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Megaflop Comparisons of Various Computers

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Megaflop Comparisons of Various Computers

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Abstract

This report describes a test program and results obtained by running this program on a wide range of computers of interest to Sandia National Laboratories. The program, written in FORTRAN, was designed to estimate the speed with which a target computer could perform floating point operations requested by a FORTRAN programmer. Input/output operations are not timed. Thus the results depend not only upon the basic underlying speed of the computer but also upon the intelligence of the FORTRAN compiler.

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Introduction

Performance testing of a computer is, at best, an inexact science. Any test that can be devised is still only an isolated test, and any general conclusions based on that test should be carefully scrutinized. It would, of course, be desirable to have a set of programs which exactly model the workload for a particular installation. However, it is impossible to build such a model. Even if it could be done, extrapolating the results to other work loads would be risky. In general, the more realistic the set of benchmark programs, the more machine-dependent they become. This is particularly true if time-sharing exercises are involved. Nevertheless, it is desirable to have a test or tests which are portable and can be used as a basis for simple comparisons of various computers.

This report describes a test program and results obtained by running this program on a wide range of computers of interest to Sandia National Laboratories. The program, written in FORTRAN, was designed to estimate the speed with which a target computer could perform floating point operations requested by a FORTRAN programmer. Input/output operations are not timed. Thus the results depend not only upon the basic underlying speed of the computer but also upon the intelligence of the FORTRAN compiler. It is entirely possible that an optimizing compiler might generate code with fewer floating point operations than generated by a nonoptimizing compiler.

However, in examining the code generated by the FTN compiler on Control Data equipment, we found that the number of floating point operations was not changed by varying the optimization parameter. Thus when changes occur in the timings by changing the optimization parameters, we are seeing the ability of the compiler to optimize the overhead associated with indexing of DO loops, IF tests, jumps, etc. Unfortunately, it is almost impossible to separate the time associated with floating point calculations from other activities.

Description of Test Program

The program, SPEED, is written in ANSI (1966) standard FORTRAN so that only one or two lines need be changed to run on any of the machines. Some computers require a PROGRAM card as the initial card, and the call to the internal clock might have to be changed. A microfiche copy of SPEED is attached to the back cover of this report.

SPEED consists of five sections or kernels which are described briefly as follows:

<u>Kernel</u>	<u>Description</u>
1	Linear Equation Solver Without Pivoting. Gaussian elimination without pivoting is used to solve systems of sizes 1,2,.... The

KernelDescription

- maximum-sized system solved is an input variable set to 60 for these tests.
- 2 Excerpt From Ordinary Differential Equation Solver. This kernel is part of the prediction step of an ODE solver, the major computation being done in a short DO loop with two additions and a multiplication.
 - 3 Forward and Backward Substitution Excerpt From Linear Equation Solver With Pivoting. The test results are obtained with 29 iterations of Forward/Backward substitution for linear systems of sizes 50 through 100.
 - 4 Excerpt From Vortex Dynamics Code. The major computational loop in this kernel is a 17-statement inner DO loop containing branching and an external reference to the square root routine.
 - 5 Excerpt From Lattice Relaxation Code. This rather complicated kernel contains several inner DO loops of varying complexity, including branching and exponentiation.

These kernels were all taken from programs in use at Sandia in 1978. The first three were adapted from software library routines while the fourth and fifth were taken from large user codes. Each kernel was modified only enough so that it would run to completion with varying input parameters without encountering arithmetic difficulties.

The number of millions of floating point operations* per second (MFLOPS) for each kernel is computed separately. Then the overall total MFLOPS is calculated by dividing the total number of millions of floating point operations for all kernels by the total time for all kernels.

The number of floating point operations performed by the program with varying inputs was arrived at by judging what economizing operations a reasonable compiler would do. It is recognized that on certain computers, changing a few lines of code could give rise to greatly different results. Thus the results of running the program unmodified must not be interpreted as the speed at which the same work could be done if the kernels were rewritten to account for the machine's architecture.

*A floating point operation is defined to be an add, subtract, multiply, or divide with each operation counting equally.

Test Results

These tests have been performed at various sites over the past 12 months. We shall identify the results as carefully as possible because it is doubtful that any of the tests could be duplicated, especially if there have been changes to the operating systems which were used.

Each test was run with the compiler and optimization parameters to give the fastest possible results. All results were obtained by running the program in single precision. Thus, for examples, results were obtained on the VAX using 32 bits and on the CDC-203 and CRAY-1 using 64 bits.

Conclusions

We have used a specially prepared FORTRAN program, SPEED, to measure the central processor capability of several computers. The program calculates the number of millions of floating point operations per second for five kernels originally written for a CDC-6600.

While it is true that the performance of any particular machine could be enhanced by tailoring the code to the architecture of that machine, we have chosen to run the code unmodified across all machines. A future report will discuss methods of improving the performance by taking advantage of the architecture.

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<u>Computer</u>	<u>Location</u>	<u>Operating System</u>	<u>Compiler</u>	<u>Word Length (Bits)</u>	<u>Date</u>
VAX 11/780	Sandia	VMS 1.6	FORTTRAN IV-PLUS	32	6/10/80
UNIVAC 1108	Sandia	EXEC-V111-Level 31	FORTTRAN V	36	4/05/80
UNIVAC 1100/82	Sandia	EXEC-V111-Level 36	FTN	36	4/05/80
CDC-6400	Sandia	NOS/BE 1.2	FTN 4.6 + 460	60	3/31/80
CDC-CYBER 172	Sandia	SCOPE 3.3	FTN	60	4/05/80
CDC-6600	Sandia	NOS	FTN	60	4/05/80
CDC-7600	Sandia	SCOPE 2.1	FTN 4.6 + 452	60	1/04/79
IBM-3033	BENDIX-KC	MV370-CMS	Level H--Extended	32	11/15/79
CYBER 170/720	CDC-MINN	NOS-485	FORTTRAN 5	60	4/30/80
CYBER 170/730	CDC-MINN	NOS-485	FORTTRAN 5	60	4/30/80
CYBER 170/740	CDC-MINN	NOS-485	FORTTRAN 5	60	4/30/80
CYBER 170/750	CDC-MINN	NOS-485	FORTTRAN 5	60	4/30/80
CYBER 170/760	CDC-MINN	NOS-485	FORTTRAN 5	60	4/30/80
CYBER 203	CDC-MINN	O.S.1.4	R1.4	64	5/22/79
CYBER 175	United Computing Systems	APEX/SL D.3.4	FTN40	60	11/16/79
CRAY-1	United Computing Systems	COS	CFT1.07	64	6/03/80
AMDAHL	Sunnyvale, CA	MVS 3.8	Level H--Extended	32	8/08/80

MEGAFLOPS

Kernel	CDC 6400	CDC 172	CDC 170/ 720	WAX 780	UNIVAC 1108	CDC 170/ 730	UNIVAC 1100/82	CDC 6600	CYBER 170/ 740	AMDAHL V7B	IBM 3033	CYBER 170/ 750	AMDAHL V7A	CDC 175	AMDAHL V7	CYBER 170/ 760	AMDAHL V8	CDC 7600	CDC 203	UCS CRAY CFT=1.07
1	.12	.15	.19	.17	.27	.27	.56	.63	.73	1.6	1.4	2.0	2.0	2.0	2.6	2.7	2.8	3.6	3.9	6.3
2	.15	.22	.24	.26	.23	.35	.47	.55	.99	1.7	1.7	2.5	1.9	2.4	2.3	2.8	2.6	2.9	5.9	11.2
3	.12	.16	.18	.25	.27	.26	.51	.60	.75	1.6	1.8	1.8	1.8	2.2	2.3	2.4	2.6	3.3	5.7	19.4
4	.13	.16	.19	.30	.22	.25	.47	.57	.65	1.8	2.0	1.5	2.2	1.5	2.5	2.2	2.9	3.1	5.3	5.4
5	.15	.16	.20	.24	.23	.28	.43	.52	.67	1.4	1.4	1.5	1.8	1.8	2.0	2.2	2.2	3.0	4.2	3.7
Total	.13	.17	.20	.24	.24	.28	.48	.57	.74	1.6	1.6	1.8	1.9	1.9	2.3	2.4	2.6	3.2	4.9	6.6

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