

TE 364 LECTURE 6

Filter Circuits

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Outline EXPLEM Exploring KNUST Exploring Exploring Exploring Exploring Exploring Exploring

Basic Filters and Terminology

- Low-pass, High-pass, band-pass and band-stop
- **OPassive Filters Synthesis**
	- Image Parameter Method
	- Insertion Loss Method
- **OMicrowave Filters**

Introduction

DA Filter

- is a two-port network
- used to control the frequency response at a certain point in an RF or microwave system
- by providing transmission at frequencies within the passband of the filter and
- attenuation in the stopband of the filter.

Basic Filter Types Engineering

Typical frequency responses include:

- low-pass,
- high-pass,
- bandpass, and
- band-reject characteristics.

Telecomm. Basic Filter Types **Engineering**

Telecomm. Basic Filter Types **Engineering**

Filter Frequency Response

Filter Frequency Response Engineering

Important Terminologies

Insertion Loss (in dB)

The ratio of the power delivered by a source to a load with and without a two-port network inserted in between.

Return Loss (in dB)

The fraction of the input power that is lost due to reflection at its in put port

Attenuation (in dB or Nepers)

The ratio of the power delivered to a matched load to that supplied to it by a matched source

Filter Classification

Active filters

can amplify the signal besides blocking the undesired frequencies **OPassive filters**

are economical and easy to design.

perform fairly well at higher frequencies

Filter Design Methods

Image parameter method

provides a design that can pass or stop a certain frequency band but its frequency response cannot be shaped.

Insertion-loss method

 \cdot Is more powerful in the sense that

it provides a specified response of the filter.

Telecomm. Image Parameter Method **Engineering**

Consider the two-port network

 \mathcal{L}_{i1} and Z_{i2} are the image impedance of the network

$$
V_1 = AV_2 + BI_2
$$

$$
I_1 = CV_2 + DI_2
$$

$$
Z_{in} = \frac{V_1}{I_1} = \frac{AV_2 + BI_2}{CV_2 + DI_2} = \frac{AZ_{i2} + B}{CZ_{i2} + D}
$$

Image Parameter Method

It can be shown that

$$
\begin{array}{c}\n\textbf{a} \textbf{r} \textbf{a} \textbf{m} \textbf{e} \textbf{t} \textbf{c} \textbf{r} \textbf{N} \textbf{e} \textbf{t} \\
\textbf{t} \\
\frac{V_2 = DV_1 - BI_1}{I_2 = -CV_1 + AI_1} \\
\frac{V_2 - DU_1 - BI_1}{I_2 - BI_1 - DZ_{i1}}\n\end{array}
$$

age Parameter Method

\nwith that

\n
$$
\frac{V_2 = DV_1 - BI_1}{I_2 = -CV_1 + AI_1}
$$
\n
$$
Z_e = -\frac{V_2}{I_2} = -\frac{DV_1 - BI_1}{-CV_1 + AI_1} = \frac{DZ_{i1} + B}{CZ_{i1} + A}
$$
\n
$$
Z_{i1} = -\frac{V_1}{I_1}
$$
\n13

Note that

$$
Z_{i1} = -\frac{V_1}{I_1}
$$

Image Parameter Method **Engineering**

It can further be shown that;

 $\mathbf{\hat{P}}$ For $Z_i = Z_{in}$ and $Z_{i2} = Z_{i0}$

 $\mathbf{\hat{z}}$ and

$$
Z_{i2} = \sqrt{\frac{BD}{AC}}
$$

Image Parameter Method **Engineering**

Furthermore;

The transfer characteristics is given by

$$
\frac{V_1}{V_2} = A + B \frac{I_2}{V_2} = A + \frac{B}{Z_{i2}}
$$

or

Parameter Method	Exercise 24
more;	
ansfer characteristics is given by	
$\frac{V_1}{V_2} = A + B \frac{I_2}{V_2} = A + \frac{B}{Z_{12}}$	
$\frac{V_1}{V_2} = \sqrt{\frac{A}{D}} \left(\sqrt{AD} + \sqrt{BC} \right)$	

Telecomm. Image Parameter Method **Engineering**

Or

$$
\frac{V_2}{V_1} = \sqrt{\frac{D}{A}} \left(\sqrt{AD} - \sqrt{BC} \right)
$$

 \triangleleft *Note that,* $AD-BC=1$ *for reciprocal networks*

OSimilarly

 A/*D* is X'former ratio taken as 1 in this case *V D AD BC V A AD BC* ¹ 2 1 *I A AD BC I D e AD BC* cosh *AD*

 \star And $e^{-\gamma} = \sqrt{AD} - \sqrt{BC}$ or $\cosh \gamma = \sqrt{AD}$

Telecomm. Image Parameter Method **Engineering**

Parameters for T and Pi-networks

Image Parameter Method

Constant *k*-filter sections

Image Parameter Method

For the low-pass T-section,

$$
Z_1 = j\omega L \qquad Z_2 = \frac{1}{j\omega C}
$$

*Therefore, the image impedance from Table is Method
ion,
 $\frac{1}{j\omega C}$
pedance from Table is
 $\frac{\omega^2 LC}{4}$

$$
Z_{iT} = \sqrt{\frac{L}{C} \left(1 - \frac{\omega^2 LC}{4} \right)}
$$

In the case of D.C.

e Parameter Method
\n
$$
z_{1} = j\omega L \t Z_{2} = \frac{1}{j\omega C}
$$
\n
$$
Z_{1} = j\omega L \t Z_{2} = \frac{1}{j\omega C}
$$
\n
$$
Z_{1} = \sqrt{\frac{L}{C} \left(1 - \frac{\omega^{2} LC}{4}\right)}
$$
\ne case of D.C.
\n
$$
Z_{1} = \sqrt{\frac{L}{C} \left(1 - \frac{\omega^{2} LC}{4}\right)}
$$
\n
$$
Z_{2} = \sqrt{\frac{L}{C} \left(\text{Normal Impedance} \right)}
$$
\n
$$
Z_{3} = \sqrt{\frac{L}{C} \left(\text{Normal Impedance} \right)}
$$

Image Parameter Method **Engineering**

For *ZiT* to be equal to 0, (*Cut-off frequency, ω^c*)

$$
\frac{\omega^2 LC}{4} = 1 \implies \omega_c = \frac{2}{\sqrt{LC}}
$$

 $\bullet^{\bullet}_{\bullet}$

Telecomm. Image Parameter Method **Engineering**

For the high-pass T-section,

e Parameter Method
ss T-section,

$$
Z_{1} = \frac{1}{j\omega C} \qquad Z_{2} = j\omega L
$$

image impedance from Table is

$$
Z_{iT} = \sqrt{\frac{L}{C} \left(1 - \frac{1}{4\omega^{2} LC}\right)}
$$

Therefore, the image impedance from Table is

$$
\begin{array}{ll}\n\text{arameter Method} & \sum_{\text{Fogomian,} \atop \text{Enghiering}} \text{Fogomian} \\
\hline\n\text{re impedance from Table is} \\
Z_{\text{tr}} = \sqrt{\frac{L}{C} \left(1 - \frac{1}{4\omega^2 LC}\right)} \\
\text{cy is} \\
\omega_c = \frac{1}{2\sqrt{LC}}\n\end{array}
$$

*****The cut-off frequency is

$$
\omega_c = \frac{1}{2\sqrt{LC}}
$$

Telecomm. Image Parameter Method **Engineering**

Example

Design a low-pass constant-k T-section that has a nominal impedance of 75 Ω and a cut-off frequency of 2 MHz.

<u><i><u>Solution</u></u>

e Parameter Method
\n*ple*
\n
$$
\frac{1}{\text{Equation.}}\text{Area}
$$
\n
$$
\frac{1}{\text{Equation.}}\text{Area}
$$
\n
$$
\frac{1}{\text{Equation.}}\text{Area}
$$
\n
$$
2_{\text{AT}} = 75\Omega = \sqrt{\frac{L}{C}} \qquad \omega_e = 2 \times 2\pi \times 10^6 = \frac{2}{\sqrt{LC}}
$$
\n
$$
L = 11.9366 \ \mu\text{H and } C = 2.122 \ n\text{F}
$$

L = 11.9366 *µ*H and *C* = 2.122 *n*F

Image Parameter Method

Image Parameter Method **Engineering**

Image Parameter Method

Image Parameter Method

Disadvantage of Image Parameter

- * The signal attenuation rate after the cut-off point is not very sharp,
- The image impedance is not constant with frequency.
- From a design point of view, it is important that it is constant, at least in its pass-band.

OSolution:

M-derived Filter Section

QConsider the following two T-sections

erived Filter Section

\n
$$
Z'_{2} = \frac{1}{Z'_{1}} \left(Z_{1}Z_{2} + \frac{Z_{1}^{2} - Z'_{1}^{2}}{4} \right)
$$
\n
$$
Z'_{1} = mZ_{1}
$$
\n
$$
Z'_{2} = \frac{Z_{2}}{m} + \frac{1 - m^{2}}{4m} Z_{1}
$$
\nderived section is designed from the values of

\ns determined for the corresponding constant-*k* filter.

\nof *m* is selected to sharp the attenuation at cut-off

Let
$$
Z'_1 = mZ_1
$$

$$
Z_2' = \frac{Z_2}{m} + \frac{1 - m^2}{4m} Z_1
$$

- Filter Section
 $Z'_2 = \frac{1}{Z'_1} \left(Z_1 Z_2 + \frac{Z_1^2 Z_1'^2}{4} \right)$
 $= mZ_1$
 $Z'_2 = \frac{Z_2}{m} + \frac{1 m^2}{4m} Z_1$
 Z' *z* = *Z*₂ + $\frac{1 m^2}{4m} Z_1$
 z i is selected to sharpen the attenuation at cut-of
 n is selected to ved Filter Section
 $\sum_{z=1}^{z} \frac{1}{Z_1^2} \left(Z_1 Z_2 + \frac{Z_1^2 - Z_1'^2}{4} \right)$
 mZ_1
 $Z_2' = \frac{Z_2}{m} + \frac{1 - m^2}{4m} Z_1$

red section is designed from the values of

expected to sharpen the attenuation at cut-off read Filter Section
 $=\frac{1}{Z'_1}\left(Z_1Z_2 + \frac{Z_1^2 - Z_1'^2}{4}\right)$
 $Z'_2 = \frac{Z_2}{m} + \frac{1 - m^2}{4m}Z_1$

d section is designed from the values of

mined for the corresponding constant-k is

selected to sharpen the attenuation at cut Filter Section
 $Z_1Z_2 + \frac{Z_1^2 - Z_1'^2}{4}$
 $\frac{Z_2}{m} + \frac{1 - m^2}{4m} Z_1$

on is designed from the values of

for the corresponding constant

d to sharpen the attenuation at a

mpedance characteristics in the d Filter Section
 $\frac{1}{Z'_1}\left(Z_1Z_2 + \frac{Z_1^2 - Z_1'^2}{4}\right)$
 $\frac{1}{Z'_2} = \frac{Z_2}{m} + \frac{1 - m^2}{4m}Z_1$

acction is designed from the values of

fined for the corresponding constant-k filter.

lected to sharpen the attenuation at • Thus, an *m*-derived section is designed from the values of components determined for the corresponding constant-*k* filter.
- The value of *m* is selected to sharpen the attenuation at cut-off
- or to control the image impedance characteristics in the pass-band.

M-Derived Filter Section **Examplement Reserved**

For the low-pass T-section,

$$
Z_1' = j\omega mL \qquad Z_2' = \frac{1 - m^2}{4m} j\omega L + \frac{1}{j\omega mC}
$$

Therefore, the transfer function is

$$
z_{\text{recomin}}^{\text{1}} = \text{Derived Filter Section},
$$
\n
$$
Z_{1}^{\prime} = j\omega m L \qquad Z_{2}^{\prime} = \frac{1 - m^{2}}{4m} j\omega L + \frac{1}{j\omega m C}
$$
\n
$$
Z_{1}^{\prime} = -\frac{\omega^{2} m^{2} L C}{1 - \left[(1 - m^{2}) / 4 \right] \omega^{2} L C} = \frac{4 \omega^{2} m^{2} / \omega_{c}^{2}}{1 - (1 - m^{2}) \omega^{2} / \omega_{c}^{2}}
$$
\n
$$
\omega_{c} = \frac{2}{\sqrt{LC}}
$$
\n
$$
z_{1}^{\prime} = \frac{2}{\sqrt{LC}}
$$

$$
\omega_c = \frac{2}{\sqrt{LC}}
$$

M-Derived Filter Section **Examplement Reserved**

From the table of parameters on slide 17,

A-Derived Filter Section
\ntable of parameters on slide 17,
\n
$$
\cosh \gamma = 1 + \frac{Z'_1}{2Z'_2} = 1 - \frac{2(m\omega/\omega_c)^2}{1 - (1 - m^2)(\omega/\omega_c)^2}
$$
\n
$$
\cosh \gamma = \frac{\omega_c^2 - \omega^2 - (m\omega)^2}{\omega_c^2 - (1 - m^2)\omega^2}
$$

$$
\cosh \gamma = \frac{\omega_c^2 - \omega^2 - (m\omega)^2}{\omega_c^2 - (1 - m^2)\omega^2}
$$

M-Derived Filter Section M-Derived Filter Section
 $\cosh \gamma \to \infty$ if
 $\omega = \frac{\omega_c}{\sqrt{1 - m^2}} = \omega_{\infty}$

$$
\Box \cosh \gamma \to \infty
$$
 if

ved Filter Section

\n
$$
\frac{\text{1: } \omega = \frac{\omega_c}{\sqrt{1 - m^2}} = \omega_{\infty}}{\sqrt{1 - m^2}}
$$
\nused to sharpen *attention cut-off*

\nmeans
$$
\omega \cong \omega_{\infty}
$$

\ncted slightly higher than ω_c

Condition used to sharpen *attenuation cut-off* Derived Filter Section
 $\frac{b\gamma \to \infty}{b\gamma}$ if
 $\omega = \frac{\omega_z}{\sqrt{1 - m^2}} = \omega_\infty$

adition used to sharpen *attenuation cut-off*

mall *m* means $\omega \approx \omega_\infty$
 ω_∞ selected slightly higher than ω_z

 \triangle Small *m* means $\omega \cong \omega_{\infty}$

 $\boldsymbol{\omega}_{\infty}$ selected slightly higher than $\boldsymbol{\omega}_{c}$

**m* is then determined from the above condition

 \triangleleft Z'_1 and Z'_2 can then be determined from equations on slide 21 1 **Derived Filter Section**
 $\frac{\sin y \rightarrow \infty}{\sin y}$ if
 $\omega = \frac{\omega_e}{\sqrt{1 - m^2}} = \omega_\infty$

andition used to sharpen *attenuation cut-off*

Small *m* means $\omega \ge \omega_x$
 ω_x selected slightly higher than ω_e
 π is then determined

 Note: image impedance of *m*-derived T-section is same as that of corresponding constant-*k* network \Box In the case of Pi-network \diamondsuit It is a function of *m* A characteristics used to design input and output network of the filter so that: Image impedance of composite network stays constant in its pass band

Note: an infinite cascade of T-networks

Can be considered as Pi-network after splitting shunt

arm.

 $2Z'$

 $\frac{1}{1}$

 Z_1'

 \Box Note: of th Z'_2 F-network is replaced by Also two halves of the series arms give \Box From the table of parameters on slide 13, *i* and Filter Section
 i and the series arms give

barameters on slide 13,
 $\frac{Z_2'}{Z_2} = \frac{Z_1 Z_2 + \left[(1 - m^2)/4 \right] Z}{Z_{iT}}$
 $\frac{Z_{iT}}{Z_1^2} = -\omega^2 L = -\left(\frac{2Z}{\alpha}\right)^2$ Derived Filter Section
 $\frac{hZ_2'}{\Gamma}$ -network is replaced by

res of the series arms give
 Z_1'
 $\frac{E_1Z_2'}{\Gamma} = \frac{Z_1Z_2 + \left[(1 - m^2)/4 \right]Z_1^2}{Z_{1T}}$
 $\frac{Z_{2T}}{\Gamma} = \frac{Z_1Z_2 + \left[(1 - m^2)/4 \right]Z_1^2}{Z_{1T}}$
 $\frac{Z_2}{Z_1} = -\omega^2$ of th Z₂T-network
alves of the serie
able of paramete
 $Z_{i\pi} = \frac{Z_1'Z_2'}{Z_{i\pi}} = \frac{Z_1Z}{Z_{i\pi}}$
w-pass constant 1
 $Z_1Z_2 = \frac{L}{C} = Z_o^2$ *M*-Derived Filter Second th Z'_2 C-network is replace halves of the series arms given table of parameters on slid $Z_{i\pi} = \frac{Z'_1 Z'_2}{Z_{i\pi}} = \frac{Z_1 Z_2 + \left[(1 - m^2)Z_{i\pi} - \frac{Z_1 Z_2}{Z_{i\pi}} \right]}{Z_1 Z_2} = \frac{L}{C} = Z_e^2 \qquad Z_1^2 = -\omega^$ Derived Filter Section
 bZ_2^T C-network is replaced by

es of the series arms give
 Z_1^2
 $\frac{Z_2^T Z_2^T}{Z_{\text{max}}} = \frac{Z_1 Z_2 + [(1 - m^2)/4]Z_1^2}{Z_{\text{max}}}$

ass constant k-filter
 $\frac{Z_1}{Z_2} = \frac{Z_2 Z_2 + [(1 - m^2)/4]Z_1^2}{Z_{\text{max}}}$ ter Section

is replaced by

s arms give

rs on slide 13,
 $+\left[\left(1-m^2\right)/4\right]$
 Z_T

-filter
 Z_T

-filter ilter Seok is replactions arms given by the set of the s

 $(1-m^2)/4|Z_1^2|$ $Z_{i\pi} = \frac{Z_1Z_2}{Z} = \frac{1}{Z}$

 \Box For the low-pass constant k-filter

M-Derived Filter Section
\nof thZ₂'T-network is replaced by
\nhalves of the series arms give
\nthe value of parameters on slide 13,
\n
$$
Z_{i\pi} = \frac{Z_{i}Z_{2}}{Z_{i\pi}} = \frac{Z_{i}Z_{2} + [(1-m^{2})/4]Z_{1}^{2}}{Z_{i\pi}}
$$
\n
$$
Z_{i\pi} = \frac{Z_{i}Z_{2}}{Z_{i\pi}} = \frac{Z_{i\pi}Z_{2}}{Z_{i\pi}}
$$
\n
$$
Z_{i}Z_{2} = \frac{L}{C} = Z_{\circ}^{2}
$$
\n
$$
Z_{1}^{2} = -\omega^{2}L = -\left(\frac{2Z_{\circ}\omega}{\omega_{\circ}}\right)^{2}
$$
\n
$$
Z_{34}^{2} = -\omega^{2}L = -\left(\frac{2Z_{\circ}\omega}{\omega_{\circ}}\right)^{2}
$$

M-Derived Filter Section **Example 19** KNUST Telecomm.

and,

$$
Z_{i\mathrm{T}} = Z_0 \sqrt{1 - \left(\frac{\omega}{\omega_c}\right)^2}
$$

Therefore,

$$
Z_{i\pi} = \frac{1 - (1 - m^2) (\omega/\omega_c)^2}{\sqrt{1 - (\omega/\omega_c)^2}} Z_0
$$

1-Derived Filter Section
\n,
\n
$$
Z_{iT} = Z_0 \sqrt{1 - \left(\frac{\omega}{\omega_c}\right)^2}
$$
\nTherefore,
\n
$$
Z_{i\pi} = \frac{1 - (1 - m^2) (\omega/\omega_c)^2}{\sqrt{1 - (\omega/\omega_c)^2}} Z_0
$$
\n
$$
or \ \overline{Z}_{i\pi} = \frac{1 - (1 - m^2) \overline{\omega}^2}{\sqrt{1 - \overline{\omega}^2}} \qquad \overline{\overline{Z}_{i\pi} = Z_{i\pi} / Z_o}
$$
\n33

Normalized image impedance of π -network versus normalized frequency for three values of *m*.

Example

Design an *m*-derived T-section low pass filter with a cut -off frequency of 2 MHz and a nominal impedance of 75 Ω. The infinity frequency *f[∞]* is 2.05 MHz.

<u><i><u>∻Solution</u></u>

erived Filter Section
\n**mple**
\nsign an *m*-derived T-section low pass filter with a cut
\nf frequency of 2 MHz and a nominal impedance of
\n
$$
\Omega
$$
. The infinity frequency f_{∞} is 2.05 MHz.
\n**tion**
\n
$$
Z_{\text{tr}} = 75\Omega = \sqrt{\frac{L}{C}} \qquad \omega_{\text{e}} = 2 \times \pi \times 10^6 = \frac{2}{\sqrt{LC}}
$$
\n
$$
L = 11.9366 \ \mu\text{H} \text{ and } C = 2.122 \ \text{nF}
$$
\n
$$
\omega = \frac{\omega_{\text{e}}}{\sqrt{1 - m^2}} = \omega_{\infty} \Rightarrow 1 - m^2 = \left(\frac{f_{\text{e}}}{f_{\infty}}\right)^2
$$

$$
m = \sqrt{1 - \left(\frac{f_c}{f_{\infty}}\right)^2} = \sqrt{1 - \left(\frac{2}{2.05}\right)^2} = 0.2195
$$

$$
mL/2 = 0.2195 \times 5.9683 = 1.31 \mu H
$$

$$
m = 0.2195 \times 2.122 = 465.78 \text{ nF}
$$

$$
M = \sqrt{1 - \left(\frac{f_c}{f_{\infty}}\right)^2} = \sqrt{1 - \left(\frac{2}{2.05}\right)^2} = 0.2195
$$

\n
$$
mL/2 = 0.2195 \times 5.9683 = 1.31 \, \mu\text{H}
$$

\n
$$
mC = 0.2195 \times 2.122 = 465.78 \, \text{nF}
$$

\n
$$
\frac{1 - m^2}{4m} L = 12.94 \, \mu\text{H}
$$

\n
$$
M = \frac{1.31 \, \mu\text{H}}{1.31 \, \mu\text{H}}
$$

\n
$$
M = 465.78 \, \text{pF}
$$

m-derived filter provides sharp attenuation at cut-off

- but attenuation in its stop-band is unacceptably low
- **Q** constant-*k* filter shows a higher attenuation in its stop-band, but the change is unacceptably gradual Composite Filters: cascading these two filters Taking advantage of each.

Since image impedance stays the same in two cases,

this cascading will not create a new impedance matching problem. However image impedance varies with frequency at the input and output ports of the network. Input and output matching therefore required

Consider the bisected pi-section below

$$
A = 1 + \frac{Z'_1}{4Z'_2} \qquad B = \frac{Z'_1}{2} \qquad C = \frac{1}{2Z'_2} \qquad D = 1
$$

The image impedances are:

$$
Z_{i1} = \sqrt{Z_1' Z_2' + \frac{Z_1'^2}{4}} = Z_{iT}
$$

Complexistic Filters
\nimpedances are:
\n
$$
Z_{i1} = \sqrt{Z_1' Z_2' + \frac{Z_1'^2}{4}} = Z_{iT}
$$
\n
$$
Z_{i2} = \sqrt{\frac{Z_1' Z_2'}{1 + Z_1'/4 Z_2'}} = \frac{Z_1' Z_2'}{Z_{iT}} = Z_{i\pi}
$$
\nted π-section can be connected at the i

 \triangle the bisected π -section can be connected at the input and output ports of cascaded constant-k and *m*-deri-ved sections to obtain a composite filter that Composite Filters

mpedances are:
 $Z_{i1} = \sqrt{Z_1' Z_2' + \frac{Z_1'^2}{4}} = Z_{iT}$
 $Z_2 = \sqrt{\frac{Z_1' Z_2'}{1 + Z_1'/4 Z_2'}} = \frac{Z_1' Z_2'}{Z_{iT}} = Z_{i\pi}$
 $\frac{Z_1 \pi}{Z_1 \pi}$ -section can be connected at the in lonstant-k and *m*-deri-ved section Composite Filters

edances are:
 $=\sqrt{Z_1'Z_2' + \frac{Z_1'^2}{4}} = Z_{ir}$
 $\sqrt{\frac{Z_1'Z_2'}{1 + Z_1'/4Z_2'}} = \frac{Z_1'Z_2'}{Z_{ir}} = Z_{ir}$

-section can be connected at the input and output ports

mstant-k and *m*-deri-ved sections to obtain a c posite Filters
 $\frac{1}{\frac{Z_2'}{R_{\text{reducl}}}}$
 $\frac{1}{\frac{Z_2'}{Z_1'} + \frac{Z_1'^2}{4}} = Z_{ii'}$
 $\frac{1}{\frac{Z_2'}{Z_1'}Z_2'} = \frac{Z_1'Z_2'}{Z_{iT}} = Z_{ii}$

on can be connected at the input and output ports

-k and *m*-deri-ved sections to obtain a Composite Filters

pedances are:
 $x_1 = \sqrt{Z_1' Z_2' + \frac{Z_1'^2}{4}} = Z_{\pi}$
 $= \sqrt{\frac{Z_1' Z_2'}{1 + Z_1'/4 Z_2'} = \frac{Z_1' Z_2'}{Z_{\pi}}} = Z_{i\pi}$
 π -section can be connected at the input and output ports

constant-k and *m*-deri-ved sectio mposite Filters

unces are:
 $Z_1'Z_2' + \frac{Z_1'^2}{4} = Z_\pi$
 $\frac{Z_1'Z_2'}{+Z_1'/4Z_2'} = \frac{Z_1'Z_2'}{Z_{rr}} = Z_{\text{in}}$

ant-k and *m*-deri-ved sections to obtain a composite

nee problem. posite Filters
 z_2 are:
 $\frac{Z'_2 + \frac{Z_1'^2}{4}}{4} = Z_{iT}$
 $\frac{Z'_1 Z'_2}{Z_{iT}} = \frac{Z'_1 Z'_2}{Z_{iT}} = Z_{i\pi}$

on can be connected

-k and *m*-deri-ved se

e problem. Composite Filters

mpedances are:
 $Z_{i1} = \sqrt{Z_1' Z_2' + \frac{Z_1'^2}{4}} = Z_{iT}$
 $Z_2 = \sqrt{\frac{Z_1' Z_2'}{1 + Z_1'/4 Z_2'} = \frac{Z_1' Z_2'}{Z_{iT}}} = Z_{i\pi}$

d π -section can be connected at constant-k and *m*-deri-ved sec

mpedance problem. **Example 2** *Z*_{*Z*</sup> *Z*_{*Z*} *Z Z*_{*Z*} *Z Z*_{*Z*} *Z Z*_{*Z*} *Z Z Z*_{*Z*} *Z Z} Z Z Z*

Low-Pass High Pass

Input and Output Matching Sections

Input and Output Matching Sections

<u>☆Example</u>

 \triangleright Design a high-pass composite filter with a nominal impedance of 75 Ω . It must pass all signals over 2 MHz. Assume that $f_{\infty} = 1.95$ MHz.

<u><i><u>Solution</u></u>

From Table 9.3 (slide 31), we find the components of its constant-*k* section as follows:

$$
L = \frac{75}{2 \times 2 \times \pi \times 2 \times 10^6} \text{H} = 2.984 \,\mu\text{H}
$$

$$
C = \frac{1}{2 \times 2 \times \pi \times 2 \times 10^6 \times 75} \text{F} = 530.5 \text{ pF}
$$

and

Composite Filters **Engineering**

Similarly, the component values for its m-derived filter section are determined as follows:

$$
m = \sqrt{1 - \left(\frac{f_{\infty}}{f_c}\right)^2} = \sqrt{1 - \left(\frac{1.95}{2}\right)^2} = 0.222
$$

$$
\frac{2C}{m} = 4.775 \text{ nF}
$$

$$
\frac{L}{m} = 13.43 \text{ }\mu\text{H}
$$

$$
\frac{4m}{1-m^2}C = 0.496 \,\mathrm{nF}
$$

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The component values for the bisected π -section to be used at its input and output ports are found as

