The HP-41 EEE(*) Experience

Teaching New Tricks to an Ol’Dog

Ángel M. Martin – November 2018

Multi-Threaded Coconuts, anybody?

(*) Extended, Expanded, Enhanced... premium unleaded

Presentation Agenda:

• Library#4 Concept and Reach
• Auxiliary FATs and Banked FATs
• Sub-functions, Launchers and Last-Function
• Auto-Complete XEQ*, Universal Execute XEQ$
• Loading and Interrogating the I/O Bus

• Advanced Modules Summary
• OS/X and Utilities ROMS
• System Extension Modules
• Emulators and Informatics ROMS
• Math Extension Modules
• Sciences & Engineering ROMS
• From Solve to Solver: Equation Libraries
• Rest & Relaxation
• Adapted Books and Literature
• Acknowledgments

• Appendix: System Memory and MLDL Modules
Library#4: A sorta MindMap

Library #4

- HEPAX_4H
- 41Z Deluxe
- Advtg. Math
- SandMatrix
- 41Z Diagnostics
- SandMath
- 41Z Deluxe
- Advtg. Math
- SandMatrix
- 41Z Diagnostics
- SandMath

- Elliptics ROM
- Areas & Sums
- ierf ROM
- Solve & Integ
- XM Stats
- Curve Fitting
- TVMS
- Special Funs.
- Recursion & MA
- Vector Calc.

- 16C Emulator
- Formula Eval
- Eval$ Apps; Equation Lib$

Auxiliary & Banked FAT Concept

- Main FAT
- 64 Fns max
- Banked FAT #1
  - Unlimited Size
- Banked FAT #2
  - Unlimited Size
- Banked FAT #3
  - Unlimited Size

- Aux FAT
  - Unlimited Size
- Aux-Banked FAT #1
  - Unlimited Size
- Aux-Banked FAT #2
  - Unlimited Size
- Aux-Banked FAT #3
  - Unlimited Size
Advanced Modules Vital Signs

The Last (Sub)Function Storage
Beware of double-duty buffers!

(last table continued on next slide)

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### AMC.OS/X Highlights

**AMC.OS/X Highlights (Con’t)**

- AECROM’s Program Generator
- HEPAX’ Disassembler & HEXEDIT
- Håkan’s RAM Editor
- Read/Write XMem to IL-Drive
- Buffer Catalog (w/ View & Deletion)
- 22 Sub-functions & LastF support

#### File type CAT Mnemonic

<table>
<thead>
<tr>
<th>File type</th>
<th>CAT Mnemonic</th>
<th>File Type ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program</td>
<td>&quot;P&quot;</td>
<td>01</td>
</tr>
<tr>
<td>Data</td>
<td>&quot;D&quot;</td>
<td>02</td>
</tr>
<tr>
<td>ASCII</td>
<td>&quot;A&quot;</td>
<td>03</td>
</tr>
<tr>
<td>Matrix</td>
<td>&quot;M&quot;</td>
<td>04</td>
</tr>
<tr>
<td>Buffers</td>
<td>&quot;B&quot;</td>
<td>05</td>
</tr>
<tr>
<td>Key Assignments</td>
<td>&quot;K&quot;</td>
<td>06</td>
</tr>
<tr>
<td>Status Registers</td>
<td>&quot;T&quot;</td>
<td>07</td>
</tr>
<tr>
<td>Complex Stack</td>
<td>&quot;Z&quot;</td>
<td>08</td>
</tr>
<tr>
<td>Polynomial</td>
<td>&quot;L&quot;</td>
<td>09</td>
</tr>
<tr>
<td>FORTH code</td>
<td>&quot;F&quot;</td>
<td>10</td>
</tr>
<tr>
<td>HEPAX Data</td>
<td>&quot;H&quot;</td>
<td>11</td>
</tr>
</tbody>
</table>

#### Special Char$ Keyboard

- "ON-key" Prompt Lengthener (also for STO/RCL)

#### Page/ROM Checksums

- Page/ROM Checksums

**AMC.OS/X Highlights [OSX3]**

- RAM Program Compile & Page Utils
- "ON-key" Prompt Lengthener (also for STO/RCL)

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Other Utility Modules

- Buffer Management Fns.
- X-Mem Management Fns.
- Hacker’s Lab
- Jump’s Calculator
- GOSUB/GOTO Decoder
- BCDBIN, BINBCD
- Håkan’s RAMEDIT
- ZENROM’s RAMED
- BLDROM’s ROMED
- VASM <> HEX Decoder

Dr. Jekyll & Mr. Hyde

- ALPHA Utilities Galore
- “Dr. Jekyll’s & Mr. Hyde” FAT
- Byte Jumpers
- Direct Byte Loading
- Multi-Digit Prompts
- HEX <> XROM
- Other (Weird & Obscure)
Enhanced Unit Management System (UMS+)

- Adds two more Dimensions (primes!)
- Adds 12 Electricity & Light Magnitudes
- Adds 29 new units to the Tables
- Features Unit Catalogs (by groups)
- New 20-Constant Library (values & units!)
- INPUT/OUTPUT Routines

<table>
<thead>
<tr>
<th>Name Description</th>
<th>Value (Units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron Charge</td>
<td>(-1.6021764 \times 10^{-19}) CB</td>
</tr>
<tr>
<td>Electron Mass</td>
<td>(-9.1093821 \times 10^{-31}) KG</td>
</tr>
<tr>
<td>Speed of Light</td>
<td>(-2.9979245 \times 10^{8}) M/S</td>
</tr>
<tr>
<td>Proton's Mass</td>
<td>(-1.6726216 \times 10^{-27}) KG</td>
</tr>
<tr>
<td>Free-fall Acceleration</td>
<td>(-9.8066500 \times 10^{0}) M/S²</td>
</tr>
<tr>
<td>Vacuum Permittivity</td>
<td>(-8.8541878 \times 10^{-12}) FD/M</td>
</tr>
<tr>
<td>Vacuum Permeability</td>
<td>(-1.2566370 \times 10^{-6}) N/A²</td>
</tr>
<tr>
<td>Gravity Constant</td>
<td>(-6.6742800 \times 10^{-11}) N*M²/KG²</td>
</tr>
<tr>
<td>Avogadro's Number</td>
<td>(-6.0221417 \times 10^{23}) 1/MOL</td>
</tr>
<tr>
<td>Gas Constant</td>
<td>(-8.314472150) J/K*MOL</td>
</tr>
<tr>
<td>Hartree Energy</td>
<td>(-4.359748226 \times 10^{-18}) J</td>
</tr>
<tr>
<td>Stefan-Boltzmann</td>
<td>(-5.6705119 \times 10^{-8}) W/M²*K⁴</td>
</tr>
<tr>
<td>Boltzmann's Constant</td>
<td>(-1.3806504 \times 10^{-23}) J/K</td>
</tr>
<tr>
<td>Vacuum Impedance</td>
<td>(-376.7303134) OHM</td>
</tr>
<tr>
<td>Planck's h Constant</td>
<td>(-6.6260689 \times 10^{-34}) J*S</td>
</tr>
<tr>
<td>Magnetic Flux Quantum</td>
<td>(-2.0678336 \times 10^{-15}) WB</td>
</tr>
<tr>
<td>Bohr Radius</td>
<td>(-5.2917720 \times 10^{-11}) M</td>
</tr>
<tr>
<td>Atomic Mass Unit</td>
<td>(-1.6605387 \times 10^{-27}) KG</td>
</tr>
<tr>
<td>Conductance Quantum</td>
<td>(-77.480916 \times 10^{-6}) 1/OHM</td>
</tr>
<tr>
<td>Faraday Constant</td>
<td>(-96.485,34) CB/MOL</td>
</tr>
</tbody>
</table>

The “Total Rekall” Schema

- Round about and back throughout…
- RCL Math (not using IO_SVC polling point)
- 92 Sub-functions & LastF support

-STK Tests Launcher
Two Decoder Ring(s)

- TRK / DTC functionality
- RCL Math (includes RC^)
- SLCT Variable for integer CASE?
  - Square^2 IND (X<1>Y, ?# IND _)
- Multiple IND (RIND/SIND) – up to 10 levels

- Register Index Mapping
  - Arguments above “99”
  - Partially occupied by STK regs
  - Falls into IND scheme over “127”
  - Warps around over “199” (IND 71)

Dare to Compare Interconnectivity

- Smooth & Flexible UI
- Sweeps the practical Stack range
- 84 function-launcher overview
- Direct zero-comparison for registers
- Supports Indirect-Indirect tests
**SELECT your Weapon!**

The Many ways to skin this cat

1. ready (Define)...
2. aim (Store, Recall, Swap)...
3. fire (Compare)!

- Wildcard variable selection & management
- Interwoven functional areas
- Proxy for surrogate Register Use

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**Auto-Complete \( \text{XEQ}^+ \) (a.k.a Bus Navigator)**

- WARP_Core Launchers & LastF

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**XEQ+ Navigation**

**Forwards Searching Behavior**
**Backwards Searching Behavior**

- **Main FAT** entry points
- **Banked FAT** entries
- **OS/CAT_3** page
- **#3 Bank**
- **Page #6**
- **Page #8**
- **Page #9**
- **Page #10**

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**Other Noteworthy WARP Components**

*Enhanced CX’s ED+ (ASCII Files)*
- Adds Lower-Case and Special Character support
- ALPHA key toggles standard <-> enhanced modes
- LCD Readable Lower-Case requires Half-Nut display
- Fully utilized by the XM Scripts in the Formula-Eval Module & Equation Libs.

*Shadow Buffer Registers Storage*
- Holds Custom Variables in Formula-Eval ROM
- Holds Stack Registers for Shuffle functionality
- Provides Back-up for RTN Stack addresses
- Proxy shortcut for SELected variable (bR0)

<table>
<thead>
<tr>
<th>Register #</th>
<th>Storage</th>
<th>RTN Stack</th>
<th>Shadow Stack</th>
<th>Scratch Var</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uint</td>
<td>bR1</td>
<td>-</td>
<td>Shadow-X</td>
<td>a</td>
</tr>
<tr>
<td>Tenth</td>
<td>bR2</td>
<td>-</td>
<td>Shadow-Y</td>
<td>d</td>
</tr>
<tr>
<td>Hundred</td>
<td>bR3</td>
<td>ng 10(a)</td>
<td>Shadow-T</td>
<td>b</td>
</tr>
<tr>
<td>Hundred-1</td>
<td>bR4</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hundred-2</td>
<td>bR5</td>
<td>-</td>
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<td></td>
</tr>
<tr>
<td>Hundred-3</td>
<td>bR6</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hundred-4</td>
<td>bR7</td>
<td>-</td>
<td></td>
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</tr>
<tr>
<td>Hundred-5</td>
<td>bR8</td>
<td>-</td>
<td></td>
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</tr>
<tr>
<td>Hundred-6</td>
<td>bR9</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Loading the I/O Bus

- **Standard I/O Bus layout**

<table>
<thead>
<tr>
<th>Block Addresses</th>
<th>Port Page Addresses</th>
<th>Primary Bank</th>
<th>Secondary Bank</th>
<th>Bank #3</th>
<th>Bank #4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>F 000-FFFF</td>
<td>Port 4, upper</td>
<td>HP-16C Emulator</td>
<td>HP-16C Emulator</td>
<td>HP-16C Emulator</td>
<td>HP-16C Emulator</td>
<td>2/4kB</td>
</tr>
<tr>
<td>E 1FFFF</td>
<td>Port 4, lower</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D 2FFFF</td>
<td>Port 3, upper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C 3FFFF</td>
<td>Port 3, lower</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B 4FFFF</td>
<td>Port 2, upper</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A 5FFFF</td>
<td>Port 2, lower</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>9 6000-FFFF</td>
<td>Port 1, upper</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>8 7FFFF</td>
<td>Port 1, lower</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>7 8000-FFFF</td>
<td>HP-IL Module</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>6 9FFFF</td>
<td>Printer IM printer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5 0FFFF</td>
<td>TGMS CX system</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>4 1000-FFFF</td>
<td>Take-over HCM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3 2000-FFFF</td>
<td>System ROM 2</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 3000-FFFF</td>
<td>System ROM 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 4000-FFFF</td>
<td>System ROM 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 5000-FFFF</td>
<td>HP-IL Module</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interrogating the I/O Bus

- **System Bus Conflict Check “CHKSYS” automated upon “CALC_ON” event**

- **Wholesale: I/O Bus Summary**
  - PGCAT, ROMLST

- **Detail: Free, Used, Banked Report**
  - FREE?, USED?, BANKED?, OSREV

- **Targeted: Auxiliary FATS anywhere?**
  - AUXFAT, SFLNCH

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Hyper-spacing sRAM (CL only)

• Conceptual scheme of the different CL sRAM blocks
• Uses can be Back-up or direct Access

Expanded Y-Registers (CL only)

• 1,024 Directly accessible Y-Regs (I)
• 3,072 available for Matrix Functions (!!!)
• STO/RCL Math, ISG/DSE, ALPHA, etc…
• Supports IND, ST, RG, and combinations
• All Programmable but not all meant for PRGM use

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Y-Registers Applications ROM

- YDUMP, YSHFT - Complete & Selective Reg. Copy
- YINPT, YOUPPT - Y-Reg. Input/Output driver
- YRAN, YSORT - Random and Sorted Y-Reg. Block
- YM<>RM - Matrix Formats Exchange (JM|B/ADV)
- Y-REG versions of PPC Matrix & Block Routines
- Y-REG versions of JMB_Matrix Routines

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HP-16C Emulator Module

- Automated Base Conversions

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HP-16C Emulator
16NPT Hotkeys

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Y-Dump, Y-Shft, Y-Inpt, Y-Ouppt, Y-Ran, Y-Sort, YM<>RM

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HP-16C Emulator Module

- Automated Base Conversions
HP-16C Emulator Navigation Tips

- Training Wheels Mode
- Comparison Tests Launchers
- Interconnected Launchers
- Mirrored Implementation

Formula Evaluation Module [FRML]

- Formula Editor in ALPHA (24-char limit)
  - Uses Buffer #6 (LIFO, 16-Registers in size)
- Extended via Chained Evaluation
- Can also use ASCII Files in Script Language
  - GTOS, XEQs, WHILEs
- Rich, 13-digit Math function library
- Direct Stack-Registers, π and Custom Variables
- Utility Fns. For data register transfer
  - STO$, X<>RG, SHFL "XYZTL"

- Full-expression Comparison Tests
- Sums, Series & Products Evaluation
- Stack Shuffle w/ Selective Clear
- Includes ALPHA registers {M, N, O, P}
  - Can also clear them on the fly

Buffer id# Buffer Reg Type Used for:

<table>
<thead>
<tr>
<th>Buffer id</th>
<th>Buffer Reg Type</th>
<th>Used for</th>
</tr>
</thead>
<tbody>
<tr>
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Formula Evaluation Module (Con’t)

- Built-in Library of Applications (Upper 4k)
- Accuracy holds to 9th decimal point
- Comparable times with “RPN” approach

- SVS, ITGS - Solve & Integrate
- AGMS - Arithmetic-Geometric Mean
- 2D & 3D Distances, Dot-Products
- CLS, FLS - Ceiling & Floor Functions
- QRTS - Quadratic Equation Roots
- LINES - Line equation thru 3 points
- P4S - Polynomial Evaluation \( n \leq 4 \)
- NFDS - Normal Density Function
- Rectangular <-> Spherical
- Julian <-> Calendar Dates
- Exponential function
- Erdos-Borwein constant

\[
E = \sum_{n=1}^{\infty} \frac{1}{2^n n^{2n}} \quad \Gamma(z) = \prod_{n=1}^{\infty} \left( 1 + \frac{z}{n} \right)^{e^{\pi i n}}
\]

\[
z = \Psi(z) e^{\psi(z)}.
\]

\[
\psi(x) = \log(x) - \frac{1}{2x} - \frac{1}{12x^2} + \frac{1}{120x^4} - \frac{1}{2520x^6} + O\left(\frac{1}{x^{7}}\right)
\]

41Z Deluxe: The Complex Leviathan

- Launchers, Drivers & Interactive U/I
- Integer/Common factor display
- Polar & Rectangular Modes
- Natural Data Entry (real part first)

- Sub-functions and LASTF support
- Two pages, two banks each

<table>
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<tr>
<th>Page</th>
<th>Main-FAT</th>
<th>Main- &amp; Sub-FATs</th>
<th>Function Tables and</th>
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<td>ZROM #01</td>
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- Automated 4-Level Complex Stack (buffer #8)
- X-Mem Backup/Restore (file id #8)
- ZSTO & ZRCL Math, Stack Functions

- ZKBBD
- Z-pad
- Z-Keys
- Complex Keyboard
The 41Z Deluxe Leviathan

- Complex Arithmetic
- Elementary Functions
- Complex Logarithms
- 2D-Vector Analogy
- Trigonometry & Hyperbolics
- Multi-valued functions Driver
- Dual Means (AGM, GHM)
- Arithmetic, Harmonic & Geometric Means
- Polynomial Evaluation & Derivatives
- Quadratic & Cubic Equation Roots

High-Level Math
- Gamma, Digamma (Ψ), LNGamma
- ZETA, Lambert, InvGamma
- Bessel 1st & 2nd kinds (!)
- Sine, Cosine Integrals; error function (via ZHGF)
- Many more Special functions (PolyLog, Lerch)
- Complex Derivatives (ZDRV)
- Complex Continued Fractions (ZCF2V)
- Discrete Fourier Transform (DFT)
- Solution to f(z)=0 (Secant, Newton, Halley)
- Polynomial Roots - using ZDRV
- Carlson & Elliptic Integrals

The SandMath Juggernaut

- The Platform: Modes, Launchers, Functional Groups
- Uses IO_SVC Polling Point

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The SandMath Juggernaut (Con’t)

- Fractions, Quadratic & Cubic Equations
- Linear Regression, GCD, LCM
- Hyperbolic Functions
- Advantage’s Number Base conversions
- Polynomial Evaluation & Derivatives
- Orthogonal polynomials

- Special Functions (Gamma, Bessel, Zeta)
- Many, many more Special functions!
- Carlson & Elliptic Integrals, AGM
- Function 1st & 2nd Derivatives
- Continued Fractions

SandMath

- RCL Math, FIX ALL Mode
- AECROM Curve Fitting
- Time Value of Money

- Combinations & Permutations
- Density & Cumulative Probability
- Time-based Seed, Random numbers
- Primes, Prime Factors, error function
- Factorials, Primorials, Pochhammer, Apery, Kaprekar...

SandMath’s Base Conversions

- Advantage’s HEX/OCT/BIN -In & -View
- Ken Emery’s BS>D, Dedicated H<>D Utils
- Automatic function selection depending on valid ranges

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The SandMatrix Behemoth

Picks up where the SandMath left things off:

- Includes ALL functionality from Advantage Matrix
- Adds new MCODE utilities (TRACE, MIDN, MZERO)
- Adds Complex Matrix Transpose, Determinant, Minors
- Features a Triple-Launcher: Matrix / Vectors / Polynomials
- Plus a combined PolyRoots / Distances Launcher
- New Matrix Editor (by rows)

The SandMatrix Behemoth (Con’t)

- CCD Array Functions
- Advantage’s Major Matrix Fns
- Enhanced Matrix Editors
- Real & Complex Matrix Minors
- Complex Matrix Determinant (N<=5)
- Complex Matrix Transpose
- Matrix Pseudo-Inverse
- Matrix Trace & Identity
- Integer Powers and Roots
- Matrix Exponential & Logarithm
- Lie Product, Matrix Square Root
- Pascal & Random Matrices

- Eigenvalues & Eigenvectors
- Characteristic polynomial
- J acobi Method for Symmetrical Matrices
- Prime Factors (Con’t)

- CL Y-Registers Support
- Up to 50x50 Linear Sys
- Main- and CL-Mem Matrix Catalogs
- Vector Calculator Functions
- Major Vector Operations Driver
- Coordinate Transformations
- Polynomial and Derivatives Evaluation
- Polynomial Arithmetic
- Polynomial Roots, Quartic Equation
- Orthogonal polynomials (Con’t)
- Polynomial Fitting
- Partial Fraction Expansion

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The SandMatrix on CL-steroids

- Supersedes the Matrix group in [YRGA]

Main Memory
319 regs

Extended Memory
(600 regs)

CL RAM
(3,072 regs)

\[
\text{det}(A) = \prod \lambda_i, \\
\text{tr}(A) = \sum \lambda_i, \\
\text{det}(e^A) = e^{\text{tr}(A)}.
\]

Time Value of Money TVM$ \ [\text{TMVY}]

From-the-scratch, MCODE HP-12C Equivalent

- Direct Formula-driven variables for N, PV, FV, PMT (13-digit math)
- Includes Advantage’s and PPC’s TVM Programs
- Newton’s Method for interest rate IS$ (13-digit math)

\[
f'(i) = \left( \frac{PMT}{i^2} \right) \times \left[ (1+i)^n - 1 \right] + n \times \left[ PMT(1+i)(1-FV) \right] \times (1+i)^{-n-1}
\]

\[
i_0 = \left[ \text{abs}(PV + n \times PMT + FV) \right]^{1/n}
\]
Extended Stats & Curve Fitting ROMS

Rounds-up SandMath functionality in stand-alone format:

- Linear Regression functions
- Primality Tests, Next Prime,
- Combinations/Permutations
- Summation Functions (Faulhaber’s et al)
- Single and Duplex Means (AGM,...)
- Ratios, GCD, LCM

- Most popular Statistical Distributions
- Probability Density Functions
- Cumulative Probability

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Stand-alone Curve Fitting Compendium:

- AECROM Filter
- Advantage’s CFIT
- Standard HP-41 / PPC’s “CV”
- W. Kolb’s MCF
- Polynomial Interpolation:
  - Alken’s / Lagrange Methods
  - General Polynomial Best Fit
- Linear Exponential Curve Fitting
- Orthogonal Polynomials Fitting

Elliptics and Orthogonal Pols ROM

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Sums & Areas ROM

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Sand² - Math and Solve & Integrate ROMS

- Complex Matrix Minors
- Complex Determinants w/ Minors
- Complex Matrix Trace
- Complex Matrix Transpose
- Column Data Sort
- Least Squares 2nd Order
- Complex Step Real-Derivative (ZNWT)
- Newton’s & Halley’s Method using DERV
- Bessel J via Continued Fractions (large arguments)
- Cubic Spline Interpolation
- Curve Fitting w/ Akima’s Method
- Harmonic Determinants
- Anti-Identity Matrices
- Over-Conditioned Systems
- Non-Linear Equation Systems
- 2D Integration (Recursive INTEG)
- 2-Non-Linear Equation System (Recursive SOLVE)

http://www.hpmuseum.org/forum/thread-6311.html?highlight=recurve
Non-linear Systems ROM

<table>
<thead>
<tr>
<th>Non-linear Systems</th>
<th>Driver-Prog</th>
<th>Math-Routine</th>
<th>Aux-Routines</th>
<th>Examples</th>
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<td>NNLS+</td>
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**Numerical Analysis**

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<td>UFL</td>
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**Differential Equations**

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**Successive Approx.**

| Real         | 5SAM        | 5FM         | 5FM, 5FM, 5FM |
| Complex      | 5SAM        | 5FM         | 5FM, 5FM, 5FM |

From SOLVE to Solver: Equation Libraries

From: \( f(x)=0 \) to: \( f(a,b,c,d,e)=0 \)

- Up to five variables to solve for (at least 3)
- Mapped to local Labels [A]-[E] - and (R01-R05)
- FOCAL driver I/O, UF-22 controlled known/unknown
- Other Constants prompted separately
- Two versions available:
  - [ISOL] "Interchangeable Solutions", uses FROOT
  - [EQLB] "Formula-Evaluation" based, uses "SLV$"
  - User can add own custom equations

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Equation Libraries in Detail

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<td>Cubic Equation</td>
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<td>( Y = AX^2 + BX + C )</td>
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Formula-Eval Based:

Science & Engineering Modules (my fav’s)

**ETSI Collection**
- Dynamic Balancing
- Helzer Method
- Heat Transfer
- Heat Exchangers
- Binary Mixes
- Liquefaction Cycles
- Refrigerant Gases
- Psychrometric Props.
- Water Hammer
- Joukowskis Airfoils
- Pump Association
- Pipe Network Analysis

**ETSI Collection** - Cont. (ETSP, FEES)
- Two-Port Networks
- Swing Equation
- Power-Flow Equations
- AC Regulator Design
- Electric Circuits
- Backwards LAP
- Logical Networks
- Frequency Response
- Transfer Functions

**Physics & Earth**
- ELIX: Orbital Mechanics
- GRVI: Gravity & Time
- NBOD: N-Body Problem
- TIDW: Tides ROM
- PRTW: US Ports
- NONL: Non-Linear ROM
- EEFD: EE Filters Design
- LPC: Laplace Transforms
- ISOL: Interch. Solutions
- INDO: Indoor Lighting
- LTNL: Geodetics ROM
- STEQ: Steam Properties

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Orbital Mechanics 101

- Ellipse Central and Focal Sector Areas and Arc Lengths
- Elliptic Integrals and other Geometry Utils
- Orbital Position Determination & Time of Flight
  - Kepler Equation and Direct approaches.
- Orbital Velocity Determination:
  - Conservation of Energy, Angular Momentum
- Solar System Orbits & Gravitational parameters
- Delta-V orbit Simulator (HP Solution Book)
- Orbit Phasing, Co-Orbital & Co-Planar rendez-vous

Odd Balls and Nerdies (gotta love them!)

Path-finding in Metro Networks [METX]
- SMAD Madrid
- SPAR Paris Metro
- 5LON London Tube
- 5LUB Berlin U-Bahn
- NYSB NYC Subway

Three Originals:
- SUD1 Sudoku & Sounds
- CITY Country Capitals
- WORD Dictionary
  - English<>Spanish
Words and Cities in detail

- Enumeration by types & kinds
- “I’m feeling Lucky” selection

R&R: Fun Stuff & Playground

- Ain’t such a thing as too much fun
**Office Informatics & Other Miscellaneous**

- **AECROM Derivatives:**
  - AEC3: 13-digit AECROM
  - PROG: Program Generation
  - GSLV: Geometric Solvers

- **HEPAX Derivatives:**
  - HPX2: CL Extended HEPAX
  - HDIS: HEPAX Disassembler
  - HTAB: Periodic Table

- **HP-IL Related:**
  - DEV2: HPIL-Development
  - ILB: IL-Buffer ROM
  - MASS: Extended Mass Storage
  - GRF1: Grafik m.d. HP41 Plotter

- **From Swap Disks:**
  - FSSY: Focal Disassembly
  - SWP2: Swap Disks Routines
  - SWP3: Swap Math
  - GSWP: Swap Games

- **Adapted Books & Literature**
  - The FOCAL Factory never sleeps...

**Jean-Marc Baillard's Projects**

- **ASTT:** ASTRO ROM
- **BSSL:** BESSL ROM
- **DIFF:** Differential Equations
- **FRID:** Fractional Ingr./Diff.
- **GMZY:** Geometry_11
- **INTG:** Integrator ROM
- **HCP:** Hyper-Complex ROM
- **JBC:** JMB_Calendar
- **JMC:** JMB_Math
- **JMX:** JMB_Matrix
- **NTHY:** Number Theory
- **POLY:** Polynomial ROM
- **QUAT:** Quaternions
- **SFEC:** Spectral Analysis
- **KNGT:** JMB_Knight’s Tour

**PPCU**

- PPC Manual Examples

**UCDO**

- CDD Manual Examples

**CCDA**

- CDD Advanced Apps

**2SWP**

- SWP Disks Routines

**3SWP**

- SAWP Math Programs

**WWDB**

- Wickes, Wlodzeck, Dearing

**JARR**

- Keith Jarret SP / XF

**MCCK**

- Alan McCormak

**KRSS**

- Karl-Heinz Krauss

**KRGM**

- G. Kruse & KH Gossman

**REGU**

- Control Systems

**VIEW**

- HP-41 in der Praxis

**QMTM**

- Prisma-Math

**PAPZ**

- Published Papers

**ULPM**

- UPL(E) Programs

**VONX**

- User’s Collections

****

- All HP Solution Books

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Acknowledgements (a.k.a. the usual suspects…)

“Standing on the Shoulders of Giants”

- Obviously to HP “of yore”, for the HP-41 System and its fabulous OS MCODE
- W&W GmbH, VM Electronics, Redshift s/w – publishers of CCD Module, HEPAX & AECROM
- Wilson “Bill” Holes and Nelson F. Crowle, head & heart of the AECROM – “Viva Las Vegas!”
- Doug Wilder, author of ROMED, Jump Distances and GOSUB/GOTO Decoders
- Häkan Thörngren, author of RAMED & several XM-Utils. Takk!
- Greg McClure co-authored the 16C Emulator and Formula Evaluation Modules, true “partner-in-crime” for numerous MCODE projects and explorations
- Wilson Bill Holes and Nelson F. Crowle, head & heart of the AECROM – Viva Las Vegas!
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- David Ingebretsen, program Sponsor and advisor
- Jean-Marc Bailard provided inextinguishable Math expertise and co-authored Math ROMs
- Mark Fleming authored the Equation Library (Formula-Eval version)
- Monte Dairymple for creating the fabulous 41CL board
- Diego Díaz, Meindert Kuipers, Jean-François Garnier – guys, your gizmos rock!
- Sylvain Côté, always glad to share his encyclopedic knowledge
- Poul Kaarup, author of the PK-Collection w/ innovative apps
- ... and many, many others that would take too long to include!

Appendix:
HP-41 System Memory
MLDL Modules

Main Memory
2.4 kB On-line

Extended Memory
4.22 kB Off-line

Mass Storage
1 MB Off-line

HEPAX RAM
32 kB On-line

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53
### Main RAM

<table>
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<tr>
<th>RAMx5</th>
<th>CLRAM</th>
<th>CPU</th>
<th>CUPRAM</th>
<th>CPUAP</th>
<th>CRUX</th>
<th>CUX</th>
<th>ENTERM</th>
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<th>MCLX</th>
<th>ASTOXX</th>
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<th>ST&gt;RG</th>
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<th>R^</th>
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<th>PACK</th>
<th>PECR</th>
<th>PDR</th>
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### I/O Area

| AROCI | AROCF | AROCT | AROSEP | AROSET | AROSF | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT | ASTOBT |
|-------|-------|-------|---------|---------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|

### General XM

| MEMRAM | FEOCOPY | RENVFL | RETYFL | FLOM | FLOI | FLSD | FLUR | REGFL | WNCWX | WNCWI | WNCWN | WNCWR | WNCXS | WNCXI | WNCWN | WNCXR | WNCXI | WNCWN | WNCXR | WNCXI | WNCWN |
|--------|---------|--------|--------|------|------|-----|------|-------|------|-------|-------|-------|--------|--------|-------|-------|-------|-------|-------|-------|-------|-------|

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### Extended Memory

Extended Memory 4.22 kB Off-line

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### Main Memory

Main Memory 2.4 kB On-line

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### HEPAX 1F

<table>
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### HEPAX RAM

HEPAX RAM 32 kB On-line

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### RAMBOX

RAMBOX 16 kB On-line / 16kB Off-line

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---

**Summary:**

- **Main Memory**: 2.4 kB On-line, 4.22 kB Off-line
- **HEPAX 1F**: Main memory unit
- **HEPAX RAM**: 32 kB On-line
- **RAMBOX**: 16 kB On-line / 16kB Off-line

---

**Note:**

- The diagram and tables provide a detailed view of the memory and I/O areas of the device, including various commands and functions.
- The memory areas are color-coded for easier identification.
- The diagram includes a representation of the memory layout, with different sections highlighted in different colors.
- The tables summarize the various memory locations and their respective functions.
- The overall layout is designed to help in understanding the memory and I/O operations of the device.
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