Milling PCBs

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Last Time

- PCBs
Milling PCBs
Computerized
Numeric
Control
Benefits

- Automation
- Precision
- Repeatability
- Flexibility
Examples

- Cutters
- Mills
- 3D Printers
- Lathes
- Knitting

stoll cnc knitting machine
John T Parsons + MIT 1949
Categories

- Additive
- Subtractive

additive

subtractive
Axes

- How Many?
  - 1D
  - 2D
  - 2.5D
  - 3D
  - 5D
  - linear

- What Kind?
  - rotary
  - linear
- how big
- shape
- constraints

by xiyan yeh @ stanford
how fast do we spin (speeds)?
how fast do we cut (feeds)?
how fast do we plunge (feeds)?
up to speed of breaking tooling
more but slower cuts
- open loop
  - crash
- closed loop
  - limit switch
  - rotary encoder
  - camera
- width of saw blade
- cut radius
- must compensate in code
extra cut to compensate for mill radius

NO UNDERCUT

UNDERCUT

by wizard191
- extra cut during start or finish of cut
- usually need to plan for this

by big blue saw
- Rectangular
- Precision – increments
- Origin – Zeroing
- Absolute and Relative
Tools

- flat end mill
- round end mill
- v bit
- drill bit
### Engraving Bit vs Flat End Mill

<table>
<thead>
<tr>
<th></th>
<th>Flat End Mill</th>
<th>Engraving Bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milling Time, large areas</td>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>Milling time, small traces/spaces</td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td>Trace Profile</td>
<td>Square</td>
<td>Tapered</td>
</tr>
<tr>
<td>PCB Features</td>
<td>Traces, Holes, Outlines</td>
<td>Traces</td>
</tr>
</tbody>
</table>

- measure with calipers
- perhaps reduce 0.2mm trace depth
- different cutters
- thicker mill cuts faster but less precise
- switch between them under program control
- attaching material to mill
- temporary attachment
- out of way of tool path
Do Double Sided Tape

- alcohol for easy removal of nitto tape

![scotch tape](image1)
![nitto tape](image2)

**scotch tape**

**nitto tape**

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Hot Glue

hot glue

omc
bolting material to bracket to t-slot bed

omc
alignment bracket

omc

toe clamps

omc

toe clamping

omc
Digital Calipers

- Step gauge (not visible)
- Inside jaws
- Inch/millimeter button
- Locking screw
- Your name
- Thumbwheel
- Depth gauge
- Outside jaws
- ABS button
- On/zero button

omc
- word addressed format for programming
- sentence like commands: letter followed by numeric argument
- command is made up of words often one letter with intuitive interpretations
- step by step commands
- read interpret execute each command

X10
Y20
<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Program number (Used for program identification)</td>
</tr>
<tr>
<td>N</td>
<td>Sequence number (Used for line identification)</td>
</tr>
<tr>
<td>G</td>
<td>Preparatory function (See below)</td>
</tr>
<tr>
<td>X</td>
<td>X-axis designation</td>
</tr>
<tr>
<td>Y</td>
<td>Y-axis designation</td>
</tr>
<tr>
<td>Z</td>
<td>Z-axis designation</td>
</tr>
<tr>
<td>R</td>
<td>Radius designation</td>
</tr>
<tr>
<td>F</td>
<td>Feedrate designation</td>
</tr>
<tr>
<td>S</td>
<td>Spindle speed designation</td>
</tr>
<tr>
<td>H</td>
<td>Tool length offset designation</td>
</tr>
<tr>
<td>D</td>
<td>Tool radius offset designation</td>
</tr>
<tr>
<td>T</td>
<td>Tool Designation</td>
</tr>
<tr>
<td>M</td>
<td>Miscellaneous function</td>
</tr>
</tbody>
</table>
Example GCode Program

G1 X5 Y-5 Z6 F3300.0 (Move to position \(\langle x,y,z\rangle=\langle 5,-5,6\rangle\) at speed 3300.0)
G21 (set units to mm)
G90 (set positioning to absolute)
G92 X0 Y0 Z0 (set current position to \(\langle x,y,z\rangle=\langle 0,0,0\rangle\))
Manufacturers Specific Commands

- G90, G91
- Spindle speed
- Coolant
- Tool changing
Programming

- like turtle graphics
  - move
  - pen up/down
- no loops
- no subroutines
### Top 10 G-code Commands

<table>
<thead>
<tr>
<th>cmd</th>
<th>comment</th>
<th>example</th>
</tr>
</thead>
<tbody>
<tr>
<td>G0</td>
<td>straight rapid traverse</td>
<td>G0 X5 Y22</td>
</tr>
<tr>
<td>G1</td>
<td>straight coordinated traverse</td>
<td>G1 F500 X10 Y50</td>
</tr>
<tr>
<td>G90</td>
<td>absolute mode</td>
<td>G90 G0 X5</td>
</tr>
<tr>
<td>G91</td>
<td>incremental mode</td>
<td>G91 G0 X5</td>
</tr>
<tr>
<td>M3</td>
<td>spindle on</td>
<td>M3 S16400</td>
</tr>
<tr>
<td>M5</td>
<td>spindle off</td>
<td>M5</td>
</tr>
<tr>
<td>()</td>
<td>comment</td>
<td>G0 X5 Y19 (rapid to left)</td>
</tr>
<tr>
<td>G53</td>
<td>select abs coord sys</td>
<td>G53 G0 X0 Y0 Z0</td>
</tr>
<tr>
<td>G55</td>
<td>select working coord sys</td>
<td>G55 G1 F1000 X50</td>
</tr>
<tr>
<td>G38.2</td>
<td>probe</td>
<td>G38.2 Z-75 F500</td>
</tr>
</tbody>
</table>
- can load g-code into othermill
- has a g-code console
- one g-code sequence is for facing spoilerboard
- send gcode to CNC machine
- machine interprets one command at a time
- usually microcontroller which is interpreting and executing

tinyg microcontroller board
Path Planning

- organize cuts efficiently
- plan motions according to dynamics
- change speeds
- bang-bang control
Ordering of Cuts

- need to plan cuts so parts are cut correctly
- cut holes out first
- much more involved for 5 axis machines

by customlasercutters
salesman has to visit $n$ city in minimum time
OtherMill File Formats

- EAGLE (.brd)
- Gerber (.gtl, .cmp, .gbr)
- G-Code (.nc, .tap, and .gcode)
CNC Input Formats

- DXF, SVG, PDF – polylines
- STL, OBJ – meshes
- AMF – materials, frep

```plaintext
solid name
facet normal ni nj nk
  outer loop
    vertex v1x v1y v1z
    vertex v2x v2y v2z
    vertex v3x v3y v3z
  endloop
endfacet
endsolide name
```
- Blank copper boards – remove copper to reveal wires and pads
- Bracket – to hold board
- Calipers – to measure
- Minimum trace width: 10 mil
- Minimum trace spacing: 10 mil
- Minimum via/pad annular ring thickness: 10 mil
- Minimum drill size: 16 mil (or smaller with nonstandard bits)
- Minimum SMD pad size: 10 mil
- Polygon isolation value: 1 mil > the largest tool you want to use
- Route traces to through-hole pins on bottom side only
- Slotted/oval holes are not supported
Ground Planes

- less copper to remove

omc
- no copper plated through holes
- through hole components connect on bottom
Increased Milling Speed

- use larger tooling
  - use drill bit equal to size of through holes
- minimize tool changing
  - order cuts using selection of layers
- faster removal
  - use alcohol for removing nitto tape
- reliability
  - use 30 degree engraving bit – more robust than 1/64” flat end mill
Double Sided Boards

- do top on bottom left corner of bracket
- do bottom flipped on bottom right corner of bracket
- switch orientation tab
no silkscreen

- consult drawings and instructions
- solid core wire – hard to place under components
- might break pads
- can break
- might break pads
- Get electronics hands on training by Thursday Sep 22nd
- Let me know if you have trouble scheduling
Basic JITPCB
Breadboard Lab check off
Milling Lab release
Then OMC at monady’s section ...
References

Other Machine Co www.othermachine.co