The Cutting Edge

NAD M2 Direct Digital Amplifier

Inventing the Future of Audio

Robert Harley

The term "digital" is often erroneously applied to amplifiers with Class D (switching) output stages, but in the case of NAD's new M2 Direct Digital Amplifier that word is appropriate. In fact, the M2 represents a major rethinking of audio-system architecture, directly converting standard-resolution or high-res digital bitstreams into signals that can drive loudspeakers.

Functionally, the M2 is an "integrated amplifier" that replaces a DAC, preamplifier, and power amplifier. The M2 eliminates from a traditional signal path all the electronics of a DAC as well as the active analog gain stages of a preamplifier and power amplifier. It does this by converting the PCM signal from a digital source directly into a pulse-width modulation (PWM) signal that turns the M2's output transistors on and off. That's it—no digital filter, no DACs, no multiple stages of analog amplification, no interconnects, no jacks, no analog volume control, no preamp. The conversion from the digital domain to the analog domain occurs as a by-product of the switching output stage and its analog filter. This is as direct a signal path as one could envision. (See sidebars for the technical details.)

NAD's M2 is a significant departure for the company that made its reputation building simple and affordable electronics. For starters, the M2 costs $5999, a new price level for a NAD "integrated amplifier." Second, the M2 is NAD's first amplifier to use a switching output stage. The company had previously rejected the technology in favor of linear amplifiers because switching output stages just didn't sound good. But the M2's output stage is significantly different from any other currently offered (see sidebar). Third, NAD believes that the M2's technology could eventually become the basis for nearly all of its amplification products. In fact, NAD suggested that the M2 was not designed to capitalize on Class D's functional advantages, but rather to establish a new benchmark of performance in amplification, no matter what the technology.

Let's look at the M2 Direct Digital Amplifier in operation. The unit looks and functions like one of NAD's upscale Masters Series integrated amplifiers, with a row of front-panel input-select buttons, a volume control, and a display. The rear panel, however, reveals that the M2 is not a conventional integrated amplifier. Five digital inputs are provided (two RCA, one AES/EBU, two TosLink, plus a TosLink loop) along with one single-ended and one balanced analog input. The digital inputs can accept any sampling frequency from 32kHz to 192kHz. Analog signals fed to the M2's analog-input jacks are converted to digital.

Once you've connected an analog or digital source to the M2 (such as a CD transport or music server) and loudspeakers via the output binding posts, the M2 functions just like a traditional integrated amplifier. You select the source from the front panel and control the volume with the large front-panel knob or from the remote control. The front-panel display shows the input sampling frequency and volume setting.

Purists will note that the M2 requires that analog signals, such as a phonostage output, be converted to PCM digital. Similarly, those who enjoy SACD will be loath to convert their SACD player's analog output to PCM, and then back to analog in the M2.

The M2 offers a number of features not found on a traditional integrated amplifier. Pushing the Menu button allows you to select the sampling frequency of the analog-to-digital converter (for analog input signals) as well as engage an upsampling feature that converts, for example, 44.1kHz to 96kHz. Analog signals are digitized at up to 192kHz/24-bit. You can also attenuate the level of the analog inputs by up to 9dB. A "Speaker Compensation" adjustment is a five-position adjustment that "allows fine tuning of the top octave to match the speaker impedance." An absolute-polarity switch rounds out the menu-accessible features. A rear-panel switch engages NAD's "Soft Clipping" feature, which limits the output to prevent audible distortion if the amplifier is overdriven. An RS232 port allows external control via a PC or control system such as Crestron or AMX. The full-function remote control selects between sources, adjusts the volume, dims the display, and can also control a NAD CD or DVD player.

The M2 doesn't seem like a switching amplifier in operation; it is heavier than most Class D amps and although it runs cooler than a traditional Class AB amplifier of comparable output power, it produces more heat than any other Class D amplifier I've had in my home.

Listening

I lived with the M2 for a couple of months, driving the Wilson Audio Alexandria X-2 Series 2 loudspeakers as well as the YG Acoustics Kipod Studio (review forthcoming). When driving the Kipod, the M2 could drive only the upper module, not the powered woofer that accepts a line-level input. I also heard the M2 with the

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Technology: Not Just Another Switching Amplifier

The M2 is different in two important ways from other amplifiers that use a Class D switching output stage. In a conventional switching amplifier, analog input signals are converted to a series of pulses that turn the output transistors fully on or fully off. The signal's amplitude is contained in the pulse widths (see sidebar "Pulse-Width Modulation"). An output filter smooths the pulses into a continuous waveform. But in the M2, PCM digital signals fed to the amplifier's input (from a CD transport, music server, or other source) stay in the digital domain and are converted by digital-signal processing (DSP) to the pulse-width modulated signal that drives the output transistors.

This difference might not seem that great at first glance, but consider the signal path of a conventional digital-playback chain driving a switching power amplifier. In your CD player, data read from the disc go through a digital filter and are converted to analog with a DAC; the DAC's current output is converted to a voltage with a current-to-voltage converter; the signal is low-pass filtered and then amplified/buffered in the CD player's analog-output stage. This analog output signal travels down interconnects to a preamplifier with its several stages of amplification, volume control, and output buffer. The preamp's output then travels down another pair of interconnects to the power amplifier, which typically employs an input stage, a driver stage, and the switching output stage. In addition to the D/A conversion, that's typically six or seven active amplification stages before the signal gets to the power amplifier's output stage.

To reiterate the contrast with the M2, PCM data are converted by DSP into the pulse-width modulation signal that drives the output transistors. That's it. There are no analog gain stages between the PCM data and your loudspeakers. The signal stays in the digital domain until the switching output stage, which, by its nature, acts as a digital-to-analog converter in concert with the output filter. The volume is adjusted in DSP.

The second point of departure between the M2 and all other Class D amplifiers is the switching output stage itself. NAD partnered with the U.K. design team of the American semiconductor company Diodes Zetex, who had developed a novel switching-amplifier technology. NAD engineers worked with Diodes Zetex for more than four years to improve upon Zetex's basic idea before it was ready for the M2. Diodes Zetex calls its amplifier a direct digital feedback amplifier (DDFA). The primary innovation is the use of feedback around the output stage to reduce distortion. Feedback, used in virtually all linear amplifiers, takes part of the output signal, inverts it, and sends it back to the input. The technique lowers distortion. But feedback isn't practical in switching amplifiers because of the delay involved in sending part of the output signal back to the input. Switching stages operate on extraordinarily precise timing; a glitch of a nanosecond can cause the output stage to lock up. The Zetex innovation is to compare the actual high-level PWM signal (at the transistor outputs) to a low-level reference PWM signal. Any difference between the actual and reference PWM signals represents a voltage error. The actual PWM signal can deviate from the theoretical ideal because of power-supply noise or droop (a drop in

Volent Paragon VL-2, a $5000 stand-mounted two-way employing a Heil Air-Motion Transformer (also on-deck for review).

I compared the M2 to my usual system of a Berkeley Audio Design Alpha DAC, Pass Labs XP20 preamp, and Pass Labs XA100.5 Class A power amplifier, all connected with MIT MA-X interconnect and MIT Oracle MA loudspeaker cable. Note that the M2 functionally replaces this entire Berkeley DAC/Pass preamp/Pass power amp/MIT system, and costs about one-tenth the price. The digital source for both systems was the AES/EBU output from a Classé Audio CDP-502 to play CDs. I tested the M2 with high-resolution bitstreams sourced from the fan-less, drive-less, PC-based music server built by Boston retailer Goodwin's High-End and described in Issue 189. When I connected the AES/EBU output from the server into the M2's AES/EBU input, the M2 instantly locked to any sampling frequency and was glitch-free.

I experienced two minor operating problems with the M2. First, the protection circuit triggered a couple of times, even with no music playing. Turning off the power reset the circuit. Second, when I turned on the M2 on one occasion I heard noise from the right channel. Turning off the unit and turning it back on corrected the problem. This happened only once in dozens and dozens of power-up cycles.

Long-time readers will know that I'm no fan of switching amplifiers. They have their virtues—small size, very little heat dissipation, light weight, and usually a considerable amount of output power for the money. But when the music starts, Class D amplifiers have left me cold. They can sound very dynamic, but exhibit considerable variability in sound quality depending on the loudspeaker they are driving, the cables, and other factors. The switching amplifiers I've heard (admittedly, I have not heard many) have exhibited a mechanical character, along with a "chalky" coloration in the midrange that robs instruments of their distinctive tone colors.

But the M2 sounded completely unlike any other Class D amplifier I've heard. It had no characteristic fingerprint that identified its technology. Rather, the M2 tended to get out of the way, reflecting the virtues and verities of the recording. Unlike other switching amplifiers I've heard, the M2's departures from neutrality were subtractive rather than additive. That is, it commits sins of omission rather than sins of commission. The M2 sounded like a very high-quality conventional (linear-amplification) playback system in many ways, with one notable exception; this amplifier was dead-quiet at any listening level and with any loudspeaker—even the 95dB-sensitive Wilson X-2. Backgrounds were truly and totally black, a quality that gave instrumental images a greater tangibility, both spatially and texturally. The dead-silent background seemed to throw instrumental images into sharper relief, enhancing the impression of three-dimensional objects existing in space. This palpability was also partially the result of the M2's somewhat forward spatial perspective which puts the listener around "Row E." The M2 also tended to "spotlight" the midrange to some degree, again adding to the impression of presence and the palpability of instrumental and vocal images. This was generally an appealing quality, although some forward-sounding and midrange-emphasized recordings, such as *In Other Words* from The Teodross Avery Quartet, were not complimentary to the M2. Conversely, naturally recorded vocals such as the outstanding *ReVisions: Songs of Stevie Wonder* by Jen Chapin, took on a "you are there" quality that was extremely involving.

The M2's bass was simply great—extended, rich, warm, powerful, and muscular. The bottom end was rich and densely saturated in tone color, wonderfully nuanced and articulate, and very fast and dynamic. I greatly enjoyed the M2's combination of weight and agility on acoustic and electric bass, particularly with virtuoso players—Stanley Clarke's acoustic bass on *The Rite of Strings* with Al DiMiola and Jean-Luc Ponty, for example. Left-hand piano voltage), slight changes in the pulse widths, transistor tolerances, or variations in the rise-time of the pulse edges. All these potential sources of errors affect the area under the pulses, which is how the analog amplitude is encoded. This error shows up as a voltage, which is digitized at a conversion rate of 108MHz, processed to compensate for subsequent modulation cycles, and then fed into a noise-shaper that adjusts the pulse shape, on a continuous basis, to compensate for errors in the output stage. In addition to decreasing distortion, this technique also lowers the amplifier's output impedance.

The reference PWM signal must be essentially perfect or else the system will correct "errors" that aren't present. The pulse widths must be precise to within five picoseconds, a level of performance commensurate with the lowest clock jitter in state-of-the-art digital-to-analog converters. In fact, you can think of the M2 as a DAC with gain and judge its technical performance using the same metrics as those employed in evaluating D/A quality. For example, at -120dB, the M2's linearity error is less than +/-0.1dB (an amazing spec, by the way), and the unit provides useful resolution down to an astounding –135dB.

The M2's topology has interesting ramifications for a system's overall noise performance. In a traditional system of digital source, analog preamplifier, and analog power amplifier, any noise introduced ahead of the power amplifier greatly degrades the system's signal-to-noise ratio (SNR). For example, if we start with a CD player with a SNR of 115dB, feed its output to a preamplifier with a SNR of 108dB, and then drive a power amplifier whose intrinsic SNR is 115dB (all great specs), the system's overall SNR is only 84.1dB referenced to 1W (all SNR numbers are unweighted). Noise at the front of the chain gets amplified by the power amplifier, no matter how quiet that amplifier is. In the M2, the only source of noise is in the DSP and the switching output stage, and the noise level is completely independent of the gain. That is, the SNR doesn't degrade at low volume. The DSP's noise is kept low in part because of the 35-bit data path. The M2 has an SNR of 91dB (unweighted, referenced to 1W) at any signal level. Indeed, I turned the gain all the way up and put my ear next to the tweeter of the highly sensitive Wilson Audio Alexandria X-2 Series 2 loudspeaker (95dB 1W/1m) and heard no noise.

There's no free lunch, however. Switching amplifiers require a serious output filter (typically a large inductor and a capacitor) to remove high-frequency switching noise from the output, and to smooth the waveform. This filter is conceptually similar to the reconstruction filter in traditional digital-to-analog conversion. Switching amplifiers are also very susceptible to audible degradation if the power supply feeding the output transistors isn't perfectly clean. That's because the output transistors either connect the output transistors' power-supply rail to the loudspeaker (in the "on" state) or disconnect them (in the "off" state). Any noise or ripple on the supply rails is connected directly to the loudspeaker. Switching amplifiers thus require an extremely quiet supply. Nonetheless, many switching amplifiers skimp on the power supply in an effort to keep size, weight, and cost low. The M2 has a more substantial power supply than I've seen in any other amplifier with a switching output stage. Three separate supplies are used, one for each audio channel and one for the control circuitry and housekeeping.

Each of the M2's amplifiers is contained on a roughly 6"-square circuit board and heat-sink assembly that attaches to a mother-board below it. It appears that each channel employs two pairs of output transistors. The rear panel is shielded, presumably to prevent radiated switching noise to get into the signal after it has been filtered. The chassis is segmented into two additional shielded modules, again to protect against switching noise pollution generated by the output stage.

lines were also well served by the M2's dynamic agility and powerful bottom-end (the Beethoven Piano Concertos led by Sir Colin Davis on the Pentatone label). The M2 conveyed the impression that it took tight-fisted control over the woofers, backed up by tremendous energy reserves. The articulation in the midbass was extraordinary; I could easily hear the initial transient of plucked acoustic bass strings, followed by the rich resonance of the instrument's body.

When an audio product performs in many ways above its price class as the M2 does, there's a tendency to judge all areas of performance against its strengths. In other words, the product itself raises its own performance bar. Keeping that in mind, I noticed a trace of hardness in the upper midrange that manifested itself as a glare on certain instruments, particularly the upper range of trumpet. This is a common characteristic of amplifiers of this price, but it was different in the M2. Where most amplifiers impose this characteristic over a wide band that makes itself nearly always audible, the M2's coloration was confined to a relatively narrow band. Consequently, I heard it only occasionally when there was energy in that region. This slight coloration didn't bother me during extended listening to the M2 alone, but was apparent when I compared it to my reference system of the Berkeley Alpha DAC and Pass XA100.5 pure Class A power amplifiers. The M2 didn't have quite the timbral liquidity and midrange warmth of the reference system. Nonetheless, the M2's overall sound was smooth and relaxed.

The treble tended to favor ease over the last measure of detail. The top octave wasn't quite as open, extended, or transparent as my reference system. Listening to a straight-ahead jazz CD I had engineered live to two-track (*Confirmation* by the Chiz Harris Quartet), drummer Harris' cymbals were not quite as vibrant. Similarly, Conte Candoli's flugelhorn took on slightly more of a golden and burnished hue than it had in life. If a component departs from neutrality, it's better that this departure be in the direction of slightly softening of the treble rather than emphasizing it. I should reiterate that you can adjust the M2's treble balance to match your system via the front-panel menu.

The M2 sounded quite detailed, although the very finest inner detail was not as nuanced as that heard in the reference system. The M2 didn't resolve the last measure of information that conveys the mechanism by which a sound was created. For example, there's a passage in "Sorceress" from Return to Forever's *Romantic Warrior* (on the newly remastered *The Anthology* CD) in which Lenny White overdubs an intricate percussion figure on timbales in counterpoint to his drumming. The reference system better revealed the nature of the timbales, making them sound more like instruments being struck and less like mere transients.

The M2 was outstanding in its ability to unravel complex musical lines. Many amplifiers of this price tend to have a flat homogeneity that prevents one from hearing quieter instrumental lines in the presence of louder ones. This aspect of music reproduction is crucial to understanding the intent of the composer or performers. The M2 was the antithesis of smeared, congested, or confused. Instead, it laid out with exquisite resolution everything that was happening in the music. Moreover, it did this in a completely natural and organic way, with no trace of the analytical.

Partly as a result of this quality, and partly a result of the M2's fabulous way with dynamic contrasts and shadings, music always had an energetic and upbeat quality. I could feel the spontaneous music-making on the previously mentioned *Confirmation* disc I'd engineered and remembered from the session. The M2 had a rhythmic coherence and sense of life that thrilled me and riveted my attention on the music. Interestingly, I noticed this quality most on bebop; Freddie Hubbard's solo on his great composition "Birdlike" from pianist George Cables' *Cables' Vision* positively soared.

Finally, the M2's A/D converter (fed by the Aesthetix Rhea Signature phonostage) was very good, but not completely transparent. It shaved off a bit of resolution at lowest levels and very slightly hardened timbres.

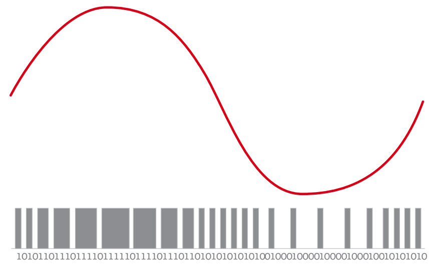
The M2's Predecessor

The M2 isn't the first switching amplifier to convert PCM to PWM. That distinction belongs to the TacT Millennium, which I reviewed at its introduction in 1999. But the M2 isn't simply a more modern version of that topology. Rather, the M2 employs an entirely new and radically different switching output stage (see sidebar). In addition, the Millennium adjusted the volume by changing the voltage of the power supply rails feeding the switching output transistors. The M2 adjusts the volume in the digital domain with the same digital signal processing (DSP) chip that performs the PCM-to-PWM conversion.

Pulse-Width Modulation

How can a series of pulses represent the continuous waveform of music? In exactly the same way that Direct Stream Digital (DSD), the encoding format behind SACD, produces music from a bitstream. In fact, PWM and DSD are conceptually identical.

Fig.1 shows the relationship between a DSD bitstream and the analog waveform that bitstream represents. The bitstream is a series of pulses of varying lengths, with the pulse length encoding the analog signal's amplitude. The pulse-train generated by DSD encoding looks remarkably "analog-like." That is, you can look at the pulse train and get an idea of what the analog waveform looks like. The relationship between the analog signal and the bitstream is so close that in theory, a DSD signal can be converted to analog with a single capacitor (DSD-to-analog conversion is more complex in practice). The bit rate of DSD as used in SACD is 2.8224 million bits per second.



Pulse-Width Modulation represents an analog waveform with a series of varying-length pulses.

In a switching amplifier, the output transistors are turned fully "on" or fully "off" by the pulse-width modulated signal. The analog signal's amplitude is encoded as the "area under the pulses"; longer pulses (longer "on" times for the output transistors) represent a higher analog-signal amplitude. This is contrasted with traditional "linear" amplifiers in which the output transistors are in a continuously variable state of conduction.

The output of the PWM stage is a series of high-level pulses that must be smoothed into a continuous waveform. Every amplifier with a switching output stage employs a large filter (an inductor and a capacitor) between the output transistors and loudspeaker terminals to perform this smoothing function and to remove switching noise.

In the Diodes Zetex amplifier module, the pulses are quantized at 108MHz. This frequency determines the number of discrete pulse widths available to represent the audio waveform. That number is 128, which appears at first glance to be too low to encode a complex musical signal. But even at 20kHz, there are many modulation cycles available within the period of a 20kHz waveform.

Conclusion

Despite costing one-tenth as much as my reference system (all the components of which are outstanding), the M2 was extremely engaging musically. Overall, I preferred the reference system, but not by as much as the price disparity would suggest. I usually wouldn't judge a $6000 product against one costing more than $50k, but the M2's outstanding performance in many areas invited the comparison. Moreover, the M2 represents a radically different approach to amplifier design, digital-to-analog conversion, and system architecture. As such, I evaluated how the M2 sounds not just in comparison with similarly priced conventional amplification and digital-to-analog conversion, but how its new technology stacks up on an absolute basis. (You should consider this when reading how the M2 falls short of a reference-quality system. I included those observations not to diminish the great achievement the M2 represents, but to put this new technology in context.)

As for the M2 as an alternative to a $3500 conventional integrated amplifier and a $2500 digital-to-analog converter, it's a slam dunk. I haven't heard, nor can I imagine, any combination of amplification and DAC at the price approaching the M2's performance. Moreover, the M2 delivers, in one chassis, decoding of high-resolution digital audio, the source-switching and control functions of a preamplifier, and 250W of amplification—all with outstanding ergonomics. I can envision the M2, or its descendents, as part of a three-piece playback-system: music server, M2-like product, and loudspeakers.

NAD's M2 is a triumph on many levels, not the least of which is that it points toward a new direction in amplifier design and system architecture. I predict that years from now audiophiles will look back on the M2 as the progenitor of the next generation of audio. tas

SPECS & PRICING

Continuous output power: 250Wpc (8 ohms); 250Wpc (4 ohms); 300Wpc (2 Ohms)
IHF dynamic power: 300W (8 ohms); 450W (4 ohms); 600W (2 Ohms)
Peak output current: >60A
Signal-to-noise ratio: >120dB (A-weighted, referenced to 200W)
Digital inputs: S/PDIF on RCA jacks (x2), AES/EBU (x1), TosLink optical (x2) plus TosLink in/out loop
Sampling frequencies supported: 32kHz–192kHz up to 24 bits
Analog inputs: Unbalanced on RCA jacks, balanced on XLR jacks
Analog-to-digital converter: Fully balanced, 192kHz/24-bit
Dimensions: 17.12" x 5.24" x 17.87"
Weight: 44.45 lbs.
Price: $5999

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