



## Volume Control and Transformer Output

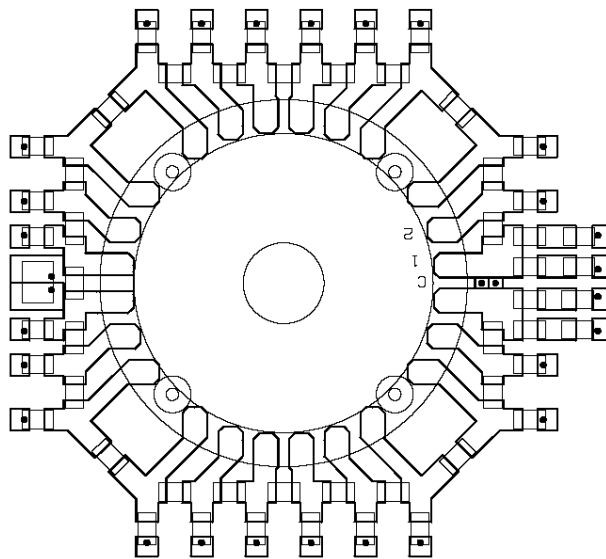
Based on the LIANOTEC® configuration, we developed a multibit digital/analog converter (DAC) whose distortion is below the limits of perception. When measuring the signal to noise ratio (SNR), we touched on the limits of measurability. On the TRINITY®-DAC, the volume control is the only module located between the actual DAC and the output stage. This dispenses with a conventional active filter which impairs the sound. The main emphasis is then placed on the volume control, and its key parameter is to maintain sound quality. Of course, for our premier product, there was no question of using a digital volume control, as is found in every digital filter.

Although customary potentiometers, e.g. equipment by Alps, Noble, or Penny & Giles, have a slightly better sound than a digital attenuator, only switched resistance splitters produce a genuinely excellent result.

### Volume Control

The quality of the volume control, of course, depends on the quality of the resistors and rotary switches. As a result, the TRINITY®-DAC uses special, application-specific, precision thin-film resistors which have a tolerance of  $< 0.1\%$ . In addition, they have very low inherent noise and a very low temperature coefficient.

In selecting the rotary switch, a key factor was seamless integration on the PCB.



*Fig. 1*

*Fig. 1 The rotary switch is integrated on the converter PCB with the required resistors to minimize signal paths in the DAC*



We use a specially produced switch with contacts made of a gold-plated silver alloy. The contacts have an extremely low transition resistance that remains constant throughout their entire service life.

Before assembly, the switch is dismantled into its constituent parts. The PCB with resistors already mounted is then inserted between the two layers of the switch. Finally, the switch contacts are soldered to the PCB using high-purity silver solder.

All the work steps described must be performed with extreme precision. The complexity of the task and the sensitivity of the components and materials mean that the process must be carried out manually by a highly skilled specialist.

This labor-intensive procedure is the only way to achieve the targeted high performance and an optimized signal path.

Contrary to conventional volume controls based on rotary switches that have impedances ranging from 100kOhms to 500kOhms, the TRINITY<sup>®</sup>-DAC volume control has an impedance of only 110 ohms.

Such a low figure is only achievable by the architecture of the volume control that comprises a number of cascaded, balanced  $\pi$  sections. A  $\pi$  section of this type is also an ideal component for a transmission line. For this reason, this type of circuit configuration is used primarily for high-frequency breadboards.  $\pi$  sections can even be connected by a transmission line without impairing their characteristics. Therefore, if the connection between the last  $\pi$  section and load resistor  $Z_2$  is a transmission line, cable capacitance and inductance will have a negligible impact on the transmission quality of the audio signals because primarily, a transmission line is a purely ohmic resistance. We finally selected 110 ohms because there are a number of excellent digital connecting cables that have an impedance of 110 ohms.

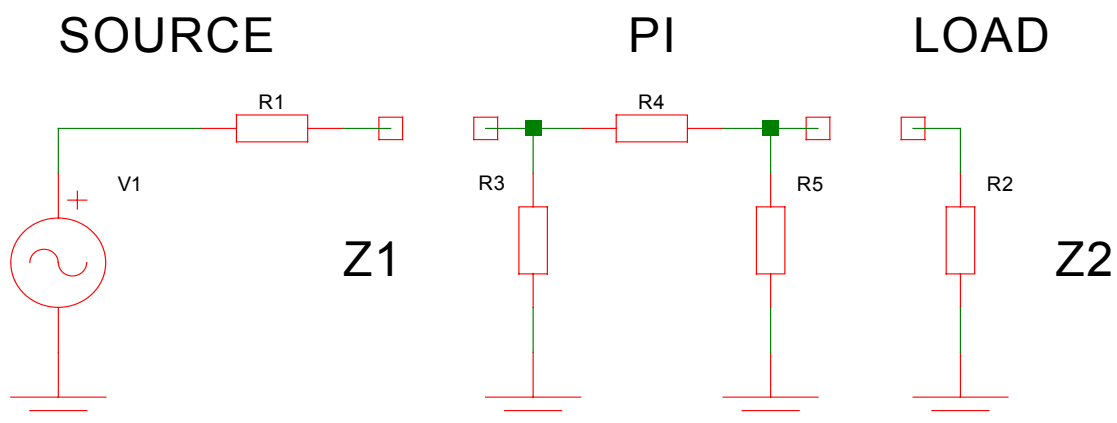


Fig. 2

*Fig. 2 A  $\pi$  section is a network that generates a known loss when it is located between two matched impedances  $Z_1$  and  $Z_2$ .  $Z_1$  represents the source impedance, and  $Z_2$  the load impedance. The loss is regarded as the ratio of powers and is independent on direction. In this case,  $Z_1=Z_2=110$  ohms.*



The ladder attenuator implemented in the TRINITY®-DAC has a special design which has several basic advantages:

1. The input and output impedances are always constant, independent of the rotary-switch position.
2. Identical, precise steps are very simple to reproduce.
3. It is sufficient to have only two resistance values.
4. The bandwidth is in the megahertz range.
5. If the connecting cable to the output stage is also a transmission line, cable capacitance and inductance have zero impact on audio-signal transmission quality.
6. The low-resistance configuration guarantees extremely low resistance noise.

The 110-ohm version of the delta section also places special demands on the driver amplifier:

1. An additional gain of 6 dB is required.
2. The amplifier output stage must supply sufficient current since impedance is very small compared to traditional designs.

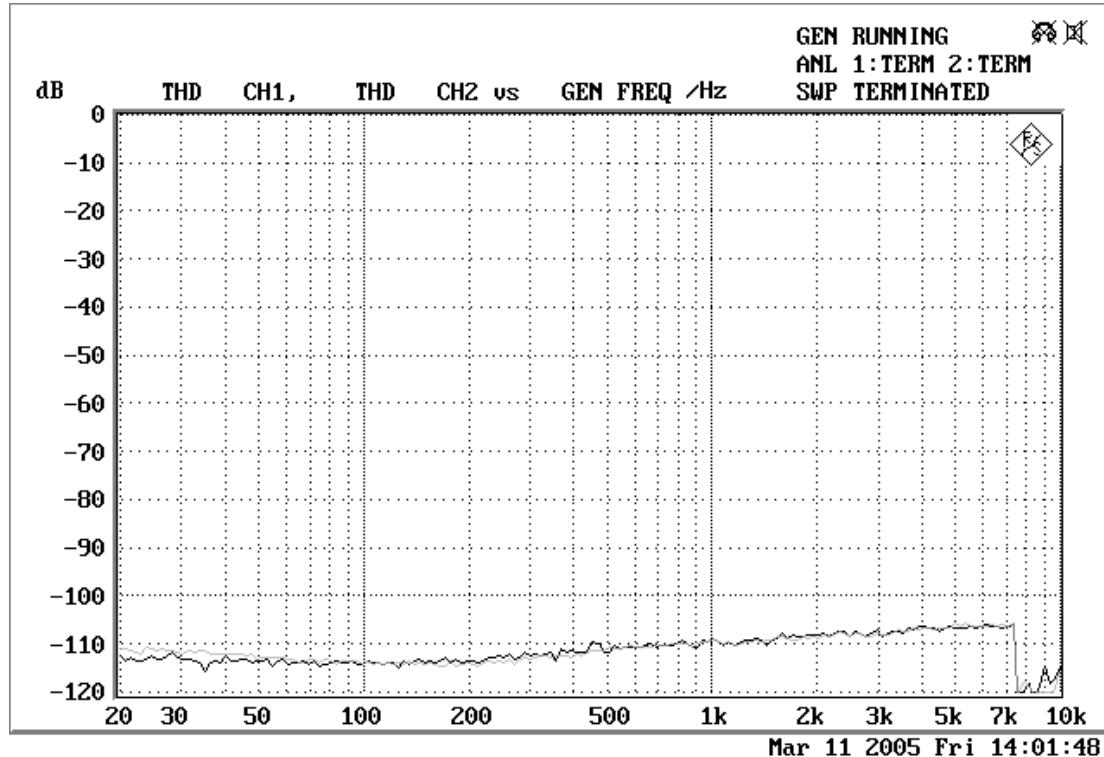


Fig. 3

Fig. 3 Harmonic distortion upstream and downstream of the volume control with a cable length of 50 cm Gotham GAC-2 AES/EBU level 0 dBFS



The test record (Fig. 3) shows that the volume control exerts no measurable influence on the audio signal.

This means that the current-to-voltage converter in the TRINITY®-DAC, which converts the output current from the actual DAC into a voltage, is capable of driving this low-impedance load without causing any additional distortion. It should be pointed out here that the output stage of the operational amplifier can drive a current of more than 1 A. However, in this context, we would not use the word "overdimensioned", since, if a 1-A output stage is capable of producing the desired result, it is not overdimensioned, but correctly dimensioned.

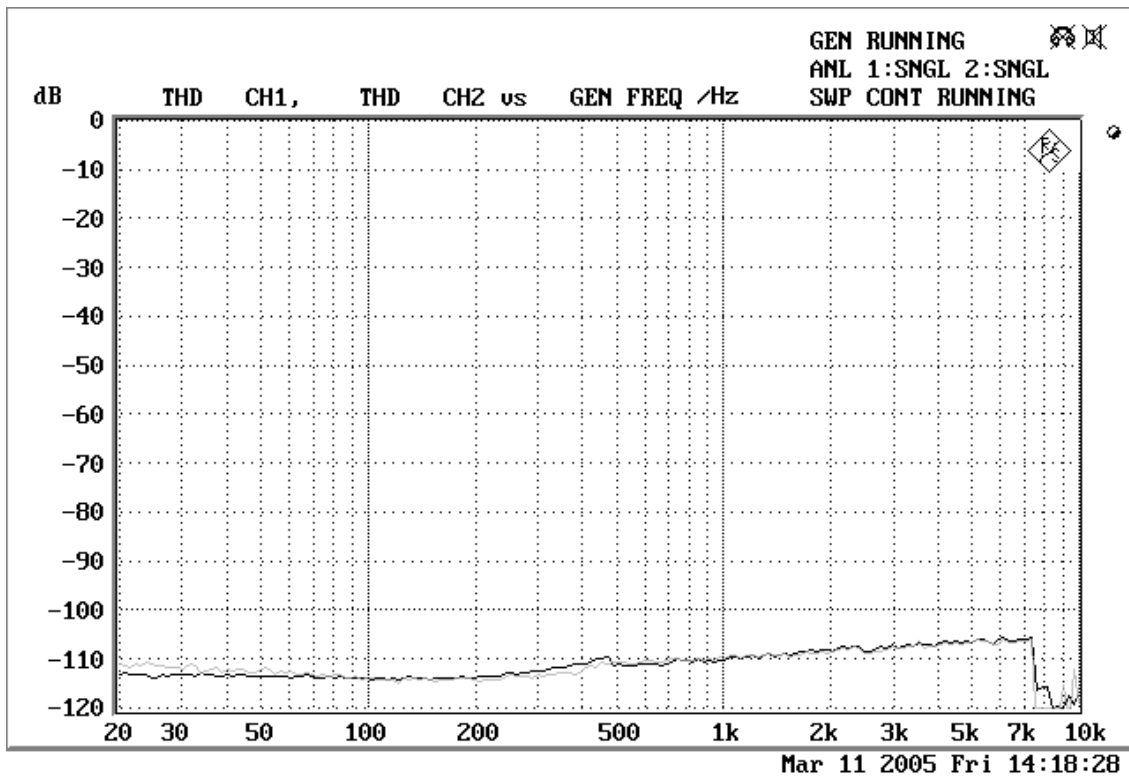


Fig. 4

Fig. 4 Harmonic distortion upstream and downstream of the volume control with a cable length of 5 m Gotham GAC-2 AES/EBU level 0 dBFS

Figure 4 shows the test record of the TRINITY®-DAC. It confirms that the length of the cable used has no measurable impact on the audio signal when the cable is designed as a transmission line. What is remarkable here is that the cable is a "simple" cable from Gotham (GAC-2).

Of course, a motor is required for the remote control of a multilayer switch of this type. Since conventional stepper motors fail to produce the required torque, a special stepper magnet was designed for the TRINITY®-DAC switch. It is housed in a separate housing milled out of solid aluminum and isolated from the housing by several elastomers.



Besides the volume control, the output sockets are also soldered directly to the PCB. The connecting cable to the output stage must be a 110-ohm cable, as used for connecting the digital components.

Since the cable to the output stage is in fact an extension of the transmission line, the 110-ohm terminating resistor Z2 must be soldered between pins 2 and 3 in the XLR plug at the cable end. This output is fully balanced and is not tied to ground. Pin 1 is connected to DAC ground and must also be connected to ground at the amplifier input-stage to optimize the function of this configuration.

## Output Transformer

The second output supplies a floating output signal. This DC decoupling is implemented by means of a transformer which is a professional studio-engineering component. The test chart below shows that the lower cutoff frequency is at 5 Hz.

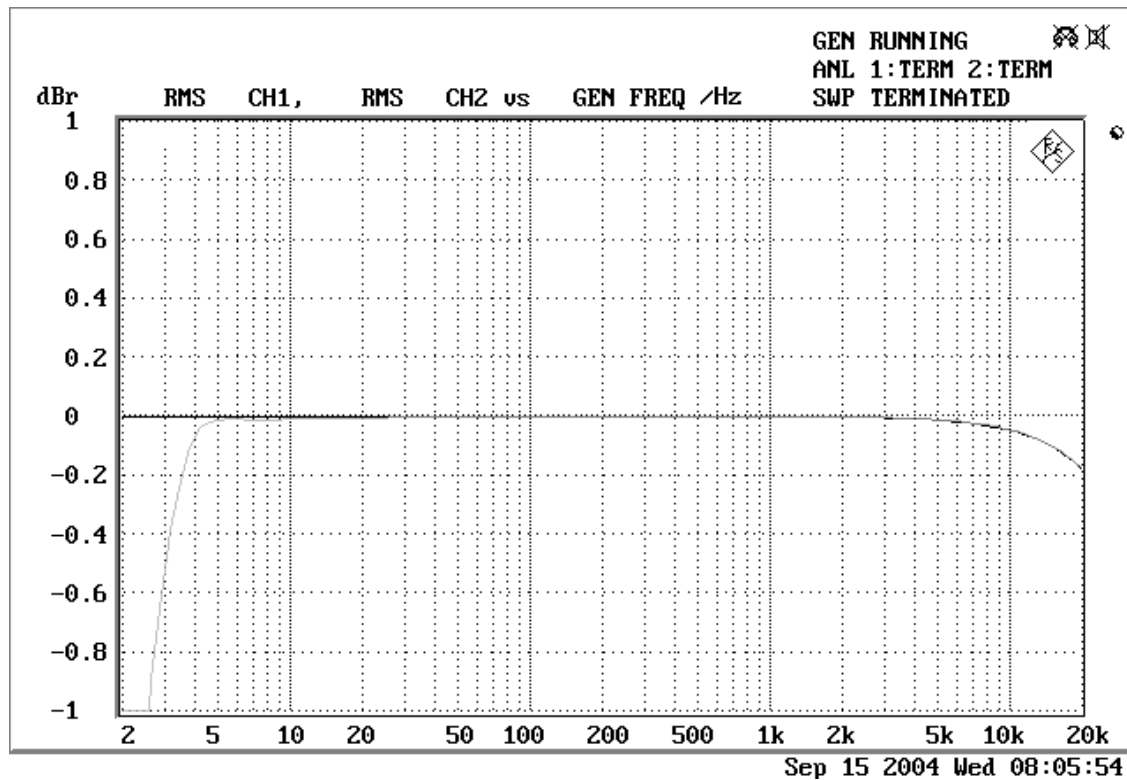


Fig. 5

Fig. 5 Frequency response of output transformer against 110-ohm output, output level 0 dBFS



Owing to saturation occurring in the output transformer, distortion increases below 100 Hz due to the application:

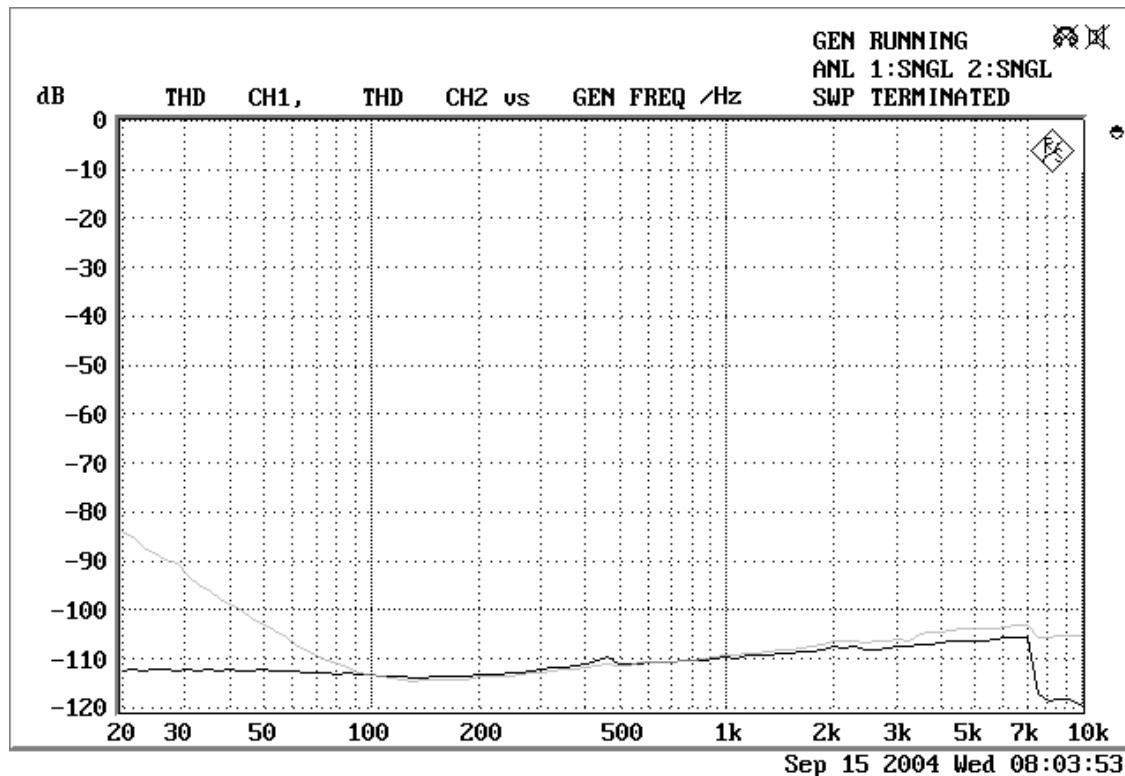


Fig. 6

*Fig. 6 Harmonic distortion of output transformer against 110-ohm output, output level 0 dBFS*

These are the two measurements that produced a difference between the two outputs. Both of the outputs were linked to the test instrument by a 50-cm cable since the cable characteristics at this length are negligible.

The transformer output must be used if the downstream amplifier only has one unbalanced input. For this configuration, we offer an XLR-RCA adapter.

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