Why microphone specifications should matter (and often don't)

The spec sheets that come with microphones can be detailed and baffling and they are also likely to present figures that cannot meaningfully be compared. DAVID JOSEPHSON from Josephson Engineering explains and clarifies.

Audio electronics have improved over the years, so the differences in performance between the cheapest and the best can be small. But there hasn't been much change in microphone transducer technology — the most popular models use designs from more than 50 years ago. How can the same design appear in a £40 microphone and a £1400 one? What makes the difference in price, and how is the sound affected?

There's an international standard for measuring the performance of studio and performance mics, IEC 60268-4, but its requirements are very broad. The result is that data from one maker can't be meaningfully compared with data from another, and many makers don't even claim to use the standard. Worse yet, many of the measurements don't apply to the way microphones are used in practice — particularly a problem for directional mics that are generally used fairly close to the sound source. Besides that, it's usually impossible to tell how far off from the 'specification' performance a given mic will be. Some makers give tolerance numbers — like frequency response +/-2dB from a given curve — others don't.

BASICS — A few basic specifications are helpful in answering questions about how a microphone will sound with your equipment. They won't tell you everything, because you need to consider the characteristics for sounds coming from different directions and distances.

You want to know the sensitivity, noise level, impedance and power requirements of the microphone so you can choose a suitable preamp to capture its output. Sensitivity is reported in millivolts per Pascal (mV/Pa) — that's the output level for a sound pressure of 1 Pascal, or 94dB. Most mics fall into one of three categories as shown in the table.

Type	Sensitivity	Preamp Gain Needed for +4 dBu
Modern dynamic and ribbon, some condenser mics with transformer output	1 – 3 mV/Pa	54-64 dB (more for quiet sources)
Modern condenser mics	10-20 mV/Pa	38-44 dB
High output condenser mics	50-60 mV/Pa	28-30 dB

Noise level is the signal that appears at the microphone output when no sound is present. It's caused mostly by noise in the electronic components inside (even the resistances of voice coils and transformer windings create noise) and the air around the diaphragm. It's common to describe this 'noise floor' as an equivalent sound pressure level using A-weighted RMS measurements, rather than the preferred ITU-R BS.468 (formerly called CCIR) quasi-peak measurement. In well designed microphones, the difference between the two numbers is around 11-12dB. Short crackles and rumble sounds that you'd want to know about are ignored by the A-weighted RMS measurements, while quasi-peak is designed to measure them. Both methods are flawed, though, in that they were designed for telephony, and report on noise in the midrange speech frequencies while mostly ignoring noise at the ends of the spectrum. Worse yet, some makers still maintain that a condenser microphone element produces no noise of its own, and therefore report only on the noise produced by the electronics. This might have been true for noisy valves in the 1950s but it isn't true today.

Rumble and hiss can be the most intrusive noises even though they're not in the midrange where human hearing is most sensitive, because they aren't masked by nearby frequencies in the programme material. Many microphones today have astonishingly low noise specs, but some do this by designing the microphone element to be more sensitive in the midrange where A-weighted noise measurements are most sensitive, and applying equalisation to correct for this in the electronics. Many microphones with an A-weighted noise spec under 10dB SPL use this equalisation method to produce a quieter midrange. Figure 1 shows the noise curves of two microphones. Curve A has a fairly uniform noise level and would be measured at about 11dB SPL mid-band. The mic in curve B produces a better number — around 8dB SPL — but has more rumble and hiss. (These curves are scaled for equivalent A-weighted SPL.)

Tip: A-weighted RMS or better yet BS.468 quasi-peak numbers are useful but rather than a single number, ask for a spectral graph of the microphone noise. This is recommended in the IEC standard. That way you can see whether one mic will have more rumble or hiss than another. A drastically shaped noise floor is also a clue that there might be some equalisation-related phase anomalies in the response.

Impedance is a parameter from the early days of telephony, expressing the load into which a microphone transfers the most power. We don't use impedance-matched circuits anymore — nearly every mic and preamp is designed for the mic to operate into a load of at least five times its characteristic impedance, or 'open circuit'. Impedance can give you some clues about the mic's sensitivity to loading, but the actual output impedance is seldom given by the microphone makers, who often give only the recommended load impedance or the 'rated' impedance. Fortunately this doesn't have a big impact on regular studio or stage use.

More important than the specific value of output impedance is whether the mic output is truly balanced. Preamps reject interference coupled into mic cables only when the entire circuit, including the cable and the mic output, has equal impedances from each signal lead to ground. This is different from the question of whether both sides of the line are driven with equal levels and opposite phase. A few interference scenarios affect single-ended 'impedance balanced' outputs more severely than they do differential balanced outputs, in whatever way it is achieved, but impedance balance is by far the more critical characteristic.

IEC 60268-4 calls for measurement of 'balance of the microphone output' and 'balance under working conditions'. We haven't seen this specification on a single microphone data sheet — in part because the measurement described isn't very precisely defined so no manufacturer has adopted it.

Microphones with internal active electronics are most often powered with phantom power according to IEC 61938. You need to know the current drawn by each microphone, and many mixers cannot supply maximum current to all their powered inputs at the same time.

Tip: Ask your preamp or mixer manufacturer how much phantom power current can be provided without going outside of the specification (44 to 52V open circuit, for P48.) How many mics can you plug in before it's not 48V anymore?

FREQUENCY RESPONSE — The most common data given for microphones is the amplitude response vs frequency for sounds arriving on-axis (from the front). For omnidirectional microphones it's easy to measure by comparison to a known flat measurement microphone. Measuring a directional microphone, even for on-axis sounds, is more troublesome because response varies with distance, and with the geometry of the sound source. And of course we're interested in knowing the frequency response in other directions too.

The international standard calls for microphones to be measured in 'free-field conditions', generally taken to mean at least one-half wavelength from the acoustic centre of the sound source. A half wavelength at 100Hz is 1.7m (8.5m at 20Hz), and people don't always put microphones that far away from the sound source. The standard helpfully permits manufacturers to use other distances or measurement methods so long as details are provided, but few makers actually do this. Manufacturers generally measure response in conditions that are similar to typical applications for a given microphone but who is to know what's being assumed?

All directional microphones have some proximity effect, in other words low frequency response is boosted when the distance between the mic and the sound source is small, and beyond some distance the low frequencies are attenuated. At some distance from a point source, a directional microphone will have roughly flat response between a low cut-off point (20-50Hz) and 1kHz. Any closer than that distance there will be a boost in the lows, starting around 200-400Hz and rising to as much as 10 or 15dB as the frequency approaches the low cut-off point. Further away than the 'flat' distance, the response will roll off gradually as the frequency is reduced — up to a point, the further away you get, the steeper the roll-off. At some distance, going further away doesn't create appreciably more bass roll-off.

Tip: Microphones aren't like lenses. You don't point the mic at what you want to pick up, trusting anything out of the frame to be ignored. Think about pointing the sides and back toward sounds you want to reject. The sounds you don't want will still be there, just reduced in volume. You can't avoid getting a mixture of direct sound, reflected sound (generally from off-axis) and leakage from other sound sources. Since all these sounds will be in the mix, it's really important that the frequency response is appropriate, even for sounds that you're trying to reject.

Figure 2 shows the response of a common cardioid microphone. Its corner frequency is around 400Hz, with a cut-off frequency of around 30Hz. Curve A shows the microphone in the far field (more than 1m), curve B at about 20cm, curve C at 5cm.

Tip: Ask the manufacturer to tell you the proximity-effect corner and low cut-off frequencies, the distance where the response is flat, and the response in far field or plane wave conditions. And then, you want the same information for other distances and directions. It's a lot of data, and while manufacturers know the performance of their microphones, it's rare for complete data to appear in the data sheet. The Audio Engineering Society Standards Committee working group on microphone characterisation has been working for more than ten years on this problem. When enough people make their buying decisions based on real information, the marketeers will think it's important enough to spend some effort on presenting it — progress is slow, but enough demand from buyers will make it happen sooner.

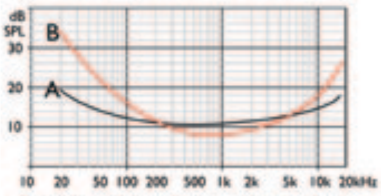

Fig. 1 - Which mic is quieter? A - more uniform noise floor, B - lower "A" weighted midband noise, more rumble and hiss

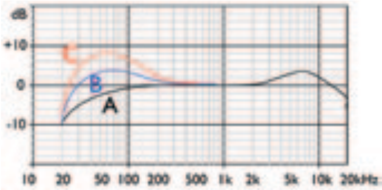

Fig. 2 Typical frequency response on-axis with proximity effect (corner frequency 400 Hz, cutoff frequency 20 Hz) A – far field, B – ~20 cm, C – ~5 cm

On-axis frequency response doesn't begin to tell you how the microphone will handle sounds arriving off-axis. If you are picking up one instrument from the front, and another is nearby but toward the rear, you'd want both to sound natural — the one towards the rear a little softer. Many cardioid mics reject well in the centre of the spectrum but not so well at the edges. The guitar cabinet you pick up on-axis sounds OK, but the bleed from the bass cabinet toward the back of the mic may actually be stronger and sound quite boomy.

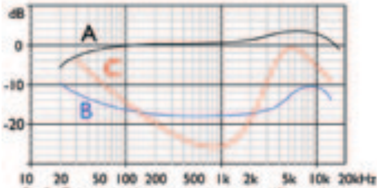

Fig. 3 - Two mics with same on-axis response (A) sound very different. B - smooth off-axis response, C - more midband rejection but nearly omni in bass and treble.

Figure 3 shows two microphones with identical on-axis frequency response (curve A). Curve B represents a microphone with fairly uniform response at 180°, while curve C shows a microphone with a deeper null in the midrange but almost no rejection at the low and high frequencies.

WHY FREQUENCY RESPONSE ISN'T EVERYTHING — People tend to want uniform frequency response over the whole range of audio. It's hard to do over a range of ten octaves (20Hz to 20kHz), particularly for directional microphones. Some microphones measure flat in standard tests, but sound bad. Others sound better, but don't measure flat. What's going on? It could be that the particular response chosen by the manufacturer is better suited for an intended range of applications — a sort of built-in EQ. In many cases it's because the mic has been designed to be made cheaply, for instance with acoustical resonators that disturb the phase response. It's a lot cheaper to make a microphone that droops past 12kHz or so and then bump the response up, than it is to get the microphone more or less flat to begin with.

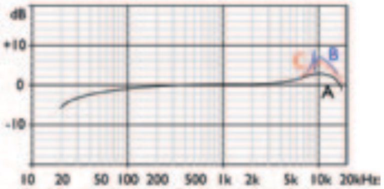

Fig. 4 A - smooth response, B - actual response of resonator equipped mic, C - same mic as B, smoothed

You can do a short experiment to illustrate this. Your ears probably aren't perfect, they have some high frequency roll-off like real microphones do. Cup your hand behind an ear and you can more easily hear some faint sound in the distance. If you're careful, you can hear the effect even of small reflectors — hold one finger or even a pencil near your ear and you can hear its effect, particularly in your ability to tell the direction a sound is coming from. Besides the frequency response changes these reflections make, the time of arrival isn't as clearly heard because you hear the original and the reflection. The psychoacoustical 'precedence effect' helps here, but overall stereo imaging nearly always suffers. We have interaural time resolution of a few microseconds… it doesn't mean we can hear above 20kHz, but we can tell where sounds are coming from solely based on tiny differences in time.

TIME DOMAIN RESPONSE — If amplitude response at different distances and directions is tricky, time domain response is nasty — particularly for real world directional microphones with niceties like baskets and grilles that protect the microphone against damage. Every element of the phase shift network that makes a mic's directional pattern, every piece of the housing and grille, and every part of the shockmount or suspension creates reflections that make tiny echoes in the time domain response of the microphone. Properly done, the echoes line up and create the desired sound colour and alterations in the frequency response. Clumsily done, the result is harshness, muddiness, smearing and all the other hallmarks of a cheap mic. People want lots of 'air' and sparkling high frequency response. Makers have a choice — clever design and expensive, precise manufacturing tolerances are one way to get extended, smooth response — but that method isn't cheap. Or, they can put in various structures that bump up the amplitude response if no one cares about the time response.

Figure 4 shows what happens when reflections from inside a microphone grille boost the high frequency response. Curve A (black) shows the response without the grille, curve B (blue) is the actual response — note the sharp peak and dip at 9kHz — and curve C (red) is how it might be shown on a datasheet with typical smoothing. The bare microphone will almost always sound better than with a reflector or resonator added to boost the response. Other design features like overly dense protective grilles may also cause reflections like this. The actual response of the resonator-equipped mic drops much more sharply at 20kHz than the simpler but more expensive microphone.

Tip: Smoothness is everything. Reflections can create steep changes in the frequency domain. Most microphone makers know this, and sometimes they smooth or average the curves, often in 1/3-octave bands to show a mic's basic sound colour. At high frequencies 1/3 octave can cover a huge span within which there is no detail, so even if the response is accurately given, if it's smoothed more than about 1/12 octave, you won't see what's really going on. ■