Simple Solder

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ABSTRACT

In this paper, the design and construction of the 'Simple Solder' device is presented. The Simple Solder aims to allow users the ability to quickly and effortlessly solder electrical components using a computer numeric controlled (CNC) device. The goal of the design, is to create an inexpensive and user friendly soldering CNC mechanism capable of fusing simple electronic pieces onto a small electrical board.

Most of the CNC soldering systems currently available to the public, are of industrial grade. For the most part, these machines have large footprints but at a high cost. At the time of this writing, there are no economical options or solutions available for home use. Generally, soldering electrical components is done manually with a soldering tool and soldering material. For these reasons, the main objective is to create a low-cost and easy to use CNC system for personal use. By making use of open-source software and easy to manufacture components, the production cost is maintained low and the simplicity and robustness of the Simple Solder high.

An initial 3D model was designed using custom components, which was ultimately abandoned due to time and complexity constraints. Instead, an Anet A8 3D printer, was modified to allow for solder extrusion, manual positioning control, and adaptability for multiple soldering irons. Through the low cost of the printer and the use of a 3D printer mount instead of the extruder, the printer was transformed into the Simple Solder. Utilizing the Repetier Host firmware and software, we were able to calibrate and change movement controls for the printer, as well as send manually generated G-code for movement and solder extrusion. It was found that the G-code editor incorporated with the Repetier Host was an excellent resource, for it automatically comments on its specific G-code functions.

Keywords

CNC Soldering, 3D printing.

1. INTRODUCTION

The motivation in creating the Simple Solder, is to produce a printable 3D CNC style soldering machine. Simple and affordable, the Simple Solder can be used by advanced and beginners alike. Simple modifications to the mounting tool, allow for a variety of soldering tools to be fitted. Once attached, it can then be used to solder electrical components with high accuracy and precision in a quick manner.

The benefits of creating an affordable CNC style soldering device, is to allow the customer to have all skills, precision, and accuracy needed to solder electrical components autonomously. Simple Solder will be targeted at beginners, hobby enthusiasts, and eventually manufacturing facilities. The secondary objective of the Simple Solder is to completely eliminate the risk of damaging electrical components or boards due to faulty connections or human error. Furthermore, it can also be used by hobby-level enthusiasts who want to replicate PCB's or electrical designs due to its repeatability and elimination of hand labor. Simple Solder will also teach the user how much material should be used.

2. SOLDERING CNCs

The two most common CNC soldering devices that are currently available are Pick-n-Place, and SMD Heat soldering machines. The Pick-and-Place machines work by picking up components that have solder paste applied to them, and then placing those components onto a printed circuit board shown in Figure 1. After all components have been positioned, the board is then placed in an oven which melts the solder paste fixing the components to the board.

Surface Mount Diode works in a similar fashion. Solder paste and flux is first applied to the board, usually with a machine. The components are then placed in position, either manually or with a machine, and a heat gun/torch flows the solder into position. SMD soldering machines are typically very precise, and capable of soldering extremely small components with high precision. However, special care must be taken to not overheat the board or components with this method. Since the torch or heat gun is a localized high temperature source, it may be more difficult to accurately control.

Both types of soldering devices are very large and are typically used for industrial mass production of circuit boards and electronics. Their high price, ranging from $2,000 to well above $250,000, may prevent potential consumers from attaining one. Currently, there are no products available that can mimic the Simple Solder's capabilities at its current size and cost. Without doubt, the system

has the potential to be very profitable and desired by a wide range of consumers.

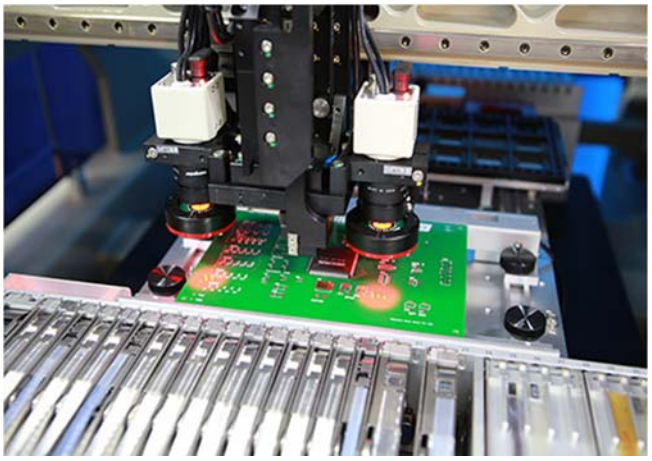

Figure 1. Pick and Place Soldering

2.1 Conceptual Design

The main goal of this project, is to create a cheap and easy to use soldering CNC machine. This mechanism, is designed to assist with small and medium component soldering. In order to guarantee repeatability with high precession and accuracy, several components were considered. In the end, the following software and hardware devices are utilized in the prototype.

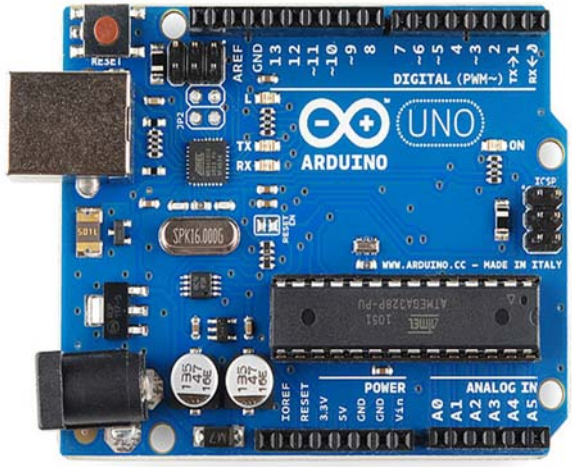

Figure 2. Arduino

Shown in Figure 2, the Arduino, is a micro-sized integrated circuit chip used for the control of electrical devices and mechanisms. It is also an open source software that features thousands of libraries, firmware revisions, use cases, and applications. It is intended for anyone making interactive projects such as the Simple Solder or other. Arduino boards can receive information from several sensors or the user and sends commands to devices such as LED technology or step motors depending on the application. The Arduino language consists of a set of C/C++ functions that can be called from code to execute the actions needed.

The original design called for the use of an Arduino Uno and a motor driver 'hat' to move the solder. A PC power supply would be used to provide 12V power. A number of Arduino-compatible firmware and control programs were considered for this project. Ultimately, LinuxCNC was chosen to control the Simple Solder prototype.

Figure 3. Linux CNC

LinuxCNC is a computer software program used for numerical control of different types of machines. Some of these are milling machines, lathes and plasma cutters, routers, cutting machines, robots and hexapods among others. The software is capable of controlling up to 9 axis or joints of a CNC machine using G-code. G-code, which has many variants, is the common name for the most widely used numerical control programming language. It is used mainly in computer-aided manufacturing to control automated machine tools. LinuxCNC has several specific kinds of usage such as touch screen, and other interactive devices. Currently, it is almost exclusively used on PC. The software makes extensive use of a real time-modified kernel, and supports both stepper-motors as planned to use. Additionally, LinuxCNC uses the model of interactions with hardware. For instance, it reads the current axis position, calculates a new target position/voltage, and then writes that to the hardware before executing the necessary movements.

Figure 4. Stepper Motor

The stepper motor is used in applications requiring about 2000 rpm or less, where high torque is needed at the low end. Typically, a servo motor is used for higher speed applications that are more dynamic and require more acceleration and deceleration. However,

the stepper motor is an electromagnetic device that converts digital pulses into mechanical shaft rotation. Some of the advantages of stepper motors are low cost, high reliability, high torque at low speeds, and their simplicity to control. These are also usually robust and are able to operate in a number of environments. This makes them more than ideal for a home environment where the CNC machines may be exposed to dirt, debris, or run for extended periods of time. The way stepper motors work, consists of a permanent magnetic rotating shaft, called the rotor, and electromagnets on the stationary portion that surrounds the motor, called the stator. Stepper motors have a step angle that determine the angular position of the shaft. Dividing one revolution by the step angle of the motor, gives the number of steps necessary to rotate the shaft to the desired positon. The Arduino controls the motor increments by sending electrical pulses to the spindle, allowing for rotation for both clockwise and counter clockwise directions.

Figure 5. 3D Printer

A 3D model is created one layer at time by similar printers to the one shown in Figure 5. This process is called rapid prototyping, or 3D printing. A common procedure of rapid printing, is to first apply a fine material such as PLA or ABS in a 3D inkjet printer. The machine then prints out several layers of powder on a bed creating a fixed object. The design is defined by a 3D STL file, which is the format used by most 3D printers. In addition to solid material pallets, the printer is able to use liquids such as photopolymers.

Nowadays, 3D printers are mainly used in applications that require short lead times but are highly complex. These include not only applications in medicine and architecture, but also in the entertainment industry. Today there are more and more companies that specialize in the printing of 3D models and provide services for businesses and individuals as planned for the Simple Solder. However, the biggest drawback for the regular user, is still the high cost of 3D printing services. Another drawback, the long time it takes to print a 3D model, depending on the complexity and resolution of the model. Furthermore, professional 3D software and 3D model designs are in a high cost range. Alternatively, there are several 3D printers available at a lower cost but at a lower printing resolution.

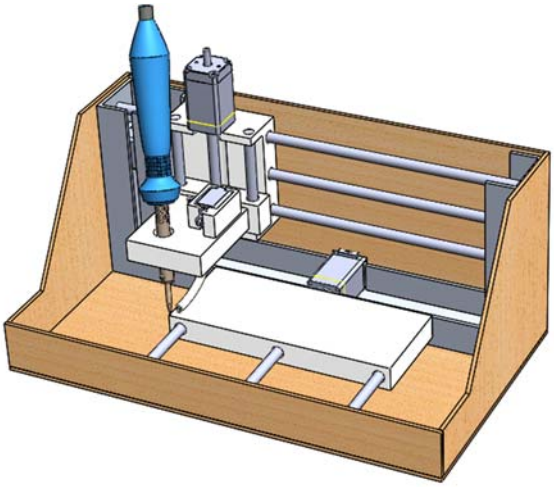

Figure 6. Initial Conceptual Design of Mill

The Initial conceptual design uses three Nema-11 stepper motors for the three primary axes. These are used due to their relatively low weight, small size, and medium torque. An additional Nema-8 stepper motor is used for the solder extrusion seen in Figure 7. The working area of the prototype is a rectangular cuboid of 7.5” x 3” x 3”, allowing the user to solder relatively large PCB boards, tall components, or allow the use of clamps, hold downs, and other devices.

A fixed y-axis gantry was chosen to minimize end-effector movement, since it would carry the heaviest components of the machine. The bed moves linearly along the y-axis with the PCB board or components that are to be soldered. Ideally, z-axis movements would only take place while the bed, x-axis, and y-axis are all stationary. This reduces play in the tip of the iron and allows for repeatable movements. The end effector, solder extruder motor, extrusion tube, soldering iron, and other features, can be seen in Figure 7.

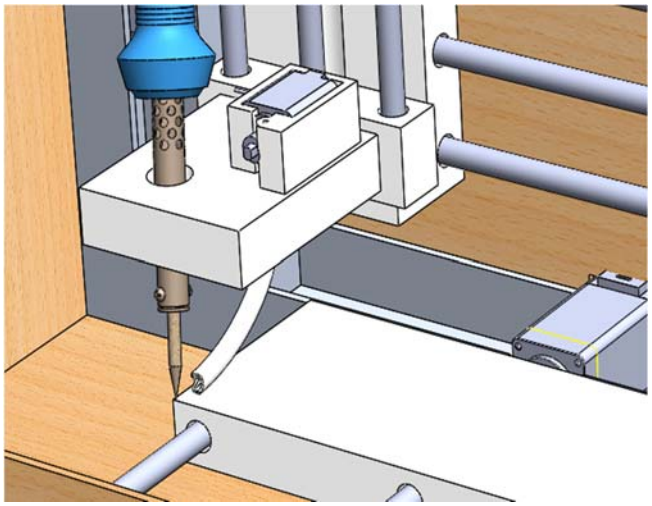

Figure 7. End Effector Detail

3. PROTOTYPE AND EXPERIMENTAL PROCEDURE

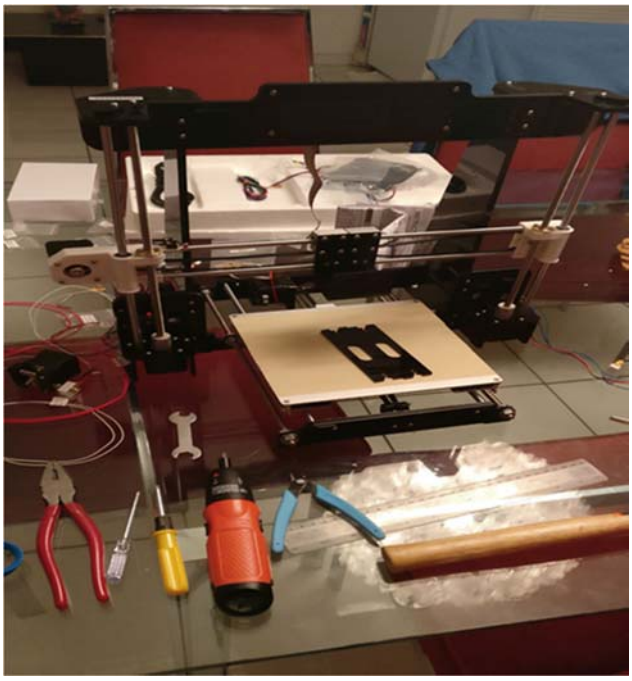

Figure 8. Simple Solder Building Phase

The CNC frame components that were used to hold the entire system together are shown in Figure 8. As stated previously, an Arduino board was used to control the stepper motors of the system. After the frame was created, a soldering tool was attach to the end effector of the system once the Arduino and LinuxCNC integration was complete. A feed system was developed that feeds soldering material to the tip of the solder iron. After all components had been assembled, testing was conducted and adjustments were made as needed.

Figure 9. The Repetier-Host

The Repetier-Host, is a simple to use control and slicing software, which is compatible with most computer boards. The initial purpose of the program is to add and position the STL files on the simulated print bed and slice them altogether. Repetier Host can handle up to 16 extruders with different filament types and colors simultaneously. Through the program, a user can also preview the end result, including individual filament colors, before printing. After the slicing process is complete, an image will show all extruder movements and support structures as shown in Figure 10.

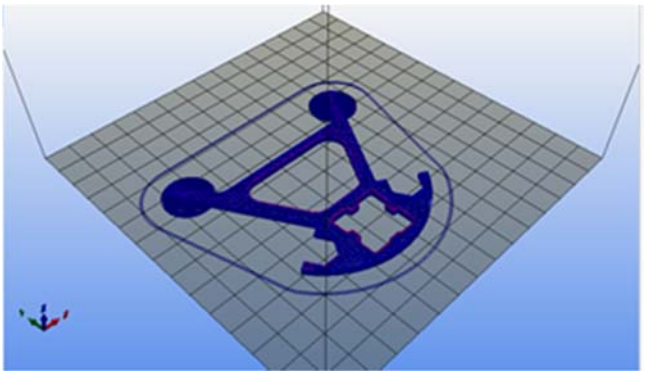

Figure 10. Slicing Example

The efficient use of the build plate can save the user a lot of time. The position and location can be selected manually or using the Repetier Host auto position feature. The software is easy to use, even for beginners, giving the user full control of the simple solder, slicer and printing process if need be. Even biotech companies utilize Repetier Host to print organs. The accessibility and control of the printers from computer platforms such as Windows or Apple products comes in very handy. Not to mention Repetier Host has the ability to run multiple printers simultaneously if applicable.

A small amount of memory is required to run codes of any size, with the new file management. Price calculations can also be recorded to get the production costs before soldering. The previews image shows a feature which allows for fully configurable, high quality rendered images before executing the program. This is essential for exact and easy recognition of solder locations on a board. Last, the Heat Up Wizard measures heating and cooling speeds needed for accurate soldering and specific soldering material amount to be melted.

3.1 Final Design Prototype

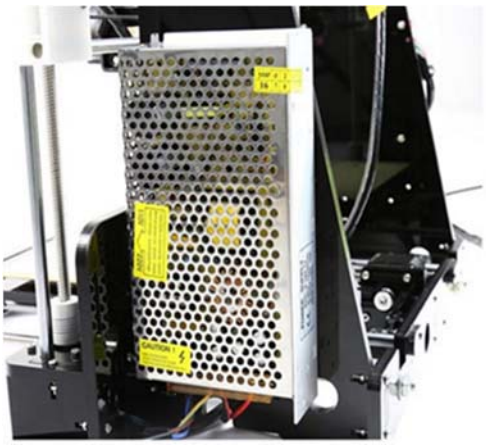

Figure 11. 12-Volt Battery

Figure 11 shows the 12-Volt battery the Simple Solder operates with. However, for the purpose of this project we will be using soldering wire, which is a 1.75 mm Tin Lead Alloy material. Built for high printing precision, stainless steel rail rods, gears, bearings, and connectors allow for the smooth execution of a given task. The system is able to print on a 220 x 220 x 240 millimeters printing volume. The accuracy achieved by the printer in the XY-axis reaches a 0.012mm and a Z-axis 0.004mm standard deviation.

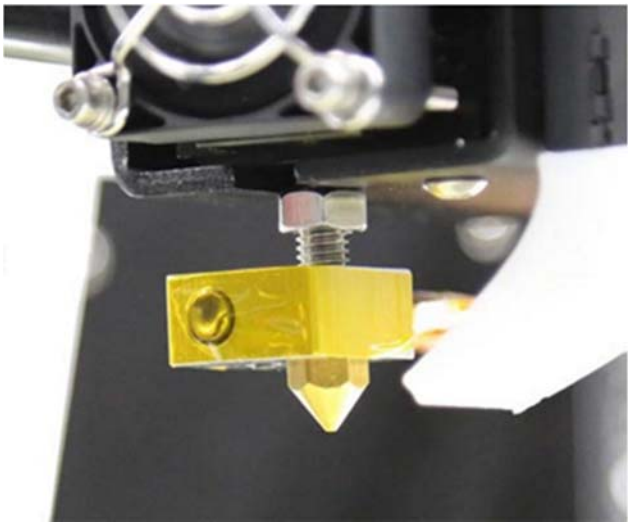

Figure 12. Soldering Nozzle

Furthermore, quick release feed gears for faster and effortless filament feeding is shown in Figure 12. This allows for the extrusion of the soldering material through a single 0.4mm diameter nozzle at a printing speed of 100 millimeters per second. Pulleys are made out of metal for improved functionality and performance as shown in Figure 13.

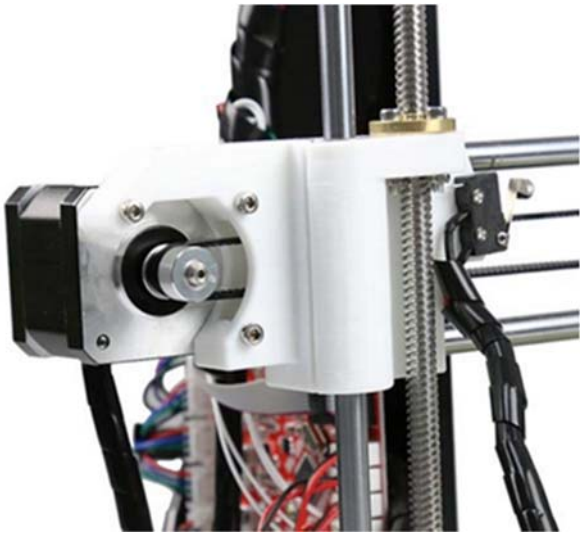

Figure 13. Servo Motor and Material

Moreover, the operating system runs on Windows XP, Windows 7, Windows 8, Mac, and Linux. For offline printing, files must be saved as a G-code, OBJ, or STL file on an SD card. For the prototype, the working temperature ranges around 10 - 30 Degree Celsius, and humidity of 20 - 50%.

The prototype is engineered to provide redefined usability, quality, and performance. The Simple Solder is made from a piano-black laser-cut acrylic plate frame with an aluminum base as shown in Figure 14. Additionally, the build your own feel, and the hands on appeal is felt while assembling it. The DIY approach provides a memorable step-by-step learning experience of 3D printers from beginning to end. As long as there is a desire for creativity, this product has a great use. Suitable for a wide range of users, young or old, professional or amateur.

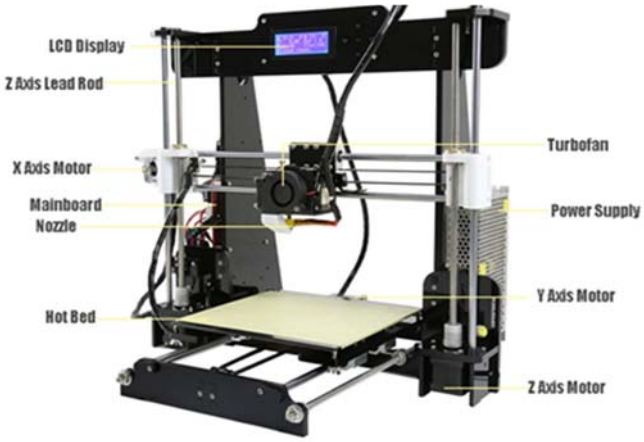

Figure 14. Anet A8 Desktop 3D printer Prusa i3 DIY Kit

4. CONCLUSION AND RECOMMENDATIONS

The original design made use of custom-fabricated components, including the frame, gantry, covers, plates, and build platform. It would have taken up the same footprint as a 13” laptop, but unfortunately would have taken longer than our time and funding constraints allowed. Instead, the approach of modifying a Prusa i3 DIY 3D printer kit to allow for easier assembly and software support was taken. A 3D printed clamp was designed to allow attachment of a soldering iron in place of the extruder nozzle, and the extruder motor was re-used to push solder onto the tip in place of plastic filament.

Repetier-Host is the control interface and firmware selected that the 3D printer platform runs on, allowing for manual G-code entry and editing. This feature allows the user to move the soldering iron tip to the desired position, without having to calibrate stepper motors, steps per revolution, or any other time consuming tuning processes. This saved a lot of time, but reduced the full operational capacity of the Simple Solder since we were limited to producing G-code manually and inputting it. For the next iteration of the prototype, we aim to build the initial design concept and make use of the lessons learned while modifying the 3D printer. Notably, the soldering iron needs to be mounted by the handle if using 3D-

printed parts due to the high heat on the metal shaft. The need for more accurate clamping designs to minimize deflection of the tip of the iron will be further explored.

Another concept that will be applied to the next iteration, is using a regular 3D printing nozzle to extrude soldering material. Since most commercially available soldering material melts around 180-190 degrees Celsius, most modern extruders such as the E3D-V6 should be capable of melting and extruding solder without the need for expensive retrofitting. This would also allow for simple integration and the ability to scale up production using commercially available parts.

Lastly, the modification of the Repetier Host firmware will be prioritized. The focus, is to allow pre-prepared CAD files to be "sliced" like traditional STL models, greatly reducing setup time and effort for the user to prepare their parts for soldering. This should be relatively easy to do since Repetier Host is open source and has clear documentation. Especially taking into consideration the control and movement commands is already completed. In addition, a G-code movement function would be called after moving into position that would lower the soldering iron tip, wait a few seconds, extrude a small length of solder, and then retract the solder and move the tip upwards. The main program would then move the iron tip to the next position and the function would be called again. These can be achieved by changing variables and tuning of the stepper motors, as well as constants like bed size, mm/step, acceleration etc. Conceptually, these are some of the new features the next iteration will include.

5. ACKNOWLEDGMENTS

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