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Is it possible to construct a circuit with just passive elements (resistor,inductor,capacitor) that will work as voltage amplifier?

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Abstract— We use different type of elements such as BJT in order to get the voltage amplified. In this paper I have tried if it is somehow possible to amplify voltage only by using resistor, inductor and capacitor which may help us to build an efficient Electrical Network.

Content— Consider a single phase series A.C. circuit with a voltage source V=Vm·Sin (ωt), Resistor of resistance R, Inductor of inductance L and Capacitor of capacitance C. Say VR ,VL and VC be the voltage across Resistor, Inductor and Capacitor. I be the current flowing through the circuit then

I=Im·sin (ωt+ φ)
VR=VRm·sin (ωt+ φ)
VL=VLm·cos (ωt+ φ)
VC=VCm·cos (ωt+ φ)
Where

$$(\mathrm{Vm})^2 = (\mathrm{VRm})^2 + (\mathrm{VLm} - \mathrm{VCm})^2$$

At resonance condition VLm-VCm=0 i.e. VLm=VCm and φ =0

$$V = VR = I \cdot R = Im \cdot Sin\,(\omega t) \cdot R$$
$$= Im \cdot R \cdot Sin\,(\omega t)$$
$$Im = \frac{Vm}{R}$$
$$\omega = \frac{1}{\sqrt{L \cdot C}}$$
$$\mathrm{VL} = \mathrm{I} \cdot \mathrm{j} \cdot \omega \cdot \mathrm{L} = \mathrm{Im} \cdot \mathrm{Sin}\,(\omega t) \cdot \mathrm{j} \cdot \omega \cdot \mathrm{L}$$
$$= \mathrm{Im} \cdot \left(\frac{1}{\sqrt{L \cdot C}}\right) \cdot \mathrm{L} \cdot \cos\,(\omega t)$$

(As multiplying j brings a π/2 phase shift)

$$= \mathrm{Im} \cdot \sqrt{\frac{L}{C}} \cdot \cos\,(\omega t)$$
$$= \frac{\mathrm{Vm}}{\mathrm{R}} \cdot \sqrt{\frac{L}{C}} \cdot \cos\,(\omega t)$$

If we take V as input voltage and VL as output then the ratio VLm/Vm will be the voltage gain (in amplitude) which is equal to $\frac{\sqrt{\frac{L}{C}}}{R}$ which is not necessary to be less 1 i.e. it may have value greater than 1 and act as voltage amplifier.

For instance L=0.1H, C=10μF and R=10Ω i.e. ω (at resonance) = 1000 rad/sec.
The voltage gain will be equal to 10 i.e. if I apply V=12 Sin (ωt) then output will be
V_L=120 Cos (ωt).

It should be noted that the output that we will get will be across the Inductor. Also the same output we can get across the Capacitor as $V_L=V_C$

For real practice say (f=100 sec-1) ω (at resonance) =2*pi*f=314 rad/sec we can choose the value of L to be 1H corresponding C=1/ (314*314) =10.14μF and take R=31.4Ω then the voltage gain will remain the same i.e. 10.

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It may happen that we cannot obtain the resonance condition exactly to the mathematical figures.
At that condition

$$I = Im \cdot \sin(\omega t + \varphi) \text{ (Where } \varphi \text{ is the initial phase)}$$

$$VL = I \cdot \omega \cdot j \cdot L = Im \cdot \omega \cdot L \cdot \cos(\omega t + \varphi)$$
$$= VLm \cdot \cos(\omega t + \varphi)$$

$$VLm = Im \cdot \omega \cdot L = Vm \cdot \omega \cdot \frac{L}{\sqrt{R^2 + \left(\omega * L - \frac{1}{\omega * C}\right)^2}}$$

For ω=314 $rad_{sec^{-1}}$, L=1H, C=10μF and R=30Ω
We have φ= -0.14 radian
VLm=vm·10.49
i.e. if I apply V=12 sin(ωt) then output will be
VL=125.88 cos (ωt-0.14)

In order to get D.C. output we can use rectifier on both input and output terminals.

In this way we can vary the value of R, L and C that is suitable for frequency and required voltage gain.

Conclusion— In short yes we can have a voltage amplifier that consists of an A.C. source as input, Inductor, Capacitor and Resistor (at least theoretically).

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