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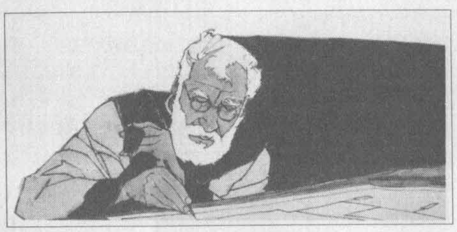
What's a dB and dBm?

That's a question often asked in the service shop, especially when working with high frequency signal sources or measurement gear, such as a spectrum analyzer.

The decibel (dB) is an arbitrarily defined unit of transmission gain (or loss) that has come into general use since about 1925. Developed for use in the telephone industry, it was named the bel, in honor of the inventor of the telephone, Alexander Graham Bell.



The ear is much more sensitive to changes of volume at low sound levels than it is at high sound levels. That is, it responds logarithmically to variations in sound intensity. Therefore any unit to express power gains or losses in communication circuits must also vary logarithmically, in order to be practical.

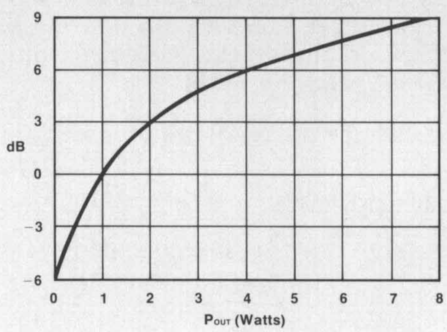
The bel was found to be very convenient for comparing two power measurements on a logarithmic rather than a linear scale because several gains (and losses) can be merely added together to determine total gain or loss. Other methods would be more complicated. The bel proved to be too large a unit however; dividing it by ten yielded the decibel, or dB.

The number, N, of dB by which the power P_{out} exceeds the reference power P_{ref} is defined by

$$N \text{ (in dB)} = 10 \log \frac{P_{out}}{P_{ref}}$$

N is negative when P_{out} is less than P_{ref}.

The non-linearity of logarithms can be seen by plotting it on linear graph paper. Assume we are measuring the output power of a variable gain amplifier. The input power (P_{ref}) is held constant at 1 watt.



Note that when P_{out} equals P_{ref} (that is $\frac{P_{out}}{P_{ref}} = 1$), the power difference is 0 dB. The non-linearity of logarithms can be observed by noting also that doubling the power corresponds to a 3 dB change. Going from 1 to 2 watts is a 3 dB change, just as changing from 4 to 8 watts is a 3 dB change. A 6 dB change corresponds to a factor of 4 times.

Several very useful conversions can be made:

1. Power Ratio to dB

Assume we have an amplifier with input power of 1 watt and output power of 2 watts. What is the gain in dB?

$$\begin{aligned} \text{Gain (in dB)} &= 10 \log \frac{P_{out}}{P_{in}} \\ &= 10 \log \frac{2}{1} \\ &= 10 \log (2) \end{aligned}$$

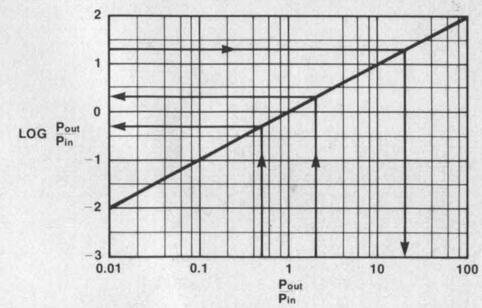


Figure 1.

From the graph of log values (Figure 1), we determine that the log of 2 is 0.3, and therefore the gain of the above circuit is 3 dB. Note that the plot is a straight line (linear) because one scale of the graph is logarithmic.

Assume now that the output power is 0.5 watts for the same 1 watt input power. What is the gain in dB?

$$\begin{aligned} \text{Gain (in dB)} &= 10 \log \frac{P_{out}}{P_{in}} \\ &= 10 \log \frac{0.5}{1} \\ &= 10 \log (0.5) \\ &= 10\ (-0.3) \\ &= -3 \text{ dB} \end{aligned}$$

Note that a 2:1 power loss corresponds to a 3 dB loss (or a gain of −3 dB).

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2. dB to Power Ratio
The above procedure can be reversed by rearranging the formula and using anti-logs, the reverse of logs.

$$\text{Since } \log \frac{P_{out}}{P_{in}} = \frac{\text{Gain (in dB)}}{10}$$

$$\frac{P_{out}}{P_{in}} = \text{Antilog} \frac{\text{Gain (in dB)}}{10}$$

Assume we have an amplifier with a 1 watt input and 13 dB gain. What is the output power?

$$P_{out} = P_{in} \cdot \text{Antilog} \frac{13 \text{ dB}}{10}$$
$$= 1 \cdot (\text{antilog } 1.3)$$
$$= 1 \cdot (20) = 20 \text{ watts}$$

The first three examples of use of the log graph are diagramed on the graph. Other values are similarly determined or can be obtained from log tables in reference texts.

3. Voltage ratio to dB
In many cases the measurement made is in voltage, not power, since voltage measuring instruments are often more available than power measuring meters. It may be convenient to know the signal level in dB and the formula can be adapted to this measurement, since power $= \frac{E^2}{R}$

$$\text{Gain (in dB)} = 10 \log \frac{P_{out}}{P_{in}}$$

$$= 10 \log \frac{\frac{(E_{out})^2}{R_{out}}}{\frac{(E_{in})^2}{E_{in}}}$$

If the input and output impedances are made up of equal resistances, this simplifies to

$$\text{Gain (in dB)} = 10 \log \frac{E_{out}}{E_{in}}^{2}$$

Another mathematical rule transfers the squared term to the coefficient, yielding

$$\text{Gain (in dB)} = 20 \log \frac{E_{out}}{E_{in}}$$

It is important to note that the above is true only for equal impedances.

Let's assume we have an amplifier which supplies a 2 volt output for a 1 volt input. The input and output impedances are equal. What is the gain in dB?

$$\text{Gain (in dB)} = 20 \log \frac{2v}{1v}$$
$$= 20 \log (2)$$
$$= 20 (0.3) = 6 \text{ dB}$$

A 6 dB gain corresponds to a power change of 4:1. Verify this by calculating the power in the 2 volt and 1 volt signals.

Probably a more common use of this equation is measuring the power output variation in an amplifier vs. frequency, gain, or other parameter.

Assume you are testing an audio amplifier for frequency response. A reference input level is established at 1K Hz and a voltmeter connected to the output measures 4.5 volts. The input signal amplitude is held constant as the frequency is varied from 20 Hz to 20K Hz. Let's assume that the maximum voltage drop from the reference is observed at 20 Hz, with 3.57 volts being measured and the maximum voltage rise of 5.67 volts is observed at 3K Hz. Calculate the output variation in dB.

$$\text{Gain (in dB)} = 20 \log \frac{V_1}{V_{ref}}$$

$$\text{Drop (in dB)} = 20 \log \frac{3.57}{4.5}$$
$$= 20 \log (0.80)$$
$$= 20 (-0.10)$$
$$= -2.0 \text{ dB}$$

$$\text{Rise (in dB)} = 20 \log \frac{5.67}{4.5}$$
$$= 20 \log (1.26)$$
$$= 20 (0.100)$$
$$= 2.0 \text{ dB}$$

Therefore, at the given power level, this amplifier has a ±2 dB response from the 1K Hz reference. Other problems of this type can be similarly calculated.

A common, but technically incorrect, usage of dB is expressing the voltage gain of a circuit, without regard to impedance. For example, an amplifier with an input impedance of 10K ohms and an output impedance of 1K ohms may require a 10 mv input to develop 1 volt at the output. Inserting 1 volt and 10 mv in the formula above yields a gain of 40 dB. It is important to note that this is the voltage gain and not the power gain. The correct definition of dB is the ratio of two power levels.

Use the voltages and impedances above to calculate input and output power, then use the formula #1 above to determine true dB gain. Do you get 50 dB?

4. dB to Voltage Ratio
The above procedure can also be reversed by manipulating the formula.

$$\text{Since } \log \frac{E_{out}}{E_{in}} = \frac{\text{Gain (in dB)}}{20}$$

$$\frac{E_{out}}{E_{in}} = \text{antilog} \frac{\text{Gain (in dB)}}{20}$$

or

$$E_{out} = E_{in} \times \text{antilog} \frac{\text{Gain (in dB)}}{20}$$

Let's assume that we want to verify that a generator meets its output specifications of a maximum deviation of 2 dB from the peak. The point of peak output is identified and measured at 2.1 volts. What voltage corresponds to a 2 dB drop from 2.1 volts?

$$E = 2.1 \text{ antilog} \frac{-2 \text{ dB}}{20}$$
$$= 2.1 (0.79)$$
$$= 1.66 \text{ volts}$$

5. Power to dBm
All of the above are relative measurements. The dBm is an absolute measurement because it is referenced to a power level of 1 mw. This means that 1 mw = 0 dBm, which is true regardless of the impedance of the system. Going back to the power ratio formula, let's substitute 1 mw for P_{ref}.

$$\text{Absolute power level (in dBm)} = 10 \log \frac{P_{out}}{1 \text{ mw}}$$

Assume that an amplifier has an output of 4 mw. What is the output level in dBm?

$$\text{Absolute level (in dBm)} = 10 \log \frac{4 \text{ mw}}{1 \text{ mw}}$$
$$= 10 \log (4)$$
$$= 10 (0.6)$$
$$= 6 \text{ dBm}$$

Another amplifier has an input level of +4 dBm and an output of 0.02 watts. What is the gain of the amplifier?

Let's first calculate the output level in dBm, noting that 0.02 watts equals 20 milliwatts.

Absolute Level (in dBm)

$$= 10 \log \frac{20 \text{ mw}}{1 \text{ mw}}$$
$$= 10 \log 20$$
$$= 10 (1.3)$$
$$= 13 \text{ dBm}$$

An output of 13 dBm and an input of 4 dBm gives a gain of 9 dB. Note that the input and outputs are absolute levels and expressed in dBm, while the gain is expressed as dB because it is a relative measurement.

6. dBm to mw

The above equation can be transformed to allow conversion of dBm to watts.

$$\log \frac{P\ \text{mw}}{1\ \text{mw}} = \frac{\text{dBm}}{10}$$

$$\frac{P\ \text{mw}}{1\ \text{mw}} = \text{antilog}\ \frac{\text{dBm}}{10}$$

How many watts correspond to a power level of +30 dBm?

$$P\ (\text{in mw}) = (1) \cdot \text{antilog}\ \frac{30}{10}$$

$$= \text{antilog}\ 3 = 1000$$

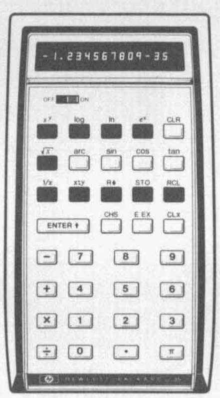
$$\text{Power} = 1\ \text{watt}$$

There exist zero references other than 1 mw. A dBV is defined using one volts as the reference level. Audio experts will be familiar with dBA, where a standard sound level is used as a reference. Some high power areas use dBk, which is a measurement referenced to one kilowatt.

While other methods of reference exist for absolute levels, using dBm appears to be most common for electronic measurements.

A graph designed to be cut out of the issue is included on page 7 for a handy reference for voltage—dBm conversion.

All of the above calculations can be made on the HP 35 mini-calculator.



HP 35 Minicalculator

1. **Power ratio to dB:**
   Punch in 1st power level [ENTER↑]
   Punch in reference power level [÷] [log] [1] [0] [×]
   Read answer on the display
2. **dB to Power Ratio:**
   Punch in dB [ENTER↑]
   [1] [0] [÷] [ENTER↑]
   [1] [0] [x^y]
   Read power ratio on the display
   To obtain actual power reading:
   Punch in reference power [×]
   Read power on display
3. **Voltage Ratio to dB:**
   Punch in voltage reading [ENTER↑]
   Punch in reference voltage reading. [÷] [log] [2] [0] [×]
   Read dB on display
4. **dB to Voltage Ratio**
   Punch in dB [ENTER↑]
   [2] [0] [÷] [ENTER↑]
   [1] [0] [x^y]
   Read voltage ratio on display
   To obtain voltage reading:
   Punch in reference voltage reading [×]
   Read voltage on display
5. **Power to dBm:**
   Punch in power reading (in milliwatts) [log] [1] [0] [×]
6. **dBm to mw:**
   Punch in dBm [ENTER↑]
   [1] [0] [÷] [ENTER↑] [1] [0] [x^y]
   Read power (in milliwatts) on display.

The graph on page 7 may be helpful in converting signal levels in dBm or watts to volts. This conversion can be calculated for any impedance using ohms law; several of the more common impedances are included on the conversion chart for convenience of use.

Precise calculations of the dBm to voltage chart for 50 ohm and other impedances can be obtained with the following steps:

Punch in dBm reading [ENTER↑]
[1] [0] [÷] [ENTER↑] [1] [0] [x^y] [ENTER↑]
[1] [E EX] [3] [÷] [ENTER↑]
Punch in impedance [×] [$\sqrt{x}$]
Read voltage (in volts) on display.

While the HP 80 business version minicalculator does not have a [log] function, the logarithms of a number can be computed with the following sequence:

[1] [i] [1] [PV]
Punch in number [FV]
[n] [R↓] [SAVE↓]
Punch in 2.3025 [÷]
Read log on display

The other functions are similar. Note that the HP 80 has a [y^x] function while the HP 35 has the [x^y]. Therefore, to calculate antilogs with the HP 80, push [x⇄y] [y^x] where the HP 35 instructions call for [x^y]

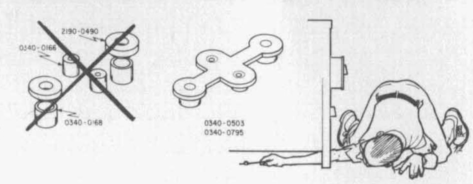
NEED ASSISTANCE WITH TRACE RECORDING?

If you use an oscilloscope camera to record waveforms, you can now get free technical assistance by telephone from Polaroid Corporation.

Trained technical experts will accept all calls, including COLLECT calls, from any point in the continental United States. They can assist you with photographic techniques and problems, or recommend hardware to mate a particular camera/oscilloscope combination.

Polaroid's Technical Assistance Line —(617) 547-5176 provides rapid access to information, without charge, to users of Polaroid's industrial cameras and instant-developing films in a wide variety of disciplines. This service is available any weekday, except holidays, from 9:00 a.m. to 5:00 p.m., Eastern Time. Customers in Canada, Europe and elsewhere can place prepaid calls or write to Richard Jagolta, Polaroid Technical Assistance, 549 Technology Square, Cambridge, Massachusetts 02139.

NEW TO-3 INSULATOR



Here is something of interest if you have ever crawled under a workbench looking for a transistor insulator dropped while changing a transistor. A one-piece insulator is available that replaces six individual pieces used in some HP products.

Two sizes are available to accommodate various heat sink thicknesses. Part number 0340-0795 has shoulders for a 3/16 inch or thicker metal and is priced at 15 cents. For thinner metals, use 0340-0503, priced at 25 cents.

Having a small stock of these available may prove economical because of the time saved when replacing a transistor.

A "NOT-SO-NEW" TROUBLESHOOTING TECHNIQUE

by Dan Struckmann

When your everyday techniques of troubleshooting seem to run you in circles, pick up a clip lead and a voltmeter!

I am sure that most of us on the bench have picked up or developed our own troubleshooting techniques. Some form of logical half-splitting with scope waveforms, voltage checks and board substitution is usually employed to trace the problem down to board level. At this point, how does the technician find the one or two defective parts in a 23-transistor, direct-coupled, dual closed-loop monster? (A pre-regulated, regulated, constant voltage, constant current programmable power supply fits this description).

This is when the technician steps back with some basic circuit logic and an understanding of the unit and narrows the region of probable cause to reduce troubleshooting time.

With the knowledge of the on-off characteristics of transistors, examine each stage of the circuit in question to determine how each stage would function if everything were working properly. Using this technique, we can usually neglect all closed feedback loops, and need not worry about in-between states!

Here's the method:

Try to force the circuit to change states (opposite to whatever stage it is presently locked in) and determine whether or not the circuit's reaction to the change is correct.

1. If the result does indeed correspond with what you had initially decided, there is a good chance that the active devices after that point are functional.

2. If the result does not correspond with what you had initially decided, generally one or more of the active devices after that point are defective.

Continue in this manner, half-splitting as you go along until a simple circuit is left.

Three very important points must be stressed. First, be sure that any forced response you may initiate will not damage any other components. Be especially careful in high power circuits such as output drivers and high current power supplies. Second, do not look for any change any farther along in the circuit than you can logically justify; for example, don't look for a level change in the output when the output stage is AC coupled. Third, keep in mind that you are looking for simple responses such as go, no-go, high or low levels, etc.

The means by which you force your response is as follows:

1. The OFF state of any transistor, FET, or SCR can be obtained by either opening the collector or emitter (in a case where you are not sure that the devise is good), or shorting the emitter base junction. Shorting the B-E of a transistor will cause it to turn off and the collector should float toward the supply voltage, indicating that the transistor is at least functional. In the case of an SCR or thyristor, either disconnect the cathode or anode or disconnect the gate lead. Disconnecting the gate will also show if the SCR is shorted.

2. An ON state of any device is simulated by shorting the emitter to collector, anode to cathode, or drain to source. For a transistor to be ON, the E-B junction must be forward biased, which should cause a correspondingly low voltage drop across the E-C junction.

With the above in mind, do what is necessary to put the device in the state you desire.

In many instances, forcing a given response might damage other components and caution must be exercised. Rotating adjustment pots in the circuits may be used to cause a change. When this is not possible, use your voltmeter to measure E-B and E-C to identify the defective device.

Now let's consider a few practical examples. Looking at Figure 1, you will notice a differential amplifier and

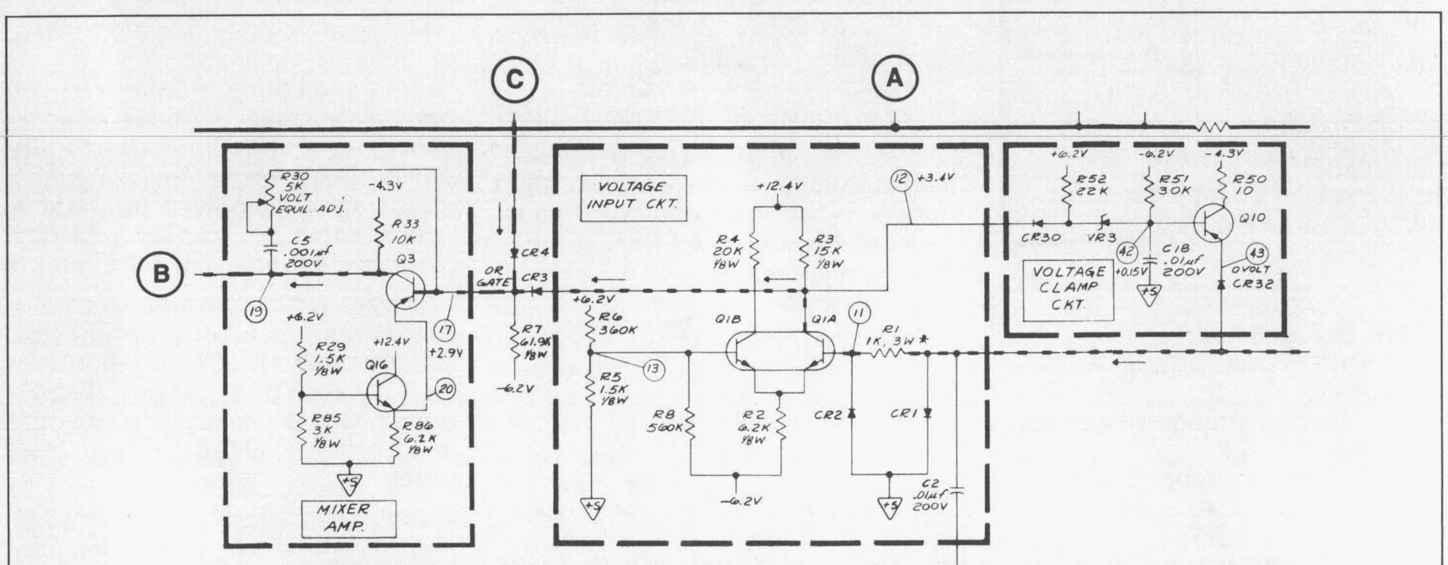


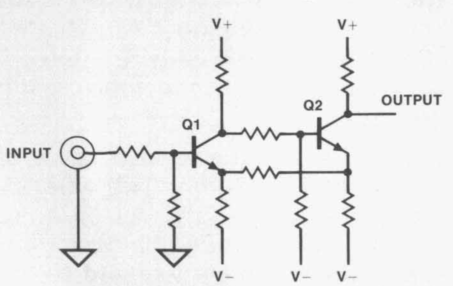
Figure 1.

associated states, all direct-coupled. This circuit is powered by positive and negative supplies and it is quite difficult, if not impossible, to determine either correct voltage levels or the logic state of a device. It may be noted also that this type of circuitry usually has one or more feedback loops tied in. Let's assume that the voltage at Point B is negative with respect to Point A (which is incorrect) and we want to determine the cause. Applying the method described earlier, determine first that forcing Point B positive will not destroy any following circuitry. Next determine a good point to "half-split" the circuit. Let's choose the collector of Q1A. Determine what state Q1A must be in to force Q3 "on," thus pulling Point B positive. A glance tells us that Q1A must be turned *on*. So, let's simulate that by using a clip lead to connect the emitter of Q1A to its collector. If the level at Point B does not change, we know that either Q3 or Q16 is bad. Point C is positive and the circuitry at or before Q1 is probably good (neglecting more obvious power supply problems at this point).

If point B had gone positive instead, we would have known that Q1 or the circuitry before Q1 had failed. The same technique is used to continue the isolation process.

This technique is especially valuable in closed loop systems (or any circuit with feedback) because it gives a known input to a stage and a given output reaction can be expected. The loop can be traversed in the forward or reverse direction, verifying the proper operation of each stage, until the defective stage is identified.

An example of a simple feedback circuit is given below in Figure 2.



Let's assume the voltage at the collector of Q2 is higher than specified. What could cause this? Q2 could be open, Q1 could be shorted, or the input level could be wrong also. So we have several possibilities, any of which singly or in combination could cause our problem. Just looking at voltage levels many times leads to confusion. The clip lead technique lends itself very nicely here because it gives us definite good/bad answers, with no guess work! That is, we do not have to guess what all the inputs or outputs may be, because we can make the inputs or outputs look like we want them to. Many times knowing what they are gives us no information. In the case above, we could short E-B of Q1 which should make the collector of Q1 go high. This should turn on Q2, causing its collector to go low. Again, given only the Q2 collector was high, we could tell whether or not Q2 was bad without making any other voltage measurements. You have probably discovered that a feedback system is difficult to repair because there are so many variables to consider when trying to decide what is happening.

The suggested approach is to force a transistor or other active element to some state. Then we know if the next element is doing what it is supposed to be doing, which is much better than guessing if the output is correct after looking at all the inputs. With the complexity of instruments and systems today, the technician is not afforded the luxury of guessing!

With a little practice and some ingenuity (one experienced technician uses a desoldering tool instead of a clip lead), a "not-so-new" tool may be added to your trade techniques. It is the extra speed and expertise gained by using techniques like this that separate the outstanding repairman from the average technician and keep him growing with the technology.

Dan Struckmann is a technician currently working in the computer peripherals design laboratory at the Cupertino Division of Hewlett-Packard. Dan joined HP in 1971 and worked at the corporate customer repair center in Mountain View. Besides finding time for ham radio, radio-controlled airplanes, and stereo, Dan is attending San Jose State University working on a degree in electrical engineering.

METRIC MULTIPLIER PREFIXES

Here's a handy reference listing of all the multiplier prefixes currently being used. This may prove helpful when working with unfamiliar units or trying to determine conversions, such as how many nano seconds are in one microsecond. Or what is the capacitance in microfarads of a 1000 picofarad capacitor.

Of course some of us who have been around awhile will recognize the picofarad (which is 10^{-12} farad) used to be called micro micro farad, and this is a good clue.

Prefix	Abbrev.	10?	Prefix	Abbrev.	10?
Tera	T	10^{12}	deci	d	10^{-1}
giga	G	10^{9}	centi	c	10^{-2}
mega	M	10^{6}	milli	m	10^{-3}
myria	ma	10^{4}	micro	μ	10^{-6}
kilo	k	10^{3}	nano	n	10^{-9}
hecto	h	10^{2}	pico	p	10^{-12}
deca	da	10^{1}	femto	f	10^{-15}
(unit)	(unit)	10^{0}	atto	a	10^{-18}

Do you want to test yourself?

1. *How many nanoseconds are in one microsecond?* ______
2. *A electronic frequency counter has displayed a measurement of 1.4532 GHz. What is this reading in KHz?* ______
3. *What is the capacitance in microfarads of a 1000 pf capacitor?* ______
4. *One inch equals 2.540 cm How many millimeters is this?* ______

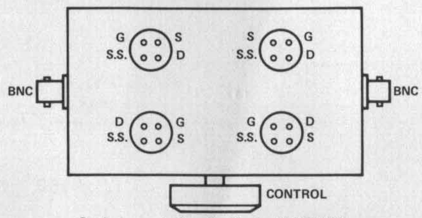
Answers to Metric Multiplier Quiz

1. 1 ns = 10^{-9} second
1 μs = 10^{-6} seconds = 1000 ($\times 10^{-9}$) seconds
therefore 1 μs = 1000 ns
2. 1.4532 GHz = 1.4532 $\times 10^{9}$ Hz = 1,453,200,000 Hz = 1,453,200 KHz
3. 1000 pf = 1000 $\times 10^{-12}$ farads = 10^{-9} farads (or 0.000 000 001)
1 μf = 10^{-6} farads = 0.000 001 farads
therefore 1000 pf = 0.001 μf
4. 1 cm = 1 $\times 10^{-2}$m
1 mm = 1 $\times 10^{-3}$m, 10 mm = 10 $\times 10^{-3}$m = 1 $\times 10^{-2}$m
therefore 1 cm = 10 mm
and 2.540 cm = 25.40 mm

MORE ON FET CHECKER

by George Stanley

Oops!, is our face red. You may have noticed in the November issue (Vol. 12, No. 4) that there was an error in Figure 4, the FET Tester. Shown below is the way the figure should have been.



Sockets are Lafayette Radio 33R87289; others may exist but are difficult to find.

CORRECTED

Here is a tip you probably figured out for yourself. In order to obtain the waveforms shown in Table 2, Page 2, of the November issue, you must have your oscilloscope *DC* coupled.

Several of you have asked about a circuit for the square wave generator, and here is one idea. Most oscilloscopes have a 10 volt P to P square wave calibration signal, but on many oscilloscopes it is often negative going and clamped to ground. We need it DC coupled and swinging around zero. You can use a 5 volt battery or power supply to move it up, but that's a bit awkward. Figure 5 shows a more novel approach.

The idea here is filter the square wave to obtain −5 VDC, and then use this voltage as an offset voltage. The only drawback is that you need a two-channel oscilloscope that is capable of presenting an A-B display.

Another drawback to using a scope is that the square wave source impedance should be 1K or less or the FET in the tester will load the square wave and reduce the amplitude. To get a good FET indication and make the circuit work, you need close to 10 volts (or more). You can easily check your scope's source impedance by loading the calibrator down until it puts out half amplitude. Then the source impedance equals the loading resistor.

If any of you have any other ideas, send them in and I'll pass them along. I'm still looking for a simple square wave circuit that puts out a DC coupled 10 volt square wave centered at zero.

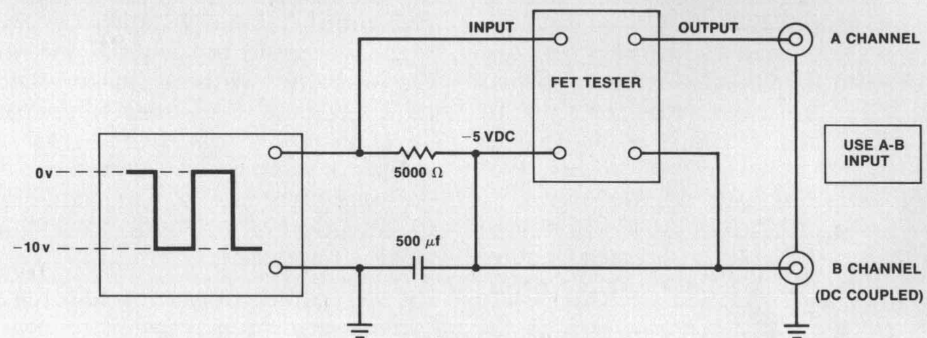
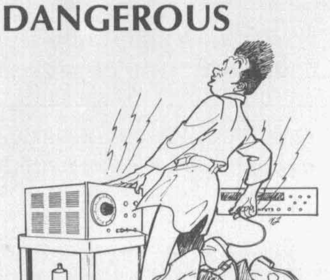


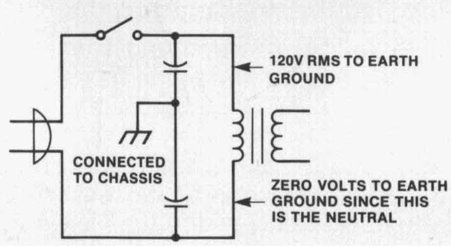
Figure 5

UNGROUNDED CHASSIS ARE DANGEROUS



Why does an ungrounded signal source pose a threat to an input circuit? This is the question sometimes asked after the input circuitry to a counter or other instrument has been destroyed.

Some companies sell inexpensive signal generators that do not use a three wire line cord, which means that the chassis is not connected to earth ground. Generally, each side of the power line will be connected to chassis with a small capacitor, typical 0.1 µF. This helps keep power line noise out of the generator, but it also places a 60V rms signal on the chassis! This is 169V p-p (relative to earth ground).



The capacitors act as an A-C divider network, since one side of the line is at ground potential. The chassis thus has a 169V p-p 60 Hz signal on it.

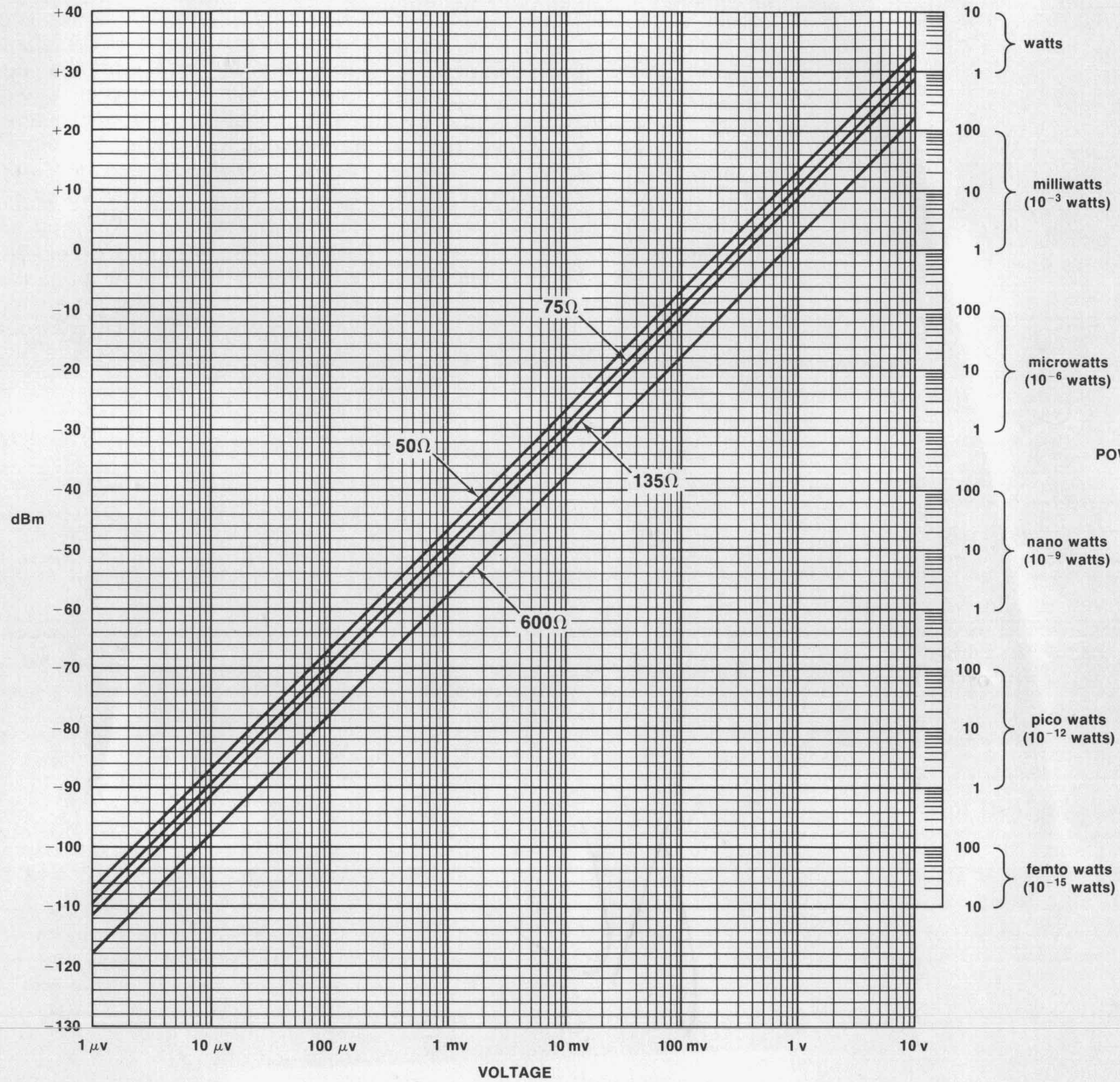
This may cause no problem when the counter is connected to this signal source if the ground connections on the input connector make contact before the center conductor. The charges on the two capacitors get shunted through the ground circuit on the counter. If the center conductor makes contact before the ground conductor, the capacitors get discharged through the input circuitry. Often the damage specification is exceeded and the input circuitry is destroyed.

Another problem becomes evident when the operator places one hand on the ungrounded chassis and the other on a grounded chassis. The 169V p-p signal may prove to be too much of a jolt!

The danger of an ungrounded signal source damaging other instruments and injuring personnel can also be alleviated with a three-wire line cord, so the chassis is connected to earth ground.

The above comments also apply to instruments (including HP) where a three-wire cord exists, but the third wire is not grounded. If you must use a three-wire to two-wire NEMA adaptor (sometimes called a suicide plug), be certain that the green wire connects to a good ground.

dBm TO VOLTAGE CONVERSION



CUT ALONG THIS LINE

To convert dBm to voltage, move to the right from the dBm scale to the line representing the impedance of the circuit being measured. Then move down and read the signal strength on the voltage scale. Use the reverse procedure to convert voltage to dBm.

A power scale has also been provided to allow conversion from voltage to power or dBm to power. Note that the relationship between power and dBm does not depend on circuit impedance.

For example, −30 dBm (which is 1 microwatt for all impedances) is 7mv for a 50Ω impedance, but it is a 24 mv for a 600Ω impedance.

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RECOMMENDED READING

The books recommended are not stocked or offered for sale by Hewlett-Packard Co. Please consult your local bookstores or contact the publisher directly for copies.

A Casebook of Basic Circuits for Electronics Instrumentation

Edited by George C. Stanley, Jr.

This text, which is intended for a Junior college electronics class, analyzes in detail a number of circuits commonly found in electronic instruments. The circuits covered are power supplies with and without feedback, the Wein bridge, differential amplifiers, integrators, trigger and shaping circuits, sampling oscillography, decade counting and divider assemblies, operational and basic feedback amplifiers, voltage-to-frequency converters and phase lock circuits.

The authors present detailed troubleshooting information and failure patterns for each of these circuits, often times commenting on some design consideration such as temperature stability or impedance conversion.

The book, which is priced at about $9.50, is available through all technical bookstores and from the publisher, Rinehart Press, San Francisco, California 94134.

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