Digital Signal Processing and its Applications
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Lecture 30 C
Realization of Discrete Filters

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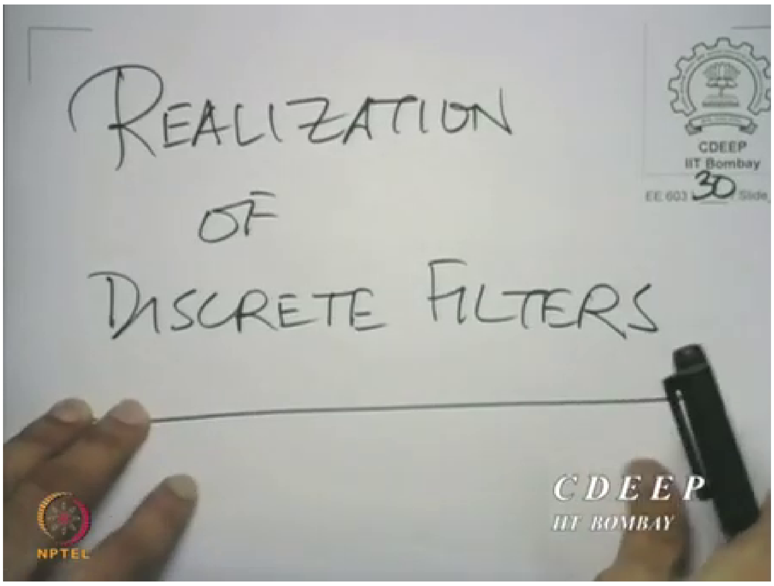

Now, so what so then for design, we now come to the next part of our endeavour in building discrete systems namely, realization and we have talked about realization before, you are not entirely new to the subject. Realization means translating a given system function into a set of components and their interconnections. So let us write that down.

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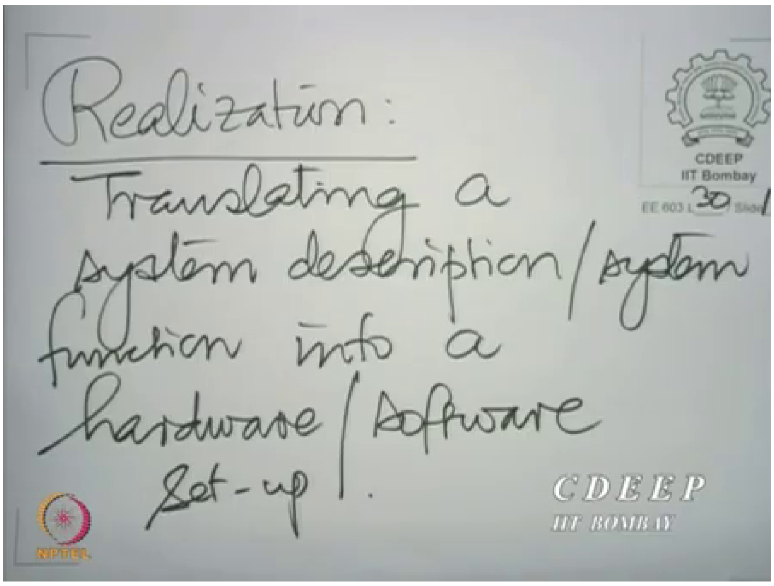

Realization means translating a system description or a system function into a hardware or software setup. I say hardware or software or a combination of the two because in today's world, it is largely software that is used. Typically what is, that is the whole advantage of discrete time systems. You see, you could set up one hardware system and then use the software to realize different filters.

That is the beauty of discrete time signal processing; you cannot do that with analog processing. In analog processing, you could perhaps conceive of a generic structure which would realize a few classes of filters but they are going to be very restricted in the class that realize. In contrast, for discrete time systems, one hardware setup, what would that hardware setup really comprise of let us see?

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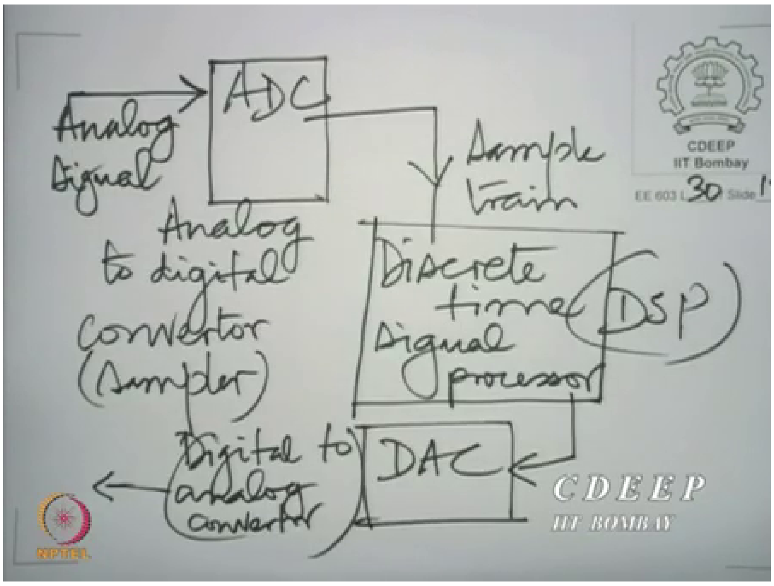

Typical hardware setup, so you have the analog signal, an analog to digital converter or a sampler. They are really synonymous for all practical purposes, which gives us a sequence or stream of samples, sample train, typically the sample train is given as an input to a discrete time signal processor or a DSP, as they call it. It is also called the digital signal processor. The output of a digital signal processor is then given to what is called a digital to analog converter.

And there we get the processor signal out. Now, you see the beauty of this is that the essential setup is the same. It does not matter what we want to do here, we could be doing a discrete time filter here, we could be doing some nonlinear operations here, we could be doing a combination of the two but we are essentially working with this setup all the time.

The setup works very well for us and this is really the typical hardware setup and the software inside this (tells) gives us full flexibility on what exactly we wish to do to the discrete time sequence that we obtained after sampling. So that is the reason why discrete time processing is attractive. Now, although there is flexibility and there is also versatile. So the same thing can do many different operations.

But versatility is not without structure. So we need to put down a systematic process, even though for translating a given system description to a realization, we will now do that. We will begin to do that today and we shall continue to do that as we proceed in the subsequent lectures.

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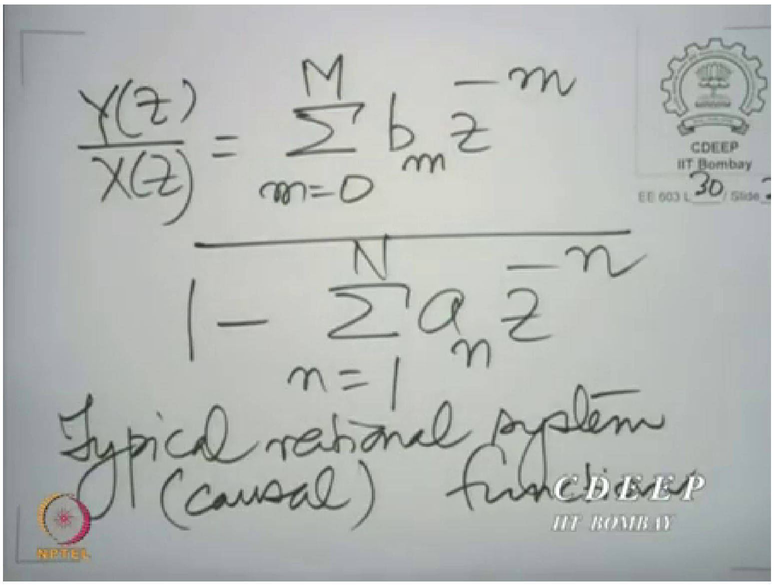

Now, let us take a typical system function, let us take the system function given by

$$Y(z)/X(z) = \sum_{m=0}^{M} [b_m z^{-m}]/[1 - \sum_{n=1}^{M} a_n z^{-n}].$$

This is a typical system function, rational system function which we would obtain. If the system is FIR, then we have no denominator for all the a's would be 0.

And moreover, if the system, we are assuming the function is also causal, you are not assuming it is stable, we are assuming it is causal. So, if it is causal, then you can always put it in this form. I leave it to you to prove that. If the rational system function is causal, then we can always write it in this form. Now, I wish to realize it. So, one simple and straightforward way is to just cross multiply.

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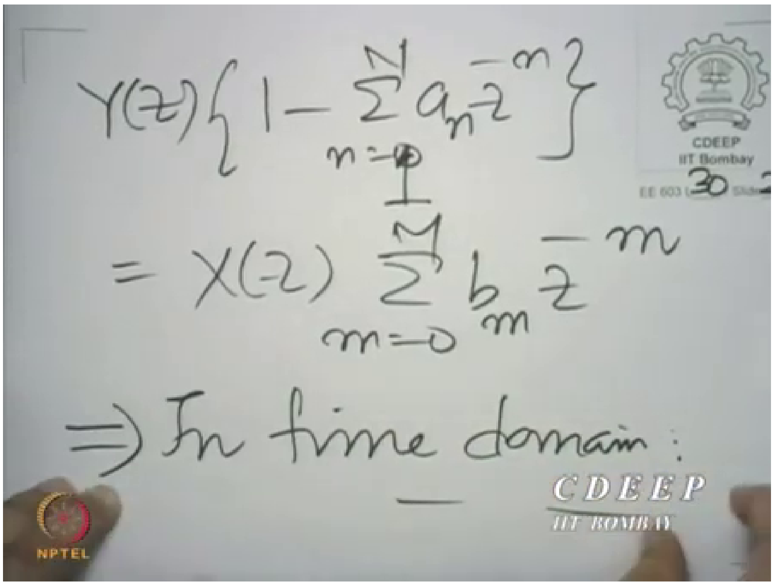

So we have,

$Y(z)\left\{1 - \sum_{n=0}^{N} a_n z^{-n}\right\} = x(z) \sum_{m=0}^{M} b_m z^{-m}$, which translates in time.

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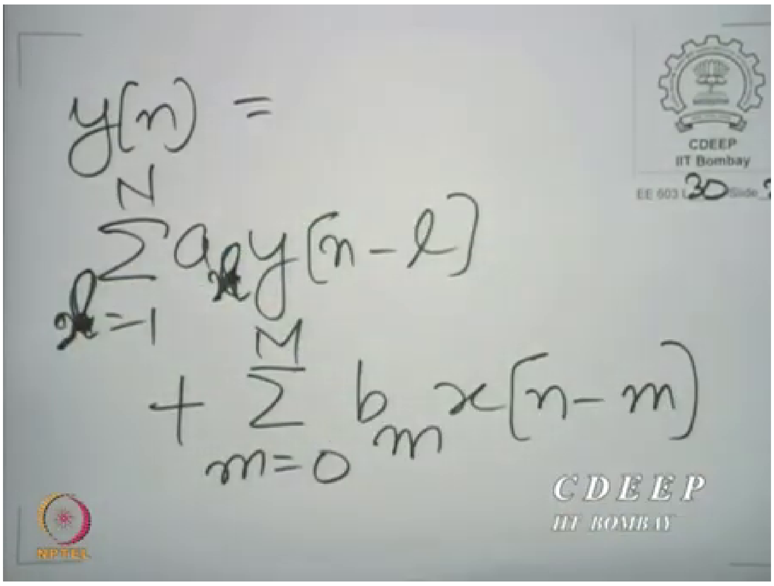

This translates to,

$$y(n) = \sum_{l=1}^{N} a_l y[n-l] + \sum_{m=0}^{M} b_m x[n-m],$$

thus now the time index can get confused. So we use a different symbol l. Now, there is a very simple way, in which we can create the system.

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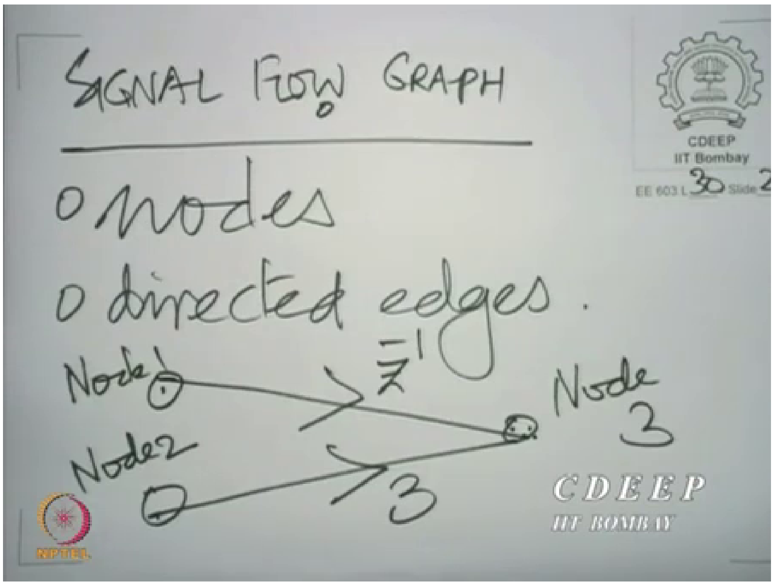

What we could do, is use what is called a signal flow graph. Now, I shall just introduce the idea of a signal flow graph. A signal flow graph is a way of representing a realization. We have seen a little bit about signal flow graphs before but will now formally introduce signal flow graphs for this course. You see a signal flow graph is a collection of what are called nodes and directed edges.

The directed edges should be thought of as trucks which have some processing machinery inside and then a depositing machinery on them. So, each edge is like a truck with some machine located on the truck and a delivery mechanism. So, it starts, you know when you have a directed, nodes are like godowns. So, a truck takes something from the godown, processes it in some way as specified on the edge and then delivers it to the place where it ends.

The processing can be as simple as multiplication or it could be delay. Now, what it means for example is that if you have these two nodes, node 1 and node 2 and you have no 3 there and you have to directed edges like this. On this direct edge we write (z^{-1})Z inverse and on this directed edge we write 3. The meaning of this is you have two trucks moving from this station to this station and from this station to this station.

This truck carries whatever is present on this node, delays it. z^{-1} means a delay, z^{-1} is a Z transform of a system delay by one sample. So, the truck carries whatever is there a node 1, delays it by one sample and deposits it on node 3. The second truck which corresponds to this edge carries whatever it is on node 2, multiplies it by 3 and deposits it on node 3.

Now, the beauty of the signal flow graph is that no matter how many trucks take away the material from a station, the material at that station is unaffected and moreover although what is present at a given station is the sum of all the trucks which deposit at that station, no effect is felt for as many trucks as take away from that station.

So there is no law of conservation there. There are some stations which are permanent sources. That is they have no trucks coming to them and there are some stations which are permanent sinks, so that they have no trucks going away and there are some stations which have some trucks coming in and some trucks going away. We should see more about signal flow graphs in the next lecture and we shall see how to evolve a general philosophy for realization of discrete time systems starting from the system function. Thank you.