ADVENTURE!

HIGH SPEED MACHINING ON A LOW QUALITY MILL

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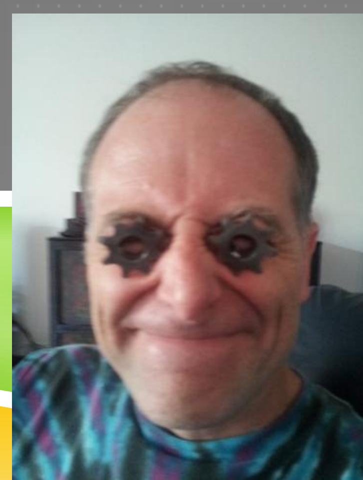
HMSC – Sept 14, 2013



HOW THIS ALL STARTED

- This is what happens when you attend industry trade shows

FEEDS AND SPEEDS

- To set speeds & feeds on my CNC mill, I rely mostly on my experience
- I am very conservative on speeds in general. This is because I've melted several mills.
  - *Good decisions come from experience. Experience is a result of bad decisions*
- Speed & feed calculators seem to give:
  - feeds that are much too high
  - speeds that are a little too slow

CALCULATIONS

- Spindle speed
  - Rpm = (CS x 4) / dia
  - For steel & ½” mill = 70 x 4 / 0.5 = 560 rpm
- Feed
  - Feed = chipload x n x rpm
  - For steel & 4 flute mill = 0.005 x 4 x 560 = 11 ipm

- I would never run this fast, even with coolant

THERE HAS TO BE MORE!

- Speeds I use for steel with carbide mills
  - 0.5 – 6 ipm
  - higher speeds require coolant
  - Even slower with tool steel mills
- I was using 0.010 – 0.025” stepover or depth per pass
- Single milling operations frequently required 45 – 60 minutes
- I wondered if I could do better

HSM – HIGH SPEED MACHINING

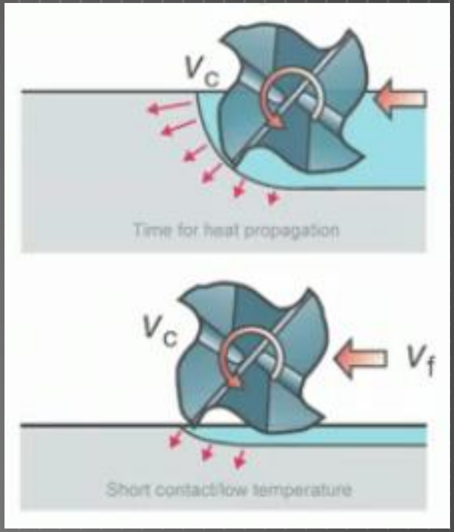
- Saw a milling center demo at Haas Factory Outlet
  - ½” carbide mill
  - Pocket depth 1.5”
  - Spindle 12,000 rpm
  - Feed 160 ipm (2.7 ips) – operator said could be higher!
  - Transits 1,000 ipm (16.7 ips)
  - Tons of coolant
  - Huge stream of chips flying out of cut
  - 6” x 6” x 2” chunk of metal mostly cut away in 12 minutes!
- I calculated about 4+ hours on my mill, using typical parameters I use

HSM – HIGH SPEED MACHINING

- DEFINITION: Achieving high metal removal rates with quick milling passes using light milling passes
  - Other definitions exist. No consensus on definition
- In general, incorporates:
  - High spindle speed (8,000 – 40,000+ rpm)
  - High feed rates
  - Unconventional milling patterns
  - Combined roughing and finishing passes
  - Less depth passes, up to full depth cuts
  - Improved accuracy
  - Longer tool life
- Concept is from 1920's, but equipment not available then
  - Rapid progress since 1980, with high speed spindles and CNC
  - Developed by mold and die industry, cutting hardened materials

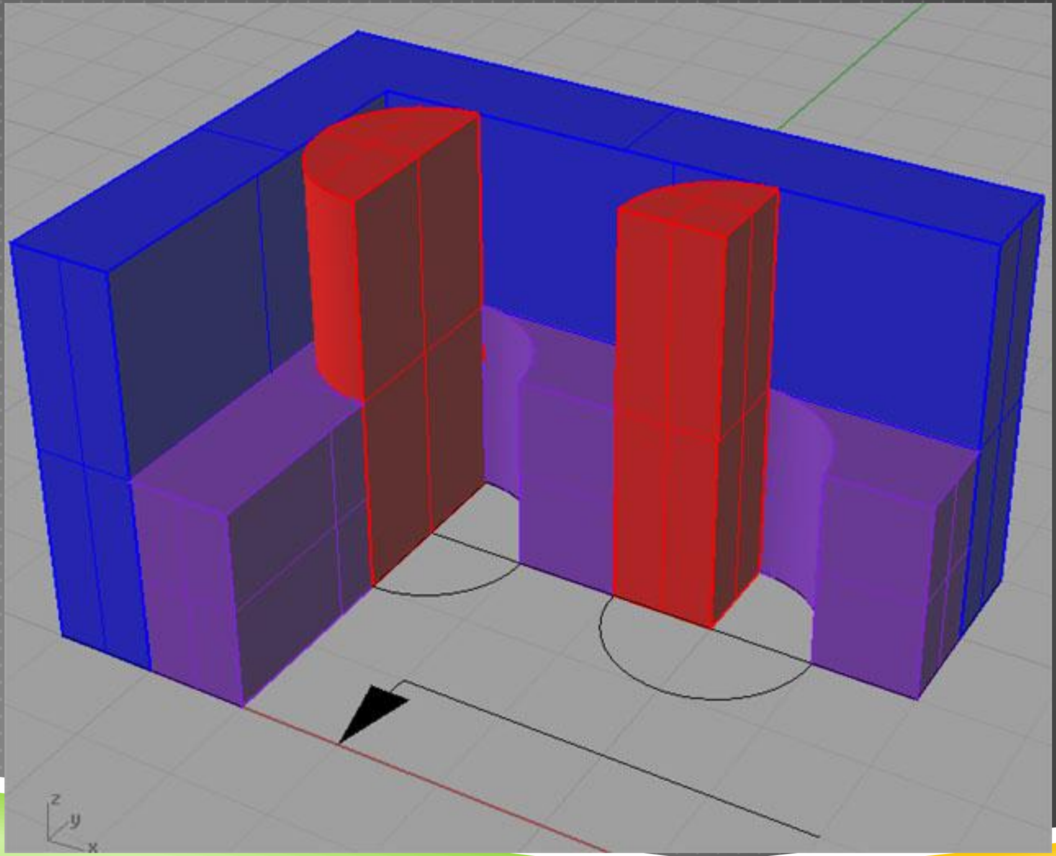
COMPONENTS OF HSM

- Fast moving small tooling ("small" generally meaning ~½")
  - As opposed to large hogging tools
  - Counterintuitive, but results in higher metal removal rates
- Low stepover
  - 5 - 15% of tool diameter
  - Better chip clearance
  - Increased mill cooling time
  - Taking the heat out with the chip
  - Minimize deflection
- Specialized G-code
- Selection of speeds in stable zones that avoid chatter



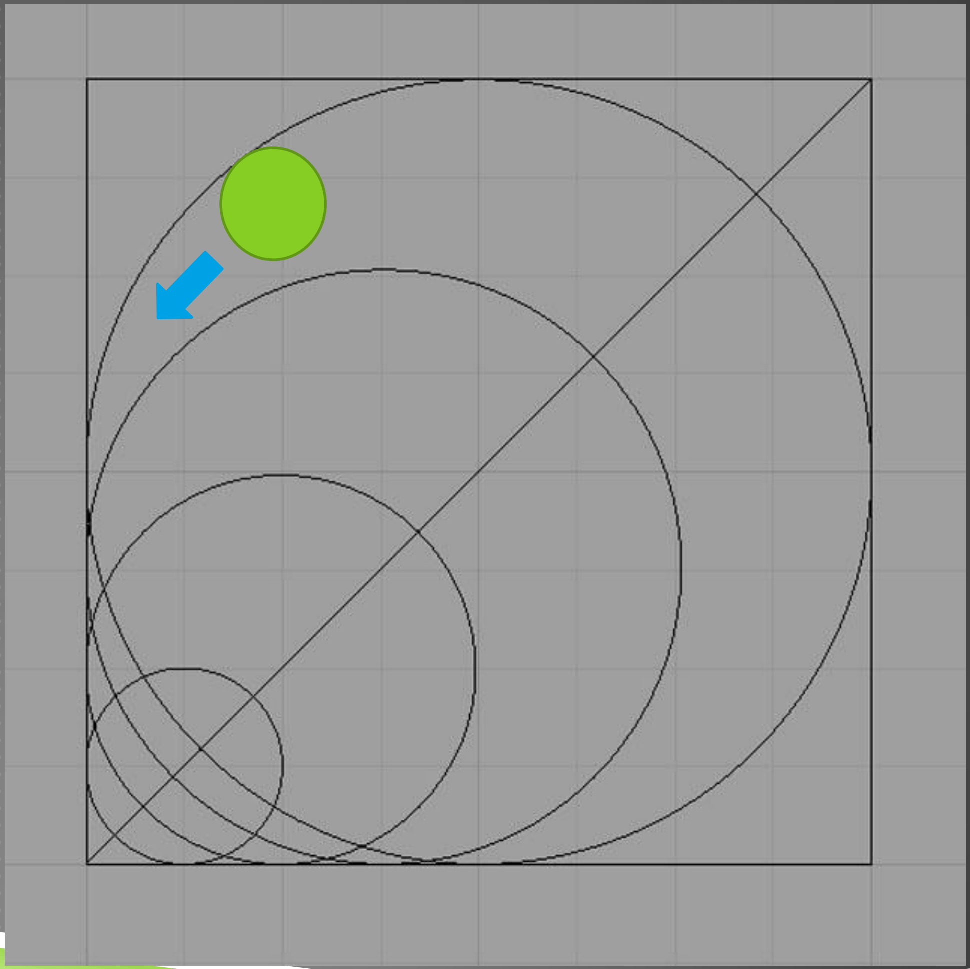
MILL LOADING IN CORNERS

- Conventional milling has 90° mill engagement on straight sections
- Increases to 180° engagement in corners
  - Doubles cutter forces
  - Halves chip clearing
  - Air cooling halved
- Feed & speed tables based on allowable in corners



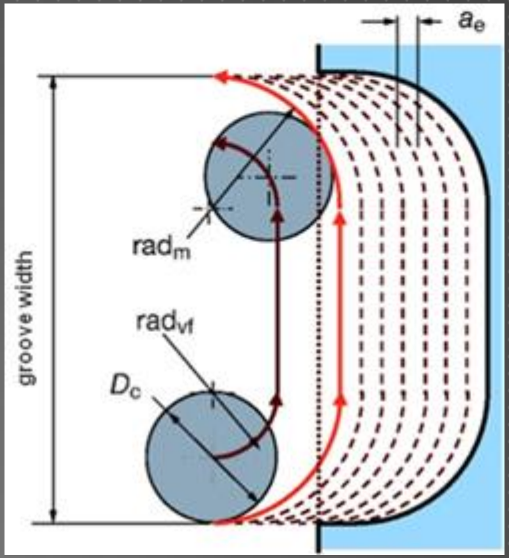
PATH TO HSM
SPIRALING INTO CORNERS

- Make series of arcs of decreasing radius to cut into corner
- Allows higher feed rate than conventional corner milling



PATH TO HSM
TROCHODIAL MILLING

- Similar concept to spiraling
- Applied to slots instead of corners
- Slots are cut using a series of looping cuts
  - Faster than a big hogging cutter
- Techniques:
  - Loops are more forgiving for slower machines
  - “D”s require faster machine

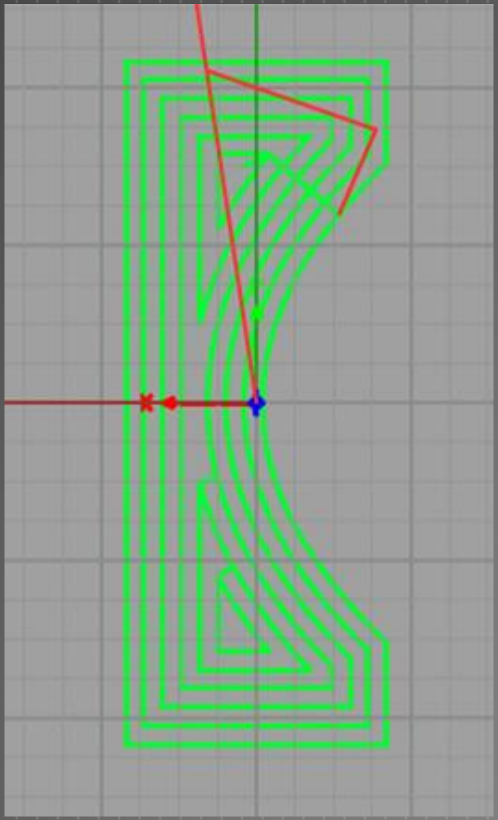


MATURING HSM

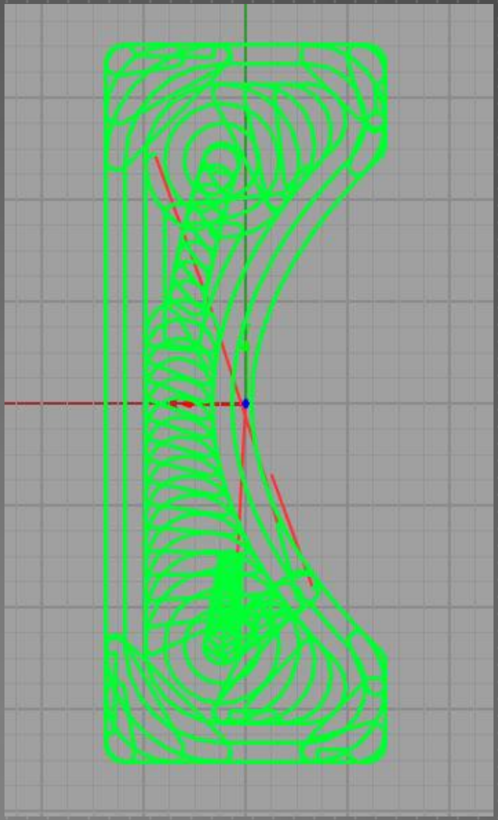
CONSTANT TOOL ENGAGEMENT

- Spiraling and Trochoidal milling are part of HSM (corners and slots)
- New strategies incorporate both plus strategies to keep tool constantly or uniformly engaged
  - Available in most major CAM programs
  - Starting to see in consumer CAM programs
  - All employ looping toolpaths

COMPARISON OF TOOL PATHS



Conventional milling path



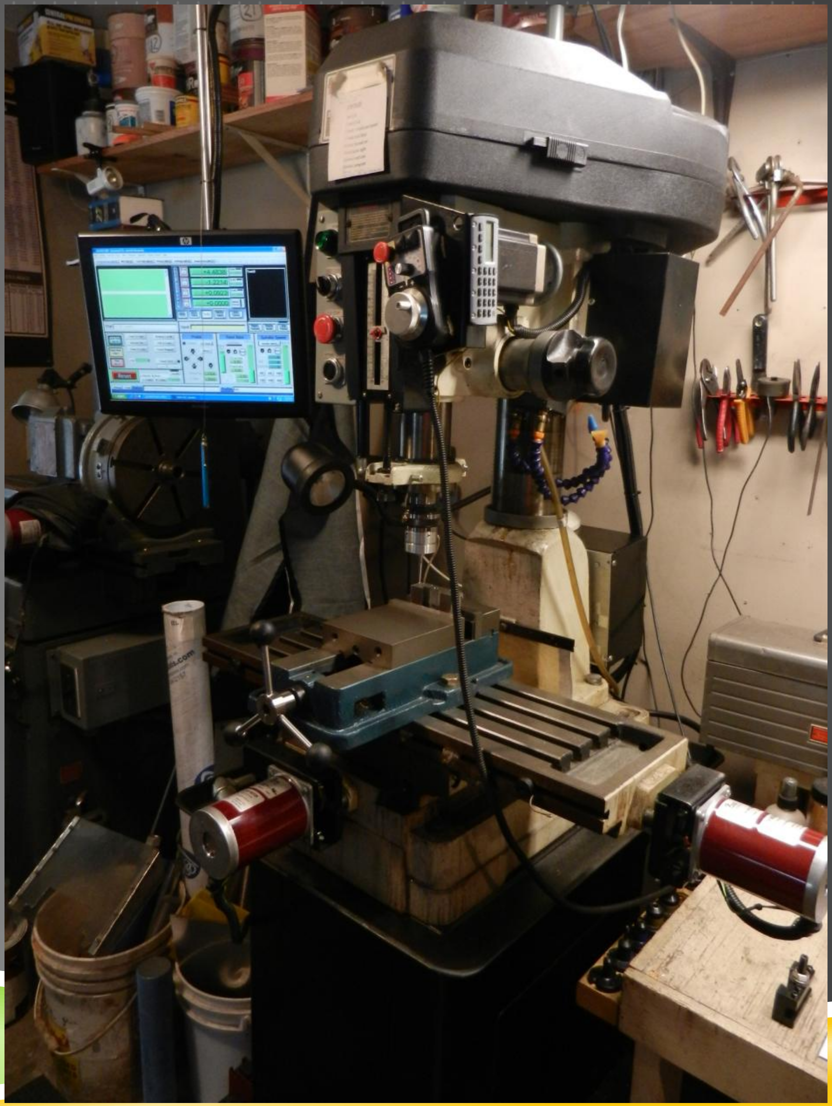
HSM milling path

COMPONENTS NEEDED FOR HSM

- CNC Machine
  - Preferably built for HSM
    - High feed rates (1,000 ipm)
    - High spindle speeds (20,000 rpm)
- Toolholders
  - Balanced if speed above 8,000 rpm
- Cutting tools
  - High quality carbide, coatings, lubricants, special HSM tools
- CAM programs
  - Must be able to create HSM toolpaths
- Principles of HSM can be applied to lesser machines

HSM ON A LESSER MILL

- Chinese Rong Fu mill/drill clone
- Originally converted to CNC by CNC Masters
- Control system completely replaced

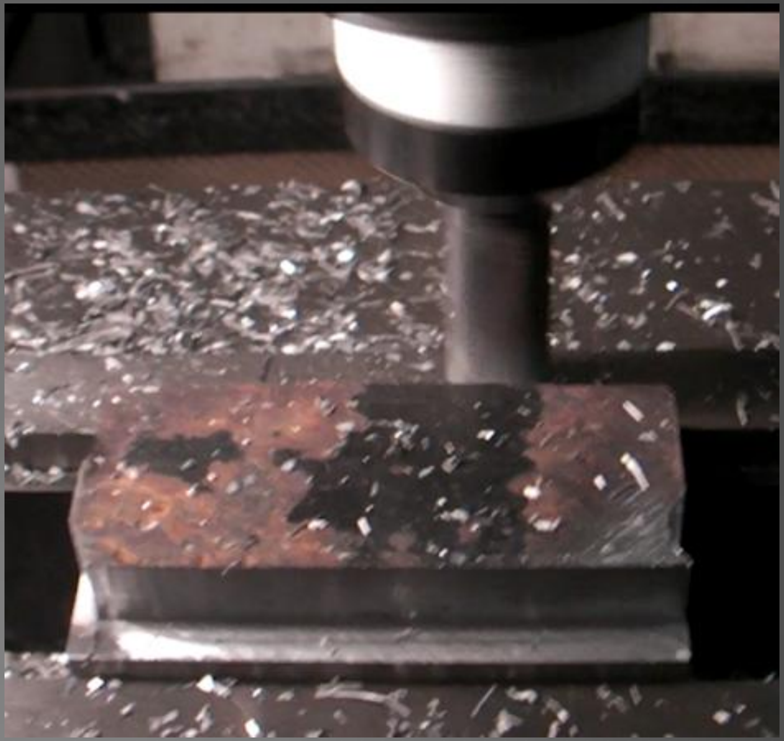


TESTING

- Ran at increasing feed rates using test programs
  - X transits, back and forth
  - Y transits, back and forth
  - Circle transits
  - Stairstep XY transits
- Stepper motor would lock up / lose steps at:
  - X 200 ipm
  - Y 150 ipm
  - XY 50 ipm!

HSM TRIAL 1

- Simple T-nut design
  - Speed 45 ipm
  - Fast transit 150 ipm
  - Spindle 4,000 rpm
  - Depth 0.4
  - Stepover 0.010
  - Total cut time 4:20
- 13,500 lines of G-code
- Crashed on lost steps in fast Y transit
- Gave me encouragement that it could be done

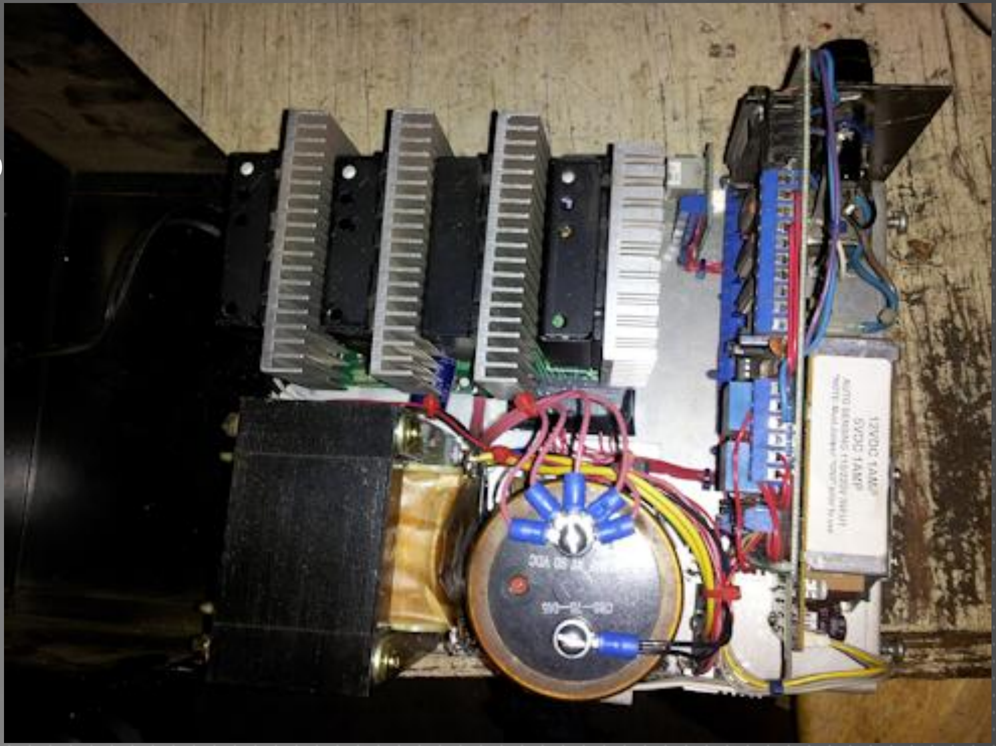


TESTING

- Initial thought was that power supply was inadequate
  - 4A, 70V
  - Tried 12A, 60V high quality supply – no change
- Next thought was that gibs not adjusted correctly
  - Re-adjusted – little effect
- Next investigation was into Mach3 parameters
  - Tried variety of kernal clock rates
  - Played with stepper motor accelerations

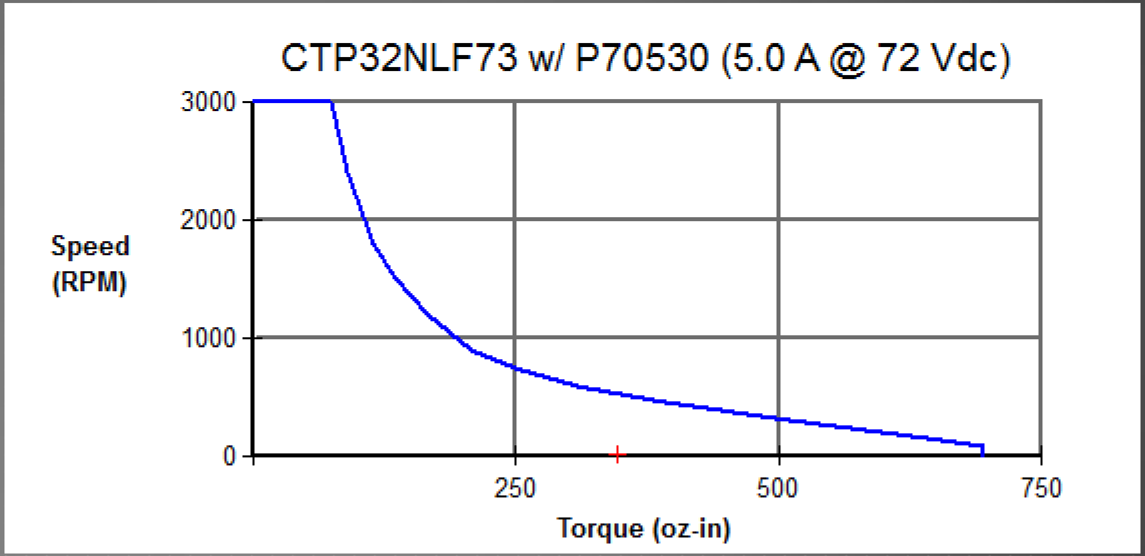
MODIFIED POWER SUPPLY

- Beefed up 70V power supply
  - Added 7,800 µF cap, replacing 1,000 µF cap
  - Had serial connections for Gecko power. Made "home runs" for each supply line



STEPPER MOTOR

- Stepper motors have less torque at higher speeds
- Y axis carries maximum load – 2 ways, vise, part
- Tried more powerful stepper motor
- Increased feed:
  - X 225 ipm
  - Y 200 ipm
  - XY 75 ipm

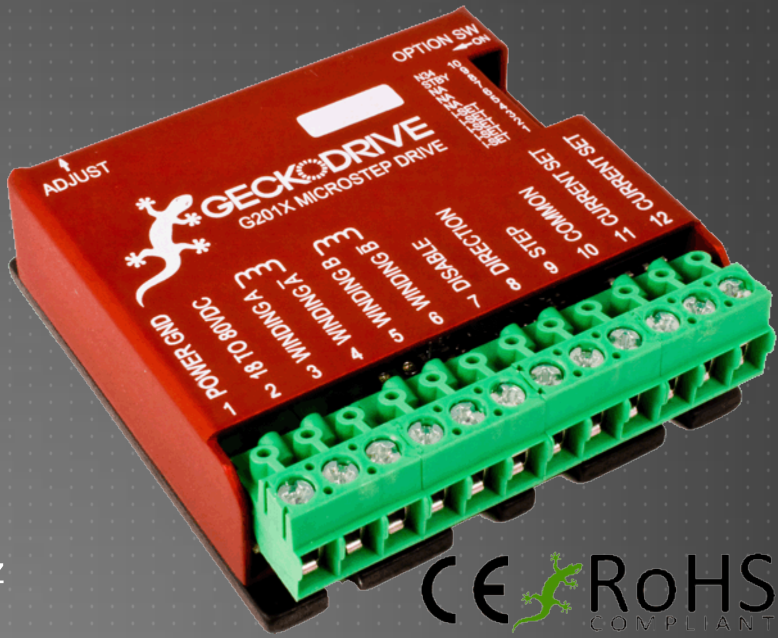


HSM TRIAL 2

- Complex Shape
- 43,900 lines of G-code
  - Speed 50 ipm
  - Fast transit 150 ipm
  - Spindle 4,000 rpm
  - Depth 0.3
  - Stepover 0.010
  - Total cut time 11:00 v 85:45 conventional
- Crashed bit at fast Y transit of 150 ipm due to lost steps
  - That was exciting

GECKODRIVE STEPPER CONTROLLER

- Looked at signals to GeckoDrives
  - Observed step signal jitter on oscilloscope at higher frequency (feed rate) signals
  - Caused by way Mach3 sends signals
  - Steppers
    - 200 steps/rev x 10 microsteps/step = 2000 pulses/rev
    - Ball screws 5 turns/inch => 10,000 pulses/in
    - 200 ipm / 60 sec/min x 10,000 pulses/in = 33 kHz pulses/sec
    - Stepper speed is 200 ipm * 5 turns/inch = 1,000 rpm



SMOOTHSTEPPER

- Purchased SmoothStepper
  - Offloads generation of step signals from computer running Mach3
  - Dedicated processor for step signals
- Increased feed rates
  - X 225 ipm
  - Y 225 ipm
  - XY 175 ipm!

HSM TRIAL 3

- Cut slots
  - Speed 50 ipm
  - Fast transit 125 ipm
  - Spindle 4,000 rpm
  - Depth 0.380 and 0.0200
  - Length x width 1.5" x 1.38" and 3" x 0.85"
  - Stepover 0.015
  - Total cut time 4:42 and 7:09
- Success, with nice finish and accuracy!

QUESTIONS?