Plotting Like It’s 1989
~
Scrap to Superformula

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~
Poughkeepsie ACM Chapter
January 2016
How It All Began

> You read that right:

- **$944** for what might have been a 20 MB drive
- **$406** for a 10 MB (!) hard drive
- **$1385** for an EGA graphics board & display

How It All Began

“I wish I still had that HP plotter … ”

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<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>To/From Whom</th>
<th>Amount</th>
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<tr>
<td><strong>Account Hardware</strong></td>
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<td>Qubie</td>
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<td>04/20/85</td>
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<td>CSS</td>
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<td>08/12/85</td>
<td>HP 7475A plotter</td>
<td>47th St Comp</td>
<td>1592.43</td>
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<td>RS232, switches, xtals...</td>
<td>DigiKey</td>
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<tr>
<td>09/10/85</td>
<td>10MB drive</td>
<td>Qubie</td>
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<td>12/06/85</td>
<td>EGA (128K) &amp; ECD</td>
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<td>EPROM eraser</td>
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http://softsolder.com/2015/02/07/business-expenses-1985-hardware/
I have two of the plotters, if you want one, it’s yours.
A Few Days Later

From: Dithermaster

Re: Old HP7475 plotters

Glad it arrived safely.

Every time I shook it more seeds came out.

http://softsolder.com/2015/02/07/business-expenses-1985-hardware/
Disassembly Begins...

http://softsolder.com/2015/04/20/hp-7475a-plotter-rehabilitation/
Plotter Control Board

http://softsolder.com/2015/04/20/hp-7475a-plotter-rehabilitation/
Rodent Hotel / Granary / Latrine

http://softsolder.com/2015/04/20/hp-7475a-plotter-rehabilitation/
Dried Capacitors

http://softsolder.com/2015/04/20/hp-7475a-plotter-rehabilitation/
LED Strip Lighting

- White 5050 SMD LEDs
  - 12 VDC @ 120 mA
  - 5 VDC boost converter
  - More internal heat
- They’d have done it
  - If they had white LEDs
  - Remember: 1980-ish

http://softsolder.com/2015/07/09/hp-7475a-plotter-led-lighting/
Fossilized Plotter Pens

• New Old Stock on eBay
  - Fiber $5+
  - Liquid ink $10+
  - Each
    • Plus postage
  - Multi-packs?

• Sealed Pouches
  - Might be good
  - … or not

• Also available: New Stock!

http://softsolder.com/2015/04/21/hp-7475a-plotter-oem-pen-body-model/
Sakura Micron Pen Adapter

- Model an HP pen
- Model a Sakura pen
- Subtract the models
  - Flange overhang
  - Very thin walls

http://softsolder.com/2015/04/22/hp-7475a-plotter-sakura-micron-pen-adapter/
Sakura Micron Pen Adapter

- Realities of 3D Printing
  - Can’t print overhangs
  - Thin walls
  - Tapered walls
  - Layer thickness
  - Solvent bonding
  - Alignment mandrel

http://softsolder.com/2015/04/22/hp-7475a-plotter-sakura-micron-pen-adapter/
Sakura Micron Pen Adapter

- Realities of 3D Printing
  - It’s really easy
  - Hands-off build
  - OpenSCAD FTW!

http://softsolder.com/2015/04/22/hp-7475a-plotter-sakura-micron-pen-adapter/
Sakura Micron Pen Adapter

http://softsolder.com/2015/04/22/hp-7475a-plotter-sakura-micron-pen-adapter/
ROM Test Pattern

• Standard pen loadout
  – Black (0.7 mm)
  – Black (0.3 mm)
  – Red
  – Green
  – Blue
  – Violet

• Close enough, I’d say...

http://softsolder.com/2015/04/23/hp-7475a-plotter-full-up-sakura-micron-pen-tests/
ROM Test Pattern

- Built-in Self Test
  - Insert A-size paper
  - Hold P1 + P2
  - Power On
- *It worked!*
  - Pens flop around
  - Low ink flow
  - Bar chart from 1982...

http://softsolder.com/2015/04/23/hp-7475a-plotter-full-up-sakura-micron-pen-tests/
Cut-down Pens

- Less floppy
  - Still too tall
- Smaller ink capacity
  - But the nibs write!
- Low ink flow
  - But the nibs write!
- This could work...

http://softsolder.com/2015/04/23/hp-7475a-plotter-full-up-sakura-micron-pen-tests/
Vinyl Cutter = Dead End

http://softsolder.com/2015/04/30/hp-7475a-plotter-roland-knife-stabilizer-improved/
Chiplotle Plotter Driver

- “Chiplotle: an HPGL (Hewlett-Packard Graphics Language) Python API”
- “Finally, a way to control your grungy old pen plotters with your shiny new laptop!”

http://music.columbia.edu/cmc/chiplotle/
Serial Port

• Remember RS-232?
  – USB-to-Serial adapter
  – Gender bender
  – DB-25 to DE-9 adapter
  – Gender bender
  – Null modem

• Ya gotta have stuff!

http://softsolder.com/2015/05/04/hp-7475a-plotter-serial-cable-for-hardware-handshaking/
Serial Port Configuration

• Remember serial data?
  – 9600 b/s (!)
  – 8 data bits
  – 1 stop bit
  – No parity

• Remember DIP switches?

• Der Blinkenlights!

http://softsolder.com/2015/05/04/hp-7475a-plotter-serial-cable-for-hardware-handshaking/
Serial Cable Wiring

• Remember serial cables?
  - 1 DCD ↔ 4 RTS
  - 2 RXD ↔ 2 TXD
  - 3 TXD ↔ 3 RXD
  - 4 DTR ↔ 5 CTS / 6 DSR
  - 5 GND ↔ 7 GND
  - 6 DSR / 8 CST ↔ 20 DTR
  - 7 RTS ↔ 8 DCD
  - 9 RI → n/c

• Hardware handshaking FTW!

http://softsolder.com/2015/05/04/hp-7475a-plotter-serial-cable-for-hardware-handshaking/
Superformula

• The [super]formula was obtained by generalizing the superellipse, named and popularized by Piet Hein, a Danish mathematician.

• The superformula ... was first proposed by Johan Gielis in 2003. Gielis suggested that the formula can be used to describe many complex shapes and curves that are found in nature.
Superformula

"Sf2d" by Tiago Charters de Azevedo - Own work. Licensed under CC BY 3.0 via Commons - https://commons.wikimedia.org/wiki/File:Sf2d.png#/media/File:Sf2d.png
Gielis Superformula

\[ r = f(\Theta) = \left( \left| \frac{1}{a} \cdot \cos \left( \frac{m}{4} \cdot \Theta \right) \right|^n + \left| \frac{1}{b} \cdot \sin \left( \frac{m}{4} \cdot \Theta \right) \right|^n \right)^{\frac{1}{n_1}} \]

https://en.wikipedia.org/wiki/Superformula
Gielis Superformula

\[ r = f(\Theta) = \left( \left| \frac{1}{a} \cdot \cos \left( \frac{m}{4} \cdot \Theta \right) \right|^{n_2} + \left| \frac{1}{b} \cdot \sin \left( \frac{m}{4} \cdot \Theta \right) \right|^{n_3} \right)^{-\frac{1}{n_1}} \]

https://en.wikipedia.org/wiki/Superformula
from chiplotle import *
import math
plt=instantiate_plotters()[0]
plt.set_origin_center()
plt.write(hpgl.VS(5))
ss=geometry.shapes.supershape(3900,3900,5.3,0.4,1,1,
    point_count=10*1000,travel=10*2*math.pi)
plt.select_pen(1)
plt.write(ss)
plt.select_pen(0)
Superformula / Supershape

http://softsolder.com/2015/05/07/hp-7475a-plotter-chiplotle-supershape/
Inside the Chiplotle Plotter Driver

def _write_string_to_port(self, data):
    if not isinstance(data, basestring):
        raise TypeError('string expected. ')
    data = self._filter_unrecognized_commands(data)
    data = self._slice_string_to_buffer_size(data)
    for chunk in data:
        # self._sleep_while_buffer_full( )
        self._serial_port.write(chunk)

• There’s a lot not to like about that...

http://softsolder.com/2015/05/05/hp-7475a-plotter-hacking-chiplotle-for-hardware-handshaking/
Comment #16 by rkward
on 2015-04-20 – 15:50

Contact me offline regarding plotter pens …
I think I have quite a few …

http://softsolder.com/2015/04/20/hp-7475a-plotter-rehabilitation
A Few Days Later

From: Keith Ward
Re: Plotter pens

Looks like it will be
the flat rate box for $20 …

*I didn't realize how many I had.*
Pens! Pens Everywhere!
New Old Stock Pens = *It Lives!*
“Disposable” Liquid Ink Pens

http://softsolder.com/2015/06/06/hp-7475a-plotter-refilling-disposable-liquid-ink-pens/
KiCad Schematic → Plotter Output

http://softsolder.com/2015/06/06/hp-7475a-plotter-refilling-disposable-liquid-ink-pens/
Refilling Plotter Pens: Opening

http://softsolder.com/2015/08/10/hp-7475a-plotter-refilling-the-pens/
CMYK → All! The! Colors!

http://softsolder.com/2015/08/20/hp-7475a-plotter-cmy-ink-mixes/
CMYK → All! The! Colors!

http://softsolder.com/2015/08/20/hp-7475a-plotter-cmy-ink-mixes/
Plotter Pen Refilling Station

http://softsolder.com/2015/08/21/hp-7475a-plotter-pen-refilling-station/
Zombie Pens

http://softsolder.com/2015/09/06/hp-7475a-plotter-zombie-pens/
Multiple SuperFormula Curves

http://softsolder.com/2015/08/05/hp-7475a-plotter-superformula-demo/
Multiple SuperFormula Curves

```python
pen = 1
for m in [3.7]:
    for n1 in [0.20, 0.60, 0.8]:
        for n2 in [1.0, 1.5]:
            n3 = n2
            e = supershape(paperx, papery, m, n1, n2, n3)
            plt.select_pen(pen)
            if pen < 6:
                pen += 1
            else:
                pen = 1
            plt.write(e)
plt.select_pen(0)
```

• There’s *a lot* not to like about that...

http://softsolder.com/2015/08/05/hp-7475a-plotter-superformula-demo/
Parameterizing: m

# prime/10 = number of spikes

```python
m_values = [n / 10.0 for n in [11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53, 59]]
```

Parameterizing: n1

# ring-ness 0.1 to 2.0, higher is larger

```
n1_values = [n / 100.0 for n in range(15, 75, 2) + range(80, 120, 5) + range(120, 200, 10)]
```
Parameterizing: n2 & n3

# spiky-ness 0.1 to 2.0, higher is spiky-er (?)

```python
n2_values = [
    n / 100.0 for n in range(10, 60, 2) +
    range(65, 100, 5) +
    range(110, 200, 10)]
```

Parameter Selection

\[ m = \text{random.choice(m_values)} \]

\[ \text{n1_list} = \text{random.sample(n1_values, numpens)} \]

\[ \text{n2_list} = \text{random.sample(n2_values, numpens)} \]
Multiple “Pretty” Plots

pen = 1
for n1, n2 in zip(n1_list, n2_list):
    n3 = n2
    print "\{0\} - m: \{1:.1f\}, n1: \{2:.2f\}, n2=n3: \{3:.2f\}".format(pen, m, n1, n2)
    plt.select_pen(pen)
    plt.write(hpgl.PA([(legendx, legendy - 100 * pen)]))
    plt.write(
        hpgl.LB("Pen \{0\}: m=\{1:.1f\} n1=\{2:.2f\} n2=n3=\{3:.2f\}".format(pen, m, n1, n2))
    e = supershape(maxplotx, maxploty, m, n1, n2, n3)
    plt.write(e)
    pen = pen + 1 if (pen % numpens) else 1

Multiple “Pretty” Plots

Because Engineer

HP 09872-60066 Digitizing Sight

http://www.hpmuseum.net/display_item.php?hw=888
Plotter User Interface

http://softsolder.com/2015/11/02/hp-7475a-plotter-one-button-demo-madness/
Chiplotle Digitizer Support!

print "Waiting for plotter... ignore timeout errors!"
sleep(40)
while NoneType is type(plt.status):
    sleep(5)

print "Load more paper, then ..."
print "  ... Press ENTER on the plotter to continue"
plt.clear_digitizer()
plt.digitize_point()

plotstatus = plt.status
while (NoneType is type(plotstatus)) or (0 == int(plotstatus) & 0x04):
    plotstatus = plt.status

print "Digitized: " + str(plt.digitized_point)
Each One Is Unique ...
... Just Like a Snowflake ...
... The Plots Never Repeat ...
... but They’re All Kinda the Same
Blog Comment: Pending Moderation

Johan Gielis

• ... the use of pens simply reminded me of Spirograph, which I loved, long time ago
• ... I also like very much the imperfection of pens
• There are many images on Google with super formula, but this is one of the best in my opinion
Piet Hein

PAST PLUPERFECT
The past, -- well, it's just like our Great-Aunt Laura, who cannot or will not perceive that though she is welcome, and though we adore her, yet now it is time to leave.

http://www.archimedes-lab.org/grooks.html
Questions?
Copyright-ish Stuff

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The rest is my own work

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Ed Nisley

Say “NISS-lee”, although we're on the half-essed branch of the tree
Engineer (ex PE), Hardware Hacker, Programmer, Author

The Embedded PC's ISA Bus: Firmware, Gadgets, Practical Tricks

Circuit Cellar www.circuitcellar.com
Firmware Furnace (1988-1996) - Nasty, grubby hardware bashing
Above the Ground Plane (2001 ...) - Analog and RF stuff

Digital Machinist www.homeshopmachinginist.net
Along the G-Code Way (2008 ...) - G-Code, math, 3D printing

Dr. Dobb's Journal www.ddj.com
Embedded Space (2001-2006) - All things embedded
Nisley’s Notebook (2006-2007) - Hardware & software collisions

Blog: The Smell of Molten Projects in the Morning
softsolder.com

September 1962
If you can't read this then make a new friend 'way up front