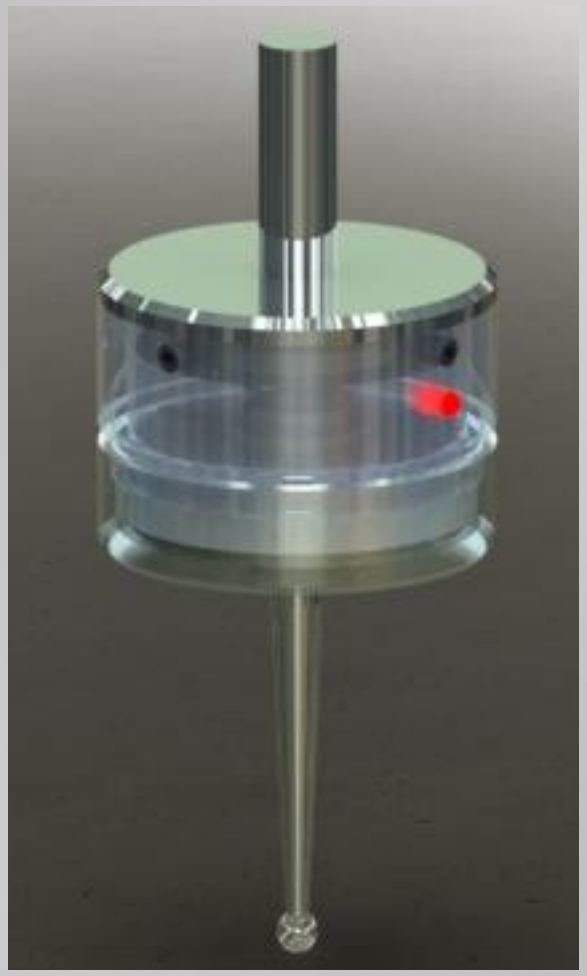
Building a Digitizing Probe



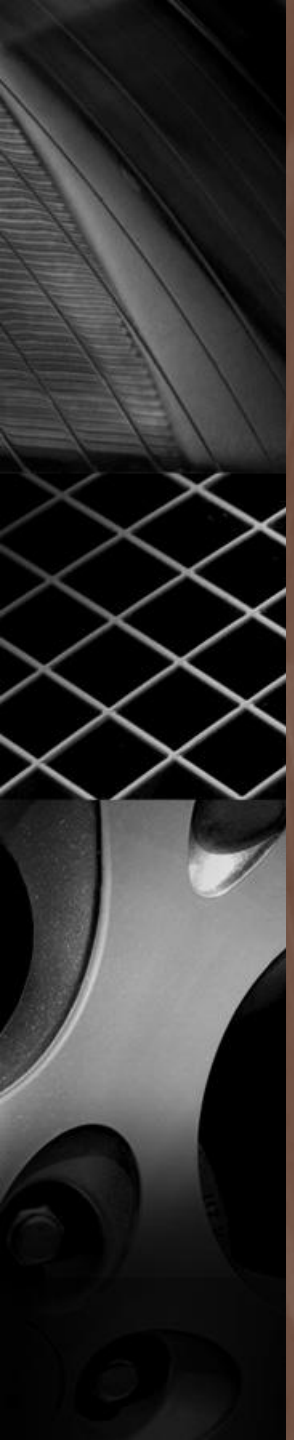
Martin Kennedy

HMSC

February 2012

Outline

- Probes and edge finders
- Design research
- Making my own design
- Probe fabrication
- Software
- Operation
- Accuracy



Types of probes / edge finders

Edge finders

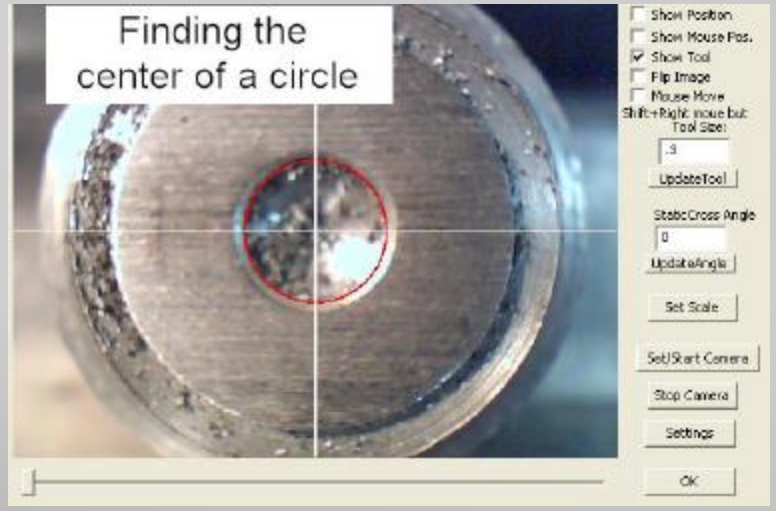
- Simple operation
- Accuracy
  - Manual 0.0002”
  - Electronic 0.0001”
- Inexpensive

Laser edge finders

- Non contact
- Beam can be focused to small point
- Repeatability
  - 0.0002”
  - Based on judgment
- Cost $125

Video edge finder

- Quick
- Accuracy 0.005”
- Interpretation required
- Automation possible

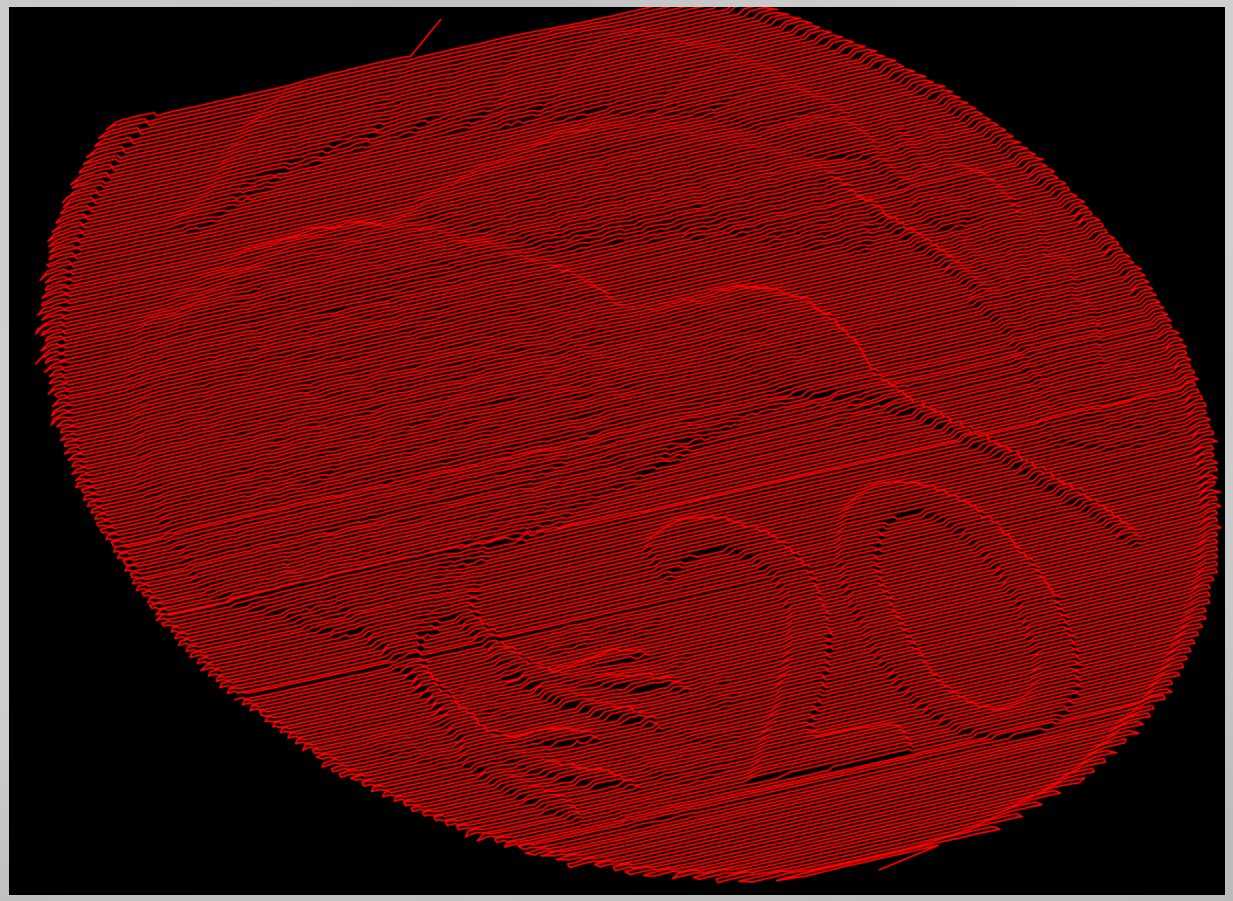


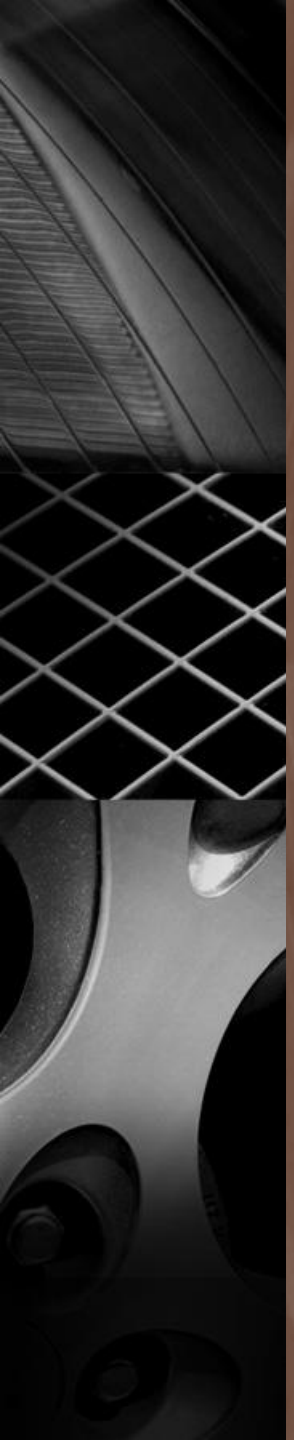
Digital probe

- No interpretation
- Accuracy 0.00002”
- Can be automated
- Can do 3D digitizing
- Very fast
- Higher cost
- Precision machining required to fabricate

3D Digitizing

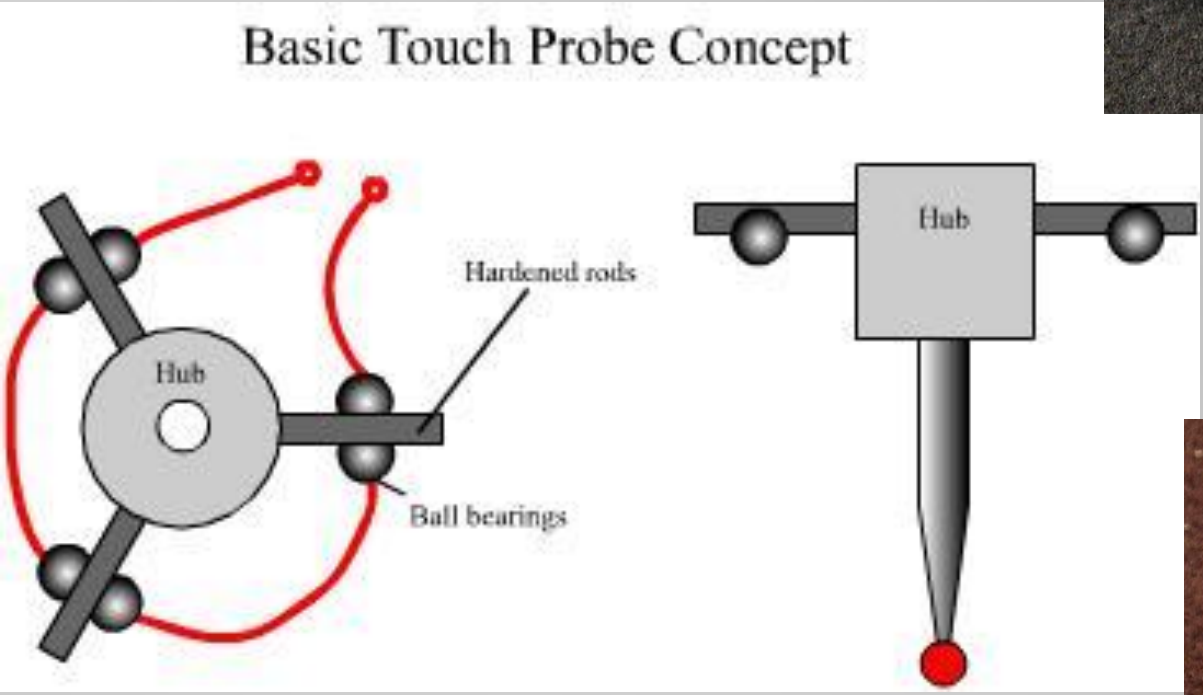
- Create point cloud from object
- Possible only with digital probe
- Video





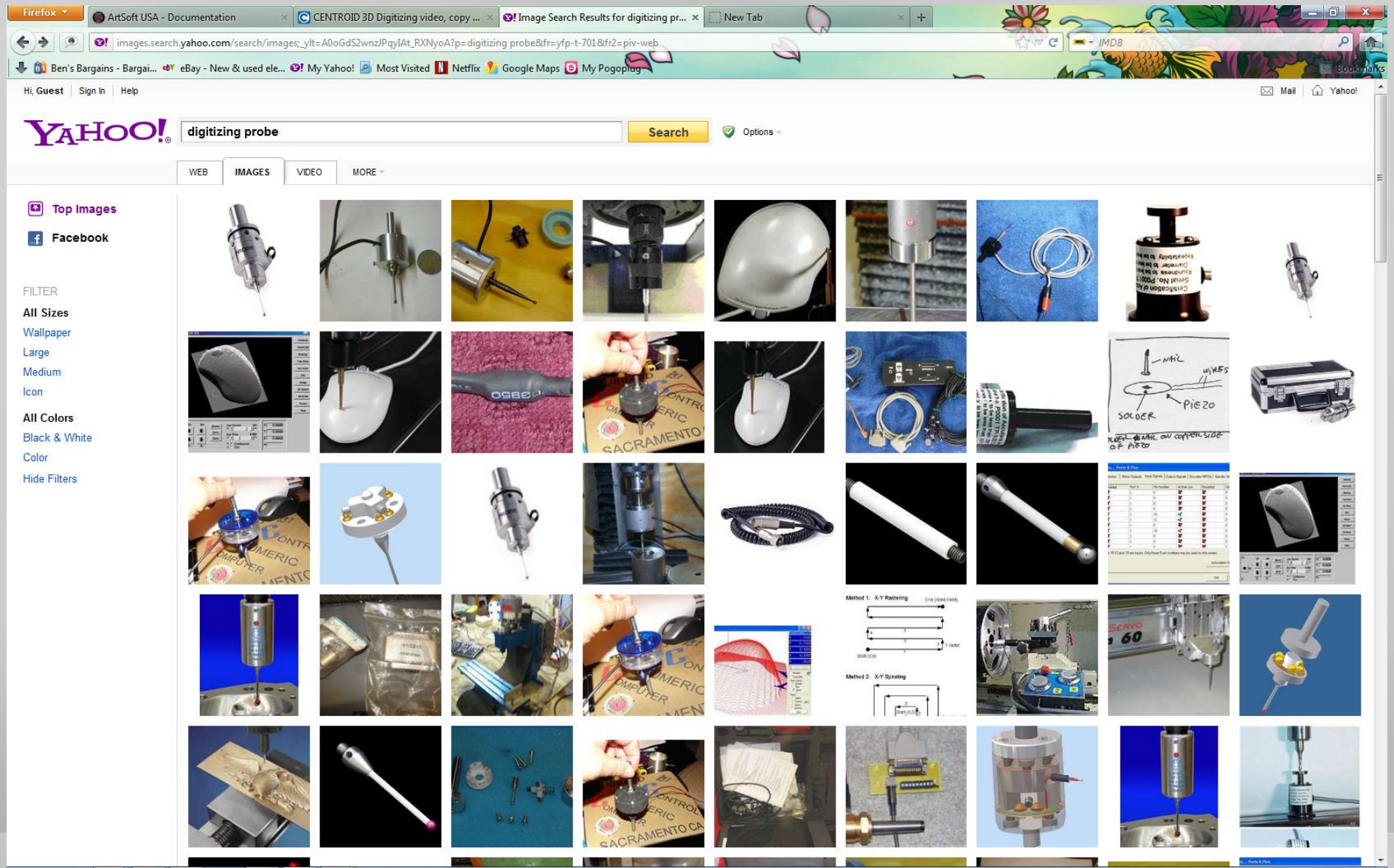
Design research

Typical operation



Three normally closed switches in series

Design research - Internet

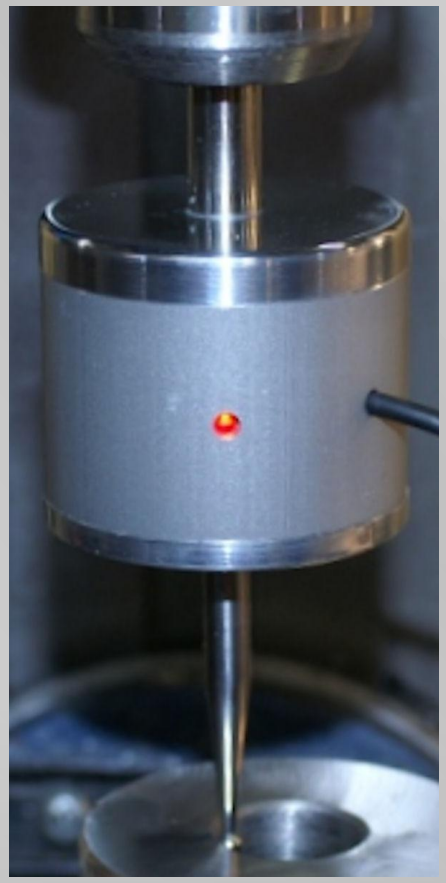


Commercial Probes

- Renishaw
- Low activation force
  - 0.3 oz xy, 2.7 oz z
- Accuracy
  - 0.35 µm (0.000014 in)
- Replaceable ruby tip module
- Wireless available
  - CNC tool changer
- Price over $1000

Low-price probe

- CNC4PC.com
- $135



Design research - Patents

United States Patent and Trademark Office

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Patent Number: US006553682 Section: Front Page 1 of 18 pages Help

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Sections:
- Front Page
- Drawings
- Specifications
- Claims

US006553682B1

(12) **United States Patent**
Willoughby

(10) **Patent No.: US 6,553,682 B1**
(45) **Date of Patent: Apr. 29, 2003**

(54) **TOUCH PROBE**

(75) Inventor: **Timothy R. Willoughby**, Lock Haven, PA (US)

(73) Assignee: **Paradyne**, State College, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/525,725**

(22) Filed: **Mar. 14, 2000**

Related U.S. Application Data

(60) Provisional application No. 60/142,333, filed on Jul. 3, 1999, provisional application No. 60/131,478, filed on Apr. 29, 1999, and provisional application No. 60/124,391, filed on Mar. 15, 1999.

(51) **Int. Cl.**[7] **G01B 5/20**
(52) **U.S. Cl.** **33/561**
(58) **Field of Search** 33/503, 556, 558, 33/559, 561

(56) **References Cited**

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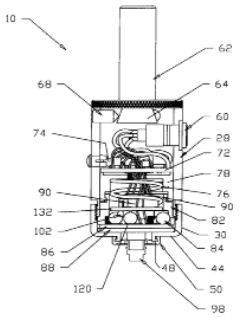
Primary Examiner—G. Bradley Bennett
(74) *Attorney, Agent, or Firm*—John J. Elnitski, Jr.

(57) **ABSTRACT**

The present invention is a touch probe which can be connected to a computer controlled machine for determining positions of and defining shapes of work pieces, edges, hole centers and contours. The probe due to it design allows for a simpler and effective alternative to previous probes. The probe includes a body, stylus, a shank and an internal assembly. The body contains the internal assembly, which provide signals to a computer. The arrangement of the internal assembly is what makes the present invention simpler to manufacture and allow the probe to be miniaturized. The internal assembly includes an upper circuit board with a Light Emitting Diode (LED), a spring, a spring cap, a stylus mount, a housing, carbide balls, a lower circuit board, a support ring and wires.

18 Claims, 13 Drawing Sheets



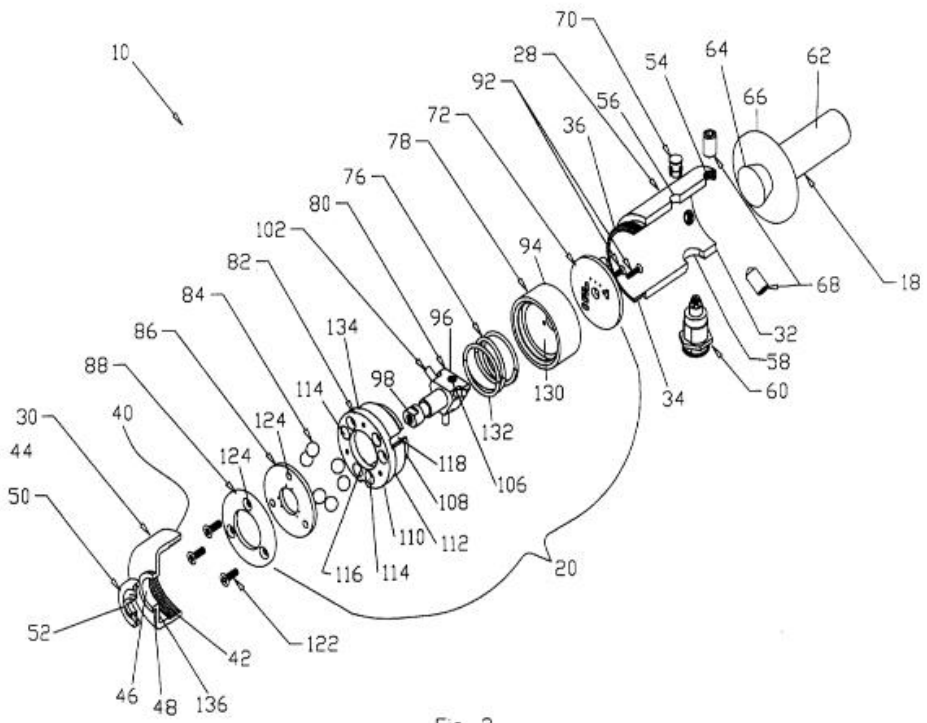
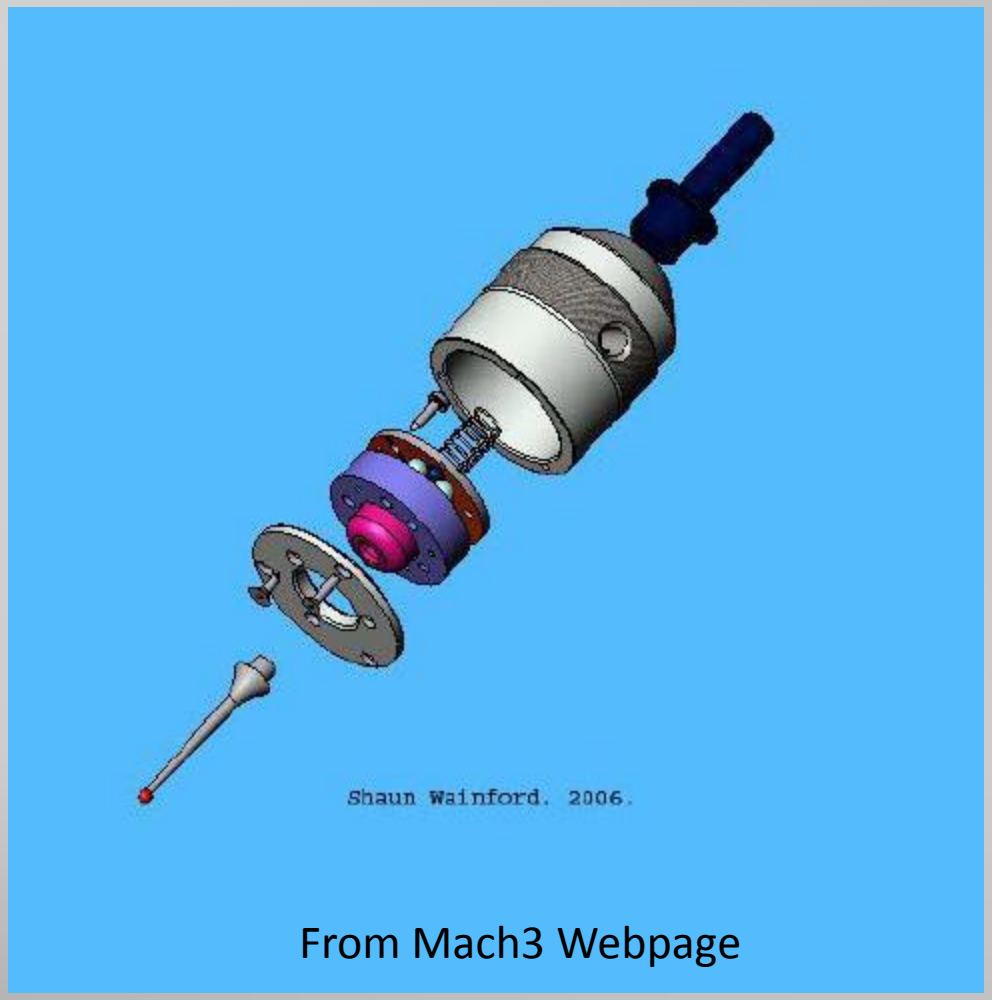
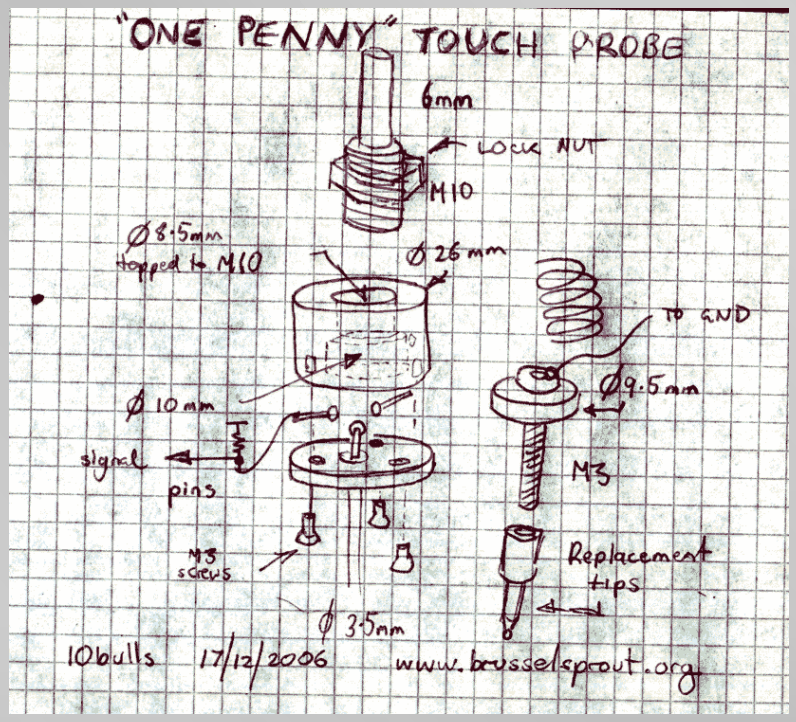


Fig. 2

Design research - homebuilt



From Mach3 Webpage



Design research - magazine

Touch-trigger Contact Probe

by J. R. Williams

Photos and drawings by Author

I had an early model contact probe and digital readout on my old milling machine that was handy for centering and edge location. My new CNC milling machine arrived on the scene ten years ago and I did not purchase the probe, as the system was too expensive for my requirements. The thought of a probe was placed on the back burner until I saw one that came with a milling machine (as advertised in Village Press publications) a few months ago.

SHANK
mat'l - stainless steel
1 req'd
(1)

TOP CIRCULAR BODY
mat'l - aluminum
1 req'd
(2)

The first task was to build a simple prototype to test my design (Photo 1). It had six steel balls placed in pairs and equally spaced, with three arms attached to the moveable probe. This configuration will always return the probe to the same position. The layout of the ball pattern was a new operation to me, as I had not programmed the machine to drill a pattern such as this before. The holes were drilled with a standard 1/4" shank center drill. Once I had the holes drilled, I made a prototype probe holder with a carrier section to hold the three arms. I used 1/8" diameter x 1/2" long dowel pins pressed into a nylon holder. This unit proved my design (Figures 1 and 2) could be workable.

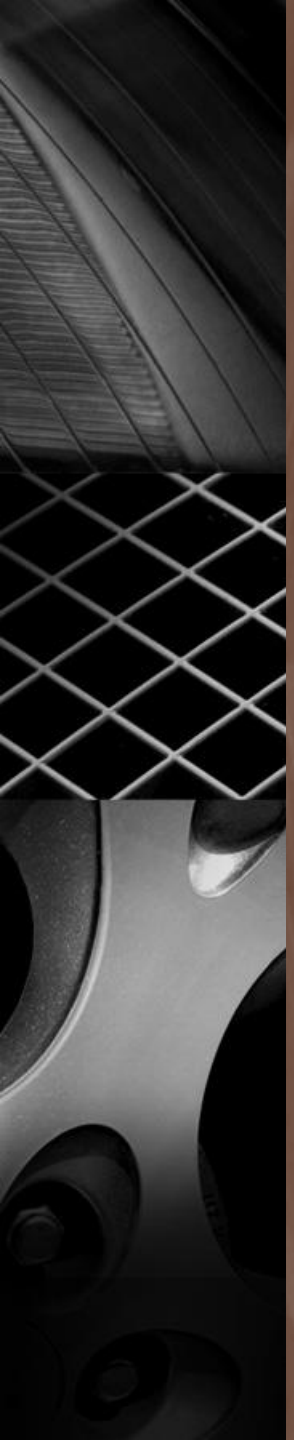
The next job was to machine a shank (Detail 1) using stainless steel bar stock. One end was threaded 3/8-24. The top circular body (Detail 2) is made of aluminum and threaded to fit the shank.

The body was turned oversize, and the final machining was done after it was screwed onto the shank, using thread sealant to hold it firmly in place. The lathe work was performed using collets. The shank section extends beyond the inner face to provide a centering mount for the spring that returns the probe to the home position.

The outer shell (Detail 3) is an aluminum tube turned to fit the top body and should be a tight fit to hold the assembly while drilling and tapping the three assembly

One more option – simplicity!

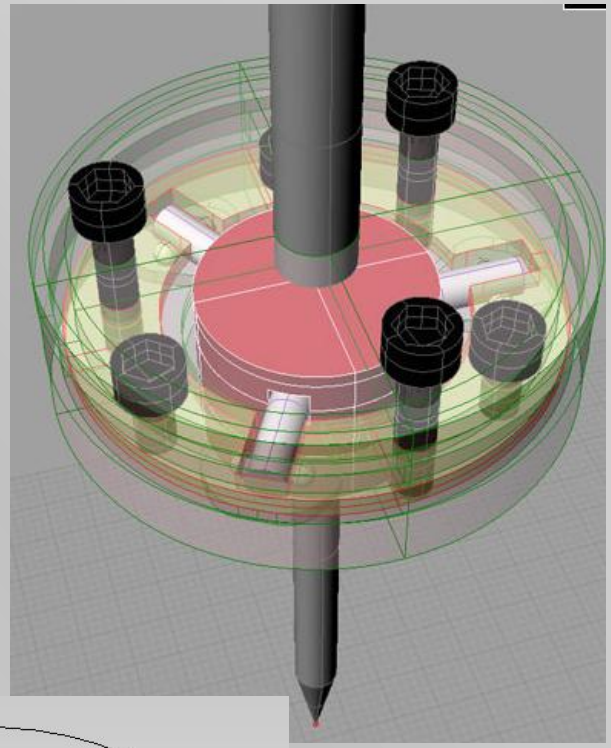
- Probe with no moving parts
- Rely on direct electrical contact at isolated probe tip
- Can’t do non-conductive stock

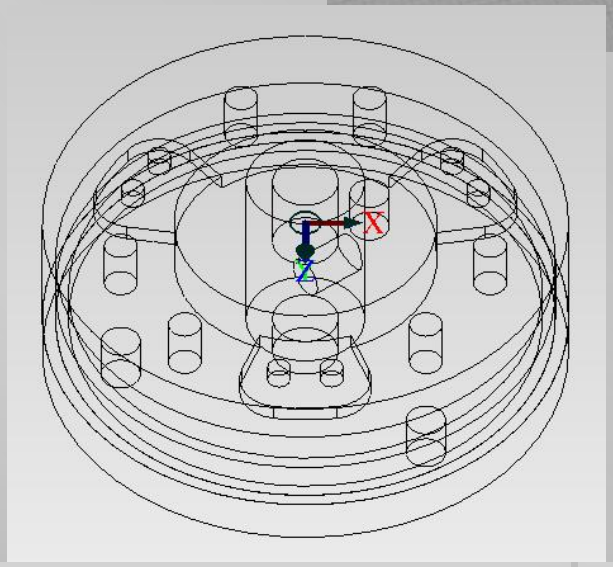


My design

First design considered

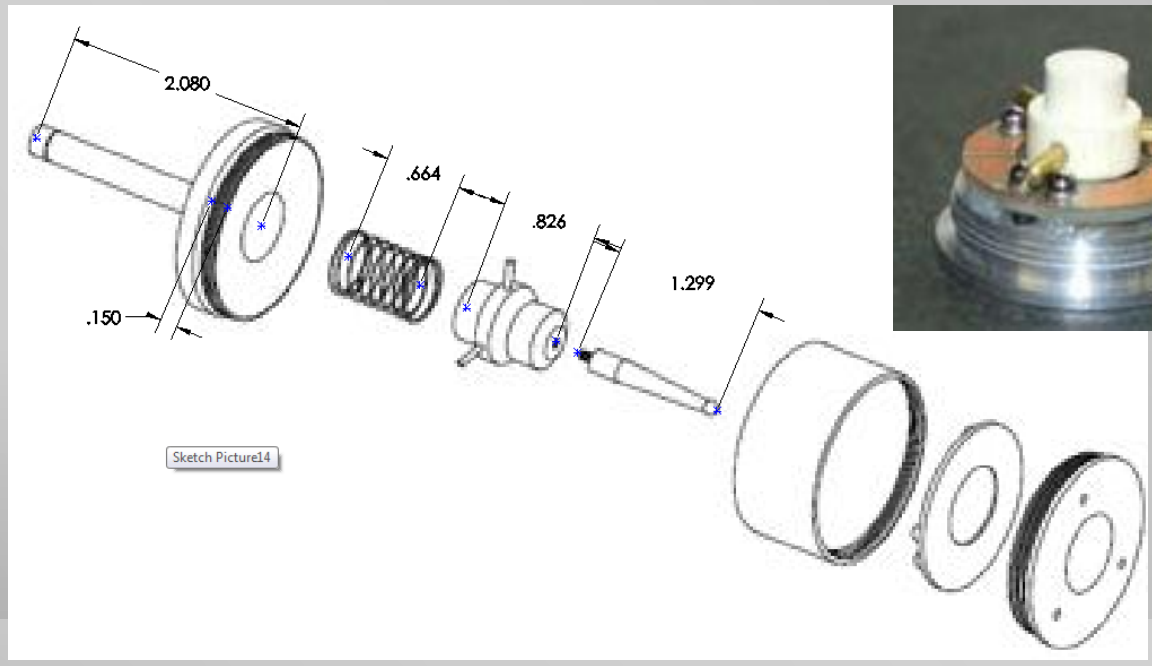
- Found on CNCzone.com discussion group
- Had 2D DXF files posted
  - Began converting to 3D model
- Body made entirely of plastic
- Liked idea of using circuit board to electrically connect and hold ball bearings
- Didn’t like tiny ball bearings used
- Didn’t like all plastic body
- Concerned about accuracy of balls

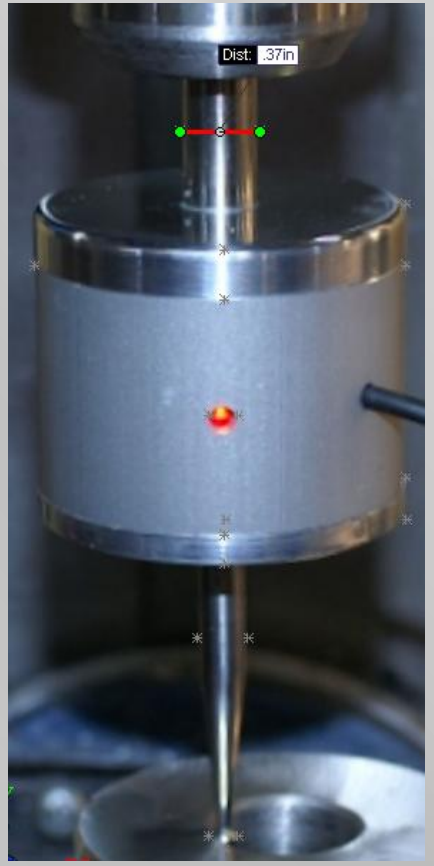




Second design considered

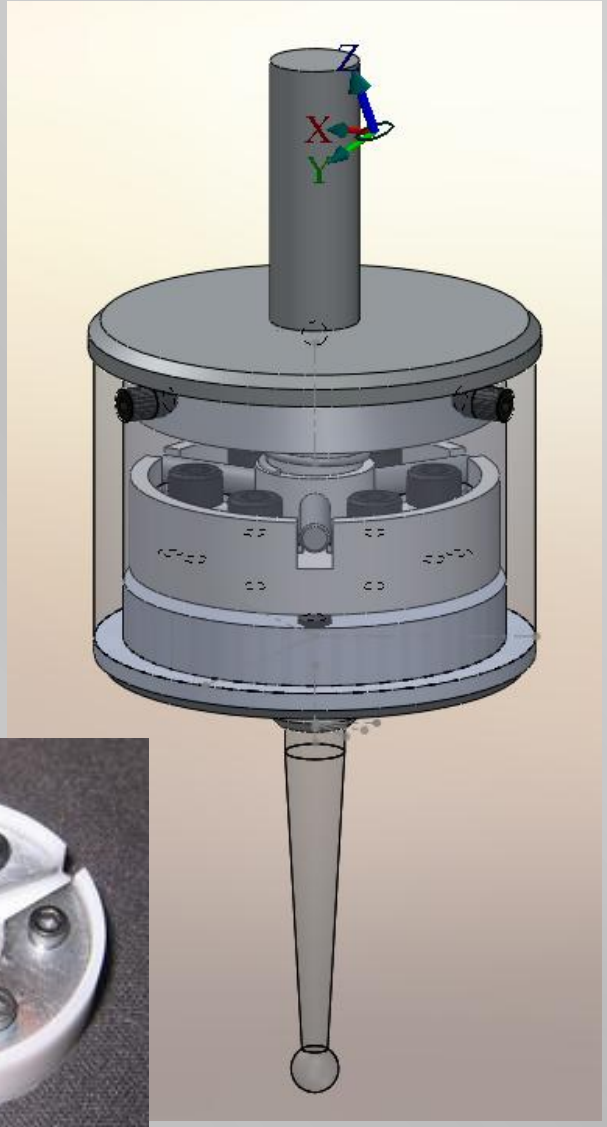
- Based on commercial unit from CNC4PC.com
- Utilized RTV and adjustment screws on bottom
- Performed photo dimensional analysis
- Challenge in design - solder ball bearings to PCB



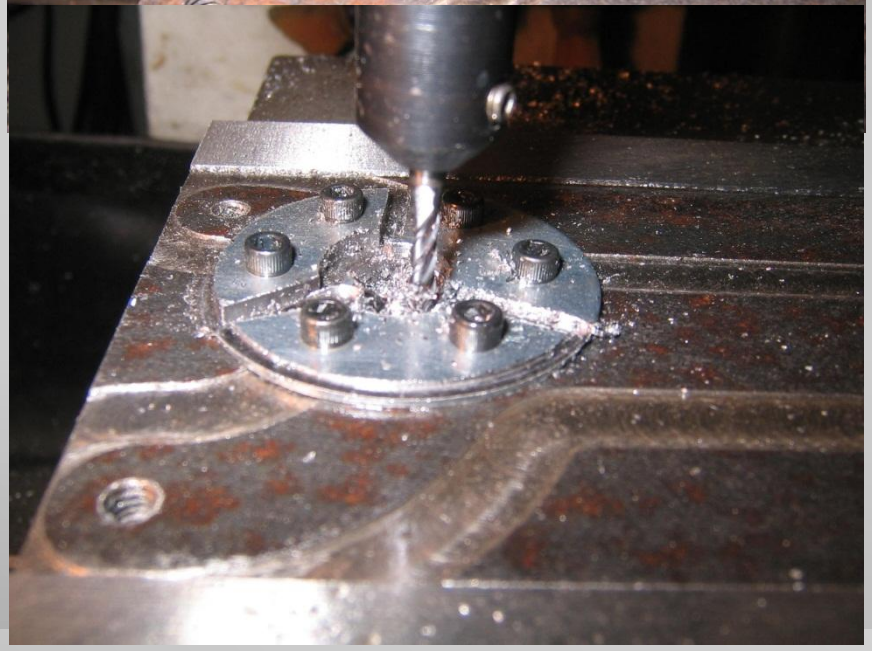


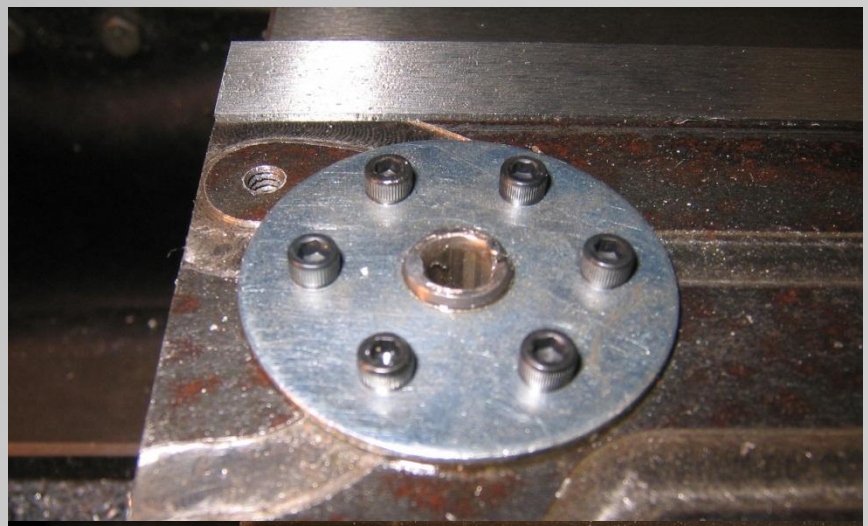
Third design considered

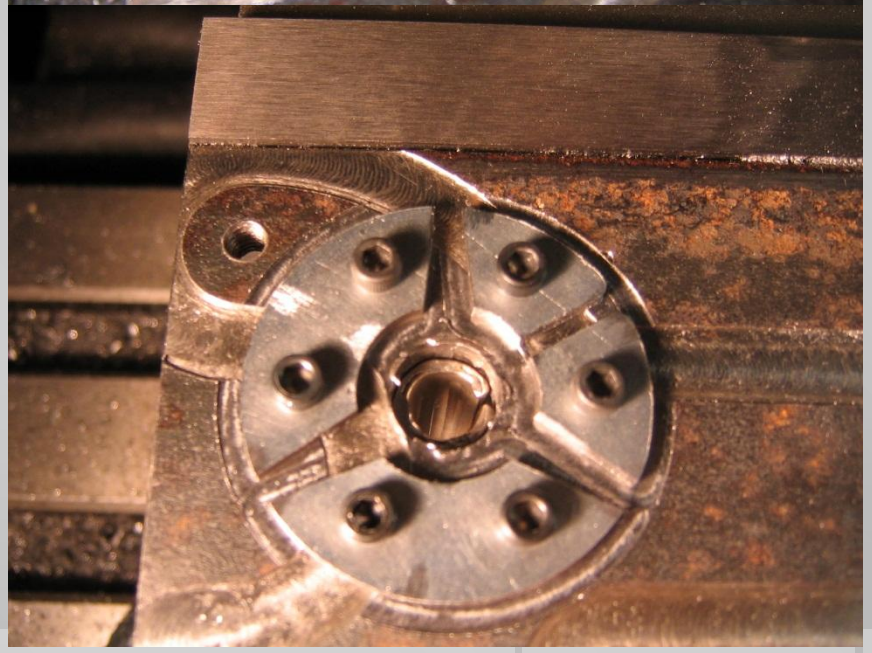
- My design, based on second concept
- Used split washer instead of ball bearings
- Incorporated top only adjustment
- Liked plastic carrier design
- After machining prototype carrier, was not sure it would be accurate enough



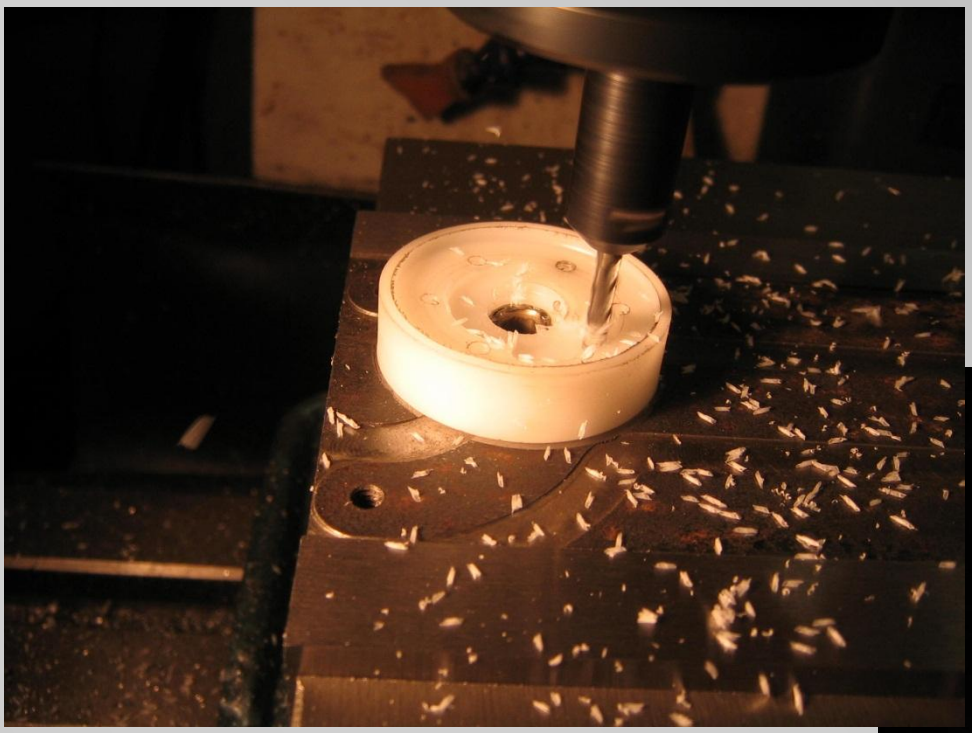
Machining washer

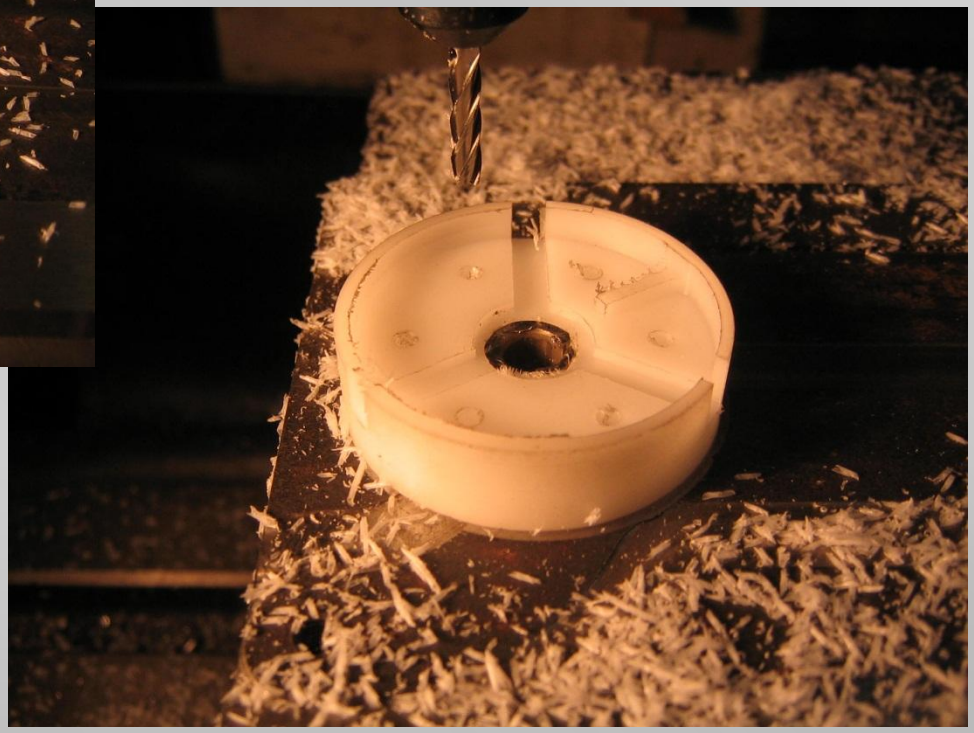






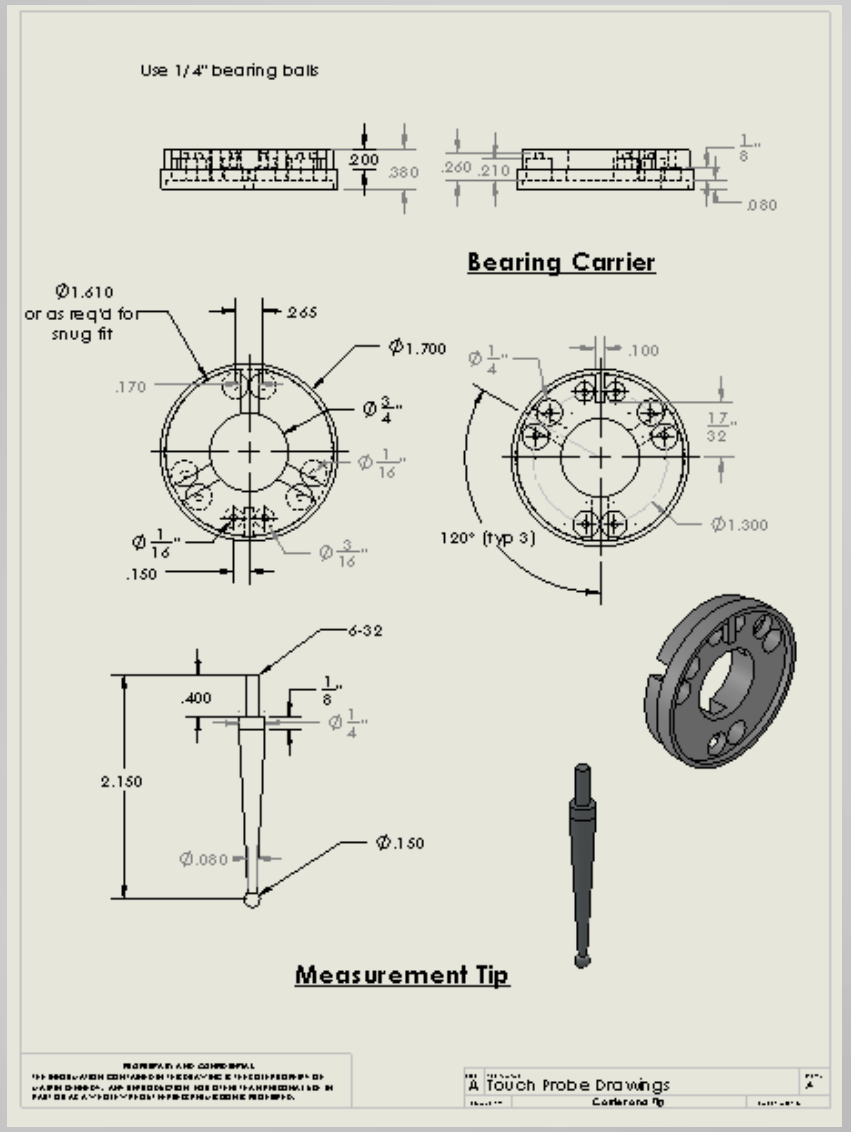
Machining Delrin carrier



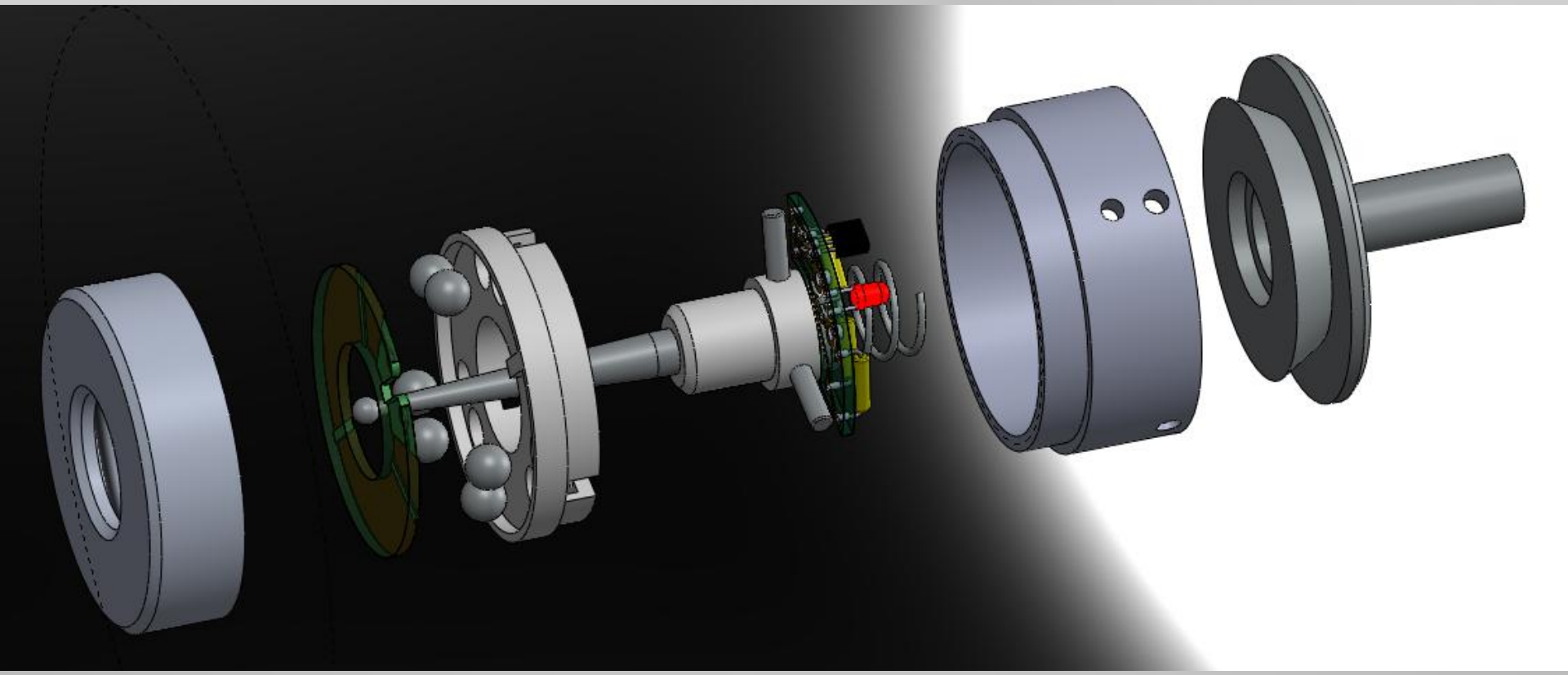


Fourth and final design

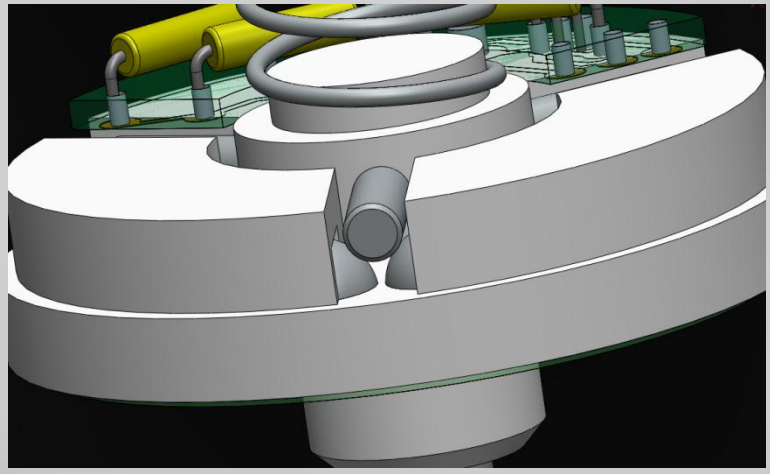
- Design carried forward from third design, but with ball bearings
- Utilized ball carrier design
- Includes bottom circuit board to align balls and provide reliable electrical contact
- Complete drawings available on HMSC website

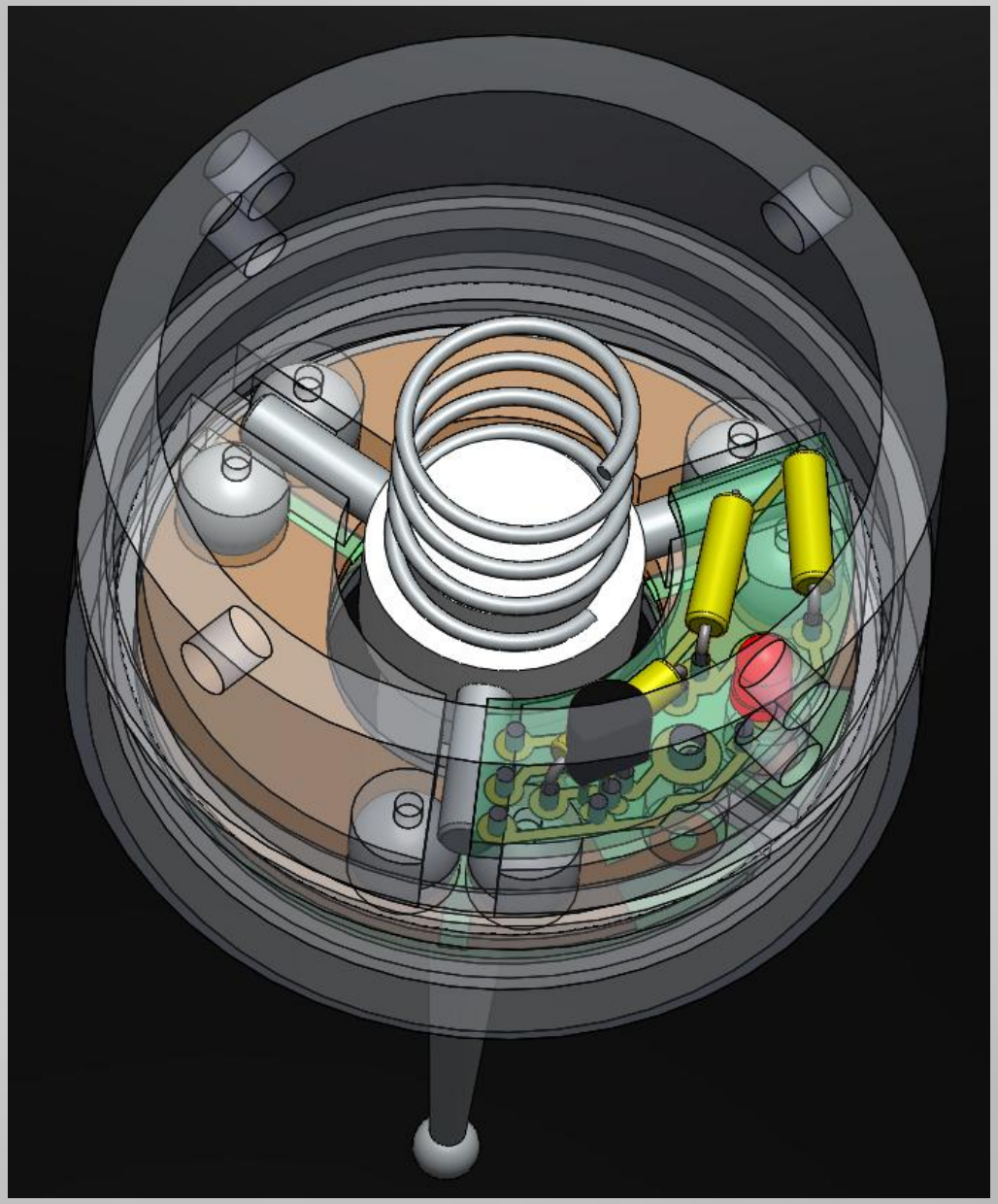


Exploded view

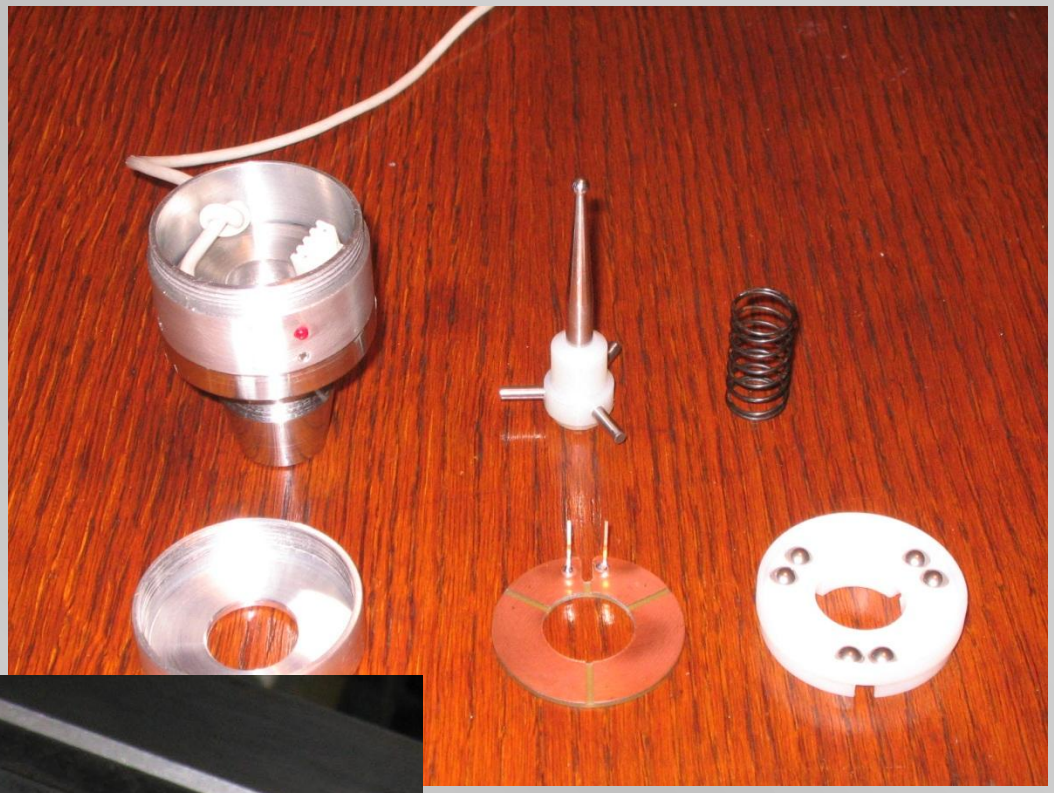


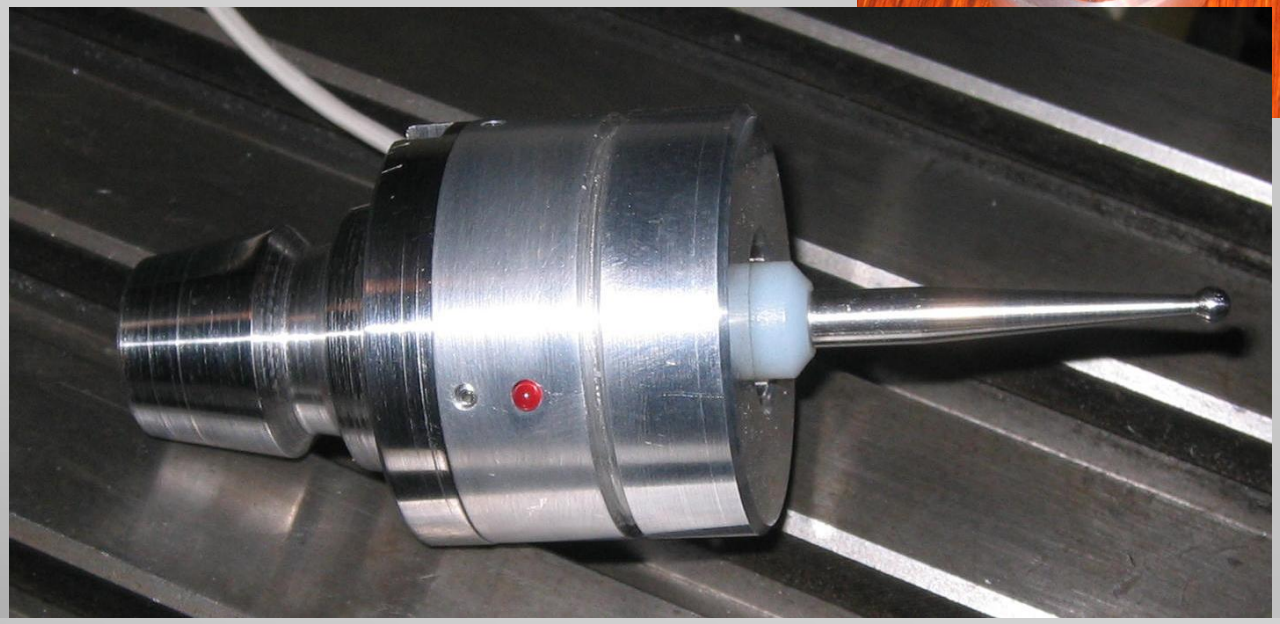
Assembly view



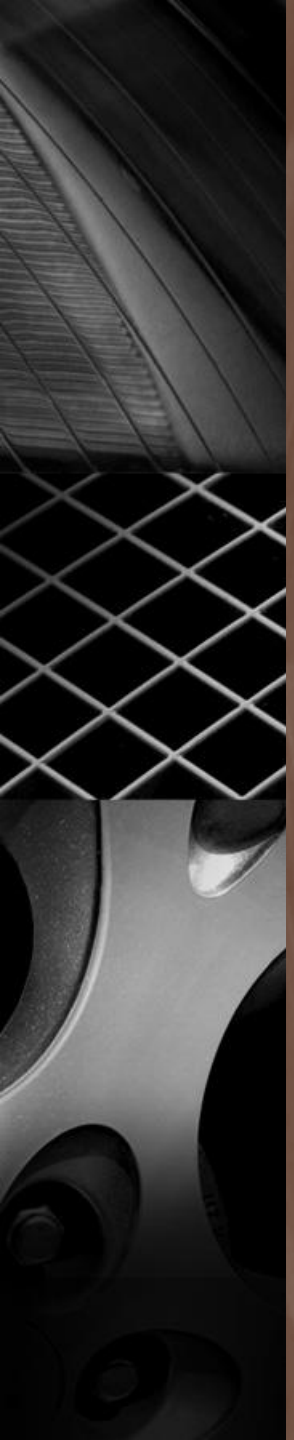


Electronic Probe



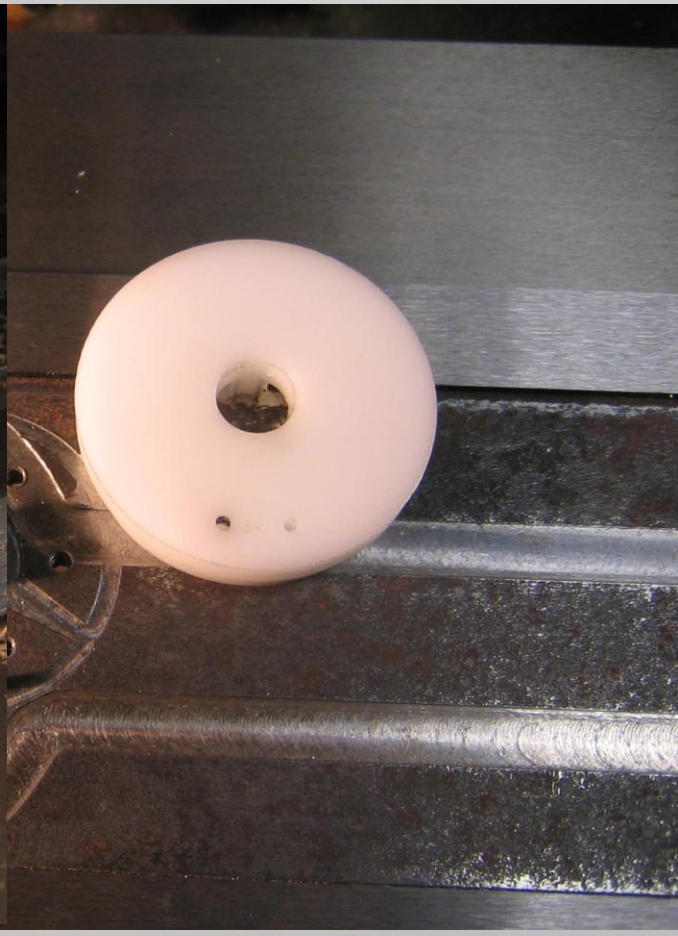


Probe incorporates
Royal Products
Easy Change tool holder

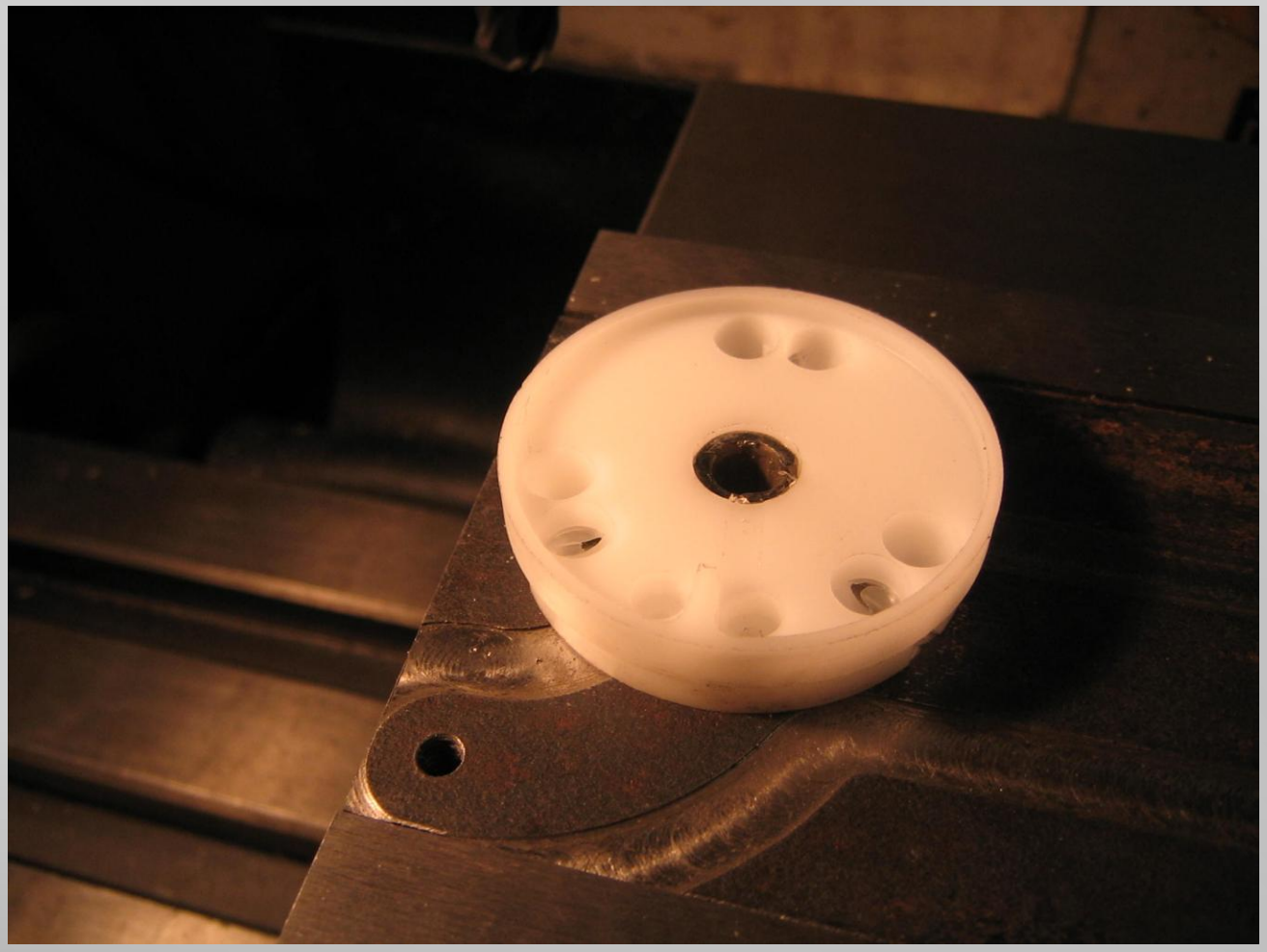


Fabrication

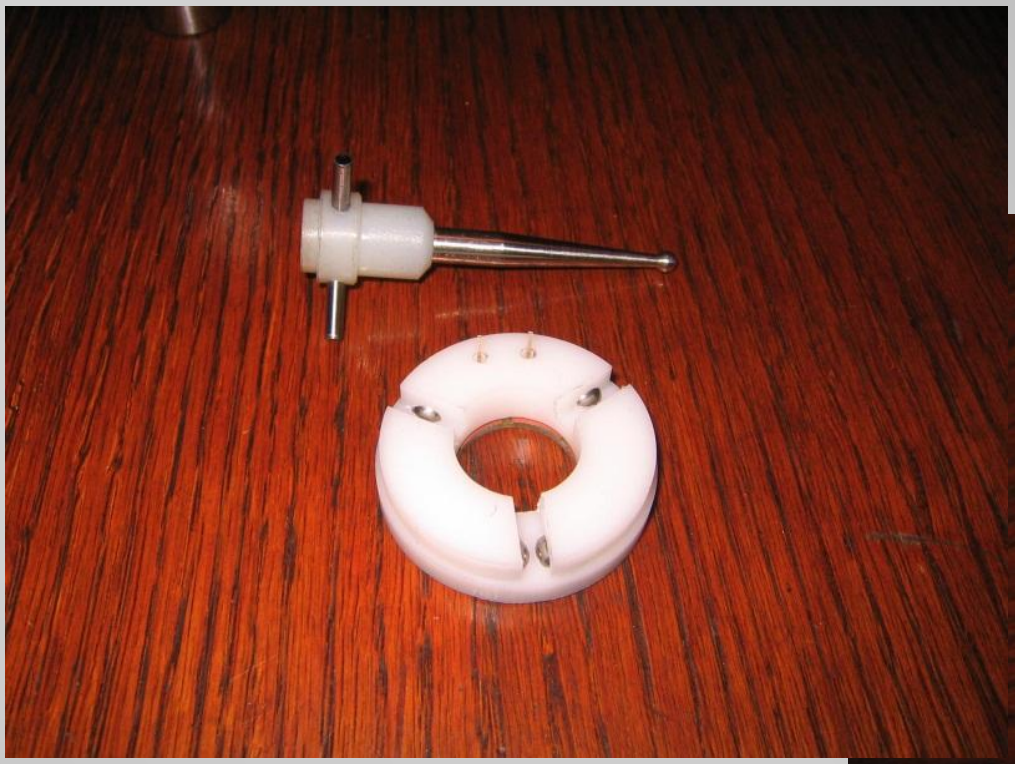
Making the Delrin carrier

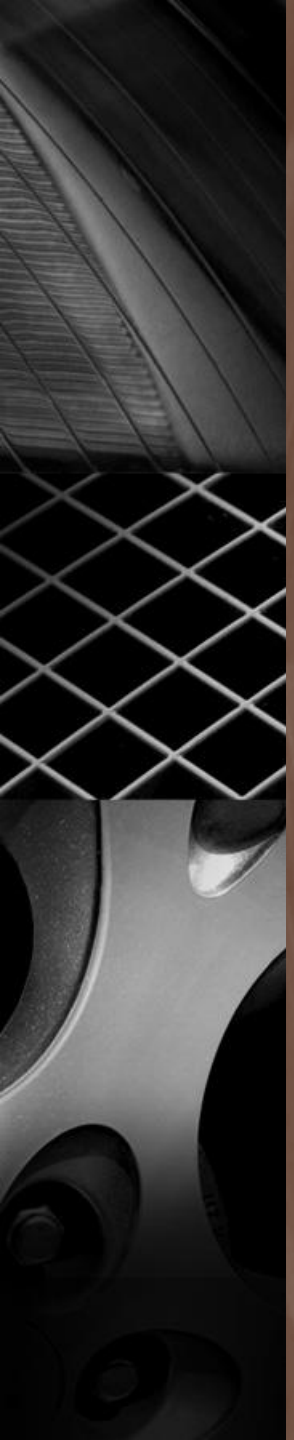


Completed carrier



Probe Mechanism

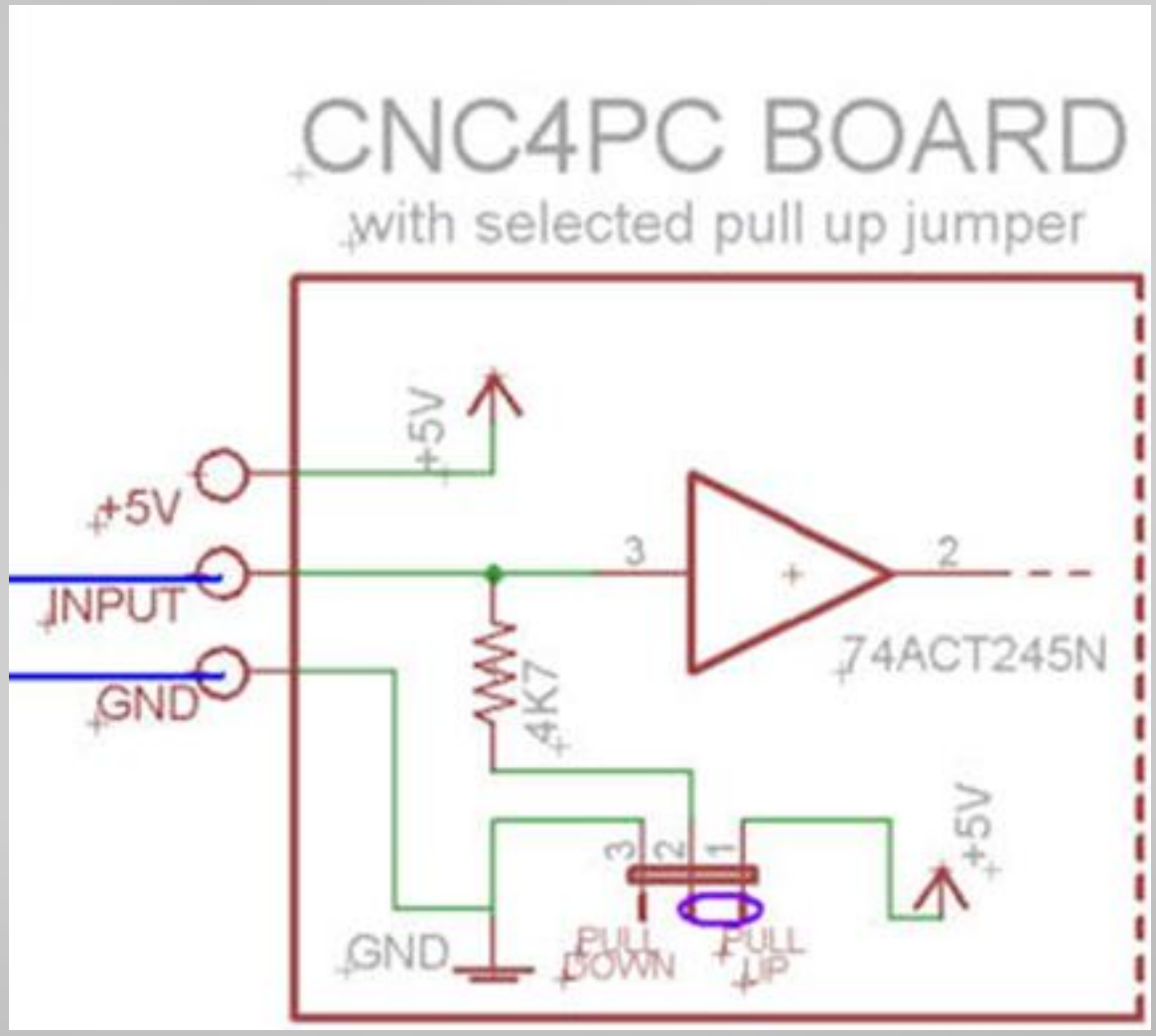




Electronics

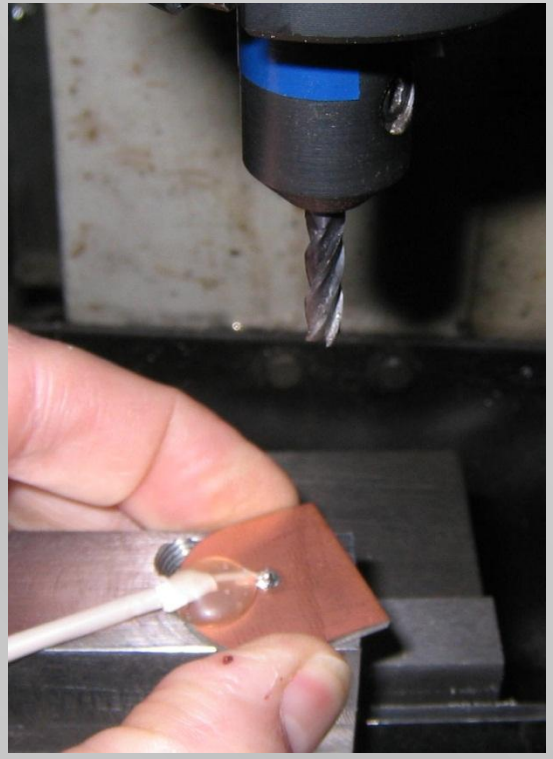
Electronics

- Interfaces with CNC Mill through CNC4PC breakout board
- Active High = input normally ground, with 5V indicating tripped
- Active Low = input normally 5V, with ground indicating tripped

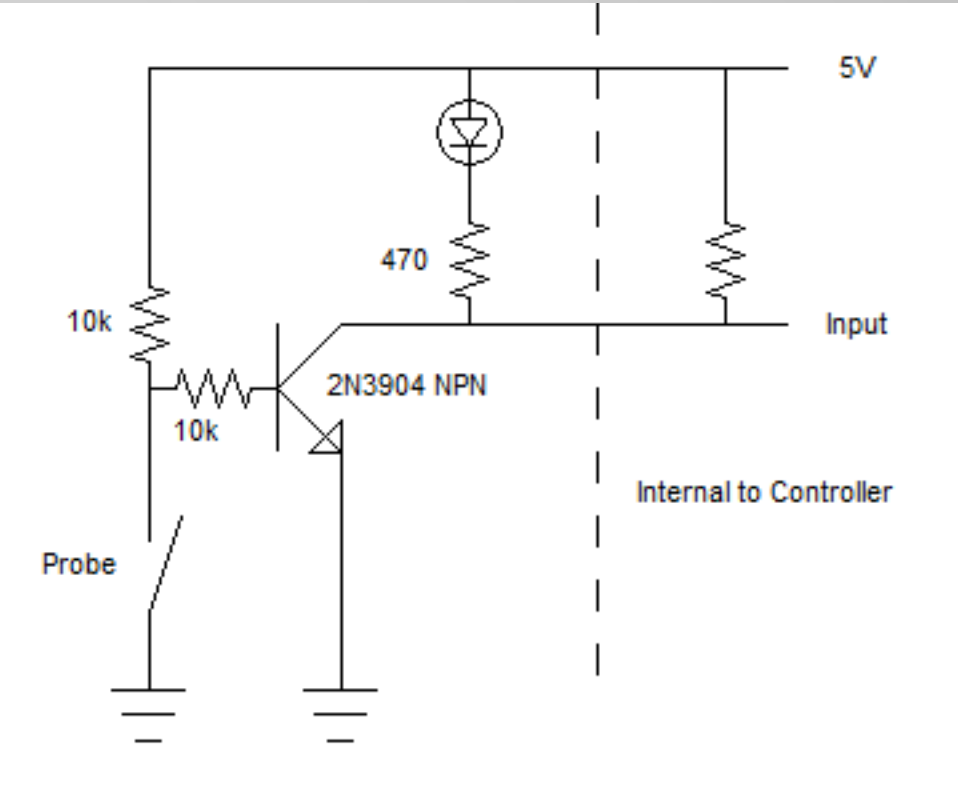


A problem!

- Probe could be directly wired in to CNC controller
  - No contact = short to ground, or Active High
  - Contact interrupted the ground, and input line would go to 5V
- Touch-off adapter works opposite
  - No contact = 5V, or Active Low
  - Contact when tool grounds out indicator
- I didn’t want to reconfigure system each time
  - I needed circuit to invert probe input line

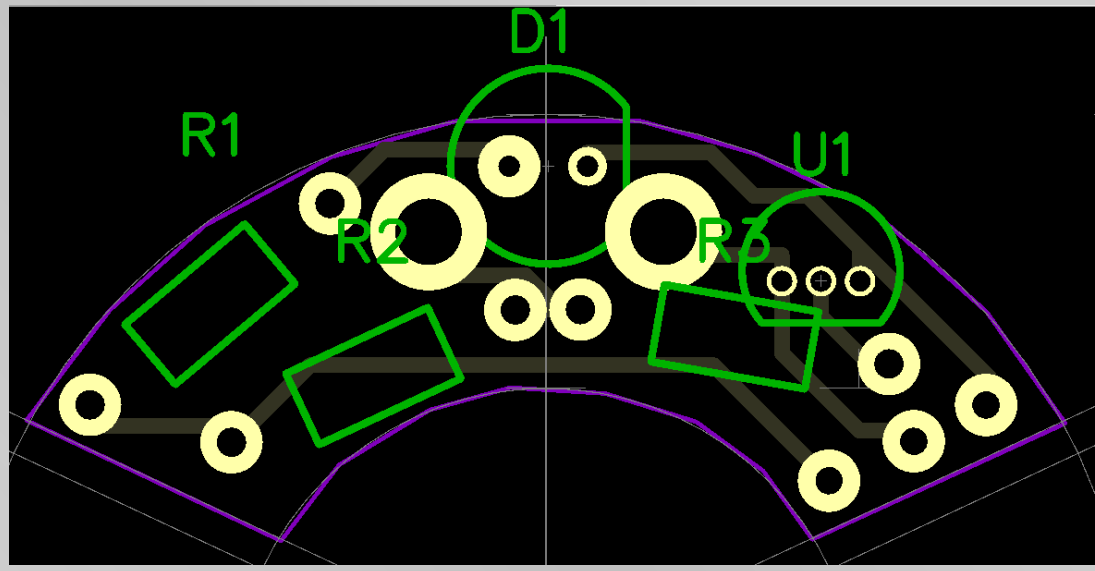


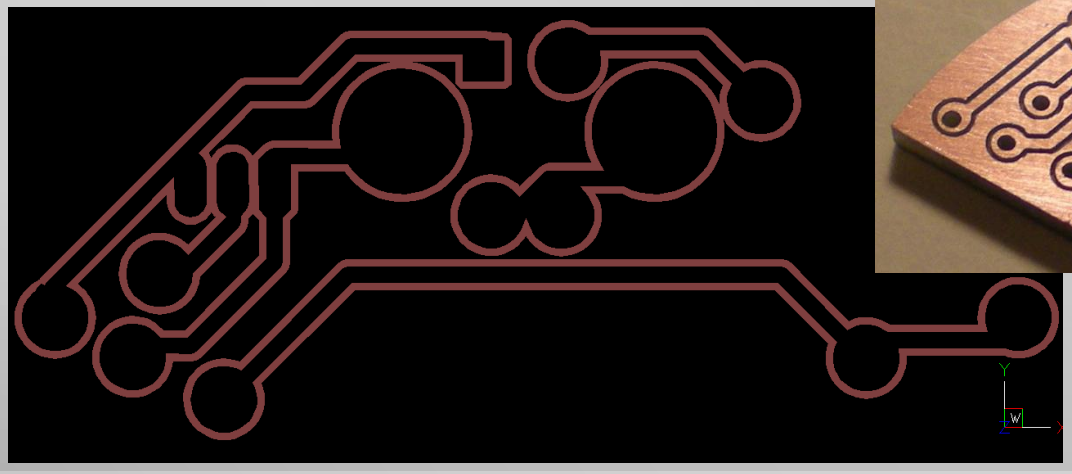
Simple inversion circuit

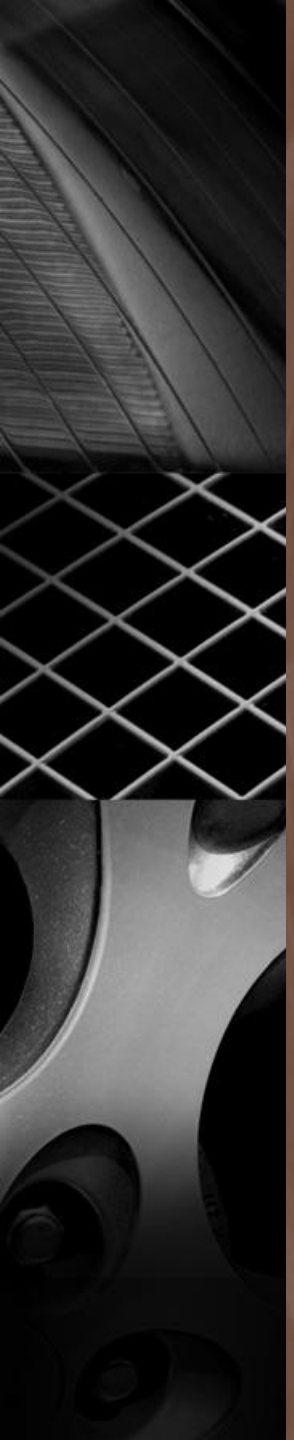


Circuit board

- Built PCB layout with Novarm DIP Trace software
- Output .DXF
- Machined board
  - Used 0.008” mill







Software

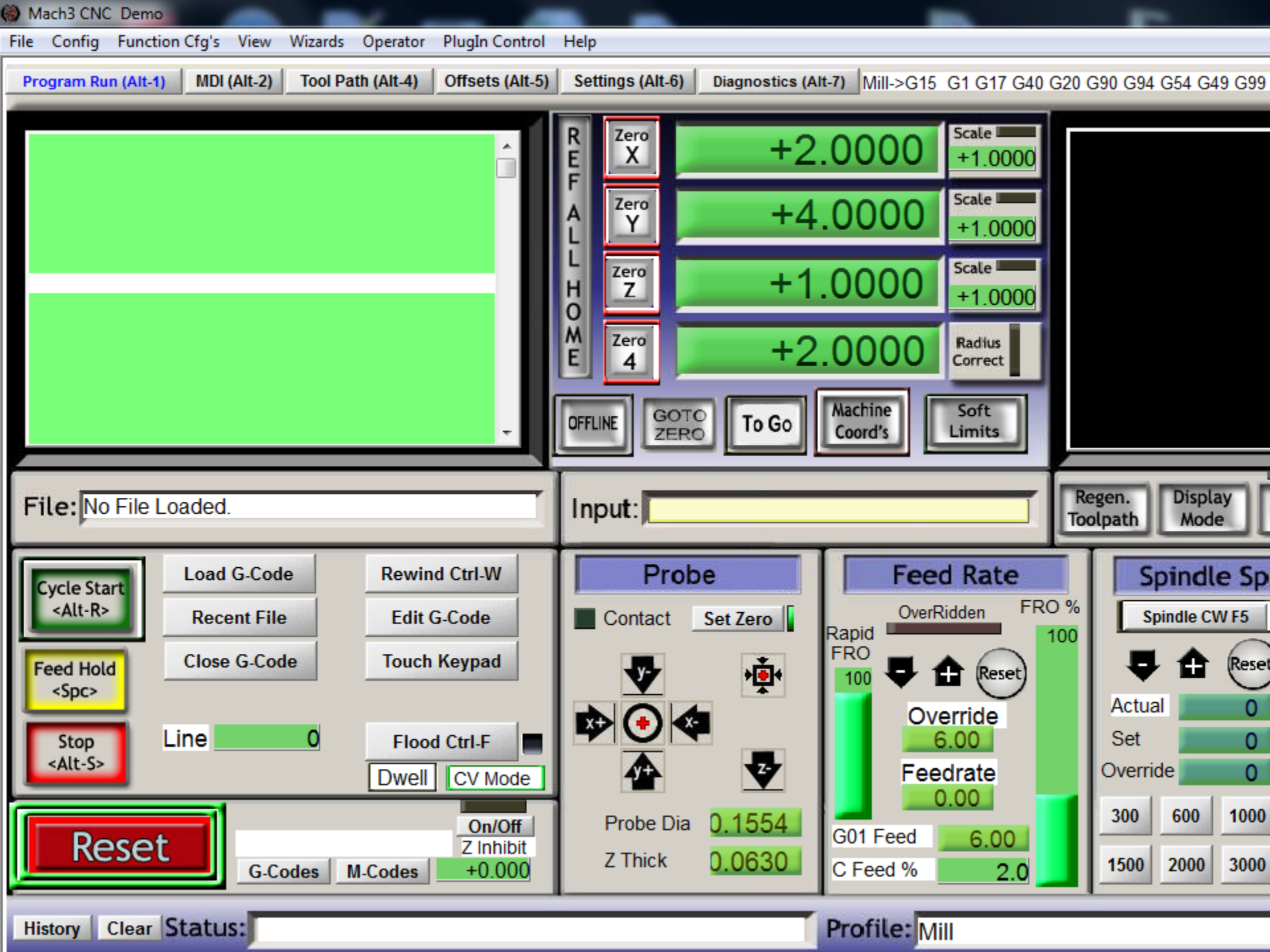
Probe driver software

- Default Mach3 screen does not include digital probes
- Mach3 has the ability to use multiple screen displays
  - Called “Screensets”
- Mach3 website has library of screens
  - A few screensets could drive digital probes
  - Freeware screensets had limited functionality
  - Screensets with more advanced algorithms were offered for sale

    Some cost more than Mach3!
- I ended up developing my own screenset

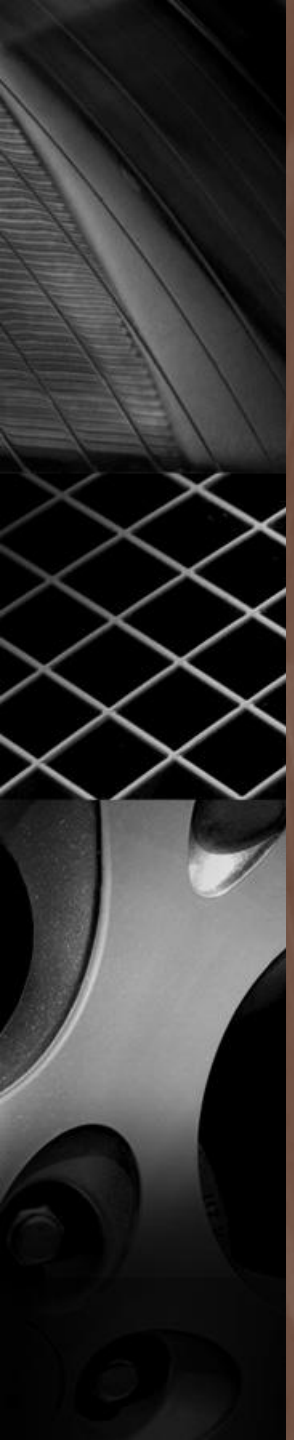
    Used MachScreen software to edit screenset and develop code to drive probe

    Also built pop-up touchscreen keypad for my touchscreen monitor


Mach3 CNC Demo
File Config Function Cfg's View Wizards Operator PlugIn Control Help
Program Run (Alt-1) MDI (Alt-2) Tool Path (Alt-4) Offsets (Alt-5) Settings (Alt-6) Diagnostics (Alt-7)
Mill->G15 G1 G17 G40 G20 G90 G94 G54 G49 G99
REF ALL HOME
Zero X
Zero Y
Zero Z
Zero 4
+2.0000
+4.0000
+1.0000
+2.0000
Scale
+1.0000
Radius Correct
OFFLINE
GOTO ZERO
To Go
Machine Coord's
Soft Limits
File: No File Loaded.
Input:
Regen. Toolpath
Display Mode
Cycle Start <Alt-R>
Feed Hold <Spc>
Stop <Alt-S>
Load G-Code
Recent File
Close G-Code
Rewind Ctrl-W
Edit G-Code
Touch Keypad
Line 0
Flood Ctrl-F
Dwell
CV Mode
Reset
On/Off
Z Inhibit
G-Codes
M-Codes
+0.000
Probe
Contact
Set Zero
Probe Dia 0.1554
Z Thick 0.0630
Feed Rate
OverRidden
FRO %
Rapid FRO
100
Reset
Override 6.00
Feedrate 0.00
G01 Feed 6.00
C Feed % 2.0
Spindle Sp
Spindle CW F5
Actual 0
Set 0
Override 0
300 600 1000
1500 2000 3000
History Clear Status:
Profile: Mill

Software development

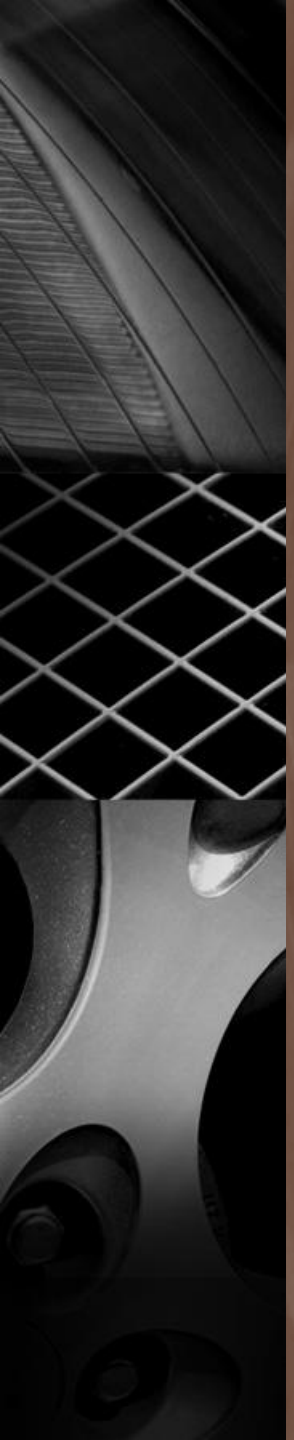
```
45  If PD = "X+" Then
46      Code "G31X" & (GetOEMDro(800) + XYMax)  'probe move and detect
47      While IsMoving()                        'wait for probe move to finish
48      Wend
49
50      If GetOEMLED (825) = 0 Then             'check to see if contact was made
51          Code "(Did not encounter stock after moving " & XYMax & """)"
52          Code "F" & CurrentFeed              'returns to prior feed rate
53          Exit Function
54      End If
55
56      Code "G0 X" & (GetVar(2000) - .025)     'move away from hit point and allow for overshot
57      While IsMoving ()
58      Wend
59
60      Code "F" & FSlow                        'set slow feedrate to recheck touch point accurately
61      Code "G31X" & (GetOemDro(800) + .1)     'probe move and detect with small allowance
62      While IsMoving()                        'wait for probe move to finish
63      Wend
64
65      Code "G0 X" & GetVar(2000)              'move back to hit point incase there was overshoot
66      While IsMoving ()
67      Wend
68
69      If SetZero = 0 Then
70          Call SetOemDro(800, -ProbeDiameter / 2) 'set the DRO for zero
71          Edge = 0
72      Else
73          Edge = GetOEMDRO(800) + ProbeDiameter / 2
74      End If
75      Code "(Edge at X=" & Format(Edge,"0.0000") & ")"    'puts message in the status bar
76      Code "G0X" & (Edge - XYClear)           'retract
77      While IsMoving ()                       'wait for probe move to finish
78      Wend
79
80      ProbeDirection = True                   'flag successful probe
```



Operation

Probe in use

- Finding center of hole - video
- Finding center of rectangle – video
- Set z axis zero for tool

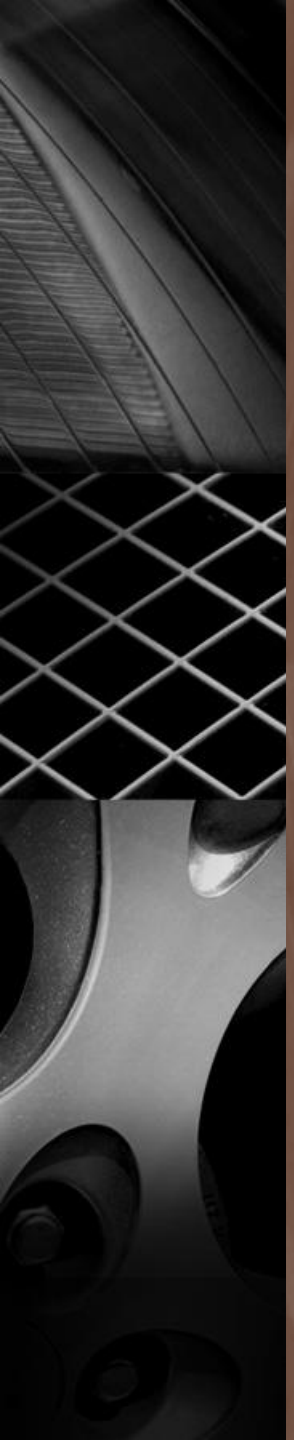


Accuracy

Calibration and accuracy

- STEP 1: Spin probe, and set probe ball at exact center using test gauge
  - Tape up cord!
  - Use four set screws to adjust
- STEP 2: Set effective ball diameter with test ring
  - Ran 10 tests, then 10 more with probe rotated 45°
  - Measured probe ball to be 0.1592” diameter
  - Tests showed effective diameter is 0.1550”

    => 0.0021” move to actuate
- Accuracy found to be ±0.0001” to ±0.0003”, depending on orientation



Questions?