School of Computing Science

CSC1104 – Computer Organisation & Architecture

Laboratory/Tutorial 1: Components and Performance of Computers

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Objectives

- Evaluate the program and CPU performance.
- Identify the major components and ports of Raspberry Pi 4 and their function.

Questions:

1. A program written in Java runs 15 seconds on a processor. A new Java compiler is released that requires only 0.6 as many instructions as the old compiler. Unfortunately, it increases the CPI by 1.1. How fast can this program run with the new compiler?

Solution:

- Execution time for old compiler = Instruction count$_{old}$ × CPI$_{old}$ × Clock cycle time.

  Hence, 15 seconds = Instruction count$_{old}$ × CPI$_{old}$ × Clock cycle time.
- Execution time for new compiler = Instruction count$_{new}$ × CPI$_{new}$ × Clock cycle time.
- Instruction count$_{new}$ = 0.6 * Instruction count$_{old}$
- CPI$_{new}$ = 1.1 * CPI$_{old}$

$$\frac{\text{Execution time for new compiler}}{\text{Execution time for old compiler}} = \frac{\text{Instruction Count}_{new} \times \text{CPI}_{new} \times \text{Clock cycle time}}{\text{Instruction Count}_{old} \times \text{CPI}_{old} \times \text{Clock cycle time}}$$

CPU execution time for new compiler =15 × 0.6 × 1.1 = 9.9 seconds.

2. Please derive the detailed size of these terms one by one.

8 GHz = 8,000 (8×10^3) MHz = 8,000,000 (8×10^6) KHz = 8,000,000,000 (8×10^9) Hz

16 GHz = 16×10^3 MHz = 16×10^6 KHz = 16×10^9 Hz

40 MHz = 0.04 GHz = 40×10^3 KHz = 40×10^6 Hz

600 MHz = 0.6 GHz = 600×10^3 KHz = 600×10^6 Hz

300 KHz = 0.0003 GHz = 0.3 MHz = 300×10^3 Hz

5000 KHz = ____0.005________ GHz = ________5_______ MHz = ____5×10^6________ Hz

4 GiByte = _4×1024_ MiByte = _4×1024^2_ KiByte = _$4\times1024\times1024\times1024$ (4×1024^3)__ Bytes

20 GiByte = _20×1024 (20×2^{10}) MiByte = 20×1024^2 (20×2^{20}) KiByte = 20×1024^3 (20×2^{30}) Bytes

100 MiByte = $\frac{100}{1024}$ (100×2^{-10}) GiByte = 100×1024 (100×2^{10}) KiByte = 100×1024^2 (100×2^{20}) Bytes

90 KiByte = $\frac{90}{1024\times1024}$ (90×2^{-20}) GiByte = $\frac{90}{1024}$ (90×2^{-10}) MiByte = 90×1024 (90×2^{10})__ Bytes

1 second = ___1000____ ms = __1×10^6____ μs = ___1×10^9____ ns = ___1×10^{12}______ ps

200 ms = ___0.2___ s = ___200×10^3___ μs = ___200×10^6________ ns = ___200×10^9_____ ps

150 μs = __150×10^{-6}____ s = ___150×10^{-3}___ ms = ___150×10^3____ ns = ____150×10^6_______ ps

600 ns = _600×10^{-9}______ s = ___600×10^{-6}___ ms = ___600×10^{-3}_____ μs = _____600×10^3____ ps

800 ps = __800×10^{-12}______ s = ___800×10^{-9}____ ms = __800×10^{-6}_____ μs = __800×10^{-3}_____ ns

3. Using a typical benchmark program running on 2 computers, the following machine characteristics result:

Computer	Clock Rate (MHz)	Performance (MIPS)	CPU Execution Time (secs)
A	5	1	12x
B	25	18	x

The final column shows that the Computer A required 12 times longer than the Computer B measured in CPU execution time.

a. What is the relative size of the instruction count of the machine code for this benchmark program running on the two machines?

b. What are the CPI values for the two machines?

Solution:

According to the MIPS rate equation as follows:

$$\text{MIPS rate} = \frac{\text{Instruction count}}{\text{Execution time} \times 10^6} = \frac{1}{\text{CPI} \times \text{Clock Cycle time} \times 10^6} = \frac{\text{Clock Rate}}{\text{CPI} \times 10^6}$$

So, we can calculate instruction count and CPI on these 2 computers.

Instruction count_A = MIPS $\text{rate}_A \times$ Execution $\text{time}_A \times 10^6 = 1 \times 12x \times 10^6 = 12x \times 10^6$.

Instruction count_B = MIPS $\text{rate}_B \times$ Execution $\text{time}_B \times 10^6 = 18 \times x \times 10^6 = 18x \times 10^6$.

Instruction count_B / Instruction count_A = $18x \times 10^6 / 12x \times 10^6 = 1.5$.

CPI_A = Clock Rate_A / (MIPS $\text{rate}_A \times 10^6$) = $5 \times 10^6 / (1 \times 10^6) = 5$.

CPI_B = Clock Rate_B / (MIPS $\text{rate}_B \times 10^6$) = $25 \times 10^6 / (18 \times 10^6) = 1.389$.

4. Consider two different computers, with two different instruction sets, both of which have a clock rate of 200 MHz. The following measurements are recorded on the two machines running a given set of benchmark programs:

Instruction Type	Instruction Count (millions)	Cycles per Instruction
Computer A		
Arithmetic and logic	8	1
Load and store	4	3
Branch	2	4
Others	4	3
Computer B		
Arithmetic and logic	10	1
Load and store	8	2
Branch	2	4
Others	4	3

Determine and compare the average CPI, MIPS rate, and execution time for each computer.

Solution:

For computer A:

- Total No. of instructions executed by Computer A are: 8+4+2+4=18 (million).
- Total number of CPU clock cycles needed by Computer A are:
  $\sum$(*instruction count$_i$ * CPI$_i$ of each instruction* = 8*1+4*3+2*4+4*3 = 40 (million-cycles).
- Average CPI of Computer A is: 40 / 18 = 2.22 (Cycles/instruction).
- MIPS rate of Computer A is $\frac{\textbf{Clock Rate}}{\textbf{CPI} \times \mathbf{10^6}}$: $200 * 10^6 / (2.22 * 10^6) = 90$.
- CPU execution time of Computer A is: *instruction count * CPI / Clock Rate* = 40 million / $(200 * 10^6)$ = 0.2 seconds.

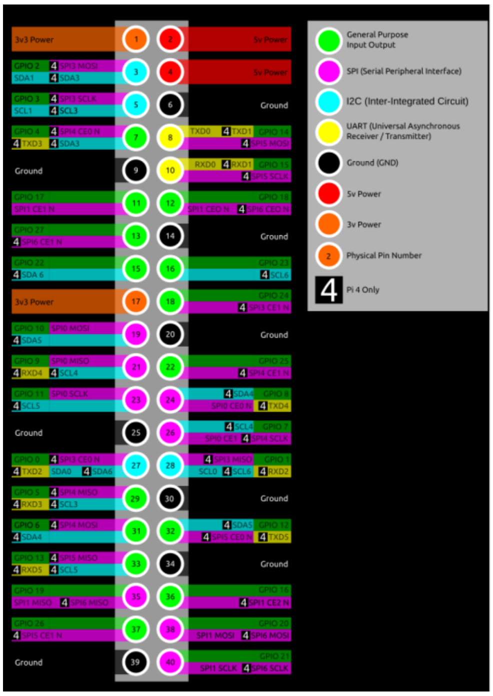
For computer B:

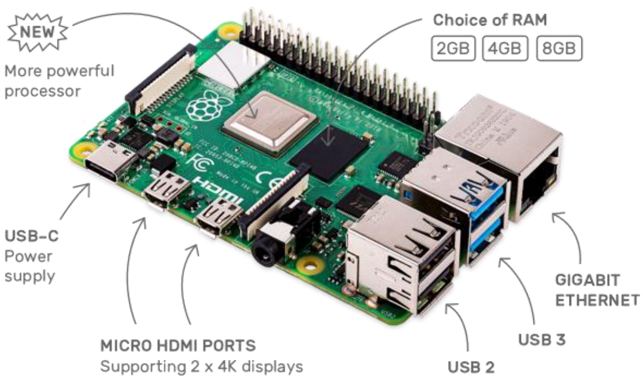
- Total No. of instructions executed by Computer B are: 10+8+2+4=24 (million).
- Total number of CPU clock cycles needed by Computer B are:
  sum(*instruction count$_i$ * CPI$_i$ of each instruction* = 10*1+8*2+2*4+4*3 = 46 (million-cycles).
- Average CPI of Computer B is: 46 / 24 = 1.92 (Cycles/instruction).
- MIPS rate of Computer B is $\frac{\textbf{Clock Rate}}{\textbf{CPI} \times \mathbf{10^6}}$: $200 * 10^6 / (1.92 * 10^6) = 104$.
- CPU execution time of Computer B is: *instruction count * CPI / Clock Rate* = 46 million / $(200 * 10^6)$ = 0.23 seconds.

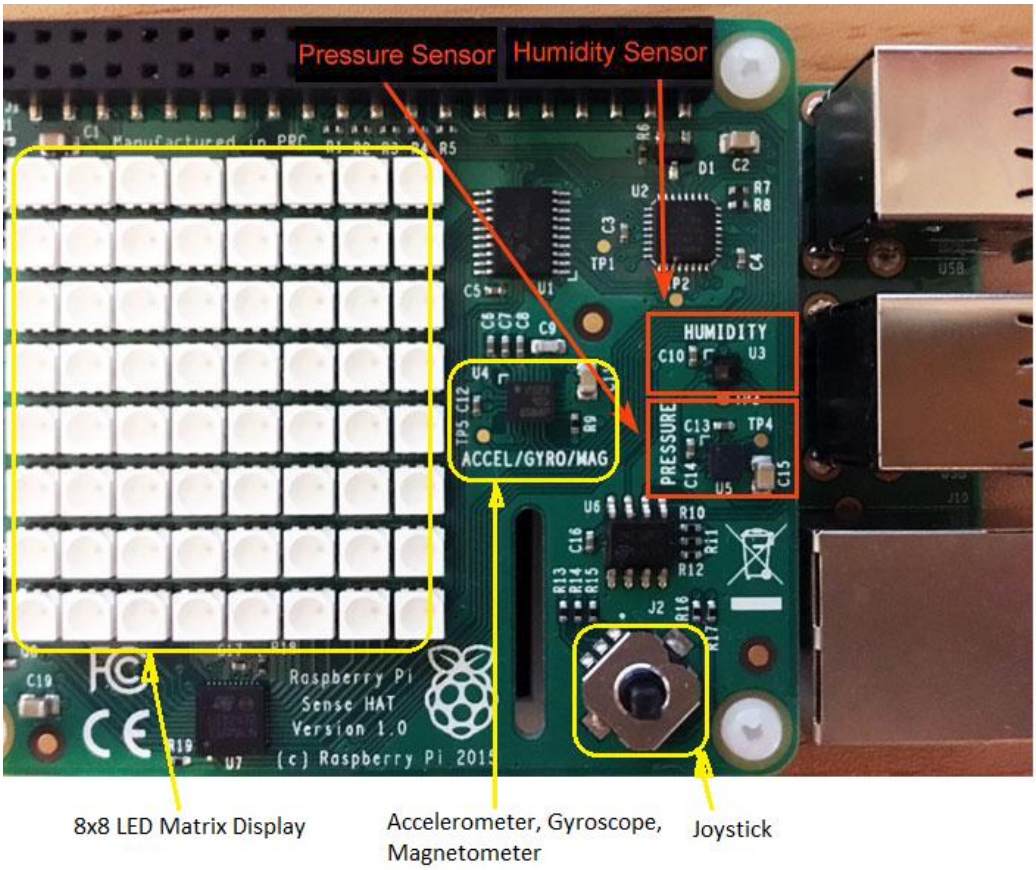
5. Please perform a literature study on the hardware structure of a Raspberry Pi 4 Model B+ platform and the sensor HAT board. Please identify its major components, ports, types of sensors and their functions.

Solution:

- The major components on Raspberry Pi 4 Model B+ are shown below.
- The major components of Raspberry Pi Sense HAT are shown next.






Pressure Sensor
Humidity Sensor
HUMIDITY
PRESSURE
ACCEL/GYRO/MAG
Raspberry Pi
Sense HAT
Version 1.0
(c) Raspberry Pi 2015
8x8 LED Matrix Display
Accelerometer, Gyroscope, Magnetometer
Joystick