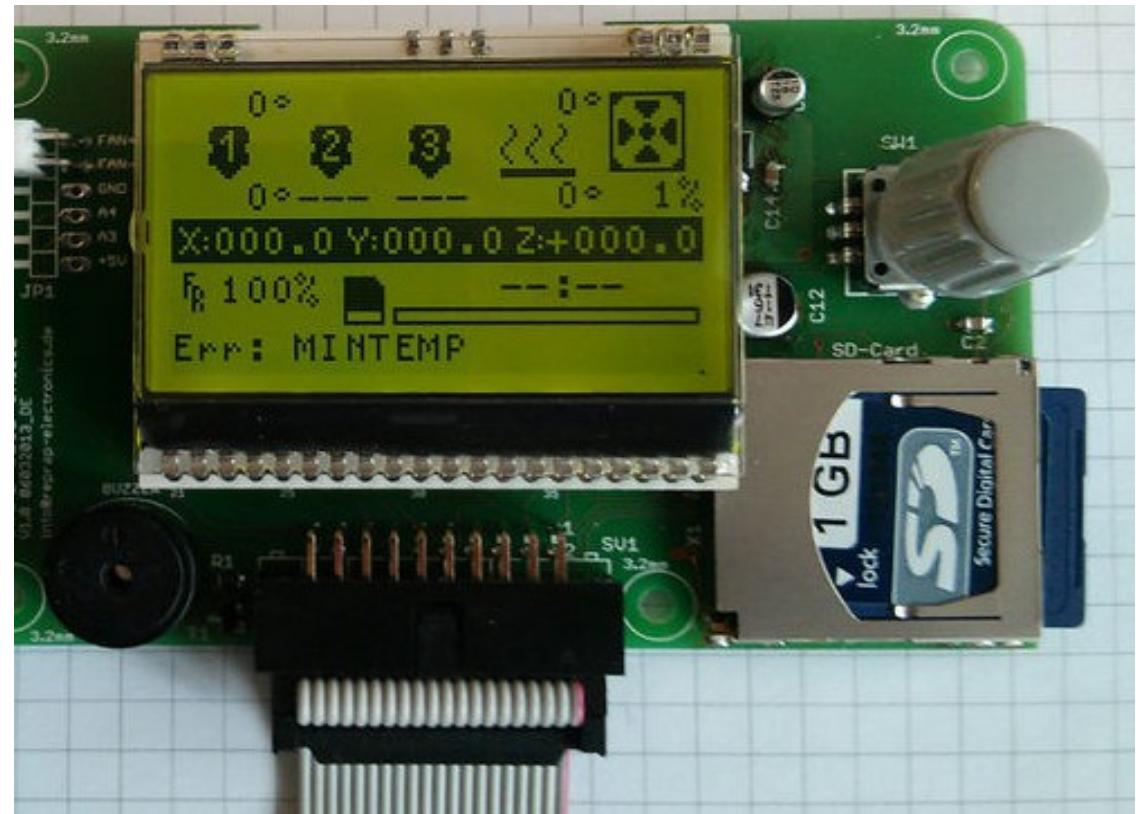


The screenshot shows the OctoPrint web interface for a Mendel 90 printer. The main area displays a temperature graph with a green cartoon octopus logo. The graph tracks 'Actual' (red line) and 'Target' (blue line) temperatures for both the print bed and the hotend. Below the graph, there are two sections: 'Temperature' and 'Bed Temperature', each showing current and target values. On the left sidebar, the 'State' section indicates the machine is paused, printing 'Nexus4Docknaked_export.gcode'. The 'Files' section lists the current file. At the bottom, there are buttons for 'Restart', 'Pause', and 'Cancel'.



Reprap 3D Drucker

- Ohne Host
 - LCD + SD-Karte + Drehgeber



Reprap 3D Drucker

- Drucker-Firmware
 - Sprinter, Teacup, sjfw, Marlin, Sailfish, Repetier, aprinter, RepRap Firmware ...
 - stammen teilweise voneinander ab

Reprap 3D Drucker

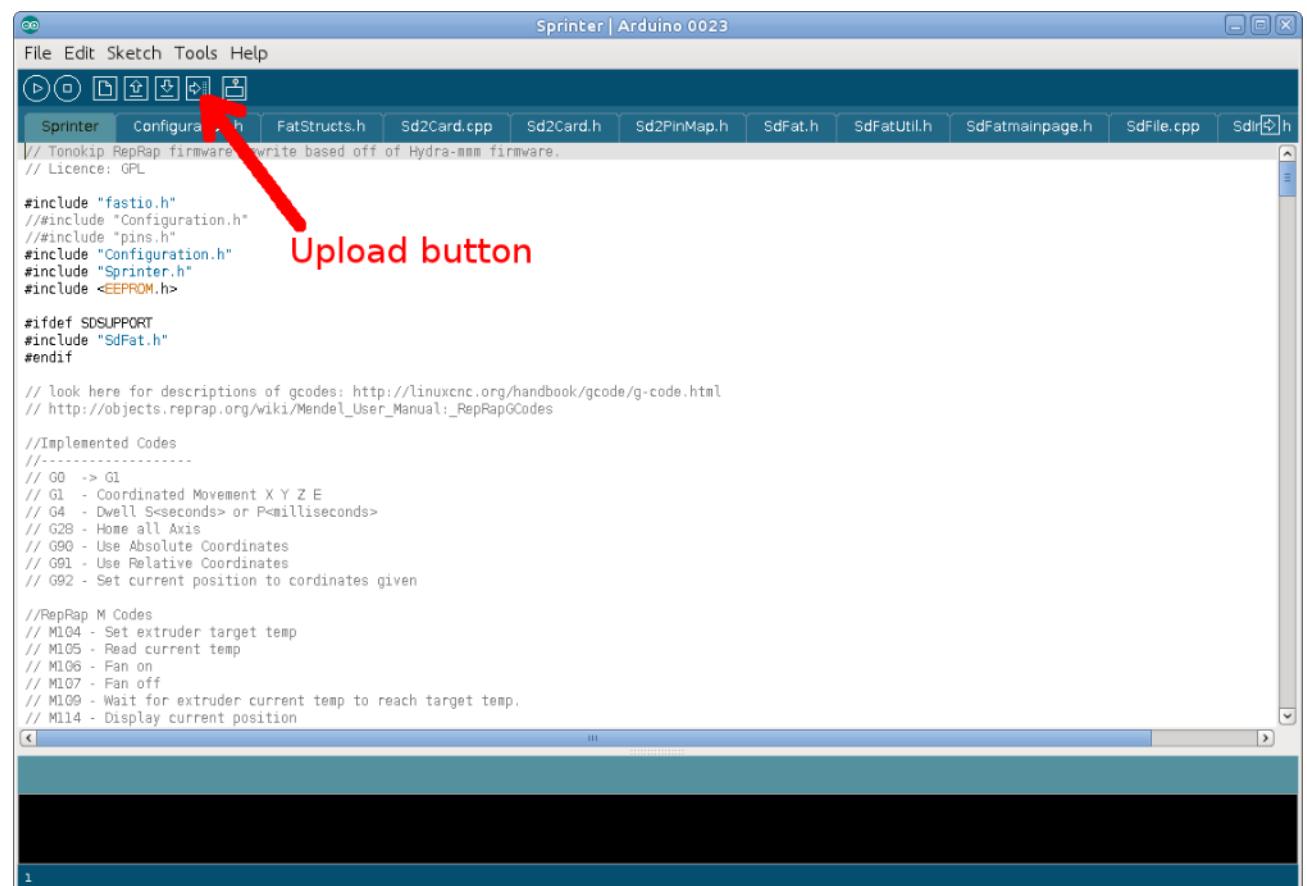
- Drucker-Firmware
 - druckerspezifische Konfiguration in Configuration.h (470 Zeilen bei aktueller Marlin-Firmware)

```
// The following define selects which electronics
// board you have. Please choose the one that
// matches your setup
// 33 = RAMPS 1.3
// 6   = Sanguinololu < 1.2
// 63  = Melzi

#ifndef MOTHERBOARD
#define MOTHERBOARD 63
#endif
```

Reprap 3D Drucker

- Drucker-Firmware
 - Compilieren und Aktualisieren über die Arduino-Umgebung





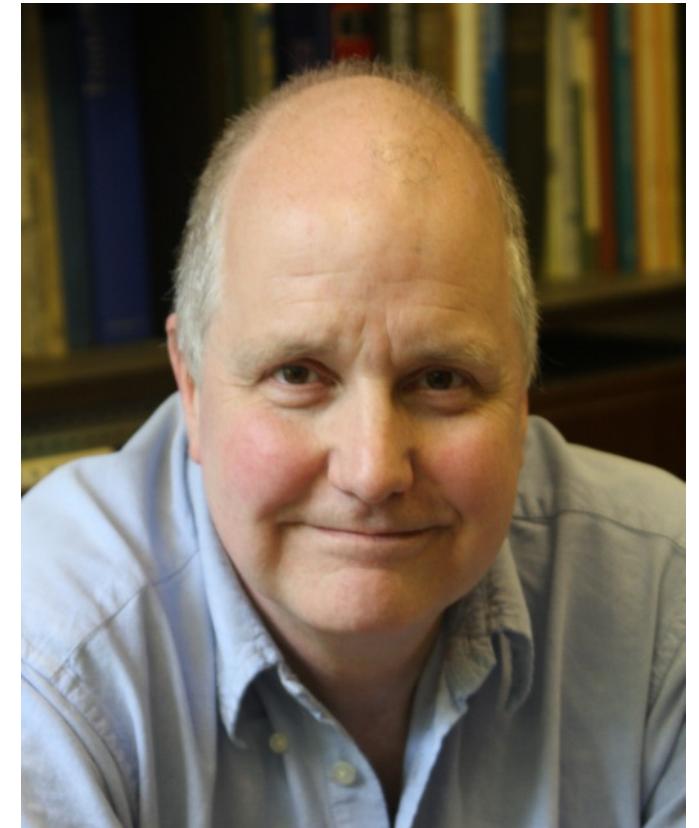
Reprap 3D Drucker

**Mendel90
in Aktion**

Reprap 3D Drucker

⌚ Reprap Geschichte

- ⌚ Beginn: Erster Blogeintrag 23.03.2005
- ⌚ Gründer: Adrian Bowyer,
Universität Bath, England



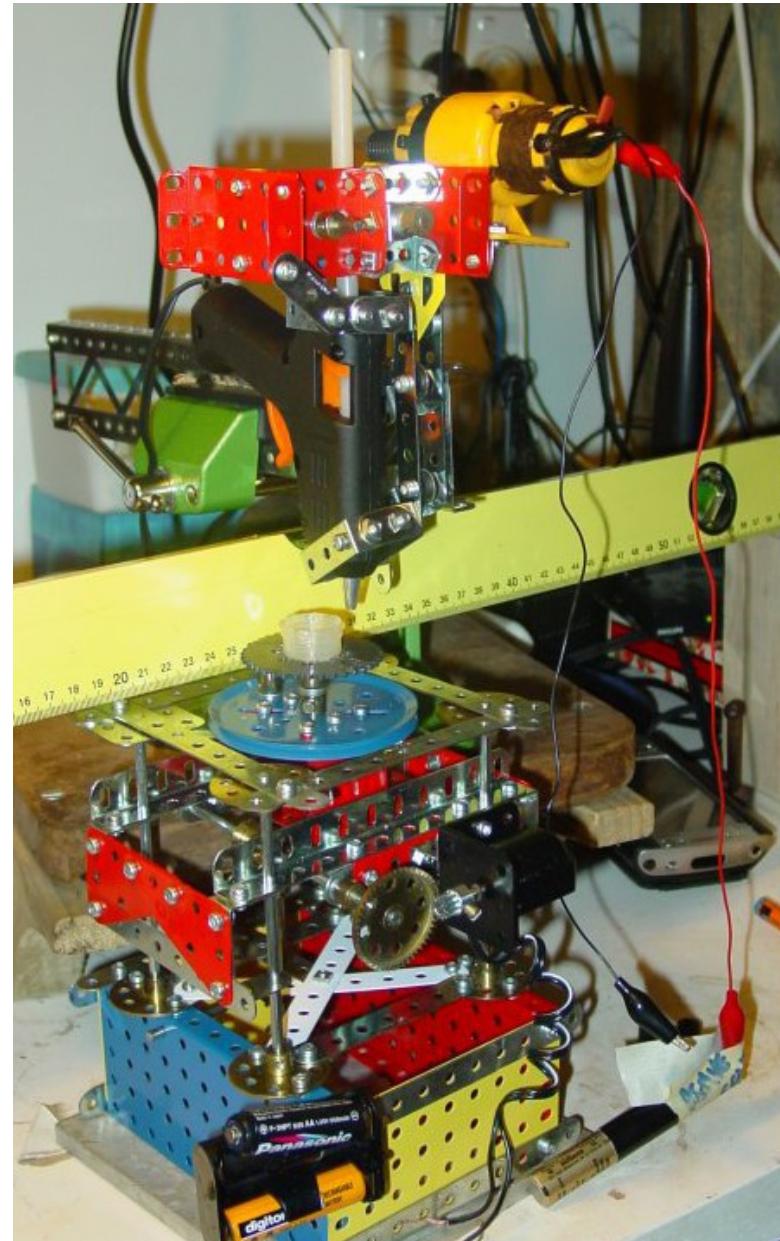
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⌚ Reprap Geschichte

⌚ 13. April 2005

„Meccano“

Vik Olliver



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⌚ Reprap Geschichte

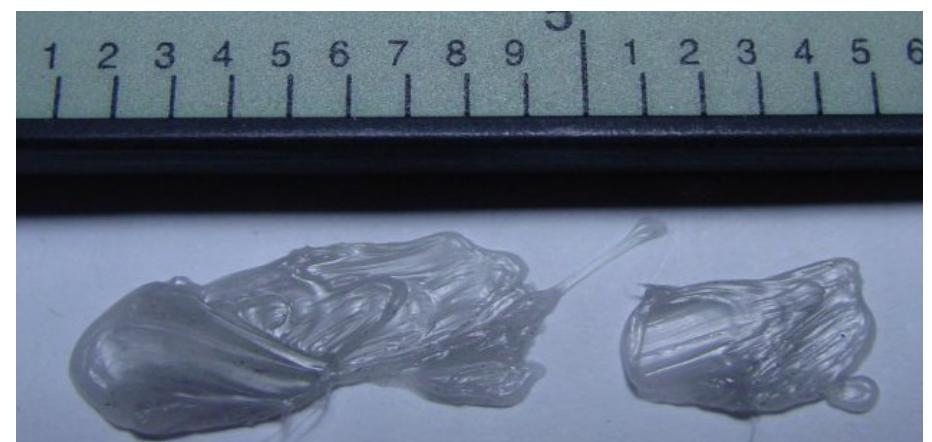
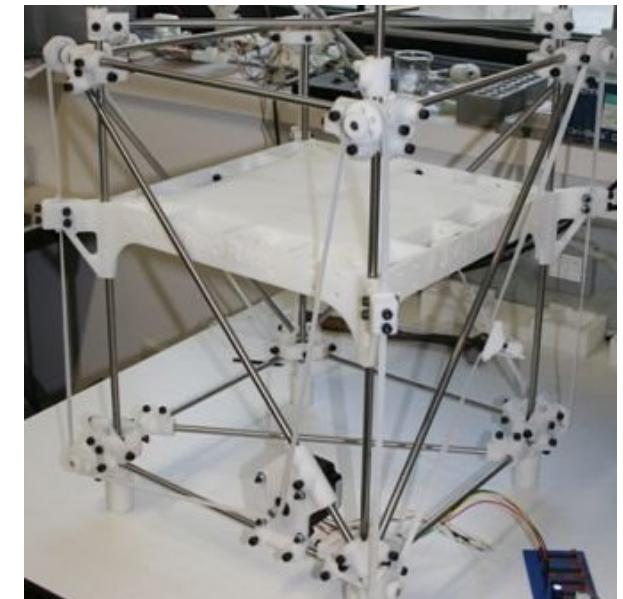
- ⌚ 28. Mai 2005 M4 Schraube wird zur Düse



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⌚ Reprap Geschichte

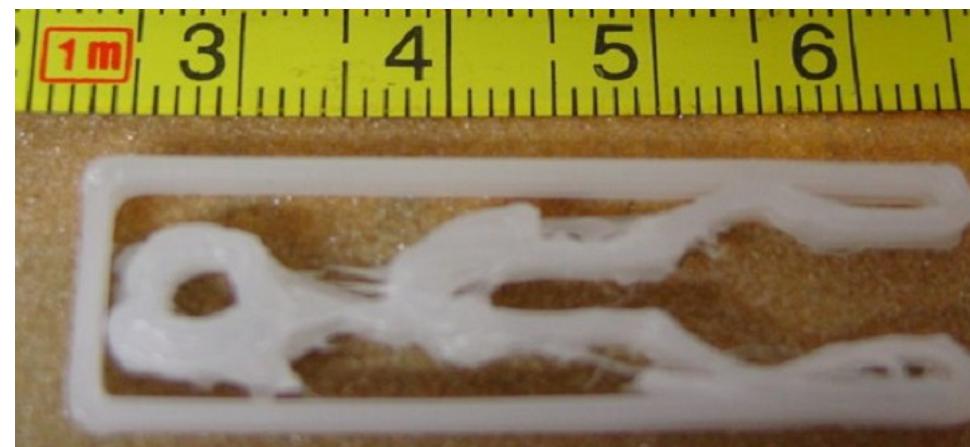
- ⌚ April 2006: ARNIE
- ⌚ Mai 2006: Ein sechseckiges und ein quadratisches Objekt



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○ Reprap Geschichte

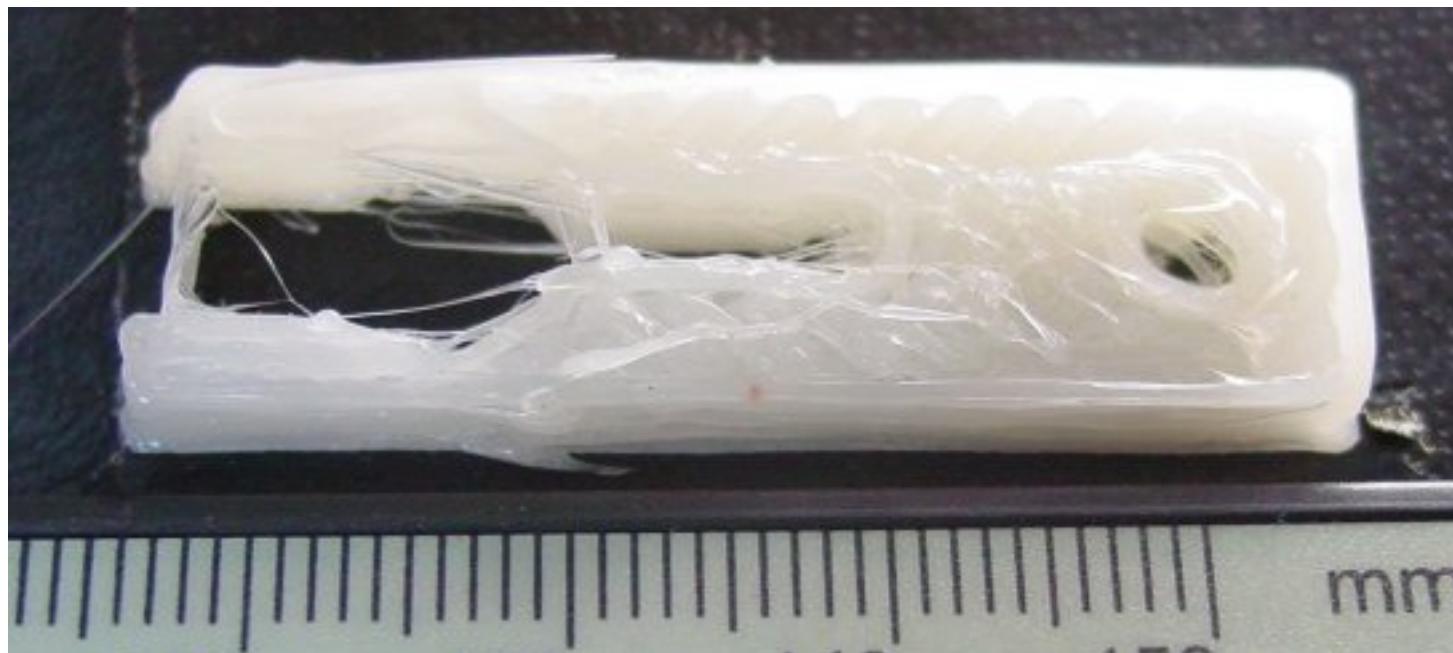
- Einen Tag später:
- 9. Juli 2006 - erster Versuch "Gripley" zu drucken



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⌚ Reprap Geschichte

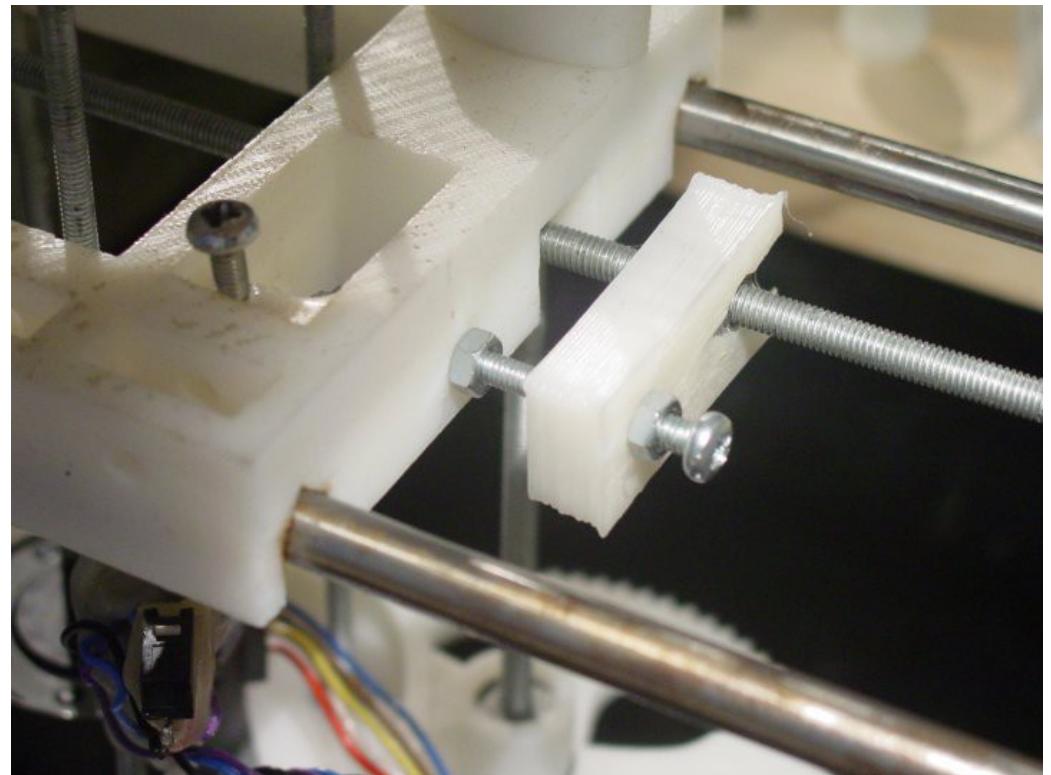
- ⌚ 17. August 2006 - Gripley zweiter Versuch



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⌚ Reprap Geschichte

- ⌚ 23. September 2006
Gripley dritter Versuch.
Erstes gedrucktes
Bauteil findet Verwen-
dung in einem
3D-Drucker



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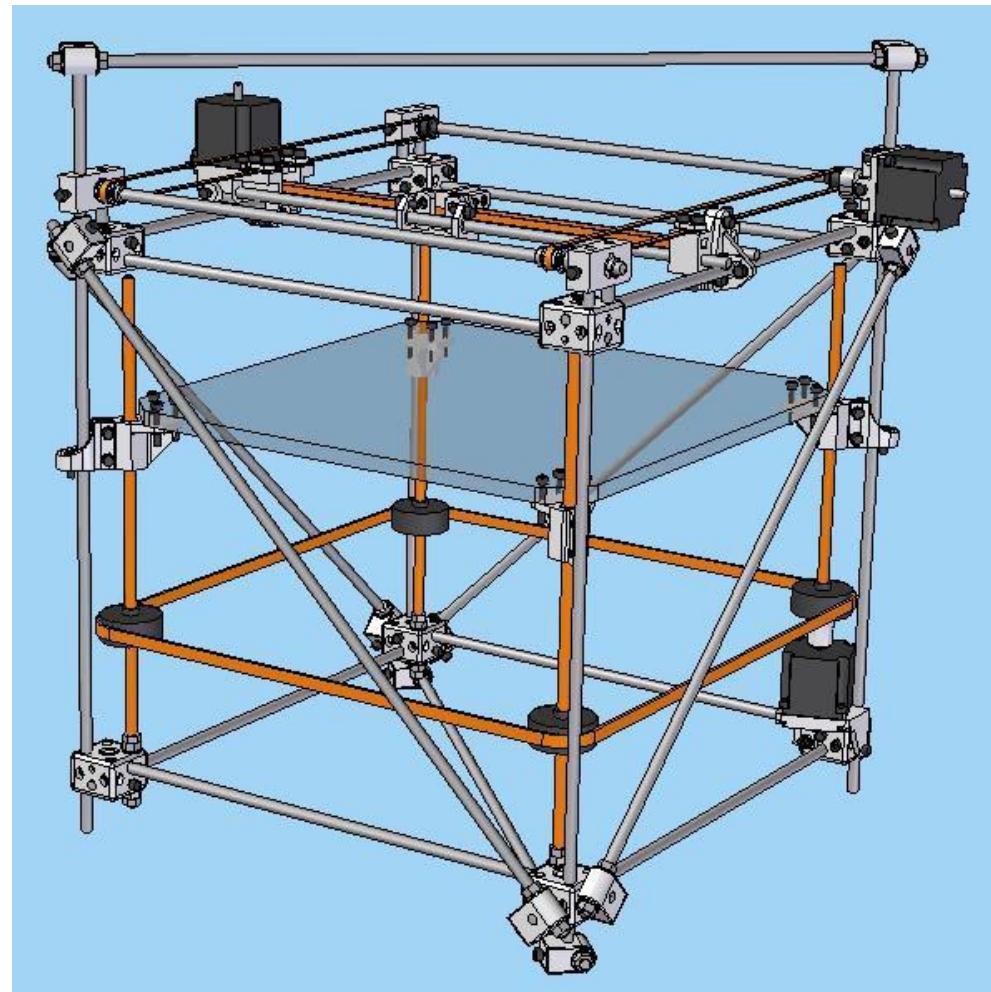
○ Reprap Geschichte

○ 8. Januar 2007

 Darwin als CAD

 Modell fertig

 gezeichnet



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⌚ Reprap Geschichte

- ⌚ 23. Januar 2007 - Elektronik für Darwin
- ⌚ 2. Februar 2007 - ARNIE funktioniert
- ⌚ 5. März 2007 - DARWIN bewegt sich
- ⌚ 9. April 2007 - DARWIN Bauanleitung online
- ⌚ 6. Juni 2007 - erste Version einer Host-Software

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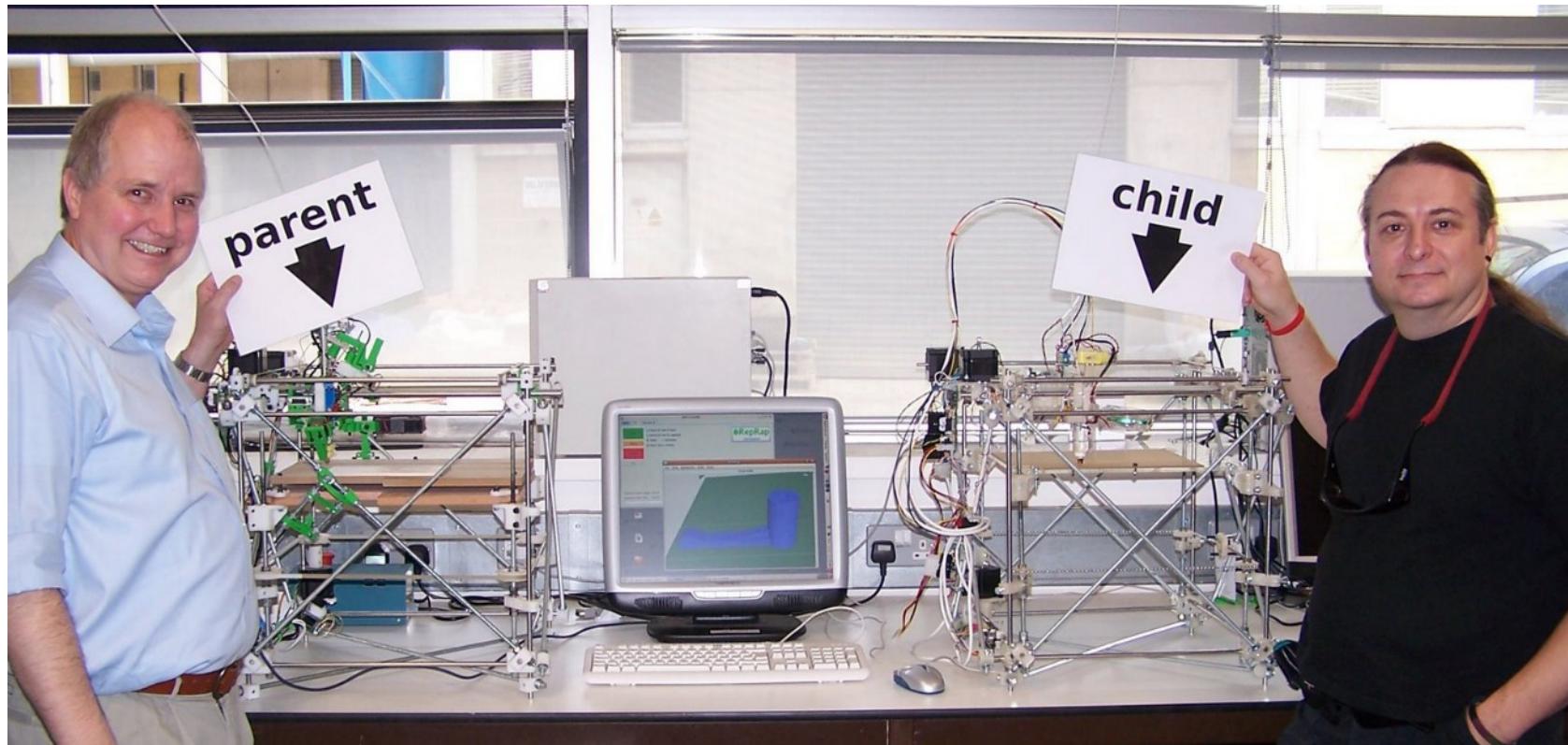
⌚ Reprap Geschichte

- ⌚ 12. Januar 2008 - Portierung der Firmware auf Arduino
- ⌚ 29. März 2008 - Arduino wird offizielle Hardware für Reprap Drucker

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○ Reprap Geschichte

- 3. Juni 2008 - Reprap druckt Teile für einen Klon



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⌚ Reprap Geschichte

- ⌚ November 2008 - Start von thingiverse.com
- ⌚ Juni 2013 - 100.000 Objekte verfügbar

Global Feed
Latest Thingiverse Activity

nicoflood collected Plotclock

 jmoney liked Fantastical Heart Gears

 lidorsho liked Plotclock

 LarsBecher collected Helix Lamp Shade

 jmoney collected Hexagon Ring

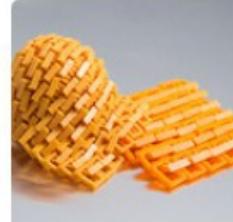
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 Fish

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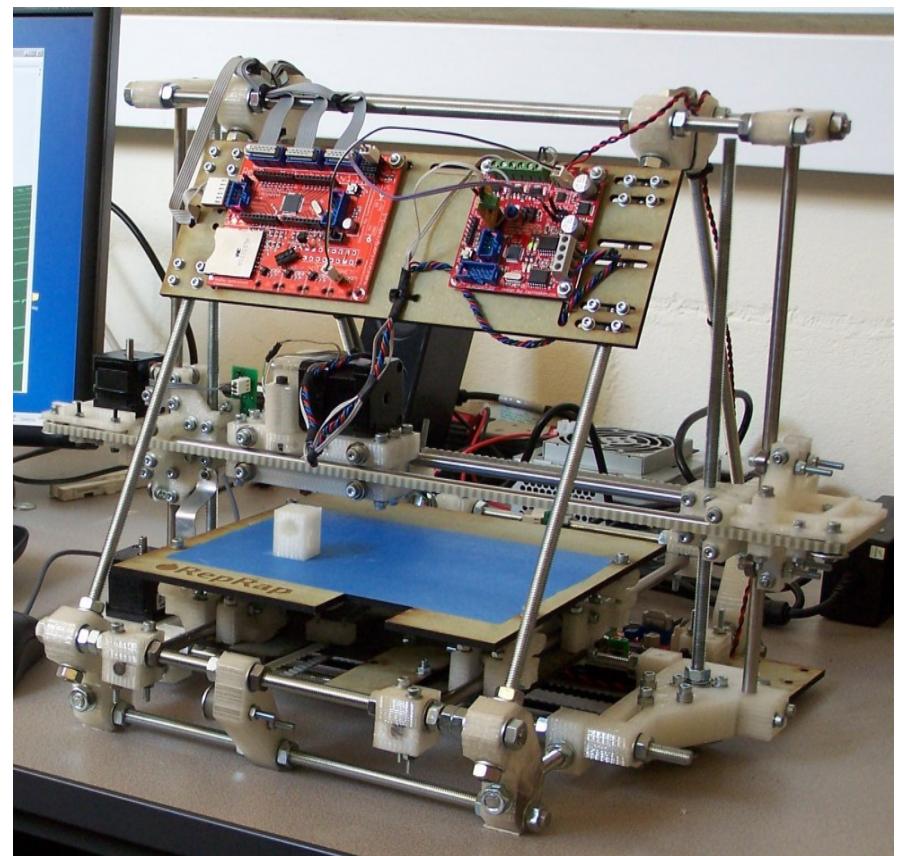
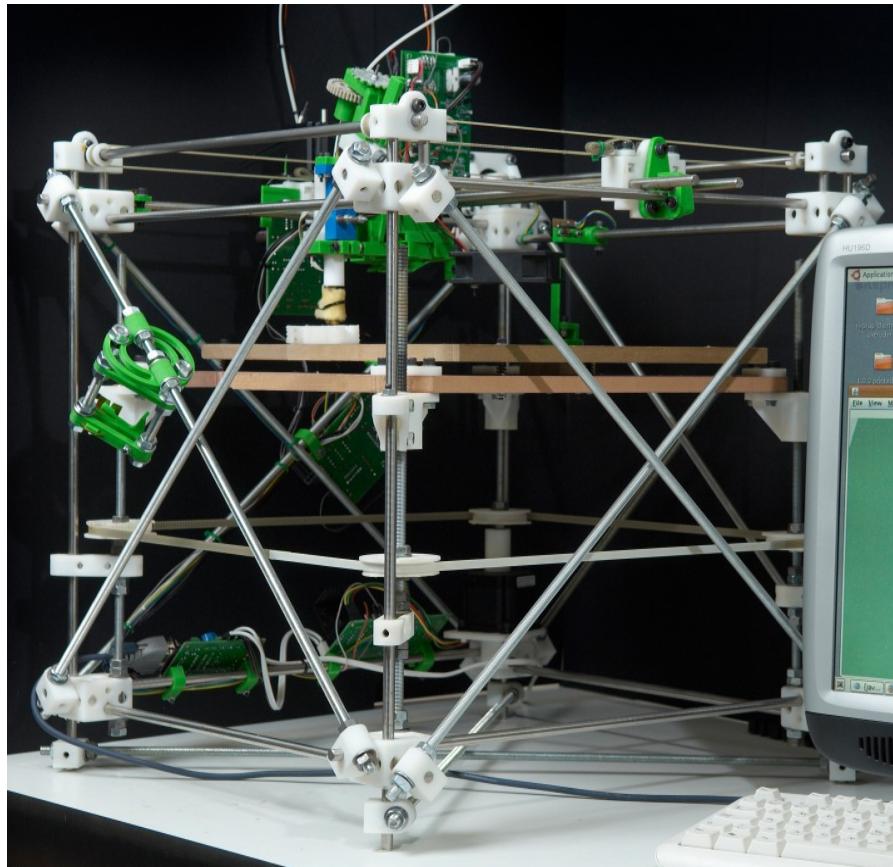
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⌚ Reprap Geschichte

- ⌚ Januar 2009 - Diskussion über einen Darwin Nachfolger - Mendel
- ⌚ 17. September 2009 - Mendel Dateien
- ⌚ 2. Oktober 2009 - Mendel druckt

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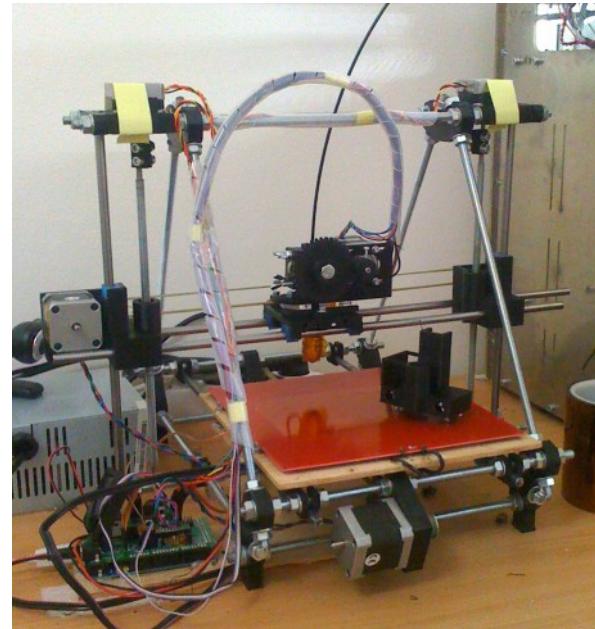
⌚ Reprap Geschichte



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⌚ Reprap Geschichte

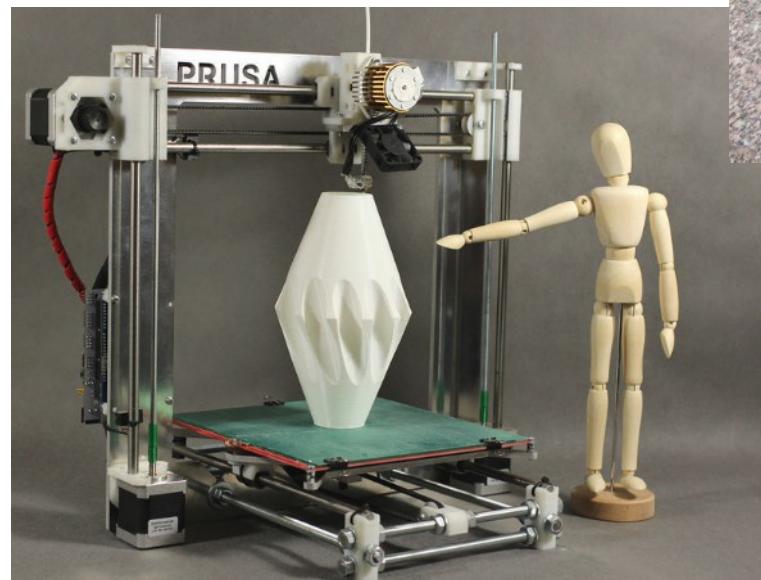
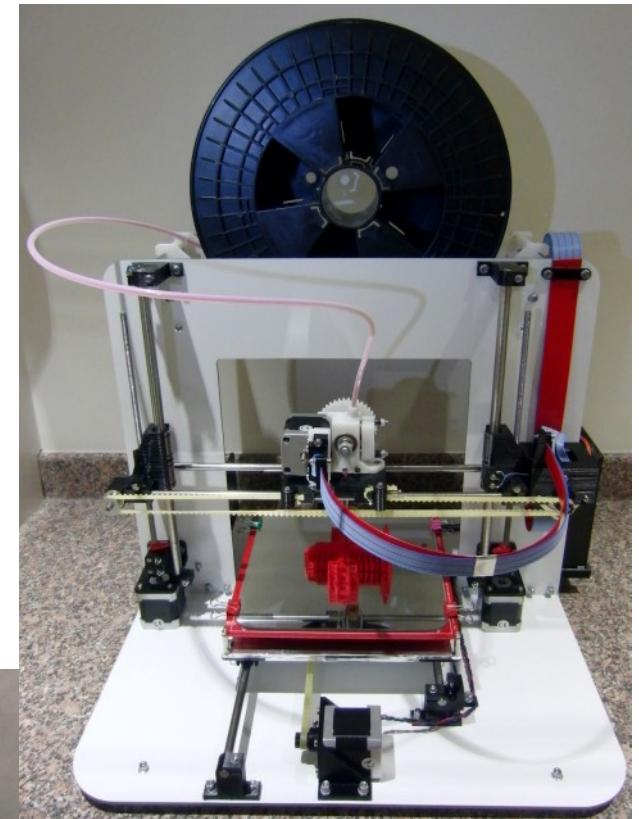
- ⌚ 4. Oktober 2010 Prusa-Mendel
(Josef Prusa)
- ⌚ 11. November 2011
Prusa-Mendel Iteration 2



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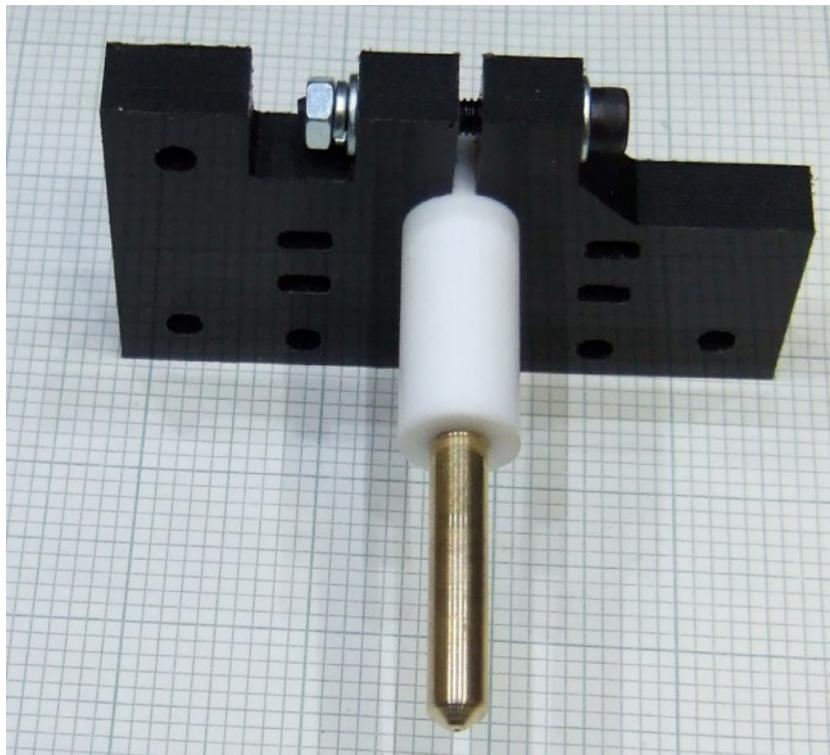
- ⌚ 26. Juli 2012 Mendel90
(Chris Palmer)
- ⌚ 1. November 2012
Prusa I3



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⌚ Reprap Geschichte

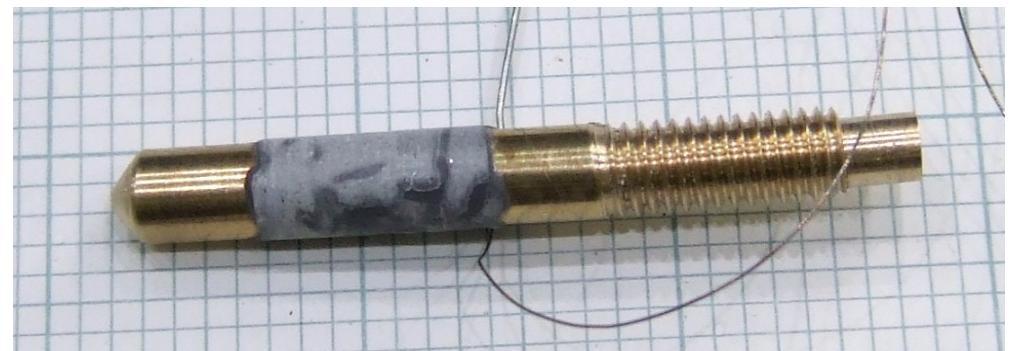
- ⌚ Ein Hotend entsteht (Juli 2007)



Reprap 3D Drucker

⌚ Reprap Geschichte

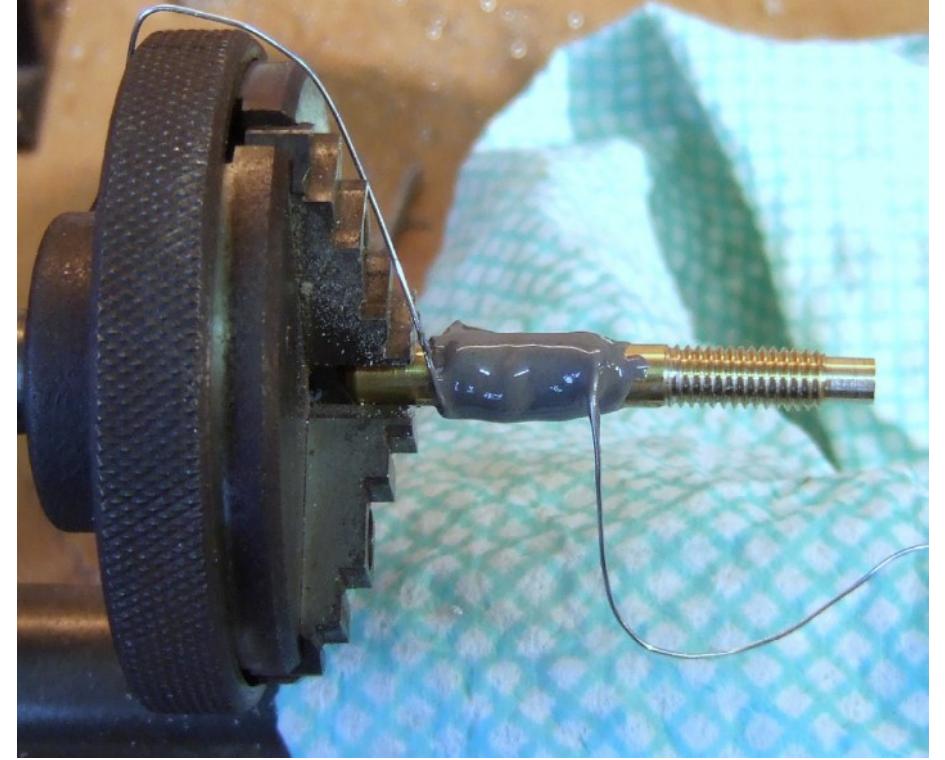
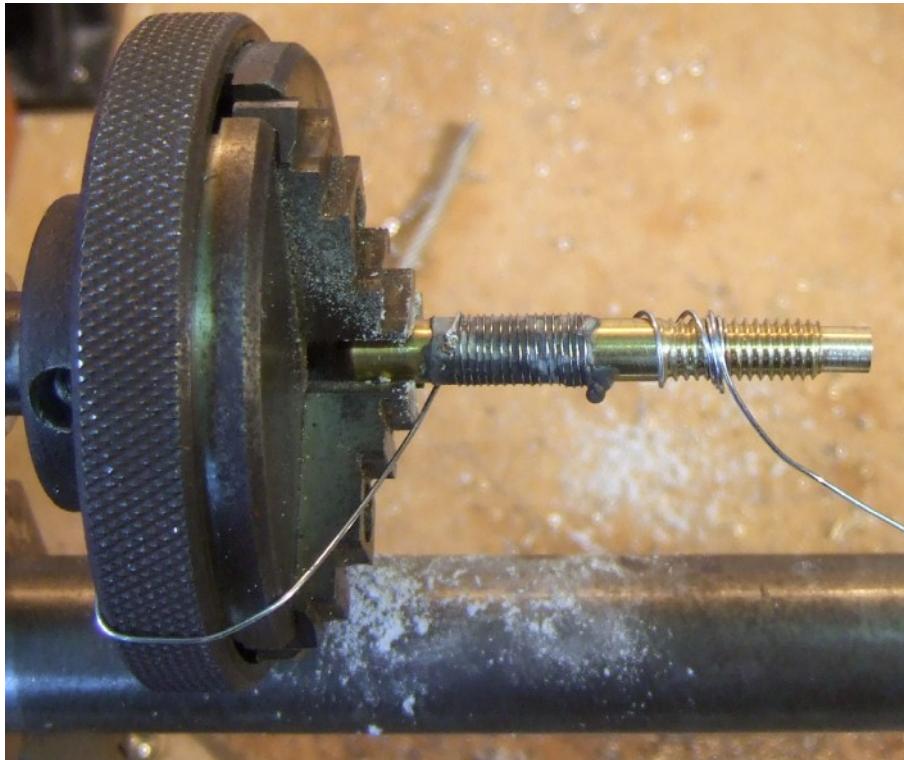
- ⌚ Ein Hotend entsteht (Juli 2007)



Reprap 3D Drucker

⌚ Reprap Geschichte

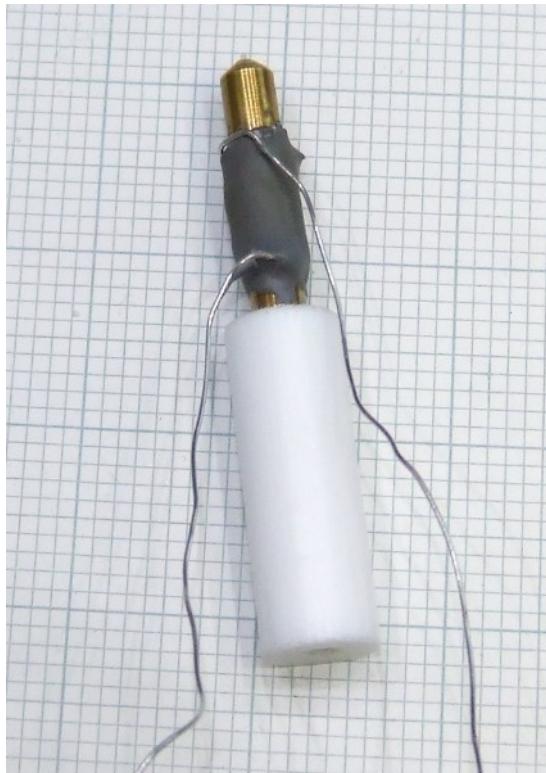
- ⌚ Ein Hotend entsteht (Juli 2007)



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⌚ Reprap Geschichte

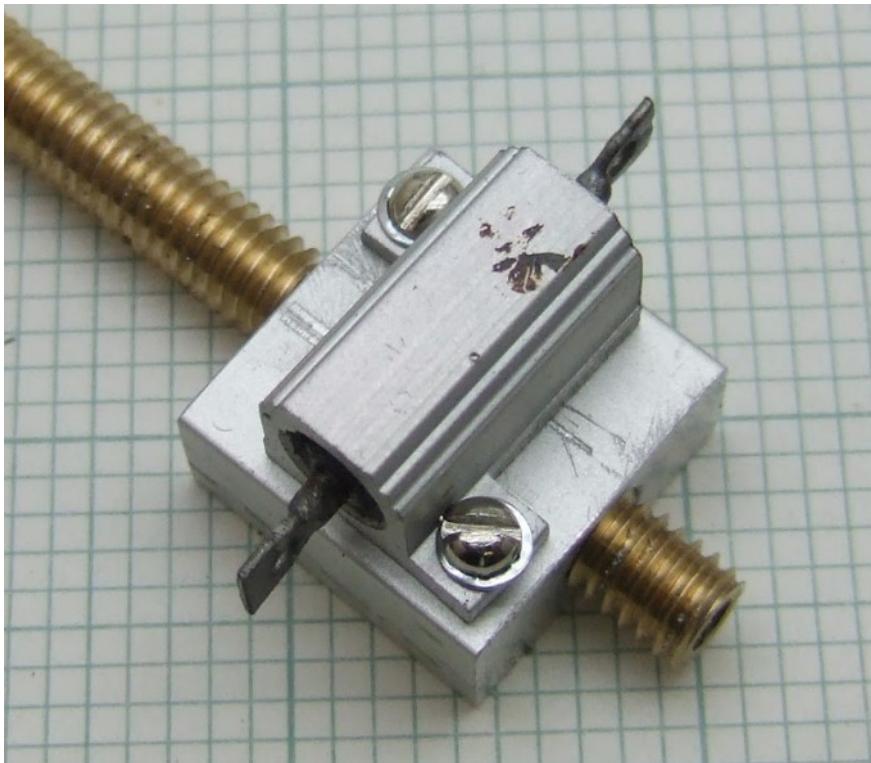
- ⌚ Ein Hotend entsteht (Juli 2007)



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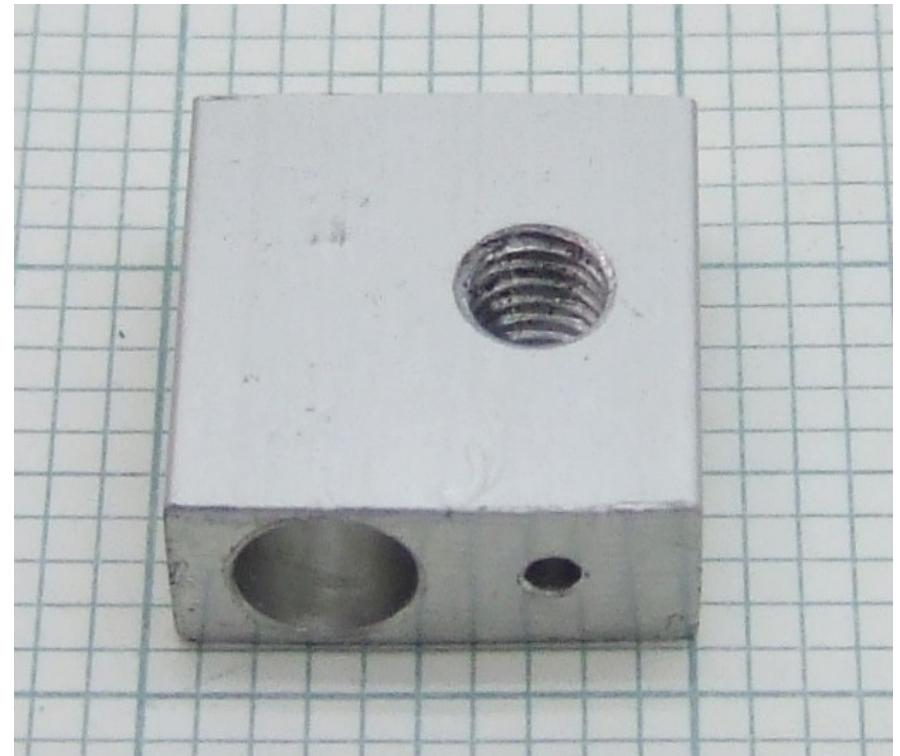
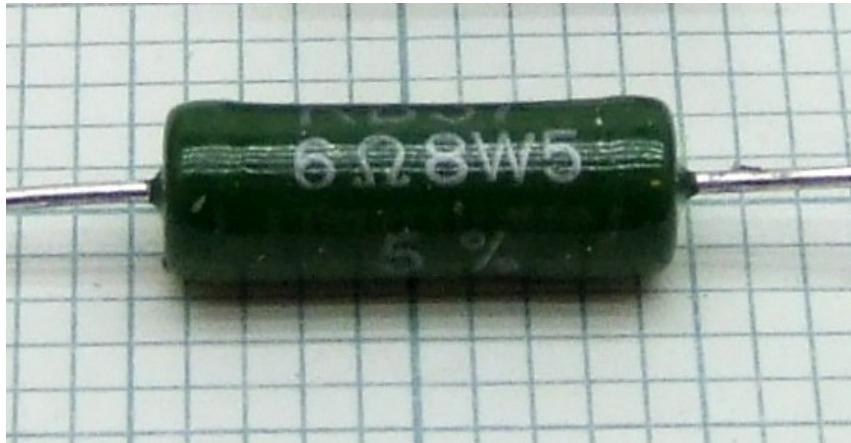
- ⌚ Ein Hotend entsteht (Januar 2009)



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↪ Reprap Geschichte

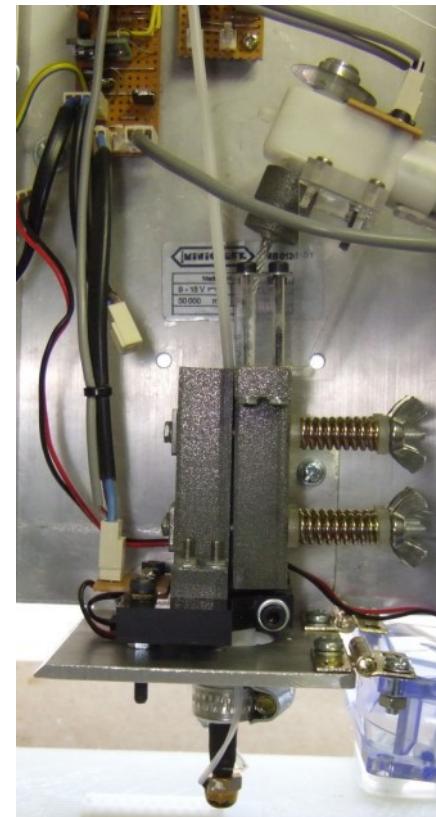
- ↪ Ein Hotend entsteht (Januar 2009)



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⌚ Reprap Geschichte

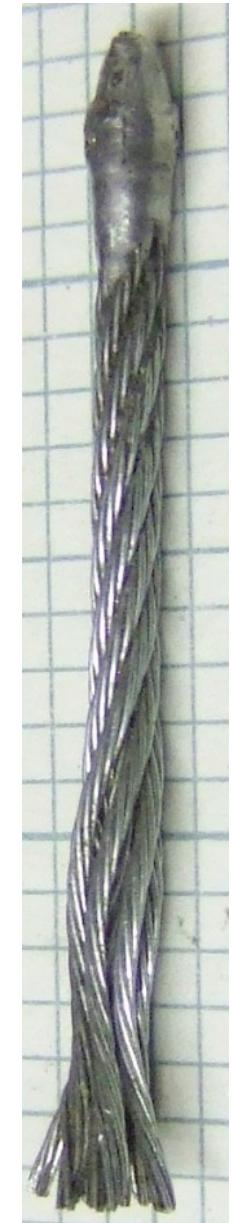
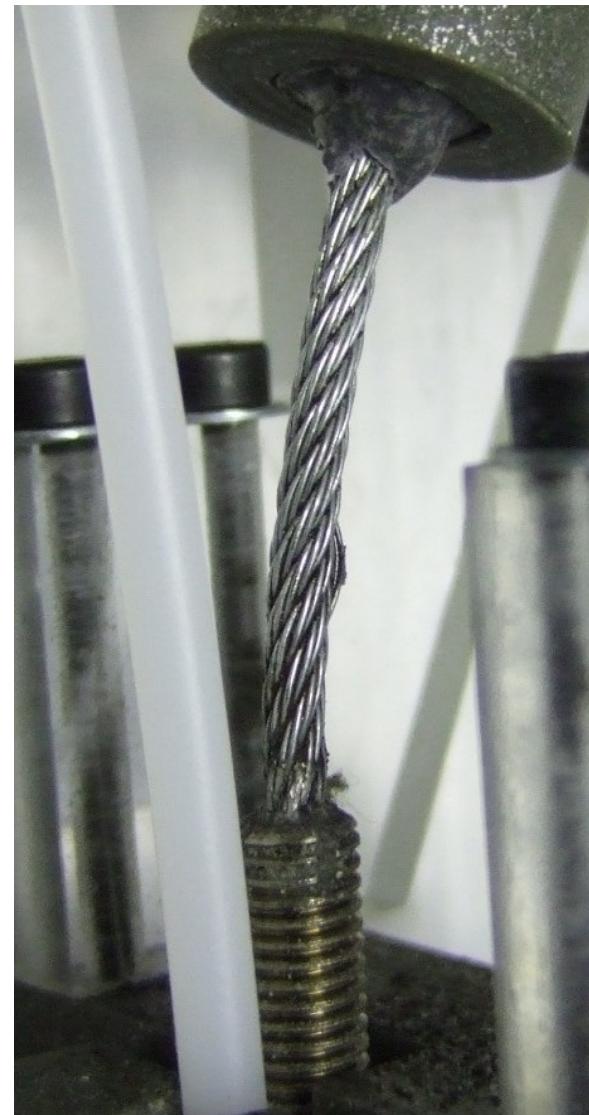
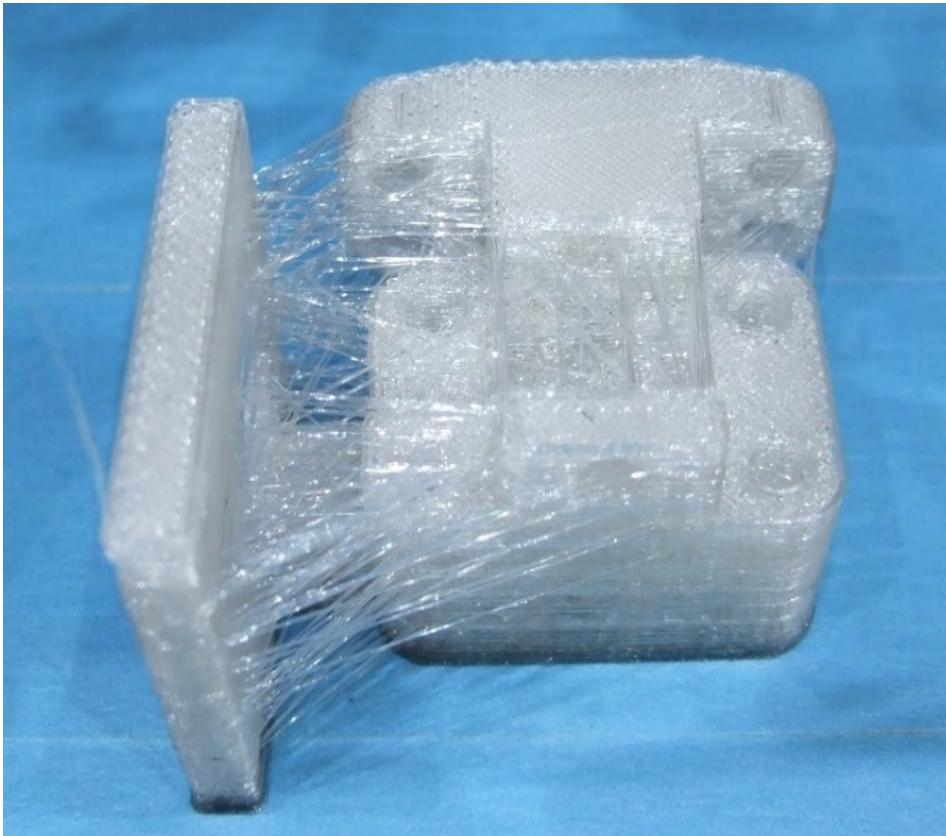
⌚ Filament-Vorschub



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↪ Reprap Geschichte

↪ Filament-Vorschub



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⌚ Reprap Geschichte

- ⌚ Filament-Vorschub (März 2009)



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Vielen Dank für Ihre Aufmerksamkeit!

Besuchen Sie doch mal das OpenLab:

Jeden Mittwoch,
ab 18:00 Uhr,
Augsburg, Elisenstraße 1,
Innenhof



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