Esto me permitirá obtener la función transferencia de un filtro pasa todo | Entre páginas 70 - 71

APF → All-pass filter !

1.



Utilizo la red Lattice para poder generar coeficientes negativos en el numerador de la función transferencia.

It is clear from Eq. (3.19) that the circuit in Fig. 3.3 can realize only transfer functions with positive coefficients. If we want to implement Eq. (3.2) with a negative coefficient in the numerator, such as $T_c$ in Eq. (3.6), we need to consider a different circuit configuration that can generate a minus sign. The circuit in Fig. 3.13a is a suitable structure that has a different (nonplanar) appearance from those considered earlier. It is known as a *lattice*. An equivalent form in which it may appear is shown in Fig. 3.13b. In this form it is known as a *bridge* circuit and is simpler to analyze. We will often find it convenient to redraw a circuit in a form where the structure becomes easier for the analysis. Proceeding thus with Fig. 3.13b, we observe that the output voltage is the difference of the voltages at nodes $A$ and $B$,

$$V_2 = V_A - V_B \tag{3.39}$$

Surge de esta ddp la salida del lattice.

where clearly, with equal resistors, ($R_1$)

$$V_A = \frac{V_1}{2}$$

The other voltage, $V_B$, comes directly from Eq. (3.31):

$$V_B = \frac{sCR}{sCR+1}V_1 \tag{3.40}$$

Substituting these two results into Eq. (3.39), we have

Diagrama de polos y ceros

$$V_2 = \left(\frac{1}{2} - \frac{sCR}{sCR+1}\right)V_1 = \frac{1}{2}\frac{1-sCR}{1+sCR}V_1 \tag{3.41}$$

Salida Lattice (RC)

The pole-zero description of this equation is shown in Fig. 3.14a where we have let $RC = 1/\omega_c$. Notice that the function has a zero in the right half-plane and a pole in the left half-plane, both on the real axis, and with equal distances from the origin. If we let $s = j\omega$, the magnitude function becomes

(#) Analizo el módulo de la transferencia.

$$|T(j\omega)| = \frac{1}{2}\frac{|1 - j\omega/\omega_c|}{|1 + j\omega/\omega_c|} \tag{3.42}$$

(#) los números complejos del num y denom son conjugados, por ende tienen igual módulo pero fase opuesta

Observe next that the numerator and denominator have identical magnitudes so that

(entonces se cancelan)

$$|T(j\omega)| = \frac{1}{2} \quad \text{for all } \omega \tag{3.43}$$

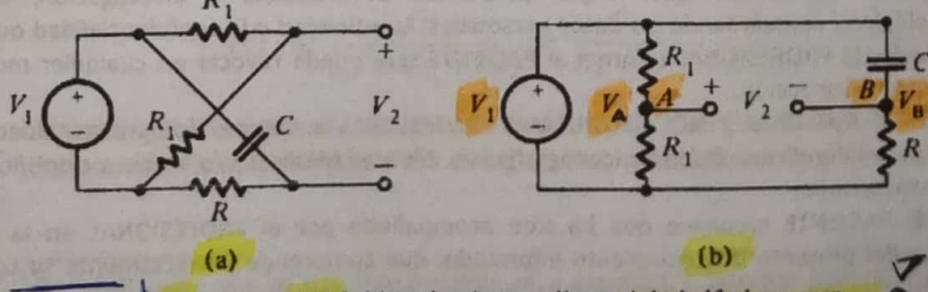
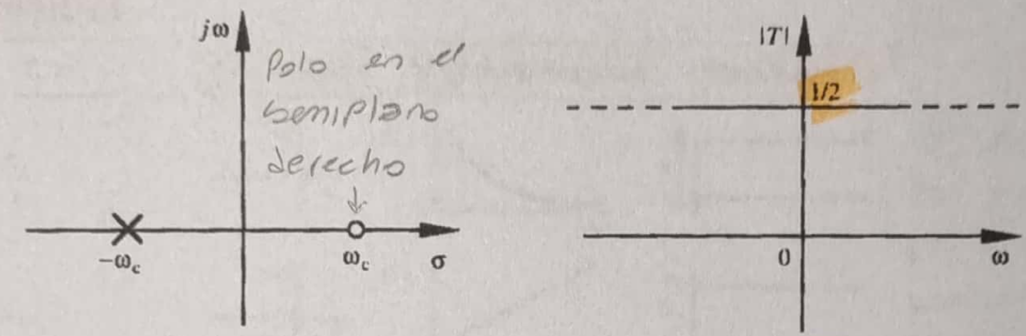



**Figure 3.13** (a) Lattice or (b) bridge circuit to realize a right half-plane zero.

El circuito "B" es más sencillo para analizar, pero es muy incómodo para cascadear en un multietapa xq tengo la salida en el medio del circuito, para eso conviene utilizar el "A"




(a) (b)

**Figure 3.14** (a) Pole-zero plot of the allpass characteristic in Eq. (3.41); (b) magnitude of allpass characteristics in Eq. (3.42).

The only apt description of this characteristic, shown in Fig. 3.14b, is *allpass*, and the concept of a cut-off frequency has no meaning. A circuit having this characteristic is known as an *allpass filter*.

Función de un APF.

The student may well wonder at this point what good such a circuit is and why it is not simply replaced by a resistive voltage divider, such as in the left branch of Fig. 3.13b. The answer is that an allpass filter provides frequency-dependent phase shift without changing the magnitude. For instance, we can find from Eq. (3.41)

Fase APF

$$\theta(\omega) = -2\tan^{-1}(\omega CR) = -2\tan^{-1}(\omega/\omega_c) \tag{3.44}$$

Notice that the allpass filter has twice the phase of the lowpass filter in Eq. (3.27). Allpass filters are important in many communications applications where they are used as phase equalizers for transmission channels, a topic we will study in more detail in Chapters 10 and 11.

la tabla de atrás

Table 3.1 presents the different types of bilinear transfer functions, their pole-zero patterns, and their magnitude and phase responses. Many of these first-order functions can be realized by the circuits in Fig. 3.3 or 3.13, but some pole-zero patterns, such as the integrator $K/s$, cannot be implemented with passive circuits. Although "a capacitor is an integrator," $Z_C = 1/(sC)$,[1] it is an impedance and not a transfer function. Also, passive implementations of bilinear functions have another problem: they cannot be loaded without destroying the transfer function. For example if we need to develop the output voltage $V_2$ of the lowpass filter in Fig. 3.4 across a prescribed load resistor $R_L$, such as in Fig. 3.15, we would seriously alter the behavior of the filter. Using voltage division or Eq. (3.19), the transfer function of this circuit is readily derived as

Explica xq un Cap no es un integrador y los problemas de las implementaciones pasivas.

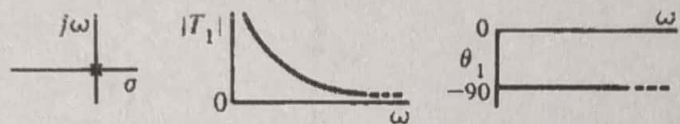
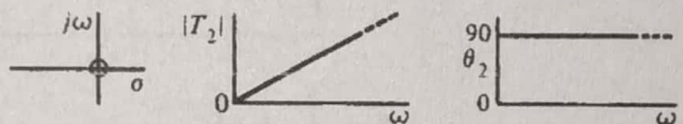
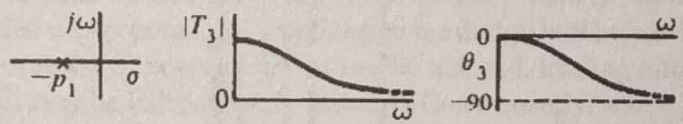
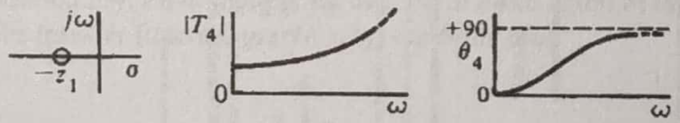
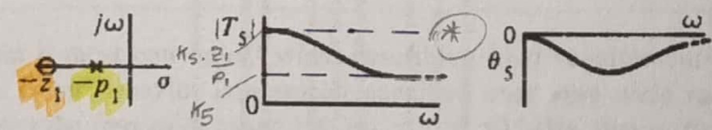
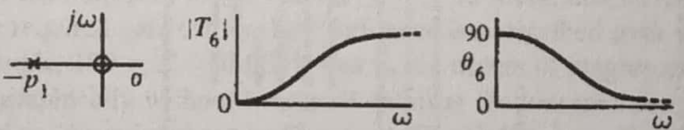
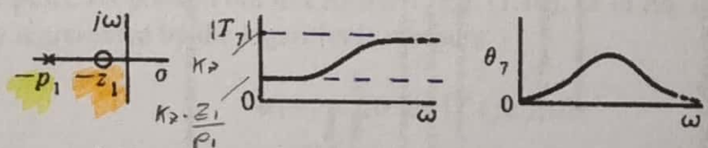
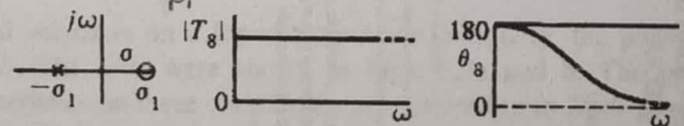
$$T(s) = \frac{G_1}{G_1 + G_L + sC_2} = \frac{G_1}{G_1 + G_L}\frac{1}{sC_2/(G_1 + G_L) + 1} \tag{3.45}$$

Comparing this expression with the nominal lowpass filter function (3.22) with $G_L = 0$ shows that not only has the dc gain $T(0)$ changed, but, what is more important and generally more

(→)

[1] We shall make use of this interpretation of a capacitor's function later when we develop active simulations of high-order filters.

**TABLE 3.1**

| | $T_n(s)$[a] | Pole and Zero / Magnitude Response / Phase Response | (*) Analizo que pasa con $w=0$ y $w \to \infty$ en algunos casos puntuales. |
|---|---|---|---|
| Integrador | $\frac{K_1}{s}$ |  | |
| Derivador | $K_2 s$ |  | |
| | $\frac{K_3}{s+p_1}$ |  | |
| | $K_4(s+z_1)$ |  | |
| Con estos dos, juega con cambiar el orden del polo y el cero, con cual está mas cerca del eje jw. | $K_5\frac{s+z_1}{s+p_1}$ |  | |
| | $K_6\frac{s}{s+p_1}$ |  | |
| | $K_7\frac{s+z_1}{s+p_1}$ |  | |
| | $K_8\frac{s-\sigma_1}{s+\sigma_1}$ |  | |

[a] All $K_j$ are assumed positive.

(→) troublesome, the pole position has shifted. This means that the 3-dB frequency has increased from $1/(R_1C_2)$ to $(1 + R_1/R_L)/(R_1C_2)$ as you can show from Eq. (3.45). Such shifts in a filter's poles (and zeros) are normally not acceptable because the specified transmission behavior is destroyed. An additional problem for some applications is that zeros and poles are not independently adjustable or *tunable*. Assume, for example, that $z_1$ and $p_1$ of the circuit in Fig. 3.3 have been designed as per specifications, but that after fabrication the zero turned out to be incorrect because of component tolerances. Thus, the zero must be tuned by adjusting either $R_1$ or $C_1$. Now note from Eq. (3.21) that varying the components $R_1$ and $C_1$ to set the correct $z_1$ will always adjust $p_1$ as well so that iterative tuning of parameters is normally necessary.

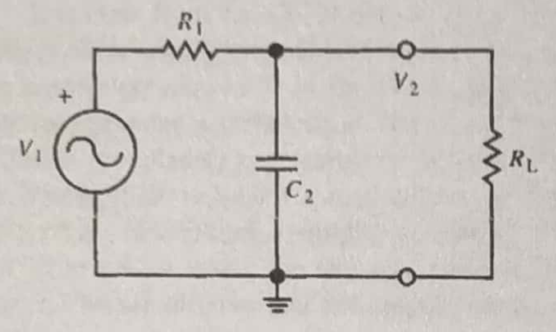



**Figure 3.15** The lowpass filter of Fig. 3.4 with a load resistor $R_L$.

For these reasons we are motivated to look for other ways to implement first-order filters. We shall find that using operational amplifiers in the design will help solve all three difficulties: arbitrary sets of real-axis poles and zeros can be realized, loading effects are minimized, and poles and zeros may be independently adjusted. Consequently, active *RC* realizations will be discussed in Section 3.4. First, though, let us look in more detail at the customary method of representing the transfer function graphically: the *Bode plot*.

## 3.3 BODE PLOTS

We will find it most convenient when describing filter requirements to use a graphic representation. Filter behavior is normally specified over very wide ranges of frequency, for example, over the frequency range 100 Hz $\le f \le$ 10 MHz, that is, five orders of magnitude. Similarly, the required gain (or loss) performance is prescribed over wide ranges of gain (or loss), for example, $100 \ge K \ge 0.0001$, that is, six orders of magnitude. To be able to picture these ranges graphically without losing all detail at the extremes, engineers have long used logarithmic plots. As pointed out in Chapter 1, Eq. (1.10), or in Eq. (3.26), the magnitude is customarily represented by the logarithmic measure

$$\alpha(\omega) = 20 \log |T(j\omega)| \text{ dB} \tag{3.46}$$

and is plotted versus $\omega$ on a logarithmic scale. Similarly, the phase in degrees is plotted versus $\log(\omega)$. The axes were shown in Figs. 3.5a and b. The plots of magnitude and phase characteristics on these coordinates are referred to as *Bode plots* after Hendrik Bode.[2] Observe that both sets of coordinates identify *semilog* plots, i.e., the abscissas have linear scales, but note that $\alpha(\omega)$ is a logarithmic measure, even if plotted on a linear scale. Let us demonstrate on a specific example, the first-order function discussed in this chapter, how a Bode plot is generated. We start from the transfer function of Eq. (3.7), evaluated on the $j\omega$-axis,

$$T(j\omega) = \frac{N(j\omega)}{D(j\omega)} = K\frac{j\omega + z_1}{j\omega + p_1} = K\frac{z_1}{p_1}\frac{1 + j\omega/z_1}{1 + j\omega/p_1} \tag{3.47}$$

We are interested in plotting magnitude and phase of $T(j\omega)$ versus logarithmic coordinates. The magnitude function of Eq. (3.47) is

[2] Hendrik Bode (pronounced *boh dah*) grew up in Urbana, Illinois, and spent most of his professional life at Bell Laboratories. After his retirement from Bell Labs, he became a professor at Harvard University.