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PCB Piezotronics Phantom Power Microphones

Photo 1: The 426A14 microphone preamp and body is supplied with adapters to allow use of both 1/2″ and 1/4″ capsules. (Photo by Cynthia Wenslow)

Stuart Yaniger explores some of the phantom power microphones that PCB Piezotronics has developed for the loudspeaker and recording market.

By
Stuart Yaniger
(United States)

A couple years back, I had the pleasure of trying out some of the measurement microphones from PCB Piezotronics, located in Depew, NY. It was the first exposure I had to this company's products, which were focused on precision high-reliability industrial applications (e.g., environmental noise control, HVAC, appliance design, aerospace, and automotive). Common to this part of the market, the mics were self-polarized, operated from a constant current interface, and used coaxial cables for connection, much like other transducers in these applications—strain gauges, vibrometers, accelerometers, and torque sensors.

The basic capsule technologies for these industrial measurement condenser mics are the same as those used in audio measurement and recording. So, given that PCB Piezotronics' product manager Mark Valentino is an avid and accomplished musician, and that the market for instrumentation-grade measurement for loudspeakers and recording is growing, it is not surprising that PCB Piezotronics has decided to offer versions of its microphones suitable for those uses.

Yes, one can certainly use the constant-current self-polarized mics here, but the installed base of studio recording and loudspeaker measurement equipment is designed for mics using phantom power (typically +48 V to +200 V) with balanced lines, so plug-and-play is not an option. Rather than expect studio and speaker measurement folks to change all of their equipment to accommodate the common interfacing for measurement mics, PCB Piezotronics introduced a new mic body/preamp, the 426A14, which runs off standard studio phantom power and has a standard balanced XLR connection.

The 426A14 is designed to work with existing PCB mic capsules (see **Photo 1**). These capsules are most self-polarized, that is, the backplate is coated with a fluoropolymer that is made into an electret by means of ion implantation and/or poling. The diaphragms are a stainless steel alloy, which tends to be more environmentally and thermally stable than the usual metallized polyester diaphragms typically found in measurement mics in this price range.

The Products

The new preamp is compatible with PCB Piezotronics' existing measurement mic capsules so that the advantages of the stability, calibration accuracy, and reliability coming with industrial measurement mics can be directly translated to audio-related acoustic measurement.

PCB Piezotronics sent me the new preamp bundled with three capsules:

- the 377C01—a 1/4″ capsule, featuring extended frequency response and high SPL capability
- the 377B02—a 1/2″ capsule, featuring a very low noise floor and high sensitivity
- the 377A06—a 1/2″ capsule, featuring a higher SPL capability than the 377B02

The basic parameters of the capsules and the part numbers for complete mics (capsule plus preamp/body) are summarized in **Table 1**.

All of the PCB Piezotronics mic capsules are self-polarized (electret) with metal diaphragms (stainless steel alloy). Metal diaphragms offer the advantage of greater environmental stability and repeatability compared to plastic diaphragms and are the common choice for industrial measurement. By contrast, most recording mics use metallized plastic (usually polyesters such as Mylar with a vapor coating of aluminum), the properties of which change significantly with changes in temperature and humidity. This usually isn't a problem in studios and homes with climate control, but for field use, this can cause issues with frequency response and sensitivity. The PCB Piezotronics mic capsules are also all calibrated for free field (i.e., the polar patterns are basically omnidirectional).

This patent-pending adapter system is quick and convenient. In order to be able to use the same preamp with different capsule diameters, PCB Piezotronics has done some clever mechanical design work. The basic preamp comes with two different metal sleeves that screw onto the body. To use the 1/4″ capsule, the cone-shaped adapter is screwed onto the preamp body, forming a streamlined and acoustically "clean" shape. To use the 1/2″ capsules, a cylindrical adapter is screwed onto the preamp, forming a smooth cylinder. This adapter system is quick and convenient for capsule changes and is certainly a cost-saver for the user who needs the versatility of different capsule characteristics for different recording or measurement applications.

Measurements

My usual measurement setup comprises an Audio Precision APx-515 analyzer, an Audio Precision APx1701 transducer interface, a calibrated Brüel & Kjær Sound & Vibration (B&K) 4133 lab microphone (NIST-traceable), and a B&K 4231 SPL calibrator. Frequency response and polar measurements are taken using a quasi-anechoic method, a Farina chirp test signal that yields an impulse response, which can be gated to remove room reflections. This provides valid data above 500 to 600 Hz or so, which is the region of interest (most precision mics are flat below that frequency). Frequency responses are normalized to the calibrated reference mic positioned in the same spot, which eliminates the frequency response variations of the acoustic source. The acoustic source was a Vanatoo Transparent Zero addressed via its Bluetooth input.

I first checked the sensitivity of the 1/2″ mics using the 4231 SPL calibrator. The results are shown in **Table 2.** Because the SPL calibrator is a borrowed unit and I do not have a 1/4″ adapter, the sensitivity of the 376A31 had to be estimated by substitution when measuring an acoustic source. The Calibration Sheet sensitivity from PCB Piezotronics was 2.18 mV/Pa, and my rough measurement confirmed this within the 1 dB or so error inherent in the substitution method.

I measure noise using the BLANK chamber, described in the PCB Piezotronics measurement mics review listed in Resources. Basically, the mic is wrapped in plastic and duct tape, then buried in a mixture of sand and kitty litter. This works remarkably well, pushing the noise floor below 4 to 5 dB SPL. My noise measurement numbers are over a 20 kHz bandwidth with A-weighting. It's important to note that when measuring random (e.g., thermal) noise, in order to get an accurate result, the Fast Fourier Transform (FFT) measurement should not be windowed. The noise measurements are shown in **Table 3.**

On-axis frequency responses from 1 to 20 kHz with each of the three capsule options are shown in **Figure 1**. The mics can be seen to be extremely flat

Model	376A31	376A32	376A33
Capsule	377C01	377B02	377A06
Diameter	1/4″	1/2″	1/2″
Sensitivity (mV/Pa)	2	50	12.6
Noise floor (dBSPL A-weighted, ref. 20μPa)	40	15.5	22
Maximum SPL (dBSPL at <3% THD)	165	137	150
Note: All models use a 426A14 phantom power preamp/body			

Table 1: This is a summary of PCB Piezotronics' phantom power microphones.

Model	376A32	376A33
Rated Sensitivity (mV/Pa)	50	12.56
Calibration Sheet Sensitivity (mV/Pa)	47.39	12.96
Measured Sensitivity (mV/Pa)	47.9	13.1
Note: All measurements taken with the 426A14 phantom power preamp/body		

Table 2: The sensitivity of PCB Piezotronics' phantom power microphones

Model	37A31	376A32	376A33
Rated Noise Floor (dBSPL A-weighted ref. 20 μPa)	40	15.5	22
Measured Noise (dbSPL A-weighted, ref. 20 μPa)	40	15	20.5
Note: All measurements are 20 kHz bandwidth, A-weighted			

Table 3: The noise measurements of PCB Piezotronics' phantom power microphones

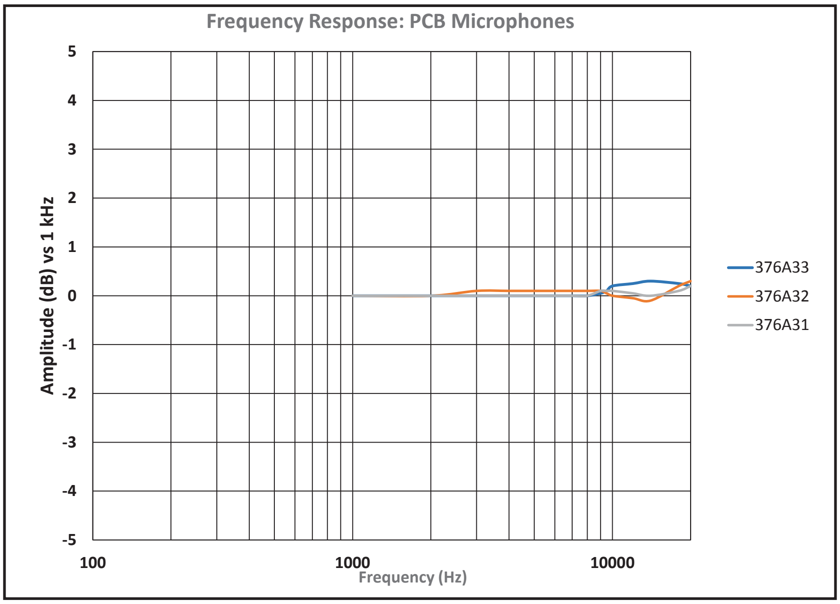

Figure 1: The on-axis frequency responses of the PCB microphones above 1 kHz are within 0.5 dB of flat, and correspond well to the supplied calibration curves.

up until the top octave, and even there, the deviations are low enough (less than 0.3 dB) to challenge my measurement accuracy. Calibration curves are included with each capsule and the supplied response curves agreed reasonably well with the measured data. The mics as supplied already have very flat frequency response, but inputting the calibration data into measurement software will assure that frequency response measurements are as accurate as possible. The nature of the mics' construction (e.g., stainless steel diaphragms) will ensure that the response curves will be accurate across a variety of environmental (temperature and humidity) ranges.

Polar patterns were acquired by rotating the microphone body, with the diaphragm position with respect to the acoustic source kept at a fixed point. Responses at each frequency were normalized to the on-axis response, and each point is a power average of six measurements with the mic angle rotated slightly (less than 5°) between each measurement to average out high frequency diffraction effects.

Figure 2 shows the polar pattern for the 1/4″ 376A31, which has an excellent omnidirectional characteristic up until the 10 kHz maximum frequency of my measurement. And even there, the polar pattern is reasonably smooth and does not have excessive roll-off. The polar pattern for the 1/2″ 376A32 is shown in **Figure 3**. It can be seen to deviate from omnidirectional at a somewhat lower frequency than the 1/4″ mic, but the response is still rather smooth and well-controlled. The 376A33's polar pattern matched that of the 376A32 within the limits of my measurement.

Distortion vs. SPL for the 376A33 is shown in **Figure 4** and compared to a similarly priced electret laboratory mic using a plastic diaphragm. These curves were obtained using a 6″ loudspeaker driver measured nearfield (about 2 mm distance to the microphone from the cone), with an amplitude-swept sine wave. The measurement frequency was 1 kHz, though lowering or raising the frequency by a factor of two had no effect on measured distortion. My test limit was 130 dB SPL due to my desire for domestic harmony. Up to that point, the distortion curves for

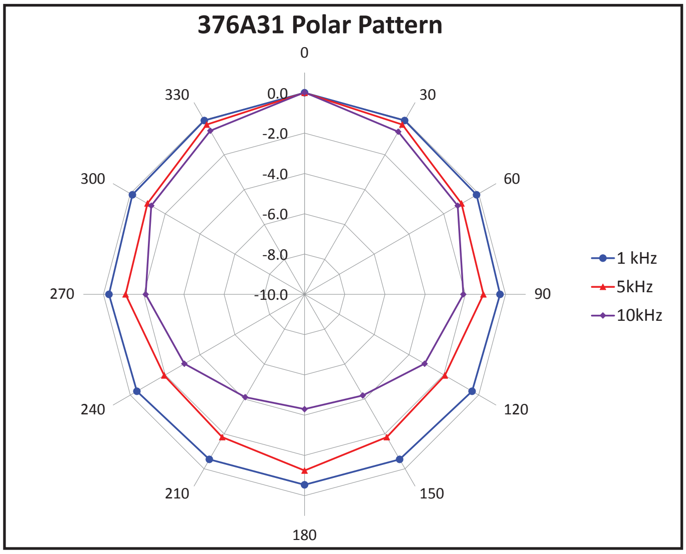

Figure 2: The polar pattern of the 376A31 mic (1/4″ capsule) shows good omnidirectional behavior up to relatively high frequencies.

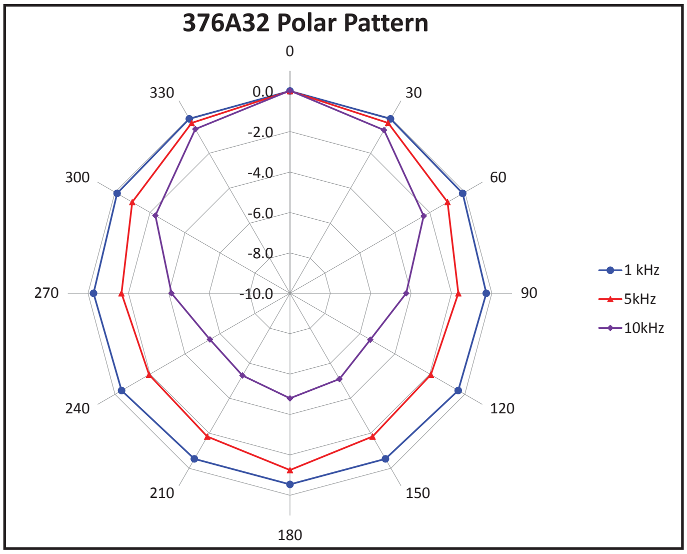

Figure 3: The polar pattern of the 376A32 mic (1/2″ capsule) is smooth and well-controlled. The 1/2″ capsule 376A33 has a polar pattern nearly identical to this.

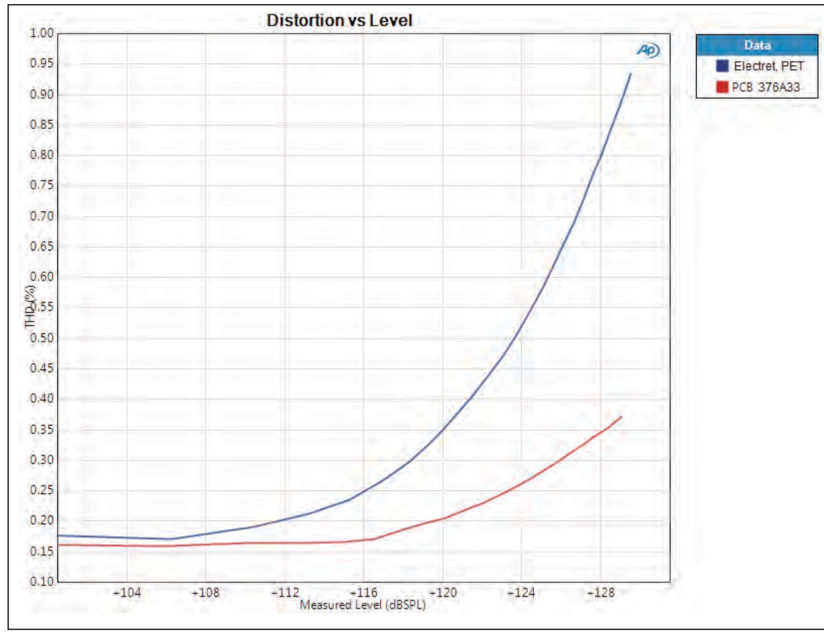

Figure 4: The distortion of the 376A33 vs. SPL is limited by the distortion of the signal source. Compared to a similarly priced phantom powered audio measurement mic, the distortion of the 376A33 is significantly lower.

the 376A31, the 376A32, and the 376A33 overlaid almost perfectly, so clearly the distortion limitation was the loudspeaker. Over the next few months, I will be experimenting with a few other ways to generate higher SPLs at lower distortion, but even extrapolating this curve, the 376A33 would be likely to comfortably exceed its specified 155 dB SPL limit for 3% distortion.

The PCB Mics in Action

I've been using these mics for loudspeaker measurement over the past year—some examples can be seen in the recent review of the Vanatoo Transparent Zero powered speakers (see Resources). The high SPL capability of the 376A31 1/4" mic makes it ideal for things like nearfield woofer measurement, and the flat frequency response, low noise, and low distortion of the 376A32 1/2" mic are great assets in measuring loudspeakers at 1 m distance. The excellent polar pattern comes in handy for in-room measurements, such as those seen in my recent review of the Sonarworks Reference 4 room correction system (see Resources). The high output (50 mV/Pa) makes mic preamp noise very non-critical, so paired with an inexpensive audio interface, this is a highly capable and reliable acoustic measurement system.

To get an idea of the PCB Piezotronics mic's performance in a recording setting, I recorded Michael Wenslow (of the WenslowShear Jazz Orchestra) warming up on his trumpet using the 376A33 mic. I chose this capsule/preamp combo, with a slightly higher noise floor but higher SPL capability because of the proximity to a rather loud brass instrument. The mic was placed about 1 m in front of the trumpet bell, and its output run through a Focusrite 2i2 interface at 24-bit resolution and a 96-kHz sample rate. The one-channel recording can be downloaded from my website (see Resources). The lack of compression and distortion as well as a relatively uncolored frequency response yield a very natural and dynamic sound. For quieter instruments or greater distances, the 378A32 would be a great choice for omnidirectional pickup. I should note that the cost of these mics is significantly lower than the closest alternatives.

I've also been doing some work recently on ultrasonic triangulation for distance and position measurement. The HC-SR04 module is very popular for this application, containing a transmitting and receiving unit on a compact circuit board. According to its datasheet, the HC-SR04 sends out a string of eight pulses at 40 kHz when the transmitter is triggered. The diagram shows the pulse train starting and stopping almost instantaneously. That struck me as a bit odd, since the transducers in ultrasonic transmitters are usually highly resonant at a single frequency, and thus they take some time for their output to build up in amplitude and then decay. Well, this calls for some measurement! The high frequency and high amplitudes suggested using the

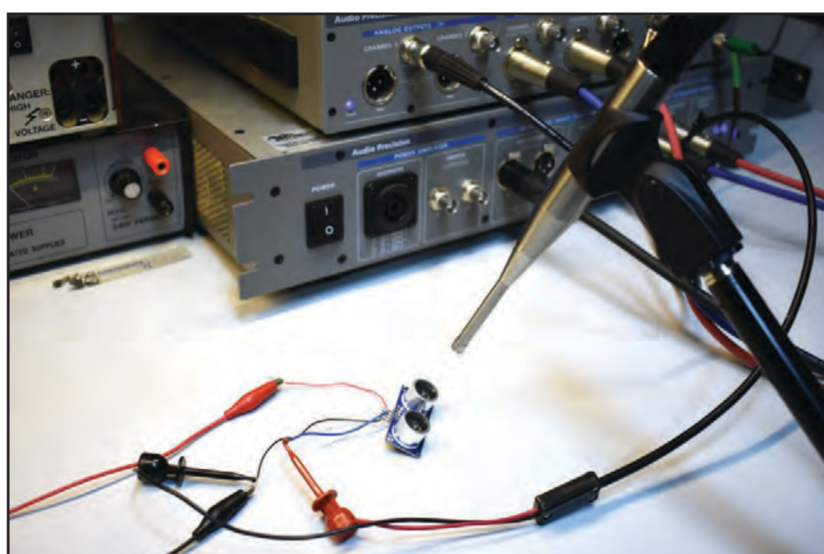

Photo 2: The 376A31 mic was used to measure the output of a popular ultrasonic transducer module. (Photo by Cynthia Wenslow)

About the Author

Stuart Yaniger has been designing and building audio equipment for nearly half a century, and currently works as a technical director for a large industrial company. His professional research interests have spanned theoretical physics, electronics, chemistry, spectroscopy, aerospace, biology, and sensory science. One day, he will figure out what he would like to be when he grows up.

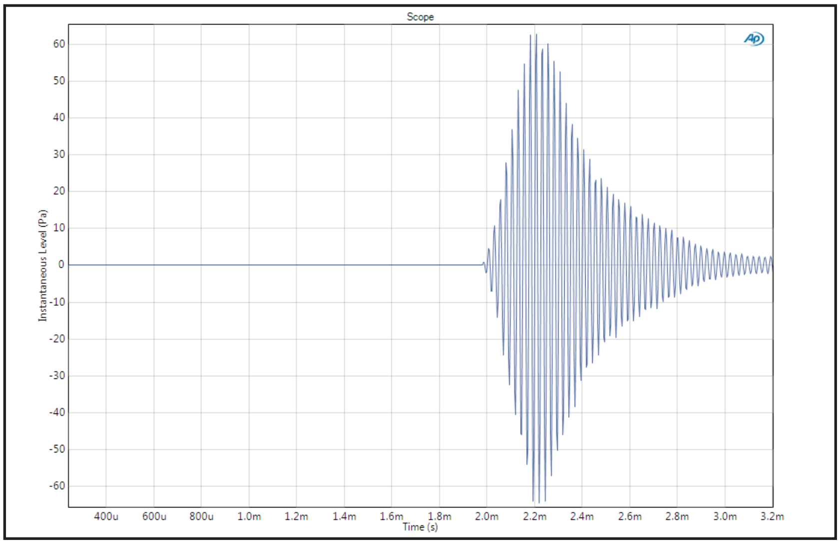

Figure 5: Measurement of the time domain acoustic signal generated by the ultrasonic module demonstrates the bandwidth and the high SPL capability of the 376A31 mic.

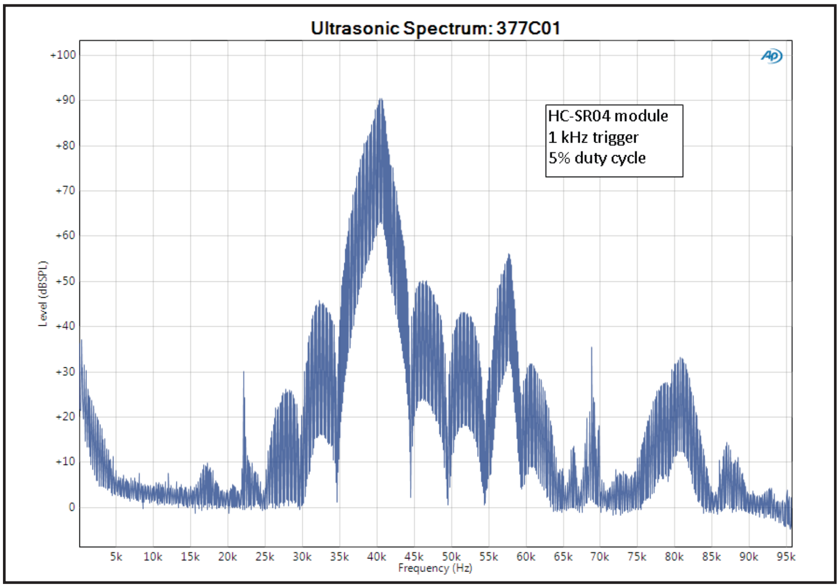

Figure 6: The frequency domain plot of the ultrasonic transducer output shows the expected nulls on either side of the fundamental from the repetition rate. Note the absence of mic distortion and the response to well above the second harmonic at 80 kHz.

Resources

"HC-SR04 Datasheet," www.mouser.com/ds/2/813/HCSR04-1022824.pdf.

S. Yaniger, "Sonarworks Reference 4 Studio Edition Loudspeaker and Headphone Correction System," *audioXpress*, July 2018.

——, "Vanatoo Transparent Zero Powered Speakers," *audioXpress*, January 2018.

——,"Innovative Measurement Microphones from PCB Piezotronics" *audioXpress*, December 2016.

SYclotron Audio, Sound clip of trumpet: https://syclotron.com/ supplement-to-pcb-phantom-power-microphones-review-in-audioxpress

1/4" 377C01 capsule because of its high-frequency response and ability to measure high SPL, which would be the case for a close-up measurement of the transmitter output.

The module was connected to a 5 V supply, and the trigger signal was provided by the Audio Precsion analyzer. I positioned the mic about 3 cm away from the transmitter's ultrasonic transducer (see **Photo 2**). The time domain signal acquired is shown in **Figure 5**. This was closer to what I expected to see—the transducer takes all eight cycles to reach full amplitude, then rings for some time afterward. The ranging function then apparently looks at the echo from the initial wave train. Note that the SPL peaks at nearly 65 Pa, which corresponds to an SPL of about 130 dB. No wonder my dog went nuts when I did this experiment! In any case, also note that the peaks show no evidence of flat-topping or distortion, a tribute to the mic's excellent performance at high SPL and frequencies.

The frequency domain plot of this measurement is shown in **Figure 6**, with deep nulls at 5 kHz above and below the 40 kHz fundamental. This is expected because of the eight-cycle burst on the leading edge of the signal envelope. The mic adds no discernible hash or distortion and it can be seen that the response holds up well to beyond the 80 kHz second harmonic.

Wrap-Up

I had been very impressed with PCB Piezotronics' instrumentation mics, so it was not surprising that the new phantom power mics would be similarly impressive. For less than half the price of comparable instrumentation mics (e.g., the B&K that I have been using as a reference), the PCB Piezotronics mics allow laboratories and loudspeaker developers a reliable, repeatable, stable, and traceable way to gather acoustic measurement data. The materials and construction used are superior to nearly all other microphones in their price class, and the compatibility with the sort of interfaces used in studios means that recording engineers have a clean, low noise, and uncolored option available at a relative bargain price. The versatility of the preamp and adapters to accommodate different diameter capsules is a major cost and convenience advantage. I have no hesitation recommending these to studio engineers and for loudspeaker designers, and as long as I have these mics, they will become my reference tool for all other microphone evaluations.

Editor's Note: All audioXpress *articles from 2001 to present can be found on the aX Cache, a USB drive available from www.cc-webshop.com.*

A Visit to PCB Piezotronics

PCB Piezotronics, based in Depew, NY (a suburb of Buffalo), has been a leading player in the industrial measurement market for over half a century. Its specialties have been transducers for vibration, acceleration, torque, shock, and similar electromechanical measurements. Readers also might be familiar with the name Larson Davis, which in 1999 became a division of PCB Piezotronics, and has its sales and marketing operations based in Farmington Hills, MI, and Cincinnati, OH. As a manufacturer of acoustic test and vibration measurement instrumentation, Larson Davis is recognized for its sound level meters, sound sources, calibration systems and even headphone test fixtures, among many other instrumentation products, all manufactured at its Provo, UT, location.

PCB Piezotronics' industrial measurement microphones, using the ICP technology discussed in a previous *audioXpress* review, have become a standard for measurement of noise in the development and certification of machinery, appliances, autos and trucks, and aerospace products. Until recently, the company has been less well-known in the audio world, though that is certainly starting to change.

Part of becoming a significant player in those markets, as well as expanding its profile in its traditional markets, has been an ongoing commitment to customer training. Not only does this make for better-educated customers who will get more accurate and useful results from their measurements, it's also a chance to show off its factory. PCB Piezotronics' training seminars cover pressure, vibration, ballistics, and of course, acoustics. I attended an acoustics seminar, which was held near the Depew facility and was taught by Dr. Andrew Barnard, who is a professor of mechanical engineering at Michigan Technological University.

The seminar was a two-day event, with Day 1 being dedicated to the fundamentals of acoustics. If you've been through a vibrations and waves course, much of this will look familiar, but it's quite fun and educational to actually watch the measurement of polar patterns of dipolar sources as a function of wavelength. The mysterious decibel (dB) was explained, with an eye toward acoustic reference levels and what decibel of sound pressure level (dB SPL) really means. Of course, the use of decibels in electrical measurement was also presented, especially in the concept of understanding microphone signal to noise and the origins of different contributions to the mic noise floor. The basic concepts of acoustical metrology such as random vs. diffuse field measurement, were also covered in depth.

An interesting sidelight detailed microphone design and construction. This includes the concept of constant charge operation of condenser mics and the way constant-current interfacing can be used to connect the mic with appropriate electronics. And that brought a thought to my mind, which had been already bubbling away in the background—the audience for this seminar was primarily people doing different sorts of industrial noise measurement, be it for product design (especially appliance and automotive) or safety compliance (e.g., noise levels of the sort that interests OSHA). The industrial sector really does the same sort of thing that people do when developing loudspeakers, measuring performance and sound reproduction spaces, and recording musicians. But despite the two similar missions, the industrial people and audio people speak completely different languages. You'll rarely hear a recording engineer mention the term "diffuse field" and likewise, a noise abatement engineer for a truck company will not be familiar with terms such as "Blumlein stereo bars." In fact, the reason for the reference to 0.775V in dBu measurements was unfamiliar to everyone in the class. (It's the voltage that causes 1 mW power dissipation in 600 Ω, long an impedance standard in sound studios.)

The metaphorical language barrier even extends to the electronics, with industrial measurement mics being almost entirely single ended constant current, and audio measurement and recording mics being balanced phantom power voltage sources. And never the twain shall meet! With my experience being almost entirely in loudspeaker measurement and music recording, this exposure to a different world and a different language was a particularly educational experience, raising my awareness of a lot of issues that we, on our side of the barrier, often ignore.

Day 2 started with a discussion on calibration and traceability. I should mention that PCB Piezotronics is now owned by MTS Systems Corp., a well-known and reputable provider of a variety of mechanical and thermal testing equipment. (Disclaimer: The company I work for in my day job has divisions that are competitors of MTS, though not in the product areas where I work.) The Modal Shop is another MTS company that specializes in calibration and measurement, and its representatives presented this part of the course. Besides the usual calibration and traceability information, they went into detail about uncertainty and error budgets, something too often ignored in reporting of measurements. Calibration methods discussed included shock tubes, a method not commonly seen in audio measurement but yields some very useful information on high-frequency response limits that's difficult to obtain using more common methods.

A tour of the factory and R&D areas was perhaps the most interesting part of the visit. PCB Piezotronics' manufacturing facility is certified under ISO 9001:2015 QMS Certified by DQS, Inc. and AS9100:2016 QMS Certified by DQS, Inc., and the measurement and calibration is certified under ISO/IEC 17025. In my professional career, I have set up and run several manufacturing sites so I can say without hesitation that this is one of the best laid out and maintained facilities I've ever seen. **Photo 1** shows a bird's-eye view of the CNC machining area for producing the mechanical components of the mics, which is notably clean, well-lit, and efficient. **Photo 2** shows the laser marking

Photo 1: The CNC machining at PCB Piezotronics' Depew facility produces the mechanical components for the microphones. (Photo courtesy of PCB Piezotronics)

process for the mic bodies—Goldfinger would be envious! Final assembly is done in a carefully controlled clean room (see **Photo 3**), reminiscent of the processes used in semiconductor fabrications.

The calibration processes include electrostatic actuation, a method which eliminates the effect of room acoustics but can generally be done only with metal diaphragms (see **Photo 4**), and a state-of-the-art anechoic chamber (with heroic noise isolation measures) for true free-field measurement (see **Photo 5**). Our tour of PCB Piezotronics' anechoic chamber and acoustical calibration lab was led by Dr. Chad Walber, an R&D engineer at the Depew facility. If you've never been inside an anechoic chamber, the experience is somewhat unnerving, with an almost oppressive feeling from the total lack of reverberant sound. The noise level is low enough that the dominant sound you hear is the blood pumping through your ears.

The most fun part for me was the demonstration of high-level acoustic pulse measurement, which took place in a basement chamber. The source was an AR15 rifle firing a round into a water trough. Ear protection required! I kept the shell of the test round as a souvenir, and fortunately didn't run into any issues with TSA. As with my measurements of a loud ultrasonic transducer, the mic used in this demonstration had a 1/4" capsule for optimum high SPL performance.

All in all, this was a very concentrated program, but the knowledge imparted and the discussions with so many experts made it more than worthwhile. I came away with a much deeper knowledge of microphone manufacturing and measurement, as well as an increased appreciation of the discipline of industrial acoustic measurement. If you have an interest in acoustic metrology or are involved in music or television sound production, this course will be extremely enlightening.

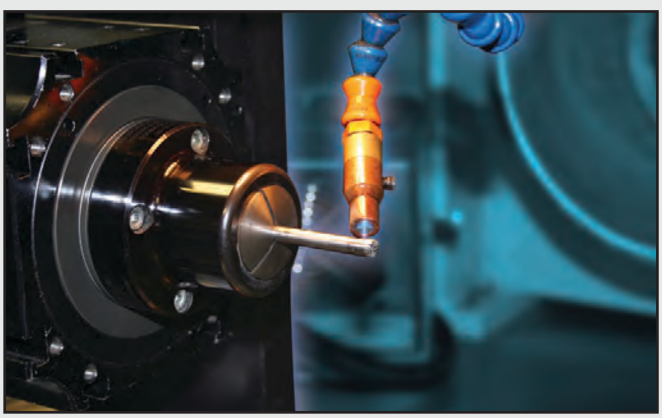

Photo 2: Microphone bodies are marked, welded, and etched using a precision laser process. This provides more robust marking than conventional printing. (Photo courtesy of PCB Piezotronics)

Photo 3: Final assembly of the mic capsules is done in a clean room environment. (Photo courtesy of PCB Piezotronics)

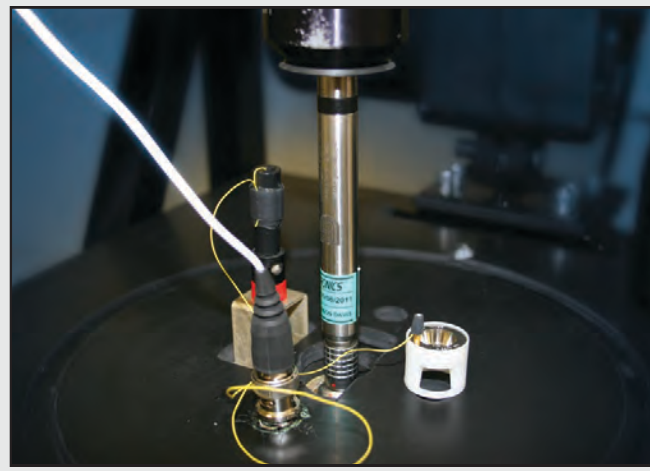

Photo 4: Electrostatic actuator calibration is performed on each mic capsule. (Photo courtesy of PCB Piezotronics)

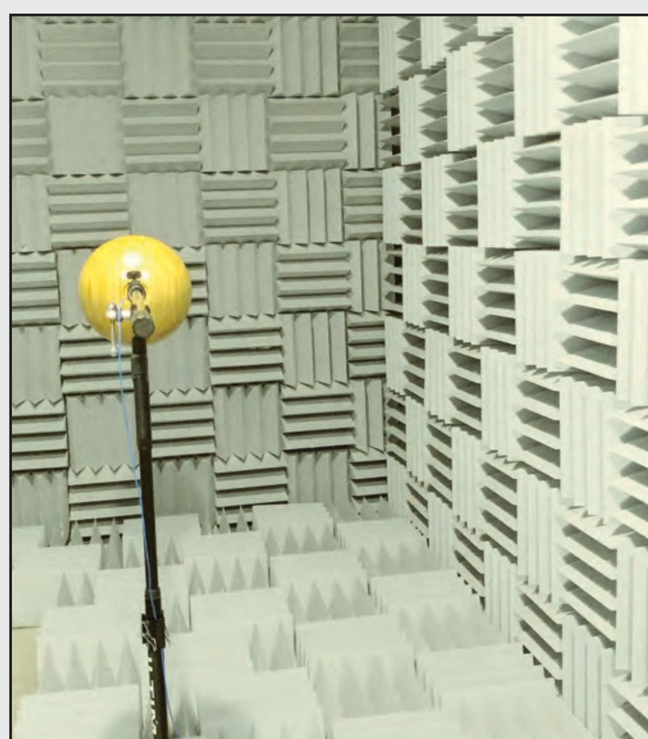

Photo 5: Calibration and development are validated in a custom-built anechoic chamber. (Photo courtesy of PCB Piezotronics)