

# Electric circuit analysis

**introduction**

# Introduction

## Introduction

One of the most important rules to remember and apply when working in any field of technology is to use the correct units when substituting numbers into an equation.

Too often we are so intent on obtaining a numerical solution that we overlook checking the units associated with the numbers being substituted into an equation. Results obtained, therefore, are often meaningless.

# Units of measurement

## UNITS OF MEASUREMENT

For example, the following very fundamental physics equation

$$v = \frac{d}{t}$$

**Where**  $v = \text{velocity}$

$d = \text{distance (m)}$

$t = \text{time (s)}$

*so the unit of measurements of velocity is*

$$v = m/s$$

# Systems of units

## SYSTEMS OF UNITS

| English                                                                                       | Metric                                                                                 |                                                   |                                                             |
|-----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------------|-------------------------------------------------------------|
|                                                                                               | MKS                                                                                    | CGS                                               | SI                                                          |
| <b>Length:</b><br>Yard (yd)<br>(0.914 m)                                                      | Meter (m)<br>(39.37 in.)<br>(100 cm)                                                   | Centimeter (cm)<br>(2.54 cm = 1 in.)              | <b>Meter (m)</b>                                            |
| <b>Mass:</b><br>Slug<br>(14.6 kg)                                                             | Kilogram (kg)<br>(1000 g)                                                              | Gram (g)                                          | <b>Kilogram (kg)</b>                                        |
| <b>Force:</b><br>Pound (lb)<br>(4.45 N)                                                       | Newton (N)<br>(100,000 dynes)                                                          | Dyne                                              | <b>Newton (N)</b>                                           |
| <b>Temperature:</b><br>Fahrenheit (°F)<br>$\left( = \frac{9}{5}^{\circ}\text{C} + 32 \right)$ | Celsius or<br>Centigrade (°C)<br>$\left( = \frac{5}{9}(^{\circ}\text{F} - 32) \right)$ | Centigrade (°C)                                   | <b>Kelvin (K)</b><br>$\text{K} = 273.15 + ^{\circ}\text{C}$ |
| <b>Energy:</b><br>Foot-pound (ft-lb)<br>(1.356 joules)                                        | Newton-meter (N-m)<br>or joule (J)<br>(0.7376 ft-lb)                                   | Dyne-centimeter or erg<br>(1 joule = $10^7$ ergs) | <b>Joule (J)</b>                                            |
| <b>Time:</b><br>Second (s)                                                                    | Second (s)                                                                             | Second (s)                                        | <b>Second (s)</b>                                           |

**TABLE 1.1** *Comparison of the English and metric systems of units.*

# System of units

## Table of Base Units

| System         | Length             | Mass             | Time          |
|----------------|--------------------|------------------|---------------|
| SI(mks)        | meter (m)          | kilogram<br>(kg) | second<br>(s) |
| Gaussian (cgs) | centimeter<br>(cm) | gram (g)         | second<br>(s) |
| British (fps)  | foot (ft)          | slug<br>*pound   | second<br>(s) |

# Power of ten

## POWERS OF TEN

The notation used to represent numbers that are integer powers of ten is as follows:

|               |                               |
|---------------|-------------------------------|
| $1 = 10^0$    | $1/10 = 0.1 = 10^{-1}$        |
| $10 = 10^1$   | $1/100 = 0.01 = 10^{-2}$      |
| $100 = 10^2$  | $1/1000 = 0.001 = 10^{-3}$    |
| $1000 = 10^3$ | $1/10,000 = 0.0001 = 10^{-4}$ |

# Powers of ten

## POWERS OF TEN

Some important mathematical equations and relationships pertaining to powers of ten are listed below, along with a few examples. In each case,  $n$  and  $m$  can be any positive or negative real number.

$$\frac{1}{10^n} = 10^{-n} \quad \frac{1}{10^{-n}} = 10^n$$

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### EXAMPLE 1.2

- a.  $\frac{1}{1000} = \frac{1}{10^{+3}} = 10^{-3}$
- b.  $\frac{1}{0.00001} = \frac{1}{10^{-5}} = 10^{+5}$

*continue*

## POWERS OF TEN

The product of powers of ten:

$$(10^n)(10^m) = 10^{(n+m)}$$

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### EXAMPLE 1.3

- a.  $(1000)(10,000) = (10^3)(10^4) = 10^{(3+4)} = 10^7$   
b.  $(0.00001)(100) = (10^{-5})(10^2) = 10^{(-5+2)} = 10^{-3}$
-

*continue*

## POWERS OF TEN

The division of powers of ten:

$$\frac{10^n}{10^m} = 10^{(n-m)}$$

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### EXAMPLE 1.4

a.  $\frac{100,000}{100} = \frac{10^5}{10^2} = 10^{(5-2)} = 10^3$

b.  $\frac{1000}{0.0001} = \frac{10^3}{10^{-4}} = 10^{(3-(-4))} = 10^{(3+4)} = 10^7$

# *Addition and subtraction*

## **POWERS OF TEN**

### Basic Arithmetic Operations

#### 1- Addition and Subtraction :

To perform addition or subtraction using powers of ten, the power of ten must be the same for each term; that is :

$$A \times 10^n \pm B \times 10^n = (A \pm B) \times 10^n$$

# *1. Addition and subtraction*

## **POWERS OF TEN**

### Basic Arithmetic Operations

#### Addition and Subtraction :

$$A \times 10^n \pm B \times 10^n = (A \pm B) \times 10^n$$

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#### **EXAMPLE 1.6**

a.  $6300 + 75,000 = (6.3)(1000) + (75)(1000)$   
 $= 6.3 \times 10^3 + 75 \times 10^3$   
 $= (6.3 + 75) \times 10^3$   
 $= \mathbf{81.3 \times 10^3}$

b.  $0.00096 - 0.000086 = (96)(0.00001) - (8.6)(0.00001)$   
 $= 96 \times 10^{-5} - 8.6 \times 10^{-5}$   
 $= (96 - 8.6) \times 10^{-5}$   
 $= \mathbf{87.4 \times 10^{-5}}$

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## 2. Multiplication

### Basic Arithmetic Operations

#### 2-Multiplication:

$$(A \times 10^n)(B \times 10^m) = (A)(B) \times 10^{n+m}$$

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#### EXAMPLE 1.7

- a.  $(0.0002)(0.000007) = [(2)(0.0001)][(7)(0.000001)]$   
 $= (2 \times 10^{-4})(7 \times 10^{-6})$   
 $= (2)(7) \times (10^{-4})(10^{-6})$   
 $= \mathbf{14 \times 10^{-10}}$
- b.  $(340,000)(0.00061) = (3.4 \times 10^5)(61 \times 10^{-5})$   
 $= (3.4)(61) \times (10^5)(10^{-5})$   
 $= 207.4 \times 10^0$   
 $= \mathbf{207.4}$
-

# 3. Division

## POWERS OF TEN

### Basic Arithmetic Operations

#### 3-Division:

In general :

$$\frac{A \times 10^n}{B \times 10^m} = \frac{A}{B} \times 10^{n-m}$$

When dividing numbers in the powers-of-ten format, first find the result of dividing the multipliers. Then determine the associated power for the result by subtracting the power of ten of the denominator from the power of ten of the numerator.

*continue*

## POWERS OF TEN

### Basic Arithmetic Operations

#### 3-Division:

$$\frac{A \times 10^n}{B \times 10^m} = \frac{A}{B} \times 10^{n-m}$$

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#### EXAMPLE 1.8

$$\begin{aligned} \text{a. } \frac{0.00047}{0.002} &= \frac{47 \times 10^{-5}}{2 \times 10^{-3}} = \left(\frac{47}{2}\right) \times \left(\frac{10^{-5}}{10^{-3}}\right) \\ &= 23.5 \times 10^{-2} \end{aligned}$$

$$\begin{aligned} \text{b. } \frac{690,000}{0.00000013} &= \frac{69 \times 10^4}{13 \times 10^{-8}} = \left(\frac{69}{13}\right) \times \left(\frac{10^4}{10^{-8}}\right) \\ &= 5.31 \times 10^{12} \end{aligned}$$

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# 4. Powers

## Basic Arithmetic Operations

### 4-powers:

In general :

$$(A \times 10^n)^m = A^m \times 10^{nm}$$

When finding the power of a number in the power-of-ten format, first separate the multiplier from the power of ten and determine each separately. Determine the power-of-ten component by multiplying the power of ten by the power to be determined.

*continue*

## Basic Arithmetic Operations

4-powers:

$$(A \times 10^n)^m = A^m \times 10^{nm}$$

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### EXAMPLE 1.9

a.  $(0.00003)^3 = (3 \times 10^{-5})^3 = (3)^3 \times (10^{-5})^3$   
 $= 27 \times 10^{-15}$

b.  $(90,800,000)^2 = (9.08 \times 10^7)^2 = (9.08)^2 \times (10^7)^2$   
 $= 82.4464 \times 10^{14}$

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# prefixes

## Prefixes

| Multiplication Factors         | SI Prefix | SI 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         |
| 0.001 = $10^{-3}$              | milli     | m         |
| 0.000 001 = $10^{-6}$          | micro     | $\mu$     |
| 0.000 000 001 = $10^{-9}$      | nano      | n         |
| 0.000 000 000 001 = $10^{-12}$ | pico      | p         |

*continue*

## Prefixes

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### EXAMPLE 1.10

- a.  $1,000,000 \text{ ohms} = 1 \times 10^6 \text{ ohms}$   
 $= 1 \text{ megohm (M}\Omega\text{)}$
  - b.  $100,000 \text{ meters} = 100 \times 10^3 \text{ meters}$   
 $= 100 \text{ kilometers (km)}$
  - c.  $0.0001 \text{ second} = 0.1 \times 10^{-3} \text{ second}$   
 $= 0.1 \text{ millisecond (ms)}$
  - d.  $0.000001 \text{ farad} = 1 \times 10^{-6} \text{ farad}$   
 $= 1 \text{ microfarad } (\mu\text{F})$
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# *CONVERSION BETWEEN LEVELS OF POWER OF TEN*

## **CONVERSION BETWEEN LEVELS OF POWERS OF TEN**

The procedure is best described by the following steps:

- Replace the prefix by its corresponding power of ten.
- Rewrite the expression, and set it equal to an unknown multiplier and the new power of ten.
- Note the change in power of ten from the original to the new format. If it is an increase, move the decimal point of the original multiplier to the left (smaller value) by the same number. If it is a decrease, move the decimal point of the original multiplier to the right (larger value) by the same number.

*continue*

## CONVERSION BETWEEN LEVELS OF POWERS OF TEN

*Example :*

Convert 20 kHz to megahertz

$$20\text{kHz} = 20 \times 10^3\text{hz}$$

$$1\text{Mhz} = 10^6\text{hz}$$

$$10^6 - 10^3 = 10^3$$

By division on the power difference :

$$\frac{20}{10^3} = 0.02\text{ Mhz}$$

*Example :*

Convert 0.01 ms to microsecond

$$0.01\text{ ms} = 0.01 \times 10^{-3}\text{s}$$

$$1\mu\text{s} = 10^{-6}\text{s}$$

$$10^{-3} - 10^{-6}$$

By division on the power difference :

$$\frac{20}{10^3} = 0.02\text{ Mhz}$$

# Conclusion

## Conclusion

In the past, the systems of units most commonly used were the English and metric.

Note that while the English system is based on a single standard, the metric is subdivided into two interrelated standards: the **MKS** and the **CGS**.

The MKS and CGS systems draw their names from the units of measurement used with each system; the MKS system uses Meters, Kilograms, and Seconds, while the CGS system uses Centimeters, Grams, and Seconds.