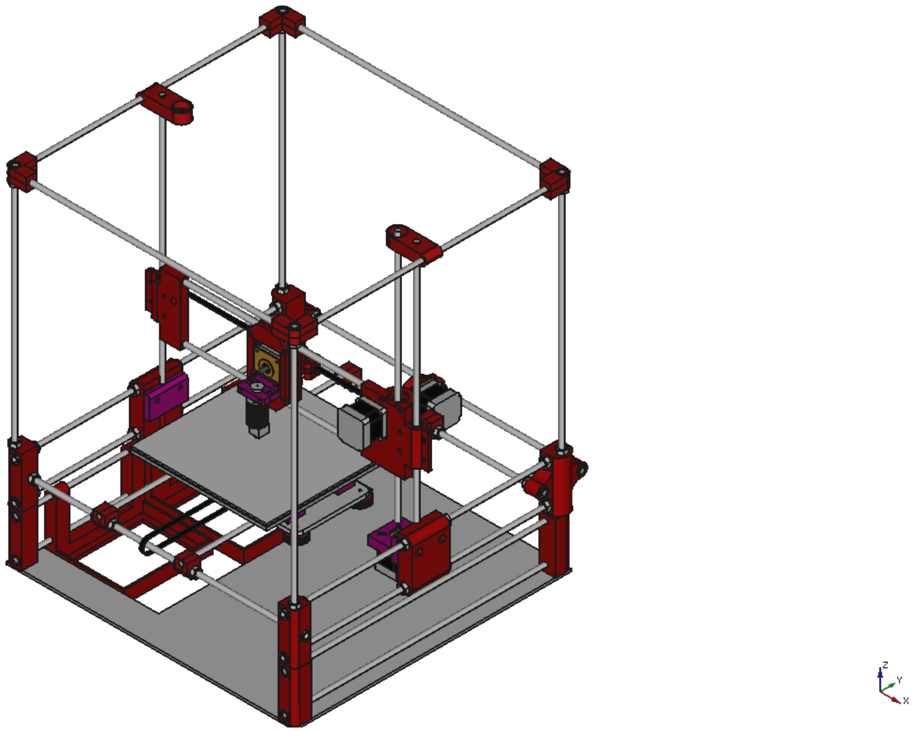
AGH

AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND ROBOTICS

Fundamentals of design of mechanisms in Mechatronic devices

3D Printers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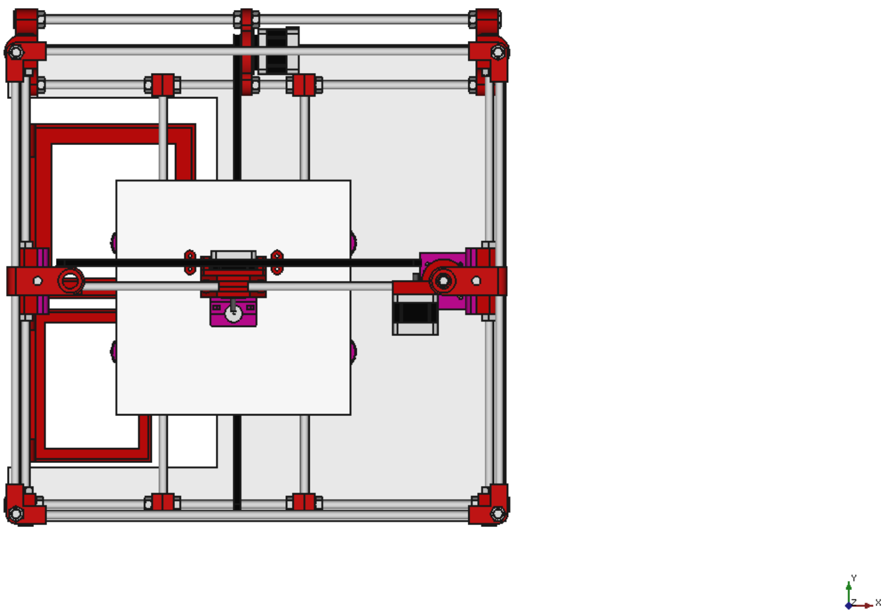
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Preliminaries

What is 3D printing?
3D printer technology has been evolving since the process was first patented in the 1980's. Since then, many different iterations have been created that rely on vastly different processes. However, the base principle remains the same. The output is a 3D model commonly, but not excluded to a plastic material, that is conceived through the formation of successive layers. Alternatively it is known as additive manufacturing, opposed to CNC milling, which forms objects by cutting away raw material.

If we take a step back and look at 3D printing as a whole, we can notice it is composed of several key parts. The first is the printing surface. Whether it be a heated aluminum sheet or a glass pane covered in tape, the plastic needs a surface to begin printing on. This surface is commonly referred to as the printing bed. The next component is the raw material. Plastic is a very common material for printing and we usually encounter it in two raw forms, either as a liquid or as rolled wire known as filament. The next component is a device that takes the plastic in its raw form and transforms it into its final form and the last component is a mechanism that places the plastic on the printing bed. If we put all these pieces together, we get a machine that produces an object in three dimensional space.

There still lies a software aspect to 3D printing. Typically, the process of designing and printing a model begins with a computer aided design program (CAD). These programs are very user friendly and allow you to see how the model will look before being printed.

Afterwards, the model is typically exported as an STL file before being converted into G-code, which is fed directly to the printer. Before the printing can begin, there are many decisions that need to be made, such as what material will be used, the resolution of the print, fill density, whether to use a heat bed, what temperature to use in order to avoid print deformations, etc. The printer also needs to be properly prepared and calibrated to achieve a successful print.

A print can last anywhere from a few minutes to a few days depending on the size, complexity and resolution of the print. The final step after the printer is finished is to finalize the part. Since the printer layers materials on top of each other, the print won't be as smooth as a molded part. Many like to sand, paint or dip the printed models in various chemicals to achieve various effects.

In all, the process is long and differs between different printers. Many things can be automated, calibration for instance, however this raises the price of these machines and make them more inaccessible to the public.

The reason printers have become so popular and accessible is because of how many of them are open-sourced. The aim of many of these projects is to create a reliable and friendly printer that can be used as a learning tool.

Types of 3D Printers
Stereolithography (SLA)
This method of printing is one of the oldest and simplest to implement. The basic premise is to have a UV laser cause a chemical reaction in a vat of photopolymer resin to form polymers. The laser draws a 2 dimensional shape and builds layers to form the complete object. This technology is rarely used to produce final products, but rather to rapidly prototype and visualize designs.

Digital Light Processing (DLP)
This process is very similar to SLA printing. DLP printers dispose of the laser and use more conventional sources of light, most commonly projectors. This light shines on a vat of liquid plastic resin which hardens quickly when in contact with large amounts of light. The object is created layer by layer exactly like the SLA method. The advantage it has over SLA printing is that it is much faster. Unlike the SLA printer where the laser slowly creates a layer of plastic, the DLP printer creates an entire layer at once.

Pros: Very high quality prints
Capable of making small parts

Cons: The resin is expensive
The finished product maybe brittle and breaks down under UV light
Takes a long time to print

Fused Deposition Modeling (FDM)
This process takes advantage of thermoplastics. Objects are built from the bottom up by heating a thermoplastic filament to its melting point and extruding it layer by layer. This has many advantages over its counterparts, it allows for printing of more materials in one build, the plastics have better chemical and physical properties and the filament is much cheaper than vats of resin.

Pros: Can make low resolution parts faster and stronger
Low cost plastic filament
Higher quality plastics
Capable of printing many materials at once

Cons: Lower quality prints

There are many more methods and processes, each more advanced than the last. However, the two leading technologies are DLP and FDM printing.

A general comparison between the two leading technologies would show that DLP printing can make prints of incredible detail at a cost of physical robustness, while FDM prints are much stronger but loose on quality of print. A common conclusion is that both are useful in an engineers workshop, they both have their use cases depending on the task on hand.

Variations of FDM Printers
With FDM printing, a plastic is heated to its melting point and extruded in a specific pattern. In order to achieve a pattern, a mechanical machine is required to draw it with the plastic. This mechanism has to be able to move in 3 dimensional space to produce the 3D structure. There are many schools of thought to achieve this. The two leading ones are Delta and Cartesian printers.

Delta Printer
These printers typically have three vertical axises, each axis allows the up and down movement of a rod. All three rods connect in the center where the extruder is located. To calculate the position of the printer head, the use of trigonometric functions are necessary.

Pros: Very fast movements
Large printing volume
Small footprint

Cons: Complex to build, maintain and calibrate
Experience extruder problems as the motor is separated from the printer nozzle

Cartesian Printer
The reason these are so popular is because they are simple. They have three axises, each moves in either the x, y or z direction. Therefore the position of the extruder is already directly accessible, as apposed to the delta printer where extra calculations are necessary. To further categorize the Cartesian printer, we can divide them into printers where the bed does the x motion and the extruder does the y and z motions or the bed does the z motion and the extruder moves in the x and y directions. These types of mechanisms are also commonly seen in CNC mills and even 2D printers except of course without the z axis.

Pros: Low cost
Simple to build, maintain and calibrate
Can print with great accuracy

Cons: Larger than delta printers
Slower than delta printers

There are many other methods of printing; Six-Axis printers, SCARA printers and Polar printers. However, as the complexity increases, so does the likelihood of a failed print or unforeseen problems.

Applications of 3D Printing
In its early days, 3D printing was seen as the successor to the production line. However, because of its high production costs, it has found other more practical uses. The traditional method of mass producing plastic parts includes creating molds and injecting them with plastic. This is a quick and reliable method and remains to be one of the most efficient mass production processes. However with each new part, a new mold has to be created. This is the advantage of 3D printers, they allow each print to be easily customized without long prep work. The process of mass production of customizable elements to create differentiating products is called mass customization and is almost exclusively possible because of 3D printing technology. An example would be the production of custom fit prosthetics or smart phone companies providing personal designed phone cases.

3D printers are perfect for rapid prototyping as they can print multiple pieces at once and don't require lengthy special prep work. Prototyping can be rather tedious with other methods such as with molding, where for every iteration of the product a new mold has to be created. Printing makes the development of new products and research much easier and more accessible as specialized tools are not needed.
The effects of 3D printing are quickly spreading to medical applications as well. Today we can order custom fit 3D printed prosthetics, but in a matter of years bio-printed organs will become accessible. 3D printers have also shown up in the apparel and jewelry business as artists have new ways of expressing their ideas. The Zero-G printer can print in zero gravity, this makes it possible to simply send a 3D printer into space and create tools only when they are needed, saving on fuel and costs. The 3D printer has become widespread and are a crucial part in many processes.

Hardware

Overview
For the electronics of the printer, we have chosen the RepRap Generation 7 Electronics. This is an open source project that provides a single board, single sided, replicable PCB. Since the board contains no smd parts, every single part is easily replaceable or upgradeable.

Hot End
The hot end ranges in quality and pricing from low cost all plastic versions to the longer lasting full metal options. Before purchasing a hot end, the materials being printed need to be considered as every hot end isn't capable of printing in all materials. Also the quality of the hot end will be reflected in the print. For our printer we have chosen the full metal 1.75 J-head nozzle with 0.2/0.4 nozzle thickness. The J-head nozzle family is a combination of many other hot end designs with the goal of designing a part with minimal required machining to achieve the simplest design at a low cost. It proves to be reliable, effective and very easy to find online.

http://reprap.org/wiki/Gen7_Board_1.4.1

Sensors
Our build will take advantage of two types of sensors; temperature and mechanical endstops.

Thermistor
The printer requires two thermistors to regulate the temperature at the hot end and the heated bed.

Mechanical Endstop
There will be a total of 5 mechanical endstops. Their main purpose is to provide feedback as to where different parts of the printer are located.

Two endstops will be located on either side of the X-axis. These will provide homing and calibration purposes. During the initial set up of the printer, the distance between the two endstops will be carefully measured and encoded in the software. With each new print, the X-carriage will travel between the two endstops and remove any error in travel distance. Once calibrated, the carriage will home to one axis to prepare for the next phase of calibration/printing.

The following two endstops will be located on the Y-axis in a similar manner and will perform the same function as described on the X-axis.

The final endstop will be located on the X-carriage, which will be activated by the extruder lever part. It will serve to provide adaptive bed leveling and set first layer printing height. The sensor will first measure the level of the bed. With the given information we may either manually level the bed with software assistance or allow the software to completely compensate for the unleveled bed. After the calibration phase is complete, the endstop will signal when the hot end has made contact with bed and decide on the appropriate initial layer height.

Gen7 Board-AVR 1.5

A single-sided open-source board with all the features required to run a printer that also includes a header to plug in extension boards for future expansion. The board can either be manufactured by the user, or by a professional manufacture.

40zł

The full list of parts can be found on:
http://reprap.org/wiki/Gen7_Board-AVR_1.5#Parts_Lists
The cost of electronic components and connectors, does not include microcontrollers.

20zł

Gen7 Board can be populated with several versions of the *ATmega***4* microcontroller. All types of this family have same pinout and features, the only difference between them is size of memory.
It could be:

- ATmega1284/A/P/PA
- ATmega644/A/P/PA
- ATmega324/A/P/PA
- ATmega164/A/P/PA

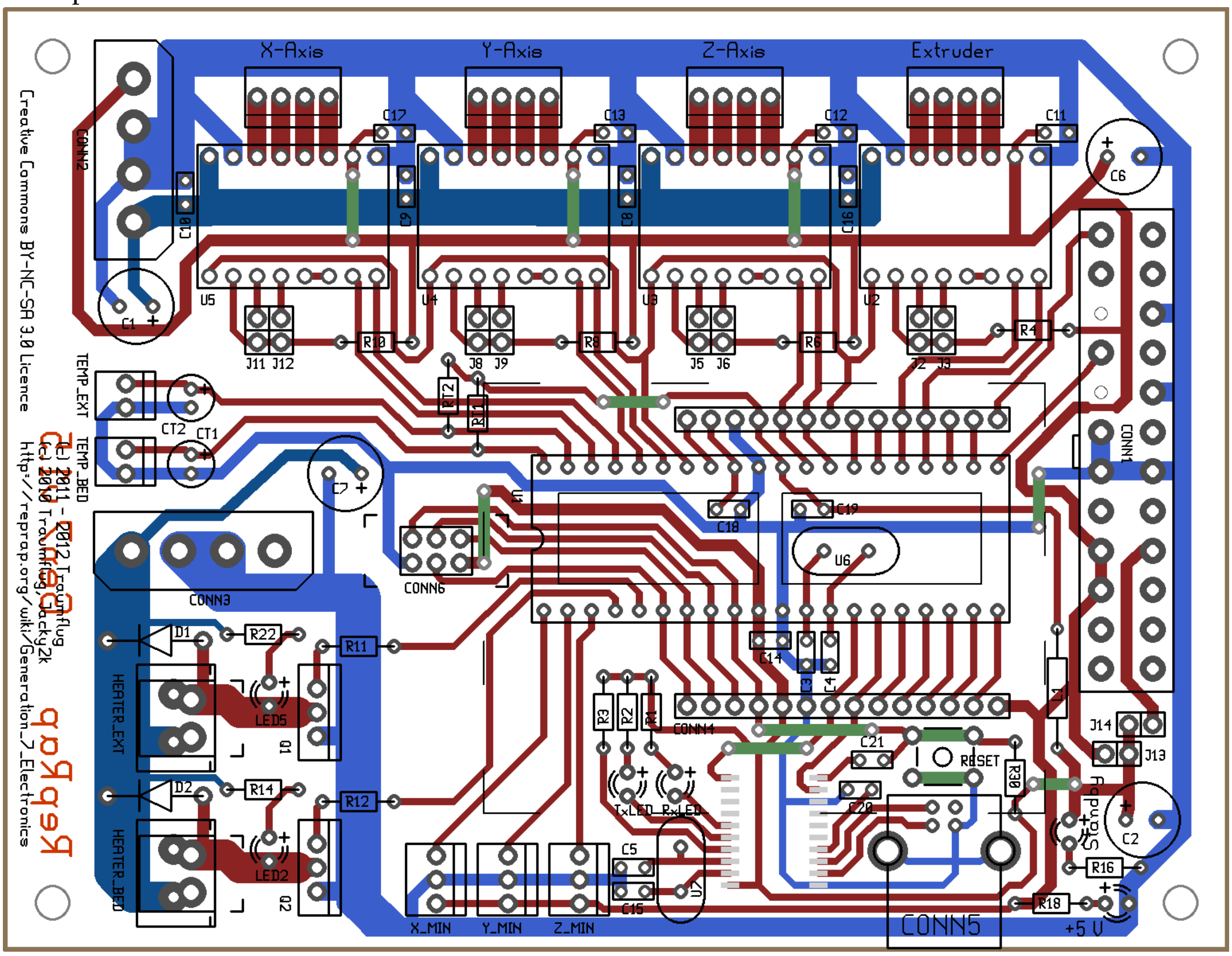
15zł
for ATmega164

to

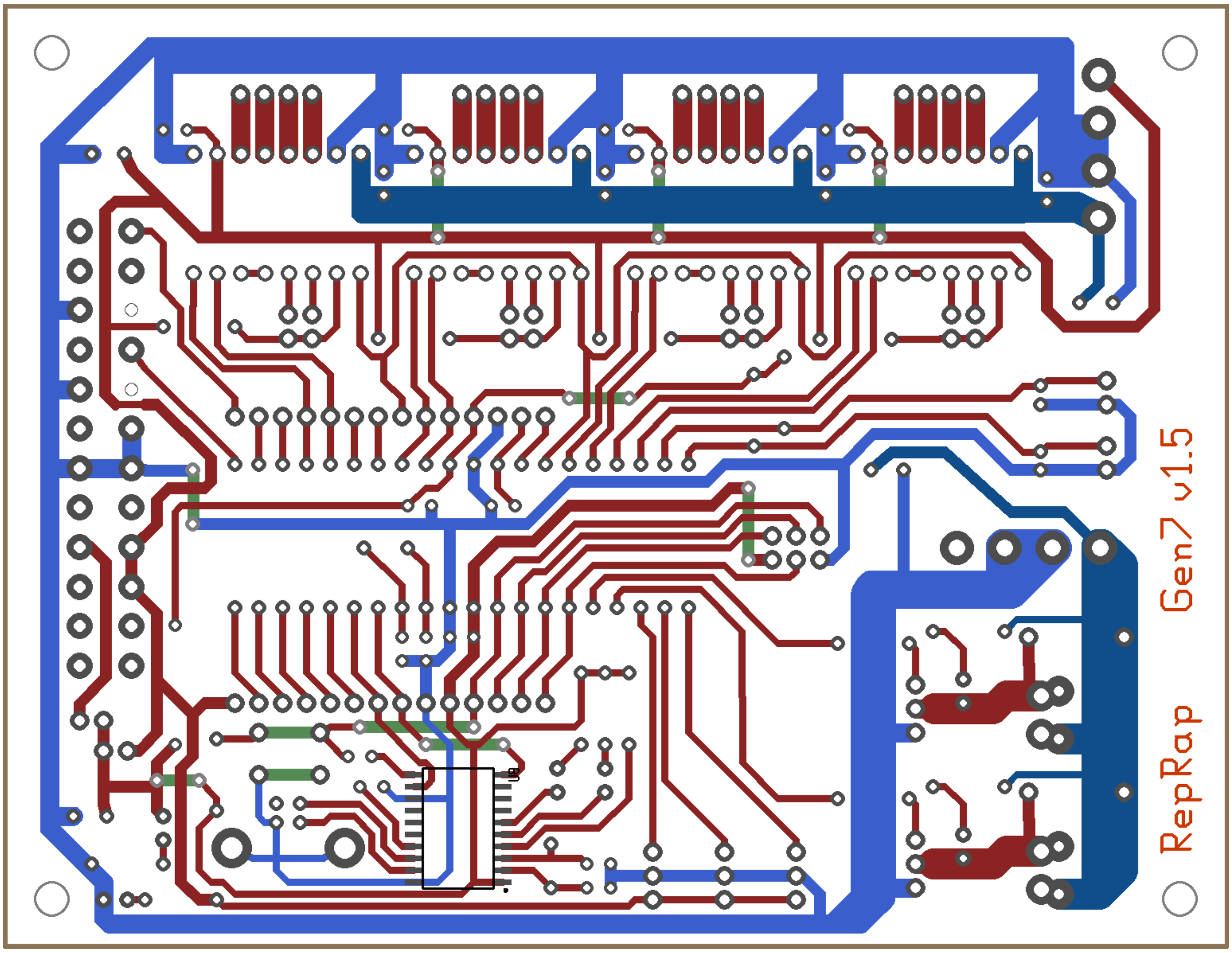
30zł
for ATmega1284

Cost for final product: **90zł**

Top view:



Bottom view:



The assembly instructions are available at http://reprap.org/wiki/Gen7_Board-AVR_1.5#Assembly_Instructions

Software

Overview

The process that begins from the conception of an idea to the finalized product requires many tools and softwares. Usually the first software that needs to be chosen is the 3D modeling software.

The decision as to which software will be the best needs to be based on your hardware, precision, experience and budget. Since 3D printing has been popularized, many user friendly modeling softwares have been released such as Cura, Craftware, 123D Catch and TinkerCAD from Autodesk and 3D Slash to name a few. These allow beginners to easily access the market and try their hand at designing. However they often lack functionality or precision.

More advanced modeling software includes Sketchup and the program that we will be using, FreeCAD. The last group of modeling softwares include professional suites, which require capable hardware and come at a larger price.

FreeCAD is a free open-source parametric 3D modeling application that runs on most operating systems. The largest advantage is that it is parametric based, meaning all objects are controlled by parameters allowing for very precise builds. The downside is that there is a learning curve to overcome and might be difficult to produce error free builds without prior experience with CAD software.

After your model is complete, it will need to be exported as an STL(STereoLithography) file. This format is an agreed upon norm, the model is described by its triangulated surface geometry. It is convenient to first convert the solid model into a mesh before exporting as an STL, however it is not always necessary.

For the actual printer interface, you will need three programs; a program for slicing, a host and the firmware. Often times, these programs are packaged into one. It can be convenient to even have several of these programs installed at once.

A very useful software is Slic3r. Slic3r, as the name suggests, slices the object into layers and decides the best way for the printer to maneuver the print. This software is printer specific, you need to provide all information about your printer including nozzle thickness, print quality, temperatures etc. Then based on the information provided, the Slic3r converts a STL object into G-code, which are step by step instructions for the 3D printer.

Slic3r is very good for the calibration phase of the printer as it allows you to very quickly change the settings. However after the printer is working and ready, Cura proves to be a better more reliable alternative.

The G-code can be loaded into the printer interface, or commonly known as the host. The host shows you information such as sensor readings, number of layers printed, estimated time left and allows manual control over the printer through G-code in the terminal or through a more friendlier user interface. For the calibration phase, pronterface is easy to work with, however we will be transitioning to repetier host after the calibration is complete.

When it comes to the firmware, the Gen7 board can run several different firmwares including Teacup, FiveD, Repetier, Sprinter, Marlin. The firmware choice is entirely up to the user. We will be using the Repetier firmware, which is a fork of the alternative sprinter firmware.

Due to the nature of 3D printing being open-source, so are most of the softwares. That is why many come at no price at all and are multi-platform. Many times it is useful to have several programs installed depending on the task at hand. For instance TinkerCAD allows for very quick modeling and having a print ready in minutes, whereas FreeCAD requires more attention to detail and the process of designing is much more time consuming, but allows for precise models.

Calculations

Stepper Motors
X/Y-axis
The X and Y axes are driven by a belt, which allows for quick changes of direction. However, since the stepper motor is operating at higher speeds, its torque will be significantly lowered. To predict the motors torque we need a dynamic performance curve for the stepper motor.
These curves differ between motor models and their drivers, therefore it will be difficult to get a precise curve for our configuration.

An exceptional printing speed is 350mm/s with maximum acceleration. However, the maximum speed largely depends on the extruder and its flow rate, which is difficult to calculate before hand. Therefore the printer will most likely be running at much lower speeds, however it is good to know the limits of the printer.

The diameter of our pulley is 15mm. Therefore one turn of the pulley moves the belt 47mm. To achieve 350mm/s, our pulley needs to turn 7.5 times per second (or 450 rpm). That will give the motor a maximum angular velocity of: $\frac{7.5\,turns}{1\,s} = 7.5\frac{2\pi\,rad}{1\,s} = 47\frac{rad}{s}$.
If we observe several dynamic curves, we can notice that most Nema 17 motors will still operate at above 15[Ncm] with such speeds. This gives a maximum pull of 20[N] on the belts.

Estimating the maximum **moving mass will be 0.75kg**, this gives our printer a maximum **acceleration of around 2600mm/s^2.** This acceleration may be lowered to increase the smoothness of the print, however the acceleration should not be further increased if the printer is to print at a **velocity of 350mm/s.**

Z-axis motors
The main purpose of these motors is to drive the Z-axis. The motors will drive lead screws, which in turn raise or lower collars attached to the X-axis. The movements are small and incremental, meaning it will not be rapidly changing directions like the other axes, this is why using a lead screw is more practical than another belt drive.

Let us assume we will be using a 4 lead M8 lead screw with a thread density of 52 threads per 10cm. Meaning to raise an object 1 cm, we need to rotate the screw 1.3 times.

We will be using the work energy theorem to calculate the torque needed to lift the X-axis.

Work needed to be done to lift the X-axis: $mgh_1 + W_h + W_{other} = mgh_2$

,where $F_x = mg$ is the force of the X-axis due to gravitational acceleration
W_h is the energy needed to change the X-axis height
$W_{other} = -\mu F_n \Delta h$ is the energy lost due to friction

After reconfiguring our equation, we get the following: $W_h = F_x \Delta h + \mu F_n \Delta h$

Work needed to be done to rotate the lead screw an angle of θ : $W_\theta = \tau\Delta\theta$
,where W_θ is the energy needed to rotate the lead screw
$\Delta\theta$ is the angle of rotation
τ is the torque of the motor

Relationship between Δh and $\Delta\theta$: $\Delta h(1.3) = \Delta\theta$

With the above relationship, we now know how the raise height of the X-axis is dependent on the angle of rotation of the lead screw. Therefore we can compare the energy needed to rotate the shaft to the energy needed to lift the shaft.
If we combine the three above equations, we get the following:

$$\tau = \frac{1}{1.3}\left(F_x + \mu F_n\right)$$

Since we want to know the maximum torque we need supplied by our motor, we need to find when the potential energy is increasing. Therefore the maximum torque required by our motor will be encountered when the X-axis is being raised. We will now only examine this one scenario.

Since the motion is strictly vertical, we know that the normal force of friction is parallel to the lead screw, more specifically we know that it is equal to F_x . This gives us the new equation:

$$\tau = \frac{F_x(1+\mu)}{1.3} \qquad \text{in} \quad [Ncm]$$

As we can see, the torque needed to drive the Z-axis is rather small. Even with a large weight of the X-axis and a large friction coefficient of 15[N] and 0.3 respectively, we need a torque of only 15[Ncm]. If we have two motors driving the Z-axis, the torque on an individual motor will be halved, further reducing the maximum torque.

$$\tau_{max} = \frac{15 \cdot 1.3}{1.3} = 15[Ncm]$$

Based on the above calculations, we may conclude that two small stepper motors of a torque of at least 10[Ncm] will suffice at driving our system. However, since one small mistake can ruin an entire print, larger motors are preferred. A larger motor can potentially avoid overheating as it may be active for many hours and more torque guarantees the motor does not skip. Also since the motor is attached to the frame in a stationary position, the additional weight added to the build by larger motors does not affect its performance.

<u>Extruder motor</u>
The function of the extruder motor is to supply the plastic to the extruder, and supply the necessary pressure to extrude the melted form from the nozzle. Here the selection of motors is much more delicate, as too large of a torque may strip the plastic filament and fail pushing it into the extruder and too small of a torque will fail to provide the necessary flow rate for a consistent print.

Another point to consider is that since the motor is attached to the X-carriage, it is being moved along both the X and Z-axes. Therefore to reduce strain on the other motors, it is preferable for the motor to be as light as possible.

To make the calculations even more difficult, the torque needed differs between plastics and operating temperatures.

That is why it is common to create a gearing system or simply attach a larger Nema 23 motor.

<u>Conclusion</u>
Choosing a stepper motor for a printer is mostly about just not choosing one that is too small. The Z-axis requires the least torque, with two motors on each side, you might be able to get away with a Nema 14 if the printer was made lightweight, however a Nema 17 stepper motor is the more reasonable choice.

The X and Y-axes require a minimum Nema 17 motor, with the possible upgrade to a Nema 23 if you want to increase speeds. However the extruder motor has to be at least a Nema 23, or a Nema 17 with additional gearing to increase the torque with the cost of printing speed.

The reason stepper motors are used in the first place is because they are low cost, reliable and easy to drive. Other options, such as servos are severely more complicated. For instance, to move a stepper motor into correct position, a single drive pulse will turn it by a specific predetermined angle into a natural stopping point for the motor shaft. Since a stepper motor can have even 100 poles, it is very accurate. A servo on the other hand has very few poles and require a much more complex encoder to position correctly.

Another advantage of stepper motors is that they provide a constant holding torque without the need to be powered. However, they fail when they need to provide high torque at high speeds.

Since printing speed is also largely limited to the plastic being printed, as high speeds can put unnecessary shear stress on the hardening filament, lower speeds are preferred. In summary, stepper motors are well in their working zone and servo replacements are not necessary for most printers.

Resolution

The resolution of the printer depends on the stepper motors and on the mechanics being used to drive each axes. Performance differs by motor; 2-Phase and 5-Phase motors, or unipolar and bipolar motors all provide different resolutions and torques.

Here are general rules to identify your motor:

- 4 Wires: Bipolar only
- 5 Wires: Unipolar only
- 6 Wires: Universal
- 8 Wires: Universal

The resolution is also dependent on the way the motor is being driven. Wave Drive, Full Step, Half Step and Microstep are the most common drive methods and each differs in performance.

Our printer will take advantage of *2-Phase 4 lead Bipolar motors of a step count of 200 steps/revolution*.

With the parameters of the motor chosen, the following calculations are trivial. With 200 steps/revolution, the smallest possible turn of the motor is 1.8 degrees.

The **X and Y axes** are both belt driven and are symmetrical, meaning the resolution of both will be identical. The radius of the timing pulley is 6mm. This gives a diameter of around 37,7mm. If the motor where to turn one step, a point on the timing pulley would have moved only 1/200 of its diameter. This is also represents how much the belt was moved. Roughly equaling 0.19mm or **190microns**.

For the **Z-axis**, we have to consider how a 1.8 degrees of rotation results in the vertical translation of the driving nut on the lead screw. Let us assume we will be using a 4 lead M8 lead screw with a thread density of 52 threads per 10cm. Meaning to raise an object 1 cm, we need to rotate the screw 1.3 times. How much will the object raise if we rotate the screw 1/200 times? Using proportions, we come to the conclusion that the motor will move the driving nut by 0.0038mm or **3.8microns**.

The print resolution also largely depends on the **hot end** and how thick the plastic is. The smallest acquirable nozzle size is 0.2mm, **200microns**. In the X and Y axis, anything with more resolution than the nozzle width is lost. As we can see, our configuration perfectly accommodates this nozzle size.

The vertical resolution directly affects the duration of the print, the more layers it has to print the longer it will take, therefore the layer height largely depends on the print on hand. However, for the maximum layer height we need additional information on the extruder's capabilities. The more resolution required, the better the control over filament flow needs to be to avoid over/under extrusion. This parameter is usually defined through practice with a specific printer.

Features

Calibration and Maintenance
Calibration is a very important to have well printed parts. There are several calibration procedures that need to be done only once, and others that are more routine. For instance, when a printer is first turned on, the amount of current going into the motors needs to be tweaked, the thermistors need to be checked if they are showing accurate temperatures and the endstops need to be correctly positioned. Other routine procedures comprise of belt tensioning, bed leveling, extruder maintenance, motor scaling (making sure that 1mm is 1mm) and checking that all the cables are correctly connected and not damaged. These steps are important to not only ensure the print will go smoothly, but also as a safety precaution.

This process can be enduring, however there are many ways to automate these processes. Self-calibration can allow for more consistent prints by avoiding human errors and can greatly speed up the preparation time of the printer.

Important aspects of calibration:

Endstop Scaling Calibration

Bed Leveling

Belt Tensioner

Modularity
Sooner or later the parts will need to be replaced or upgraded. Having a printer that can easily disassemble without unscrewing twenty bolts will prove to be more comfortable to work with. However, sturdiness of the printer is obviously a priority. The goal is to have a printer that is easy to disassemble, yet doesn’t sacrifice on quality of print.

Project Summary	
Printer Type:	Cartesian Fused Deposition Modeling Printer The parts are produced by using 3D Printer technology.
Software:	CAD: *FreeCad* Host: *Pronterface* Slicer: *Slic3er* Firmware: *Repetier*
Motors:	*Nema 17/23 Stepper motors* Theoretical Resolution X/Y-axis: 0.19mm w/ $v_{max}=350\,mm/s$, $a_{max}=2600\,mm/s^2$ Z-axis: 0.0038mm These are the maximum possible resolution values, however in practice these velocities and accelerations are only useful for calibration and testing. Actual printing speeds are much lower and greatly range depending on the print. Plastic: 0.2mm (thickness)
Hot End:	Full metal 1.75 J-head nozzle with 0.2/0.4 nozzle thickness. Maximum temperature of 250deg, capable of printing with PLA and ABS.
Electronics:	Gen7 Board-AVR 1.5 Supports two thermistor sensors, three endstop sensors, bed heating, hot end heating, pololu stepper motor drivers, usb connection interface, and additional modules. The printer will include a heated bed, which greatly improves ABS adhesion to printing surface and prevents warping due to temperature changes. There will also be a cooling fan for the Gen7 board to ensure a cool operating temperature for long prints.
Sensors:	5 Endstop sensors (Two connected in parallel for the X and Y axis) 2 Thermistors (Heatbed and HotEnd)
Additional Features:	Self-calibrating - Software bed leveling, Axis distance calibration Modular - Its stack structure allows for quick replacement of parts Self-contained - External processing power is not required apart from modeling Open source – The entire project may be found on github https://github.com/drdurczok/3DPrinter

List of parts:

Parts	**Qty**	**Price per element**	**Sum**
RepRap Gen7 Electronics	1	180 zł	180 zł
ATX12V/BTX PSU	1	30 zł	30 zł
Nema 17 Stepper motor	3	50 zł	150 zł
Nema 23 Stepper motor	1	60zł	60zł
Full metal 1.75 J-head, 0.2 nozzle	1	60 zł	60 zł
PCB 20x20cm heat bed	1	20 zł	20 zł
Plexi glass 4mm (20x20cm)	1	4.50 zł	4.50 zł
Plexi glass 4mm (12x20cm)	1	4.50 zł	4.50 zł
Heat sink (3x3cm)	3	10 zł	30 zł
Fan	1	10 zł	10 zł
Mechanical Endstops	5	6 zł	30 zł
LM8UU Linear Ball Bearing 8mm diameter	10	3 zł	30 zł
608ZZ 8x22x7 Metric Roller Bearing	3	3 zł	9 zł
L630ZZ 3x6x2.5 Metric Roller Bearing	1	3 zł	3 zł
Smooth Rod M8	6	22 zł	132 zł
Threaded rod M8 + Nuts	1	40 zł	40 zł
GT2 2mm pitch 6mm wide Timing Belt	5 meters	30 zł	30 zł
Aluminum GT2 Pulley	2	20 zł	20 zł
Plastic Elements		150 zł	150 zł
Compression Springs 8-10-30mm	5	2 zł	10 zł
Cables	10 meters	20 zł	20 zł
Kapton tape 40 mm	1	40 zł	40 zł
Screws M8/M3, nuts, washers, pulleys		50 zł	50 zł
Coupler	2	5 zł	10 zł
48D30D27M8 Series EN 448R Foot Level	4	5 zł	20 zł
TOTAL			1064 zł