4. COMPONENTS AND CIRCUITS – NR6H

Chapter 4 Part 1 of 3

ARRL General Class
Sections 4.1, 4.2

Current, Voltage, and Power

CURRENT

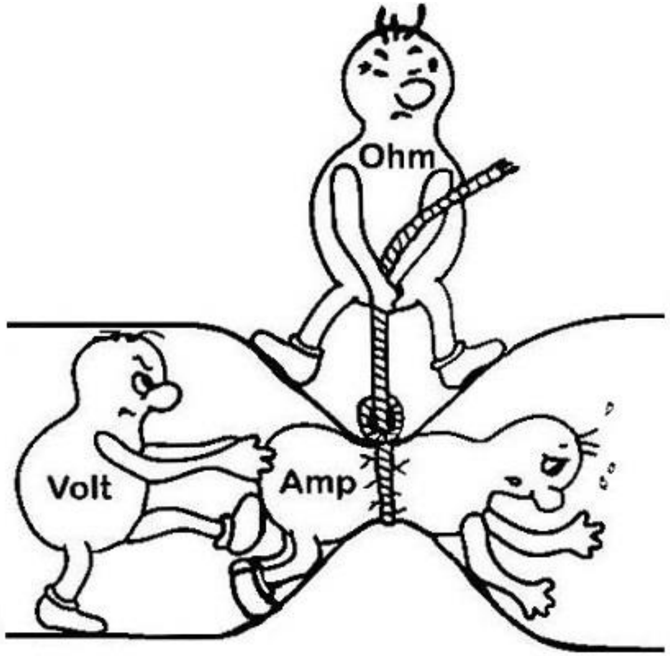
- The flow of electrons
- Measured in ampéres (A) with a ”ammeter”

VOLTAGE

- The force/pressure that makes electrons move
- Measured in volts (V) with a ”voltmeter”

POWER

- The product of voltage and current
- Measured in watts (W)

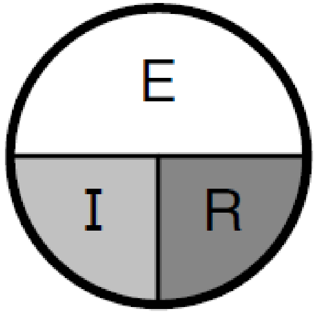


Ohm’s Law

-”The current through a conductor between two points is directly proportional to the voltage across the two points”

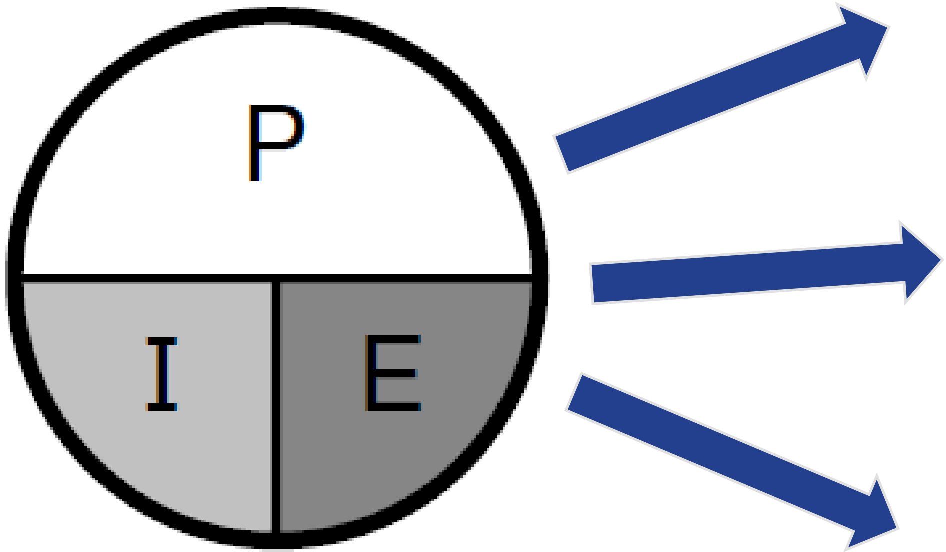
The proportional factor is Resistance:

$$V = IR \quad \text{or} \quad I = \frac{V}{R} \quad \text{or} \quad R = \frac{V}{I}$$



Note: Voltage written either as E, V or U

Power – the rate of work



$$P = E \times I$$

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

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

E = Voltage
I = Current
P = Power

Power algebra

Substituting the Ohm's law equivalents for voltage and current allows power to be calculated using resistance

Substitute I for E/R:

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

Substitute E for I x R:

$$P = E \times I = (I \times R) \times I = I^2 \times R$$

Power calculation example

To find out how many watts of electrical power are used if 400 VDC is supplied to an 800 Ω resistor

$$P = \frac{E^2}{R} = \frac{400 \times 400}{800} = 200W$$

Power calculation another example

How many watts are being dissipated when a current of 7.0 mA flows through a 1.25 kΩ resistor ?

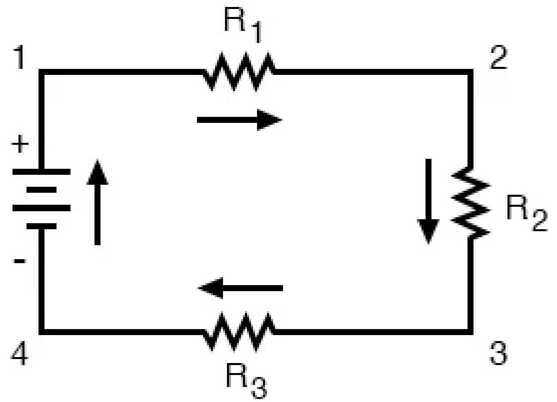
$$P = I^2 \times R$$

$$P = 0.007^2 \times 1250 = 0.06125W = 61.25mW$$

Name	Symbol	Factor
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
		10^{0}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

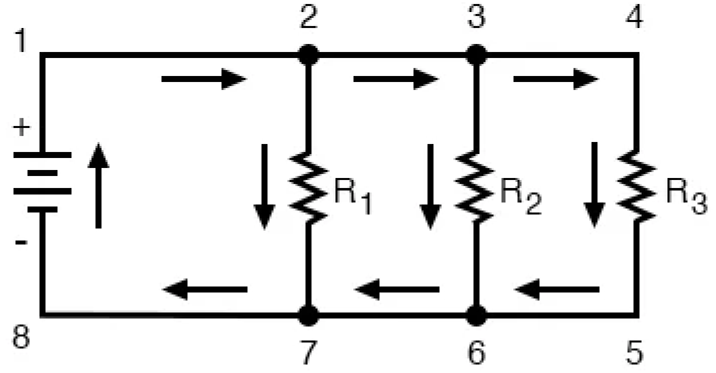
Circuits – Series and Parallel

Circuit: Any complete path through which current can flow



Series Circuit: Two or more components are connected so that the same current flows through all of the components

Parallel Circuit: Two or more components are connected so that the same voltage is applied to all of the components



Decibels (dB)

Bel is a unit-less ratio

- Like percent, but logarithmic
- One decibel (dB) is 1/10th Bel
- Convenient when working with large ratios

POWER

$$dB = 10 \log_{10}(P / P_{ref})$$

0dB = no change (“unity”)
3dB = double power (“gain”)
6dB = 4x power
-3dB = half power (”attenuation”)
-6dB = ¼ power

VOLTAGE

$$dB = 20 \log_{10}(E / E_{ref})$$

0dB = no change
6dB = double voltage
12dB = 4x voltage
-6dB = half voltage
-12dB = ¼ voltage

Examples

-"Amplifier puts out 100W with 2W input"

$10 \log_{10}(100 / 2) = 17$dB (gain)

-"Measuring 4V on the input, and 1V on the output of an attenuator"

$20 \log_{10}(1 / 4) = -12$dB (attenuation/loss)

Remember: dB is a ratio. You should note what the ratio is relative to.

- *dBm = relative to 1mW*
- *dBV = relative to 1Vpp*
- *dBu = relative to 1µV/m*
- *dBd = relative to a dipole*
- *dB$ = relative to one US$ (iPhone 14 = 29dB$, Tesla X = 50dB$, Bezos = 112dB$)*

Calculate ratio from dB

POWER

$dB = 10 \log_{10}(P / P_{ref})$

$Ratio = P / P_{ref} = \log^{-1}(dB / 10)$

VOLTAGE

$dB = 20 \log_{10}(V / V_{ref})$

$Ratio = V / V_{ref} = \log^{-1}(dB / 20)$

Inverse log
(referred to as *antilog*)

Written as : $\log_{10}^{-1}$

or : $\log^{-1}$

On scientific calculators

LOG^{-1}

ALOG

10^X

INV/SHIFT then LOG

Converting dB to percentage and back

$$dB = 10 \log \left(\frac{Percentage\ Power}{100\%} \right) \qquad Percentage\ Power = 100\% \times \log^{-1} \left(\frac{dB}{10} \right)$$

$$dB = 20 \log \left(\frac{Percentage\ Voltage}{100\%} \right) \qquad Percentage\ Voltage = 100\% \times \log^{-1} \left(\frac{dB}{20} \right)$$

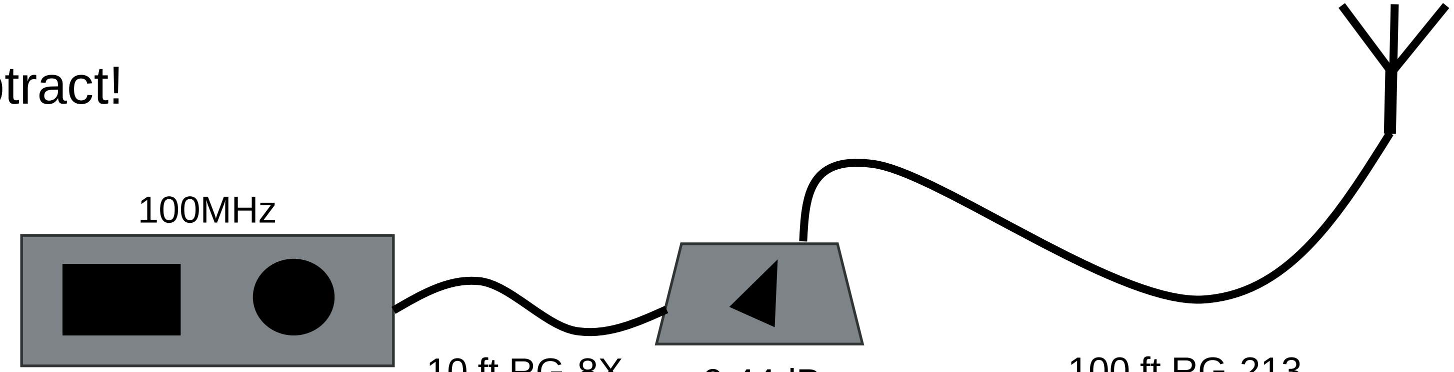
Application example: Suppose you are using an antenna feed line that has a loss of 1dB. You can calculate the amount of transmitter power that's actually reaching your antenna and how much is lost in the feed line.

$$\text{Percentage Power} = 100\% \times \log^{-1} \left(\frac{-1}{10} \right) = 100\% \times \log^{-1}(-0.1) = 79.4\%$$

79.4% of the transmit power reaches the antenna … 20.6% is lost in the feed line.

Practical use of dB

dB add and subtract!



Coax Cable Signal Loss (Attenuation) in dB per 100ft*								
Loss*	RG-174	RG-58	RG-8X	RG-213	RG-6	RG-11	RF-9914	RF-9913
1MHz	1.9dB	0.4dB	0.5dB	0.2dB	0.2dB	0.2dB	0.3dB	0.2dB
10MHz	3.3dB	1.4dB	1.0dB	0.6dB	0.6dB	0.4dB	0.5dB	0.4dB
50MHz	6.6dB	3.3dB	2.5dB	1.6dB	1.4dB	1.0dB	1.1dB	0.9dB
100MHz	8.9dB	4.9dB	3.6dB	2.2dB	2.0dB	1.6dB	1.5dB	1.4dB
200MHz	11.9dB	7.3dB	5.4dB	3.3dB	2.8dB	2.3dB	2.0dB	1.8dB
400MHz	17.3 B	11.2dB	7.9dB	4.8dB	4.3dB	3.5dB	2.9dB	2.6dB

-0.36 - 0.44 - 2.2 = -3.0dB

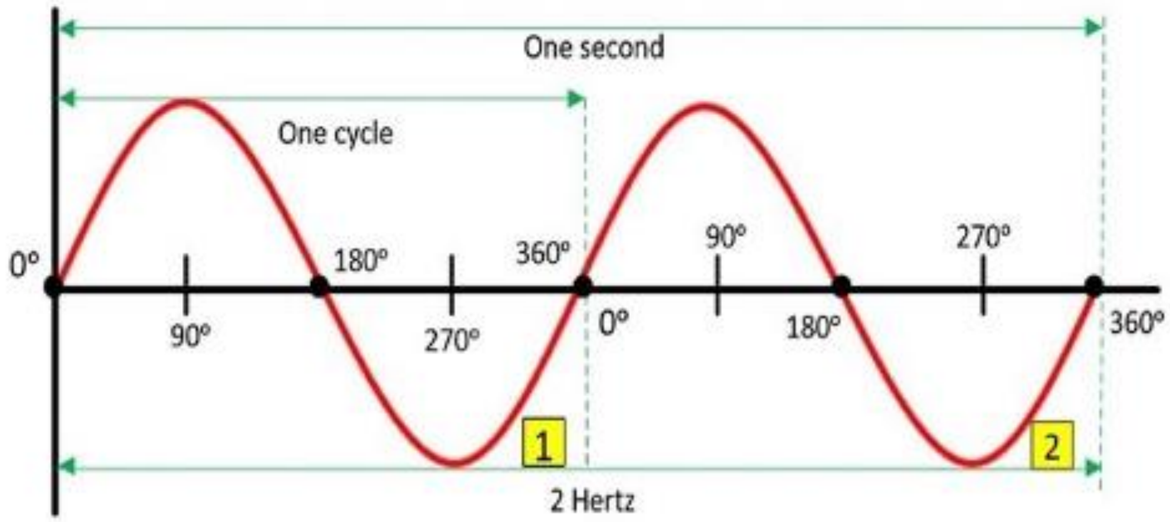
Frequency

A complete sequence of AC current (alternating current) flowing, stopping, reversing, and stopping again is a cycle

The number of cycles per second is the current's frequency (f), measured in hertz (Hz)

A **harmonic** is a frequency at some integer multiple (2, 3, 4, etc.) of a lowest or fundamental frequency

- The harmonic at twice the frequency is the second harmonic, at three times is the third harmonic (there is no first harmonic)



Wavelength

Speed of light in space (c) is 300 million (300×10^6) meters per second
…somewhat slower in wires and cables

Wavelength (λ) of radio wave is the distance it travels during one complete cycle

- $\lambda = c / f$
- $f = c / \lambda$

A radio wave can be referred to by frequency OR wavelength because the speed of light is constant

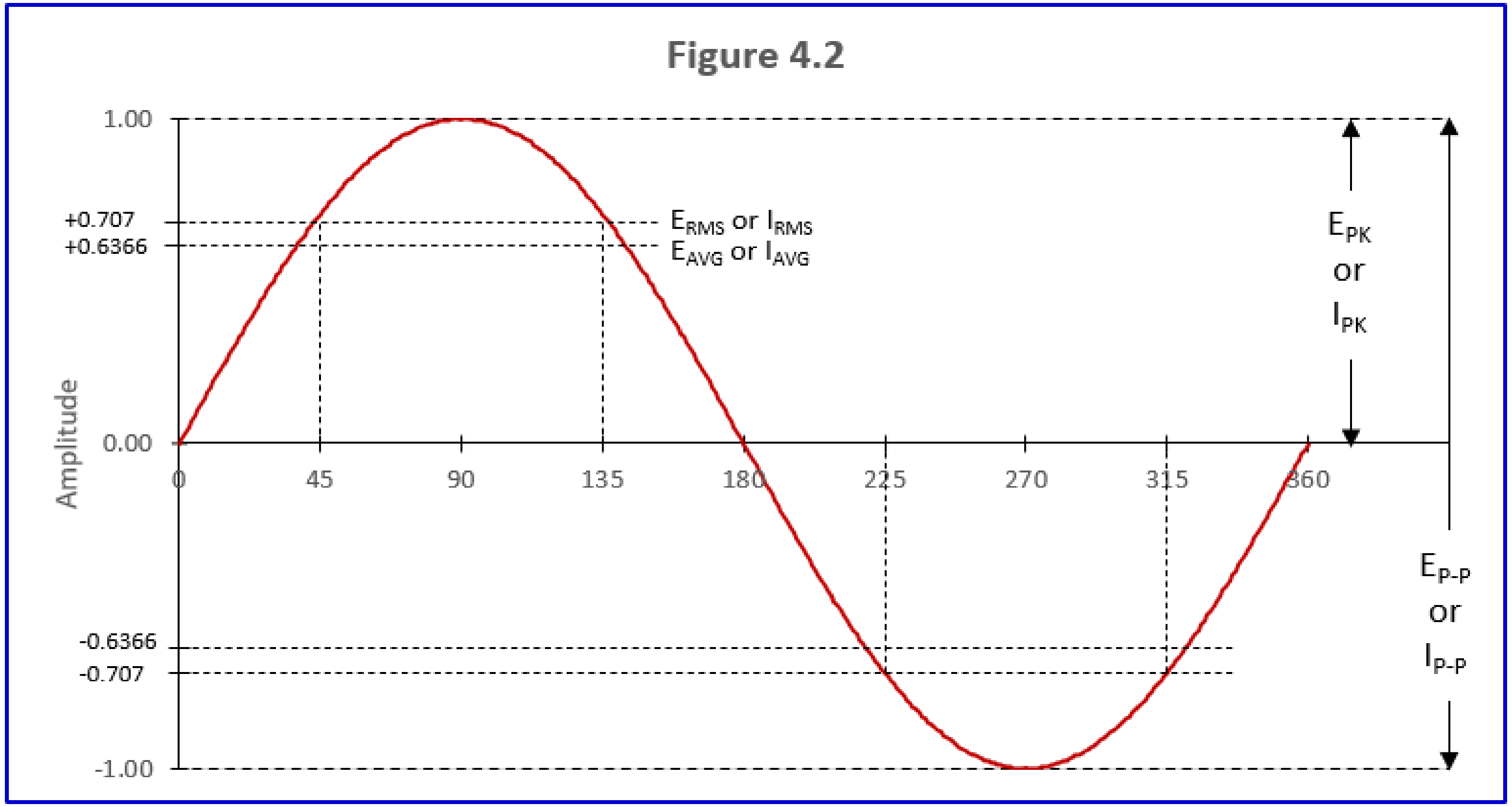
1ft = 0.305m
$c = 983 \times 10^6$ ft

100MHz → $300 \times 10^6 \; / \; 100 \times 10^6 = 3$m

70cm = 0.7m → 300 / 0.7 = 428 MHz

AC Power : P = E x I

But what voltage are we using?



AC Power, RMS

RMS = Root Mean Square

The RMS value of an AC signal is equivalent to the DC voltage that would be required to produce the same heating effect (power).

The RMS for a sine wave is 0.707 (1/√2) times the sine wave’s peak voltage

- $V_{RMS} = 0.707 \times V_{PK}$
- $V_{PK} = 1.414 \times V_{RMS}$
- $V_{PP} = 2 \times V_{PK}$

- Only true for pure sine wave!

Waveform Calculation Examples

A sine wave with a peak voltage of 17 V has what RMS value?

$$V_{RMS} = 0.707 \times V_{PK} = 0.707 \times 17\text{ V} = \mathbf{12\text{ V}}$$

A sine wave with a peak-peak voltage of 100 V has what RMS value?

$$V_{RMS} = 0.707 \times \frac{V_{P\text{-}P}}{2} = 0.707 \times \frac{100}{2} = \mathbf{35.4\text{ V}}$$

A sine wave with an RMS voltage of 120.0 V has what peak-to-peak voltage value?

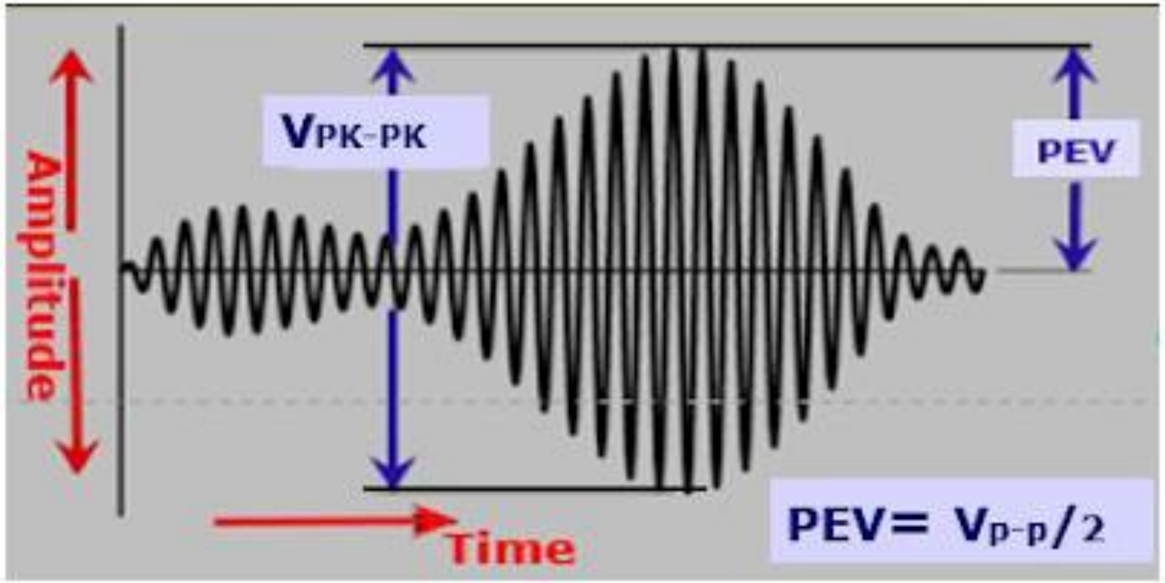
$$V_{P\text{-}P} = 2 \times 1.414 \times 120 = 2.828 \times 120 = \mathbf{339.4\text{ V}}$$

PEP : Peak Envelope Power

PEP (Peak Envelope Power) is the average power of one complete RF cycle at the peak of the signal's envelope.
It is a convenient way to measure or specify the maximum power of amplitude-modulated signals.

To calculate average AC power, you need to know the load impedance and the RMS voltage at the peak of the envelope.

$$\text{PEP} = \frac{V_{RMS}{}^{2}}{R} = \frac{(0.707 \times PEV)^{2}}{R}$$



PEP Calculations

If PEV is 50V across a 50Ω load, the PEP power is:

$$\text{PEP} = \frac{(50 \times 0.707)^2}{50} = \frac{35.35^2}{50} = \frac{1249.62}{50} = 25\text{W}$$

If a 50Ω load is dissipating 1200W PEP, the RMS voltage is …

$$\text{VRMS} = \sqrt{PEP \times R} = \sqrt{1200 \times 50} = 245\text{V}$$

PEP Calculations

If an oscilloscope measures 200 VP-P across a 50 Ω load, what would be the PEP power?

$$PEP = \frac{\left[\frac{0.707 \times 200}{2}\right]^2}{50} = \frac{4999}{50} = 100\text{ W}$$

For the same device at 500 VP-P, the PEP power would be:

$$PEP = \frac{\left[\frac{0.707 \times 500}{2}\right]^2}{50} = \frac{31241}{50} = 625\text{ W}$$

PEP special cases

PEP equals the average power if an amplitude-modulated signal is not modulated

- An example of this is when modulation is removed from an AM signal (leaving only the steady carrier) or when a CW transmitter is keyed

An FM signal is a constant-power signal, so PEP is always equal to average power for FM signals.

An average-reading wattmeter connected to your transmitter reads 1060 W when you close the key on CW. What is your PEP output?

1060 W

QUESTIONS?

ONLINE EXAM REVIEW AND PRACTICE QUESTIONS:

http://www.arrl.org/examreview