Phase-Locked Loops
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Lecture – 21
Range Extension for Phase Error Detectors

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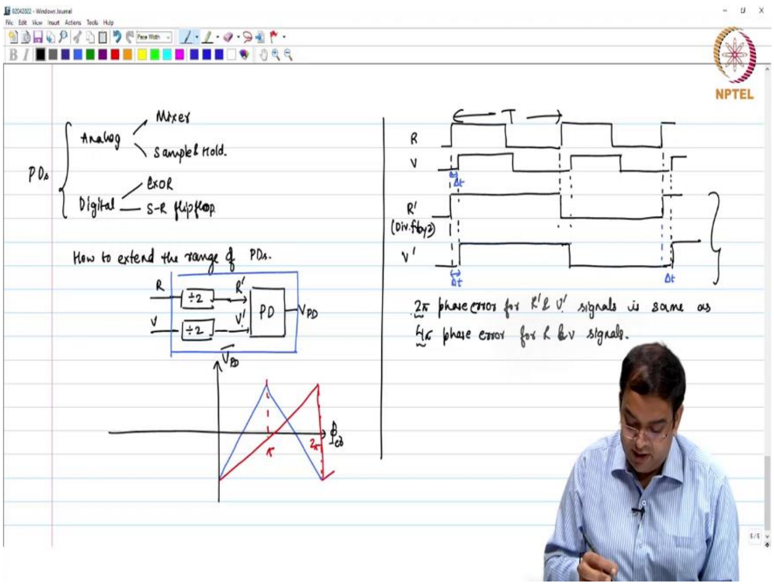

Welcome to this session. Earlier we have learnt about the analog and digital phase error detectors. So far in analog phase error detectors, we have seen mixer and sample and hold. In case of digital, we have seen EXOR or Exclusive-OR gate. Also, we have seen S-R flip-flop based phase error detector under the digital PDs, and we found the linear range and other things.

Now, if you look at it, the range in both cases of digital PDs is actually limited. So, given the R and V input signals, what you see here is that the linear range is either 0 to $\frac{\pi}{2}$ or 0 to π at the maximum in case of digital PDs. So, what can we do if we would like to extend the range of the phase error detector?

So, the question which you need to ask is how to extend the range of phase error detectors, I can just write it directly. So, for example, you have your PD, I will just draw it as a block. It can be your EXOR gate, it can be your S-R flip-flop here. We are just looking at square waves right now. So, I will limit myself to digital. This is R and this is V, and we are talking about the clocks which are having the same frequencies for now. So, it gives you V_{PD} output.

So here, just to recall what you have seen earlier is that with respect to the phase error between the R and V signals, the $\overline{V_{PD}}$ was either like this, that was for the EXOR case or it was like this on the positive side. On the negative side, you will follow the similar characteristics. So, this is π and by the way this is 2π, it does not extend more than that.

So, what I want to do is, actually I want to extend the range of the phase error between R and V signals. So, the PD which we are having operates on these two, if you reduce the frequency here for R and V, then your range will actually get extended. So, what it means, let us see. So, let us say I have my actual R and V signals like this, and the V signal has, it has the phase error, that is fine. I am keeping the frequency same.

If I divide these frequencies and get outputs R' and V', so, if I do that, what will happen here is, this is our R', this is like dividing the frequency f by 2. Similarly, your V' is going to look like this. This is dividing the clock by 2. In digital case, you might have seen this operation quite often, this is V'. So, the phase error which you have between R and V remains here. The only thing is that it is measured at half the rate now.

Now, if I give these R and V signals, if I give R' and V' signals to the bang-bang PD, what will I get? I will measure the phase error between R' and V' signals and this phase error between R' and V' signals looking at the plot here, 2π phase error for R' and V' signals is same as 4π phase error for R and V signals, isn't it? So, because this 2π phase error for R and V signals is actually w.r.t. time period 2T, here this 4π is measured with respect to T, here this 2π is measured with respect to 2T. So, that is the way you can do it. So, what can be done? So, if I get my R signal here, I put a frequency ÷ 2 and here also I put the frequency ÷ 2, so this can be our new phase error detector with extended range.

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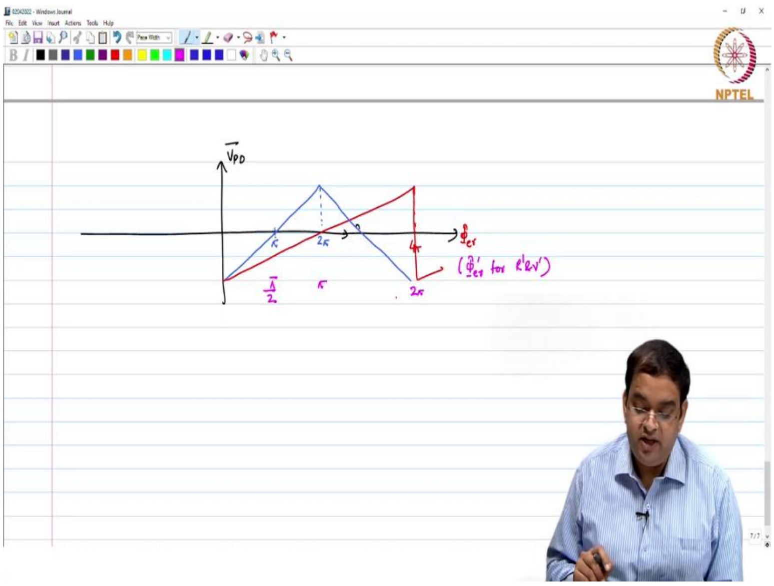

So, let me just redraw this. So, I am going to measure the phase error with respect to R and V, this is $\overline{V_{PD}}$. So, this is going to be 2π and π. The phase error is measured between R and V signals, keep that in mind, and for our S-R based PD, that is going to be 4π. It should not come like this, it should go like this and the red one is here.

In addition, if you think about it with respect to R' and V', so, φ_{er}' for R' and V' signals, this is $\frac{\pi}{2}$, this is π and this is 2π. Because we are referring with respect to the original signals, that is why what you see here is that the range gets extended.

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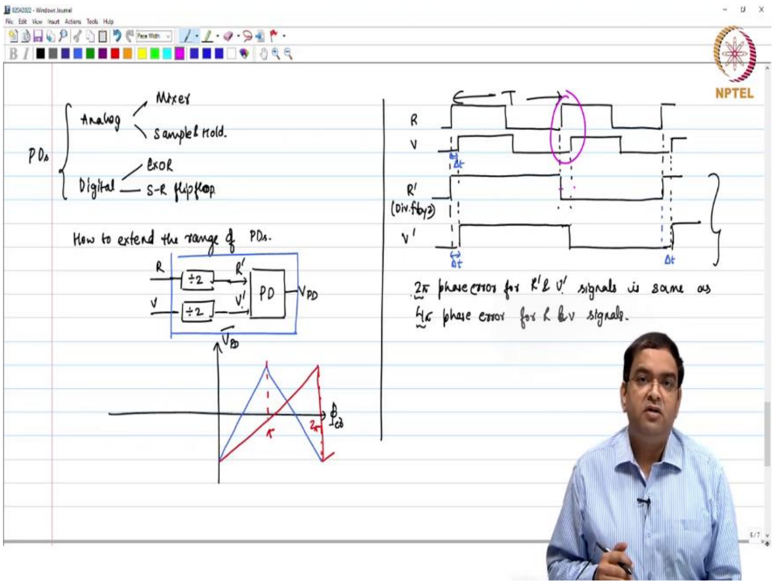

So, if you want to extend the linear range of the phase error detectors in case of these two digital phase error detectors, you can do it by having divide ratio. Well, if it sounds good, there is a drawback of it and the drawback is that now you are measuring the phase error at half the frequency. So, if there is any phase error here, in this particular case, well, that phase error will not be entertained in case of the S-R based PD. In case of the EXOR based PD, what will happen is that it is going to change the duty cycle and the duty cycle will then affect the phase error. But your rate of measurement of the phase error reduces as you try to extend the range of the phase error detector in this case. Thank you.