Impedance Matching Circuits

(Part 2)

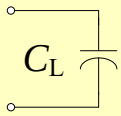
Dr. José Ernesto Rayas-Sánchez

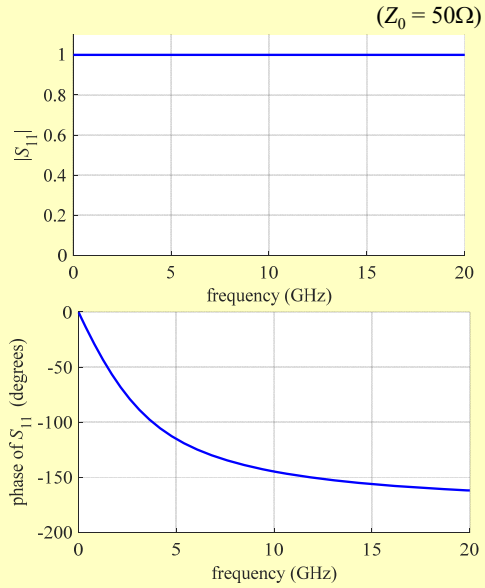
Outline

- Capacitive Loads
- Resistive compensation of capacitive loads
- Inductive compensation of capacitive loads
- Matching capacitive loads with an inductor
- Matching capacitive loads with L-sections
- Other practical techniques

Capacitive Load – Example

C_L = 1pF





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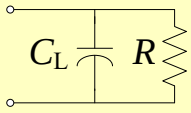
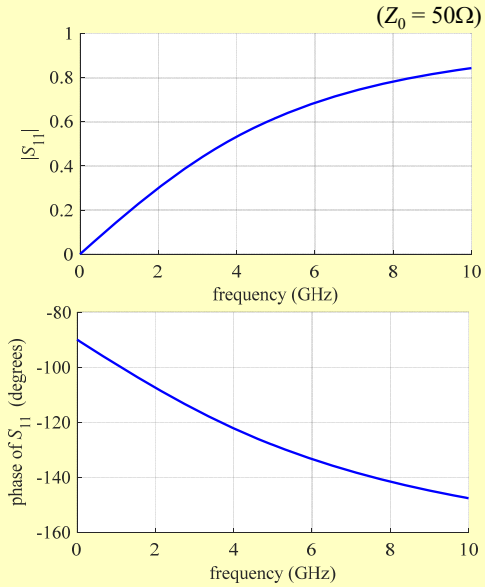
Capacitive Loads – Resistive Compensation

C_L = 1pF, R = 50Ω





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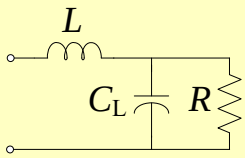
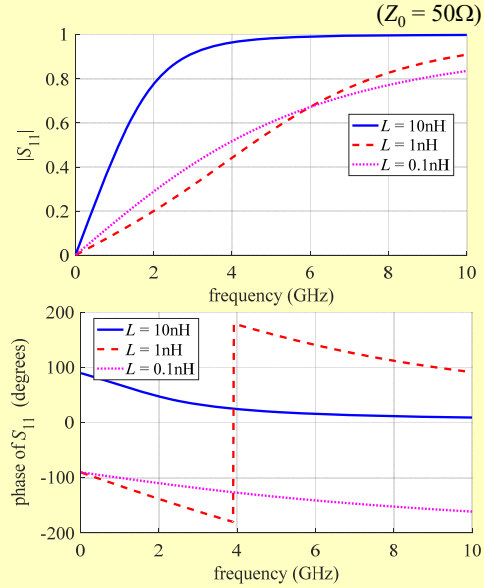
Capacitive Loads – Inductive Compensation

$C_L = 1\text{pF}$, $R = 50\Omega$



($Z_0 = 50\Omega$)



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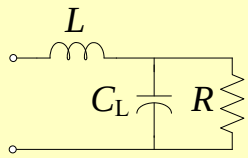
Matching Capacitive Loads – Example

Calculating R and L:

($Z_0 = 50\Omega$)



$X = \omega L$; $B_L = \omega C_L$

$C_L = 1\text{pF}$

$$f_{max} = \frac{1}{4\pi Z_0 C_L} = 1.59\,\text{GHz}$$

Let $f_0 = 1\,\text{GHz}$

$$B_L = 2\pi f_0 C_L = 6.283\,\text{mS}$$

$$4Z_0^2 B_L^2 < 1$$

$$R = \frac{1 \pm \sqrt{1 - 4Z_0^2 B_L^2}}{2Z_0 B_L^2} = \begin{cases} 450.36\,\Omega \\ 56.24\,\Omega \end{cases}$$

$$X = \frac{B_L R^2}{1 + B_L^2 R^2} = \begin{cases} 141.48\,\Omega \\ 17.67\,\Omega \end{cases} \qquad L = \frac{X}{2\pi f_0} = \begin{cases} 22.52\,\text{nH} \\ 2.81\,\text{nH} \end{cases}$$

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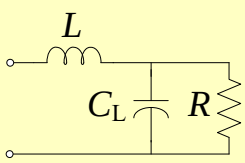
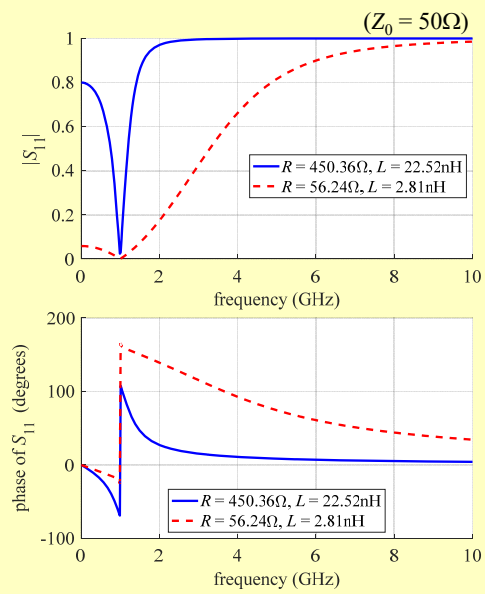
Matching Capacitive Loads – Example (cont.)

Using calculated R and L:

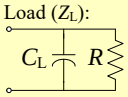
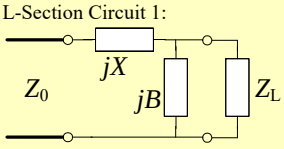
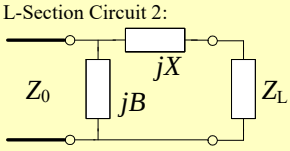
C_L = 1pF





Matching Capacitive Loads – Example (cont.)

Using an L-Section: (Z_0 = 50Ω)

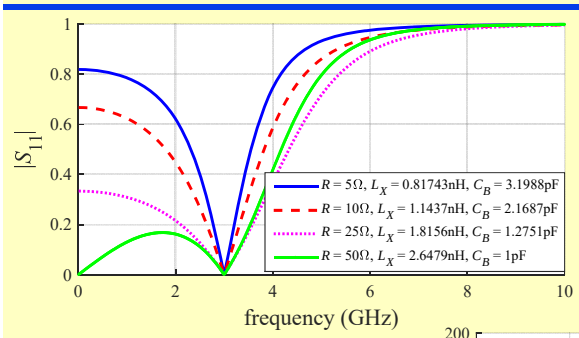
Load (Z_L):	L-Section Circuit 1:	L-Section Circuit 2:
 C_L = 1pF f_0 = 3GHz $Z_L = \dfrac{R}{1+2j\pi f_0 R C_L}$	 $B = \dfrac{X_L \pm \sqrt{R_L/Z_0}\sqrt{X_L^2 - R_L Z_0 + R_L^2}}{X_L^2 + R_L^2}$ $X = (Z_0/R_L)[B(R_L^2 + X_L^2) - X_L]$	 $X = \pm\sqrt{R_L(Z_0 - R_L)} - X_L$ $B = \dfrac{X + X_L}{(X + X_L)^2 + R_L^2}$

Matching Capacitive Loads – Example (cont.)

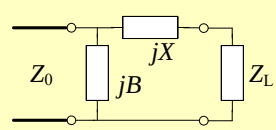
Using an L-Section: ($Z_0 = 50\Omega$)

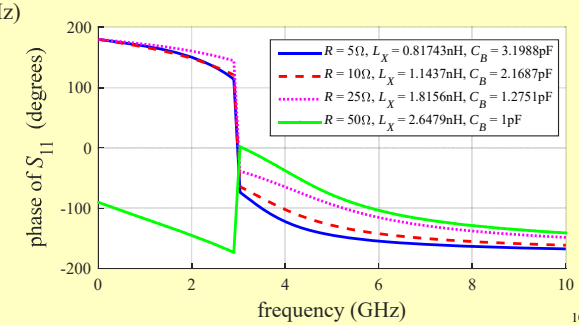
R (Ω)	Re{Z_L} (Ω)	Im{Z_L} (Ω)	Circuit	X (Ω)	B (S)	L_X (nH)	C_X (pF)	L_B (nH)	C_B (pF)
5	4.956	-0.46709	2	15.4082 -14.474	0.060295 -0.060295	0.81743	3.6653	0.87986	3.1988
10	9.6569	-1.8203	2	21.5583 -17.9177	0.040879 -0.040879	1.1437	2.9608	1.2978	2.1687
25	20.4572	-9.6402	2	34.224 -14.9436	0.024034 -0.024034	1.8156	3.5501	2.2073	1.2751
50	26.4793	-24.9562	2	49.9124 -3.5e-15	0.01885 -0.01885	2.6479	1.5e+16	2.8145	1
80	24.4353	-36.8475	2	61.8411 11.8539	0.020457 -0.020457	3.2808 0.62887		2.5933	1.0853
150	16.6771	-47.1533	2	70.7272 23.5794	0.028271 -0.028271	3.7522 1.2509		1.8765	1.4998
500	5.5663	-52.461	2	68.1878 36.7343	0.056507 -0.056507	3.6175 1.9488		0.93885	2.9978
1000	2.8066	-52.9028	2	64.4115 41.394	0.082013 -0.082013	3.4171 2.196		0.64687	4.3509

Matching Capacitive Loads – Example (cont.)

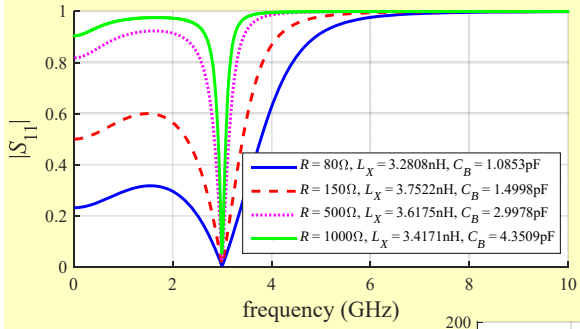


($Z_0 = 50\Omega$)

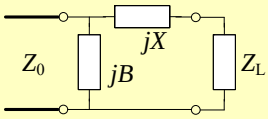


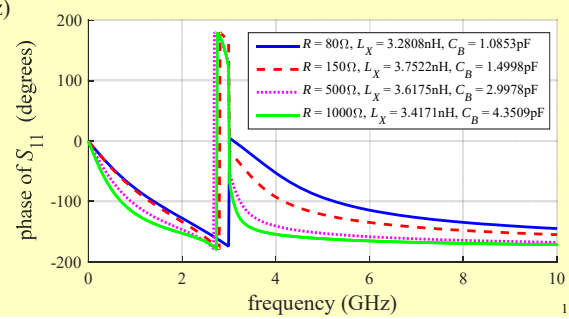


Matching Capacitive Loads – Example (cont.)



($Z_0 = 50\Omega$)





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Other Practical Techniques

H. Johnson, "High-speed digital design," *IEEE Microwave Magazine*, vol. 12, pp. 42-50, Aug. 2011.

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Other Practical Techniques (cont.)

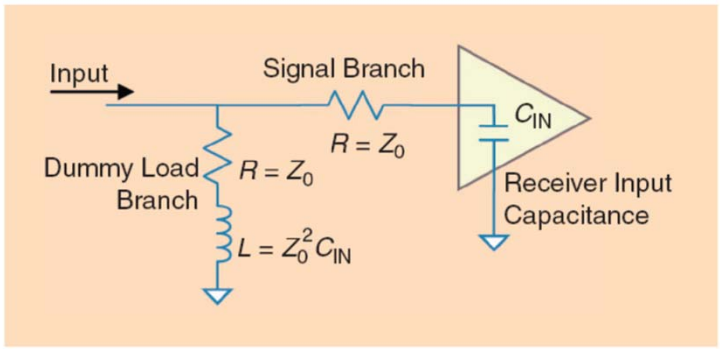
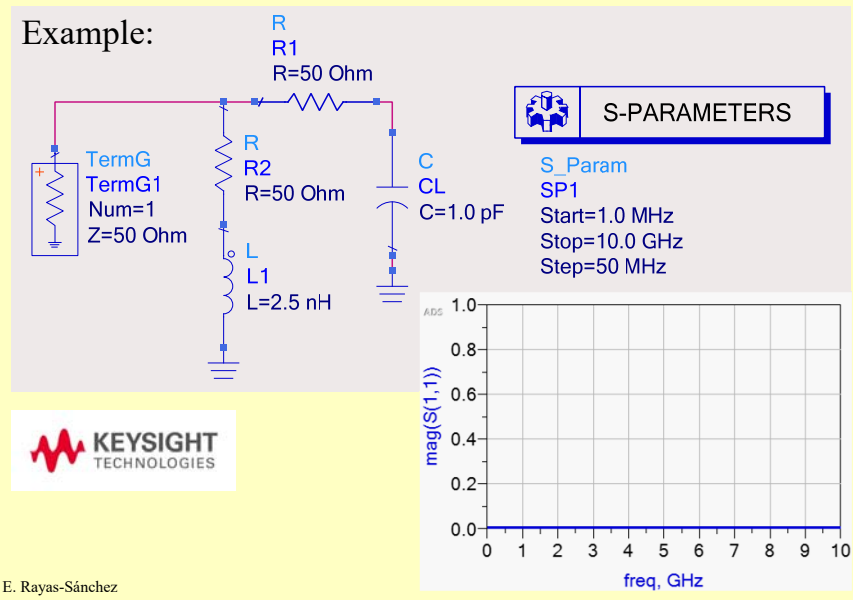


Figure 5. *The input impedance of this constant-resistance network, if perfectly implemented, equals Z_0 at all frequencies.*

H. Johnson, "High-speed digital design," *IEEE Microwave Magazine*, vol. 12, pp. 42-50, Aug. 2011.

Other Practical Techniques (cont.)

Example:



Other Practical Techniques (cont.)

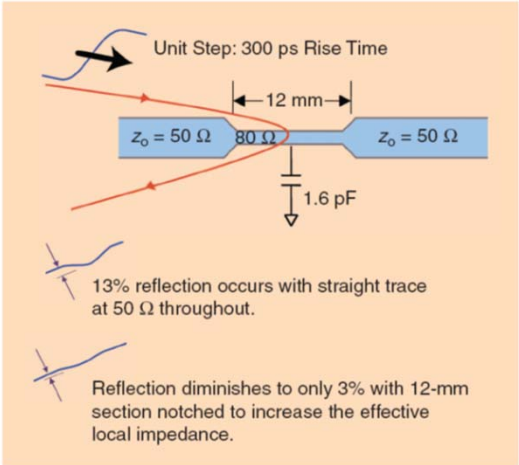


Figure 6. *A skinny section of printed circuit board trace mitigates the reflections from a small capacitive load.*

H. Johnson, "High-speed digital design," *IEEE Microwave Magazine*, vol. 12, pp. 42-50, Aug. 2011.