Kirksaeter's SL-60 Loudspeaker

Reviewed by Joseph D'Appolito and Rita & Dennis Colin

I ran a series of impedance, frequency response, and distortion tests on the Kirksaeter SL-60 loudspeaker. *Figure 1* is a plot of system impedance magnitude. At low frequencies the plot displays the double-peaked curve of a vented system.

The impedance minimum of 4.9Ω at 48Hz indicates the vented-box tuning frequency. There are additional local impedance minima of 4.9Ω at 250Hz and 3120Hz. Impedance phase lies between +36° and –42° over the full audio range. This system can reasonably be rated at 5Ω and should be an easy load for most amplifiers.

FREQUENCY RESPONSE

Figure 2 shows two far-field frequency-response curves for the SL-60. For this measurement I placed the microphone along the tweeter's axial centerline at a distance of 1.2m. This is a quasi-anechoic response[1] that is valid above 200Hz. The plotted responses have been normalized to 1m to obtain system sensitivity.

The SL-60 has two pairs of binding posts for bi-wiring. The dotted curve was obtained with the tweeter polarity indicated by the color coding on the binding posts. The broad dip at 3kHz is typical of a tweeter connected with the wrong polarity. Fortunately, it was an easy matter to reverse tweeter polarity and rerun the test. The solid curve was obtained with the tweeter connection reversed.

A little detective work will determine the actual tweeter polarity. *Figure 3* shows SL-60 step response with the normal and reversed tweeter connections. With the normal connection the initial rise produced by the tweeter is in the negative direction. With the connection reversed, the initial rise is positive-going—a strong clue that the tweeter is wired with its polarity opposite to that of the woofer.

Figure 4 is even more revealing. Here I have plotted system excess phase. Again, the dotted curve is for the factory-marked tweeter connection. Notice that it produces 180° more phase shift at 15kHz than with the tweeter connection reversed. Whether this was a wiring error at the factory or whether Kirksaeter intends the system to be connected this way was not clear at the time of these tests. I performed all further testing with the tweeter connection reversed.

Near-field woofer and port responses (*Fig. 5*) are summed by the MLSSA system, giving proper weighting to the difference in area of the woofer and the port, to obtain the complete near-field low-frequency system response. The dip in woofer response at 50Hz is another indication of the vented-box tuning. Port acoustic output is also a maximum at this frequency. Woofer crossover inductance can cause the box-tuning frequency obtained with the impedance curve to be lower than that indicated by the woofer near-field response. When this happens, the latter is a more accurate measure of box tuning.

The system low-frequency response (*Fig. 5*) was spliced to the quasi-anechoic response (*Fig. 2*) at 218Hz to get the full-range system response. This result is shown in *Fig. 6*. Over the two octaves centered on 1kHz, sensitivity averages 86.8dB SPL/2.83V/1m. Relative to this level, response peaks 6.6dB at 16kHz. The –3dB low-frequency point is 60Hz.

Figure 7 illustrates the crossover action. Acoustic crossover occurs just above 3kHz. Notice the woofer peak at 6kHz.

CUMULATIVE SPECTRAL DECAY

The SL-60 cumulative spectral decay (CSD) response is presented in *Fig. 8*. This waterfall plot shows the frequency content of the system response following a sharp impulsive input at time zero. On the CSD plot, frequency increases from left to right and time moves forward from the rear. Each slice represents a 0.05ms increment of time. The total vertical scale covers a dynamic 32dB range.

Ideally the response should decay to zero instantaneously. Inertia and stored energy that take a finite amount of time to die away, however, characterize real loudspeakers. A prominent ridge parallel to the time axis would indicate the presence of a strong system resonance.

The first time slice in *Fig. 5* (0.00ms) represents the system frequency response. Tweeter decay time is good, but there is a strong delayed woofer resonance mode at 1830Hz beginning at about 0.75m. A ridge due to the woofer peak shown in *Fig. 7* also appears at about this time.

WOOFER/TWEETER TIMING

SL-60 step response shown in *Fig. 3* indicates that tweeter output arrives at the test mike before woofer response. *Figure 9A*, which shows a better view of this behavior, is a plot of excess group delay versus frequency referenced to the tweeter's acoustic phase center. This is a plot of signal delay in mil-

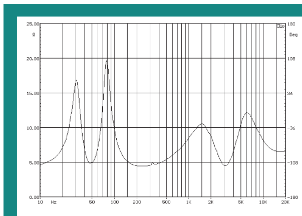

FIGURE 1: Kirksaeter Silverline SL-60 impedance.

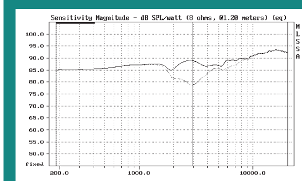

FIGURE 2: SL-60 response: normal (dotted), tweeter reversed (solid).

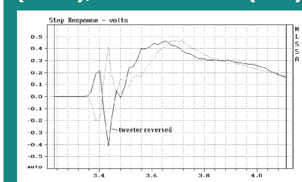

FIGURE 3: SL-60 step response: normal (dotted), tweeter reversed (solid).

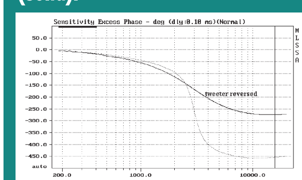

FIGURE 4: SL-60 excess phase: normal (dots), tweeter reversed (solid).

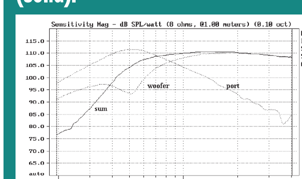

FIGURE 5: SL-60 near-field port and woofer (dotted), their sum (solid).

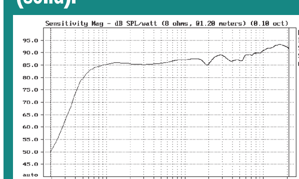

FIGURE 6: SL-60 full-range frequency response.

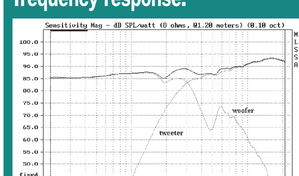

FIGURE 7: SL-60 system and driver responses on expanded scale.

liseconds versus frequency. (A detailed description of excess group delay can be found in reference 1.) In a time-coherent system this plot would be a flat line.

Above 10kHz excess group delay is essentially zero because it is referenced to the tweeter arrival time in this frequency range. The curve rises gradually below 10kHz, reaching a plateau below 1kHz of 161µs, or 0.161ms. This plot shows that over its operating frequency range, the woofer is 161µs behind the tweeter. Both drivers are connected with positive polarity (using the reversed tweeter connection), but the system is not time-coherent.

Figure 9B shows SL-60 excess group delay with the tweeter in its normal connection. With this connection, signal delay in the crossover region exceeds 0.8m. This level of delay will cause gross waveform distortion.

POLAR RESPONSE

Polar response is examined in *Figs. 10* and *11*. *Figure 10* is a waterfall plot of horizontal polar response in 10° increments from 60° left (–60°) to 60° right (+60°) when facing the speaker. All off-axis plots are referenced to the on-axis response, which appears as a straight line at 0.00°. Thus, the plotted curves show the *change* in response as you move off axis. For good stereo imaging the off-axis curves should be smooth replicas of the on-axis response, with the possible exception of some tweeter rolloff at higher frequencies and larger off-axis angles.

You can see the expected rolloff of tweeter response at higher frequencies and larger off-axis angles. This performance is fairly typical of 25mm dome tweeters. *Table 1* lists the horizontal off-axis responses at 15kHz and all angles up to ±60°. Below 8kHz horizontal coverage is fairly broad. There is a mild response dip below the crossover frequency and at angles beyond ±30°. Again, this is fairly typical of two-way systems.

TABLE 1
HORIZONTAL POLAR RESPONSE AT 15KHZ

ANGLE	RESPONSE (DB)
10	–0.6
20	–2.5
30	–4.6
40	–6.9
50	–9.6
60	–10.8

The average response over a 60° horizontal angle (±30°) in the forward direction is shown in *Fig. 11*. Peaking of the average forward response above 10kHz is reduced somewhat relative to the on-axis response. This may make the audible effect of the peaking less apparent since the human ear integrates direct and reflected sound when judging the overall spectral balance of a loudspeaker.

Figure 12 is a waterfall plot of vertical polar response. Responses are shown in 5° increments from 20° below (–20°) the tweeter axis to 20° above it. Response changes very little as you move below the tweeter axis.

The worst-case change at 20° below the tweeter axis is only –4.4dB. However, response changes rapidly beyond 5° above the tweeter axis. At +20°, response dips 19dB at 2880Hz. For broadest vertical coverage the SL-60 should be tipped back about 10°. (Alternatively, listeners can lie on the floor.)

INTERMODULATION DISTORTION

Next I measured intermodulation distortion. In this test two nearby frequencies are input to the speaker. Intermodulation distortion produces output frequencies that are not harmonically related to the input and are much more audible and annoying than harmonic distortion. Let the symbols f_1 and f_2 represent the two frequencies used in the test. Then a second nonlinearity will produce intermods at frequencies of $f_1 \pm f_2$. A third nonlinearity generates intermods at $2f_1 \pm f_2$ and $f_1 + 2f_2$.

I examined woofer intermods first by inputting 900Hz and 1kHz signals at equal levels. These frequencies should appear predominantly in the woofer output. I adjusted total SPL with the two signals to 85dB at 1m. I usually run IM distortion tests at 90dB SPL. However, because steady tones are used in the IM test, I thought it safer with this small monitor to use a lower power level.

The SL-60 system output spectrum for this test is shown in *Fig. 13*. The two largest spectral lines represent the input signals. There are ten distinct IM distortion products. The largest is third-order at 1100Hz and is 48.6dB below the main output, which is equivalent to 0.37% distortion.

Total IM distortion is approximately 0.55%. Although the overall level is not that high, the multiplicity of distortion products is troubling. I suspect the ferrite core coil used in the woofer crossover causes this behavior.

I measured tweeter intermods with a 10 and 11kHz input pair also adjusted to produce 85dB SPL at 1m (*Fig. 14*). The only significant IM product at 12kHz is 54dB below the main output at 0.02%, which is a very low level of distortion. However, the spectral lines at 10 and 11kHz do not drop immediately into the noise level; rather, there is a broadening of the spectrum at the base of the lines. This is possibly caused by mechanical noise in the tweeter suspension, and is a form of spectral contamination. I look to the reviewer for any possible consequences of this noise.

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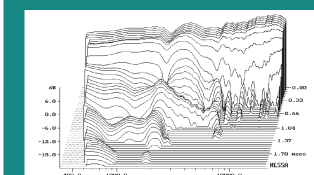

FIGURE 8: SL-60 cumulative spectral decay.

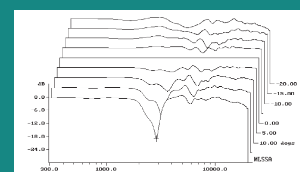

FIGURE 12: SL-60 vertical polar response.

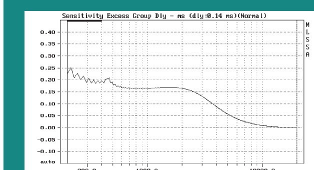

FIGURE 9A: SL-60 excess group delay: "reversed" tweeter connection.

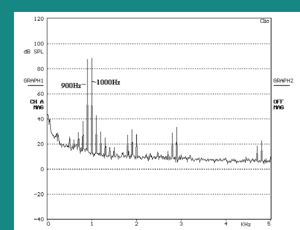

FIGURE 13: SL-60 woofer intermodulation distortion.

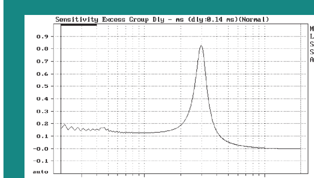

FIGURE 9B: SL-60 excess group delay: "normal" tweeter connection.

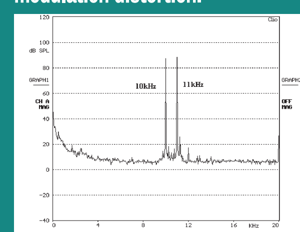

FIGURE 14: SL-60 tweeter IM distortion.

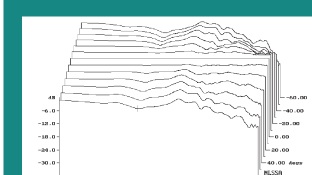

FIGURE 10: SL-60 horizontal polar response.

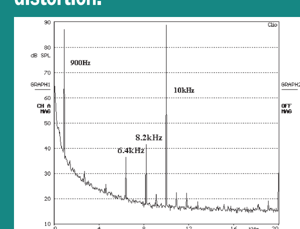

FIGURE 15: SL-60 woofer/tweeter IM test.

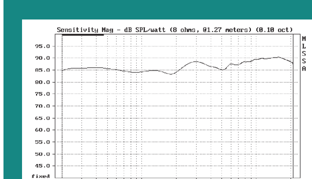

FIGURE 11: SL-60 average response over ±30°.

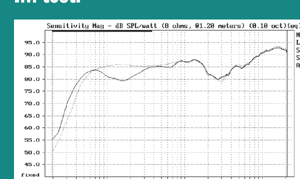

FIGURE 16: SL-60 against wall (solid), free-stand (dotted).

Reviewed by Rita and Dennis Colin

DESCRIPTION

Two-way mini monitor, 5″ woofer, 1″ titanium dome tweeter, ported enclosure. Price $698. Available from Kingcaid Acoustics, 1943 Linden Lane, Hatfield, PA 19440, 215-361-1559, FAX 215-361-8908. Unlike most speakers, these are meant to be placed against a wall (no more than 2″ away); they are reportedly used in recording studios, wall-mounted above the mixing console.


PHOTO 1: SL-60 with grille.

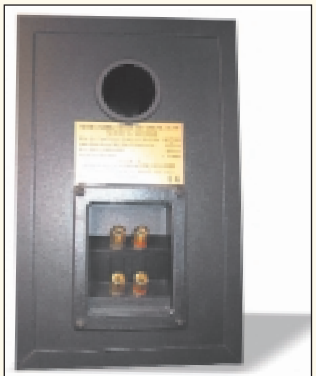
PHOTO 2: Back view.


PHOTO 3: Putting the woofer and tweeter drivers in place.

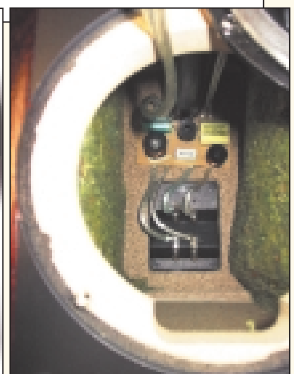
PHOTO 4: Cable connections inside the SL-60.

EQUIPMENT AND SETUP

We used a Nakamichi AV-1 receiver (100W/ch) and a Yamaha CDC 755 CD changer. While not a $90,000 analog tube setup, the fidelity is good enough to evaluate excellent loudspeakers.

The listening room is approximately 20′ × 18′ × 8½′ (3000ft^3), moderately damped with stuffed chairs, drapes, and carpet, and well-dispersed by numerous openings. Many other speakers sound excellent with this setup, including the Swans M1 ("Test Drive" in *SB* 3/99, p. 36). We mounted the SL-60s against a long wall, about 8′ apart, with tweeters at seated ear height (3″).

SOURCE MATERIAL

Per Ed Dell's request, we used the *Hi-Fi News and Record Review* Test Disc CD, tracks 2, 4, 5, 6, 7, 10, and 14. We also listened to a variety of other material we're familiar with, including:

- *Blue*, Le Ann Rimes, Curb D4-777821
- *Tango*, Julio Iglesias, Columbia/Sony CK 67899
- *Marches in Hi-Fi*, Fiedler/Boston Pops, RCA 09026 6149-2
- *Ocean Front Property*, George Strait, MCA MCAD-5913

To break in the unit, I applied a bass-boosted pink-noise signal, about 1W average, >10W peak for six hours.

THE KIRKSAETER SOUND

Unfortunately, it has one. With every piece of source material, both of us immediately and strongly noticed a suppressed upper midrange and an extremely bright treble response. Suspecting an out-of-phase tweeter connection, I reversed the bi-wired tweeter feeds. There was some reduction of the hollow "suckout" sound, but the same basic thin and tinny sound remained.

Next, I moved the speakers out into the room and noticed little difference (somewhat less lower bass, somewhat smoother mid-bass, but same basic character). So I replaced them against the walls.

SOME COMMENTS

1. Female voices sound 100′ away, no presence.
2. Male voices sound like marbles with a lisp.
3. Drums sound brittle, no solidity.
4. Saxophone sounds hollow, missing "warmth" harmonics.

Now, I don't mean to be unkind, but this pronounced tonality simply overwhelmed our experiences, making any good aspect, such as smooth extended bass (maybe 50Hz) and good imaging, difficult to appreciate.

5. Bass sounded smooth, well-damped, and extended to about 50Hz.
6. Stereo spread, soundstaging, and ambience were sometimes very good. The positioning of the narrator and instruments in "Peter and the Wolf," for example, was natural-sounding. But the exaggerated highs sometimes seemed to cause excessive stereo spread, particularly on *Marches in Hi-Fi*.
7. Distortion sounded excessive above moderate levels.

I think the drivers in this system are inherently good, with smooth response free of audible resonance. Also, the woofer response itself seems good. (We listened with the tweeters disconnected; what came out sounded normal for such a test.) Therefore, this speaker may be of interest to those who enjoy crossover design; the cabinet and drivers appear to be of sufficient quality to enable you to achieve high-quality sound with the right crossover.

COMMENT ON JOE'S MEASUREMENTS

I've never heard measurements speak louder!

1. The frequency responses are exactly what we heard.
2. The distortion anomalies (re other speakers) that Joe mentioned—both the high order of low-frequency IM and the broadband high-frequency "noise pedestals"—may have contributed to our rapidly developed sense of "ear fatigue," or intolerance of the sound.
3. The lower-midrange dip caused by wall mounting, while audible, didn't significantly change the speakers' basic tonality. Apparently the Haas (precedence) effect informs the ear as to a sound source's basic nature even with close reflections (in this case about 1ms). This shouldn't be surprising, since our hearing has over 120dB range, and can discriminate over 4000 discrete frequencies in less than 1 cycle of whatever frequency while separating dynamic spectral structures in as fast as perhaps 0.1ms.
4. In spite of the preceding, the speakers sounded most like Joe's wall-mounted frequency response; it's just that the wall-induced effect was nowhere as objectionable as the CO dip and extreme HF rise. So I fully agree that the single most significant indicator of loudspeaker sound quality is the direct, first-arrival, on-axis frequency response.

Other factors will influence the sound, of course, but nothing can completely conceal or compensate a significantly non-flat primary response. After all, the human race has been practicing sound-source-nature determination for many millennia. We're only here because some of our predecessors had developed the ability to hear quickly the presence of an approaching tiger; those who didn't quickly became cat food!

TECHNICAL DATA	SILVERLINE 60
Type of speaker:	Mini bookshelf-Satellite
Music peak power:	120W peak
Music impulse power:	80W peak to peak
Continuous power rating, DIN:	45W
Frequency response:	45-25,000Hz
Recommended amplifier:	20-40W
Crossover Frequencies:	2.500Hz, double 2-ways
Impedance:	4-8Ω
Woofer, long excursion:	15cm coated fiber cone
Midrange:	none
Tweeter:	25mm soft metal dome
Weight net:	5kg, 11 lb
Width × Depth × Height in cm:	19 × 25 × 29.5cm
Width × Depth × Height in inch	7.5″ × 10.5″ × 11.5″
Black/solid glossy Mahogany	Black/Mahogany décor strips