时钟周期

CPI (Average Clocks Per Instruction)

表示每条[计算机指令](https://www.baidu.com/s?wd=%E8%AE%A1%E7%AE%97%E6%9C%BA%E6%8C%87%E4%BB%A4&tn=44039180_cpr&fenlei=mv6quAkxTZn0IZRqIHckPjm4nH00T1Y3PHmLPH7-rju-mvcdnyRv0ZwV5Hcvrjm3rH6sPfKWUMw85HfYnjn4nH6sgvPsT6KdThsqpZwYTjCEQLGCpyw9Uz4Bmy-bIi4WUvYETgN-TLwGUv3EnH0zn1fsPWTz)执行所需的[时钟周期](https://www.baidu.com/s?wd=%E6%97%B6%E9%92%9F%E5%91%A8%E6%9C%9F&tn=44039180_cpr&fenlei=mv6quAkxTZn0IZRqIHckPjm4nH00T1Y3PHmLPH7-rju-mvcdnyRv0ZwV5Hcvrjm3rH6sPfKWUMw85HfYnjn4nH6sgvPsT6KdThsqpZwYTjCEQLGCpyw9Uz4Bmy-bIi4WUvYETgN-TLwGUv3EnH0zn1fsPWTz)

1. If computer A and Computer B are 8Mhz and 3Ghz respectively, what is their clock times respectively?

***∵ clock time = 1 / clock rate***

***∴ A: 1 / 8Mhz = 0.125μs***

***B: 1 / 3Ghz = 0.33…ns***

2.There are 4 classes of instructions, A, B, C, D. Suppose compiler has two choices: Sequence 1 and Sequence 2, as described below:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Class | A | B | C | D |
| CPI for class | 1 | 2 | 1 | 3 |
| IC in sequence 1 | 3 | 1 | 5 | 1 |
| IC in sequence 2 | 2 | 4 | 1 | 3 |

Which choice will be better? Why?

***∵ the same cycle time***

***∵ CPU time = sum(CPI \* CI) \* T***

***∴ (1\*3 + 2\*1 + 1\*5 + 3\*1)\*T = 13\*T < 20\*T = (1\*2 + 2\*4 + 1\*1 + 3\*3)***

***∴ Sequence 1 will be better.***

3. Computer A has 5GHz clock. It takes 100s CPU time to finish one given task. We want to design Computer B to finish the same task within 20s CPU time. The clock cycle number for computer B is 2 times as that of Computer A. So, what clock rate should be designed for Computer B?

***∵ The clock cycle number for computer B is 2 times as that of Computer A***

***∵ CPU time = clock cycle number / clock rate***

***∴ 100s = N / 5GHz***

***20s = 2\*N / f***

***∴ f = 50GHz***

4.There are two computers: A and B.

Computer A: Cycle Time = 500ps, CPI = 4.0

Computer B: Cycle Time = 200ps, CPI = 5.0

If they have the same ISA, which computer is faster? How many times it is faster than another? what clock rate should be designed for Computer B?

***∵ the same CPI***

***∴ the same IC***

***∵ CPU time = Cycle Time \* CPI \* IC***

***∴ 500ps \* 4.0 \* ISA = 2\*ISA ns > 1\*ISA ns = 200ps \* 5.0 \* ISA***

***∴ Computer B is faster.***

***∵ clock rate = 1 / Cycle Time***

***∴ B: 1 / 200ps = 5Gs***

5 <§1.6> Consider three different processors P1, P2, and P3 executing the same instruction set. P1 has a 3 GHz clock rate and a CPI of 1.5. P2 has a 2.5 GHz clock rate and a CPI of 1.0. P3 has a 4.0 GHz clock rate and has a CPI of 2.2.

a. Which processor has the highest performance expressed in instructions per second?

∵ instructions per second = clock rate \* 1s / CPI

***∴ instructions per second : P1: 3GHz \* 1s / 1.5 = 2e9***

***P2: 2.5GHz \* 1s / 1.0 = 2.5e9***

***P3: 4.0GHz \* 1s / 2.2 = 1.8181…e9***

***∴ 2.5e9 > 2e9 > 1.8181…e9***

***∴ P2 has the highest performance.***

b. If the processors each execute a program in 10 seconds, find the number of cycles and the number of instructions.

***∵ CPU time = the number of cycles / clock rate***

***CPU time = the number of instructions \* CPI / clock rate***

***∴ the number of cycles: P1: 10s \* 3GHz = 3e10***

***P2: 10s \* 2.5GHz = 2.5e10***

***P3: 10s \* 4.0GHz = 4.0e10***

***the number of instructions: P1: 10s \* 3GHz / 1.5 = 2e10***

***P2: 10s \* 2.5GHz / 1.0 = 2.5e10***

***P3: 10s \* 4.0GHz / 2.2 = 1.8181…e10***

c. We are trying to reduce the execution time by 30% but this leads to an increase of 20% in the CPI. What clock rate should we have to get this time reduction?

***∵ execution time = CPI \* IC / clock rate***

***∵ the same IC***

***∴ t = CPI \* IC / f1***

***(1 - 30%) \* t = (1 + 20%) \* CPI \* IC / f2***

***∴ f2 ≈ 1.714 \* f1***

***∴ f2 : P1 : 1.714 \* 3GHz = 5.142GHz***

***P2 : 1.714 \* 2.5GHz = 4.285GHz***

***P3 : 1.714 \* 4.0GHz = 6.856GHz***

If they have the same ISA, which computer is faster? How many times it is faster than another?

***∵ execution time: the former : t***

***the latter : 0.7\*t***

***∴ t > 0.7\*t***

***∴ t / (0.7\*t) ≈ 1.429***

***∴The latter is 1.429 times faster than the former.***

6 <§1.6> Consider two different implementations of the same instruction set architecture. The instructions can be divided into four classes according to their CPI (class A, B, C, and D). P1 with a clock rate of 2.5 GHz and CPIs of 1, 2, 3, and 3, and P2 with a clock rate of 3 GHz and CPIs of 2, 2, 2, and 2. Given a program with a dynamic instruction count of 1.0E6 instructions divided into classes as follows: 10% class A, 20% class B, 50% class C, and 20% class D, which implementation is faster?

***∵ CPU time = sum(IC \* CPI) / clock rate***

***∴ CPU time:P1:(10%\*1+20%\*2+50%\*3+20%\*3)\*1.0E6/2.5GHz=1.04ms***

***P2:(10%\*2+20%\*2+50%\*2+20%\*2)\*1.0E6/3GHz=0.66…ms***

***∴ 1.04ms > 0.66ms***

***∴ P2 is faster.***

a. What is the global CPI for each implementation?

***∵ global CPI = sum(IC \* CPI) / IC***

***∴ global CPI: P1: (10%\*1+20%\*2+50%\*3+20%\*3)\*1.0E6/1.0E6=2.6***

***P2: (10%\*2+20%\*2+50%\*2+20%\*2)\*1.0E6/1.0E6=2***

b. Find the clock cycles required in both cases.

***∵ clock cycles = sum(IC \* CPI)***

***∴ clock cycles: P1: (10%\*1+20%\*2+50%\*3+20%\*3)\*1.0E6=2.6E6***

***P2: (10%\*2+20%\*2+50%\*2+20%\*2)\*1.0E6=2E6***

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Clock Rate** | **CPI**  **Class A** | **CPI**  **Class B** | **CPI**  **Class C** | **CPI**  **Class D** |  |
| P1 | 2.5GHz | 1 | 2 | 3 | 3 |  |
| IC指令数 | 0.1\*10^6 | 0.2\*10^6 | 0.5\*10^6 | 0.2\*10^6 |  |
| P2 | 3.0GHz | 2 | 2 | 2 | 2 |  |
| IC指令数 | 0.1\*10^6 | 0.2\*10^6 | 0.5\*10^6 | 0.2\*10^6 |  |

7 <§1.6> Compilers can have a profound impact on the performance of an application. Assume that for a program, compiler A results in a dynamic instruction count of 1.0E9 and has an execution time of 1.1 s, while compiler B results in a dynamic instruction count of 1.2E9 and an execution time of 1.5 s.

a. Find the average CPI for each program given that the processor has a clock cycle time of 1 ns.

***∵ execution time = clock cycle time \* CPI \* IC***

***∴ CPI : compiler A : 1.1s / (1ns \* 1.0E9) = 1.1***

***compiler B : 1.5s / (1ns \* 1.2E9) = 1.25***

b. Assume the compiled programs run on two different processors. If the execution times on the two processors are the same, how much faster is the clock of the processor running compiler A’s code versus the clock of the processor running compiler B’s code?

***∵ the same execution times***

***∵ execution time = IC \* CPI / clock rate***

***∴ clock rate ： compiler A : 1.0E9 \* 1.1 / t = 1.1E9 / t***

***compiler B : 1.2E9 \* 1.25 / t = 1.5E9 / t***

***∴ 1.5E9/t / (1.1E9/t) = 1.3636…***

***∴ 1.3636… times***

c. A new compiler is developed that uses only 6.0E8 instructions and has an average CPI of 1.1. What is the speedup of using this new compiler versus using compiler A or B on the original processor?

***∵ execution time = clock cycle time \* CPI \* IC***

***∴ execution time : 1ns \* 1.1 \* 6.0E8 = 0.66s***

***∴ 1.1s / 0.66s = 1.66…***

***1.5s / 0.66s = 2.2727…***

***∴ The new compiler is 1.66… times faster than compiler A and is***

***2.2727… times faster than compiler B.***