DIRECT HARDWARE MEASUREMENTS

1. 410,000 (±10%) VIRTUAL MEMORY REFERENCES PER SECOND

330,000 (±10%) INSTRUCTION EXECUTIONS PER SECOND

$\frac{410}{330}$ = 1.25 REFERENCES/INSTRUCTION

−.5 INST. FETCHES/INST.

.75 OPERAND REF./INST.

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2. 0.5% − 2.0% FAILURES ON SEARCH OF ASSOCIATIVE MEMORY (STORES 16 RECENTLY USED PAGE TABLE WORDS)

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3. 24,000 ± 8000 ADDRESS BASE REGISTER LOADS PER SECOND

$\frac{24}{330}$ = 7% UPPER BOUND ON UTILITY OF MORE REGISTERS

4×10^6 virtual memory reference / sec — 3900 – 4500

2.7 μsec / reference — or = 4100

256K, 1CPU, 10 sec. period, 14 users ⇝ 60% idle time

AM not founds

$\frac{69,880}{3,952,000} \rightarrow \frac{28,920}{4,533,000}$ — 2% → .5%

10 sec average

~~AM Vect~~ — 16·36

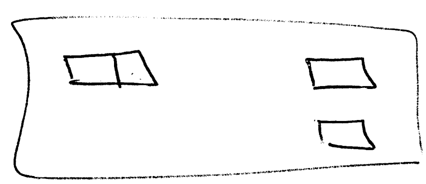
EAPu — 165 000 → 374 000 — 16 000 · 37000

~200,000 / 10 sec.

20,000 / sec. — (~6%)

Instruction / sec. — 31~~8~~,000 → 360,000 inst / sec

average 370,000 — $\frac{45}{360}$ $\frac{5}{40}$

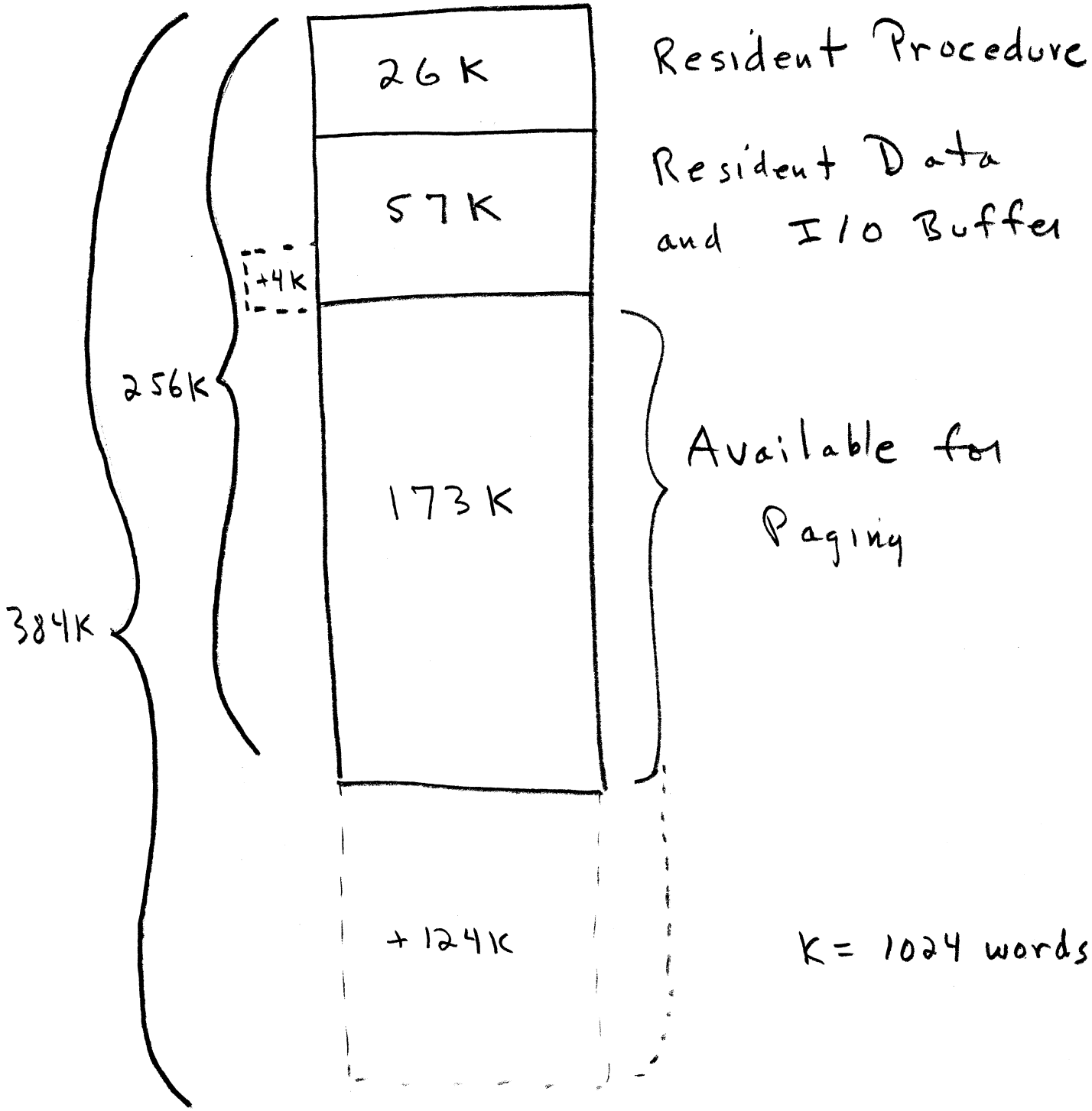


~~RTCD; Recvi; 5600 → 7200 in 10 sec.~~

RTCD — 4600 → 9500 in 10 sec. — or ~ 7000 / 10 sec

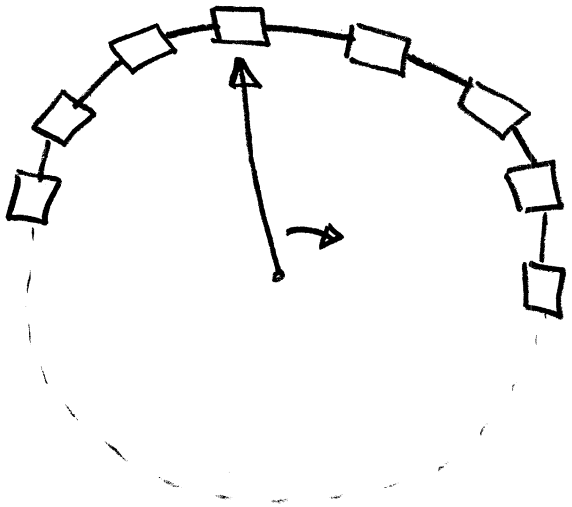
700 / sec.

Real Memory Usage



Demand Paging Measurements

1.



Average # of steps = 4.1 ± 0.5

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2. Run time between page faults

20 ms. ⟷ 70 ms

heavy load	light load
small configuration	large core

Model ?

3. LAP TIME = .97 sec.
(full load)

C/W LOAD DURATION ~ 1 sec.

$$\text{CORE USAGE} = \frac{1 + .97}{1} \approx 2$$

(UPPER BOUND ON PREDICTIVE PAGE-REMOVAL VALUE)

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4. Missing Page handling

10-20%	{ computation for missing page switch to another process
10-20%	IDLE
25-35%	TOTAL TIME SPENT

PAGE HANDLING + SWITCH TIME = 3.4 ms.
(about 1200 instructions)

5. DRUM $\frac{\text{READ}}{\text{WRITE}}$ RATIO = 2

(Pure Procedures)

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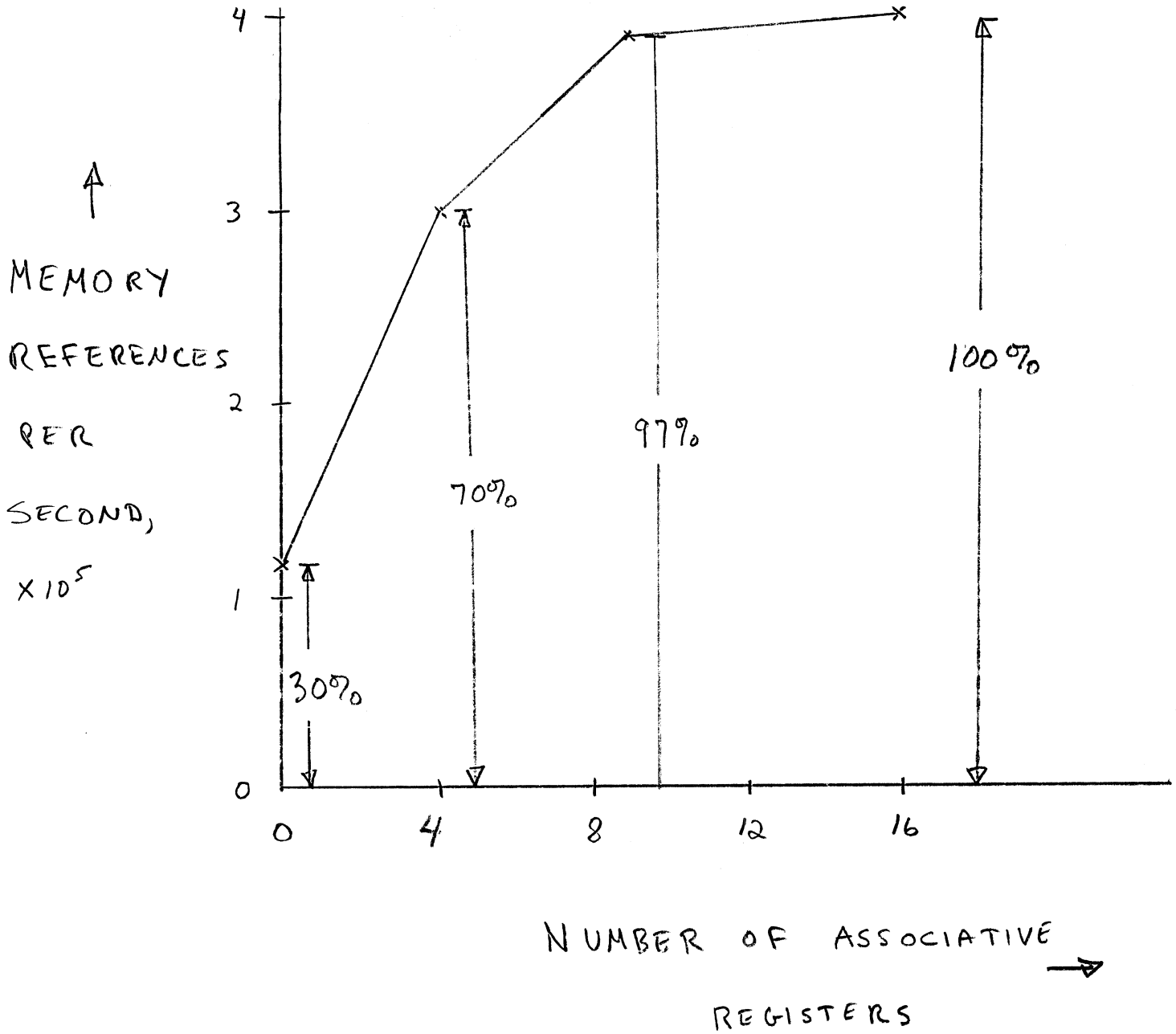
6. PAGING RATE

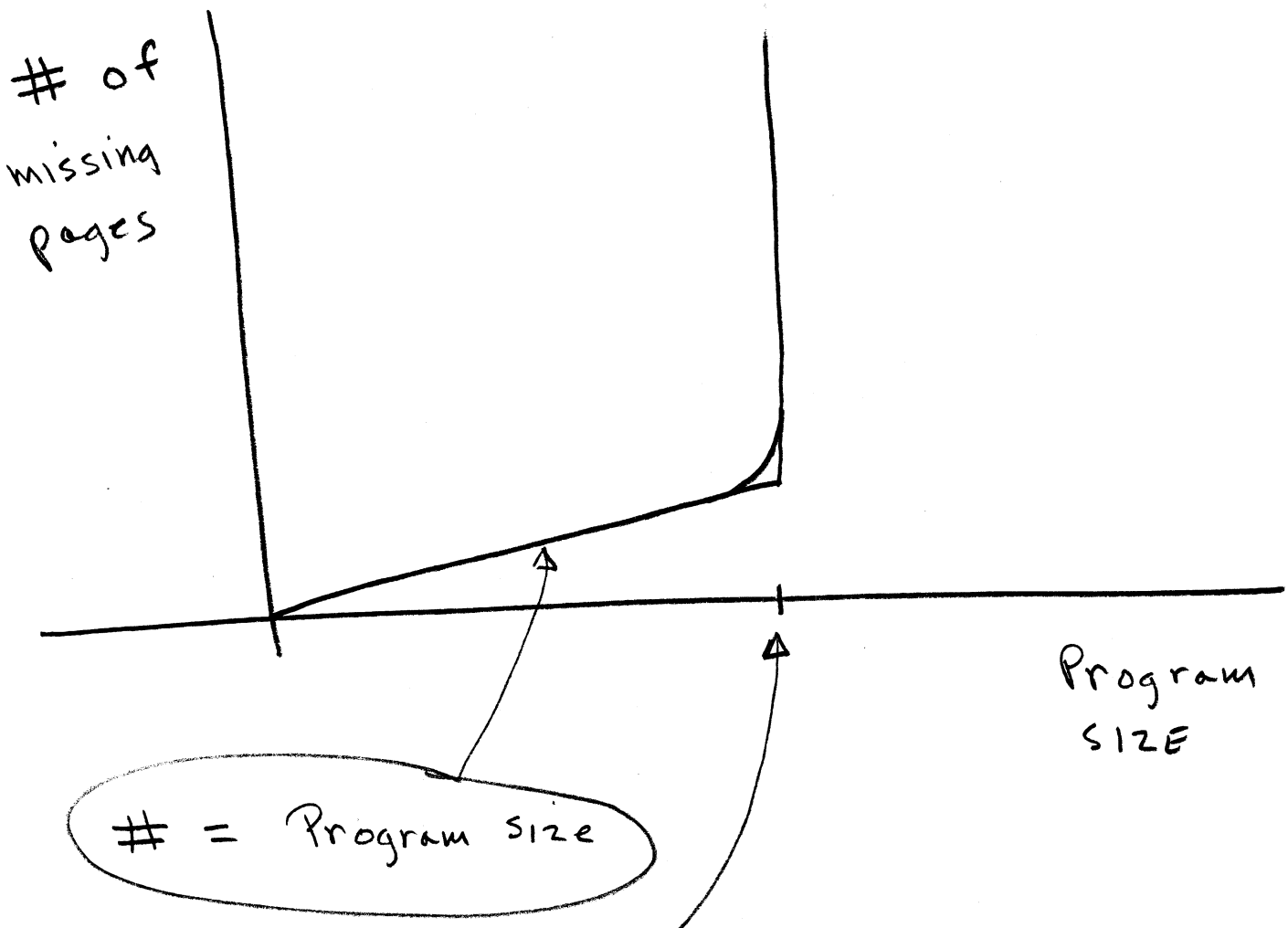
60	p/s	High Performance Drum
12	p/s	Fixed Head Disk
72	p/s	full load

- No automatic move
  (static storage assignment)

- Waiting times in balance


MEMORY REFERENCES PER SECOND, X10^5
4
3
2
1
0
0
4
8
12
16
30%
70%
97%
100%
NUMBER OF ASSOCIATIVE REGISTERS

PAGING THRESHOLD FOR "Incompressible" Program



85-90K fully loaded 256K system

170K unloaded " "

SYSTEM CAPACITY

Criteria

- Interactive response time mushrooms
- IDLE TIME VANISHES
- Queues build up

FOR 256k, 1 CPU system,

12	System Programmers
1	Batch Compiler
2	I/O streams (Tape, Printer)
20	General Users
35	Maximum Simultaneous Load

330,000	Inst. / sec
98%	Success on AM search
~~700~~	Calls / second
20 000	Base register loads / second
4.2	Average steps to ~~locate~~ allocate a core page
22.5 ms	Average run time between missing pages
.950 sec	Mean lifetime of an idle page
15 %	Multiprogramming idle time
15%	Time spent paging and switching processes
3.44 ms	Time required to process a missing page.
35	users
5.4 sec	average response time
1.9	drum reads per drum write
~~47~~ 38 sec	real time per average interaction

MPM103
5/7/70
users = 27
MFTN3
7.3b
256 Kcore
1 CPU

********** MULTICS PERFORMANCE ANALYSIS **********

USER NO	COMMAND	TIME	CPU TIME	NO OF P.F.
0	login	1546	2.053	145
	edm	1555	3.804	365
	fortran	1556	3.227	247
	edm	1601	1.969	231
	fortran	1603	3.280	279
	rename	1603	1.101	74
	print	1604	.757	43
	a_prime$prime	1605	2.376	162
	list	1606	.532	47
	df	1607	.855	86
	edm	1616	2.955	318
	fortran	1617	2.419	194
	edm	1621	1.722	200
	fortran	1623	2.718	234
	rename	1624	.460	37
	print	1625	.519	33
	b_prime$prime	1626	1.620	113
	list	1627	.462	41
	df	1628	.564	67
	logout			

********** SUMMARY **********

USER NO	TOTAL CPU TIME	TOTAL REAL TIME	TOTAL NO OF P.F.	NO OF INTER-ACTIONS	AVERAGE CPU TIME	AVERAGE RESPONSE TIME	AVERAGE NO OF P.F.	
USER 0	31.340	2425	2771	66	.474	9.6 (4.6)	41	
	17.901	1187	1534	33	.543	9.0 (5.0)	46	first half
	13.439	1206	1237	33	.407	10.0 (4.3)	37	second half

(4.6) ← average excluding "fortran"

Note: The response times of "fortran"s were exceptionally large in this experiment (14.3 sec, 60.6 sec, 17.3 sec, and 86.1 sec). Those of other commands were all less than 9 seconds.

MPM103

```
rm$inc apt
        777777777777     4:06.0 200100000002 761454055666   8:55.6 016101000002
PDP8 -> 761454057212       31.9 100100000004 761454055702   1:03.5 234100000003
        761454057414    61:00.6 001100000004 761454055727   1:22.0 200100000002
        761454056146       40.0 300100000000 761454056043   1:19.9 001100000004
        761454055770       55.4 200100000002 761454056224     10.2 100100000000
        761454057462    62:81.6 034100000002 761454056671     19.6 001100000004
        761454057565    62:87.0 001100000004 761454057734      9.0 001100000004
        761454056157       24.9 300100000000 761454057064   1:01.7 001100000004
        761454056706     1:35.4 200100000002 761454057524     62.4 200100000002
        761454056764       41.1 200100000002 761454057750     81.7 200100000002
        761454057170       35.5 034120000001 761454056507     12.7 001100000004
        761454056777     2:43.2 001100000004 761454057630      8.8 001100000004
        761454057361       29.4 001100000004 761454057664     90.6 001100000004
        761454057157       37.5 001100000004 761454057307     34.7 001100000004
        761454057447       18.4 001100000004 761454057717     21.1 001100000004
        761454057473       26.3 200100000002 000000000000          000000000000
        000000000000            000000000000 000000000000          0000000000

QUIT
r 1630  .180  14

fsm -all

Total metering time    0:44:20

Deactivations          3193
Ast grace          -7:02:35  <--- not correct
Used ASTs               323
Free ASTs                 0
Held ASTs               117
Seg Faults             4740

                 #            ATB

Needc           123038       21.621 msec.
Steps           528521        5.033 msec.
Laps              2750         .967 sec.
Skip wired        6980      381.109 msec.
Skip used       335617        7.926 msec.
Skip mod         62842       42.331 msec.
Skip os             44    60457.817 msec.

174 pages, 19 wired.      <--- 256 K core
Average steps          4.296

                DRUM        DSU270        DS10

Left            1016          3534           0  <--- ?
Reads         110045          9736           0
  ATB         24.173       273.228       0.000
Writes         57101          5825           0
  ATB         46.587       456.677       0.000
ATB I/O       15.915       170.949       0.000
% Cncty           12            29  <------  0  ---- pretty high
N Errors           0             4  <---     0
F Errors           0             0           0
                                    |
r 1631  1.211  43                   +------- These errors occurred sometime between
                                             16:11 and 16:31.
```

tcm -all

Total metering time 0:46:04

Ave queue length	7.98
Max eligible	3
Te first (seconds)	2
Te last (seconds)	2
Ti max (seconds)	8

IDLE TYPE	TIME	%
Total idle	0:09:56	21.59
Multi-prog idle	0:09:46	21.23
Non-multi-prog idle	0:00:08	.31
Zero idle !	0:00:01	.05

} The system is highly saturated.

COUNTER	TOTAL	ATB	#/INT
Interactions	1978	1.398 sec	
Loadings	2677	1.033 sec	1.353
Blocks	2218	1.246 sec	
Wakeups	2204	1.254 sec	
Waits	119659	23.103 msec	60.495
Notifies	329192	12.062 msec	
Schedulings	2797	.988 sec	1.414
Pre-empts	139941	19.754 msec	70.749

ttm

Time	%Int	%Cum	Ave	%T	%CumT
0.0	76	76	.204	14	14
.5	13	89	.747	9	23
1.0	5	94	1.243	6	29
1.5	2	96	1.818	3	32
2.0	1	97	2.351	2	34
2.5	1	98	2.842	2	36
3.0	0	99	3.426	1	38
3.5	0	99	3.864	0	38
4.0	0	99	4.507	1	39
4.5	0	99	4.951	1	40
5.0	0	99	5.442	1	41
5.5	0	99	5.946	0	41
6.0	0	99	6.556	1	42
6.5	0	100	6.871	0	43
7.0	0	100	7.691	1	44
7.5	0	100	8.107	54	100

DEPTH	%P:	TBPF	%GTW	TBS	%CPU
1	44.0	21.4	36.5	16.3	51.4
2	32.3	18.6	36.6	10.3	32.8
3	24.9	12.5	28.1	7.0	17.2

} The mean time between page faults is very short because of smaller core area available to the users.

r 1633 1.823 60

Interesting numbers

- CPU speed / memory accesses / second
- Associative memory effectiveness
- Calls / second

} hardware measurements

Paging parameters

- average steps (constant over wide range of changes)
- mean run time between p.f.
- loop time (mean lifetime of an idle page)

Time spent in page fault handling

- page fault machinery
- multiprogramming machinery
- idle time available

Total cost of a p.f. in cpu time and instruction count

* of users

- average response time
- average queue length

} at saturation

Multiprog depth / core space available

* of segments in supervisor / user process

Multilevel storage

- read/write ratios;
- overall paging rate

User load

average real time to complete an interaction

average compute time per interaction (median / mean)

(other numbers not yet available - old TTY days)

Wall crossing cost / Supervisor cost

Interference effect w/ 2 CPU's

/ calls / second

/ EAP's / second