Circuit Analysis for Analog Designers
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Lecture - 25
Opamp-RC biquadratic sections (contd)

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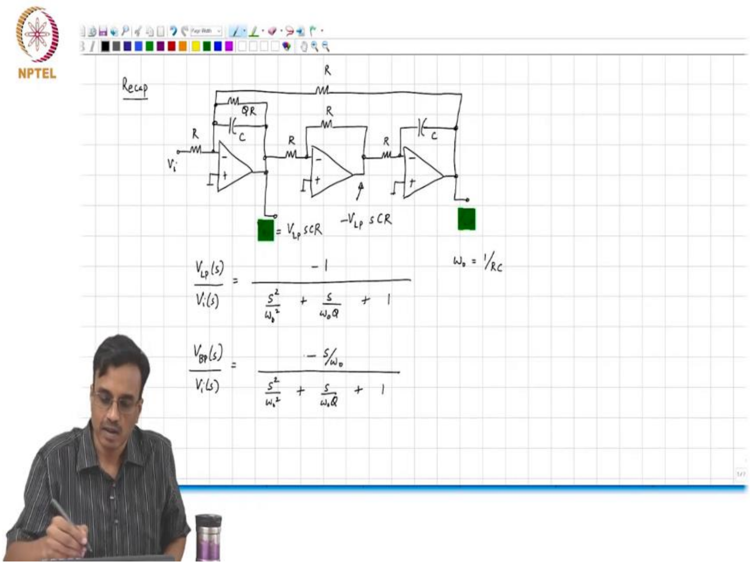

A quick recap of what we were doing in the last class, we derived the active RC biquad. It consists of three op-amps and you basically have as you can see an integrator this is also an integrator right, except that when this becomes an integrator only when Q tends to infinity, right.

And that the addition of the resistor makes the integrator is the leaky one. So, you can think of a biquad as a feedback loop consisting of a leaky integrator and a non-leaky integrator and put in put inside a loop. And this choice of resistors and capacitors makes a $\omega_0 = \frac{1}{RC}$ and that resistor Q times R is just there to set the quality factor of the closed loop.

This is the low pass output and this is the band pass output and what comment can we make about the band pass transfer function $\frac{V_{BP}(s)}{V_i(s)}$. Is that an inverting band pass or is it an non inverting band pass? Inverting band pass.

Yeah, so, the what is the transfer function? What is this is V LP times minus sorry V LP times yeah minus; this is an inverting integrator times s CR correct. So, this must be V LP plus V LP times s C R. V LP the low pass transfer function is an inverting low pass. So, what we get is an inverting band pass transfer function.

And that is basically as you can see minus s over omega naught divided by the same denominator s square by omega naught square plus s over omega naught Q plus 1.

$$\frac{V_{BP}(s)}{V_i(s)} = -\frac{\frac{s}{\omega_0}}{\frac{s^2}{\omega_0^2}+\frac{s}{\omega_0 Q}+1}$$

And let us know we just starred this circuit and see if this alternative ways of realizing the same low pass transfer function.

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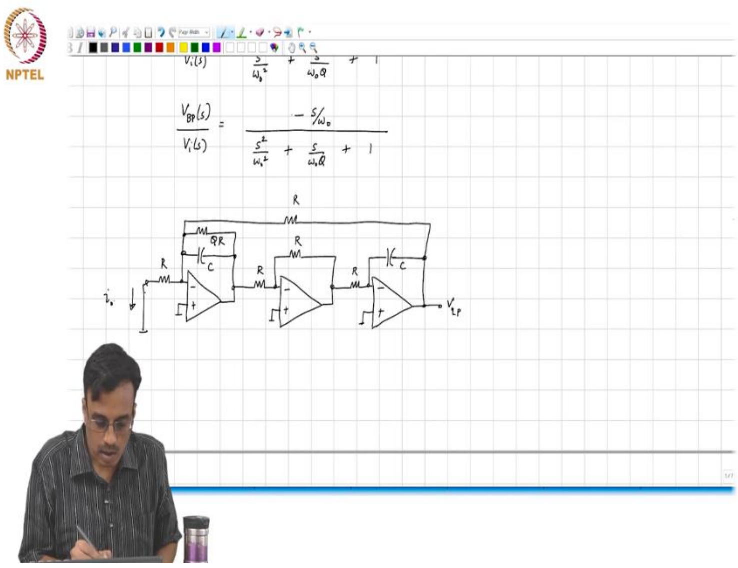

And this just illustrates the point that 1 can always use this method of adjoints to kind of come up with the alternative circuits which do not look quite like the original one. So, remember if you find if this is the input and this is the output, which we call V LP the voltage transfer function is an inverting low pass transfer function. Now, if we form the inter-reciprocal network, what would we do to form the inter-reciprocal network?

Pardon.You flip each op-amp ok alright. What do we do with vi and V the input and the output voltages? So, we are not interested in the input voltage anymore we are interested in the; this is the output current and what we do here?

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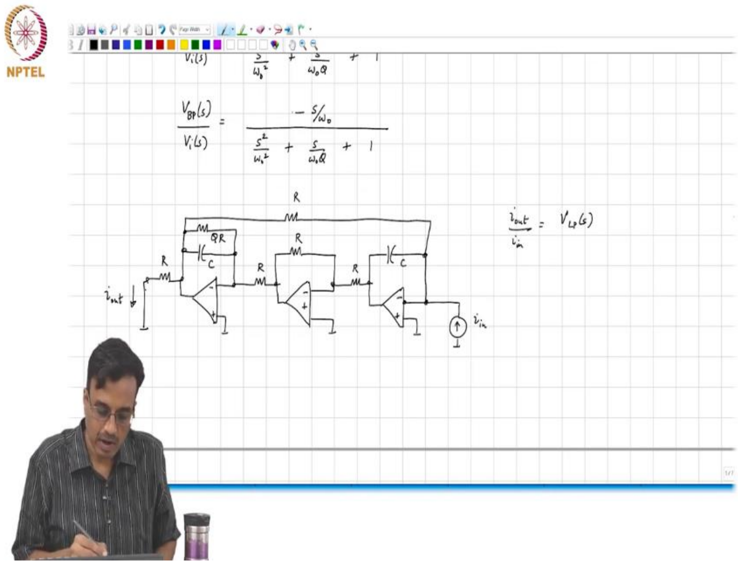

We drive with a current source alright. And what do we do with the op-amps we flip all of them? And that happens this way alright. So, the i out so, what comment can we make about i out by i in? Is the. Is the same is V LP of s correct. And if now in this circuit if I basically say ok well, I am going to replace V in this current source with V in and R alright.

$$\frac{i_{out}}{i_{in}} = V_{LP}(s)$$

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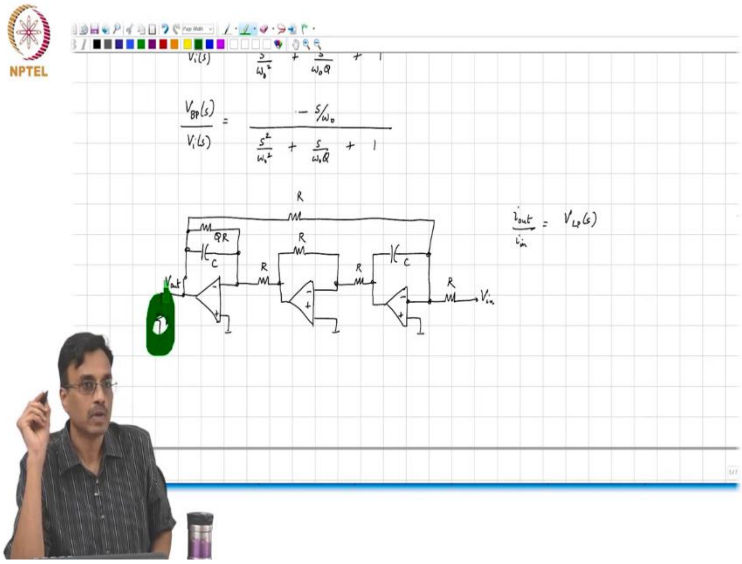

And if I call this V out I mean is going to redraw the resistor vertically; this is V out. Well, the question I am asking you is this a resistor even relevant. Is that resistor relevant?

It is not relevant. So, I mean it does not matter and what is V out in terms of that the i out that was flowing. i out times r.

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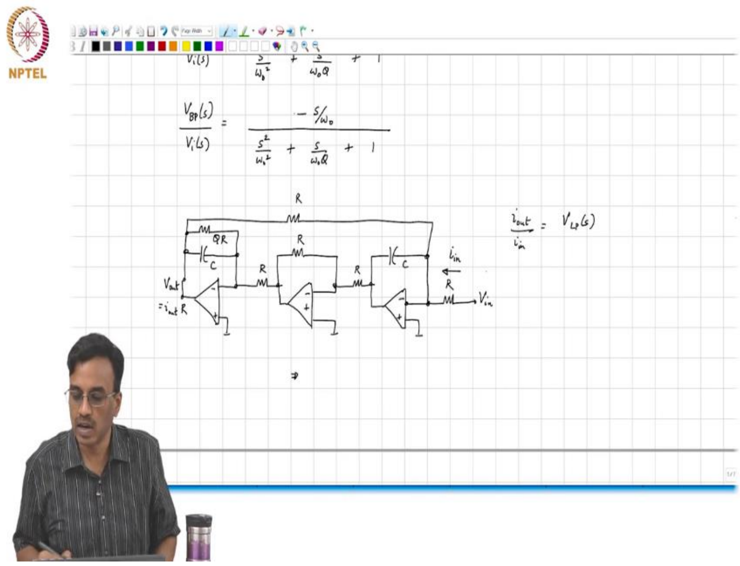

This is simply i out times R and what is i in that was flowing how I mean how is that related to V in? V in by R. So, basically what is the conclusion therefore, we know that i out by i in is the low pass transfer function. So, relating i out to V out and V in what do we see? What is the i out? Yes.

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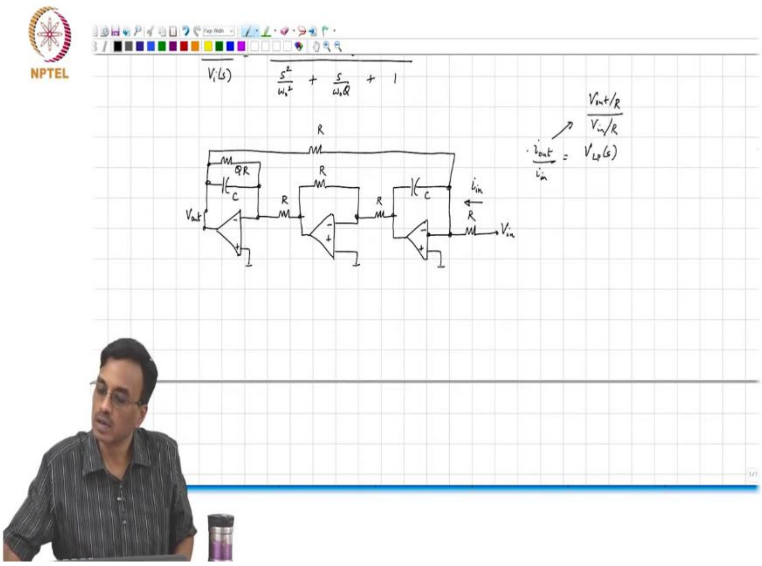

V out by R; and what is i in? V in by R. So, equivalently this is like saying V out by V in is nothing but V LP of s alright and. So, starring at let me just place the other picture for you.

$$i_{out} = \frac{V_{out}}{R}$$

$$i_{in} = \frac{V_{in}}{R}$$

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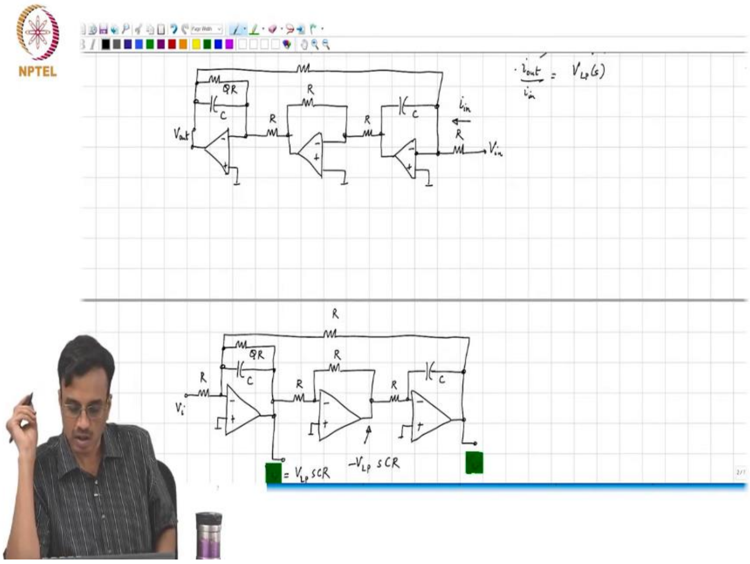

Starring at this picture and this picture you know apart from the obvious difference of you know signal going from left to right and right to left what else can we conclude? What is the difference between the two pictures? Both of them have the same transfer function correct what is the difference between the two?

So, equivalently this is saying that Q R the damping resistor can be placed as far as the low pass transfer function is concerned it is not necessary to place the damping resistor here, though that is how we derived it one could as well place the damping resistor here.

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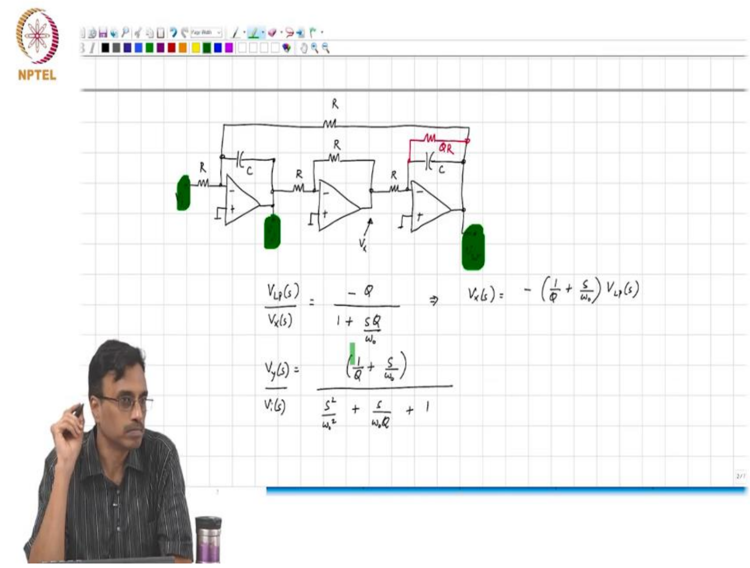

And this will also lead to the same low pass transfer function alright ok. Can you comment about the band pass nature of this transfer function now? Will this be band pass? What comment can we make about this transfer function? This is low pass we know that what comment can we make about this transfer function? Let us call that V x what is V LP of s by V x of s. What is the d c gain? Minus Q divided by 1 plus s Q RC, which is Q by omega naught alright.

$$\frac{V_{LP}(s)}{V_x(s)} = -\frac{Q}{1 + \frac{sQ}{\omega_0}}$$

And therefore, what therefore, what is V x of s is 1 plus s Q or if you divide the numerator its minus 1 over Q plus s by omega naught times V LP of s, which means what is what is V y?

$$V_x(s) = -\left(\frac{1}{Q} + \frac{s}{\omega_0}\right) V_{LP}(s)$$

What is the transfer function corresponding to V y that the output of the first integrator? A plus V x which is nothing but 1 by Q plus s by omega naught divided by s square by omega naught square plus s upon omega naught Q plus 1.

$$\frac{V_y(s)}{V_i(s)} = \frac{\left(\frac{1}{Q} + \frac{s}{\omega_0}\right)}{\frac{s^2}{\omega_0^2} + \frac{s}{\omega_0 Q} + 1}$$

So, the question is you know while it is true that the transfer function from here to the output when we change the position of the damping resistor remains the same, the internal transfer function is do not remain the same right. So, this is no longer a pure band pass there is some other there is a low pass component also ok.