SPEED OF COMPUTER SYSTEMS

The Current Speed Of A $2,000 Personal Computer Is Faster Than The $10,000,000 Cray Computer Of 1975

H.1 INTRODUCTION

The calculation of element stiffness matrices, solution of equations and evaluation of mode shapes and frequencies are all computationally intensive. Furthermore, it is necessary to use double-precision floating-point arithmetic to avoid numerical errors. Therefore, all numbers must occupy 64 bits of computer storage. The author started developing structural analysis and design programs on the IBM-701 in 1957 and since that time has been exposed to a large number of different computer systems. In this section the approximate double-precision floating-point performances of some of these computer systems are summarized. Since different FORTRAN compilers and operating systems were used the speeds presented can only be considered accurate to within 50 percent.

H.2 DEFINITION OF ONE NUMERICAL OPERATION

For the purpose of comparing floating-point speeds the evaluation of the following equation is defined as one operation:

$$A = B + C * D$$ Definition of one numerical operation

Using double precision arithmetic, the definition involves the sum of one multiplication, one addition, extracting three numbers from high-speed storage, and

transferring the results to storage. In most cases, this type of operation is within the inner DO LOOP for the solution of linear equations and the evaluation of mode shapes and frequencies.

H.3 SPEED OF DIFFERENT COMPUTER SYSTEMS

Table H.1 indicates the speed of different computers used by the author.

Table H.1. Floating-Point Speeds of Computer Systems

YEAR	COMPUTER Or CPU	OPERATIONS PER SECOND	RELATIVE SPEED
1963	CDC-6400	50,000	1.0
1967	CDC-6600	100,000	2.0
1974	CRAY-1	3,000,000	60.0
1980	VAX-780	60,000	1.2
1981	IBM-3090	20,000,000	400.
1981	CRAY-XMP	40,000,000	800.
1990	DEC-5000	3,500,000	70.
1994	Pentium-90	3,500,000	70.
1995	Pentium-133	5,200,000	104.
1995	DEC-5000 upgrade	14,000,000	280.
1998	Pentium II - 333	16,500,000	330.

If one considers the initial cost and maintenance of the various computer systems, it is apparent that the overall cost of engineering calculations has reduced significantly

during the past 20 years. The most cost effective computer system, at the present time, is the INTEL Pentium type of personal computer system. At the present time, a very powerful personal computer system, that is five times faster than the first CRAY computer, can be purchased for approximately $2,500.

H.4 SPEED OF PERSONAL COMPUTER SYSTEMS

Many engineers do not realize the computational power of the present day inexpensive personal computer. Table H.2 indicates the increased speed of personal computers that has occurred during the past 18 years.

Table H.2. Floating-Point Speeds of Personal Computer Systems

YEAR	INTEL CPU	Speed MHz	Operations Per Second	Relative Speed	COST
1980	8080	4	200	1	$6,000
1984	8087	10	13,000	65	$2,500
1988	80387	20	93,000	465	$8,000
1991	80486	33	605,000	3,025	$10,000
1994	80486	66	1,210,000	6,050	$5,000
1995	Pentium	90	4,000,000	26,000	$5,000
1996	Pentium	233	10,300,000	52,000	$4,000
1997	Pentium II	233	11,500,000	58,000	$3,000
1998	Pentium II	333	16,500,000	82,500	$2,500

One notes that the floating-point speed of the Pentium II is not significantly different than the basic Pentium chip. The increase in clock speed, from 90 to 333 MHz, has accounted for the increase in speed during the last three years.

H.5 PAGING OPERATING SYSTEMS

The above computer speeds assume all numbers are in high-speed memory. For the analysis of large structural systems it is not possible to store all information within high-speed storage. If data needs to be obtained from low-speed disk storage, the effective speed of a computer can be reduced significantly. Within the SAP and ETABS programs the transfer of data to and from disk storage is conducted in large

blocks in order to minimize disk access time. This programming philosophy was used prior to the introduction of the paging option used in the modern Windows operating systems.

In a paging operating system, if the data requested is not stored in high-speed memory, the computer automatically reads the data from disk storage in relatively small blocks of information. Therefore, the modern programmer need not be concerned with data management. However, there is a danger in the application of this approach. The classical example, that illustrates the problem with paging, is the following example of adding two large matrices together. The FORTRAN statement can be one of the following forms:

```
    DO 100 J=1,NCOL            DO 100 I=1,NROW
    DO 100 I=1,NROW            DO 100 J=1,NCOL
100 A(I,J)=B(I,J)+C(I,J)  100 A(I,J)=B(I,J)+C(I,J)
```

Since all arrays are stored row-wise, the data will be paged to and from disk storage in the same order as needed by the program statements on the left. However, if the program statements on the right are used the computer may be required to read and write blocks of data to the disk for each term in the matrix. Hence, the computer time required for this simple operation can be very large if paging is automatically used.

H.6 SUMMARY

Personal computers will continue to increase in speed and decrease in price. Intel's Merced 64-bit CPU chip will be released in 1999. It is the opinion of many experts in the field that the only way significant increases in speed will occur is by the addition of multi-processors to the personal computer systems. The NT operating system supports the use of multi-processors.