stereophile

Erick Lichte D/A CONVERTER & POWER SUPPLY

Bel Canto e.One DAC3.5VB & e.One VBSI

Minnesota pride is a funny thing. As Garrison Keillor points out weekly on A Prairie Home Companion, to be a Minnesotan, the first and crucial step to be taken is that of self-effacement. It is unclear to me whether this is the cause or symptom of Minnesotans ability to endure brutal winters, excel at the creation and consumption of hot dish (which the rest of the God-fearing world knows as casseroles), or their miraculous lineage from generations of Norwegian bachelor farmers. Whatever it is, Minnesotans tend to quietly get their jobs done with little more fanfare than a cup of coffee and a slice of rhubarb pie.

And yet, Minnesota has a streak of innovation and progressiveness that is something special. The Twin Cities of Minneapolis and St. Paul are home to an amazing arts scene that boasts two professional orchestras, an opera company, a vibrant theater community, two major art museums, and more choirs than there are Minnesotan lakes. Not only is Minnesota home to such big-name innovators as Target, Best Buy, General Mills, and 3M, but also countless smaller tech companies, including the audio brands Audio Research Corporation, Magnepan, Atma-Sphere, and Bel Canto.

Though I was born in Wisconsin (Go Packers!), I have come to love my adopted state of Minnesota. I take a quiet pride in the good things we do here. So when I heard that Bel Canto, a company that designs and builds its products in Minneapolis's warehouse district, was coming out with the e.One DAC3.5VB, a new DAC-preamp boasting a brand-new type of power supply, I jumped at the chance to review it.

Gettin' Off the Grid

The DAC3.5VB boasts a black-painted steel chassis and a beautifully milled faceplate of naturally finished aluminum, making it look like a cross between a modernistic jewelry box and a sample of Scandinavian industrial art. The overall visual vibe is somewhere between elegant and cute.

But what makes the DAC3.5VB a truly innovative product is its use of a newly designed power supply, the VBS1 (1 048€). VBS stands for Virtual Battery Supply. It's well known that the sensitive signals involved in digital conversion and preamplification benefit from a very pure and steady source of power. A few companies have designed products that run entirely off the grid, on batteries. Bel Canto's head designer, John Stronczer, loved the sound of these designs, but was unwilling to use such a "dirty" technology as lead-acid batteries: "I set out trying to capture the performance advantages of a lead-acid battery without any of the disadvantages, and the result was the VBS1 and the internal VB power-supply board used in our DAC3.5VB-VBS1 combination. The VBS1 features a switching power supply that provides 12V DC, followed by some heroic LC filtering and energy storage. There is nearly half a farad (500,000µF) of total capacitance and over 100 joules of energy storage in the VBS1. Filtering is near 100dB by 100Hz, and isolation is extremely high because of the small size and parasitic capacitance of the switching transformer. [The] audioband noise of the VBS1 is lower than the output noise of most audio preamplifiers! Our goal is to create the most pristine environment possible for the delicate musical signal."

The VBS1 can power up to three VBS-capable Bel Canto products. Its 12V of DC reach the DAC3.5VB via a stock umbilical power cord or an upgraded VB-REF cord (347€), about which more below.

Ins and Outs

The e.One DAC3.5VB (2 450€) accepts a ton of inputs: RCA and BNC digital, balanced AES/EBU digital, TosLink, ST fiber-optic, and a single pair of analog RCA. All of the DAC3.5VB's digital inputs are able to accept signals up to 24-bit/192kHz. It can output its signal via balanced or single-ended terminals, and all of these inputs and outputs are neatly laid out on the rear panel of a box roughly half the width of a normal audio component.

The D/A section of the e.One DAC3.5VB is largely the same as the one found in Bel Canto's e.One DAC3, reviewed by John Atkinson in November 2007. However, the DAC3.5VB's jitter-rejection circuitry is new. "We use an asynchronous approach to jitter rejection with a free-running low-jitter oscillator located near the DAC itself," John Stronczer, told me. "There's a steep 2Hz jitter-rejection filter, so by 10Hz any jitter-derived artifacts are attenuated by more than 20dB (10x), and by 100Hz [by] more than 80dB (10,000x). This process is effective for all digital inputs, no matter the source. Even a very high-jitter source like the [digital output of the] Apple Airport Express can be used for high-performance audio playback, because this way you don't suffer the typical corruption to dynamics and inner detail that jitter produces."

The ST fiber-optic input is meant to be fed from Bel Canto's own Light Link 24/96 USB interface (245€). This converts audio data with up to 24 bits depth and 96kHz sample rate from your computer's USB output to AES/EBU, to be then transmitted via an ST fiber-optic cable. Since a USB cord is good for only about 15', the Light Link can accept a short, high-quality USB cable, then make longer runs possible via an ST cable. Glass fiber-optic cable is specified for a data transmission rate greater than 150 megabits/second over lengths up to 1000m, but since audio's maximum data rate is less than a tenth of that, any jitter induced will be minuscule. Fiber-optics also provide isolation between a typically noisy computer and your audio system, and are immune to RFI, EMI, and other radiated noise.

The DAC3.5VB has one universal button/ volume control on its faceplate; however, the DAC is more easily and completely operate with the remote control. The remote, though functional, is not in the same league of elegance or cachet as the DAC itself—a piece of plastic with too many buttons, it occasionally frustrated me. An eight-character programmable display on the front of the DAC lets you keep track of which input you've selected. You can also temporarily disable inputs you're not using, so you can cycle through them faster with the remote. The DAC3.5VB's display is defeatable—you can set it to pop on when you change the volume or input, then go dark after a second or so. A lone button on the rear panel allows the user to set the Output Level to Fixed or Variable. To achieve proper line level in Fixed mode, the DAC's volume control needs to be at its maximum setting of "100" while in Variable mode, then switched to Fixed mode with the simple push of that button. The DAC3.5VB's volume control is a 24-bit digital attenuator that scrolls through 200 positions, from "0" to "100," in increments of 0.5dB.

Laying cable

I hooked up Bel Canto's e.One DAC3.5VB and e.One CD2 CD player to the e.One VBS1 power supply with the stock umbilical cords and let the trio play for a few hundred hours. You know the drill: During the break-in period the sound got more musical and warm and resolving, the sky turned bluer, the grass smelled greener, etc., etc. During the DAC3.5VB's stay at my home it fed a number of different amps: Sarah Palin's favorite, the Rogue M180 monoblocks, as well as Mystère's ia21, Pass Labs' Aleph 3, Plinius's SA103, and Simaudio's Moon i3.3 integrated amp. This allowed me to listen to the DAC3.5VB as both a straight DAC and as a combination DAC, preamp, and volume control.

I experimented with a number of cabling options and found that various AC power cords feeding the VBS1 did indeed affect the sound. Each cord brought its own signature to my system, but via the VBS1 that signature was much smaller: The power cords made an audible difference when powering the VBS1, but not nearly as much difference as when the same cables have directly fed other DACs. The VBS1 needed a good power cord, but not as badly as did many other components I've used.

I also experimented with running a number of balanced AES/EBU digital cables from the e.One CD2 to the DAC3.5VB, including DH Labs' Silver Sonic D-110, Wireworld's discontinued Gold Starlight 5, Illuminati's Orchid, and Canare's DA 206. The Gold Starlight 5, though it passed along a lot of info, slammin' bass, and a terrific soundstage, also had a slightly glary upper midrange/low treble. The Illuminati Orchid was very polite and smooth, but its top was rather rolled off, its midrange not very colorful, and its soundstage narrower than the other cables'. The Orchid seems like the sort of cable that was made back when digital didn't sound as good as it does today. The Canare DA 206 sounded nice, but lacked a bit of body in the mid- to upper bass. I really liked DH Labs' Silver Sonic D-110; it had a great soundstage and a smooth, super-extended treble. I felt I could hear more in the 10–18kHz range through the DH Labs than through any of the other cables, yet the treble was very easygoing. The DH Labs was nice and full in the mid- and upper bass, but lacked the Wireworld's slam in the lowest bass. Still, I settled on the DH Labs Silver Sonic D-110 for the duration of my review. Though the differences among these cables weren't earth-shattering, they made me aware of how resolving and neutral the DAC3.5VB was. It was a promising start.

A month or so into the review, John Stronczer sent me an upgraded VBS umbilical to run from the VBS1 to the DAC3.5VB. This VB-REF cable, made for Bel Canto by Minneapolis-based Sain Line Systems (who make most of the cables I use in my system), was terrific. While all of the other power and digital cables offered slightly different perspectives and flavors, the VB-REF offered sound that was truly better in every way. It opened up the soundstage even more, reduced treble grain, and lowered the perceived noise floor. At 347€, the VB-REF is no cheap add-on, but I'd call it a necessary one if you want to realize the DAC3.5VB's full potential. I left the VB-REF cable in for the duration of my listening.

The Sound of Silence

The e.One DAC3.5VB didn't sound like anything. Tonally, it had no sonic character of its own. Bass was very extended and full, yet had nice slam. The bass-drum machines in Kraftwerk's nicely remastered Trans Europe Express (CD, Kling Klang 5099930830325) were delivered with both speed and weight. (It frightens me that this album was made when I was still in diapers.) The DAC3.5VB's midrange was fleshy, even, and full of texture. Gidon Kremer's violin in Vladimir Martynov's exquisite Come In! (CD, Nonesuch 79582-2) offered the right balance of the instrument's wooden body, steel strings, and rosined bow.

The DAC3.5VB's treble was among the cleanest, clearest, and most extended I've heard, and imposed no emphasis or grain on any recording I played. For me, the differences between the good and the best digital sound can be most easily heard in the top octaves. Good digital gear gets the tonal balance in the top octaves right, but smears and smooshes treble sounds into slightly homogenized information. The best digital gear delineates each treble sound in space and with a distinct timbre—sibilants sound like sibilants, shakers like shakers, cymbals like cymbals—each surrounded by the proper halo of acoustic. In this regard, the DAC3.5VB produced among the best digital sound I've heard.

The DAC3.5VB truly excelled in two areas: soundstaging and quietness. It produced broad, deep soundstages on which there was great separation between instruments, and the proper perspective of texture

between instruments miked closely and those farther off. This was very evident with Roy Halee's beautiful engineering of the title track of Simon and Garfunkel's Parsley, Sage, Rosemary and Thyme, collected in The Columbia Studio Recordings 1964–1970 (CD, Columbia/Legacy C5K 63815). Through the DAC3.5VB, the track's distant, duple-timed glockenspiel was both a point source of unreflected sound as well as a ringing shimmer that lit up the entire width of the recording studio. Meanwhile, the swirling harpsichords sat strikingly close in the mix, the Bel Canto presenting the tangible texture of each plucked string.

The DAC3.5VB's quiet backgrounds made possible startling degrees of micro- and macrodynamics. By definition, dynamics are the magnitude of difference between loud and soft sounds. When background noise is diminished, notes and sounds appear to jump higher and faster away from the background, and thus sound more dynamic. For example: Crinkling a cellophane wrapper in a quiet church sounds far more dynamic than the same action done in a moving subway car. On the microdynamic level, the plucked banjo notes in Sufjan Stevens' "The Mistress Witch from McClure (or, The Mind That Knows Itself)," from his excellent The Avalanche (CD, Asthmatic Kitty AKR022), were tactile and palpable. I could hear the tension of the pick applied to each string, and how that energy was instantly released to become the instrument's familiar clanging, jangling, nasal ring.

On the level of macrodynamics, the DAC3.5VB's low noise made orchestral crescendos, as in Eiji Oue and the Minnesota Orchestra's vivid reading of Respighi's Pines of Rome (CD, Reference RR-95CD), all the more thrilling. As I tell the choirs I conduct, you can't have a meaningful forte unless you have a great pianissimo. The DAC3.5VB was able to bring the background noise to a convincing ppp, which made the ff of my hometown orchestra marching down the Appian Way all the more realistic and exciting. If you're looking for some sort of rounded-off, euphonic-sounding digital front-end, the DAC3.5VB is not for you. But that doesn't mean it sounded cold or analytical. Its beauty came from truth.

Light Link Liker

I'm no expert or enthusiast of computer audio—I just dabble. In the past, I've used the USB inputs of the various DACs I've had on hand, but I admit that I've never been wholly enamored of the process and mystery of getting good sound out of my laptop. Between overcoming my operating system, working with USB (a connection not naturally suited to transmitting high-end audio signals), and the quality of the DAC's USB input, I have yet to get sound as good as what a dedicated disc transport gives me. Usually, the computer sound is more grainy and flat than that of dedicated audio gear. But again, I haven't tried all that hard to make my laptop a genuine high-end source component.

To my delight and surprise, using the J. River Media Center program (another Minneapolis company) with Bel Canto's Light Link 24/96 and e.One DAC3.5VB, I was easily able to get sound from my laptop that was as good as what I got from BC's e.One CD2, and to play high-resolution files through my system. Using the Light Link 24/96 and the DAC3.5VB, I became a real fan of Bel Canto's approach to computer audio.

Setting the Benchmark

In John Atkinson's review of Bel Canto's e.One DAC3 in November 2007, he directly compared it with Benchmark's DAC1 (697€). It's now 2011, and I thought I'd set up a shoot-out between each company's latest models, the e.One DAC3.5VB and the DAC1 HDR (1 328€). I matched the volume levels between the DACs with a RadioShack SPL meter and the test tones on Editor's Choice (CD, Stereophile STPH015-2), then played some tunes, beginning with a track from that same disc: pianist Robert Silverman's reading of Liszt's Liebestraum.

There was very little tonal difference between the DACs. Each presented a very neutral and revealing picture of this piano playing in this hall, the Bel Canto letting me more easily "see" the piano's outline in relief against its acoustic surroundings.

It was when I turned to music with more complicated mixes and more information at the frequency extremes that the Bel Canto outshone the Benchmark. The DAC3.5VB had deeper bass, a sweeter, more extended, more grain-free treble, a more liquid midrange, and a bigger, more layered soundstage. Don't get me wrong, the Benchmark DAC1 HDR is a fantastic product, but I feel that the DAC3.5VB's clearly superior performance entirely justifies its significantly higher price. In fact, I think the Bel Canto e.One DAC3.5VB is in a league altogether different from the still-impressive Benchmark DAC1 HDR.

You Betcha

I thoroughly enjoyed my time with Bel Canto's e.One DAC3.5VB. It does everything you might ever need a DAC to do, and I'd put its sound as being among the best I've heard. In fact, the only other digital sound I've enjoyed significantly more (in an environment I was familiar with) was when I heard the Meridian 808i.2 CD player (11 913€) at John Atkinson's house. Yes, I do think the e.One DAC3.5VB is good enough to stand comparison with a front-end of the Meridian's caliber and price. The Bel Canto's styling, build quality, and performance make it an obvious contender for Class A of our "Recommended Components," and one of the best D/A converters I've heard. And though I've heaped an embarrassing amount of praise on the e.One DAC3.5VB, I'm sure the good Minnesotans at Bel Canto won't let this review go to their heads.

Specifications

e.One DAC3.5VB: DC-powered digital-to-analog converter (needs 12V DC supply).
Inputs: AES XLR, S/PDIF BNC/RCA, ST fiber-optic, TosLink, RCA analog.
Maximum data input rate: 24-bit data at 192ks/s.
Master clock jitter: 2 picoseconds RMS.
Maximum output level: 5.5V RMS (balanced XLR), 2.5V RMS (RCA).
Output impedance: 200 ohms (balanced XLR), 100 ohms (RCA).
Frequency response: 20Hz–20kHz, ±0.25dB. THD+N: <0.0015%, 5.5V RMS, balanced out, 1kHz.
Output noise: 3µV RMS, A-weighted, 20Hz–20kHz.
Dynamic range: 126dB, A-weighted, 20Hz–20kHz.
Power usage, on: 8W.
Dimensions: 8.5" (216mm) W by 3.5" (88mm) H by 12.5" (318mm) D.
Weight: 14 lbs (6.5kg).
Serial Number Of Unit Reviewed: D35-054.
Price: 2 450€.

e.One VBS1: power supply.
Maximum output: 12V DC at 3A.
Output voltage: 12V DC, ±5%.
Output voltage noise: <6µV RMS, unweighted, 20Hz–30kHz. Power usage, on: 5–20W typical, 1–3 devices powered.
Dimensions: 8.75" (223mm) W by 3.5" (88mm) H by 12.5" (318mm) D.
Weight: 13 lbs (6.2kg).
Serial Number Of Unit Reviewed: VBS-108.
Price: 1 048€.

e.One REF DAC Control System: (DAC3.5VB plus VBS1): 3 466€.
Light Link 24/96: 245€ with 2m optic-fiber cable.
VB-REF: power cable: 347€.

Associated Equipment

Digital Sources: Theta Digital Miles and Bel Canto e.One CD2 CD players (S/PDIF output); CEntrance DACport, Benchmark DAC1 and DAC1 HDR D/A converters; Sony Vaio laptop computer.
Power Amplifiers: Pass Labs Aleph 3, Plinius SA103; Rogue Audio M180 monoblocks.
Integrated Amplifier: Mystère ia21, Simaudio Moon i3.3.
Loudspeakers: Revel Performa F30.
Cables: Digital: Stereovox HDVX coaxial, Wireworld Gold Starlight 5 AES/EBU, Silver Sonic D-110 AES/EBU, Illuminati Orchid, Canare DA 205.
Interconnect: Sain Line Systems Pure Balanced & Pure.
Speaker: Kimber Kable BiFocal X. AC: Sain Line Systems Reference.—Erick Lichte

Measurements

I used Stereophile's loan sample of the top-of-the-line Audio Precision SYS2722 system to perform the measurements on the Bel Canto e.One DAC3.5VB (see www.ap.com and the January 2008 "As We See It"); for some tests, I also used my vintage Audio Precision System One Dual Domain and the Miller Audio Research Jitter Analyzer. For these tests, the DAC3.5VB was powered by Bel Canto's e.One VBS1 12V DC supply.

The DAC3.5VB successfully locked on to datastreams with sample rates of up to 192kHz. The volume control operated in accurate 0.5dB steps. The Bel Canto's maximum output level at 1kHz was 5.32V balanced and 2.66V unbalanced (the latter is 2.5dB higher than the CD standard's 2V RMS), and was sourced from output impedances of 199.5 and 100 ohms, respectively, at all frequencies. Both outputs preserved absolute polarity (ie, were non-inverting), with the XLR jacks wired with pin 2 hot.

The frequency response was flat within the audioband (fig.1), and was not affected by the loading down of the output to 600 ohms. The response shape followed the same gentle rolloff above the audioband, disturbed only by the sharp drop-off just below half the sample rate with 44.1kHz sampling (blue and red traces) and 96kHz sampling (cyan and magenta). With 192kHz data (green and gray), the response was down 3dB at 75kHz. Note, however, the 0.2dB channel imbalance in this graph. While this will not be audible, I was surprised to see it at all. Channel separation was superb, with any crosstalk below –125dB in the midrange (fig.2).

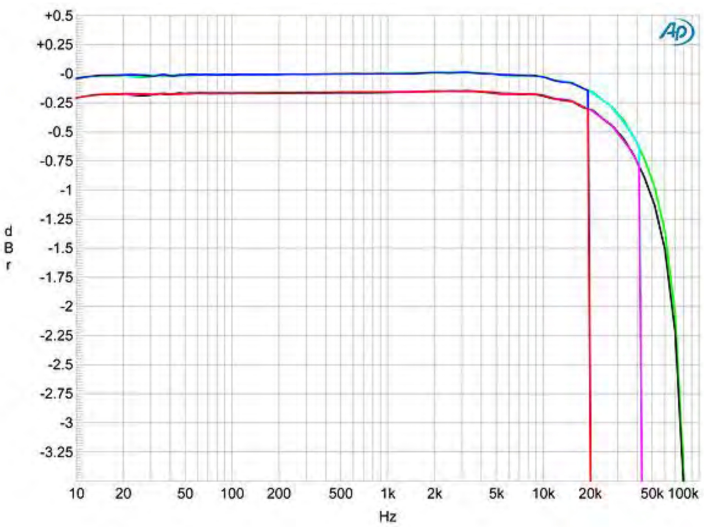

Fig.1 Bel Canto DAC3.5VB, frequency response at –12dBFS into 100k ohms from balanced outputs with data sampled at: 44.1kHz (left channel blue, right red), 96kHz (left cyan, right magenta), 192kHz (left green, right gray). (0.25dB/vertical div.)

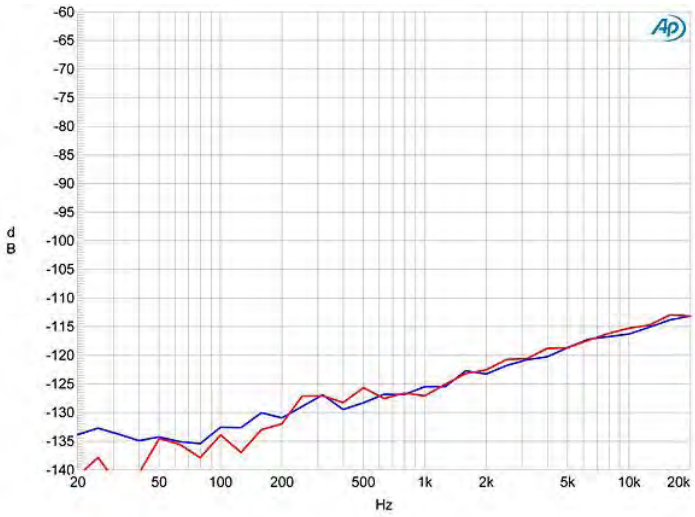

Fig.2 Bel Canto DAC3.5VB, balanced channel separation (R–L blue, L–R red; 10dB/vertical div.).

The original DAC3, which I reviewed in November 2007, was a resolution champ (see http://tinyurl.com/45ckkuh); the DAC3.5VB was just as good. The top pair of traces in fig.3 shows the spectrum of the Bel Canto's output, produced by sweeping a 1/3-octave bandpass filter from 20kHz to 20Hz while the processor decoded dithered 16-bit data representing a 1kHz tone at –90dBFS. The trace is dominated by the recorded dither noise. Increasing the word length to 24 bits gave the middle pair of traces in fig.3; the noise floor has dropped by up to 24dB, implying a resolution of at least 20 bits, which is easily enough to allow the DAC3.5 to reproduce a dithered 24-bit tone at –120dBFS (bottom traces). Peculiarly, repeating this analysis with an FFT technique didn't give as big a drop in the noise floor (fig.4). Perhaps some ultrasonic noise was folding down into the audioband. However, when I repeated the test using either the SYS2722's internal 20kHz "brickwall" low-pass filter or an external 6th-order low-pass filter, I got the same result.

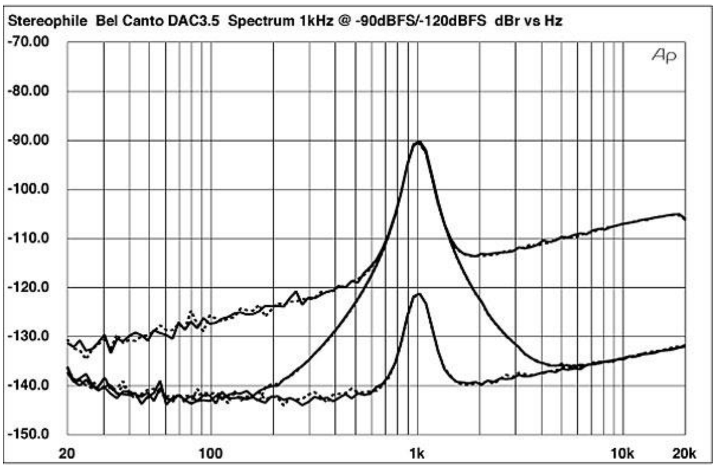

Fig.3 Bel Canto DAC3.5VB, 1/3-octave spectrum with noise and spuriae of dithered 1kHz tone at –90dBFS with 16-bit data (top) and 24-bit data (middle), and of dithered tone at –120dBFS with 24-bit data (right channel dashed).

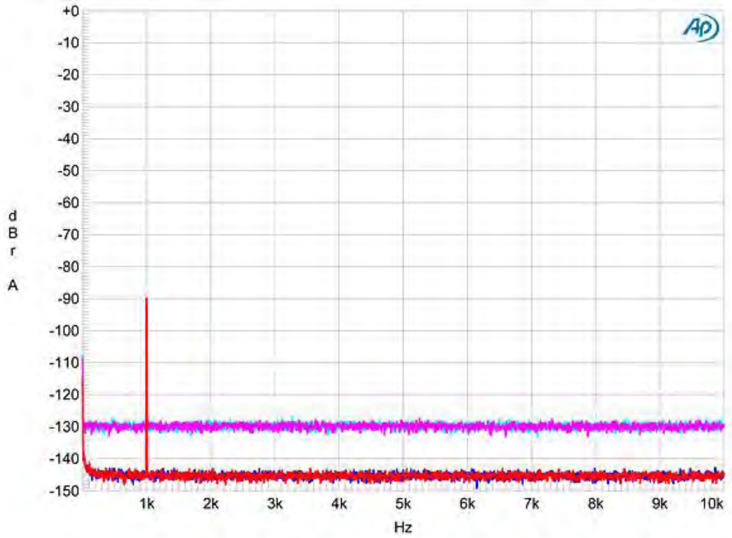

Fig.4 Bel Canto DAC3.5VB, FFT-derived spectrum with noise and spuriae of dithered 1kHz tone at –90dBFS with: 16-bit data (left channel cyan, right magenta), 24-bit data (left blue, right red).

Fig.5 shows a similar spectral analysis, with the DAC3.5VB fed 24-bit data representing dithered 1kHz tones at –90 and –120dBFS from my MacBook via a Bel Canto USB Link 24/96 and an ST optical cable. Both tones are easily resolved, and the noise floor is no higher than in fig.4, confirming that the USB Link correctly handles 24-bit data. It also operated correctly with data having sample rates up to 96kHz.

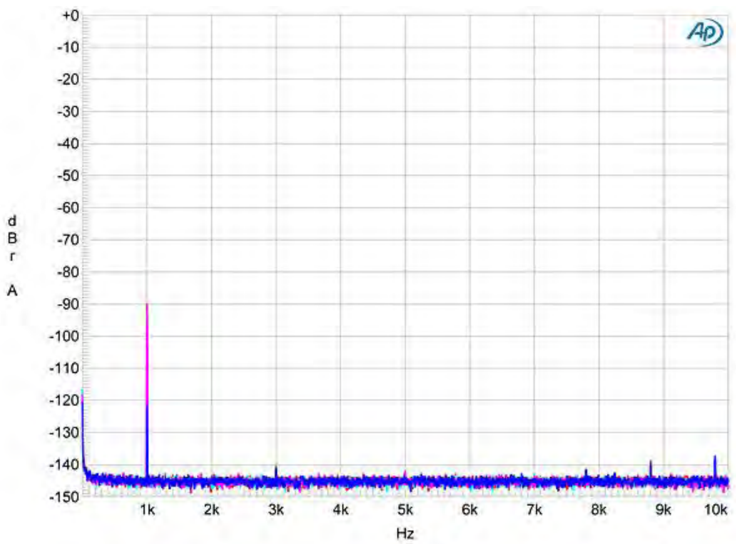

Fig.5 Bel Canto DAC3.5VB, FFT-derived spectrum with noise and spuriae of dithered 1kHz tones at –90dBFS (left channel cyan, right magenta) and –120dBFS (left blue, right, red). 24-bit data sourced from MacBook via Cardas USB cable, Bel Canto USB Link 24/96, and ST optical link.

Linearity error with 16-bit data was negligible below –110dBFS (not shown), but the DAC3.5VB didn't reproduce an undithered tone at exactly –90.31dBFS (fig.6) as cleanly as had the earlier DAC3. Increasing the bit depth to 24 gave a good if somewhat noisy representation of a sinewave (not shown); this surprised me, given the DAC3.5's superb low-level resolution shown earlier. Though the circuit still includes the Burr-Brown PCM1792 24-bit DAC chip used in the DAC3, the earlier model's Cirrus Logic CS8421 asynchronous sample-rate converter has been replaced by a Burr-Brown SRC4392 chip. I don't see why that should have made any difference to these measurements, but perhaps it is possible that jitter in the incoming datastream increases the level of random data in the output of the SRC chip. I don't know.

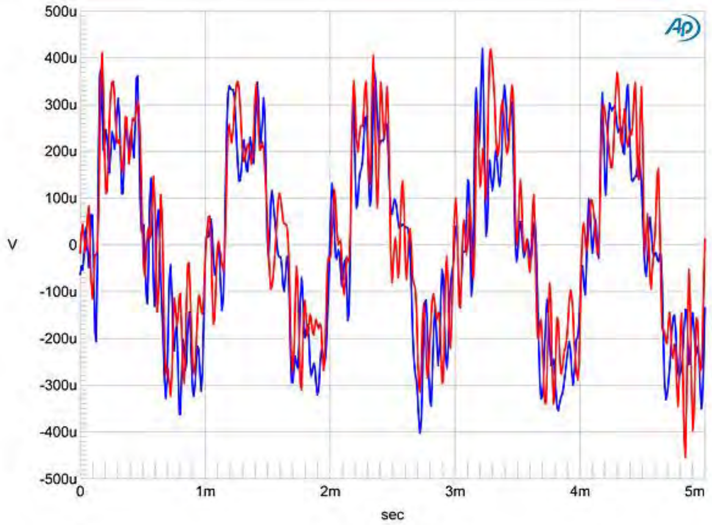

Fig.6 Bel Canto DAC3.5VB, waveform of undithered 1kHz sinewave at –90.31dBFS, 16-bit data (left channel blue, right red).

The Bel Canto's output stage, which appears to use high-quality OPA1632 differential-output op-amp chips, offers very low distortion even into very low impedances. Fig.7, for example, shows the spectrum of the DAC3.5VB's output while it drove a full-scale 50Hz tone into 600 ohms. While the second and third harmonics can be seen in both channels, these lie at –100 and –104dB, respectively. Some higher-order harmonics can be seen in the right channel (red trace), though these are even lower in level than the low-order harmonics. Intermodulation distortion was similarly vanishingly low (fig.8).

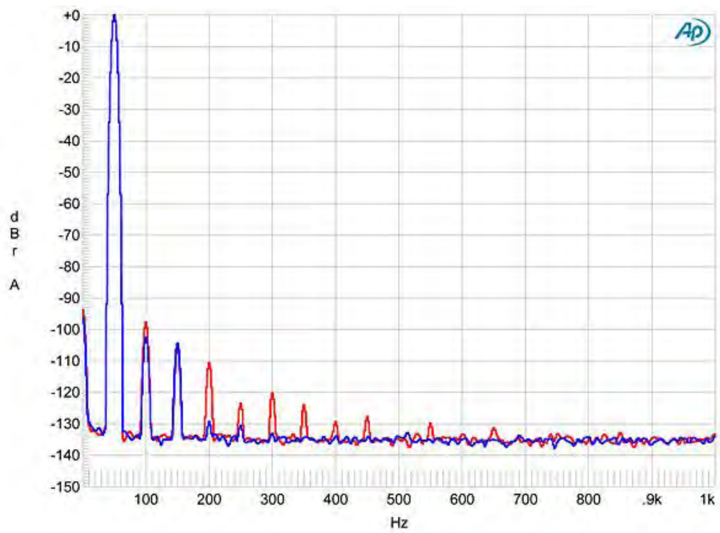

Fig.7 Bel Canto DAC3.5VB, spectrum of 50Hz sinewave, DC–1kHz, at 0dBFS into 600 ohms (left channel blue, right red; linear frequency scale).

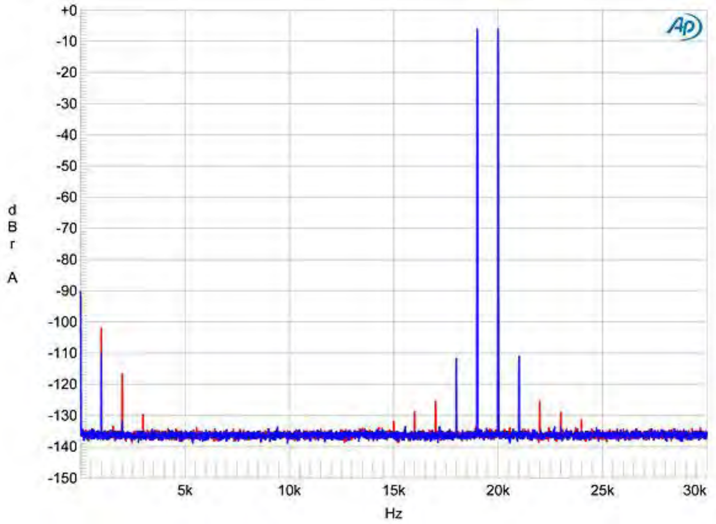

Fig.8 Bel Canto DAC3.5VB, HF intermodulation spectrum, DC–24kHz, 19+20kHz at 0dBFS into 100k ohms (left channel blue, right red; linear frequency scale).

When I originally tested the Bel Canto USB Link 24/96, in May 2009, its jitter rejection was not quite as low as I had wished. The ST-output version auditioned by Erick Lichte was much better in this respect, particularly when coupled with the DAC3.5VB. Fig.9 shows the spectrum of the DAC3.5's output while it was fed the 16-bit J-Test signal from my MacBook via the USB Link and an ST optical cable. The central spike is clean and well defined at its base, the sidebands are almost all at the residual level of the harmonics of the low-frequency squarewave, and the jitter level is below the resolution limit of my Miller Analyzer. The noisefloor is higher than I would have expected, however.

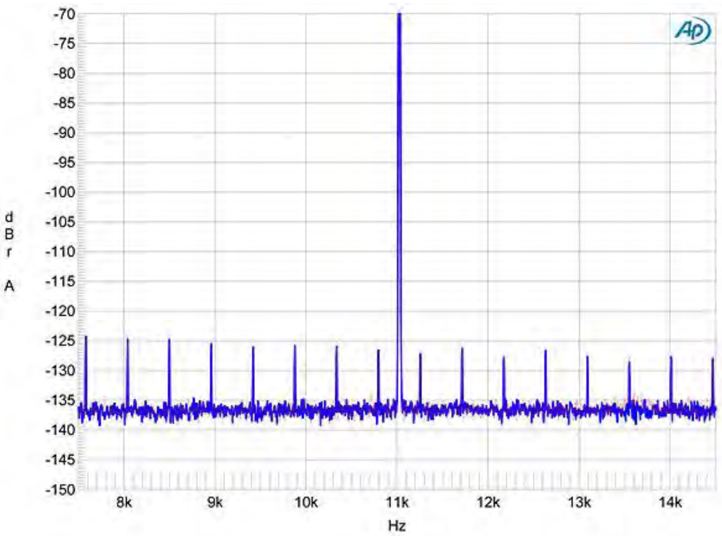

Fig.9 Bel Canto DAC3.5VB, high-resolution jitter spectrum of analog output signal, 11.025kHz at –6dBFS, sampled at 44.1kHz with LSB toggled at 229Hz: 16-bit data via USB from MacBook/USB Link 24/96/ST optical (left channel blue, right red). Center frequency of trace, 11.025kHz; frequency range, ±3.5kHz.

The spectrum of the DAC3.5VB's output remained as clean when I fed it the same 16-bit datastream via an AES/EBU link from the Audio Precision SYS2722 (fig.10, cyan and magenta traces), though now a single pair of low-level sidebands of unknown origin can be seen at ±92Hz. To my surprise, while changing to a 24-bit J-Test signal eliminated the odd-order squarewave harmonics (fig.10, blue and red traces), as anticipated, the noise floor remained at the 16-bit level. It looked as if some noise modulation was present, in that the level of the noise floor depended on the level of the signal.

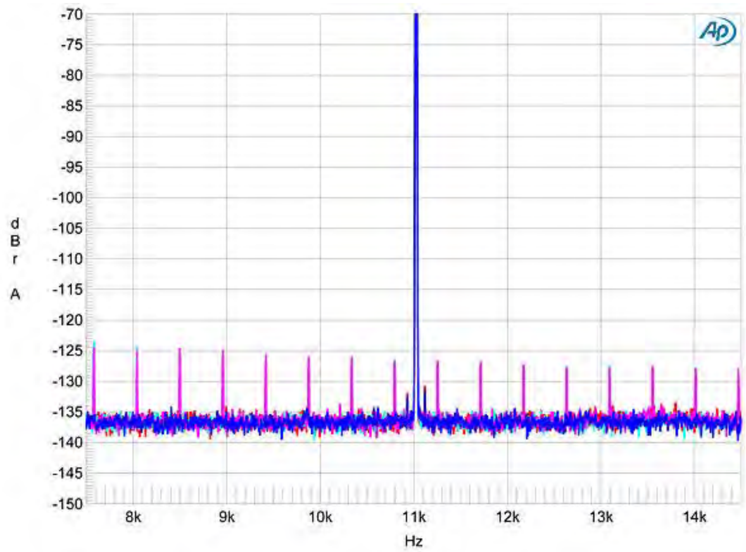

Fig.10 Bel Canto DAC3.5VB, high-resolution jitter spectrum of analog output signal, 11.025kHz at –6dBFS, sampled at 44.1kHz with LSB toggled at 229Hz: 16-bit data via AES/EBU (left channel cyan, right magenta); 24-bit data via AES/EBU (left blue, right red). Center frequency of trace, 11.025kHz; frequency range, ±3.5kHz.

I investigated this by looking at the low-frequency spectrum of the Bel Canto's output while it decoded a 1kHz tone at 0dBFS (fig.11, top blue and red traces), at –40dBFS (middle cyan and magenta traces), and at –60dBFS (bottom blue and red traces). You can see that the level of the noise floor does depend on the signal level, with the drops in signal level from 0 to –40dBFS and from –40 to –60dBFS each lowering the overall noise floor by about 5dB. (Again, this behavior was not affected by low-pass filtering the signal.) This is very unusual; perhaps Bel Canto's design team have optimized the circuit's behavior to maximize low-level resolution, the tradeoff being very slightly higher noise levels with high-level signals. Or, as jitter has an increasing effect as the signal level rises, again perhaps it is possible that fig.11 is showing the effect of jitter on the behavior of the SRC chip.

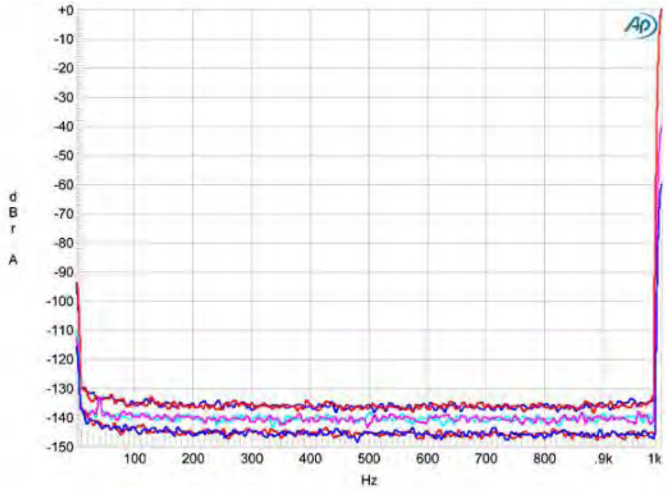

Fig.11 Bel Canto DAC3.5VB, spectrum of 1kHz sinewave, DC–1kHz, at: 0dBFS into 100k ohms (left channel blue, right red), –40dBFS (left cyan, right magenta), –60dBFS (left blue, right red). (Linear frequency scale.)

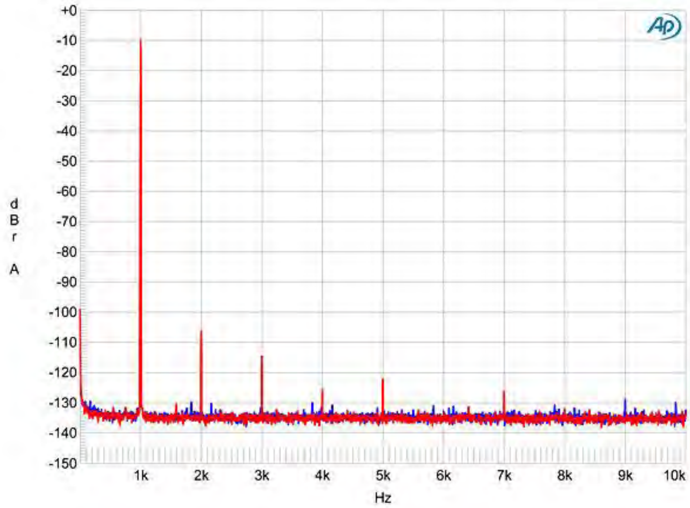

Fig.12 Bel Canto DAC3.5VB, analog input, spectrum of 1kHz sinewave, DC–10kHz, at –10dBFS into 100k ohms (left channel blue, right red; linear frequency scale).

Although EL didn't use them, the DAC3.5VB has a pair of analog inputs that allow it to be used as a line preamplifier. The signal at these inputs is digitized at 192kHz with an AKM 5386 A/D converter chip, then fed to the DAC3.5VB's digital processor section. The analog inputs have an input impedance of 11.9k ohms at all frequencies, and the response is flat up to just below 96kHz, confirming that the ADC operates at 192kHz.

Bel Canto specifies this analog input as having a maximum input level of 2.5V. With a 1kHz tone at 2.5V, the THD+noise in the processor's analog output was 0.0045%. Increasing the input level to 2.63V increased the THD+N to 1%, suggesting that the A/D converter does output full-scale digital data just above 2.5V. Below that level, the ADC didn't seem to introduce any more distortion than the DAC3.5VB's D/A section. Fig.12, for example, shows the spectrum of the DAC3.5VB's output while it was fed an analog 1kHz tone at a level equivalent to –10dBFS. All the harmonics are very low in level. Repeating the test with an analog signal equivalent to a level of –90dBFS gave a spectrum (not shown) with the noise floor at around –140dBFS. This suggests that the AKM converter is operating with at least 18-bit true resolution, which is excellent performance.

Other than that noise-modulation issue, which I doubt will have audible consequences, Bel Canto's e.One DAC3.5VB offered superb measured performance with high resolution and low jitter.—John Atkinson