Chapter 20: Conducted Emissions and Susceptibility

20.1 For a Δ-to-Δ, three-phase balanced system in normal operation, none of the generators or loads are connected to ground. The main advantage of this system is that when a ground fault occurs the system does not shut down. One disadvantage is that when a ground fault does occur, the line-to-ground voltage will increase placing additional electrical stress (such as arcing) on the system. Imagine that a separate light bulb is connected from each of the three lines to ground as an indication of whether a fault has occurred. Explain why if a ground fault occurs (e.g., a short circuit from one of the load ends to ground) that one of the light bulbs will turn off and the others will burn more brightly.

20.2 Provide one situation where it would not be desirable to place a surge suppression device outside of a shield or metal chassis.

20.3 Sketch the *i*-*v* curve for two, identical zener diodes connected in parallel.

20.4 Explain how the circuit shown in Figure 1 functions as a balanced, bidirectional, transient suppressor circuit.

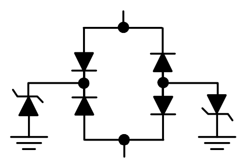


Figure 1

20.5C Using SPICE, verify that each of the circuits given in Figure 2 function as a bipolar voltage transient protector. State all assumptions (and major parameters used in the analysis).

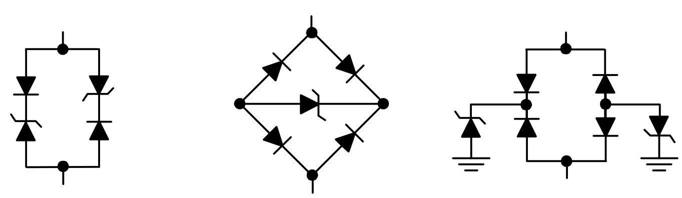


Figure 2

20.6 Why should an ordinary diode, when reversed biased, not be used as a voltage suppressor?

20.7 Using energy form factors and without integrating, determine the total energy in the current waveform shown in Figure 3 (assuming a clamping voltage of 150 V). The waveform is the sum of a sinusoidal pulse and an exponentially damped sinusoid. (The results of a later problem related to the form factor for an exponentially damped sinusoid can be used.)

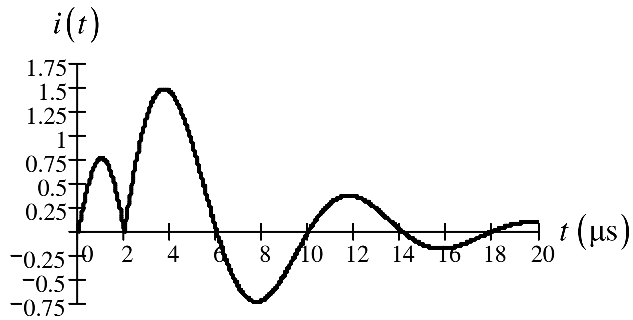


Figure 3

20.8C Verify that the energy form factors, *K*, not already derived in this chapter but listed in this chapter's table are correct.

20.9C The energy form factor for the current waveform

$$I_{pk}\sin\left(\frac{\pi}{\tau}t\right)e^{-\frac{\ln 2}{\tau}t}u(t)$$

was given as approximately 0.91 in this chapter. However, I_{pk} in this expression does not correspond to the peak positive value of the waveform. If I_{pk} actually corresponds to the peak positive value of this function, then verify that the new energy form factor is approximately 1.3 and the equation for the current waveform is

$$1.38I_{pk}\sin\left(\frac{\pi}{\tau}t\right)e^{-\frac{\ln 2}{\tau}t}u(t)$$

20.10 For the following current waveform,

$$\frac{I_{pk}e^{1}}{\tau}te^{-\frac{t}{\tau}}u(t)$$

analytically verify that the peak value of the waveform is I_{pk} and that it occurs at $t = \tau$. Then, determine the energy form factor for this function.

20.11 Determine the energy in the current waveform shown in Figure 4 (assuming a clamping voltage of 100 V) by formally integrating the power. Do not use energy form factors.

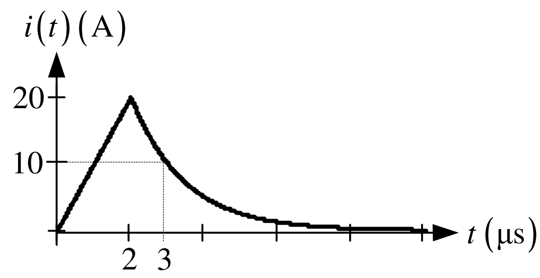
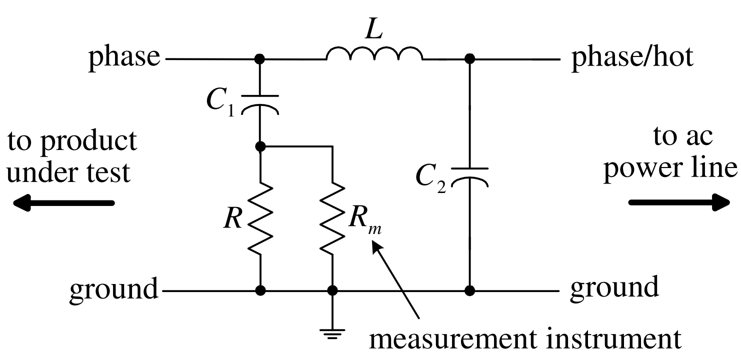


Figure 4

20.12 Assume that the total system leakage is limited to 100 mA for medical applications at 400 Hz. Determine the maximum value of the capacitance to ground for each leg of a three-phase four-wire circuit.

20.13C Design a new LISN that is good from 50 kHz to 20 MHz. Repeat the entire numerical analysis given in this chapter for the $50\ \mu\text{H}\|50\ \Omega$ LISNs.

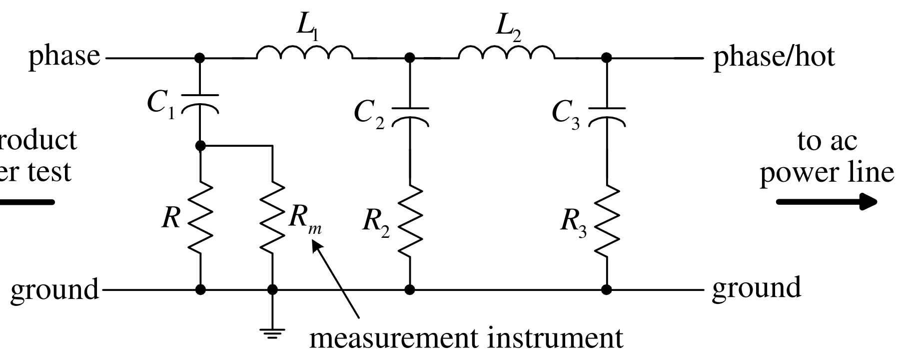
20.14 For the LISN given in Figure 5, C_2 is changed from 1 μF to 20 μF. Determine the major consequences of this change.



$R = 1\ \text{k}\Omega,\ R_m = 50\ \Omega,\ C_1 = 0.1\ \mu\text{F},\ C_2 = 1\ \mu\text{F},\ L = 50\ \mu\text{H}$

Figure 5

20.15C For the LISN given in Figure 6, it was stated in this chapter that at 10 kHz, considered near the low-frequency limit of this LISN, the *LC* sections are not performing much low-pass filtering. By adding an *LC* section, compared to the LISN shown in Figure 5, at the power line side, a short circuit or very-low impedance at the power line will not completely nullify the effect of R_2C_2 (because of the nonzero impedance of L_2). Thus, this additional *LC* section is performing some decoupling or isolating. Numerically determine whether all of these statements are true for the entire circuit shown in Figure 6. Clearly state all assumptions.



$R = 1\ \text{k}\Omega$, $R_m = 50\ \Omega$, $R_2 = 5\ \Omega$, $R_3 = 10\ \Omega$, $C_1 = 0.25\ \mu\text{F}$
$C_2 = 8\ \mu\text{F}$, $C_3 = 1.2\ \mu\text{F}$, $L_1 = 50\ \mu\text{H}$, $L_2 = 250\ \mu\text{H}$

Figure 6

20.16 A local transmitter used by law enforcement is interfering with a TV via its ac power cord. What is a potential cheap solution for reducing this interference?

20.17 Between a shielded cable and the input of a differential amplifier, a parallel *RC* circuit is placed between the shield and the local ground ($R = 50\ \Omega$, $C = 0.01\ \mu\text{F}$). Why? Before the input of a single-input amplifier fed by a coaxial line, a parallel *RC* circuit is connected between the inner conductor of the cable and the ground ($R = 1\ \text{k}\Omega$, $C = 330$ pF). Why?

20.18 Determine the *abcd* matrix for the *RL* circuit shown in Figure 7.

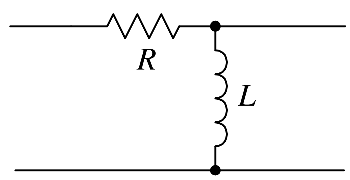


Figure 7

20.19 Determine the *abcd* matrix for a series *Z* impedance.

20.20 Determine the *abcd* matrix for an ideal transformer with a voltage step-up ratio of 1:*n*.

20.21 Provide a counter example (different from any given in this chapter) to show that the short-circuit or open-circuit load tests do not necessarily provide the minimum and maximum values for the input impedance for a network that is not purely resistive.

20.22 Determine the differential-mode and common-mode impedances for the circuit given in Figure 8.

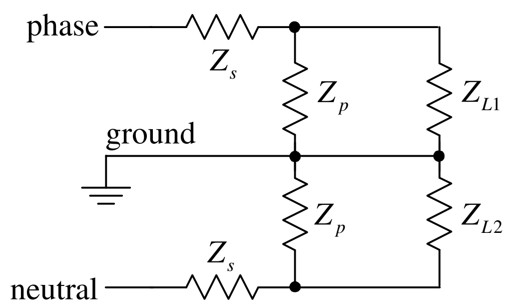


Figure 8

20.23 Discuss how a 0.01 μF, 1.4 kV capacitor can be conveniently used inside a house to determine whether RF noise is passing through the power lines and coupling via the power cord to a TV. What safety precautions should be observed?

20.24 Provide at least five examples (not discussed in this book) of nonlinear junctions that can potentially detect AM stations.

20.25 Show (mathematically) how a nonlinear device can reduce the signal level of a FM signal (referred to as FM "quieting"). A strong, very close, FM radio station is interfering with a concert audio system: the demodulated signal is heard over the speakers. What can be done? Why is this occurring for an FM station?

20.26 A "good buddy" CB (citizen's band) operator is heard across the speakers of a stereo system. Explain how the speaker wires are acting as the antenna for the interfering signal. (It is unlikely that the RF picked up directly by the speaker wires is sufficiently strong to drive the speakers.)

20.27EC Using the polynomial approximation with three powers (dc plus c_1, c_2, and c_3), plot the input voltage and the output current for a real diode assuming a small-signal AM single tone signal input with 100% modulation. Use the standard exponential diode equation. Clearly show the distortion that is present in the output. Repeat the analysis for 75%, 50%, and 25% modulation. Assume a reasonable operating point for the diode. For 100% modulation, vary the operating point and note the change, if any, in the output current waveform.

20.28 One end of a very high-frequency diode is attached to a one inch piece of aluminum wire. The diode is then glued to an insect and used as part of a locator/tag system. If a 900 MHz pulsed signal with a 1 μs pulse width is directed at this nonlinear device, determine an approximate expression for the voltage across the diode. Assume that the maximum electric field near the insect is 10 V/m. State all assumptions.