

fig-FORTH on a (Simulated) PDP-11

Paul Hardy, 25 February 2017

Why fig-FORTH?

- Historic: open source before open source was cool
- High-quality production code & documentation
- Staying power; quoting “figFORTH Refuses to Die” by C. H. Ting, in *Systems Guide to figFORTH*, 1989:
 - **Consistency:** uniform implementation across many CPUs
 - **Well factored kernel:** under 50 machine-dependent words
 - **Source code in regular assembly:** easy to understand
 - **Simplicity:** includes only what’s necessary
- 16-bit memory model strikes a good balance for many embedded applications

Why the PDP-11?



Source: Wikipedia

- Clean architecture — not just a pretty face[plate]
- 2 simulators:
 - **SIMH** (Hobbyist)
 - **Ersatz-11** (Hobbyist & Commercial, with support)
- 16-bit word length — same as fig-FORTH model
- Stack ops allowed on all 8 registers — ideal for Forth
- Great macro assembler

Meet the new FOSS, Same as the old FOSS

PDP-11 FORTH USER'S GUIDE

John S. James
September 1979

```
.TITLE F.I.G.
;*****
;
; PDP-11 FORTH          INTRODUCTION          PDP-11 FORTH
;*****
;
; PDP-11 FORTH          RT-11, RSX-11M, AND STAND-ALONE          JANUARY 1980
;
;
;   DEVELOPED BY THE
;   FORTH INTEREST GROUP / FORTH IMPLEMENTATION TEAM
;   P.O. BOX 1105
;   SAN CARLOS, CA. 94070
;
;   IMPLEMENTED BY
;   JOHN S. JAMES
;   P.O. BOX 348
;   BERKELEY, CA. 94701
;
;   THIS SYSTEM IS IN THE PUBLIC DOMAIN AND CAN BE USED
;   WITHOUT RESTRICTION. PLEASE CREDIT THE FORTH INTEREST
;   GROUP IF YOU REPUBLISH SUBSTANTIAL PORTIONS.
;
;   THE FORTH INTEREST GROUP / FORTH IMPLEMENTATION TEAM
;   ALSO HAS DEVELOPED NEARLY IDENTICAL VERSIONS OF THIS
;   SYSTEM FOR THE
;   8080
;   6800
;   6502
;   9900
;   PACE
```

OS Choice: Why RT-11?

- Simple
- Real Time
- RT-11 file systems are readable by other DEC OSes
- Original fig-FORTH PDP-11 distribution was on an 8" RX01 floppy disk in RT-11 format
- Lower-case is highly overrated 😊

Ersatz-11 PDP-11 Simulator

- 1) Get an RT-11 disk image (SIMH archives, etc.)
- 2) Use PUTR to copy FORTH.MAC and FORTH.DAT onto RT-11 disk image (MS-DOS)
- 3) Create an “e11.ini” initialization file to your liking
- 4) Run “e11” executable (MS-DOS or GNU/Linux)
- 5) Use PUTR to copy files from RT-11 disk image back to PC

Use Shift+Enter (MS-DOS) or Control-P (GNU/Linux)
to return to e11> prompt.

Comment out “quit” line in e11.ini first.

Copying Forth: PUTR

```
C:\WINDOWS\system32\cmd.exe
C:\dsk>putr
PUTR V2.01 Copyright (C) 1995-2001 by John Wilson <wilson@dbit.com>.
All rights reserved. See www.dbit.com for other DEC-related software.

COPY mode is ASCII, SET COPY BINARY to change
<C:\DSK>>mount x: forth.dsk /rt11
<C:\DSK>>dir x:

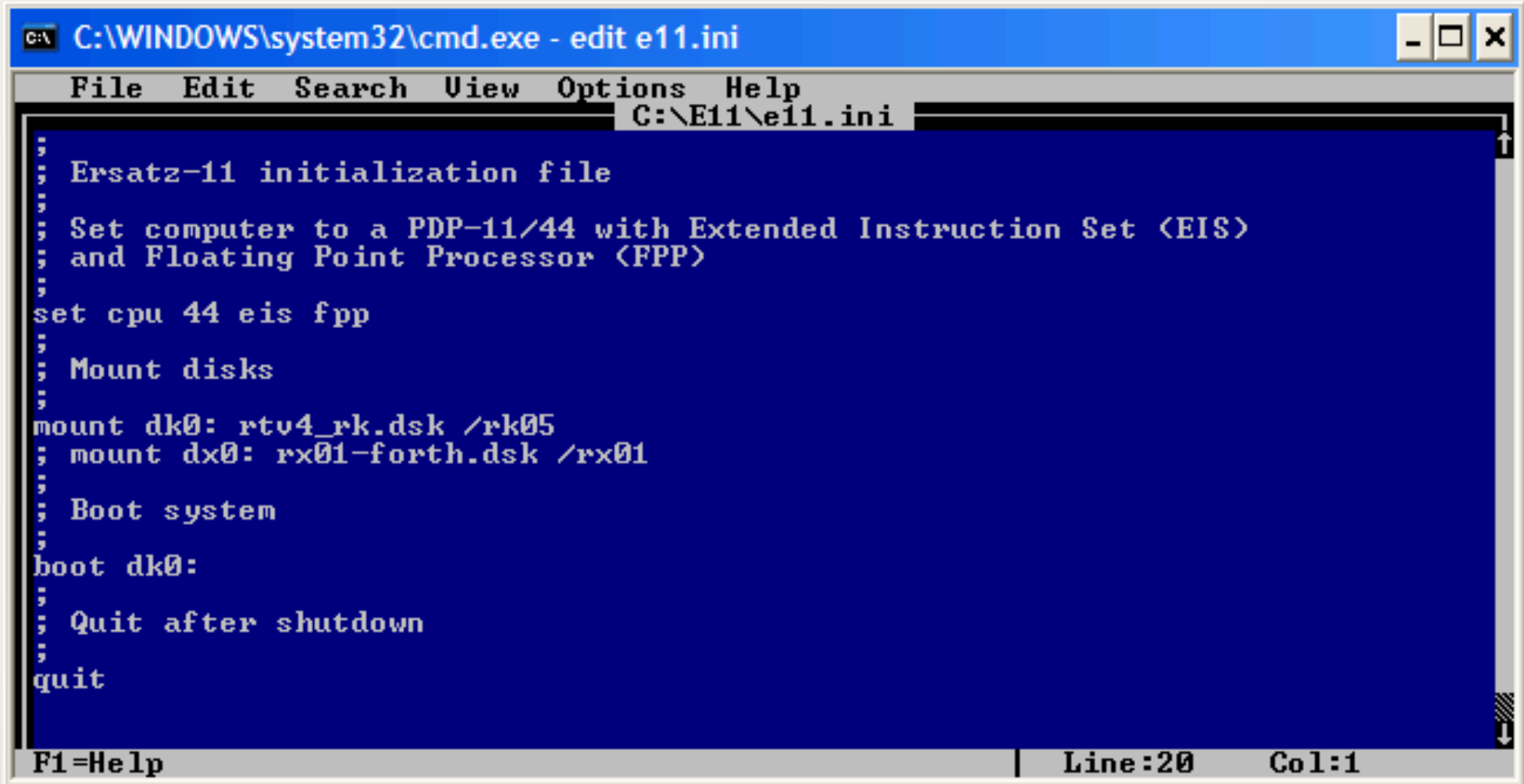
Volume in drive X has no label
Directory of X:\*. *

10-Jun-2009
FORTH .DAT      136   21-Jan-1980
FORTH .MAC      145   21-Jan-1980
 2 Files, 281 Blocks
 0 Free blocks

<C:\DSK>>mount y: rtv53.dsk /rt11
<C:\DSK>>copy x:forth.mac y:
FORTH .MAC
<C:\DSK>>copy x:forth.dat y:
FORTH .DAT
<C:\DSK>>quit

C:\dsk>
```

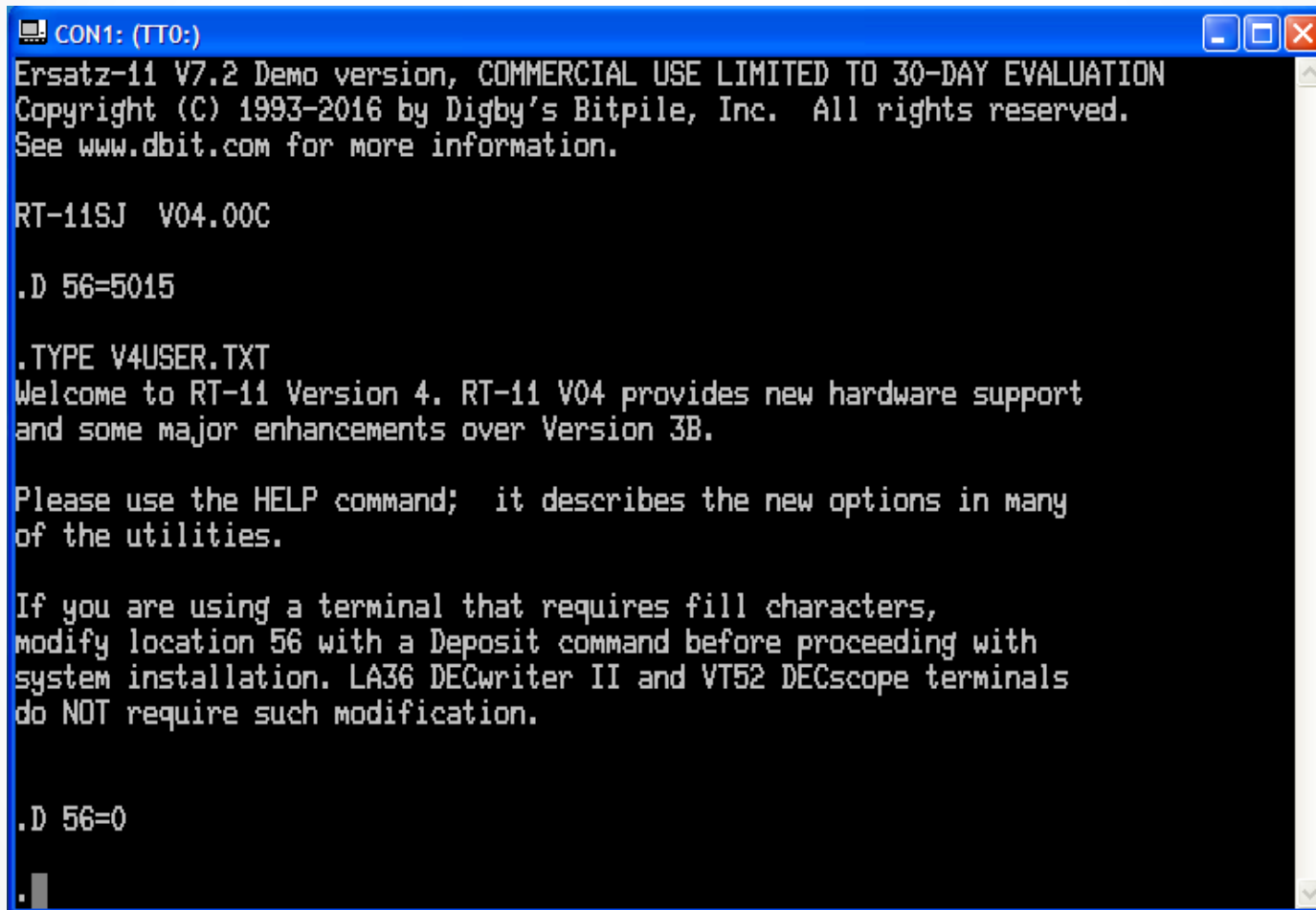
Ersatz-11: e11.ini

A screenshot of a Windows command prompt window titled "C:\WINDOWS\system32\cmd.exe - edit e11.ini". The window has a menu bar with "File", "Edit", "Search", "View", "Options", and "Help". The current file being edited is "C:\E11\e11.ini". The text in the window is as follows:

```
; Ersatz-11 initialization file  
;  
; Set computer to a PDP-11/44 with Extended Instruction Set (EIS)  
; and Floating Point Processor (FPP)  
;  
set cpu 44 eis fpp  
;  
; Mount disks  
;  
mount dk0: rtv4_rk.dsk /rk05  
; mount dx0: rx01-forth.dsk /rx01  
;  
; Boot system  
;  
boot dk0:  
;  
; Quit after shutdown  
;  
quit
```

At the bottom of the window, there is a status bar with "F1=Help" on the left, a vertical line separator, "Line:20" in the middle, and "Col:1" on the right.

Ersatz-11: Booting RT-11



```
CON1: (TT0:)
Ersatz-11 V7.2 Demo version, COMMERCIAL USE LIMITED TO 30-DAY EVALUATION
Copyright (C) 1993-2016 by Digby's Bitpile, Inc. All rights reserved.
See www.dbit.com for more information.

RT-11SJ V04.00C

.D 56=5015

.TYPE V4USER.TXT
Welcome to RT-11 Version 4. RT-11 V04 provides new hardware support
and some major enhancements over Version 3B.

Please use the HELP command; it describes the new options in many
of the utilities.

If you are using a terminal that requires fill characters,
modify location 56 with a Deposit command before proceeding with
system installation. LA36 DECwriter II and VT52 DECscope terminals
do NOT require such modification.

.D 56=0
```

SIMH PDP-11 Simulator

- 1) Get an RT-11 disk image (SIMH archives, etc.)
- 2) Attach Paper Tape Reader (PTR) to FORTH.MAC
- 3) Boot RT-11
- 4) Copy PC: [i.e., the paper tape] to FORTH.MAC
- 5) Repeat steps 2 through 4 to copy FORTH.DAT
- 6) Compile FORTH.MAC, producing FORTH.LST
- 7) Attach Paper Tape Punch (PTP) to FORTH.LST
- 8) Copy FORTH.LST to PC: to transfer FORTH.LST

Use Control-E to return to sim> prompt.

SIMH: Booting RT-11

```
$ pdp11
```

```
PDP-11 simulator V3.9-0
```

```
sim> attach rk0 ./Disks/rtv4_rk.dsk
```

```
sim> boot rk
```

```
RT-11SJ V04.00C
```

```
.D 56=5015
```

```
.TYPE V4USER.TXT
```

```
Welcome to RT-11 Version 4. RT-11 V04 provides new hardware support  
and some major enhancements over Version 3B.
```

```
Please use the HELP command; it describes the new options in many  
of the utilities.
```

```
If you are using a terminal that requires fill characters,  
modify location 56 with a Deposit command before proceeding with  
system installation. LA36 DECwriter II and VT52 DECscope terminals  
do NOT require such modification.
```

```
.D 56=0
```

```
.
```

SIMH “Paper Tape” I/O

```
sim> attach ptr forth/FORTH.MAC
sim> attach rk0 ./Disks/rtv4_rk.dsk
sim> boot rk

RT-11SJ V04.00C

.D 56=5015

.TYPE V4USER.TXT
Welcome to RT-11 Version 4. RT-11 V04 provides new hardware support
and some major enhancements over Version 3B.

Please use the HELP command; it describes the new options in many
of the utilities.

If you are using a terminal that requires fill characters,
modify location 56 with a Deposit command before proceeding with
system installation. LA36 DECwriter II and VT52 DECscope terminals
do NOT require such modification.

.D 56=0
█
```

SIMH: Copying Forth

```
.COPY PC: FORTH.MAC
Files copied:
PC:          to DK:FORTH.MAC

.DIR FORTH.MAC

FORTH .MAC   145
 1 Files, 145 Blocks
2153 Free blocks

█
```

COPY PC: FORTH.MAC — from PTR to RT-11

COPY FORTH.LST PC: — from RT-11 to PTP

Compiling Forth...

```
.DIR FORTH.*
```

```
FORTH .LST      275  01-Jan-80      FORTH .SAV      52  01-Jan-80
FORTH .COM       1  01-Jan-82      FORTH .DAT     141  01-Jan-80
FORTH .MAC     145  01-Jan-80      FORTH .OBJ      38  01-Jan-80
```

```
 6 Files, 652 Blocks
2152 Free blocks
```

```
.TYPE FORTH.COM
```

```
MACRO /LIST:FORTH.LST /ALLOCATE:300 FORTH.MAC
```

```
LINK FORTH.OBJ
```

```
.
```

...The Easy Way

```
.@FORTH
```

```
.MACRO /LIST:FORTH.LST /ALLOCATE:300 FORTH.MAC  
ERRORS DETECTED: 0
```

```
.LINK FORTH.OBJ
```

```
.
```

RT-11: Starting Forth

.R FORTH

FIG-FORTH V 1.3

1 LIST

SCR # 1

0 (LOAD SCREEN)

1 DECIMAL

2 1 WARNING ! (GET ERR MSGS, NOT #S)

3

4 CR ." LOADING EDITOR... " 6 LOAD 7 LOAD 8 LOAD 9 LOAD

5 CR ." LOADING ASSEMBLER... " 10 LOAD 11 LOAD 12 LOAD 13 LOAD

6 14 LOAD 15 LOAD

7 CR ." LOADING STRING PACKAGE... " 19 LOAD 20 LOAD 21 LOAD

8 22 LOAD

9 CR

10 : BYE FLUSH CR ." LEAVING FORTH. HAVE A GOOD DAY." CR BYE ;

11 CR

12

13

14

15

OK

Forth: Loading Screen 1

1 LOAD

```
LOADING EDITOR... R ISN'T UNIQUE I ISN'T UNIQUE  
LOADING ASSEMBLER... R0 ISN'T UNIQUE # ISN'T UNIQUE  
LOADING STRING PACKAGE...  
BYE ISN'T UNIQUE  
OK
```

Forth: Trig

24 LIST

SCR # 24

```
0 ( TRIG LOOKUP ROUTINES - WITH SINE *10000 TABLE)
1 : TABLE <BUILDS 0 DO , LOOP DOES> SWAP 2 * + @ ;
2 10000 9998 9994 9986 9976 9962 9945 9925 9903 9877
3 9848 9816 9781 9744 9703 9659 9613 9563 9511 9455
4 9397 9336 9272 9205 9135 9063 8988 8910 8829 8746
5 8660 8572 8480 8387 8290 8192 8090 7986 7880 7771
6 7660 7547 7431 7314 7193 7071 6947 6820 6691 6561
7 6428 6293 6157 6018 5878 5736 5592 5446 5299 5150
8 5000 4848 4695 4540 4384 4226 4067 3907 3746 3584
9 3420 3256 3090 2924 2756 2588 2419 2250 2079 1908
10 1736 1564 1392 1219 1045 0872 0698 0523 0349 0175
11 0000          91 TABLE SINTABLE
12 : S180 DUP 90 > IF 180 SWAP - ENDIF SINTABLE ;
13 : SIN ( N -> SIN) 360 MOD DUP 0< IF 360 + ENDIF DUP 180 >
14   IF 180 - S180 MINUS ELSE S180 ENDIF ;
15 : COS ( N -> COS) 90 + SIN ;
```

OK

24 LOAD

OK

```
0 SIN .
0 OK
90 SIN .
10000 OK
10000 SIN .
-9848 OK
7 SIN .
1219 OK
345 SIN .
-2588 OK
15000 SIN .
-8660 OK
15000 COS .
-5000 OK
29000 COS .
-9397 OK
```

RT-11: Setting the Date

BYE

LEAVING FORTH. HAVE A GOOD DAY.

.

.DATE 21-JAN-80

.DATE

21-Jan-80

.R FORTH

FIG-FORTH V 1.3

1 LOAD

LOADING EDITOR... R ISN'T UNIQUE I ISN'T UNIQUE

LOADING ASSEMBLER... R0 ISN'T UNIQUE # ISN'T UNIQUE

LOADING STRING PACKAGE...

BYE ISN'T UNIQUE

OK

RT-11, Y2K, and Forth

28 LIST

SCR # 28

```
0 ( RT-11 SYSTEM-CALL EXAMPLE - DATE)
1 CODE DATE 12 400 * # R0 MOV, 374 EMT, R0 S -) MOV, NEXT, C;
2 : YEAR ( -> N ) DATE 31 AND 72 + ;
3 : DAY ( -> N ) DATE 32 / 31 AND ;
4 : MONTH ( -> N ) DATE 1024 / 15 AND ;
5
...
```

OK

28 LOAD

OK

```
: Y2K DATE DUP 16384 / 3 AND 32 * SWAP 31 AND 1972 + + ;
```

OK

| Y | Y | M | M | M | M | D | D | D | D | Y | Y | Y | Y | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | | | 3 | | | 2 | | | 5 | | | 0 | |

```
DATE .
1704 OK
OCTAL
DATE .
3250 OK
DECIMAL
OK
DAY .
21 OK
MONTH .
1 OK
YEAR .
80 OK
Y2K .
1980 OK
```

Forth Assembler (Octal)

```
CODE DATE
```

```
12 400 * # R0 MOV,
```

```
374 EMT,
```

```
R0 S -) MOV,
```

```
NEXT,
```

```
C;
```

MACRO-11

```
MOV      #12*400, R0 ; bytes 12 0
```

```
EMT      374          ; OS trap
```

```
MOV      R0, -(S)    ; stack push
```

What's With the Octal?

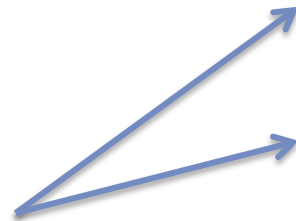
- 8 General Purpose Registers:

- R0..R5
- R6 (SP, "Stack Pointer")
- R7 (PC, "Program Counter")

Stacks grow downwards

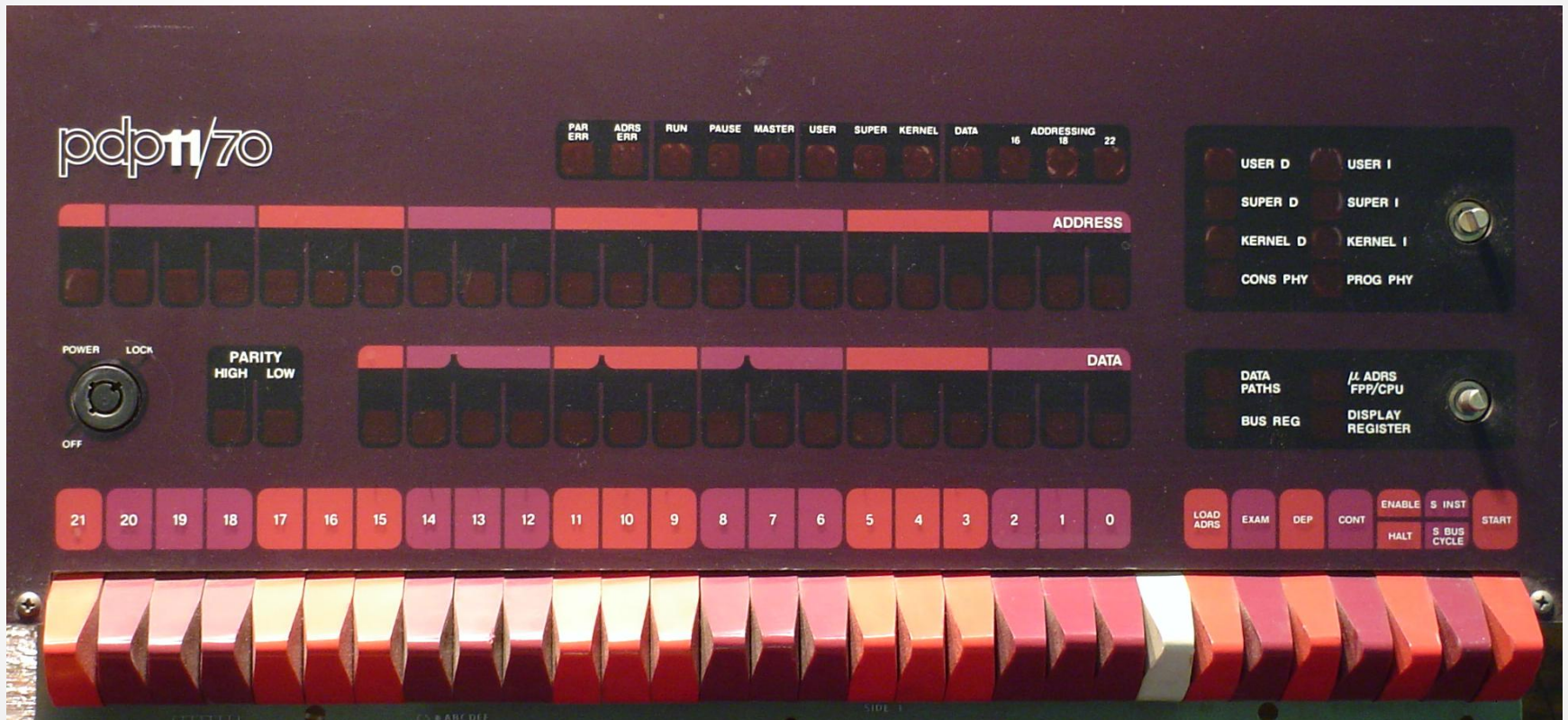
- 8 Register Addressing Modes:

- 000: Register
- 001: Register Indirect
- 010: Post-increment
- 011: Post-increment indirect
- 100: Pre-decrement
- 101: Pre-decrement Indirect
- 110: Index
- 111: Index Indirect



Hence PDP-11 machine code is usually viewed in octal.

Octal Fashion Statement



Source: Wikipedia

Yep, they sure don't make 'em like that anymore!

Trick Questions

- To reverse-engineer a PDP-11 file system, you have to read file names encoded in “RADIX-50” notation.
Q: How many unique character codes are possible in a RADIX-50 letter?
- The original FORTH.MAC PDF scan has a boot block listing at the end that mentions RX01 “Track 21”.
Q: What track number is “Track 21”?

What's Next?

- Seek glossaries for: micro-Forth, Forth-77, Forth-78
- Recreate standalone Forth on bootable PDP-11 RX01 disk image



Source: Wikipedia

Resources

- FORTH.MAC, FORTH.DAT, etc.:
<http://www.stackosaurus.com/figforth>
- RT-11v4 & v5.3 (note hobbyist license):
<http://simh.trailing-edge.com/software.html>
- Ersatz-11 (Demo Version): <http://www.dbit.com/demo.html>
- PUTR: <http://www.dbit.com/putr/>
- Empty PDP-11 Disk Images (for system generation):
<http://www.dbit.com/pub/pdp11/empty/>
- SIMH: <http://simh.trailing-edge.com/>
- Original Forth Interest Group Files:
<http://www.forth.org/fig-forth/contents.html>