ALTEC ENGINEERING NOTES

AMPLIFIER IMPEDANCE EFFECTS ON THE TRANSFER CHARACTERISTIC OF FILTERS AND EQUALIZERS

By J. Noble, Director of Engineering

TECHNICAL LETTER NO. 192

The increasing use of equalizers and filters in sound systems has raised questions regarding the propriety of feeding such networks from feedback amplifiers without build-out resistors or isolating pads. The question is raised, since feedback amplifiers typically have internal output impedances which are a fraction of their rated load impedance, hence even though the network may be reflecting the proper load to the amplifier, the amplifier is providing a source to the network which is far less than the source specified.

For years it has been common practice to specify output impedance as a percentage of load impedance for power amplifiers because this gave an indication of speaker damping and distribution system regulation. Line level devices, however, have seldom been characterized in this way for lack of need, thereby preventing a simple calculation of build-out resistor value to achieve an optimum network match.

Before making any hard and fast rules about the need for build-out resistors, let's explore the behavior of several common filters and equalizers. In the following, reference will be made to "matched source" and "zero impedance source" for filter inputs and "matched load" and "infinite load" for filter outputs.

The matched source condition would represent looking back at the source from the filter terminals and seeing the specified filter impedance. The zero source impedance would represent a constant voltage source or an amplifier with so much feedback that external loads cannot affect its output voltage. Practical amplifiers fall somewhere between the two.

Matched load condition represents looking toward the load from the filter output terminals and seeing the specified filter impedance. The infinite load impedance would represent an amplifier with an input impedance ten or more times the specified network impedance.

CASE I - "Pi" Network (9065A and 9066A)

Figure 1 shows a typical low pass "Pi" filter. From examination this is not a constant impedance network since at some high frequency capacitors across input and output terminals will be a virtual short circuit. High pass configurations have capacitors and inductors interchanged, thus presenting a low terminal impedance at some low frequency. This three-element network should provide 6 dB per octave attenuation per element, or a total of 18 dB per octave. Examination of Figure 1 shows this to be true when the filter is fed from a matched source. If the filter is fed from a zero impedance source, the input capacitor of the filter can have no effect since by definition the output voltage of a zero impedance source is not effected by load. Therefore, the network is reduced to a two-element "L" type filter providing attenuation of 12 dB per octave. A secondary effect that may be experienced with some amplifiers when the "Pi" filter is connected without building out resistors, is an increase in intermodulation distortion from signals appearing in the stop band where the filter presents a downward mismatch to the amplifier. The 1592A mixer, for instance, does not exhibit the distortion problem and provides a slope between 12 and 18 dB per octave.

"PI" NETWORK MATCHED LOAD

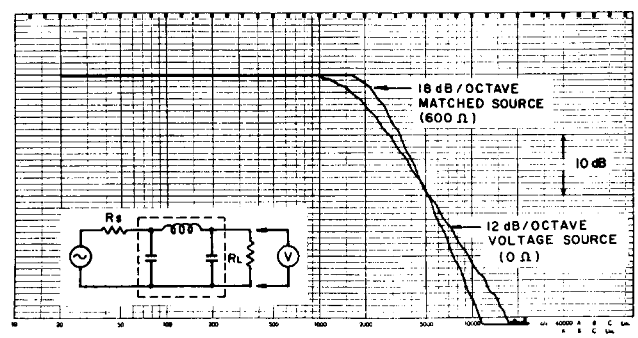

Figure 1

In the foregoing we have examined the effect of source impedance on the "Pi" filter assuming proper output termination. Let's now look at the effect of output termination. Figure 2 shows a curve of matched source impedance and infinite load. Even here the filter behaves rather well, the rise in response before cut-off being only 3 dB. If we ignore both input and output match and send from a zero source impedance with an infinite load, the upper curve of Figure 2 is the result. From examination we can see this to be a logical result. The series inductance and output capacitor of the filter form a series resonant circuit across the output of the generator. Current and resonance are limited only by the coil Q. Since the output appears across one leg of the series resonant circuit, output voltage, like current, is limited only by coil Q. If a load is placed across the output, this tends to reduce Q and limit voltage rise. If the source resistance is raised from zero, it will limit current at resonance, hence limit voltage rise across the output.

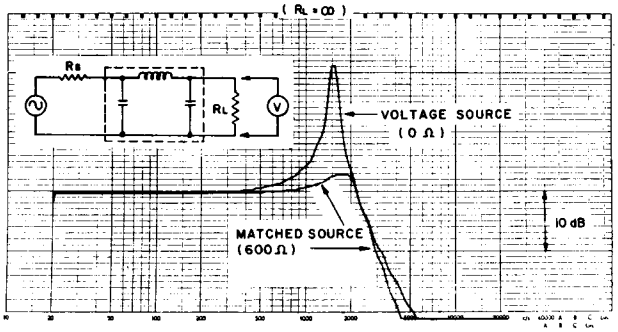

Figure 2

CONCLUSION

A "Pi" filter works reasonably well if either the source or the load match the filter impedance. To achieve smoothest response and ultimate attenuation, however, both source and load impedances should match the filter.

CASE II - Constant Impedance "T" Network (9067B, 9068B, 9069B)

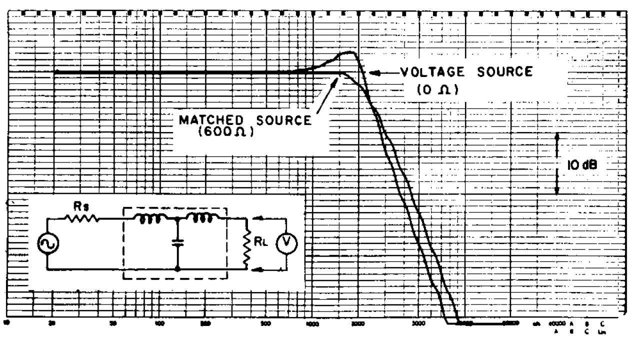

Figure 3

Figure 3 shows curves of a "T" Network properly terminated and fed from both a matched source and a zero impedance source. The matched source shows a smooth response with 18 dB per octave attenuation as expected. If the source impedance is reduced to zero, a rise of approximately 3 dB prior to cut-off is experienced. This is caused by resonance of the first two elements of the filter.

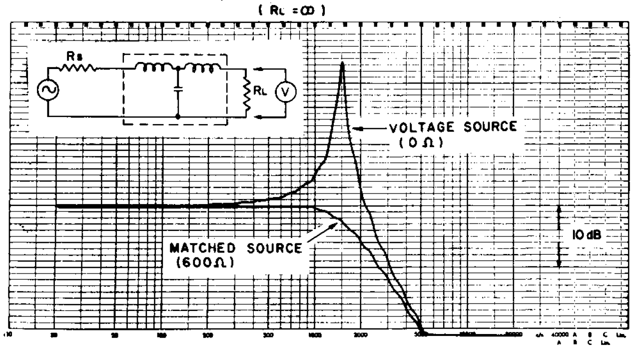

Figure 4

Figure 4 shows the drastic effects that are produced when the "T" Network is operated without termination. With a matched source the attenuation rate is reduced to 12 dB per octave. With a zero impedance source, the peak before cut-off is very large. This is again caused by resonance of the first two filter elements which are without damping with zero source and infinite load impedances.

CONCLUSION

A "T" filter works reasonably well from a zero impedance source so long as the filter output is properly terminated. For smoothest response and ultimate attenuation, both source and load impedances should match the filter.

CASE III - "Bridge T" - Constant Impedance Networks with Limited Action (9060A, 9061A, 9062A, 9063A, 9073A and 9013 Series Equalizers)

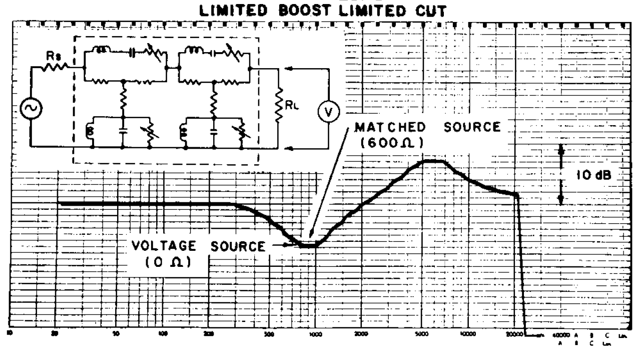

Figure 5

We have called these limited action networks since the amount of boost or attenuation is limited by resistors with the Bridge T configuration. Figures 5 and 6 show a constant impedance "T" type limited action program equalizer. Response curves are virtually unaffected by source and load impedances.

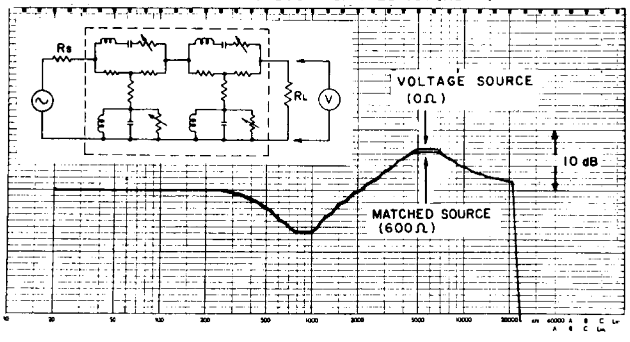

Figure 6

CONCLUSION

Resistors in the networks sufficiently control coil Q's so that response is virtually unchanged by source or load impedances.

The following chart, Chart 1, lists most of the popular ALTEC line-level amplifiers which might be employed in a system to drive filters or equalizers. Values in the output impedance column represent the internal impedance of the amplifier when the output is connected for 600 ohm load. Values in the series resistor column are the values of resistor which must be added in series with one leg of the output to make the source impedance equal 600 ohms. Values in the dB loss column represents a loss in gain which is incurred by inserting the building-out resistor. It should also be recognized that the dB loss figure is also a power loss between the amplifier output and the filter input. Hence, an amplifier having a maximum output capability of +20 dBm using a build-out resistor incurring a matching loss of 4 dB, would be capable of delivering +20 -4 or +16 dBm to the filter input.

The load impedance which amplifier inputs present to filters or other sources, is available from the amplifier specification. For instance, 1590A, 1593A, 1594A, 1595A power amplifiers all have specified input impedances of 15,000 ohms. This provides a matched termination for the secondary of the 15095 Transformer when it is used so that the 600 ohm side of the transformer which appears at the amplifier input terminals is, in fact, 600 ohms.

Table I

AMPLIFIER TYPE	OUTPUT IMPEDENCE (600Ω LOAD)	SERIES RESISTOR	dB LOSS
1566 A	130Ω	470Ω	4.3
1567 A	160Ω	430Ω	4.0
1581 A	90 Ω	510Ω	4.8
1591 A	220Ω	390Ω	3.3
1592 A	130Ω	470Ω	4.3
9470 A	60Ω	510Ω	5.2
9472 A	90Ω	510Ω	4.8
9473 A	80Ω	510Ω	4.9
9475 A	60Ω	510Ω	5.2
436 C	390Ω	220Ω	1.7
438 C	390Ω	220Ω	1.7

On certain amplifiers, primarily older tube type designs, input impedance is considerably higher than the 15,000 ohm 15095 Transformer secondary. The 1568A, 1569A and 1570B Amplifiers have rated input impedances of 70,000 ohms, for instance. This is 4.65 times the secondary impedance of the transformer, hence the input impedance will be 4.65 times 600 ohms or 2700 ohms. A 750 ohm resistor will have to be placed across the input which in parallel with 2700 ohms will provide the desired 600 ohms.

On other amplifiers such as 1591A and 436C, which are sometimes used as booster amplifiers in the link, the input is referred to as "bridging" with source impedances up to 15,000 ohms. In these cases the 15,000 ohm side of the transformer appears at the amplifier input terminals. Since the "bridging" impedance is at least ten times the desired source impedance, a 620 ohm resistor can be connected across the amplifier input terminals to provide termination for 600 ohm networks.