

# Product Review

## DacT CT102 Power Supply

Reviewed by Charles Hansen

Danish Audio ConnecT A/S, Skannerupvej 14, DK-6980 Tim, Denmark, US eFax (+1) 248 282 0645, www.dact.com. Price: EUR 282.00, Dimensions: 10cm W × 9cm D × 4cm H.

The DacT CT102 is an audio power supply specifically designed to be used with DacT's CT100 phono stage module and CT101 line stage module. It can also be used with other high-end audio electronics circuits. The features described in the user guide are low dynamic output impedance, extremely wide bandwidth, and fast regulation. The regulated output voltage can be jumper selected for either ±15V DC or ±20V DC. Maximum output current is 200mA per rail, with output short-circuit protection on each rail.

### INSIDE THE POWER SUPPLY

Photo 1 shows the PC board top view with the heatsinks for four bipolar power transistors. There are six 8-pin DIP linear ICs on the PC board whose identities have been masked by red, blue, or green paint. In the event of problems the CT102 would need to go back to DacT for service.

The PC board is a high-quality single-sided design with gold-plated PC tracks. You can see the attention to the power and grounding track layout in Photo 2. The many parallel traces produce a single-point connection for all

the filter capacitors on the PC board. The board has four isolated mounting holes and gold-plated input/output pins.

### TOPOLOGY

A schematic was not furnished with the power supply, but the block diagram in Fig. 1 will convey the principle of operation. A 100–250V AC mains adapter with 48V DC output—supplied with the CT102 module (Photo 3)—is a switching power supply that operates at about 28kHz. The 48V DC enters the CT102 card through low-pass LC EMI filters and is impressed across Q1 and Q2, a pair of common-emitter bipolar power transistors, which are biased such that they produce a low-impedance output ground reference point at their collectors, forming ±24V DC supply rails for the output regulator transistors Q3 and Q4.

The output power transistors each have a control loop amplifier that monitors the output voltage and compares it to a 2.5V precision reference. The control loop also monitors the output current and provides for fold-back current limit in case of an overload or short circuit. A 4700µF filter capacitor on each regulated rail provides energy storage

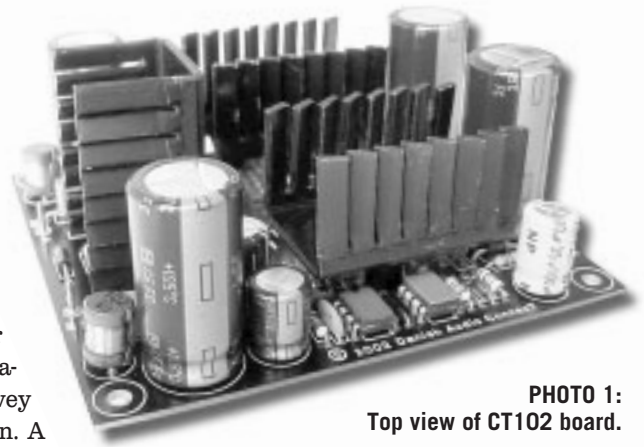


PHOTO 1: Top view of CT102 board.

for transient current needs. Diodes are used for both input and output reverse polarity protection.

### DC REGULATION TESTS

My first task was to determine the DC regulation of the CT102 power supply with its AC power adapter. The initial no-load voltages when I first powered up the CT102 were ±14.92V DC. With a balanced ±200mA maximum rated load, the voltages at the CT102 output terminals were +14.78 and -15.00V DC. I operated the CT102 at full load, 200mA into 75Ω for one hour.

At the end of this period, all three heatsinks were cool to the touch. The no-load voltages after the heat run were still ±14.92, while the full-load voltages had dropped to +13.48 and -13.16V DC. Decreasing the load to ±22mA produced DC voltages of ±14.84.

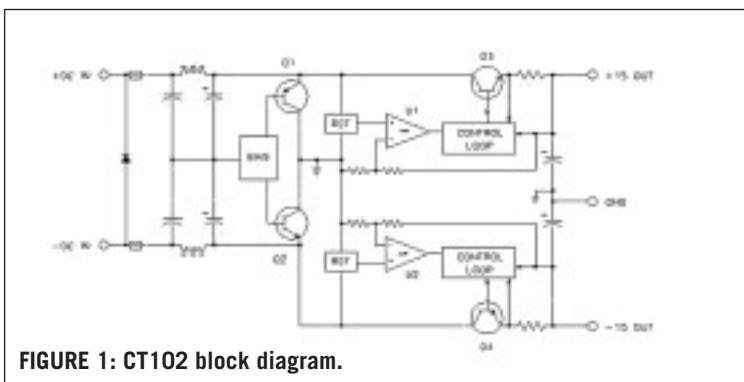


FIGURE 1: CT102 block diagram.

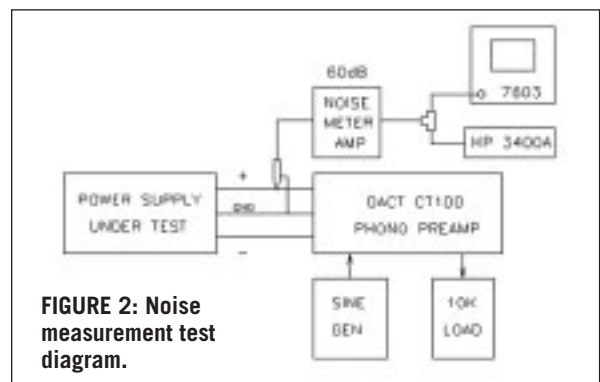


FIGURE 2: Noise measurement test diagram.

Next I applied unbalanced loads, with one supply fully loaded and the other at no load. With only the positive supply loaded, the output voltages were +13.84 and -14.97V DC. Loading just the negative supply yielded +14.45 and -13.25V DC.

The heatsink for the two power transistors that form the phantom neutral became a bit warmer as the transistors worked to maintain a balanced input voltage ground reference. The mains adapter output voltage into the CT102 was 46.5V DC for both unbalanced load conditions. The DC output impedance for the power supply worked out to be  $0.25\Omega$  for the positive supply and  $0.39\Omega$  for the negative supply.

The AC adapter used with the CT102 is a switching power supply. The broadband ripple from the mains adapter on the input DC bus was 15mV RMS, composed primarily of the 28kHz switching frequency component. There was virtually no evidence of any 60Hz power line artifacts using an analog scope. The

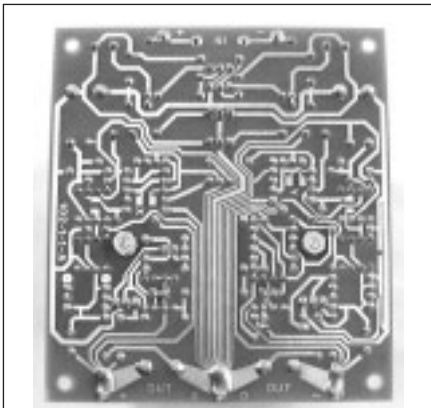


PHOTO 2: Bottom view of CT102 board.

adapter no-load DC voltage was 47.8V DC, dropping slightly to 46.6V DC when the  $\pm 15$  outputs were full loaded to 200mA.

Its line regulation was very good. In response to my isolated variable AC supply, it jumped into action at 28V AC line voltage, producing 30V DC with some noticeable switching noise. It dropped out at 20V AC with a decreasing line voltage. The CT102 was able to produce  $\pm 15$ V DC at 200mA with a line voltage to the mains adapter of 34V AC. The minimum  $\Delta V_{in-V_{out}}$  was 2.33V DC on the positive output and 1.71V DC on the negative output, in order to maintain that 200mA output.

### TESTING FOR NOISE

Measuring the noise of a power supply involves isolating the very small AC noise signal (less than 1mV RMS) from the 15V DC supply rail. The measurement needs to be performed over a wide bandwidth, 1MHz or more. One means of displaying the AC noise content is with a high-quality analog oscilloscope in AC input mode. But determining the RMS value is another matter.

My most sensitive wideband meter is an HP 3400A true-RMS AC voltmeter, but its lowest range is 1mV full-scale (FS), and there are no scale markings below 0.1mV. When I attempted to measure the RMS noise on the CT102, it was a tentative 0.05mV.

Clearly, I needed something to amplify the AC noise signal so I could read it on one of the higher scales on the 3400A. I designed a 60dB gain ( $A_v=1000$ ) "Noise Meter Amplifier" (NMA) for this purpose, and powered it

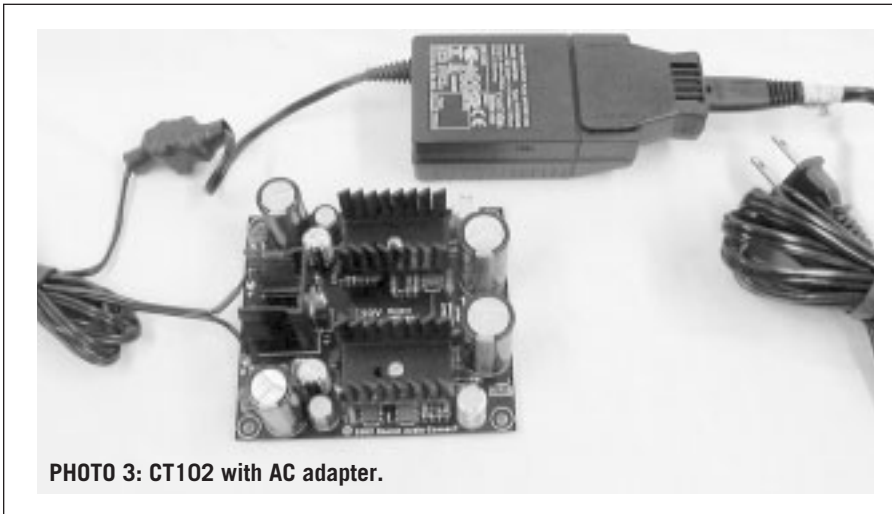
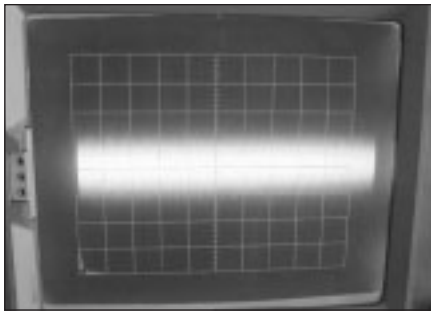
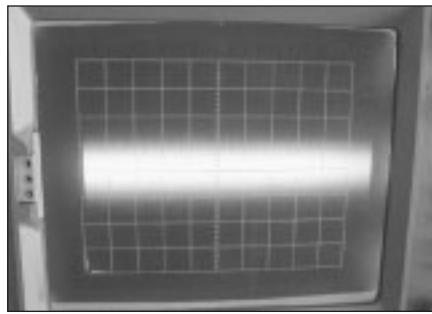


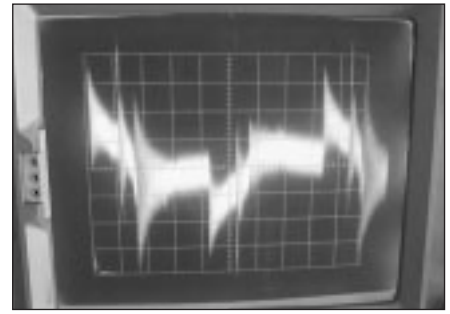
PHOTO 3: CT102 with AC adapter.



**PHOTO 4:** Noise meter amp scope, input open ( $10\mu\text{V}/\text{div}$  RTI,  $2\text{ms}/\text{div}$ ,  $4.7\mu\text{V}$  RMS).



**PHOTO 5:** Battery noise scope ( $10\mu\text{V}/\text{div}$  RTI,  $2\text{ms}/\text{div}$ ,  $4.9\mu\text{V}$  RMS).



**PHOTO 6:** CT102 noise scope ( $20\mu\text{V}/\text{div}$  RTI,  $2\text{ms}/\text{div}$ ,  $18\mu\text{V}$  RMS).

with two 9V batteries to keep the noise introduced by the amplifier itself to a minimum. AC coupling is used at the input, and the gain of 1000 allows me to directly read the noise in  $\mu\text{V}$  on the HP 3400A mV scales.

The noise amplifier circuitry will generate noise of its own through the input noise voltage and current of the op amps ( $e_n$  and  $i_n$ ) and the thermal Johnson noise from all its resistors, so care is needed in the selection of components. I used two low-noise AD745N op amps that Walt Jung graciously provided from his sample stock (the 8-pin DIP version is no longer available), each with a gain of 30dB ( $A_v=31.62$ ). I built the circuit on a ground plane PC board, and at 60dB gain it proved to have 3.6mV RMS residual output noise with the input shorted, and 4.7mV RMS with the input open (using the HP 3400A). The noise floor referred to the input (RTI) is thus  $3.6\mu\text{V}$  RMS and  $4.7\mu\text{V}$  RMS, respectively. This is the output noise divided by the noise gain of the amplifying circuit.

In addition to the CT102, I wanted to test some other power sources to obtain comparative data. I selected the following supplies:

- Battery power (two 12V 1.3Ah sealed Panasonic lead-acid cells, with  $2200\mu\text{F}$  35V caps in parallel as recommended by DacT).
- The CT102 supply set for  $\pm 15\text{V}$  DC and using its AC power adapter.
- The  $\pm 15\text{V}$  DC regulated preamp power supply by Gary Galo in TAA 4/90, page 47, using LT1085 and LT1033 TO-220 linear regulators.
- A  $\pm 15\text{V}$  DC regulated power supply using LM340-15 and LM320-15 TO-220 linear regulators (equivalent to 78T15 and 79T15).

- An HP 6236B supply with dual-tracking transistor regulated outputs (vintage late 1970s), set for  $\pm 15\text{V}$  DC.

Initially, I loaded each supply rail with Caddock MP915 TO-style non-inductive power film resistors. I used a  $200\Omega$  and  $500\Omega$  in series to get  $\pm 21\text{mA}$  load current. The Mouser part numbers are 684-MP915-200 and 684-MP915-500, respectively. Next, I connected each supply to the DacT CT100 phono preamp, which draws  $\pm 22\text{mA}$  quiescent current.

Finally, I connected the CT100 to my sine-wave generator to measure the amount of amplified signal that was passed to the power-supply rails at various frequencies. This is a function of the power-supply rejection ratio (PSRR) of the phono preamp as well as the dynamic impedance of the power-supply regulator circuitry.

The test setup block diagram is shown in Fig. 2. A Tek scope probe connects the power-supply rail to the input of my NMA. The output of the NMA is T-connected to a Tek 7A16A vertical amplifier plugged into a Tek 7603 100MHz scope mainframe and the HP 3400A true RMS AC voltmeter.

I have a Tek 7A22 differential amplifier whose lowest range is  $10\mu\text{V}/\text{div}$ , but it is limited to  $\pm 1\text{V}$  input at this range. While the AC noise was lower than this, I was worried that the initial connection to the 15V rail would couple an overvoltage transient into the 7A22. It was safer to amplify the noise, then connect it to the standard vertical amplifier.

As I mentioned earlier, the wideband residual noise referred to the input (RTI) for my NMA with the input open is  $4.7\mu\text{V}$  RMS, or  $-113\text{dB}$  relative to a preamp output of  $2\text{V}$  RMS (dBr). A

scope photo of the open circuit NMA noise is shown in Photo 4. I connected the 12V DC battery to the NMA input and measured a broadband RTI noise level of  $4.9\mu\text{V}$  RMS ( $-112\text{dBr}$ ), with a scope photo in Photo 5.

Both photos are with the scope vertical amplifier set at  $10\text{mV}/\text{div}$ , which is equivalent to  $10\mu\text{V}/\text{div}$  RTI. I chose a time base setting of  $2\text{ms}/\text{div}$  to make any 60Hz or 120Hz power line ripple easy to spot. There was essentially no difference whether I used the Caddock resistors or the CT100 phono preamp as the load.

The next step up in noise level is with the CT102 power supply and its AC adapter. The wideband noise on the positive rail measured  $18\mu\text{V}$  RMS RTI, while the negative rail showed  $19\mu\text{V}$  RMS RTI noise ( $-100\text{dBr}$ ).

The scope photo of the positive rail noise is shown in Photo 6, with the vertical scale increased to  $20\text{mV}/\text{div}$  ( $20\mu\text{V}/\text{div}$  RTI). While it looks quite messy, this noise is actually a low  $160\mu\text{V}$  p-p. Again, there was no difference whether I used the Caddock resistors or the CT100 phono preamp as the load.

## OTHER POWER SUPPLIES

The regulated DC supply designed by Gary Galo had an RTI noise of  $42\mu\text{V}$  RMS on the positive rail and  $50\mu\text{V}$  RMS ( $-92\text{dBr}$ ) on the negative rail. Photo 7 shows the scope trace, which has more of a white noise characteristic than the CT102. The vertical scale here is now  $100\text{mV}/\text{div}$  ( $100\mu\text{V}/\text{div}$  RTI). The  $4700\mu\text{F}$  input and output filter caps are Panasonic TS.

The next supply was the LM340/LM320 design. This has a similar topology to Gary Galo's design, except it uses regulator ICs with a fixed  $\pm 15\text{V}$  DC

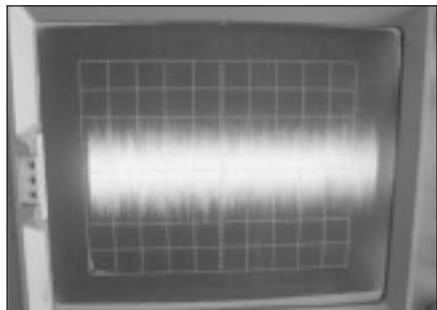
output rather than adjustable regulator ICs. Both rails showed 105 $\mu$ V RTI noise (-86dB). The scope photo, again at 100mV/div, is shown in *Photo 8*. A bit of 120Hz full-wave rectification ripple is now present. This may be due in part to the less expensive Xicon 4700 $\mu$ F filter caps used in this particular supply.

My final supply test used the HP 6236B. Despite the large 2N3055 TO-3 power transistors and Mallory filter

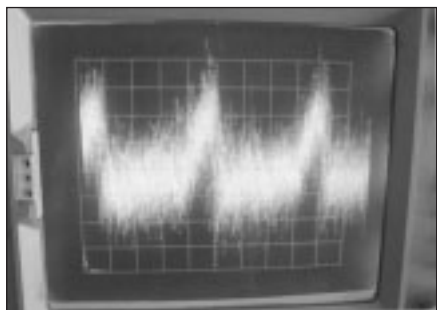
caps, the RTI noise was the highest of the bunch at 340 $\mu$ V RMS RTI (-75dB). This is actually below its specified 0.35mV RMS or 1.5mV p-p ratings. *Photo 9* shows the resultant scope trace, which was made at 500 $\mu$ V/div (500 $\mu$ V/div RTI).

My final test series was to apply a

sine-wave signal to the CT100 phono preamp and drive it to 2V RMS output into 10k. I monitored the power-supply rails for any sign of the sine-wave test signal. I restricted my tests to the CT102 and Gary Galo supplies. Neither supply showed any disturbance beyond its residual level until about 10kHz.



**PHOTO 7: Galo supply noise scope (100 $\mu$ V/div RTI, 2ms/div, 42 $\mu$ V RMS).**



**PHOTO 8: LM340/LM320 supply noise scope (100 $\mu$ V/div RTI, 2ms/div, 105 $\mu$ V RMS).**

From there up to 50kHz, the amount of signal on the power-supply rails increased steadily, reflecting the falloff in PSRR (and CMRR) of the preamp and the increasing impedance of the power-supply itself.

I took two photos with a 20kHz 2V RMS output signal with the scope time base set for 50µs/div. In *Photo 10*, the scope photo of the Gary Galo regulator, the 20kHz signal is now high enough to modulate the wideband noise, which has increased from 42µV RMS to a still very respectable 68µV RMS RTI (-89dB<sub>r</sub>). The vertical scale is 100mV/div or 100µV/div RTI.

*Photo 11* shows the +15V rail noise at 20kHz from the CT102 at 20mV/div (20µV/div RTI). While the wideband noise is still 19µV RMS RTI (-92dB<sub>r</sub>), the ghost of the 20kHz signal is just noticeable above and below the broadband noise.

The CT102 noise is specified with an IHF "A" weighting filter, so I also measured the rail noise with "A" weighting. It was 3.5mV RMS (3.5µV RTI, or -115dB relative to 2V RMS). The noise relative to 0.775V over a 22kHz bandwidth is -118dB<sub>u</sub>.

## CONCLUSION

The discrete transistor regulators in the CT102 produce a very low noise level. While not on a par with a pure battery supply, the CT102 has wideband noise levels -8dB better than the excellent Gary Galo IC regulator supply. This margin increases with frequency. *Table 1* shows the CT102 ratings compared with the measured results.

*Manufacturer's response:*

1. CT102 has a built-in current limit at 200mA. We are using a constant-current limiting principle rather than the fold-back current limiting principle that is mentioned in the review.

If CT102 is asked to deliver (determined by the load impedance) a current right at or above the current limit, it will no longer function as a voltage generator (which it is intended to be) but will function as a constant-current source of around 200mA. Therefore, in testing or using CT102, it's important to ensure that it operates within its voltage generator load range. It's our opinion that when the reviewer uses 200mA output current for several of his tests, he might have gone just to the limit or outside the intended operating

area of CT102.

We are uncertain whether this is the case or whether there was something wrong with the switch mode wall adapter that we supplied the reviewer. We have indications that some of the initial switch mode adapters were not able to supply the full output current when operated at 110-115V mains.

2. Our output noise figures are different from the reviewer's noise measurements, so we need to communicate with him about what causes the differences.

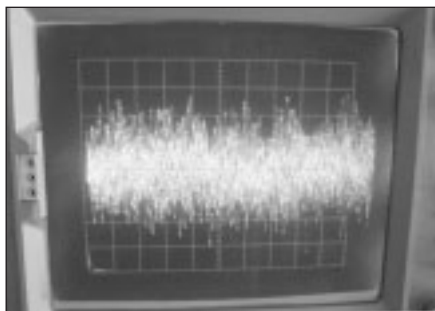
Specifically, when testing various CT102 specifications using a load of 75Ω, the risk is that CT102 goes into its current source mode. In other words, the excellent voltage source properties of CT102 are lost. We are questioning the 75Ω load resistor itself. First of all, it has a tolerance and could turn out being lower than 75Ω, leading to a current draw higher than 200mA. Even more critical, when it comes to the long-term test, is where the power dissipated by the 75Ω resistor will lead to it becoming hot. This normally results in a drop in resistance, meaning a larger current than 200mA.

So while testing the maximum output current that CT102 will deliver is a natural part of a review, we suggest testing other specifications to be carried out at a current below maximum current for the reasons given. Our published data is factory tested at 190mA and specified at 100mA output current. Normally, we would expect measuring output impedance, and so forth, carried out at somewhat below short-circuited output current; for instance, 150mA.

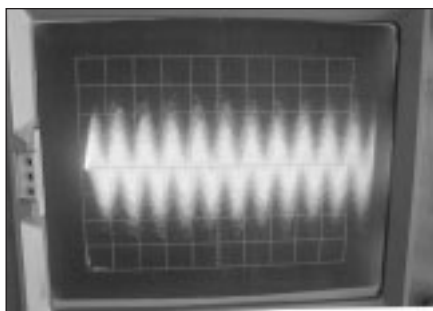
The result here is that the reviewer's measured DC output impedance goes way high compared to what it would be if CT102 was operated in its voltage generator range. We have verified and still reach the figure saying that the CT102 output impedance typically is 0.001Ω from DC to 5kHz, slowly rising above 5kHz to 0.006Ω at 100kHz.

**TABLE 1**  
**CT102 KEY SPECIFICATIONS, MEASURED PERFORMANCE**

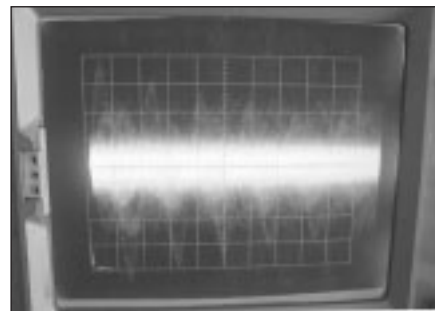
PARAMETER	MANUFACTURER'S RATING	MEASURED RESULTS
Output voltage (jumper selectable)	±15V DC or ±20V DC	Verified
Maximum steady-state output current	200mA	Verified
Peak output current	10A (short-circuit protected)	Not tested
Output impedance	0.001Ω at 1kHz 0.002Ω at 20kHz 0.006Ω at 100kHz	0.25Ω at DC
Output noise (wideband)		19µV RMS (-100dB relative to 2V RMS)
Output noise (IHF A)	-126dB	-115dB
Full-load regulation	No spec	±11%/-14%



**PHOTO 9:** HP6236B supply noise scope (500µV/div RTI, 2ms/div, 340µV RMS).



**PHOTO 10:** Galo supply noise at 20kHz scope (100µV/div RTI, 50µs/div, 68µV RMS).



**PHOTO 11:** CT120 supply noise at 20kHz scope (20µV/div RTI, 50µs/div, 19µV RMS).

Adding to this is the uncertainty about the current output capability of the switch mode adapter that we shipped for the review, which means that the CT102 output current and specs might have been degraded when operated at 110VAC (we are suspecting this problem might occur only when operating the adapter at 110V mains).

The fact that the reviewer finds a rather higher DC output impedance also at 22mA out does indeed indicate that there is something wrong with the switch mode adapter we supplied.

Other corrections to the review are as follows:

Under the section titled Topology, fold-back current limiting should be constant-current limiting.

Under Other Power Supplies, we anticipated 50 $\mu$ V noise to be -100dB rather than being -92dB. Maybe a misunderstanding on our side?

When measuring CT102 output noise we are deducting the analyzer's own noise. Our typical noise figures are:

- Measured noise (IHF-A weighted): 0.9 $\mu$ V.
- Analyzer own-noise (IHF-A, input shorted): 0.8 $\mu$ V.
- Calculated CT102 output noise:  $\sqrt{[(0.9)^2 - (0.8)^2]} = 0.41\mu\text{V} = -127.7\text{dB}$  relative to 1V.
- Measurements carried out using the Panasonic VP-7722P Audio Analyzer.
- This leaves a big difference between the reviewer's and our noise figures, and we do not find any obvious explanation on the differences.

The review initially states that the features we claim for CT102 are low dynamic output impedance, extremely wide bandwidth, and fast regulation. This is correct. It would have been interesting if the review had discussed whether these parameters are considered relevant for an audio power supply.

Also, the review does not conclude in detail whether the claimed features have been obtained. A comparison between CT102 and the other kinds of power supplies already discussed in the review would have been very interesting. The review does mention in the conclusion that ". . . the CT102 has wideband noise levels -8dB better than the excellent Gary Galo IC regulator. This margin increases with frequency." We had hoped that the review would document

more precisely how the margin increases with frequency, as we are especially claiming high-frequency features.

The conclusion does not deal with our claim that CT102 has a very low dynamic output impedance over a large frequency range. Although we find this feature extremely important for audio electronics circuits, the output impedance is only measured at DC (and we find the measured DC value to be different from what they ought to be, possibly because of a faulty switch mode adapter). For instance, high-frequency output impedance measurements might have put the specifications of CT102 in perspective even when compared to battery power supplies.

Finally we trust CT102 is a world-class audio power supply and that its abilities have not been fully and correctly expressed in the review. If the worse-than-we-expected measurements are caused by a faulty mains adapter supplied by DACT, it is, of course, our responsibility. However, we hope to be given a chance to show that the tested CT102 including mains adapter is not a typical specimen. ❖

Allan Isaksen  
Danish Audio Connect