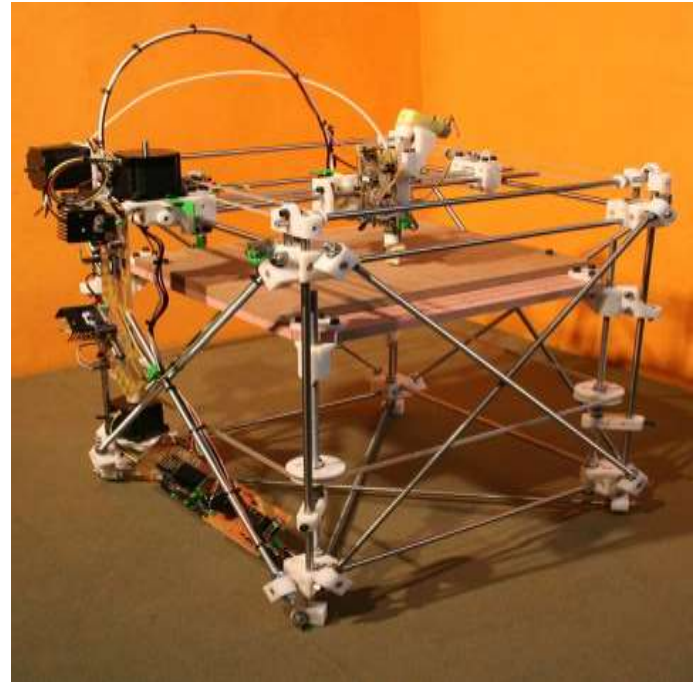# Design of hobby 3D printers

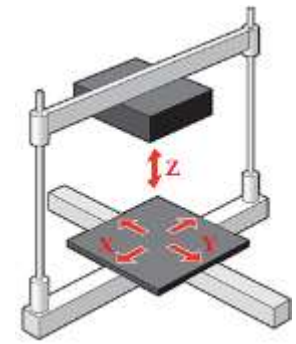Ing. Petr Keller, Ph.D.

Choice of technology:

- FLM technology

- DLP technology

- (3DP Technology)

RepRap 1.0 Darwin
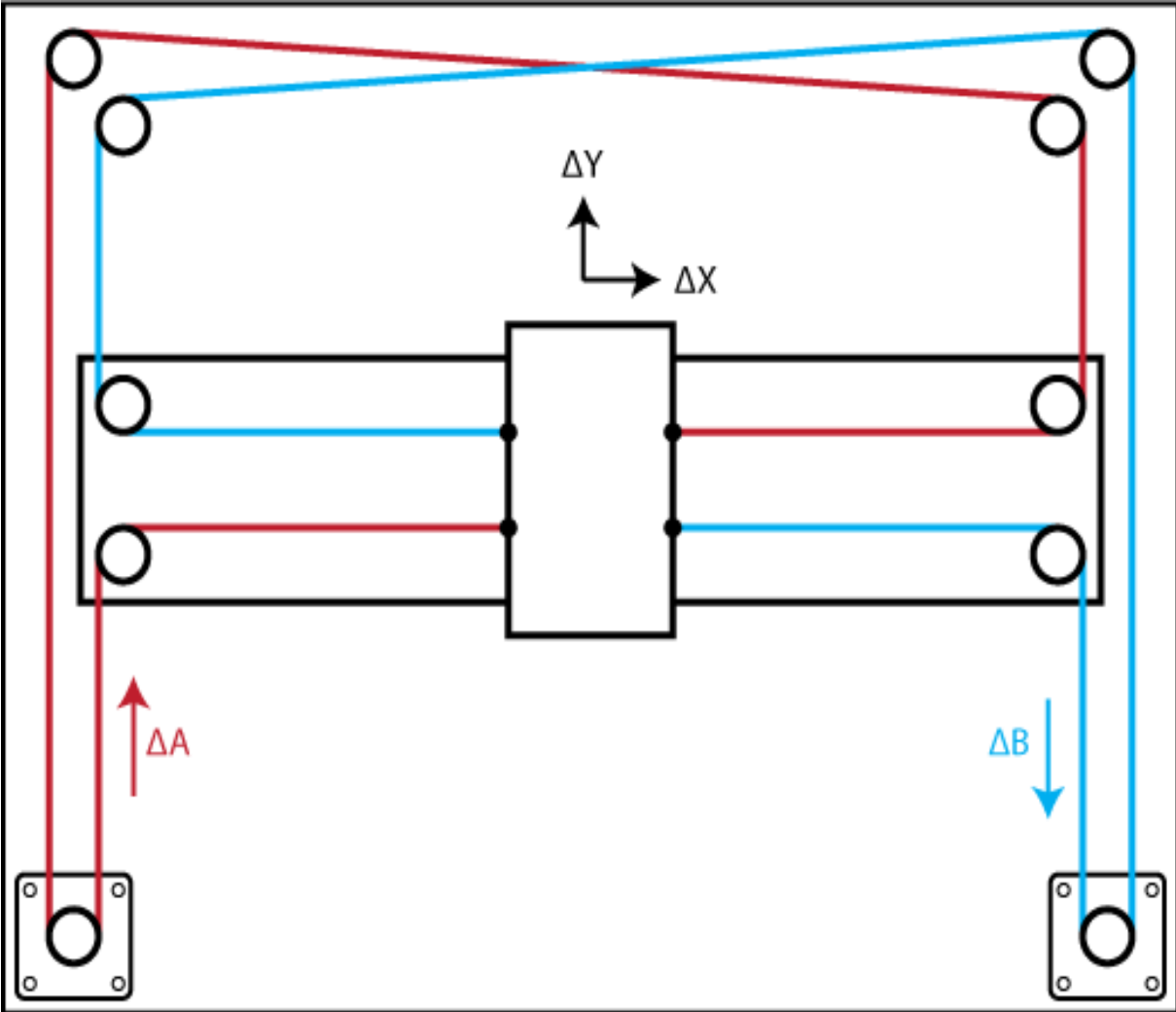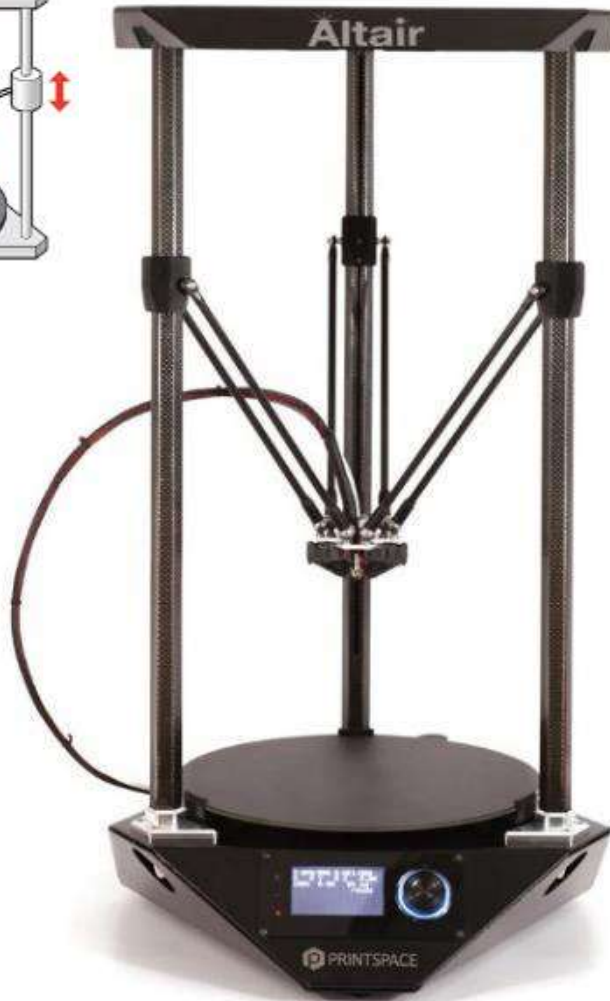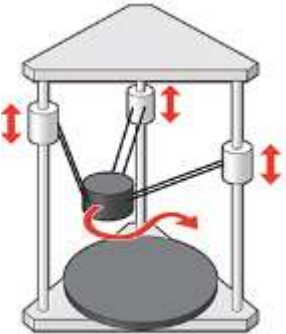
Types of FLM printers

Cartesian

Left: Prusa printer, where the nozzles move in the Z axis
Right: Sigma R17 printer, where the printing plate moves in the Z-axis
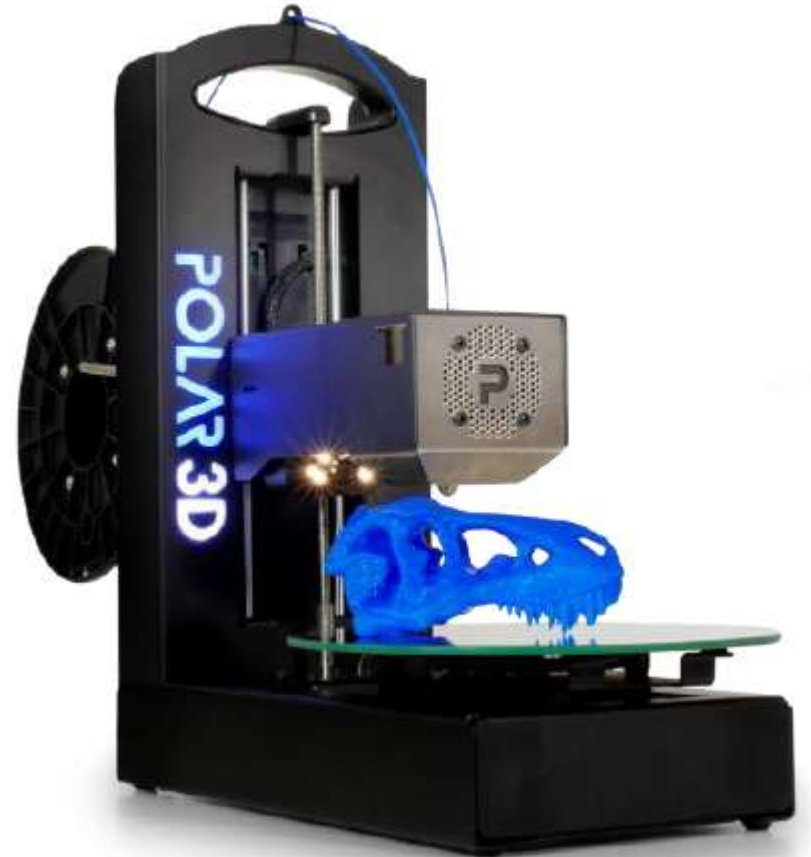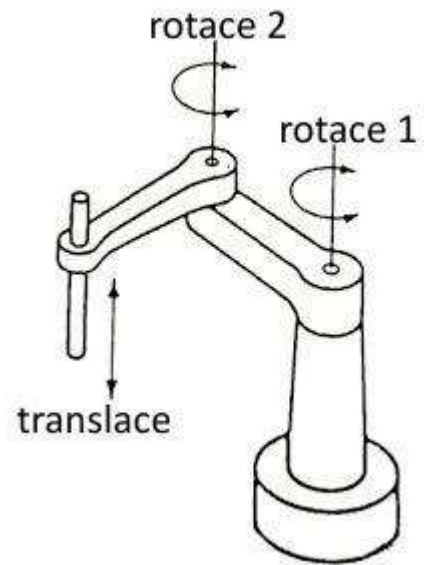
CoreXY

Delta

Polar
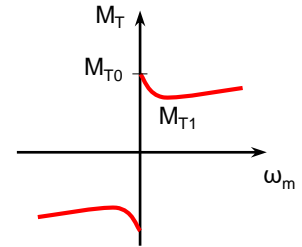
Robotic - e.g. SCARA concept

rotace 2

rotace 1

translace

Principles of machine design for servo drives (stepper motors)

- minimal clearance – $x_v < 10\mu m$ (20μm)

- minimal passive resistance – $\dfrac{M_{T0}}{M_{T1}} \leq 1{,}2$

  (otherwise there is a risk of irremovable jerky movements)

  - minimisation of friction in guides   - rolling guides
    - sliding with special materials (Teflon, etc.)
    - hydrostatic

  - minimising friction in drive mechanisms
    - ball screw
    - hydrostatic screws (expensive)
    - linear drives (trend)

- maximum stiffness – evaluated by natural frequency $f_0 = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}} \geq 50Hz$ (30HZ)

- appropriate moment of inertia – $J_Z \leq 3\, J_m$
  J_Z – reduced moment of inertia of the load (calculated per motor)
  J_m – motor moment of inertia

Example of the design of one linear axis of a CNC machine

- section of linear axis design with ball screw and rolling guide

end switches
(reference position)

covering of the
screw and guide

table

servomotor with integrated
incremental rotary encoder
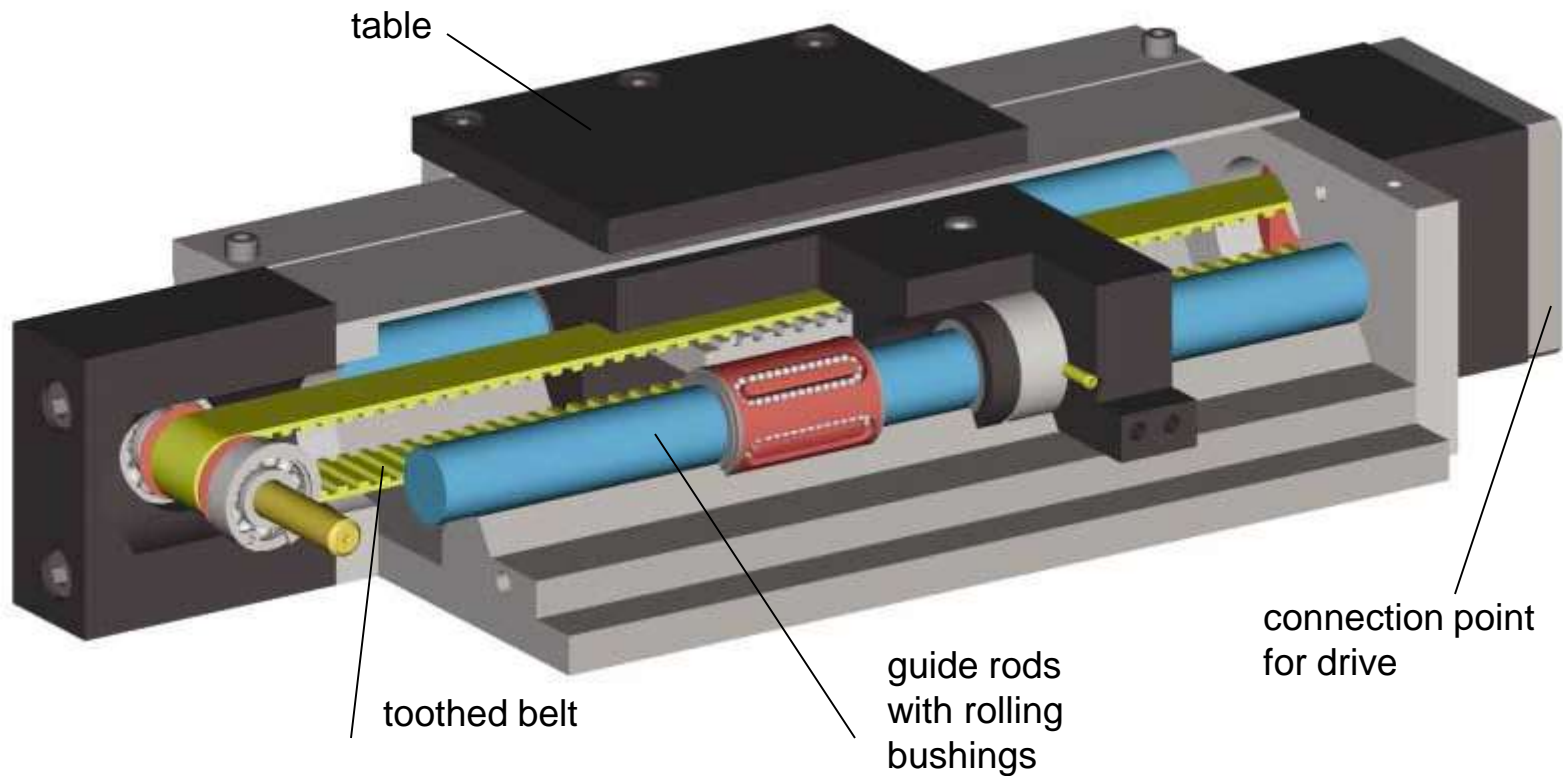
ball screw
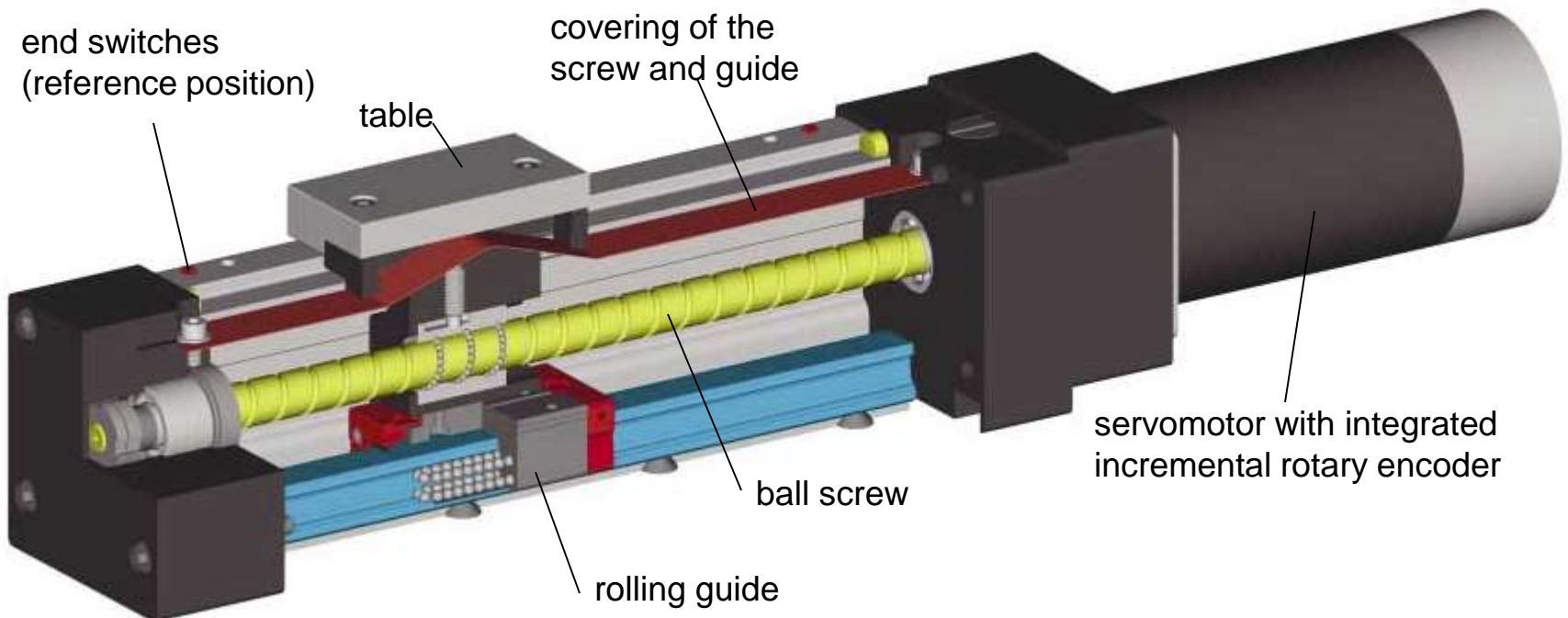
rolling guide

Example of the design of one linear axis of a CNC machine

- section of linear axis structure with toothed belt and rolling guide with guide rods of circular cross-section

table

connection point for drive

toothed belt

guide rods with rolling bushings

Example of the design of one linear axis of a CNC machine

- section of rotary axis design with worm and worm wheel

rotary table

machine frame

worm and worm wheel

servomotor with integrated
incremental rotary encoder
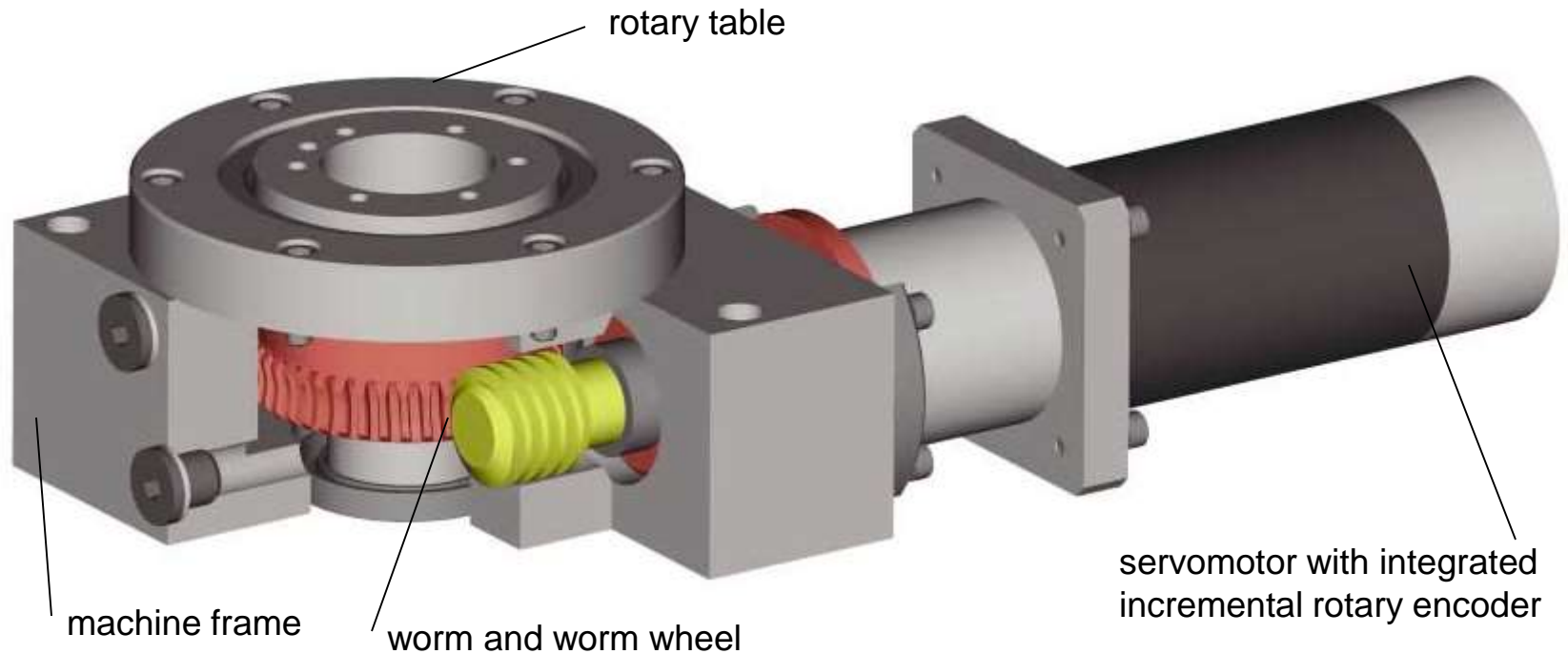
Example of the design of one linear axis of a CNC machine

- rotary axis design with a gapless globoid cam

Basic components of the FFF 3D printer:
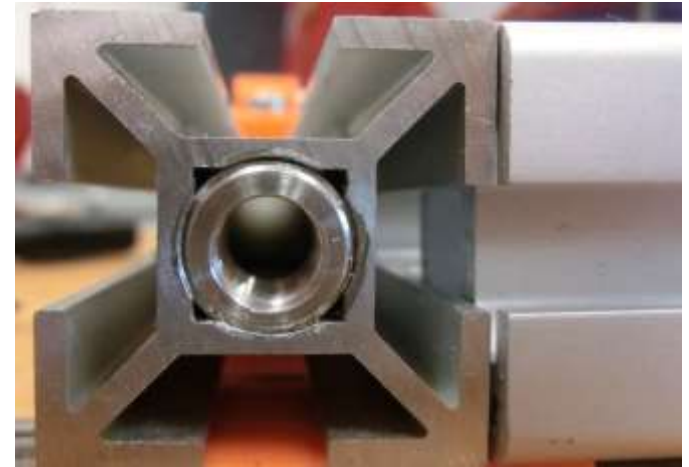
- Frame

The bottom frame of the Rebel 2 printer, where the "combi" profiles connect the printed plastic plates

Connection of "combi" profiles via threaded insert and M6 screw

Basic components of the FFF 3D printer:

- Drives

Threaded rod M6 and flexible hose coupling

Stepper motor with integrated trapezoidal screw

Drive with a trapezoidal screw mounted in bearings at both ends, connected to the motor via a flexible coupling
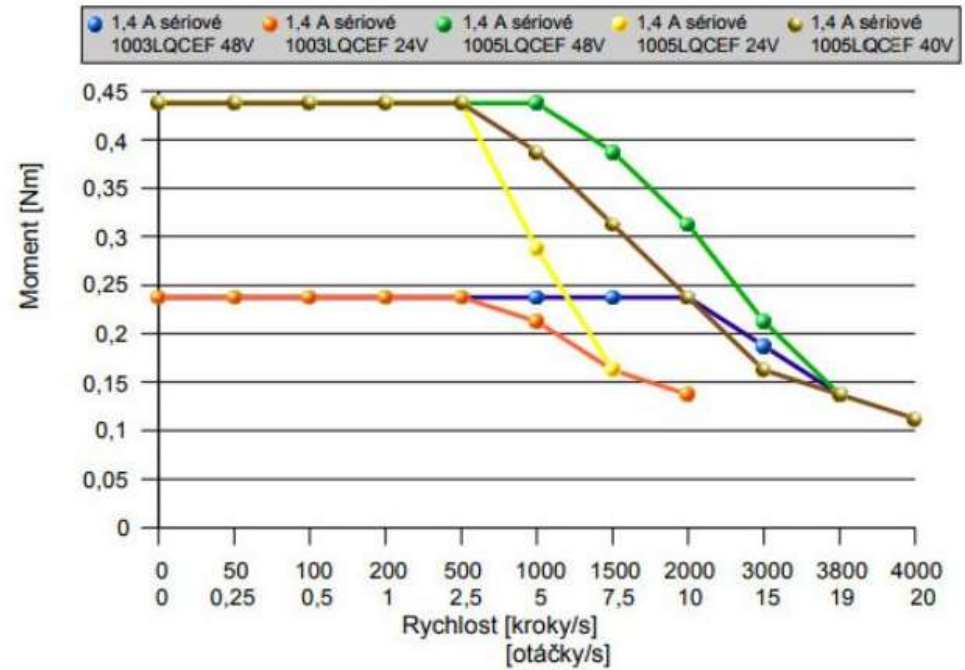
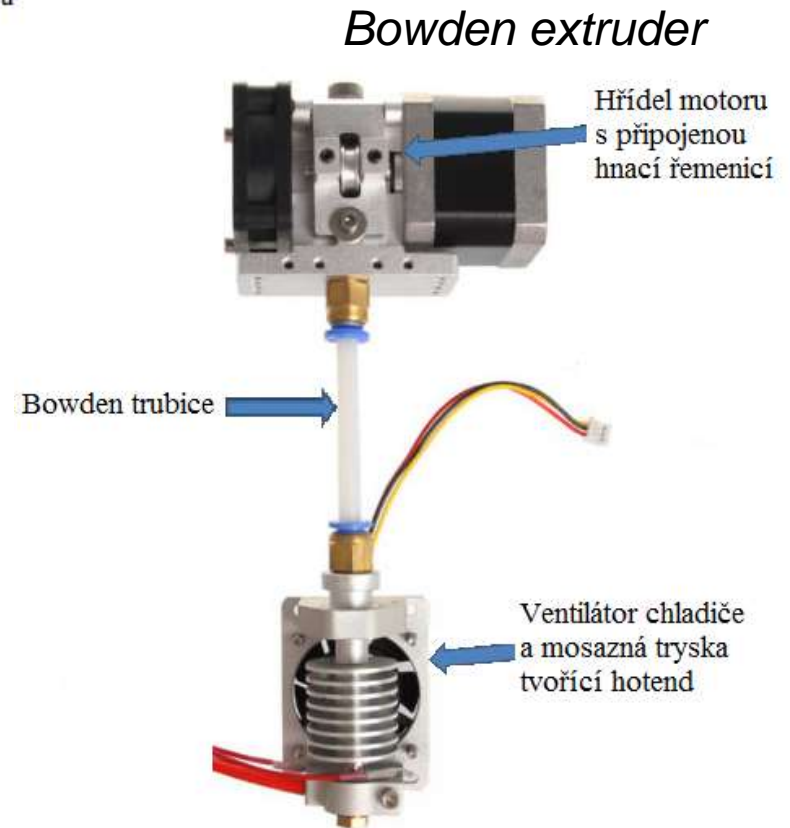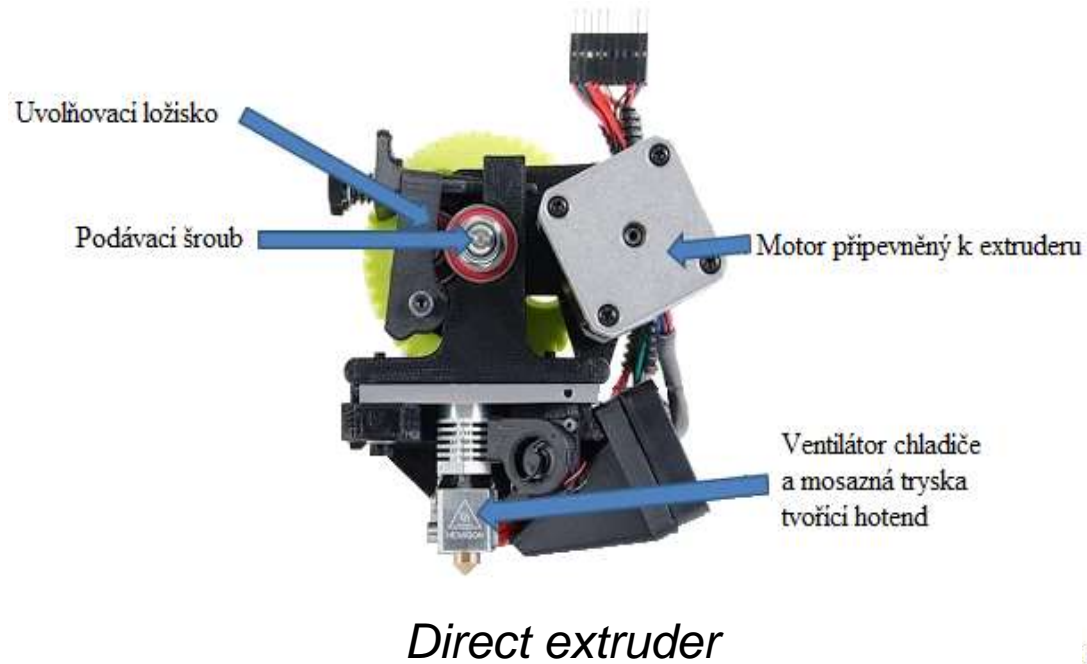***Basic components of the FFF 3D printer:***

- Stepper motors

Bipolar stepper motor
Microcon SX17-1005

Momentová charakteristika motoru SX17-1003LQCEF,
SX17-1005LQCEF s CD30x, CD30M (24; 48 VDC);
SX17-1005LQCEF s SD14RE (40 VDC)

• 1,4 A sériové 1003LQCEF 48V	• 1,4 A sériové 1003LQCEF 24V	• 1,4 A sériové 1005LQCEF 48V	• 1,4 A sériové 1005LQCEF 24V	• 1,4 A sériové 1005LQCEF 40V

Moment [Nm]

0	50	100	200	500	1000	1500	2000	3000	3800	4000
0	0,25	0,5	1	2,5	5	7,5	10	15	19	20

Rychlost [kroky/s]
[otáčky/s]

Basic components of the FFF 3D printer:

- Extruder

Uvolňovaci ložisko

Podávaci šroub

Motor připevněný k extruderu

Ventilátor chladiče a mosazná tryska tvoříci hotend

Direct extruder

Bowden extruder

Hřídel motoru s připojenou hnací řemenicí

Bowden trubice

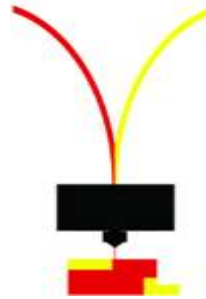Ventilátor chladiče a mosazná tryska tvořící hotend

Basic components of the FFF 3D printer:

- Types of extruders
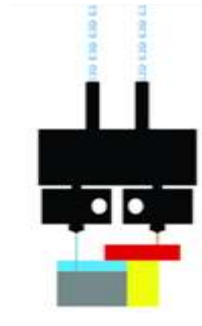
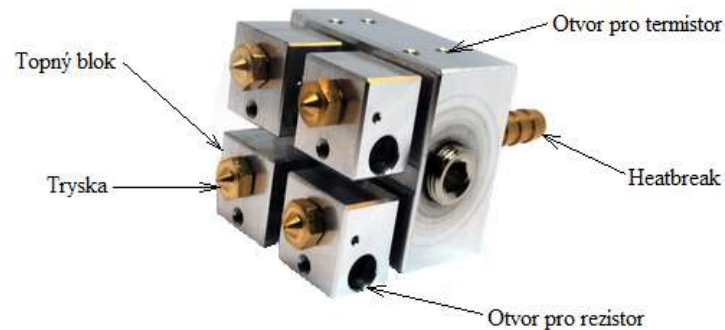|	E3D	Cyclops	Kraken	Chimera
No. of input materials	1	2	4	2
No. of output materials	1	1	4	2
Material mixing	No	Yes	No	No
Individual melting	Yes	No	Yes	Yes
Cooling type	Air	Air	Water	Air
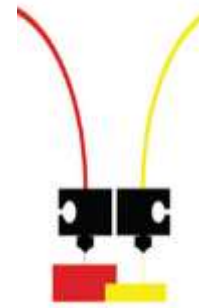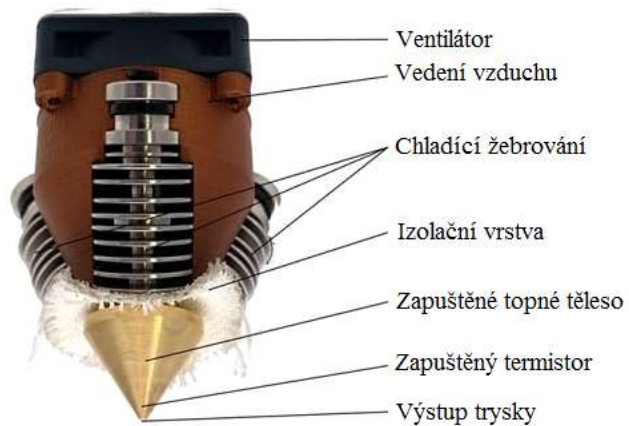
Diamond nozzle
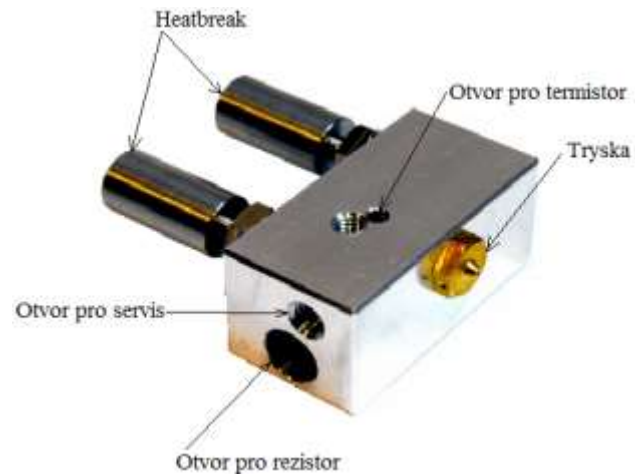
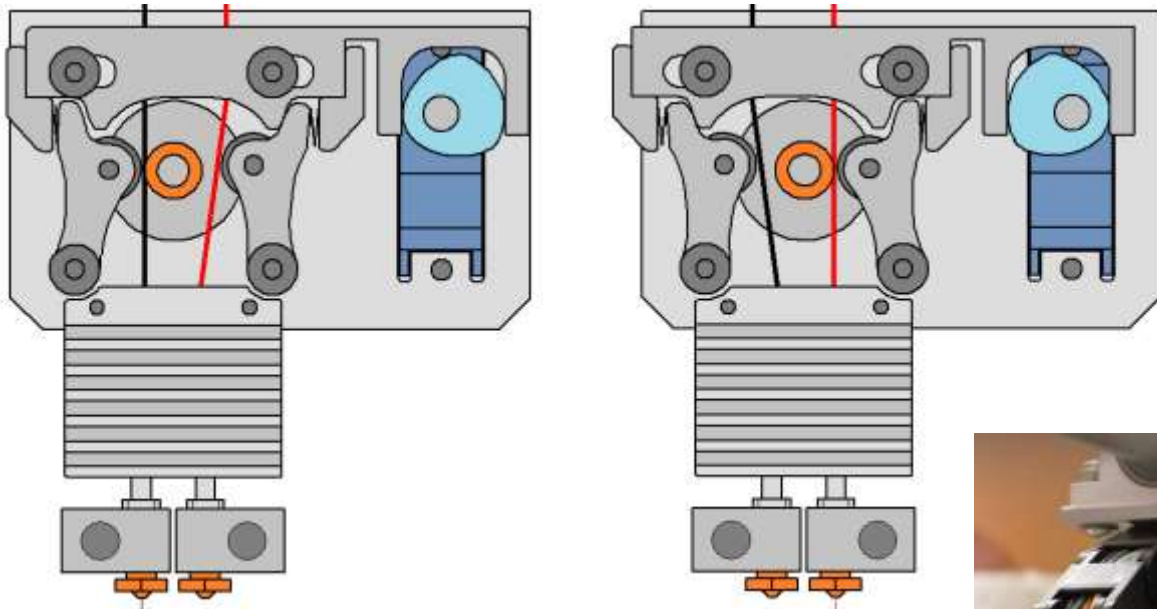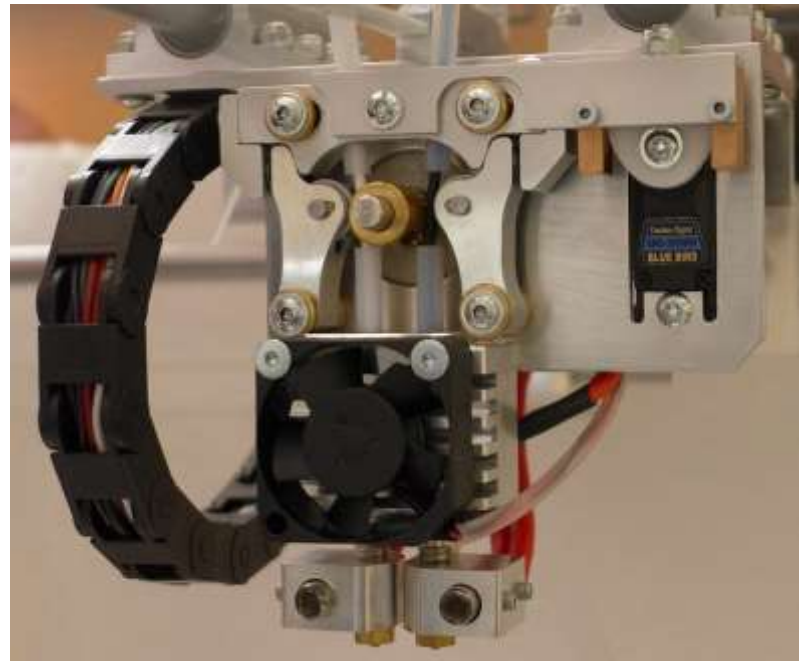Cyclops

Prusa i3 MK2 Multi-Material

Kraken

Dual head - TUL - KSA design

Basic components of the FFF 3D printer:

- Filament feed wheels

China production

Machined at KSA

Basic components of the FFF 3D printer:

- Stepper motor drivers

	A4988	DRV8825
Max. current	2A	2.5A
Max. microsteps	16	32
PCB colour	Green or red	Purple
Trimmer for current adjustment	Yes – at pin Dir	Yes – at pin En
Typical value of Rs	0.05 Ohm or 0.1 Ohm or 0.2 Ohm	0.1 Ohm
Calculation for Vref setting	Vref = I_TripMax * 8 * Rs	Vref = I_TripMax * 5 * Rs
Number of PCB layers	2	4

Basic components of the FFF 3D printer:

- Stepper motor drivers

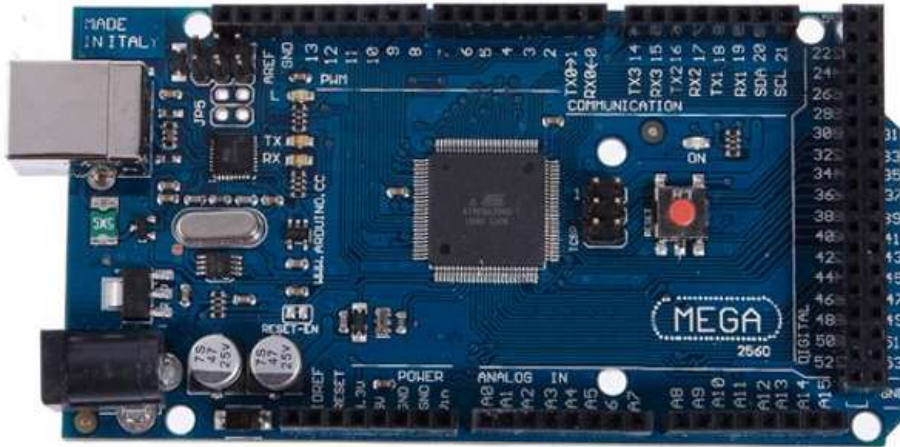| SilentStepStick	TMC2100 (5V)	TMC2100 (3-5V)	TMC2130 (3-5V)	TMC2208 (3-5V)
SilentStepStick				
Interface	Step/Dir	Step/Dir	Step/Dir or SPI	Step/Dir
Configuration	CFG Pins	CFG Pins	CFG Pins or SPI	CFG Pins or UART
Native Microsteps*	up to 1/16	up to 1/16	up to 1/256	up to 1/256
microPlyer Microsteps	1/256	1/256	1/256	1/256
Logic Voltage VIO	5V	3 - 5V	3 - 5V	3 - 5V
Motor Voltage VM	4.75 - 46V	5.5 - 46V	5.5 - 46V	5.5 - 36V
Motor Phase Current	1.2A RMS, 2.5A Peak	1.2A RMS, 2.5A Peak	1.2A RMS, 2.5A Peak	1.2A RMS, 2.0A Peak
VM always needed**	no	yes	yes	yes
Internal V-Regulator**	disabled	enabled	enabled	enabled
RDSon	>=0.5 Ohm	>=0.5 Ohm	>=0.5 Ohm	<=0.3 Ohm
stealthChop (quiet)	yes	yes	yes	yes
spreadCycle	yes	yes	yes	yes
coolStep	no	no	yes	no
stallGuard	no	no	yes	no
dcStep	no	no	yes	no

Basic components of the FFF 3D printer:
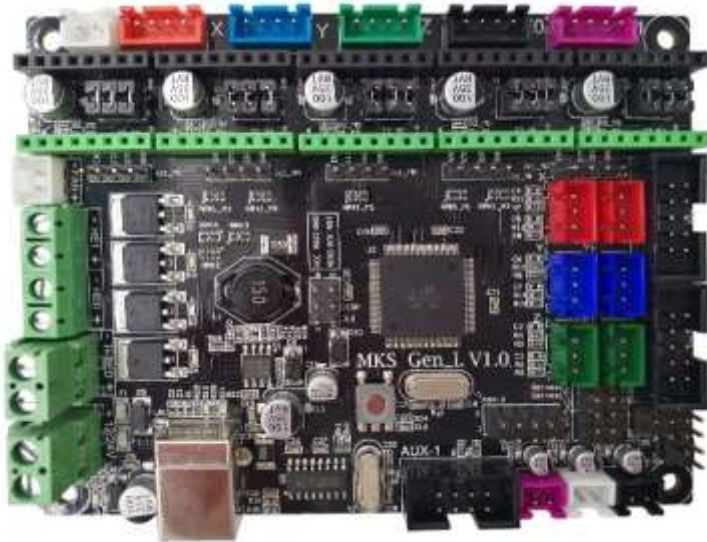
- Control electronics

Arduino Mega 2560
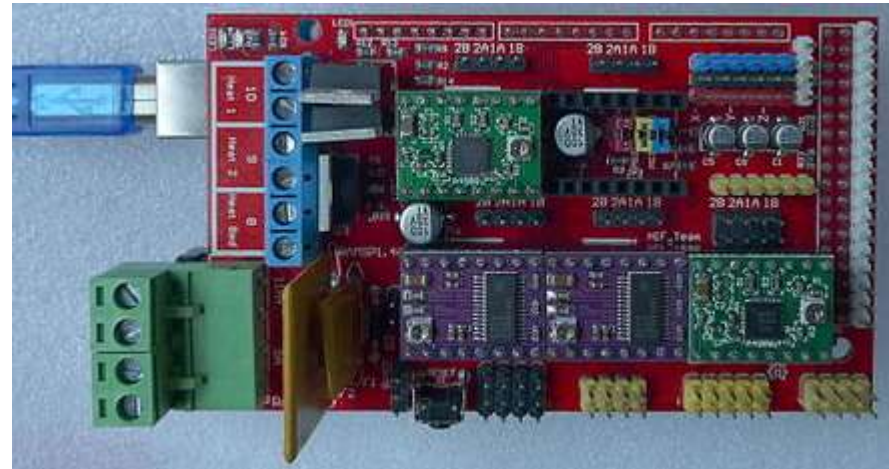
RAMPS 1.4

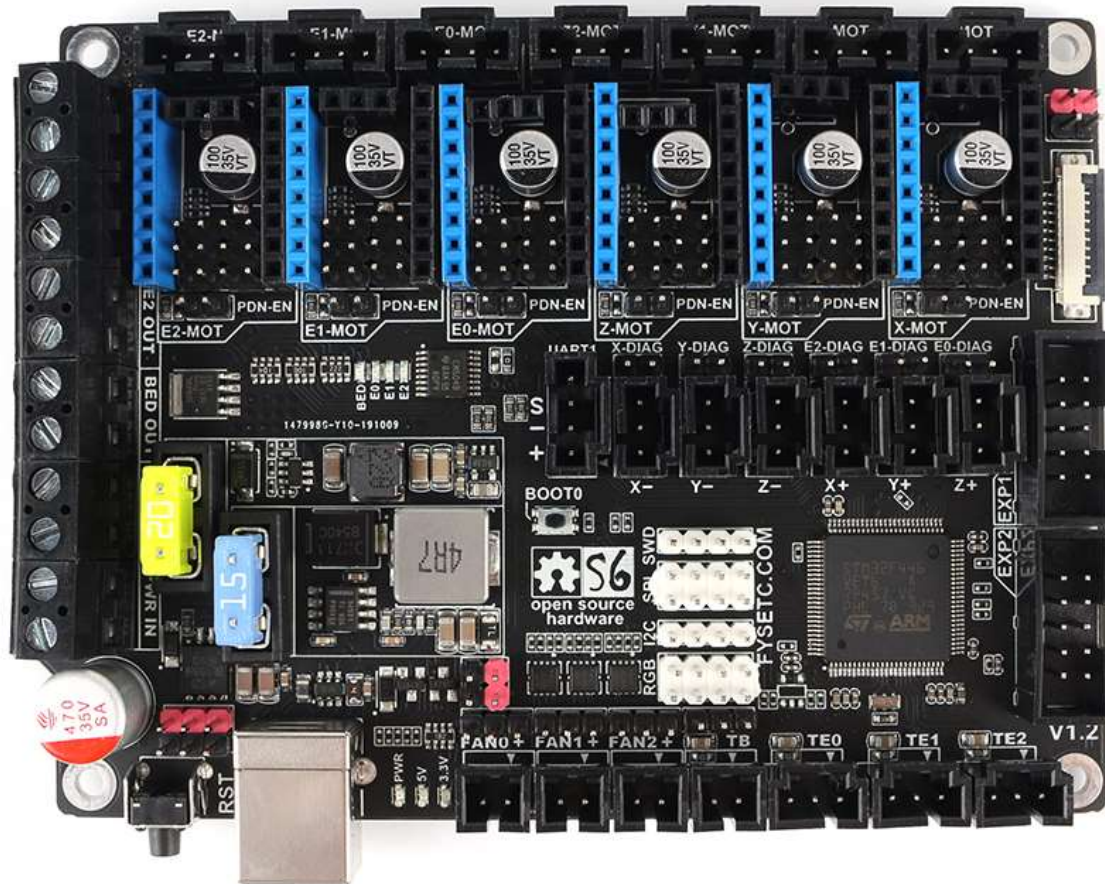## Basic components of the FFF 3D printer:

- Control electronics

Control board MKS-GEN L V1.0

Control board Einsy Rambo 1.1a with
integrated drivers for stepper motors (4 x
Trinamic TMC2130)

Basic components of the FFF 3D printer:

- Control electronics

Control board FYSETC S6 (24V, 15A max. / 20A pro bed)

Basic components of the FFF 3D printer:

- Firmware

  Repetier – web configurator:
  https://www.repetier.com/firmware/v100/index.php

  Marlin – configuration description:
  http://marlinfw.org/docs/configuration/configuration.html

Overview of the most common materials for FLM technology:

Materiál	Odolnost				Přibližná teplota pro zpracování [°C]	Rozpustnost
	UV záření	Kyseliny	Hydroxidy	Teplota (do 90°C)		
ABS	+	✓	✓	✓	210-250	estery, ketony, xyleny, chloroform, etylén dichloridu, aceton
PLA	✗	+	✗	✗	180-220	tetrahydrofurén, hydroxid sodný, chloroform
Nylon (PA6)	+	+	✓	✓	230-280	kyselina sírová (96%)
CPE	✓	✓	✓	✗	255-275	-
PC	+	+	✗	✓	230-280	dimethylformamid, chloroform
PP	+	✓	✓	✓	210-230	xyleny
PET-G	+	✓	✓	✗	210-235	-
ASA	✓	✓	✓	✓	230-270	xyleny, chloroform
PMMA	✓	+	✗	✗	220-250	chlorované uhlovodíky, estery, ketony, ethery, xyleny, aceton, chloroform