Stress Testing Programs

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Summary

The report provides details of a series of stress tests that cover processor integer and floating point calculations, cache and memory speeds, disk and other drives, including local network traffic, and graphics hardware. The programs can either be run standalone or multiple copies of any at the same time. Some detailed results are provided plus reference to more comprehensive reports. Links to download the test programs is provided, also the source code for those who wish to compile them for other systems or modify them for other purposes [No restrictions except use of existing or modified codes is at your own risk].

The programs are based on experience in designing and running stress programs, that were used for acceptance test purposes, on hundreds of computers purchased by the UK Government for Departments and Universities, including mainframes, minicomputers, mini-servers, workstations and supercomputers from the 1970s to the 1990s.

Objectives for these later programs are to automatically check results of numeric calculations or data comparisons, save results in a text based log file and, when appropriate, identify ongoing speed of operation and provide variable parameters to specify:

1. running time
2. which test or test functions to run
3. data size to test a particular cache or RAM in memory tests
4. different log files for running multiple copies of a program concurrently
5. interval for displaying and logging intermediate results

The programs are available, compiled fro both 32 bit and 64 bit systems, to run under Windows or Linux, mainly with run time parameters that can be executed from a BAT or script file, to enable parallel operation of multiple tasks.

Integer Test - This memory/arithmetic exerciser comprises 8 write then read and 8 read only tests, using different hexadecimal data patterns, with arithmetic carried out by assembly code, arranged for fast data streaming. Performance is measured in MB/second and MIPS.

Floating Point Test - This is another memory/arithmetic exerciser but compiled to use SIMD SSE functions. Speed is measured in MFLOPS. achieving up to 6 per CPU MHz.

Drive Test - The program code is essentially the same as used in the acceptance trials mentioned above. Four files are written, sized in multiples of 10.3 MB, with data blocks comprising 164 different binary patterns, then read, with data checked, for a chosen time. Sequential reading is then repeated but with blocks selected randomly from the four files. Finally, each block from one file is read repetitively, normally involving data cached in main memory. Speed is measured in MB/second.

Graphics GPU Power Test - The test uses options available in my CUDA benchmark for GeForce graphics, carrying out floating point calculations at high speed.

Graphics Display Test - the range of display functions vary from simple coloured objects to a complex kitchen design application, produced using OpenGL Besides having options to select which function to run and running time, window size can also be specified and that can cover multiple screens. Note, for Linux, approval was given to Canonical to include this benchmark in the testing framework for the Unity desktop.

Introduction

In the late 1960s, I was head of the section, with up to 20 staff, responsible for designing and supervising acceptance trials of all UK Government purchased computers, including those centrally funded for universities, and personally handling those for the largest systems. Then, the tests mainly involved running engineering diagnostics, with limited user applications for scientific systems. The diagnostics were mainly functional tests, and user programs produced vast amounts of printed output. At that time, our Software Branch repeatedly asked "What are we going to do for testing these new Operating Systems?", without any suggestions.

In 1970, my responsibilities changed to technical appraisal and acceptance trials of scientific systems. Then, I sat down at a terminal and, in a short time, produced a series of Fortran programs to use in testing computers with multiprogramming Operating Systems. The 17 test programs comprised 5 for CPU, 4 for disk drive, 3 for magnetic tape drive, and one each for line printer, card reader, card punch, paper tape reader and paper tape punch. All had parameters to adjust the running time to the required 15 minutes, stand alone time, with built-in self checking or only a few lines of output to scrutinise. The exception was, of course, the line printer test with the usual variable patterns. The program naming convention was FO for Fortran, PR for processor etc., then the number, including FOPR00 to FOPR04 CPU tests. Later our Whetstone Benchmark was included as FOPR12. I never finished FOGP00, the graph plotter test. Anyway, the programs enabled thorough testing, via Operating Systems, with 100% CPU utilisation, up to 8 hours at a time, with significant concurrent activity on disk drives or magnetic tape units, plus adequate activity on the slow peripherals.

Listings of the Fortran programs are included in my book [Computer System Reliability/Roy Longbottom (Wiley series in computing), 1980], that also included details of the acceptance testing procedures. The first use of the programs was on an IBM 360/65 mainframe computer, in 1971. From 1972 to the 1990s, the programs were used on all system acceptance trials of scientific and commercial type computers. I also collected running time details of 134 different scientific mainframes and minicomputers as an aid to providing details of relative performance.

My personal involvement in designing and supervising acceptance test was for the larger scientific systems for Government Departments and Universities, including that IBM 369/65 and others including IBM 3860/85, IBM 360/195, Univac 1108, CDC 7600 and Ferranti-ICL Atlas II. By 1997. As reported in my book, there was a 62% pass rate on the last 400 system trials, 14% failures and 24% with a conditional pass. These included 100s of fault incident reports. In fact, the record was on one of mine with more than 100, mainly induced by my programs.

The Cray 1 supercomputer became available in the late 1970s, and one was ordered for the UK, when I took on the task of producing completely vectorisable versions of my processor tests. Fortunately, in 1978, serial 1 Cray 1B was available at the UK Rutherford Appleton Laboratory, enabling me to check out the programs for testing the new Cray 1A. A year later, a CDC Cyber 205 supercomputer was ordered, involving a repeated exercise. The latter was the first system I encountered with proven heat related failures. Both of these involved pre-delivery trials in the USA, followed by on-site testing.

The stress tests, used for acceptance test purposes, were designed to run under batch processing, normally for 15 minutes stand-alone time, with results checked manually. Objectives for later programs are to automatically check results of numeric calculations or data comparisons, save results in a text based log file and, when appropriate, identify ongoing speed of operation and provide variable parameters to specify:

1. running time
2. which test or test functions to run
3. data size to test a particular cache or RAM in memory tests
4. different log files for running multiple copies of a program concurrently
5. interval for displaying and logging intermediate results

On modern systems, including PCs, tablets and smartphones, it can be useful to run stress testing programs to help to identify the reason for such as system failures or slow performance, with the most significant problems being heat related. On older systems, overheating tended to produce application or system failures. This can still apply on modern computers, but current designs incorporate facilities to avoid overheating by reducing the controlling clock speeds. Then failures can be avoided but, without warning, the systems might be running at half speed or less.

Then we have the battery powered devices where, again without warning, run slower as the battery discharges. Also there can be reliance on power saving options that only use maximum power, and introduce running at full speed, when really needed. This appears to be influenced by the controlling Operating Systems, that do not always control the functions correctly. An example in this report is the case where initial speed was slow when using a single processor core, but operated at maximum speed when a program was using multiple cores.

Below are details of a series of stress tests that cover processor integer and floating point calculations, cache and memory speeds, disk and other drives, including local network traffic, and graphics hardware. The programs can either be run standalone or multiple copies of any at the same time. Some detailed results are provided plus reference to more comprehensive reports. Links to download the test programs is provided, also the source code for those who wish to compile them for other systems or modify them for other purposes [No restrictions except use of existing or modified codes is at your own risk].

Go To Start

DOS and Windows PC CPU Tests

The first stress tests produced for PCs were based on the acceptance test programs that were most successful in identifying faults. The best one for identifying intermittent CPU failures was FOPR02. This carries out the binomial expansion, then summation, of (p + q) ^ n, where p + q = 1.0, with numerous variations in the variables and multiplying each summation together, to produce a final result close to 1.0. With fixed parameters, the final result of different runs should be identical.

Then there was FOPR04, carrying out similar calculations, with an visibly obvious sumcheck, via various mathematical functions, next most effective CPU test, that also identified questions of different compilers, or CPU hardware, not producing identical results of calculations.

CPR4DOS.EXE was my first CPU stress test that included the binomial calculations with those from FOPR04, to run via DOS. This is available in DOSTests.zip.

An example of results is below. Firstly, there is a run using fixed numbers of passes, with example sumchecks from early CPUs, showing some differences between 80486DX2 and Pentium calculations.

Next, the required minimum running time has to be entered. Verified results are then displayed and logged, for each pass, also running time difference as a guide to constant performance.

FPtest.exe, a real Windows version, was produced later and is available in burn9xnt.zip (Archive). The execution window has text entry boxes for minimum seconds per test (comprising multiple passes of initial run) and minimum repeat minutes.

An example of logged results is below (next page). Intermediate results are also displayed, at a slow flashing rate. Again note different sumchecks on the quoted PCs. A second set of results is also provided, to show that the program still runs on a more modern PC, with a Core i7 CPU and **Windows 10**, where sumchecks are the same as from an old Pentium processor. The benchmarks can also be run from a command prompt, where an extra parameter is available to specify the log file name, enabling multiple copies to be run.

```
 ######################### DOS Version #########################

    PR04 C++ Functions Test Copyright © Roy Longbottom 1997

 Based on FOPR04 a TSU Acceptance Trials Program from another era

                                               Example  Sumcheck
                                              Pentium    80486DX2
 Functions          Answer            Sumcheck

 Sin, Cos     0.99999999999445120     -5532       -5532      -5532
 Exp, Tanh    1.00000000000012900      5776        5776       5776
 Log, Exp     0.99999999999111260     -6174       -6174      -6789
 Log10, Sqrt 1.00000000000002800      3440        3440       4263
 Complex      0.99996001225587480      5038        5038       4551
 Imag, Real   1.00000000000051100      4756        4756       4756
 Max, Min     0.99999999999253160     -6210       -6210      -6210
 Atan, Fmod   0.99999999999363160     -5941       -5941      -5508
 Binomial     1.00000000000094100      4574        4574       4574

 Time taken     83.70 seconds

 Start at Thu Mar 20 09:30:25 1997
 End   at Thu Mar 20 09:31:49 1997

 Enter minimum run time minutes to check for consistent results 1


 Extra pass 1 of 1

 Functions          Answer            Sumcheck

 Sin, Cos     0.99999999999445120     -5532        Result OK
 Exp, Tanh    1.00000000000012900      5776        Result OK
 Log, Exp     0.99999999999111260     -6174        Result OK
 Log10, Sqrt 1.00000000000002800      3440        Result OK
 Complex      0.99996001225587480      5038        Result OK
 Imag, Real   1.00000000000051100      4756        Result OK
 Max, Min     0.99999999999253160     -6210        Result OK
 Atan, Fmod   0.99999999999363160     -5941        Result OK
 Binomial     1.00000000000094100      4574        Result OK

 Time taken     84.10 seconds        0.48 seconds difference from first run

 Start at Thu Mar 20 09:32:30 1997
 End   at Thu Mar 20 09:33:54 1997


 ************************* 0 errors so far (see output file C092417.TXT)

 Finished
```

Windows Version on Next Page

```
####################### Windows Version #######################

   Floating Point Reliability Test Version 2.0 by Roy Longbottom

Windows NT Version 5.0, build 2195,
CPU AuthenticAMD Features Code 0183F9FF Model Code 00000630 950 MHz

Minimum 10 seconds per test and 5 minutes repeating tests

             Start of test Sat Oct  6 14:49:30 2001

                                               Example Sumcheck
Functions         Answer         Sumcheck  Athlon Pentium   80486

Sin, Cos     1.00000000000000000       10      10      10      10
Exp, Tanh    1.00000000000002300     5681    5681    3697    4306
Log, Exp     1.00000000000305200     4346    4346    4508    4346
Log10, Sqrt 1.00000000000036600     5501    5501    4132    4680
Complex      0.99999600112830790     4976    4976    4976    4549
Imag, Real   1.00000000000005100     4258    4258    4258    4258
Max, Min     0.99999999999253160     5305    5305    5305    5305
Atan, Fmod   0.99999999999165060     6533    6533    5131    6063
Binomial     0.99999999998445720     5881    5881    5881    5881

Time taken for one pass     1.87 seconds

First tests SUMCHECKS same as Athlon

Repeat tests

123456789 Sat Oct  6 14:52:33 2001
123456789 Sat Oct  6 14:54:04 2001
123456789 Sat Oct  6 14:55:35 2001
123456789 Sat Oct  6 14:57:06 2001

Repeat tests time taken     6.08 minutes, 4 repeats

Consistent results obtained in passes of repeat tests

               End of test Sat Oct  6 14:56:06 2001
```

```
##################### Windows 10 Results #####################

  Floating Point Reliability Test Version 2.0 by Roy Longbottom

Windows NT Version 6.2, build 9200,
CPU GenuineIntel, Features Code BFEBFBFF, Model Code 000306E4, 3711 MHz

Minimum 10 seconds per test and 5 minutes repeating tests

             Start of test Tue Nov 28 12:02:03 2017

                                               Example Sumcheck
Functions         Answer         Sumcheck  Athlon Pentium   80486

Sin, Cos     1.00000000000000000       10      10      10      10
Exp, Tanh    1.00000000000002400     3697    5681    3697    4306
Log, Exp     1.00000000000305100     4508    4346    4508    4346
Log10, Sqrt 1.00000000000035700     4132    5501    4132    4680
Complex      0.99999600112830790     4976    4976    4976    4549
Imag, Real   1.00000000000005100     4258    4258    4258    4258
Max, Min     0.99999999999253160     5305    5305    5305    5305
Atan, Fmod   0.99999999999165030     5131    6533    5131    6063
Binomial     0.99999999998445720     5881    5881    5881    5881

Time taken for one pass     0.51 seconds

First tests SUMCHECKS same as Pentium

Repeat tests

123456789 Tue Nov 28 12:03:34 2017
123456789 Tue Nov 28 12:05:04 2017
123456789 Tue Nov 28 12:06:34 2017
123456789 Tue Nov 28 12:08:04 2017

Repeat tests time taken     6.01 minutes, 4 repeats

Consistent results obtained in passes of repeat tests

               End of test Tue Nov 28 12:08:04 2017
```

Go To Start

DOS and Windows PC Drive Tests

The disk test is based on FODK01, used in acceptance trials, that wrote up to ten files, then read blocks from the files in random order. Each data block written comprised a particular binary pattern, intended to identify pattern conscious faults. The random reading order was restricted to a predetermined sequence. Besides inducing normal disk drive problems, this program identified two major design problems. The first was on a large IBM mainframe, with an early version of the MVT Operating System, where the the random access procedure could read data from the the wrong file. The second was on a CDC CYBER 205 supercomputer, where the data patterns were corrupted on the disk bus.

CDK1DOS.EXE writes four files, each of a minimum size of about 10 Mbytes. Block size is 64 KB and a different data pattern is written to 164 blocks. The files are then read sequentially twice and data compared with the appropriate pattern. Some random access is induced in one pass via reading the same block from the four files in a different sequence but the disk might minimise this via its buffer. Next each block is read a number of times where they likely to remain in the buffer and be read at maximum DMA speeds. This is also in DOSTests.zip, that includes a more detailed description.

DiskTest.exe, the full Windows version, in burn9xnt.zip (Archive), writes four files using different data patterns for each block. The files are then read and data checked for a chosen time. The files are each read sequentially then all four sequentially but the blocks being selected from files randomly. Finally, each block from one file is read repetitively where the data will probably reside in the disk's buffer and reading will be at DMA speeds. The run time window has data entry boxes for file size, reading minutes and DMA seconds for each of 164 data patterns.

The benchmarks can be run from a command line, with an extra parameter for log file name, allowing multiple copies to be run (see ZIP files). They can also be executed from a remote local network system, to provide a network test. Below are generated data patterns and reading sequences, plus example DOS and Windows log files (20 years apart).

######################## Data Patterns and Reading Sequence ########################

No.	Pattern	Or	No.	Pattern	Or	No.	Pattern	Or	No.	Pattern	Or
1	0	0	2	1	1	83	-1	ffffffff	84	-2	fffffffe
3	2	2	4	4	4	85	-3	fffffffd	86	-5	fffffffb
5	8	8	6	16	10	87	-9	fffffff7	88	-17	ffffffef
7	32	20	8	64	40	89	-33	ffffffdf	90	-65	ffffffbf
9	128	80	10	256	100	91	-129	ffffff7f	92	-257	fffffeff
11	512	200	12	1024	400	93	-513	fffffdff	94	-1025	fffffbff
13	2048	800	14	4096	1000	95	-2049	fffff7ff	96	-4097	ffffefff
15	8192	2000	16	16384	4000	97	-8193	ffffdfff	98	-16385	ffffbfff
17	32768	8000	18	65536	10000	99	-32769	ffff7fff	100	-65537	fffeffff
19	131072	20000	20	262144	40000	101	-131073	fffdffff	102	-262145	fffbffff
21	524288	80000	22	1048576	100000	103	-524289	fff7ffff	104	-1048577	ffefffff
23	2097152	200000	24	4194304	400000	105	-2097153	ffdfffff	106	-4194305	ffbfffff
25	8388608	800000	26	16777216	1000000	107	-8388609	ff7fffff	108	-16777217	feffffff
27	33554432	2000000	28	67108864	4000000	109	-33554433	fdffffff	110	-67108865	fbffffff
29	134217728	8000000	30	268435456	10000000	111	-134217729	f7ffffff	112	-268435457	efffffff
31	536870912	20000000	32	1073741824	40000000	113	-536870913	dfffffff	114	-1073741825	bfffffff
33	1	1	34	5	5	115	-2	fffffffe	116	-6	fffffffa
35	21	15	36	85	55	117	-22	ffffffea	118	-86	ffffffaa
37	341	155	38	1365	555	119	-342	fffffeaa	120	-1366	fffffaaa
39	5461	1555	40	21845	5555	121	-5462	ffffeaaa	122	-21846	ffffaaaa
41	87381	15555	42	349525	55555	123	-87382	fffeaaaa	124	-349526	fffaaaaa
43	1398101	155555	44	5592405	555555	125	-1398102	ffeaaaaa	126	-5592406	ffaaaaaa
45	22369621	1555555	46	89478485	5555555	127	-22369622	feaaaaaa	128	-89478486	faaaaaaa
47	357913941	15555555	48	1431655765	55555555	129	-357913942	eaaaaaaa	130	-1431655766	aaaaaaaa
49	3	3	50	51	33	131	-4	fffffffc	132	-52	ffffffcc
51	819	333	52	13107	3333	133	-820	fffffccc	134	-13108	ffffcccc
53	209715	33333	54	3355443	333333	135	-209716	fffccccc	136	-3355444	ffcccccc
55	53687091	3333333	56	858993459	33333333	137	-53687092	fccccccc	138	-858993460	cccccccc
57	7	7	58	455	1c7	139	-8	fffffff8	140	-456	fffffe38
59	29127	71c7	60	1864135	1c71c7	141	-29128	ffff8e38	142	-1864136	ffe38e38
61	119304647	71c71c7	62	15	f	143	-119304648	f8e38e38	144	-16	fffffff0
63	3855	f0f	64	986895	f0f0f	145	-3856	fffff0f0	146	-986896	fff0f0f0
65	252645135	f0f0f0f	66	31	1f	147	-252645136	f0f0f0f0	148	-32	ffffffe0
67	31775	7c1f	68	32537631	1f07c1f	149	-31776	ffff83e0	150	-32537632	fe0f83e0
69	63	3f	70	258111	3f03f	151	-64	ffffffc0	152	-258112	fffc0fc0
71	127	7f	72	2080895	1fc07f	153	-128	ffffff80	154	-2080896	ffe03f80
73	255	ff	74	16711935	ff00ff	155	-256	ffffff00	156	-16711936	ff00ff00
75	511	1ff	76	1023	3ff	157	-512	fffffe00	158	-1024	fffffc00
77	2047	7ff	78	4095	fff	159	-2048	fffff800	160	-4096	fffff000
79	8191	1fff	80	16383	3fff	161	-8192	ffffe000	162	-16384	ffffc000
81	32767	7fff	82	65535	ffff	163	-32768	ffff8000	164	-65536	ffff0000

Sequences	File	Sequences	File
1	0 1 2 3	11	2 1 0 3
2	1 2 3 0	12	3 2 1 0
3	2 3 0 1	13	0 1 2 3
4	3 0 2 1	14	1 2 3 0
5	0 2 1 3	15	2 3 0 1
6	1 3 2 0	16	3 0 2 1
7	2 0 1 3	17	0 2 1 3
8	3 1 2 0	18	1 3 2 0
9	0 3 1 2	19	2 0 1 3
10	1 0 3 2	20	3 1 2 0

Example Results on Next Page

Example Results

```
######################### DOS Version #########################

   Disk test dk01 in C++ by Roy Longbottom  Job D110732Z

   Disk C Free disk space   1164.3 Mbytes will use     28.2

    0.22 seconds for data generation and display

   File writing starting on Tue Mar 18 11:07:50 1997

    4 files written each 7389184 bytes (data*22)

    8.57 seconds writing files at     3.29 MB/sec Tue Mar 18 11:07:59 1997

   39.67 seconds read pass   1 at     0.71 MB/sec Tue Mar 18 11:08:39 1997
   50.15 seconds read pass   2 at     0.56 MB/sec Tue Mar 18 11:09:30 1997
   66.58 seconds read pass   3 at     0.42 MB/sec Tue Mar 18 11:10:37 1997
   46.51 seconds read pass   4 at     0.61 MB/sec Tue Mar 18 11:11:23 1997

     Finished Files Erased on Tue Mar 18 11:11:23 1997

####################### Windows Version #######################

                           Commands

 DiskTest A[uto], M[B] bbbbb, R[dmin] mmmm, D[MAsec] sssss, [L]og tttt.txt

 Auto runs the program, logs the results and exits automatically
 bbbbb is MB per file - rounded up to multiples of 10.3 MB
 mmmm is file reading time in minutes
 sssss is seconds that each DMA run of 164 tests is repeated
 tttt.txt is log file name, useful if multiple copies run

  DiskTest Auto, MB 10, Rmin 1, DMAsecs 1, Log BatLog.txt

    Disk Reliability Test Version 2.0 by Roy Longbottom

Windows NT Version 6.2, build 9200,
CPU GenuineIntel, Features Code BFEBFBFF, Model Code 000306E4, 3711 MHz
From GlobalMemoryStatus: Size 2097151 KB, Free 2097151 KB
Disk/partition 266239 MB, Free 128830 MB

File size    10.3 MB x 4 files, minimum reading time 1 minutes

             Start of test Tue Nov 28 21:44:42 2017

File 1    10.3 MB written in    0.30 seconds
File 2    10.3 MB written in    0.27 seconds
File 3    10.3 MB written in    0.31 seconds
File 4    10.3 MB written in    0.28 seconds

             Start reading Tue Nov 28 21:44:43 2017

Reading     168 x    10.3 MB in     1.00 minutes

42 read passes, 4 Files of    10.3 MB in     1.00 minutes

           Start Repeat Read Tue Nov 28 21:45:43 2017

Passes in 1 second(s) for each of 164 blocks of 64KB:

  500   560   560   560   560   560   560   520   540   560   560   540
  520   540   540   560   560   520   460   520   520   560   540   560
  580   580   560   500   500   520   560   560   560   560   580   580
  580   560   520   560   540   540   560   520   520   540   560   560
  560   560   560   560   560   560   540   500   560   580   580   540
  580   560   540   500   560   540   520   560   520   560   580   580
  480   500   520   560   540   580   540   540   580   580   540   580
  580   560   560   560   560   540   560   500   520   580   540   560
  560   560   560   560   560   540   580   580   560   500   520   560
  560   560   560   540   560   540   540   520   540   560   560   560
  560   520   540   500   560   580   580   540   480   560   520   500
  560   560   540   560   580   520   520   580   560   500   560   560
  560   580   560   580   600   540   500   560   560   540   560   560
  500   520   560   500   560   560   560   500

89840 read passes of 64KB blocks in     2.79 minutes

 No errors found during reading tests

               End of test Tue Nov 28 21:48:41 2017
```

Go To Start

Livermore Loops Benchmark

Details and results of this benchmark can be found in this ResearchGate PDF document. In its original form, it was found to produce the wrong results of numeric calculations on an overclocked PC. This lead to additional run time parameters being added to enable the program to be used as a stress test. Both 32 bit and 64 bit versions for Windows are included in Win64.zip with source code from newsource.zip.

There are 24 Livermore Loops (kernels of numerical application) that are run three times with different data sizes. For a stress test a number, representing the running time of each loop, has to be added to the execution command (example lloops64.exe secs 5). For 5 seconds per loop, running time of 72 would be expected to be around 6 minutes. Further details can be found in burnin4cpu.htm (Archive).

The output of the stress test is indicated below, the three sections are displayed and checksum verified, with errors saved in the log file. The checksums can be different when the benchmark is produced by alternative compilers, but the displayed errors can be used to produce an alternative set of numbers to check. With no errors, the log file entries are as shown below.

```
 Display as tests are running

Kernel       Floating Pt ops
No  Passes E No     Total      Secs.  MFLOPS Span     Checksums          OK
------------ -- ------------- ----- ------- ---- ---------------------- --
 1  28 x2148  5 1.299110e+010  4.98 2606.36   27 3.855104502494961e+001 16
 2  46 x2541  4 8.228774e+009  5.04 1633.72   15 3.953296986903060e+001 16
 3  37 x1949  2 6.230563e+009  5.03 1239.56   27 2.699309089320672e-001 16
 4  38 x1943  2 3.544032e+009  5.00  709.31   27 5.999250595473891e-001 16
 5  40 x 515  2 1.713920e+009  5.01  342.30   27 3.182615248447483e+000 16
 6  21 x1610  2 2.596608e+009  5.02  517.20    8 1.120309393467088e+000 15
 7  20 x1455 16 1.564416e+010  5.02 3113.69   21 2.845720217644024e+001 16
 8   9 x1084 36 1.461059e+010  5.10 2862.39   14 2.960543667875005e+003 15
 9  26 x1193 17 1.265534e+010  5.02 2522.64   15 2.623968460874251e+003 16
 To
 24 three times

 Log File

 Reliability test   5 seconds each loop x 24 x 3

 Part 1 of 3 start at Tue Apr  5 12:53:14 2011
 Part 2 of 3 start at Tue Apr  5 12:55:11 2011
 Part 3 of 3 start at Tue Apr  5 12:57:11 2011

 Numeric results were as expected
```

Go To Start

Windows Integer Stress Tests

BusSpeed reliability test is run using **BusSpd2k.exe** benchmark that can be found in busspd2k.zip. The program can be run by entering details in the test window for data size, in KB, to suit caches or RAM, and seconds to run each test, of 12 for the later version. Alternatively, it can be run via BAT files, examples of which are in the ZIP file. This has an additional parameter for the log file name, to allow multiple copies of the program to be run. Further details are provided in burnin32.htm (Archive).

The program uses assembly code and eight 64 bit MMX registers. The original version had six tests to write and read the data multiple times, with a different data pattern for each test. For every other pass, an inverse binary pattern is used (e.g. repeated hex A5 and 5A). A later version included six additional read only tests. Reading involves adding and subtracting, where the final result should be the same as the original. This is checked after multiple passes and the first few wrong results reported for each pattern. The aim is to produce maximum data transfer and calculation speeds.

Note MB/second for the first tests is for writing and reading, where bus data traffic would be twice that.

Below are examples of results of versions 1 and 2, from the same system. I Think that it was overclocked and that was responsible for the identified failures.

IntBurn64.exe has the same Windows interface as the reliability section for BusSpd2k and, essentially, the same C/C++ code, but assembly code operating on normal 64 bit registers. The benchmark and source codes can be found in more64bit.zip, with further details and results in burnin64.htm (Archive). Along with other stress testing programs, IntBurn64 can be used for a memory paging stest. See: paging.htm (Archive).

The logged output from IntBurn64 is the same as that from BusSpd2k stress test function, with an additional indication of maximum processing speed in MIPS, derived from the known instruction count in the assembly code used. The program also has a run time command parameter to define four different screen positions for main windows, enabling clear display of multiprocessor activity. For more details see the next page.

None of the HTM reports, for these integer Windows benchmarks, identified particularly high temperatures. but see Linux tests below. However, they did identify some problems, including a memory fault, where the often recommended Memtest86 failed to identify it, after running for hours. For this particular fault, I came to the conclusion that my tests were transferring data at a much faster speed, probably as data comparisons are carried out after numerous calculations.

```
 ##########################################################################

             BusSpd2k RAM Reliability Test Version 1

  1     960 MB/sec   Pattern 0000000000000000   Result OK         2 passes
  2     930 MB/sec   Pattern FFFFFFFFFFFFFFFF   Result OK         2 passes
  3     965 MB/sec   Pattern A5A5A5A5A5A5A5A5   Result OK         2 passes
  4     964 MB/sec   Pattern 5555555555555555   Result OK         2 passes
  5     963 MB/sec   Pattern 3333333333333333   Result OK         2 passes
  6     963 MB/sec   Pattern F0F0F0F0F0F0F0F0   Result OK         2 passes

                       Example Errors

  1     966 MB/sec   Pattern 0000000000000000   Result OK         2 passes
  2     925 MB/sec   Pattern FFFFFFFFFFFFFFFF   Result OK         2 passes
  3     963 MB/sec   Pattern A5A5A5A5A5A5A5A5   Result OK         2 passes

    ERROR found checking data after generation - Test 4
    147456K 4 byte words checked and 16 errors found
    First 12 errors
    Pattern 55555555 Was 555555A5 Word 57358593
    11 More (not shown here)

 ##########################################################################

             BusSpd2k L1 Cache Reliability Test Version 2

 Write/Read
  1    2046 MB/sec   Pattern 0000000000000000   Result OK   1248737 passes
  2    2052 MB/sec   Pattern FFFFFFFFFFFFFFFF   Result OK   1252555 passes
  3    2055 MB/sec   Pattern A5A5A5A5A5A5A5A5   Result OK   1254052 passes
  4    2053 MB/sec   Pattern 5555555555555555   Result OK   1253050 passes
  5    2054 MB/sec   Pattern 3333333333333333   Result OK   1253647 passes
  6    2052 MB/sec   Pattern F0F0F0F0F0F0F0F0   Result OK   1252231 passes
 Read
  1    7345 MB/sec   Pattern CCCCCCCCCCCCCCCC   Result OK   8966800 passes
  2    7340 MB/sec   Pattern 0F0F0F0F0F0F0F0F   Result OK   8959600 passes
  3    7343 MB/sec   Pattern A5A5A5A5A5A5A5A5   Result OK   8964300 passes
  4    7340 MB/sec   Pattern 5555555555555555   Result OK   8960700 passes
  5    7347 MB/sec   Pattern 3333333333333333   Result OK   8968400 passes
  6    7340 MB/sec   Pattern F0F0F0F0F0F0F0F0   Result OK   8960400 passes

                 Example Errors - slow speed, overheating?
 Write/Read
  1    2051 MB/sec   Pattern 0000000000000000   Result OK    250363 passes
  2     666 MB/sec   Pattern FFFFFFFFFFFFFFFF | ERROR
 1K 4 byte words checked and 1 errors found
 1 errors
 Pattern FFFFFFFF Was 00000000 Word 14
```

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Windows Multiprocessor Integer Stress Tests

Details of multiprocessor stress tests can be found in dualcore.htm, burnin4cpu.htm and quad core 8 thread.htm. Following are some results that suggest tests that might be required, to produce maximum stress on a modern system. These relate to a quad core CPU with hyperthreading (identified as 8 cores), plus four channel high speed RAM. Firstly, an example of commands to run four IntBurn64 tests concurrently, then an example of logged data for one test.

```
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                Example BAT file commands to test four CPUs:

Start IntBurn64 KB 100000, Secs 5, auto, P1, Log ITestx1.txt
Start IntBurn64 KB 100000, Secs 5, auto, P2, Log ITestx2.txt
Start IntBurn64 KB 100000, Secs 5, auto, P3, Log ITestx3.txt
Start IntBurn64 KB 100000, Secs 5, auto, P4, Log ITestx4.txt

 ##########################################################################

     Single 100 MB Memory Test, average GB/second 12.3 Write/Read 16.8 Read

            64 Bit Integer Reliability Test Version 1.2 for 64 bit OS

  Test 100000 KB at 5 seconds per test, Start at Fri Dec 01 16:59:41 2017

  Write/Read
  1   12101 MB/sec  Pattern 0000000000000000   Result OK       299 passes
  2   12294 MB/sec  Pattern 0000000000000000   Result OK       304 passes
  3   12300 MB/sec  Pattern A5A5A5A5A5A5A5A5   Result OK       305 passes
  4   12298 MB/sec  Pattern 5555555555555555   Result OK       305 passes
  5   12295 MB/sec  Pattern CCCCCCCCCCCCCCCC   Result OK       304 passes
  6   12295 MB/sec  Pattern 0F0F0F0F0F0F0F0F   Result OK       304 passes
 Max   2595 64 bit MIPS
 Read
  1   16818 MB/sec  Pattern 0000000000000000   Result OK       880 passes
  2   16815 MB/sec  Pattern FFFFFFFFFFFFFFFF   Result OK       880 passes
  3   16804 MB/sec  Pattern A5A5A5A5A5A5A5A5   Result OK       880 passes
  4   16690 MB/sec  Pattern 5555555555555555   Result OK       825 passes
  5   16726 MB/sec  Pattern 3333333333333333   Result OK       880 passes
  6   16808 MB/sec  Pattern F0F0F0F0F0F0F0F0   Result OK       880 passes
 Max   2496 64 bit MIPS

 Minimum seconds - generate/check data   0.0165363, compare   0.0073533

             Reliability Test Ended Fri Dec 01 17:00:44 2017

 ##########################################################################

            Quad Core 8 Thread 3.7 GHz, Turbo 3.9 GHz, Core i7 CPU
                  4 Channel RAM Maximum Speed 51.2 GB/second

                         Four 100 MB Memory Tests

                1       2       3       4      All  1 Test    Gain

R/W MIPS       1418    1442    1501    1441    5802    2595    2.24
R/W MB/s       6637    6734    9973    6698   30041   12264    2.45

Rd MIPS        1499    1501    1503    1475    5978    2496    2.40
Rd MB/s        9934    9973   10037    9871   39815   16777    2.37


      CPU MIPS for One, Four and Eight CPU Tests at 8 KB L1 Cache Size

              1      2      3      4      5      6      7      8  Total   Gain
Tests

 1  R/W   5682                                                     5682
     Rd   6096                                                     6096

 4  R/W   5471   5465   5542   5597                               22075   3.89
     Rd   5681   5918   5708   6052                               23359   3.83

 8  R/W   3665   3675   3668   3591   3665   3611   3667   3652  29194   5.14
     Rd   3306   3346   3323   3413   3356   3549   3373   3330  26996   4.43
```

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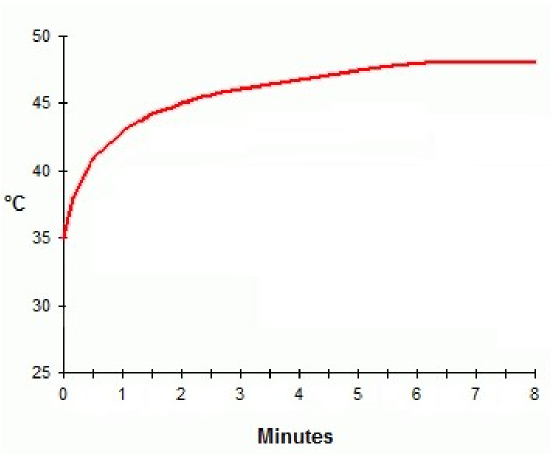
Windows Floating Point Stress Tests

SSE3DSoak.exe uses assembly code SSE, SSE2 or 3DNow Single Instruction Multiple Data (SIMD) floating point instructions to soak test the CPU, Cache or RAM at high speeds whilst checking results for correct values. SSE, SSE2 and 3DNow Run buttons are provided for separate CPU, Cache and RAM tests. The program produces 1024 random floating point numbers used in all tests. For the CPU test, 32 add or multiply instructions manipulate a few at a time from registers within a loop. The Cache test uses the same 32 instructions but with data from L1 cache within the main loop. The RAM test is biased towards fast data transfer and can also use cache sized data. Every fifth pass the memory is filled with 16 or 32 of the random numbers with the first set being read and checked for correctness. The main loop uses 8 load/add and 8 load/subtract instructions to produce a sum check of zero. CPU and Cache tests check that results are the same as the first pass which also calibrates the testing loops to run for up to one second (on a fast CPU).

Drop down lists are provided to select running time (1 minute to 24 hours), and memory size used, between 4 KB and 4 MB for cache tests and 4 KB to 1024 MB for RAM tests (to test using data in L1 cache, L2 cache or RAM). An example of the log file is shown below. Further details can be found in burnin32.htm (Archive) with the benchmark and source code in sse3dnow.zip.

SSEburn64.exe uses the same Windows test panel and assembly code instructions as SSE3DSoak, excluding AMD 3DNow functions, and compiled for 64 bit operation. The program code and execution file are in more64bit.zip. Below is an example of commands to run four copies of the benchmark at the same time, followed by performance details using one and four CPUs. More information and results are provided in burnin64.htm (Archive). See Linux tests for details of excessive CPU temperatures whilst running stress tests. Below is an example of what might be expected on a PC, running SSEburn64, in good working condition and in a cool environment (quad core 3 GHz Phenom II - measurement does not represent an actual temperature but is a relative reading that can be used for thermal management, with a maximum value is 70°C).




```
 ##############################################################################

  SSE CPU Test at 5 minutes Example Log File

   1.01 Minutes at 14558 MFLOPS, No Errors
   2.00 Minutes at 14754 MFLOPS, No Errors
   3.01 Minutes at 14821 MFLOPS, No Errors
   4.00 Minutes at 14854 MFLOPS, No Errors
   5.01 Minutes at 14874 MFLOPS, No Errors

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              3.9 GHz Core i7 Example BAT File Commands

 Start SSEBurn64 SSE, Cache, KB 128, Mins 5, auto, P1, Log Testx1.txt
 Start SSEBurn64 SSE, Cache, KB 128, Mins 5, auto, P2, Log Testx2.txt
 Start SSEBurn64 SSE, Cache, KB 128, Mins 5, auto, P3, Log Testx3.txt
 Start SSEBurn64 SSE, Cache, KB 128, Mins 5, auto, P4, Log Testx4.txt

 ##############################################################################
```

	CPU MFLOPS	L1 4 KB Cache MFLOPS	L2 128 KB Cache MFLOPS	L3 Wrt/Rd 2 MB Memory MB/sec	L3 Read 2 MB Memory MB/sec	RAM Wrt/Rd 64 MB Memory MB/sec	RAM Read 64 MB Memory MB/sec
SSE	14558	23217	23290	18894	34158	13286	18950
SSE2	7485	11462	11618	20294	34158		
SSE CP1		21962		9162	29771	7291	11566
SSE CP2		29771		2783	29452	7033	11619
SSE CP3		22040		5003	30301	7371	10032
SSE CP4		21766		10432	29817	7074	10683
Total 4 CPUs		95539		27380	119341	28769	43900
Performance Gain		4.12		1.45	3.49	2.17	2.32

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Windows Graphics Stress Tests

CUDA MFLOPS - CUDA, from nVidia, provides programming functions to use GeForce graphics processors for general purpose computing. It can produce outstanding speeds in MFLOPS, as demonstrated by my benchmarks, described in my CUDA MFLOPS Benchmarks.pdf report, that also contain results. The benchmarks have run time parameters that determine which test to run, number of threads to use, testing duration in minutes and reporting rate in seconds. Examples of running the single and double precision versions are in cuda1.htm and cuda2.htm respectively. The benchmarks and source codes are in gigaflops-benchmarks.zip.

Below is an example of results on a PC with a Phenom II X4 3.0 GHz CPU, 64-Bit Windows 7 and a GeForce GTS 250 graphics card, from a near ten minute test, where GPU temperature was noted. Here, performance was constant, over the period, with up to a 30°C temperature increase.

```
 CUDA MFLOPS Benchmark 1.1 Mon Nov 09 11:11:31 2009

 CUDA devices found
 Device 0: GeForce GTS 250  with 16 Processors 128 cores

 Using 256 Threads

 Calculate      Reliability Test 10 minutes, report every 15 seconds

 Repeat CUDA 761 times at  1.52 seconds. Repeat former 9 times

 Results of all calculations should be 0.741250

 Test  4 Byte  Ops/   Repeat  Seconds   MFLOPS    Errors     First      Value
        Words  Word   Passes                                  Word

  1  10000000    32     6849   13.736   159563   None found
  2  10000000    32     6849   13.732   159605   None found
  3  10000000    32     6849   13.730   159623   None found
  4  10000000    32     6849   13.730   159629   None found
  5  10000000    32     6849   13.734   159575   None found
  6  10000000    32     6849   13.732   159607   None found
 to
 40  10000000    32     6849   13.753   159362   None found

 Minutes            0   0.5  1.0  1.5  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0
 Temperature °C    42   59   63   67   69   71   71   72   72   71   70   71
```

VideoD3D9 Benchmark has run time parameters, enabling it to be used as a stress test, with 64 bit and 32 bit versions available. Details of VideoD3D9_64, VideoD3D9_32 are provided in this PDF report and can be downloaded in Windows-Graphics-Benchmarks.zip.

Below are commands to run SSEBurn64 and VideoD3D9_64 in stress testing mode, followed by example results, reported at intervals of around 1 minute. An example of CPU and GPU temperatures obtained are provided in burnin64.htm (Archive), along with other details and test results.

```
  Commands

  Start SSEBurn64 SSE2, Cache, KB 4, Mins 10, auto, P3, Log T11.txt
  Start VideoD3D9_64 Auto, Test 6, Width 640, Height 480, P1, Secs 600, Log T21.txt

 SSE2 Cache Test Results                      DirectX9 D3D Test Results

  1.00 Minutes at 2174 MFLOPS, No Errors       665.9 Frames Per Second over 60 seconds
  2.01 Minutes at 2189 MFLOPS, No Errors       653.4 Frames Per Second over 60 seconds
  3.00 Minutes at 2195 MFLOPS, No Errors       651.1 Frames Per Second over 60 seconds
  4.00 Minutes at 2197 MFLOPS, No Errors       650.6 Frames Per Second over 60 seconds
  5.00 Minutes at 2199 MFLOPS, No Errors       651.6 Frames Per Second over 60 seconds
  6.01 Minutes at 2199 MFLOPS, No Errors       652.5 Frames Per Second over 60 seconds
  7.02 Minutes at 2201 MFLOPS, No Errors       648.0 Frames Per Second over 60 seconds
  8.01 Minutes at 2180 MFLOPS, No Errors       740.0 Frames Per Second over 60 seconds
  9.00 Minutes at 2164 MFLOPS, No Errors       744.1 Frames Per Second over 60 seconds
 10.00 Minutes at 2152 MFLOPS, No Error        680.3 Frames Per Second Overall
```

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Linux Versions

Most of the benchmarks and source codes for 32 bit and 64 bit compilations are available in linux_burn-in_apps.tar.gz, with more details and results in linux burn-in apps.htm (Archive). These are all run from Terminal commands or shell scripts.

PC Drive Tests - drivestress32 and drivestress64 {See). Run time commands are somewhat dufferent to the Windows version, as shown below.

```
L - log file number N for IOStressN.txt   M - Minutes to read all files
S - Seconds to read each block of 1 file  R - file size Repeat multiplier x 10.25 MB
F - File path for drive or partition      C - Use Linux RAM based File Cache

Example: ./drivestress64 Log 0, Mins 2, Secs 1, Repeats 1,  FilePath ~/all64/burndis
```

Livermore Loops - lloops and lloops_64 (See). An example command to define the running time of each of the 72 loops is ./lloops_64 secs 5.

Integer Stress Tests - intburn32 and **intburn64** (See). An example of shell script cpmmands to run multiple copies is shown below. In this case (with Ubuntu), the commands can define terminal window sizes and position.

The linux burn-in apps.htm report includes results of **Paging/Swapping Tests**, where data transfer speed varied between 9 and 5000 MB/second.

```
                    Example Shell Script Commands

       xterm -geometry 80x25+10+10   -e ./intburn64 KBytes 4, Secs 5, Log 1 &
       xterm -geometry 80x25+600+10  -e ./intburn64 KBytes 4, Secs 5, Log 2 &
       xterm -geometry 80x25+10+500  -e ./intburn64 KBytes 4, Secs 5, Log 3 &
       xterm -geometry 80x25+600+500 -e ./intburn64 KBytes 4, Secs 5, Log 4
```

CUDA Graphics Stress Tests - cudamflops32SP and cudamflops64SP (See above) and CUDA MFLOPS Benchmarks.pdf. Run time commands are somewhat different to the Windows version, as shown in linux burn-in apps.htm (Archive). The CUDA benchmark source codes can be found in linux cuda mflops.tar.gz. Below is an example of GPU temperature rises, running a CUDA and three CPU stress tests.

```
  Quad Core 3.0 GHz Phenom, GeForce GTS 250 running 3hree CPU tests plus

  CUDA command -  xterm -e ./cudamflops32SP Mins 10, FC

 Minute 0      1      2      3      4      5      6      7      8      9     10    Rise
      ------------------------------------- °C  -------------------------------------

 GPU   48     69     74     75     75     76     76     76     76     76     76     28
```

OpenGL Graphics Stress Tests - videogl32, videogl64 (See). - Benchmarks and source codes are in linux-graphics-benchmarks.tar.gz with more details in My Graphics Benchmarks.pdf report and linux opengl benchmarks.htm (Archive).. Following are details of a test on a CPU with Hyperthreading (4 core 8 threads), running videogl64 at the same time and 8 CPU stress tests.

Note, approval was given to Canonical to include this benchmark in the testing framework for the Unity desktop.

```
  Script for Core i7 3.7 to 3.9 GHz CPU, GeForce GTX 650

 ./burninsse64 KWords 5, Section 3, Minutes 10, Log 1, &
 ./burninsse64 KWords 5, Section 3, Minutes 10, Log 2, &
 ./burninsse64 KWords 5, Section 3, Minutes 10, Log 3, &
 ./burninsse64 KWords 5, Section 3, Minutes 10, Log 4, &
 ./intburn64 Log 5, KBytes 4, Seconds 50 &
 ./intburn64 Log 6, KBytes 4, Seconds 50 &
 ./intburn64 Log 7, KBytes 4, Seconds 50 &
 ./videogl64 Width 1920, Height 800, Mins 10, Test 4

                  Average MB/Second
              Stand Alone   Test Speed       Ratio

  burninsse64       23485        62789         2.67
  intburn64 Wr/Rd   25094        44420         1.77
  intburn64 Rd      40874        77916         1.91

  videogl64 FPS      1128          850         0.75

 Minute 0      1      2      3      4      5      6      7      8      9     10    Rise
       ---------------------------------- °C  ----------------------------------------

 CPU   30     54     58     61     62     62     62     62     62     62     62     32
 GPU   30     42     45     46     47     48     48     48     48     49     50     20
```

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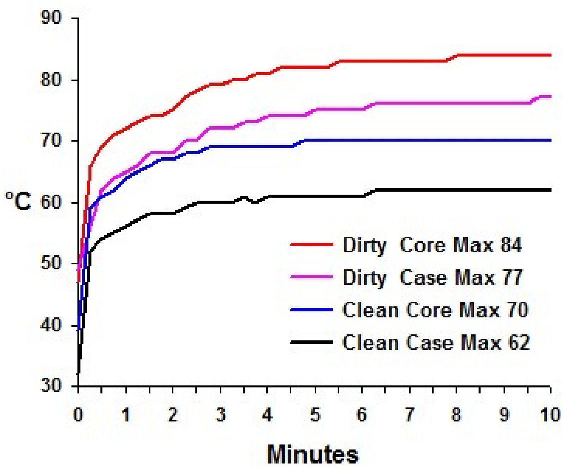
Linux Floating Point Stress Tests

The 64 bit and 32 bit tests, **burninsse32** and **burninsse64**, are based on the OpenMP benchmark described in openmp mflops.htm (Archive), where the program compiled without OpenMP directives ran very fast, due to the GCC compiler generating optimised code using SSE instructions. Here, the arithmetic operations executed are of the form x[i] = (x[i] + a) * b - (x[i] + c) * d + (x[i] + e) * f with 2, 8 or 32 operations per data word. Below are details of run time parameters, a script to test 4 CPUs and results.

```
          Run Time Parameters

          S or Section 1, 2 or 3 for 2, 8 or 32 operations per word
          L or Logfile number N = 0 to 99 for name logN.txt
          K or KW or KWords cache or RAM data words used
          M or Minutes for running time

          Results are reported every 15 seconds

                  Example Script to test four CPUs on 3.9 GHz Core i7

       xterm -geometry 80x25+10+10   -e ./burninsse64 KW 2, Section 3, Mins 1, Log 1 &
       xterm -geometry 80x25+600+10  -e ./burninsse64 KW 2, Section 3, Mins 1, Log 2 &
       xterm -geometry 80x25+10+500  -e ./burninsse64 KW 2, Section 3, Mins 1, Log 3 &
       xterm -geometry 80x25+600+500 -e ./burninsse64 KW 2, Section 3, Mins 1, Log 4

                Example Results for one test, others almost identical

         Pass     4 Byte  Ops/   Repeat     Seconds    MFLOPS           First   All
                   Words  Word   Passes                               Results  Same

            1       2000    32  5487500       15.00     23410     0.352167547   Yes
            2       2000    32  5487500       15.00     23407     0.352167547   Yes
            3       2000    32  5487500       15.01     23404     0.352167547   Yes
            4       2000    32  5487500       15.01     23404     0.352167547   Yes
```

As reported in linux burn-in apps.htm (Archive), this test revealed a number of heat related problems. The first, reported here, was on a desktop PC, with a core 2 duo CPU, where CPU temperatures using Windows applications appeared to be high. This was confirmed by running burninsse32, although performance was not reduced over the test period. On opening the PC case, the CPU heatsink was found to be clogged up with dust. After blowing out the dust with a compressed air spray, the Linux tests were rerun and measured maximum temperatures were 14°C to 15°C lower, as shown on the right.

However, further tests revealed a problem associated with Ubuntu's Frequency Scaling Monitor. When set as "On-Demand", on running one copy, speed was reduced at the start, with CPU GHz indicated as 1.6. Yet, running with two copies, CPU MHz ran at 2.4 GHz continuously, with proportional increase in MFLOPS speed.



Anther problem was on a laptop, again with a Core 2 Duo PC. This overheated after booting, causing the CPU to run at less than half speed. Unlike using Windows, with power on to Ubuntu, initial CPU temperatures were high with the fan not appearing to run as fast as it might. On one occasion, the system turned off the power in the middle of a test. Sometimes the laptop started at a lower temperature and did not overheat, with the fan apparently running at high speed.

Below are speeds and recorded temperatures of tests using data from L1 and L2 caches, showing worse than half speed operation at high temperatures.

									Later near constant speed higher °C rises							
Words	**5K**		**5K**		**100K**		**100K**		**5K**		**5K**		**100K**		**100K**	
Ops/wd	**2**		**32**		**2**		**32**		**2**		**32**		**2**		**32**	
Minute	**°C**	**MFLOPS x2**	**°C**	**MFLOPS x2**	**°C**	**MFLOPS x2**	**°C**	**MFLOPS x2**	**°C**	**MFLOPS x2**	**°C**	**MFLOPS x2**	**°C**	**MFLOPS x2**	**°C**	**MFLOPS x2**
0	65		65		65		65		51		51		51		51	
0.5	96	4716	91	10168	85	3639	95	9135	70	4662	73	9344	72	3150	77	9242
1	98	3362	94	4756	89	3630	94	4416	75	4627	78	9513	77	3351	81	9892
1.5	91	2076	87	4443	91	3636	91	4347	78	4446	81	9520	80	3512	84	9515
2	87	2054	86	4452	91	3631	89	4403	81	4520	83	9526	81	3274	86	9297
2.5	85	2054	85	4235	92	3632	87	4457	82	4654	84	9635	83	3426	87	9559
3	84	2036	84	4237	93	3630	85	4384	83	4378	85	9631	84	3385	89	9342
3.5	82	3098	83	4376	93	3642	85	4404	84	4198	86	9639	85	3389	90	9807
4	89	4773	83	4420	94	3626	84	4439	84	4644	87	9560	85	3214	91	10173
Max	98	4773	94	10168	94	3642	95	9135	84	4662	87	9639	85	3512	91	10173
Min	65	2036	65	4235	65	3626	65	4347	51	4198	51	9344	51	3150	51	9242
Diff	33	2737	29	5933	29	16	30	4788	33	464	36	295	34	362	40	931

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