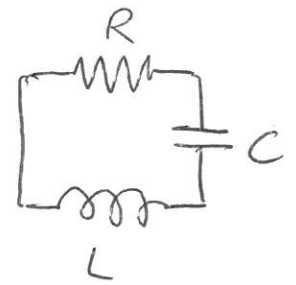
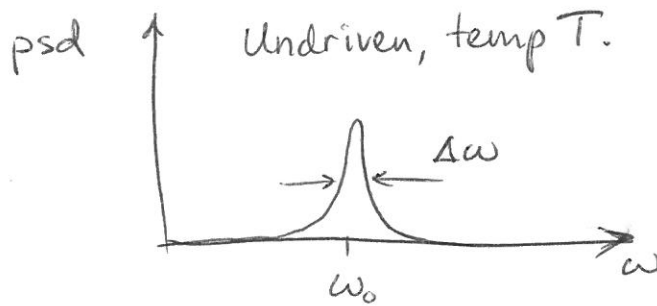


# Johnson noise



Need to  
Consider an overdamped RLC circuit.

For a warm-up, examine the underdamped RLC circuit



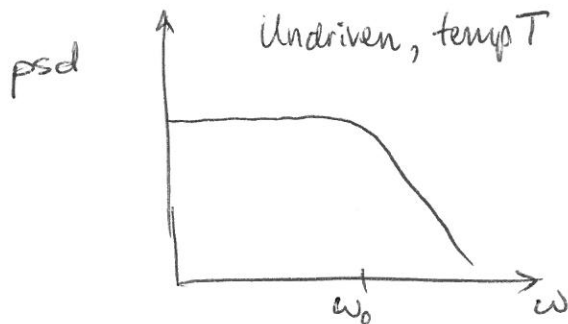
Energy stored is  $k_B T$   
 $Q = \frac{\omega_0}{\Delta\omega} = \frac{\omega_0 L}{R}$

$$\omega_0 \approx \frac{1}{\sqrt{LC}}$$

[small correction when  $Q \rightarrow 1$ ]

Avg Energy in capacitor ~~is~~  
 $\frac{1}{2} C \langle V^2 \rangle = k_B T$

Overdamped case ( $Q < 1$ )



example  $Q = \frac{\omega_0 L}{R} = 1$

Bandwidth (log scale)

over which noise will be observed.

$$\langle V^2 \rangle = \frac{kT}{C} = \underbrace{kT L \omega_0^2}_{\substack{\text{from resonant} \\ \text{freq formula}}} = kT L \underbrace{\frac{R}{L} \omega_0}_{\substack{\text{constraint} \\ \text{from } Q=1}} = kT R \omega_0$$