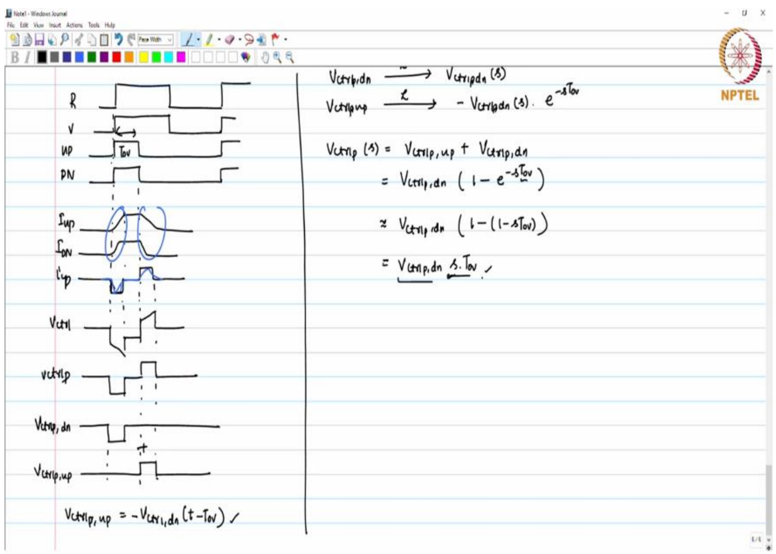
Phase-Locked loops
Dr. Saurabh Saxena
Department of Electrical Engineering
Indian Institute of Technology Madras

Lecture – 55
Circuit-level Design of Charge Pump: Part V

(Refer Slide Time: 00:15)



Hello, welcome to this session. So, in the previous session, we looked at reference spur which comes at the output because of the offset in the charge-pump. Then there is another spur which comes because of the mismatch in the transition time. So, what happens is as we have seen earlier that during the locked state, you have R and V pulses for the charge-pump like this, assuming they are in this manner, and you have V pulse in this form. So, as we know the UP and DN pulses are in this manner.

But the UP and DN current, because of the mismatch in the transition for UP and DN currents, you have I_{UP} slightly delayed normally because it is a PMOS, and you have I_{DN} which critically works faster, it is like this. So, your i_{cp} current happens to be you can say something whatever that error is, you have some current because of this and then here you have current like this. This is a very simple representation. Ideally, you see that there is a variation here and variation here, so it will not look like a square wave. You may see something of this kind.

But I am approximating that with the square wave. And even if it is not, what you can do is you can always write the Fourier series and you get different components. This is going to happen because of the mismatch in the transitions. So, what is going to happen is because of this i_{cp} current, you will have a change in the control voltage. So, V_{ctrl} because of this, the square portion is, will be, you apply your i_{cp} like this, so you will have a jump, integration, jump back. And then you are going to see a jump again, integration and then jump back. So, on an average, your V_{ctrl} voltage is going to be equal to 0.

That is what, in steady state, that should happen. So, whatever the current mismatch you have between UP and DN, that will average out. So, this is going to happen to V_{ctrl}. Now, again, I am going to do the same thing. I am going to write this as $V_{ctrlp} + V_{ctrli}$ and the spur is going to be dominated by V_{ctrlp}. This is V_{ctrl}, spur is dominated by V_{ctrlp}. Then, if you, if I would like to write it, I can say this is like $V_{ctrlp,dn} + V_{ctrlp,up}$.

So, one can write,

$$V_{ctrlp,up} = -V_{ctrlp,dn}(t - T_{ov})$$

You can say it is shifted by T_{ov} with a negative sign. This period is T_{ov}, isn't it? It is T_{ov}, it is shifted by negative sign. So, if I find the frequency content of, if I go and figure out what is there $V_{ctrlp,up}$ or the coefficient of $V_{ctrlp,up}$ or $V_{ctrlp,dn}$, then the coefficient for $V_{ctrlp,up}$ will be available by using this relation. So, we have,

$$V_{ctrlp,dn} \xrightarrow{L} V_{ctrlp,dn}(s)$$

$$V_{ctrlp,up} \xrightarrow{L} -V_{ctrlp,dn}(s).\, e^{-sT_{ov}}$$

So, overall V_{ctrlp} if you look at it, we get,

$$V_{ctrlp}(s) = V_{ctrlp,up} + V_{ctrlp,dn}$$

$$V_{ctrlp}(s) = V_{ctrlp,dn}(1 - e^{-sT_{ov}})$$

If the overlap period is quite small, then I can approximate $e^{-sT_{ov}} \approx 1 - sT_{ov}$. So, this will effectively become,

$$V_{ctrlp}(s) = V_{ctrlp,dn}\big(1 - (1 - sT_{ov})\big)$$

$$V_{ctrlp}(s) = V_{ctrlp,dn}\, sT_{ov}$$

So, what you see here is that the control voltage is getting an extra filtering with respect to frequency.

So, if it is at higher frequency, your control voltage will get more amplified. Now, this is whatever V_{ctrlp} we are going to get, you get this extra factor here in contrast to the voltage which you got because of the current mismatch. So, that is something extra to look at. Now, what we have done here is if you think about it, we have separated V_{ctrlp} as $V_{ctrlp,dn}$ and $V_{ctrlp,up}$. By the way, V_{ctrl} is appearing at every reference frequency. So, V_{ctrlp} is going to have a dominant component at the reference frequency.

And we just did the Laplace to get a simplified frequency filtering for that and what you are going to see is that it is going to get filtered at ω_R. Now, using the same analysis which we did before for the charge-pump mismatch, you can find the spur at the output of the PLL with V_{ctrlp} as the cause for change in the reference spur. Thank you.