Portfolio#3
Number Systems

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- **What Are Number Systems**

Ancient cultures developed a diverse range of numbering systems, but the most striking is the system developed by the Babylonians starting around 5,000 years ago. This system was a weighted positional system, using a base of 60 rather than the base 10 used in modern decimal systems. The Babylonians did not have a zero symbol, using a space instead. The influence of the number 60 is still seen in modern time and angle measurements. Additionally, binary concepts, often associated with modern computing, were used as early as 4,000 years ago for weighing stones with a balance (Dimitrov et al., 2017).

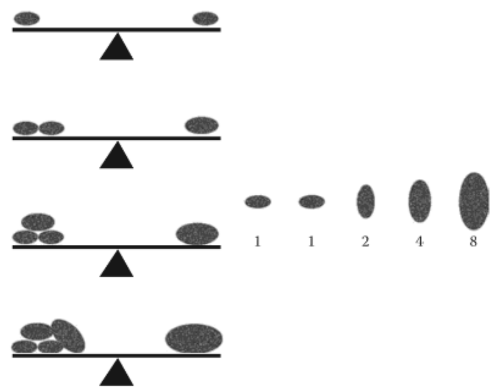
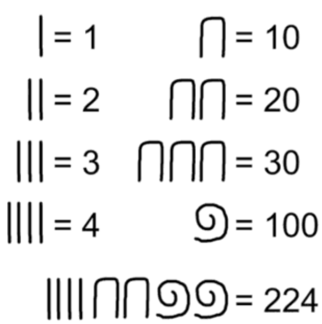


FIGURE 1.1 (See color insert)
Four-thousand-year-old binary number system.

The ancient Romans used letters to represent their numbers, a system known as Roman numerals, which are often introduced to children. In this system, specific letters correspond to specific values: I represents 1, II represents 2, III represents 3, IV stands for 4 (with 1 placed before 5), V represents 5, X denotes 10, L signifies 50, C stands for 100, D represents 500, and M equals 1000. By combining these letters, larger integers can be formed. For example, the number 1998 is written as MCMXCVIII in Roman numerals (Kneusel, 2015).

Fig. 1.1 Egyptian numbers. The ancient Egyptians wrote numbers by summing units, tens, and hundreds. There were also larger valued symbols which are not shown. Numbers were written by grouping symbols until the sum equaled the desired number. The order in which the symbols were written, largest first or smallest first, did not matter, but common symbols were grouped together. In this example, the smallest units are written first when writing from left to right to represent 224



The Romans built their numbers from earlier Egyptian numbers. Of course, we do not use either of these number systems for serious computation today for the simple reason that they are hard to work with (Kneusel, 2015).

A number system in mathematics is a well-defined system of representing, writing and expressing a numerical value which occurs in the measures of different dimensions and calculations. Numbers—the numeral values—are different for different types of computing system (Wahed, 2022). Number systems are very important to understand because the design and organization of a computer depends on the number systems (Dixit, 2005). When you input some letters, words, graphics, audio, video, etc., the computer translates them into its equivalent binary numbers (Bansal et al., 2017).

Whenever you will count anything, you will use numbers such as 1, 2, 3, etc. But a computer is a machine and it understands only machine language i.e. the language of 0's and l's. The computer does not understand human languages and whatever input is given to it is converted into machine language. Various number systems came into existence like octal number system and hexadecimal number system which uses the combination of digits to represent different quantities (Bansal et al., 2017).

The modern civilization is familiar with Decimal Number System, in which ten digits, namely 0 to 9 are used to represent any number. Once the famous Mathematician Laplace stated, "It is India that gave us the ingenious method of expressing all numbers by means of ten symbols, each symbol receiving a value of position as well as an absolute value, a profound and important idea which appears so simple to us now that we ignore its true merit." Thus, the importance of a number system does not lie in the number of symbols used in it but what is important in it is the concept of face value (absolute value) and the place value (value of position) of a symbol (Dixit, 2005). The value of each digit in a number depends on the following:

1. Face value of the digit: It represents the digits themselves like 1, 2, 5 and 6 in the number 1256.
2. Place value of the digit: It represents the units, tens, hundreds, thousands, etc.
3. Base value of the number system: It represents the number of digits used in it. For example, decimal number system uses 10 digits, so its base is 10 (Bansal et al., 2017).

- **Types of Number Systems**

Understanding number systems is crucial for comprehending how computers work. Each system is designed for specific functions, including the representation and manipulation of data within computers (BYJU'S, n.d.). The useful number system types are:

1. Binary Number System
2. Octal Number System
3. Decimal Number System
4. Hexadecimal Number System (Dixit, 2005).

Different number systems have unique applications. For instance, binary is used in digital electronics, octal in Unix file permissions, decimal in financial transactions, and hexadecimal in programming languages for concise representation (Club Z! Tutoring, n.d.).

Binary Number System. Binary is fundamental in computing, as it aligns with the on/off states of electronic circuits (GeeksforGeeks, 2020). The binary number system, as the name suggests, consists of two digits namely 0 and 1. These binary digits are called bits. Thus, the word bit stands for either of the binary digits. Since this system uses two digits only, it has the **base** or **radix 2**. In binary notation, each digit's positional value is twice that of the digit to its right, mirroring the structure of the decimal system but with a base of 2. Binary numbers are typically written with the base indicated as a subscript next to the least significant digit (LSD). For example,

$$(101101.1011)_2$$

It can be represented as shown below (Dixit, 2005).

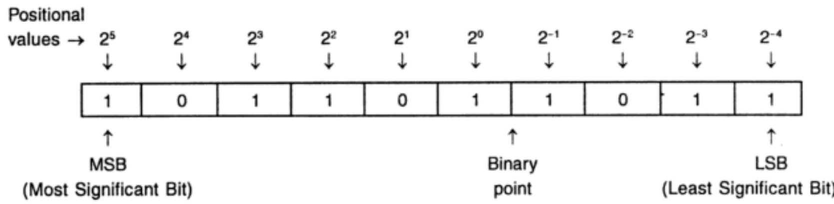


Fig. 1. Binary number shown with positional values.

Octal Number System. This number system has **base** or **radix 8**. The basic digits of this system are 0, 1, 2, 3, 4, 5, 6, and 7. In modern programming languages, octal numbers are typically reserved for character codes and will be rarely seen outside of that context (Kneusel, 2015). The octal number system is also a positional value system, wherein each octal digit has its own value or weight expressed as a power of 8. For example,

$$(157246.3174)_8$$

It can be represented as shown below (Dixit, 2005).

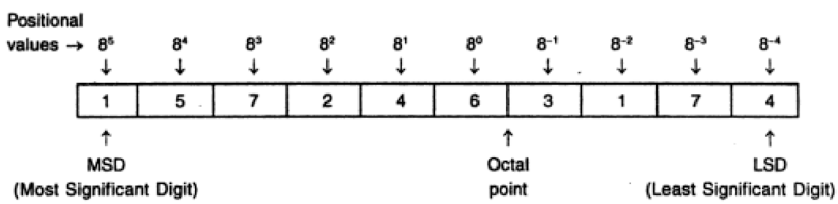


Fig. 2. Octal number shown with positional values.

Decimal Number System. The decimal system is integral in everyday life and forms the basis for most mathematical calculations (Cuemath, n.d.). This system has roots in ancient civilizations, notably the Hindu-Arabic numeral system, which introduced the concept of zero and positional notation, significantly influencing mathematics and commerce (Britannica, 2024). The decimal number system uses ten digits (0 through 9) to represent numbers. Numbers such as 12876, -1024, 68.74, and +768 are examples of decimal numbers. The system also employs the decimal point and ± signs. The **base** or **radix** of the decimal system is **10**, reflecting the number of digits used. In this system, while the base is 10, the fundamental digits are 0 through 9. The value of each digit in a decimal number depends on its face value, the base of the system, and its position within the number. For example,

$$351479.8265$$

Since no base is mentioned, the base is taken as 10. It can be represented as shown below (Dixit, 2005).

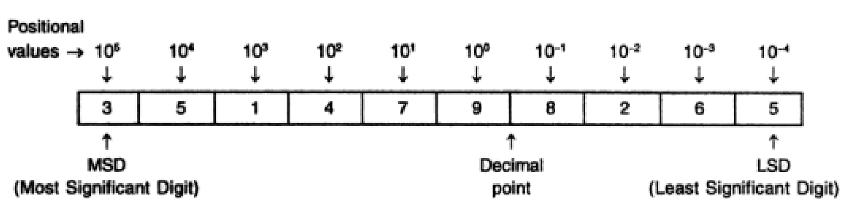


Fig. 3. Decimal number shown with positional values.

Hexadecimal Number System. The hexadecimal number system, popularly known as the hex system, has sixteen symbols and therefore has the **base** or **radix 16** or **H**. Hexadecimal is widely used in programming and computer science, particularly for memory addressing and color codes in web design (BYJU'S, n.d.). The hexadecimal number system represents an information in the concise form. The sixteen symbols used in this system are: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F.

The equivalence between hex-numbers and decimal numbers is given below:

Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F

The hexadecimal number system is also a positional value system, wherein each hexadecimal digit/letter has its own value or weight expressed as a power of 16. For example,

$$(6A9E83.C5BD)_{16}$$

It can be represented as shown below (Dixit, 2005).

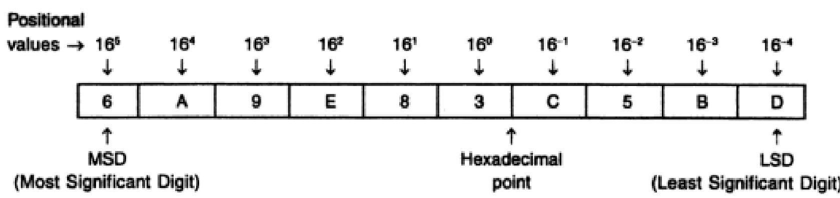


Fig. 4. Hexadecimal number shown with positional values.

The following table illustrates the relationship between binary, octal, decimal, and hexadecimal number systems (Dixit, 2005).

Binary	*Octal*	*Decimal*	*Hexadecimal*
0000	0	0	0
0001	1	1	1
0010	2	2	2
0011	3	3	3
0100	4	4	4
0101	5	5	5
0110	6	6	6
0111	7	7	7
1000	10	8	8
1001	11	9	9
1010	12	10	A
1011	13	11	B
1100	14	12	C
1101	15	13	D
1110	16	14	E
1111	17	15	F

- **Uses and Significance of Each Number System**

The various number systems—binary, octal, decimal, and hexadecimal—serve essential roles in mathematics and computing. Each system has unique characteristics and applications that contribute to its significance in different contexts.

Binary. The binary number system is fundamental to computing as it aligns with the on/off states of electronic circuits, serving as the foundation of all digital computing systems. It is employed to represent various types of digital data, including numbers, text, images, and audio. Additionally, binary plays a crucial role in Boolean algebra, which focuses on logic and truth values where statements are assigned either 0 or 1. The simplicity of the binary system, with only two digits (0 and 1), facilitates its implementation in computing devices that rely on on/off switches (Encyclopedia.com, n.d.; Brioli, 2023). As the backbone of all computing processes, binary enables the execution of complex algorithms and operations, making it indispensable in modern technology (ScienceDirect.com, n.d.).

Octal. The octal number system serves as a shorthand for binary, with three binary digits corresponding to one octal digit. This makes it a convenient way to represent binary data more compactly. In contemporary programming languages, octal numbers are commonly used for character codes, simplifying the representation of characters in code (BYJU'S, n.d.).

Decimal. The decimal number system, or base 10, is the most widely used number system in daily life, essential for counting, measuring, and performing arithmetic operations. It uses ten digits (0-9) and is intuitive for users, making it crucial for financial transactions, scientific measurements, and everyday arithmetic. Its universal acceptance across cultures facilitates global communication and commerce, while its straightforward structure supports complex calculations and advanced mathematical concepts, including fractions and decimals. This ease of use and standardization make the decimal system accessible and fundamental in both personal and professional contexts (Smith & LeVeque, n.d.).

Hexadecimal. Hexadecimal numbers are compact and efficient, using less memory compared to other number systems, which allows for storing more numbers within computer systems. Their reduced size simplifies input-output handling and streamlines data processing. The ease of converting between hexadecimal and binary enhances its utility in computer programming. Additionally, hexadecimal notation is commonly used to represent computer memory addresses, further demonstrating its practicality and relevance in computing (Awati, 2022).

In conclusion, each number system is uniquely suited to specific applications, contributing significantly to mathematics and technology. Their distinct characteristics not only facilitate efficient data representation and manipulation but also enhance our ability to perform complex calculations and communicate effectively in various fields. Understanding these systems is essential for anyone engaged in mathematical or technological pursuits.

Analysis/Reaction

This portfolio dives into the world of number systems, a topic that might seem distant from our daily interactions with technology. But as a computer science student, I have come to realize just how crucial these systems are for the digital world we navigate.

Four main number systems are highlighted: binary, octal, decimal (the one we use every day), and hexadecimal. While the decimal system reigns supreme for everyday tasks due to its alignment with the 10 digits of our hands, binary is the secret language of computers. Since computers operate on on/off switches, binary's use of just 0s and 1s perfectly aligns with this functionality. It is the foundation for representing all digital data - numbers, text, images, audio, video, and more.

The other systems come in handy for specific purposes. Octal acts as a shorthand for binary, making it easier to work with long strings of 0s and 1s. Hexadecimal, with its compact nature, allows for efficient storage and manipulation of data.

I found it fascinating how these seemingly abstract concepts power the automation we take for granted. Every click, swipe, or search query involves the underlying conversion between human-readable commands and the language of computers. Understanding number systems unlocks a deeper appreciation for the complex processes happening behind the scenes.

It is emphasized that each system has its strengths. Decimal continues to be the dominant system for everyday calculations, while binary forms the core of digital data. Octal and hexadecimal offer efficiency and convenience in specific computing contexts. Mastering these systems equips us, computer science students, to better understand the technology we use and potentially build upon it in the future.

In conclusion, while we may not consciously think about number systems every day, they are the invisible language that makes our digital world function. As computer science students, delving into this foundational knowledge empowers us to not just use technology, but to potentially create and shape its future.

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