



Fully differential amplifiers and transmission lines

FULLY DIFFERENTIAL AMPLIFIERS aim at amplifying high-frequency signals while rejecting the noise that always exists in mixed-signal systems. You wire these amps on pc boards and in cabling schemes such that any injected noise is common-mode rather than single-

ended. The amplifier-input stage rejects common-mode noise very well, so having two signal wires in close proximity carrying the signal to the amplifier inputs makes the best case for noise rejection.

At high frequencies, signal wires become transmission lines, and, in many cases, coaxial cable or twisted-wire pairs carry signals to preserve their integrity. The electromagnetic propagation of a high-frequency signal along a cable causes reflections from both ends of the cable. These reflections mix with the signal, causing distortion, potential overload, and noise. R_S is the signal-source output impedance, R_T is the termination impedance, and Z_O is the cable characteristic impedance. When $R_S=R_T=Z_O$, the reflection coefficient, ρ , becomes zero (see equations 1 and 2), and there are no reflections from the source or the termination.

$$\rho = \frac{Z_O - R_T}{Z_O + R_T} \quad (1)$$

$$\rho = \frac{Z_O - R_S}{Z_O + R_S} \quad (2)$$

The signal couples into the non-inverting input of an op amp, so the amplifier-input resistance is

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high, and you can neglect it (Figure 1). R_S terminates the source in Z_O , and R_T terminates the cable in Z_O ; thus, $R_T=R_S$. The gain-setting resistors, R_F and R_G , connect to the inverting-op-amp input, where they have no effect on the termination-resistor calculations. The circuit-gain calculation follows:

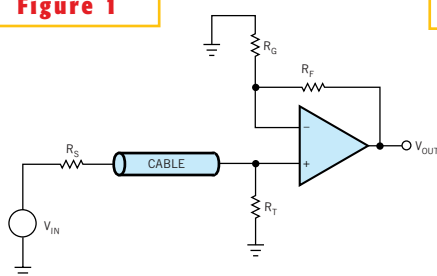
$$G = \frac{R_T}{R_T + R_S} \frac{R_F + R_G}{R_G} = \frac{1}{2} \frac{R_F + R_G}{R_G} \quad (3)$$

The termination-resistance calculations of a fully differential circuit are more complicated than those for a single-ended circuit because the gain-setting resistors come into play (Figure 2). The only way to keep these resistors out of the calculations is to buffer the inputs, and that option is intolerable costwise and spacewise. First, the gain-setting resistors, R_1 and R_3 , are in parallel with R_T , lowering its effective value. Second, the source impedance can't equal zero; hence, it affects the overall circuit gain. These calculations get com-

plicated; my next column will offer the solution to the termination/gain-setting-resistor problem. □

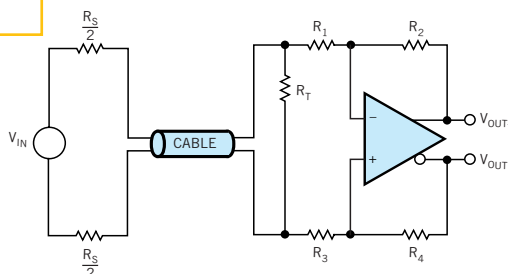
Ron Mancini is staff scientist at Texas Instruments. You can reach him at 1-352-569-9401, rmancini@ti.com.

Figure 1



A single-ended transmission line drives a noninverting op-amp receiver with no interaction with the op-amp resistances.

Figure 2



The fully-differential-termination scheme is much more complicated than the single-ended scheme because the calculations involve the gain-setting resistors.