Digital VLSI System Design

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Lecture – 55

Project Design Suggested For FPGA/ASIC Implementations

We have seen how to design VLSI systems using Verilog and we have considered both implementations on FPGA board as well as without it.

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Here is suggested a number of applications for you to design on FPGA or ASIC.

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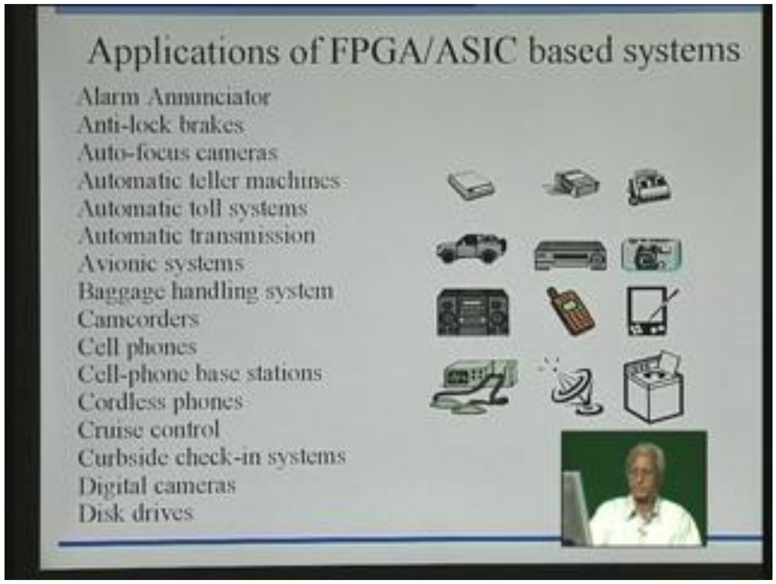

There are around 60 or more applications, some of which have already been done by other people, in industries as well as R&D institutions. We will touch some in brief to start with, and then go over to taking two design applications and consider a little more elaborately the specification, the block diagram, etc., for you to start on your own application. The first one in the list here is what is called alarm annunciator. As the name implies, we need to monitor different engineering parameters in industries. It may be a power plant, a cement plant, a sugar plant or a steel plant – anything that you can conceive of; in fact, even a thermal nuclear plant, whatever you want.

For all these, you would have seen probably on TV or in magazines or journals, huge control panels over which sit some flashing lamps – that is precisely what is called as alarm annunciator. There are many sequences in that and over 80 sequences at least I have [03:59]. If you are really interested, you can contact me for more specification on this, but I am not going to furnish any specification right in this lecture. You can also go for automobiles and do some intelligent controller meant for anti-lock brakes – it is also called as ABS brake. This is in vogue especially in foreign countries. When you apply the brake continuously and if the road is slippery, naturally there will be a disastrous consequence if you jam on your brakes.

So you will have to do what is called a pumping action, you have to give on the brake, but you cannot really control intelligently on the spur of the moment. You need some controller that will monitor the actual road condition and accordingly intelligently apply the brakes intermittently. For that, you need a controller. You can design such a controller and that is the second one. Naturally, you can have a camera that will focus all by itself. You just shoot any scene and it will automatically adjust its focal length. All these call for a lot of intelligence being embedded in the chip that you are going to design.

What is shown here for different applications are already in vogue as embedded systems, wherein normally 8051 controller, microprocessor controller or even any other processor such as 8085 or 68000 is used or you can use what is called PIC – peripheral interface connect. Such devices are basically controllers. You can design that using either an FPGA or ASIC. There are other applications such as automatic teller machines, which you are already familiar with, and if you go to the toll gate, you may have to pay some Octroi or other charges there – such things can be designed by you. Automatic toll systems are [06:22] here.

Once again coming back to automobiles, you have automatic transmission. This is only to dispense away with the application of the gear, which we do manually. Once you start your engine and then engage the gear system, you forget about the gear thereafter until you come to your destination and stop the engine. Till then, you have to have once again an embedded system controller, which will do this. This will dynamically change because you may have to climb up the hill or go down the hill, there may be a lot of ups and downs or pitfalls everywhere en route, the road may be slippery, it may be raining or snowing.

All these conditions dynamically change. Accordingly, you will have to see what the conditions are and then apply that which will make a safe transition from one gear to another. You cannot really dispense with the gear change – it is there, but the only thing is it is automatic. All you have to do is just start your engine and then just engage the gear at say d1 or d2 or d3, depending upon the place you are in. Normally a d1 is enough – I have seen personally that it climbs even big flyovers with ease.

Next, after automatic transmission, what you see is avionic systems, air-borne systems. There are many parameters to be measured and you can implement all these, say latitude, altitude, wind speed and so on – these are some of the examples. If you have gone to the airport, you would have seen lot of baggage going to and fro from one place to another. The sources of the baggage may be many and likewise, the destinations may be many. You need to control all the conveyer belts or the security system within. Without opening the baggage, you have some X-ray taken on that, your baggage and contents are reported – all this you can automate.

The camcorders that you use as video cameras belong to the analog domain. You have a tape to record but this would demand again an ASIC design. The cell phone too is well known. For communication, you normally use analog and digital is the processing. You can design at least the digital part of the cell phone. When you have cell phones, you need to have base stations from which signals are relayed to the next one and so on – that is how you get cell phone messages. If you want to have a cordless phone, once again you may require some IC.

Again, coming to automobiles, you can have cruise control – you can just speed up to the limit that you want to go. This is especially useful if you are going on freeways – you call them highways in eastern countries. Once you lock on to a particular… just accelerate to the desired speed, let us say 50 miles per hour, and press the button, it will take over and maintain that speed. You can release your foot from the accelerator and concentrate on just applying the brake when the occasion demands. Otherwise, the cruise control will take care to keep your vehicle steady at 50 miles per hour.

Next is curbside check-in systems and this is generally for parking. If you want to park your car, you have to naturally pay for it. There will be automatic machines that take in this and issue a receipt. You can think of such applications. Another is the digital camera, which is very well known. Next, disk drives.

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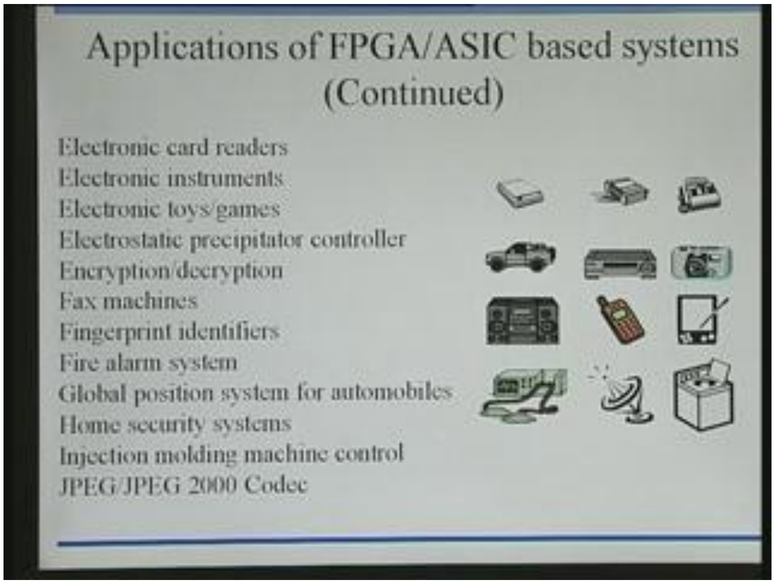

Then, you have electronic card readers – it is basically an identity card. You have innumerable electronic instruments, for example, the DMM that you use to measure voltage, current, etc. Once again, all these would call for different chips to be designed, be it FPGA or ASIC. You have electronic toys and games – there also, lot of scope is there for you to develop such controllers. Next one is electrostatic precipitator controller. This we will take as one of the two for considering the detailed specification. This is used for ash disposal in thermal power plants. Next is encryption/decryption – you can think of hardware. This is mostly in vogue as software and now, the demand has come for hardware encryption as well as decryption and you can apply to any part of the ATM or any such place where you want security.

If you want to send your data, your program code, etc., all this calls for encryption and decryption and you can do so; many researchers are already on the job and quite a few VHDL implementations have also come. Then, you have the fax machine or if you want to identify fingerprints, you can have another system for that. Then, if you want to have a fire alarm system, especially in multi-story buildings, huge complexes, you do require such systems wherein you want to detect the smoke or fire. For smoke, etc., Americium nuclear material is being used – basically, it is to detect the smoke and you can also detect fire by using a thermistor and so on. There will be a central control where you report zone after zone if it is a huge complex and within this zone, there can be many such detectors; every detector is identified and its location is announced if there is a fire; in the event of fire or smoke, you can have an annunciation there.

For automobiles, you can think of global position system to pinpoint where the automobile is or so that it directs the driver – a road map can be created on that. There is plenty of scope for work here in global position system and currently lot of research is going on in this area. Then, home security system if you want theft control protection or you want to have gas leak or right in the kitchen. In United States, I have seen quite many such places linked and a lot of sensors are put there to detect the high temperature increase or smoke or gas leak and so on; this will be normally connected through wireless to the nearest police station or fire station – you can think of designing such systems.

Another application is for injection molding machine control. Normally, for ABS, you use plastic made components such as plastic casing for your cell phone or any other equipment that you think of. You can use for timing control and that is what is called injection molding machine control. We have already seen a camera example – JPEG codec is also one such. If you want a still picture, you need JPEG; if it is DCT based, which we have already seen, you need JPEG; and if it is DWT based (discrete wavelet transform based), you need JPEG 2000. If you want a motion picture to be processed in JPEG2K like thing, you have a motion JPEG2K for the same.

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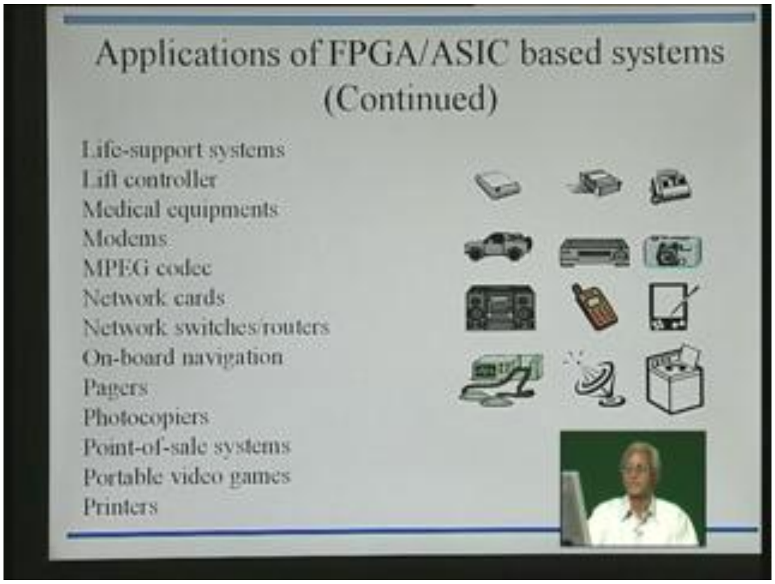

There is plenty of scope for you to develop algorithms, architecture, and finally implementation as FPGA or ASIC. Then, life support systems – basically one of the medical equipment which is [15:17] down once again and there are various things like ECG. I am not a medical person, so I cannot reveal much about it. You have the lift controller, which is a very good candidate – FPGA or ASIC implementation can be very easily done for a lift controller. You can use it for modems and MPEG codec also, some of which we have already touched earlier. MPEG-1, MPEG-2 or MPEG-4, MPEG 7 – all this can be implemented. Of course, many people have already used it for network cards and so is the case for network switches, routers etc., – you can also attempt some of this.

Then, if you want on-board navigation whether it is air or ship, you can use it for navigation purposes; whatever engineering parameters are to be monitored and controlled, we can use FPGA once again and so also ASIC. You know pagers – I do not have to explain all that. So is the case for photocopiers. You would have gone through shopping malls and supermarkets. You have a point-of-sale system there. All your bills are being routed there and all the items that you purchase will be separately labeled and will have a bar code. Then, what you have to do is just expose this bar code and the point-of-sale system will accumulate all that and convert it into a bill. Once you make your payment either through your credit card or ATM card, finally, a transaction takes place. For that, you need point-of-sale systems. Next, portable video games, battery-operated portable video games and later on, normal video games using bigger displays will also be shown. The printer too is well known and many people have done.

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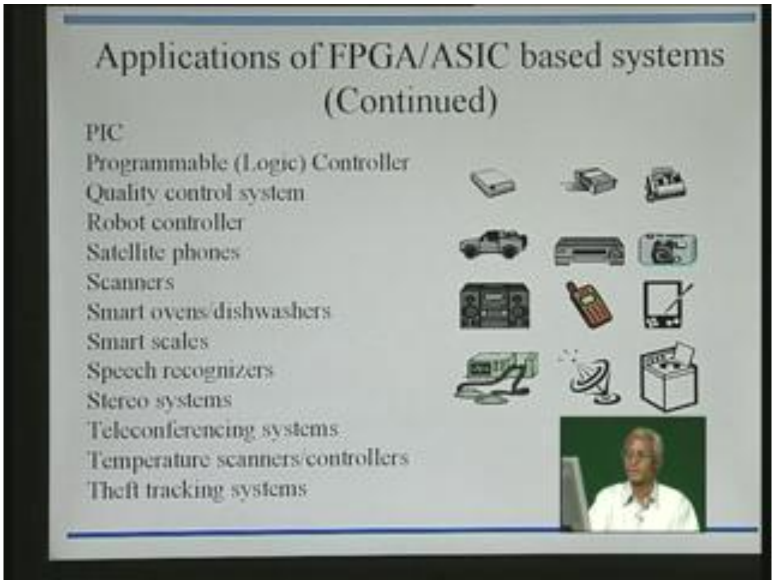

Peripheral interconnect is what I have mentioned already – this is basically a logic controller. What is coming next is the programmable logic controller or programmable controller. This is higher end of PLC and programmable controller can not only solve logic, but also acquire data in a limited way. This is well known for many of the industrial applications and PIC is one such very limited thing confined to say 32 I/Os etc., with one timer etc., and normally that goes as an embedded system controller.

If you want to have a quality control system, you can build a system that will do this. For example, if you have an assembly of painted cars coming, you can have a camera and then capture the video frame, and then compare it with the good known finish. With this, whether it is, you can record pass or fail – all this can be done if you have a good control system and that is what we mean by quality control system. You can apply the same thing for any other industrial product. Robot control is very well known – it is basically using different motors, especially… what is the motor called here? I will recollect later on and tell you what type it is.

Then, you can have satellite phones and scanners. Then, smart ovens you can have. Everywhere you need a lot of control to be done, timing to be done. So is the case with dishwashers. For all this, you need control. In the robot controller, a stepper motor is normally used there and you can have a smart scale, for example, taking your weight or when you purchase, you can have a weight and this can be linked with the point-of-sales terminal that we have already seen.

You can have speech recognizers and then stereo systems. Of course, it appears simple an application, but these things are becoming more and more complicated these days. It demands particular ICs to be used. You can use teleconferencing systems and for this, you can have JPEG or motion JPEG or MPEG-1 codec, etc. – you can use for teleconferencing. Then, you can conceive of temperature scanner or a controller for industrial purposes. That can be multi-channel, say eight channel or sixteen channel or even more – even hundreds of channels are there. You can design a controller that will take in JK thermocouples or thermistor, thermocouple or even simple temperature sensors like AD590. You can have another system – theft tracking system. This is normally installed even in automobiles, cars, etc. For that, you can design such systems.

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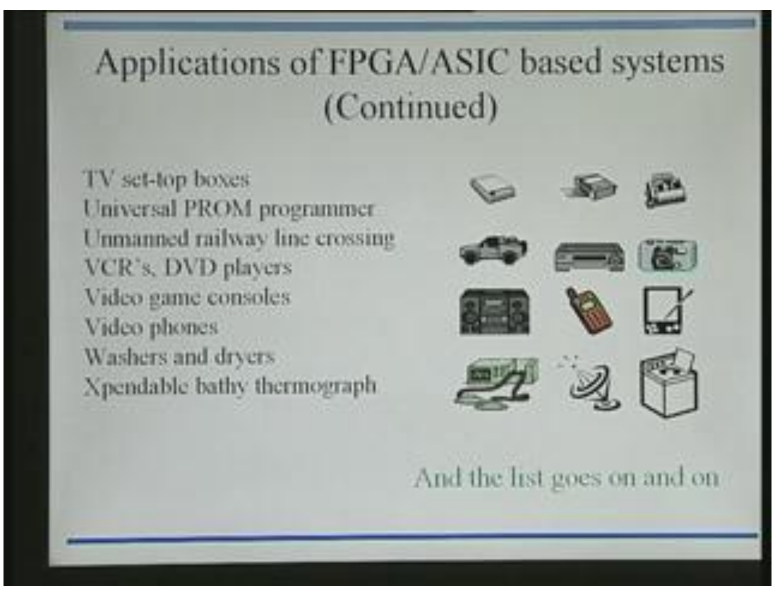

Then, you can have TV set top boxes. Many cable operators are offering limited number of channels. You need to pay only for the number of TV channels that you want to see and for that, you need this. Of course, you can have a universal PROM programmer and you can design a PROM program for that, for not only PROM but also PALs and some microcontrollers. All this can be programmed and multiple of them. Many features can be introduced in this. If you want, you can make a digital IC tester and you can have various ICs – you can see what is already covered or what is not covered and you can always add. Another application that normally is not touched by many people is the unmanned railway line crossing. You see so many accidents taking place because railway lines are unmanned. I would suggest that one of you seriously take it up. I even have a detailed specification but I am not going to cover it. You can try this – once again, it is basically FPGA to start with and then you can migrate to ASIC later on when it is frozen.

Even VCRs and DVD players come with a lot of ICs and you can think of that as well, although there are so many players around. Video game consoles we have already seen earlier and this is an extension of higher end version, which you would have seen in many video parlors. Of course, video phones you can use – we have already seen that; JPEG or MPEG we have already covered; along with video conferencing, we can use video phones as well, so you can think of this. We will be clubbing JPEG as well as MPEG, video phones and video conferencing and be covering them a little more in depth in terms of block diagram as well as the basic specification along with the electrostatic precipitator, which we mentioned earlier.

We can design washers and dryers. The last one I have listed here (maybe around 61 or 62 – I will leave it to you to count) is expendable bathythermograph, which I have myself handled decades back; I heard that it is still in vogue. This is to sense the temperature of the ocean without stopping the ship as such and it normally uses a thermistor from 4.7 K at the tip of a spool which will…. There will a spool with twin bonded wire and it can be launched from the ship's rear end. When the probe touches the water, the recording commences.

You can have a strip chart recorder for continuous analog recording or AND/OR rather and digital output periodically sampled. The depth it can cover is 0 to 1500 feet and as it goes deeper and deeper, the temperature becomes colder and colder. By using this, you can find out what is embedded in the ocean bed, whether mineral or oil; school of fish can also be caught using this. You can conceive of such applications. The list goes on and on. In short, it is limited only by your imagination.

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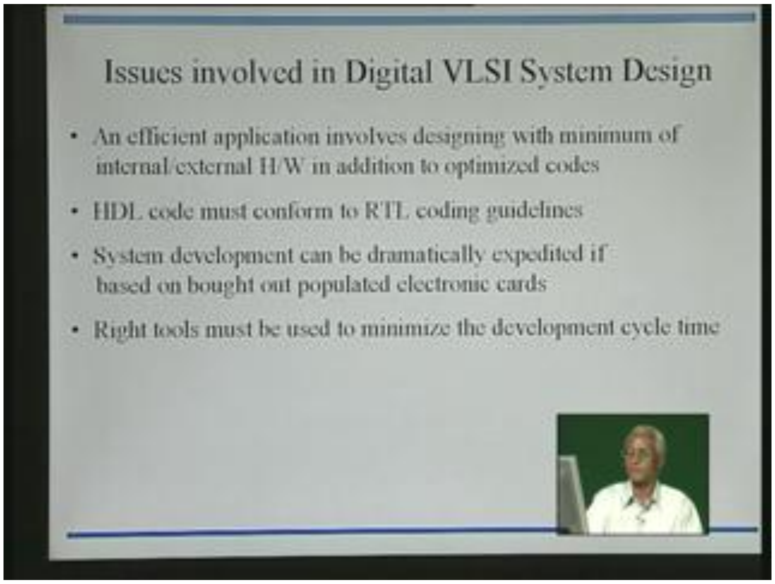

We will go for two of the applications and before that, let us just recollect what we had to take care of, what are the issues involved in digital VLSI system design, which you are already familiar with – I will again remind you what is to be done. An efficient application involves designing with minimum of internal/external hardware in addition to optimized codes. You had to not only optimize your Verilog code but also reduce the hardware, both internal and external. Internal is what is inside the FPGA that you have coded – it also means ASIC. The design, the chip area is what I mean by internal area. External means you need to connect the interface signals – no system will work without the interface. In fact, if you look at the cost considerations, it is the external hardware that takes up more of the cost rather than the internal hardware – this is true for most of the applications.

You have to take care of both internal as well as external hardware while designing and naturally, it calls for a minimum of hardware because that is going to determine your system cost. This is in addition to the optimization of your codes, which we have already seen many times. The HDL code, Verilog or VHDL, must conform to RTL coding guidelines – this we have been repeatedly saying; without it, no chip will work normally. Even if it works, it will start malfunctioning and will give all sorts of problems later on.

The next point is that system development can be dramatically expedited if based on bought-out populated electronic cards. In fact, we have used digital I/O card as well as the FPGA card, which is the populated card – populated and tested so that you are relieved of the burden of developing this hardware. That is the positive end. The negative side is that it may not suit your application and so you may have to make some amendments as we have done here, by cutting and connecting elsewhere in the form of expansion I/O ports and so on. You need to add more push button switches and in some cases, you may have to add interfaces such as opto-isolators, relays, etc., and will have to take care of all this before you do.

First, you have to make an overall assessment before you take up the system development and that is what we mean by going for populated electronic cards. At least when the quantity is less, it is a good idea to go for populated cards. Once the hardware is proven, you can tailor make for the particular application and thereby, you can make a cost-effective system if it is going to be in large numbers. If it is not going to be in large numbers, you can rest content with the populated cards themselves. This is an important thing. The next point is that the right tools must be used to minimize the development cycle time.

We have already seen that simulation and synthesis as well as the place en route tools having been used. If you go out, you should not just download institution tools and then be content. They will have a lot of limitations and you cannot really make any worthwhile product that you want to sell in the market. If you are aiming for R&D work also, you have to have the right tools and in the proper mix – you have to use them in the right measure and that expedites the development cycle time. Let us consider two such applications.

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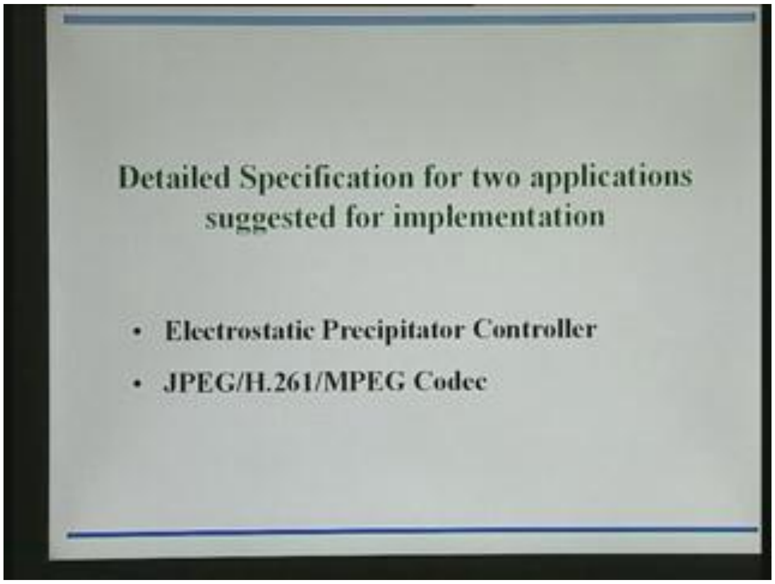

The first application is the electrostatic precipitator controller, the second one is the JPEG and this H.261 you can correct it as 263 – I think that is the latest one and this is for video phones as well as for video conferencing. MPEG codec: JPEG and MPEG based on DCT, we have already seen as DCTQ. We need to add more modules to that in order to make the second application feasible. What we are going to cover is only detailed specification along with the block diagram, but it is up to you to study and see different sites or the references I have given towards the end. If you still want more information, you can always contact me.

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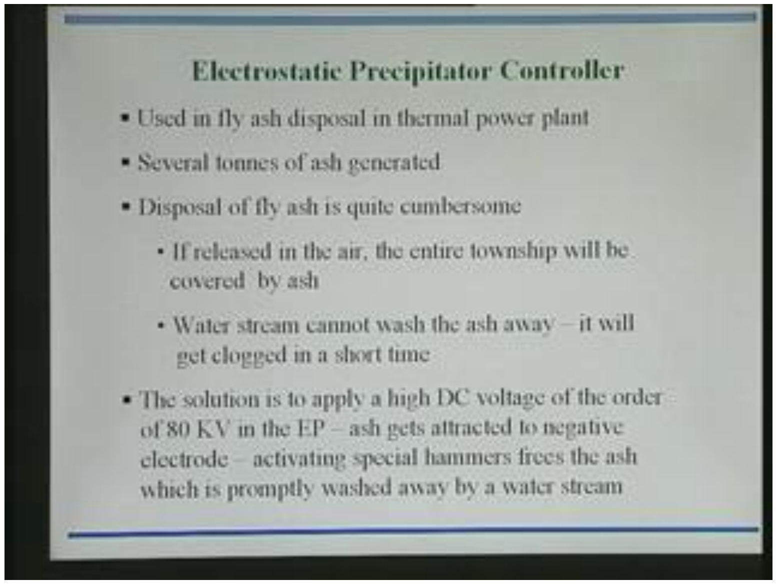

Let us go to the first application. This called the electrostatic precipitator controller. It is used in fly ash disposal in thermal power plant. When you go to a thermal plant, you will be told that there will be several tons of ash generated every hour and it is going to be a very cumbersome affair to dispose of the ash. For example, if you released it in the air, the entire township will be covered by ash. This I have practically seen, because I have myself handled one of these controllers. Of course, what I designed did not bring about that covering, but I have seen such a thing – few malfunctioning units had covered the entire township, including suburban trains (in which I used to travel).

Another problem is water stream cannot wash the ash away. It will get clogged in a short time, no matter how big the opening is. The remedy for this is as follows: apply a very high DC voltage of the order of 80 Kilovolt in the EP (electrostatic precipitator abbreviated). If you do that, what will happen is the basic electrode is negatively charged and positive charge is on the entire chamber. Naturally, the ash along with the flue gas is pumped in at a very high rate and naturally, it brushes past all this positive because the whole chamber along with the tubing that connects will be basically positively charged. Naturally, the ash gets this charge and once it enters the chamber, it will see the electrodes crisscrossing the entire chamber.

The chamber can be very huge – as big as a studio here, and it will be full of electrodes and that is negatively charged. Any ash that already has positive charge would naturally get attracted to the electrodes and gets deposited all over the electrodes. In order to get rid of this ash, what we have to do is we have to activate special hammers so as to free the ash. Once you free it, it will fall down owing to gravity and collect at the bottom. At the bottom, there will be a stream of water going and like a tame bull, it will be washed away very conveniently. Each ash particle acquires the same negative charge. So I think one particle of ash will be repulsed so that they do not cling to each other. Without this application of 80 Kilovolts, naturally, at the slightest of excuse, the ash gets airborne and that is how it fills the entire township, if left straightaway.

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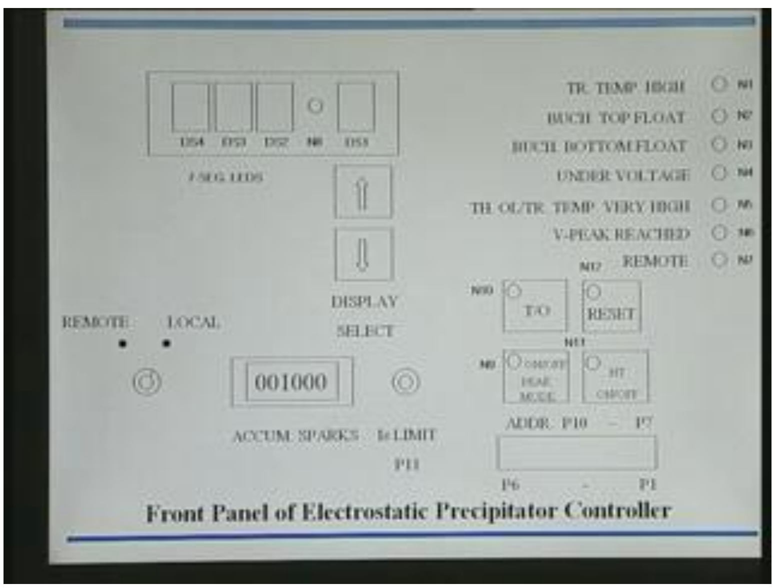

The control panel is like this. This is required because when you design a system, what is apparent to the customer is the actual control panel. You see here four digits display, one digit called DS1. This is to tell you which mode we are in. This is not even hexadecimal, we will explain what displays are there. You have N1 through N8 displays for various parameters. For example, in order to generate a 80 Kilovolts, you need a high-voltage transformer [32:59]. Normally, you would see that on the thermal power plant right on the top. Most of the thermal plants have that right on the top and that is abbreviated as TR meaning transformer. If it is high, this LED must be on (Refer Slide Time: 33:15). If it is very high…. Otherwise, thyristors are there in order to generate a DC supply from the AC supply – we use thyristors for that. The thyristors are also to be fired from this controller – what we are going to design. Any thyristor overload (overload means it basically reflects as current there) will also have to be sensed and indicated here. You have a transformer and therefore there will be some oil cooled. So you need top float or bottom float – you have to know the oil position there.

This unit itself will work only up to a particular voltage. If the voltage goes below a particular level, it has to indicate the under voltage. Normally, it is —40 percent. If the line voltage goes below, it will indicate here. This we have already seen. Then here, we mentioned that we apply very high voltage in order to collect the ash. Needless to say, the flue gas that goes past these electrodes at a rapid rate along with the ash will make the electrostatic precipitator current highly fluctuating. The voltage also will go up or down accordingly and so it always sees some valleys and peaks – it goes up and down and so also the current. When that voltage peak has been arrived at, that also will have to be indicated and that is what is here.

You can put this controller in either a local mode or remote mode – that is indicated here. The switch for doing that is shown here and there are two positions. Since high voltage is involved and the current at a particular moment may be quite high, sparking may take place – it may be as bad as lightning that you see up on the skies. Naturally, that will lead to deterioration of the electrodes and eventual breakdown or burnout and so you have to count this sparking – here, we use the terminals sparks. Accumulators sparks will have to be displayed in an electromagnetic counter. Even if there is a power failure, this will have to preserve what all it has accumulated till date.

If you want to set the precipitator current, you can use the [35:47] meter here. This is the part meter that we are going to see in the block diagram. We have P1 through P10, a bone spot meter here, there will be label here. You can open that and then set. Once set, it will normally not change till you want to make some other setting. There will be two BCD switches here, just underneath address. They furnish the decimal identification number for the controller. You can set from 0 through 99 – that means 100 such controllers can be networked.

There can be one common computer system from which you can control or change the parameters of any of this controllers. The intake for many of the thermal plant is quite high, because I remember that for every 1 Megawatt of power that you generate, you need 1 unit for this. Normally, they have units of twelve. Even if one fails, ash will get airborne. You have a keyboard also here. It is not only a keyboard here that you see with these four plus two keys but this is to also change the mode – up arrow as well as down arrow,

There are three other LEDs in order to measure the current, voltage, etc. Then, you have a timer that you can switch on so that when you apply HT…. This HT is 80 Volts or whatever you want to apply. This is a toggle mode and if you press once, it will be switched on. How rapidly it should climb up to the high voltage will have to be determined and you can determine that by a switching on a timer. If you want it fast, you just repeatedly press this and it will speed up, expedite the slope. You can go for what is called peak mode – it is basically to measure the peak, etc. These are all the controls that you need to understand in order to design.

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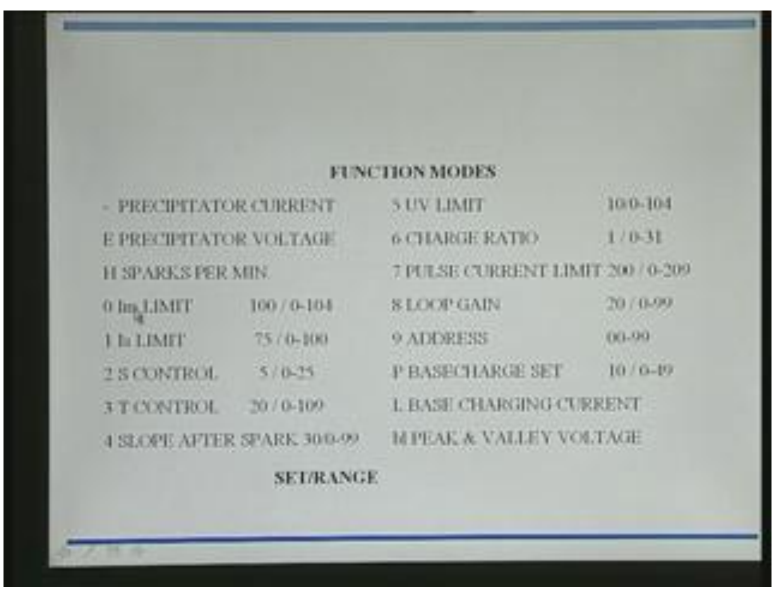

Now, we will go into the some of the function modes. For example, you can display minus there. If you do, it will indicate the precipitator current on the three digits that you have seen earlier. Here (Refer Slide Time: 38:05) will be displayed the precipitator current. You use this display and use one of these keys in order to go from one mode to other. The minus mode takes the precipitator current. It displays the actual precipitator current. It is actually rated up to 1 Amp maximum and 80 Kilovolt is the DC voltage, which is next. E stands for the precipitator voltage. How many sparks have occurred per minute is also very important because safety is very important. That can be got in H mode.

Then, the maximum current that you can set is determined by the 0 mode – Imaximum limit. What is the normal standard current that you want to set? Normally, you set for 75 and these are all the set points for that. The maximum is 100 and the range is 0 to 104. This 10 corresponds to…. You know we are going to use an eight-bit ADC and it is unsigned. So the 256 would correspond to 5 Volts, 0 to 5 Volts is 0 to all fs eight bits. This 104 corresponds to that all fs. That is what you have to know and so is the case for all other parameters. There are so many other parameters that you need to set initially. All these will have to be non-volatile and therefore, part meter has been used, which you have already seen previously – setting P1 through P10 there.

There are other parameters called slope control, timer control and so on. You do not have to know the details of this. All that you have to know is 5 Volts should correspond to… not 5 Volts actually, all fs; 5 Volts would correspond to 256 in decimal, 255 is the one that corresponds to this or 100 or 104 in ADC output and so is the case here. T control and slope after spark. What is to be set is here and the range that you will need to cater to is here. So 0 would correspond to 0 of ADC output binary eight-bit and ff in hexadecimal of course; 255 in decimal would correspond to 99 for this case, elsewhere 109 and so on. So is the case for this under voltage – UV is not ultraviolet, we have already seen that it is under voltage and that also you can set here. Normally, 10 is set here and up to 40 also can be set.

There are other parameters: charge ratio, pulse current, loop gain. This is normally for one of the precipitator current or the voltage – what is the gain to be set because there are analog channels as well. This is the address that I have mentioned already – this is the unit address, precipitator controller address. Base charge set, charging current and peak and valley voltage are the parameters you need to see the charging current, how fast it is charging and what is the base charging current.

All have the same notation, so 5 Volts would correspond to two digits in decimal for eight-bit ADC output. You need to find the peak as well as the valley voltage. So the three-digit display that you have in blank mode will alternately give the peak as well as valley voltage. Note that the settings are there only for this and not for this, because these are all actual field measurements – for example, all these. That is what is given as set and range here.

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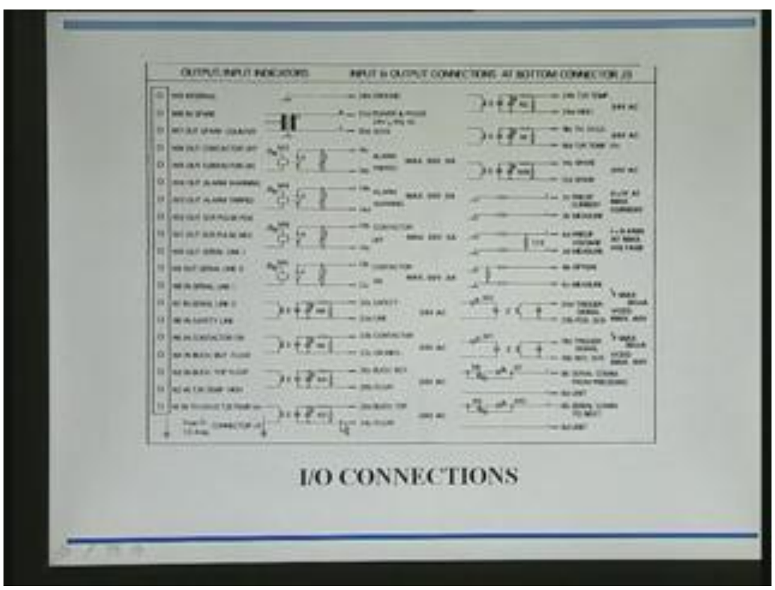

Actually, the rear end of the unit will have all this I/O connections. I do not have to go into the details because we have already covered different LEDs, etc., for example, alarm warning. All this was there in that. This is thyristor overload, temperature high and precipitator current – all these are actual places where you want to connect, basically I/O connection. Do not take these very seriously. Here comes the I/O card.

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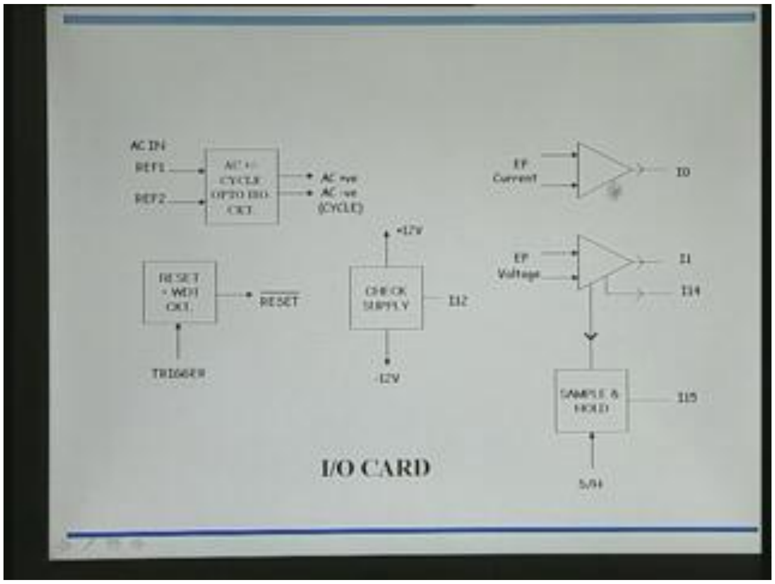

There are basically two cards or three cards rather. One is the I/O card as well as where the signal conditioning will have to be done. It has electrostatic precipitator current. This is the analog op-amp you have to use. You have to use in differential mode a two stage amplifier. This first stage is for CMRR adjustment so unity gain and so is the case here, except that this will be sensing the actual current. You have a register here and let the voltage flow here. For current, you need to measure the voltage and for voltage, you need to measure the current. There will be a resistor here for this, whereas there is no resistor here. That is all the requirement here.

This goes as the I0 channel and this goes as I1 channel as well as I14 channel – intermediate voltage also is required here. We need a sample and hold circuit. For that, there is a control required and this is the fifteenth channel. I0 through I15 are different analog channels here. You have to check the supply as well. You need a watch clock timer here and a trigger will have to be created. You need to know which is the positive cycle or negative cycle – that is what is here. You need to connect the transformer here in order to know which cycle you are in.

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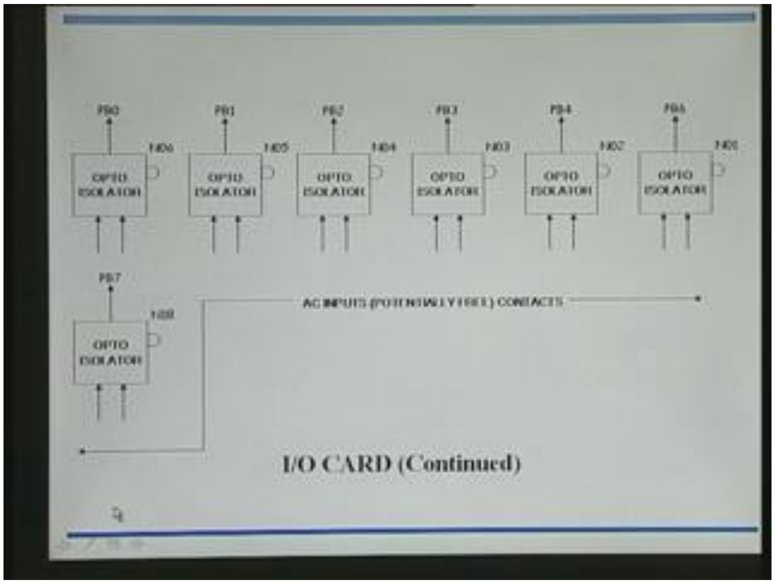

Here are the seven circuits for opto-isolated inputs. It is potentially free contact for various parameters that we need to measure, which we have already seen earlier as temperature high and so on. There are seven.

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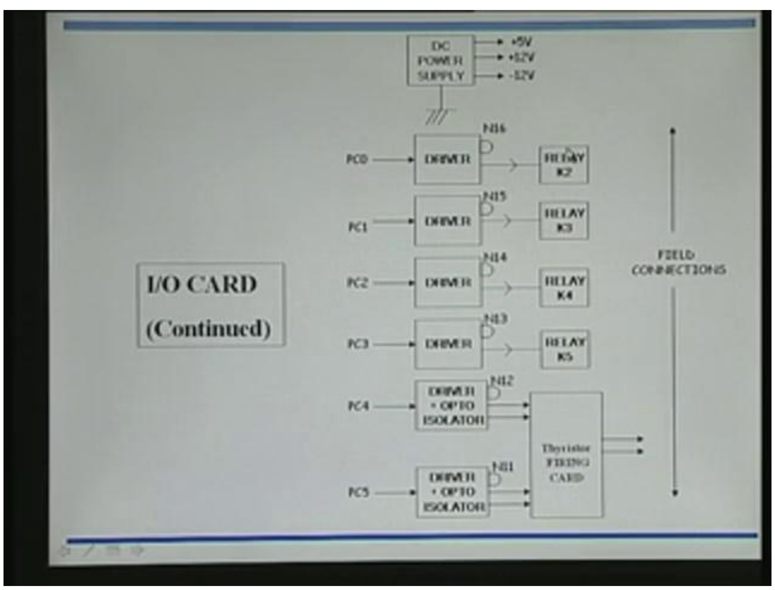

The I/O card also has four relays at the output and there are drivers. These ports are the ones that we will have to connect to the FPGA board and the power supply is shown here.

This will go to field connection and these are all the opto-isolators, the output here – there are two such numbers here. There is a firing card here that will house a pulse transformer in order to give to the gate of the thyristor.

There are two outputs that will control the full wave thyristor for both positive cycle as well as the negative cycle.

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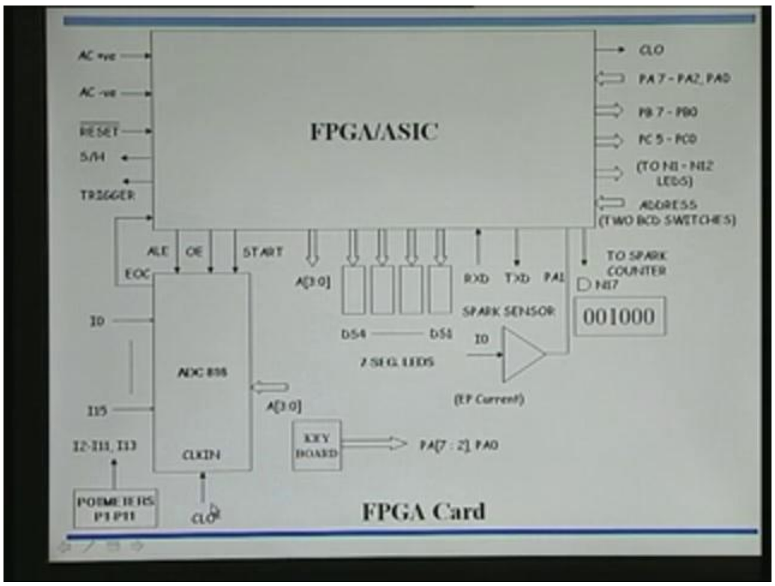

This is the FPGA that we will have to design and AC positive, negative we have seen. We had to have reset from watch [44:49] timer, we have to create sample and hold from FPGA and we have to also create the trigger. For ADC, you need a start pulse, then output enable pulse, then ALE is also required so that you can give the address also from here – which channel you are referring to. At one time, you can only measure only one channel input as such. This we have already seen and I2 through I11 and I13 are for pot meters.

There is a clock output here, which is also pumped in from the FPGA here. You have four LEDs, which we have already seen right in the panel. You also need to have serial transmission, so RXD and TXD are required. You need a spark sensor, this I0 channel is applied electrostatic precipitator current and it goes to one of the ports here. There are so many other ports such as the ones listed here and many LEDs are also required for displaying different things – these are all basically output. We have already seen that two BCD switches are also required.

You require one-bit output in order to apply pulse whenever a spark takes place. This is the electromagnetic counter – there is also an LED to indicate when it is active. A keyboard is also there and this you can connect to this in a matrix fashion or independently as a port and then sense which key has been pressed. This keyboard is what we have already seen in the front panel. This is what is the FPGA card for the first application.

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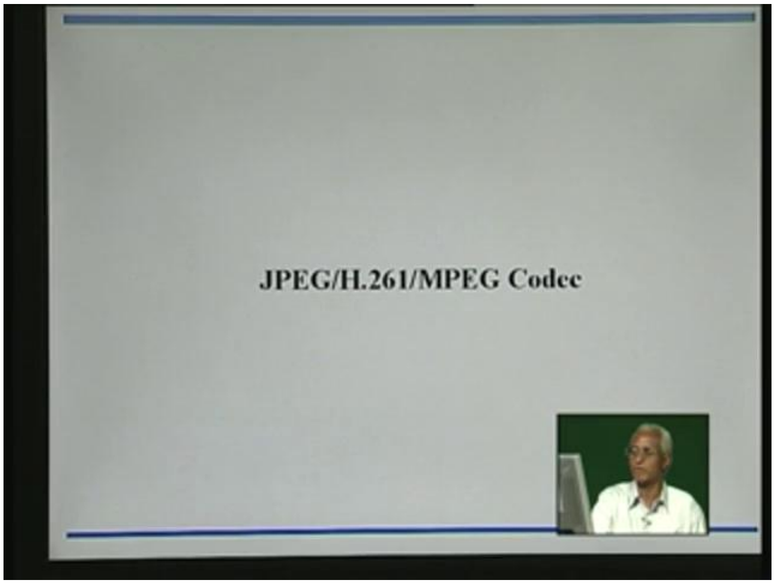

In the second application, you are already familiar with JPEG and MPEG as well as video phone.

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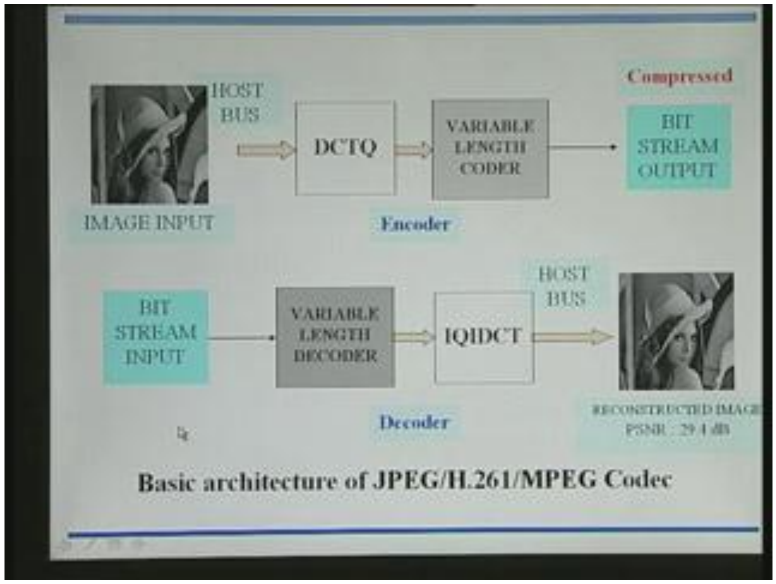

That is what is shown here. Image input is applied, DCTQ we have already seen in depth. What you have to design is the variable length coder as well as its inverse. This is at the encoder end – the bit stream is the output here and it is received here at the decoder and then, the inverse operation will have to be done. IQLDCT also we have already seen how to do. Out comes the reconstructed image. This is the hardware reconstructed image, which we have already shown to you as DCTQ previously. Around 30 dB, you have got a fairly good image.

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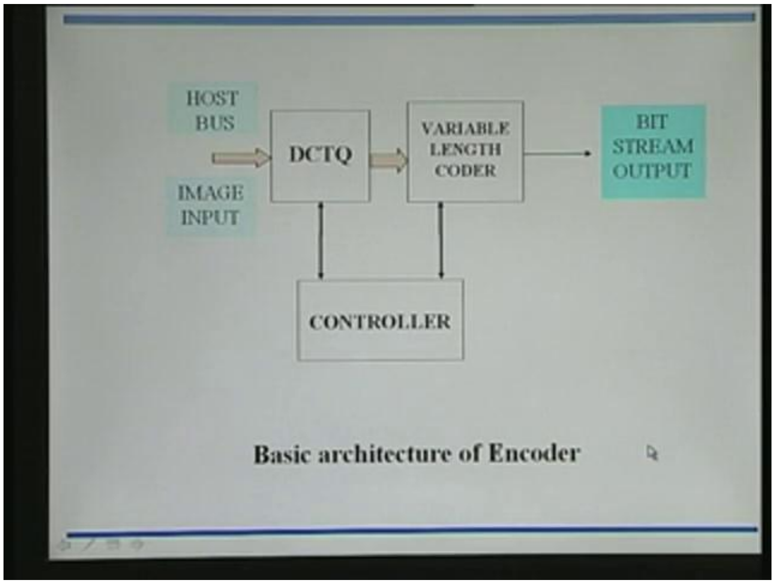

What all you have to do is you need to design the variable length decoder before you output the DCTQ output on to the stream. You also need to have a controller at the encoder end.

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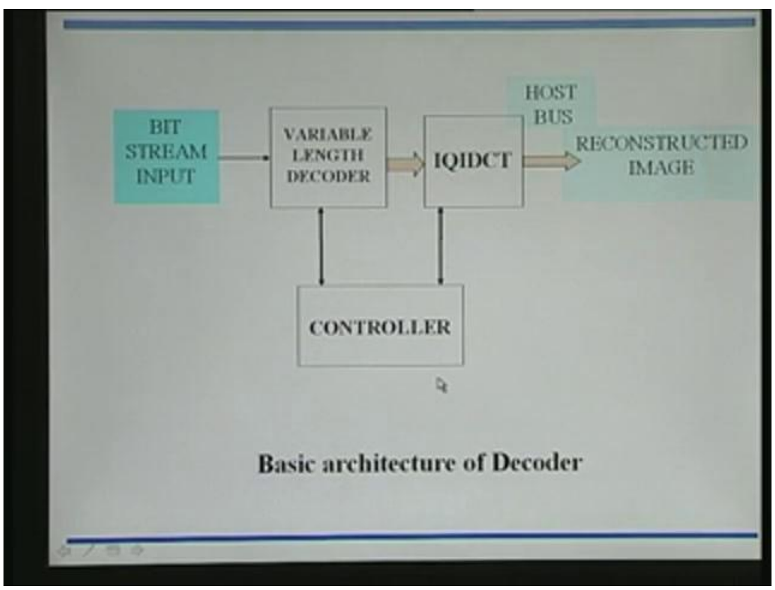

Next is the decoder. It is just the inverse operation in order to get the reconstructed image.

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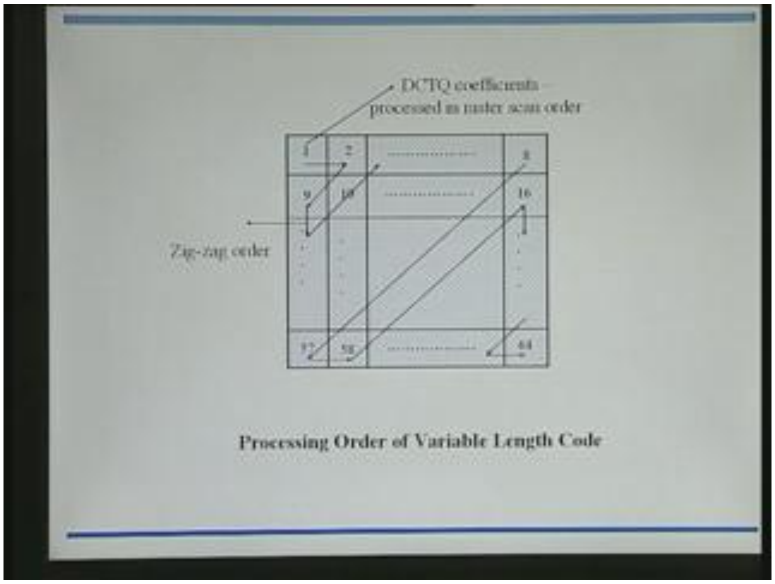

The DCTQ is actually created in raster scan order as 1, 2, 3, 8, then 9 and so on. This is per block – per block is eight by eight pixels. In VLC, you have to code in this fashion: 1, 2, then 9, then go on to 17, then 10 and so on. It goes diagonally and it is called zigzag order and right up to 64. This is for the variable length code processing.

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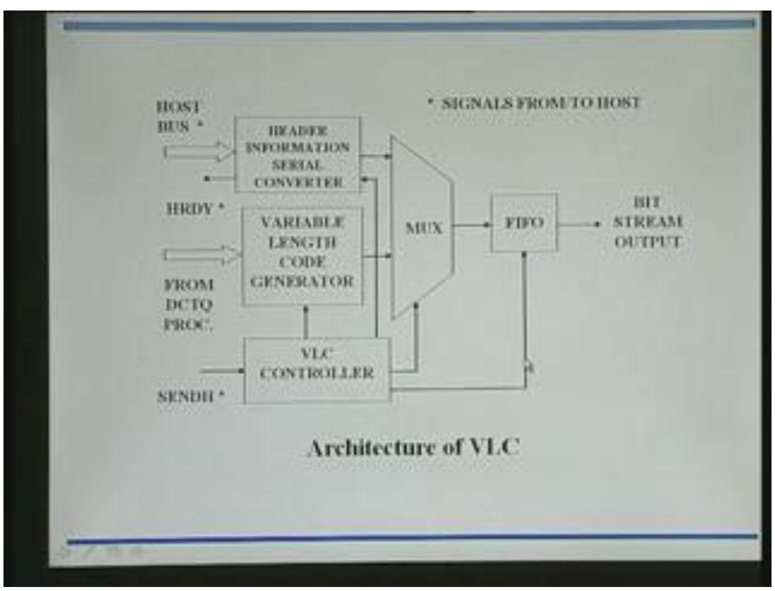

The block diagram for the variable length coder is here. This is the main unit wherein DCTQ is fed and each of the coefficients is translated into a variable bit. At the lowest end, it will be two bits and at the highest end, 28 bits. Finally, all said and done, you get a compressed bit stream here. You need a FIFO so that you accumulate first all the bits and then finally transmit in a controlled manner.

If you want, you can add one more called rate control and there is a MUX here, so that we can get either the normal VLC or the header information. Header information is what you give say through the host bus as to what is the picture size that you are going to send and what is the bit rate – all that information can be sent here and that can be sent through the host. The reference for this application is given at the end and there are papers as well to that effect from the speaker.

There is also a controller that handles all these activities. When to send the header is indicated by the host – the host will have to give this here. When the whole VLC is ready will have to be given by you, the designer – to say that, the header ready signal is asserted. The host bus is what is connected here.

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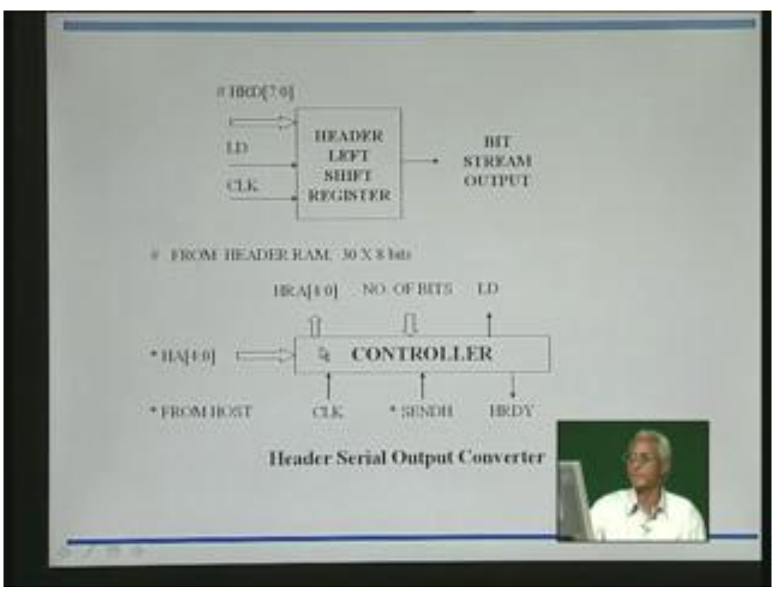

Next, we have a central controller for the VLC with send header, header ready and clock. From host, you need to give the address as to where you want to send the header. The header is up to 128 bits and so several bytes are required – in fact, 30 bytes are required. You need the address for byte count and that is what you give here. The number of bits you have to send out through the bit stream and it will also have to be given by the host.

This load is from the controller, which is to load the header register. These are all internal things you should get from the RAM, which was written by the host in the header RAM. Get one byte and load it here. This is a left shift register. You output that particular bit after bit as a stream here. That is how you get the…. This is called as header serial output converter.

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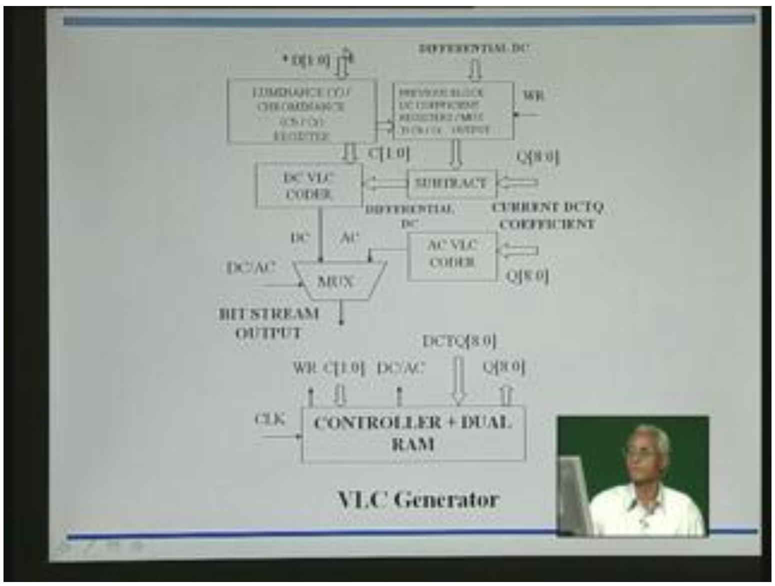

Next is the basic VLC generator. This also has a controller with many DCTQ quantization, which you get from the previous stage. Whether it is a DC quotient or AC quotient is being set from here. Color component, which component you are processing is input here and then, the write signal is there. Of course, there is the clock. You have basically DCTQ applied here (Refer Slide Time: 50:27) and you have a subtractor here, which will take the previous block DCT DC value and then that is registered here in these registers.

For three color components, three registers are there and depending upon luminance or Cb Cr which can be input here from the host, which will identify which color component you are processing. For each color component, you have to process separately. The very first coefficient that you give is DC coefficient. You have to take the previous value of the DC, previous block and the present block and subtract the two. The present is applied here, previous is applied here, take their difference and then apply the DC VLC coder, which is nothing but a VLC table that is furnished in the reference – that will be given here. If it is AC coder, that is also governed by the same table. Once again, you input here. For this, you have to find out from the table which code we have to pump in here, depending upon DC or AC. There is a MUX and there is a control there, which will finally output at the bit stream here.

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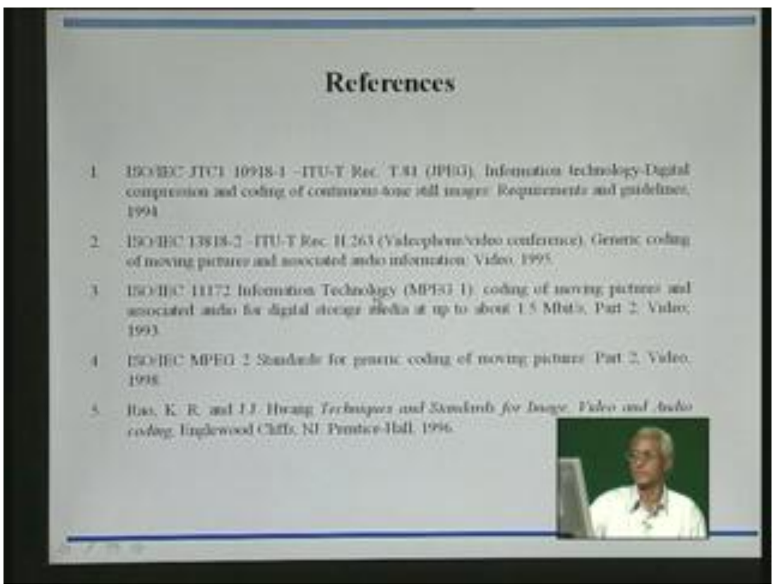

The references I hope are clear. Are you clear? You will get more clarity if you refer to the references here. These are all the standard references for JPEG H.261 and for MPEG-1, then MPEG-2. This is a very good book by K. R. Rao for techniques and standards for image processing.

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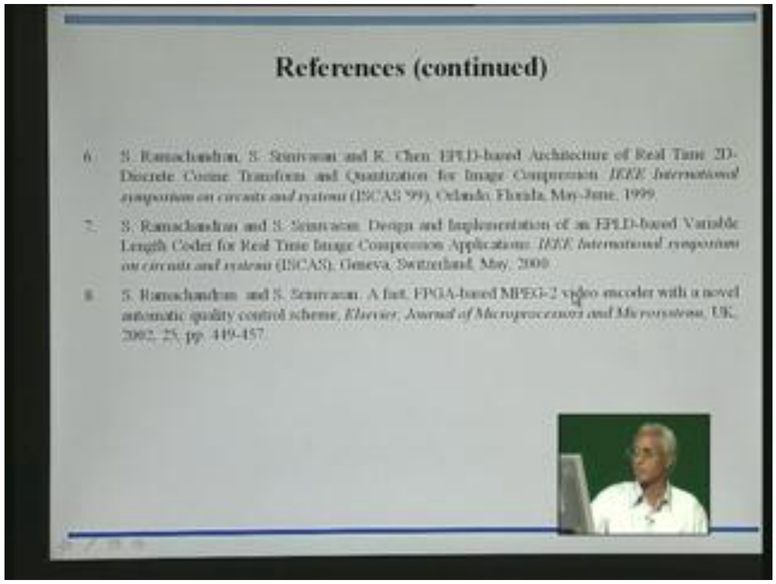

Next is from the speaker and there are three papers. One is to the effect of DCTQ and another is for VLC here. These are all IEEE conferences at Florida and Geneva. You can refer these references. There is also a journal paper in Elsevier for MPEG-2 video encoder. If you apply these three put together with the standards, you can easily code for the VLC as well as for VLD.

In the last 50 or so lectures, my colleague Dr. Ramachandran and I have given you an overview and a detailed design knowledge of digital VLSI system design. As introduced to you in the introductory lecture, in the first lecture, we went through the digital system design or advance systems design and more important than the systems being advanced, systematic design procedure and how to use various tools available to convert the design into hardware description language and from there, to simulate it, synthesize it and place and route an FPGA.

Many examples are shown during the course of these lectures, many demonstration were made, codes were given and you have been given a very long list of ideas on which you can work further to make your own designs. You can very freely use any of the codes that was developed in the class because they have all been tested and demonstrated – all are working codes. So any of those codes you want to, you can always use in your design for your system and make your design effort simpler to that extent,

Secondly, you do not have to limit yourself to the ideas given. These are only various ideas we had about what you can do yourself. There are many more things you can think of – in innovation, your creativity is the limit. You can go and do all those designs, come up with newer and newer designs, but the basic point is whatever we have taught you are basics and along with this, you can improve your knowledge. As I said, it is technology independent – it does not matter what technology it is.

The designs are portable – you can also try it on another FPGA even though we have used Xilinx FPGA as an example in this course. All these things you can do yourself and that way, you can enjoy the whole thing. I hope you were able to understand and follow most of these lectures and whichever lectures you have not followed, go on repeatedly seeing them again and again. If you repeatedly see them, you will get to know the idea. Sometimes, when you do not understand something, it is because you missed the earlier lecture or missed the concept in one of the earlier lectures. The idea is to go back those lectures and see them again and again. Then, you will get a good idea.

But more importantly, it is not enough if you just see lectures. You have to try it yourself. Take simple examples, start writing codes, compile them, simulate them to start with – do not even have to synthesize and place and route. It depends on the facilities available in your college or the workplace, but once you are confident with simulation, then you go looking for hardware and then start your synthesis process, place and route and try new ideas. You can submit project proposals either for competitions or for your own project in the class or in industries. If you are working in an industry, you can use these ideas and then come up with solutions for existing products [56:18] designing or new products– your manager will appreciate all that.

Both of us would be extremely happy if you feel that these lectures have been useful to you in your quest of knowledge in the domain of digital VLSI design. As I said earlier in one of my introductory lectures, digital is only one aspect of VLSI design. VLSI design has analog design. Analog is less than 10 percent of the total design but effort-wise, it is non-trivial. You can try mixed signal design where both analog and digital will reside together in one single IC – single design. Then, there are issues like CAD (computer aided design) tools, fabrication issues, low power designs and so many other things. Once you are interested in VLSI, there are so many areas you can pursue. We would expect you to use these things properly and we will be happy if you have derived the benefit that we had in mind for these lectures for you. I hope you enjoyed listening to these lectures as much as we enjoyed teaching you this material. Thank you.