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LASER PRINTERS. See ELECTROPHOTOGRAPHY.
LASER PULSE COMPRESSION. See PULSE COMPRESSION.
LASERS. See LASER BEAM MACHINING.
LASERS, CHEMICAL. See CHEMICAL LASERS.
LASERS, DISTRIBUTED FEEDBACK. See DISTRIBUTED FEEDBACK LASERS.
LASERS, DYE. See DYE LASERS.
LASERS, EXCIMER. See EXCIMER LASERS.
LASERS, FREE ELECTRON. See FREE ELECTRON LASERS.
LASER SPECKLE. See ELECTRONIC SPECKLE PATTERN INTERFEROMETRY.
LASERS, SUBMILLIMETER WAVE. See SUBMILLIMETER WAVE LASERS.

LATTICE FILTERS

This article discusses filters of a special topology called lattice filters which can be very useful for system phase correction. Here the focus is on the analog lattice described in terms of admittance, scattering, and transfer scattering matrices. A synthesis technique based on the constant-resistance method that yields a cascade realization in terms of degree-one or degree-two real lattices is included. Also included is an example to illustrate the technique.

DEFINITION

A lattice structure is one of the form of Fig. 1(a). In the case of analog circuits, it is taken to be the two-port of Fig. 1(b) with the port variables being voltages and currents, in which case the branches are typically represented by their one-port impedances or admittances. When the lattice is a digital lattice, the structure represents a signal flow graph where the branches are transmittances and the terminal variables are signal inputs and outputs, as shown in Fig. 1(c). Here we treat the analog lattice only; a treatment of the digital lattice can be found in Refs. 1–3.

ANALOG LATTICE

The analog lattices are most useful for the design of filters based upon the principle of constant R structures. These are especially useful for phase correction via all-pass structures

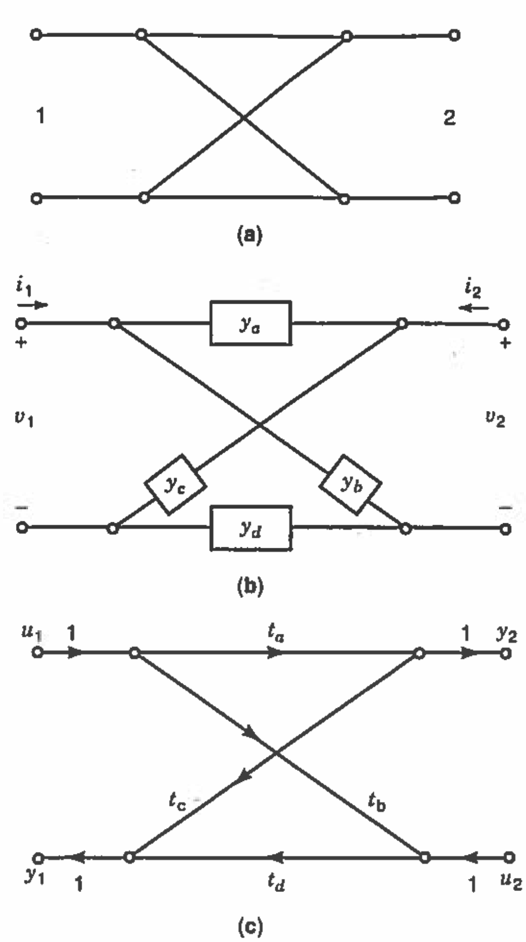

Figure 1. (a) Generic lattice structure. (b) Analog lattice two-port with v_1 and i_1 being the input port variables and v_2 and i_2 the output port variables. Here y_a, y_b, y_c, and y_d represent the one-port admittances of the four branches of the lattice. (c) Digital lattice signal flow graph. Here the branches are transmittances and the terminal variables are signal inputs (u_1 and u_2) and outputs (y_1 and y_2).

as we now show through the use of symmetrical constant R lattices (4, Chap. 12; 5, p. 223; 6, Chap. 5).

We assume that the lattice branches are described by the respective admittances, y_a, y_b, y_c, y_d in which case the two-port admittance matrix Y has symmetry around the main and the skew diagonals

$$Y = \begin{bmatrix} y_{11} & y_{12} \\ y_{12} & y_{11} \end{bmatrix} \tag{1}$$

$$y_{11} = \frac{(y_a + y_b)(y_c + y_d)}{y_a + y_b + y_c + y_d} \tag{2}$$

$$y_{12} = \frac{y_b y_c - y_a y_d}{y_a + y_b + y_c + y_d} \tag{3}$$

In the case where the lattice is symmetrical as well about an horizontal line drawn through its middle, called a symmetrical lattice,

$$y_d = y_a \quad \text{and} \quad y_c = y_b \tag{4}$$

we see by inspection

$$Y = \frac{1}{2}\begin{bmatrix} y_a + y_b & y_b - y_a \\ y_b - y_a & y_a + y_b \end{bmatrix} \tag{5}$$

From Eq. (5) we note that the mutual (off-diagonal) terms can have zeros in the right half s-plane even when y_a and y_b may not. Consequently, the lattice can give nonminimum phase responses in which case it can be very useful for realizing a desired phase shift, possibly for phase correction.

SYNTHESIS BY THE CONSTANT-*R* LATTICE METHOD

Admittance Matrix

The constant-R lattice is defined by using dual arms. Specifically, writing $G = 1/R$, we obtain

$$Ry_b = \frac{1}{Ry_a} \Longrightarrow y_a y_b = G^2 \tag{6}$$

which results in

$$Y_R = \frac{1}{2y_a}\begin{bmatrix} G^2 + y_a^2 & G^2 - y_a^2 \\ G^2 - y_a^2 & G^2 + y_a^2 \end{bmatrix} \tag{7}$$

The name of this structure results from its beautiful property that if it is terminated at port 2 on an R-ohm resistor, the input impedance is an R-ohm resistor, as calculated from the input admittance

$$Y_{in} = \frac{\det Y + Gy_{11}}{G + y_{22}} = \frac{G\left(y_a + y_b + 2\frac{y_a y_b}{G}\right)}{y_a + y_b + 2G} = G \tag{8}$$

and as illustrated in Fig. 2. The transfer voltage ratio is given by

$$\frac{V_2}{V_1} = \frac{-y_{21}}{G + y_{22}} = \frac{y_b - y_a}{y_b + y_a + 2G} = \frac{y_a - G}{y_a + G} \tag{9}$$

Also we have

$$V_1 = \frac{V_{in}}{2} \tag{10}$$

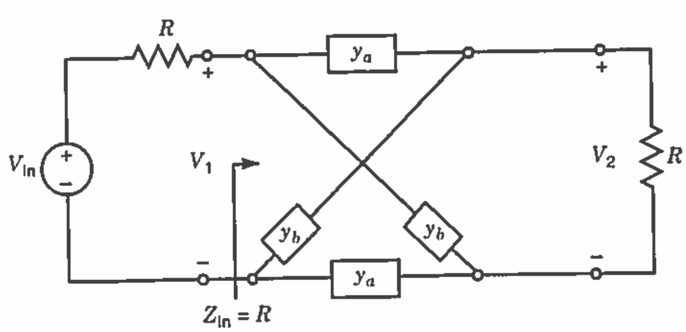

Figure 2. Symmetric analog lattice terminated on an R-ohm resistance at the output port.

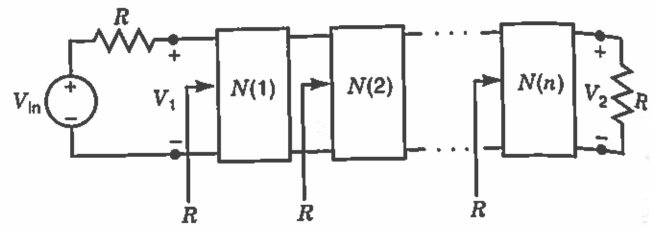

Figure 3. Cascade of n constant-R two-port lattices of the type shown in Fig. (1b) terminated on an R-ohm resistance at the output port.

From Eq. (6) we can obtain the lattice arm impedances y_a and $y_b = G^2/y_a$ since Eq. (9) gives

$$y_a = G\frac{1 + \frac{V_2}{V_1}}{1 - \frac{V_2}{V_1}} \tag{11}$$

In order for a passive synthesis to proceed, y_a must be positive real, the requirement for which is that $y_a(s)$ be analytic in the right half s-plane, $\mathrm{Re}(s) > 0$, and

$$\mathrm{Re}\{y_a(s)\} \geq 0 \quad \text{in} \quad \mathrm{Re}(s) > 0 \tag{12}$$

Translated into the voltage transfer function, after some algebra on Eq. (11), this is seen to be equivalent to

$$\left|\frac{V_2}{V_1}\right| \leq 1 \quad \text{in} \quad \mathrm{Re}(s) > 0 \tag{13}$$

In other words, if the voltage transfer function is rational in s and bounded in magnitude by 1 in the right-half plane, it is guaranteed to be synthesized by a passive symmetrical constant-R lattice with an R-ohm termination.

However, this synthesis in one whole piece of V_2/V_1 may require rather complex lattice arms, in which case we can take advantage of the constant-R property to obtain a cascade of lattices. Toward this consider Fig. 3, which shows a cascade of constant-R two-ports loaded in R. As is clear from Fig. 3 we obtain a factorization of the voltage transfer function into the product of n voltage transfer functions, one for each section:

$$\frac{V_2}{V_{in}} = \frac{1}{2}\left[\frac{V_2}{V_1}\right]_{N(1)}\left[\frac{V_2}{V_1}\right]_{N(2)}\cdots\left[\frac{V_2}{V_1}\right]_{N(n)} \tag{14}$$

In order to synthesize a given realizable voltage transfer function, we can perform a factorization of V_2/V_1 into desirably simple factors and realize each factor by a corresponding constant-R lattice. The factorization can be done by factoring the given transfer function into its poles and zeros and associating appropriate pole–zero pairs with the V_2/V_1 terms of Eq. (14). Usually the most desirable factors are obtained by associating the poles and zeros into degree-one or degree-two real factors.

Lossless Synthesis

A particularly interesting case is when the lattice is lossless, which is expressed by

$$y_a(-s) = -y_a(s) \qquad \text{for a lossless lattice} \tag{15}$$

from which we see by Eq. (9) that

$$\frac{V_2(s)}{V_1(s)}\frac{V_2(-s)}{V_1(-s)} = 1 \qquad \text{for a lossless lattice} \tag{16}$$

In this lossless case we see that for $s = j\omega$ the magnitude of the voltage transfer function, from port 1 to 2, is unity; the circuit is all-pass and serves to only introduce phase shift for phase correction and for the design of constant time-delay networks (7, pp. 144–152). If V_2/V_1 is written as the ratio of a numerator polynomial, $N(s)$, over a denominator polynomial, $D(s)$, then in the all-pass case we have $N(s) = \pm D(-s)$, in which case the phase shift becomes twice that of the numerator, which is then

$$\angle\left(\frac{V_2(j\omega)}{V_1(j\omega)}\right) = 2\arctan\left[\frac{\mathrm{Im}(N(j\omega))}{\mathrm{Re}(N(j\omega))}\right] \tag{17}$$

By placing the zeros of $N(s)$ one can usually obtain a desirable phase shift. In particular, maximally flat delay can be obtained by choosing $N(s)$ to be a Bessel polynomial (7, p. 151).

Example. For $R = 5$, design a cascade of two lattices and compare with an equivalent single lattice for the all-pass function

$$\frac{V_{out}(s)}{V_{in}(s)} = \frac{1}{2}\frac{s^2-3s+2}{s^2+3s+2} = \frac{1}{2}\frac{(s-2)(s-1)}{(s+2)(s+1)} \tag{18}$$

For the first lattice of a cascade of two, using Eqs. (11) and (6) with $V_2/V_1 = (s-2)/(s+2)$, this gives

$$y_a = \frac{sG}{2} = \frac{s}{10} \quad \text{and} \quad y_b = \frac{2G}{s} = \frac{1}{2.5s} \tag{19}$$

and for the second lattice, with $V_2/V_1 = (s-1)/(s+1)$, we obtain

$$y_a = Gs = \frac{s}{5} \quad \text{and} \quad y_b = \frac{G}{s} = \frac{1}{5s} \tag{20}$$

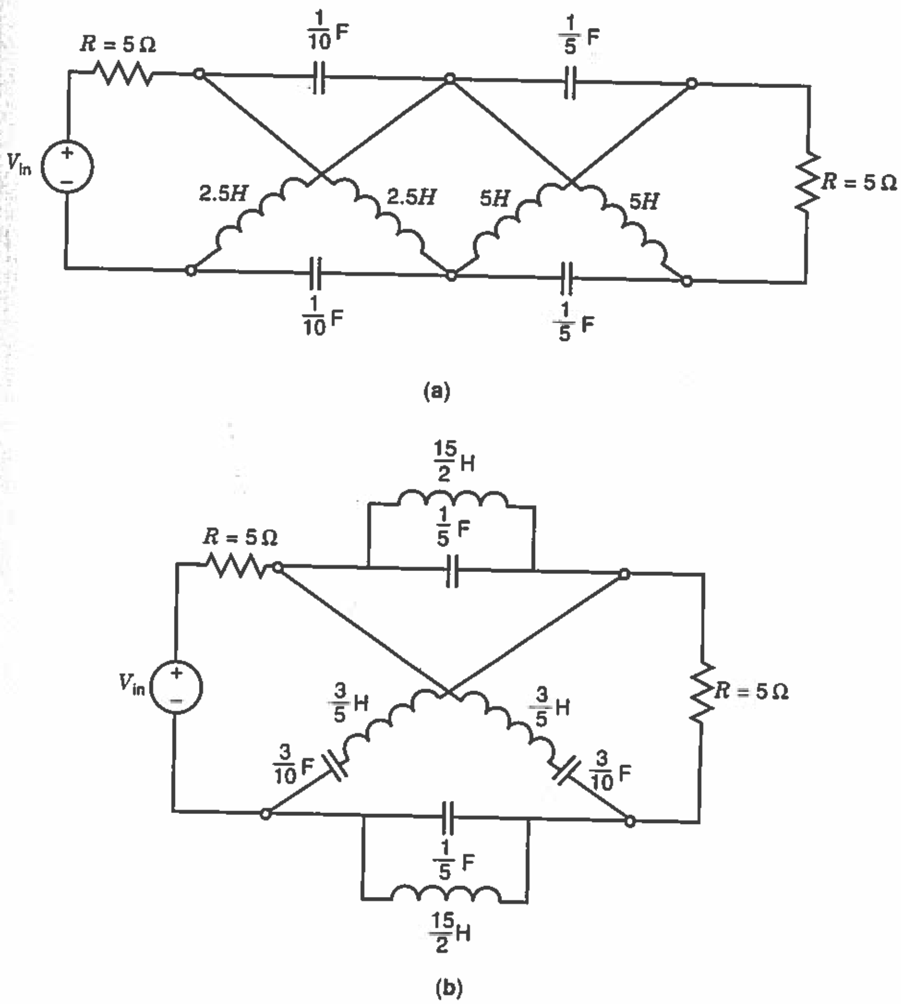

Figure 4. Lossless lattice synthesis of an all-pass transfer function of degree two. (a) Synthesis using a cascade of two lattices of degree 1 Arms. (b) Equivalent realization using a single lattice of degree 2 Arms.

In the case of a single lattice, for V_2/V_1 twice the first expression of Eq. (18), we have

$$y_a = \frac{G(s^2+2)}{3s} = G\left(\frac{s}{3} + \frac{1}{\frac{3}{2}s}\right) \quad \text{and} \quad y_b = \frac{3Gs}{s^2+2} = \frac{G}{\frac{s}{3} + \frac{1}{\frac{3}{2}s}} \tag{21}$$

The final cascade of lattices and equivalent lattice are given in Fig. 4(a) and Fig. 4(b), respectively.

Scattering Matrix

It is also of interest to look at the scattering matrix referenced to R, S, for the constant-R lattice which can be found from the augmented admittance matrix, Y_{aug}, of the lattice filter as illustrated in Fig. 5(a):

$$S = I_2 - 2RY_{aug} \tag{22}$$

where I_2 is the 2 × 2 identity matrix. By symmetry, we have from Fig. 5(b)

$$y_{aug11} = y_{aug22} = y_{in} = \frac{1}{2R} \tag{23}$$

and thus

$$s_{11} = s_{22} = 1 - 2R\frac{1}{2R} = 0 \tag{24}$$

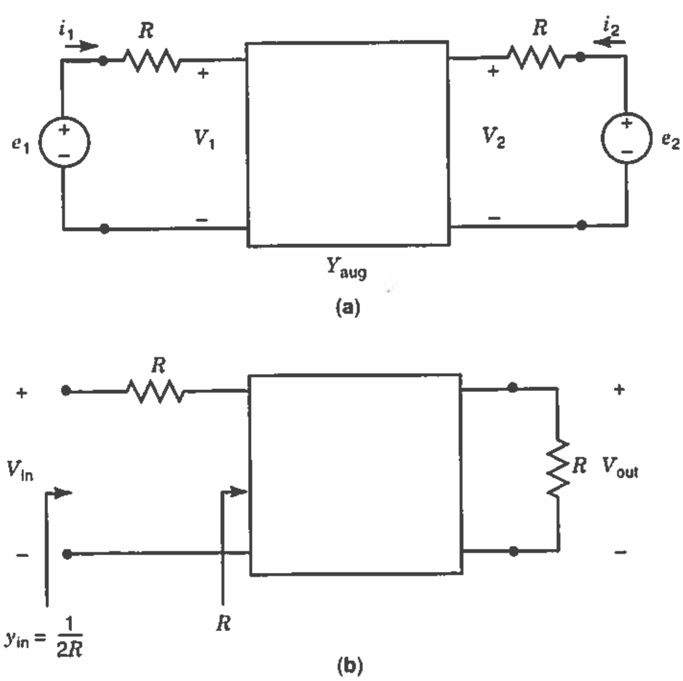

Figure 5. (a) Network pertinent to the interpretation of the scattering parameters. (b) The R-terminated two-port used to evaluate the input admittance y_{in}. This two-port configuration is obtained from Fig. (5a) by setting $e_2 = 0$ and applying an input voltage V_{in}.

The entries s_{12} and s_{21} are calculated in terms of y_a and G using Eq. (11):

$$s_{12} = s_{21} = 2\left[\frac{V_2}{e_1}\right]_{e_2=0} = 2\frac{V_{out}}{V_{in}} = \frac{V_2}{V_1} = \frac{y_a - G}{y_a + G} \tag{25}$$

The above results give the following scattering matrix:

$$S = \begin{pmatrix} 0 & \dfrac{y_a - G}{y_a + G} \\ \dfrac{y_a - G}{y_a + G} & 0 \end{pmatrix} \tag{26}$$

The zeros on the diagonal of S indicate that the constant-R lattice is matched to its terminations. Since cascade synthesis can proceed via factorization of the transfer scattering matrix (3), it is of interest to note that the transfer scattering matrix, $T(s)$, is given by

$$T(s) = \frac{1}{s_{12}}\begin{pmatrix} 1 & -s_{22} \\ s_{11} & \det S \end{pmatrix} = \begin{pmatrix} \dfrac{y_a + G}{y_a - G} & 0 \\ 0 & \dfrac{Y_a - G}{y_a + G} \end{pmatrix} \tag{27}$$

When working with the digital lattices of Fig. 1(c), the transfer scattering matrix is particularly convenient since its factorization is readily carried out using Richard's functions extractions of degree-one and degree-two sections [see (3) for details].

TRADE-OFFS AND SENSITIVITY

Despite its versatility, the lattice structure presents several disadvantages of a practical nature. As seen in Fig. 4, there is no possibility of a common ground between the input and the output terminals of a lattice circuit. Although generally it is difficult to obtain a transformation of the lattice to a circuit with common input–output ground, a Darlington synthesis can be undertaken with the desired result (8, Chap. 6). The lattice also uses at least twice the minimum number of components required since the upper arms repeat the lower arms. Furthermore, since the transmission zeros are a function of the difference of component values as seen by Eq. (5), small changes in these may distort the frequency response, the phase in particular, considerably (6, p. 148). However, if corresponding arm components simultaneously change in a lossless lattice, so that the constant-R property is preserved, then the sensitivity of $|V_2(j\omega)/V_1(j\omega)|$ is zero since it is identically 1.

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LAW. See CONTRACTS; LAW ADMINISTRATION; SOFTWARE MANAGEMENT VIA LAW-GOVERNED REGULARITIES.

LAW ADMINISTRATION

This article covers the use of electronics in law practice in the United States. To understand the subject better, there is a significant discussion of the unique characteristics of legal practice in the United States. The term *electronics* is used in the widest sense and encompasses the use of computers to manipulate words primarily. In addition, the use of electronics in the law is more of a practical application of the theory.

The legal profession has been both ahead of its time and behind its time in the use of electronic resources to assist in managing its information. The legal profession in the United States depends on the Common Law doctrine of precedents. In a Common Law country the decisions of a higher court govern the decisions of the lower courts. Combined with the laws and the regulations of the federal, state and local government, this produces a vast quantity of decisions, laws, and regulations that must be consulted before rendering a decision or giving legal advice. With the ever increasing flow of data has led the legal profession to adopt new technologies to manage this vast amount of information.

Over the centuries, American legal publishing has evolved into one of the best manually indexed field resulting primarily from the work of West Publishing Company and Shepards. West was the first publisher to publish systematically the state and federal decisions in 1876. The set became known as the National Reporter System. Before that, a lawyer had to rely on the court decisions that were published by a specific court, usually by the court reporters who made their living by selling the decisions. The other group of early legal books were codifications. Sometimes this was done by a government, such as the Code Napoleon. More likely, they were the treatises on a specific subject containing a report of significant cases. The primary universal codification was Blackstone's Commentaries that were first published in 1788 in England. Because the US legal system is based on English Common Law, the Commentaries became the standard legal treatise until a significant body of American law developed.

The concern of the lawyers is that the case being used to prove their point has to be "good law" meaning that the same court or a higher court has not overruled the decision subsequently. Shepards is the company that analyzes court decisions to determine if they affect previous decisions. The various sets of books of Shepards evolved into gigantic lists of tables that showed if a case was still "good law." They also indicated if the case had been cited (referred to) by other courts in and out of its jurisdiction.

Until the 1970s, the study and research into law required an ever increasing collection of books. This was an advantage for large law firms (more than 50 lawyers) because they could afford the high overhead of purchasing, maintaining, and housing the books. Solo practitioners and small law firms had to rely on bar association libraries or law schools to do their research. These law libraries usually required the services of professional law librarians.

The first successful use of electronics in the legal profession was the Ohio Bar Automated Research (OBAR) started in the late 1960s. At first, OBAR dealt only with Ohio law but it started to encompass Federal and other state materials. OBAR was acquired by Mead Paper and became Lexis/Nexis (Nexis is the nonlegal portion of Lexis). West, the largest US publisher of legal decisions, later created a competitor, Westlaw. Competition between the two created two vast databases of legal materials that are now replacing books as the primary place for legal research. Although both are full-text systems, Westlaw has a controlled vocabulary and digest system (3,4). There are two Internet services; Lois, www.pita.com, and Versus, www.versus.com, which offer lower but less expensive alternatives.

Both Lexis and Westlaw have developed enhancements to their on-line databases that also show if a case is still "good law." These programs rely on a computer analysis of the cases to determine if the case can be used as authority. These two programs have moved the researcher away from Shepards, but there is concern that neither program has the editorial work that made Shepards so indispensable (1).

Although West and Shepards were the first nationwide publishers, many more entered the field. Few matched the universal reporting, most developed subject-specific publications. These are extremely attractive to lawyers because they combine the laws, regulations, cases, and commentaries in one book or set of books. Because the law is constantly changing, most of the publications now are supplemented by pocket parts or are looseleaf publications, and the outdated pages are replaced with new pages containing updated information. Electronic databases eliminate the need for paper updates and they can be updated instantaneously but at a higher cost.

A legal citation is an abbreviated method of citing that is usually based on *The Bluebook: A Uniform System of Citations* (2). Because courts require official legal documents to provide specific citation information to any cited case, statute, or regulation, the legal profession has always relied on The Bluebook, which usually relies on West's National Reporter Systems volumes and pages. This has required any full text legal database to imbed in the electronic data information reflecting the material's location in the printed source. West's claim of copyright on its arrangement of printed material has forced competing vendors to either license the pagination information or challenge West in court. This litigation is still making its way through the courts.

The use of electronic legal information has transformed legal research in the last few years. The fundamental change is

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