HEWLETT PACKARD

HP-65

Programmable Pocket Calculator

TIMING OPERATIONS

2340-014

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PREFACE

This report is intended to give users of the HP-65 Programmable Pocket Calculator an approximation of the time required to execute each instruction in a running program. None of the times listed in this report can be considered exact. The manufacturing specification for the clock is 178 kHz ±7.5%. This means that the cycle time for a microinstruction can vary from one calculator to another, between 292.6 and 340.1 ms. Furthermore, execution times for some of the functions are so data dependent that even an average time would not be meaningful. In these cases rough approximations of the lower and upper bounds on the execution time are given. Wherever the execution time is a constant or wherever an average time is given, the reader should get a fairly good idea of the relative speed of each instruction with respect to the others.

Several instructions were not timed, either because it was impossible or because they are never or not usually used in the run program mode. These instructions are DSP, SST, R/S, f/f^{-1} PREFIX, f/f^{-1} PRGM, and g DEL.

We hope that the reader will find the information presented here helpful in future programming of the HP-65.

1. Data Entry

In entering a number into the X-register, the user may use any or all of the following keys: [n] (where n = 0, 1, ..., 9), [·], [EEX], and [CHS].

In timing the digit keys we determined that it takes about **50 ms** per digit plus about **3 ms** if the digit has not been preceded by another digit or by a decimal point. When preceded by [EEX], the execution for each digit is about **28 ms.**

We timed each of the instructions [CHS], [EEX], and [·] by themselves and in combination with each other and the digits. (If [·] is used by itself, 0.0 is entered into X. If [EEX] is used by itself 1.0 is entered into X).

The execution time for [·] is about **23 ms** when it is preceded by a digit and about **50 ms** otherwise.

The execution time for [EEX] is about **25 ms** if a mantissa has been entered; otherwise, execution time is about **53 ms.**

The execution time for [CHS] is about **15 ms** unless it is preceded by [EEX], in which case it takes about **26 ms.**

Other keys used in entering and transferring data are: [STO], [RCL], [ENTER↑], and [CLX].

Function	Execution Time
[STO] [n]	64 ms
[RCL] [n]	64 ms
[ENTER↑]	17 ms
[CLX]	15 ms

2. Arithmetic Functions

The execution times for the four arithmetic functions ([+], [−], [x], [÷]) depend on the arguments used. However, variations from the average times given below are relatively small.

Function	Average Execution Time
[+]	48 ms
[−]	50 ms
[x]	70 ms
[÷]	110 ms

3. [g] Functions

All of the [g] functions except for the conditionals and the [DSZ] instruction are discussed here. The exceptions are discussed in the section on skip instructions.

Execution times for some of the [g] functions are completely independent of the register contents. The table lists execution times for these functions.

Function	Execution Time
[g] [DEG]	39 ms
[g] [RAD]	39 ms
[g] [GRD]	40 ms
[g] [x⇄y]	17 ms
[g] [R↓]	17 ms
[g] [R↑]	17 ms
[g] [NOP]	15 ms
[g] [π]	56 ms
[g] [LST x]	20 ms

The functions [g] [ABS] and [g] [1/x] have execution times that are relatively independent of the argument used. The average execution time for these functions appear in the table below.

Function	Average Execution Time
[g] [ABS]	53 ms
[g] [1/x]	136 ms

The execution time for [g] [y^x] varies quite a bit depending on the arguments in the X- and Y-registers.

Function	Execution Time	
	Lower Bound	Upper Bound
[g] [y^x]	350 ms	750 ms

The execution time for [g] [n!] increases with n.

Function	n	Execution Time
[g] [n!]	1	205 ms
[g] [n!]	10	310 ms
[g] [n!]	69	1116 ms

4. [f] and [f⁻¹] Functions

All of the functions which are prefixed by [f] or [f⁻¹] are discussed here except for the test flag instructions which are discussed in the section on skip instructions. Execution times for the following functions are constant.

Function	Execution Time
[f] [SF 1]	36 ms
[f⁻¹] [SF 1]	38 ms
[f] [SF 2]	38 ms
[f⁻¹] [SF 2]	37 ms
[f] [STK]	40 ms
[f⁻¹] [STK]	38 ms
[f] [REG]	55 ms
[f⁻¹] [REG]	55 ms

In timing the functions [f] [LN], [f⁻¹] [LN], [f] [LOG], and [f⁻¹] [LOG], we found that the execution times for these functions vary considerably depending on the argument used. We timed the functions over a range of inputs and found the following:

Function	Execution Time	
	Lower Bound	Upper Bound
[f] [LN]	200 ms	450 ms
[f⁻¹] [LN]	150 ms	450 ms
[f] [LOG]	400 ms	550 ms
[f⁻¹] [LOG]	200 ms	500 ms

The functions [f] [$\sqrt{x}$] and [f⁻¹] [$\sqrt{x}$] wre timed over a range of inputs. Execution times are only slightly dependent on the argument used.

Function	Average Execution Time
[f] [$\sqrt{x}$]	146 ms
[f⁻¹] [$\sqrt{x}$]	101 ms

Execution times for the trigonometric functions vary depending on the argument used as well as on the angular mode the machine is set in. The approximate ranges for each function in each mode are given below.

Function	Range of Execution Times		
	Degrees	Radians	Grads
[f] [sin]	500 to 1700 ms	300 to 1500 ms	450 to 1550 ms
[f] [cos]	500 to 1700 ms	300 to 1500 ms	450 to 1550 ms
[f] [tan]	250 to 1450 ms	100 to 1200 ms	200 to 1200 ms
[f^{-1}] [sin]	450 to 950 ms	350 to 800 ms	400 to 900 ms
[f^{-1}] [cos]	550 to 1000 ms	400 to 800 ms	450 to 900 ms
[f^{-1}] [tan]	200 to 700 ms	50 to 550 ms	150 to 650 ms

The ranges quoted above are very rough approximations. They were determined by taking the lowest and highest execution times which we found for the few arguments tested and then rounding down and up, respectively, to determine lower and upper bounds.

For arguments in the normal range (i.e., 0° thru 90°), the execution times will be considerably closer to the lower bound. The reason the range is so large is that prescaling takes most of the time for large input arguments. This, of course, does not apply to the inverse functions.

The execution times for the conversions [R→P] and [→D.MS] are practically independent of the arguments used but there is a considerable variation depending on the angular mode of the machine, as shown below.

Function	Average Execution Time		
	Degrees	Radians	Grads
[f] [R→P]	825 ms	696 ms	785 ms
[f^{-1}] [R→P]	890 ms	746 ms	807 ms
[f] [→D.MS]	96 ms	228 ms	137 ms
[f^{-1}] [→D.MS]	173 ms	332 ms	254 ms

In timing the functions [f] [D.MS+] and [f^{-1}] [D.MS+] we found very little variation from the average times shown below.

Function	Average Execution Time
[f] [D.MS+]	346 ms
[f^{-1}] [D.MS+]	346 ms

The execution times for the conversions [→OCT] and [INT] are affected only minimally by the choice of argument. The table below lists the average times.

Function	Average Execution Time
[f] [→OCT]	132 ms
[f^{-1}] [→OCT]	89 ms
[f] [INT]	46 ms
[f^{-1}] [INT]	57 ms

5. Skip Instructions

The execution times for the skip instructions depend mainly on whether the skip is executed or not. The times were determined by setting up a situation where the skip would not be executed and then timing the program. Then two [g] [NOP] instructions were inserted following the skip instruction and a situation where the skip would be executed was set up. The program was then timed again.

Execution times for the conditional skip instruction [g] [x≠y] and [g] [x=y] are practically constant, while for [g] [x≤y] and [g] [x>y] there may be a variation of ±5 ms from the average time shown below, depending on the numbers being compared.

Function	Execution Time	
	Skip Case	No-Skip Case
[g] [x≠y]	32 ms	20 ms
[g] [x≤y]	57 ms	38 ms
[g] [x=y]	32 ms	19 ms
[g] [x>y]	57 ms	40 ms

In timing the function [g] [DSZ], the procedure described for the skip instructions was used.

The skip is only executed when register R_8 is decremented from 1 to 0. Thus, the execution time for the skip case is a constant.

In the nonskip case the execution time depends on the contents of register R_8. Thus, the time for the non-skip case is an average. Deviations from the average are generally within ±5 ms.

Function	Execution Time	
	Skip Case	No-Skip Case
[g] [DSZ]	60 ms	55 ms

Execution times for the test flag instructions appear below.

No-Skip Cases

Function	Flag Status	Execution Time
f TF1	Set	40 ms
f^{-1} TF1	Clear	40 ms
f TF2	Set	40 ms
f^{-1} TF2	Clear	40 ms

Skip Cases

Function	Flag Status	Execution Time
f TF1	Clear	55 ms
f^{-1} TF1	Set	59 ms
f TF2	Clear	55 ms
f^{-1} TF2	Set	59 ms

6. Subroutines and Go-To's

In this section execution times for subroutine calls and go-to's are discussed.

In timing a subroutine call, we decided to time the call and the return together since this was the only convenient way to get an accurate timing.

The call to B was the only instruction in the loop of main program A. There were no instructions in subroutine B. LBL B was followed immediately by RTN.

The number of memory words separating subroutines A and B was varied. We found no cases where the execution time differed by more than 2 ms from the average.

We found that the average time required to execute both the subroutine call and the return is **52 ms.**

The GTO was timed using a procedure similar to that used for subroutine calls. The execution time varies depending on the label used and its position relative to the GTO . The range of execution times is about **40** to **50 ms.**

With both subroutine calls and go-to's there is no simple relationship between the position of the label relative to the transfer instruction and the time required to execute the transfer. This is due to the fact that memory is circulating in a dynamic shift register.