Enigmas, etc.

Load Locus Again

■ **Takashi Ohira**

Let us translate the zero-voltage-derivative switching (ZVDS) introduced in last month's puzzle into plane geometry. For the power amplifier shown in Figure 1 to perform ZVDS operation, the load impedance $Z = R + jX$ should meet a specific condition. We can illustrate this specific condition as a continuous locus on the R–X plane. Which of the following shapes does the locus exhibit?

(a) straight line
(b) hyperbola
(c) parabola
(d) semicircle

Solution to Last Month's "Enigmas, etc." Challenge

Looking at the shunt capacitor C_1, Kirchhoff's current law leads us to

$$I_{\mathrm{DC}} - i(t) = C_1 \frac{dv}{dt}. \tag{1}$$

On the other hand, we recall the RF output current waveform

$$i(t) = I_P \sin \omega t + I_Q \cos \omega t. \tag{2}$$

Substituting (2) into (1), the voltage slope results in

$$\begin{aligned} v'(t) &= \frac{dv}{dt} \\ &= \frac{1}{C_1}(I_{\mathrm{DC}} - I_P \sin \omega t - I_Q \cos \omega t). \end{aligned} \tag{3}$$

When the transistor turns on at $t = T/2$, this equation reduces to

$$v'\left(\frac{T}{2}\right) = \frac{1}{C_1}(I_{\mathrm{DC}} + I_Q). \tag{4}$$

Note that $\omega = 2\pi/T$; thus, $\omega t = \pi$ at this specific moment.

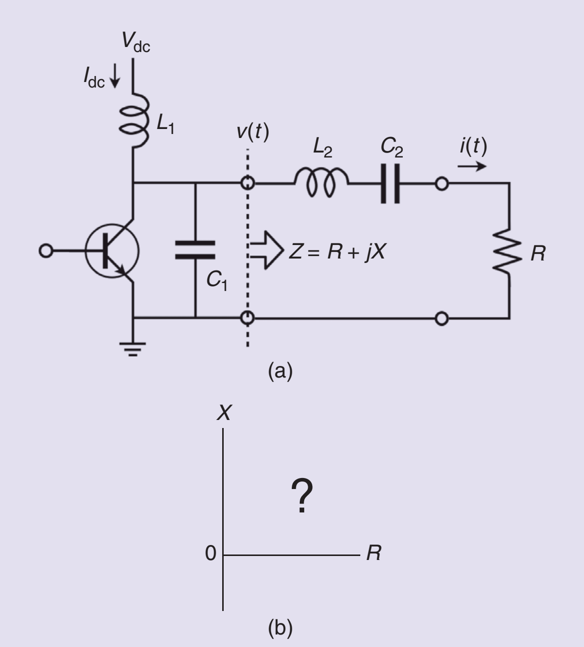

Figure 1. *Looking rightward at (a) the resonator loaded with R, we observe the complex impedance $Z = R + jX$, where $X = \omega L_2 - 1/\omega C_2$. To perform ZVDS, what shape of locus would Z have on (b) the R–X plane?*

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To meet the ZVDS condition, we force (4) to be zero. Since C_1 is a finite quantity, we must make

$$I_{\mathrm{DC}} = -I_Q. \tag{5}$$

Therefore, the correct answer is (d).

The concerned dc-to-RF current relationship seems complicated because it involves time differential calculus. However, the result is quite elegant and easy to remember as given in (5). To further visualize the ZVDS condition, we will convert it into plane geometry in the next puzzle.

References

[1] A. Grebennikov and F. H. Raab, "A history of switching-mode class-E techniques," *IEEE Microw. Mag.*, vol. 19, no. 5, pp. 26–41, July–Aug. 2018. doi: 10.1109/MMM.2018.2821062.

[2] T. Ohira, "Load impedance perturbation formulas for class-E power amplifiers," *IEICE Commun. Express*, vol. 9, no. 10, pp. 482–488, 2020. doi: 10.1587/comex.2020XBL0085.

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numerous types of oscillators including basic, *LC* cross-coupled, Colpitts, ring, and voltage-controlled; phase-locked loops, frequency multipliers, power enhancement amplifiers, and power-combining techniques. The chapter also discusses the tradeoffs involved in choosing oscillator techniques and other devices for THz design and operation.

Chapter 3, "THz Detectors and Related Topics," provides an overview of the diverse methods used for detecting THz electromagnetic waves, such as thermal detectors, including bolometers, pyroelectric detectors, thermopiles, and Golay cells. The rectification of an ac signal can also be used for detection. The last method discussed is the heterodyne technique, in which the signal is downconverted by a mixer and then detected using a conventional low-frequency ac signal detector. This chapter also includes many details of THz detection technologies, such as array detector schemes as well as many mixer technologies, such as the superconductor insulator superconductor mixer. The author includes an interesting example of the super array detector used to discover the first image of a black hole using the Event Horizon Telescope.

Chapter 4, "THz Propagation and Related Topics," covers many basic wave propagation fundamentals, such as Gaussian beams and ray-transfer matrices. The chapter details antenna theory, radiation patterns, directivity, radiation efficiency, and antenna gain. The author clears up the confusion about antenna effective aperture. Chapter 4 also gives a few examples of antennas: short dipoles, loop antennas, and wideband half-wave folded dipole antennas, patch antennas, spiral antennas, and log periodic antennas. Finally, the chapter briefly introduces waveguides with their associated modes.

Chapter 5, "THz Optical Methods," starts with the optical approach to THz research. It is intended to serve as a quick guide to optics-based THz for electronics-based THz researchers. Two major topics are discussed: THz wave generation and detection, including pulse and continuous wave (CW) generation and detection. The discussion of THz pulse generation includes photoconductive antennas, optical rectification, and more. THz CW generation covers photomixing, optical rectification, and lasers. For THz detection, the chapter discusses detection with photoconductive antennas and electro-optic crystals.

Chapter 6, "THz Applications," reviews the four most representative THz applications: spectroscopy, imaging, communication, and radar. The author starts each subject with a basic introduction and then goes into THz applications, providing examples. In active imaging applications, a developed imaging processing chip is introduced; the author shows the setup, along with a color photo of a detected rat brain tumor. For passive imaging, another chip is introduced, and a color photo of a detected person is presented. The last subject covered, THz tomographic imaging, is explained using a few example experiments. The author also explains the opportunities and the challenges in communication and radar applications. Finally, Chapter 6 includes a few developed THz communication and radar chips.

In summary, the book is at the forefront of THz technology. Dr. Rieh has researched THz technology for years. That, plus his many years of extensive experience in the industry makes this book the best guide and reference for researchers, professionals, engineers, and graduate students.