FILTER DESIGN HANDBOOK -

LUMPED ELEMENT FILTER DESIGN

STEP 1: DETERMINE 'g' PARAMETERS FOR LP DESIGN

\[ PLR = \frac{P_{inc}}{P_{out}} = \frac{1}{1 - 11(\frac{f}{f_c})^2} \]

-BINOMIAL- MAXFLAT

Fig 8.26

TABLE 8.3

CHEBYSHEV (0.5 or 3dB RIPPLE)

Fig 8.27

TABLE 8.4

"Design a binomial, filter with a cutoff frequency \( w_c \) that is \( x \) dB down at \( freq = \omega \)"

\[ n = \text{choose } n \text{ curve that is above } x \]

at \( \frac{|w|}{w_c} = -1 \)

Fig 8.26 or 8.27

\[ \frac{|w|}{w_c} = -1 \]

Read \( g \) values from Table 8.3 or 8.4; \( g_0 = 1 \)

\[
\begin{array}{c|cccc}
N=n-1 & g_1 & g_2 & g_3 & g_4 \\
1 & 2.0 & 1.0 & & \\
2 & 1.41 & 1.41 & 1.0 & \\
3 & 1.0 & 2.0 & 1.0 & 1.0 \\
\end{array}
\]
**Step 2: Draw LP Filter**

(a) \[ \frac{1}{g_0} \ \frac{1}{g_1} \ \frac{1}{g_2} \ \frac{1}{g_3} \]

(b) \[ \frac{1}{g_0} \ \frac{1}{g_1} \ \frac{1}{g_2} \ \frac{1}{g_3} \]

**Larger Filter:**

\[ \frac{1}{g_0} \ \frac{1}{g_1} \ \frac{1}{g_2} \ \frac{1}{g_3} \ \ldots \ \frac{1}{g_n+1} \]

These designs assume \( w = 1 \) and \( Z_0 = 1 \)

**Step 3(a): Denormalize Low Pass**

**Filter (a):**

- \( R_g = Z_0 g_0 \)
- \( C = g_1 / (Z_0 w_c) \)
- \( L = Z_0 g_2 / w_c \)
- \( R_L = Z_0 g_{n+1} \)

**Filter (b):**

- \( R_g = 1 / (Z_0 g_0) \)
- \( C = g_1 / (Z_0 w_c) \)
- \( L = Z_0 g_2 / w_c \)
- \( R_L = 1 / (Z_0 g_{n+1}) \)

*If \( R_L \) not matched, use \( \frac{1}{4} \) TX to match*

**Step 3b: Convert from LP to HP & Denormalize**

(a) \[ \ldots \]

(b) \[ \ldots \]

**Filter (a):**

- \( R_g = Z_0 g_0 \)
- \( C = 1 / (Z_0 w_c) \)
- \( L = Z_0 g_2 / w_c \)
- \( R_L = Z_0 g_{n+1} \)

**Filter (b):**

- \( R_g = 1 / (Z_0 g_0) \)
- \( C = 1 / (Z_0 w_c) \)
- \( L = Z_0 g_2 / w_c \)
- \( R_L = Z_0 g_{n+1} \)
**STEP 4**: CONVERT LP TO BP OR BANDSTOP

Denormalize

![Attenuation Graph]

Fractional Bandwidth

\[ \Delta = \frac{\omega_2 - \omega_1}{\omega_0} \]

\[ w_0 = \sqrt{\omega_1 \omega_2} \]

\[ \omega_{LP} = \frac{1}{\Delta} \left( \frac{\omega_0 - \omega_0}{\omega} \right) \]

(Figure often given in %, multiply \( \Delta \) by 100)

Look at Fig 8.26 or 8.27 using

See Table 8.6 for conversions

\[ \frac{\omega_{LP}}{\omega} = 1 \]

**Band Pass Example:**

(a) \[ g_0 \quad g_1 \quad g_2 \quad g_3 \]

(b) \[ \frac{g_0}{g_1} \quad g_3 \quad \frac{g_2}{g_3} \]

To Denormalize:

(a) \[ R = g Z_o \]

(b) \[ R = 1/(g Z_o) \]

\[ L = L Z_o \]

\[ C = C / Z_o \]

\[ L = L Z_o \]

\[ C = C / Z_o \]
**Coupled Line Filter (CLF)**

Width of all lines given $Z_0$

Lengths & impedances stay the same. Spacing changes.

Remember to calculate $\lambda = \frac{c_0}{f \sqrt{\epsilon_{reff}}}$.

**Equation (3.19c)**

Steps (1,2,4,b): same as for lumped element.

**But**: Do NOT Denormalize

**Step 5 - CLF**

$Z_0 J_1 = \sqrt{\frac{\pi \Delta}{2g_1}}$

$Z_0 J_i = \frac{\pi \Delta}{2 \sqrt{g_{i-1} g_i}}$ for $i = 2, 3, \ldots, N$

$Z_0 J_{N+1} = \sqrt{\frac{\pi \Delta}{2 g_N g_{N+1}}}$

**Step 6 - CLF - Find Even & Odd Impedances**

$Z_{0e} = Z_0 \left[ 1 + J Z_0 + (J Z_0)^2 \right]$

$Z_{0o} = Z_0 \left[ 1 - J Z_0 + (J Z_0)^2 \right]$

Find $\varepsilon$ with Fig 7.30 or linecalc
**Stub Filter (SF)**

\[ \lambda = \frac{g}{f \sqrt{V_{eff}}} \]

Note: \( \lambda \) is \( \lambda_c = \frac{g}{f \sqrt{V_{eff}}} \)

Length stays the same \( (\lambda/8) \)

Impedances (widths) change

**Steps (1, 2, 3, 4)**

Same as for lumped elements, Do Not Denormalize

\[ y_0 \quad g_1 \quad y_3 \quad \cdots \quad y_{N+1} \]

**Step 5 - SF**

Replace \( g_i \) with series stub with impedance \( Z_i = y_i \)

(Not critical \( \frac{1}{g} \) with parallel stub w impendence \( Z_i = g_i \)

to draw filter, Go to oc Step 6)

\[ g_0 \quad g_1 \quad y_8 \quad y_3 \quad \cdots \quad y_{N+1} \]

**Step 6 - SF** Use Kuroda Identities (Tab 8.7)

- Add \( \lambda/8 \) line to front (or front & back of filter).
- Apply Kuroda identity - moves line "inside"

Add line & repeat

Multiply impedances of all lines by \( Z_0 \)
STEP 0: IMPEDANCE FILTER (SIF)

Impedance stays the same, Lengths change
Calculate widths for \( Z_{low} \) & \( Z_{high} \)
Calc. \( \beta = \frac{2\pi}{f_{ref}} \)
\( \beta_s = \frac{C}{Z_{low}} \)

Steps (1, 2, 4a) Same as lumped element Design.

DO NOT denormalize.

Step 5 - SIF

Choose \( Z_0 \) high (thin line) depending on how thin a line can be manufactured
\( Z_0 \) low (fat line) depending on available space

Step 6: Find Lengths

\( g_1, g_2, g_3 \)

\( \beta_l_i = \frac{g_i Z_0}{Z_{high}} \) g values for \( L \)
\( \beta_c_i = \frac{g_i Z_{low}}{Z_0} \) g values for \( C \)

Values given in RADIANS: \( \lambda_e = 360^\circ = 2\pi \) radians
Line calc in Degrees