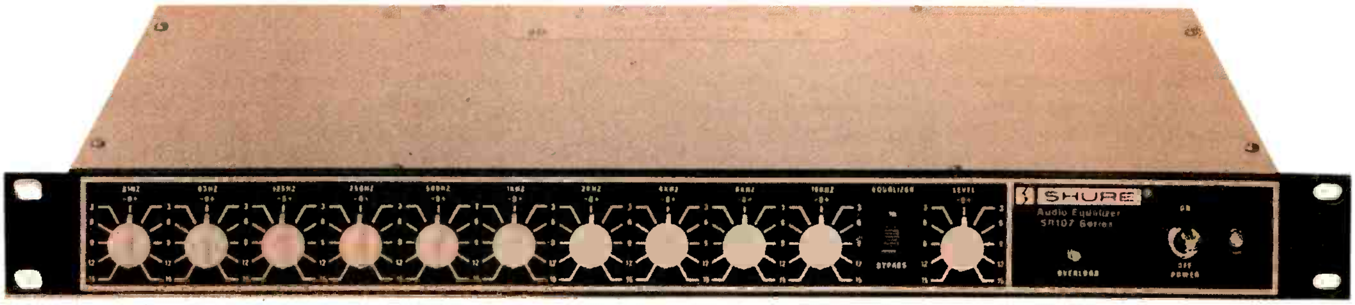
Equipment PROfiles

Shure Model SR107 Audio Equalizer



MANUFACTURER'S SPECIFICATIONS

Frequency Response: 30 Hz to 20 kHz, ±2 dB.

Signal-to-Noise Ratio: 99 dB.

Output Noise: −84 dBV, 300 Hz to 20 kHz.

Hum & Noise: −83 dBV, 20 Hz to 20 kHz.

Clipping Level: +18 dBm.

Impedance: Input, 70 kilohms, balanced bridging; line output, 115 ohms actual, balanced.

Harmonic Distortion: 1 per cent maximum at +12.2 dBm.

Filter Center Frequencies: Accurate within ±10 per cent.

Filter Boost/Cut: ±15.5, ±2 dB maximum at center frequencies.

Dimensions: 19 in. (48.3 cm) W x 1¾ in. (4.4 cm) H x $8\frac{9}{16}$ in. (21.8 cm) D.

Weight: 7.8 lbs. (3.5 kg).

Price: $250.00.

The Shure SR107 octave-band audio equalizer is a single channel device designed primarily for professional applications. The unit is one of the Shure SR professional audio products, and it is made for rack mounting and requires just 1¾ inches of height. The 10 filters are centered on standard ISO frequencies from 31.5 Hz to 16 kHz, and each of the filters can be knob adjusted over a range of ±15 dB. A front-panel also has the *Equalizer In/Bypass* and power *On-Off* switches and a peak-responding LED indicator. On the back panel are the input and output connections, a gain control, and accessory power jacks. The input is at line level in a balanced, bridging configuration. Connection can be made with either a three-pin (XLR-type) or three-circuit phone plug. One side of the balanced line can be grounded in the plug, or elsewhere externally, for unbalanced operation. *Gain* has an adjustment range from unity to +20 dB voltage gain to accomodate various input/output requirements and is effective whether the equalization filters are switched in or not. There are three outputs: *AUX* on a two-circuit phone jack which is an unbalanced low-impedance output, *Line* is a balanced output on a three-circuit phone jack and also switch selectable to a 3-pin male XLR-type socket, Mike is a balanced microphone-level output on the same socket with the *Mike/Line* switch in *Mike*. There are also jacks to provide accessory power of 27 V d.c. at up to 10 milliamperes. This can be a very handy feature for use with special add-on circuits, including some of the Shure accessories.

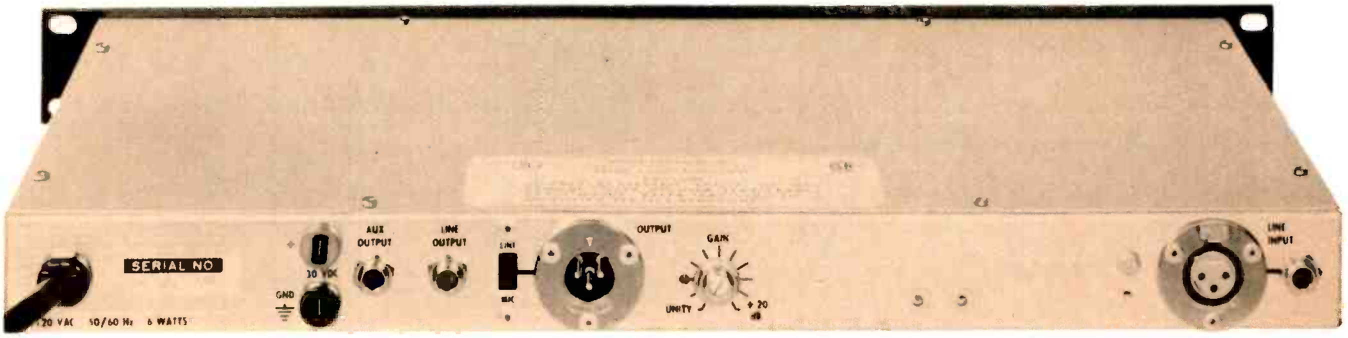
The box enclosure for the circuitry is one piece with the exception of the attached front panel and the top cover, which can be easily removed for any maintenance needs. The majority of the components are on two PCBs. The soldering was generally excellent, although some flux residue was noted.

Circuit Description

The input signal is fed through a stepdown transformer which introduces a 6-dB loss. The following attenuator provides an additional loss ranging from 11 to 26 dB, corresponding to settings of the *Level* control from zero CCW to −15 dB. The following input amplifier has a gain of anywhere from 14 to 34 dB, dependent upon the setting of *Gain* on the rear panel. Two cascaded differential amplifier stages comprise the boost and cut circuitry. Each of the amplifiers is connected to five of the 10 active gyrator resonators. These octave-spaced filters can be controlled over a ±15 dB range with front panel knobs. The configurations are minimum phase for good combining and minimum ripple. The *Level* control, referred to earlier, also provides up to ±15 dB voltage gain when turned CW from zero. This varies the gain of the output amplifier from +5 to +20 dB. By having the level control act at two different points, a total of 30 dB of gain change is obtained with minimum noise and reduced likelihood of overload. This is a good design approach, and Shure deserves credit for it. The bypass switch removes the equalizer filters from the signal path and disconnects the level control. In either mode, the output amplifier drives the output transformer which has mike and line-level taps, the *AUX* output through a fixed attenuator, and the driver for the LED overload indicator.

Performance

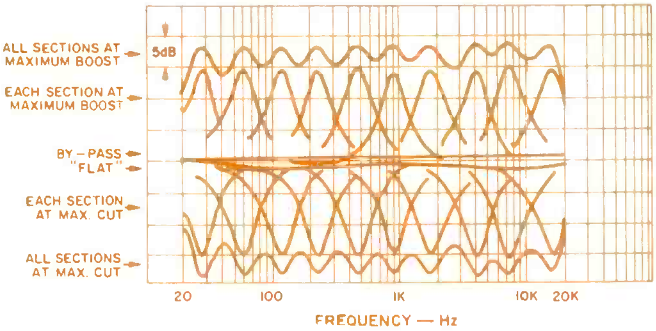
Swept-frequency responses were taken of the SR107 under various conditions. The first plot was made with the unit in *Bypass*. Then, with the equalizer switched in, all filter sections were adjusted for a zero-dial indication, and another plot was made. There were some discrepancies from the ruler-flat response of the first run, but the spread of deviations was small and not significant. The next series of sweeps were made with each filter section in turn set to maximum boost, and then to maximum cut. Finally, plots made with all filters at maximum boost and then at maximum cut. The maximum boosts and cuts for the individual sections were consistently close to ±15 dB. With all filters at the maximums, the ripple was about three dB. This was good for an octave-spaced equalizer, demonstrating the combining characteristics of the



minimum phase design. The center frequencies of all of the filters were within 8.0 per cent of the standard ISO frequencies, and the great majority within 5.8 per cent. The unit, therefore, easily met the specified 10 per cent which is adequate for such purposes. To show some of the variations possible with such an equalizer, six of the filters were adjusted in three dB steps up to the maximum. The 63 and 125 Hz and 4 kHz sections were boosted and the 500 and 1000 Hz and 16 kHz sections were cut. Note that when two adjacent filters are boosted or cut, ripple first appears at about ±9 dB. There is also somewhat greater action than with a single section because of the combining effect.

To get more of a feel of the capability of the equalizer, a "room-like" response was created. The 20 Hz to 20 kHz sweep was modified with a 1/3-octave equalizer to introduce purposeful roughness, including a crossover-like notch at 800 Hz and a peak around 6.5 kHz. It was impossible for the unit to remove all of these worst-case variations, but the spread from maximum to minimum had been reduced from close to 15 dB to less than 9 dB. The peaks in the curve had been made much more even, and the pink-noise energy in each octave band was much more equal. The sweep made of the SR107 itself with the settings used shows that extreme measures were not used. The earlier figure with variations in boost and cut settings had shown the narrowing of the filter responses with increasing amounts of boost/cut, characteristic of such equalizers. Simple calculations gave values of filter *Q* less than 1.0 at +5 dB and more than 2.5 at +15 dB. Roughly, filter *Q*= Center Frequency/3-dB Bandwidth. *Q*, therefore, increases with reductions in bandwidth for a constant center frequency. A 500-Hz square wave was fed to the equalizer with the 2- and 4-kHz filters at +6 dB. The scope photo shows the initial high overshoot with fairly fast damping, but the true value is just reached as the waveform steps to opposite polarity. The indications are that ringing is quite close. A 200-Hz square wave showed obvious ringing on the output when the 4-kHz filter was boosted to +10.5 dB. The waveform is modified when this filter is set to −10.5 dB, but there is no ringing. The results shown here are those to be expected with any equalizer that exhibits the same filter *Q*.

Fig. 1—Frequency responses of the Shure SR-107 equalizer.



The harmonic distortion was measured with the specified 3.2 V output, all filters at +15 dB, and the *Gain* and *Level* controls both at maximum. This certainly must be classified as a worst-case condition, but the SR107 easily met the specified 1 per cent anywhere from 30 Hz to 20 kHz. The 2nd harmonic was the highest level product, reaching a maximum of 0.3 per cent at 30 Hz. Typically, the 2nd harmonic was just over 0.1 per cent at this high level. The 3rd harmonic was also a maximum of 0.3 per cent at 30 Hz, but was around 0.03 per cent for the majority of the frequency range. With the input signal lowered to reduce the output voltage to 1.0 V, the relative distortion was reduced measurably with a number of readings less than 0.03 per cent. With 3.2 V out, the IM distortion was 0.145 per cent, much less than the specified 0.25 per cent. With 5-dB less drive, the IM distortion dropped to a low 0.04 per cent. The signal-to-noise ratio with a 20 Hz to 20 kHz bandwidth (unweighted) was 83 dBV (relative to 1.0 volts), and 99.8 dB relative to the measured 6.9 V clipping level. This is a bit better than the specified 99 dB, and certainly excellent performance with this unweighted measurement. Actually, the A-weighted figure was almost exactly the same as most of the noise energy was contained in the highest frequencies.

The checks on noise levels had to be made with great care because some of the specified levels were below those of the instrumentation normally used for filtering. The figures in Table I are given in both "mV" and "dBV" which is the decibel value relative to 1.0 V. Note that on a voltage basis, the dBm reference is 2.2 dB lower, being 0.775 V.

Table I—Noise levels.

	Output Noise, 300-20 kHz		Hum & Noise, 20-20 kHz	
Conditions	Spec.	Meas.	Spec.	Meas.
Controls at zero,	−84 dBV	−84.8 dBV	−83 dBV	−84.7 dBV
Unity gain	0.063 mV	0.058 mV	0.071 mV	0.058 mV
Level control at +15 &	−69 dBV	−70.7 dBV	−67 dBV	−69.2 dBV
Filter controls at −15	0.50 mV	0.29 mV	0.56 mV	0.35 mV
Equalizer switched to	−91 dBV	−89 dBV	−88 dBV	−89 dBV
bypass	0.028 mV	0.035 mV	0.040 mV	0.035 mV

Table II—Voltage gains to the three outputs.

	Gain-to-Line Output, dB		Gain-to-*AUX* Output, dB		Gain-to-Mike Output, dB	
Gain Setting	Spec.	Meas.	Spec.	Meas.	Spec.	Meas.
Zero	0	0	−27	−26.8	−50	−49.5
+20 dB	+20	+19.7	−7	−7.1	−30	−29.8

These excellent results show that the demanding specifications were exceeded in the performance tests with one minor exception. In bypass mode, the noise in a 300-Hz- to-20-kHz bandwidth was measured to be 35 microvolts instead of the specified 28 microvolts, a difference of less than 10 microvolts. The voltage gains from the line input to the three outputs were measured for *Gain* settings of zero and +20 dB; these are shown in Table II.

All input and output impedances were found to be very close to the specified values. The input impedance is a

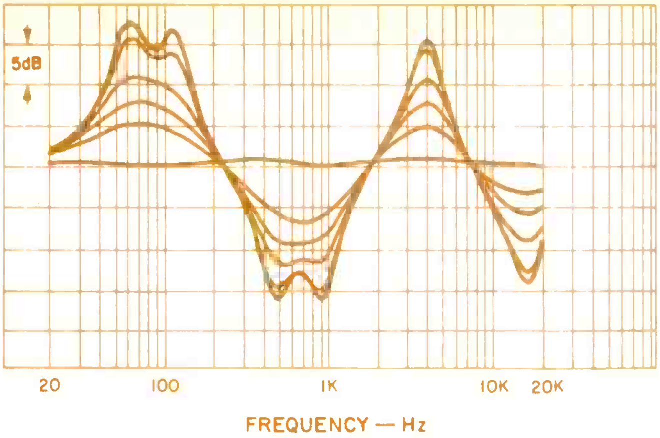


Fig. 2—"Flat" response and the settings of 3, 6, 9, 12, & 15 dB for 63 and 125 Hz (+), 500 and 1000 Hz (−), 4 kHz (+), and 16 kHz (−).

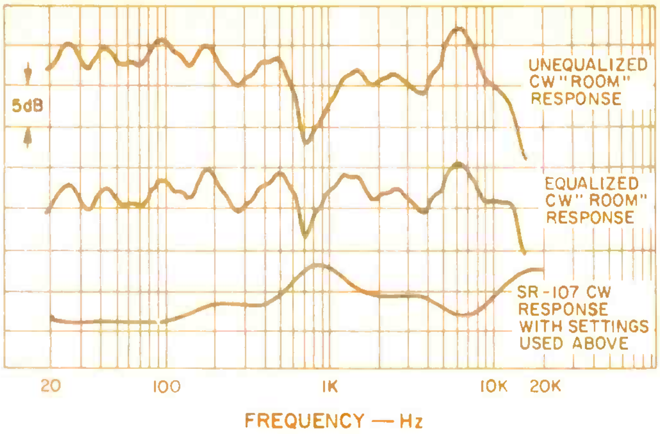


Fig. 3—Equalization of room-like response.

balanced 70 kilohms for balanced bridging from sources of 10 kilohms or less. The *Mike*, *Line* and *AUX* output impedances are 1.0, 115, and 630 ohms respectively, for use with 25- to 600-ohm mike-level inputs, for use with 600-ohm lines, and for use with unbalanced auxiliary circuits of 600 ohms or more, respectively. The *Level* control provided an additional dB of gain control at each end beyond the specified ±15 dB. Clipping first appeared at 6.9 V (+19 dBm) at the *Line* output, 0.35 V at the *AUX* output and 25.4 mV at the *Mike* output. The clipping was very symmetrical, and the measured levels were all higher than the spec. The overload indicator turned on 2.9 dB below clipping with a 1.0-kHz test tone. The response time was fast enough to show at least a flicker to a single-cycle 10-kHz tone burst just at clipping level. The overload detector was not polarity sensitive, a good feature.

In Use Tests

The Shure equalizer was mounted in a portable rack along with other sound reinforcement equipment for use in a public auditorium. The small, 1¾-inch height made it possible to carry some extra items that would have been pushed out by a

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Filter Boost, Q, and Ringing

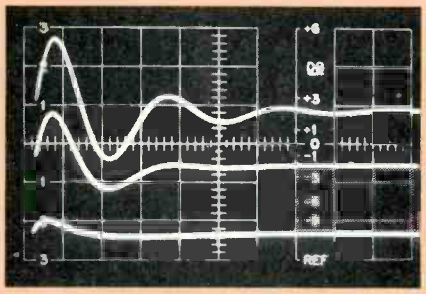

Fig. 1—Equalizer output with a 500-Hz square-wave inut, with the 3600 filter at +4 (bottom), + 8 (middle), and +12 dB (top).

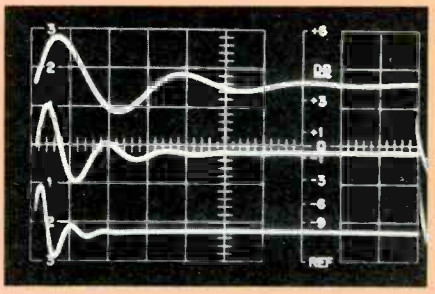

Fig.2—Equalizer output with 170-Hz square-wave input with a 12-dB boost successively in 1800- (top), 3600- (middle), and 7200-Hz filters.

It is common practice to refer to equalizers with filter center frequencies one octave apart as octave-band equalizers. The level changes, however, are not equal across the width of the octave, and the responses become more and more pointed with more boost (or cut). If the bandwidth changes as the boost (or cut) is varied, then the filter cannot be simply specified as having a certain bandwidth. On the other hand, filters used in many analyzers have flat tops out to the roll-offs at the ends of the bands, and the filter slopes are typically 24 dB/octave or greater. An analyzer's octave-band-filter half-power (−3dB) points are always one octave apart.

If we define the response of a filter as a percentage of an octave, then we can express the bandwidth thus: $BW_{oct} = BW_{Hz}/0.707 \times f_{ctr}$. For example, a true octave-band filter with a center frequency of 1000 Hz would have a 707 Hz bandwidth, i.e. from 707 to 1414 Hz. Filter bandwidth can also be stated in terms of Q, or Quality Factor. From the ANSI standard for acoustical terminology: "The quantity Q is a measure of the sharpness of resonance or frequency selectivity of a resonant vibratory system having a single degree of freedom, either mechanical or electrical." In the following notes appear two statements which will aid in the discussion below. "Q is approximately equal to . . . .(3) $2\pi W/\Delta W$, where 'W' is the stored energy and 'ΔW' is the energy dissipation per cycle, and (4) $f_r/\Delta f$, where 'f_r' is the resonance frequency and 'Δf' is the bandwidth between the half-power points."

From the above, we can see that $Q = f_{ctr}/BW_{-3\ dB}$. With a simple arithmetic manipulation, we can see that $Q = 1.4/BW_{octaves}$. A one-octave filter, therefore, has a Q of 1.4. Many filters are resonant systems, and the value of Q tells us what to expect. Critical damping, where there are no oscillations in the response to a step input, occurs when $Q = 0.5$. If Q is greater than 0.5, there will be at least some oscillation. The larger Q is, the less damping there is, and the longer it will take for the oscillations to die away.

Note (3) above tells us that high Q is associated with low energy dissipation per oscillation cycle, for it is the damping that uses up the resonating energy. It may be difficult for the reader to think that a multi-band equalizer might be a collection of resonators. Indeed it will be, however, regardless of design particulars, if and when filter responses are

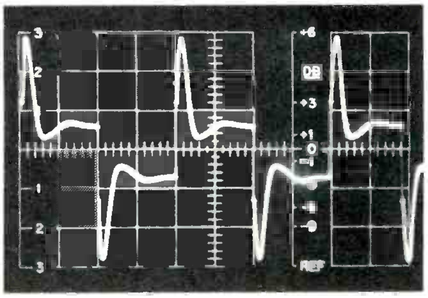

Fig. 4—Equalizer output with a 500-Hz square-wave input and the 2- and 4-kHz filters at +6 dB.

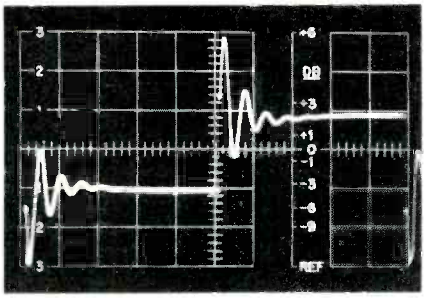

Fig. 5—Equalizer output with a 200-Hz square-wave input with the 4-kHz filter at +10.5 dB.

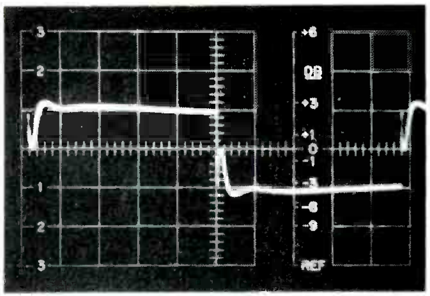

Fig. 6—Equalizer output with a 200-Hz square-wave input with the 4-kHz filter at −10.5 dB.

larger unit. With the multiple input/output options available, interconnections were easily made and changed as desired. This capability is one of the more useful features of the SR107. The equalizer gains were set to match the other equipment in the system. Initial equalization was done using pink noise. Mike gains were increased to the point of feedback, with a compressor used to keep power output at a low level. Some suppression was secured with the Shure unit with a slight increase in available gain. Greater suppression was possible, but only with an unacceptable loss in system response. During the performance, some readjustment was made to filter settings, further improving the sound. There is an appeal to the graphic-type display of many equalizers, and the first reaction to the SR107 knobs and rotary controls was negative. In practical use, however, adjustments are made to get the best sound, not to make the front panel look like a response curve. My own choice goes with Shure's design . . . rotary controls to keep rack height at a minimum.

The instruction book is completely professional in character, consistent with the equalizer itself. Specifications and operating instructions are well detailed. The coverage of applications is thorough, and the service and circuit information is excellent. The Shure SR107 10-octave filter-equalizer delivers excellent performance with professional construction and interfacing capability, all at a good price. The limitations mentioned in the text are generic in nature, not SR107 discrepancies. *Howard A. Roberson*

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peaked causing high *Q*s. These considerations tell us that even octave-band filters (*Q* = 1.4) may resonate, or ring, with step-type inputs. If a filter is boosted to where the bandwidth is 1/3-octave, the *Q* will be over 4, a good condition for sensitivity to ringing. The ringing will be at the filter center frequency, dissipating the energy stored in the filter from the input signal. On the other hand, the boosting used may correct deficiencies elsewhere in the total system with a better overall result.

A series of tests were run on a well-known "octave-band" equalizer to demonstrate the point made above. The first photo shows the output of the equalizer with a 500-Hz square-wave input. Just the top of the waveform is shown to provide more detail on ringing effects. The filter centered at 1800 Hz was boosted to +4, +8, and +12 dB, and the results are shown at the bottom, middle, and top, respectively. The start of ringing is quite apparent with +8-dB boost, and lasts most of the square-wave cycle with +12 dB. There is also an increase in the amplitude of the overshoot at the leading edge with higher boosts. In the next illustration, a 170-Hz square wave was the input signal, and +12-dB boost was set one at a time on the 1800-, 3600-, and 7200-Hz filters. The results are shown from top to bottom, with ringing obvious in all cases. Note that the ringing is shorter in time as the filter frequency is increased, but that it takes the same number of cycles for the oscillation to die away. This is consistent with the earlier discussion on the relationship between Q and the energy dissipation per oscillation cycle. As each of the filters has the same Q, the dissipation rate (per oscillation cycle) is the same. The third photo shows the entire waveform of a 270-Hz square-wave output with a +12-dB boost on the 1800-Hz section. The oscillation is being damped, but it continues to the end of each step in level. In other words, the ringing is continuous. With the boost reduced to +7 dB, the settling is quite rapid.

There are a number of conclusions to be drawn from the discussion and the test results. First of all, the typical equalizer must be used with considerable caution if boosts greater than a few dB are desired. Do not try to use a multiband equalizer to correct for room response deficiencies, crossover notches, or other holes. Trying to boost "nothing" could generate a ringing with certain input signals. Put the emphasis on reducing unwanted peaks elsewhere in the system. Then, some boost can be used judiciously for the best total system response. Use your ears to aid in getting the best overall filter settings.

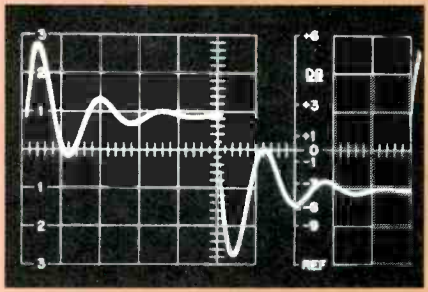

Fig. 3—Equalizer output with 270-Hz square-wave input with the 1800-Hz filter at +12 dB.

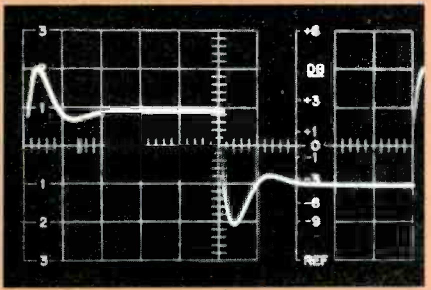

Fig. 4—Equalizer output with 270-Hz square-wave input with the 1800-Hz filter at +7 dB.

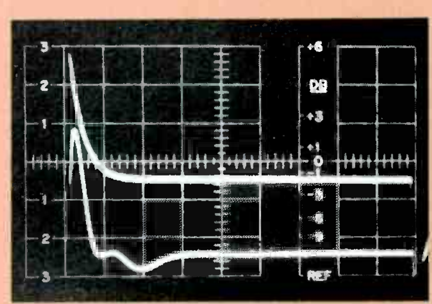

Fig. 5—Preamp output (top) with 1-kHz square-wave input and a +10-dB boost at 10 kHz with the tone control. Equalizer output (bottom) with the 1-kHz square-wave input and filters set to match the preamp frequency response.