Deriving steps per mm for an LVE system V.1

Robert B Jess[1], Jonathan Widdowson[1,2], Feihu Zhao[1], Christopher Wright[1]

[1]Swansea University; [2]Procoll Ltd

Version 1

Oct 14, 2022

dx.doi.org/10.17504/protocols.io.ewov1o8jplr2/v1

Robert B Jess
Swansea University

DISCLAIMER

ABSTRACT

Modification of off-the-shelf fused filament fabrication (FFF) 3D printers with a syringe pump, used as a large volume extruder (LVE) is a common method for the creation of low-cost laboratory 3D bioprinters. Open-source syringe pumps with accompanying firmware exist, however they require researchers to choose accurate control of the syringe pump over rich control over the 3D printer system. The combination of open-source syringe pump hardware controlled with 3D printer electronics and firmware gives the best of both worlds, however this firmware is not designed to control fluids, consequently some parameters may need to be calculated differently. FFF printer firmware (such as RepRapFirmware) uses E-steps-per-mm to translate the movement of the stepper motor into the extrusion of filament pre-nozzle. This method finds the value of this parameter for a bioprinter with a bowden-tube based LVE.

DOI

dx.doi.org/10.17504/protocols.io.ewov1o8jplr2/v1

PROTOCOL CITATION

Robert B Jess, Jonathan Widdowson, Feihu Zhao, Christopher Wright 2022. Deriving steps per mm for an LVE system. **protocols.io**
https://dx.doi.org/10.17504/protocols.io.ewov1o8jplr2/v1

KEYWORDS

3D Bioprinting, Bioprinting, LVE, Steps, Stepper Motor, Software, Firmware, Control, Syringe pump, Mathematic

CREATED

Sep 20, 2022

LAST MODIFIED

Oct 14, 2022

PROTOCOL INTEGER ID

70293

GUIDELINES

This method is for an LVE that is based around the MOST Open Source Syrigne Pump [1], or similar syringe pumps such as the Poseidon from Patcher Lab [2], connected to the printer carriage and print head via a bowden tube.

[1] Joshua M. Pearce, Bas Wijnen (2016). "Open-source syringe pump". Appropedia. Retrieved October 13, 2022.
[2] A. Sina Booeshaghi, Eduardo da Veiga Beltrame, Dylan Bannon, Jase Gehring and Lior Pachter, "Principles of open source bioinstrumentation applied to the poseidon syringe pump system", Scientific Reports 9, Article number: 12385 (2019)

MATERIALS TEXT

Open Source Syringe Pump		
Syringe Pump		
MOST OSSP	**n/a**	

DISCLAIMER:

DISCLAIMER – FOR INFORMATIONAL PURPOSES ONLY; USE AT YOUR OWN RISK

The protocol content here is for informational purposes only and does not constitute legal, medical, clinical, or safety advice, or otherwise; content added to protocols.io is not peer reviewed and may not have undergone a formal approval of any kind. Information presented in this protocol should not substitute for independent professional judgment, advice, diagnosis, or treatment. Any action you take or refrain from taking using or relying upon the information presented here is strictly at your own risk. You agree that neither the Company nor any of the authors, contributors, administrators, or anyone else associated with protocols.io, can be held responsible for your use of the information contained in or linked to this protocol or any of our Sites/Apps and Services.

Take measurements

1 Take the following measurements:

Thread Pitch (mm)	
Thread Starts	
Internal radius of the syringe (mm)	
Internal radius of the bowden tube (mm)	
Motor Steps	
Micro-Stepping	

Finding the thread's lead

1 Most lead screws are single start, and the one recommended in the MOST OSSP is single start, this means that the lead (the distance the carriage travels with one rotation of the lead screw) is equal to the pitch (the distance between the crests of the thread).

If you are using a multi-start lead screw the following formula should be used to calculate the thread's lead:

$$Lead = Pitch \times Number\ of\ Starts$$

Deriving the revolutions per mm

2 The ratio between the syringe and the Bowden tube can be calculated as follows:

$$\pi l_s {r_s}^2 = \pi l_b {r_b}^2$$

$$l_b = \frac{l_s {r_s}^2}{{r_b}^2}$$

$$\therefore$$

$$l_s : \frac{l_s {r_s}^2}{{r_b}^2}$$

Citation: Robert B Jess, Jonathan Widdowson, Feihu Zhao, Christopher Wright Deriving steps per mm for an LVE system https://dx.doi.org/10.17504/protocols.io.ewov1o8jplr2/v1

Where l_s is the distance travelled by the syringe plunger, l_b is the resultant distance the gel travels through the bowden tube, r_s is the internal radius of the syringe, and r_b is the internal radius of the bowden tube.

The ratio between the motor and the syringe is equal to the ratio between the motor and the linear distance travelled by the syringe plunger is:

$$1 : Lead$$

From this we know, when l_s = lead, the ratio between the lead screw and the Bowden tube, is:

$$1 : \frac{l_s {r_s}^2}{{r_b}^2}$$

This makes the revolutions per mm:

$$\frac{{r_b}^2}{l_s {r_s}^2}$$

Finding the E-Steps-per-mm

3 Multiply the motor steps by the micro-stepping by the length of filament produced through thr bowden tube with one revolution of the stepper motor

$$espmm = MotorSteps \times Micro\ Stepping \times \frac{{r_b}^2}{l_s {r_s}^2}$$