Math for the Ham Radio Operator

A prerequisite math refresher for the math phobic ham

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Why is This Lesson for You?

The Technician and General Class license requires the study and understanding of:

- The science and art of radio and electronics.
- The math needed to deal with the scientific concepts.
- The technology (calculator) to do the math.

For some, these three challenges are frustrating to deal with all at the same time.

The result … "memorize the answers."

Math Vocabulary

What are equations and formulas?

What is a variable?

What does solving an equation mean?

Solving and Evaluating – Getting the final answer!

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Useful Formulas for General Exam

Resistors in Series $R_1 + R_2 + R_3 + R_N = R_T$

Resistors in Parallel $\dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_N}} = R_T$

Two Resistors in Parallel $\dfrac{R_1 R_2}{R_1 + R_2} = R_T$

Power formulas $P = E \times I$ $P = I^2 \times R$ $P = \dfrac{E^2}{R}$ $PEP = \dfrac{(E_{RMS})^2}{R}$

Ohms Law: $E = I \times R$ $I = \dfrac{E}{R}$ $R = \dfrac{E}{I}$

AC Voltage: $E_{Peak} = 1.414 E_{RMS}$ $E_{RMS} = 0.707 E_{Peak}$ $E_{Peak-Peak} = 2 * E_{Peak}$

Transformer Turns Ratio: $\dfrac{E_S}{E_P} = \dfrac{N_S}{N_P}$ $\sqrt{\dfrac{Z_P}{Z_S}} = \dfrac{N_P}{N_S}$

Power Gain in decibels: $Gain = 10\log_{10}\left(\dfrac{P2}{P1}\right)db$ $\dfrac{P2}{P1} = 10^{\frac{Gain(db)}{10}}$

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Solving an Equation

Solving an equation means to manipulate the variables to find an equation for the answer we are looking for.

After the equation is solved, it can be evaluated for a numeric value.

Other ways to do it:

- Guessing and then improving the guess.
- Computer programs
- Look up tables and graphs

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Solving an Equation

When we solve an equation, we move what we are looking for to one side of the equal sign, and move everything else to the other side.

There are short cuts to this process, but we are going to stress doing it <u>one-step-at-a-time</u> to reinforce learning the concepts.

It may seem tedious at first, but well worth the effort for later.

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Solving an Equation

We usually solve equations by “moving” variables from one side of the equal to the other.

- The equation must remain in “balance”.
- What you do to one side must be done to the other.
  - Add the same value to both sides.
  - Multiply both sides by the same value.
  - Divide both sides by the same value.

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Solving an Equation

The equation for Ohm’s Law is: E = I*R

- If we know the values of I and R, we can easily calculate E by replacing the variables with the actual numbers. Suppose:
  - I is 10, R is 50 (we will disregard units for now)
  - Therefore: E = 10*50
  - E = $\boxed{500}$ (in this case volts)

Finding R when E and I are known

If we know E (the voltage) and I (the current) and want to find R (the resistance), we need to solve the equation for R and then do the arithmetic.

To do this, we need to move the “I” from the right side to the left side so that the “R” is all by itself on the right side of the equation.

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Solving E=IR for R

E = I*R

Divide both sides by I

$$\frac{E}{I} = \frac{I * R}{I}$$

I/I = 1

(This is called canceling the I's.)

$$\frac{E}{I} = \frac{\cancel{I} * R}{\cancel{I}}$$

$$\frac{E}{I} = R$$

Not necessary to swap the sides.

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Evaluating a Formula!

The equation for total resistance in a series circuit is:

$$R_1 + R_2 + R_3 + R_N = R_T$$

If: R_1= 33, R_2=56, R_3=2200, R_4=5600

Find R_T

33 + 56 + 2200 + 5600 = R_T (Use Calculator)

R_T = $\boxed{7889}$

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Solve for two resistors!

The equation for two resistors in a parallel circuit is:

$$\frac{R_1 R_2}{R_1 + R_2} = R_T$$

- Multiply R_1 times R_2
  - Write the number down
- Add R_1 and R_2
  - Write the number down
- Divide the first number by the second to find the answer.
- (This is not the fastest way to evaluate.)

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Plug in the numbers and crank!

$$\frac{R_1 R_2}{R_1 + R_2} = R_T$$

- $R_1 = 50$
- $R_2 = 200$

- $R_1 * R_2 = ?$
  - 50 * 200 = 10,000
- $R_1 + R_2 = ?$
  - 50 + 200 = 250
- 10,000/250 = $\boxed{40}$
- Could use “(“ and “)” on calculator to group $R_1 + R_2$.

What about R's in parallel!

The equation for equivalent resistance for resistors in a parallel circuit is:

$$\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_N}} = R_T$$

- Do each fraction in the denominator in turn $1/R_n$
  - Write the numbers down
- Add all fraction results together.
  - Write the number down
- Divide 1 by the sum of the fractions.
- Could use 1/X function

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Messy without a calculator!

$$\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_N}} = R_T$$

- $R_1 = 50$
- $R_2 = 100$
- $R_3 = 200$

- $1/R_1 = ?$
  - 1/50 = 0.02
- $1/R_2 = ?$
  - 1/100 = 0.01
- $1/R_3 = ?$
  - 1/200 = 0.005
- Sum of fractions = ?
  - 0.02 + 0.01 +0 .005 =0.035
- 1/Sum of fractions = ?
  - 1/0.035 = $\boxed{28.6}$

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Using the square function!

$$P = \frac{E^2}{R}$$

- Multiply E by E or use the X^2 function and write the number down.
- Divide the squared number by R.

Plug in the numbers!

$$P = \frac{E^2}{R}$$

- $E^2 = 300^2 = 90{,}000$
- $P = 90{,}000/450 = \boxed{200}$

- E = 300
- R = 450

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Find V_{RMS}

$$V_{Peak} = 1.414 V_{RMS}$$

- Solve for V_{RMS}
- Divide both sides by 1.414.
- $V_{Peak} / 1.414 = \cancel{1.414}\ V_{RMS} / \cancel{1.414}$
- Cancel 1.414s on right.
- $V_{Peak} / 1.414 = V_{RMS}$
- Move unknown to Left side.

$$V_{RMS} = V_{Peak} / 1.414 = 0.707\ V_{Peak}$$

$\longrightarrow$

Find the value!

$$V_{Peak} = 1.414 V_{RMS}$$

$V_{Peak} = 100$

- Solve for V_{RMS}
  - $V_{RMS} = V_{Peak} / 1.414$
- Plug in value for V_{Peak}
  - $V_{RMS} = 100/1.414$
  - $100/1.414 = \boxed{70.7}$

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Using two formulas!

$$V_{Peak} = 1.414 V_{RMS}$$

$$PEP = \frac{(V_{RMS})^2}{R}$$

$V_{Peak} = 200$

$R = 50$

Find: PEP

Solve for V_{RMS}

- $V_{RMS} = 200 / 1.414 = 141.4$
- Write the number down

Plug the value in for V_{RMS}.

- $V_{RMS}^2 = 141.4^2 = 19{,}994$
- Write the number down

Divide the square by 50

- $19994/50 = \boxed{399.9}$

An Equation of two Ratios!

$$\frac{E_S}{E_P} = \frac{N_S}{N_P}$$

$$\cancel{E_P} \times \frac{E_S}{\cancel{E_P}} = \frac{N_S}{N_P} \times E_P$$

Solve for E_S

- Multiply both sides by E_P
- The E_P values on the left cancel

- Formula is:

$$\boxed{E_S = \frac{N_S \times E_P}{N_P}}$$

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Finding the Secondary Voltage!

$$E_S = \frac{N_S \times E_P}{N_P}$$

$N_S = 300$

$N_P = 2100$

$E_P = 115$

$E_S = ?$

Multiply N_S by E_P

- 300 * 115 = 34,500
- Write the number down

Divide by N_P.

- 34500/2100 = $\boxed{16.4}$

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The ratio of two numbers!

$$\sqrt{\frac{Z_P}{Z_S}} = \frac{N_P}{N_S}$$

A ratio is a fraction which compares two numbers.

It tells us how many times larger the numerator is than the denominator. i.e., 2, 10, 3.1, ½, etc.

The right side of this equation is a ratio.

The left side is the square root of a ratio.

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Find the Impedance Ratio!

$$\sqrt{\frac{Z_P}{Z_S}} = \frac{N_P}{N_S}$$

$Z_P = 1600$

$Z_S = 8$

Divide Z_P by Z_S

- $1600/8 = 200$
- Write the number down

Find Square root of 200.

- $200^{1/2} = 14.1$

Ratio of N_P to N_S = 14.1 / 1

- Ratio is $\boxed{\text{14.1 to 1}}$

$\longrightarrow$ 

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Logarithms

Logarithms (logs for short) are used for handling very large and very small numbers within the same formula without losing resolution.

Definition of a log of a number:

- "base to the log power" equals the number.
- Base may be any number but 10 is commonly used.

The main use of logs in radio is to express gains or losses as a number measured in decibels (db).

The logs of numbers may be added for multiplication or subtracted for division.

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Log Definitions

Log formula:

$$L = \log_{10} N$$

The number L is the log base 10 of the number N. Logs are found using a table or a calculator. They can be positive or negative.

Anti-log formula:

$$N = 10^{L}$$

The number N is 10 raised to the power L. Antilogs are found using a table or a calculator. They are always positive.

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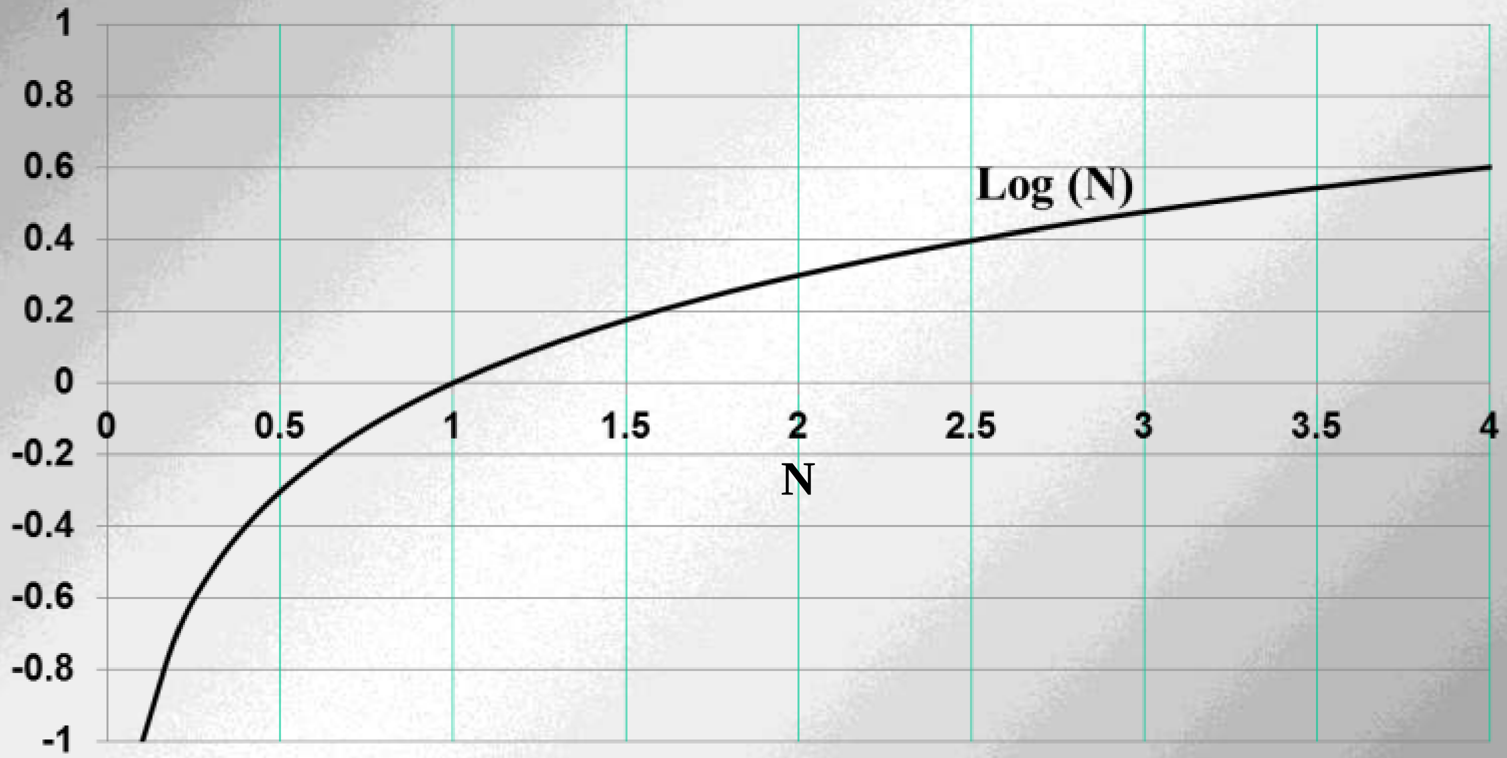
Log graphs are not a straight line



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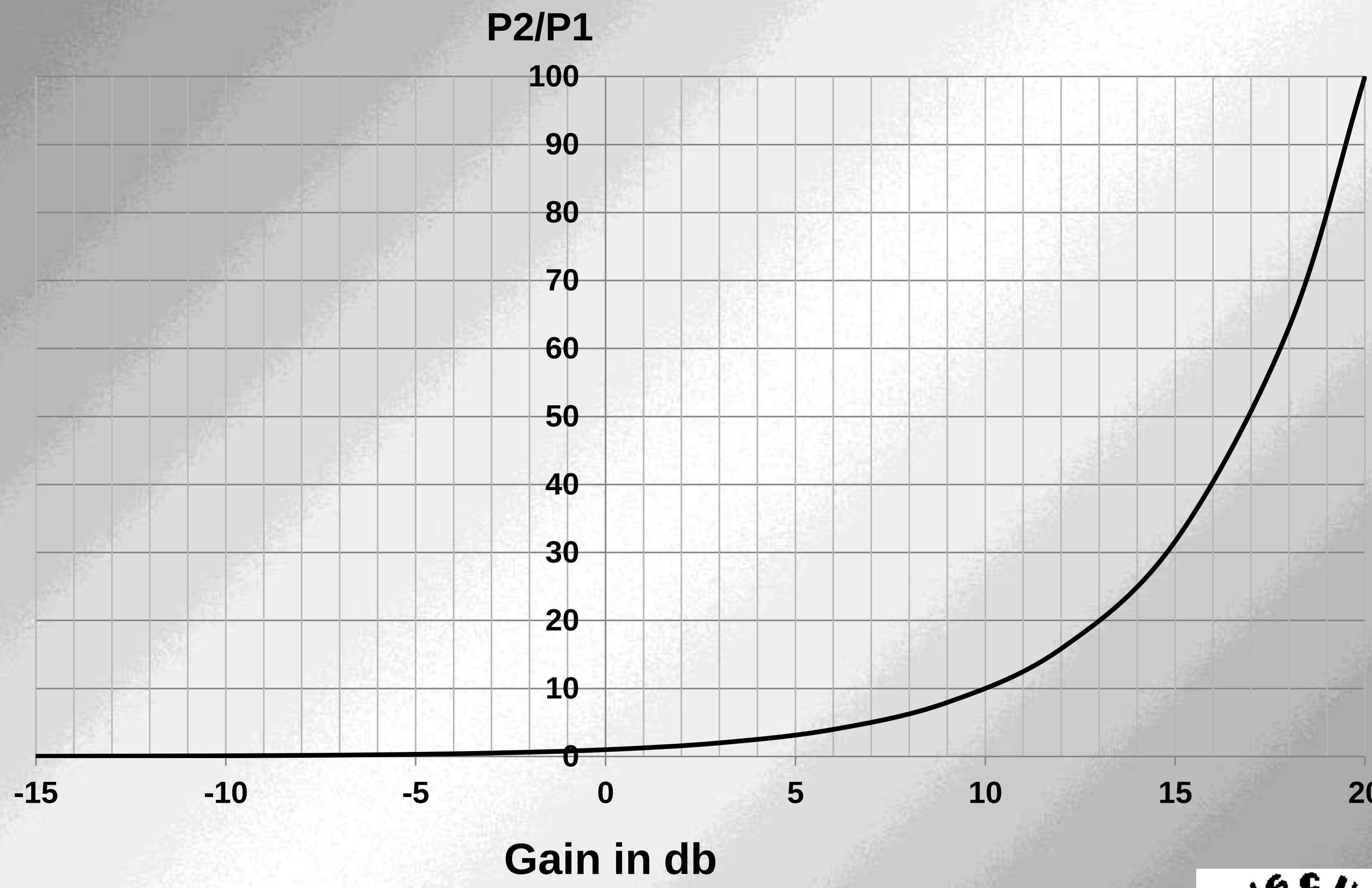
Converting Power Gain to db!

$$Gain = 10\log_{10}\left(\frac{P2}{P1}\right)db$$

Make sure you see that this formula is similar to:

$$L = \log_{10} N$$

- Gain is the same as L.
- P2/P1 is the same as N.
- 10 is just a scaling number.
- db is a unit.



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Convert a gain to db!

$$Gain = 10\log_{10}\left(\frac{P2}{P1}\right)db$$

- Divide P2 by P1.
  - Write the number down.
- Press the log key on your calculator and enter the value of P2/P1.
  - Write the number down.
- Multiply the result by 10.

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Find the value in db!

$$Gain = 10\log_{10}\left(\frac{P2}{P1}\right)db$$

P2 = 200

P1 = 50

Find: Gain in db

- Divide P2 by P1
  - 200/50 = 4
  - Write the number down.
- Find the log:
  - Log (4) = 0.602
  - Write the number down.
- Multiply by 10:
  - 0.602 * 10 = $\boxed{6.02}$

Converting db gain to a number!

Eq. 1

$$Gain = 10\log_{10}\left(\frac{P2}{P1}\right)db$$

Eq. 3

$$\frac{P2}{P1} = 10^{\frac{Gain(db)}{10}}$$

We can solve the basic log equation (Eq. 1) for P2/P1.

- The end result will be Eq. 3. (The steps will not be shown because you won't need to know them.)
- You should write down and know how to use Eq. 3 for calculating the gains of amplifiers or antennas when db is stated.

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Find the value of the gain!

<u>Eq. 3</u>

$$\frac{P2}{P1} = 10^{\frac{Gain(db)}{10}}$$

Gain = -1db

P2/P1 = ?

Divide Gain by 10

- -1/10 = -0.1
- Write the number down.

Find $10^{-0.1}$

- $10^{-0.1} = \boxed{0.794}$

P2/P1 is less than 1 if Gain(db) is negative

Calculator Operations

Although this presentation suggests writing down intermediate results, you can take advantage of the Algebraic Calculator to have fewer steps.

A good strategy:

- Multiply the first two values in the numerator
- Divide by the first value in the denominator.
- Multiply by the next value of the numerator
- Divide by the next value of the denominator.

Use parenthensis on the calculator to combine sums.

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Calculator Operations

$$\frac{33 * 56}{33 + 56} = \boxed{20.8}$$

- Enter 33, X, 56, /, (,33, +, 56,), =
- Most calculators have parenthesis keys.
- Divide key may be / or Division Symbol.
- Round off the answer. Don’t use more digits in the answer than the values contained. Round 20.8 to 21.

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Calculator Operations

$$\frac{1}{\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}} = C_T$$

- Use the 1/X or X^{-1} Key.
- Enter value of C1. Press X^{-1}. Press +.
- Continue with C2 and C3. Press =.
- Press X^{-1}. Be careful with decimal places.
- Answer will be less than any of the values.

Calculator Operations

$$\frac{1}{\frac{1}{C1}+\frac{1}{C2}+\frac{1}{C3}} = C_T$$

C1 = 0.018 uF

C2 = 0.056 uF

C3 = 0.10 uF

- Enter 0.018, X^{-1}, +, 0.056, X^{-1}, +, 0.10, X^{-1}, =
- Read: 83.41269841
- Press X^{-1}, =
- Read: 0.011988582. Answer is $\boxed{0.012.}$
- Note: If you combine microfarad and nanofarad, you might have the wrong value. Convert all values to the same units.

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Handling Large and Small Numbers

Electronics and Radio use a large range of sizes – billionths to billions. Scientific Notation – Powers of 10 – lets us use small numbers for calculating by using prefixes like

- pico, nano, micro, milli for small sizes.
  - Examples: picofarad, microhenry, millimeter
- Kilo, Mega, Giga, Terra for large sizes.
  - Examples: KiloHertz, MegOhms, GigaByte
- Abbreviations: pF, mH, KHz, MHz, GB

<u>Make sure numbers for calculation are the same unit, i.e., combine picoFarads with picoFarads.</u>

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Prefixes for Powers of 10

Prefix	Abbreviation	Power of 10
Pico	p	10 E-12
Nano	n	10 E-9
Micro	u	10 E-6
Milli	m	10 E-3
Kilo	K	10 E3
Mega	M	10 E6
Giga	G	10 E9
Terra	T	10 E12

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Move the decimal point to convert

To From	Pico p	Micro u	Milli m	Unit	Kilo K	Mega M	Giga G
Pico p		← 6	← 9	← 12	← 15	← 18	← 21
Micro u	→ 6		← 3	← 6	← 9	← 12	← 15
Milli m	→9	→3		← 3	← 6	← 9	← 12
Unit	→12	→6	→3		← 3	← 6	← 9
Kilo K	→15	→9	→6	→3		← 3	← 6
Mega M	→18	→12	→9	→6	→3		← 3
Giga G	→21	→18	→12	→9	→6	→3	

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