Computer Graphics
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Lecture-2
CRT Display Devices

Welcome back everybody to the video lecture on Computer Graphics. Today we are going to discuss about CRT display devices or cathode ray tube display devices. In the lecture on introduction to computer graphics, of course we have seen various types of I/O devices which are used in the field of computer graphics and a few of them are used for output as well as for input. The output devices are the monitors and the input devices are the keyboard or mouse. Let us look at a few examples of computer graphics devices especially the input and output devices, the CRTs cathode ray tube as they are called.

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Then we have the EGA, CGA, VGA or SVGA monitors. The graphic adapter stands for EGA, CGA we have the Color Graphics Adapter. We have the Video Graphics Adapter VGA and Super Video Graphics Adapter SVGA, plotters, various types data matrix for displays, laser printers, films, flat panel devices, video digitizers, scanners, LCD panels, keyboard, joystick, mouse, touch screen, track ball etc. So these are various examples of computer graphics devices. Out of these we are essentially going to discuss about CRT monitors in this lecture.

CRT monitors are the most commonly used display devices. Of course there are other better types of display devices which are coming out based on solid state technology, it could be the flat panel devices, or the plasma devices, the organic LEDs and other devices but most commonly in the world and specifically in our country most of the display devices are based on CRT monitors. So, what are the different types of CRT display devices which have been there or available? The first one of them, the simplest one is the Direct View Storage Tube or the DVST.

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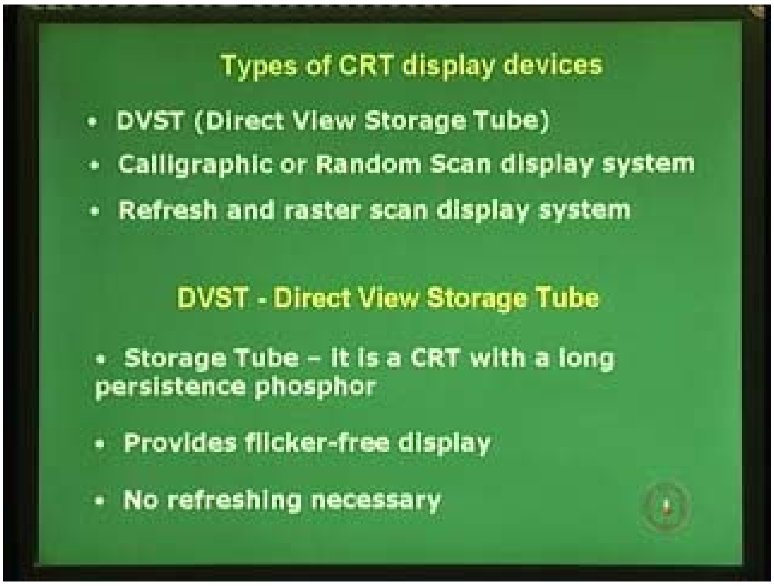

The second one is the calligraphic or random scan display system. The third one is the refresh and raster scan display system. All these three devices we will discuss in details but the common part of these display devices is the concept of the cathode ray tube or CRT. We will first look at the very basic and the simple one which is the DVST or the Direct View Storage Tube. The storage tube is a CRT with a long persistence phosphorus or phosphor, we will see what it means. It provides flicker free display, there is no flicker in the display and it does not need to refresh the contents of the screen. These are the three fundamental properties of Direct View Storage Tube or DVST.

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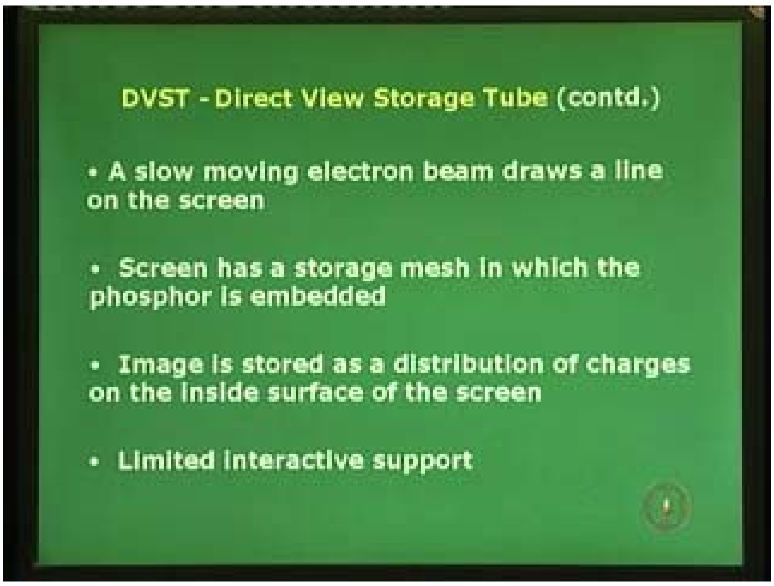

Essentially the DVSD consists of a CRT where we are having a slow moving electron beam which draws a line on the screen. We will move to the diagram of the CRT screen to see how the electron beam is generated and how it is guided on to a particular point on the screen. But this electron beam is essentially the basic component of the CRT which is responsible for drawing a line on the screen, we will see later on how it is controlled. The screen for a DVIST or a DVST has a storage mesh in which the phosphor is embedded. Image is stored as a distribution of charges on the inside surface of the screen and the DVST has a very limited interactive support.

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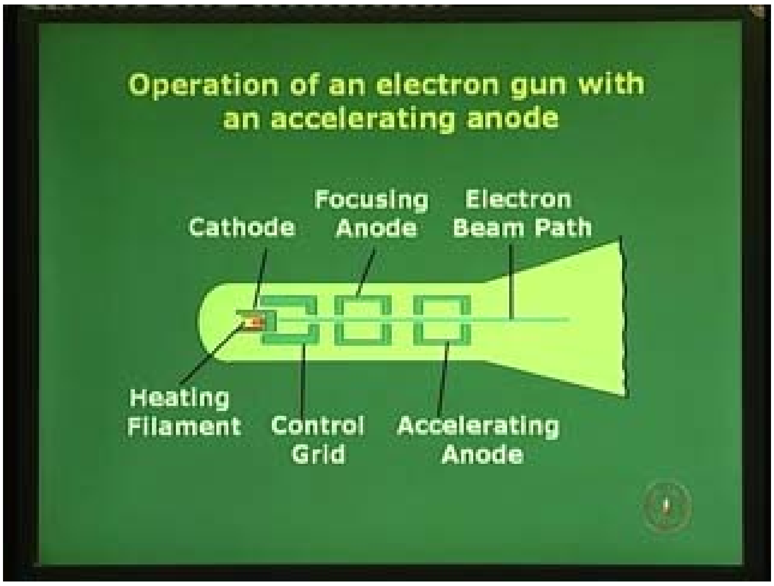

This is a typical diagram that illustrates the operation of a CRT or a CRT based monitor. It is an operation which shows how an electron gun with an accelerating anode is used to generate an electron beam which is used to display points or pictures in the screen. On the left hand side of the CRT you have a heating filament which is responsible to heat up the cathode element of the CRT and that is what generates the electrons. After the heating element is heating this cathode the electron simply boils off from the cathode and it is guided by a set of devices which are all essential cylindrical in nature and it helps to guide this electronic beam path towards the screen.

We have three functions here; a control grid, a focusing anode and an accelerating anode. These are essentially three cylindrical devices which are struck inside the cylindrical CRT device and three of these have three independent tasks. What does the control grid do? Well when we observe a picture on a screen some part of the picture may be bright some pictures may be dark. This brightness or darkness or illumination or the intensity on the screen is basically controlled by the intensity of the beam which strikes a particular point on the screen. This intensity of the screen is controlled by controlling the intensity of the electron beam which is coming out of the cathode. If we look at the picture once again; the electron beam is coming out of the cathode and the intensity of the beam is controlled by the control grid.

The electron beam consists of electrons which are negatively charged. The control grid is a cylindrical device which is also negatively charged. It is a high negative voltage which is applied to the control grid. Now, if the electrons are also negatively charged and the control grids are also negatively charged both of them repel each other. So the amount of the voltage at the control grid will essentially allow a certain amount of the electrons of the electron beam to pass through it and the amount of electron beam or the amount of electron which pass through cylindrical control grid will be controlled by the negative voltage in the control grid. So if you reduce the amount of voltage in the control grid it means the negative voltage is reduced and you are allowing more electrons to pass through it where the intensity of the beam will be higher and the amount of intensity on the screen will also be higher.

Whereas if you increase the voltage of the control grid you are allowing fewer amounts of electrons to pass through the intensity of the electron beam which is passing through the control grid will now be less and you will have less brightness on the screen. So that is the function of the control grid which has negative voltage. The other two parts of the CRT are the focusing anode and accelerating anode. Well, the structure and design of the CRT varies from one type of device to another. But typically you have the cylindrical structures of the focusing anode or the accelerating anode and both of these cylindrical devices the focusing anode and the accelerating anode are actually positively charged unlike the control grid. They will have positive voltage.

The control grid had a negative voltage because it had to repel or stop a few electrons from going through it necessarily depending upon the intensity of the beam which is required to strike on the screen. The focusing anode and the accelerating anode have two different tasks but essentially they have positive voltage. Essentially the focusing anode is responsible to focus the beam on to a particular point on the screen. It is similar to a lens focusing a beam of light on a particular point on the screen instead of focusing light we are actually focusing the electrons on to a particular spot or point on the on the screen. So that is the job of the focusing anode. We can say it is an electro static lens that means it is focusing on the electron beams unlike an optical lens which focuses the beams and the light beam on to a surface.

In this case it is a surface electron beam focused on to a screen and the accelerating anode is necessary because we want the electrons to strike the screen at a very high speed to emit light. So the acceleration of the beam is also provided by the accelerating anode which also has a positive voltage. It allows the electrons to accelerate then leaves it towards the screen.

Till now we have seen the electron beam path in this picture which is going straight after it has passed through these three stages. The first stage controls the intensity, the second stage controls the focusing, the third stage gives the speed or the acceleration. Now this will go and strike the center of the screen, as it is going straight what happens or how will you implement the deflections of the beam because the screen is basically a square matrix. You not only need the beam to go and hit the center of the screen to create a point but you also need the beam to move all around this image if you want to create a picture. So you need horizontal deflection as well as vertical deflections of this electron beam so that you can cover the entire screen. All the points or the entire phosphor coatings of the screen should be covered which you need to deflect. This deflection of the beam is implemented by another stage which we will see in the next slide.

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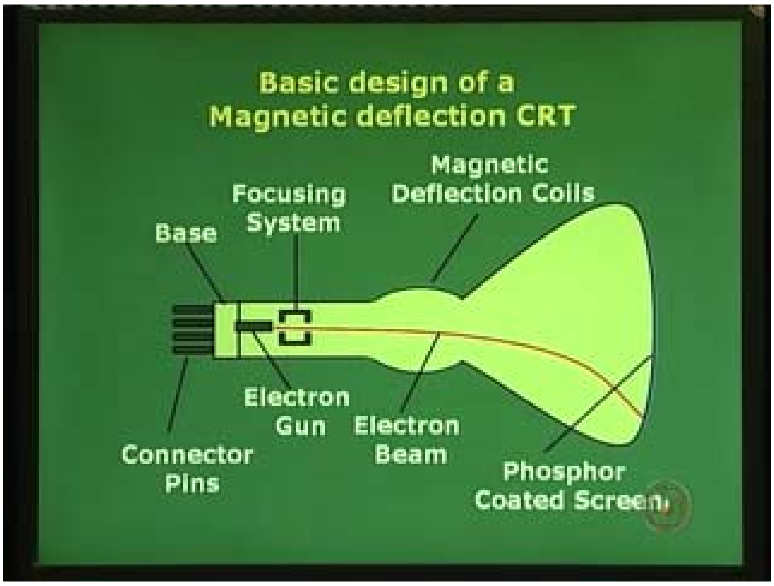

Basic design of a magnetic deflection CRT: this is a diagram where we only show that there exists an electron focusing system at the base of the CRT. Of course it does not show the other components like the acceleration and the control systems which are part of what we commonly term as the electron gun, the base of the CRT. In fact the electron gun terminology is typically used for the stage of accelerating anodes and also the stages of the control grid to control the intensity. But after the beam is focused it comes out almost in a straight path and it has to be deflected.

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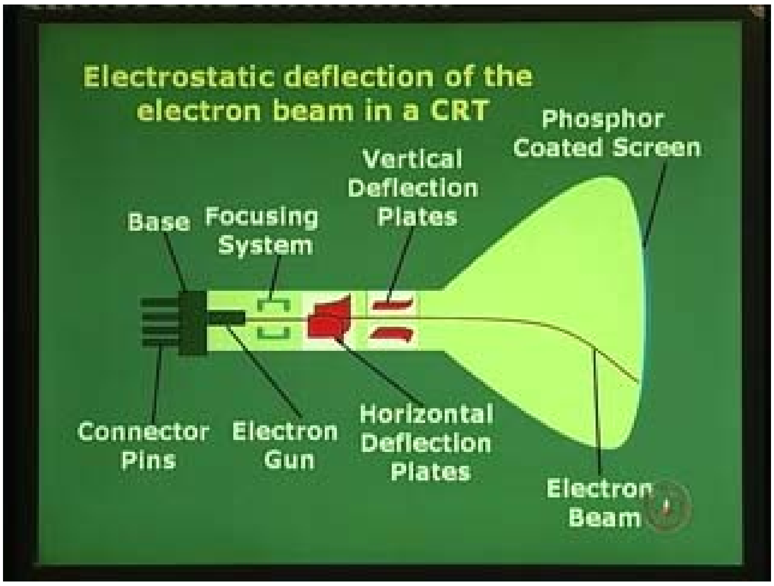

So, if you look at the diagram this beam is deflected by magnetic deflection coils which actually are on the top, bottom and on the two opposite sides also of the CRT. And this magnetic deflection coil generates a magnetic field which helps to deviate or divert this magnetic or this electron beam on to any portion on the screen, on the phosphors coated screen. This is one mechanism by which the deflection could be obtained for an electron beam.

We move on to the next picture which shows that this deflection is also possible with the help of electrostatic fields. The previous one was an electromagnetic field generated by magnetic coils. In this case, it has electrostatic fields generated by capacitance deflection plates. We are talking of electro deflection of the electron beam in a CRT and we have the same base electron gun focusing system and then the beam comes out straight and passes through two plates.

You can assume these to be the capacitive plates generating an electrostatic field and the first stage as you see in the picture we have the horizontal deflection plates, the horizontal deflection plates which are responsible for horizontal deflection of the electron beam and then it passes through the vertical deflection plates which are responsible for vertical deflection of electrons.

If you look now, the horizontal deflection plate is essentially are vertical through which the electron beam is passing, assume this to be horizontal deflection plates which is essentially vertical. It is aligned or positioned and helps the beam to rotate or deviate or divert in horizontal direction. The vertical deflection plates are physically horizontal but it generates an electrostatic field which is vertically oriented and that is the reason why this is responsible for the vertical deflection of the electron. So these two together helps you to position or divert the beam at any point on the phosphor coated screen as you can see on the right hand side. So essentially there are two types of deflection mechanisms; one is based on the capacitive electrostatic mechanism and another by electromagnetic using magnetic coils.

Therefore, two types of deflection mechanisms are possible in a CRT and these are diagrams which illustrate what is essentially in it. The CRT which is used in oscilloscope for electronic experiments typically will have the deflection plates whereas the TV monitors typically will use magnetic coils for deflection. You can open it up and see for yourself that it is the standard used. Coming back to DVST or Direct View Storage Tube in which the CRT is a very essential part of course almost all of these display devices will have some sort of mechanisms of electron gun with deflection plates or magnetic coils to deflect the plates. So the CRT is essentially a common part of all the three different types of display devices.

We are discussing about Direct View Storage Tubes. We have seen few of the essential parts but DVST or direct view storage devices have very limited applications. That is they have very serious drawback and the first drawback is that modifying any part of the image requires redrawing the entire modified image. If you want to modify any part you have to modify the entire image so animation is almost ruled out when you are using Direct View Storage Tube. That is the first drawback.

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The second is, changing in the image requires generating a new charge distribution in the DVST. That means we were saying that we have phosphor coating screen on the front and the beam is allowed to go and strike at any point and deflection is attained by deflection coils or electrostatic fields. And whenever the phosphor is struck by the electron beam it emits light. That is the mechanism that you draw the picture or the picture is visible. Now, when we need to modify some part the beam has to go and do that on the entire screen and that is why the change in the image requires you to generate a new charged distribution in the phosphor coated screen in the case of DVST and the process is usually very slow. That is my next point. It is a slow process of drawing; it typically takes a few seconds to draw a very complex picture.

DVST requires a few seconds to draw quite a good amount of complex picture. You can erase the picture erasing takes about 0.5 seconds and all lines and characters must be erased in this screen. Remember, characters are also drawn by short strokes or short lines in the DVST. And you can say virtually no animation is possible when you are using a DVST mechanism which is something like static picture which is visible, you can erase and redraw it again something like what you see in a cathode ray oscilloscope, a CRO for electronic experiments you almost get a static picture of course with variations but it is redrawn.

We move to the next type of device which is probably closer to the TV monitors that we use today, not exactly the same; they are called the Calligraphic or Random Scan display system. I repeat again Calligraphic or Random Scan display system and we see how this is different from the DVST. It is also called a vector, vectored, stroke or line drawing displays. Characters for the random scan, we will henceforth call this as random scan display or a line drawing display, Calligraphic term is also used but we will call it as a random scan. Characters are also made of sequence of strokes or short lines.

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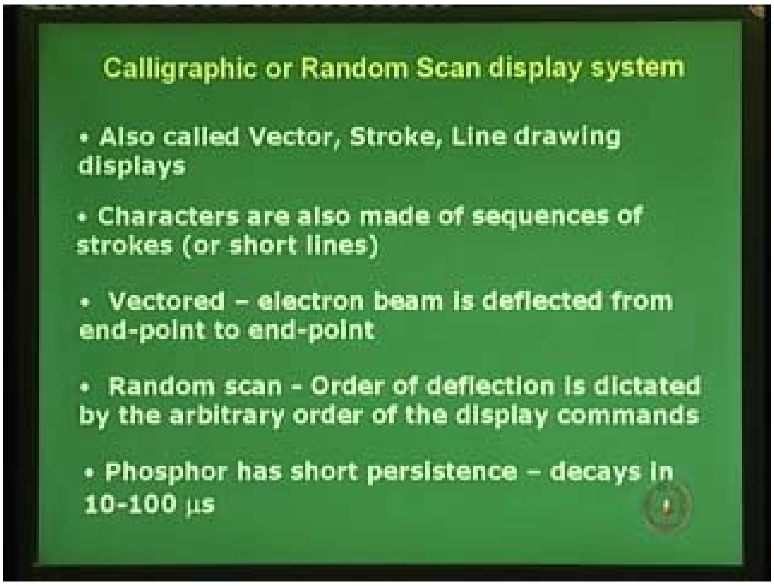

You cannot draw a complete character without drawing short lines that is what it basically means. It is also called vectored because the electron beam is deflected from one end point to another and those sequence of commands which helps the electron beam to move from one point to another in order to draw short strokes or lines are called vector type of movement and hence it is called due to the vector type of movement and definitions of the picture in terms of lines, characters made of lines and so on it is also called a vector system. It is also called a random scan because there is no strict order.

The order of deflection of the beam is basically dictated by the arbitrary order of the display commands. Since there is no strict order, the order could be in any random form that is why it is also called a random scan because the order of deflection has no strict rule and the order of the display commands is based on which the beam is deflected. The phosphor is different, the phosphor on the screen in the case of random scan is different from that of a Direct View Storage Tube or DVST because the DVST had a long persistence phosphor. In this case the DVST has a short persistence and the illumination of the phosphor, the light which it emits once the electron beam strikes a phosphor in order to know it emits light.

The amount of time over which the phosphor emits light after the electron beam is withdrawn is called as short persistence, we will come to that definition. But that decay of the amount of light which it emits, in the case of a random scan the decay is very fast whereas in the case of a DVST which has long persistence the light was on for a very long time and that is why once it is drawn it used to be there for quite a long time. And the decay in the case of random scan is in the order of about 10 -100 microseconds typically in the order of about fraction of a millisecond is what you can say that the phosphor has a short persistence. So that means the picture must be redrawn. The beam must comeback to that point otherwise that point will stop emitting light. There is a need for refresh, this is the first thing we are getting that the display must be refreshed.

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Each point the beam must come back to that point after a very short time otherwise the picture will simply vanish from the screen. And it is true for all the points in the screen for a random scan display. So display must be refreshed at regular intervals of time and the minimum recommendation is as you see on the screen 30 hertz or 30 frames per second fps, we will talk of this frame in a very short while, we will see what this frame is all about but you can safely assume that the frame is just one picture. This full picture is one frame. So, frame must be revisited or recreated at about 30 times per seconds or 30 frames per seconds or a frequency of 30 hertz is the frequency of refreshing the screen. That is minimum recommended for what I will call as a flicker-free display.

This unit of 30 hertz or 30 frames per second comes out on the concept of persistence of the vision of the eye, not to do with the screen parameters or display parameters. That is the persistence of vision for which if a picture is presented at a higher rate with very short gaps in terms of even milliseconds you will see a consistent or a constant picture or a flicker-free display. If you reduce it to below 30 to 25 hertz the screen will start to flicker in front of your eye. So to provide flicker-free display the refreshing mechanism must operate at 30 hertz or more.

Since we talk of a refresh, the first time we are introducing the concept of graphics memory which comes into play in a big way, we will call it a refresh buffer or it is a part of a system memory buffer or system memory which is used basically for refreshing or the picture contents or commands for the random scan are kept there in the refresh buffer. It is defined as a memory space, as you can see a memory space allocated to store the display list or the display program, the program which creates the display list. That means the commands which are to be used to draw the pictures, strokes, lines etc and which are used by the CPU or the display processor to draw the picture is kept in a refresh buffer.

Of course, I have not given you the architecture of a simple or a general computer graphics system, but we will come to that in a moment. But refresh buffer is a very important component or part of the graphic system where at the entire display program is basically kept. The display processor, the CPU itself could act as a display processor but you can have a dedicated display processor inside your computer graphics system which could do the task of computer graphics or run a program of algorithms of computer graphics without overloading or disturbing the CPU.

If the CPU does the computer graphics job for you it will be highly competent or intensely overloaded then the system performance may go down. So it is better to display processor which could do the computer graphics operations for you. So, computer graphics system will have a display processor in general and it interprets these commands which are there in the refresh buffer display program or the display list and it also interprets these commands in the display buffer for plotting. The display processor must also cycle through the display list to refresh the phosphor. That is another task and the display program has commands for point plotting, line plotting and also character plotting.

I think now we will go through the conceptual block diagram. It is probably not architecture truly but a block diagram will give you the architecture in a very short time. The conceptual block diagram of Calligraphic or a Random Scan refresh display, Calligraphic or Random display refresh is what you can talk about. So, on the left hand side you can see the host CPU here which drives your graphic processor or display processor which in turn loads the contents of your graphic screen or the refresh buffer or the display buffer which we discussed about and the contents of the display buffer are passed on to a display controller.

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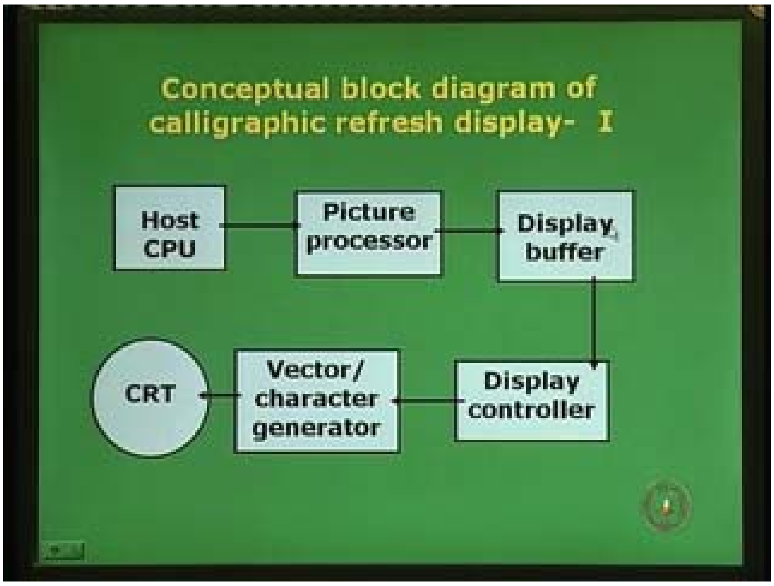

The display controller has some specific job; we will come to that in a moment. It interprets these display buffer contents and passes it on to a vector character generator which is basically the interface to the CRT. It will generate all the analog voltages which are necessary to the deflection of the beam. Deflection of the beam and the intensity of the beam are all generated by the display controller and also by the vector character generator and that is passed on to the CRT for display, this is one model. I put this as display one because this is one conceptual block diagram for the display device.

You can have a slight modified diagram of the refresh display, I will say it as two, a conceptual block diagram which is slightly modified as you can see the modification is that the picture processor here which was actually just after the host CPU in the previous figure has come down after the display buffer or after the display controller, that is possible. It depends upon what sort of framework you want to have. Sometimes it is necessary to put the picture processor after the display buffer or display controller which will interpret the commands and do the processing very fast and do not want the host CPU to be overloaded with computer graphics commands or computer graphics algorithm too much. You need to just say, I want these kinds of pictures with certain output primitives.

We discussed about output primitives in the introduction lecture where the primitives consists of lines, filled regions, characters and so on. So I want the picture processor or the graphic processor to do certain operations on these output primitives and I do not want the CPU to do that. So, the CPU might just send that I want these output primitives drawn at specific points with these attributes or features and the picture processor has to interpret. The picture processor has to interpret these commands from the display buffer and generate correspondingly, short and short descriptions for the vector character generator. If you see this screen, now the picture processor interprets from the controller and sends signals to the vector corrector generator to generate corresponding signals to the CRT.

If we revisit the block diagram of one back again and the block diagram two, if you compare these as we go back and forth, the position of the picture processor has changed basically. In the case of block diagram one as you see here now it was next to the CPU and it was driving the display buffer. In the case of block diagram two the CPU drives the display buffer and picture processor takes input from the display controller and gives it to the vector generator. It is the question of implementation, which one suits ones requirement in designing a computer graphics system. You can put the processor just after the CPU or after the refresh buffer. So go back and continue on Random Scan display systems. The display processor we typically assume one of the two models of the block diagram, it sends digital and point coordinate values to a vector generator.

We will see what we mean by digital and point coordinate values. Well, it is something like this, the vector generator needs to know what line you need to draw, and from what point x1y1 to x2y2 on the screen and it also needs to know what should be the intensity of this line. I repeat it needs coordinate values x1y1 to x2y2 from which point to the end point, first point to the second point it needs to draw a line, so the intensity of the line.

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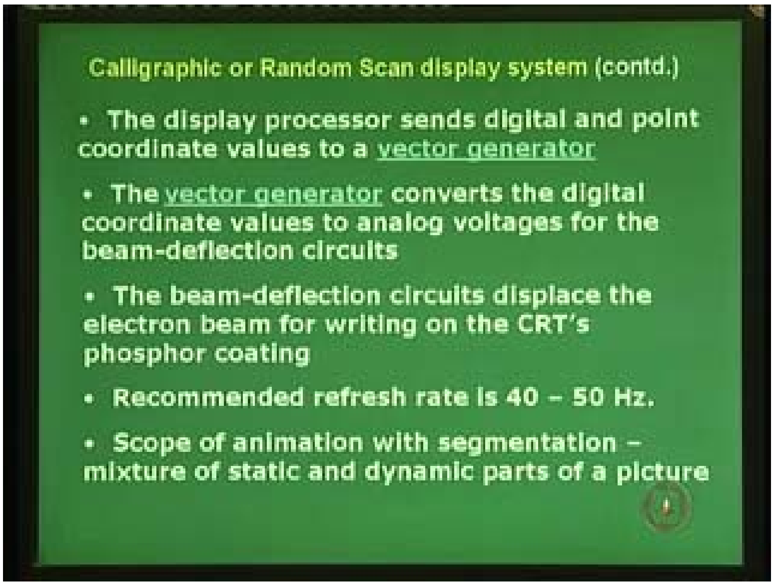

So if you come back to the screen that means you need to send not only point coordinate values but a digital value for the intensity. That is what is given to the vector generator by the display processor after interpreting the command. The vector generator converts the digital coordinate values to analog voltage for the beam deflection circuits because it must know from which point x1y1 to which point x2y2 it must draw so the beam has to be deflected first, switched off and deflected to the point x1y1 then switched on with a particular intensity and the deflection voltage must be set in such a manner that the beam is deflected slowly in a linear manner to another point x2 y2. So the vector generator does all such tasks, generates in fact this, analog voltages from digital coordinate values and digital intensity values. The beam deflection circuits display the electron beam for writing on the CRTs phosphor coating that is true.

Of course, when the beam moves and is switched on, the phosphor gets the beam and it starts emitting light at all those points. Recommended rate was 30 hertz usually, the minimum requirement was 30 hertz but the refresh rate recommended is 40 to 50 hertz but absolutely have complete flicker- free display, typically about 50 even 60 hertz , it is better to go beyond that. Scope of animation is possible in a Random Scan or Calligraphic display. It was not possible in DVST but it has limited support. The random scan has limited support of animation. We will say that the scope of animation lies with segmentation.

What do you mean by segmentation here? You have a mixture of static parts and dynamic parts of a picture. I will say I have two regions or two segments of a picture. Some parts could be static and some parts could be dynamic where I will create the animation. That is possible in case of Random Scan. The static part I will draw once and I need to refresh that but the contents of the static part in my display list or display program of display buffer which was a sequence of commands, that is never going to change because if I refresh, I will keep on refreshing the display list or display program in terms of the short lines I draw on the screen. There is another region which I will call as a dynamic part of the screen, a small part may not be the whole part. That small part is responsible for the dynamics or the animation of this screen and there the contents could change. How do I change the contents? Typically I go back to the refresh buffer and say I have a dynamic part in my refresh buffer where the contents could change. I could write there from the CPU or write that contents from the picture processor, those contents of drawing the lines instead of drawing a line from x1y1 x2y2 I say I will change.

What do I implement by animation? I will say next I will draw a line from a point x3y3 to x4y4. So I had a line from x1y1 to x2y2 and after sometime if I draw a line from x3y3 to x4y4 so I will first see a line like this and I will see another line like this and that will create animation for me. So I can implement that in a short part of the screen for a Random or Calligraphic display system and I need to update the refresh buffer, just the animated part and the dynamic part of the refresh buffer could create animation for me, the rest of the part could be static, I do not want to change the contents but I will keep refreshing the entire display list or entire display program, that I need to update because the static part also has to be refreshed along with the dynamic part. So the dynamic part changes but the static part is all static, there is absolutely no change. The random scan display system basically draws the set of lines in any order.

We discussed about there is no strict order that is why it is called random but it essentially draws lines. How does it draw? Just look at this mechanism, (Refer Slide Time: 33:52) we assume that we have a screen here and then an electron gun and the blue line is the electron beam which is hitting on the one point of phosphor on the screen. And assume that the beam is switched on and it starts to move. As it starts to move wherever it hits the phosphor screen all that will start emitting light. Let us say the beam has moved in a linear manner and it has also turned. So, you see that part wherever the beam has scanned so far. It will start illuminating or emitting light. And of course dictate what sort of color you want. This is the second stage. We keep on moving the beam. Now let us see the picture where it has moved. This picture almost shows what I am trying to draw.

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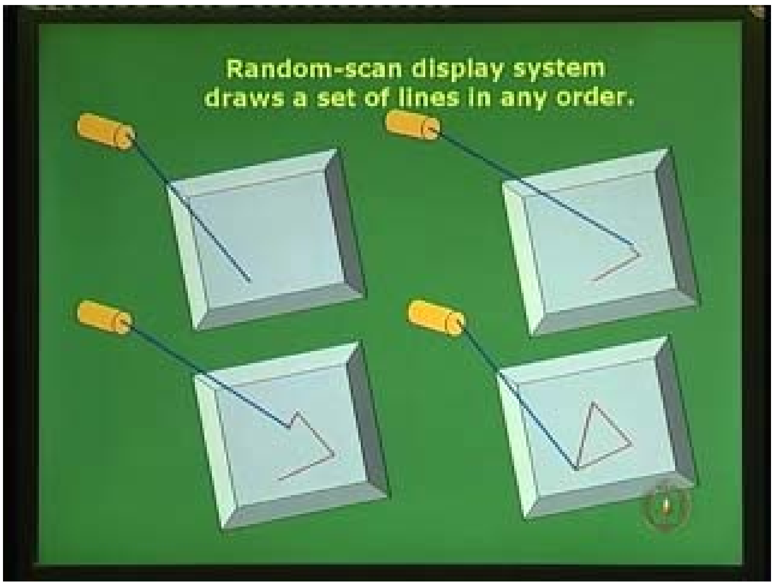

I have finished the second line and I am moving towards the third line so I am probably going to draw a triangle. So all these points on the triangle where the beam has moved still is emitting light, short persistence but still emitting light because it is happening very fast at about 30 or 40 hertz. And when the entire picture is completed the beam comes back to a particular point where a full triangle is drawn. Essentially what I have drawn is I have made the beam to travel from a vertex X1Y1 to another vertex x2y2 to a third vertex x3y3 and then come back to x1y1.

In this figure basically I have drawn a triangle by making the beam move from first vertex to second vertex to third vertex and come back. I repeat again, x1y1 to x2y2 to x3y3 and then come back again to x1y1. I finish this cycle then I am able to draw a triangle. That is what I have drawn. These four shots of the figure show that essentially I have finished a triangle. But the job does not end there. The job does not end there because you have to refresh the display and the same thing keeps happening again and again. The electron beam moves from vertex 1 to vertex 2 to vertex 3 and comes back to vertex 1. And this cycle keeps on going at around 40 to 50 hertz and you see only a triangle with certain intensity. So this order of drawing is also very important.

I can move from x1y1 to the point x2y2, x3y3 and come back or nobody stops me from traversing or making the electron beam move from point x1y1 to point x2y2 to point x3y3 and then come back to point x1y1. I can move in any order. I can start from the third vertex,move to first vertex and move to a number. It is basically an order which is important. the order is not that important but the points are important so that you create these lines in any order and since you are refreshing at 30 or 40 hertz you get a flicker-free static display of this triangle.

Let us see how this line drawing can be generated in a Random Scan or Calligraphy scan disc. This is an ideal line drawing; forget the part of the filling part. We will see how region filling can be done with the help of the again line drawing. But let us worry about only the lines drawing. We have a house with a window and a door and there is a moon do not worry about the filling part I have done the filling myself to give it slightly a better appearance but do not worry and do not think about how to fill those regions. I am bothered about the lines being drawn and again just keep in mind the region filling is nothing but again a set of line drawings for the time being that’s an ideal output I want. And you see it on the screen when you are watching it on the TV monitor actually something is getting refreshed over the number of these lines. So how do you start? You do it by vector scan method or Random Scan method and this is the screen which is blank.

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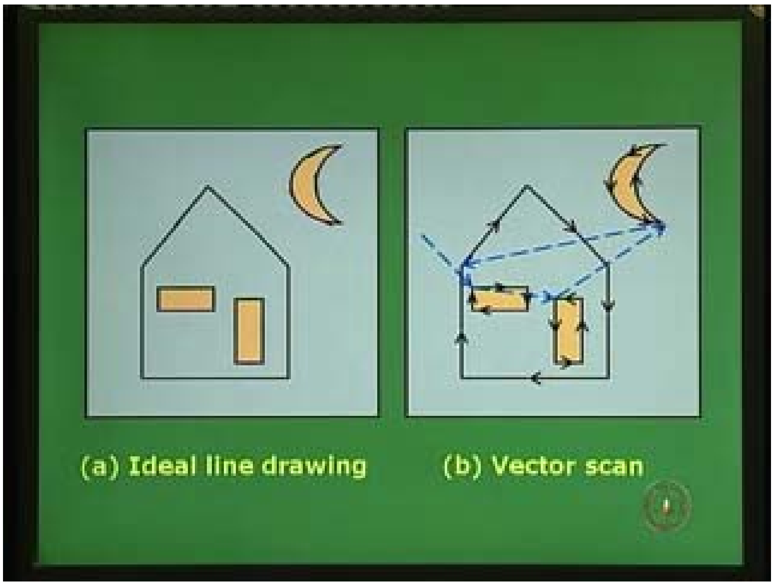

So what I do is, beam is somewhere on the screen and it is switched off but it must be diverted to one of the points, starting points somewhere let us say, this is my trace, this is not my actual beam, this is the point, this dashed line shows that the beam is switched off and it is moved from one point to another and that point here with the arrow points 2 is nothing but the top left vertex of the rectangle structure. On the left hand side this is the point. The ideal line, this vertex is where the beam has come and stopped and it is switched off.

Now what I do is I draw this small rectangular filled region. The arrow marks show in what order I draw the lines. I hope it is clear that I basically draw four lines there and the beam is switched on at this point. The beam is switched on and traversed, it first moves horizontally, then vertically down, then horizontally left and then vertically up. So it basically finishes a rectangle. A small rectangular strip is drawn by switching on this beam and traversed in this caution. When it moves in the horizontal direction you need horizontal deflection voltages to be switched on, when it is moving in the vertical direction you need the vertical beams to be switched on and the other voltages can be switched off. So the beam was off, the blue dashed line shows that the beam was off and it has been brought to that vertex, the vertex here has come and then is moved like this horizontally to the right vertically down, horizontally left, vertically up again and it has come back to this point let us say and rectangle down. Of course, the filling also will be done.

Next we need to draw the other figure. What do you do? You switch off the beam and move it. You switch off the beam and move it, the path is shown again by the dashed blue line where the beam is switched off and it moves and it is able to draw the next rectangle here. This is how it is drawn. Remember I am trying to keep an arbitrary order here. You can start with the house, draw the moon come back to this rectangle, absolutely no problem. I have drawn it the reverse way.

I have drawn the two rectangles first. We will see what is drawn next. That is meant by random order. Not only that, not only in terms of what type of structures I am drawing in sequence to implement a particular rectangle as you can see the second rectangle is drawn in a different order, the first rectangle was drawn in a order where I move horizontally right, vertically down, horizontally left and vertically up. In this case it is completely different just the reverse track or trajectory is what I do. I switch on the beam here bring it vertically down take it horizontally right, take it vertically up and then finally horizontally left, just the reverse order. I can follow any order of drawing lines that is the most basic thing which you must understand in terms of random scan. As long as the picture is drawn it does not matter in what order you are drawing. So these two triangles are drawn.

Now I need to complete two other figures, the moon and the outside structure of the building. So what do I do? I move to some other point, I am probably moving here. I move here to draw the moon first, the beam is again switched off, I keep repeating, dashed discontinuous blue lines are the trajectory when the beam is switched off. Continuous black lines means the beam is switched on, so the beam is switched off and it has gone to a place where it has to draw the moon, it draws it like this. Now it is essentially drawing two curves. These curves are also implemented using short lines so it draws the right hand trajectory, goes to the top vertex of the moon and then comes back. The arrows indicate the trajectory by which the lines move and you go here and back and the moon is drawn. Again the beam has to be switched off because it has to be taken to one of the points where you have to start to draw the house. So, it is a vector scan and we have to implement the ideal line drawing on the left hand side the part which is on your left is the house so you have to switch off the beam and take it to one of the points so you have to come back to the point which is the left top vertex of the house and we start to draw. Let us see how it is drawn.

The beam shall be switched off and it has traversed from right to left along the dashed blue line you switch it on now and then start moving it diagonally across to the top vertex, diagonally down right to one of the vertices there, then vertically down, horizontally left, beam is on and finally vertically up and that completes the entire diagram. As you can see if I take off the blue lines from the diagram on the right hand side which is a vector scan and the arrow marks of course then you get the ideal line drawing.

I repeat, if I take off the arrow marks and the blue lines on the screen which indicates the trajectory of the beam movement when it is switched off, the blue lines, dashed discontinuous lines indicate the trajectory when it is switched off and continuous black lines indicate the trajectory when it is switched on. If you remove those markers and the arrow marks you basically get back the ideal line drawing. So this is a mechanism by which a drawing is done in a vector scan and a random scan mode.

Of course, the activity does not stop. The entire thing is repeated again and again at the rate of 40 frames per second or at least 30 frames per second so that we do not have flickers. If it is drawn at the rate of about 20 or 30 frames per second or as low as about 5 frames per second you will start having flicker in the screen. To avoid the flicker on the screen you must present this entire cycle which I showed you with animation just now must be repeated at around 40 to 50 frames per sec or 40 hertz frequency of refresh rate. So that we have the display otherwise you will start to have flicker on the screen. Minimum recommended rate is 30 hertz.

So, continuing with the random scan display system we come to these terms which we have been using in terms of the phosphor material properties or emitting light when an electron beam strikes the screen the first term which you must know in terms of the CRT display devices and phosphor coating is the phosphors florescence. Phosphor's florescence is the light emitted as electrons are unstable electrons. Unstable means there are flying through the vacuum. The CRT inside is a vacuum and the electron simply fly in a straight line they can be diverted by the magnetic coil or electrostatic plates obviously but they are unstable. These unstable electrons fly and lose their excess energy in terms of kinetic energy while it strikes the phosphor. So we are talking of the phosphor florescence which is light emitted as these electrons lose their excess energy while the phosphor is being struck by those electrons. So the phosphor is struck by an electron, the electrons lose their energy from unstable state, they are moving to another state and that energy is all emitted by means of two energies.

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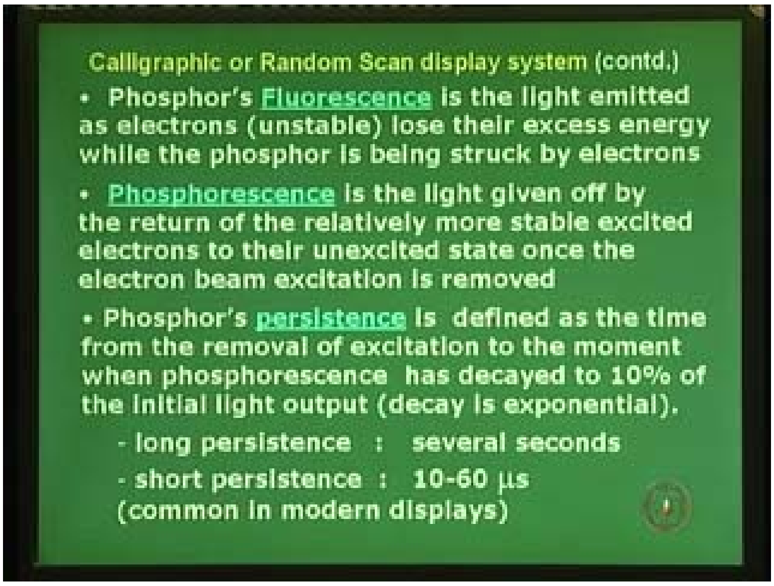

One is the heat energy disappeared at the point and number two is the light energy. So in a very short time the light will be emitted and will go off the beam but must come back. Otherwise that if you want the light to be emitted at that particular point where the beam is at start then continuously you have to refresh the beam at the particular point because the light emitted for a very short time, fraction of a millisecond and it again goes dim. But the florescence definition talks about that light emitted as electrons lose their excess energy while the phosphor is being struck by electrons.

Phosphorescence is another term. Phosphorescence is the light given off by the return of the relatively more stable excited electrons to their unexcited state once the electron beam excitation is removed. Florescence was the light emitted when it got struck and excess energy is being dissipated. Phosphorescence is the decay basically the light given off by the return of the relatively more stable excited electrons to their unexcited state once the electron beam excitation is removed. So I take off the beam, as the beam is struck the florescence is coming out, so as I take it out this is the phosphorescence which talks about the light which is coming out but it will decay with time. That small amount of light for which the light energy is emitted is emitted is dictated by the phosphorescence property of the phosphor.

Phosphor‘s persistence is defined as the time from the removal of excitation to the moment when phosphorescence has decayed to 10% of the initial light output. I did say decay is exponential, the phosphorescence, the term which we coin in slide number two the decay is exponential but we did not talk about the time and the time over which this decay takes place and it has almost gone down to if not 0 about 10% of the original light output that is the florescence which was coming out when the beam was being struck. The beam is being removed, phosphorescence takes place and the persistence talks about the time.

The time duration which the phosphor’s phosphorescence starts from an initial value and exponential decay, I mind you, it reaches up to 10% of the original value. So that is the exponential path by which the decay takes place and that amount of time typically. Those with electronic and electrical background can compare this decay time with an RC discharge time decay in the electrical and electronic circuits which is used in most digital and analog circuits as well. That amount of time is called the phosphor’s persistence. It is the decay which is exponential and the time is persistence and the concept is phosphorescence. Remember, DVST Direct View Storage Tube was a long persistence which could run for several seconds. So you can draw it and wait and redraw it again after a long time. Refresh may not be there or even if it is there it could be sluggish.

Short persistence for a random scan display system takes about 10 to 60 microseconds which is common in most modern displays. The short persistence exists with random scan displays, the time which we have for this recording. I will just introduce one slide of refresh and raster scan display system and wind up the lecture. And in the next lecture we will continue on the refresh and raster scan. We have discussed two types of display devices.

I think in this lecture I must introduce the third display device before winding up. But we will talk about more details of the third display devices later on in the next lecture. I have introduced DVST or Direct View Storage Tube, I have introduced a Calligraphic or Random Scan display system and we discussed about architecture of display systems, we discussed about the diagram of a CRT. And the third display device which is much better than the previous two is called a refresh or a raster scan display system. The refresh and raster scan display system is used in most modern display systems including television screens. How it is different? The DVST and the Random Scan display system were essentially line drawing devices. We had seen the line drawing was used to draw the line, draw the picture or the house with the door and the window and the moon were all drawing lines. The refresh CRT or the raster scan CRT, remember, it is different from Random scan, forget DVST.

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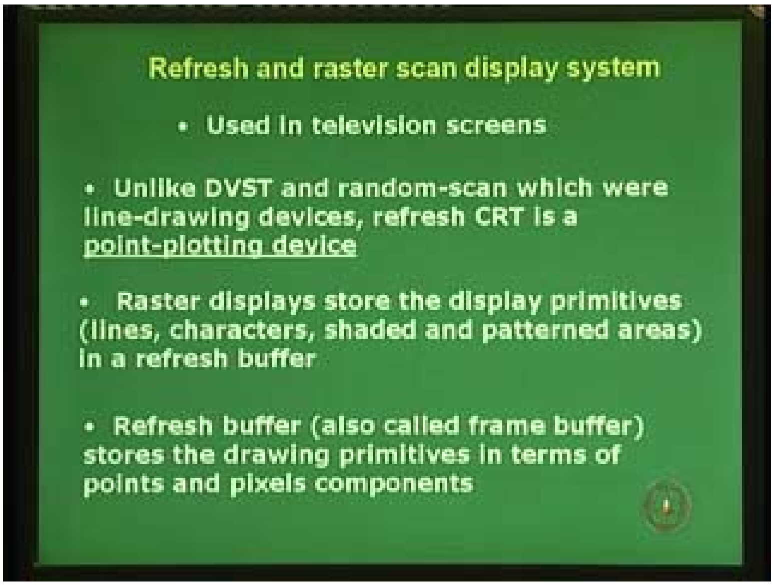

Comparing these terms random scan and refresh scan or raster scan are used interchangeably. I can use the term refresh and raster they are meaning the same or I can use refresh raster they basically means the same thing. The third type of display device which I am talking about is different from the Random Scan in the sense that Random Scan was a line drawing device or a line drawing system like the device DVST or Direct View Storage Tube. The refresh CRT as given here in this slide is basically a point plotting device. Things appear to be very tough but it gives you a lot of advantage. If you draw points here unless like drawing lines in the case of random scan that is the essential difference you must keep in mind. The raster display stores the display primitives like lines, characters, shaded areas or pattered areas in the refresh buffer.

Remember, the raster display stores the display primitives. We talked about display primitives like lines, characters and areas in a refresh buffer. The random scan also stores this. The random scan also stores this in the refresh buffer but it stores with the help of storing lines. In this case it stores also lines but with the help of points. The refresh buffer also called the frame buffer, we will use these terms interchangeably. Refresh buffer is also called the frame buffer which stores the drawing primitives in terms of points and pixel coordinates rather than storing line commands.

Draw line or line drawing commands were essentially the tools or the basic utilities for random scan or DVST. In this case we are talking of points or pixel components to store the drawing primitives in the case of a refresh or raster scan. This is the architecture of the typical raster graphics system. A typical computer system will have all of these except may be the video controller where the system monitor could be directly driven from the system memory but essentially any sort of video conferencing is essential. We have the system bus and input – output devices like the keyboard, the mouse or some other I/O devices.

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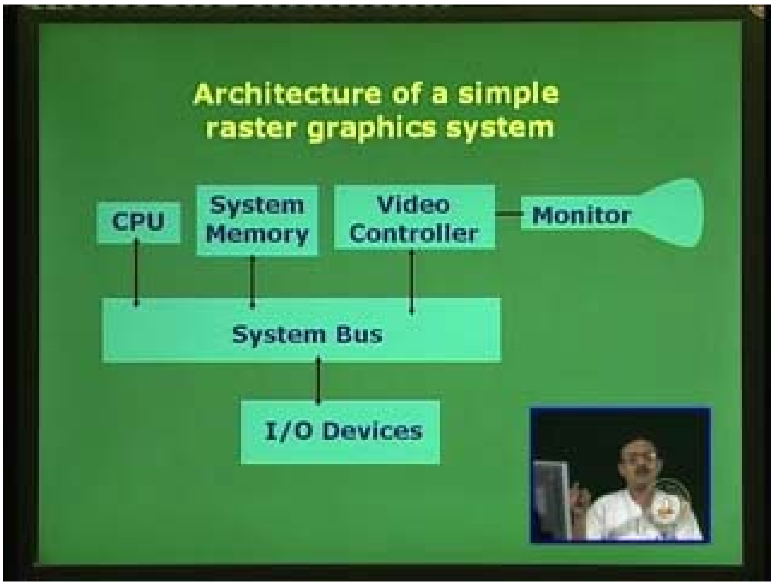

We have the central processing unit which typically does all the tasks of monitoring the system as well as computer graphic commands if necessary if you do not have separate graphics processor. We have a system memory refresh buffer could be a part of the system memory. The video controller could take commands through the CPU, through the system bus from the CPU the commands are all in the system memory or frame buffer and the video controller is the one which converts the line drawing primitives and draws it on the screen or the monitor. So that is the typical architecture of a simple raster system which does not have a graphics processor.

We will see in the next lecture a slightly more complex architecture of a raster graphic system where you have a graphics processor and a separate frame buffer identified from the system memory and then we will see how these components are used to design a refresh or a raster scan system and then will see how it is going to be different from the way random scan display systems were used to draw pictures with the help of lines. in this case using the refresh buffer we use points to draw raster scan raster scan as given in this slide raster scan are drawn with the help of points, random scan is drawn with the help of lines and we also need a few more functionalities or a modified or advanced architecture of a graphics system with the use of frame buffer, with the use of picture processor separately to draw a screen.

So we wind up and we will move over to the next lecture when we discuss more details, more specifics about raster or refresh raster scan display systems, thank you very much.