Chapter 17: Baluns and Balanced Circuits

17.1 Repeat the analysis contained in this chapter for the 1:1 current balun but assume that $R_2 = 0$ and there is a resistance R_g between the input and output grounds. [Goedbloed]

17.2 An illegal hookup to a CATV line is performed with twin-lead instead of coax. What is a major negative consequence of this connection? Assume that the characteristic impedances of the twin-lead and coax are equal.

17.3 With most current baluns, there is a major assumption concerning reactances. What is this assumption?

17.4 It is stated that the goal of a balun is to provide a large impedance to the common-mode signal, and it does not matter if the impedance is inductive, resistive, or both. For this reason, lossy ferrite beads are used for baluns at higher frequencies. Discuss the validity of these statements.

17.5 For the 4:1 voltage balun discussed in this chapter, determine the expression for the input impedance seen by the balanced side if the unbalanced impedance, Z_u, is equal to $R_u + j\omega L_u$. Then, sketch the Bode magnitude plot of the impedance seen by the balanced side, clearly labeling all break frequencies and slopes. Over what frequency range and under what assumptions is this impedance equal to $4R_u$? Over what frequency range and under what assumptions is this impedance equal to $4j\omega L_u$?

17.6C Derive the current and input impedance expressions given in this chapter for the Guanella 1:4 balun.

17.7 It is proposed that instead of using a common-mode choke around each shielded <u>lead</u> that all shielded <u>leads</u> be wound around one toroid. Provide an advantage and a disadvantage of this proposal.

17.8 Using the model for a common-mode choke shown in Figure 1, determine the expression for the differential-mode impedance for each coil. Sketch the Bode magnitude plot for this impedance clearly labeling the low-frequency amplitude, critical frequencies, and slopes.

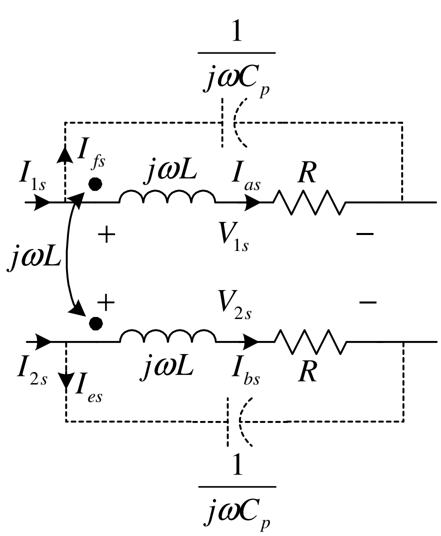

Figure 1

17.9 Assume that one conductor of a parallel line can be modeled as a 1 Ω resistor shunt by a 2 Ω resistor to ground and the second conductor can be modeled as a 3 Ω resistor shunt by a 6 Ω resistor to ground. As in this chapter, apply a common voltage, v_{CM}, to both inputs and determine the resultant output voltage. Then, apply a voltage, v_{DM}, across the inputs and determine the resultant output voltage. Is this line susceptible to common-mode interference? Should the definition given in this chapter for a balanced system be changed? Explain.

17.10 Why is Litz wire not normally used with current baluns?

17.11 Given the following input voltages relative to ground for a differential amplifier

$$v_1(t) = 3.0\cos(2\pi \times 60t) + 0.001\cos(2\pi \times 3{,}000t)$$
$$v_2(t) = 3.1\cos(2\pi \times 60t) - 0.001\cos(2\pi \times 3{,}000t)$$

and the output voltage of the amplifier relative to ground

$$v_0(t) = 0.5\cos(2\pi \times 60t) + 0.1\cos(2\pi \times 3{,}000t)$$

calculate the differential-mode and common-mode components of the input signal (using any of the definitions provided in this book), differential-mode gain, common-mode gain, and *CMRR* in dB. Is this a reasonable value for the *CMRR*?

17.12 Determine the exact expression for the *CMRR* for the classical three-op amp instrumentation amplifier assuming that $R_3 = R_4$ and that the two resistors labeled R_2 are mismatched by ΔR (i.e., set one resistor equal to R_2 and the other resistor equal to $R_2 + \Delta R$). Then, find an approximation for this *CMRR* expression assuming ΔR is small compared to all of the resistances. How does this expression compare to the single op-amp approximation? Based on this comparison, is the difference amplifier or the instrumentation amplifier more sensitive to resistance imbalance?

17.13 One source is single-ended floating while another source is balanced floating. How can these two sources be distinguished through voltage and dc resistance measurements?

17.14 It is stated that most EMI from an arc, after it couples to an ac line, is differential in nature. Discuss the validity of this statement.

17.15 Lightning strikes nearby to a power line. Will the resultant transient signal on the line be common mode or differential mode in nature?

17.16 A corded telephone is being interfered with by a CB radio. It is not certain whether the interference is picked up by the drop wire from the pole to the house or by the wiring inside the house. The telephone contains a nonlinear carbon microphone. Why is the nonlinear nature of the microphone being stressed? It is uncertain whether the interference is common mode or differential mode. State how to correct this interference problem using only capacitors. Provide the type, value, and position of the capacitors. The input impedance of the telephone is 600 Ω.

17.17 In reference to the transducer/voltage regulator/ac power multiple isolation transformer situation in this chapter, suggested another set of grounds for these isolation transformers that might be more effective for other situations. Explain your reasoning.

17.18S Using data sheets, verify the information contained in the optoisolators discussion in this chapter.

17.19 It is stated that differential-mode currents produce transverse induction fields while common-mode currents produce longitudinal induction and radiating fields. Explain. [Tsaliovich]

17.20 If a large, conducting nonmagnetic shield is placed between two conductors, will the coupling due differential mode currents be affected? Examine the direction of the electric and magnetic fields generated by the currents.

17.21 The primary of a transformer is connected to a coaxial cable. The secondary of the transformer is connected to a twin-lead line. Where should the secondary be grounded so that the twin-lead remains balanced?

17.22 How effective is a transformer in reducing the coupling of primary common-mode currents to the secondary if the primary is not balanced? Why would the primary of a transformer not be balanced?

17.23 At the junction of two coaxial cables connected in series, the inner conductor of the first cable is connected to the outer conductor of the second cable and the outer conductor of the first cable is connected to the inner conductor of the second cable. This will reverse the polarity of a signal when passing from the first to second cable. One source suggested that a common-mode choke be inserted at the junction of the two cables. Determine whether this has any significant effect on the operation of this phase reversal circuit.

17.24 For the circuit shown in Figure 2, assume that R_s is not negligible. First, determine I_{1s} and I_{2s}. Second, determine I_{Ds} and I_{Cs}. Third, determine expressions for the differential-mode and common-mode impedances seen by the supply voltage.

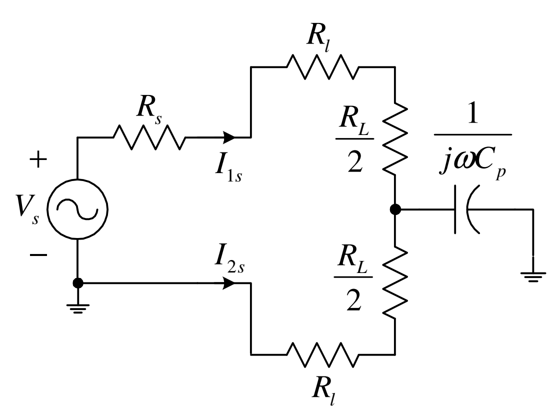

Figure 2

17.25C Using a symbolic manipulation program (or by hand if not available), verify all of the equations provided in this chapter for the input resistance, output resistance, and attenuation (N) for the π and O pads.

17.26C Using a symbolic manipulation program (or by hand if not available), verify all of the equations provided in this chapter for the input resistance, output resistance, and attenuation (N) for the T and H pads.

17.27C Using a symbolic manipulation program (or by hand if not available), verify all of the equations provided in this chapter for the input resistance, output resistance, and attenuation (N) for the L and U pads.

17.28C Using a symbolic manipulation program (or by hand if not available), verify all of the equations provided in this chapter for the input resistance, output resistance, and attenuation (N) for the bridged T and H pads.

17.29 For the π and O pads, verify that for a short-circuited output,

$$\frac{\Delta R_i}{R_i} = \frac{-2}{N+1}$$

and for an open-circuited output

$$\frac{\Delta R_i}{R_i} = \frac{2}{N-1}$$

17.30 Repeat Problem 17.29 for the T and H pads.

17.31 Repeat Problem 17.29 for the L and U pads.

17.32 A very long balanced antenna (rhombic) has a 600 Ω termination resistor. To reduce static charge buildup on the antenna, how should a ground be connected to this resistor?

17.33 Rigorously show that the best possible attenuation (lowest N) that can be obtained from an L pad for fixed R_i but uncontrolled R_L is when $R_b = \infty$ (when $R_i > R_L$) and $R_a = 0$ (when $R_L > R_i$).

17.34C Design a π, T, L, or bridged T filter if the desired input resistance is 1 Ω and the load resistance is 50 Ω. The input resistance should not change by more than 10% when the load varies from 25 to 75 Ω. Compare the attenuation, N_{dB}, of these four different types of filters. On the same set of axes, plot the input resistance for each of these filters as the load varies from 25 to 75 Ω. Which filter is least sensitive to load variation?

17.35C Design a π, T, L, or bridged T filter if the desired input resistance is 50 Ω, the load resistance is 50 Ω, and $N = 5$. The input resistance should not change by more than 10% when the load varies from 25 to 75 Ω. Compare the power attenuation, N_{dB}, of these four different types of filters. On the same set of axes, plot the input resistance for each of these filters as the load varies from 25 to 75 Ω. Which filter is least sensitive to load variation?

17.36C For a four-terminal (two-port) resistive network with an input resistance of R_i and load resistance of R_L, show that

$$\frac{\Delta R_i}{R_i} = \frac{2\left(\frac{\Delta R_L}{R_L}\right)}{2N + (N-1)\left(\frac{\Delta R_L}{R_L}\right)}$$

is approximately equal to

$$\frac{\Delta R_i}{R_i} = \frac{1}{N}\frac{\Delta R_L}{R_L}$$

when $\Delta R_L / R_L$ is small. The variable N is the ratio of the power into the pad (from the source side) to the power to the load. Determine the percent error in using this approximation, and plot it versus $\Delta R_L / R_L$ for various values of N.

17.37C Design a π or T resistive pad that that has an input resistance of 50 Ω, output resistance of 100 Ω, and attenuation of 17 dB. All of the resistors in the pad should be greater than 100 Ω.

17.38 It is stated that the T pad is often used (over other pads) when the source and load resistances are about the same value. Determine if this guideline has any validity.

17.39 A certain residential outlet is wired so that one receptacle of the outlet is connected to one phase of the power distribution system and the other receptacle of the same outlet is connected to the other phase of the power distribution system. Why is this done? (Actually, for residential systems, there is only one voltage phase entering the dwelling, consisting of one neutral and two hot wires of opposite sign. It is common, however, to describe these opposite sign voltages, relative to the neutral, as being two separate phases.)