4th Year Project: Soldering Machine

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1 Existing Solutions

There are a number of hobbyist solutions to deal with SMD parts:

- Solder paste + heat:
  - Solder stencils: Expensive setup costs, very quick to use. Not suitable for this project.
  - Manual solder paste application: Mostly expensive dispenser, or with a syringe.
  - Hot air gun: Can be relatively difficult to get the right temperature profile.
  - Converted toaster over: seems quite common.
- Soldering by hand:
  - Dragging a bead of solder along pins, then cleaning up with solder sucker/wick. This requires a lot of feedback, which is difficult to automate.
  - Some devices (SOIC?) have slightly bendy pins. A small amount of downwards pressure on the pin onto a tinned pad works.

2 Project Idea

When finished, the machine should be able to be connected to a computer via a USB port. A custom GUI will load the necessary design files (for example the holes to be drilled, pads to be soldered), generate the necessary GCODE, and send it to the printer.

3 Requirements

3.1 X/Y axes

A device pitch of 0.4mm (distance from centre of one pin to the next) is on the lower end of SMD ICs. Using solder paste, devices will shift slightly upon heating to self-align. A requirement is that the device should be placed to a small fraction of its pitch, so there is no danger of incorrect connections. I have decided to aim for an accuracy of +-0.05mm in placement. This should be sufficient, but may be difficult to achieve in practice.

3.2 Board size

A maximum board size of 100x100mm would be sufficient for the vast majority of boards. I have chosen 100x100mm because that is the maximum board size using the free version of EAGLE, a popular design package. As a result, there are a lot of designs that use the maximum size, and it would be useful if this project allowed those designs to be populated.

4 Design

4.1 X/Y axes

The X/Y axes have the same requirements: +-0.05mm accuracy. There is the choice between moving the various tools over a stationary bed, or keeping the tools stationary and moving the bed. I have decided to move only the bed, because it means that the pick and place functionality does not have to move the parts, simply lift and lower them. This should reduce the risk of the parts shifting on the needle, or falling off. It also allows for the use of more tools since weight is no longer a concern.

Driving mechanisms:

- Toothed belts + pulleys + stepper motors: Simple, as used in reprap 3d printers. Can be run open loop very easily. Requires: stepper motor + driver, belt, pulley.
- Threaded rod + stepper motors: Cheap, slower but probably fast enough. M3-5 easy to couple to motor shafts (http://www.thingiverse.com/thing:9622).
- Closed loop: dc motors + feedback. Linear potentiometers: relatively expensive, and potential issues with electrical noise. Rotary encoders: cheap, accurate (m4 pitch is 0.5mm, not much travel/turn, might only need 10 slot encoder)

Linear slides:

- Drawer slides: cheap, surprisingly high precision.
- 3d printed bushings + steel rod. If 3d printer existance assumed, then very cheap solution.
- LM8UUs (or smaller): About 1 each, so probably too expensive.

4.2 Z axis

The Z axis will not require as much precision as the X and Y. Potential mechanisms:

- Micro servos: cheap (2 on ebay). Require no drivers, and simple to drive. Z axis potentially does not need to be linear (UP/DOWN only?) so rotary->linear mechanism simpler. If not linear, then hinging out of the way is a cheaper mechanism than slides.

4.3 Part placement

- Manual placement. Much more of a problem for a large number of SMD resistors/capacitors etc, than larger components.
- Vacuum "tweezers". Mechanically relatively simple, but problems of intelligent control, as well as well as storing the components before placement. As an experiment, I tried using an aquarium pump in reverse (by attaching the silicone tubing to the inlet instead of the outlet) connected to a fairly large diameter needle (ID: Xmm).

4.4 Heated Bed

Soldering to a hot board is easier (smaller temperature difference). Probably not worth the cost/complexity.

4.5 Flux application

Flux application may be a significant problem, unless a manual brush with a solder pen is sufficient.

4.6 Drill

Drilling holes in pcbs is a time-consuming process to do by hand. If this machine could drill the holes automatically, it would reduce the total time taken significantly. A small brushless motor with a collet would be enough. The biggest challenge will be mechanically coupling the motor to the drill bit. This is not intrinsically difficult, but it should be made in a way that is accessable to people without the use of a lathe (?)

4.7 Soldering iron

Designing a mount for a cheap and widely available soldering iron may well be cheapest.

4.8 Electronics/Firmware

I have decided to use an avr chip to translate GCODE to stepper motor commands for the following reasons:

- Cost: an atmega328 is 2-3, a usb-serial chip is ¡2, which is not much.
- Mature open source firmware (GRBL, https://github.com/grbl/grbl) is available for gcode->stepper conversion, which leaves more time to focus on other parts of this project.

5 Tools

I have a small mill, a 3d printer and a lathe. It may be worth considering that a lot of people/schools have access to a laser cutter and perhaps mill/lathe, so if possible all custom components could be 3d printed or lasercut.

6 Vacuum Placing

6.1 Prototype

To test how effectively small parts could be placed with a vacuum, I made a simple test setup:

- 12V diaphragm air pump (8.89 - ebay)
- 6mm OD/4mm ID silicone tube (2.69/m - ebay)
- various needles (need more info here)
- MOSFET
- 330Ω resistor

The pump draws 200mA at 12V, which is easily controlled with a MOSFET. Using a 1.8mm ID needle, SOIC-20 parts were picked up, and had significant friction against the needle - essential to avoid slipping or rotating. It was important to place the needle as centrally as possible on the part to avoid generating any imbalance that allowed the part to fall.

Figure 1: Pump with hose and needle.

6.2 Conclusions

A vacuum needle solution is workable, and a good choice for this project. Things that need to be considered for use in the final project:

- The pump takes a certain time to generate a vacuum because of the relatively large internal volume of the pump and silicon tube. It will be important to measure this, and add a margin of error so that full suction is applied to each device before any movement takes place. Similarly, when turning off the pump, the pressure must return to atmospheric before the device can be considered to have been placed succesfully. In testing, the pump I used took less than a second to leak sufficiently for this to occur, but if another pump were to be used, it may be necessary to place a tiny hole in the air line so that pressure drops quickly.
- It is important to place the needle very near to the centre of mass of the device. The majority of devices will be symmetrical, which will make this easier.
- The needle must be able to be raised and lowered to the correct heights. It may be possible to push the needle down with a weak spring, with a micro servo that raises it - this would remove any need to know the exact height of each device. This will need to be tested.

Figure 2: SMD resistor being picked up.