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A Review of Key Equalizer Specifications and What They Mean

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Here is a short tutorial that reminds engineers how to develop the proper specifications for amplitude and delay equalizers

Whether designing or buying an equalizer, the key specifications must be understood in order to make the right design decisions or unit selections. This tutorial article offers a review of equalizer technical specifications and what they mean, along with discussion of some of the applications that are most affected by particular specifications. In commercial electronics, technical specifications are often subordinate to unit cost and adequate performance is sometimes acceptable without optimization. In government electronics, reliability considerations can be paramount and high unit costs will occur. Reliability is crucial in the commercial field of medical electronics

Equalizers correct amplitude and/or group delay aberrations in receivers and transmitters for applications in communications, radar, and electronic countermeasures. Equalizers are available as both passive and active units, with specifications that may be in either the frequency domain or the time domain. Passive equalizers are characterized per frequency responses between matched source and matched load. Active equalizers are characterized by Bode plots applicable to voltage transfer responses through frequency selective amplifiers. This article will primarily discuss frequency domain specifications for analog passive equalizers.

Passive Equalizer Realization

External passive equalizers often use lumped or distributed circuit elements to correct undesired transmission responses of other circuits such as filters and transmission lines. In a usable frequency range, signal integrity requires carefully controlled transmission paths. Typical transmission responses with linear, parabolic, or ripple behavior are corrected by equalizers normally operated between a matched source (generator) and matched termination (load). To achieve desired correction(s), equalizers are designed for various transmission response shapes. Good results are obtained when applicable computer programs are used to predict equalizer performance and determine necessary circuit element values. At microwave frequencies, electromagnetic simulation can be used for equalizer design as an alternative to empirical techniques of the past. Finally, reflections at circuit interfaces must be carefully controlled to avoid signal integrity degradation.

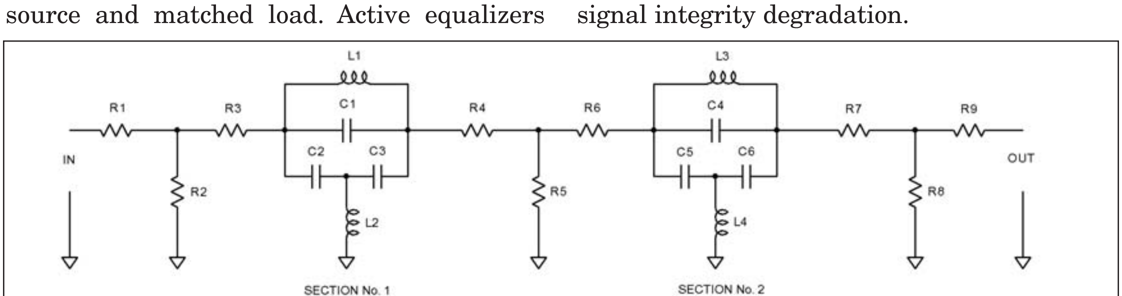

Figure 1 · L-C equalizer using two bridged-T sections.

Lumped-circuit equalizers have been realized using cascaded bridged-T circuits which ideally are constant resistance circuits. A typical schematic of an L-C two section equalizer is shown in Figure 1. Fixed pad attenuators are employed at equalizer input, output, and interstage to reduce interactions between source, load and adjacent sections. To meet Intelsat transmission requirements for satellite communications links, 70 MHz elliptic function band pass filters of different carrier sizes (bandwidths) were cascaded with bridged-T group delay equalizers. These L-C filter-equalizers circuits were subsequently replaced by SAW band pass filters that were inherently linear phase units requiring no external equalization. These SAW filters were physically smaller and provided sharper selectivity at reduced unit cost. SAW units also took over at 140 MHz and other frequencies. Further front end cost reduction is being achieved using direct conversion architecture which eliminates intermediate frequency circuits such as filters and equalizers [1].

Transmission-line equalizers have been employed at microwave frequencies using a circulator coupled unit with a reactive circuit connected to the second port. At microwave frequencies, the reactive circuit is usually realized using cavity resonators. The ferrite circulator, configured as a four port unit, is a reflective unit that provides useful source/load isolation. Reactive circuits, using one and two resonators, have been popularly known as C and D Sections. This reflective type of equalizer can also be realized using operational amplifiers [2]. Such an equalizer could be ultimately realized as an applications specific integrated circuit (ASIC). Alternate C and D sections can be implemented using coupled transmission lines without ferrite circulators.

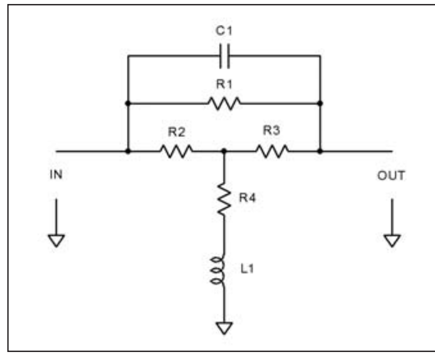

Figure 2 · L-C equalizer using one bridged-T highpass section

For equalization of coaxial transmission lines, the equalizer usually provides amplitude response correction that is inherently high pass. This can be achieved using one or more bridged-t sections. The high pass bridged-tee unit is a constant resistance circuit similar to the preemphasis circuit used with analog communications links. The schematic diagram of an L-C equalizer using one bridged-T high pass section is shown in Figure 2.

The transversal equalizer has been implemented at microwave frequencies. It permits both manual and computer controlled switching of fixed increments of equalization. The transversal equalizer is compatible with digital electronics and can be used for adaptive equalization.

Computed amplitude and group delay responses for some lossless and lossy C and D sections have been published in a prior article [3]. Also, the circulator coupled equalizer can employ reactive circuits with greater than two coupled resonators.

Equalization fit is crucial to attainment of signal integrity objectives. Transmission performance specifications are highly dependent upon the specific type of applicable modulation. Equalizer realizations are often dependent upon performance and cost tradeoffs which can entail several design iterations.

Notes on Equalizer Specifications

1. Transmission and Reflection Responses—

Usable Transmission Responses: Maximum Insertion Loss in dB over specified frequency range(s), maximum phase non-linearity in degrees over specified frequency range (s), maximum differential group delay in unit of time over specified frequency range.

Usable Reflection Responses: Minimum Return Loss in dB over specified frequency range (s).

Source/Load Impedance: Ohms (50 and 75 ohm impedances are typical above audio)

2. Filter Interfaces—

Specify equalizer input/output interfaces such as coaxial connectors, standard waveguide size, solder lugs, surface mount tabs, etc.

3. Mechanical—

Location of interfaces and adjustable (if any) circuit elements. A mechanical outline drawing showing mounting information is usually necessary.

4. Environmental—

Specify both operating and storage temperature, humidity, altitude, shock and vibration, salt spray, etc. This can affect acceptable unit surface finishes. Government specifications should be included when applicable.

5. Reliability—

–This can be specified as availability. Government specifications should be included when applicable.

Unit cost is directly related to the number of specifications imposed and their stringency. Imposition of source inspection and workmanship standards can also affect the cost. Unit costs will go down as production volume goes up.

Miscellaneous Considerations

NOTE: Specifications must be altered for self-equalized filters rather than external equalizers.

Numerous structures are available for equalizers. Each equalizer structure has its own problem areas relating to materials and manufacturing processes. Special attention is required when working at high signal levels. High average power levels can result in overheating while high peak power levels can result in voltage breakdown. Some equalizer structures are sensitive to shock and vibration. Circulator coupled equalizers are sensitive to adjacent magnetic fields; superconducting units require control of temperature. In some applications, intermodulation distortion in passive equalizers can become a problem area. Switched filter equalizers can vary from simple mechanical switching to local/remote computer controls.

Acknowledgement

Equalizer design and development can entail a wide of technology. The contributions of many other engineers and technicians are gratefully acknowledged. For reasons of brevity, some useful equalization techniques have not been discussed, and a bibliography of prior work was not included beyond the cited references.

References

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