Constant-resistance termination

IN 1945, HENDRIK W BODE published *Network Analysis and Feedback Amplifier Design*, codifying in one classic book the filter and feedback-amplifier theory upon which much of the electronics industry still relies.

Of the many secrets his seminal work reveals, one of my favorites is the constant-resistance network (**Figure 1**). The **figure** shows only one of many forms of this circuit. As long as you scale the components such that the time constant, Z_0C_{IN}, equals the time constant, L_2/Z_0, then, in response to a step input, the rate of decrease in the admittance of the R-C leg precisely matches the rate of increase in the admittance of the L-R leg. The result is that the impedance, $Z(f)$, of the whole circuit remains constant at all frequencies. At least, it remains constant until some limit above which the parasitic aspects of the circuit take over and the C and L components no longer behave like Cs and Ls.

This circuit occasionally sees application in digital systems as a terminating network. For example, suppose C_{IN} represents the unavoidable input capacitance of a receiver. You may then use components R_1, R_2, and L to complete the circuit, forming at the input a compensated termination that returns no echo regardless of the value of C_{IN}.

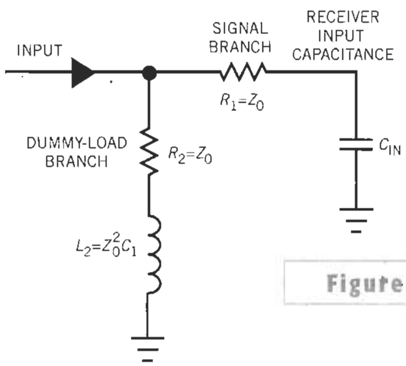

Figure 1

The input impedance of this constant-resistance network equals Z_0 at all frequencies.

In that case, the received signal, having passed through R_1 before arriving at the input terminal of the receiver, is delayed by the group delay, $\tau_{group}=R_1C_{IN}$ of the filter thus formed. The filter's 10 to 90% rise time, $\tau_{10\text{-}90\%}=2.2\cdot R_1C_{IN}$, degrades the rise time of the incoming signal. Provided these two artifacts are acceptable, the termination works in an ideal fashion.

Many other constant-resistance structures are possible. The general theory says that if you replace C_{IN} by any network a and L_2 by any network b having the impedance relationship $b=Z_0^2/a$, the input impedance of the whole structure will still equal exactly Z_0 at all frequencies. This remarkable property is provable using ordinary algebra, although the calculations are hideous and time-consuming. One can only imagine how many long nights Bode spent in his office at Bell Labs coming up with this theory. The general theory of constant-resistance networks becomes very important when you wish to construct an equalizing filter at the end of a long transmission line. By carefully crafting impedance a, you can construct just about any arbitrary equalization function at the input terminals of the receiver. You then use impedance b to balance the network such that the input impedance of the whole structure looks like a perfect end termination.

THE GENERAL THEORY OF CONSTANT-RESISTANCE NETWORKS BECOMES VERY IMPORTANT WHEN YOU WISH TO CONSTRUCT AN EQUALIZING FILTER AT THE END OF A LONG TRANSMISSION LINE.

Constant-resistance filters differ significantly from lossless L-C ladder filters, such as the popular Cauer filters you may have encountered. A lossless filter works by either passing power through the network or reflecting it back to its source. A constant-resistance filter works by either passing power through the network to the receiver or shunting it off to the balancing leg of the filter, where it dissipates harmlessly in the form of heat.□

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