

Lab 1.5.9: Converting Numbers Overview

Estimated Time: 25 Minutes

Objective

Upon completion of this lab, the student will be able to identify the places in binary and decimal numbers and know the value of each. Also, the student will work with powers of ten and relate them to decimal places, as well as work with powers of two and relate them to binary places. Finally, the student will manually convert between simple binary numbers and decimal numbers and describe the differences between binary and decimal number systems.

Equipment

This is a written lab exercise. No equipment is necessary.

Scenario

Having sharp skills in number systems will aid in a career as an IT professional. With the ability to convert numbers without the use of a calculator, the student will be able to solve problems that may arise quickly and easily.

Procedures

This lab will help the student learn to work with the binary number system. The student will convert binary numbers (Base 2) to decimal numbers (Base 10) and then from decimal to binary. Computers and networking equipment, such as routers, use binary numbers. A binary number is a series of BITS (short for Binary Digits) that are either ON (a binary 1) or OFF (a binary 0). They are encoded internally in the PC on microchips and on the computer motherboard bus as electrical voltages. Understanding binary numbers and how they relate to decimal numbers is critical to understanding how computers work internally.

Step 1

The decimal number system is based on powers of ten. This exercise will help to develop and understand how the decimal number system is constructed. With Base 10, the right-most place has a value of one (as with Base 2). Each place moving to the left is valued ten times more. Ten to the zero power is one ($10^0 = 1$), 10 to the first power is 10 ($10^1 = 10$), 10 to the second power is 100 ($10^2 = 10 \times 10 = 100$), ten to the third power is 1000 ($10^3 = 1000$), and so on. Just multiply the number in each place with the value of each place (for example, $400 = 4 \times 10^2 = 4 \times 100$). Remember that any number (other than zero) to the zero power is one.

The following chart shows how the decimal number system represents the number 352,481. This will help in understanding the binary number system.

Exponent	10^5	10^4	10^3	10^2	10^1	10^0
Expanded	100000	10000	1000	100	10	1
Numeral	3	5	2	4	8	1
	3 x 100,000	5 x 10,000	2 x 1,000	4 x 100	8 x 10	1 x 1

The number 352,481, if read from left to right in expanded decimal form, is (3 x 100,000) + (5 x 10,000) + (2 x 1,000) + (4 x 100) + (8 x 10) + (1 x 1), for a total of 352,481 (a six-digit number).

Here is another way to look at it that makes it easier to add up the decimal number values:

Position of digit (from right)	Value of bit position (10^X or ten to the power of)	Number value from 0 to 9	Calculation	Decimal Value
1st Decimal Digit	10^0 or 1	1	1 x 1	1
2nd Decimal Digit	10^1 or 10	8	8 x 10	80
3rd Decimal Digit	10^2 or 100	4	4 x 100	400
4th Decimal Digit	10^3 or 1,000	2	2 x 1,000	2,000
5th Decimal Digit	10^4 or 10,000	5	5 x 10,000	52,000
6th Decimal Digit	10^5 or 100,000	3	3 x 100,000	300,000
Decimal Value (Total of 6 digits)				352,481

Step 2

Binary means “two” and each digit in a binary number can only have two values (0 or 1). Understanding Binary numbers is key to understanding how computers work. The value of each binary digit, or bit, is based on powers of two.

This exercise will help develop an understanding of powers of two, which is what all computers and data communications use. With Base 2, the right-most place has a value of 1 (as with Base 10). Each place moving to the left is valued two times more. Two to the zero power is one ($2^0 = 1$), two to the first power is two ($2^1 = 2$), two to the second power is four ($2^2 = 4$), two to the third power is eight ($2^3 = 8$), and so on. Just multiply the number in each place (either a 0 or a 1) by the value of each place (for example, $8 = 2^3 = 1 \times 8$) and add up the total. Remember that any number (except zero) to the zero power is one.

Binary Number Conversion Example

The following table shows the detailed calculations (starting from the right side) to convert the binary number 10011100 into a decimal number.

Position of digit (from right)	Value of bit position (two to the power of)	Is bit a One (on) or a Zero (off)	Calculation	Decimal Value
1 st Binary Digit	$2^0 = 1$	0	0×1	0
2 nd Binary Digit	$2^1 = 2$	0	0×2	0
3 rd Binary Digit	$2^2 = 4$	1	1×4	4
4 th Binary Digit	$2^3 = 8$	1	1×8	8
5 th Binary Digit	$2^4 = 16$	1	1×16	16
6 th Binary Digit	$2^5 = 32$	0	0×32	0
7 th Binary Digit	$2^6 = 64$	0	0×64	0
8 th Binary Digit	$2^7 = 128$	1	1×128	128
Decimal Value. (Sum total of 8 bits)				156

Step 3

Look at the binary number bit status. If there is a 1 in a given position add the value shown. If there is a 0 in a given position then do not add it.

Solve for the decimal value.

Exponent	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Bit Position	8	7	6	5	4	3	2	1
Value	128	64	32	16	8	4	2	1
Binary Number Bit	1	0	0	1	1	1	0	0

Decimal Value: _____

Exponent	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Bit Position	8	7	6	5	4	3	2	1
Value	128	64	32	16	8	4	2	1
Binary number bit status	1	1	1	0	0	0	1	1

Decimal Value: _____

Exponent	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Bit Position	8	7	6	5	4	3	2	1
Value	128	64	32	16	8	4	2	1
Binary number bit status	0	1	1	1	0	0	0	0

Decimal Value: _____

Exponent	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Bit Position	8	7	6	5	4	3	2	1
Value	128	64	32	16	8	4	2	1
Binary number bit status	1	1	0	1	1	0	1	0

Decimal Value: _____

Step 4

Convert the decimal values of 209, 114, 58, and 165 to the binary equivalents. To do this, look at the decimal value and then subtract binary values starting from 128 (the highest value binary bit for these number). If the number is larger than 128 then put a 1 in the 128 (or 2^7) column. Subtract 128 from the number and then see if there is 64 or greater left over. If there is, put a one there. Otherwise, put a zero and see if there is 32 or greater left over. Continue until all eight bits are defined as either a zero or a one.

Exponent	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Bit Position	8	7	6	5	4	3	2	1
Value	128	64	32	16	8	4	2	1
Binary number bit status								

Binary Value of 209: _____

Exponent	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Bit Position	8	7	6	5	4	3	2	1
Value	128	64	32	16	8	4	2	1
Binary number bit status								

Binary Value of 114: _____

Exponent	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Bit Position	8	7	6	5	4	3	2	1
Value	128	64	32	16	8	4	2	1
Binary number bit status								

Binary Value of 58: _____

Exponent	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Bit Position	8	7	6	5	4	3	2	1
Value	128	64	32	16	8	4	2	1
Binary number bit status								

Binary Value of 165: _____

Step 5

Check the answers by converting the numbers back to decimal.

Troubleshooting

Learning how to calculate binary numbers without the use of a calculator is an important skill in the IT Industry. The ability to perform number conversions can save time, especially in the field where calculators are not always available.

Reflection

Using the system learned to solve decimal to binary conversion, convert the decimal number 255 to binary.
