CHAPTER - 7

Bench Mark Analysis
So far it has discussed the various types of computers and computing devices in Chap-2, Chap-3 and Chap-5. All of these computers namely silicon, organic and DNA computers get studied by certain performance factors. The performance of all these studied by speed, memory and accuracy which is the ultimate goal for designing all these three types of computing systems. A comparative bench mark analysis has done in accordance with the organic molecular system comparing with silicon system and DNA molecule system.

Molecules are considered to be an alternative material substrate for the implementation of information processing devices in nanoscale [202]. The Fig 7 shows the various range of approaches to utilizing molecules in computing. Molecular electronics explore the possibilities using organic materials as the architectures familiar from silicon-electronics. Biomolecular computing is concerned with the use of macromolecules and supramolecular systems and based on the mechanisms found in nature [202].

![Fig. 7 Research directions within the field of molecular computing [202]](image)

The performances of logical devices are analyzed from molecular diodes to transistors, integrated chip, and very large scale circuit design with different materials (silicon, organic and DNA). The further discussion has been done in this chapter mostly overviews the comparative study between silicon based, organic molecule based and DNA based molecular system & devices with basic performance factors of computing. It overviews the performance factors parameters such as material compatibility, chemical
registrant, dimension, temperature variation, specific heat, hybridization property, moulding shrinkage and tunneling effect etc. This chapter indicates a theoretical model of comparison for speed, accuracy and memory by taking various electronic devices such as diode, transistors, integrated circuit, very large scale circuits with a bench mark analysis to silicon based computer, organic molecule based computer and biological based DNA Computer in parallel with various performance factors. It reflects a standard formula to go for a speed, accuracy and memory of processor taking into different performance factors.

7.1 Types of Systems

7.1.1 Analyzing Silicon Based System

The design of silicon computer started with the evolution from diode design, triode design, transistor design and later progress to integrate circuit design and VLSI (Very Large Scale Integrated) circuit design. Even nanoscale miniaturization efforts have been made to make these devices take as much as small space, still it is taking more space for physical existence. The memory is not quite enough for larger data. The speed of computing of these devices is not so fast for large data and more even more complicated computing cannot be done at mean time. To understand the functions of these devices, it is necessary to understand the basic structure of all semiconductor devices, the physical properties, thermodynamic properties and mechanical properties.

7.1.2 Analysis of Molecular Computer Design

Molecular computation in particular focuses on the computational power of molecules with specific to that made of organic molecules and attempts to realize information processing. By using molecules; it is expected to go for information processing in a faster parallel processing, smaller in size and efficient-energy-saving[222]. So we are expecting the emerging of a brand-new technology in terms of a new model of computation. An organic molecule as devices mainly focuses on Polyphenylene-based molecular-scale electronic devices, conjugated aromatic organic molecules as conductors or wires and aliphatic organic molecules as insulators. To understand the functions of these devices, it is necessary to understand the basic chemical structure of the organic based molecular devices responsible for computation with various performance factors.
7.1.3 Analysis to DNA Computer Design

The primary molecule that could be used as potential basis for carrying out symbolic computation is DNA (Deoxyribonucleic Acid). Biological molecules as devices considered as DNA based electronic devices and oligonucleotides which generates a signal representations in DNA computing paradigm.

7.2 Performance Factors

The various performance factors of electronic devices have noted below.

7.2.1 Material Effect

As previous chapters have been discussed design concepts of silicon, Organic Molecule and DNA based system and the computing devices, now it can be analyze how different materials affect the performance of these three types of design. The various materials that has discussed are metal oxide, conducting material and insulation material. It has discussed also how energy and electrical flow can affect on the performance of computer. As per example with silicon computer presence of silicon, and argentenium affect the performance, similarly in molecular (organics) computer the presence of alkali, organic, aliphatic also affect the performance. So also in case of biological materials, taking a known sequence of DNA, where conducting chemicals reflects electronic properties that can useful in finding computation power out of DNA.

7.2.2 Bond effect

Different kinds of bonds exist when we analyze the material for making a conductor or insulator in designing electronic devices like silicon diode, molecular diode, and DNA diode. Basically we have two categories of bonds, they are I) intramolecular bond (bonds within the molecule) and II) intermolecular bond (Bonds between the molecules). Intramolecular bond contains covalent bond, ionic bond and metallic bond.
7.2.3 Tunneling Effect

Tunnel effects come when two molecules approaching towards each other and their atoms come in contact with another different molecule which is closest. At this point of approaching, the nature of the electrons surrounding the atoms is slightly changed; each reflects some characteristics of the other. Some of the characteristics of tunnel effect are i) where energy finds difficult to appear, but particles can appear easily ii) the wave nature of particles produce tunnel effect and iii) the tunnel effect can be applied to various fields.

7.2.4 Particle Effect

Different atomic and subatomic particles are existing which play a major role with their valence and energy in the designing and analysis process of silicon, molecular and DNA computer. An atom generally consists of a nucleus with positively charged protons and neutral neutrons surrounded by negatively charged electrons.

7.2.5 Size Effect

Because atoms and molecules are so small, it is difficult to determine their sizes. Special instruments are normally needed for such measurements. As electrons move around nucleus, it is reasonable that the size of an atom depends on valence electrons in outermost orbit. The atom seems very small in size, if electrons are very close to the nucleus.

7.2.6 Surface Effect

In case of silicon based system, electric current measures by ejecting electrons from a sodium metal surface. The opposing voltage need to stop all the electrons indicates a measure of the maximum kinetic energy in electron volts and the minimum energy is called photoelectric work function to eject an electron from the surface. The same principle applied to a molecular surface which facilitates electric current flows. The genome signal in a DNA molecule also detected and electric properties studied with different catalyst added to DNA surface.
7.2.7 Structure effect

In a silicon based system the energy levels determined from structure of atomic orbital. Similarly in an organic based system the different chemical structure of the molecule analyzed depending on the positions of atoms and molecules called as molecular orbital. In organic molecules the structure matters much than the simple molecules. The same way a DNA based system which is combinations of nucleotides and its structure vary depending on the position of nitrogen bases. So structure effect plays a very major role in energy and intensity level study. Atom generally is the smallest building block of matter made of neutrons, protons and electrons.

7.2.8 Chemical Registrants

Every electrical component is identified by register and used in many varied ways. Registers are the components manufactured in many types and sizes. The resistors which are made of chemical molecules show different types of resistivity factors which are responsible in designing molecular based electronic devices.
7.2.9 Conductance

Conductance is the opposite of resistance. The ability of a material to pass electrons is determined by conductance. The magnitudes of conductance factors are exactly the same as resistance, but they affect conductance in the opposite manner. Conductance is directly proportional to area, and inversely proportional to the length of the material. Material temperature is definitely a factor, but in a constant temperature, the conductance of a material can be determined.

7.2.10 Specific Heat

The heat per unit mass required to raise the temperature by one degree celsius is called as specific heat. The relationship between heat, temperature and specific heat shown as \( Q = cm\Delta T \), where \( Q \)=Heat, \( c \)=specific heat, \( m \)=mass and \( \Delta T \)=change in temperature. If phase change is encountered the above relationship does not hold good as phase change does not change the temperature even if you add or remove heat.

7.2.11 Hybridization Property

Mixing of atomic orbitals to form new orbitals by atomic bonding properties is called as hybridization. Taking into consider hybrid orbital, we use to describe the process of hybridization as change from atomic orbitals to bonding orbitals. These orbitals are helpful in determining the shape of molecules orbitals for molecules.

7.2.12 Moulding Shrinkage

Packaging is the major factor when we design any microchip for computer design. If we use plastics, it has profound shrinkage behavior. This leads to the fact that the molded thermoplastic parts are smaller in dimensions than produced mold. The total shrinkage is calculated by taking into consider after shrinkage condition. The part begins to shrink in the injection mold as it goes on cool. This process may also continue after demolding.
7.3 A Comparative Benchmark Analysis

A comparative analysis to the speed, memory and accuracy level for various there
types of computer has shown below in accordance with the various performance factors
discussed above.

![Diagram](image)

**Fig.7.3 Paradigm to Silicon, Molecule and DNA Computer**

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1 Manas Ranjan Pradhan,"Performance analysis-A paradigm approach to Molecular Computing” published in the proceeding of National conference on Information Technology and its application organized by CIST (Centre for Information Science and Technology) & Department of Studies in computer Science, University of Mysore held on 21\textsuperscript{st}-22\textsuperscript{nd} Nov, 2009.
Let us consider X, Y and Z are the silicon computer, organic molecule Computer and DNA Computer.

Let us take parameter M, S, A for Memory, Speed and Accuracy of the computer.

Let us notate our performance factors as follows

1. Material Effect \( (M_E) \)
2. Bond Effect \( (B_E) \)
3. Tunneling Effect \( (T_E) \)
4. Particle Effect \( (P_E) \)
5. Size Effect \( (S_E) \)
6. Surface Effect \( (S_{rE}) \)
7. Structure effect \( (S_{rE}) \)
8. Chemical Registrants \( (C_{RE}) \)
9. Conductance \( (C_E) \)
10. Specific heat \( (S_{PE}) \)
11. Hybridization property \( (H_E) \)
12. Moulding shrinkage \( (M_{DE}) \)

The performance factor \( (P) \) can be calculated with the proposed mathematical model as

\[
P \ (\text{Memory}) = P \ (X, Y, Z) \times K_1
\]

\[
P \ (\text{Speed}) = P \ (X, Y, Z) \times K_2
\]

\[
P \ (\text{Accuracy}) = P \ (X, Y, Z) \times K_3
\]

Where \( K_1, K_2, K_3 \) are the performance factors responsible for memory, speed and accuracy at different level of design. \( K_1, K_2, K_3 \) will differ in the way that, first some of the performance factors may not come for all types of materials, second as the material is combination of so many types of atoms the performance factor may differ[221].
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\[ P(X, Y, Z)_{\text{memory}} = \sum K_1 \ast (L_1), \]

Where \( L_1 = M_E, B_E, T_E, P_E, S_E, S_{rE}, S_{tE}, C_R_E, C_E, S_P_E, H_E, M_D_E \)

\[ P(X, Y, Z)_{\text{Speed}} = \sum K_2 \ast (L_2), \]

Where \( L_2 = M_E, B_E, T_E, P_E, S_E, S_{rE}, S_{tE}, C_R_E, C_E, S_P_E, H_E, M_D_E \)

\[ P(X, Y, Z)_{\text{Accuracy}} = \sum K_3 \ast (L_3), \]

Where \( L_3 = M_E, B_E, T_E, P_E, S_E, S_{rE}, S_{tE}, C_R_E, C_E, S_P_E, H_E, M_D_E \)

\( L_1, L_2, L_3 \) will again vary depending on Diode, Transistor, IC, VLSI Category.

Diode: \[ L_{1(D, MD, DD)} = \sum L_1(X, Y, Z), \]

\[ L_{2(D, MD, DD)} = \sum L_2(X, Y, Z), \quad L_{3(D, MD, DD)} = \sum L_3(X, Y, Z). \]

Transistor: \[ L_{1(T, MT, DT)} = \sum L_1(X, Y, Z), \]

\[ L_{2(T, MT, DT)} = \sum L_2(X, Y, Z), \quad L_{3(T, MT, DT)} = \sum L_3(X, Y, Z). \]

Integrated Chip: \[ L_{1(IC, MIC, DIC)} = \sum L_1(X, Y, Z), \]

\[ L_{2(IC, MIC, DIC)} = \sum L_2(X, Y, Z), \quad L_{3(IC, MIC, DIC)} = \sum L_3(X, Y, Z) \]

VLSI: \[ L_{1(VLSI, MVLSI, DVLSI)} = \sum L_1(X, Y, Z), \]

\[ L_{2(VLSI, MVLSI, DVLSI)} = \sum L_2(X, Y, Z), \quad L_{3(VLSI, MVLSI, DVLSI)} = \sum L_3(X, Y, Z) \]

[420]
The L1, L2, L3 plays a major role in calculating the performance factors depending on silicon, organic and DNA material.

With the above proposed paradigm, it is a hope to find out the performance level with below prediction or more than this. The atomic mass and atomic number with its orbital and angle view produce different level of energy stage which not only restricted to crystal level but with a vision to go for minute level of particle study. The nuclear magnetic radiation material will play a major role to studying molecular computing in large computing environment with enterprise level implications.

With an overview to different proposals and experiment by different researchers as discussed in previous chapters, if it is considered size as such n^n bits in an organic or molecular computer, and n^l in a biomolecule with n-bits for access of memory.

Similarly n^{(l-R)} bits of speed with molecules, where l=number of carbon molecules and R=residue factors and with DNA string n^{l-} speed. If we are considering the accuracy level it will be n, (n+1-R) and (n+1)^L percentage for Silicon, Molecular and DNA computing system respectively. This calculation is in bit level, which we will consider for hertz level after finding a concrete formula for the performance factors.
Considering n-bits of memory

\( l = \text{no. of Carbon molecule,} \)

\( L = \text{Length of DNA strand or Polyphenylene chain and} \ R = \text{Residue} \)

<table>
<thead>
<tr>
<th>Types</th>
<th>Memory(M)</th>
<th>Speed(S)</th>
<th>Accuracy(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X (Silicon Computer)</td>
<td>n%</td>
<td>n-bits</td>
<td>n-bits at instant</td>
</tr>
<tr>
<td>Y (Molecule Computer)</td>
<td>(n+1-R)%</td>
<td>( n^n )</td>
<td>( n^{n^R} ) bits</td>
</tr>
<tr>
<td>Z (DNA Computer)</td>
<td>(n+1)*L %</td>
<td>( n^L ) Bits</td>
<td>( n^L = ) at instant</td>
</tr>
</tbody>
</table>

Table 7.3 A proposed MSA comparison of Silicon, Organic and DNA based computer

With the performance analysis factors, it is a hope to get more accuracy, speed, and memory for the so far studied molecular computing which is in midway between silicon and high through put DNA computing. We have analyzed different kinds of chemical materials which are helpful in designing the molecular Computer and we need to test the performance. The future perspective after the study of silicon, molecular(organic) and DNA computer design lies entirely on quantum computer, where we will take sub-atomic world as the basic of study with help of quantum physics.

**Summary**

This chapter gives a hypothetical comparative analysis of memory, speed and accuracy of three different types of computers (silicon based, organic molecule based and DNA based) in accordance with various performance factors responsible for computation.