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DIY Microphone Calibration

By Ron Tipton

This hands-on tutorial shows you how to inexpensively calibrate a microphone.

Microphone calibration has been the subject of many articles and technical papers, some of which I've included in the References and Bibliography sections. I won't cover so-called "primary" calibration because it is too expensive and too time consuming for those of us who just want to have a reasonably accurate measurement microphone. I will discuss two methods of "secondary" calibration: the electrostatic actuator and microphone comparison.

THE ELECTROSTATIC ACTUATOR

This is a non-acoustical method, and although the equipment is a bit expensive[1], it can yield excellent results. Because of the way this method has evolved, it is applicable to only the class of measurement microphones that come in 1/4, ½, and 1″ sizes—that is, the outside diameter of the microphone barrel. Bruel and Kjaer[2] measurement microphones are well known, but my favorite is the inexpensive model ECM-8000 made by Behringer[3], which I discuss later in this article.

To use this method, remove the microphone cartridge protection grille and replace it with an electrostatic actuator. They come in 1 and ½″ sizes, and a ½ to ¼″ adapter is available for ¼″ microphones. **Photo 1** shows a ½″ actuator. Place the microphone and actuator in an enclosure to isolate the measurement from external noise sources (**Photo 2**). In the measurement setup (**Fig. 1**), the swept sine wave input can be from a computer sound card and the spectrum analyzer can also be software based.

The actuator driver is probably beyond the realm of the home-constructor because it amplifies the input signal to about 25V RMS and then imposes it on 800V DC to drive the actuator. The actuator does not produce a sound wave (a non-acoustical method) but rather electrostatically couples the diaphragm in the actuator to the diaphragm in the microphone. Energy is transferred through the electrostatic field and the microphone "thinks" it's in a sound field.

My primary reason for introducing the actuator is because this is how measurement microphone manufacturers calibrate the product we will use as the reference microphone in the comparison method. It would be useful to be able to periodically check the calibration of the reference microphone, but the actuator and driver are a bit pricey. It turns out there is a less expensive way to verify the calibration.

THE COMPARISON METHOD

Briefly stated, this is done by comparing the microphone to be calibrated with a reference microphone. But as the saying goes: "The devil is in the details."

One reference I found[4] made a convincing case for needing a sound source (loudspeaker) with a nearly flat frequency response. Hence, I spent quite a bit of time designing and building the coaxial speaker shown in **Photo 3**. The response is fairly flat but the microphone placement is so critical that it was impossible

PHOTO 1: Half-inch electrostatic actuator.

PHOTO 2: Microphone Calibration Workstation, model 9350C from the Modal Shop, Inc., www.modalshop.com. When the lid is closed, some sound isolation is provided for the microphone calibration.

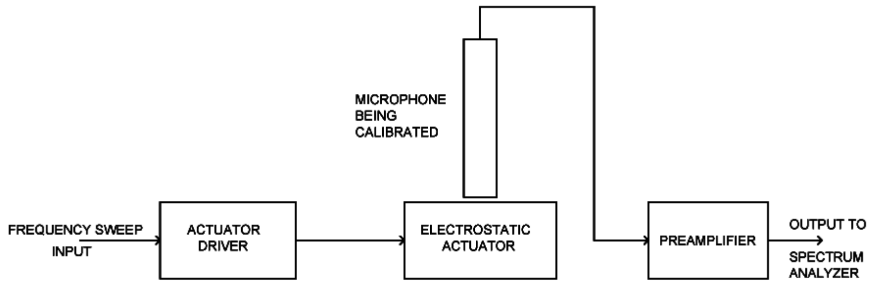

FIGURE 1: Electrostatic actuator method block diagram. In practice, the actuator and microphone would be enclosed to reduce ambient noise pickup.

for me to produce repeatable results. (Unless you are doing these measurements out of doors or in an anechoic chamber, you are always seeing the combined response of the speaker and the room.)

At this point, I wasn't sure where to go with this project. I finally decided to just try a speaker and see what happened. I picked one of the four that I had built for the MaxxBass article (*aX* 11/04). It has a Hi-Vi F6 driver in a 0.35 ft^3 sealed box with a measured Q(tc) of 0.71. The frequency response is down about 40dB at the low and high ends of the spectrum compared to the midrange, but it worked well enough. It is essential to make the measurements at a high enough signal level so the signal-to-noise ratio is adequate over the full spectral range, but this is not difficult to do.

Photo 4 shows this speaker and the microphone holder I built. The wooden frame is about 18 inches square, but this is not critical. I did round the speaker-facing edges of the boards to minimize reflections. The spring-loaded microphone holders are type MUS-MY200 from American Musical Supply[5] supported on a 5/16″ diameter threaded rod. (I have discovered that this holder is also available from Parts Express[6] as catalog number 242-025). I used three holders to investigate the off-axis response. The best results are attained by substituting the microphones in the on-axis center holder. The speaker cone to microphone spacing is 15 to 18″ with the setup shown in the photo—this distance is not especially critical.

The comparison block diagram is shown in **Fig. 2**. A switch box for the preamplifier inputs and outputs would be helpful, but so far I have just switched connectors. First, I will list the needed equipment and then I will give you the step-by-step details for calibrating the unknown microphone, in this case a TDL® model 818 (**Photo 5**).

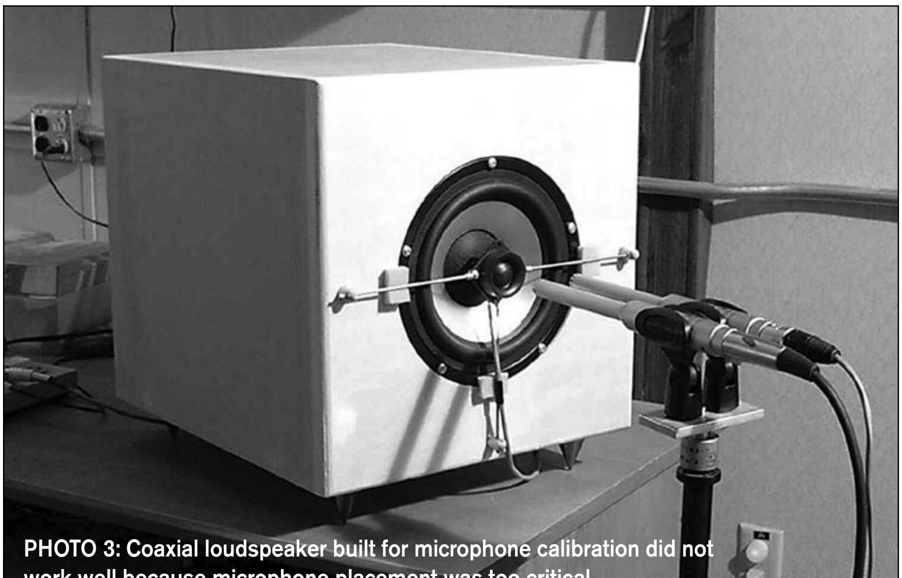

PHOTO 3: Coaxial loudspeaker built for microphone calibration did not work well because microphone placement was too critical.

1. Reference microphone, Behringer ECM-8000[6]. (It would be helpful to buy three, as I will explain later.) You will notice that the microphone spec sheet indicates +15 to +48V of phantom power is needed, which is true. But at 15V the sensitivity has decreased and the decrease isn't specified. I have measured it at about -2.5dB, but it varies from microphone to microphone.
2. Phantom power supply for the microphone, 48V DC. (I used a TDL model 492 because I had one available.) The model 432 preamplifier supplies the 818 microphone.
3. Low-noise microphone preamplifier with at least 40dB of gain. Even though the microphones are substituted, both channels are needed because the right channel also supplies power to the 818 microphone. (I used a TDL model 432.)
4. Audio power amplifier. Not critical, a few watts up will do. The one I used has a gain of 18dB, which required a *TrueRTA* output setting of -25dB or higher for a good measurement signal-to-noise ratio.
5. Microphone and audio cables. I like the *Dayton Audio* cables from Parts Express[6].
6. *TrueRTA* software[7] and a computer with a sound card. (*TrueRTA* will run under Windows 98SE and up.)

CALIBRATION PROCEDURE

1. Try to keep your measurement environment as quiet as possible. Listen for noises that you are accustomed to hearing and turn them off if possible or wait for them to stop. These noises include air conditioning or furnace blowers, fans, refrigerators, and so on.
2. Turn on all the equipment and launch *TrueRTA*. The combination of the speaker and room responses will probably be rather "ragged" because QuickSweep is performed in 1/24-octave mode.
3. Put the reference microphone in the holder and make sure its cables are connected correctly. Sit quietly in your chair and tap the QuickSweep key. You will hear the "chirp" from the speaker and the frequency response will appear on the screen. Save this response to Memory 2 (Alt-2).

4. Substitute the microphone to be calibrated for the reference and change the cable connections. The model 818 gets its operating voltage (+5V DC) from the right channel of the 432 preamplifier. Sit quietly, hit QuickSweep, and save the response to Memory 3 (Alt-3).
5. You will probably find that the two curves on the screen have an offset between them. For the 818 with its lower sensitivity this was about -3dB. Bring up the *TrueRTA* Utility menu and select Shift. Shift the lower curve up so that it coincides as closely as possible with the upper curve. The Shift works repeatedly, so keep at it until you get a good match in the center portion of the spectrum.

   Bring up the Utility menu again and select Difference. Subtract one input from the other. You may need to try it both ways and keep the one that shows a rolloff (rather than a "roll-up") at the low end of the spectrum. The difference is your calibration curve; save it to Memory 4 (Alt-4).

   Because of the jaggedness of the 1/24-octave curves, I tried 1/3-octave smoothing of the microphone data before differencing. But this didn't seem to work too well because it exaggerated the amplitude differences at the low and high ends of the frequency spectrum. It seems better to smooth the difference curve, and 1/2-octave smoothing seems about optimum. Why is it fair to do this? Because microphones tend to have smooth responses with only gradual roll-ups or rolloffs.
6. Bring up the File menu and select Save. This lets you save the Workbench (all three curves) to your choice of file name and directory. From the View menu select Hide All Memories. Then click on the Memory 4 icon. The difference curve alone will reappear.

   From the File menu select Export Data and save the calibration data as a text (ASCII) file to your choice of file name with a .txt extension. This file can be used in a variety of programs, including *TrueRTA*, as a microphone calibration file. **Figure 3** shows the 1/24-octave microphone data and the difference with 1/2-octave smoothing.

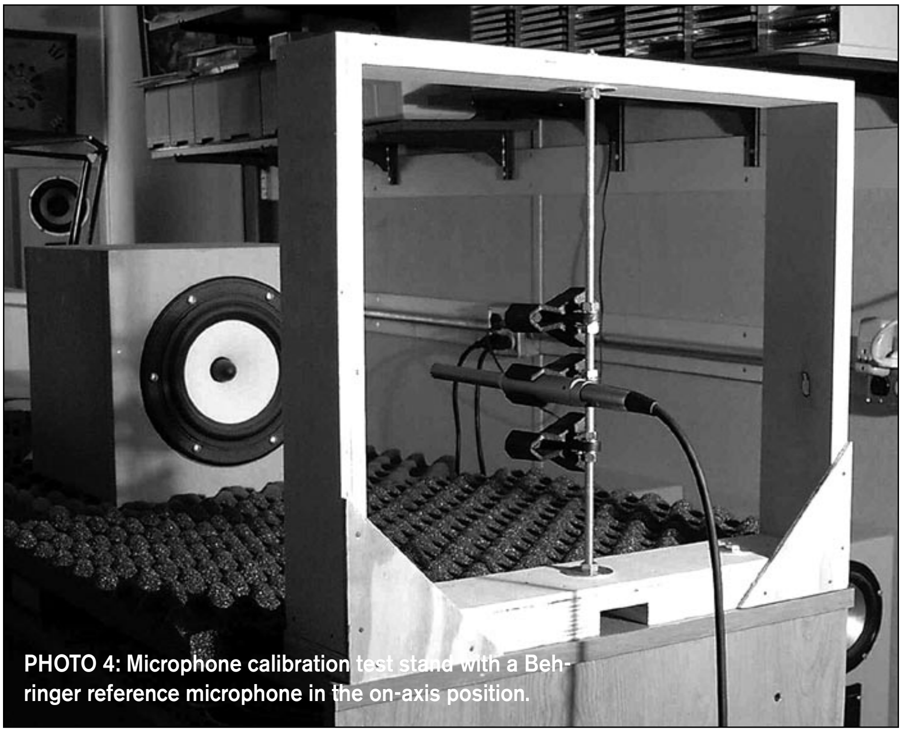

PHOTO 4: Microphone calibration test stand with a Behringer reference microphone in the on-axis position.

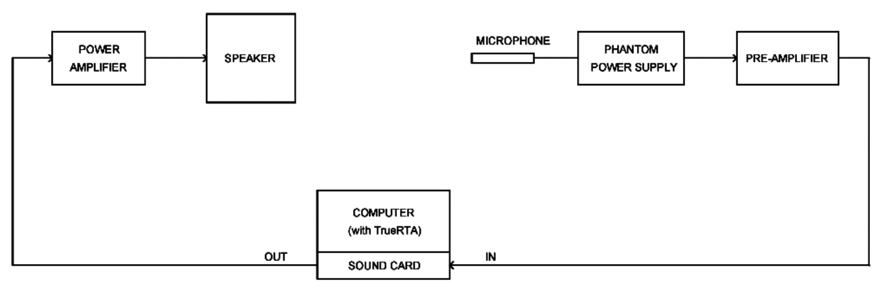

FIGURE 2: Comparison method block diagram. The microphone to be calibrated is substituted for the reference microphone.

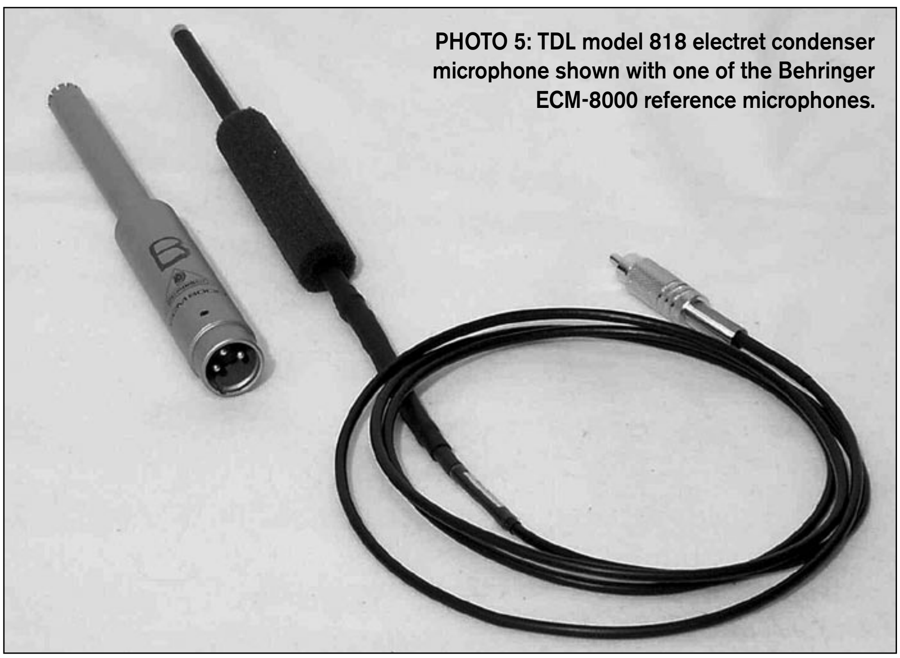

PHOTO 5: TDL model 818 electret condenser microphone shown with one of the Behringer ECM-8000 reference microphones.

Now you have a relative calibration curve, but is there a way to get an absolute reference value so you could use the microphone for making sound pressure level measurements (SPL)? Yes, there is.

The Behringer ECM-8000 has a nominal (but pretty close) sensitivity of 10mV/Pascal with a 48V phantom supply. Put the ECM-8000 back in the holder and substitute a physical voltmeter for the input to the computer sound card. (You can probably use *TrueRTA* for this, but I prefer a "real" voltmeter.) Using a 1000Hz sine wave output (from *TrueRTA*), adjust the output level and preamplifier gain for a 1V RMS reading on the voltmeter.

Now substitute the newly calibrated microphone and measure its output level, keeping the level and gain controls unchanged. Suppose the voltmeter now reads 680mV RMS. This gives your microphone a sensitivity of 6.8mV/Pascal. Knowing that 1 Pascal equals 94dB SPL lets you use your microphone for SPL measurements.

Earlier I suggested you buy three Behringer microphones. Why? First, they are inexpensive—less than $50 each. But more important, with three you can verify that they are all functioning correctly or if not, which one has gone bad. With just two, you can inter-compare them and if there is a difference all you know is that one of them has "taken a dive." But with three, you inter-compare A with B, A with C, and B with C; and thus find the "bad apple" if one exists. True, this is an expenditure of another $100, but this is much cheaper than buying an electrostatic actuator and accessories for the same purpose.

SOME FINAL WORDS

Useful microphone calibration and verification is well within the means and ability of any audio enthusiast who cares to take it up. The fact is, with careful work, most any mid-range speaker is up to the task. Also, using the Shift and Difference functions built into *TrueRTA* makes easy work of getting the calibration data.

I tried two other speakers with comparable results. One of them, a 3″ TangBand model W3-879S with a response of ±5dB from 100Hz to 20kHz, gave a very smooth difference from 50Hz up but very rough below 50Hz. Because of its small size, its response is down about 60dB at 20Hz. But this could still be a good choice if you are primarily interested in the mid and high frequencies. (Although the W3-879S has been discontinued, there are current TangBand models with similar specs.)

I have also tried using MLS software for microphone calibrations such as *Praxis*[8], *Sample Champion*[9], and *WinMLS*[10]. But I have found that windowing the impulse response to get the frequency response is critical. I have had better results with less work using the QuickSweep feature in *TrueRTA*. However, you may have better results with MLS.

FIGURE 3: Reference and model 818 microphone data shown with the difference curve. TrueRTA using QuickSweep. Half-octave smoothing was applied to the difference data.

REFERENCES

1. For example, a minimal system from G.R.A.S. Sound & Vibration costs about $3600 and consists of a type 14AA High Voltage Actuator Amplifier, a type AL0010 Calibration Stand, and a type RA0014 ½″ Actuator. You can take a look at the specs at www.gras.dk.

2. Bruel and Kjaer is a Danish company founded in 1942 to develop instruments for acoustic measurements. You can find a wealth of product and technical info on their website: www.bksv.com (Denmark) or www.BKhome.com (USA).

3. Behringer is a German company that makes all kinds of audio instruments. Take a look at their website: www.behringer.com.

4. Case Study: Secondary Microphone Calibration by Substitution Method. www.fouraudio.com.

5. American Musical Supply, 1-800-458-4076, www.americanmusical.com.

6. The Behringer microphone (catalog number 248-625) and Dayton Audio cables are available from Parts Express, 1-800-338-0531, www.parts-express.com.

7. *TrueRTA* software is available from True Audio, www.trueaudio.com.

8. *Praxis Audio Measurement System*, Liberty Instruments Inc., www.libinst.com.

9. *Sample Champion*, www.purebits.com.

10. *WinMLS*, Morset Sound Development, www.winmls.com.

BIBLIOGRAPHY

Here are some other references that I found useful:

1. Microphone Comparison. www.purebits.com.

2. Jobling, B., "Electrostatic Actuators—A Role in Calibration. www.iop.org/EJ/article/1751-8121/41/16/164033/a8_16_164033.pdf.

3. Nedzelnitsky, V., "Laboratory Microphone Calibration Methods at the National Institute of Standards and Technology, U.S.A. ts.nist.gov/MeasurementServices/Calibrations/acoustics.cfm. Scroll down to near the bottom of the screen and click on the report name, it's a pdf file.

4. Electrostatic Actuator Power Supply User's Guide, www.bswa-tech.com.

5. Bruel, P. V. and Harry Zaveri, "Of Acoustics and Instruments—Memoirs of a Danish Pioneer." Part 1 was published in the February 2008 issue of *Sound & Vibration* magazine with Part 2 following in the August 2008 issue. Sound & Vibration, PO Box 40416, Bay Village, OH 44140. 1-440-835-0101, www.SandV.com.