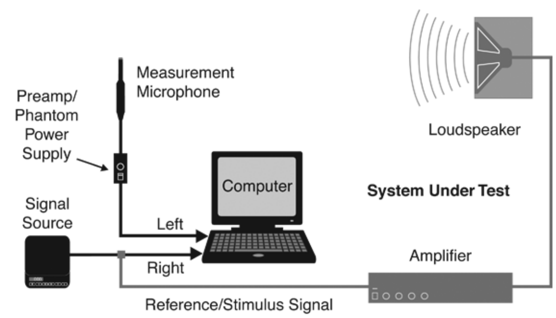
Tech Note

# Anatomy of a Measurement Rig:
## Probes, Preamps and Processors

### Feed The Brain




The primary job of a measurement rig is to acquire electrical and acoustical signals and feed them to the processor so that it can analyze, compare, slice, dice, fold, spindle and mutilate those signals and produce multi-colored charts, graphs and the all-important squiggly lines. "But my software can produce squiggly lines all by itself without all those bothersome wires, preamps and microphones. Isn't that enough?" Maybe. Depends on whether you are getting paid to pose or produce results. We shall assume that you fall into the latter category, and therefore, the reason you have employed an analyzer is to measure your system and learn something about the signals passing through it, and in turn, what your system is doing to those signals as they pass through. Your job is to decide what you want to measure, and from that, determine what measurement signals you need.

The point here is, the effectiveness of an analyzer is tied directly to its ability to acquire the measurement signals you need — and of course, those signals must be of a usable **quality** (see Note at the end of this document) and format. With this basic functionality in mind, and for the purposes of this discussion, we shall divide our measurement rigs into three basic parts: probes (signal acquisition), preamps (signal transmission) and processors (signal analysis).

### Probes (Signal Acquisition)

Put simply, our probes are where we grab our measurement signals. We can split this group into two types: electrical and acoustical.

#### Electrical Probes

Once we have determined what electrical signals we want to grab — the points in the system signal flow we want to use as measurement points – accessing those electrical signals is basically a wiring exercise, generally accomplished via patching into device outputs or by splitting the signal path. This is why the measurement rigs for engineers who work on many, varied systems normally include a wiring kit with a healthy selection of adapters, y-cables, impedance matching connectors and other wiring knick knacks/ doohickies (pardon the technical jargon).

When grabbing your electrical signals, it is important to note that, while standard practices of splitting the signal path and routing it into your preamp/audio I/O normally does not produce noise issues (worse case: noise introduced into the signal path), it is a good idea to always be aware of system grounding and is often a good idea to carry some isolation transformers in your bag'O'tricks just in case.

### Acoustical Probes

Ok, ***microphones.*** There, we've said it. Microphones are a critical part of our measurement rig. They are our analyzer's window onto our acoustical environment and the signals that are arriving at our audience, artists' and our own ears. As tiny transducers, they are also the most variant component in our measurement rigs; from mic to mic, and also over time. In a perfect world, our microphones would act as completely neutral acoustical probes — perfectly omni-directional with razor-flat frequency response from DC to light and 200+ dB of dynamic range. In the world in which we live and work, this is sadly not the case. It is only the ideal to which our mics aspire. So let's get real about our measurement microphones.

The short take on the measurement mics we use for our rigs is that we need need to be honest about how close to our "ideal" mic we actually need. It is relatively simple (and inexpensive) proposition in this day and age to produce a microphone that has a good free-field, omni-directional pattern with a respectably flat frequency response between 50 Hz and 5 kHz (and reasonably flat from 20-18k), and with a dynamic range that is generally usable for measurements between 30-130 dB SPL. For a large number of our real-world applications that may be all you require for your rig (and you can save money to spend on other cool gear.)

The microphone costs start increasing when you:

- expand the flat FR (particularly in extending and flattening the VHF response)
- extend the dynamic range, either raising the max SPL or dropping the self noise
- require tighter overall sensitivity ranges (mic to mic)
- require exactly matched responses
- require individual measurement plots for every mic
- increase the ruggedness and environmental capabilities

All of this is to say, you always can spend huge money on your measurement microphone if you so desire, but may not need to for every single application you can name.

## Preamps (Signal Transmission)

This section should really be called, "Preamps, Cables and Audio I/O" - but that would defeat our cute alliterative naming scheme. Also, while "signal transmission" includes all the connecting cables in your measurement rig, we will, for the purposes of this discussion, assume they are of professional quality and functioning properly (but don't just go making that assumption in practice — always check 'em), and focus on the preamps and computer audio IO (interface.) Often these two functions are combined in one device, but not in all cases. Here, we shall address the two functions separately.

Our measurement rigs require preamps to perform four critical tasks:

1. Allow adjustment of incoming measurement signals to appropriate levels for our computer audio interface. In determining our choices of preamps, we must consider what type/level of signals we will be accessing (mic, instrument, commercial line level, pro line-level), and what type of connectors will be needed (XLR, 1/4", RCA, BNC).

2. Allow adjustment of measurement signals for appropriate levels for our measurement purposes. Throughout the course of standard measurement processes, it is often desirable to be able to finely adjust the levels of multiple measurement signals relative to each another.

3. Allow measurement signal selection and routing. In many cases, you may be using multiple mic and line signals which you need to select from over the course of your measurement sessions. While one can employ the old stone-knives-and-bearskins approach of just re-patching cables on the fly, multiple, routable preamps (mixers, switchers) make the job easier, cleaner, and less error prone.

4. Provide phantom power for measurement microphones.

There are many ways that these preamp requirements can be met. In touring and permanently installed systems, it may be beneficial to build the measurement preamp requirements into the system's existing signal preamp and routing scheme (i.e. feeds directly from the mix console or system dsp units). It is important however to remember requirements 1&2 above, and make sure that the "built-in" measurement signal feeds have their own, separately adjustable levels apart from the main system drives — we can't very well go asking the mixer to turn up or down during a performance just to make our measurement signals happy.

### Computer Audio I/O

Once we have our measurement signals, the final step along the signal transmission path is the analog to digital conversion (A/D) and the journey into the computer processor (sorta sounds like an Orlando theme park ride). The big question is, "How do we get there from here?" The most convenient path is to use the converters built into the computer, their stereo line-level inputs, however, over the past ten years, most PC laptops have dropped that input from their built-in components in favor of a simple mono-mic input (Mac laptops still have them standard.) If one is available to you, it is certainly a viable option as those inputs usually meet/exceed our humble requirements. In the all-too-frequent case that your laptop does not have a stereo line-level input, or where your measurement rig requires more than two input channels, the standard solution is an external audio IO unit. Over the same past ten years (not coincidentally), there have been a number of computer audio interfaces that have come on the market that satisfy our requirements — most of which including our required preamps.

When considering an audio IO unit for your measurement rig, the primary concerns (apart from your preamp requirements) are generally:

- **Physical Connection Format** - USB, USB 2, FireWire (IEEE1394) 400, FireWire 800, PCMCIA card, dixie cups on strings? The question is which is easiest, and will it carry the number of signals you need. USB (1&2) are the most commonly available connections built into laptops and are generally the preferred connection type for simple two channel (stereo) input. USB 2 and FireWire connections are required for multi-channel input (3+ channels).

- **Audio Driver Format** - Just because the signals get into your computer doesn't mean your measurement software can use them. It is very important to determine what driver formats your program can access (i.e. wav/wmd/mme, ASIO, coreaudio). This issue is further compounded by OS version issues and is the source of severe headaches for users and developers alike.

- **Powering Mode -** buss-powered or externally powered. Simple stereo USB units often utilize the buss power available via the USB connection (500 mW max). This is extremely convenient as it adds portability (no need to plug in to AC) and ease of set-up to your rig. It is also a great feature when traveling between countries that use different standard AC voltages because the buss powered unit gets its power from the computer, which normally utilize auto-ranging power supplies. Once you are into multi-channel IO's, it is pretty much guaranteed that buss power will not suffice and you will need to plug into local AC for power.

- **Form Factor** - simply put, what type of audio connectors does it have and how big is it. For those of you who need an extremely portable measurement rig, rack-mount gear is most probably too big for your requirements. A corollary to this issue then is ruggedness/roadability - sure it's portable in size, but is it built to withstand the transportation demands/conditions placed on it?

The proper choice of audio IO and preamps is truly defined by the intended use for the measurement rig - what systems are going to be measured, under what condition and whether or not (and how) the rig is going to be transported. No one solution works for every user and use case. Often times, it is preferable to field a basic set of stereo preamps and IO, and then supplement that with additional preamps and signal routers (mixers, switchers) when the complexity of the rig and system requires.

### ** A Note on Measurement System Signal Path Quality

A word on signal transmission quality in our measurement rigs: While it may be counter-intuitive, for 99.52367% (roughly speaking) of common applications, the signal quality that our analyzer rigs require to produce good measurements is, by pro-audio standards, not really that high - particularly when compared to the signal quality demanded for studio recording or even simple listening. What we require from the signal transmission path in our measurement rigs is really quite humble.

**Frequency Response** - Flat (+/-.25 dB) throughout the measurement bandwidth - a spec that should be easily achievable from 20 Hz to 20 kHz by all levels of audio gear. The biggest offenders here are unexpected filters, HPFs caused by wiring issues or faulty DC blocking and phantom isolation circuits, LPF's from long transmission lines and poorly implemented anti-aliasing filters, and of course the random unintentionally inserted EQ filter (a frustratingly common occurrence when grabbing measurement signal feeds off of extra board and processor outputs.) Generally, this can be checked by simply examining the heavily averaged spectrum (RTA) of a known spectrally flat pink noise source. Any major FR deviations will show themselves quickly.

**Channel Consistency (in FR and Latency)** - the requirement that the measurement signal channels have virtually the same response and latency (which is by far the norm) so that dual-channel system response measurements - made through the comparison of two signal channels - are not biased by any FR or Latency differences between the signal channels of the measurement rig. A quick way to check this is by applying the exact same signal to both input channels (or all channels in the case of a multi-channel rig) and then performing transfer function (FR) and delay (IR) measurements between channels. The FR should be flat in magnitude and phase (signifying no latency issues), and the delay between the channels should be zero. It is possible that your delay measurement could show zero time offset, and yet the phase response shows some deflection from flat in the VHF - this occurs when the two channels are off by a factor of 1/2 sample due to uncorrected interlacing in the ADC (the ADC samples at 96 kHz and alternates between channels to produce two 48kHz signals - the driver should correct for this 1/2 sample latency offset)

**Signal to Noise and THD** - Hold onto your hats. For most applications in standard measurement rigs, we only truly need an SNR of >70 dB and THD performance <1%!! Of course we expect performance much higher in the electrical path of our measurement rigs, but for the basic requirements of the spectrum, FR and IR measurements we most commonly make, this level of performance will not significantly impact our data. Think of it this way, it is not uncommon to have the SNR of the acoustic environment for our measurement be far below 70dB (the old Spectrum arena in Philadelphia comes to mind). The key here is to be aware of your noise floors (acoustic and electrical), measure well above them, and use all the tools at your disposal to help protect and improve your data quality (Amplitude and Coherence Thresholding, and liberal application of data averaging.) - Note: this is also why few measurement systems and situations see any appreciable difference between the use of 16bit and 24bit A/D conversion.

**Channel Isolation -** Verify that there is no significant cross-talk between your measurement channels (>70 dB isolation @ 1kHz). There are a couple easy ways to do this. The simplest is to input a sine wave on one channel, and then view the spectrum of the other. Another way is to measure a piece of electronic gear with a bit of delay/latency. If there is significant (in terms of our measurement world) cross-talk, a look at the IR measurement will show an impulse at zero time as well as the correct delay through the device.

The measurement signal path quality requirements detailed above would probably be horrifying to a recording engineer, audiophile nut or even your standard pro-audio system engineer. But for the purposes of acquiring valid, stable and useful measurements with our rigs, that is where the bar is set. And this is good news for 99.52367% of us, meaning our measurement rigs don't need to be comprised of high-end, esoteric, built-from-unobtainium gear. Standard professional quality gear in functioning order will do most of us just fine. There are of course exceptions created by the demands of situations like measuring very low noise levels (low NC measurements) - and those are the applications, that's when you need spend the extra $$ on your signal chain.

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