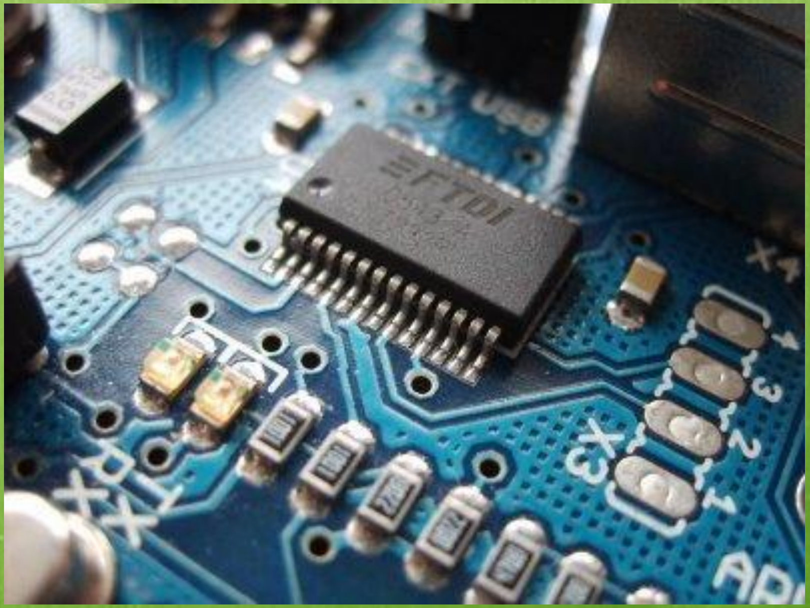
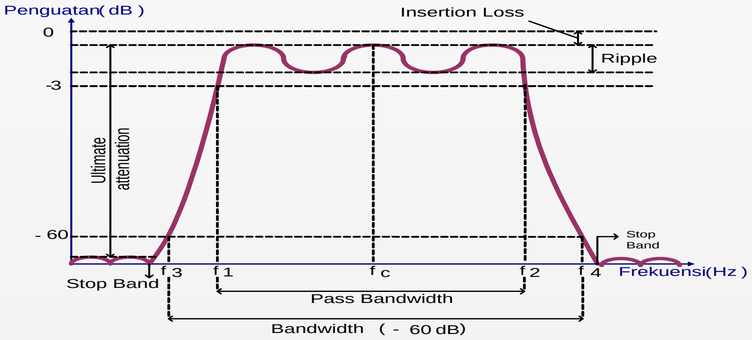
DTG2D3

ELEKTRONIKA TELEKOMUNIKASI



RANGKAIAN RESONATOR



By : Dwi Andi Nurmantris

RANGKAIAN RESONATOR

Ruang Lingkup Materi

- Rangkaian resonator paralel (Loss less components)
- Resonator dengan “L dan C mempunyai rugi-rugi/komponen Losses
- Transformator Impedansi Tujuan: Menaikkan Q dengan menaikkan Rs (atau R_L)
- Rangkaian Resonator paralel ganda
  Tujuan: Untuk memperbaiki shape faktor.

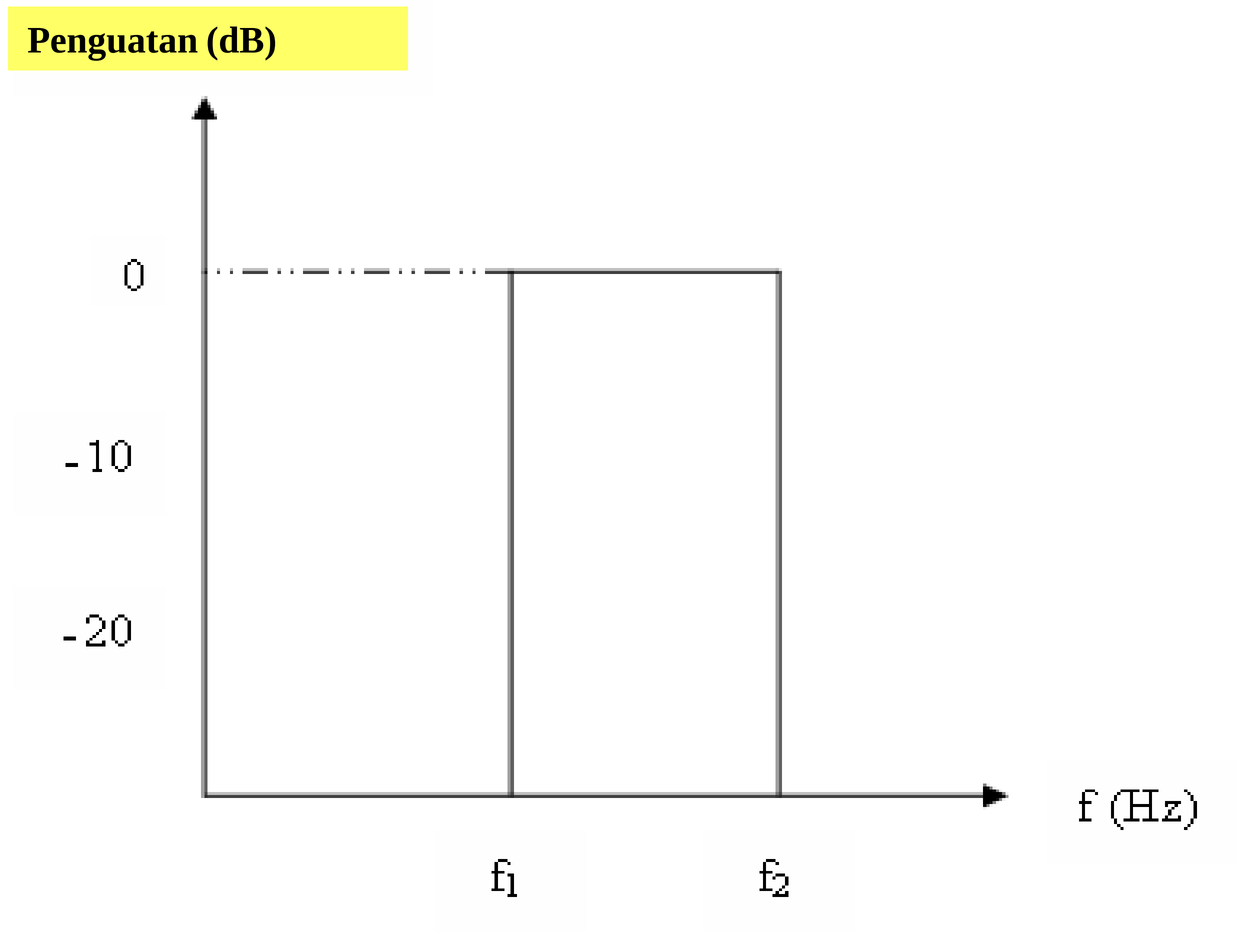
RANGKAIAN RESONATOR

Fungsi Rangkaian Resonator

- Memilih / meloloskan sinyal pada frekuensi tertentu, meredam secara *significant* di luar frekuensi yang diinginkan.
- Jadi rangkaian resonator: Rangkaian yang dapat meloloskan frekuensi tertentu dan menghentikan frekuensi yang tidak diinginkan

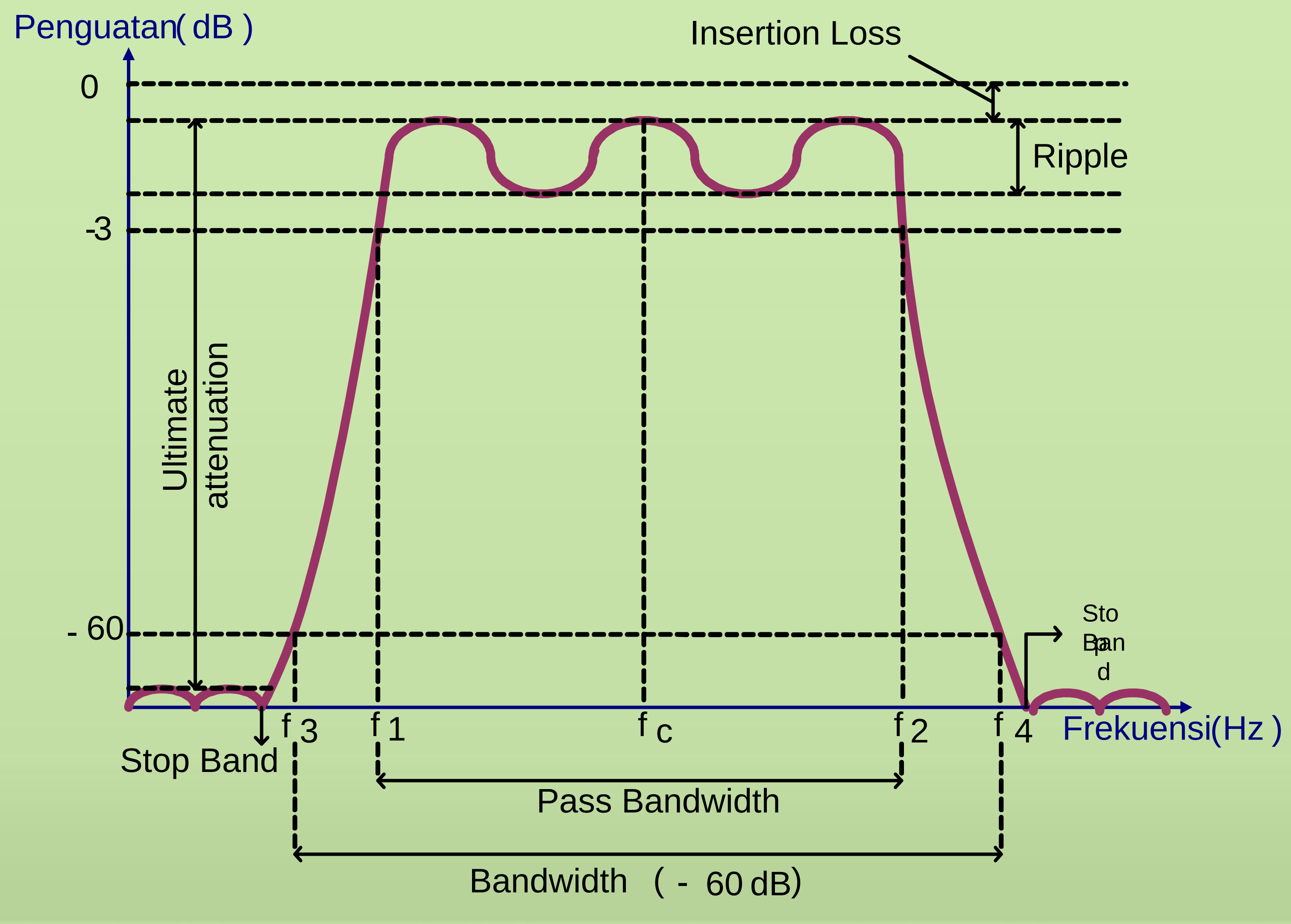
RANGKAIAN RESONATOR

Karakteristik Respon Ideal Rangkaian Resonator



RANGKAIAN RESONATOR

Respon Rangkaian Resonator "Praktis"



RANGKAIAN RESONATOR

Beberapa Definisi

- **Resonansi** : kondisi dimana komponen reaktansi dari suatu impendansi berharga nol pada frekuensi tertentu.
- **Bandwidth / lebar pita** : Perbedaan antara frekuensi atas dan frekuensi bawah ($f_2 - f_1$), respon amplitudonya -3 dB dibawah respon passband. Jadi yang diloloskan hanya diantara f_1 dan f_2, diluar frekuensi tersebut diredam secara signifikan.
- **Faktor kualitas (Q) :** parameter untuk mengukur tingkat selektivitas rangkaian.

$$Q \cong \frac{fc}{BW\,3dB} = \frac{fc}{f_2 - f_1}$$

RANGKAIAN RESONATOR

Beberapa Definisi

- **Faktor bentuk** (Shape Factor = SF) : Perbandingan BW 60dB (redaman besar)terhadap BW 3 dB (redamankecil) pada rangkaian resonator (seberapa miring terhadap ideal).

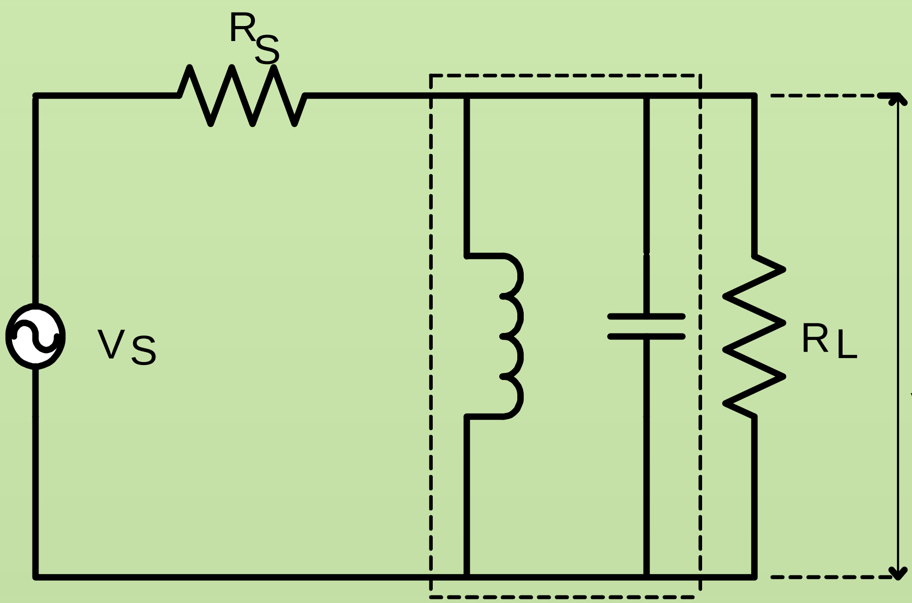
$$SF \cong \frac{BW\,60dB}{BW\,3dB} = \frac{f_4 - f_3}{f_2 - f_1}$$

- **Ultimate Attenuation** :Redaman minimum akhir yang diinginkan/dikehendaki rangkaian resonansi diluar passband.
- **Ripple / Riak** :Ukuran dari kerataan passband rangkaian resonansi yang dinyatakan dalam dB.

RANGKAIAN RESONATOR

Beberapa Definisi

- **Insertion Loss** : loss yang ditimbulkan oleh pemasangan suatu rangkaian (komponen tidak ideal) antara sumber tegangan dan suatu beban.



Vout = $R_L / (R_L + R_S) . V_S$
= 0.5 V_S (Misal)
(tanpa C dan L)

Vout = $R_L / (R_L + R_S) . V_S$
= 0. 45 V_S (Misal)
(dengan penambahan C dan L)

- **Tuning/ penalaan** : pengaturan harga L dan C agar dapat beresonansi pada frekuensi kerjanya.

RANGKAIAN RESONATOR

dB/octave dan dB/decade

dB/octave

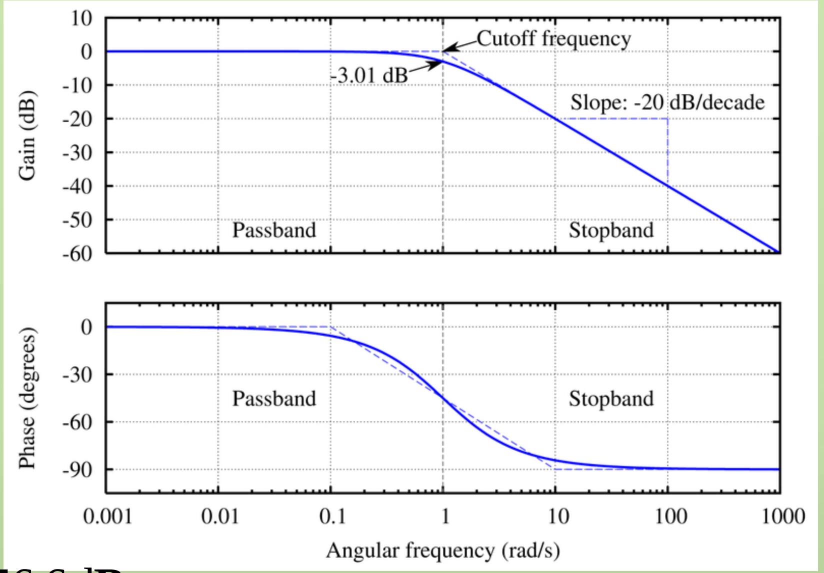
- an **octave** is a doubling or halving of a frequency
- The distance between the frequencies 20 Hz and 40 Hz is 1 octave.
- Example :An amplitude of 52 dB at 4 kHz decreases as frequency increases at −2 dB/octave, what is the amplitude at 13 kHz?

$$\text{number of octaves} = \log_2\left(\frac{13}{4}\right) = 1.7$$

$$\text{Mag}_{13\ \text{kHz}} = 52\ \text{dB} + (1.7\ \text{octaves} \times -2\ \text{dB/octave}) = 48.6\ \text{dB}.$$

dB/decade

- One **decade** is a factor of 10 difference between two frequency (an order of magnitude difference) measured on a logarithmic scale.
- The distance between the frequencies 10 Hz and 100 Hz is 1 decade.
- Example :An amplitude of 0 dB at 4,7 MHz decreases as frequency increases at −20 dB/decade, what is the amplitude at 3,2 GHz?



$$\text{number of decade} = \text{Log}_{10}\left(\frac{3{,}2\times10^{9}}{4{,}7\times10^{6}}\right) = 2{,}83\,\text{decade}$$

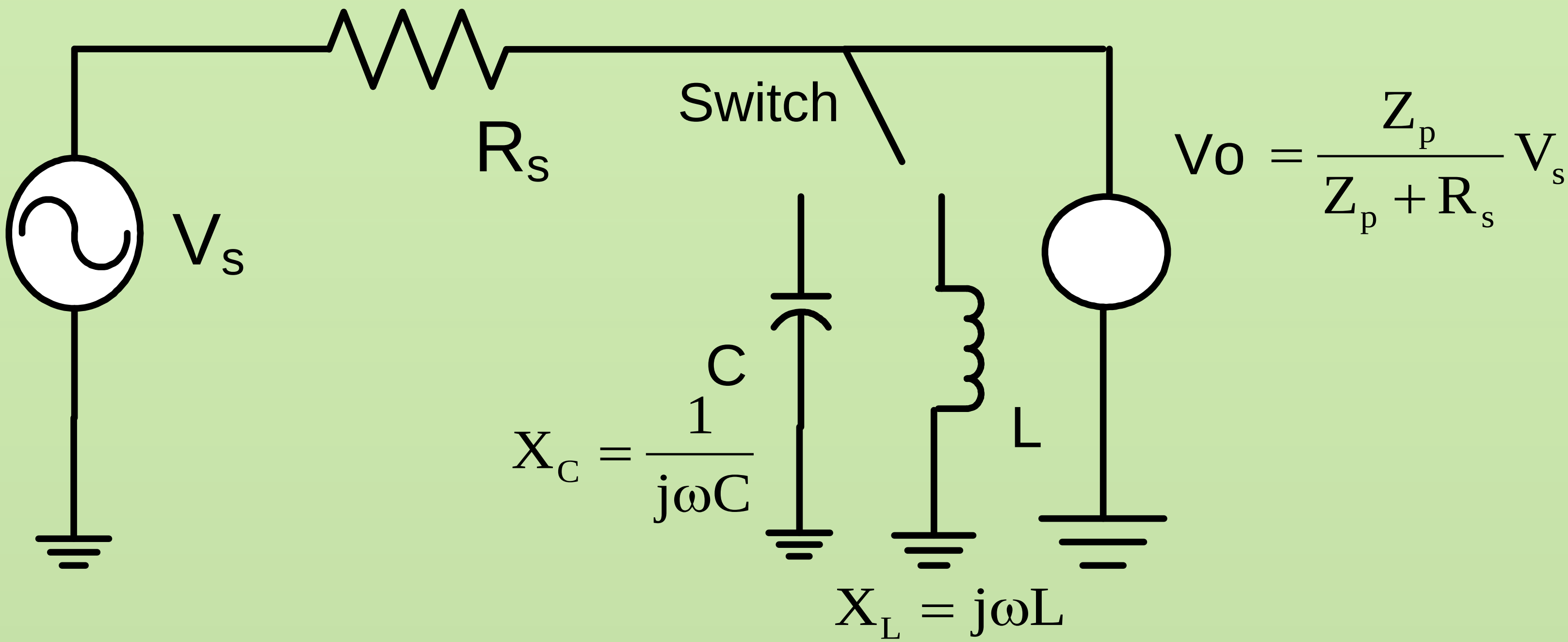
$$\text{Mag}_{3,2\text{Ghz}} = 0\text{dB} + \left(2{,}83\,\text{decade}\times -20\text{dB}/\text{decade}\right) = -56{,}6\,\text{dB}$$

RANGKAIAN RESONATOR

Rangkaian resonator paralel
(Loss less components)

RANGKAIAN RESONATOR

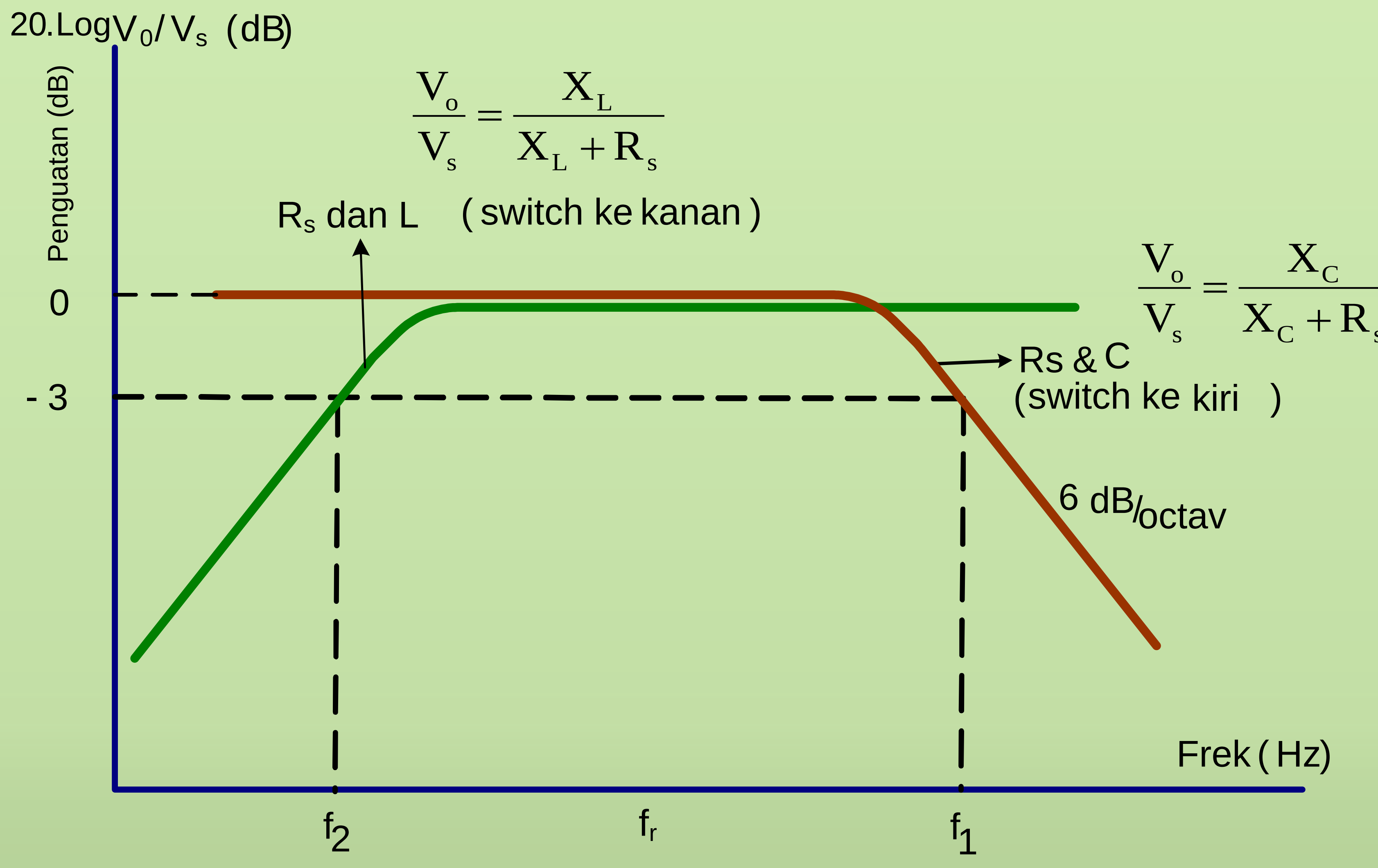
Rangkaian Paralel Single-Pole BPF



- Rangkaian LC parallel dapat dimodelkan sebagai ideal band pass filter, dimana :
  - Induktor ideal
  - Kapasitor ideal
  - Beban dibuka / ‘open’

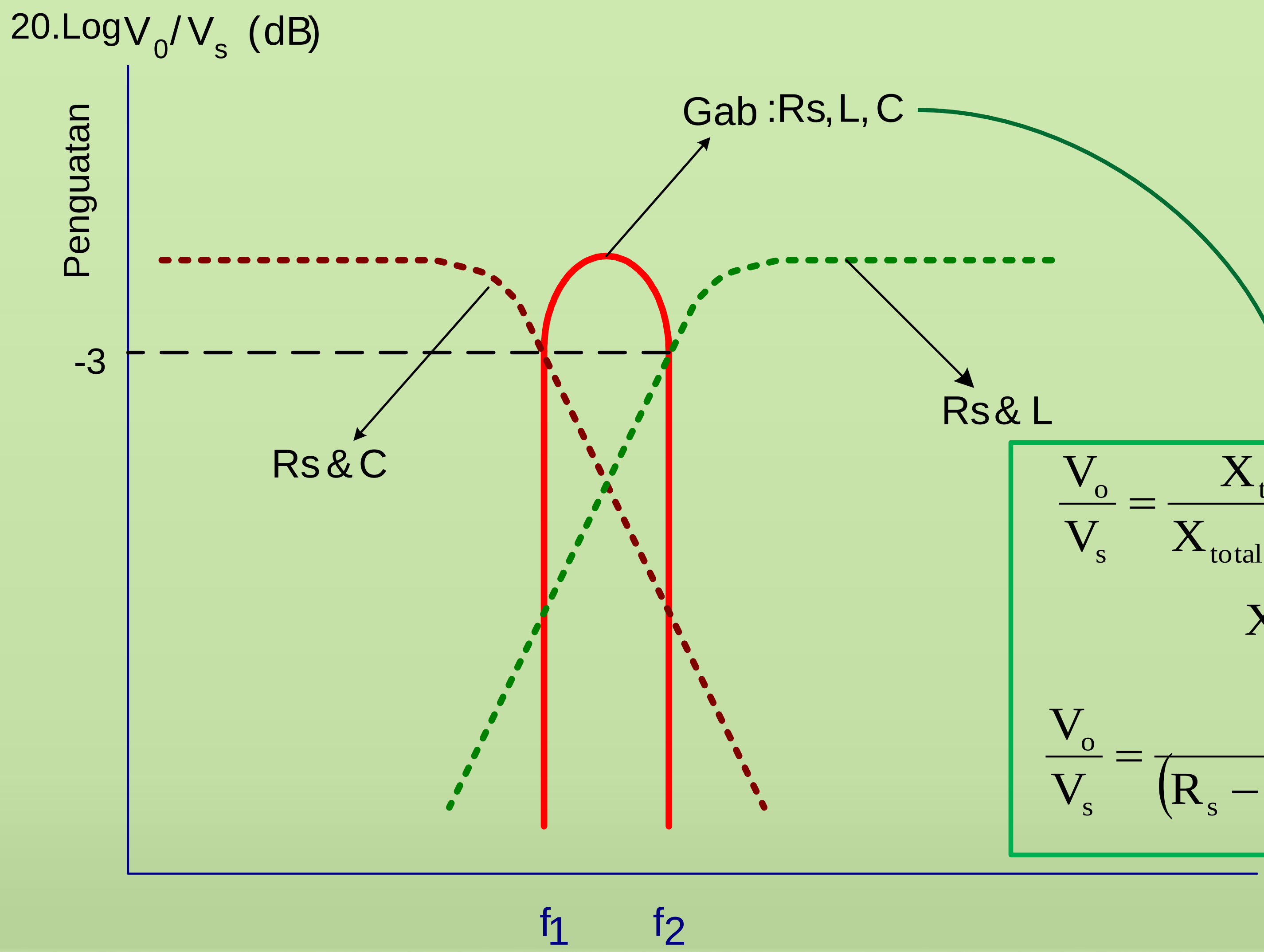
RANGKAIAN RESONATOR

Respon Vo/Vs Jika Menggunakan “C kecil” dan “L Besar”



RANGKAIAN RESONATOR

Respon Vo/Vs Jika "C diperbesar" dan " L diperkecil"



$$\frac{V_o}{V_s} = \frac{X_{total}}{X_{total} + R_s}$$

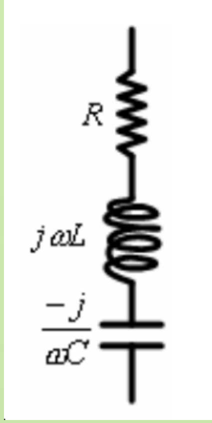
$$X_{total} = \frac{X_C X_L}{X_C + X_L}$$

$$\frac{V_o}{V_s} = \frac{j\omega L}{\left(R_s - \omega^2 R_s LC\right) + j\omega L}$$

RANGKAIAN RESONATOR

Rangkaian Resonansi

Resonansi seri



$$Z_{tot} = R + j\omega L + \frac{1}{j\omega C}$$

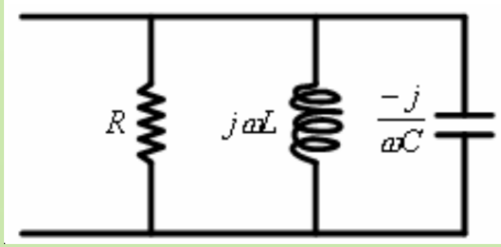
$$\omega L - \frac{1}{\omega C} = 0 \rightarrow \omega L = \frac{1}{\omega C}$$

$$\omega^2 = \frac{1}{LC}$$

$$f_o = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$$

Frekuensi resonansi seri

Resonansi parallel



Admitansi total :

$$\frac{1}{\mathbf{Z}_{tot}} = \frac{1}{R} + \frac{1}{j\omega L} + \frac{1}{-j/\omega C} = \frac{1}{R} - \frac{j}{\omega L} + j\omega C$$

$$\frac{1}{\mathbf{Z}_{tot}} = \frac{1}{R} + j\left(\omega C - \frac{1}{\omega L}\right)$$

saat resonansi :

$$\omega C - \frac{1}{\omega L} = 0 \rightarrow \omega C = \frac{1}{\omega L}$$

$$\omega^2 = \frac{1}{LC}$$

$$f_o = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$$

Frekuensi resonansi paralel

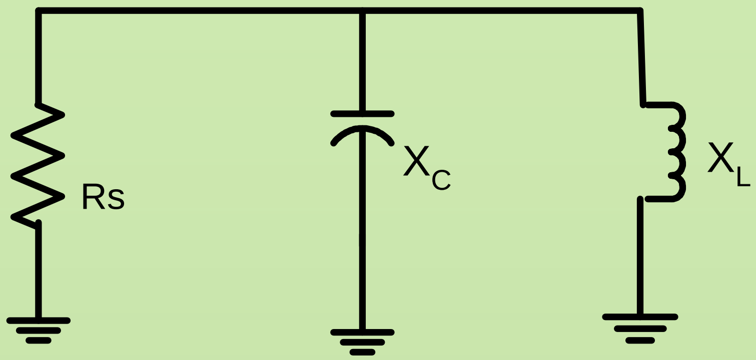
RANGKAIAN RESONATOR

Rangkaian Resonator saat R_L Open

Saat rangkaian resonansi

Xc = XL = X Paralel

$$X_C = \frac{1}{2\pi f C} \qquad X_L = 2\pi f L$$



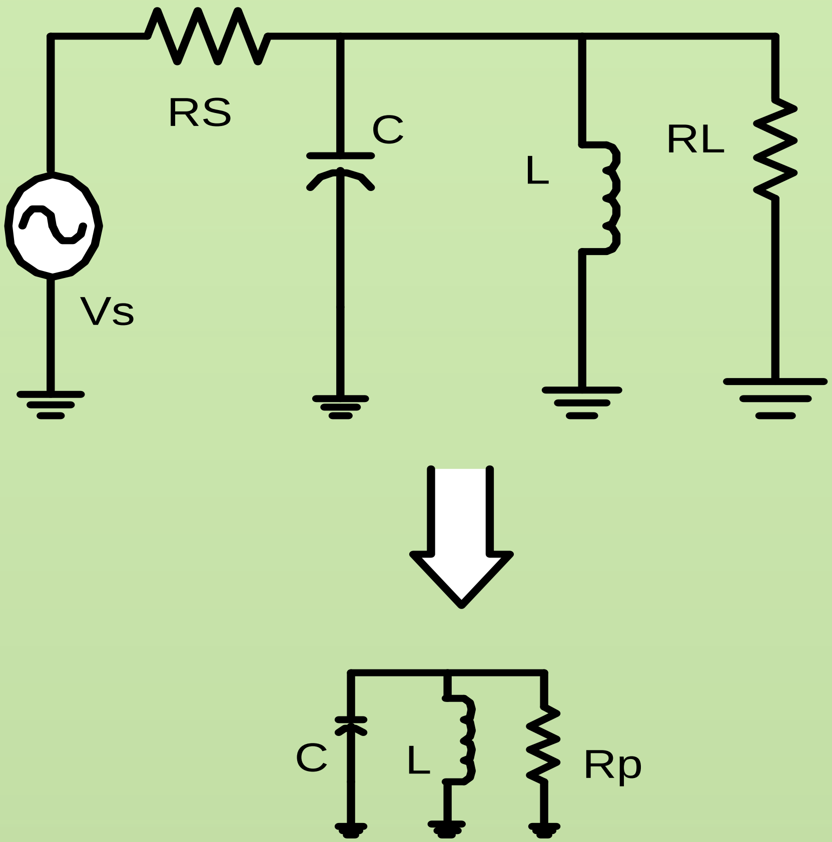
Sehingga $f_r = f_c = \dfrac{1}{2\pi\sqrt{LC}}$

$$Q = \frac{f_c}{BW_{3dB}} = \frac{f_r}{f_2 - f_1} \cong \frac{R_{paralel}}{X_{paralel}}$$

Dan nilai $Q = \dfrac{R_{paralel}}{X_{paralel}} = \dfrac{Rs}{2\pi f_r L} = \dfrac{Rs}{1/2\pi f_r C} = 2\pi f_r CRs$

RANGKAIAN RESONATOR

Rangkaian Resonator saat Beban Rl (< ~) ,L dan C ideal



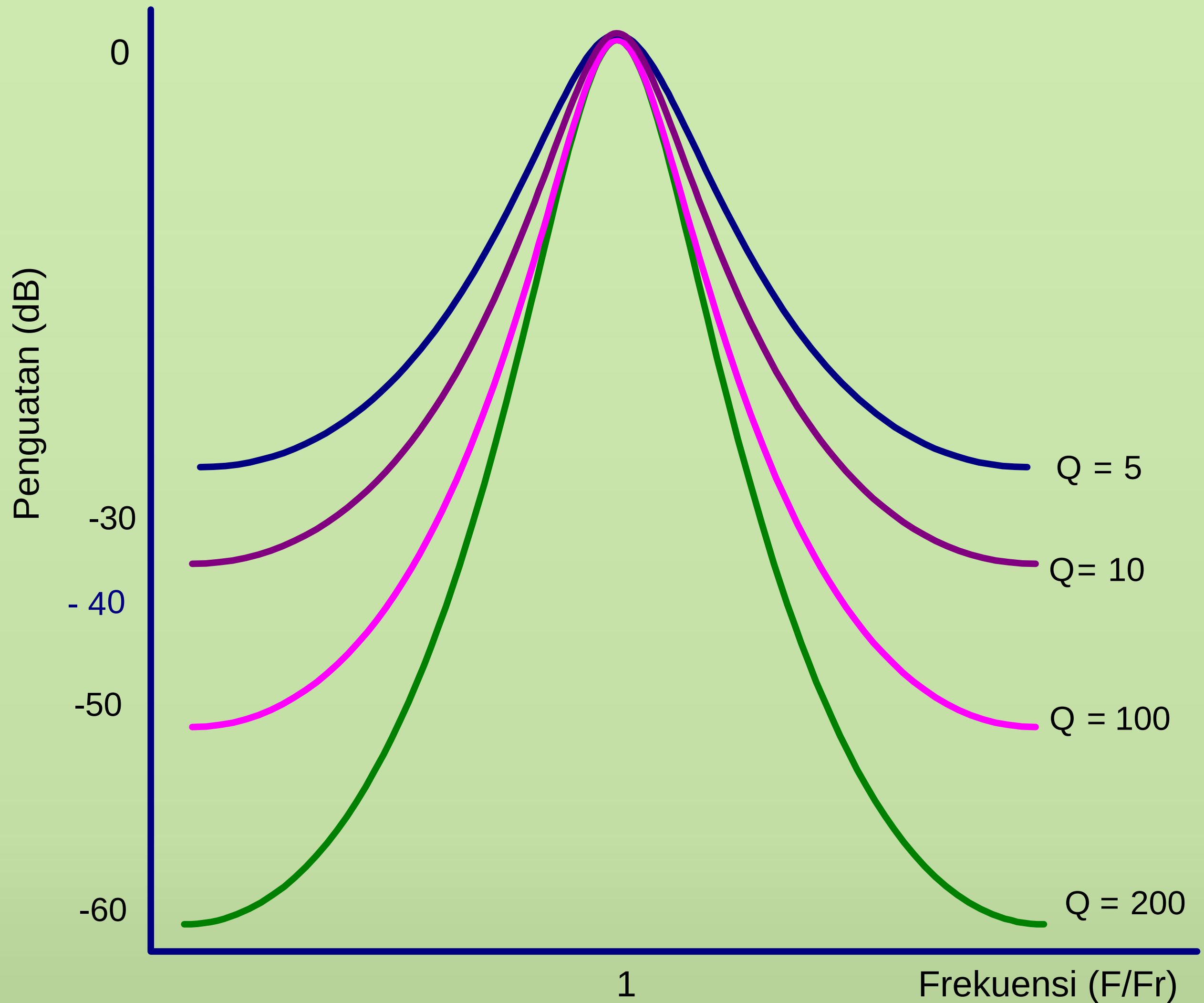
$$Rp = Rs \,//\, Rl = \frac{Rs \bullet RL}{Rs + RL}$$

Sehingga

$$Q = \frac{Rp}{Xp} = \frac{Rp}{2\pi frL} = 2\pi frCRp$$

RANGKAIAN RESONATOR

Respon Rangkaian Resonator



RANGKAIAN RESONATOR

Contoh Soal

1. Suatu generator dengan R_S= 50 Ω , C dan L tanpa rugi-rugi . C= 25 pF dan L= 0,05 μ H , R_L= open circuit. Tentukanlah nilai :
   a. fc = fr = …?
   b. Q = …?
   c. Bw 3dB..?
2. a. jika soal no.1 diatas nilai R_S= 1000 Ω hitung nilai Q

   b. Jika soal 2.a diatas diberi nilai R_L = 1000 Ω hitung nilai Q

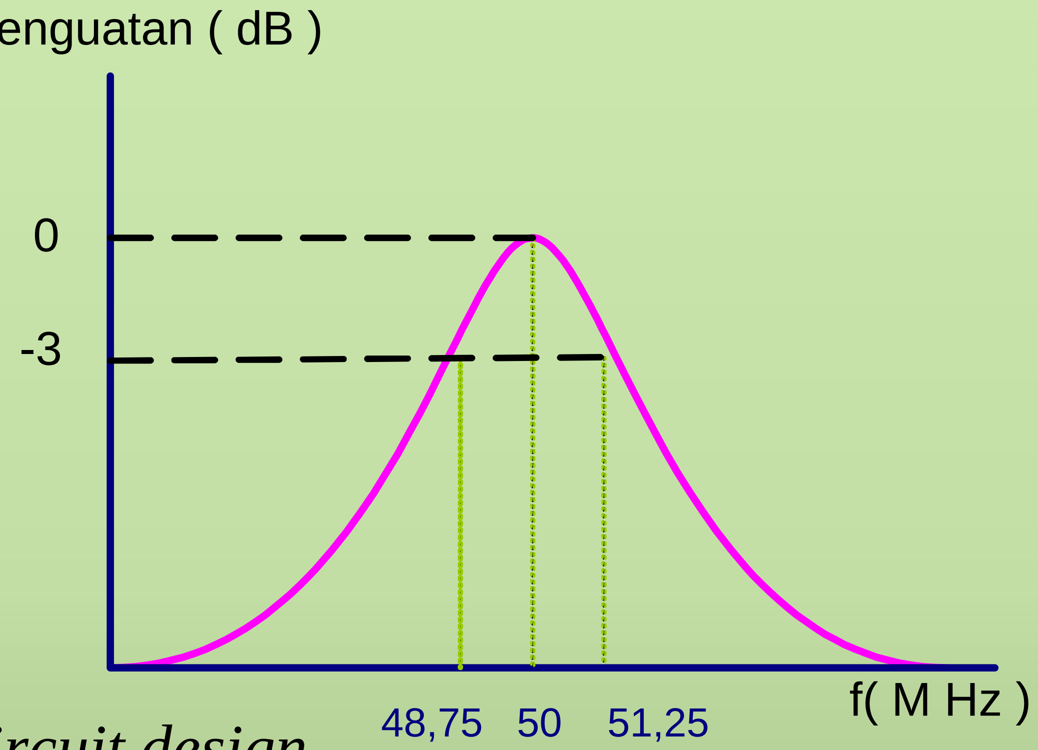
RANGKAIAN RESONATOR

Contoh Soal

3. **Rancanglah** suatu rangkaian resonator yang mempunyai spesifikasi sbb :

$R_S = 150\ \Omega$; $R_L = 1\ k\ \Omega$; C dan L ideal

Respon sbb :



➔ example 2-1 *RF Circuit design*

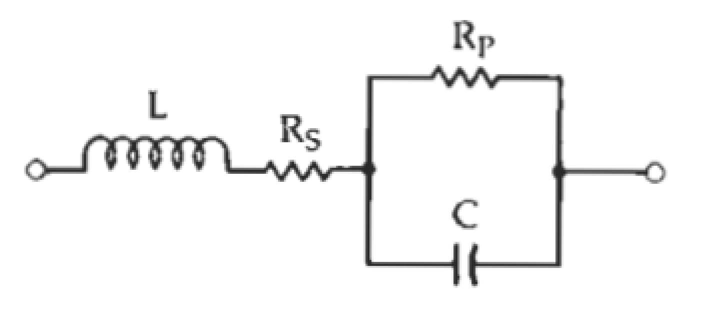
RANGKAIAN RESONATOR

Resonator dengan “L dan C mempunyai rugi-rugi/komponen Losses

RANGKAIAN RESONATOR

Kapasitor dengan Rugi-rugi

Capacitor Equivalent Circuit



C equals the capacitance,
Rs, is the heat-dissipation loss
Rp, is the insulation resistance, and
L is the inductance of the leads and plates

Power Factor In a perfect capacitor, the alternating current will lead the applied voltage by 90". This phase angle will be smaller in a real capacitor due to the total series resistance

$$PF = \cos \phi$$

Effective Series Resistance (ESR), this resistance is the combined equivalent of Rs and Rp and is the ac resistance of a capacitor.

$$ESR = \frac{PF}{\omega C}(1 \times 10^6)$$

Dissipation Factor-The DF is the ratio of ac resistance to the reactance of a capacitor

$$DF = \frac{ESR}{X_c} \times 100\%$$

Q (Quality Factor) used as a measure of the quality of the capasitor

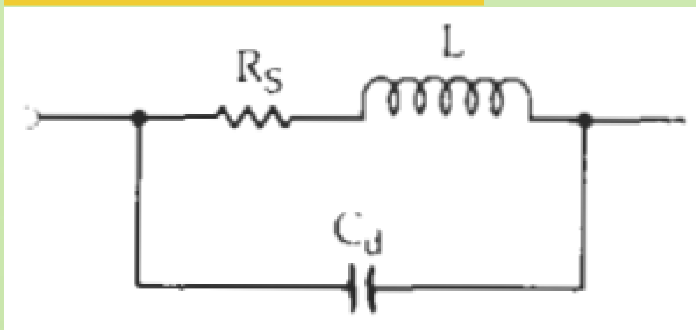
$$Q = \frac{1}{DF} = \frac{X_c}{ESR}$$

The Q of most capacitors is quite high over their useful frequency range, and the equivalent shunt resistance they present to the circuit is also quite high and can usually be neglected

RANGKAIAN RESONATOR

Induktor dengan Rugi-rugi

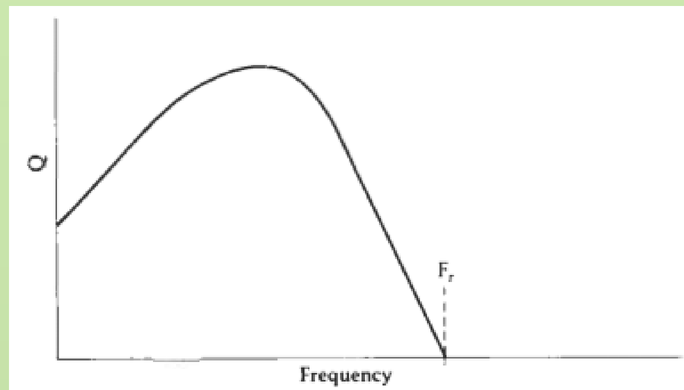
Inductor Equivalent Circuit



L is Inductance,
Rs, is the heat-dissipation loss
Cd is an aggregate of the individual parasitic distributed capacitances of the coil

$$Q = \frac{X}{R_s}$$

Q (Quality Factor) used as a measure of the quality of the inductor.



If the inductor were wound with a perfect conductor, its Q would be infinite and we would have a lossless inductor. Of course, there is no perfect conductor and, thus, an inductor always has some finite Q

At low frequencies, the Q of an inductor is very good because the only resistance in the windings is the dc resistance of the wire-which is very small
But as the frequency increases, skin effect and winding capacitance begin to degrade the quality of the inductor

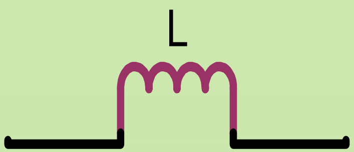
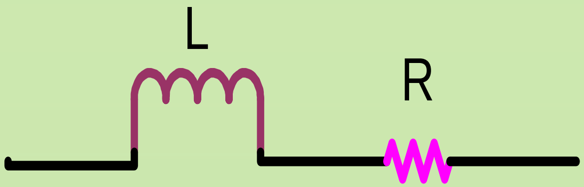
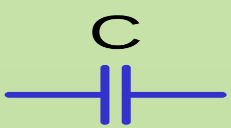
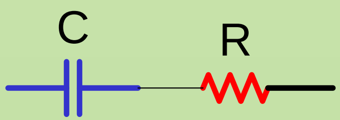
RANGKAIAN RESONATOR

Akibat dari komponen Losses / ada rugi-rugi komponen :

- Q tidak mungkin lebih besar dari Q untuk Lossless komponen
- Respon resonator mengalami redaman pada frekuensi resonansi
- Frekuensi resonansi sedikit tergeser dengan adanya Losses / rugi

RANGKAIAN RESONATOR

Pengertian dan Model L dan C dengan rugi-rugi :

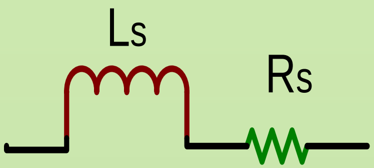
L – Ideal  Menyimpan **seluruh energi dalam** Medan Magnet	**L** praktis dengan rugi-rugi  **Ada** energi **yang** dibuang / dilepas berupa panas di resistor
C – Ideal  Menyimpan **seluruh** energi dalam **Medan Listrik**	C praktis dengan rugi-rugi  Ada **sebagian energi** yang **dilepas berupa panas di resistor**

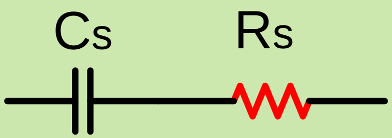
RANGKAIAN RESONATOR

Tingkat rugi-rugi pada L/C dinyatakan dalam factor kualitas Q

- Untuk L/C seri dengan R :

Rseri $\approx$ Rs





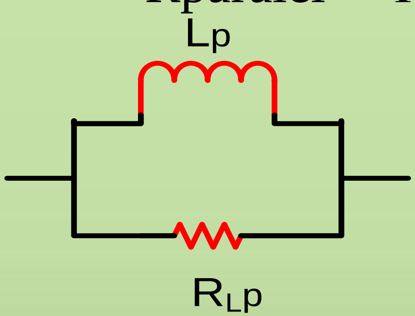
$$X_S = 2.\pi.f.L_S$$

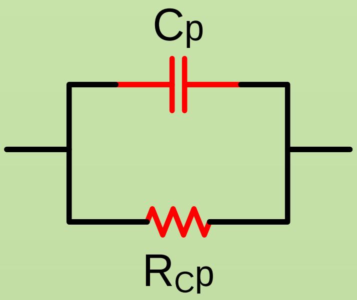
$$X_S = \frac{1}{2\pi f C_S}$$

$$Q_S \cong \frac{X_S}{R_S}$$

- Untuk L/C paralel dengan R : (Kadang Induktor L atau Kapasitor C dengan rugi-rugi juga dimodelkan sebagai rangkaian paralel dengan R-nya)

Rparalel $\approx$ Rp





$$X_p = 2\pi f L_p$$

$$X_p = \frac{1}{2\pi f C_p}$$

$$Q_p = \frac{R_{Lp}}{X_p} = \frac{R_{Cp}}{X_p}$$

RANGKAIAN RESONATOR

Konversi dari "seri" ke "paralel" ekivalennya, jika Rs dan Xs diketahui maka Xp dan Rp bisa dicari

Untuk Q < 10,

$$R_p = Rs\left(Q^2 + 1\right)$$

$$X_p = \frac{R_p}{Q_p}$$

$$Q_p = \frac{R_p}{X_p}$$

$$Q_s = \frac{X_s}{R_s}$$

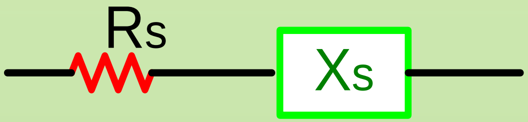
$$Q = Q_s = Q_p$$

Untuk Q > 10,

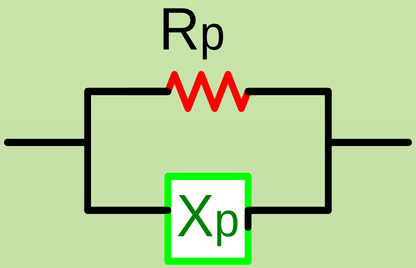
$$R_p \approx Q^2.R_s$$

$$X_p \approx X_s$$

Seri



Paralel Ekivalen



Qp, Qs, Q :Faktor kualitas Komponen

RANGKAIAN RESONATOR

Contoh Soal

1. Suatu inductor 50 nH dengan hambatan rugi-rugi yang disusun secara **seri** sebesar 10 Ω. Pada f = 100 MHz. Carilah besarnya L dan R **baru** jika ditransformasikan ke rangkaian ekivalen **Paralel**nya !

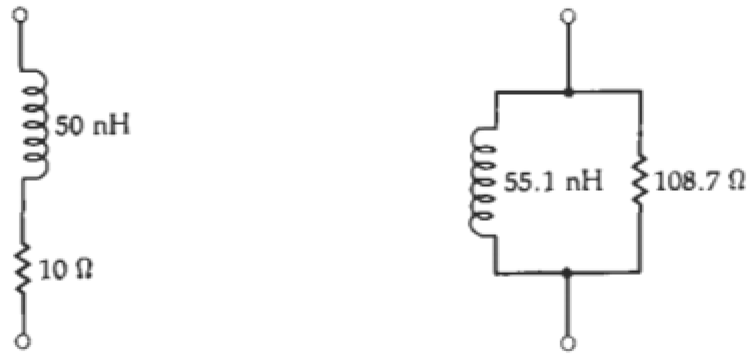
   ➔ example 2-2 *RF Circuit design*

RANGKAIAN RESONATOR

Solusi

EXAMPLE 2-2

Given a 50-nanohenry coil as shown in Fig. 2-15A, compute its Q at 100 MHz. Then, transform the series circuit of Fig. 2-15A into the equivalent parallel inductance and resistance circuit of Fig. 2-15B.



(*A*) *Series circuit.* (*B*) *Equivalent parallel circuit.*

Fig. 2-15. Example of a series-to-parallel transformation.

Solution

The Q of this coil at 100 MHz is, from Chapter 1,

$$Q = \frac{X_s}{R_s}$$

$$= \frac{2\pi(100 \times 10^6)(50 \times 10^{-9})}{10}$$

$$= 3.14$$

Then, since the Q is less than 10, use Equation 2-7 to find R_p.

$$R_p = (Q^2 + 1)R_s$$

$$= [(3.14)^2 + 1]\ 10$$

$$= 108.7 \text{ ohms}$$

Next, we find X_p using Equation 2-8:

$$X_p = \frac{R_p}{Q_p}$$

$$= \frac{108.7}{3.14}$$

$$= 34.62$$

Thus, the parallel inductance becomes:

$$L_p = \frac{X_p}{\omega}$$

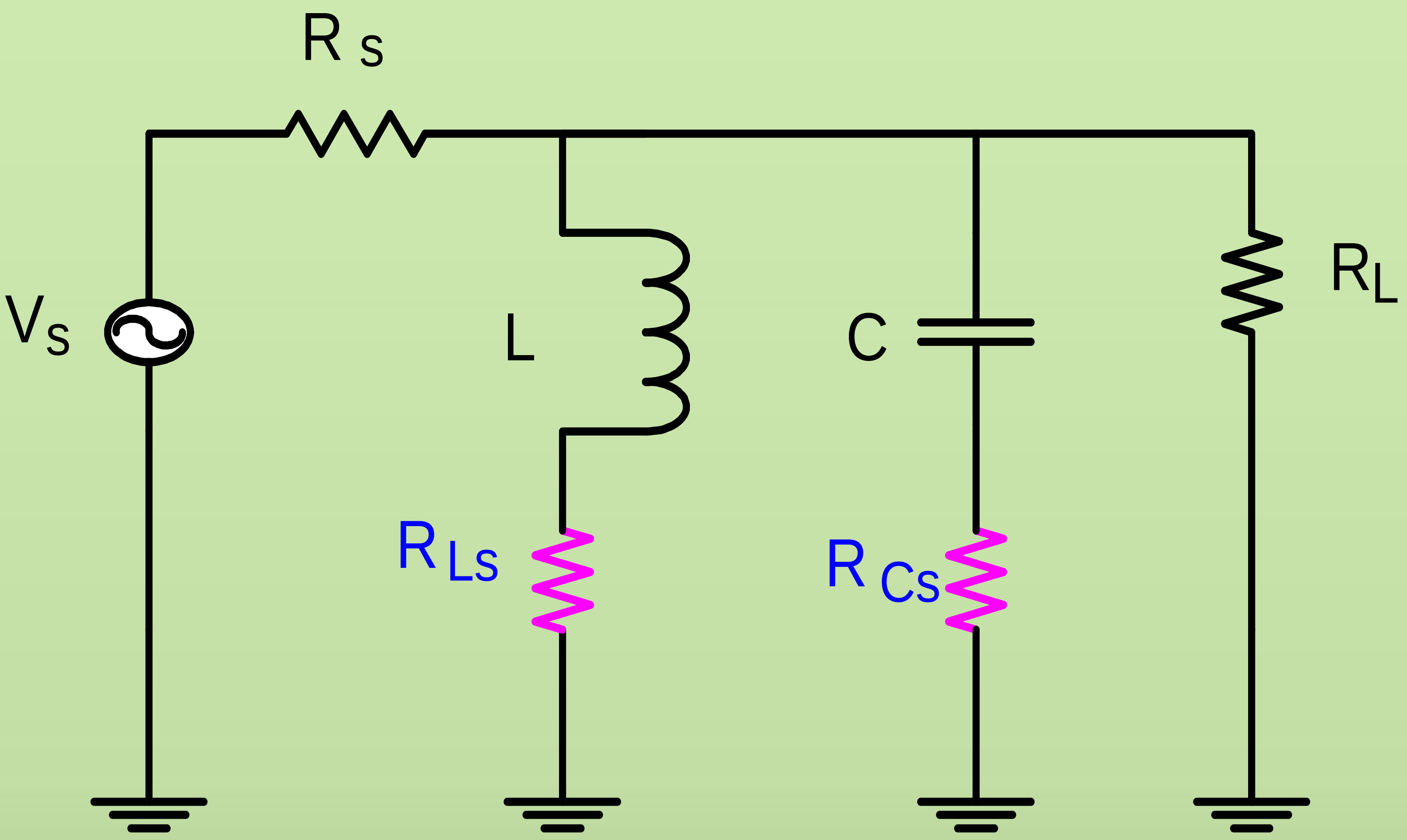
$$= \frac{34.62}{2\pi(100 \times 10^6)}$$

$$= 55.1 \text{ nH}$$

These values are shown in the equivalent circuit of Fig. 2-15B.

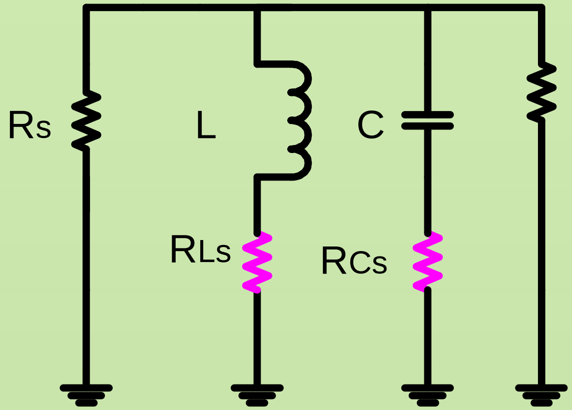
RANGKAIAN RESONATOR

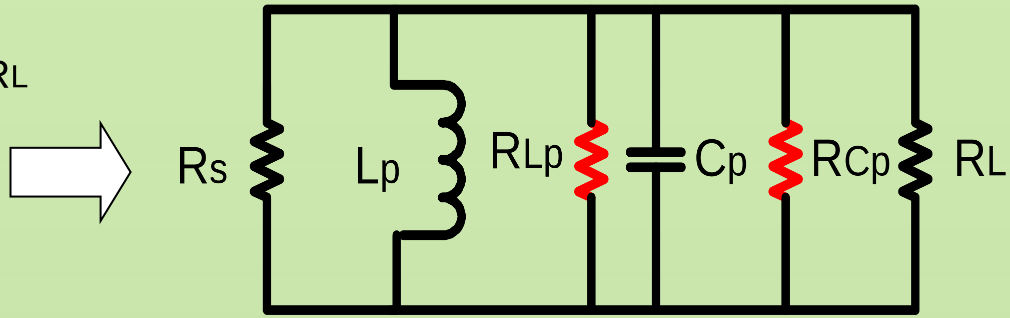
Rangkaian Resonator menggunakan L dan C dengan rugi-rugi

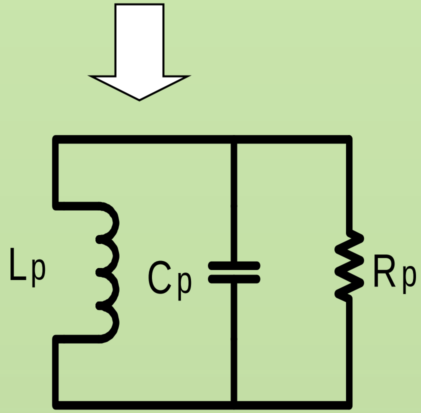


RANGKAIAN RESONATOR

Rangkaian Ekivalen untuk menentukan Q (Vs short):





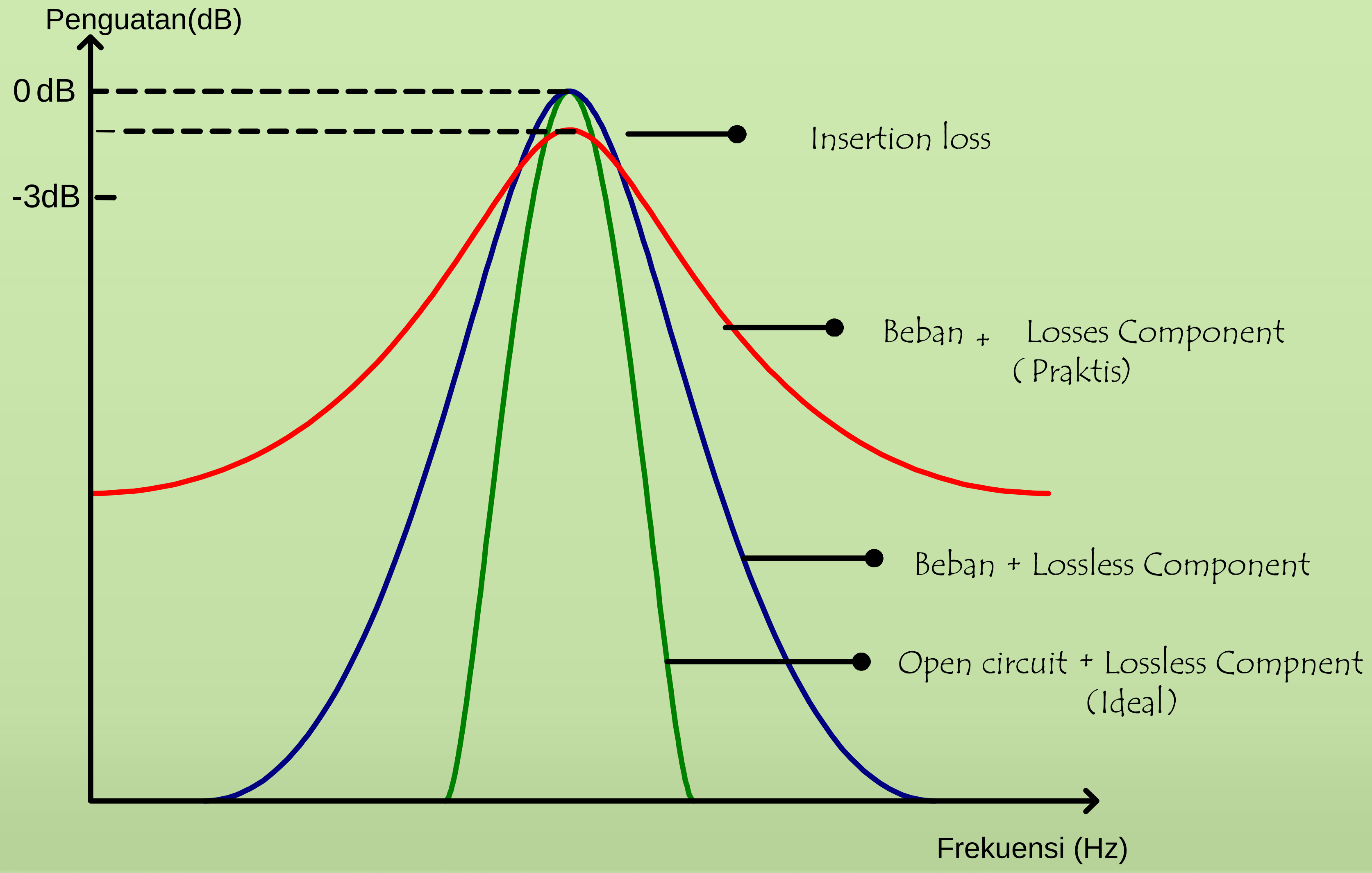


$$Q_{sistem} = \frac{f_c}{BW_{3dB}} = \frac{R_p}{X_p} = \frac{R_{LP} \mathbin{//} R_S \mathbin{//} R_L}{X_P}$$

$$X_p = 2\pi f L_p \text{ atau } X_p = \frac{1}{2\pi f C_p}$$

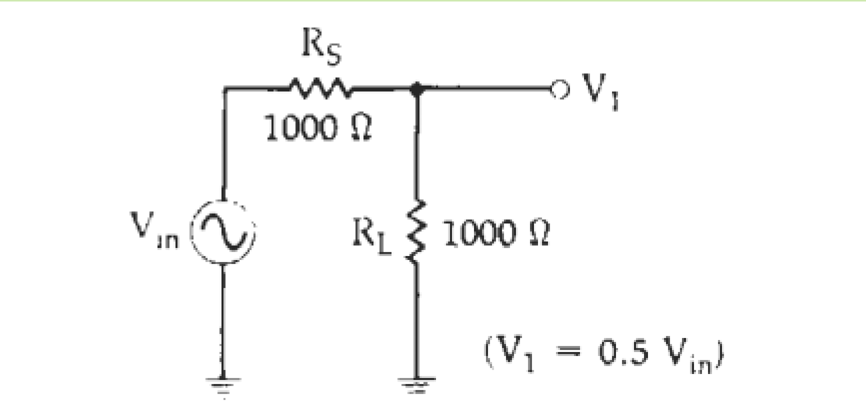
RANGKAIAN RESONATOR

Perbandingan Respon LC untuk 3 kondisi:

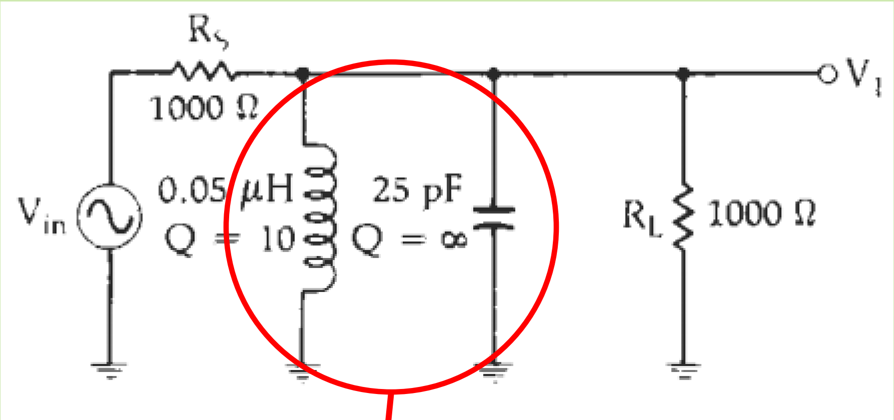


RANGKAIAN RESONATOR

Pengaruh Komponen Losses (Q komponen) terhadap insertion Loss

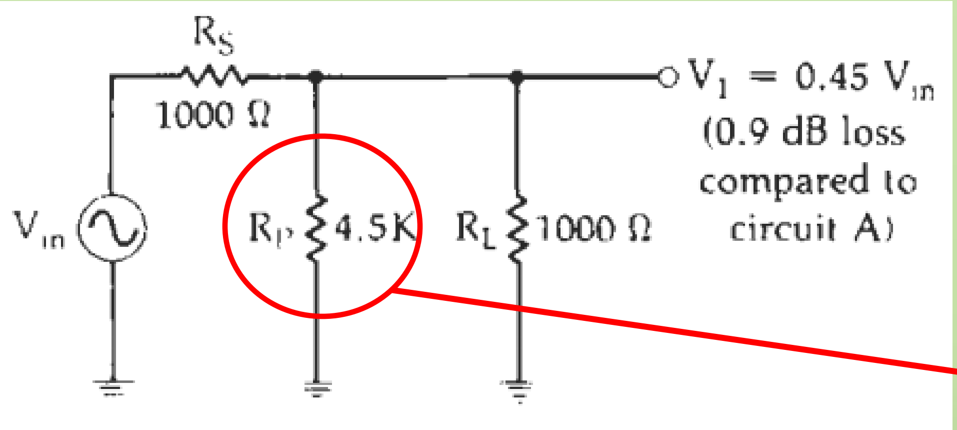


(A) *Source connected directly to the load.*



(B) *Insertion of a resonant circuit.*

Penambahan rangkaian resonansi dengan komponen L tidak ideal



(C) *Equivalent circuit at resonance.*

Akibatnya seolah-olah muncul impedansi paralel Rp yang mengakibatkan Insertion Loss

$$IL = 20\log\frac{0,45}{0,5} = 0,9dB$$

RANGKAIAN RESONATOR

Contoh Soal

1. Rancanglah rangkaian resonansi sederhana supaya menghasilkan BW3dB = 10 MHz pada frekuensi tengah 100 MHz!! Komponen yang dipakai sebagai berikut :
   a. Hambatan sumber dan beban masing-masing 1000 Ω, Kapasitor yang digunakan Ideal (Lossless C)
   b. Sedangkan Induktor mempunyai factor Q = 85

   Kemudian Carilah besarnya “Insertion Loss” rangkaian tersebut!

   ➔ example 2-3 *RF Circuit design*

EXAMPLE 2-3

Design a simple parallel resonant circuit to provide a 3-dB bandwidth of 10 MHz at a center frequency of 100 MHz. The source and load impedances are each 1000 ohms. Assume the capacitor to be lossless. The Q of the inductor (that is available to us) is 85. What is the insertion loss of the network?

Solution

From Equation 2-1, the required loaded Q of the resonant circuit is:

$$Q = \frac{f_c}{f_2 - f_1} = \frac{100\text{ MHz}}{10\text{ MHz}} = 10$$

To find the inductor and capacitor values needed to complete the design, it is necessary that we know the equivalent shunt resistance and reactance of the components at resonance. Thus, from Equation 2-8:

$$X_p = \frac{R_p}{Q_p}$$

where

X_p = the reactance of the inductor and capacitor at resonance,
R_p = the equivalent shunt resistance of the inductor,
Q_p = the Q of the inductor.

Thus,

$$R_p = (85)X_p \qquad \text{(Eq. 2-11)}$$

The loaded Q of the resonant circuit is equal to:

$$Q = \frac{R_{total}}{X_p}$$

$$10 = \frac{R_{total}}{X_p}$$

where

R_{total} = the shunt resistance, which equals $R_p \| R_s \| R_L$. Therefore, we have:

$$10 = \frac{\frac{R_p(500)}{R_p + 500}}{X_p} \qquad \text{(Eq. 2-12)}$$

We now have two equations and two unknowns (X_p, R_p). If we substitute Equation 2-11 into Equation 2-12 and solve for X_p, we get:

$$X_p = 44.1\text{ ohms}$$

Plugging this value back into Equation 2-11 gives:

$$R_p = 3.75\text{K}$$

Thus, our component values must be

$$L = \frac{X_p}{\omega} = 70\text{ nH}$$

$$C = \frac{1}{\omega X_p} = 36\text{ pF}$$

The final circuit is shown in Fig. 2-17.

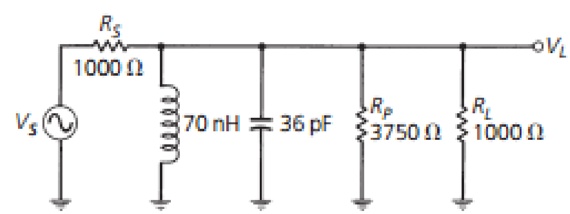


FIG. 2-17. Resonant circuit design for Example 2-3.

The insertion-loss calculation, at center frequency, is now very straightforward and can be found by applying the voltage division rule as follows. Resistance R_p in parallel with resistance R_L is equal to 789.5 ohms. The voltage at V_L is, therefore,

$$V_L = \frac{789.5}{789.5 + 1000}(V_s) = .44\,V_s$$

The voltage at V_L, without the resonant circuit in place, is equal to 0.5 V_s due to the 1000-ohm load. Thus, we have:

$$\text{Insertion Loss} = 20\log_{10}\frac{0.44\,V_s}{0.5\,V_s} = 1.1\text{ dB}$$

RANGKAIAN RESONATOR

Kesimpulan

- Faktor Kualitas Q dari rangkaian resonator (Loaded Q) ditentukan oleh :
  - Impedansi Sumber *(Source Resistance)* R_S
  - Impedansi Beban *(Load Resistance)* R_L
  - Pemilihan Besar Nilai Komponen L dan C
  - Faktor Kualitas dari Komponen

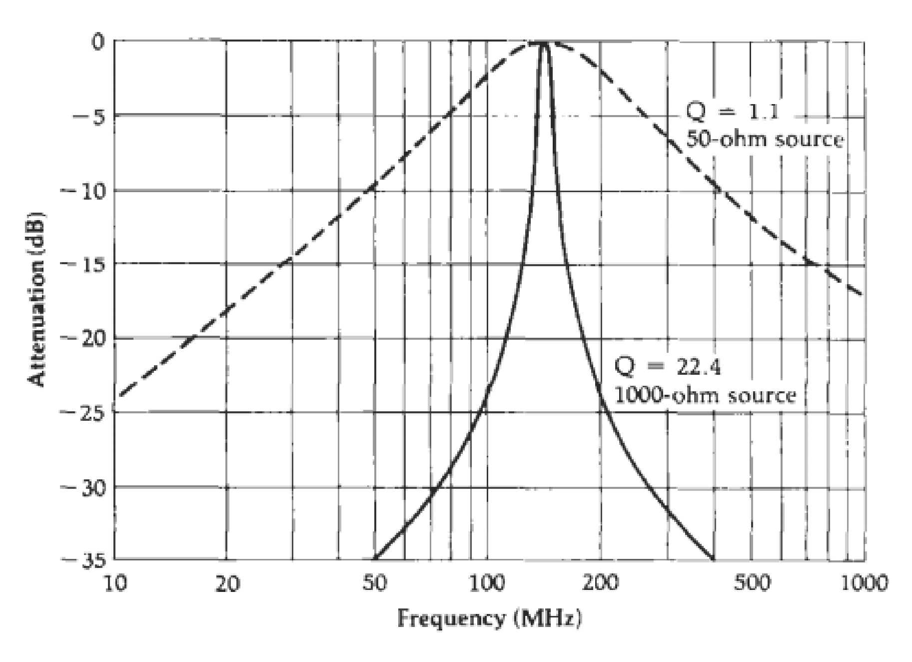
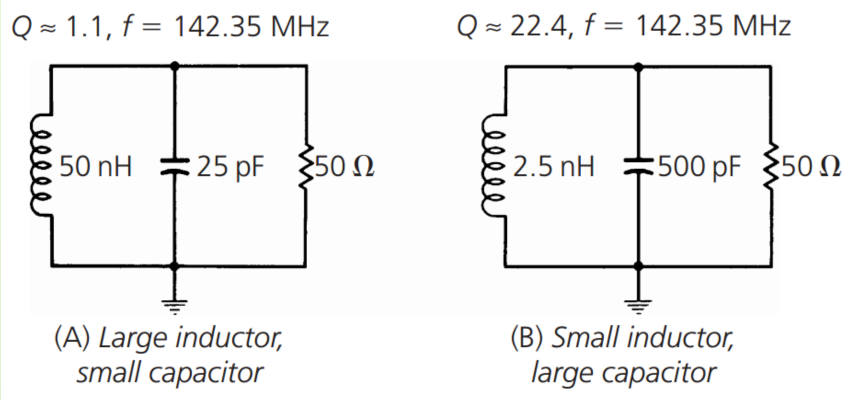
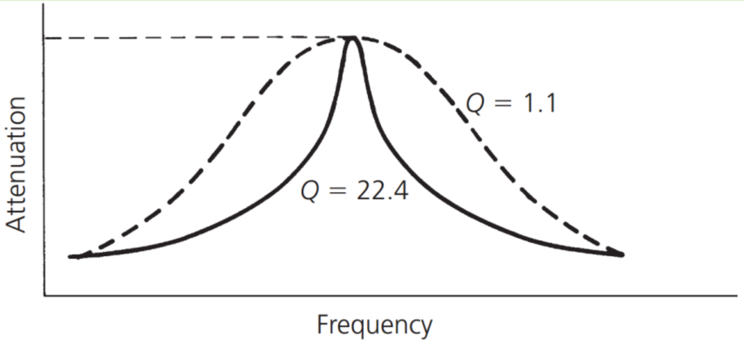


Fig. 2-10. The effect of R_S and R_L on loaded Q.





RANGKAIAN RESONATOR

Transformator Impedansi
Tujuan: Menaikkan Q dengan menaikkan Rs (atau R_L)

RANGKAIAN RESONATOR

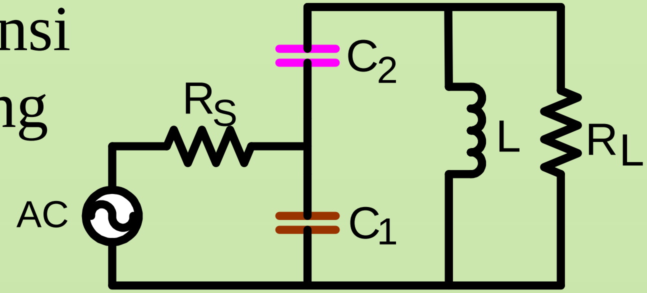
TRANSFORMATOR IMPEDANSI

- low values of source and load impedance tend to load a given resonant circuit down and, thus, tend to **decrease its loaded Q** and **increase its bandwidth**
- This makes it very difficult to design a simple LC high Q resonant circuit for use between two very low values of source and load resistance
- even if we were able to come up with a design on paper, it most likely would be impossible to build due to the extremely small (or negative) inductor values that would be required
- One method of getting around this potential design problem is to make use of one of the **impedance transforming circuits** that will fool the resonant circuit into seeing a source or load resistance that is much larger than what is actually present
- the **impedance transforming circuits** are useful for designs that need loaded Q's that are greater than 10

RANGKAIAN RESONATOR

TRANSFORMATOR IMPEDANSI → Tapped Capacitor

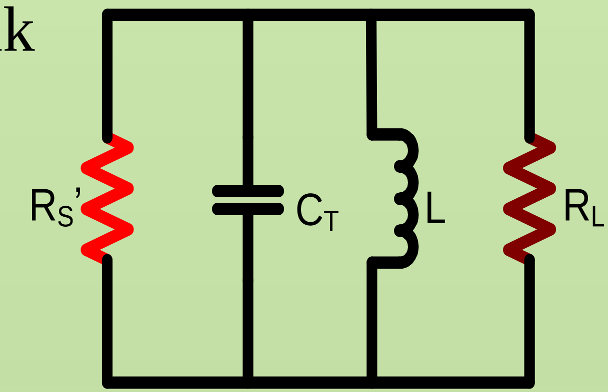
- Transformasi Impedansi dengan **kapasitor** yang di-tapped di tengah



$\longrightarrow Rs' > Rs$

- Rangkaian ekivalen untuk mencari Q

  Rs' = RL → transfer daya maximum



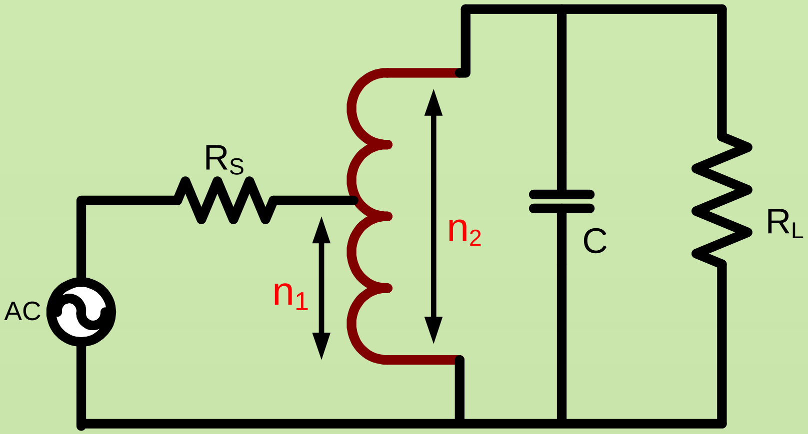
$$Rs' = Rs\left(1 + \frac{C_1}{C_2}\right)^2$$

$$C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

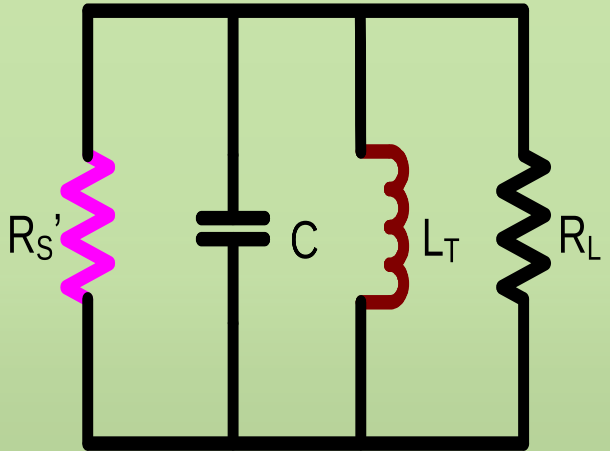
RANGKAIAN RESONATOR

TRANSFORMATOR IMPEDANSI

- Transformasi Impedansi dengan **Induktor** yang di-tapped



- Rangkaian ekivalennya



$$Rs' = Rs\left(\frac{n_2}{n_1}\right)^2$$

RANGKAIAN RESONATOR

Contoh Soal

- Rancang suatu Resonator dengan spesifikasi sbb:

  $Q = 20$ pada $f_c = 100$ MHz

  $R_s = 50$ ohm , $R_L = 2000$ ohm

  Gunakan rangkaian transformasi impedansi C tapped dengan asumsi $Q_L = 100$ pada 100 MHz

- ➔ example 2-4 *RF Circuit design*

EXAMPLE 2-4

Design a resonant circuit with a loaded Q of 20 at a center frequency of 100 MHz that will operate between a source resistance of 50 ohms and a load resistance of 2000 ohms. Use the tapped-C approach and assume that inductor Q is 100 at 100 MHz.

Solution

We will use the tapped-C transformer to step the source resistance up to 2000 ohms to match the load resistance for optimum power transfer. (Impedance matching will be covered in detail in Chapter 4.) Thus,

$$R'_s = 2000\,\text{ohms}$$

and from Equation 2-13, we have:

$$\frac{C_1}{C_2} = \sqrt{\frac{R'_s}{R_s}} - 1$$
$$= 5.3$$

or,

$$C_1 = 5.3C_2 \qquad \text{(Eq. 2-16)}$$

Proceeding as we did in Example 2-3, we know that for the inductor:

$$Q_p = \frac{R_p}{X_p} = 100$$

Therefore,

$$R_p = 100X_p \qquad \text{(Eq. 2-17)}$$

We also know that the loaded Q of the resonant circuit is equal to:

$$Q = \frac{R_{total}}{X_p}$$

where

R_{total} = the total equivalent shunt resistance,

$$= R'_s \| R_p \| R_L$$
$$= 1000 \| R_p$$

and, where we have taken R'_s and R_L to each be 2000 ohms, in parallel. Hence, the loaded Q is

$$Q = \frac{1000R_p}{(1000 + R_p)X_p} \qquad \text{(Eq. 2-18)}$$

Substituting Equation 2-17 (and the value of the desired loaded Q) into Equation 2-18, and solving for X_p, yields:

$$X_p = 40\,\text{ohms}$$

And, substituting this result back into Equation 2-17 gives

$$R_p = 4000\,\text{ohms}$$

and

$$L = \frac{X_p}{\omega}$$
$$= 63.6\,\text{nH}$$
$$C_T = \frac{1}{X_p\omega}$$
$$= 39.78\,\text{pF}$$

We now know what the total capacitance must be to resonate with the inductor. We also know from Equation 2-16 that C_1 is 5.3 times larger than C_2. Thus, if we substitute Equation 2-16 into Equation 2-14, and solve the equations simultaneously, we get:

$$C_2 = 47.3\,\text{pF}$$
$$C_1 = 250.6\,\text{pF}$$

The final circuit is shown in Fig. 2-18D.

RANGKAIAN RESONATOR

Rangkaian Resonator paralel ganda

(Coupling Mechanism)

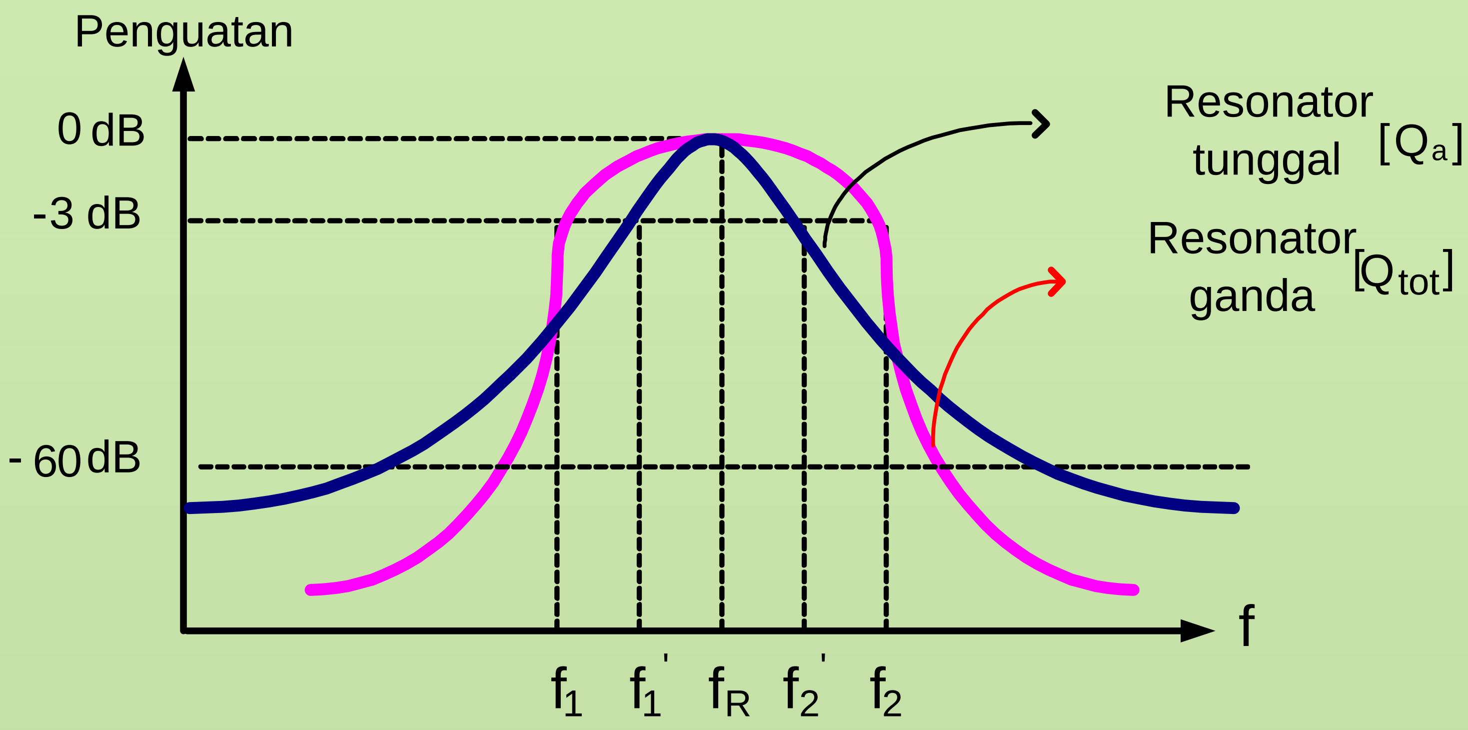
RANGKAIAN RESONATOR

Rangkaian Resonator Paralel Ganda

- In many applications where steep passband skirts and small shape factors are needed, a single resonant circuit might not be sufficient
- In situations such as this, individual resonant circuits are often **coupled together** to produce more attenuation at certain frequencies than would normally be available with a single resonator, that's called **Coupling Mechanism of Resonant Circuit**
- The most common forms of coupling are:
  - Capacitive Coupling
  - Inductive Coupling
  - transformer (mutual) Coupling
  - active (transistor) coupling
- The coupling mechanism that is used is generally chosen specifically for each application, as each type of coupling has its own peculiar characteristics that must be dealt with.

RANGKAIAN RESONATOR

Respon 'Resonator ganda'

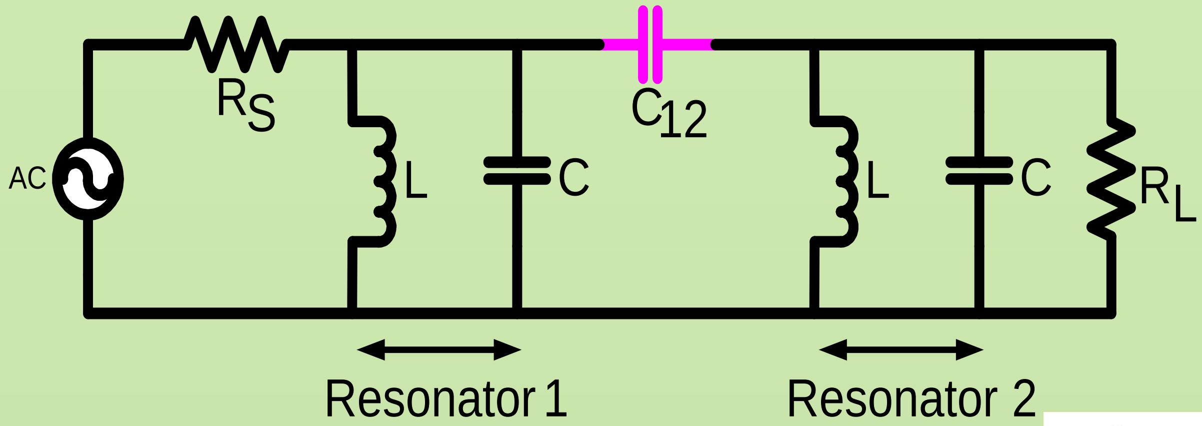


Pada kondisi critical coupling

$$Q_{total} = Q_{ganda} = 0{,}707 \times Q_a$$

RANGKAIAN RESONATOR

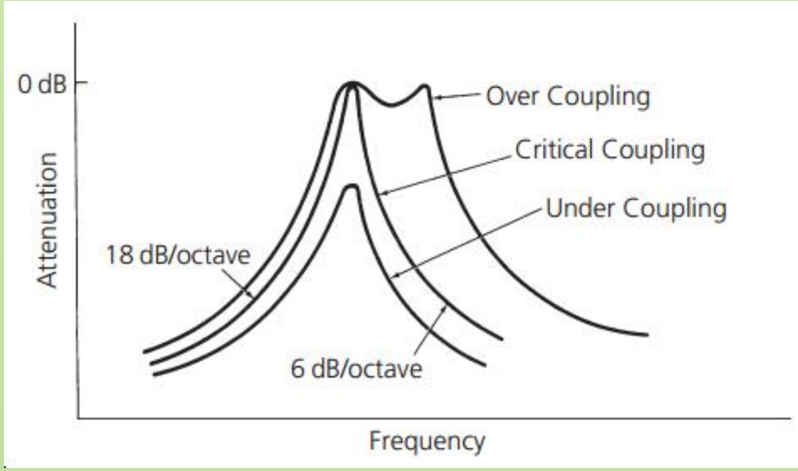
Capacitive Coupling



Advantages : Simplicity and Inexpensive

$$C_{12} = \frac{C}{Q_a}$$

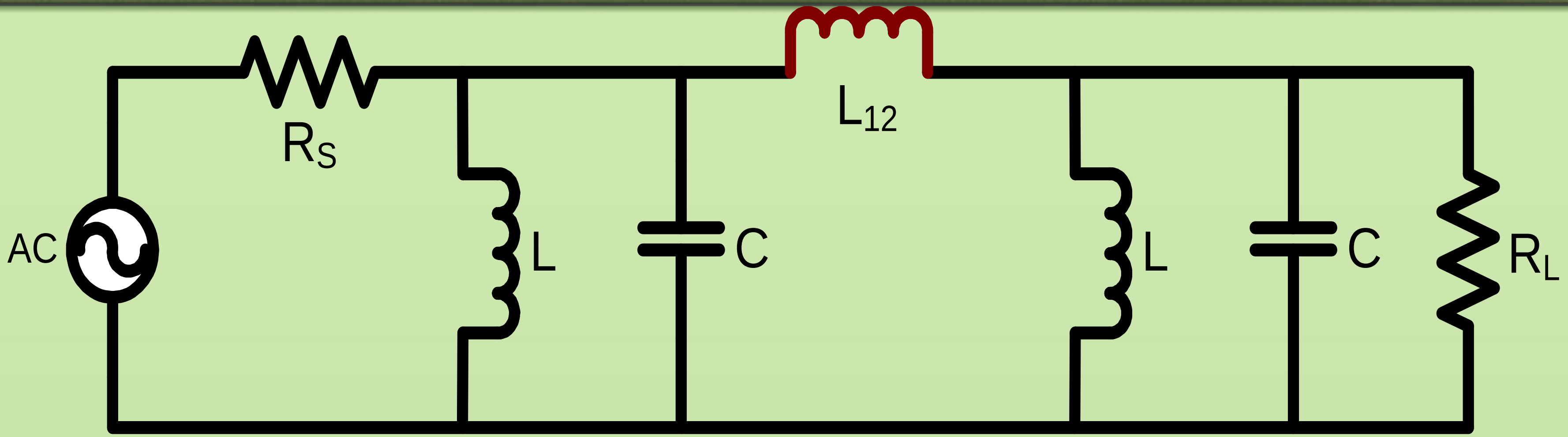
$$Q_a \approx Q_{awal} \approx Q_{single}$$



Q_a = faktor kualitas rangkaian single resonator

RANGKAIAN RESONATOR

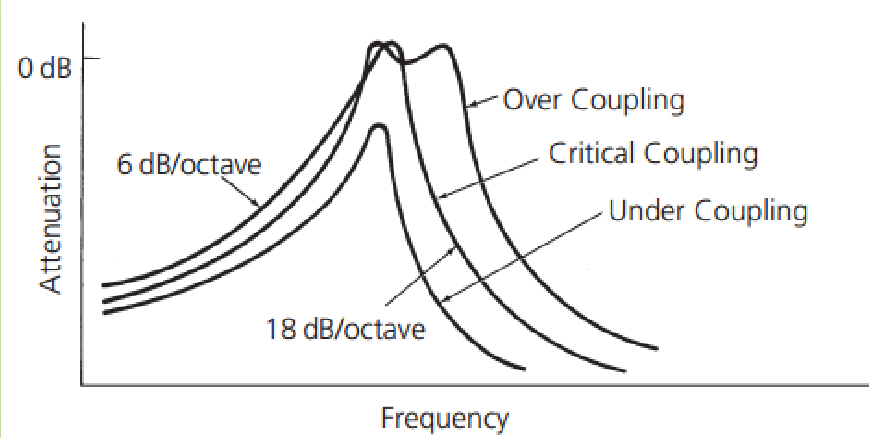
Inductive Coupling



$$L_{12} = Q_a \times L$$

$$Q_a \approx Q_{awal} \approx Q_{single}$$

Qa = faktor kualitas rangkaian single resonator

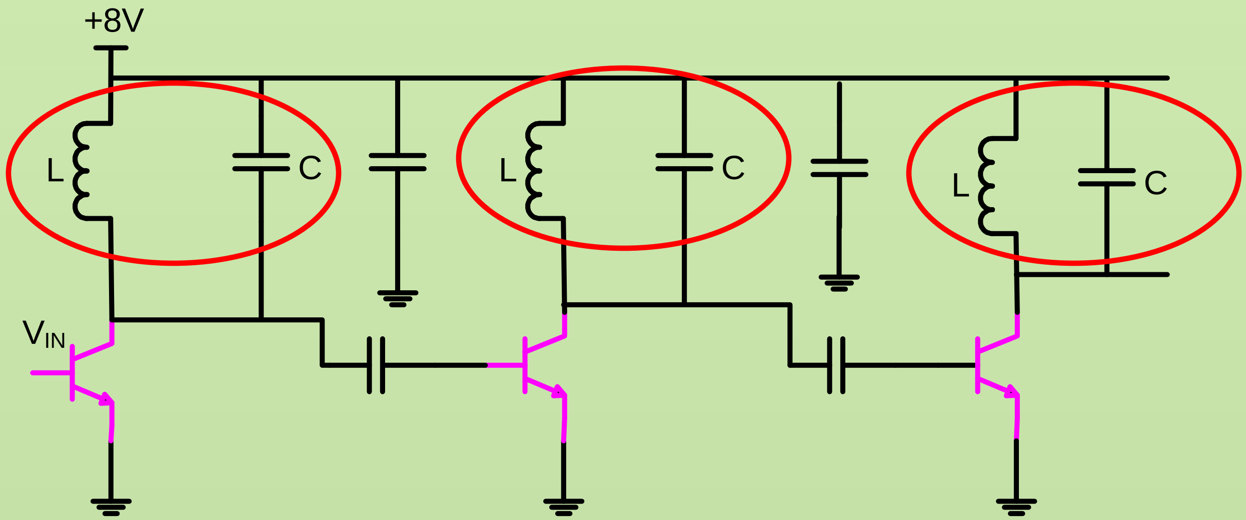


(A) *Inductive coupling*

RANGKAIAN RESONATOR

Active Coupling

High Loaded Q/ Very Narrow bandwidth 3dB



$$Q_{akhir} = Q_{total} = \frac{Q_1}{\sqrt{2^{1/n} - 1}}$$

Q_1 : faktor kualitas resonator tunggal

n : banyaknya rangkaian resonator kaskade

RANGKAIAN RESONATOR

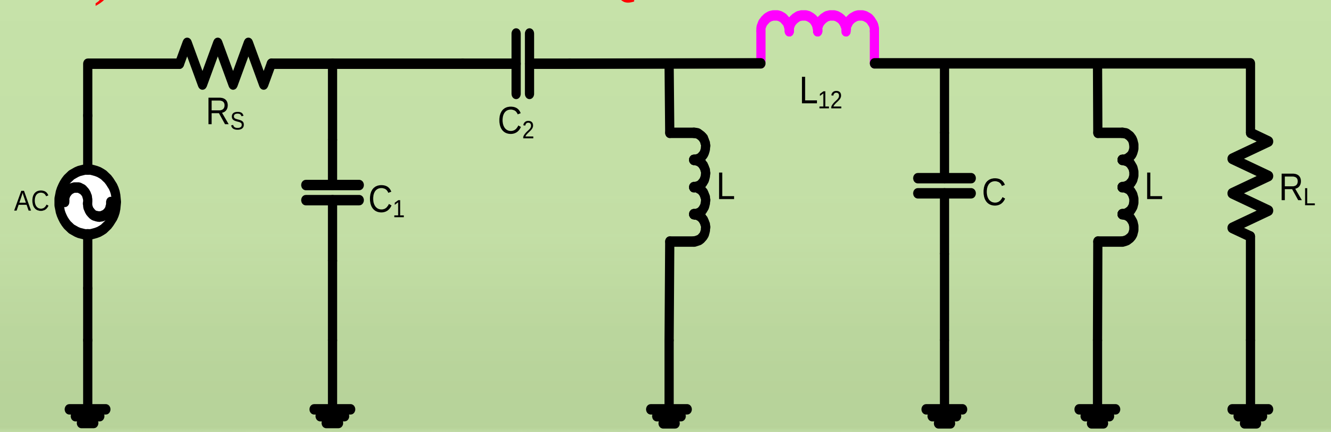
Contoh Soal: ➔ example 2-5 *RF Circuit design*

Desainlah suatu rangkaian resonator yang terdiri dari 2 buah resonator identik yang dihubungkan seri dengan kopling induktor (diset pada kondisi critical coupling), sehingga terpenuhi spesifikasi sbb:

f_c = 75 MHz ; BW_{3dB} = 3,75 MHz ; Rs = 100 ohm

R_L = 1000 ohm ; Asumsikan Q_L = 85 pada fc

- Terakhir gunakan transformasi impedansi C yang di tapped (di sumber) untuk menaikkan Q!



EXAMPLE 2-5

Design a top-L coupled two-resonator tuned circuit to meet the following requirements:

1. Center frequency = 75 MHz
2. 3-dB bandwidth = 3.75 MHz
3. Source resistance = 100 ohms
4. Load resistance = 1000 ohms

Assume that inductors are available that have an unloaded Q of 85 at the frequency of interest. Finally, use a tapped-C transformer to present an effective source resistance (R_s') of 1000 ohms to the filter.

Solution

The solution to this design problem is not a very difficult one, but it does involve quite a few separate and distinct calculations which might tend to make you lose sight of our goal. For this reason, we will walk through the solution in a very orderly fashion with a complete explanation of each calculation.

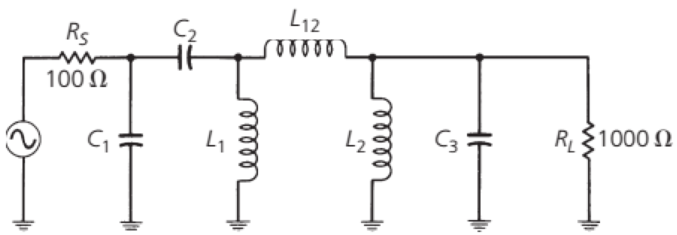


FIG. 2-27. Circuit for Example 2-5.

The circuit we are designing is shown in Fig. 2-27. Let's begin with a few definitions.

Q_{total} = the loaded Q of the entire circuit

Q_p = the Q of the inductor

Q_R = the loaded Q of each resonator

From our discussion on coupling and its effects on bandwidth, we know that

$$Q_R = \frac{Q_{total}}{0.707}$$

and,

$$Q_{total} = \frac{f_e}{B} = \frac{75\text{ MHz}}{3.75\text{ MHz}} = 20$$

so,

$$Q_R = \frac{20}{0.707} = 28.3$$

Thus, to provide a total loaded Q of 20, it is necessary that the loaded Q of each resonator be 28.3. For the inductor,

$$Q_p = \frac{R_p}{X_p} = 85$$

or

$$R_p = 85X_p \qquad \text{(Eq. 2-22)}$$

The loaded Q of each resonant circuit is

$$Q_R = \frac{R_{total}}{X_p} \qquad \text{(Eq. 2-23)}$$

where,

R_{total} = the total equivalent shunt resistance for each resonator and

$= R_s' \| R_p$

$= R_L \| R_p$

since both circuits are identical. Remember, we have already taken into account the loading effect that each resonant circuit has on the other through the factor 0.707, which was used at the beginning of the example. Now, we have:

$$R_{total} = \frac{R_s' R_p}{R_s' + R_p}$$

EXAMPLE 2-5—Cont

Substituting into Equation 2-23:

$$Q_R = \frac{R_s' R_p}{(R_s' + R_p) X_p}$$

and,

$$X_p = \frac{R_s' R_p}{(R_s' + R_p) Q_R}$$

$$= \frac{1000 R_p}{(1000 + R_p) 28.3} \qquad \text{(Eq. 2-24)}$$

We can now substitute Equation 2-22 into Equation 2-24 and solve for X_p.

$$X_p = \frac{(1000)(85X_p)}{(1000 + 85X_p) 28.3}$$

$$= 23.57 \text{ ohms}$$

and,

$$R_p = 85X_p$$

$$= 2003 \text{ ohms}$$

To find the component values

$$L_1 = L_2 = \frac{X_p}{\omega}$$

$$= 50 \text{ nH}$$

and,

$$C_s = \frac{1}{\omega X_p}$$

$$90 \text{ pF}$$

Now all that remains is to design the tapped-C transformer and the coupling inductor. From Equation 2-12:

$$R_s' = R_s \left(1 + \frac{C_1}{C_2}\right)^2$$

or,

$$\frac{C_1}{C_2} = \sqrt{\frac{R_s'}{R_s}} - 1$$

$$= 2.16$$

and,

$$C_1 = 2.16 C_2 \qquad \text{(Eq. 2-25)}$$

We know that the total capacitance that must be used to resonate with the inductor is 90 pF and

$$C_{total} = \frac{C_1 C_2}{C_1 + C_2} \qquad \text{(Eq. 2-26)}$$

Substituting Equation 2-25 into Equation 2-26 and taking C_{total} to be 90 pF yields:

$$90 \text{ pF} = \frac{2.16 C_2^2}{3.16 C_2}$$

and,

$$C_2 = 132 \text{ pF}$$

$$C_1 = 285 \text{ pF}$$

To solve for the coupling inductance from Equation 2-20:

$$L_{12} = Q_R L$$

$$= (28.3)(50 \text{ nH})$$

$$= 1.415 \, \mu\text{H}$$

The design is now complete. Notice that the tapped-C transformer is actually serving a dual purpose. It provides a DC block between the source and load in addition to its transformation properties.


THANK
YOU