

NIDA SERIES 130E INTRODUCTION TO ELECTRICITY

BASIC ELECTRICITY **UNIT I - DC CIRCUITS** 

# **LESSON 3**

# METRIC NOTATION

# **OBJECTIVES**

On completion of this lesson, the student will have learned to:

- 1. Convert decimal numbers to numbers expressed in powers of ten and back again to decimal numbers.
- 2. Convert decimal numbers to numbers expressed with metric prefixes and back again to decimal numbers.
- 3. Add, subtract, multiply, and divide numbers expressed in powers of ten and metric prefixes.

# PREREQUISITES

Basic math skills of adding, subtracting, multiplying and dividing. Also basic skills for adding and subtracting positive and negative numbers.

# EQUIPMENT REQUIRED

None

# **OVERVIEW**

Solving math problems which use very large and very small numbers is both difficult and time consuming.

Very large and very small numbers consist of many digits, often zeros. Anyone who has worked with a lot of zeros knows that mistakes in math are easy to make with such numbers.

Powers of ten and metric prefixes are shorthand methods for expressing very large and very small numbers. When you express numbers in this shorthand, your numbers contain only a few digits.

You can, therefore, perform math operations with greater accuracy. You'll also find your work is much easier, your work goes faster, and your problems take less space to write.

This lesson teaches students to express decimal numbers in powers of ten and metric prefixes.

Students then learn how to perform basic math operations, using numbers expressed in powers of ten and metric prefixes.

# INTRODUCTION

You will make a lot of electrical measurements in your electronics studies. These measurements often involve very large and very small numbers. What's more, you'll often have to add, subtract, multiply, and divide the numbers.

Imagine yourself multiplying 20,000,000 by .000071.

That's a lot of work. It's also difficult, and it takes a lot of time and space to write out.

Mistakes are easy to make when you work with all those zeros, too. Coming up with a wrong answer like 142 or 14,200 is easy.

The problem would be a lot easier if you could just forget about the zeros. Without the zeros, you could multiply  $71 \times 2$  to get 142. The only difficulty then would be figuring out where to put the decimal.

That's exactly what you can do if you use powers of ten. Whether you need to add, subtract, multiply, or divide, you can forget about the zeros. And you also can keep track of exactly where to put the decimal point.

Of course, you could just write 20 million and 71 millionths instead of 20,000,000 and .000071. That isn't any better, though.

We do have another way to write numbers, a way that is both shorter and easier: with metric prefixes.

With metric prefixes, you can write 20,000,000 as 20 Mega or 20 M and .000071 as 71 micro or  $71\mu$ . That really is a lot better, isn't it?

You're probably thinking that even though it looks easier, it's really harder because you don't know anything about metric prefixes.

Think again. You're a lot more familiar with metric prefixes than you think you are.

- When did you last check your electric bill? How much electricity did you use? Some of you might measure your electricity in dollars. The electric company, however, measures electricity in kilowatt hours.
- Do you run or know someone who runs? A lot of runners like to run in races. Did you ever hear of a 5 k (kilometer race)?
- When did you last hear on TV or read in the newspaper about our country's military weapons? Most of these news reports also talk about the size of the weapons, like 10 megaton bombs.

This lesson won't turn you into a mathematician. It will, however, teach you to use powers of ten and metric prefixes. Then you'll be able to add, subtract, multiply, and divide very large and very small numbers easily and accurately. You might even find you enjoy it.

Let's start with powers of ten, since that's what we base metric prefixes on.

#### POWERS OF TEN

The number system you've used all your life, whether you know it or not, is the decimal system. We also call this system the base-10 system. That's because the system uses ten digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9.

We can use powers of ten in this base-10 system. With powers of ten, we can keep track of where to put the decimal point in very large and small numbers.

#### CONVERTING DECIMAL NUMBERS TO POWERS OF TEN NUMBERS

Let's write the number one million. You already know how to write it as a decimal number with 6 zeros: 1,000,000. Since the number 10 is the base number in our decimal number system, we can also break 1,000,000 down into tens.

Then we could write 1,000,000 as  $10 \times 10 \times 10 \times 10 \times 10 \times 10$ . This is actually longer than the original 1,000,000, but it does show us one thing. It shows us that we used the number 10 as a multiplier 6 times.

#### Example 1: Multiplying the 10s for 1,000,000 Broken Down into Tens.

$\frac{10}{10} \times \frac{10}{10} = 1,000$	See how you can multiply out the 10s to equal 1,000,000? We underlined the number 10 each
$\frac{10}{10} \times 1,000 = 10,000$ $\frac{10}{10} \times 10,000 = 100,000$ $10 \times 100,000 = 1,000,000$	time we used it as a multiplier. As you can see, we used 10 six times as a multiplier.

With this information, we can say one million equals ten to the sixth power. We write ten to the sixth power like this:

#### $1,000,000 = 10^{6}$

The number 10 is the **base number**. The base number is always 10, by definition, in our decimal number system.

The little number 6 is the <u>exponent</u>, or the power. An exponent shows how many times you use the base number as a multiplier. This example shows that we used the base number 10 as a multiplier 6 times.

The entire unit is a **power of ten**. A power of ten consists of a base number 10 with an exponent. We call the unit a power of ten because the exponent raises the base number to a power specified by the exponent number.

For 1,000,000, the power of ten exponent is a positive number: +6. Here are more decimal numbers for which the power of ten exponent is a positive number:

#### Example 2: Powers of Ten with Positive Exponents.

$10^{0} = 1$	Notice that all the exponents are positive.
$10^{1} = 10$	Also notice that all the decimal numbers
$10^{2} = 100$	equal 1 or more than 1.
$10^{3} = 1,000$ $10^{4} = 10,000$ $10^{5} = 100,000$ $10^{6} = 1,000,000$	The reverse is also true. If a number equals 1 or is greater than 1, the exponent is always positive.

Now, instead of one million, let's write one millionth. We can write it as .000001 or as  $1 \div 1,000,000$ .

We can also write one millionth in a fraction, as you see to the right:  $\frac{1}{1,000,000}$ 

When we break the 1,000,000 in that fraction<br/>down into tens, we get:1Now let's write the fraction using powers of ten: $\frac{1}{10 \times 10 \times 10 \times 10 \times 10 \times 10}$ Now let's write the fraction using powers of ten: $\frac{1}{10^6}$ We get the exponent for this power of ten<br/>using math operations you'll learn later. $\frac{1}{10^6} = 10^{-6}$ 

The base number is 10, but this time the exponent is not a positive number. It's a negative number: -6. Here are more decimal numbers for which the power of ten exponent is a negative number:

#### Example 3: Powers of Ten with Negative Exponents.

$10^{-1} = .1$ $10^{-2} = .01$	Notice that all the exponents are negative, yet all the base numbers are positive.
$10^{-3} = .001$ $10^{-4} = .0001$ $10^{-5} = .00001$ $10^{-6} = .000001$ $10^{-7} = .000001$	Also notice that when an exponent is negative, the base number always equals less than 1. The reverse of this is true, too. Numbers less than 1 always have negative exponents.

Converting decimal numbers to powers of ten has been quite easy so far. That's because the decimal numbers have all been multiples of 1. We have ignored the 1 so far because 1 times any number equals that number. For example: 1 x 3 = 3 and 1 x 1,000,000 = 1,000,000.

Not all numbers expressed in powers of ten, however, are multiples of 1. For instance, take the number 2,000,000. How do you express this number in powers of ten?

#### Example 4: 2,000,000 Expressed in Powers of Ten.

We all know:	$2,000,000 = 2 \times 1,000,000.$
We also know:	$1,000,000 = 10^6$ .

Substituting  $10^6$  for 1,000,000, we find: 2,000,000 = 2 x  $10^6$ .

As you can see, a decimal number expressed in powers of ten really consists of two units or factors. These factors are the:

- Power of ten.
- Numerical coefficient.

The power of ten for the number 2,000,000 is  $10^6$ . The numerical coefficient is 2.

You already know about the power of ten. Now you know that the <u>numerical coefficient</u> is the number to the left of the power of ten. This is the number you multiply by the power of ten.

Let's go back over some of these new terms before going on. Figure 1 shows the number 2,000,000 expressed in powers of ten. The labels in the figure identify the new terms.



Figure 1. 2,000,000 Expressed in Powers of Ten

Now here are the definitions for these four new terms. As you read the definition of each term, locate the term in Figure 1.

# **DEFINITIONS**

BASE NUMBER: Always 10 in the decimal number system.

**EXPONENT**: Number that shows how many times you use the base number as a multiplier.

**<u>POWER OF TEN</u>**: A base number and an exponent.

**NUMERICAL COEFFICIENT:** A number multiplied by the power of ten.

#### Example 5: Decimal Numbers Expressed in Powers of Ten.

The process of converting decimal numbers to powers of ten is easy to follow with this two-step method.

25,000,000	=	25 x 1,000,000	=	25 x 10 <sup>6</sup>
326,000	=	326 x 1,000	=	326 x 10 <sup>3</sup>
8	=	8 x 1	=	8 x 10º
.005	=	5 x .001	=	5 x 10 <sup>-3</sup>
.000456	=	456 x .000001	=	456 x 10⁻ <sup>6</sup>

A shorter way to convert decimal numbers is to move the decimal point in the decimal number. You simply move the decimal left or right as needed to determine the numerical coefficient. The number of digits you move the decimal is the same as the value of the exponent.

This method is not as confusing as it sounds. The following example will help you see how simple it really is.

Moving the Decimal Point in a Decimal Number That Equals 1

or Is Greater Th	an 1.	
$25,000 = 25,000. \times 10^{\circ}$		As you can see, the samples all
$25,000 = 2,500.0 \times 10^{1}$	or 2,500 x 10 <sup>1</sup>	show 25,000 expressed in powers of ten. The exponent is always positive because the
$25,000 = 250.00 \times 10^2$ $2\overline{1}$	or 250 x 10 <sup>2</sup>	number 25,000 is greater than 1.
$25,000 = 25.000 \times 10^{3}$ $\overline{3}\overline{2}\overline{1}$	or 25 x 10 <sup>3</sup>	Starting with the first number in
25,000 = 2.5000 x 10 <sup>4</sup> 4321	or $2.5 \times 10^4$	Note that the decimal point moves one place to the left and
$25,000 = .25000 \times 10^5 \\ .5\bar{4}\bar{3}\bar{2}\bar{1}$	or .25 x 10 <sup>5</sup>	the exponent increases by 1 with each number.

Now start at the last number in the example and read each number going up the list. Note that the decimal point moves one place to the right and the exponent decreases by 1 with each number.

When the exponent of a power of ten changes, the value of the power of ten also changes. This is logical since the value of an exponent depends on how many places the decimal moves.

For instance, let's increase the exponent of  $10^2$  by 1. Now we have  $10^3$ . Since  $10^2 = 100$  and  $10^3 = 1,000$ , you can see that increasing the exponent has increased the power of ten value.

Example 6:

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Changing negative exponents works just the same. Remember, though, that with negative exponents, you are increasing or decreasing a number which equals less than 1. You also must remember how to add and subtract when you have negative numbers.

Here are a couple of problems to refresh your memory about adding and subtracting when you have negative numbers.

#### Example 7: Adding and Subtracting with Negative Numbers.

5 + (-1) = 4 5 - (-1) = 6 -5 + (-1) = -6 -5 - (-1) = -43 + (-2) = 1 3 - (-2) = 5 -3 + (-2) = -5 -3 - (-2) = -1

Do you see a pattern here? Look again. Every time the problem contains two negatives (-), the negatives cancel each other out. They become, in effect, a positive (+).

Thus, 5 - (-1) is the same as 5 + 1. Both equal 6. And -3 - (-2) is the same as -3 + 2. Both equal -1. Just for practice, work the following problems and write your answers in the blanks provided.

1. 6 - (-3) =	2. 6 + (-3) =	36 + (-3) =
49 - (-7) =	59 + (-7) =	6. 9 - (-7) =

Let's increase the exponent of  $10^{-2}$  by 1. This means we will be adding a positive number to a negative number. In this case, we have -2 + 1 = -1. The negative number has increased by 1. Now let's do the same thing with the  $10^{-2}$ , which equals .01 (one hundredth). Increasing the exponent by 1 gives us  $10^{-1}$ , which equals .1 (one tenth). By increasing the exponent, we increased the number (.1 is larger than .01).

Now let's decrease the exponent of  $10^{-2}$  by 1. Since -2 - 1 = -3, the power of ten becomes  $10^{-3}$ , which equals .001 (one thousandth). We have decreased the number, since .001 is less than .01.

#### Example 8: Moving the Decimal Point in a Number that Equals Less Than 1.

$$.00025 = .00025 \times 10^{\circ}$$
  

$$.00025 = 0.0025 \times 10^{-1} \text{ or } .0025 \times 10^{-1}$$
  

$$.00025 = 0.0025 \times 10^{-2} \text{ or } .025 \times 10^{-2}$$
  

$$.00025 = 0.0025 \times 10^{-3} \text{ or } .25 \times 10^{-3}$$
  

$$.00025 = 0.0025 \times 10^{-4} \text{ or } 2.5 \times 10^{-4}$$
  

$$.00025 = 0.0025 \times 10^{-4} \text{ or } 2.5 \times 10^{-4}$$
  

$$.00025 = 0.0025 \times 10^{-5} \text{ or } 25 \times 10^{-5}$$

The samples all show .00025 expressed in powers of ten. As you can see, moving the decimal to convert .00025 to powers of ten works the same as with 25,000.

The exponent is always negative because .00025 is less than 1. The base number is always positive even though the exponent is negative. Read down the list. Notice that the negative exponent increases by 1 (i.e., you add a -1) when you move the decimal one place to the right. Now read up the list. The negative exponent decreases by 1 (i.e., you subtract a -1) when you move the decimal one place to the left.

The two examples above illustrate that:

- 1. The value of the exponent is the same as the number of digits the decimal point moves.
- 2. Moving the decimal affects the value of the exponent.
  - Decimal moves left -- exponent increases.
  - Decimal moves right -- exponent decreases.
- 3. Moving the decimal affects the value of the numerical coefficient.
  - Decimal moves left -- numerical coefficient decreases.
  - Decimal moves right -- numerical coefficient increases.

Here are some more examples to show the effect of moving the decimal.

Example Q.	Decimal Number	Converted to	Powers of	Ton with	Docitivo I	Typopont
Example 9.	Decimal Number	Converted to	FOWERS OF		FUSILIVE I	Exponent.

$3,300 = 3,300 \times 10^{\circ}$	As the decimal moves left, the coefficients decrease
$3,300 = 330 \times 10^{1}$	(33 is less than 330). At the same time, the
$3,300 = 33 \times 10^2$	exponents increase (2 is more than 1). Notice that
$3,300 = 3.3 \times 10^3$	the exponent value is the same as the number of
$3,300 = .33 \times 10^4$	digits the decimal moves.

#### Example 10: Decimal Number Converted to Powers of Ten with Negative Exponent.

$.0033 = .0033 \times 10^{\circ}$	As the decimal moves right, the coefficients
$0.0033 = 0.033 \times 10^{-1}$	increase (.33 is more than .033). At the same
$.0033 = .33 \times 10^{-2}$	time, the exponents decrease $(-2 \text{ is less than } -1)$ .
$.0033 = 3.3 \times 10^{-3}$	
$.0033 = 33 \times 10^{-4}$	of digits the decimal moves.

The following rule states how moving the decimal affects the exponents.

# <u>RULE</u>

A power of ten exponent <u>increases</u> by 1 each time the decimal moves 1 digit to the <u>left</u>.

A power of ten exponent <u>decreases</u> by 1 each time the decimal moves 1 digit to the <u>right</u>.

One difficulty with using powers of ten is that you have to choose from more than one answer. In electronics, however, we have a preferred answer. The numerical coefficient always is a number between 1 and 10 in the preferred answer. To convert a coefficient to the preferred answer, just increase or decrease the exponent as needed and move the decimal accordingly.

# Remember: Always convert your answer to the preferred answer unless your instructor specifically tells you to do otherwise.

#### Example 11: Expressing Powers of Ten with Preferred Answers.

6,120,000,000.	$= 6.12 \times 10^9$	Let's use the first number,
57,000.	$= 5.7 \times 10^4$	6,120,000,000, to illustrate. You
23.	$= 2.3 \times 10^{1}$	can write this number other ways too,
.031	$= 3.1 \times 10^{-2}$	such as $612 \times 10^7$ . The preferred
.00008	$= 8 \times 10^{-5}$	answer, though, is 6.12 x $10^9$
.00000099	$= 9.9 \times 10^{-8}$	because the coefficient (6.12) is
		between 1 and 10.

#### CONVERTING POWERS OF TEN NUMBERS TO DECIMAL NUMBERS

If you remember the exponent rule, converting a power of ten number to a decimal number is easy. Decimal moves left; exponent increases. Decimal moves right; exponent decreases. All you do is move the decimal either left or right until the power of ten equals 10°, which equals 1.

#### Example 12: Converting 7.1 x 10<sup>5</sup> (Positive Exponent) to its Equivalent Decimal Number.

7.1 x 10 <sup>5</sup> 71. x 10 <sup>4</sup> 710. x 10 <sup>3</sup> 7,100. x 10 <sup>2</sup> 71,000. x 10 <sup>1</sup> 710 000 x 10 <sup>0</sup>	= $71. \times 10^4$ = $710. \times 10^3$ = $7,100. \times 10^2$ = $71,000. \times 10^1$ = $710,000. \times 10^0$ = $710,000$	Move the decimal to the right, one digit at a time. Move it as many digits as you need to decrease the exponent to where the power of ten equals $1 (10^{\circ})$ .
710,000. x 10 <sup>0</sup>	= 710,000	power of ten equals 1 (10°).

# Example 13: Converting 3.12 x $10^{-4}$ (Negative Exponent) to its Equivalent Decimal Number.

		Move the decimal to the
3.12 x 10 <sup>-4</sup>	$= .312 \times 10^{-3}$	left, one digit at a time.
.312 x 10⁻³	$= .0312 \times 10^{-2}$	Move it as many digits as
.0312 x 10 <sup>-2</sup>	$= .00312 \times 10^{-1}$	you need to increase the
.00312 x 10 <sup>-1</sup>	$= .000312 \times 10^{\circ}$	exponent to where the
.000312 x 10 <sup>0</sup>	= .000312	power of ten equals 1
		(10 <sup>°</sup> ).

### Remember: The exponent increases when you move the decimal point left. The exponent decreases when you move the decimal point right. This is true for both positive and negative exponents.

# REVIEW

Let's review by going over some examples of what you have learned so far in this lesson.

<u>Review Example 1</u>: Converting Decimal Numbers to Powers of Ten.

800	$= 8 \times 10^2$	Decimal moves 2 digits to the left.
125,000	= 1.25 x 10 <sup>5</sup>	Decimal moves 5 digits to the left.
15	$= 1.5 \times 10^{1}$	Decimal moves 1 digit to the left.
.36	= 3.6 x 10 <sup>-1</sup>	Decimal moves 1 digit to the right.
.000831	= 8.31 x 10 <sup>-4</sup>	Decimal moves 4 digits to the right.

<u>Review Example 2</u>: Converting Powers of Ten to Decimal Numbers.

7 x 10 <sup>3</sup>	= 7,000	Decimal moves 3 digits to the right.
5.1 x 10⁵	= 510,000	Decimal moves 5 digits to the right.
3.3 x 10⁻³	= .0033	Decimal moves 3 digits to the left.
1.001 x 10 <sup>-6</sup>	= .000001001	Decimal moves 6 digits to the left.
3 x 10 <sup>0</sup>	= 3	Decimal does not move.

# Exercise 1: Powers of Ten.

Convert these numbers to their power of ten or decimal number equivalents. Write your answers in the blanks provided.

1. 27,000 =		5.	$5 \times 10^4 =$	
2. 490,000 =	<del>7</del>	<i>.</i>	$6.7 \times 10^3 =$	
3. 999,000,000 =		3.	5.9 x 10 <sup>9</sup> =	
4000066 =		).	3 x 10 <sup>-3</sup> =	
500000056 =	10	).	4.8 x 10 <sup>-5</sup> =	

# PREVIEW

At the beginning of this lesson we told you using powers of ten makes math operations easier. Do you remember the two decimal numbers we used in the introduction? They were 20,000,000 and .000071. Do you remember multiplying these decimal numbers at the beginning of the lesson?

What happens if we convert these numbers to powers of ten and then multiply them? You'll learn how to do that later in this lesson. We'll do it here, though, to whet your appetite.

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We can multiply these numbers as decimal numbers: $\times \begin{array}{c} 20,000,0\\ \hline 20,000,0\\ \hline 20,000,0\\ \hline 1,400,000,0\\ \hline 1,420,000,0\\ \hline 1$	OC, we can convert to powers of 10 at multiply the resulti numbers: ,420	int the numbers ind ing $2 \times 10^7$ $\times \frac{7.1 \times 10^{-5}}{14.2 \times 10^2}$ = 1,420
Follow this process for the 2nd meth	od:	
Convert to powers of 10: Multiply the coefficients: 2 $\times \frac{7.1}{14}$	20,000,00 and .0000	$00 = 2 \times 10^7$ $071 = 7.1 \times 10^{-5}$
Add the exponents of the powers of	ten: $10^7 + 10^{-5} - 10^2$	
Combine the numerical coefficient w	th the power of ten:	14.2 x 10 <sup>2</sup>
Convert the power of ten number to	a whole number:	1,420

As you can see, this is the same answer we got when we multiplied the two decimal numbers:  $10,000,000 \times .000071 = 1,420$ .

# METRIC PREFIXES

What is a prefix? The dictionary defines prefix as "something that comes before". In other words, a prefix is a group of letters with specific meaning which comes before the beginning of a word. Here are some words with the prefixes underlined: <u>reheat</u>, <u>prewash</u>, and <u>non</u>stop.

A metric prefix, like any prefix, is a group of letters with a specific meaning. Metric prefixes, however, come before or attach to the beginning of units of measure such as mile, foot, meter, or liter. We use metric prefixes to specify the quantity of the unit of measure. Do you remember our illustrations at the beginning of the lesson?

- The word <u>kilo</u>watt on your electric bill is the same as saying 1,000 watts.
- Running a 5 <u>kilo</u>meter (5 k) race is the same as running a 5,000 meter race.
- A news report about a 10 <u>mega</u>ton bomb is the same as a news report about a 10,000,000 ton (of TNT) bomb.

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We base metric prefixes on powers of ten. Writing numbers expressed in metric prefixes is even shorter than writing them in powers of ten. To learn to use metric prefixes, you must first learn the specific meaning of those you'll find in electronics.

Take the number 6,000 for example. Converted to powers of ten, 6,000 equals  $6 \times 10^3$ . Converted to metric prefixes, however, you have the following:

$$6,000 = 6 \times 10^3 = 6 \text{ k} (6 \text{ kilo})$$

If you had the choice, which one would you use?

You can express all decimal numbers with metric prefixes, even those whose equivalent power of ten numbers have negative exponents. Table 1 lists the metric prefixes commonly used in electronics. The table also shows the symbols for the metric prefixes with their equivalent decimal and powers of ten numbers.

NUMBER	POWER OF TEN	PREFIX	SYMBOL
1 000 000 000	10 <sup>9</sup>	Giga	G
1 000 000	10 <sup>6</sup>	Mega	М
1 000	10 <sup>3</sup>	kilo	k
1	10 <sup>0</sup>		
0.001	10 <sup>-3</sup>	milli	m
0.000 001	10 <sup>-6</sup>	micro	μ
0.000 000 001	10 <sup>-9</sup>	nano	n
0.000 000 000 001	10 <sup>-12</sup>	pico	р

 Table 1. Metric Prefixes

# CONVERTING DECIMAL NUMBERS TO METRIC PREFIX NUMBERS

To convert decimal numbers to metric prefix numbers, you must first convert the decimal numbers to their equivalent powers of ten. The exponent of the power of ten must be a multiple of three.

Look back at Table 1. Notice that all the power of ten exponents are multiples of three. If the power of ten exponent is not a multiple of three, you will end up with the wrong metric prefix number.

# Example 14: Converting Decimal Numbers to Metric Prefix Numbers.

Table 2 shows the process of converting decimal numbers to metric prefix numbers.

	POWER		
DECIMAL NUMBER	Preferred	Multiple of 3	METRIC PREFIX
7,000,000,000	7 x 10 <sup>9</sup>	7 x 10 <sup>9</sup>	7 Giga or 7 G
6,800,000	6.8 x 10 <sup>6</sup>	6.8 x 10 <sup>6</sup>	6.8 Mega or 6.8 M
31,000	3.1 x 10 <sup>4</sup>	.031 x 10 <sup>6</sup> 31 x 10 <sup>3</sup>	.031 Mega or .031 M 31 kilo or 31 k
528	5.28 x 10 <sup>2</sup>	528 x 10 <sup>°</sup>	528
6	6 x 10 <sup>°</sup>	6 x 10 <sup>°</sup>	6
.9	9 x 10 <sup>-1</sup>	900 x 10 <sup>-3</sup> .9 x 10 <sup>0</sup>	900 milli or 900 m .9
.08	8 x 10 <sup>-2</sup>	80 x 10 <sup>-3</sup>	80 milli or 80 m
.00073	7.3 x 10 <sup>-4</sup>	730 x 10 <sup>-6</sup>	730 micro or 730 $\mu$
.000000087	8.7 x 10 <sup>-9</sup>	8.7 x 10 <sup>-9</sup>	8.7 nano or 8.7 n

Notice that the decimal numbers 31,000 and .9 have two correct answers. 31,000 equals both .031 M and 31 k, and .9 equals both 900 m and .9. In situations like this, metric prefix numbers are just like powers of ten numbers. You must choose the preferred answer.

With metric prefixes, the **preferred answer** is the one in which the metric prefix number equals, or is greater than, 1. For 31,000 and .9 in Table 2 above, the preferred answers are 31 k and 900 m.

When converting decimal numbers to metric prefix numbers, remember:

- (1) Make sure your power of ten exponent is a multiple of three or your metric prefix number will be wrong.
- (2) Always convert your answer to the preferred answer.

# CONVERTING METRIC PREFIX NUMBERS TO DECIMAL NUMBERS

To convert metric prefix numbers to decimal numbers, you simply reverse the above process. First, convert the metric prefix number to its equivalent power of ten. Then convert the power of ten to its equivalent decimal number by moving the decimal left or right.

Look again at Table 2. This time, look at the table in reverse, so the Metric Prefix column is your first column.

### **Example 15:** Converting Metric Prefix Numbers to Decimal Numbers.

Table 3 shows the process of converting metric prefix numbers to decimal numbers.

METRIC PREFIX	POWER OF TEN	DECIMAL NUMBER
26 p	26 x 10 <sup>-12</sup>	.00000000026
192 <i>µ</i>	192 x 10 <sup>-6</sup>	.000192
1 m	1 x 10 <sup>-3</sup>	.001
5	5 x 10 <sup>°</sup>	5
670	670 x 10 <sup>°</sup>	670
2.3 k	2.3 x 10 <sup>3</sup>	2,300
414 M	414 x 10 <sup>6</sup>	414,000,000

 Table 3. Converting Metric Prefix Numbers to Equivalent Decimal Numbers

#### REVIEW

Using metric prefixes is easy once you understand powers of ten. For now, you probably need to refer to Table 1 to determine which prefix to use. You'll use the prefixes and their symbols so often, however, that you won't need the table for very long.

If you're having any problems, go back over the first part of this lesson. Be sure you're comfortable working with both powers of ten and metric prefixes before going on.

# Exercise 2: Metric Prefixes.

Convert these numbers to their metric prefix or decimal number equivalents.

1.	10,000 =	6.	3.4 M =
2.	16,000,000 =	7.	2.88 k =
3.	.00006 =	8.	7.9 m =
4.	.0034 =	9.	8.4 <i>µ</i> =
5.	128 =	10.	7 =

# MATH OPERATIONS

In electronics you will frequently perform math operations using powers of ten and metric prefix numbers. Thus, you must know how to add, subtract, multiply, and divide with both powers of ten and metric prefix numbers.

First, you'll learn how to add, subtract, multiply, and divide with powers of ten. Then, you'll apply what you've learned about math operations with powers of ten to metric prefix numbers.

#### POWERS OF TEN

Learning how to do math operations with powers of ten numbers is easier if you study the operations separately. That's because to work one problem, you do one thing with the power of ten and a different thing with the coefficient. What you do to each one depends on whether you're adding, subtracting, multiplying, or dividing.

You will learn math operations with powers of ten numbers in the following order:

- Addition and Subtraction.
- Multiplication.
- Division.

#### Addition and Subtraction

Let's start by presenting the rule for adding and subtracting powers of ten numbers:

# <u>RULE</u>

**NUMERICAL COEFFICIENTS**: Add or subtract the coefficients, as the problem directs.

<u>POWERS OF TEN</u>: Exponent values must match. If not, change exponent value(s) as needed so they are the same. Do not add or subtract exponents. The exponent value in the answer is the same as the value of the matching exponents in the problem.

#### **Example 16:** Powers of Ten Numbers That Have the Same Exponents.

6 x 10 <sup>3</sup>	6 x 10 <sup>3</sup>
+ <u>2 x 10<sup>3</sup></u>	- <u>2 x 10<sup>3</sup></u>
8 x 10 <sup>3</sup>	4 x 10 <sup>3</sup>
3 x 10⁻ <sup>6</sup>	3 x 10 <sup>-6</sup>
+ <u>2 x 10<sup>-6</sup></u>	<u>− 2 x 10<sup>-6</sup></u>
5 x 10 <sup>-6</sup>	1 x 10⁻ <sup>6</sup>

Notice that we subtracted the coefficients in the subtraction problems and added the coefficients in the addition problems. Notice also that the power of ten exponent in each answer is the same as the matching exponents in the problem. We did not add or subtract the power of ten exponents. Why do the exponents have to match when you add and subtract powers of ten numbers? Also, why don't you add or subtract the exponents?

The reason is that trying to add  $2 \times 10^{\circ}$  and  $1 \times 10^{1}$  is like trying to add 2 feet and 3 yards. You can't add 2 feet and 3 yards unless you change yards to feet or feet to yards so they match. Once you change the 3 yards to 9 feet, for example, the problem is easy: 2 feet + 9 feet = 11 feet.

Adding and subtracting powers of ten numbers works exactly the same. You can't add  $2 \times 10^{\circ}$  and  $1 \times 10^{1}$  because the exponents don't match. The value of the coefficients is not the same because the value of the exponent affects where the decimal is.

Let's change the exponents of  $2 \times 10^{\circ}$  and  $1 \times 10^{1}$  so they match. You can change whichever one you want, just like you did with the feet and yards. In this case, let's change the  $10^{1}$  to  $10^{\circ}$ , as shown in the next example.

#### Example 17: Changing Exponents So They Match for Adding and Subtracting.

This example shows you the individual steps for changing power of ten exponents so they match.

Exponents do not match, so change one:	$(2 \times 10^{\circ}) + (1 \times 10^{1})$
Now the exponents match:	$(2 \times 10^{\circ}) + (10 \times 10^{\circ})$
Add the numerical coefficients:	2 + 10 = 12
Combine the answer with the power of ten:	12 x 10°
Convert to the preferred answer:	1.2 x 10 <sup>1</sup>

When you combine the separate steps, you come up with a problem that looks like this:

 $(2 \times 10^{\circ}) + (1 \times 10^{1}) = (2 \times 10^{\circ}) + (10 \times 10^{\circ}) = 12 \times 10^{\circ} = 1.2 \times 10^{1}$ 

In the lesson exercises, however, your problems will look a little different. The next example shows what your exercise problems will look like. It also shows how you should write your answers.

Example 18:	Adding and	Subtracting	When Power of	Ten Exponents	Are Different.
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$$4 \times 10^{3} = 40 \times 10^{2}$$
  
+  $3 \times 10^{2} = + \frac{3 \times 10^{2}}{43 \times 10^{2}} = 4.3 \times 10^{3}$ 

or:

$$4 \times 10^{3} = 4.0 \times 10^{3} + 3 \times 10^{2} = + 0.3 \times 10^{3} + 0.3 \times 10^{3} = 4.3 \times 10^{3}$$

Notice that you can change the exponents to either 2 or 3. You can use either way shown in the example to get the preferred answer (with coefficient between 1 and 10).

$$4 \times 10^{3} = 40 \times 10^{2}$$
  
- 3 × 10<sup>2</sup> = 3 × 10<sup>2</sup>  
37 × 10<sup>2</sup> = 3.7 × 10<sup>3</sup>

or

$$4 \times 10^{3} = 4.0 \times 10^{3}$$
  
- 
$$3 \times 10^{2} = \frac{0.3 \times 10^{3}}{3.7 \times 10^{3}} = 3.7 \times 10^{3}$$

Again you can choose which exponent value to use. You choose the exponent value that gives the preferred answer. You save time if you don't have to convert the answer.

$$8 \times 10^{-3} = 80 \times 10^{-4}$$
  
+ 1 x 10^{-4} = 1 x 10^{-4}  
81 x 10^{-4} = 8.1 x 10^{-3}

or

$$8 \times 10^{-3} = 8.0 \times 10^{-3}$$
  
+  $1 \times 10^{-4} = 0.1 \times 10^{-3}$   
 $8.1 \times 10^{-3} = 8.1 \times 10^{-3}$ 

This problem is just like the first two, with one exception. This time the exponents of the powers of ten are negative instead of positive.

$$8 \times 10^{-3} = 80 \times 10^{-4}$$

$$- 1 \times 10^{-4} = 1 \times 10^{-4}$$

$$79 \times 10^{-4} = 7.9 \times 10^{-3}$$
or
$$8 \times 10^{-3} = 8.0 \times 10^{-3}$$

$$- 1 \times 10^{-4} = 0.1 \times 10^{-3}$$

$$7.9 \times 10^{-3} = 7.9 \times 10^{-3}$$

In this problem, the exponents of the powers of ten are also negative instead of positive.

# Exercise 3: Adding and Subtracting Powers of Ten.

Work the following problems, adding or subtracting as directed. Remember to convert your answers to the preferred answer if the coefficient is not between the numbers 1 and 10.

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1.	$5 \times 10^2$ + <u>4 × 10<sup>3</sup></u>	2.	$5 \times 10^{3}$ + <u>4 × 10<sup>2</sup></u>
3.	5 x 10 <sup>-2</sup> + <u>4 x 10<sup>-3</sup></u>	4.	$5 \times 10^{-3}$ + <u>4 x 10^{-2}</u>

5.	$5 \times 10^{-1}$ + <u>4 × 10<sup>1</sup></u>	6.	$4 \times 10^{-1}$ + <u>5 x 10<sup>1</sup></u>
7.	$5 \times 10^3$ - <u>4 × 10<sup>2</sup></u>	8.	4 x 10 <sup>-2</sup> - <u>5 x 10<sup>-3</sup></u>
9.	4 x 10 <sup>1</sup> - 5 x 10 <sup>-1</sup>	10.	$5 \times 10^{1}$ - 4 x 10 <sup>-1</sup>

#### **Multiplication**

The rule for multiplying powers of ten states:

<u>RULE</u>

<u>NUMERICAL COEFFICIENTS</u>: Multiply the numerical coefficients.

**<u>POWERS OF TEN</u>**: Add the powers of ten exponents.

# Example 19: Multiplying Powers of Ten with Positive Exponents.

Let's multiply these numbers:	$(3 \times 10^3) \times (6 \times 10^2)$
Multiply the coefficients:	$3 \times 6 = 18$
Add the exponents $(3 + 2 = 5)$ :	$10^3 + 10^2 = 10^5$
Combine the coefficient and power of ten:	18 x 10⁵
Convert to the preferred answer:	1.8 x 10 <sup>6</sup>
Convert to the decimal equivalent:	1,800,000

When you combine the separate steps, you come up with a problem that looks like this:

$$(3 \times 10^3) \times (6 \times 10^2) = 18 \times 10^5 = 1.8 \times 10^6 = 1,800,000$$

Let's prove that when you multiply powers of ten, you add the exponents and that the answer above is correct. We do this by performing the following math operations:

First convert each power of ten to its decimal equivalent.

 $10^3 = 10 \times 10 \times 10 = 1,000$  $10^2 = 10 \times 10 = 100$  Next multiply the decimal number equivalents of  $10^3$  (1,000) and  $10^2$  (100). This gives you 100,000, the decimal number equivalent of  $10^5$ .

$$1,000 \times 100 = 100,000 = 10^5$$

Then combine the  $10^5$  decimal equivalent (100,000) with the product of the coefficients (3 x 6 = 18).

 $18 \times 100,000 = 1,800,000$ 

This answer matches the answer in the example above, thus proving that your method was correct.

#### Example 20: Multiplying Powers of Ten with Negative and Positive Exponents.

Multiply these numbers:	(1 x 10 <sup>3</sup> ) x (1 x 10 <sup>-3</sup>	)
First multiply the coefficients:	$1 \times 1 = 1$	
Now add the exponents:	$10^3 + 10^{-3} = 10^0$ (3)	3 + -3 = 0)
Combine the two and convert to the decimal equivalent:	$1 \times 10^{\circ} = 1$	
State the completed problem:	(1 x 10 <sup>3</sup> ) x (1 x 10 <sup>-3</sup>	$t = 1 \times 10^{\circ} = 1$
Prove the answer is correct as follows:		
Convert the powers of ten to their decimation	al equivalents:	$10^3 = 1,000$ $10^{-3} = .001$
Now multiply the decimal equivalents of to get 1, the decimal equivalent of 10°:	10 <sup>3</sup> and 10 <sup>-3</sup>	1,000 x .001 = 1
Multiply your answer (1) by the product of	of the two	

coefficients  $(1 \times 1 = 1)$ : This answer matches the answer in the example above, thus proving that your method

was correct.

#### Example 21: Multiplying Powers of Ten Numbers.

4 x 10 <sup>3</sup>	1 x 10 <sup>-4</sup>	6 x 10 <sup>-3</sup>
× <u>2 x 10<sup>-2</sup></u>	× <u>2 x 10<sup>-3</sup></u>	× <u>1 x 10<sup>-2</sup></u>
8 x 10 <sup>1</sup>	2 x 10 <sup>-7</sup>	6 x 10 <sup>-5</sup>

UNIT I

#### **Division**

The rule for dividing powers of ten states:

#### <u>RULE</u>

<u>NUMERICAL COEFFICIENTS</u>: Divide the numerical coefficients.

**<u>POWERS OF TEN</u>**: Subtract the powers of ten exponents.

#### Example 22: Dividing Powers of Ten with Positive Exponents.

Let's divide these numbers:		$(6 \times 10^6) \div (2 \times 10^2)$
First divide the coefficients:		$6 \div 2 = 3$
Next subtract the exponents (6 -	2 = 4):	$10^6 - 10^2 = 10^4$
Combine the coefficient and powe	r of ten:	3 x 10 <sup>4</sup>
Convert the answer to its decimal	equivalent:	30,000
State the completed problem:	$(6 \times 10^6) \div (2 \times 10^6)$	$10^2$ ) = 3 x $10^4$ = 30,000

Let's prove that when you divide powers of ten, you subtract the exponents and that the answer above is correct. We do this by performing the following math operations:

First convert each power of ten to its decimal equivalent:

 $10^6 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1,000,000$  $10^2 = 10 \times 10 = 100$ 

Next divide the decimal number equivalents of  $10^6$  (1,000,000) and  $10^2$  (100). This gives you 10,000, the decimal number equivalent of  $10^4$ .

$$1,000,000 \div 100 = 10,000 = 10^4$$

Then combine the  $10^4$  decimal equivalent (10,000) with the answer from dividing the coefficients (6 ÷ 2 = 3).

$$3 \times 10,000 = 30,000$$

This answer matches the answer in the example above, thus proving that your method was correct.

# Example 23: Dividing Powers of Ten with Negative and Positive Exponents.

Divide these numbers:	$(1 \times 10^{-3}) \div (1 \times 10^{2})$
First divide the coefficients:	$1 \div 1 = 1$
Now subtract the exponents:	$10^{-3} - 10^2 = 10^{-5} (-3 - 2 = -5)$
Combine the two and convert to the decimal equivalent:	$1 \times 10^{-5} = .00001$
State the completed problem: $(1 \times 10^{-3}) \div (1 \times 10^{-3})$	$10^2$ ) = 1 x $10^{-5}$ = <u>.00001</u>
Prove the answer is correct as follows:	
Convert the powers of ten to their decimal equivalents:	$10^{-3} = .001$ $10^{2} = 100$
Now divide the decimal numbers to get the decimal equivalent of 10 <sup>-5</sup> :	$.001 \div 100 = .00001 = 10^{-5}$
Then combine the $10^{-5}$ decimal equivalent with the coefficient $(1 \div 1 = 1)$ :	1 x .00001 = <u>.00001</u>

This answer matches the answer in the example above, thus proving that your method was correct.

# Example 24: Dividing Powers of Ten Numbers.

### **Exercise 4:** Multiplying and Dividing Powers of Ten.

Work the following problems, multiplying or dividing as directed. Remember to convert your answers to the preferred answer if the coefficient is not between the numbers 1 and 10.

<sup>1.</sup> $3 \times 10^2$	2.	5 x 10 <sup>2</sup>
$\times \underline{2 \times 10^3}$		$\times$ <u>3 x 10<sup>3</sup></u>

<sup>3.</sup> 
$$3 \times 10^{-2}$$
  
×  $2 \times 10^{-3}$   
<sup>4.</sup>  $5 \times 10^{-2}$   
×  $3 \times 10^{-3}$ 

<sup>5.</sup> 
$$3 \times 10^{-2}$$
  
×  $2 \times 10^{3}$   
<sup>6.</sup>  $3 \times 10^{2}$   
×  $2 \times 10^{-3}$ 

<sup>7.</sup> 
$$6 \times 10^3$$
  
 $\div 2 \times 10^2$ 
<sup>8.</sup>  $6 \times 10^{-3}$   
 $\div 2 \times 10^{-2}$ 

<sup>9.</sup> 
$$6 \times 10^{-3}$$
  
 $\div 2 \times 10^{2}$   
<sup>10.</sup>  $6 \times 10^{3}$   
 $\div 2 \times 10^{2}$   
<sup>10.</sup>  $2 \times 10^{-2}$ 

### METRIC PREFIXES

Work in electronics often requires that you perform math operations with numbers expressed in metric prefixes. You already know how to convert decimal and powers of ten numbers to metric prefix numbers. Therefore, going one step farther, performing math operations, will be easy.

When two metric prefix numbers have the same prefix, you can simply add or subtract, as directed. When the prefixes are different or if you are multiplying or dividing, you first convert the metric prefix numbers to powers of ten. Then you perform the math operation, as directed, following the rules you learned for working with powers of ten numbers.

Here are some problems to show you how to perform math operations using metric prefix numbers.

Example 25:	Math	operations	with	metric	prefixes.
-------------	------	------------	------	--------	-----------

3 k	5 μ	5 M	3 k
+ <u>2 k</u>	+ $4 \mu$	– <u>2 M</u>	– <u>2 k</u>
5 k	9 μ	3 M	1 k
6 M = 6 + $20 k = + 20$ or	$x 10^{6} = 6000 x$ $x 10^{3} = + 20 x$ $6020 x$ $= 6.00 x$ $= + .02 x$ $6.02 x$	$10^{3}$ $\frac{10^{3}}{10^{3}} = 6.02 \times 1$ $10^{6}$ $\frac{10^{6}}{10^{6}} = 6.02 \text{ M}$	0 <sup>6</sup> = 6.02 M
6 k = 6 - $200 = -200$	$x \ 10^3 = 6000 \times \frac{x \ 10^0}{x \ 5800} = -\frac{200 \ x}{5800}$		$0^3 = 5.8 \text{ k}$
-	= 60	x 10 <sup>3</sup>	
	_ 0.0	$\times 10^3$	
	<u>.</u> Z		
	5.8	$x 10^{\circ} = 5.8 \text{ K}$	

$2 \mu = 2 \times 10^{-6}$	$8 M = 8 \times 10^{6}$
× <u>3 k</u> = × <u>3 × 10<sup>3</sup></u>	÷ $2 m = 2 \times 10^{-3}$
<u>6 × 10<sup>-3</sup></u> = 6 m	$4 \times 10^{9} = 4 G$
$25 k = 25 \times 10^{3}$ $\times 5 \mu = \times 5 \times 10^{-3}$ $125 \times 10^{0} = 125$	$120 = 120 \times 10^{0}$ ÷ <u>2 k</u> = ÷ <u>2 x 10<sup>3</sup></u> 60 x 10 <sup>-3</sup> = 60 m

### Exercise 5: Math Operations with Metric Prefixes.

Add, subtract, multiply, and divide these metric prefix numbers as directed. Write all answers in metric prefix numbers.

1.	2 k	2.	2 m
	+ 400		+ 900 $\mu$
3.	4 m	4.	6 M
	– <u>2 m</u>		– <u>900 k</u>
5.	6	6.	2 k
	– <u>800 m</u>		– <u>2 m</u>
7.	2 p	8.	1 k
	× <u>8 k</u>		× <u>1 m</u>
9.	3 M	10.	10 <i>µ</i>
	÷ <u>2 k</u>		÷ <u>2 k</u>

# <u>SUMMARY</u>

Here is a summary of what you should have learned in this lesson on metric notation. Notice that the summary separates the lesson into two segments: the facts you should know and what you should be able to do.

# FACTS YOU SHOULD KNOW

- You can express all decimal numbers in powers of ten numbers.
- Powers of ten numbers consists of a numerical coefficient multiplied by a power of ten.
- A power of ten consists of a base number and an exponent.
- The power of ten exponent is positive when the equivalent decimal number equals 1 or more than 1.
- The power of ten exponent is negative when the equivalent decimal number equals less than 1.
- The exponent value decreases when you move the decimal point to the right.
- The exponent value increases when you move the decimal point to the left.

# WHAT YOU SHOULD BE ABLE TO DO

- Convert decimal numbers to powers of ten numbers and to metric prefix numbers.
- Convert metric prefix numbers to powers of ten numbers and to decimal numbers.
- Add, subtract, multiply, and divide powers of ten numbers and metric prefix numbers.