Chapter 4
Voltage, Current, and Power

Voltage and Current

Resistance and Ohm's Law

AC Voltage and Power

ARRL The national association for AMATEUR RADIO

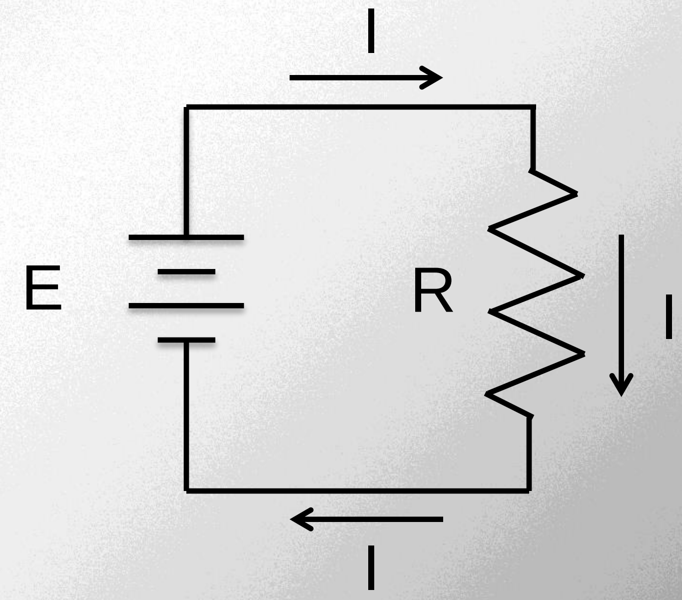
E, I, and R in a Series Circuit

A circuit is a closed path.

E represents the voltage in the circuit – a battery.

I represents the current in the circuit – the same at all points.

R represents the resistance of the circuit.

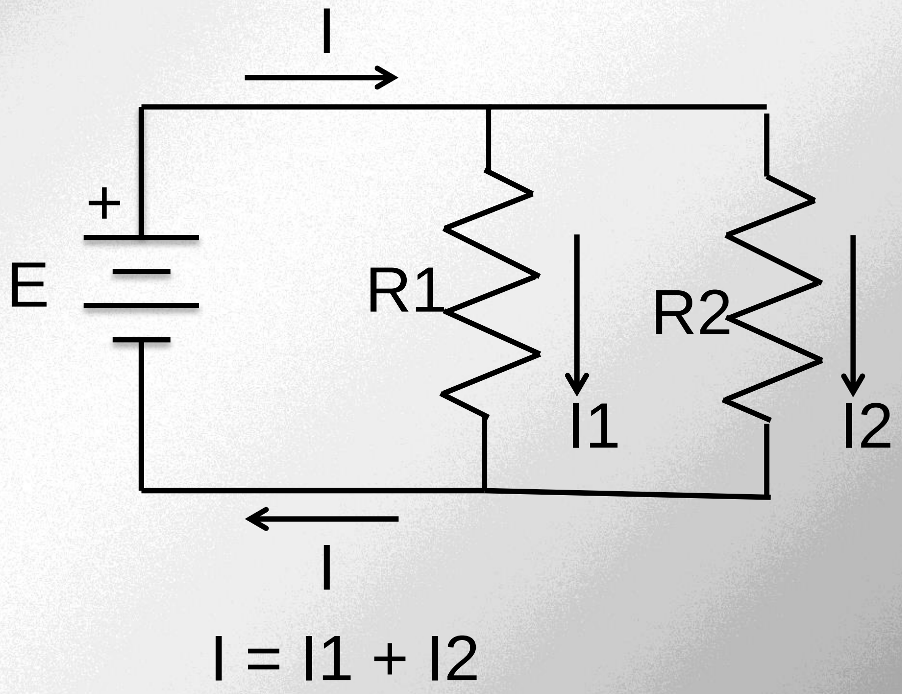


→

Currents in a Parallel Circuit

When two or more resistors are in parallel, each resistor takes part of the current I.

I = I1 + I2 is part of Kirchoff's Law.



→

Ohm’s Law (E = I * R)

Ohm’s Law is the proportional relationship between Voltage and Current.

Current is proportional to diameter of conductor but inversely proportional to length of conductor.

- Larger conductor – More current for a given voltage.
- Longer conductor – More voltage for same current.

→

Ohm's Law

A picture to remember Ohm's Law

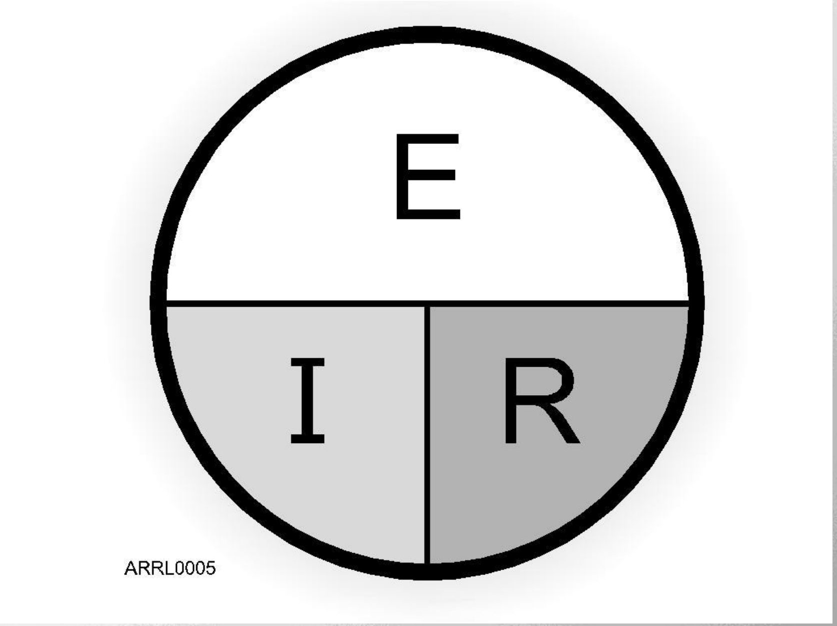
- E is voltage – Volts
- I is current – Amperes
- R is resistance – Ohms

Cover the one you don't know:

E = I R

I = E Over R

R = E Over I



One Ohm, one Amp, one Volt

→

ARRL The national association for AMATEUR RADIO

W6CUS HEBARC INC

Basic Types of Current

Direct Current (DC)

- Electrons move in one direction.
- Can fluctuate (pulse or ripple) in magnitude, but still only in one direction.

Alternating Current (AC)

- Electrons reverse direction at a frequency.
- Current goes from zero to positive to zero to negative to zero ….

AC and DC may be mixed together.

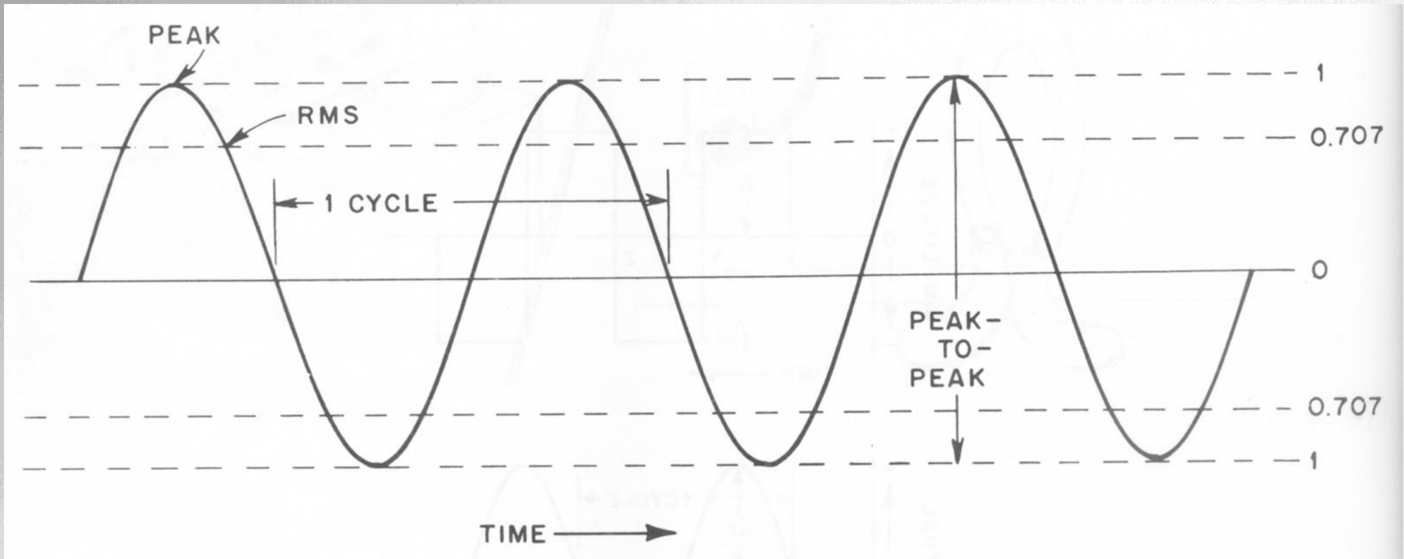
AC may be sinewave, pulse, triangle, random …

Alternating Current Defined

An Alternating Voltage reverses polarity periodically in a cycle from positive to negative.

- The alternating voltage forces charges (electrons) to move back and forth through the conductor.
- The current is called Alternating Current or AC.
- The combination of a Positive period and a Negative period is called a Cycle.
- Frequency is the number of cycles in one second. (Hertz or Hz) ⟶

AC Vocabulary



This AC Voltage is a Sine Wave.
Other AC Voltages may be rectangular or triangular or irregular shapes.

→

Electrical Power

Power (Watts) is the rate of doing work. Work is equivalent to Energy (Joules). Work is basically the effort expended to move a mass.

- Movement caused by a Force over a distance.
- Movement caused by a Pressure over a distance.

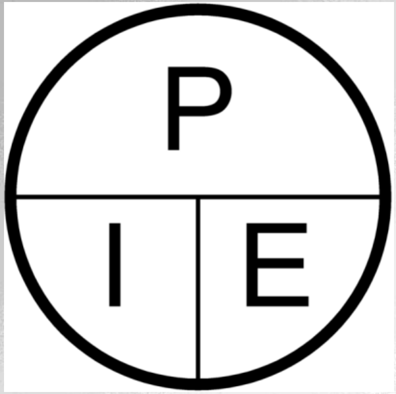
If something doesn't move, there is no work produced.

Heat produced is also a measure of work.

Power can be different at different points of a circuit.

→

Memory Device for Power Formula



The Pie Chart – Cover the one you want.

- Cover P: P = I * E
- Cover I: I = P / E
- Cover E: E = P / I

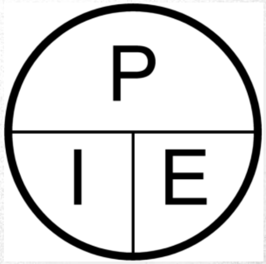
One Volt, One Amp, One Watt

ARRL The national association for AMATEUR RADIO

→

W6CUS HEBARC INC

Other Formulas for Power

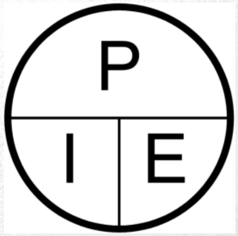


P = I * E works when you know I and E. But if you only know E and R or I and R you can do some substitution.

1) P = I * E;   2) E = I * R;   3) I = E/R

- Substitute I*R for E ➔ P = I * (I*R) ➔ $P = I^2 R$
- Substitute E/R for I ➔ P= E * (E/R) ➔ $P = E^2/R$
- Use $P = I^2 R$ when you know I and R.
- Use $P = E^2/R$ when you know E and R.

DC Power vs. AC Power



P = I * E works for DC circuits where voltage and current are constant.

- 12 Volts pushing 2 Amps = 24 Watts
- 1.5 Volts pushing 300 mA = 450 mW

But in an AC circuit, the voltage and current are constantly changing.

- Power at an instant is voltage at that instant times current at that instant.
- Sometimes the power is zero and sometimes it is maximum.

ARRL The national association for AMATEUR RADIO

→

W6CUS HEBARC INC

Effective Voltage for AC Power

The voltage used for power calculations in AC is the equivalent dc voltage value that would do the same amount of work (or heat).

- A simple average of AC voltage is lower than the effective value.
- The effective voltage is a weighted average called Root Mean Square (RMS).

→

Important Points about RMS

- **<u>For Sine Waves Only</u>**, the RMS voltage is 0.707 times the peak voltage!!!!
- AC voltmeters may indicate RMS voltage, but value may be wrong if wave is distorted.
- Some Digital Multimeters measure *True RMS* and are more accurate on distorted waves.

ARRL The national association for AMATEUR RADIO

→

W6CUS EBARC INC

Converting Peak Voltage to RMS

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

$$V_{RMS} = \frac{V_{Peak}}{1.414} = .707(V_{Peak})$$

$$V_{P-to-P} = 2(V_{Peak})$$

Remember:

1.414 = Square root of 2

0.707 = 1 / Square root of 2

→

Peak Envelope Power

Peak Envelope Power, PEP, is the power based on the highest Peak Voltage. Sometimes we know the R and can measure $V_{Pk\text{-}Pk}$ on an oscilloscope.

Convert Peak or Peak-to-Peak voltage to RMS. Then:

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

ARRL The national association for AMATEUR RADIO

W6CUS HEBARC INC

Using Decibels

Decibels (dB) are used to compare power levels and gains or losses in a system.

- Gains and losses of a system in dB are additive.
- Decibels are logarithmic.
- Matches the physical responses of hearing and sight.
- A large range of decades of values can be compared with smaller numbers, i.e., a Gain of 1,000,000 is 60dB, 1,000 is 30dB, 100 is 20dB

Commonly used to compare input to output power.

Positive ➔ Gain; Negative ➔ Loss.

→

dB and Power Ratio Calculations

If you know the powers at two points, P2 and P1, in a system, you can calculate the gain in dB.

Gain as a ratio: $$Gain = \frac{P_2}{P_1}$$

Gain in db: $$G_{db} = 10\log_{10}(Gain)$$

G_{db} to ratio: $$Gain = 10^{\frac{G_{dB}}{10}} = \frac{P_2}{P_1}$$

$$\longrightarrow$$

ARRL The national association for AMATEUR RADIO

W6CUS HEBARC INC

G5B05

How many watts are dissipated when a current of 10.4 milliamperes flows through 1.0 kilohms resistance?

A. Approximately 108 milliwatts

B. Approximately 10.8 Watts

C. Approximately 10.4 Watts

D. Approximately 10.4 milliwatts

Answer: A

Solution

$P = I^2 R$; (I Squared R)

$I = 10.4 * 10^3$ Amps ; (10.4 E-3)

$R = 1.0 * 10^3$ Ohms ; (1.0 E3)

P = (10.4 E-3)**2 * 1.0 E3

P = 1.08 E-4 * 1.0 E3; (E-4 * E3 = E-1)

P = 1.08 E-1 = 108 E-3 Watts

P ~ 108 mW

G5B06

What is the output PEP from a transmitter if an oscilloscope measures 200 volts peak-to-peak across a 50 ohm dummy load connected to the transmitter output?

A. 1.4 watts

B. 100 watts

C. 353.5 watts

D. 400 watts

Answer: B

ARRL The national association for AMATEUR RADIO

W6CUS HEBARC INC

Solution

Vpk-pk = 200V

R = 50ohms

Vpk = Vpk-pk/2 =200V/2 = 100V

Vrms = 0.707 * Vpk = 0.707 * 100 = 70.7V

PEP = $Vrms^2/R$

PEP = $(70.7V)^2$ / 50ohms = $5000V^2$ /50ohms

PEP = 100W

G5B07

What value of an AC signal produces the same power dissipation in a resistor as a DC voltage of the same value?

A. The peak-to-peak value

B. The peak value

C. The RMS value

D. The reciprocal of the RMS value

Answer: C

G5B09

What is the RMS voltage of a sine wave with a value of 17 volts peak?

A. 8.5 volts
B. 12 volts
C. 24 volts
D. 34 volts

Answer: B

ARRL The national association for AMATEUR RADIO

W6CUS HEBARC INC

G5B10

What percentage of power loss would result from a transmission line loss of 1 dB?

A. 10.9 percent

B. 12.2 percent

C. 20.5 percent

D. 25.9 percent

Answer: C

Solution

DB = -1 = 10 Log(G)

Log(G) = -1/10 = -0.1

G = AntiLog (-0.1) = $10^{-0.1}$ = 0.794

Loss = 1 – 0.794 = 0.205

%Loss = 100 * Loss = 100 * 0.205 = 20.5%

If you can remember that a gain of 1DB is 1.26 times, then the power after the loss is 1/1.26 = 0.793 so the loss is ~0.20 or 20%.

ARRL The national association for AMATEUR RADIO

W6CUS EBARC INC

G5B11

What is the ratio of peak envelope power to average power for an unmodulated carrier?

A. 0.707

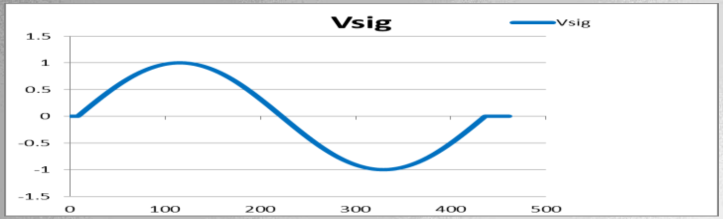
B. 1.00

C. 1.414

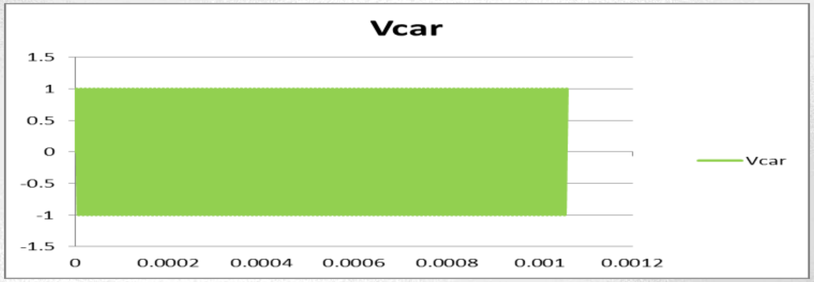
D. 2.00

Answer: B

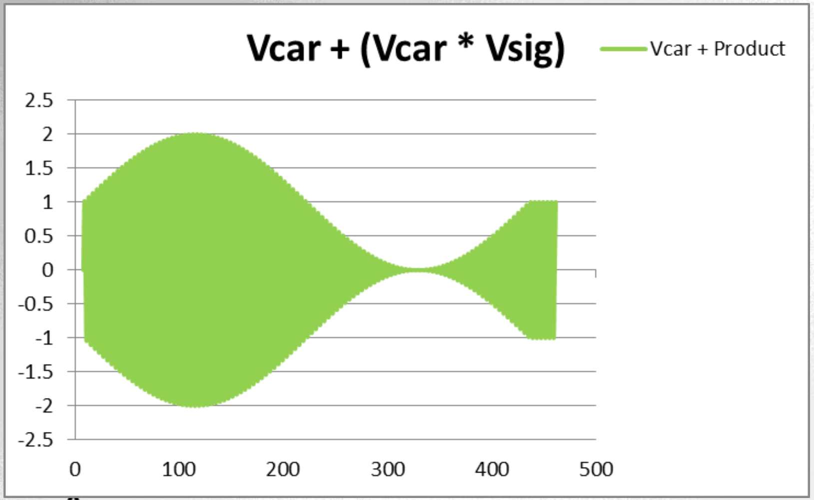
Audio Signal



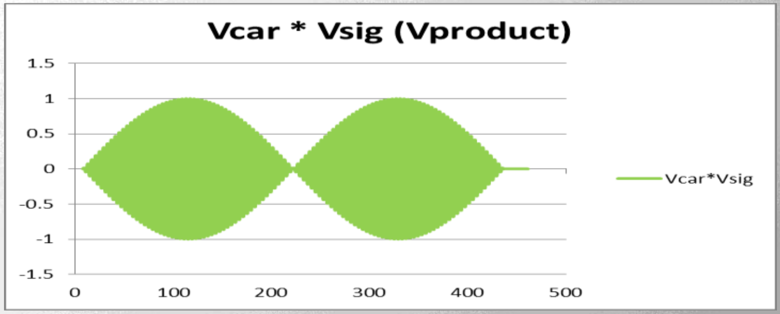
Unmodulated RF



AM with Carrier



AM With No Carrier



ARRL The national association for AMATEUR RADIO

G5B12

What would be the RMS voltage across a 50 ohm dummy load dissipating 1200 watts?

A. 173 volts

B. 245 volts

C. 346 volts

D. 692 volts

Answer: B

ARRL The national association for AMATEUR RADIO

W6CUS EBARC INC

Solution

P = 1200W

R = 50 Ohms

P = I * E; I = E/R; P = (E/R) * E

P = E*E/R = E^2/R

P * R = E^2

E = Square Root (P * R)

E = Square Root(1200 * 50)

E = 244.9 V

G5B13

What is the output PEP of an unmodulated carrier if an average reading wattmeter connected to the transmitter output indicates 1060 watts?

A. 530 watts

B. 1060 watts

C. 1500 watts

D. 2120 watts

Answer: B

G5B14

What is the output PEP from a transmitter if an oscilloscope measures 500 volts peak-to-peak across a 50 ohm resistive load connected to the transmitter output?

A. 8.75 watts

B. 625 watts

C. 2500 watts

D. 5000 watts

Answer: B

ARRL The national association for AMATEUR RADIO

W6CUS HEBARC INC

Solution

Vpk-pk = 500V

R = 50ohms

Vpk = Vpk-pk/2 =500V/2 = 250V

Vrms = 0.707 * Vpk = 0.707 * 250 = 176.75V

PEP = $Vrms^2$/R

PEP = $(176.75V)^2$ / 50ohms = $31240.6V^2$ /50ohms

PEP = 624.8W

ARRL The national association for AMATEUR RADIO