Analog Circuits
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Lecture-25
DAC/ADC

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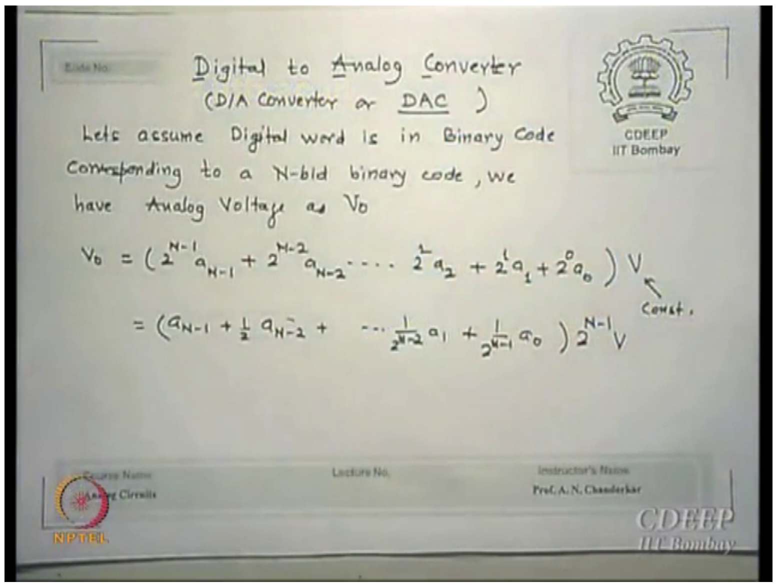

Okay, the first of the two which I was talking was digital to analog converters also called D slash A converter or in simply as in your terms everything you want to shorten that essentially I have digitized I have a digital world generally it can be coded in number of ways one the most standard coding is binary codes or BCD codes. Sometimes what else could I do gray code some excess codes XX3, XX4 is feminine guidance some specific applications.

But generally most case the digital data is binary okay. So, any analog voltage which is equal to equivalent of that digital data is shown here. Let us say I have a digital number a binary number N bit number. So, what is the way we write in the case of digital numbers clean 1010 essentially gives a coefficient of 2 to the power n whatever we are writing. So, first is still to the power 0 to the power 1, 2 to the power 2 to the power 2 or 3 and a0, a1, a2 are essentially 10.

If this term occurs then even is 1 if this does not occur a0 is 0 okay that is what the number essentially we are talking. If you have an N bit number from 2 to the power 0 to 2 to the power n

-1 this is how I represent digital number is that correct standard way of converting NLR decimal to binary rather any code to any code. Then I say with this digital number I multiplied by some constant V. As I repeat this can be 1 this can be 0 this can be whatever the actual digital number you have accordingly 1010 will appear okay.

So, I write I take 2N - 1 out, so I write V0 is now a N - half N - 2 half 1 upon 2 to the power N - 2 a into N - 1 a 0 into. So, now I see so if these are the numbers and these are the coefficient now with age I if I can make a circuit which does this job then I am converting given data into analog voltage. This is constant V is my fixed I am fixing it, so this is constant. So, given a digital number its coefficient in this form 10 whatever I write and write in this form.

And I get I get equivalent if I add all these terms I will get equivalent analog voltage that is what we are trying to do. So, depends on a is 0 a1 a2 this we will be vary minus 0 will be varying if this is 1, this is 1, this is 1 all are 1. Let us say so 1 + half + 1 by 4 + 1 by 8 + 1 keep doing till end and then this is 2 to the power say 8 7 that is in to V. So, you just write add all of it and you get the whole analog voltage for.

You change some numbers are 0's so there will be different V0 is that clear. if I is or not once then there will be some other V0 will appear. So, proportionally whatever is your digital number I can create equivalent analog emulation. So, we are converting a digital data into analog data. It is not so trivial but we will see how you will do it this is the principle. I am using typically what that does therefore if you see a block diagram.

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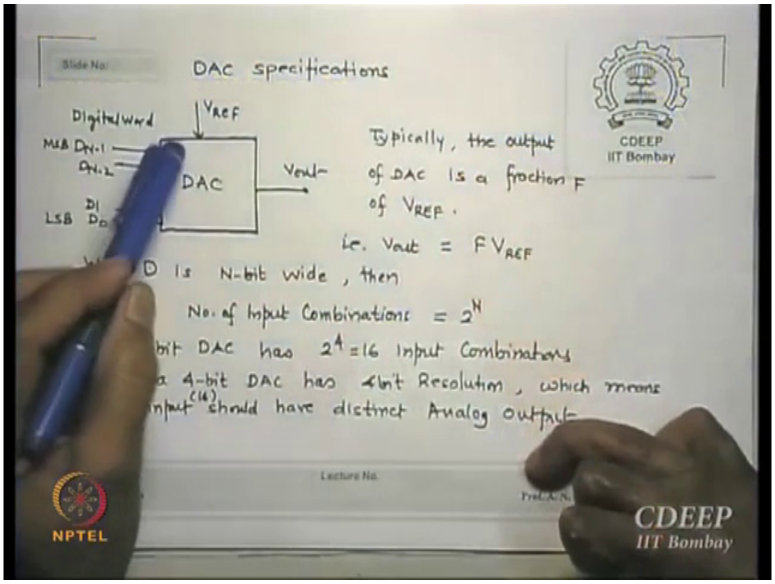

You have a DAC which has a voltage which we call reference which V REF. It receives a digital word which is M bit wide so I have in our data like D0, D1, D2, D3, DN - 1 the first one down is less significant the uppermost is most significant bit okay. What that does uses the digital data input does some tricks with this V reference this is that proportion and a constant I was talking. It is this V reference is something which we are deciding, how much voltage I want and then I will get an output.

What we say the V output is some way related to fraction of the reference voltage and this fraction of course is a function of digital data okay is that correct. Fraction is a function of digital data 1010 to whatever total you get F will be different V reference is my reference voltage. So, F times V reference be V out. And they already said these the word which is M bit wide. So, how many combinations it can give at the input possible 2 to the power N.

Let us say I have a 4-bit number so how many input combinations possible 16 combinations 000 0011 keep doing 111 4 one’s. So, 16 combinations so larger the width of the word larger input combinations will come is that clear to you. Now my problem starts something like this so for example a 4-bit DAC needs four bit resolution and what does that mean. The word which I am now saying first time is the word resolution.

Now what is the resolution I am saying since I have a 16 input combinations okay but each input combination there will be some V0. Let us say VO1, VO2, VO3 and I must be able to separate this VO1 from VO2 from VO3, VO4 sufficiently accurately so that each input combination has a discrete value of V0 which is different from other VO‘s is that resolution word clearly to you. I want to resolve all 16 input combinations at the output independently which can be separated as if and they will be separated equally because each bit changes only by one.

So, for each this it will shift by equal amounts, so I want to see what is essentially in mechanical what do we say these counts. So, what is the smallest this I can do which will separate the two words or two bits two different input words. Please remember this word are the 8 combination let us say are 4 combinations are two 4-bit word that means D0, D1, D2, D3. So, there will be possible 16 combinations for you and this 16 each should give me V0 which is distinctly separate from the last is that clear.

This word is called resolution if I make 8 bit that so what will be the relation related to 2 to the power how many combination I can get to the power of 8 which is 256 input combinations. So, one can see now the same this number if I reduced into 256 separation will be smaller is that correct separation will be smaller. The smallest accuracy which I can create, so I say what is the advantage of earlier last time I showed you some graph you recollect that graph.

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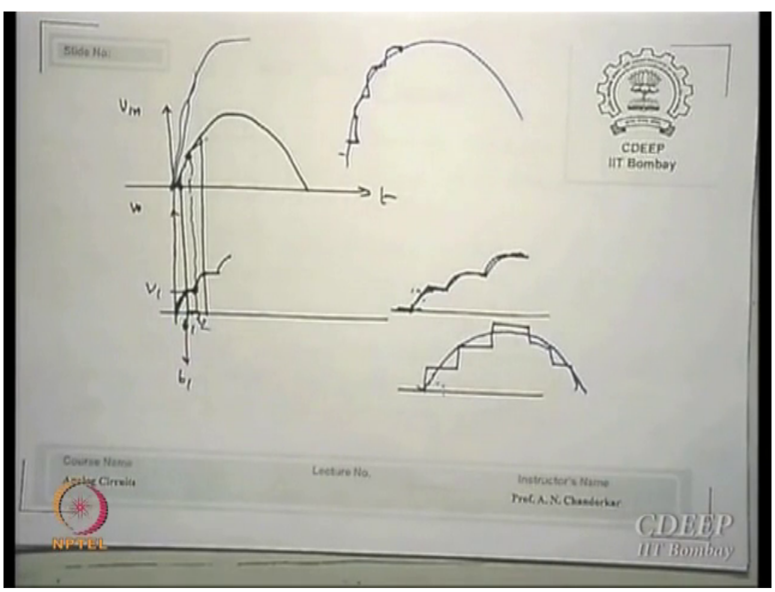

I was trying to discretize something last time I show what is the game I say as close I discretize I will actually replicate digital to analog or vice a versa I ask close the digital data is as close will be mine our similar thing will be the analog equivalent. So, is that what we are why resolution should be higher because it will do more accurate conversions? So, one of the major feature of any A to D or D to A converter is its resolution how much it results, is that clear.

Smallest number is related to what LSB least significant bit so for that least significant bit what is the next possible number I can resolve next bit is what I am looking that is called the resolutions. So, I am interested in so if I why not makes a 24 bit DAC or 32 bit that what will have what will happen the hardware which will require to create larger resolution will be larger in actual valued self. (FL) most DAC's are 8 bit resolution.

If you want more accuracy you have 10 bit, 12 bit of course you pay something if you increase bits which this I am not going to tell you there are many, many problems in increasing the resolutions there are many errors some of them are called differential errors, some are integrated error, some are aperture errors, some are quadrature errors. There are to gain errors there are missing bits. So, there are large problems in conversions.

Also another ADC which we use very often it is called Sigma Delta Modulators it is very important modulation in whole of the analog circuit area. It is a actually a 1 bit modulator or converter but we can do 8 bit collection, 16-bit, 32-bit many things we can do which is what we will see later that why Sigma Delta Modulators. But right now assume whatever simple things I am talking just for the heck of information acting okay.

So, this fact is understood by you that I am looking for better resolution if I want to have accuracies of my choice, so fair enough.

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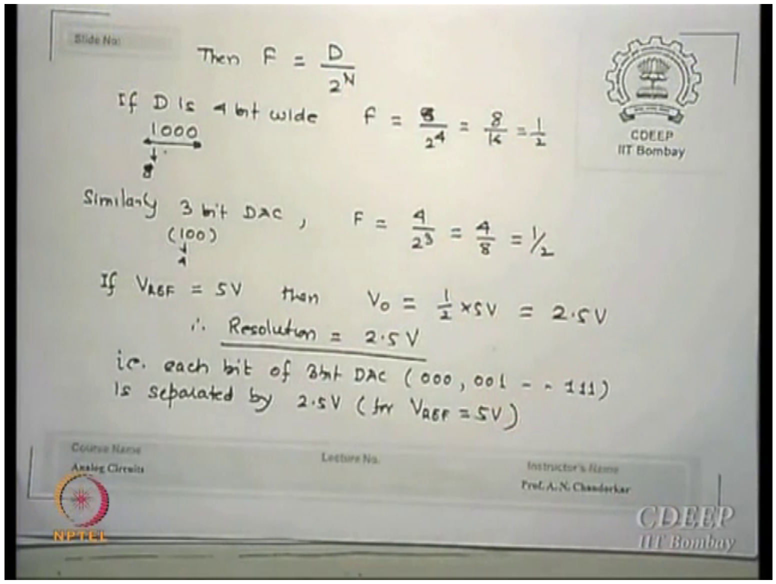

So, I define a term F which is fraction which is given by D which is the word date digital world divided by 2 to the power N. I give you definition so that you understand. If D is a 4-bit word 4 bit wide what is the 4-bit number smallest 4-bit number smallest 4-bit number which has the one at the MSB, so 100 otherwise what will be next 1001 1011 1101 and 1111 these are four possible numbers. Smallest among them is 1000 so, what if this 100 essentially in decimal 8. So, we define the weight of D is whatever is the smallest this number 8 divided by 2 to the power 4 because M-bit you said and is 4.

So, 2 to the power 4 8 by 16 is called the fraction which we are looking for. How much is the fraction here half is that clear. So, V out will be how much we reference by half be referenced by 2 okay. Take another case if you have a 3 bit wide DAC what is the smallest 3 bit numbers I can create 1000, so it is 4, 2 to the power 3 is 8, 4 by 8, F is again half is that clear. Let us say if V Reference is 5 volt then V0 will be half into 5 by this 2.5.

It is a fraction of a reference is the word the bit-sized word with width you are talking if you have a 4-bit word the smallest four bit is 1000 and then next number is 1001 no because the I I are you have a point then I will not use the first 2 that only I will use only 2 bit numbers ha so for bit width has the resolution which is at the MSB what is the minimum number I can create. Because I am going for the 0 to MSB, so I want to look at MSB what is what number I am going to resolve okay.

The smallest image V, I am looking is 1000, so, if we have a devaluation of 2.5 volt each of them so every bit will now go to next will be 2.5 volt away from it, so 5 volt next will be 7.5 fraction of that. Now there is something that is the reference I am creating which can be any value I put 5 volt, you can put 1 volt yeah that is the maximum up to which I will go that is the fraction of that only I am looking how much I will do so for the just look at the figure then you I come back to it.

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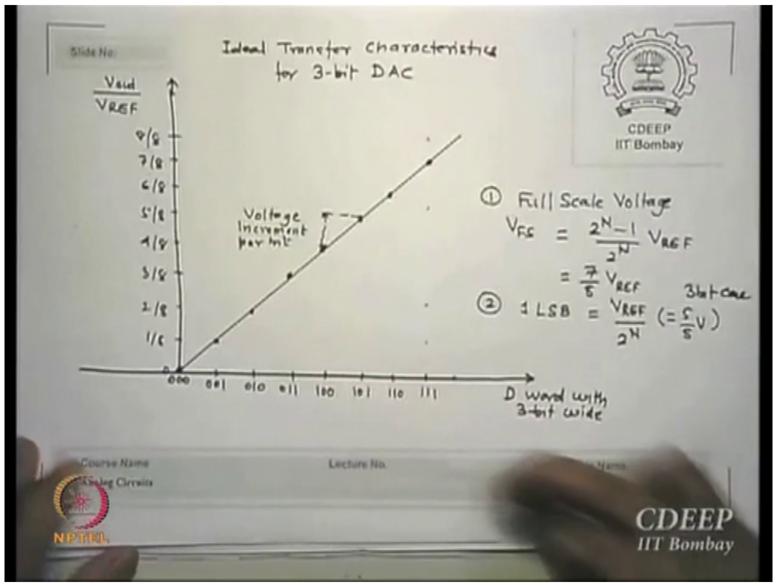

If you are saying here is more than things which should be clear to you this is my 3 bit wide number okay. What are the numbers 000 001 up to 111 that without the 8 possible combination of 3 bit wide numbers. So, I say okay I plot here V out by V Reference okay I applaud here V out by V Reference the ratio okay. Then I say what I am really looking is at 0, I want 000 0 for 000 output voltage should be 0 because all bits are 0, so output is 0.

The next time when I come with 001 okay then I say it should be 1 by 8th of the fraction should be 1 8 for 11 on what should be the fraction therefore this is 1 2 8 3 8 at 111 which is the highest 3 bit number how much it will be 7 by 8. So, at 7 by 8 and beyond this it will not be for 3 bit number is that correct. So, the maximum number which I can create using a 3 bit DAC is 7 8 off V out by V Reference or 7 8 of V Reference is the maximum voltage I can create.

And how much is the resolution I am creating one 8th of V Reference correct 180 that is what I said you. So, if you are 3 bit number 1 by 2 to the power 3 is the resolution. F is the fraction resolution is 1 8th smallest number which I can separate on the output is 1 8th of operator. So, what is the full scale replica this for the 3 bit code full scale is how much was full scale here, 7 by 8 generally what should I write 2 to the power M - 1 divided by 2 to the power M.

Put M = 3, 8 - 1 is 7, 2 to the power 3 is 8, so 7 by 8 is that clear. So, in general for any M bit code the maximal VFS which I can get the full scale as it is called is 2 to the power M - 1 upon 2 to the power M times V Reference in our case for 3 bit it is 2 to the power 3 - 1 by 2 to the power 3 which is 7 8 that is the; Now this something which I am assuming what is this curl looks like red line is that correct the problems which I said in real life this achieving the proportionality is the cause of error there okay.

So, we may not get the kind of steps we are getting and there is an issue how much we can tolerate. So, what is the smallest reference this V Reference is that resolution is clear smallest resolution is 1 LSB which is V Reference divided by 2 to the power M in our case if it was 8, 1 8th of V Reference is the smallest voltage I can separate is that correct. If I want better one than what should I do? I want this to be better than 5 volts.

What should I do I go from three bit wide number that to 4 bit wide - then I will get V Reference by 16 is that clear. If I make 12 bits I will get 1 upon 2 to the power 12 into V Reference. So, smaller the resolution I am asking for larger is the bit size of the DAC I will have to use and larger the size of bits will say hardware you will start proportionately increasing that point clear, is that ok. So, this is an issue which DAC people have to attend to.

That is you can see what we said at 100 it is the; see I want to have 3 values at which I am looking whether I am in straight line 000 full scale and the midpoint. So, I looked into half, I looked into 7 by 8, I looked into 0 and I joined this curve I say I believe that linearity is maintaining myself that means equal spacing of 1 it is possible is that clear okay.

Now how do I implement this (FL) - R2 by R1 R1 + R2 by R1 times V in can be transferred to V0 (FL) here is the first circuit which is the easiest circuit called binary weighted DAC okay. Before ok before this just see this switch.

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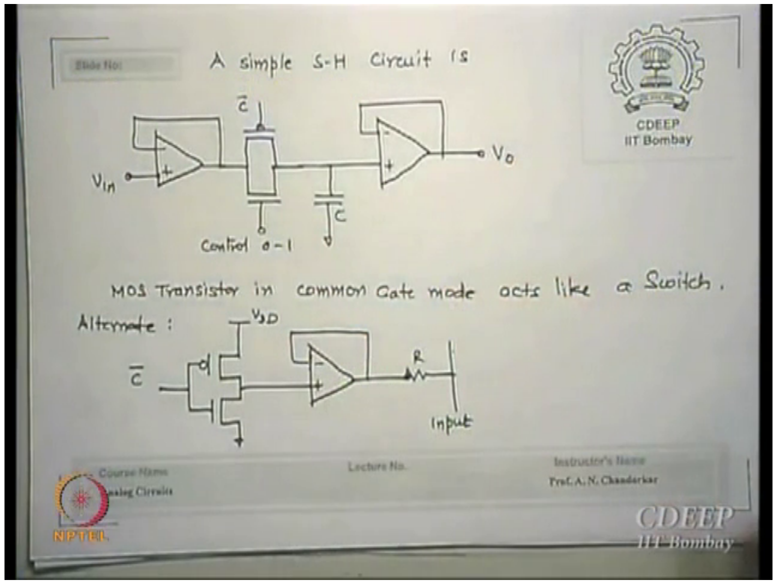

A switch which I am going to show in my this is the second switch do not this we are already using sample old this is another switch which I am going to use in by the next DAC representation. What is the first thing I am putting here an inverter a CMOS inverter receive an input C bar which is my control. So, how much is here, see it is a follower so that is C but can you think if C bar is 0 what is the output here, 1.

So, what will be output here 1, is that followed, if it is 1 what will be output here 0 so what will be output here 0. So, (FL) is that clear if I give 0 here I get 1 if I do 1 here I get 0 if it is 1 I have 1 here if it is 0. So, I on this in between I did because I want to buffer it up okay this is my inverter and I am creating 10 from an inverter depending on the input I give I can create input to this, this is input of OPAMP I should write.

This is the line which I am showing you input to the OPAMP now I will show you but we are anyway looking for 1 and 0. So, let it saturate so only thing is that 0 is not - VA says but it is single ended power supply so the lower end is only 0 no why should you 5 volt is sufficient for almost every circuit and OPAMP more so bank are 5 volt supply the experiment which you give me a 741 which we give you is essentially we are using it 15 to show you good working on OPAMP.

All OPAMP 85 76 I LM 321 323 any numbers you talk there are mostly 5 volts and these are even lower than that 2.5 volts there is a circuit which is our 2.1 moon we are looking for 1.8 volt supply now so there are powerful I told her what is day before I started all this power supplies which allow some power (FL) Switch in the sense either it transfers 1 all your transfer 0 switch what ends you know what else is next no.

Whenever it is 0 it is transferring 0 whenever it is my I am switching actually whenever it is 0 I am transferring 1 whenever it is 1 I am transferring 0 it is control because depend on the control I will create 1 or 0 no no just do not do that, this is the difference this is what I am going to use some circuit and I thought what is that block inside is this here is what?

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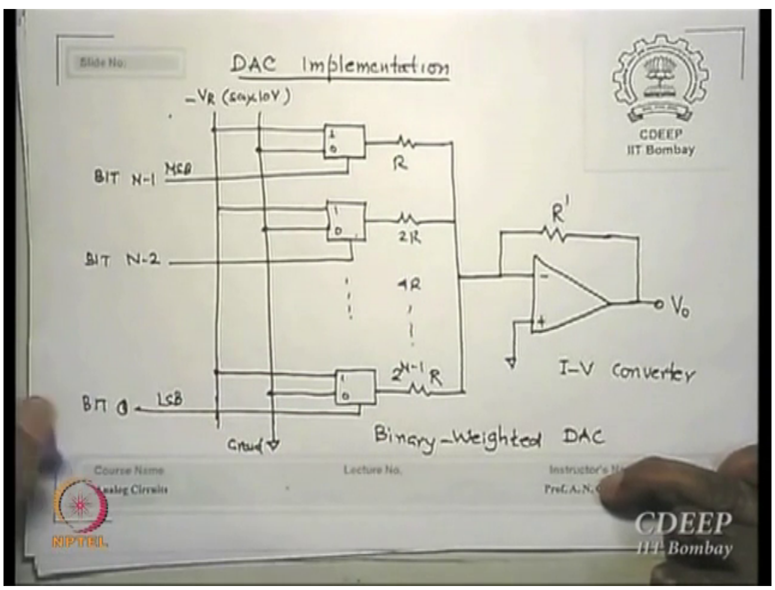

Let us see what I am saying here is that switch okay. This all square blocks are switches. The switch receives two inputs one is - we are the other is ground 1 and 0. And it is controlled by bit which were bit and - 1 that is MSB and LSB is exactly how many of them will be as many bits do Jack you want those many will be this is MSB this is LSB. R each such which first switch has the resistance R second has 2R third will be 4R 2 to the power.

And finally in we will be or 0 the bit will be 2 to the power M - 1 are please remember the highest MSB will get only R and LSB we get 2 to the power M - 1 power these are the resistances they are connected here this is that line is that man ok, this line, this line is this line each R is connected at this line each which is connected at this which is the input to the OPAMP, T bar is this individual, control 1 and 0 are the bits and a number voltage.

As I am entering through this switch that is the VDD or ground only thing as I am putting VR as - why did I put - can you think by - inverting (FL) The way I am doing it if this is this bit is 0 the upper one passes is that ok, if this bit is 0 what is the switch performance input is 0 output becomes 1, so this one is transferred this is like equivalently what is it looking like a circuit (FL) it is a MUX equivalent of a MUX.

So, what is doing it if this bit is 0 it transfers 1 if this or maybe vice versa sorry I mean I can do otherwise I can put a opposite of that if it is 0 let us say it transfers 0 if it is 1 you transfers 1 okay sorry I made a mistake because that is why I did some other side. Please I will do for all such bits you have there are a number of such switches. Now depending on the 0 or 1 on this which is your bit data okay either voltage or either this volt or 0 will appear at this. (FL) is that okay.

Since which allows either this or ground to pass at this depending on the bit availability 0 or 1, I can pass voltage or 0 volt okay. If it is 0 it does not add anything if it is 1 it that is the voltage it adds to that number is that correct. So, this into R dash upon R is that correct this into R dash we R dash upon R into - VR if this is 1, I get a V0 because of this else R dash upon R times V that is 10 volts V Reference is that clear to you.

If this bit is 1, I will also get only thing is now why it is R dash upon 2R, you see my first figure which I showed is that clear. (FL) So, is that this equation now clear what is that equation this is a summer is that correct (FL) is that clear to you (FL) is that correct (FL) so it does not add to the output. So, I now represent a output voltage which is corresponding to let us say it give some numbers.

Say let us say 10 and 1 and let us say all others are 0 (FL) R dash upon R into M + R dash upon R1 upon how much let us say it is the 8 bit number so how much 2 to the power R dash that is 8 so R dash upon 1 upon 8R (FL) is that clear. But that can be opposite also it s a only a nomenclature. I can always put what you are saying is valid I am not denying I should not have shown that, that was switched somewhere else I just copied.

All that I need is this irrespective whether I call it C bar what I am going to get is 0 will transfer to 1 is that correct. All that I should do therefore I should put another one to create CC bar so that I will transfer exactly 00 here 11 here because that is what my switch is asking (FL) you cannot connect (FL) there is a circuit called DC to DC converters (FL) so there is something which we do when we put in between them. (FL)

Okay, you have a point, but there is not a correct part in circuits you must drive current (FL) which I do not know which circuit is going to come from (FL) is that clear to you. Buffer does not really give currents. But buffer actually gives impedance (FL) I am least interested in other part of the circuit because this R is now is not going to load anything now. (FL) I do not want this to connect with the my inputs okay.

So, this is buffering only the impedance high impedance to low impedance states okay this is driving the input itself this is digital. (FL) is that summer clear to you (FL) what I am implementing is this is that clear. So, DAC essentially can be created by putting some switches as I showed + supplies + a current to voltage converter or OPAMP and actually converse D to A at the output is that clear (FL) is that okay.

So, how much accuracy you want you decide and then put money for that. (FL) and then we will stop on this.

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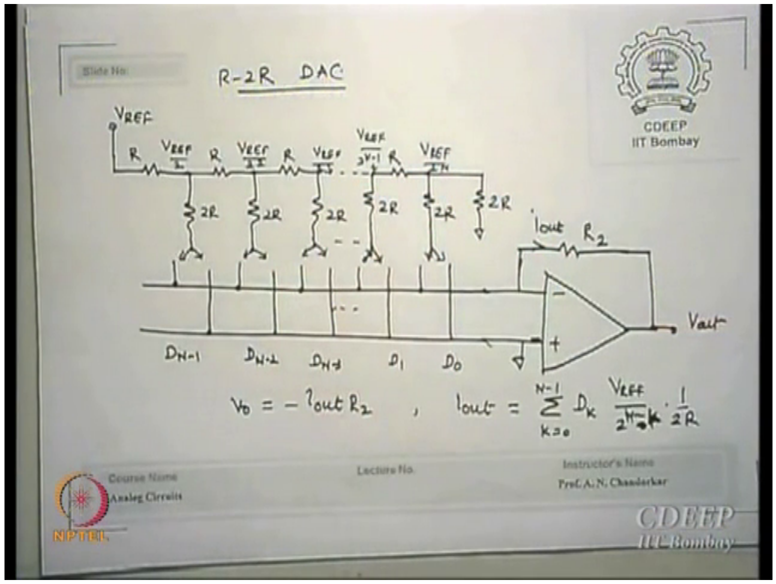

DAC this is R to R DAC, (FL) not the our pole 0 normal switch (FL) it is much easier circuit than the one which you are a normal switches (FL) you need not want to draw all nine of them draw at least three 1, 2 and in some yourself okay. You first forget this R to R only look for this right side simple OPAMP. If P+ is grounded virtual ground but no current can sync here is that correct, no current can sink here.

There is no red if there is no connection on this line where it is floating. If this has no input no connection to this line output remains 0 no current, I out because remember I out cannot flow if this is that virtual ground there is no sync path. (FL) One this is I am looking for a case when in which this floats that means output is 0 the second time I want this to really go to through R2 V Reference some value of me.

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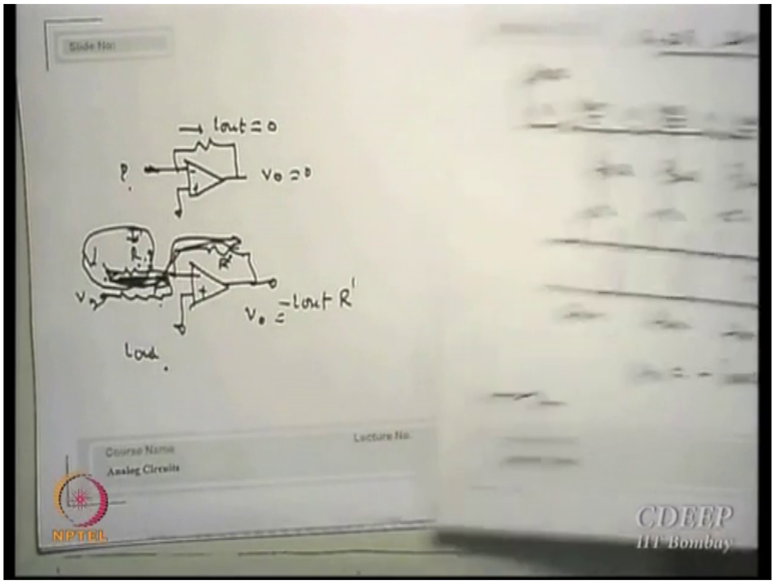

Essentially (FL) two cases I am looking for one is this is my ground and floating nothing here okay. So, I out it is 0, no input output is 0 and therefore V0 is also 0,taken case positively that no negative a virtual ground but virtual ground does not sync anything. This is floating so current cannot flow there, so, if current can flow output is 0 okay. Now second case V – (FL) yeah yeah you are right if there is no current the output voltage is I times R.

But if there is no current here, the current is output is 0 so output will go to 0. Initial condition if there is nothing there oh you are saying if there are the last capacitor there it will preach our yes it retains last charge but initially it will always be a GP. It does not float it remains at floating at 0, output remains at 0 no nothing is going there. If there is a V and this is R whatever I am going to get if this is the circuit then what is the output current going from here will pass through there and V0 will be essentially I out - I out times this R, R dash is it not.

So, if I and I out will be proportional to total path it is going to see total I. I will be decided by this and this values is that current from a source V by R + so much will be I out V- this is R = RV - = that. So, we find out how much is, I out. So, if I out be the function of this is that correct, I out is a function of this. If this value changes V out to change, if I out which is a function of this R, if that R changes or this voltage changes then I out will change and therefore V0 will change is that correct.

If this combination allows me at different values at different equivalent of a digital bit then different outputs will be available is that correct. Similarly now what I can do I can do number of such resistances with number of V1, V2 sum here also again. So, I can have different VR, VR combination as I did in the last case I can sum all coefficients with different V and different R to get V0 sum of everything is that correct.

So, that is the output voltage which is some off each bit is that correct. Now how do I create this I repeat the two cases I am interested in, in which negative is floating okay the other is it is connected through R2 some difference was value. So, what I do is there are the D is the date each, each in the bit. If the bit is 0 okay I want please remember bit is 0 how much V0 I should get 0 is that correct. (FL)

Depending on the bit I have either I will connect here or I will connect here is that correct. If it is a 0 bit I will connect here, if it is a 1 bit I will connect here it in that clear, this is what SPDT does will not go into detail how I do it this switch but this is what switching we do. So, if I put R to R network R to R, R to R network R to R an additional toward to the ground I can say when they are floating this voltage will be V Reference by 2 ratio of the 2.

Then it is further each will give V Reference by 2 half of that, half of that, half of that, half of that 2 to the power each will be half every time are by 2R V+ is always grounded, V+ is always grounded. So, when this goes to connection here actually I am giving 0 potential to every one of them this is floating so obviously nothing is getting transferred from the data side is that correct. So, if corresponding through data's either I will connect here or I will connect here.

If I connect here what does that mean I am transferring reference voltage part of the reference voltage at the output, if I am connecting to the ground I am not transferring anything that is 0. So, if it is 0, I connected to the ground if it is one I connected to the V-1 is that correct. So, depending on the value whether it is 0100, I either it will go to V Reference by 2 + V Reference by 2 whatever bits are one’s.

Each will come on through R to R combinations is that correct and I out N – K, K is the bits number I am talking K = 0 to N - 1 which bit number 012, so DK V Reference upon 2 to the power N - K into 1 upon 2R okay you are this is the output current if D0, K0 which term will go that is if this is 0 then I out is 0 correspondingly + next term is 1, this is 1 and this is N - 1 whatever that value by 1 upon 2R will be transferred at the output.

Keep transferring + + 0 + 0 + 1 whatever constant you have and you will get output voltage which is sum of all one bits at their position. Why this number is coming what is this actually going to do me that whole expression you keep remembering. All that I am doing I am still doing this N -1 half N - 1 1 upon 2 N – 1, why same summer I am using is that correct, same summer I am using by this circuit and this is essentially it is much easier to implement because only two kinds of resistors are required no switches directly of that kind.

This single pole double pole is slightly interesting switch some other day I will show how SPDT works is that clear. So, which this is what is this DAC is called it is called R to R, R to R. It is called R2R DAC very famous. (FL) Since the output voltage has something to with R I can adjust the value of V0 by adjusting V Reference and the R value I choose is that correct. So, resolution can be adjusted by choice of R as well as V Reference to be there.

So, for a smaller number of resolution bits I can still get voltages separated by small numbers is that correct by adjusting R values is that clear to you. This is slightly modification over binary weighted DAC's that is why they are used. Last but not few to figures and we end it two minutes.
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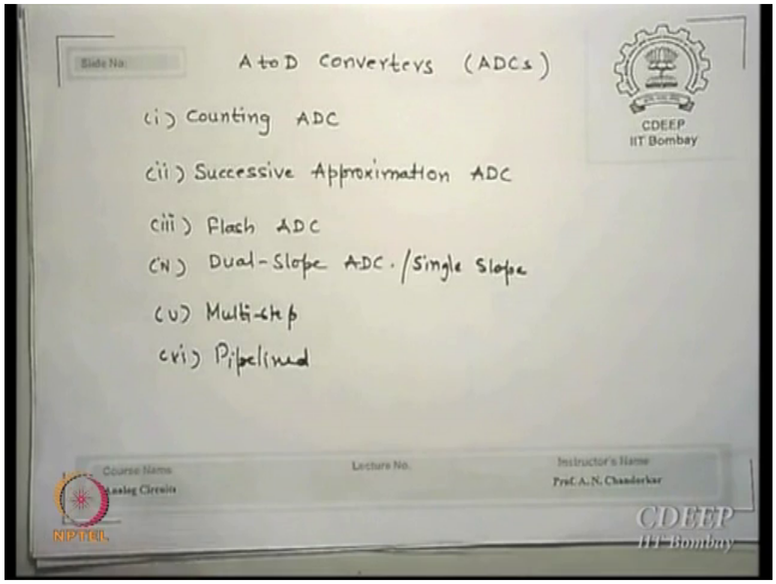

Will only show two of them and not discuss read in the; (FL) this is not given in Sedra Smith not given in the books which I referred to you as analog books. Why but they are mixed signals, so they are not but you can read any digital book any digital they will have metrics. (FL) There they say OPAMP is not available we do not mind. (FL) There are four kinds of popular (FL) these are the easiest to show and this one is used maximum flash.

What is the word flash means? Instantaneously in a flash (FL) why it is called fly flash there (FL) what is the advantage over EEPROM sorry square ROMS, why it is flash is so important. In EPROM you have to put ultraviolet light for a long time 30 minutes to erase the data. It is also all erase (FL) EROMs you it is bitwise each bit is it is one by one electrically. Flash allows electrically it is like every EPROM in one go all of it.

That is why it is called flash all gone and it is electrical so you do not need any light etc to be actually you will like a problem (FL) ketchup has to be taken out put it below you with this and first you read and then you use it back. In flash you do not do it electrically you erase everyone that is the only problem is he EPROMS as much longer life than flash. (FL)

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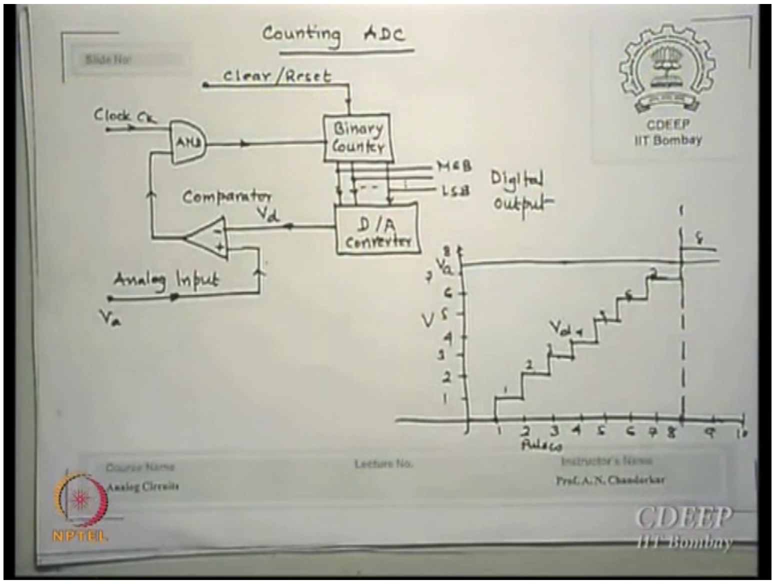

Counting please draw the circuit very interesting simple circuit nothing great happening here. I have clocks pulses which is my input to an gate and the other input to an gate is coming from a comparator okay. The output of and gate is given to binary counter as an input binary counter (FL) what is that ripple counter means output of the first flip-flop the second flip-flop okay. There is no common clock this is not synchronous it is the asynchronous counter okay.

The a synchronous counter than he is in commence a clock (FL) clock input there a next time output of the first FFQ is given to a clock of the next stage what does that mean if you are 16 pulses the next will show you one, one in eight pulses (FL) so eight pulses after eight pulse we found only one that is why it is called counted eight pulses counted as one through four flip-flops okay 0001(FL) and we say you are counted 8 pulses.

So, here is the counter I repeat clock is 1 input pulse s this, this is a comparator which is V Sigma analog input okay. The other input of a comparator is coming from D to A converter (FL) D to A converter which is essentially binary counter (FL) is that correct when it becomes 0 after time I decide now clocks will not go okay and why pulse (FL) flip-flop can be reset to 000 okay. Otherwise it remains small so it always come it does not partisan.

Remember we said does not participate when one when it is 0 it is called the sidebar (FL) if I start first pulse come the counter (FL) anyway does not matter very much but for the sake of it.

(FL) is that clear. (FL) Since it is only one bit Vd is always smaller than VA if it is this, this remains one and if it is remains one the next clock is allowed okay. As long as this is one next pulse filter then what is the new bit will appeared 0011(FL) please remember in the second bit one without the power 2 to the power 1 (FL) is that correct. Now start looking here number of pulses at 0 the analog output the output at this step which is coming through Vd is 0.

Till the second pulse come this remains 1 (FL) as long as you keep increasing pulses. (FL) is that clear why it is straight case because when the clock is they still the next clock edge the voltage is retained (FL) Let us say that is how the VA was, as soon as it crock (FL) what does that mean Vd is now higher than VA comparator output 0 and output 0 reset binary counter stops at the last value whatever before it.

It said it shows you whatever the last bits here which allows Vd to be higher than this. When the next clock starts before that you start clear and recounting next bit you can give another VA and can start counting bit is that correct. (FL) This is a 3 bit ADC 2 to the power 3 is 8, 8 pulses will create 8 possible combinations therefore it is a 3 bit ADC is that what clear. Every clock pulse D to A (FL) whatever MSB to LSB data you are seeing is equivalent of that.

Because (FL) so each bit output will be proportional to the analog which you are giving is that correct. (FL) is that clear is that point clear (FL) it will show the bits this is called A to D converters and is called counting wide for counting (FL) as soon as I process VA it stops here is the digital number ok this is called counter.

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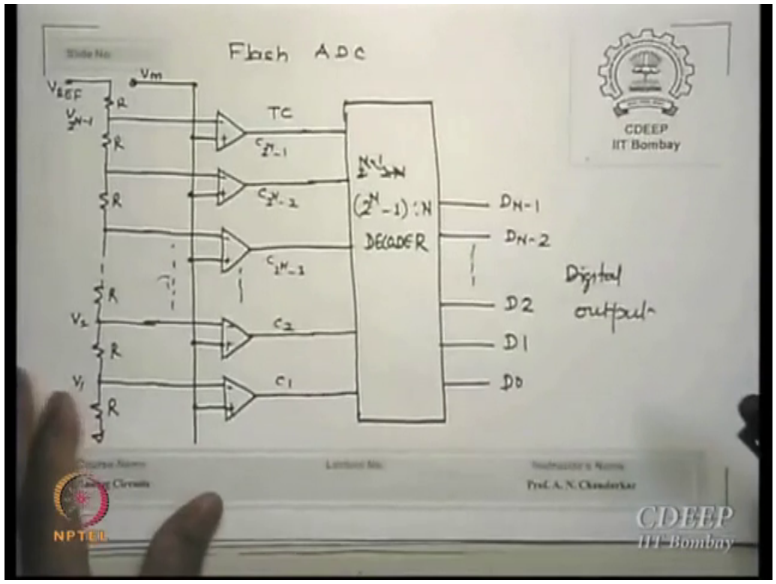

Last but not the least subset important(FL) okay one of the fastest available ADC is shown here. (FL)

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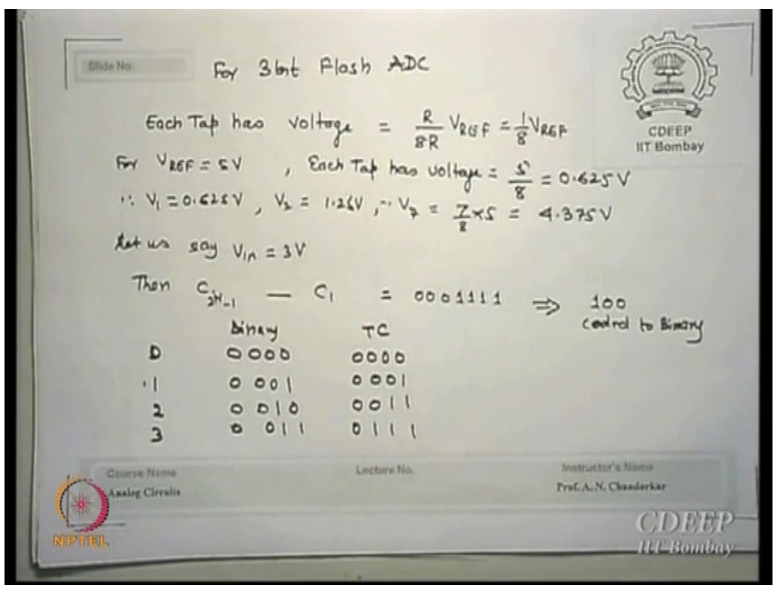

This is called TC (FL) thermometer course essentially now you must remember we have talked about decoders encoders everything (FL) from lower bits to higher bits is called encoding from higher to lower weight is called decoding it need not be in the binary form that is 2 to the power 3 in a to the power 3 - 1 because any code to any code (FL) truth table is basically that so anything to anything from lower bits if you go to higher bits it is called encoding from higher bits you go to lower bits it is called decoding.

However in our digital course we kept saying 8 to 3, 3 to 8 because we want to keep binary values but I suppose definition (FL) if higher bits to lower bits a shift I say it is a decoding if going from lower to higher bit I call it encoding okay. (FL) This one of them is my analog input which is my analog each is a comparator (FL) example they take each tap as a voltage (FL) 1 upon 8, so R upon 2 8R into V Reference is 1 8 through the references each tap has this voltage.

Which is the tap voltage I am saying if this is my reference potential R upon 8R is the voltage here is that correct, so, this voltage is essentially R upon 8R into V Reference so, this is essentially what do we say it is tap voltage. (FL) And keep putting as many bits like for example V7 will be 7 by 8 into 5 which is 4.375 volts. Let us say V in is 3 volt, let us say V in is 3 volt then what is the temperature code we are looking for 0's 8-bit 7 bit code.

By the way temperature quotes are 7 bit code 2 to the power N - 1 bit codes. So, it is 00 why did it is not even 00 is always 00 so it is never used. So, 00111 3 volt ok no sorry no coded to binary equivalent (FL) 100 is 4 okay, okay and this is essentially equal to 00 (FL) So, correspondingly C1 will be how much 30111, C2 I say (FL) I repeat this each is the tap of 0.625 pole compared with V input (FL) we will create one's and 0 that the output these data corresponding to V in is then decoded out to a smaller value of data which is D0 to DN – 1.

And bit code which you can create this is called flash ADC what is the why it is called flash anything which does simultaneously some things we call it flash okay we call it flash. Any parallel circuit is therefore acting like a flash anything in serial it acts like very slow because the output of first has to wait to become input of the next okay. So, it will always be always slow. (FL) Only thing I must tell you the output you get here are temperature codes.

This finishes analog circuit course as I envisage for a second year class plus I hope I had tried my level best to enthuse you. So, we finish whatever is required for OPAMPS, so what we started with basic circuit basic transistors remodels then we say okay basic amplifiers theory of amplifications we did discuss frequency response then we say use it can I increase gains are different this so put an integration of that so I use DPAMPS.

And I say why not use DPAMPS and other amplifiers are used to create even better amplifier which we call OPAMPS and then I say okay opens can be used in varieties of base linear and nonlinear circuits and I say okay if OPAMPS are; then I discuss much about feedbacks then using feedback and this OPAMPS we say okay we can create oscillators and we say okay if you use op amps with digital or some part of these networks we can also create A to D and D to A converters you