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dB ***what!?***
One of the most common and confusing units is "dB" - another variant is always turning up. This note is an attempt to clarify a few of the most common and their typical use(s). These are not "official" definitions, rather "working definitions" that most of us use in our daily activities.

dB

Used to indicate a relative gain (or loss) of Voltage, Current or Power (may be used to obtain actual values provided one of the values is known).

Obtaining dB
- *Voltage:* $dB = 20 \times \log_{10} (V_1 / V_2)$
- *Current:* $dB = 20 \times \log_{10} (I_1 / I_2)$
- *Power:* $dB = 10 \times \log_{10} (P_1 / P_2)$ *(1)*

Obtaining actual value:
- *Voltage:* $V_1 = V_2 \times 10^{(dB / 20)}$
- *Current:* $I_1 = I_2 \times 10^{(dB / 20)}$
- *Power:* $P_1 = P_2 \times 10^{(dB / 10)}$

Gain (or increase) is positive (+) and loss (or decrease) is negative (-).

dBa

dB adjusted (typically).

A specialised Power level for a specific telecommunications device, using Psophometric power level (and a defined noise level) as a reference.

dBa = dBmp + 84

dB(A)
or dBA

dB "A Weighted" (typically).

An absolute "Weighted" measurement for Audio Sound Pressure Level.

Obtaining dB(A): $dB(A) = 20 \times \log_{10} (P / 0.00002)$
Obtaining the Pressure: $P = 0.00002 \times 10^{(dB(A) / 20)}$

dB(A) provides a subjective measurement of Sound Pressure Level, unlike dB(SPL) which provides the absolute value. At low and high frequencies a dB(A) measurement will typically be less than a dB(SPL) measurement.

dB(A) uses the same reference as dB(SPL) (2×10^{-5} Pascals R.M.S.), however dB(A) is obtained using an "A Weighting Filter" which simulates the frequency response (40 phon curve) of the human ear.

2×10^{-5} (0.00002) Pascals R.M.S. is defined as the "threshold of hearing".

dBi

dB Isotropic (typically).

When used in R.F. applications it specifies relative gain of one antenna over an isotropic antenna in free space.

dBm

dB milliwatt.

dBm is an absolute Power level using 1mW (1 milliwatt or 0.001 Watts) as a reference.

Obtaining dBm: $dBm = 10 \times \log_{10} (P_1 / 0.001)$
Obtaining the Power: $P_1 = .001 \times 10^{(dBm / 10)}$

Values above 1 mW are positive (+) and values below 1 mW are negative (-). Power in above is measured in Watts (W).
When used in Audio Systems, 600Ω is commonly used as the impedance in calculations.

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dBm0

dB milliwatt, 0 reference.

dBm0 is an absolute Power level (dBm) using a designated "0 Test Point" as a reference. The "0 Test Point" is the location in the system where the level is 0 dBm. Often a point is indirectly referenced to the "0 Test Point" by use of dBr.

dBm0 = dBm - dBr

dBm0p

dB pilot Typically.

When used in Transmission Systems it is used to specify various absolute Power levels of "Pilot Tones".

dBmp

dBmp Psophometric power level referred to 1 mW.

dBmV

dB millivolt.

dBmV is an absolute Voltage level using 1mV (1 millivolt or 0.001 Volts) as a reference.

Obtaining dBmV: $dBmV = 20 \times \log_{10} (V_1 / 0.001)$
Obtaining the Voltage: $V_1 = .001 \times 10^{(dBmV / 20)}$

Values above 1 mV are positive (+) and values below 1 mV are negative (-). Voltage in above is measured in Volts (V).
When used in Video Systems, 75Ω is typically used as the impedance in calculations.

dBr

dB reference.

Relative Power level measurement.

Gain (+) and Loss (-) will indicate the difference in dB from the reference point (designated: 0 dBr).

dBrnC

dB relative measurement (typically).

A specialised Power level for a specific telecommunications device, using Psophometric power level (and a defined noise level) as a reference.

dBrnC = dBmp + 90

dBSPL
or dB(SPL)

dB "SPL" (typically).

An absolute measurement for Audio Sound Pressure Level.

Obtaining dB(SPL): $dB(SPL) = 20 \times \log_{10} (P / 0.00002)$
Obtaining the Pressure: $P = 0.00002 \times 10^{(dB(SPL) / 20)}$

dB(SPL) provides the absolute measurement of Sound Pressure Level.

dB(SPL) uses 2×10^{-5} Pascals R.M.S. as a reference. 2×10^{-5} (0.00002) Pascals R.M.S. is defined as the "threshold of hearing".

dBu

dB un-referenced

dBu is an absolute Voltage Level. 0dBu is the voltage required to produce the dissipation of 1milliwat (power) in a 600Ω load (approx: 0.775 V_{rms}).

Obtaining dBu: $dBu = 20 \times \log_{10} (V_{rms} / 0.775)$
Obtaining V_{rms}: $V_{rms} = 0.775 \times 10^{(dBu / 20)}$

In a 600Ω system, 0dBm and 0dBu are the same. The accuracy of the V_{rms} equation may be improved by use of 0.7745967 in place of 0.775. Voltage to dBu tables are included later.

dBμV

dB microvolt.

dBμV is an absolute Voltage level using 1 μV (1 microvolt) as a reference.

When V_1 is measured in μV
Obtaining dBμV: $dB\mu V = 20 \times \log_{10} (V_1)$
Obtaining the Voltage: $V_1 = 10^{(dB\mu V / 20)}$

When V_1 is measured in Volts
Obtaining dBμV: $dB\mu V = 20 \times \log_{10} (V_1 \times 10^6)$
Obtaining the Voltage: $V_1 = [\, 10^{(dB\mu V / 20)}] / 10^6$

Note: 1 Volt = 1000 millivolts = 1,000,000 μV

Values above 1 μV are positive (+) and values below 1 μV are negative (-).
Often used in R.F. and CCTV Applications.

dBV

dB Volt.

dBV is an absolute Voltage level using 1V (1 Volt) as a reference.

Obtaining dBV: $dBV = 20 \times \log_{10} (V_1)$
Obtaining the Voltage: $V_1 = 10^{(dBV / 20)}$

Values above 1 V are positive (+) and values below 1 V are negative (-). Voltage in above is measured in Volts (V).

dBW

dB Watt.

dBW is an absolute Power level using 1W (1 Watt) as a reference.

Obtaining dBW: $dBW = 10 \times \log_{10} (P_1)$
Obtaining the Power: $P_1 = 10^{(dBW / 10)}$

Values above 1 W are positive (+) and values below 1 W are negative (-). Power in above is measured in Watts.

dBx

dB crosstalk (typically).

A specialised Power level often used in Telecommunications for describing crosstalk coupling in positive values.
0 dBx = -90 dBm

Some useful and helpful relationships.

A relationship between Power and Voltage - with the same Resistance.

Starting with Power Relationships:	$P_1 = V_1^2 / R$ and $P_2 = V_2^2 / R$.
Using the dB Power Equation:	$dB = 10 \times \log_{10} (P_1 / P_2)$
Substitute these into dB Power Equation:	$dB = 10 \times \log_{10} ((V_1^2 / R) / (V_2^2 / R))$
Cancelling the R's:	$dB = 10 \times \log_{10} (V_1^2 / V_2^2)$
Grouping the squares together:	$dB = 10 \times \log_{10} ((V_1 / V_2)^2)$
Finishing this process gives:	$dB = 2 \times 10 \log_{10} (V_1 / V_2)$
Finally, the familiar dB Voltage Equation:	$dB = 20 \times \log_{10} (V_1 / V_2)$

A similar method is used for Current and Power ($P_1 = I_1^2 \times R$).

A relationship between Power and Voltage - with the different Resistances.

The resistances (R) used in the above are the same. If they are different then the following equations may be used.

Starting with Power Relationships:	$P_1 = V_1^2 / R_1$ and $P_2 = V_2^2 / R_2$.
Using the dB Power Equation:	$dB = 10 \times \log_{10} (P_1 / P_2)$
Substitute these into above:	$dB = 10 \times \log_{10} ((V_1^2 / R_1) / (V_2^2 / R_2))$
Collecting a few terms:	$dB = 10 \times \log_{10} ((V_1^2 / V_2^2) \times (R_2 / R_1))$
And using a property of Logs:	$dB = 10 \times \log_{10} (V_1^2 / V_2^2) + 10 \times \log_{10} (R_2 / R_1)$
Grouping the squares together:	$dB = 10 \times \log_{10} ((V_1 / V_2)^2) + 10 \times \log_{10} (R_2 / R_1)$
finishing this process gives:	$dB = 2 \times 10 \log_{10} (V_1 / V_2) + 10 \times \log_{10} (R_2 / R_1)$
finally, the familiar dB Voltage Equation:	$dB = 20 \times \log_{10} (V_1 / V_2) + 10 \times \log_{10} (R_2 / R_1)$

A similar method is used for Current and Power ($P_1 = I_1^2 \times R_1$).

Doubling the Power = 3dB.

Setting the ratio:	$P_1 / P_2 = 2.0$
Using the dB Power Equation:	$dB = 10 \times \log_{10} (P_1 / P_2)$
Substituting the above:	$dB = 10 \times \log_{10} 2$
Gives:	$dB = 10 \times 0.301029996$
Which is approx:	3dB

Halving the Power = -3dB.

Setting the ratio:	$P_1 / P_2 = 0.5$
Using the dB Power Equation:	$dB = 10 \times \log_{10} (P_1 / P_2)$
Substituting the above:	$dB = 10 \times \log_{10} 0.5$
Gives:	$dB = 10 \times -0.301029996$
Which is approx:	-3dB

Doubling the Voltage = 6dB

Setting the ratio:	$V_1 / V_2 = 2.0$
Using the dB Power Equation:	$dB = 20 \times \log_{10} (V_1 / V_2)$
Substituting the above:	$dB = 20 \times \log_{10} 2$
Gives:	$dB = 20 \times 0.301029996$
Which is approx:	6dB

Halving the Voltage = -6dB.

Setting the ratio:	$V_1 / V_2 = 0.5$
Using the dB Power Equation:	$dB = 20 \times \log_{10} (V_1 / V_2)$
Substituting the above:	$dB = 20 \times \log_{10} 0.5$
Gives:	$dB = 20 \times -0.301029996$
Which is approx:	-6dB

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Tables: Volts (rms) to dBu (and reverse).

Comments:

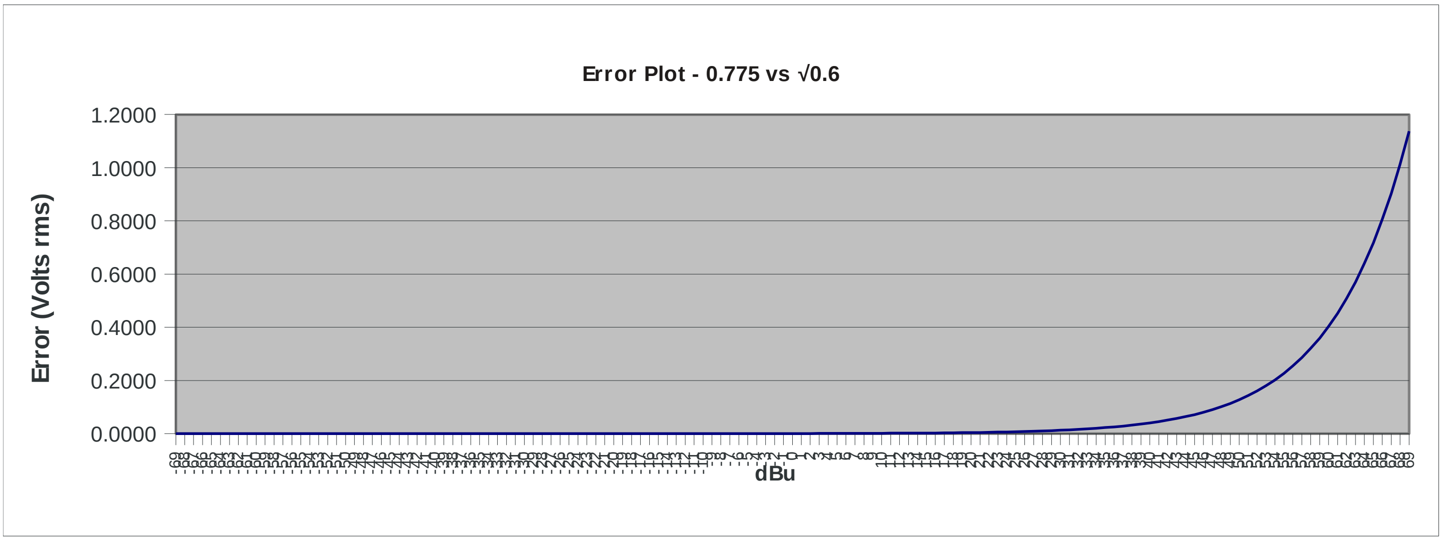
- In **600Ω** Systems, dBm may be substituted for dBu in these tables.
- For greater accuracy, the value of 0.7745966692414830 was used in calculations. The approximation 0.775 gives acceptable results in most situations, however the true value is found by: $V_{rms} = (1 \times 10^{-3} \times 600)^{1/2} = (0.6)^{1/2} = \sqrt{0.6}$ (resultant Voltage across a 600Ω load when dissipating 1mW).
  A plot of the error between this table and 0.775 is provided below.

0 to +69 dBu

dBu	Volts	dBu	Volts	dBu	Volts	dBu	Volts	dBu	Volts	dBu	Volts	dBu	Volts
0	0.7746	10	2.4495	20	7.7460	30	24.4949	40	77.4597	50	244.9490	60	774.5967
1	0.8691	11	2.7484	21	8.6911	31	27.4837	41	86.9112	51	274.8373	61	869.1118
2	0.9752	12	3.0837	22	9.7516	32	30.8372	42	97.5159	52	308.3725	62	975.1594
3	1.0941	13	3.4600	23	10.9415	33	34.6000	43	109.4147	53	345.9996	63	1094.1469
4	1.2277	14	3.8822	24	12.2765	34	38.8218	44	122.7653	54	388.2180	64	1227.6530
5	1.3774	15	4.3559	25	13.7745	35	43.5588	45	137.7449	55	435.5877	65	1377.4493
6	1.5455	16	4.8874	26	15.4552	36	48.8737	46	154.5524	56	488.7375	66	1545.5235
7	1.7341	17	5.4837	27	17.3411	37	54.8372	47	173.4106	57	548.3724	67	1734.1059
8	1.9457	18	6.1528	28	19.4570	38	61.5284	48	194.5699	58	615.2840	68	1945.6989
9	2.1831	19	6.9036	29	21.8311	39	69.0360	49	218.3110	59	690.3600	69	2183.1100

0 to - 69 dBu

dBu	Volts	dBu	Volts	dBu	Volts	dBu	Volts	dBu	Volts	dBu	Volts	dBu	Volts
0	0.7746	-10	0.24495	-20	0.07746	-30	0.024495	-40	0.007746	-50	0.0024495	-60	0.0007746
-1	0.6904	-11	0.21831	-21	0.06904	-31	0.021831	-41	0.006904	-51	0.0021831	-61	0.0006904
-2	0.6153	-12	0.19457	-22	0.06153	-32	0.019457	-42	0.006153	-52	0.0019457	-62	0.0006153
-3	0.5484	-13	0.17341	-23	0.05484	-33	0.017341	-43	0.005484	-53	0.0017341	-63	0.0005484
-4	0.4887	-14	0.15455	-24	0.04887	-34	0.015455	-44	0.004887	-54	0.0015455	-64	0.0004887
-5	0.4356	-15	0.13774	-25	0.04356	-35	0.013774	-45	0.004356	-55	0.0013774	-65	0.0004356
-6	0.3882	-16	0.12277	-26	0.03882	-36	0.012277	-46	0.003882	-56	0.0012277	-66	0.0003882
-7	0.3460	-17	0.10941	-27	0.03460	-37	0.010941	-47	0.003460	-57	0.0010941	-67	0.0003460
-8	0.3084	-18	0.09752	-28	0.03084	-38	0.009752	-48	0.003084	-58	0.0009752	-68	0.0003084
-9	0.2748	-19	0.08691	-29	0.02748	-39	0.008691	-49	0.002748	-59	0.0008691	-69	0.0002748



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Decibels - it's all the "logs" fault - a few (too many) words about them.

As hard as it is to believe, Decibels and their "correct use" can make life simpler - in certain situations - the major problem is that their use is often obscure or inappropriate. So what is it about Decibel measurements that give them this useful but at times exasperating quality. A great deal of it (practically everything really) is because they are based on logarithms, in this particular case those of "base 10" ($\log_{10} x$).

The mathematical expressions: **ln x**, **$\log_{10}$ x**, **10^x** and **e^x** often cause many to fidget and remember that the dog needs watering or the garden is due for it's next oil change. It could be because they hated Maths at school (and have made it their life's ambition to avoid it at all costs), or have not used them for so long that the whole thought of having to wade through a text book is just too hideous to contemplate.

But once again modern technology has reduced every problem to a couple of buttons, so provided they are pressed in the right order you need know nothing more! So it's possible sleep at night (just like you did through all those the Maths classes where they taught you what they mean).

<u>So it's all the logs problem.</u>

Logarithms (more affectionately known as "logs") are a mathematical function with some rather useful properties. They have been around since - a long time in the in the past - well before calculators. They were a part of everyday life; particularly where large numbers were being multiplied or divided. This miracle was performed as follows:

Consider the problem of multiplying 2,123,450.213 by 124,325.93621 (or dividing them for that matter).

This is something every normal person can do in their head (without a calculator, slide rule or log tables for that matter), but just in case the power fails one night and your life depends on the answer, this is how you do it using logs:

Firstly:	$\log_{10}$ 2,123,450.21300 = 6.327042083
and	$\log_{10}$ 124,325.93621 = 5.094561738.
Add the logs together:	6.327042083 + 5.094561738 = 11.42160382
Get the antilog:	$10^{11.42160382}$ which is 263,999,900,000.

Now that was not hard! Instead of some pretty tedious long hand multiplication, you simple use logs, add the numbers, then use anti-logs to get the final result. Just for the record, the log and anti-log values were obtained from a calculator, log tables are far too slow! and who has a copy?

<u>What's in a base?</u>

Now it's pretty important to point out that these logarithms are base 10, why pick 10? Well 10 is a nice number, money comes in 10's, pies and cakes come in 10's. Base 10 logs are often written: $\log_{10}$ N, the inverse: antilog N, alog N, or 10^N (where N is the number).

There are also logs using the base "e" - the so-called Natural logarithms (frankly anyone finding 2.718281828…. natural should seek help immediately). Base e logs are often written: ln N, the inverse: e^N (where N is the number). You may also see them called Hyperbolic or Naperian logs.

There are also those of base 2 (digital computers have a vague interest in this area?).
Base 2 logs are often written: $\log_2$ N, the inverse: 2^N (where N is the number).

Finally there are all the other bases that exist (every other number you can think of). As an example lets use base 11.7031 (it looks quite useful?) To convert a $\log_{10}$ N to base 11.7031, we do the following:

$\log_{11.7031} N = \log_{10} N \times \log_{11.7031} 10$

Summary.

We have seen some pretty odd things:

1. We can multiply (divide) numbers by taking the "log", then adding (subtracting) and the finding the anti-log.
2. Big numbers become small after you take the log, and small number become big numbers after taking the anti-log.
3. 10, e, 2 and other bases are just for convenience - they are nothing special (except for those people seeking help).

To illustrate point 2 (above), Figs 1 to 3 (next page) are some graphs of logs (base 10 of course).
It can be seen that the values range between 0.001 and 1000 on the horizontal axis, and the log values (vertical axis) range between -3 and 4. Putting this into perspective, a range of 1,000,000 on the horizontal axis results in a change of 7 (that's correct, good old plain number seven) in the vertical axis. With this in mind it's little wonder that Decibels (remember them?) can be a little confusing when they rely on such crazy mathematical functions.

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The important point in all these graphs is how large the values change along the horizontal axis compared with how small the values change in the vertical axis.

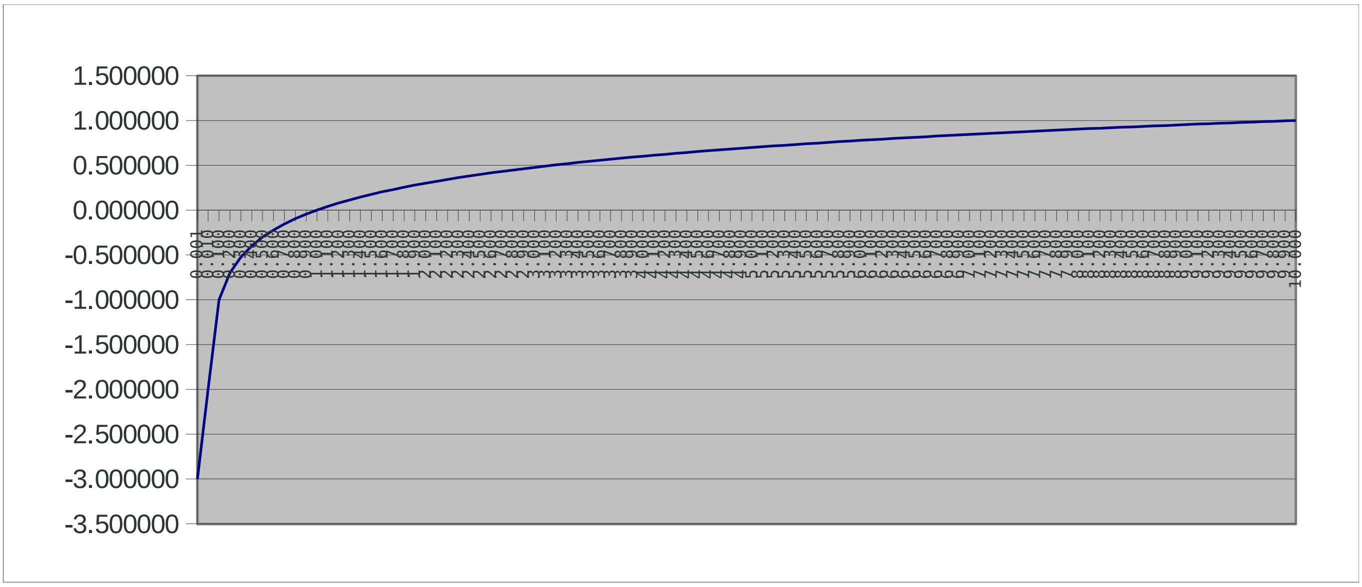

Fig 3. Log_{10} of values: 0.001 to 10

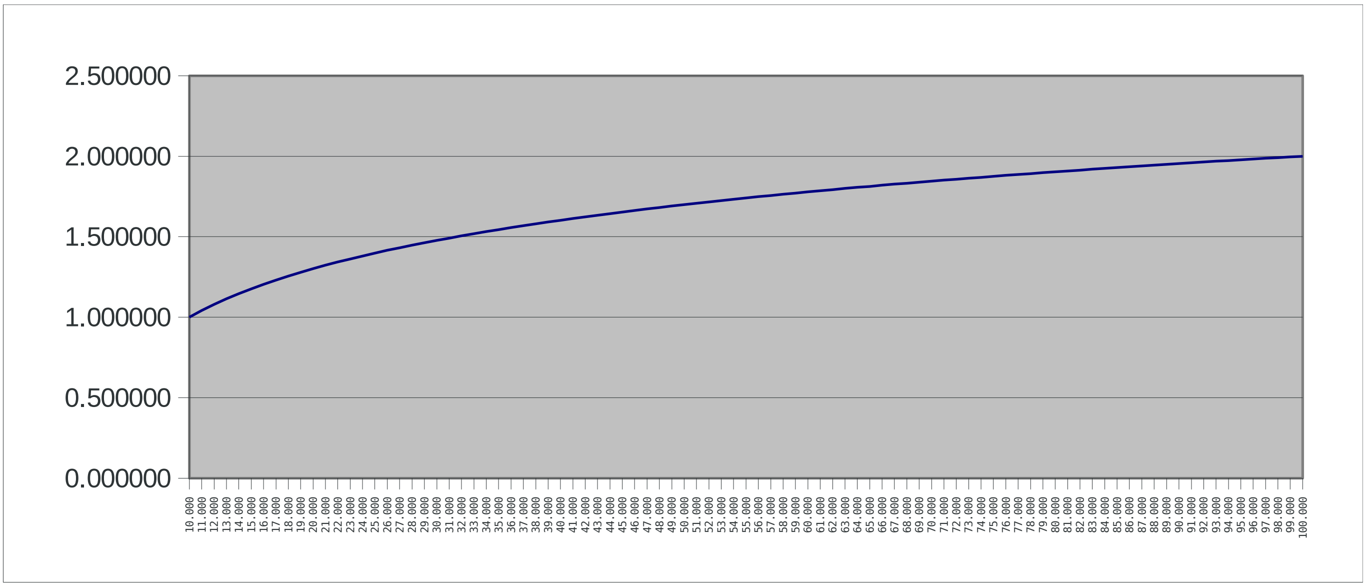

Fig 3. Log_{10} of values: to 10 to 100

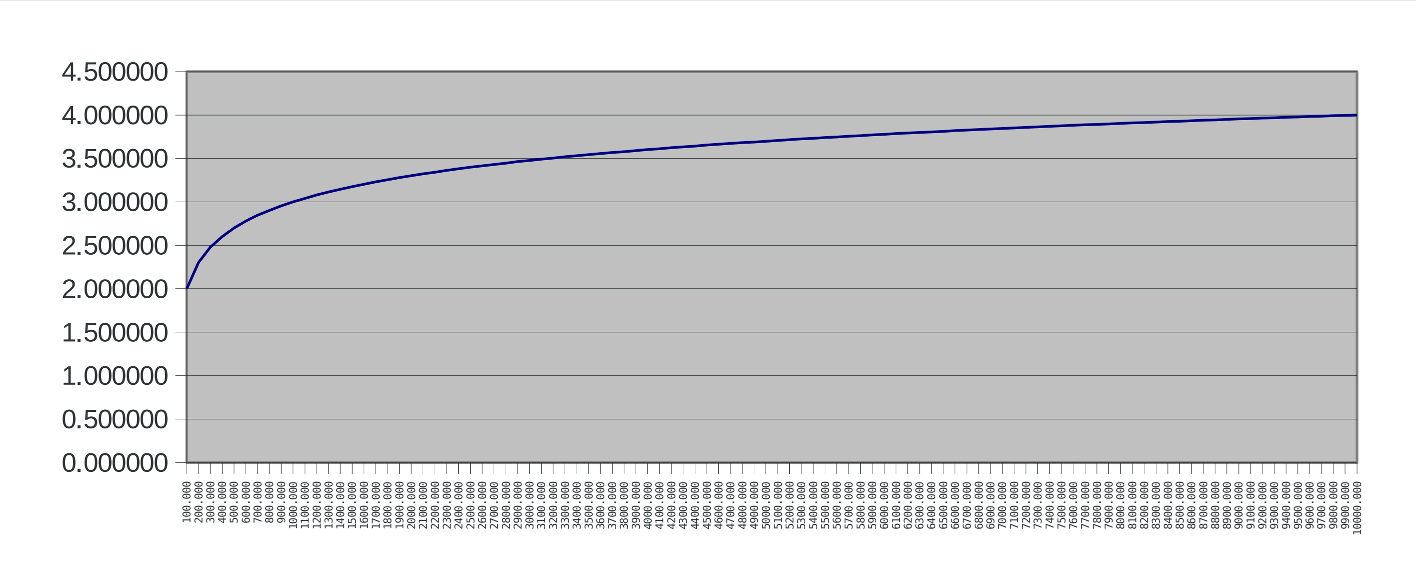

Fig 3. Log$_{10}$ of values: to 100 to 1000

<u>Finally - some Laws of Logarithms.</u>
Tedious, tedious, tedious but here they are (in base 10)…

Product:	$\log_{10} (p \times q) = \log_{10} p + \log_{10} q$
Quotient:	$\log_{10} (p / q) = \log_{10} p - \log_{10} q$
Power:	$\log_{10} a^n = n \times \log_{10} a$
Change of Base:	$\log_a N = \log_b N \times \log_a b$
Inverse:	10^x (where $x = \log_{10} N$)

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rms (or Root, Mean, Square) - a few notes to the already confused.

It sounds silly, looks silly (below is how you calculate it) so it's going to be pretty tough trying to make rms sound useful. As a pure mathematical animal its use is fairly broad, but fortunately it's use in electrical work is reasonably restricted. If we cast our mind back to AC and DC Voltages (and Currents) we recall there are some differences between them; basically one oscillates and the other is constant. It turns out that rms is a reasonably neat way to link (or relate) the two. Along the way there should be a lot of waffle about "Average Values", "Instantaneous Values" and an rambling tour of other ways to measure Voltages, Currents and Power (they all have a use but can leave one wearisome at the best of times). Just as the eyelids start to falter there is one final type to be mentioned: "Effective Value", believe it or not this is another name (although rarely used) for rms.

So the rms (or Effective) Value of an Alternating Current is that value which produces the same heating effect as a given DC Current in the same resistance. Now that's really useful. All that to find out about "heating" and "same resistances"....

But below the surface there is something quite important going on; an alternating Current (eg. the mains (sine wave) which varies) and a constant current (eg. a torch battery which is constant) can be related via a simple expression. Granted we are concerned with power (heating effect) but none the less it does provide some important foundations upon which to base even less obvious principles of even greater obscurity.

A few little oddities.

For a pure **sine wave**, rms Voltage = Peak Voltage / √2 (the same goes for rms Current also).
Often the figure 0.7071 is used in calculations: rms Voltage = Peak Voltage x 0.7071.
This figure (0.7071) is nothing more than 1 / √2.

The most important comment about this is that 0.7071 is **only correct for a sine wave**.

If you have a triangular wave, square wave, sawtooth wave (these do exist) or some other waveform, then you will need to consult a manual, book, or some other disreputable source.

To verify this (for a sine wave) simply set the following in the equation below:

- F(t) = Sin(t)
- a = 0
- b = 2π
- and go for it!

$$\sqrt[2]{\frac{1}{(b-a)}\int_a^b \sin^2(t)\,dt}$$

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