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The Design of Microphone Preamplfiers

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Audio professionals are familiar with the tradeoff between a console's quality and its cost. Console builders must make a conscious, deliberate choice of design philosophy and component selection to best target the budget and needs of their particular audio niche. Even the most expensive consoles cannot avoid certain inherent tradeoffs. And for low- and mid-priced recording boards, deep sacrifices are an all-too-common occurrence.

One console function which is routinely immolated is the microphone preamplifier. As a result, engineer's often find it desirable to bypass console mic amps in favor of dedicated, external preamps. To derive the most benefit from your audio path, it helps to have an understanding of different microphone preamp designs, what they sound like, and what designs are currently available.

In just a few years, the professional audio market has seen a rapid upturn in manufacturers producing stand-alone mic amps. At recent count, somewhere in the neighborhood of one-hundred different mic preamp designs are available; ranging in price from around $100 to $7,500 per channel*.

One reason outboard mic preamps are gaining in popularity is that creative engineers, producers, and artists desire a broader sonic color palette from which to express their work. When you consider that mic preamps may amplify signals in excess of 1000:1, it's no wonder that this single link becomes a key contributor to sonic coloration.

Outboard mic preamps are not for everybody, though. Some engineers simply track through the console most of the time for convenience. Moreover, on big budget "union" recordings, such as movie scoring dates, a decision for outboard solutions might be offset by the additional time, cost, and complexity incurred. Likewise, in a hectic production facility, a staff engineer simply may not have the time to configure a rack of outboard pres. However, when sonics are the key consideration, outboard mic preamps are almost always the best choice.

DESIGN TECHNIQUES

Contemporary mic amp design can be categorized into four types of active elements: discrete semiconductor, vacuum tube, integrated circuit, and hybrid (i.e., any combination of the prior three). Within these categories are found FETs, bipolars, IC function modules, IC opamps, discrete opamps, and so forth.

Irrespective of which active devices are chosen for a mic amp, a key design consideration remains the coupling of input, interstage, and output circuits. Common coupling methods include transformers, capacitor, servo, and direct. All mic preamps use at least one of these coupling methods, and many offer a combination.

Within these classifications exists a wide array of design techniques and specifications, far beyond the scope of this article. It suffices to say that each design approach, when done well, has a definite place in professional audio and can provide the engineer with subjective and objective solutions not achievable in the studio console.

Most stand-alone mic preamp channels offer, at minimum, a balanced XLR3 input with switchable phantom power and gain control. Per standards, phantom voltage is usually supplied in series with 6,810 ohm resistors, though these resistors should be modifiable for use with specialty microphones. Gain control is found either stepped or infinite. Infinite controls offer more precise set capability, whereas stepped switching offers precise stereo gain matching between channels and perfect resetability. Your specific recording requirements will dictate which gain control method is better for you.

Other functions found on modern preamps may include high impedance DI inputs, overload indicators, VU meters, separated input and output gain controls, attenuation switching (pads), remote gain control capability, phase switching, balanced/unbalanced switching, selectable input impedances, and more.

Preamp input impedance seems an issue of both personal taste and objective criteria. One preamp specifies an input impedance of less than 1,000 ohms, while another shows a figure of 7,800 ohms. A large number of mic preamps, however, claim a frequency dependent input impedance between 1,000 and 2,000 ohms. By definition, a minimum ratio of about 5:1 between preamp input impedance and microphone output impedance is required for proper bridging. Too little input impedance will increase noise and unduly load most microphones.

Many mic amp specifications play a purely objective role. These include voltage gain (usually just called "gain"), input noise, common mode rejection, and so forth. Other objective specifications, such as THD, slewing, frequency response, and phase response, curiously do not always translate into specific predictable sound quality. Specifications should be treated with respect, but your ears should be the final judge of any preamp's performance.

Concerning objective specifications, many are extremely useful. For instance, if the preamp will be used in environments where very long cable runs and emi problems are common, assure yourself that the unit's CMRR is sufficiently high. Assure also that adequate protection has been afforded from strong RF fields.

Another key objective parameter is voltage gain. Some mic preamps offer minimum gains which may be too high for sensitive microphones on loud sources. Padding these signals is an alternative. However, in such preamps, noise is often increased. Moreover, when using low sensitivity microphones, such as the Beyer M-160 (1mV/Pa), a preamp with less than 60dB gain may not always be suitable.

SOUND QUALITY vs. DESIGN

Every element in an audio signal path impacts sonic quality. This is true for every resistor, connector, switch contact, and solder joint in a device. Moreover, sonic coloration in mic preamps seems most effected by the selection of active elements, i/o coupling, and basic topology.

In designing a critically accurate mic preamp for use with symphony orchestra and other sensitive sources, we had an opportunity to test and listen to various mic preamp circuits implementing discrete transistors, IC opamps, and IC function modules. I'll briefly characterize our assessment of each, though the reader should understand that these opinions are limited to the topologies we explored.

These original tests did not include vacuum tubes units, though it is widely accepted that tubes provide a sonic character often unattainable with semiconductor technology. Good tube designs with high quality coupling can capture a remarkably pleasing perspective on vocal and instrumental timbre. It's not hard to understand why fine tube mics, compressors, EQ's, and preamps are in great demand today.

CHIPS and INTEGRATED CIRCUITS (ICs)

We began our analysis with function module mic preamplifiers. These little gems are near-complete preamps in a single IC package - add a power supply and you're almost ready to roll. The benefits of function modules include very low cost, good technical specifications, design simplicity, and ease of manufacturing. They are commonly used in low- and mid-grade mixing consoles.

In our tests, we auditioned various topologies built around two common function module IC's - the Burr Brown INA-103 "transimpedance" mic preamp chip and the Analog Devices SSM-2017 mic preamp. Overall, we preferred the Analog Devices part, though both ICs were compromised sonically. Subtle audio coloration was especially apparent in the upper mid-range and extended upper frequencies where both devices imposed an "electronic" sheen to the signal - especially at higher dynamic levels. This effect can actually be artistically useful when highlight and spot mics are required to "cut through" a thick mix. These chips provide a valuable, affordable solution in many of today's entry-level mic preamps and mixing consoles.

Another textbook design uses a single IC opamp; often preceded by a transformer. Chips such as the venerable 5534A exhibit good gain-bandwidth, low noise, and excellent THD numbers. Better front end specifications can be achieved on these designs by the inclusion of an input coupling transformer in which the microphone is correctly bridged. If the secondary impedance of the transformer is well matched to the noise resistance of the IC, acceptable technical performance can be achieved; especially if a superior transformer is used.

Our tests with mid-line transformers ($20-$40) proved disappointing. Low frequencies, such as found in bass drum or large organ (60 Hz and below) especially suffered. Even the finest transformers we tested nevertheless lent a certain character which was immediately recognizable, though the better transformers were much better behaved than their budget counterparts. Such transformer coloration was immediately apparent on larger dynamic excursions and deep frequency extensions.

Ironically, transformer coloration, whether slight or drastic, is often artistically desirable. In Neve Retro (article, R-E-P Magazine), the process of rebuilding old Neve console strips was explained. Rupert Neve has said that the harmonic distortion produced by those 1960's era "class-A biased" designs contributed to his console's unmistakable sonic character. Old Neve's, as well as modern transformer-coupled designs, are sought out continually by top engineers for this reason.

CLASS A and HYBRIDS

Finally, we extensively tested two families of discrete front ends; a Class A bias approach and multiple discrete-hybrid designs incorporating some number of discrete transistor gain elements before, or in feedback with, monolithic operational amplifiers.

The sound quality of the all-discrete class A circuits are reminiscent of vintage Neve mic amps, but the designs are difficult to manage technically. Finding the proper tradeoffs in operating currents, gain settings, audio specs, stability, and overall sonic neutrality can be elusive. There are some very well made class A mic preamps in production today which should be given serious consideration. They can offer a unique sonic personality which is difficult (if not nearly impossible) to emulate in non class A designs.

Being generally dissatisfied with variations on the prior design techniques (not that we couldn't achieve good sounding mic preamps with these designs -- far from it! We heard something usable in just about every design we built and tested. However, recall that our objective is starkly accurate reproduction of critical acoustic music, predominantly classical. To this end, we were as yet not satisfied), we went on to test a wide range of discrete hybrid designs.

In these tests, we kept gravitating back to variations of massed discrete transistors configured in the "double balanced" approach; believed first presented in basic form in a 1984 paper by Philips Microelectronics of Australia. This approach retains the balanced microphone signal in a mirrored circuit - essentially two identical mic preamp circuits in parallel - one for the positive polarity of the balanced microphone and one for the negative polarity. In this way, unbalancing the input and rebalancing the output (yet another common source of sonic coloration in the majority of today's mic preamps) is unnecessary.

Coupling methods in all topologies tested provided yet another challenge towards accurate sonics. Transformers again revealed their subtle colorations and were rejected in favor of capacitive and servo coupling. And in comparing various forms of interstage servo circuits, we found different degrees of unusual low frequency artifacts -- possibly a result of the additional active interface required. Ultimately, carefully selected capacitive coupling was found most accurate for both front end and interstage coupling. Later designs dispensed with interstage capacitive coupling, leaving only front-end coupling from input to output — with an optional "all DC" path from input to output for use with non-phantom microphones, such as ribbons.

In selecting coupling, a large number of capacitive methods were auditioned. A wide range of sonic coloration was noted between many alternatives. Surprisingly, some capacitors advertised as specifically designed for "audiophile" applications were judged inferior to the eventual use of carefully selected high voltage, very low impedance electrolytics bypassed with ultra-stable polyethylene terephthalate film capacitors.

Often, layout topology, power supply, and ground sensing proves just as critical to sonic realism as active and passive circuit topology and devices. Much time was invested in auditioning both audible and objectively measured effects of alternative grounding, local (multi-stage) power supply regulation, decoupling, and audio layout paths. In such exhaustive listening tests , a point of diminishing returns is usually reached, wherein the design is considered finished to the best of our ability and formally released to production.

SUMMARY

All microphone preamplifiers exhibit unique coloration to a lesser or greater degree. In audio electronics, there is no such thing as a straight wire with gain. Further, because of the differences between each preamp's unique loading and gain characteristics, any microphone will respond differently when matched to different preamps. With the seemingly infinite combination of mics, preamps, and source material, it's in the engineer's best interest to continually review and experiment with variations and technique.

We can argue that accuracy is the critical measure of mic preamps. And in many applications, such as when recording the acoustic environment of a symphony orchestra, absolute accuracy is crucial. But the question must be asked: "by who's definition or opinion of accuracy?" Ultimately, every engineer must answer this question on their own.

We at Millennia have complete confidence in our carefully evolved test methods of comparing sonic realism in audio circuits. Please audition a Millennia preamp in your most critical recording environments and let us know if you agree. A large cross-section of today's most discriminating engineers, artists, and producers daily rely on Millennia audio paths. They have listened carefully, as we have, and agree with our results.