

Lamm Industries L2 Reference preamplifier

Jonathan Scull, May 2001

The L2 Reference sits at the top of Lamm Industries' preamplifier line. According to the manual, its "unique" circuitry uses specially selected, superlinear, high-voltage MOSFET transistors that ensure class-A operation from input to output, with no overall negative feedback at any stage. *All* stages, including the high-current output buffers, are single-ended.



The L2 has a separate power supply that features a choke filter—an old technology that is once again popular in high-end circles—and vacuum-tube rectification and voltage regulation. According to Grand Lamm Vladimir Shushurin, special care was taken in designing the high-voltage (+350V), high-speed tube voltage regulator:

"Using this voltage regulator, in conjunction with other technical aspects, enables the reproduction of the tiniest nuances and three-dimensional subtleties in the music palette, provided they weren't lost in the recording process, of course. A somewhat unusual combination of high-voltage tube power supply and superlinear high-voltage MOSFETs allows the L2 to achieve an *enormously* large output voltage swing while retaining practically constant harmonic content of the signal, with an absolute dominance of the second-order harmonic."

According to Shushurin, special attention was also directed toward optimization of the L2's output impedance, allowing it to drive "without audible sonic degradation the significant capacitive loads created by many modern interconnect cables." Many? Dunno about *that*, but I'll leave it to Shushurin to duke it out with the cable guys. The L2 worked just fine with all the cables I had on hand; the most pleasing match was Synergistic Research Designer's Reference, especially with Active Shielding engaged. (I ran balanced to my Krell 350MC monoblocks for best sound, not to mention that these amps don't offer single-ended inputs. However, all the *front*-end connections were single-ended as no balanced inputs are offered on the L2.)

According to Lamm, "Each preamplifier is carefully handcrafted with matched components of the highest quality, some of which include military-grade low-noise Dale metal-film resistors; unique TKD stepped potentiometers with 41 steps; PRC wire-wound resistors; Electrocube and Roederstein film capacitors; high-frequency switching-grade Cornell Dubilier electrolytic capacitors; specially selected long-life vacuum tubes; high-quality heavy-duty gold-plated RCA connectors; and gold-plated Neutrik XLR connectors." The power supply features a custom-designed, super-low-noise toroidal power transformer, and the L2 works on all of the world's various AC line voltages (100V, 120V, 220V, 230V, 240V) "without elaborate modification."

Other features include three single-ended inputs, one tape loop (also on RCAs), balanced *and* single-ended outputs, an output-signal phase-inversion switch, and built-in remote power on/off facilities for Lamm power amplifiers. An electronic protection circuit mutes the outputs until the preamplifier has stabilized after turn-on, and also permits muting at the flick of a switch during normal operation. The L2 *also* automatically mutes when the AC line voltage drops below a predetermined level or is cut off entirely.

Description

Nothing much to it: Two black, relatively nondescript boxes with high-quality switches recessed in long, oval depressions, and a pair of knobs on the control unit. Each chassis has little rack-mount-type handles.

'Round back of the power supply chassis, right to left, sit a standard IEC mains-in, a nice big ground connector, the Power Output umbilical connector, the remote trigger connectors, and something I haven't seen on a high-end preamp in a while: two switched AC outlets, 500W max.

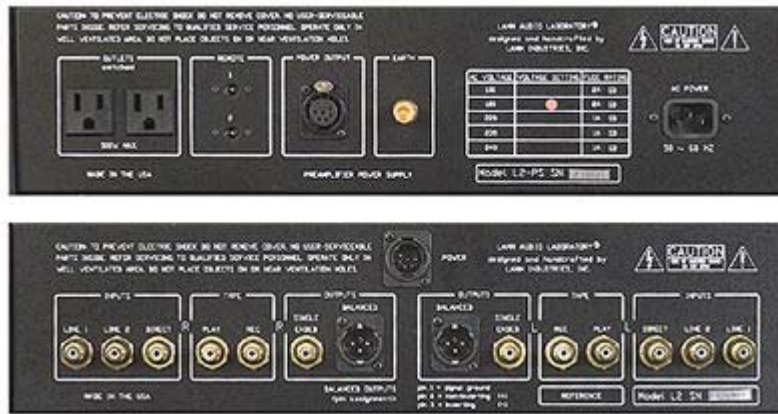
The preamplifier chassis' array of front-panel controls echoes the mirror-imaged, dual-mono circuitry inside. The volume potentiometers sit to either side of an imaginary vertical center line; outside to inside on each side of that line, the first three switches are the same: Line 1/Line 2, Tape/Source, Line/Direct. The fourth switch on the left selects Mute/Operate for both channels, the fourth switch on the right selects Phase (both channels, of course).

While the control section is dual-mono, the power supply is not. According to Shushurin, "There is *no* interaction between the channels because of the low impedance of the power supply itself."

Around back, it's all done with mirrors again: Single-ended-only input choices for each channel are Line 1, 2, and Direct, the tape loop is next to Direct; closest to the back panel's center line are the outputs, including an XLR balanced out. Above the input/output array is the 5-pin XLR socket for the umbilical to the power supply.

If, as Shushurin explains, the L2 uses "truly balanced, fully differential" circuits, I was puzzled why there are no balanced XLR inputs. "I ground the negative input on the RCAs, so I use only single-ended inputs, very simple." Over the phone, I could almost hear him shrug.

The Direct inputs route the signal directly to the volume potentiometers, bypassing the Line 1/Line 2 and monitor Tape/Source switches. In that way, the L2 reminded me a lot of the YBA Signature 6 Chassis, which has a similar dual-mono topology with a direct input bypassing some switching: rather than convenience, purism in the service of the music.



The Lamm L2 is *not* remote-controlled; you have to heave your audiophile butt outa that listening chair to select inputs and make changes in volume. The exercise will do you good.

Setup and Tweakage Tweakage at \$13,690 retail? Yeah, you heard me. Here's the deal: The Lamm L2 is for the deeply committed enthusiast willing to spend the time and attention required to tweak it for best sound. Don't wanna fuss? Then buy a [Mark Levinson Reference No.32](#) for only a bit more. The No.32 is built like a tank, and footers, placement, and other tweaks make *no* difference whatsoever to its sound—it's all been taken care of by Madrigal. But if you're an involved type who likes to play *and* achieve big-time results for your efforts, read on.

I began auditioning by setting the L2 and power supply on separate shelves in a PolyCrystal rack, and straight into the wall for good ol' unprocessed New Yawk powah—no footers or tweaks of any kind. *What* great sound! I dunno, there's something about terrific components that one picks up on straight away—I just knew it sounded so right and could only get better. I *love* when that happens! I was slack-jawed as an ass from the start; the sound was wonderfully fine on a variety of front-end components and amps.

But understand—despite its name, Lamm *Industries*, Vladimir Shushurin's operation isn't exactly Krell or Madrigal/Harman International. "Industries," my big beezer. While Lamm gear isn't exactly built in a Brooklyn garage, the name is a bit grandiose for the reality of these lovingly handbuilt and tested-to-death electronics. Fully half the L2's manual consists of specs, graphs, and charts, and a "Proof of Performance Report" is included with each unit. It's lovely to see this kind of individual attention paid to each unit produced. In fact, this preamp is about the furthest you can get from the mass market. It's an audiophile with *that* kind of mindset—and the bucks to afford such gear—who will best appreciate the L2.

It was obvious to me where Lamm had put its money: design and parts. The casework is plain and unremarkable, relatively lightweight, and downright knobby-looking, with chassis screws bristling up everywhere. While the Levinson No.32 is

suaveness personified, the L2 is much more utilitarian in its purity of design. As a result—hold on to your audiophile hats—the best results were obtained by suspending the power supply (which contains five tubes) on three stacks of three each Golden Sound DH Squares, a graphite-bearing footer with some "give" to it. (See this month's "Fine Tunes" for details.) The power-supply section also sounded very good on Bright Star's Air Mass isolation base or Signal Guard closed-cell foam stand. But both took up too much room on the shelf, so the DH Squares were elected; they sounded almost as good and took up much less space.

After cycling through several sets of footers, I found that the control unit *definitely* sounded best on Nordost Pulsar Points. The more expensive titanium TP4s were noticeably better than the aluminum PP4s, but only when a weight of some kind was placed in the center of the L2's top cover. And not just any weight—I tried several record weights and a Shakti Stone, and settled on the original (quite heavy *and* atrociously gold-colored) Forsell turntable record weight with its rubberized bottom surface, which damped the cover *and* coupled the unit to the footers beneath. The L2's top rang ominously when tapped; it sounded much more dead with the record weight on top. Not exactly beautiful-looking, but it's the sound that counts. And I used a Shakti Stone atop the power supply's toroidal transformer for best sound.

Nor would any old power cord do. For the L2, the PS Audio Lab Cable just edged out the Synergistic Research Master Coupler. As before, I found the SS5 setting on the PS Audio P300 Power Plant to be *the* setting that did it for me for all the front-end components.

While I found the best sound using all Synergistic Research Designer's Reference interconnects, single-ended and balanced, for the long run to the Krells, AudioQuest Everest speaker cable sounded *fabulous* with these amps. This was unexpected—I'd let it lie around while waiting for more of AQ's Amazon interconnect to try. (The first batch was wired the wrong way around, so everything played backwards. Just a joke...)

Sound on the Lamm

Describing the sound of the Lamm L2 is not hard at all. Now, you might think that's bad: "Oh, it has a sound of its own. It shouldn't—especially at that price!" That's correct; it shouldn't. And it doesn't.

I fed the L2 signals from a variety of topnotch components: SACD and CD from the Accuphase 100/101 duo; upsampled 16/44.1 CDs from the dCS 972 and dCS Purcell/Elgar Plus combo; CD from the Linn CD12; and tasty vinyl treats from the Forsell Air Force One/van den Hul Grasshopper IV GLA via the BAT VK-P10 phono stage with XLO Reference phono cable. Typically, I popped the outputs of the Accuphase into the Direct input, with the dCS and P10 into Lines 1 and 2, respectively. Sometimes I pulled the phono and fed the Linn into Line 2. And sometimes, when I felt the need (which wasn't often), I fed the Source of the Moment into the Direct input for the best of the best, although the Line inputs evinced *very* little degradation for having to traverse two more switches within the L2.

Throughout it all, I was enchanted by the sound. The L2 did *not* sound the same with every front-end component, but always sounded superb, in *all* cases offering up what I thought the best the source could offer.



The highs were simply breathtaking, even if somewhat paradoxical in nature: sweet and very pleasingly harmonic, yet remaining *clean*, extended, soaring, pure, and detailed. Not *once* did the L2 tip over into the chaffy, harsh, or overly analytical, or make me wince in any way—yet I was *sure* I was hearing as far up into the audible spectrum as I ever had. Beautiful and

inspiring. It made me hum with pleasure.

Listening to Jascha Heifetz saw his fiddle in half in the last movement of the Sibelius Violin Concerto (Walter Hendl/CSO, RCA/Classic LSC-2435) was jaw-dropping and awe-inspiring. His aggressive playing was intact, the string tone alive with a tonal palette one usually only dreams about. Similarly, the string tone on Mozart's Piano Concerto 8, K.246, with Vladimir Ashkenazy on piano and István Kertész conducting the LSO, sucked me in and wouldn't let go until the very end, and not even then! The extension and sweetness, *plus* the dynamics, detail, and tonal color, mesmerized me. The space, the air, the sense of being there were entirely palpable, so enjoyable. Isn't that what it's all about?

The massed vocals on *Musica Sacra*, a hybrid SACD (Opus3 19516), were beyond reproach. The big chorus was perfectly delineated, set out on a wide, layered soundstage, every voice perfectly explicated, the whole greater than the sum of its parts. It was truly inspiring to hear, the *huge* space of the recording seemingly perfectly reproduced in our loft. Within that complex weave of voices was something that touched my soul, that made my heart beat faster and no doubt released a flood of endorphins into my hungry brain. The disc sounded silky-smooth, yet detailed beyond my experience. Notes: "Such purity, such *divinity*, it makes the hairs stand straight up on the back of my neck—and elsewhere!" The sense of acoustic decay was wonderfully reproduced, the depth and transparency beyond reproach. Powerful stuff.

Craving more of those drop-dead-gorgeous highs, I popped Telarc's *The Very Tall Band* in the Accuphase transport, on both SACD (CD-83443-SA) and CD (CD-83443). The VTB is Oscar Peterson on piano, Milt Jackson on vibes, Ray Brown on bass, and Karriem Riggins on drums, recorded live at the Blue Note in 1998. Try track 3, "I Remember Clifford." Notes: "Listening to Milt's vibes are what the L2 is all about—cool, precise, and mellifluous...sweet yet extended. The outstanding midrange doesn't call attention to itself but makes me bow my head in appreciation of its rightness, all part of a very coherent musical picture."

I was having such a good time listening to classic jazz that I thought it time for a *real* orgy. I set up *For the First Time* (Pablo PACD-2310-712-2), by the Count Basie Trio (Ray Brown and Louis Bellson); *Satch and Josh...Again* (Fantasy OJCCD-960-2), with Oscar Peterson and Count Basie on duelin' pianos, John Heard on bass, and Louis Bellson on drums; *This One's for Blanton* (Analogue Productions CAPJ 015), with the Duke and Ray Brown, recorded in Las Vegas in '72; and *Duke Ellington and his Orchestra Featuring Paul Gonsalves* (Fantasy OJCCD-623-2), with, among others, Johnny Hodges on alto sax and Jimmy Hamilton on clarinet and tenor sax.

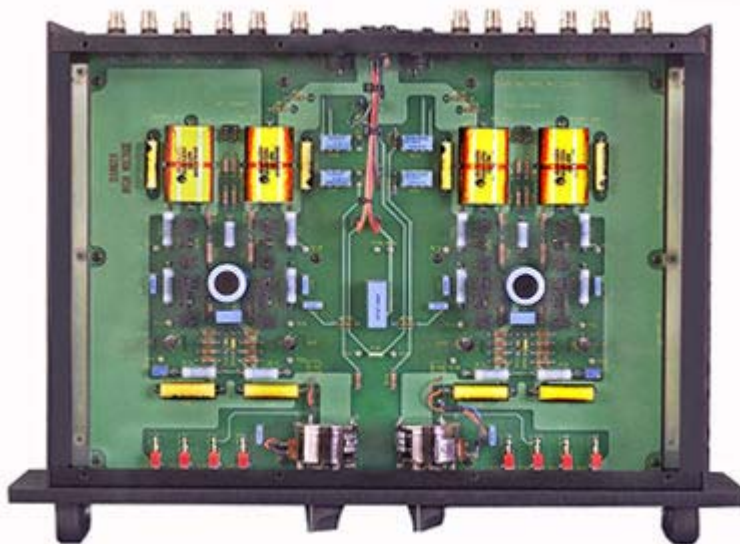
It was a great listening session. I came away from it "holding" the music, as it were. It was *in* me and it stayed there. (I looked for leaks.) Maybe it was the L2's hybrid build, its tube regulation—whatever. It seemed to give the music passing through its circuits that extra sense of roundness that tubes do so well. *Not* the softness or euphony some tube designs delight in, but an *emotional* softness. The music seemed to enter my soul via osmosis rather than as an e-mail to my head.

The midrange was flawless in all the recordings noted above, and with everything else I played through the L2. There was a kind of magic attraction, a magnetic pull in the midband; I wanted to lean *into* it, to get closer to it, to actually *become* the midrange! There was something just so *human* about it, so satisfying, so resonant with my own body electric (apologies to Ray Bradbury)—lots of detail, rich but very clean. I couldn't find a lousy-sounding midrange in *any* of the recordings I had on hand, even with New Pop recordings like St. Germain's *Tourist* (Blue Note 5 25114 2) or Thievery Corporation's *Sounds from the Thievery Hi-Fi* (Eighteenth Street Lounge Music ESL5).

Moving slightly down the frequency scale, the midbass was miraculous as well—very controlled and detailed, but rich and resonant with harmonics and overtones. Listening carefully to Ray Brown on *This One's for Blanton*, I enjoyed his big, fat bass sound with *no* overhang whatsoever. If you pick up this recording, you'll find the Duke's piano sound a bit weird, as if he's playing an upright, although the pic on the cover gives no hint of that.

Try "Things Ain't What They Used to Be" and "Sophisticated Lady." Mr. Brown's bass has to be heard at this high level of playback to believe that it can ever sound that good. This AAD disc, originally produced by Norman Granz, was mastered from the original master tapes by Doug Sax at the Mastering Lab using all-tube electronics. It was lovely to hear two grand masters, Duke and Brown, tickle each other musically, so light in their touch, so musical in their ways. If you get the album, dig the hat the Duke's wearing! (He's really *Dude* Ellington!)

Just to make sure I wasn't hallucinating, I played *The Virtuoso Oboe, Vol.2* (Vanguard VSD-2074) on my Forsell 'table. The disc features works by Mozart, Handel, and Albinoni performed by André Lardot, the Boskovsky Quartet, and the Chamber Orchestra of the Vienna State Opera. Okay, so I only listened to the Mozart and Handel...*but then I listened to it again.* Transcendent. Whatever the L2 was giving me in the midrange, I *needed* it, and what I needed is what I think *all* audiophiles ultimately need—that special communication with the music.



Regarding deep bass...well, if I was going to pick a nit, here's where I'd pick it. But I don't know if it's really a nit or not. Listening to Bruno Walter's recording of Mozart's Symphonies 38 and 40 on SACD (Sony SRGR703), *Boulez Conducts Ravel* on SACD (Sony SS 89121), plus some of the really deep stuff on Peter Kruder's *Peace Orchestra* (G-Stone G-CD 004), I thought: If I *could* level a complaint, it would be that the Lamm sounded a bit lighter down there in the bass than I'm used to hearing from the awesome Krell 350MC monoblocks--or the Linn Klimaxes, for that matter. Or do other preamps exaggerate slightly? Hard to tell, and in the greater scheme of things, it doesn't matter. What was there was deep enough, tight enough, and doggone it, I liked it!

What have I left out...female vocals? Loved 'em. *Welcome to Portishead* (Go! Live GLCD001) was fabulous, palpable, round, super-sexy, airy, wide, deep, low-distortion, and fun to hear. And I never heard Patricia Barber sound so fine as on her *Nightclub*, on fine-sounding CD (Premonition/Blue Note 5 27290 2) and *especially* on the HQ-180gm vinyl (Premonition 90749).

The Fulfillment of Yearning

The L2 is a wonderful preamplifier. You *can* listen to it and enjoy it without all the tweaking I did, but my diligence on that front put it right up there next to the Mark Levinson No.32 Reference, for about the same price. The Levinson comes off rather more detached, more emotionally neutral, while the L2 has soul, baby, and lots of it—but without being obvious or euphonic about it.

In the end, it's up to you, your tastes, and your wallet.

The defense rests.

Sidebar 1: Specifications

Description: Dual-mono, tubed, line-level preamplifier with separate power supply. Inputs: 3 single-ended, 1 tape loop on RCAs. Outputs: 1 set each balanced, single-ended. TKD stepped potentiometers and built-in remote on/off for Lamm Industries power amplifiers. Choke-filtered hybrid design: tube rectification, solid-state output. Tube complement: one 12AX7/ECC83 voltage regulator, one 6C19P voltage regulator, one 5651A voltage reference, two 12AX3 rectifiers. Maximum voltage gain: 14.87dB \pm 0.2dB. Input sensitivity: 135mV RMS. Frequency response: 20Hz-20kHz, +0/-0.2dB; 4Hz-140kHz, +0/-3dB. THD: <0.03%. Slew rate: 30V/ μ s. Noise: >82dB (unweighted). Input impedance: 41k ohms. Output impedance: 130 ohms. Power consumption: 75W.

Dimensions: 19" W by 4.5" H by 14" D (both). Weights: preamplifier, 15.42 lbs (7kg); power supply, 19 lbs (8.63kg).

Serial number of unit reviewed: F10010.

Price: \$13,690. Approximate number of dealers: 9. Warranty: 5 years.

Manufacturer: Lamm Industries, 2621 E. 24th St., Brooklyn, NY 11235. Tel: (718) 368-0181. Fax: (718) 368-0140. Web: www.lammindustries.com.

Sidebar 2: Associated Equipment

Analog source: Forsell Air Force One turntable and tonearm, van den Hul Grasshopper IV GLA cartridge.

Digital source: [Accuphase DP-100 SACD transport](#), [Accuphase DC-101 SACD processor](#), [Linn Sondek CD12 CD player](#), [dCS 972](#) and [Purcell D/D converters](#), [dCS Elgar Plus D/A processor](#).

Preamplifiers: Mark Levinson No.32 Reference, BAT VK-50SE, Conrad-Johnson 16LS.

Power amplifiers: Krell FPB 350MC and Linn Klimax Solo 500 monoblocks, Forsell Statement.

Loudspeakers: JMLab Utopia.

Cables: Digital: XLO The Limited, RCA and AES/EBU. Interconnect: Synergistic Research Designer's Reference Discrete and Active Shielding. Speaker: AudioQuest Everest, Cardas Golden Cross, TARA The One, XLO The Limited, Synergistic Research Designer's Reference, Linn K400. AC: PS Audio Lab Cable, Synergistic Research Designer's Reference Master Couplers², Coincident CST.

Accessories: ASC Studio Traps, Argent RoomLenses, API Ultra Enhancers, PS Audio P300 Power Plant with MultiWave upgrade, Signal Guard platforms, Black Diamond Racing shelves and cones, DH Labs Cones and Squares, Nordost Pulsar Points, Bright Star Air Mass/Big Rock combo, PolyCrystal amp stand, equipment racks, cones, and cable towers.—**Jonathan Scull**

Sidebar 3: Measurements

All measurements were made through the Lamm L2 preamplifier's Direct inputs (which bypass the input switching) and at both the balanced and unbalanced outputs. The input impedance was a reasonably high 42.4k ohms. The maximum unbalanced voltage gain was a moderate 8.83dB, this increasing by the expected 6dB, to 14.84dB, at the balanced outputs.

The absolute polarity was preserved from both sets of outputs with the front-panel switch set to "0 degrees," confirming that the XLR jacks are wired with pin 2 hot. Setting the polarity switch to "180 degrees" inverted the unbalanced output but not the balanced output. The unbalanced output impedance was a low 124 ohms in the midband, increasing inconsequentially to 134 ohms at 20kHz, but significantly to 3.35k ohms at 20Hz, due to the limited size of the output coupling capacitor. (These figures doubled from the balanced outputs.) The Lamm L2 should not be used with power amplifiers having an input impedance of less than around 22k ohms if the low frequencies are not to sound lightweight.

The dual volume controls are well-matched and operate in reasonably accurate 1dB steps over most of their range. The unity-gain setting was 1 o'clock balanced and 3 o'clock unbalanced. The 12 o'clock positions gave an attenuation of 20dB from both outputs. Interchannel crosstalk (not shown) was unmeasurable, while frequency response (fig.1) was identical from both balanced and unbalanced outputs, and flat within the audioband. The ultrasonic rolloff reached -2dB at 200kHz.

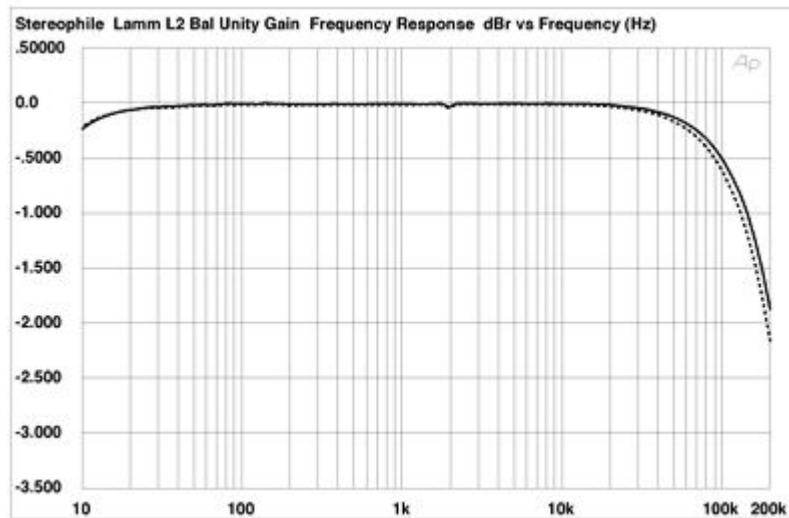


Fig.1 Lamm L2, balanced frequency response at unity-gain volume-control setting (0.5dB/vertical div.).

Levels of distortion into our standard 100k ohms load were very low, and identical at all audioband frequencies. The unbalanced figure at 2V output was 0.006%, the balanced at 4V around 0.002%. And as well as being so low in level, the harmonic spectra were low-order. Fig.2 shows the spectrum of a balanced 50Hz tone driven at 4V into 100k ohms: the only harmonic to poke its head above the -100dB level is the third (150Hz), at -93dB. As balanced operation cancels even-order harmonics, it was not surprising to see the second harmonic (100Hz) join the third from the unbalanced jack (fig.3), at a level of -83dB. This spectrum was again taken into 100k ohms; the second harmonic rose by 10dB into 10k ohms (not shown), but even into a demanding 1k ohm load (fig.4), the harmonics remained below -60dB (0.1%) and retained their subjectively consonant relationship.

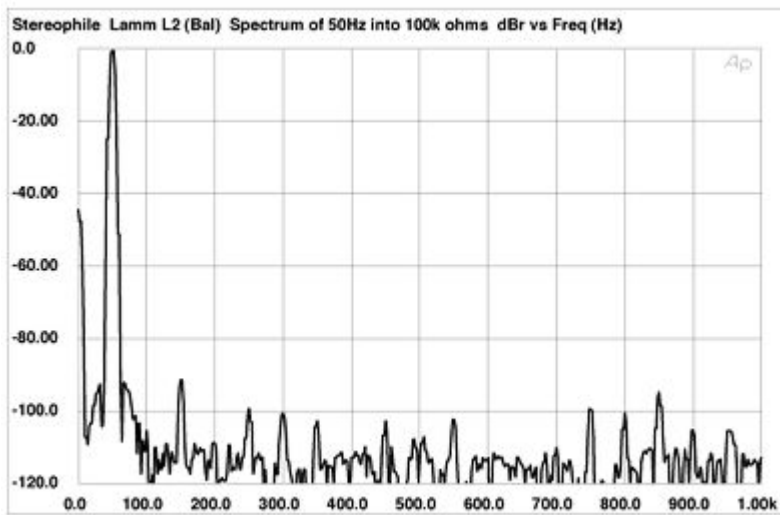


Fig.2 Lamm L2, balanced spectrum of 50Hz sinewave, DC-1kHz, at 4V into 100k ohms (linear frequency scale).

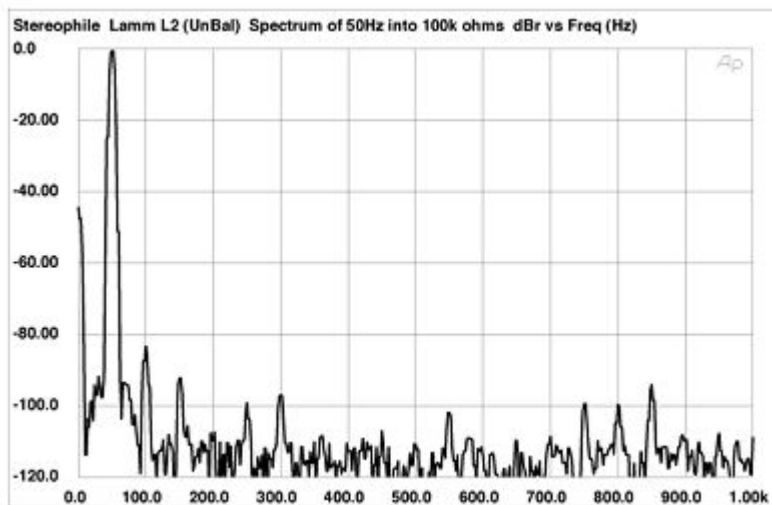


Fig.3 Lamm L2, unbalanced spectrum of 50Hz sinewave, DC-1kHz, at 2V into 100k ohms (linear frequency scale).

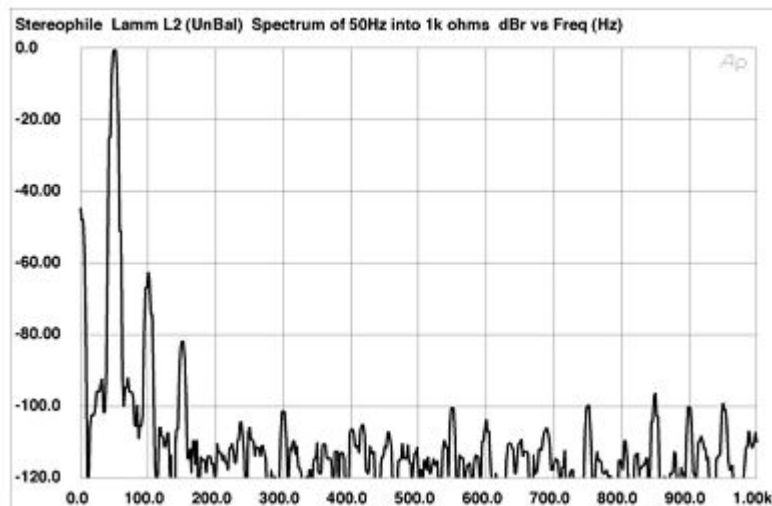


Fig.4 Lamm L2, unbalanced spectrum of 50Hz sinewave, DC-1kHz, at 2V into 1k ohm (linear frequency scale).

Levels of intermodulation distortion were also extremely low. Fig.5 shows the spectrum of the unbalanced output driving an equal mix of 19kHz and 20kHz tones into 100k ohms. The only apparent modulation product is the difference tone at 1kHz, this lying at -80dB (0.01%). This was virtually unchanged into 10k ohms (not shown), which is about the lowest typical power-

amplifier input impedance the L2 is likely to see—though it did rise to -54dB (0.2%) into the punishing 1k ohm load (fig.6). But from the balanced outputs at 10V, the intermodulation spectrum was one of the cleanest I have ever seen (fig.7).

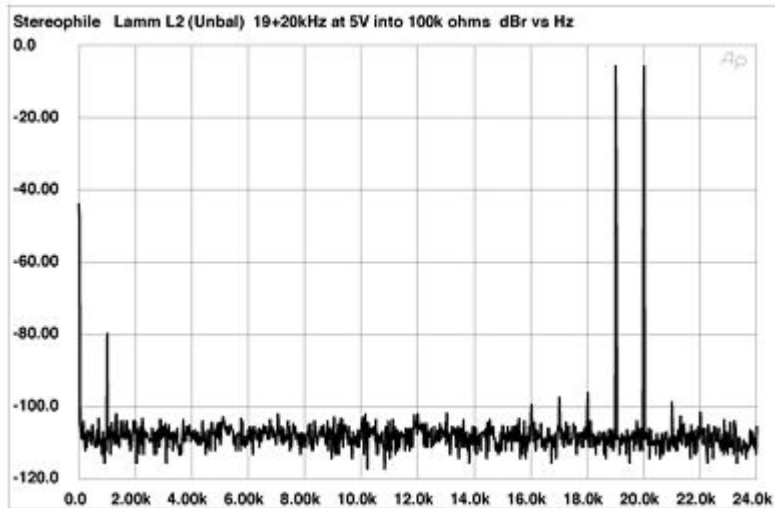


Fig.5 Lamm L2, unbalanced HF intermodulation spectrum, DC-24kHz, 19+20kHz at 5V into 100k ohms (linear frequency scale).

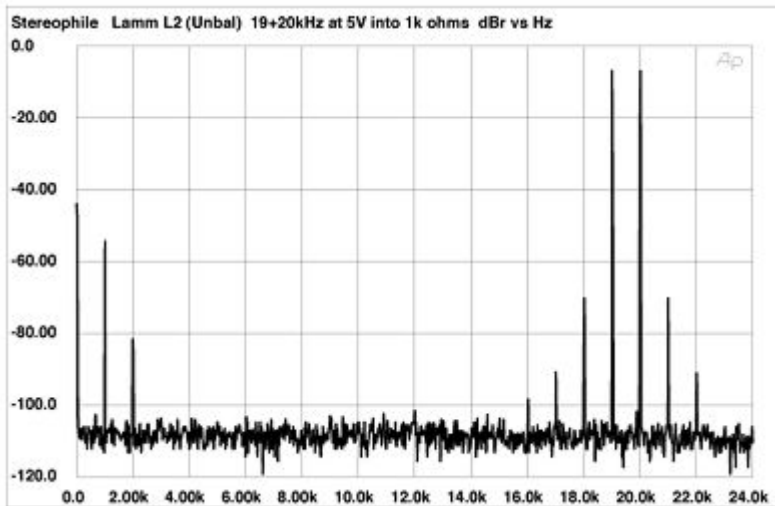


Fig.6 Lamm L2, unbalanced HF intermodulation spectrum, DC-24kHz, 19+20kHz at 5V into 1k ohm (linear frequency scale).

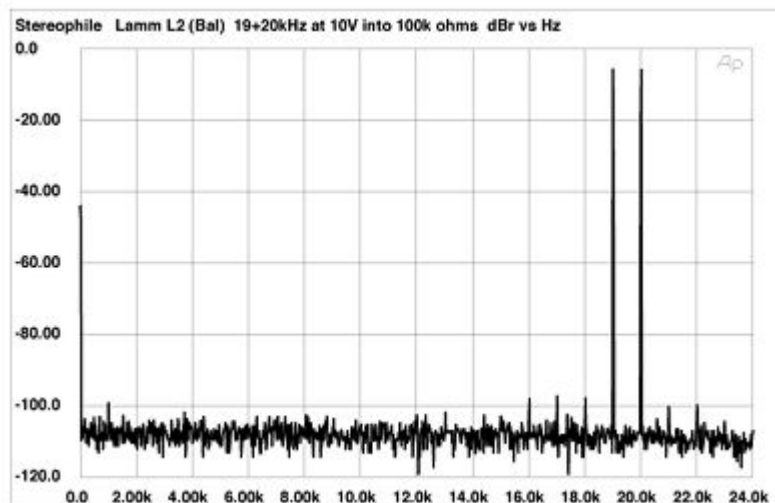


Fig.7 Lamm L2, balanced HF intermodulation spectrum, DC-24kHz, 19+20kHz at 10V into 100k ohms (linear frequency scale).

Finally, the use of MOSFET gain devices run at very high voltages results in the Lamm preamplifier offering enormous dynamic range. Figs.8 and 9 show the level of distortion and noise plotted against output voltage from the unbalanced and balanced outputs, respectively. The minimum value in each trace shows the point where the measured THD+N percentage changes from being dominated by noise to showing the actual level of distortion. Into 100k ohm loads, this occurs at around 1.5V unbalanced and 15V balanced. The former is the approximate point where an amplifier with an unbalanced input will approach its clipping point; the latter is way above a balanced power amplifier's clipping point, meaning that what distortion is present in the L2's output may well be masked by noise at any sensible operating volume.

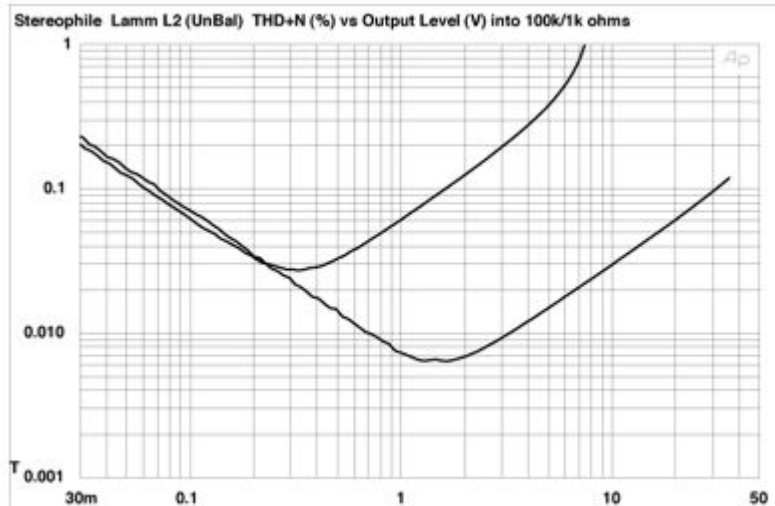


Fig.8 Lamm L2, unbalanced distortion (%) vs output level (V) into (from bottom to top at 1V): 1k ohm, 100k ohms.

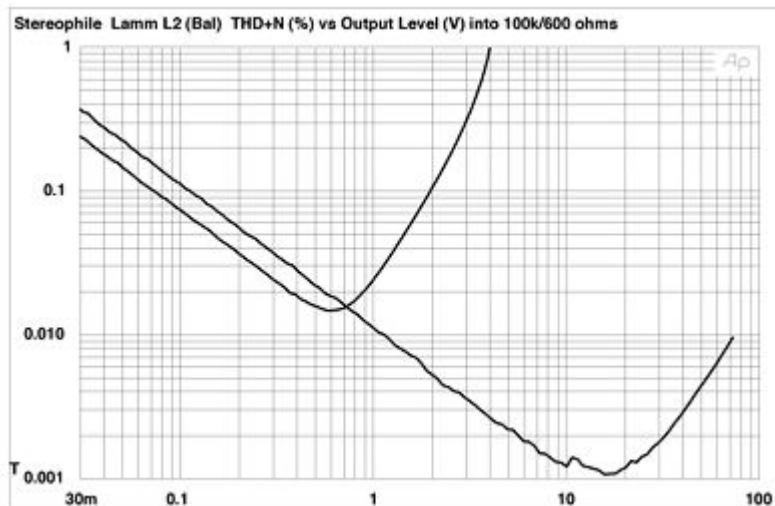


Fig.9 Lamm L2, balanced distortion (%) vs output level (V) into (from bottom to top at 2V): 600 ohms, 100k ohms.

But note that above these output voltages—all the way to the point where the traces stop because the Audio Precision signal generator has reached its maximum output level—the L2 has not reached its actual hard clipping point. Instead, the transfer function gradually becomes more curved as the output level reaches into the tens of volts.

Power amplifiers with very low input impedances should be avoided because of the rising source impedance at low frequencies, and the restricted output voltage into low loads indicated by figs.8 and 9. These measurements reveal the Lamm L2 to be a well-engineered preamplifier with a sensibly arranged gain/distortion structure. I did wonder, however, whether the L2's responses to Jonathan's mechanical tweaks were connected to its very resonant chassis.—**John Atkinson**