The New Golden-Ear Amplifier

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In Two Parts—Part 2

Continuing the description of the complete amplifier installation by discussing the design and construction of the preamplifier and the tone-control sections.

THE PRE-AMPLIFIER AND CONTROL UNIT used with the new Golden-Ear amplifier differs from conventional in several respects. First, 1.5 volt miniature battery type pentodes with d.c. on the filaments are used in the phono-preamp; second, feedback with practically no frequency boosting function is applied over the first stage and directly to the pickup; thirdly, the tone control circuit, through perhaps over-elaborate for normal use, is extremely flexible and provides direct boosting of treble and bass and narrow-band interference elimination; and, finally, the arrangement of volume and tone controls is such that with no special devices, tone compensation is automatically achieved with variations in volume level.

Description

A pair of 1U5's with d.c. on the filaments is used in cascade for the phono pre-amp, *Fig.* 5. The filaments are in series and the 3 volts d.c. is supplied by a rectifier fed by a 7-volt filament winding. Contact-potential bias is employed and deposited carbon resistors are used for the bias resistors, the plate loads, and the loading resistor for the magnetic pickup. As a result of these measures the noise level is very low.

Between 6 and 10 db of feedback is applied from the output of the first tube to the pickup. This further reduces the noise level, and damps the pickup, leveling the response and reducing resonant peaks. The time constant of the network is proportioned to produce bass boost below 50 cps. It is difficult to obtain sufficient bass boost at 25 or 30 cps with a single bass-boosting network. The 6 db boost at 30 cps produced by the feedback, plus that of the normal equalizer, produces a very satisfactory response and yet results in a much lower hum-level (given a low-rumble turntable) than with conventional circuits. The total noise—thermal and hum—is reduced bv these measures to less than 10 microvolts or more than 40 db below the output of a GE pickup. We never seemed to be troubled much by hum with the old reliable 6SC7 in the GE circuit; but the new preamp was a revelation, although its unmasking effect makes record scratch, as well as wanted increments of music, more evident.

The equalizing networks *Fig.* 6, are of the interstage type developed by Boegli and use his constants. A choice of six curves is available. The total gain of this phono-preamp is in excess of 500, after feedback, which is fairly comparable to that of the 6SC7 and sufficient in this case since additional amplification is available in following stages. Another VR tube is used to decouple and to reduce hum of the power supply, in the plate-supply line to the 1U5's.

The phono preamp is constructed on a separate sub-chassis and mounted with rubber shock absorbers on the pre-amp chassis. The equalizer elements for each curve are mounted inside bakelite tubes, sealed, and the switch is mounted directly adjacent to the sub-chassis to provide short leads.

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Tone Control Circuit

The prototype amplifier contains a two-channel mixer with a choice of five inputs, through push-buttons, for each channel, as indicated in *Fig.* 7. For average home use, however, a single channel with a single switch will no doubt suffice and in that case one volume control and both 0.47-meg isolating resistors can be eliminated. Miniature tubes are used throughout to minimize Miller effect. The plate load of the mixer and of the following stages is made low to flatten the response curve, and degeneration is provided by eliminating cathode by-pass capacitors in the straight-through stages, V_1 and V_2. The preamp contains a two-section filter (in addition to the two-section filter in the power supply) for decoupling and for hum elimination, and in consequence the hum level is very satisfactory, despite the absence of cathode by-pass capacitors.

The tone-control section is somewhat unusual and consists of five parallel amplifiers. The first, or upper section, is a reference or straight-through channel and is proportioned to provide as flat a response as possible over the whole range. The volume control in this channel is the master volume control and, as we shall see, provides automatic tone compensation.

The next two sections, V_3 and V_4 are the bass and treble boost sections. The frequency discriminating network is of the Wien-bridge type. This type yields a peaked, resonant curve, rather than a mere high-pass or low-pass slope. The peak is broad but the slope beyond ½- and 2-times resonance is at approximately 6 db per octave. The resonant peak is determined by the formula $1/2\pi RC$, and can be changed by changing the values of either the capacitors or the resistors or both. In the prototype amplifier the capacitances are switched in each channel to provide a total of six peaking points in each channel—30, 60, 100, 300, 400, and 800 in the bass channel, and 1000, 2000, 4000, 8000, 16,000, and 30,000 cps in the treble channel. This is useful for experimental, measurement and laboratory purposes, but for ordinary home use a single curve will suffice. The values given yield excellent results and provide an important dividend.

The upper three channels are paralleled in the output and fed to one side of the

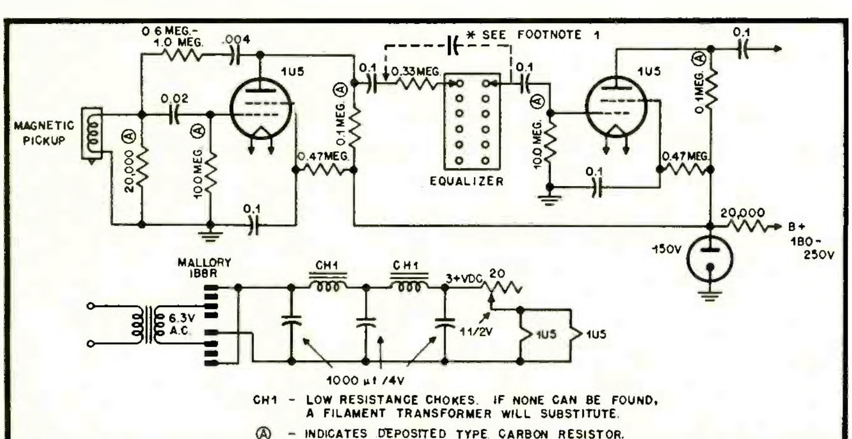

Fig. 4. Phonograph preamplifier and associated filament power supply.

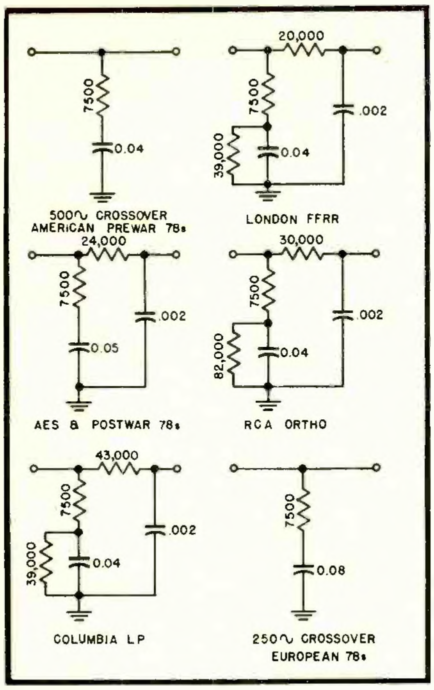

Fig. 5. Interstage equalizer networks used in the phono preamp.

cross-coupled input of the Golden-Ear amplifier. Because of this parallel arrangement the boosting is direct and (subject to the qualification noted below) independent of the volume level of the unequalized range. In other words, if the output lacks bass, the bass control is turned up, the bass is increased with no necessity for changing the volume control. The equalization curves have a slope on the far side of the peak, reducing the likelihood of aberrational operation which results when, for instance, such transients as the very-low-frequency wave form of a fading short wave signal, are boosted together with the wanted bass.

The analytical mind, however, will discern that the amount of boost is dependent on the setting of the volume control in the master or reference channel. Assuming equal amplification in the three sections, the maximum boost at each end when the tone controls and the reference volume control are maximum is about 6 db; but can be 20 db or more when the master or reference control is near minimum. This fact is, therefore, exploited to provide automatic tone compensation with changes in volume level. With the values given in the diagram, this compensation complements the Fletcher-Munson curve closely enough for very pleasing results. If twin-triodes are used, the cost of this type of tone control is little or nothing more than that of the conventional arrangement, because the direct boosting eliminates the need for additional amplification to make up for insertion loss, and because the cost of a compensated loudness control is eliminated. It might be pointed out that if the "loudness control" effect is not desired, equalization can be maintained with changes in volume level simply by leaving the loudness control in a near-minimum position and regulating volume at the tuner or mixer.

In any event, the result is an extremely useful and flexible tone control circuit.

To give the boost channels higher gain, they are provided with a higher plate load and the cathode resistor is bypassed. More than 20 db of boost is available between 30 and 50 cps, and more than 15 db between 15.000 and 20,000 cps with very little effect on the mid-frequency range.

The Attenuation Channels

The attenuation channels, V_5 and V_6 make use of the differential qualities of the cross-coupled inverter. If in-phase signals are fed to both grids of the Golden-Ear amplifier, cancellation will occur at the points of no phase difference and equal amplitude. The two attenuation channels are fed from the same source and operate under the same parameters (except for the frequency-discriminating network) as the reference channel; therefore, the output is of the same phase. If this output is then fed to the lower grid of the cross-coupled inverter, that portion of the signal which is in phase is attenuated and that portion which is both in-phase and of equal amplitude is completely nulled.

This phenomenon offers interesting possibilities which the author is just beginning to explore. We have never found much use for the usual type of rolloff attenuators. If the program source is good and properly equalized, and if the main amplifier is distortion free, there is no need for rolloffs. But there is one problem in high-fidelity reproduction which has always needed a good solution—and that is the minimization or elimination of certain interferences, such as the 10,000-cps beat note on the broadcast band; heterodynes on the short-wave bands; hum and turntable rumble in phonograph reproduction; line-hum in network programs, etc. The two lowest channels in the tone-control circuit represent an attempt to deal with these interferences. So far the attempt, though still in the experimental stage, is very promising.

The high-frequency channel works better than the low frequency channel because at these frequencies the parameters can be varied more easily. The .65-henry choke and the miniature 400-μμf variable capacitor form a series resonant circuit with a resonant point which can be varied from about 3000 to 12,000 cps. Because the Q of the circuit is high the resonant curve is sharp and steep. The phase shift is fairly complementary to that of the reference channel and excellent attenuation effects are obtained. The effect is that of steep rejection notches rather comparable at audio frequencies to the rejection notch of a crystal filter at radio frequencies. Single-tone heterodynes or narrow bands of interference—such as monkey chatter—can be completely eliminated by tuning the resonant circuit to the frequency of interference and adjusting the rejection control (volume control in this channel) until the interference is nullified. The 10,000-cps adjacent channel beat note can be eliminated in

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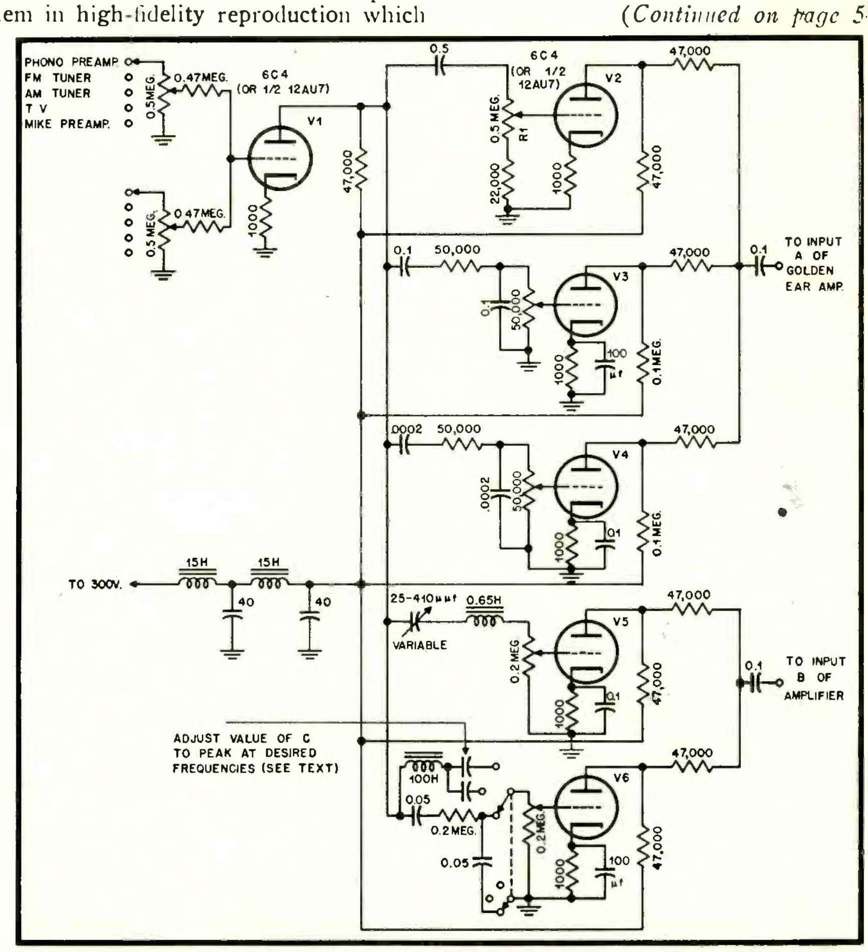

Fig. 6. Tone-control or mixer-equalizer section.

this manner with very little effect on the audio frequencies below 8000 cps. Similarly, beat notes within the 3000 to 12,000 cps range are also nullified with an aberrating effect on the rest of the spectrum small enough so that the over-all effect is a great improvement.

It is somewhat more difficult to achieve comparable results at the low end of the audio range because the size of inductors and capacitors becomes too great for easy variation. We intend to fit a variable inductor of about 100 henries with a knob control; meanwhile, in its absence we resonate the circuit with parallel capacitances by cut and try methods. Though our experiments are still limited, they indicate that 60-cps hum can be nulled with relatively little effect on the rest of the bass spectrum, if the inductor is of sufficiently high Q. Similarly, turntable rumble can be minimized—once the resonant frequency is found—with less attenuation of the rest of the bass, than with rolloff attenuation. For general rolloff below 50 cps a Wien bridge filter resonant at 10 cps is switched in. This produces good nulls of interference below 40 cps with little attenuation above 50 cps. No values are given for the inductor-capacitor combinations since they will have to be determined by cut and try methods in any case. The two positions for 60-cps hum and for turntable rumble, can be worked out empirically with whatever inductor is at hand.

We repeat that our experience with this method of nulling interference is still limited; but the results are promising and the circuit is commended to other experimenters for additional investigation. This method of control does produce some distortion, but it is by no means as great as that produced by band-elimination filters inserted directly in the signal channel.

For maximum decoupling and best over-all transient response the preamplifier is fed from a separate power supply rather than from that which supplies the Golden Ear amplifier. Actually, this is not extravagant. In our case the same supply provides voltage to the FM tuner. This supply is entirely conventional and needs to provide 250 to 300 volts at about 50 ma. The filament winding feeding the preamp filaments is returned to a point about 35 volts positive to keep the hum level minimum.

Appendix 1

The New Golden Ear amplifier is very simple to adjust. The following procedure is recommended:

(1). With power tubes removed, adjust balance of the voltage amplifier section, by adjusting R_1 for zero voltage between plates of 9002's.

(2). With power tubes still out, adjust bias control until a VTVM indicates that the proper bias voltage (−55 for 6AR6's and −35 to −38 for 807's, etc.) appears at the output tube grids.

(3). Insert power tubes and balance them by adjusting R_3 for equal plate currents.

(4). Now adjust over-all feedback to desired point.

(5). Balance entire amplifier by connecting "off" grid of input to signal grid, feeding signal to input, and adjusting R_1 for null in output.

Appendix 2

Since the preceding article was written, the output stage of the amplifier has been converted to the Ultra-Linear circuit by substituting an Acrosound T-300 output transformer, removing the neutralizing capacitors, and adjusting bias for Class A operation. (Since in Ultra-Linear operation the screen is isolated from the plate, interelectrode capacitances are the same as in tetrode operation and no neutralization—of the output tubes—is necessary). Both the power sensitivity and the power efficiency were greatly improved. The power output with 6AR6 tubes approaches 40 watts with less than 1 per cent distortion. Since the distortion levels of the original version were already too low for accurate measurement with available instruments, we cannot state the degree of improvement in the Ultra-Linear version quantitatively. But the listening quality is still further improved. Especially notable is the ability to handle high power peaks with a cleanness unprecedented in the author's experience. This is partly, of course, the result of the greater power reserve, but appears also to reflect an improved transient response especially at low frequencies. In any case, whether measured by instrument or ear, the Ultra-Linear version seems to the author to approach the ideal amplifier so closely that it is difficult to conceive how further improvement could be effected, much less discerned. Unless it is desired to use a standard output transformer already on hand, the author highly recommends the Ultra-Linear configuration.

For a detailed analysis of the development and theory of the new Golden Ear circuit and a description of the low-cost version the reader is referred to:

"Extending Amplifier Bandwidth," by Joseph Marshall. *Radio-Electronics* Sept. and Oct. 1953.

"The Junior Golden-Ear Amplifier," by Joseph Marshall. *Radio-Electronics,* November, 1953.

Component Specifications

For the information of those who may be interested in constructing the Golden Ear amplifier, it must be admitted that the original model was built with surplus parts. However, the following components or their equivalents would serve satisfactorily in the amplifier:

Power transformer .... Stancor 8412
Input choke .... Stancor C-1721
Filter choke .... Stancor C-1420
Bias supply chokes ...... Stancor C-1003
Output transformer
UTC LS-57 for triodes
Acrosound T-300 for Ultra-Linear.
Extra filament transformer
Stancor P-5014.