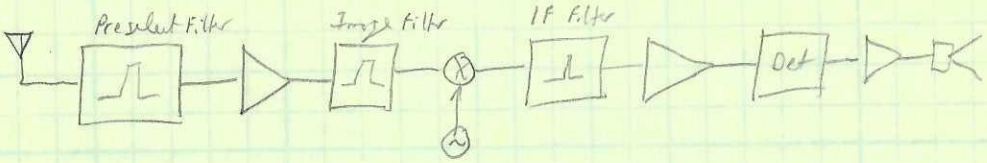
10/29

Filters

Recall RX Block Diagram



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

☆ Show Spectrum 80 - 180 MHz

Filter Basics (Next pages)

Filter Technologies

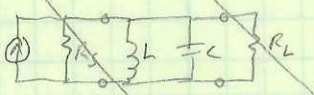
☆ Show RS Cell Phone

LC	100KHz – 2 GHz
Crystal / Ceramic	100 KHz – 150 MHz
SAW	50 MHz – 2 GHz
Dielectric Resonators	500 MHz – 5 GHz
TX Line (Microstrip	> 2 GHz
Cavity	≥ 1 GHz
Helical	150 M – 1 GHz

LC Filters

Single (1 pole)

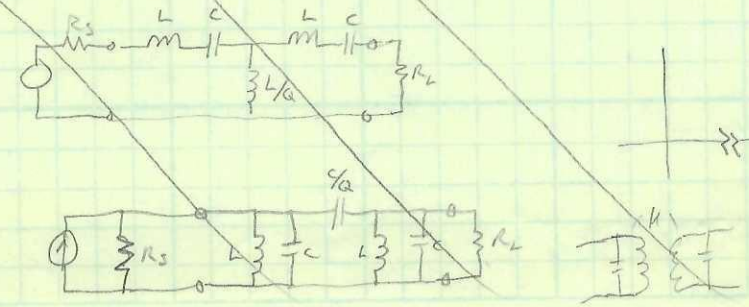
$B = f_0/Q \qquad Q = \frac{X}{R_S + R_L}$

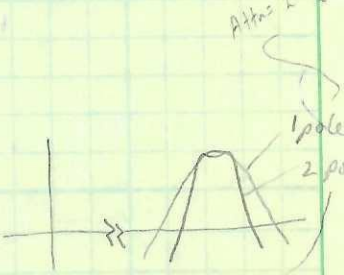


$B = f_0/Q \qquad Q = \frac{R_S \| R_L}{X}$

☆ Show FMRX & Cop

Higher Order coupled resonators



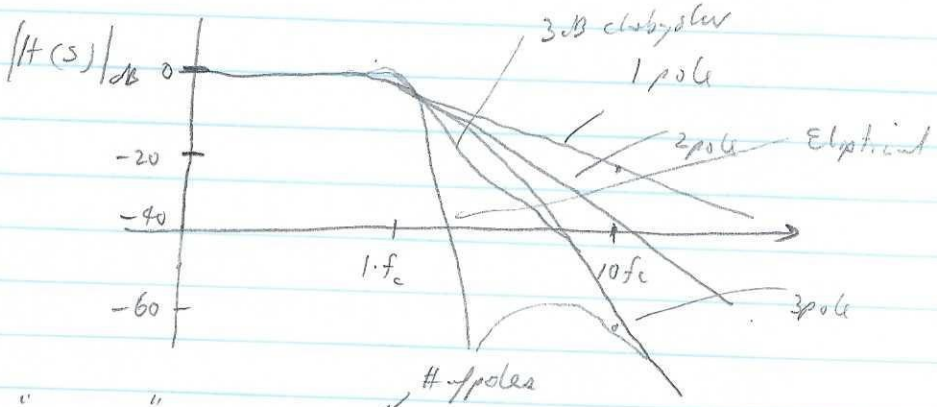


☆ Show Response

Filter ~~Basics~~ Response

$V_i \rightarrow |H(\omega)| \rightarrow V_o$

Recall LPF Response e.g. $H_{LP_n}(s) = \dfrac{1}{s^3+2s^2+2s+1}\Big|_{s \to j\omega = j2\pi f}$



Butterworth Filter "Rolloff" $\approx -20n$ dB/decade
$= -6n$ dB/octave

Example: (3 pole filter)

At $2f_c$ (one octave) -18 dB
At $10f_c$ (one decade) -60 dB

Chebyshev & Elliptical filters $\approx -20n$ dB/decade
$> -6n$ dB @ first octave

Band pass Filter Response

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

$s = j(\omega + \omega_0)$

$s^2 = -1(\omega^2 + \omega_0^2 + 2\omega\omega_0)$

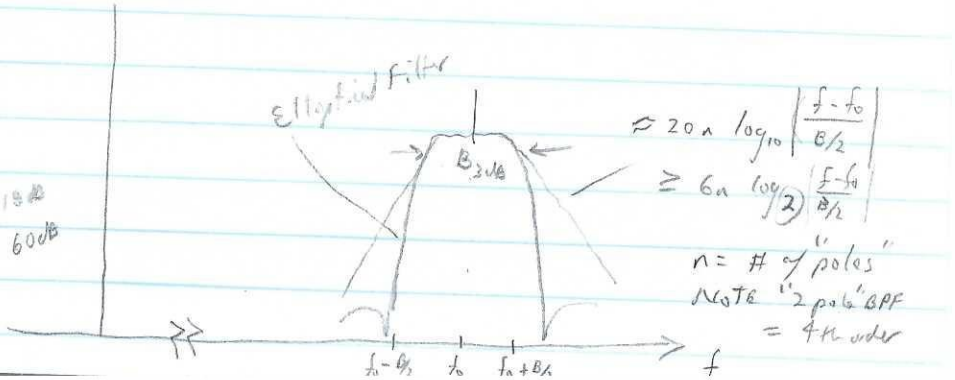
$= -\dfrac{2\omega\omega_0}{B\cdot\omega}$

$= B/2$

≈ 1

$\Rightarrow j$

Example "3 pole BPF" $B/2$ from center
At 2 $B/2$ -18 dB
10 $B/2$ -60 dB

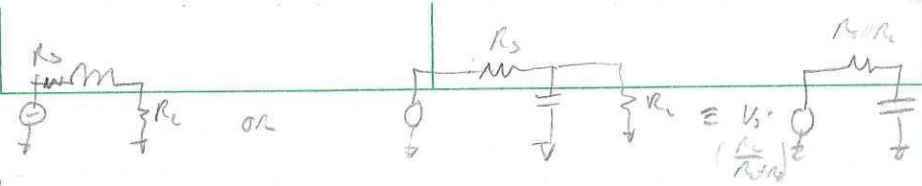


$\approx 20n \log_{10}\left|\dfrac{f-f_0}{B/2}\right|$

$\geq 6n \log(2)\left|\dfrac{f-f_0}{B/2}\right|$

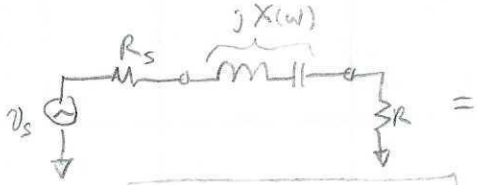
n = # of "poles"
NOTE "2 pole" BPF = 4th order

1 Pole LPFs →



BPF Implementations

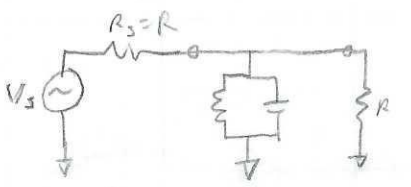
Simple, 1 pole LC:

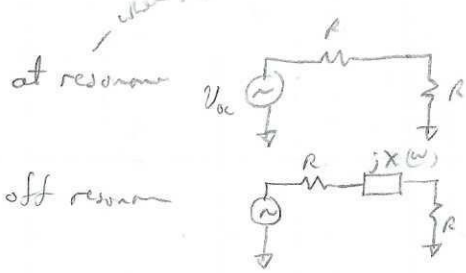


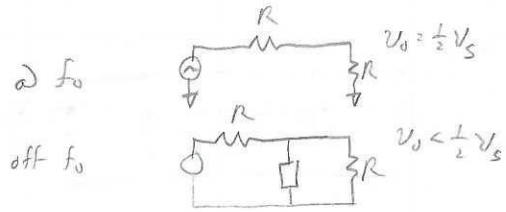
$sL \rightarrow \frac{s^2 + \omega_0^2 L}{B s}$

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

$B = \frac{f_0}{Q} \quad Q = \frac{X_L/f_0}{2R}$





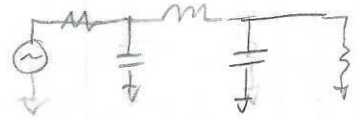


Response

$B = \frac{f_0}{Q} \quad Q = \frac{R/2}{X_L/f_0} \quad Atten_{dB} = 20 \log \left| \frac{\Delta f}{B/2} \right|$

Higher Order Filters Realizations

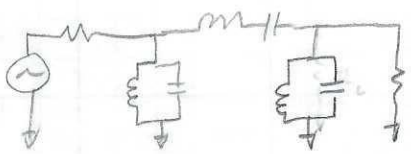
LP Ladder Filter Prototype



↓ LP → BP conversion

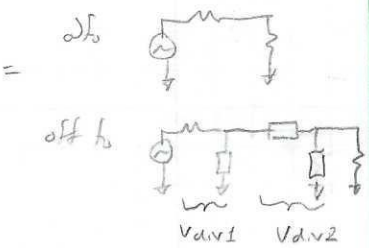
(See textbook)

BP Ladder Filter



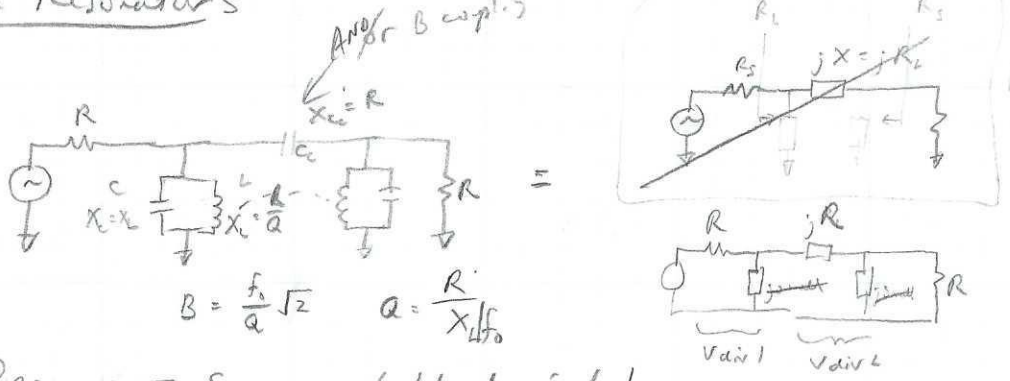
Resp

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



Show VGs

Coupled Resonators



$B = \frac{f_0}{Q}\sqrt{2}$ $\quad Q = \frac{R}{X_L f_0}$

Response – Same as ladder derived design

☆ Slow VG

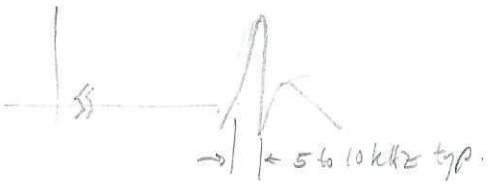
BPF Technologies (Show VG of Each – Discuss operation later)

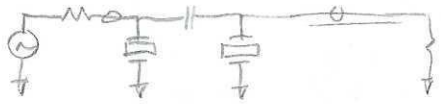
Construction	Typ Freq Range
LC	
Lumped LC	100 KHz – 500 MHz
Helical	300 MHz – 1.5 GHz
Electro Acoustic (smaller, Better)	
Crystal/ceramic	100 KHz – 150 MHz
Surface Acoustic Wave (SAW)	50 MHz – 2 GHz
TX Line	
Microstrip	> 2 GHz
Dielectric Resonator	> 500 MHz
Cavity	> 1 GHz

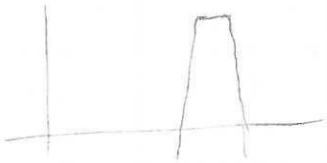
Problem: LC filters have limited Q

Solution:

Crystal Filters

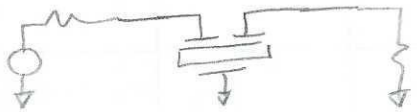






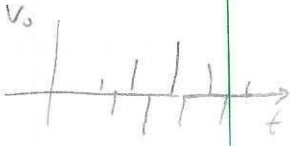
Monolithic / Ceramic Filters

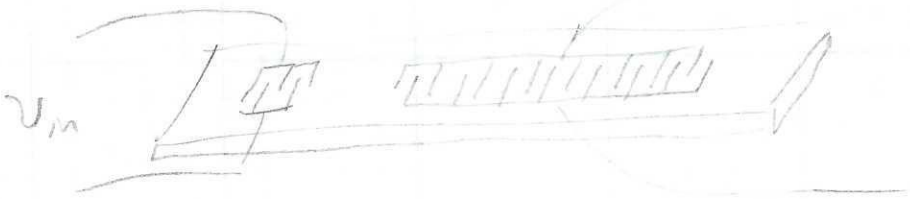
Higher order on single die

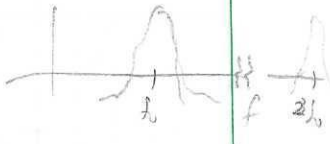


SAW

5a overhead

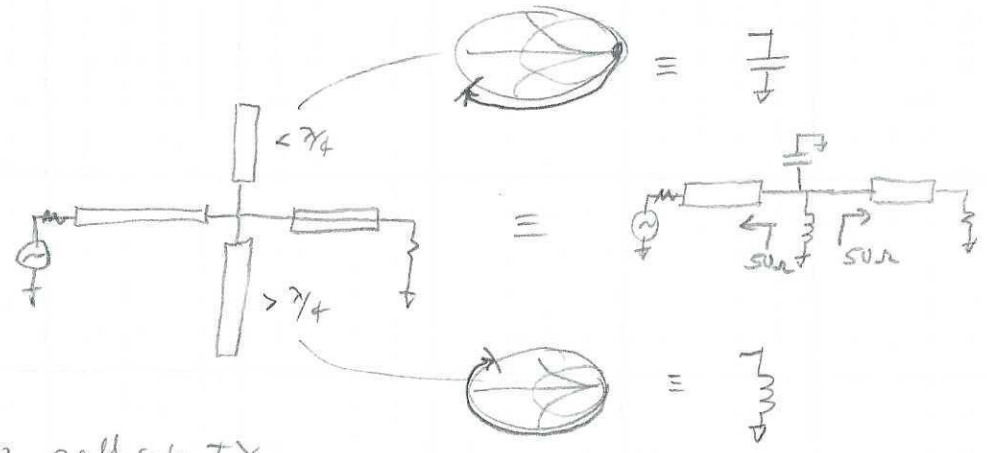






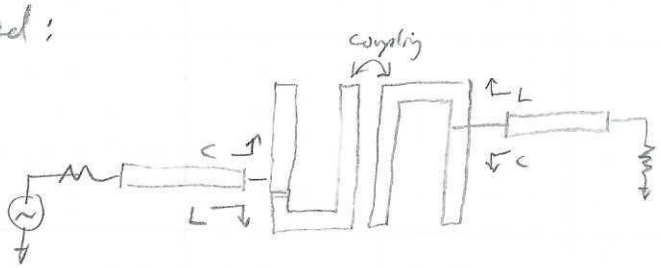
TX Line

Simple:



* Show cell site TX

Edge coupled:



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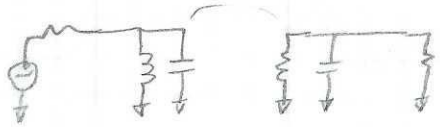

Dielectric Resonator (aka. ceramic)

Filters

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

$\Rightarrow v_p \sim 1/10\, c$

$\Rightarrow \lambda \sim 1/10\, \lambda_{freespace}$