FAB-IN-A-BOX: WORKFLOW

Eagle .PNG CAD.PY .RML

Virtual Machine Environment

FABNET

Stepper Control multifab

```python
mtm.move(z = z_up, rate = retract_speed)
mtm.move(0.175, 1.618, z_up, traverse_speed)
mtm.move(z = z_down, rate = plunge_speed)
mtm.open_group(0)
mtm.move(0.866, 1.618, z_down, cutting_speed)
mtm.move(0.866, 1.616, z_down, cutting_speed)
mtm.move(0.88, 1.616, z_down, cutting_speed)
```
MTM MULTIFAB
Ilan Moyer and Maxim Lobovsky
THE XY STAGE: KINEMATICS

Y AXIS

X AXIS

Shuttle/Tool Holder
The XY Stage: Structure

Four C-Chanel Extrusions

Symmetric Bolt Pattern
THE XY STAGE: MECHANISM

- Drive Pulleys
- Synchronization Shaft
- Drive Shaft
- Shuttle Bushings
- Rollers
- Drive Belts
- Belt Tensioner
- Idler Pulleys
- Stepper Motor
THE XY STAGE: MECHANISM
THE Z AXIS: DRIVE MECHANISM

- Stepper Motor
- Guide Rail (x2)
- Leadscrew
- Helical Beam Coupler
- Bushings
- Leadnut
- Tube
- Thrust Bearing Assy
TOOL-HEADS AND CAPABILITIES
5 AXIS TRUNNION
STRENGTHS

• Low Inertia -> High Acceleration
• Direct Drive -> High Speed
• 200mm^3 Work Volume
• Fixed Table -> Tall 3D Prints

WEAKNESSES

• Low Stiffness -> No Heavy Milling
• Low Basic Resolution: 0.0035” (~0.0015 with half stepping.)
STEPPER MOTOR SELECTION

Lin Engineering 4209M-02P
Resistance = 2.35 Ohms
Inductance = 3.2 mHenries

Lin Engineering 4209L-03P
Resistance: 58 Ohms
Inductance: 82 mHenries

NOTE: t_rise is the time for motor current to reach 100%.
DRIVE VOLTAGE SELECTION

Current Rise Time: 12V

Max Speed: 12V
41% Power @ 400mm/s

Max Speed: 24V
75% Power @ 400mm/s
DRIVE ELECTRONICS

Allegro A3967
- 8 μSteps/Step
- 750mA/Phase

Allegro A3982
- 2 μSteps/Step
- 2A/Phase
THE NETWORK

Virtual Machine Environment

NETWORK + POWER

Stepper Motor Control

DC Motor Control

RC Servo Control

NETWORK + POWER

FTDI USB <> RS485

7.5V POWER SUPPLY

12-24V POWER SUPPLY

FABNET

5 - 6 VOLTS

x 8
GENERAL PACKET FORMAT

[
[UNICAST|MULTICAST]
[SOURCE IP][SOURCE PORT]
[DEST. IP][DEST PORT]
[LENGTH]
[----PAYLOAD----]
[CRC CHECKSUM]
]

MOTION CONTROL

http://mtm.cba.mit.edu/fabinabox/vm/076-001e.py

Virtual Machine Object

http://mtm.cba.mit.edu/fabinabox/vm/076-001e.py

NODE URL: http://mtm.cba.mit.edu/vm/076-001e.py
USING LOCAL VMO: 076-001e.py

Control Firmware
MOTION CONTROL

VM Environment on PC

MACHINE DESCRIPTION

VM Object

MOTION CONTROL CODE

MICRO-CONTROLROLLER

Firmware
FIRMWARE

• PACKET HANDLING
• BRESENHAM LINE ALGORITHM
• CIRCULAR QUEUE
• ANTI-BACKLASH
RULE #1: Always step along major axis.
RULE #2: Step in minor axis if error > 0.5 steps.
BRESENHAM ALGORITHM... THE TRICK:

How do you know when the error is > 0.5?
Don’t you need to know the slope?

ALWAYS STEP IN X AXIS.
SLOPE = (Y STEPS) / (X STEPS)
ERROR = (Y STEPS)
ACCUMULATE ERROR EACH X STEP.
WHEN ERROR > 0.5(X STEPS), TAKE A STEP IN Y.
OR, WHEN 2 x ERROR > X STEPS.
VIRTUAL MAJOR AXIS
FOR DISTRIBUTED MOTION CONTROL

mtm.move(8,3,1)

X STEPS = 8
Y STEPS = 3
Z STEPS = 1

VIRTUAL STEPS = 8 = MAXIMUM STEPS

2-AXIS CONTROLLER

1-AXIS CONTROLLER
CIRCULAR BUFFER: ACCOUNTS FOR RAPID SERIES OF MOVES, SUCH AS WHEN GOING AROUND AN ARC.
3 AXIS MOTION CONTROL

mtm.move(x,y,z,rate)

**VME**

**Machine Hardware Description**

i.e. step angle, linear reduction, control system topology, etc...

vmo.spin(x_steps, y_steps, z_steps, move_time)

**VMO**

**PC-BASED FIRMWARE**

Does complex calculations such as floating point and division.

[key, dir., max_steps, x_steps, y_steps, z_steps, counter_top]

**MCU**

**MCU-BASED FIRMWARE**

Does timing-critical calculations and I/O control.
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