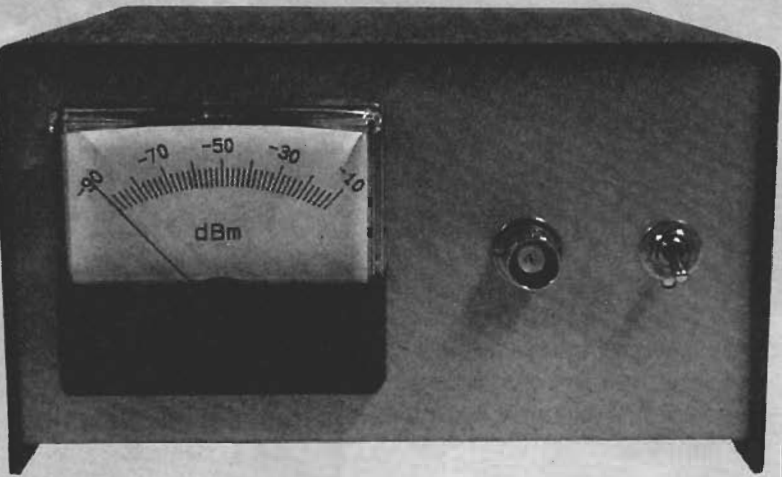

dB METER

Build this decibel meter and measure field strength, read filter outputs, and check oscillator injection values.

JOHN PIVNICHNY

A SIGNAL-LEVEL METER WITH A LOGarithmic or decibel scale can be a very useful test instrument for the electronics experimenter or radio amateur. The decibel (dB) can express many different electrical quantities in convenient form. Decibels compress widely varying electrical values onto a more manageable logarithmic scale. For example, the range of powers extending from 100 watts down to 1 microwatt is a ratio of 100,000,000 to 1 but it is expressed as only 80 dB.

This article explains how to build and use a decibel meter that covers an 80-dB range. Gains and losses through circuits such as attenuators, amplifiers, and filters, when expressed in dB, can be added together to produce the total gain or loss. (See the box for more information on decibels.)

Conventional linear reading, radio-frequency voltmeters typically cover only 20 to 30 dB before it is necessary to change ranges. This means that you must constantly switch the meter range as you tune across a filter's response curve. The procedure for checking several filters with different center frequencies becomes tedious. With this meter, you just record the decibels and you're done!

If you want to adjust the injection level for a mixer circuit to −30 dBm with conventional test equipment, you must make some calculations to convert a voltage reading to power. However, if you build this meter you won't have to make any calculations because the meter is calibrated directly in dBm, a unit of power referenced to a milliwatt (1 mW or 0.001 watt).

Power can be measured in dBm regardless of the circuit's input or output impedance, but this meter is designed so that if a circuit's impedance is known and specified, dBm measurements can be based on voltage. For the 50-ohm input of this decibel meter, 1 milliwatt of power corresponds with a voltage of 0.224 volts RMS. You just feed in the signal and read the dBm level on the meter scale.

WHAT IS A DECIBEL?

A decibel (dB) is a power or voltage measurement unit referred to another power or voltage. Log means common logarithm, power (P) is in watts, voltage (V) is in RMS volts.

$dB = 10 \log (P2/ P1)$

$dB = 20 \log (V2/ V1)$

A decibel meter is an instrument that directly measures the power level of a signal in decibels above or below an arbitrary reference level. It is also called a dB meter.

The dBm unit or *decibels above 1 milliwatt* is defined as 10 times the common logarithm of the ratio of a given power in watts to 0.001 watt.

$dBm = 10 \log (P/0.001)$

A negative value such as −17 dBm means decibels below 1 milliwatt. As long as the impedance is known and specified, dBm can be computed with voltage. For a 50-ohm resistance, 1 milliwatt of power corresponds to a voltage of 0.224 volts RMS. Using this value in the decibel equation yields:

$dBm\ (50\ ohms) = 20 \log (V/ 0.224)$

The dBV unit or *decibels above 1 volt* is a voltage level equal to 20 times the common logarithm of the ratio of a given voltage in volts to 1 volt.

$dBV = 20 \log (V)$

How does the meter work?

The decibel meter converter is based on circuitry within the CA3089E, a monolithic IC FM system from Harris Semiconductor. The device provides all the functions of a comprehensive frequency-modulation, intermediate-frequency system, but only part of this capability is needed for this decibel meter.

Figure 1 is the schematic for the decibel meter. The circuit consists essentially of IC1, the CA3089E, a 0 to 100-microampere meter M1, on-off switch S1, a few resistors and capacitors, and a diode. Most of the electronic components are inserted and soldered on a small circuit board that is mounted on standoffs above the bottom of the lower half of a metal project case. However some components are mounted on the back of the meter.

Figure 2 is the plot of DC volts out of METER OUT pin 13 of IC1 (33 kilohms to ground) vs. the input signal in microvolts on IF IN pin 1 converted to decibels

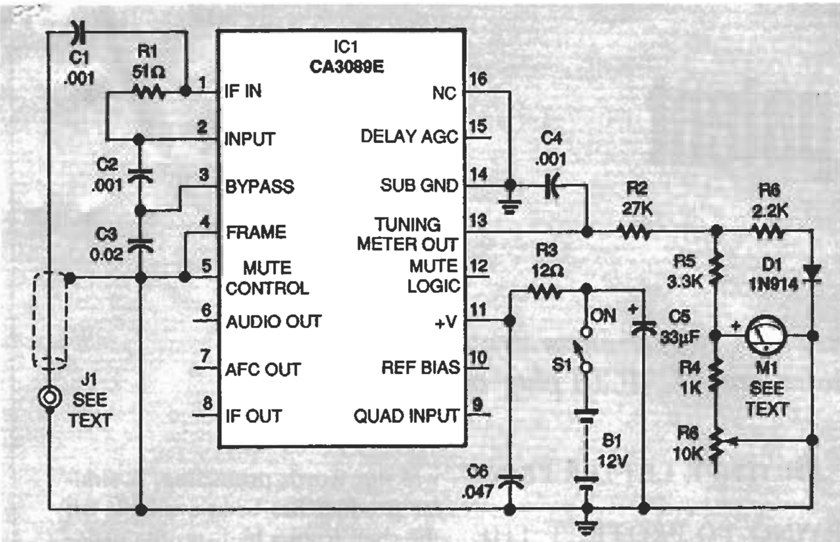

FIG. 1—SCHEMATIC FOR THE DECIBEL METER. The principal component is the CA 3089E FM IF IC because it contains the decibel conversion circuitry

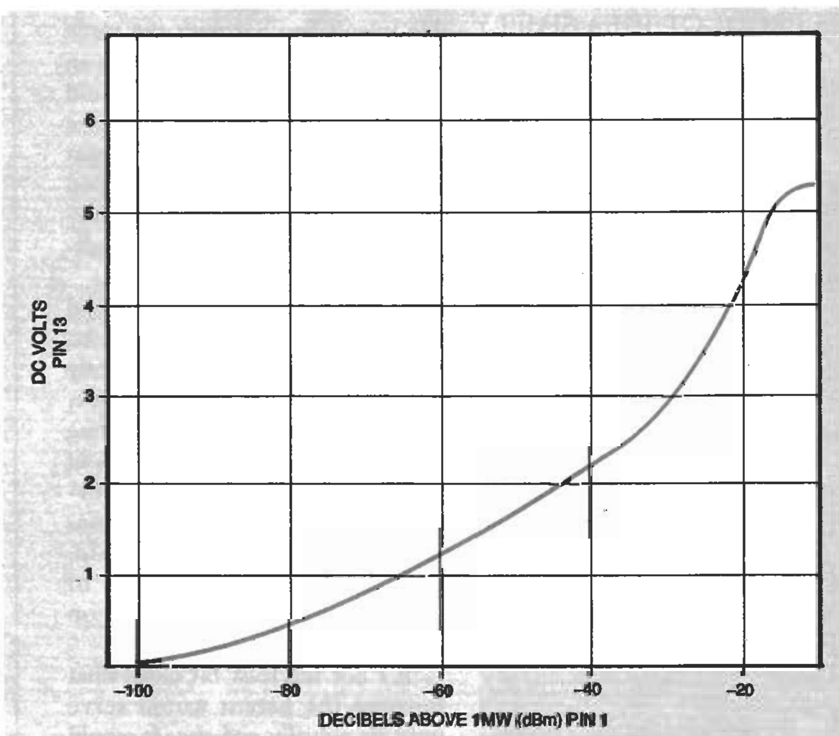

FIG. 2.—PLOT OF VOLTAGE AT IC1, pin 13 vs. the input signal in microvolts on IC1, pin 1 converted to decibels above 1 milliwatt.

PARTS LIST

Resistors are ¼-watt, 10%, unless otherwise specified.
R1—51 ohms
R2—27,000 ohms
R3—12 ohms
R4—1000 ohms
R5—3,300 ohms
R6—2,200 ohms
R7—10,000-ohms, trimmer potentiometer

Capacitors
C1, C2, C4—0.001µF ceramic disc
C3—0.02µF ceramic disc
C5—33µF aluminum electrolytic, radial-leaded
C6—0.047µF ceramic disc

Semiconductors
IC1—CA3089 CMOS FM IF, Harris Semiconductor or equiv.
D1—1N914 silicon diode, glass axial-lead package

Other components
S1—toggle switch, SPST, panel-mount
J1—BNC receptacle connector, panel-mount
M1—meter, 0 to 100 µA (scale modified to dBm units, see text)
B1—eight alkaline AA cells in holder

Miscellaneous: circuit board (see text); project case, metal, 3 × 5¼ × 5⅞-inches; RG-174/U cable, 6 inches; battery holder for eight AA cells; three 4-40 × ¾ screws; nine 4-40 hex nuts; four 6-32 screws; two ¾-inch 6-32 threaded standoffs; aluminum channel; 3 inch length (see text), 12-volt battery clip, insulated hookup wire, solder.

The following options are offered by Unicorn Electronics, Inc., Valley Plaza Drive, Johnson City, NY 13790 (607) 798-0260:
- Kit of parts including all electronic components, an etched and drilled circuit board, drilled case, and meter with dBm scale—$49.95
- Meter with dBm scale—$18.75
- Circuit board, etched and drilled—$3.00

Add $3.50 shipping and handling. Send check or money order. New York State residents add local sales tax.

above 1 milliwatt. IC1 detects the signal level and generates a nearly logarithmic DC output. To linearize the high end of this curve, diode D1 and resistor R6 shunt some of the DC current as the voltage on pin 13 rises above 3 volts.

The battery pack consisting of eight AA alkaline cells makes the instrument portable and eliminates the possibility of 50/60 Hz hum interfering with the readings. The meter draws only about 16 milliamperes, so battery life will be long. The meter will provide accurate readings as long as the output of the battery pack remains above 8 volts. No regulation of this DC is required.

Building the dBM meter

The electronic circuitry is mounted on a small 1½ × 2-inch circuit board. The components can be wired by point-to-point methods or they can be mounted on a PC board. A foil pattern for the circuit board is included in this article for those who wish to make their own. However, a finished circuit board can be purchased from the source given in the Parts List.

All of the electronic components are readily available from mail-order electronic distributors and electronics retail stores. Meter M1 has a custom-drawn scale graduated in 2 dBm units from −10 dBm to −90

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dB METER

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dBm. A pattern for the meter graduations is included in this article for a meter with a scale length (chord) of 1½ inches. However, a meter with decibel graduations can be purchased from the source given in the Parts List. An off-the-shelf, standard sheet metal project case is suitable for packaging this project.

If you make your own circuit board, be sure to drill holes in each or three corners for mounting the finished board on standoffs to the bottom of the project case. Refer to the parts placement diagram, Fig. 3. Insert and solder the components to be located on the circuit board, observing the correct orientation of the pins of IC1 and the polarities of electrolytic capacitor C5 and diode D1. After all soldering is complete, check to be sure there are no inadvertent solder bridges or cold solder joints, and make any repairs necessary. Set the completed circuit board aside.

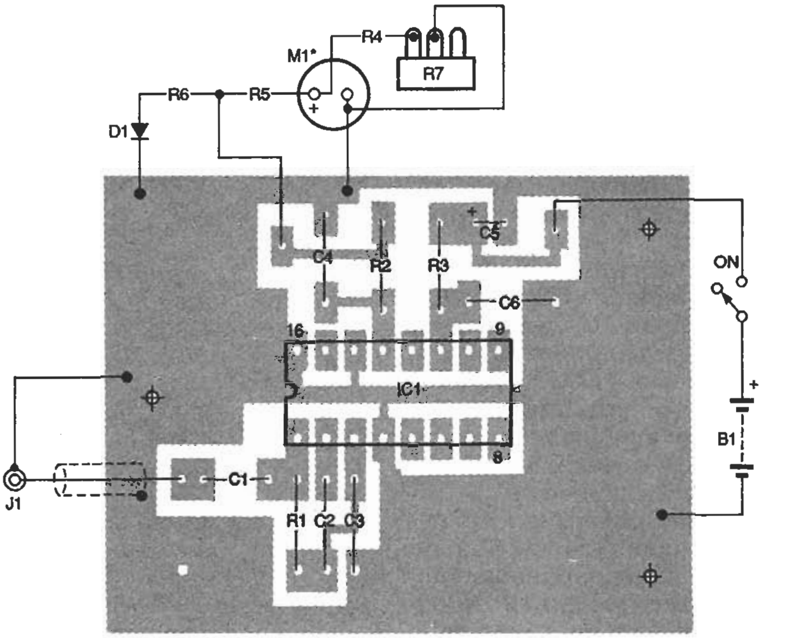


FIG. 3—PARTS LAYOUT for the decibel meter. Some components are mounted on the case wall and on the back of the meter.

Metal case cutouts

The prototype decibel meter was built into a standard, two-part metal project case that measured 5⅞ inches wide × 3 inches high × 5¼ inches long, but any other case of comparable size will be suitable. A metal case will shield the circuitry of the decibel meter from external RF fields.

Refer to the assembly diagram Fig. 4. Carefully lay out and center punch all of the holes to be drilled or formed in the bottom and sidewall of the lower half of the case. Cut a 1¾ inch diameter mounting hole for meter M1, and appropriate-sized holes for switch S1, and jack J1. Also drill the holes necessary for mounting the circuit board to the base of the case (using the pre-drilled mounting holes in the circuit board as a pattern). Then drill the holes for clamping the eight-cell battery pack B1 to the bottom of the case within the case.

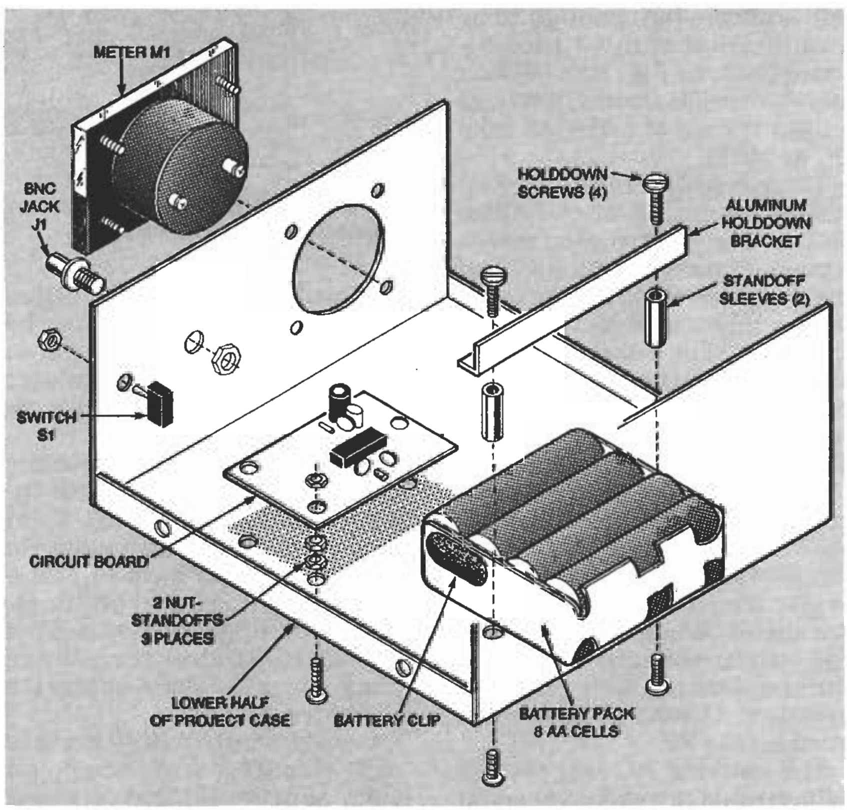


FIG. 4—EXPLODED VIEW OF THE DECIBEL METER in a standard, two-part metal project case. The battery pack hold-down bracket is made from aluminum channel stock.

Cut lengths of insulated hookup wire long enough to reach from the circuit board to meter M1, switch S1, and connector J1 when all components are assembled in the case, leaving sufficient slack. Cut a length of shielded RG-174/U coaxial cable to make a connection from pin 1 of IC1 to BNC jack J1. Strip, insert, and solder

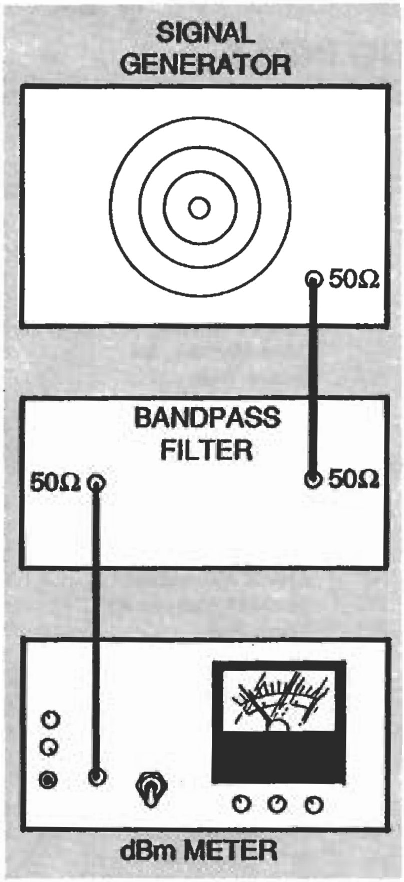


FIG. 5 —TYPICAL DECIBEL METER test setup for measuing the characteristics of a bandpass filter.

the ends of the wires and cable and insert and solder one end of each on the circuit board as shown. Insert the ends of the red and black wires from a 9-volt snap connector in the circuit board and solder them in place.

Insert and fasten meter M1, jack J1, and switch S1 in the panel holes cut for them and fasten them in position with the appropriate lockwashers, nuts and ring nuts. Attach two solder lugs to the terminals of meter M1 with screws.

Position the circuit board in the bottom half of the case on three screws with two nuts on each to act as standoffs. Then fasten the board in position with three nuts. Solder all hookup wires and the coaxial cable to the panel-mounted components, as shown in parts placement diagram Fig.3.

Insert the eight alkaline AA cells in the battery holder and clamp the battery holder to the bottom of the case.

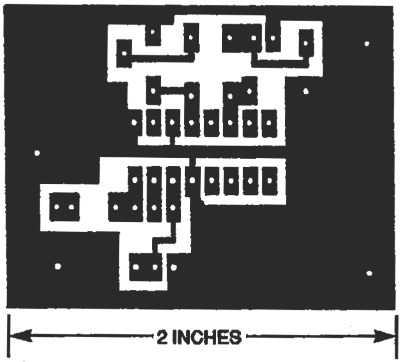
Test and checkout

For most amateur radio and hobbyist experiments, the meter can be coarsely calibrated after the wiring is complete. Couple a signal into BNC jack J1 and adjust signal amplitude for a 2-volt DC level on pin 11. Then adjust 10-kilohm trimmer potentiometer R7 until the meter reads −50 dBm (in the center of the scale). The decibel meter is now complete and ready to be used.

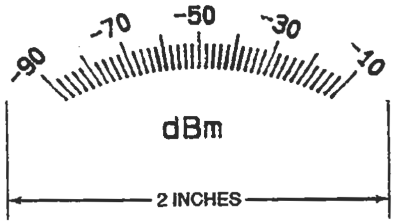
Meter limitations

The CA3089E was designed primarily for use at 10.7 MHz. As a result, the frequency response of the decibel meter is limited to the high-frequency region. Harris Semiconductor rates the CA3089E for use between 2 and 20 MHz. Below 2 MHz, the responses of the peak detectors within the integrated circuit start to roll off. However, the meter can be used for comparison purposes with signals above 20 MHz. The absolute value on the meter scale will be lower than expected as the frequency response drops off. The prototype provides useful readings up to 50 MHz.

Input impedance is fixed at 51 ohms by the resistor R1 between pins 1 and 3. This makes it easy to extend the meter's usefulness in measuring stronger signals through the use of 50-ohm attenuators. Any signal strengths above 0.1 volt peak should be attenuated with the 50-ohm attenuator before introducing them into the meter so that the reading will be remain on-scale. The absolute maximum limit for IC1 before it is damaged or destroyed is 1.2 volts.



FOIL PATTERN FOR CIRCUIT board



PATTERN FOR dBm graduations of meter scale

Measuring decibels.

Figure 5 is a diagram for a typical test setup for measuring the passband of a receiver's input filter. If it is a bandpass filter, read dBm at the center frequency, then tune the generator higher in frequency while recording the dB level after each adjustment. Finally, tune below the center frequency to record the lower skirt.

Crystal filters are evaluated the same way, but a very stable generator with very fine vernier tuning is required for the best results. Keep in mind that most crystal filters have termination resistances higher than 50 ohms, usually somewhere between 200 and 2000 ohms. Consequently, impedance transformation resistors or circuits will be required to match the 50-ohm meter and generator.

To read oscillator levels, feed the signal into the BNC jack on the front panel and read dBm directly. The meter will also function as a sensitive, wide-range, field-strength meter with a one-quarter- wave antenna at the input.

How to measure dBV

In a circuit with a 50-ohm input, the dBm unit is 20 times the logarithm of the ratio of the RMS voltage in a circuit to the value of 0.224 ohms. (See the box "What is a Decibel?")

The peak decibels above 1 volt or dBV unit is 20 times the logarithm of the ratio of the voltage to one volt. This can be read directly from the meter scale by taking the reading and subtracting 10 dB. Thus for dBV measurements, the meter will cover the range of −20 dBV to −100 dBV. However, that range can be shifted higher with a 50-ohm attenuator. Ω