Phase-Locked Loops
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Lecture – 8
Types and Order of PLL

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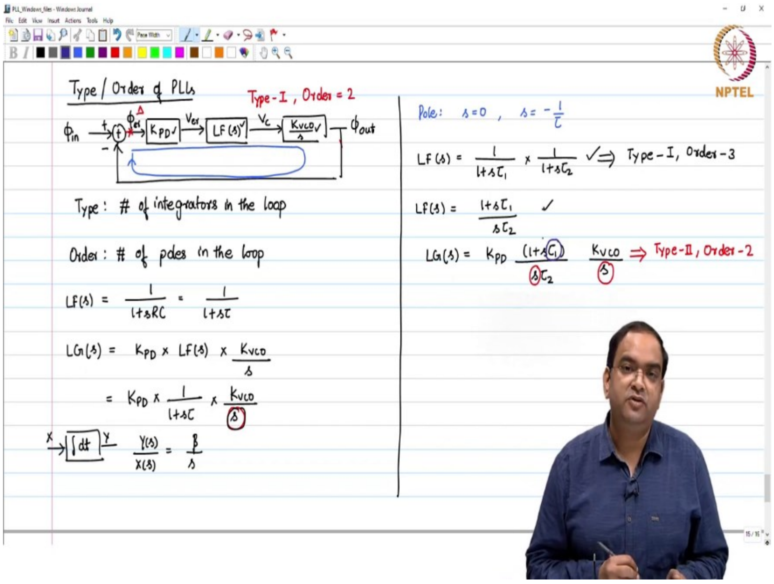

Welcome everyone. In this session, we are going to talk about the type and the order in PLLs. And to begin with, the type and order of PLLs are defined when we are having loop filters of different kinds. If we restrict ourselves to the loop filter, a simple RC loop filter which we had earlier, then the type and order are not going to change.

So, basically the type and order of a PLL change mostly because of the loop filter. So, here I will use the small signal model. When we are talking about the order of the PLL, generally it means that what is the highest degree of the polynomial in the transfer function. So, order refers to that mostly. Type is a new definition which we will look at.

So, we have K_{PD}, we have the loop filter transfer function, $LF(s)$, and then we have the VCO which has transfer function $\frac{K_{VCO}}{s}$ and this is what we have. So, here is φ_{in} and this we have φ_{out}, phase error, positive, negative, you have V_e, you have V_c, like this. So, the type is defined as the number of integrators in the PLL loop and order is defined as number of poles in the loop.

So, if we consider the simple PLL which we saw earlier, that particular PLL was having, this is the same block diagram and let me just write it. In that particular simple PLL which we have seen, the loop filter function was given by,

$$LF(s) = \frac{1}{1 + sRC} = \frac{1}{1 + s\tau}$$

where, τ is the time constant.

So, if this is the case, the method or the way you are going to find it out is that first, you find the loop gain of the PLL. What is the loop gain? It is the gain through the loop. So, technically, whenever we want to find the loop gain, what we are going to do is that we will break the loop somewhere, apply a change like Δ and see what comes back. So, if I break the loop here, apply Δ, Δ will get multiplied by K_{PD}, then by $LF(s)$ and then by $\frac{K_{VCO}}{s}$. So, the loop gain of this particular PLL is given by,

$$LG(s) = K_{PD} \times LF(s) \times \frac{K_{VCO}}{s}$$

$$LG(s) = K_{PD} \times \frac{1}{1 + s\tau} \times \frac{K_{VCO}}{s}$$

So, how many integrators are there in this particular loop? There is only one integrator. When we say integrator, it is like you have a block whose input to output transfer function is given by,

$$\frac{Y(s)}{X(s)} = \frac{\beta}{s}$$

So, β is constant and you have a pole at 0. When you have a pole at 0, then this particular block will behave like an integrator. So, in place of this, I have an integrator. You can have a constant, that is not a problem. So, in our PLL loop, there is one integrator always and where does this integrator come from? This integrator comes from the voltage controlled oscillator where you change the frequency of the oscillator and by changing the frequency, you change the phase. So, this integrator is inherent in the PLL block. So, one integrator is always present. Then, how many poles do we have in this case? So, one pole is at $s = 0$, and the other pole is at $s = -\frac{1}{\tau}$. It is a left half plane pole. So, there are two poles in the system and one integrator, so this PLL will be called as Type-I. It is normally written in Roman and Order is 2.

So, the PLL which we have seen is Type-I and Order-2. Now, it is not always necessary that as you increase the order, your type should also increase, not necessarily. I will just take an example, let us say,

$$LF(s) = \frac{1}{1 + s\tau_1} \times \frac{1}{1 + s\tau_2}$$

If I choose this loop filter and everything else in the PLL remains the same, then this is going to give you a PLL of Type-I and Order-3 because there are 3 poles. So, you can increase the order of the PLL without increasing the type of the PLL.

These are just examples that how the choice of the loop filter is going to change the type and order of the PLL and by the way, this type and order are not just terms which you will use in passing by, but the type of the PLL decides many more things about the operation of the PLL. We will see that.

So, if I have the loop transfer function as follows:

$$LF(s) = \frac{1 + s\tau_1}{s\tau_2}$$

So, in this case, if you use the loop filter as shown here, the loop gain of the PLL will be,

$$LG(s) = K_{PD} \times \frac{1 + s\tau_1}{s\tau_2} \times \frac{K_{VCO}}{s}$$

So now, you see that in this case, you are having two integrators or two poles at zero and two poles at zero are behaving as two integrators also. So, a PLL with this loop gain will be Type-II and Order-2.

So, you see the difference between the type and order that you can change each of them. But all the PLLs which have an oscillator and PLLs will have an oscillator, you should be sure enough that they will be at least Type-I. Type-I, Order-1 is the minimum that you can have. And by the way, in this particular example, you have a zero also, at $-\frac{1}{\tau_1}$.