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Lundahl 1592 Transformer

By Charles Hansen

The LL1592 is a four-winding (two each, equal primaries and secondaries) high-level audio input transformer with mu-metal laminations. The windings are arranged to give a high degree of symmetry if you use the transformer for phase splitting. The transformer primary and secondary are separated by an electrostatic (Faraday) shield. Like all audio transformers, the LL1592 eliminates the inherent ground noise coupling mechanism.

A schematic of the LL1592 is shown in **Fig. 1** in the recommended configuration with the Faraday shield winding connected to the low side of the secondary. The secondary winding also shows the series RC termination network I used for measurements—a 390pF polystyrene capacitor and a 7k15 metal film resistor. The manufacturer-suggested values for best square-wave response are 400pF and 7k, which are non-standard. My RC termination network yields virtually the same time constant as the non-standard values recommended by Lundahl.

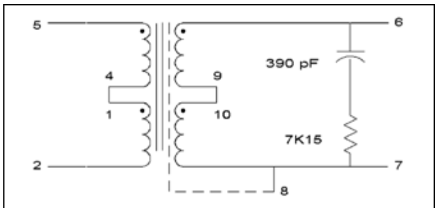

FIGURE 1: LL1592 schematic.

MEASUREMENTS

There is quite a bit of opportunity for "operator error" when testing the LL1592 because each specification calls for a different source and/or load resistance, and the absence or presence of the suggested RC terminating network.

The LL1592 maintains normal polarity. The input impedance measured approximately 37k at 1kHz, with the four DC winding resistances quite closely matched, between 276Ω and 281Ω. The winding-to-winding capacitance was 730pF, and the winding inductance was 614H, which should enhance low-frequency response. The leakage inductance (secondary shorted) was less than 1μH.

I recorded the output frequency response for resistive loads of 100k, 40k, and 10k with an input source impedance of 600Ω as specified in the datasheet. This response is shown in **Fig. 2**. At the nominal specified load of 40k with the termination network connected (solid lines), the frequency response for the LL1592 was within ±1dBu to 60kHz, with an input signal of +4dBu (1.228V RMS) at 1kHz. I also took data for loads of 600Ω and an IHF line load, but the response was down -12dB at 600Ω and is off the graph. There is about 0.5dB response peak at about 50kHz. Insertion loss at 1kHz with a 40k load was -0.38dBu.

Without the termination network (dashed lines) the high-frequency response peak increased to +2.5dB at the higher secondary loads, and a bit less at the lower loads. These peaks also occurred just above 50kHz at 100k load and increased in frequency as the load resistance decreased.

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Dimensions: 47 × 28 × 20mm
Net weight: 83gm

I was initially confused by the phase splitting balance specification of >46dB, and asked Per Lundahl for some clarification. The test calls for measuring the difference between the two secondary voltages with the primaries still in series, a 20k load on each secondary (a 2:1+1 connection), and the RC termination network across the two series-connected secondaries. He defined this test as the ratio of the secondary output (5V RMS for this test) to the difference between the voltage at each secondary. I saw

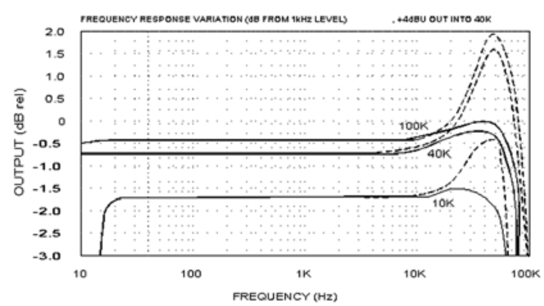

FIGURE 2: LL1592 frequency response.

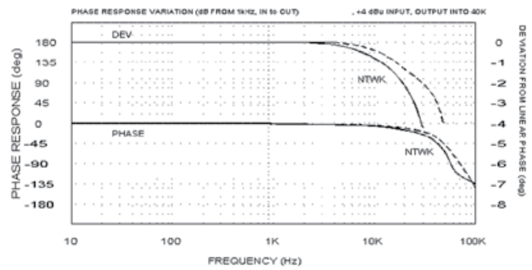

FIGURE 3: LL1592 phase response and deviation from linear phase.

46.4dB at 50kHz using the prescribed measurement technique, but it was a higher 48.9dB without the RC network, perhaps due to some advantage gained by a bit more HF peaking.

The phase shift with frequency is shown in **Fig. 3**, output with respect to input, referenced to 0dB at 1kHz (lower curve using left side vertical legend). The source impedance is 600Ω, and the output load is 10k. The deviation from linear phase[1], using the right side vertical legend, is within the specified 2° out to 29kHz without the RC terminating network. With the network (solid lines), the phase shift—and thus the deviation from linear phase—increases more rapidly.

Figure 4 shows THD+N vs. frequency for the LL1592. I engaged the test set 80kHz low-pass filter to limit the out-of-band noise. In all instances the monitor output of the distortion test set, after the fundamental notch filter, showed the third harmonic, as would be expected of a magnetic core transformer. The LL1592 THD+N is relatively insensitive to output loading. There is just a hint of a dip in distortion at 60Hz at the higher values of load resistor, which may have been the result of the transformer being mounted on a prototype PC board without audio connectors and a metal case. The Lundahl transformer is fairly immune to external magnetic fields.

Figure 5 shows output THD+N versus input voltage into 40k at 20Hz, 1kHz, and 20kHz. Using a 40Hz input signal (not shown), the LL1592 endured a huge 25V RMS (+30.2dBu) before "clipping" at 1% THD+N. Beyond this point the increasing 3rd harmonic distortion due to impending core saturation caused the sine wave peak to flatten. Distortion was not affected by adding the RC termination network.

If you want to convert the graph voltages to dBu, the formula is

$$dBu = 20*\log(Vin/774.597)$$

I viewed the response of the LL1592 to three 2.5Vpp square-wave test frequencies on an analog scope using a 40k load and 600Ω source impedance. The response at 40Hz showed a reasonable amount of tilt with about 0.7Vpk of critically damped ringing on the leading edge of each transition. The ringing was at roughly 77kHz. The 1kHz and 10kHz square waves were nearly perfect except for the ringing. Changing the secondary load did not materially affect either the shape of the square waves or the ringing frequency. Removing the RC termination network increased the peak of the ringing about 16%.

I did find that the square-wave accuracy and the peak level of the HF ringing very much depends on the input impedance of the signal source. With a 50Ω source impedance, the 10kHz square wave had the highest peak on the leading edge. Increasing the source resistance to 2k while maintaining the same output level caused the leading edge of the 10kHz square wave to round over and the peak of the ringing to decrease. The best compromise between squareness and the peak added by ringing was at 1k7, but the number of cycles of ringing increased to cover almost the entire width of the top of the square wave. This indicates that the high-frequency response will be sensitive to the input source impedance.

Table 1 shows the manufacturer's specifications and my measured results for comparison.

COMPARISON

The Jensen[2] ISO-MAX CI-2RR is designed primarily as an isolation transformer for solving ground loop problems. The Lundahl has dual primary and

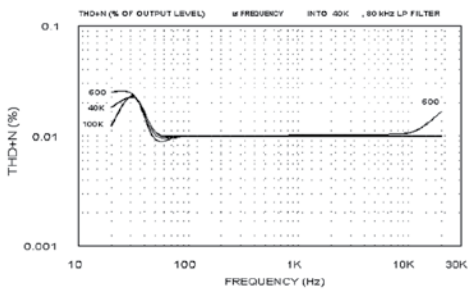

FIGURE 4: LL1592 THD+N vs. frequency.

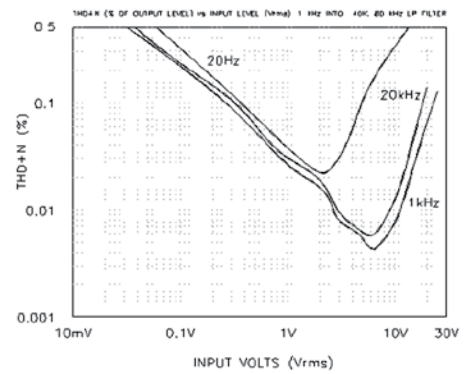

FIGURE 5: LL1592 THD+N vs. input voltage.

TABLE 1 MEASURED PERFORMANCE

Parameter	Manufacturer's Rating	Measured Results
Static Resistance, Pri and Sec:	**270Ω nominal**	**276Ω to 281Ω**
Distortion (series connection):		
+20dBU (10.94V RMS), 40Hz	0.1% typical	0.14%
+29dBU (21.83V RMS), 40Hz	<1%	0.93%
Self Resonance Point	**>120kHz**	
Frequency Response, ref 1kHz:		
Source 600Ω, Load 20k, no network	10Hz – 50kHz, ±1.0dB	10Hz – 62kHz, ±1.0dB
Source 600Ω, Load 100k, with network	10Hz – 100kHz, ±1.0dB	10Hz – 88kHz, ±1.0dB
Phase Splitting Balance, Source		
600Ω, Load 20k + 20k, with network	**>46dB, 10Hz – 50kHz**	**46.4dB at 50kHz**
Deviation from Linear Phase (DLP)[1]:		
Source 600Ω, Load 10k	10Hz – 20kHz, <2°	2° at 29kHz
Input Impedance, Zi, 1kHz, +4dBu:	**NS**	**Approximately 37k**
Insertion Loss, 1kHz, +4dBu:	**NS**	**-0.38dBu**
Capacitance, 1kHz, input to output:	**NS**	**30pF, no network**
Isolation:		Not Tested
Between Windings	3kV	
Windings and Shield	1.5kV	

secondary windings that make it more versatile. The Jensen has flatter frequency response and its built-in RC termination network does a better job of removing any HF peaking. I did not experiment at all with alternate RC time constants on the Lundahl termination network to try to improve the HF peaking.

Both transformers have very good deviation from linear phase performance. I would say they have similar THD versus frequency curves, with the Jensen showing a bit lower midrange distortion, and the Lundahl a bit flatter at the low end. You can drive the larger Lundahl transformer harder (higher input voltage and better handling of low output impedances), especially by taking advantage of the series winding configuration.

Both transformers gave a good account of themselves. Your choice may depend on whether you need the added versatility of the Lundahl dual windings. aX

REFERENCES

1. "High-Frequency Phase Specifications—Useful or Misleading?" Deane Jensen, 1986 AES Paper 2398 (E-8).

2. "Inside the ISO-MAX," Hansen, C., *audioXpress*, pp. 44-49, Oct. 2006.