Introduction

Electronics is a fast changing field in the world today, and will continue to change at a very rapid rate for many years to come. It is exciting to be a part of this change, and many more people are becoming excited by the prospects of the electronics field.

To most people, electronics still remains a bit of magic. It is fine to keep some people in the dark, but a person who truly wants to learn about the field needs more than just magic as an answer to how things work.

Electronics can be a difficult subject to study, but it doesn't really have to be that way. *Many of the electronics theory books go to great lengths to try and explain the theory behind a certain subject. They will ignore the necessary math until the end of* the chapter, where there are lots of questions that cannot be solved without calculations. As a result, the student feels he has not learned the subject because he cannot answer the questions. Other students will spend so much time concentrating on the math that the theory is lost.

Electronics Math is intended to change the way people have been learning electronics. I believe a great deal of effort needs to be placed on learning the math involved in electronics. However, understanding the theory of how things work is just as important. This book makes every effort to show step-by-step procedures for understanding the mathematics necessary to solve problems. At the same time, theories are also explained.

Everything in this book is from the technician's point of view and, as a result, many things have been simplified. Electronics will always be magic to some, but students using this book will find they understand the math much better, and the theory of operation will also be easier to understand.

The subject matter of this book concentrates on the basic circuits, such as dc circuits and circuits containing inductors and capacitors. There is also a separate chapter dealing with the sine wave.

The chapters presented here are considered the building blocks of electronic circuits. Many students have trouble understanding electronics at all levels of study be-

Chapter 1

10^3 = kilo 10^{-3} = milli

10^6 = mega

10^{-6} = micro 10^9 = giga

Scientific and Engineering Notation

There are times when it is necessary to deal with very large or very small numbers, but working with numbers like these is somewhat cumbersome using ordinary arithmetic. The term scientific notation suggests science and technical fields have a definite need for such a mathematical system. In electronics, it is especially appropriate *to use a system that makes using numbers easier. In electronics and other engineering* fields, a modification of scientific notation, called engineering notation is used.

SIGNIFICANT FIGURES

Mathematics, with its many rules and precise calculations gives the impression that it is an accurate as well as precise tool. This is true of the math itself, however, the numbers that are used for those calculations is questionable to their degree of accuracy. Therefore, it makes sense that if the numbers are questionable, then the accuracy of the calculations is questionable. For example, when a meter is read, the meter has a tolerance and the person reading it has a tolerance. The value of resistors used in calculations will often have a 10 percent tolerance.

With all the different tolerances being introduced to our calculations, there needs to be a way of determining which digits of a number are reliable and accurate and which figures are questionable, or for that matter, not needed due to their unreliability. The way a number can be written and show the importance of each figure is called significant figures.

Often when writing numbers in electronics, the most commonly used number of figures is three. This is a common occurrence, not a rule.

Rules for Determining Significant Figures

Rule 1 Non-zero numbers (the digits 1 through 9) are always significant figures.

Rule 2 A zero used as a place holder between two non-zero digits is considered to be a significant figure.

Rule 3 A zero to the right of the last digit to the right of a decimal is considered a significant figure.

Rule 4 A zero used only as a place holder, either on the right or the left side of the decimal point, *if it is not between two non-zero digits, is not considered a* significant figure

Rule 5 When a number is greater than one, a decimal point can be placed following the number to show that all of the digits are significant, including zeros.

Examples

1234 has four significant figures
1230 has three significant figures
1200 has two significant figures
1034 has four significant figures
1030 has three significant figures
1030. has four significant figures
.00123 has three significant figures
0.0123 has three significant figures
0.0104 has three significant figures
.2050 has four significant figures
25.0 has two significant figures
25.5 has three significant figures
53.05 has four significant figures
50.50 has three significant figures
005 has one significant figure
00500 has one significant figure

ROUNDING NUMBERS

The process of rounding numbers is used to make working with numbers easier. It can be seen that the digit in a number with the least significance often has little power in changing the value of a number. For example, there is very little difference between $100 and $102

Whenever it is necessary to round numbers, first determine how many significant figures will appear in the final number. The next digit to the right will determine the outcome of rounding.

Rules for Rounding Numbers

Rule 1 Determine how many significant figures are to be used in the final number. The next number to the right determines the outcome of rounding.

Rule 2 If the number to the right is 5 or more, drop this digit and all the digits to the right. *Add 1* to the last figure kept. Replace the digits dropped with zeros to maintain the place value of the figures remaining.

Rule 3 If the number to the right is less than 5, drop this digit and all the digits to the right. Replace the digits dropped with zeros to maintain the place value of the figures remaining.

Examples (rounded to three significant figures)

806956 = 807000	.1009 = .101
875.5 = 876	.0000003553 = .000000355
9083.2 = 9080	80.78 = 80.8
.00387 = .00387	104 = 104
.008737 = .00874	98 = 100

Practice Problems

Round to three significant figures.

1. 5609	2. 5605
3. 5603	4. 29888
5. 359,999	6. 568.8
7. 573.09	8. 333.1
9. 12.09	10. 23.15
11. 54.51909	12. 56.99103
13. 8.2	14. 8.4300
15. 9.00199	16. 00.00333333333
17. 0.9000999	18. .0009315
19. 0.009999	20. 0.19999999
21. .6666666666	22. 0.005555555
23. 0.7447471747	24. 0.0909090909
25. 0.0125125125	

POSITIVE AND NEGATIVE NUMBERS

Scientific notation expresses a number as a power of 10 in either positive or negative form. All numbers have a value of either positive or negative. The positive and negative signs are written in front of the number and becomes part of the number. For example; positive three is written +3 or simply 3, negative three is written −3. If no sign is written, we will always assume the number to be positive.

Keep in mind fractions and decimals will still have the same relationships, even if the number is negative.

Addition and Subtraction with Signed Numbers

Adding and subtracting positive and negative numbers is similar to adding and subtracting whole numbers. Study the rules and examples that follow.

Rules for Adding and Subtracting Signed Numbers

Rule 1 If the signs of the two numbers being added are alike; add the numbers and keep the sign. Examples

$8 + 2 = 10 \qquad 4 + 3 = 7 \qquad .2 + .5 = .7$

Note In the examples shown above, both signs of the numbers are positive and the numbers are added. Result is positive. In the examples shown below, both signs of the numbers are negative and the numbers are added with the result being negative.

$-8 + -2 = -10 \qquad -4 + -3 = -7 \qquad -.2 + -.5 = -.7$

Rule 2 If the signs of the two numbers being added are unlike, subtract the numbers and take the sign of the larger number.

Examples

$-8 + 2 = -6 \qquad 8 + -2 = 6 \qquad -.2 + .5 = .3$

Note In the examples shown above, the signs of the two numbers are unlike. The numbers are subtracted, least from the greatest, and the result takes the sign of the greater number.

Rule 3 When subtracting two numbers, change the sign of the number being subtracted to its opposite, change the subtraction sign to addition, and then follow the rules for addition. Examples

$7 - 3 = 7 + -3 = 4 \qquad -7 - 3 = -7 + -3 = -10$
$7 - -3 = 7 + +3 = 10 \qquad -7 - -3 = -7 + +3 = -4$

Note When subtracting more than one number always start at the left and work to the right.

Practice Problems

Complete the operation.

1. $-6 + 4$	2. $7 + 3$
3. $8 + -2$	4. $9 - 5$
5. $-9 - -5$	6. $10 - -6$
7. $-3 + 9$	8. $-2 + -5$
9. $-1 - 6$	10. $-1 - 1$
11. $-3 - -3$	12. $1 - 2 - 4$
13. $-3 - 5 + -6 - -3$	14. $10 - 6 + 3 - -10 - 3 + 6$
15. $0.3 - 0.5 - 0.8 + 1.5$	16. $2.5 - 3.2 + 6.8 + -.8$
17. $0 + 8 - 0.01 - 0 - 0.03$	18. $-4.02 + 8.12 + 3.14 - 18.0$
19. $4.5 - 10.6 - 3.02 + .01$	20. $-\frac{3}{4} - \frac{5}{8}$

Multiplication and Division with Signed Numbers

When multiplying and dividing signed numbers disregard the signs and multiply or divide. Then follow the rules shown below.

Rule 1 Disregard the signs and multiply (or divide) the numbers. If the signs are like, the product (or quotient) is positive.

Examples

$4 \times 2 = 8 \qquad -4 \times -2 = 8$

Rule 2 If the signs are unlike, the product (or quotient) is negative

Examples

$4 \times -2 = -8 \qquad -4 \times 2 = -8$
$8 \div -2 = -4 \qquad -8 \div 2 = -4$

The remainder of this chapter deals with the rules and operations of scientific notation.

Practice Problems

Complete the operation.

Note Parentheses written together ( )( ) signify multiplication. Division is represented by the use of the division symbol ÷ or using the fraction bar.

1. $(2)(3)$	2. -4×5
3. 5×-3	4. -6×3
5. $(-2)(3)$	6. $(-1)(-2)$
7. $0 \times 3 \times -5$	8. $.4 \times .5$
9. 0.3×-0.6	10. -2^2
11. -2^3	12. $20 \div 4$
13. $25 \div -5$	14. $-30 \div 6$
15. $-45 \div -9$	16. $\frac{-8}{2}$
17. $\frac{2}{-12}$	18. $\frac{2 \times -3}{-1}$
19. $-\frac{3 \times -4}{-2 \times -2}$	20. $\frac{(-3)(-3)(-3)}{(-1)(-1)(-1)}$

SCIENTIFIC NOTATION

Scientific notation is a mathematical tool used to make numbers much easier to work with. Even with the use of a calculator, it is still helpful to use scientific notation when dealing with the types of numbers found in electronics.

Scientific notation is the writing of a number as a number between 1 and 10, times a power of 10. First it is necessary to see how numbers that are multiples of ten are expressed as powers of ten.

Table 1-1. Powers of 10.

Number	Power of 10	Read as
1,000,000	10^6	ten to the sixth power
100,000	10^5	ten to the fifth power
10,000	10^4	ten to the fourth power
1,000	10^3	ten to the third power
100	10^2	ten to the second power
10	10^1	ten to the first power
1	10^0	ten to the zero power
.1	10^{-1}	ten to the negative first power
.01	10^{-2}	ten to the negative second power
.001	10^{-3}	ten to the negative third power
.0001	10^{-4}	ten to the negative fourth power
.00001	10^{-5}	ten to the negative fifth power

The following key points should be noted

- Numbers that are greater than 1 have a positive power of 10.
- Numbers that are less than 1 have a negative power of 10.
- 10 to the zero power (10^0) equals 1. Any number to the zero power equals 1.

Rules for Writing Numbers in Scientific Notation

Rule 1 When a number is greater than 1, express it in scientific notation by moving the decimal point to the *left* enough places so the number is written between 1 and 10. Count the number of decimal places the point was moved and that is the positive power of 10.

Examples

$85{,}500 = 8.65 \times 10^4 \qquad 563{,}000{,}000 = 5.63 \times 10^8$

$230 = 2.30 \times 10^2 \qquad 7{,}602 = 7.602 \times 10^3$

$7.3 = 7.3 \times 10^0 \qquad 20 = 2.0 \times 10^1$

Rule 2 When a number is less than 1, express is in scientific notation by moving the decimal point to the *right* enough places so the number is written between 1 and 10. Count the number of decimal places the point was moved to determine the negative power of 10.

Examples

$.1 = 1.0 \times 10^{-1} \qquad 0.023 = 2.3 \times 10^{-2}$

$0.000356 = 3.56 \times 10^{-4} \qquad 0.03004 = 3.004 \times 10^{-2}$

$.000098 = 9.8 \times 10^{-5} \qquad .00000030 = 3.0 \times 10^{-7}$

Sometimes numbers are already written as a number times some power of 10. When this is the case, it is usually seen that the number is not expressed between 1 and 10. It is then necessary to rewrite the number to follow the form of scientific notation.

Example

$\times 10^4 = 3.65 \times 10^6$

The easiest way to solve this type of problem is to first write the number in its proper form, with a power of 10 corresponding to the initial amount of the decimal move. The next step would be to add the exponents according to the rules of signed numbers.

Step 1 $365 = 3.65 \times 10^2$ write the number in proper form
Step 2 $10^2 + 10^4 = 10^6$ add the powers of 10
Step 3 3.65×10^6 combine steps 1 and 2 for the final answer

More Examples

$560{,}000 \times 10^{-5} = 5.6 \times 10^0$
Step 1 $560{,}000 = 5.6 \times 10^5$
Step 2 $10^5 + 10^{-5} = 10^0$

$890{,}000{,}000 \times 10^{-3} = 8.9 \times 10^5$
Step 1 $890{,}000{,}000 = 8.9 \times 10^8$
Step 2 $10^8 + 10^{-3} = 10^5$

$0.00035 \times 10^8 = 3.5 \times 10^4$
Step 1 $0.00035 = 3.5 \times 10^{-4}$
Step 2 $10^{-4} + 10^8 = 10^4$

$0.00000057 \times 10^{-4} = 5.7 \times 10^{-11}$
Step 1 $0.00000057 = 5.7 \times 10^{-7}$
Step 2 $10^{-7} + 10^{-4} = 10^{-11}$

Sometimes it is necessary to remove the power of 10 and return to the original number, without scientific notation. When this is necessary, there are two basic rules to follow.

Rule 1 If the power of 10 is positive, move the decimal to the right, the number of places stated by the power of 10.

Example

$8.6 \times 10^6 = 8{,}600{,}000.$
$56.7 \times 10^3 = 56{,}000$

Rule 2 If the power of 10 is negative, move the decimal to the left, the number of places stated by the power of 10.

$0.0034 \times 10^{-5} = 0.000000034$
$56.3 \times 10^{-1} = 5.63$

Practice Problems

Write each in the form of scientific notation.

1. 876,000	2. 1,030,000,000
3. 32,000	4. 25
5. 5.8	6. .03
7. 0.00056	8. 00.00405
9. .0000001000	10. .200
11. $13{,}000 \times 10^5$	12. 520×10^4
13. 0.0045×10^7	14. 0.000039×10^3
15. 0.000000056×10^5	16. $52{,}000 \times 10^{-3}$
17. $3{,}200 \times 10^{-6}$	18. $.00046 \times 10^{-5}$
19. 0.00705×10^{-2}	20. 0.0000004×10^{-7}

Practice Problems

Write each as a standard numeral.

1. 4.8×10^5	2. 7.85×10^2
3. 8.9×10^0	4. 34.6×10^1
5. 457×10^5	6. 1.0×10^{-1}
7. 2.01×10^{-2}	8. 00.003×10^{-5}
9. 100×10^{-3}	10. $100{,}000 \times 10^{-6}$
[illegible] $.0035 \times 10^5$	12. 0.00000400×10^5
[illegible] $\times 10^{-3}$	14. 5600×10^3
15. $.00000065 \times 10^8$	16. 9.8×10
17. 1.09×10^{-4}	18. 0.00000078×10^0
19. 10×10^0	20. 1×10^1

ENGINEERING NOTATION

Engineering notation is a variation of scientific notation. In electronics and many other scientific and technical fields there are certain powers of 10 that are used more often than others. Names have been placed on certain powers of 10 to make the use of them even easier.

The names of the powers are given in multiples of three. For example: 10^3, 10^6, 10^9, 10^{-3}, 10^{-6}, 10^{-9}, etc. Refer to Table 1-2. Notice how the powers of 10 that are positive also have corresponding powers that are negative.

The engineering notation names have prefixes that are written in front of, and attached to the unit name. For example, when dealing with volts as the unit of measure, engineering notation prefixes could be millivolts, microvolts, kilovolts, or megavolts. Refer to Table 1-2 for a list of names and powers of 10 commonly used in electronics.

Writing Numbers Using Engineering Notation

Convert 48,000 watts to engineering notation. The first step would be to write the number in modified scientific notation, that is to say, use a power of 10 that is a multiple of 3. Then Step 2 would be to replace the power of 10 with the multiplier name. Refer to Table 1-2.

Step 1 48,000 watts = 48×10^3 watts
Step 2 10^3 = kilo . . . therefore . . . 48 kilowatts

Table 1-2. Engineering Notation.

Multiply By	Power of 10	Multiplier Name	Symbol
1,000,000,000,000	10^{12}	tera	T
1,000,000,000	10^9	giga	G
1,000,000	10^6	mega	M
1,000	10^3	kilo	k
1	10^0	basic unit	(no multiplier)
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n
0.000 000 000 001	10^{-12}	pico	p

Convert 305,000,000 hertz to engineering notation.

Step 1 305×10^6 hertz or 0.305×10^9 hertz (writing the number with a power of 10).
Step 2 305 megahertz or 0.305 gigahertz.

Note When it is not specified which multiplier name to use, either can be selected, depending on the application in the problem.

Convert 0.0025 amps to engineering notation.

Step 1 2.5×10^{-3} amps
Step 2 2.5 milliamps

Sometimes it is necessary to take a number that is already written in scientific notation and change the multiplier name to make it more convenient to use. The easiest way to do this is by removing the multiplier given and replacing it with the proper power of 10. At this point, most students find it best to rewrite the number, without the use of scientific notation. In other words, this returns the number back to the basic unit. Once it is returned to the basic unit, it is simply a matter of moving the decimal the correct number of places to have a power of 10 equal to the multiplier desired.

Examples:

Convert 2500 milliamps to amps.
Step 1 2500 milliamps = 2500×10^{-3} amps
Step 2 2500×10^{-3} = 2.5 amps

Convert 475 kilovolts to megavolts.
Step 1 475 kilovolts = 475×10^3 volts
Step 2 475×10^3 volts = 475,000 volts
Step 3 0.475×10^6 volts = 0.475 megavolts

Convert .255 μA (microamps) to mA (milliamps).
Step 1 .255 μA = $.255 \times 10^{-6}$ amps
Step 2 $.255 \times 10^{-6}$ = .000000255 amps
Step 3 .000000255 = $.000255 \times 10^{-3}$ amps
Step 4 .000255 milliamps

Convert .001 pf (picofarads) to μF (microfarads).
Step 1 .001 pf = $.001 \times 10^{-12}$ farads
Step 2 $.001 \times 10^{-12}$ = .000 000 000 000 001 farads
Step 3 .000 000 001 $\times 10^{-6}$ farads
Step 4 .000 000 001 microfarads

Practice Problems

Change each to the units shown.

1. 2,400,000 Ω	______	kΩ	______	MΩ	(ohms)
2. 353,000 Hz	______	kHz	______	MHz	(hertz)
3. 2500 W	______	mW	______	kW	(watts)
4. 25 V	______	mV	______	kV	(volts)
5. .01 H	______	μH	______	mH	(henries)
6. 1.5 kΩ	______	Ω	______	MΩ	(ohms)
7. 25 MHz	______	kHz	______	GHz	(hertz)
8. .03 GHz	______	MHz	______	Hz	(hertz)
9. 56 MV	______	kV	______	V	(volts)
10. 75 kW	______	W	______	MW	(watts)
11. 25 mA	______	μA	______	A	(amps)
12. 1500 μA	______	A	______	mA	(amps)
13. 1000 μF	______	pf	______	f	(farads)
14. .001 pF	______	μF	______	nf	(farads)
15. .025 mV	______	μV	______	V	(volts)
16. 7500 mW	______	W	______	μW	(watts)
17. 500 V	______	kV	______	mV	(volts)
18. 2,400 mV	______	V	______	kV	(volts)
19. 1 A	______	kA	______	mA	(amps)
20. 10 V	______	mV	______	kV	(volts)

The following key point should be noted.

- When converting from one multiplier to another, the actual value of the number does not change, even though the decimal place moves.

Multiplication and Division with Engineering Notation

In electronics, there are a great deal of calculations, most of which involve the use of powers of 10. Calculations can be performed through the use of scientific notation or through the use of engineering notation, with multiplier names. Using multiplier names is much more common and therefore, the method that will be concentrated on here.

There are a few basic rules to learn, as there is in any form of mathematics.

Rules for Multiplication and Division

Rule 1 To multiply numbers that contain powers of 10, multiply the numbers and add the powers of 10 exponents.

Example

Multiply 20 kilo × 5 milli

St[illegible] multiply the numbers 20 × 5 = 100
S[illegible] add the powers of 10 exponents
kilo = 10^3
milli = 10^{-3}
$10^3 + 10^{-3} = 10^0 = 1$
Step 3 combine step 1 (the number) with step 2 (the power of 10)
final answer = 100

- When a positive multiplier is multiplied by a negative multiplier of the same size (kilo and milli) the result is canceled unit multipliers. The final answer will be in basic units.

Multiply 100 × 25 milli

Step 1 multiply the numbers 100 × 25 = 2500
Step 2 add the powers of 10 exponents
100 is in basic units = 10^0
milli = 10^{-3}
$10^0 + 10^{-3} = 10^{-3}$
Step 3 combine the number with the power of 10
2500 milli
Step 4 adjust the decimal in the number to better fit the multiplier
2500 milli = 2.5 (basic unit)

Rule 2 To divide numbers that contain powers of 10; divide the numbers and subtract the powers of 10 exponents.

Example

Divide: $\dfrac{100}{25 \text{ milli}}$

Step 1 divide the numbers 100 ÷ 25 = 4
Step 2 subtract the powers of 10 exponents
100 is in basic units = 10^0
milli = 10^{-3}
$10^0 - 10^{-3} = 10^3$
Always subtract the denominator (bottom) from the numerator (top).
Step 3 combine step 1 (the number) with step 2 (the power of 10)
final answer = 4 kilo

- When a positive multiplier is divided into basic units, the result is a negative multiplier of equal size (kilo divided into basic units results in milli). Also, basic divided by negative gives a positive.

Rule 3 Whenever the power of 10 is moved from the numerator to the denominator or the denominator to the numerator, move the power of 10 by changing the sign of the exponent.

Example (to show moving of power only)

$$\frac{1}{\text{micro}} = \frac{1}{10^{-6}} = \frac{10^6}{1} = \text{mega}$$

$$\text{kilo} = 10^3 = \frac{1}{10^{-3}} = \frac{1}{\text{milli}}$$

Note Although, at this time it may be difficult to see a use for rule 3, shown above, it often comes in quite useful. The same operation can be performed by using the rules for division by allowing the 1 shown in the examples to be 10^0.

When working with multiplier names, it is necessary to keep in mind that there are units to deal with. Rather than dealing with the units in this chapter, it is felt the with. In electronics, multiplication, or division of two units often leads to a new unit altogether. An excellent example of this is Ohm's law. E (volts) = I (amps) × R (ohms).

Practice Problems

Complete the operation. Write the answer in engineering notation with the most convenient multiplier. Show the correct power of 10 in answer.

1. 100 kilo × 1 milli
2. 20 mega × 3 milli
3. 10 × 1.5 kilo
4. 4 kilo × 2 micro
5. 5 × 6 nano
6. $\frac{10}{2 \text{ kilo}}$
7. $\frac{50}{25 \text{ milli}}$
8. $\frac{20 \text{ micro}}{5}$
9. $\frac{25 \text{ giga}}{5 \text{ mega}}$
10. 2 × 3.14 × 1 kilo × .01 milli
11. 2 × 3.14 × 10 mega × 10 milli
12. $\frac{1}{2 \times 3.14 \times 1 \text{ mega} \times 1 \text{ micro}}$
13. $\frac{1}{2 \times 3.14 \times 1 \text{ kilo} \times 10 \text{ pico}}$
14. $\frac{2 \text{ giga} \times 3 \text{ kilo}}{6 \text{ mega} \times 1 \text{ milli}}$
15. $\frac{5 \text{ milli} \times 4 \text{ micro}}{2 \text{ nano} \times 2 \text{ kilo}}$

Addition and Subtraction with Engineering Notation

Addition and subtraction with numbers having powers of 10 is an arithmetic function found quite often in the study of electronics.

There are two common ways of adding and subtracting. The first method is by keeping the power of 10 for both numbers the same. The second method is by converting both of the numbers back to basic units and using regular arithmetic. Both methods should be learned since they are both used at different times.

Rules for Adding and Subtracting with Engineering Notation

Rule 1 When the powers of 10 are the same; add or subtract the numbers, keeping the same power of 10.

Examples:

2 kilo + 3 kilo = 5 kilo
4 milli + 6 milli = 10 milli
300 + 5 kilo = .3 kilo + 5 kilo = 5.3 kilo (it is necessary to make the units the same)

Rule 2 If the powers of 10 are not the same; it is often easier to convert the numbers to basic units and use regular arithmetic.

Examples:

100 milli + 1 = .1 + 1 = 1.1 basic units
1.5 kilo + .06 mega = 1500 + 60,000 = 61,500 = 61.5 kilo

2.7 mega + 10 = 2,700,000 + 10 = 2,700,010 = 2.7 mega

Note In this last example, the very small basic unit of 10 was dropped. Using the rules for rounding to three significant figures, this is acceptable.

Practice Problems

Complete the operation. Write the answer in engineering notation with the most convenient multiplier. Show the correct power of 10. Round to three significant figures if needed.

1. 3 kilo + 41 kilo
2. 305 + 609
3. 75 kilo + 1200
4. .85 mega + 150 kilo
5. 75 mega − 25 kilo
6. 2.2 kilo − 850
7. 10 + 2500 milli
8. 25 kilo + 10 milli
9. 85 milli + 1000 micro
10. .90 milli + 150 micro
11. 8 milli − 2 milli
12. 10 milli − 10 micro
13. .1 milli − 90 micro
14. 250 micro + 1500 nano
15. 25 nano + 100 pico
16. .01 micro + .001 micro
17. 15 pico + 25 pico
18. .01 micro + 1500 pico
19. 1.0 + 0.1 milli
20. 201 + 20.1

CHAPTER SUMMARY

This first chapter dealt mostly with writing numbers in either scientific notation or engineering notation. Keep in mind that although engineering notation is used most of the time in electronics, and other technical areas, the multiplier names are used to replace powers of 10.

The following key points should be noted.

- Numbers that are greater than 1 have a positive power of 10.
- Numbers that are less than 1 have a negative power of 10.
- 10 to the zero power (10^0) equals 1. Any number to the zero power equals 1.
- When converting from one multiplier to another, the actual value of the number does not change, even though the decimal place moves.
- When a positive multiplier is multiplied by a negative multiplier of the same size (kilo and milli) the result is canceled unit multipliers. The final answer will be in basic units.
- When a positive multiplier is divided into basic units, the result is a negative multiplier of equal size (kilo divided into basic units results in milli). Also, basic divided by negative gives a positive.

with. In electronics, multiplication, or division of two units often leads to a new unit altogether. An excellent example of this is Ohm's law. E (volts) = I (amps) × R (ohms)

Practice Problems

Complete the operation. Write the answer in engineering notation with the most convenient multiplier. Show the correct power of 10 in answer.

1. 100 kilo × 1 milli
2. 20 mega × 3 milli
3. 10 × 1.5 kilo
4. 4 kilo × 2 micro
5. 5 × 6 nano
6. $\frac{10}{2 \text{ kilo}}$
7. $\frac{50}{25 \text{ milli}}$
8. $\frac{20 \text{ micro}}{5}$
9. $\frac{25 \text{ giga}}{5 \text{ mega}}$
10. 2 × 3.14 × 1 kilo × .01 milli
11. 2 × 3.14 × 10 mega × 10 milli
12. $\frac{1}{2 \times 3.14 \times 1 \text{ mega} \times 1 \text{ micro}}$
13. $\frac{1}{2 \times 3.14 \times 1 \text{ kilo} \times 10 \text{ pico}}$
14. $\frac{2 \text{ giga} \times 3 \text{ kilo}}{6 \text{ mega} \times 1 \text{ milli}}$
15. $\frac{5 \text{ milli} \times 4 \text{ micro}}{2 \text{ nano} \times 2 \text{ kilo}}$

Addition and Subtraction with Engineering Notation

Addition and subtraction with numbers having powers of 10 is an arithmetic function found quite often in the study of electronics.

There are two common ways of adding and subtracting. The first method is by keeping the power of 10 for both numbers the same. The second method is by converting both of the numbers back to basic units and using regular arithmetic. Both methods should be learned since they are both used at different times.

Rules for Adding and Subtracting with Engineering Notation

Rule 1 When the powers of 10 are the same; add or subtract the numbers, keeping the same power of 10.

Examples:

ilo + 3 kilo = 5 kilo
illi + 6 milli = 10 milli
00 + 5 kilo = .3 kilo + 5 kilo = 5.3 kilo (it is necessary to make the units the same)

Rule 2 If the powers of 10 are not the same; it is often easier to convert the numbers to basic units and use regular arithmetic.

Examples:

100 milli + 1 = .1 + 1 = 1.1 basic units
1.5 kilo + .06 mega = 1500 + 60,000 = 61,500 = 61.5 kilo

2.7 mega + 10 = 2,700,000 + 10 = 2,700,010 = 2.7 mega

Note In this last example, the very small basic unit of 10 was dropped. Using the rules for rounding to three significant figures, this is acceptable.

Practice Problems

Complete the operation. Write the answer in engineering notation with the most convenient multiplier. Show the correct power of 10. Round to three significant figures if needed.

1. 3 kilo + 41 kilo
2. 305 + 609
3. 75 kilo + 1200
4. .85 mega + 150 kilo
5. .75 mega − 25 kilo
6. 2.2 kilo − 850
7. 10 + 2500 milli
8. 25 kilo + 10 milli
9. 85 milli + 1000 micro
10. .90 milli + 150 micro
11. 8 milli − 2 milli
12. 10 milli − 10 micro
13. .1 milli − 90 micro
14. 250 micro + 1500 nano
15. 25 nano + 100 pico
16. .01 micro + .001 micro
17. 15 pico + 25 pico
18. .01 micro + 1500 pico
19. 1.0 + 0.1 milli
20. 201 + 20.1

CHAPTER SUMMARY

This first chapter dealt mostly with writing numbers in either scientific notation or engineering notation. Keep in mind that although engineering notation is used most of the time in electronics, and other technical areas, the multiplier names are used to replace powers of 10.

The following key points should be noted.

- Numbers that are greater than 1 have a positive power of 10.
- Numbers that are less than 1 have a negative power of 10.
- 10 to the zero power (10^0) equals 1. Any number to the zero power equals 1.
- When converting from one multiplier to another, the actual value of the number does not change, even though the decimal place moves.
- When a positive multiplier is multiplied by a negative multiplier of the same size (kilo and milli) the result is canceled unit multipliers. The final answer will be in basic units.
- When a positive multiplier is divided into basic units, the result is a negative multiplier of equal size (kilo divided into basic units results in milli). Also, basic divided by negative gives a positive.

Table 1-2. Engineering Notation.

Multiply By	Power of 10	Multiplier Name	Symbol
1,000,000,000,000	10^{12}	tera	T
1,000,000,000	10^{9}	giga	G
1,000,000	10^{6}	mega	M
1,000	10^{3}	kilo	k
1	10^{0}	basic unit	(no multiplier)
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n
0.000 000 000 001	10^{-12}	pico	p

Practice Problems

Change each to the units shown.

1. 2,400,000 Ω ____________ kΩ ____________ MΩ (ohms)
2. 353,000 Hz ____________ kHz ____________ MHz (hertz)
3. 2500 W ____________ mW ____________ kW (watts)
4. 25 V ____________ mV ____________ kV (volts)

5. .01 H ____________ μH ____________ mH (henries)
6. 1.5 kΩ ____________ Ω ____________ MΩ (ohms)
7. 25 MHz ____________ kHz ____________ GHz (hertz)
8. .03 GHz ____________ MHz ____________ Hz (hertz)
9. 56 MV ____________ kV ____________ V (volts)
10. 75 kW ____________ W ____________ MW (watts)
11. 25 mA ____________ μA ____________ A (amps)
12. 1500 μA ____________ A ____________ mA (amps)
13. 1000 μF ____________ pf ____________ f (farads)
14. .001 pF ____________ μF ____________ nf (farads)
15. .025 mV ____________ μV ____________ V (volts)
16. 7500 mW ____________ W ____________ μW (watts)
17. 500 V ____________ kV ____________ mV (volts)
18. 2,400 mV ____________ V ____________ kV (volts)
19. 1 A ____________ kA ____________ mA (amps)
20. 10 V ____________ mV ____________ kV (volts)