

# Rectilinear XI

## A LOW-COST BOOKSHELF SPEAKER SYSTEM FOR CRITICAL LISTENING

### Design Goals

The Rectilinear XI was designed to make available to critical listeners a budget-priced bookshelf speaker of genuinely accurate response and very low distortion, including low *time delay distortion*. The utmost simplicity of design was sought in order to eliminate unessential parts and keep labor costs down, as long as no compromise in performance would result. Particular emphasis was placed on high efficiency without loss of bass response, as well as on relatively constant impedance across the frequency spectrum. These characteristics were considered necessary to make the speaker compatible with receivers and amplifiers of moderate price and therefore of modest power output. The subjective listening quality of the Rectilinear XI was to be judged by the same standards as that of higher-priced speakers in the Rectilinear line.

### Basic Configuration

The Rectilinear XI is a two-way speaker system utilizing an extended-range woofer and an extended-range tweeter, both of the moving-coil principle. The cabinet is of normal bookshelf size but somewhat unconventional in that it is a tube-vented bass reflex enclosure instead of being completely enclosed.

### Woofer

The most sophisticated woofer ever used in a low-priced speaker system is the heart of the Rectilinear XI. Its diameter is 10 inches, which is optimum size for a two-way bookshelf speaker. The butylized cloth surround, in combination with the spider and voice coil construction used, permits unusually large cone excursions without distortion.

Since the operating range of the woofer is from 45 to 1800 Hz, provision must be made for unimpaired response far up into the midrange. This cannot be accomplished with a small-diameter voice coil driving a large diaphragm; therefore a large voice coil of 2-inch diameter is used. It is remark-

able that this massive bass driver approaches the lighter and more specialized midrange speakers used in three-way systems as far as lack of coloration and low time delay are concerned.

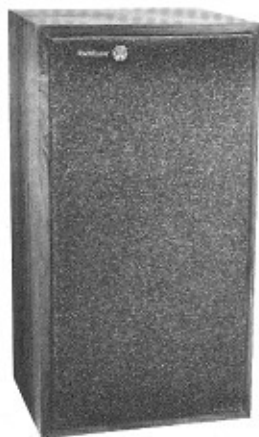
Since high efficiency is essential to the design concept of the Rectilinear XI, the woofer requires an unusually efficient magnet structure. The 1-lb. Alnico V slug used is probably the largest found on any 10-inch speaker. (Not to be confused with heavier but less powerful ceramic magnets.) An extra-long magnetic path is provided so that maximum electrical damping is applied to the moving mechanism. This results in unusually low distortion at high output levels, which is not an easy feat in a bass reflex design.

The response of the woofer begins to roll off naturally (i. e. mechanically) at 2000 Hz. This facilitates steep attenuation by means of an extremely simple crossover network.

### Tweeter

This is a 3-inch unit that covers the range from 1800 to 17,000 Hz, a span of more than three octaves. To avoid breakup at the bottom of this range requires a relatively large voice coil with a 9/16-in. diameter. Low moving mass is assured, however, by the special paper used in fabricating the cone and by the characteristics of the surround material. The resulting response is exceptionally flat, smooth and free from distortion. Total magnet weight is 8 oz. (including a 3-oz. ferrite slug).

FIGURE 1:  
Rectilinear XI in oiled walnut.



Rectilinear XI bookshelf speaker

## Crossover Network

The woofer and tweeter of the Rectilinear XI are crossed over at 1800 Hz, which is a highly exposed part of the audio range, not far from the point of maximum sensitivity of the average ear. This is unavoidable when no separate midrange driver can be used; however, the crossover network is so simple and so precisely tailored to the specific characteristics of the drivers that no discontinuity in response is audible.

The network elements consist of an air-gapped iron-core choke in series with the woofer and a capacitor in series with the tweeter. This makes it a quarter-section network with an electrical attenuation slope of 6 dB per octave in each direction. Actual attenuation, though, is not far from 18 dB per octave below the crossover point, since the latter was selected to coincide with the natural roll-off point of each driver. This is a case of eating your cake and having it, too: a sharp-cutoff crossover with a minimal network.

A wide-range tweeter level control is provided, accessible on a recessed panel in back of the speaker, so that the high-frequency output may be adjusted to suit the acoustic environment.

## Cabinet

The outside dimensions of the Rectilinear XI are 23" by 12" by 10½" deep. The cabinet is of extremely rigid one-piece construction, in ¾-inch stock, with heavily damped walls. It is filled with sound-absorbent material and the drivers are mounted from the front with silicone rubber (the same as used in the window seals of space capsules). The cabinet edge is only ¼-inch deep to eliminate diffraction effects. The finish is oiled walnut.

The enclosure is tuned for optimum bass response by means of tube venting, in a sophisticated application of the bass reflex principle. Bass reflex cabinets are seldom used in bookshelf speaker systems, but in the case of an unusually efficient speaker like the Rectilinear XI, this is the best technique for maintaining efficiency down into the low bass without roll-off. (In a completely enclosed cabinet, response would drop 6 dB from 120 Hz to the fundamental



**FIGURE 2:**  
*Rectilinear XI with grill cloth removed.*

resonance of 60 Hz. Or, alternately, mid-bass efficiency would have to be sacrificed.)

## Impedance and Efficiency

The nominal impedance of the Rectilinear XI is 8 ohms. As the curve in Figure 3 indicates, impedance never drops below 7.5 ohms, assuring that the speaker cannot overload solid-state amplifiers of limited power capability. Maximum impedance is at 65 Hz, where the woofer and tube-vented cabinet show a single impedance peak of 29.4 ohms. This relatively low figure is an indication of the excellent damping (low Q) of the bass reflex design used.

Efficiency is close to the ultimate achievable in a low-cost bookshelf system. Any amplifier capable of about 10 clean watts per channel will drive the speaker to window-rattling levels.

## Frequency Response

Although Rectilinear engineers strongly believe that there are more important speaker specifications than pressure amplitude response (the conventionally cited "frequency response"), the curve of the Rectilinear XI happens to be spectacularly flat. Figure 4 shows the results of a single uninterrupted frequency run taken from a single microphone position, rather than a misleading composite of the separate response curves of the woofer and tweeter. As can be seen, the slight rise in bass response is the only departure from almost amplifier-like linearity.

## Dispersion

The superior design of the tweeter and the shallow edge of the enclosure assure an excellent radiation pattern right up to the highest frequencies. Dispersion is wide enough to make high-frequency transients fully audible off axis, without loss of quality.

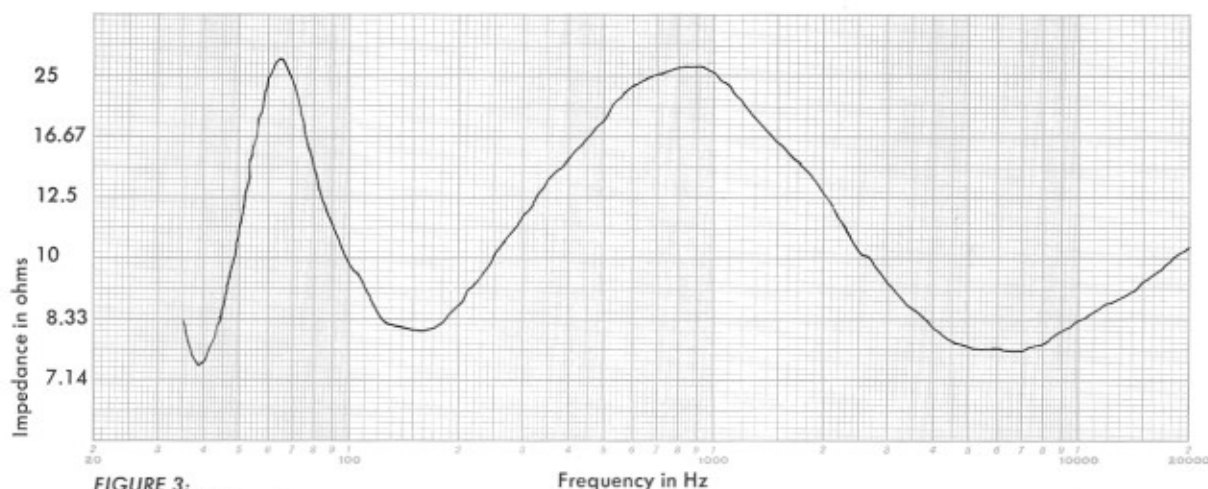


FIGURE 3:  
Rectilinear XI impedance.

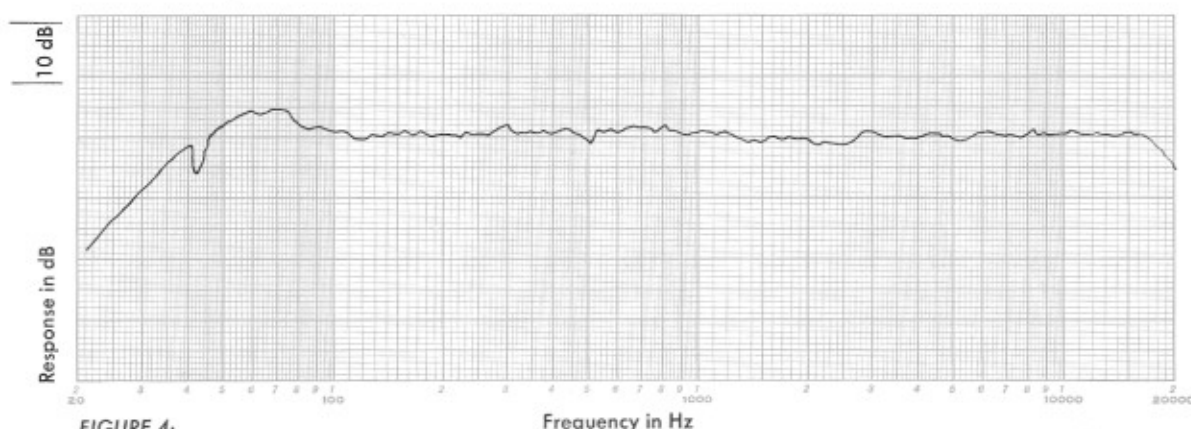


FIGURE 4:  
Rectilinear XI frequency response on axis; tweeter control turned up to maximum.

Frequency of fundamental	50 Hz	60 Hz	70 Hz	80 Hz	500 Hz	1100 Hz	3500 Hz	5000 Hz	7500 Hz
2nd harmonic distortion	1.8	1.4	1.0	2.2	*	0.18	0.04	0.12	0.19
3rd harmonic distortion	1.1	1.8	0.4	0.9	0.32	0.13	0.32	0.28	0.13
4th harmonic distortion	0.56	*	*	*	*	*	*	*	*
higher harmonics	*	*	*	*	*	*	*	*	*

\*negligible

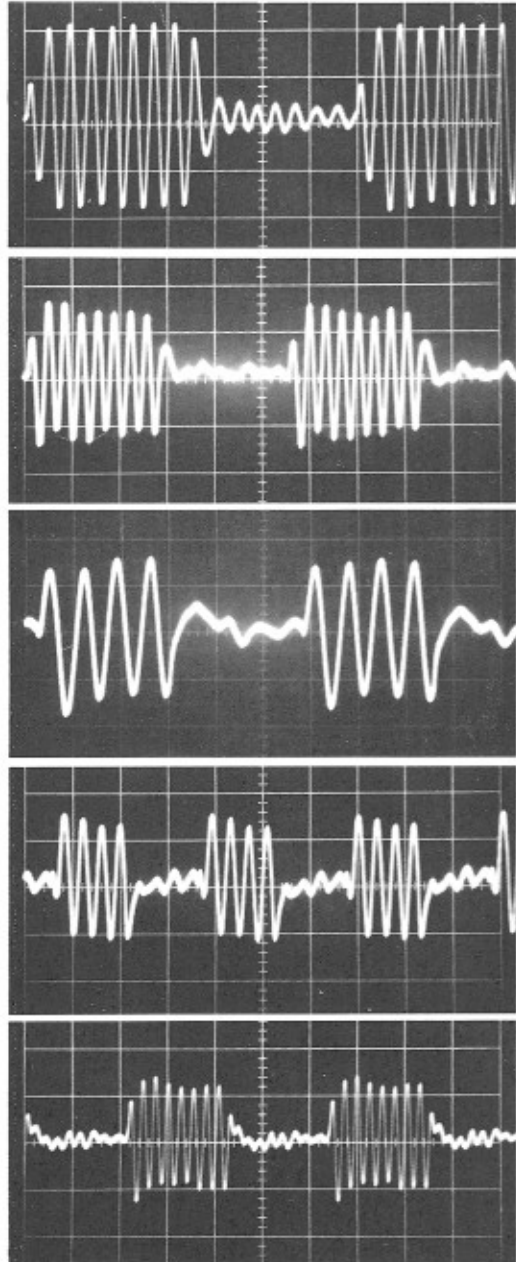
FIGURE 5:  
Harmonic distortion in %, with 1 watt input.

## Harmonic Distortion

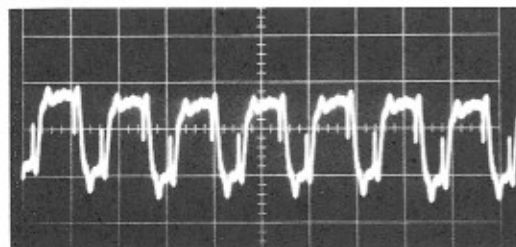
The chart in Figure 5 gives a complete harmonic analysis of spurious response with a fundamental input of 1 watt at key frequencies. This is a more revealing specification than total harmonic distortion expressed in a single figure. Since 1 watt of actual program material produces an extremely loud level through an efficient speaker like the Rectilinear XI, the percentages shown indicate virtually nonexistent distortion.

## Transient Response

The tone-burst photographs in Figure 6 are proof that the Rectilinear XI reproduces transients with outstanding fidelity and freedom from ringing throughout its frequency range. However, an even more severe test of transient performance is the reproduction of square waves, usually reserved for testing amplifiers. The square wave photograph in Figure 7 would be considered mediocre for an amplifier but is little short of astonishing for a speaker.



**FIGURE 6:**  
Tone-burst tests for transient response and ringing.  
(From top to bottom) 75 Hz, 150 Hz, 300 Hz,  
1200 Hz, 7500 Hz.



**FIGURE 7:**  
Reproduction of 350 Hz square wave.

### Time Delay Distortion

It is becoming increasingly apparent that phase response (phase angle plotted against frequency) is a more significant criterion of speaker performance than what is ordinarily called frequency response

(pressure amplitude plotted against frequency). Between two reasonably advanced speaker systems, the one with the better amplitude response is not necessarily the one that sounds better (i.e., more natural or lifelike). But the one with the better phase response will be almost invariably preferred by the critical listener.

Superior phase response is dependent on low time delay distortion. Time delay distortion occurs when a speaker does not produce an acoustical output the instant an electrical input is applied to it. There is a measurable split second of delay between input and output. The delay is nearly always frequency-dependent, being greater at low frequencies as a result of higher inertial mass. The consequent disturbance of phase relationships is now suspected to be the chief cause of "canned," unnatural speaker sound.

All speakers produce some time delay distortion, but the Rectilinear XI is superior in this respect to any other two-way system. The tight acoustic coupling of the woofer, the simplicity of the crossover network and the unusually low mass of the tweeter all contribute to outstandingly low time delay figures throughout the frequency range.

### Summary of Specifications

Size:	23" by 12" by 10½" deep
Drivers:	10" woofer, 3" tweeter
Crossover Frequency:	1800 Hz
Nominal Impedance:	8 ohms
Minimum Power Requirement:	10 watts rms
Maximum Power Handling Capacity:	70 watts IHF music power
Frequency Response:	45 to 17,000 Hz, ±3 dB
Time Delay:	woofer, 0.7 to 1.0 millsec.; tweeter, better than 0.1 millsec.
Control:	tweeter level
Connection to Amplifier:	choice of binding posts or banana jacks
Cabinet:	oiled walnut
Shipping Weight:	28 lbs.
Price:	\$69.50

RECTILINEAR RESEARCH CORPORATION  
107 Bruckner Boulevard  
Bronx, N. Y. 10454