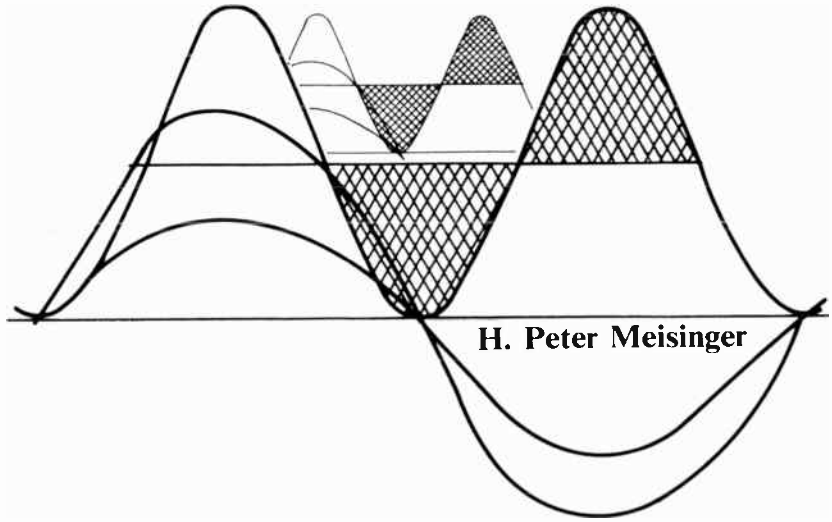
What's Watts



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In the early days of hi-fidelity, amplifier power ratings were quoted in watts. To the early hi-fi component manufacturer, the advertised watts in reality meant average watts. As hi-fidelity became more popular, a myriad of new inflated power ratings began to appear. (e.g. music power, peak power, etc.). In a seeming attempt to clarify power ratings, "the rms watt" has come into recent usage.

Recently, a great deal of discussion has taken place regarding the use of the term rms watts (1). The industry, in general, has adopted the use of the terms rms power, or rms watts. Many of the well-known testing laboratories also use these terms. Unfortunately, the terms rms watts, and rms power are incorrectly used.

In the laboratory, amplifier power is determined by measuring the voltage across a calibrated resistor with an rms voltmeter. This would lead to the seemingly logical conclusion that the watts determined in this manner would be rms watts. This is simply not true.

Ammeters and voltmeters that are used to measure alternating currents or alternating voltages invariably are calibrated in terms of the rms value of a sine wave unless otherwise specified. However,

1. The product of rms volts times rms amperes yields *average watts*, not rms watts.
2. The product of rms amperes squared times the circuit resistance yields *average watts, not rms watts.*
3. rms voltage squared divided by the circuit resistance yields *average watts, not rms watts.*

First, let us deal with voltage and current (amperes). The circuit shown in Figure 1 indicates an alternating current sine wave generator whose peak voltage is determined by the oscilloscope to be one volt. The generator is loaded by a one ohm resistor. Since current (amps) = $\frac{\text{volts}}{\text{ohms}}$, the numerical value of the current will be the same as the numerical value of the voltage since the divisor is equal to one (ohm).

Figure 2 illustrates the instantaneous current (I), instantaneous voltage (E) and instantaneous power in a resistive circuit.

The peak power is equal to the product of the peak voltage and the peak current.

$$P_{peak} = E_{peak}\, I_{peak}$$

Similarly, the power at any instant in time is equal to the product of the instantaneous voltage and instantaneous current.

$$W_{inst.} = E_{inst.}\, I_{inst.}$$

The instantaneous power curve of Figure 2 is this product, and is seen to be a sine wave of double frequency without negative values.

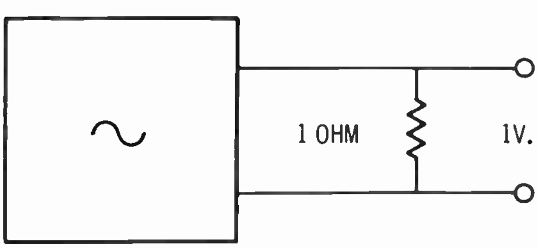

Fig. 1—indicates an alternating current sine wave generator whose-peak voltage is one volt.

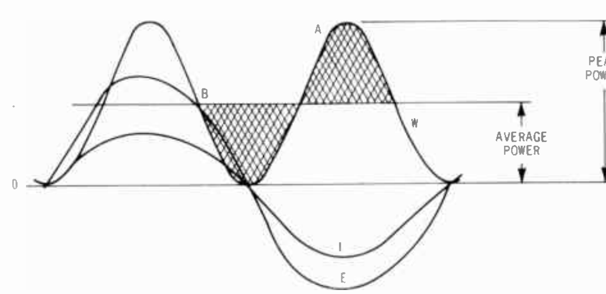

Fig. 2—illustrates the instantaneous current voltage and power in a resistive circuit.

(1) **J.R. Ashley "What's a Watt (rms)?"** ***J. Audio Eng. Soc. Vol. 19, p. 793 (Oct. 1971)***

J. G. McKnight comments on "What's a Watt (rms)?" ***J. Audio Eng. Soc. Vol. 20, p. 46 (Jan-Feb 1972)***

John Eargle and Bart Locanthi "RMS Power: Facts or Fancy" ***J. Audio Eng. Soc. Vol. 20, p. 45, (Jan-Feb 1972)***

A line drawn equidistant between the peaks and valleys of the power curve represents the average power and is seen to be equal to fifty percent of the instantaneous peak power. This is graphically illustrated by observing that the shaded top section of the sine wave fits perfectly into the shaded adjacent valley. This represents the average power.

Since the average power line is drawn at the mid-point of the power curve,

$$\text{Average power} = \frac{\text{Peak voltage} \times \text{peak current}}{2} = \frac{\text{E peak}}{\sqrt{2}} \times \frac{\text{I peak}}{\sqrt{2}}$$

In figure 1:

$$\frac{1}{\sqrt{2}} \times \frac{1}{\sqrt{2}} = .707 \times .707 = 0.5 \text{ watts average power}$$

$$\text{I rms} = \frac{\text{I peak}}{\sqrt{2}} = \frac{1}{\sqrt{2}} = \frac{1}{1.4} = 0.707 \text{ of the peak value}$$

Therefore, the rms value of voltage or current equals .707 of the peak value, or conversely, the peak value equals 1.414 times the rms value.

NOTE: This is true for voltage and current, not power.

In dealing with voltage and current, the terms "rms" and "effective" are used interchangeably. The real significance of *rms* (or *effective*) voltage and current is the fact that it will cause the same amount of heat to be generated in a resistance as a numerically equal d.c. source. In other words, *average* sine wave a.c. watts generate the same amount of heat in a resistance as a numerically equal d.c. source. The watt-hour meter in your home measures average watts or heating effect, not rms watts.

rms, when used with voltage or current, permits $W = I^2 R$ and $W = \frac{E^2}{R}$ to be used alternately between direct current and sine wave a.c. since the heating effect is the same in either case.

An additional proof of the above was rather simply done using one of the new scientific pocket calculators. All computations were made to ten places, however, with the limited number of sampling points only three place accuracy can generally be assumed.

Table 1 shows the calculation of average and rms current and voltage and average and rms watts.

Column 1 lists the instantaneous value of voltage (or current). Thirty six values were computed (every five degrees of phase angle). There were totaled and divided by 36 to give us the average value of voltage or current. Average value is useful in electronic circuits. For example, the full wave rectifier where average electron drift is important.

Column 2 shows the rms value of the voltage or current in Figure 1, which is also the average value of the power in Figure 1. Each of the instantaneous values in column one were squared. The column was then totaled and divided by 36 (the number of instantaneous points computed). Computations were made to ten places with the pocket calculator. The average turned out to be precisely 0.5, the same value shown in the graphical construction above.

Since $W = I^2 R$ $\quad W\ max = I^2\ max\ (1) = 1$ watt peak

Since we are dealing with a one ohm load, each of the values in column two indicates instantaneous power as well as the square of the instantaneous current or voltage.

rms stands for root-mean-square. This means that we take the square root of the average of the squares. Since 0.5 is the average of column two, $\sqrt{0.5}$ or .707 equals the rms value of the voltages or currents squared shown in column two, and 0.5 represents the average of the power shown in column two.

It is important to note that each of the instantaneous values shown in column two represents the instantaneous current squared or the instantaneous voltage squared or the instantaneous power.

Some misinformed individuals have thought rms power to be .707 of the peak power. It sounds logical since rms voltage and current are .707 of their peak values. Let us examine the true value of rms power just to prove how untrue this really is. The figures in column two represent the instantaneous power in figure one. Column three shows the squares of each of the instantaneous power values of column two. The average of the sum of the powers squared is 0.375. The rms value of power is therefore, $\sqrt{.375} = 0.6123724357$. Quite a different value than .707, showing that rms power is not 0.707 times the peak power.

The 0.612 figure for rms power serves no useful purpose and I suspect has never been used for amplifier power ratings.

In dealing with power, we want to deal with the heating effect of a.c. as we deal with the heating effect of d.c. The watt is a unit of power (or rate of energy transfer), and is equal to:

10^7 ergs per second, or
3.4129 btu per hour, or
44.27 Ft-lbs. per minute, etc.

Therefore, amplifiers would be more properly rated for continuous sine wave average power (watts). rms (effective) values are fine for voltage and current but should not be used for power.

Recently, it has been implied that the use of the term rms power is just another ploy by sales departments to advertise inflated power ratings. If this were true, manufacturers would quote rms power figures as 0.612 of the peak power. However, many recent interviews reveal that this is not true. Manufacturers are measuring average power and then improperly advertising rms power. Since average power = 0.5 peak power and rms power = 0.61237 peak power (not .707).

$$\frac{.5}{.61237} = .816 \text{ to } 1 = \text{ratio of average to rms watts}$$

or

$$\frac{.61237}{.5} = 1.22 \text{ to } 1 = \text{ratio of rms to average watts}$$

Therefore, the manufacturer that measures 100 watts average power and quotes 100 watts rms power could legitimately quote 122 watts rms power. Current industry practice may be fallacious, but it is not dishonest.

1. The average value of a sine wave voltage or current equals .636 of the peak value.
   1a. The peak value of a sine wave voltage or current equals
   1.57 of the average value
2. The root mean square (rms) value of a sine wave voltage or current equals
   .707 of the peak value
   2a. The peak value of a sine wave voltage or current is equal to
   1.414 times the rms value
3. The square of the sine wave rms voltage divided by the circuit resistance equals the *average* watts (power), not rms watts

$$W_{avg} = \frac{E^2_{rms}}{R}$$

NOTE: This is the average, not the rms watts.

4. The square of the sine wave rms current multiplied by the circuit resistance equals the average watts (power), not rms watts.

$$W_{avg} = I^2_{rms} R$$

5. The product of the rms voltage and the rms current equals the average watts (power), not rms watts.

$$W_{avg} = E_{rms} \times I_{rms}$$

6. A wattmeter reads average, not rms watts.
7. The average power in a circuit is one half of the peak power.

$$W_{avg} = 0.5\ W\ peak$$

8. rms power is equal to .61237 of the peak value. There are no instruments (voltmeters, ammeters or wattmeters) that are calibrated in terms of rms power. Furthermore, it is a rather useless term.

$$W_{rms} = .61237\ W\ peak$$

9. Since
   Wavg = .5 Wpeak
   Wrms = .61237 W peak
   .61237 = 1.22 to 1 = ratio of rms to average watts

$\frac{.61237}{.5}$ = 1.22 to 1 = ratio of rms to average watts

$\frac{.5}{.61237}$ = .816 to 1 = ratio of average to rms watts

TABLE I

VOLTAGE CURRENT AND POWER VALUES FOR FIGURE I

E max = 1 volt I max = 1 volt W max = 1 watt

Degrees	E inst. (volts) or I inst. (Amps)	I inst.² or E inst.² or W. inst. (Watts)	W inst.²
5	.0871557427	.00759612349	.00005770109
10	.1736481775	.0301536895	.00090924499
—	— — — —	— — — — —	— — — — —
175	.0871557427	.00759612349	.00005770109
180	–0–	–0–	–0–
TOTAL	22.90376554	18.	13.49999998
Average	$\frac{22.90376554}{36}$ = .636	$\frac{18}{36}$ = 0.5	$\frac{13.49999998}{36}$ = .375
RMS	.636 to 1 = ratio of average to peak voltage or current	0.5 = .7071067812 .7071067812 to 1 = ratio of rms to peak voltage of current	.375 = .6123724357 .6123724 to 1 = ratio of rms to peak watts