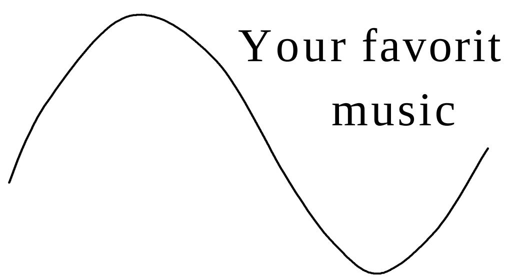
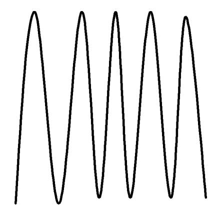
A Few Basics--Modulation, AM & FM

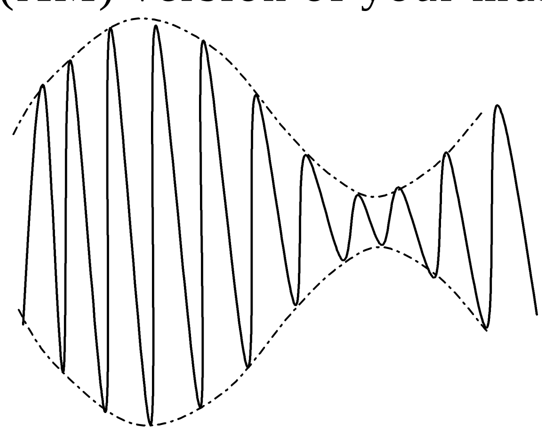


Your favorite music

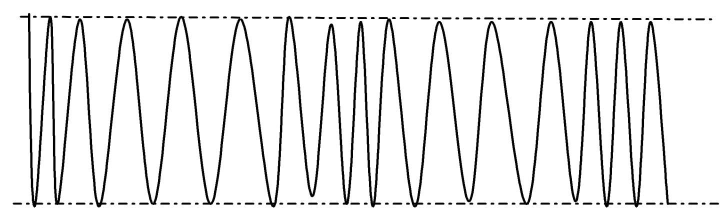


Your station's carrier frequency

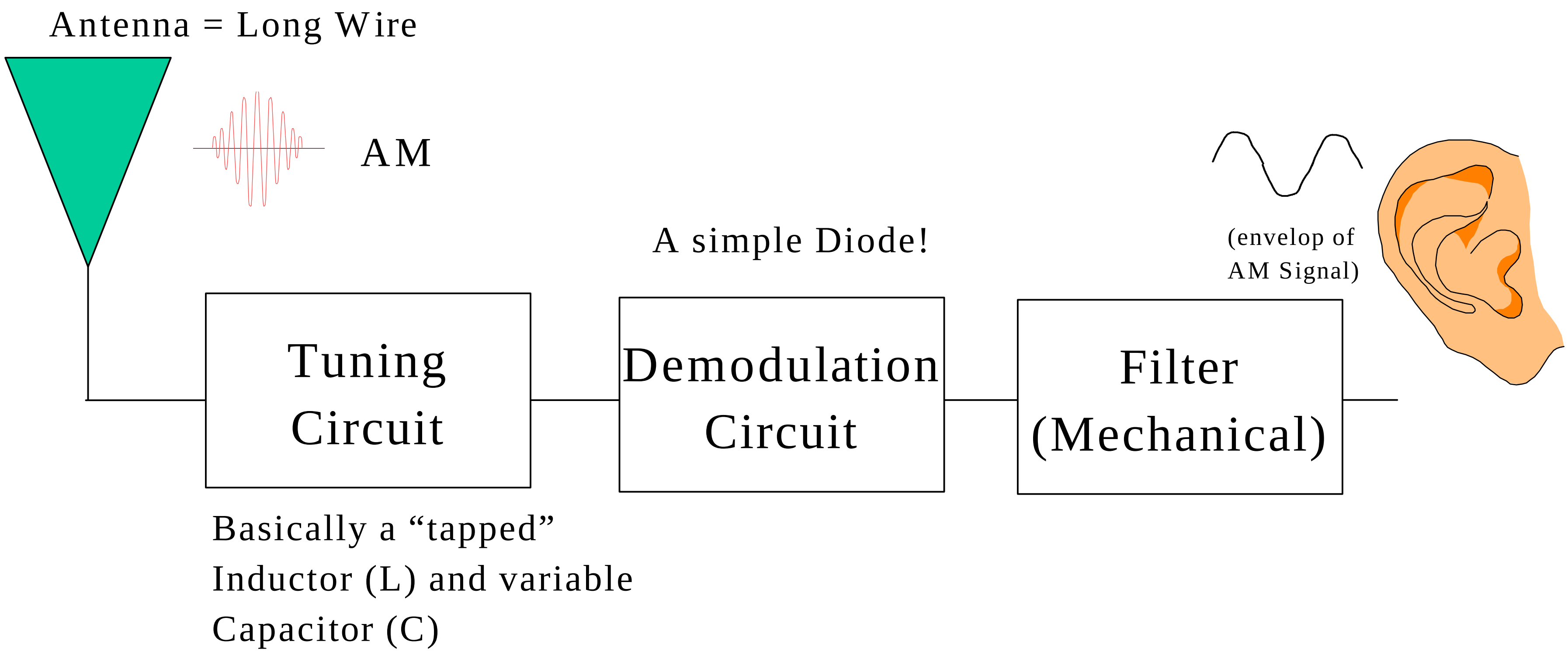
The Amplitude Modulated (AM) version of your music



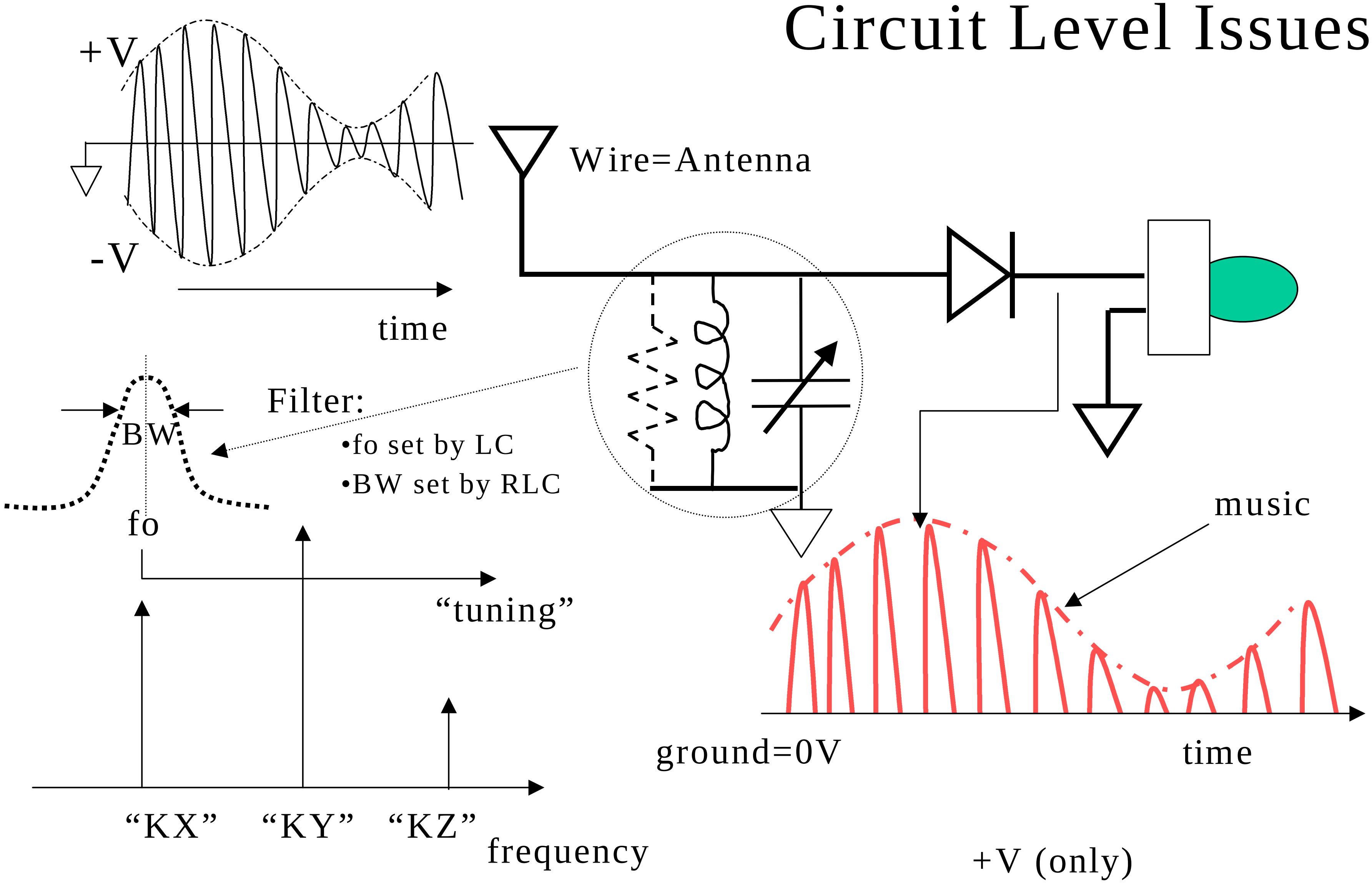
The Frequency Modulated (FM) version of your music



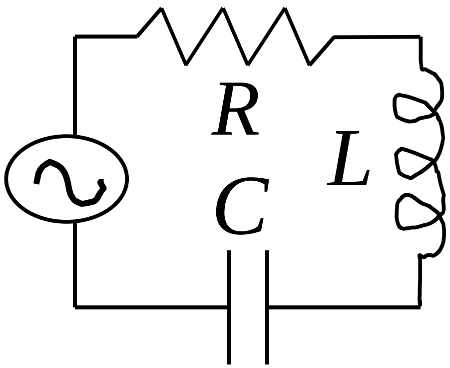
Demodulation is about recovering the original signal--Crystal Radio Example



Signal Flow in Crystal Radio--
Circuit Level Issues



Series Resonant “Tank” Circuit



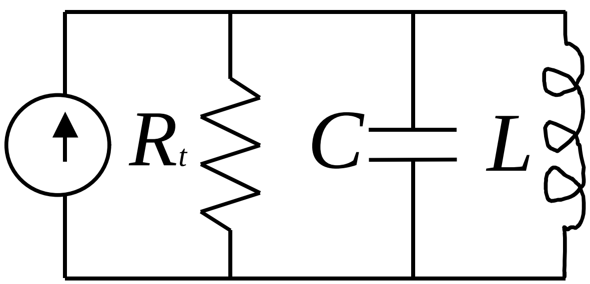
$$Z(jw) = R\left[1 + jQ_s\left(\frac{w}{w_o} - \frac{w_o}{w}\right)\right]$$

where :

$$Q_s \equiv \frac{w_o L}{R} = \left(\frac{X_s}{R_s}\right)$$

$$w_o = \frac{1}{\sqrt{LC}}$$

Parallel Resonant "Tank" Circuit



$$Y(jw) = G_t\left[1 + jQ_p\left(\frac{w}{w_o} - \frac{w_o}{w}\right)\right]$$

where :

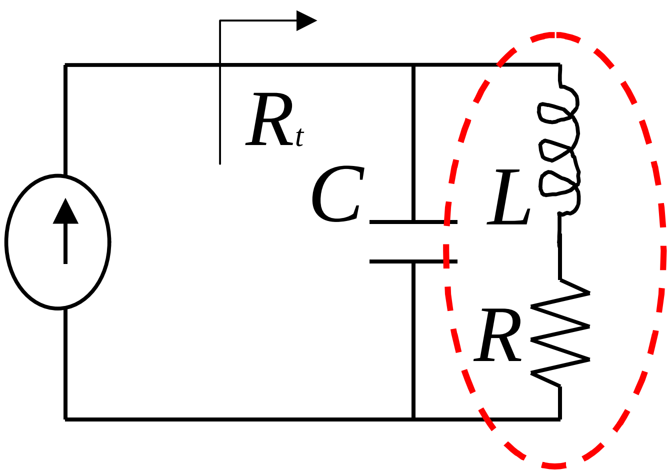
$$Q_p = \frac{w_o C}{G_t} = \frac{R_t}{1/w_o C} = \left(\frac{R_p}{X_p}\right)$$

<u>About notation and components</u>:

- We'll use the "p" and "s" subscripts (per text) and their definitions in terms of respective R and X values (where X is either ωL or $1/\omega C$)
- Components are NOT ideal! (see Chapter 6 reading)
- Basically, when talking about resonant circuits we want to have equivalent tank circuit (either series or parallel per above to cases)

Example of non-ideal Inductor

(and transforming back to equivalent tank circuit)



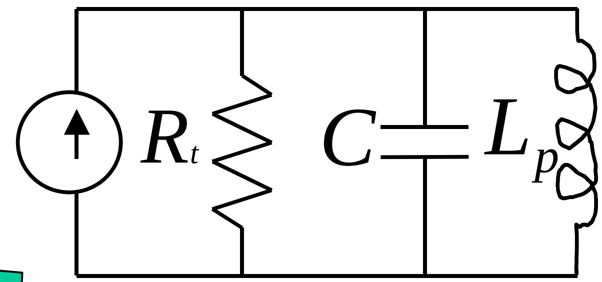
Conversion…series-to-parallel

$$L_p = L\left(\frac{Q_s^2 + 1}{Q_s^2}\right)$$

$$R_t = R\left(Q_s^2 + 1\right)$$

$$where:$$

$$Q_s = \frac{w_o L}{R}$$



<u>Final equivalent resonant “tank” circuit</u>:

- •transformed L now sets resonant frequency
- •let’s see how these transformations work…

A bit more about “Q”

We can think about (and/or measure) the quality factor (Q) in two ways--parallel (sub_p) or series (sub_s).

As discussed in text (section 6.7.2) there is ultimately only one “Q” for the circuit, we’ll call it Q_c

The definitions of the parallel and series (component) Q’s are as follows:

$Q_p = R_p / X_p$ (parallel or “shunt”)

$Q_s = X_s / R_s$ (series)

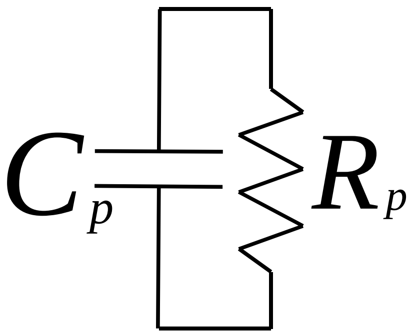
Based on simple math, comparing the series and parallel cases for either capacitor or inductor:

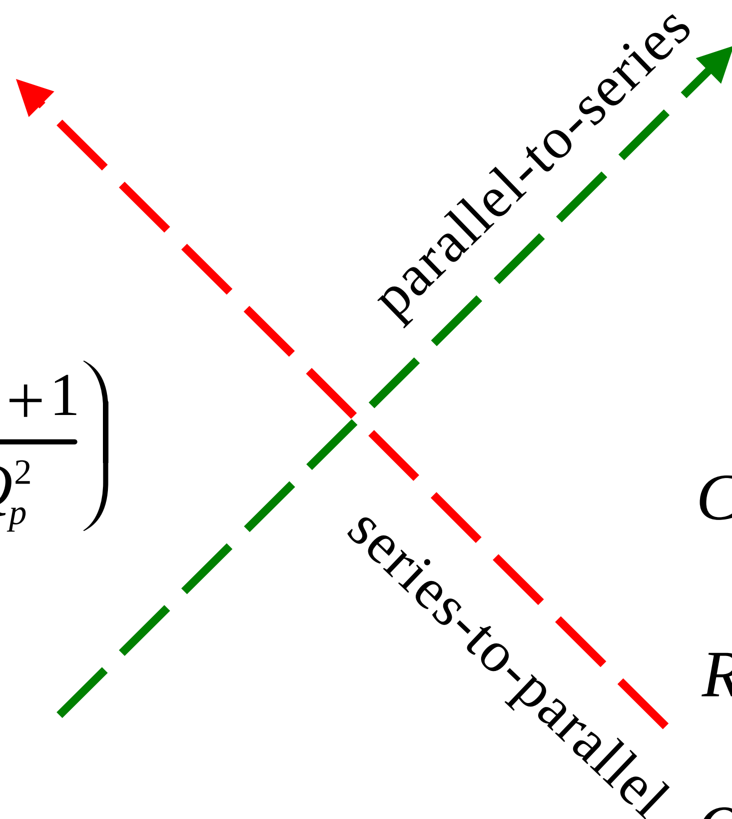
$R_p = (Q_c^2 + 1)\, R_s$

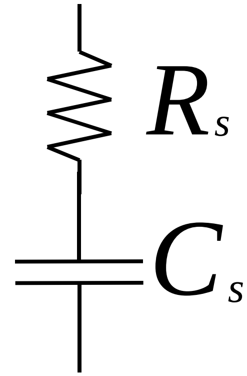
and $Q_c = Q_p = Q_s$

We can derive all of the following relationships based on using the above relationships

Conversion Relationships--Capacitors







$$C_{s-eq} = C_p\left(\frac{Q_p^2+1}{Q_p^2}\right)$$

$$R_{s-eq} = \frac{R_p}{1+Q_p^2}$$

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

$$X_p = 1/wC_p$$

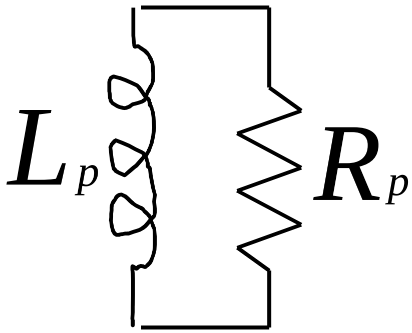
$$C_{p-eq} = C_s\left(\frac{Q_s^2}{Q_s^2+1}\right)$$

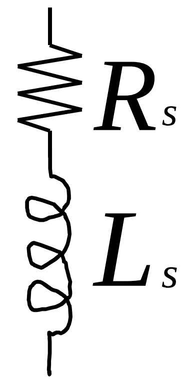
$$R_{p-eq} = R_s\left(Q_s^2+1\right)$$

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

$$X_s = 1/wC_s$$

Conversion Relationships--Inductors





parallel-to-series

series-to-parallel

$$L_{s-eq} = L_p\left(\frac{Q_p^2}{Q_p^2+1}\right)$$

$$L_{p-eq} = L_s\left(\frac{Q_s^2+1}{Q_s^2}\right)$$

$$R_{s-eq} = \frac{R_p}{1+Q_p^2}$$

$$R_{p-eq} = R_s\left(1+Q_s^2\right)$$

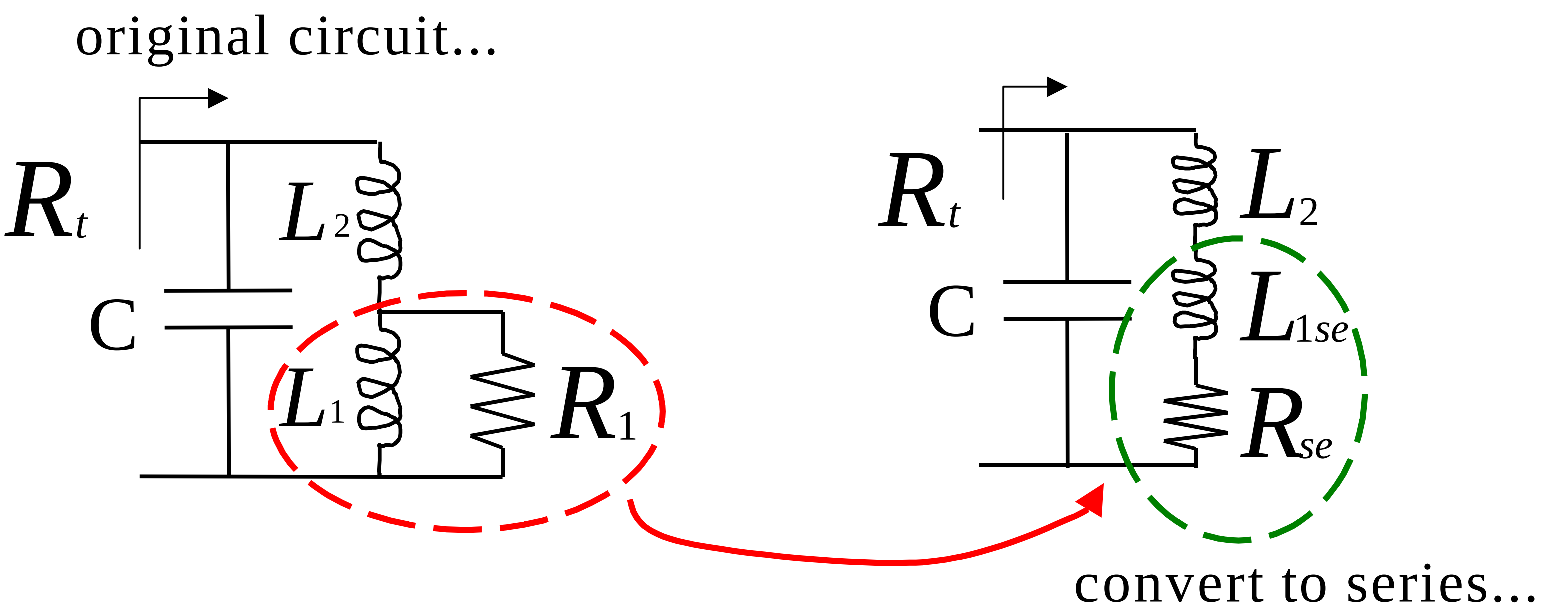
$$Q_p = \frac{R_p}{X_p}$$

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

$$X_p = wL_p$$

$$X_s = wL_s$$

Another Example…(a.k.a. Lab 1)



<u>Following steps</u>:

- Combine L1+L2(series equivalent)=L(new)
- Convert L(new) & Rse back to parallel
- Result gives final equivalent tank circuit

Design-Oriented Example

(including use of transformer concepts*… text (Sect. 6.8.2))

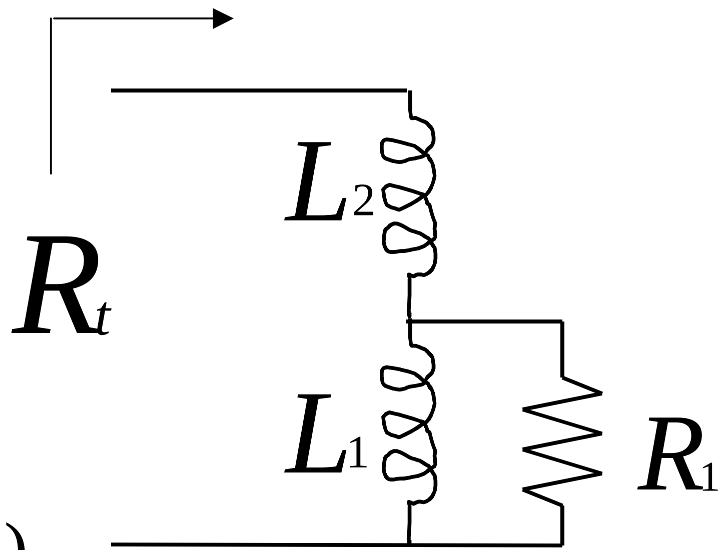
$$N \equiv \frac{L_1 + L_2}{L_1}$$

$$\frac{R_t}{R_1} = N^2$$

$$(per\_book\_notation:)$$

$$N = \frac{n}{n_1}$$

$$L_T = L = L_2 + L_1$$



<u>Example</u>:

R_1=50Ω

In order to have R_t=2KΩ,

N^2=40 or N=6.3=L_T/L_1

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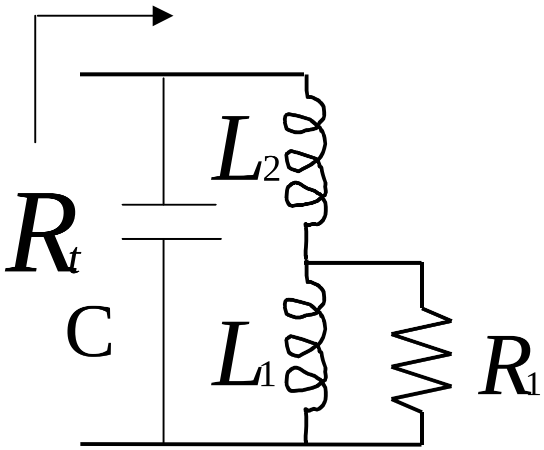
*caution: this simple relationship works for Q_p>10,

otherwise one needs to do the transformations per above example

Useful (more complete) Design Equations

(per supplemental book by Krauss…last year's text)



$$For\_Q_c = Q_t \approx w_o / BW \geq 10$$

$$C \approx \frac{1}{2p \cdot BW \cdot R_t}$$

$$L \approx \frac{1}{w_o^2 C}$$

$$N = \left(\frac{R_t}{R_1}\right)^{\frac{1}{2}}$$

$$\frac{Q_t}{N} = Q_p ...If\_\frac{Q_t}{N} \geq 10$$

Qp<10

Qp>10

$$For\_Q_p \triangleleft 10:$$

$$Q_p = \left(\frac{Q_t^2 + 1}{N^2} - 1\right)^{\frac{1}{2}}$$

$$L_1 = \frac{R_1}{w_o Q_p}$$

$$L_{1\_se} = \frac{L_1 Q_p^2}{Q_p^2 + 1}$$

$$L_2 = L - L_{1\_se}$$

$$For\_Q_p \geq 10:$$

$$Q_p = \frac{Q_t}{N}$$

$$L_1 = \frac{L}{N}$$

$$L_2 = (N-1)L_1 = L - L_1$$