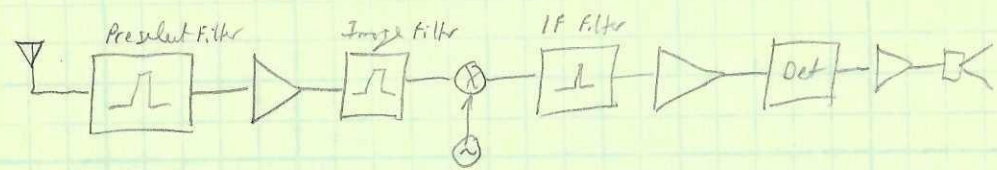


10/29
Filters

Recall RX Block Diagram



Filters critical to ability to select desired station
prevent image response
Spurious

★ Show Spectrum 80-180 MHz

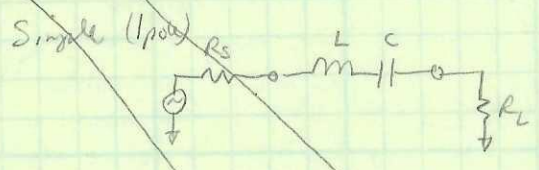
Filter Basics (Next page)

Filter Technologies

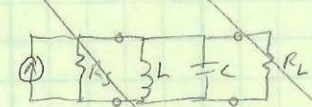
★ Show RS Cell Phone

- LC: 100kHz - 2GHz
- Crystal / Ceramic: 100kHz - 150MHz
- SAW: 50MHz - 2GHz
- Dielectric Resonators: 500MHz - 5GHz
- TX Line (Microstrip): > 2GHz
- Cavity: ≥ 1GHz
- Acoustic: 150MHz - 16GHz

LC Filters

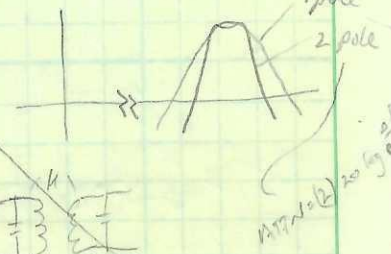
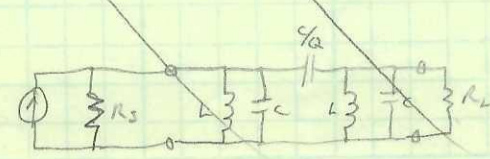
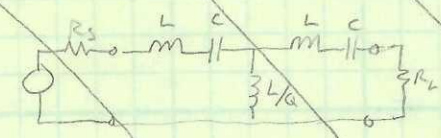


$$B = \frac{f_0}{Q} \quad Q = \frac{X}{R_s + R_L}$$



$$B = \frac{f_0}{Q} \quad Q = \frac{R_s || R_L}{X}$$

★ Show FMRX & log
Higher Order coupled resonators



★ Show Response

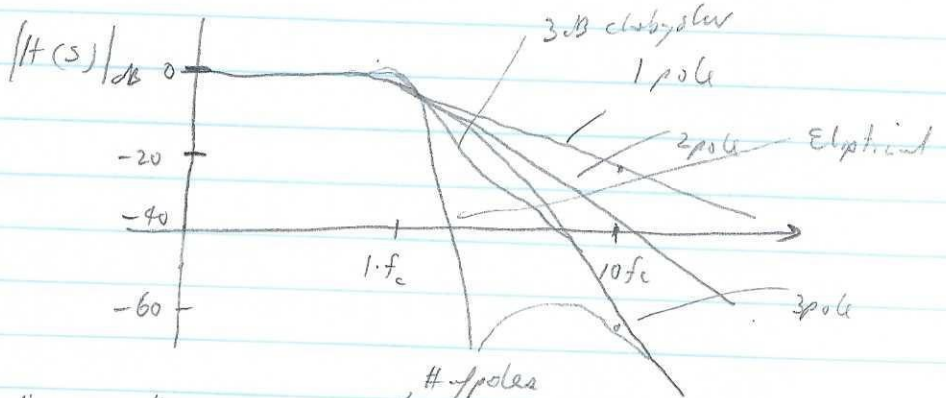
Some LC Parallel LC LC coupled resonator
Passivity Stability
coupled with/without
Resonator coupled resonator
Response
Filter Design
model
P2T devices
Show response



Filter ~~Basic~~ Response

$$V_i \rightarrow [H(s)] \rightarrow V_o$$

Recall LPF Response e.g. $H_{LP}(s) = \frac{1}{s^3 + 2s^2 + 2s + 1} \quad s \rightarrow j\omega$



Butterworth Filter "Roll-off"

$$\begin{aligned} & -20n \text{ dB/decade} \\ & = 6n \text{ dB/octave} \end{aligned}$$

Example: (3 pole filter)

At $2f_c$ (one octave) -18 dB

At $10f_c$ (one decade) -60 dB

Chebyshev & Elliptical filters

$$\approx 20n \text{ dB/decade}$$

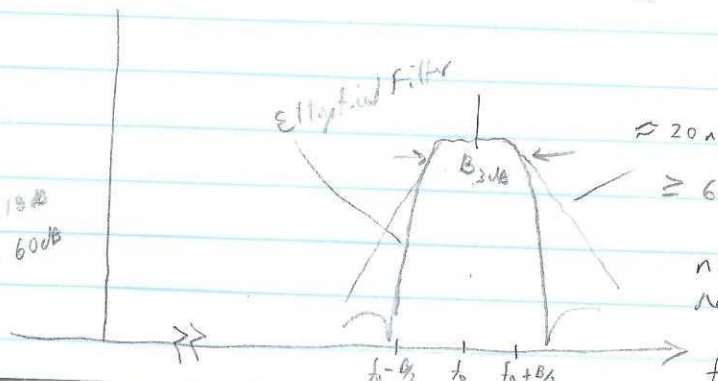
$$> 6n \text{ dB/2 first octave}$$

Band pass Filter Response

Derived from LP response by $s \rightarrow \left(\frac{s^2 + \omega_0^2}{Bs} \right)$

$$\begin{aligned} s &= j(\omega_c + \delta) \\ s^2 &= -1(\omega_c^2 + 2\omega_c\delta + \delta^2) \\ &= -\omega_c^2 - 2\omega_c\delta - \delta^2 \\ &\approx -\omega_c^2 - 2\omega_c\delta \\ &= -\omega_c^2 - 2\omega_c(j\omega_c\delta) \\ &= -\omega_c^2 + 2\omega_c^2\delta \\ &= \omega_c^2(2\delta - 1) \\ &= \omega_c^2(2\delta - 1) \\ &\Rightarrow j \end{aligned}$$

Example "3 pole BPF"
At $2 \frac{1}{2} f_c$ -18 dB
At $10 \frac{1}{2} f_c$ -60 dB



$$\approx 20n \log_{10} \left| \frac{f - f_0}{B/2} \right|$$

$$\geq 6n \log_{10} \left(\frac{f - f_0}{B/2} \right)$$

$n = \# \text{ of poles}$
NOTE "2 pole" BPF
= 4th order

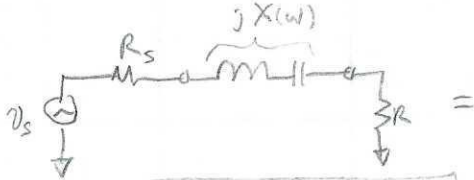
1 Pole LPFs

BPF Implementations

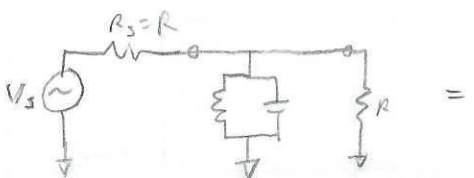
Simple, 1 pole LC:

$$sL \rightarrow \frac{s^2 + \omega_0^2}{Bs}$$

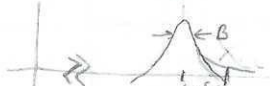
$$sL + \frac{1}{sC} = \frac{s^2 LC + 1}{sC}$$



$$B = \frac{f}{Q} \quad Q = \frac{X_L/f}{2R}$$



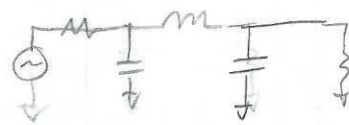
Response



$$B = \frac{f_0}{Q} \quad Q = \frac{R/2}{X_L/f_0} \quad \text{Atten}_{dB} = 20 \log \left| \frac{\omega f}{B/2} \right|$$

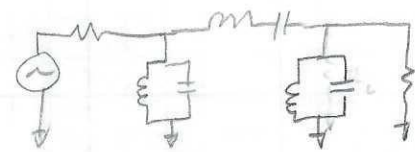
Higher Order Filters Realizations

LP Ladder Filter Prototype



LP → BP conversion

BP Ladder Filter



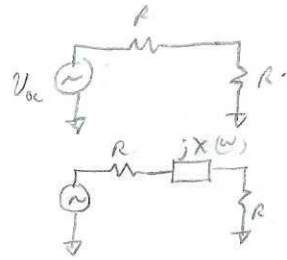
Resp



$$\text{Atten} = 20 N \log \left| \frac{\omega f}{B/2} \right|$$

Show VGS

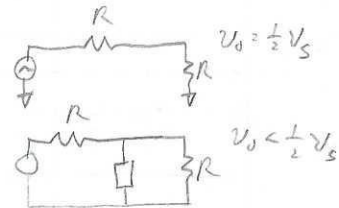
at resonance $V_{oc} = \frac{R}{R_s + R} V_s$
 off resonance $V_o = \frac{R}{R_s + R + jX(\omega)} V_s$
 $\ll \frac{1}{2} V_s$ if $X \gg R$



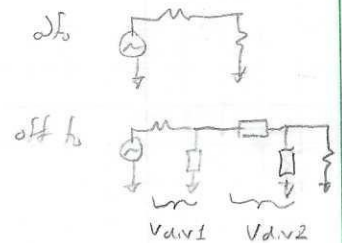
$$V_o = \frac{R}{R_s + R} V_s = \frac{1}{2} V_s \text{ if } R = R_s$$

$$V_o = \frac{R}{R_s + R + jX(\omega)} V_s \ll \frac{1}{2} V_s \text{ if } X \gg R$$

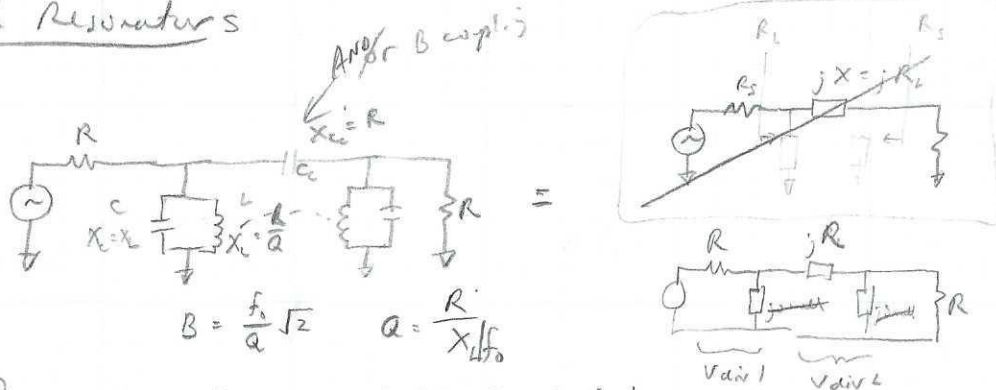
at $2f_0$
 off f_0



512 notes / (See text book)



Coupled Resonators



$$B = \frac{f_1}{Q} \sqrt{2} \quad Q = \frac{R}{X_{L/f_0}}$$

Response - same as ladder derived design

★ Slow VG

BPF Technologies (Show VG of Each - Discuss operation later)

Construction

- LC
 - Lumped LC
 - Helical

Typ Freq Range

- 100 kHz - 500 MHz
- 300 MHz - 1.5 GHz

Electro Acoustic (smaller, better)

- Crystal/ceramic
- Surface Acoustic Wave (SAW)

- 100 kHz - 150 MHz
- 50 MHz - 2 GHz

TX Line

- microstrip
- Dielectric Resonator
- Cavity

- > 2 GHz
- > 500 MHz
- > 1 GHz

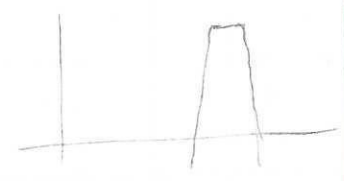
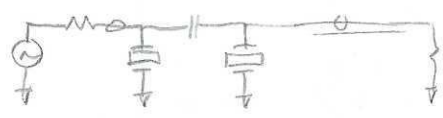
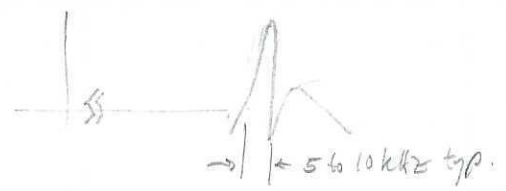
13-782 500 SHEETS, FILLER, 5 SQUARE
 42-381 50 SHEETS, VEAS, 5 SQUARE
 42-380 100 SHEETS, VEAS, 5 SQUARE
 42-382 100 SHEETS, VEAS, 5 SQUARE
 42-392 100 RECYCLED WHITE, 5 SQUARE
 42-393 200 RECYCLED WHITE, 5 SQUARE
 Made in U.S.A.



Problem: LC filters hard limited @

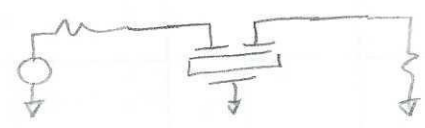
Solution:

Crystal Filters



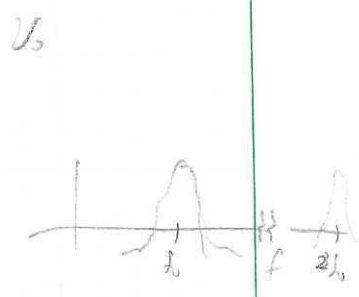
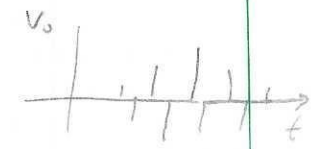
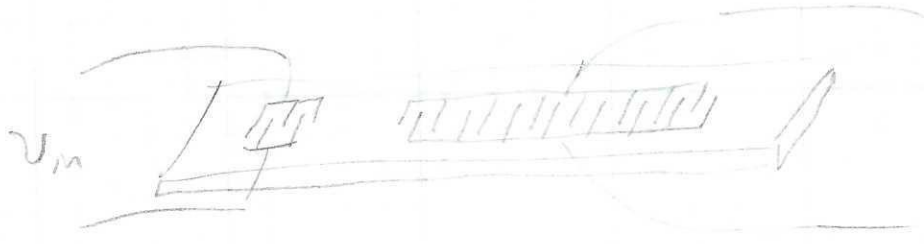
Monolithic / Ceramic Filters

Higher order on single die



SAW

Sa overhead

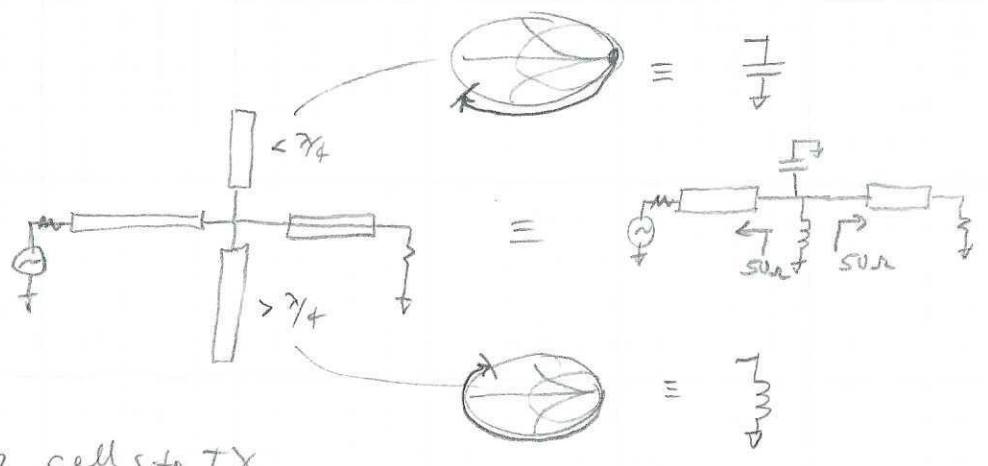


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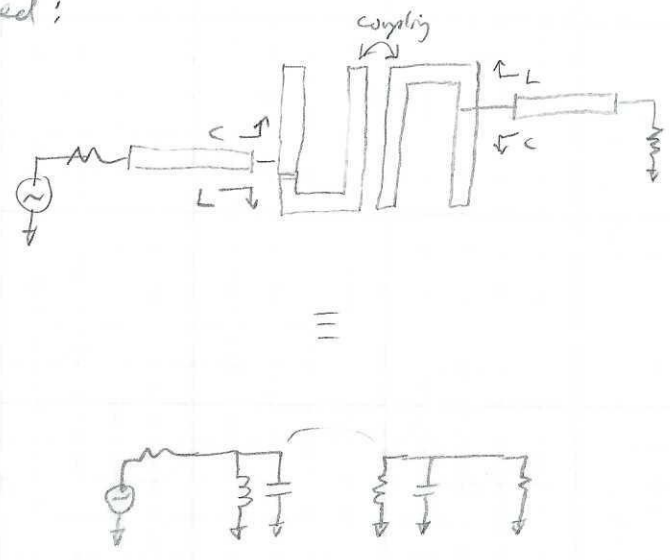
Made in U.S.A.

TX Lin
Single:



* Show cell site TX

Edge coupled:



D-electric Resonator (aka. ceramic)

filters

Build coax TX line w/ $\epsilon_r \sim 100$

$$\Rightarrow v_p \sim \frac{1}{10} c$$

$$\Rightarrow \lambda \sim \frac{1}{10} \lambda_{free\ space}$$

13-782 500 SHEETS, FILLER 1 SQUARE
42-381 50 SHEETS, EYE-EASE 1 SQUARE
42-382 100 SHEETS, EYE-EASE 1 SQUARE
42-383 200 SHEETS, EYE-EASE 1 SQUARE
42-392 100 RECYCLED WHITE 1 SQUARE
42-393 200 RECYCLED WHITE 1 SQUARE
42-395 200 RECYCLED WHITE 1 SQUARE
Made in U.S.A.

