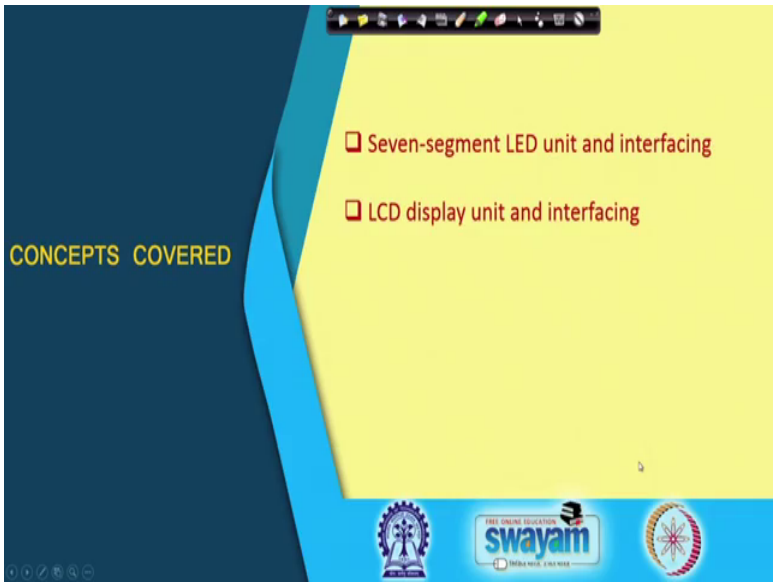
Embedded System Design with ARM
Prof. Indranil Sengupta
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture – 15
Output Devices, Sensors and Actuators (Part I)

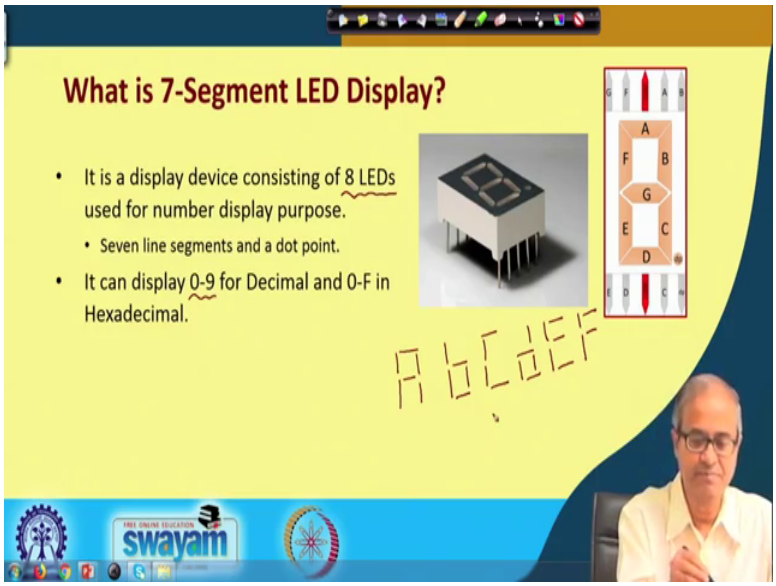
Now in this lecture, we shall be starting with a brief discussion on the various Output Devices, Sensors and Actuators, which will be required for the actual experiments and demonstrations that we shall be showing you using the STM 32 and the Arduino boards. So, the title of this talk is output devices sensors and actuators the first part.

(Refer Slide Time: 00:45)



So, in this lecture we shall be talking about 2 different output devices some of it is characteristics, one is the very familiar 7 segment LED display units that many of you know of. And, the second is the liquid crystal display LCD display unit ok.

(Refer Slide Time: 01:07)



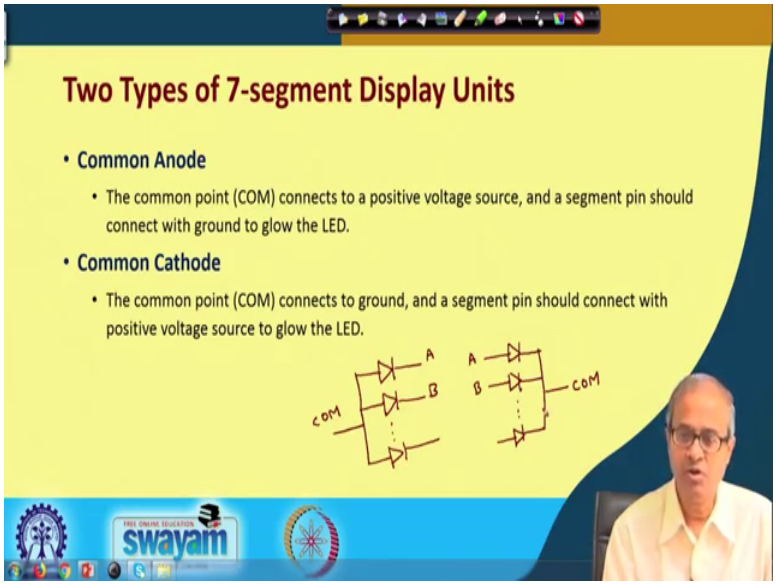
So, let us start with 7 segment LED display unit. So, what is a 7 segment display unit? So, many of you may already be familiar with this kind of a device. So, it is a display device which consists of 8 light emitting diodes, which are arranged in a particular fashion, there are 7 of these LEDs, which are arranged in the form of a 8 like pattern and there is a dot point. This kind of displays are very useful for displaying numeric characters 0 to 9 by suitably activating or displaying these individual segments, which are all light emitting diodes or LEDs, which are shaped in the form of a bar by glowing or a not glowing them selectively, you can display any arbitrary numeric character right.

Not only the numeric character 0 to 9 well you can also display the hexadecimal characters abcdef. For example, you can display A like this, you can display b in lower case like this, C can be display like this, d can be display again in lower case like this, E can be displayed like this and F can be displayed like this. So, in addition to 0 to 9, you can also display the hexadecimal characters. Therefore, the 7 segment units are very useful as a 7 segment as a you can say hexadecimal display device ok. So, this is how it looks like, there are 7 segments as I told you which are numbered A B C D E F and there is a dot point.

And your typical display unit, which looks like this there are 10 pins 5 on this side, 5 on the other side and these 10 pins they have connections to all the individual segments and

also there is a common terminal, which is available on both the sides, which is marked red.

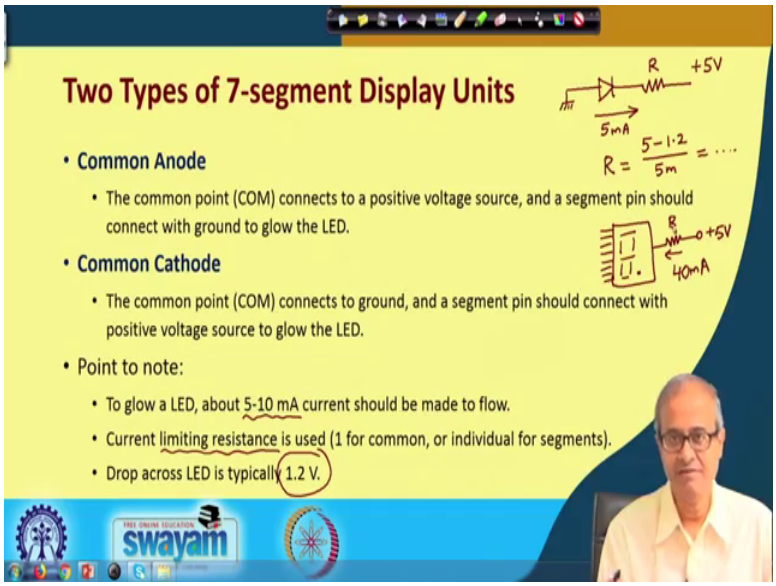
(Refer Slide Time: 03:27)



Now, depending on how the light emitting diodes are connected inside these 7 segment display units can be of 2 types either common anode or common cathode, common anode means a inside there are so many LEDs. So, I am showing these LEDs like this, there are 8 LEDs is in total. If the anode terminals are all connected together and this is your common point then we say that this is a common anode kind of our display.

But if it is the other way around means you have the LEDs like this and if the cathode terminals are connected together and this is the common terminal that you are getting from outside you call this a common cathode kind of display and the individual segments A B C D E F are available on these terminals like this and so on. So, depending on how they are connected internally, you can have 2 different kinds of display units common at anode or common cathode.

(Refer Slide Time: 04:47)



Now the point to note is that, this is important when you are actually displaying a 7 segment display unit to a microcontroller that about 5 to 10 milliampere current is required to be pass through an LED for it to glow at full intensity; this is the minimum amount of current you have to pass. And typically, we use some current limiting resistance, which will limit the total flow of current through an individual LED right. And the other point to note is that, when an LED is glowing it is forward biased, the voltage across it is typically 1.2 volt for some LED, it can be more also ok.

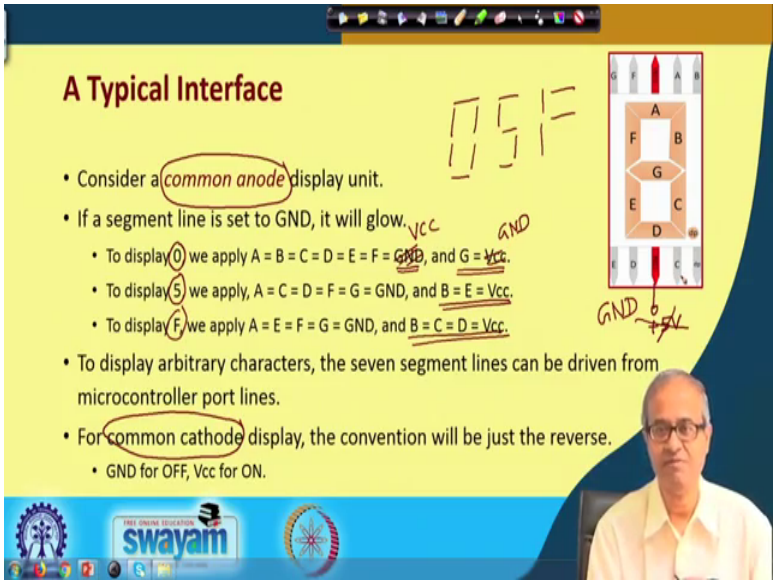
So, if we look at one individual LED. So, what we mean to say is that you need to have a current limiting resistance connected in series to it and let us say on one side, I connect a 5 volts. And, in the other side I connect ground and I want a current of let us say, 5 milliampere to pass through it then the value of this resistance can be very easily calculated, like you can say this resistance value will be this 5 volts minus the voltage drop across the LED 1.2 divided by the current you are passing 5 milliampere. So, this will give you the value of the required resistance.

Now, sometimes what we do is that when you have a 7 segment display unit, where there are. So, many LEDs inside there are 7 segments and also a dot point, there are 8 LEDs inside. So, there are 8 segment terminals. So, the best thing will be to connect a one resistance to each of these individual terminals so, that the current through each of the segments can be fixed at 5 milliampere, but for the sake of interfacing to make it simple

instead of using 8 resistances, what you can do in the common terminal, you can use a small resistance and let us say for common anode, you can connect it to 5 volts and whichever segment you want to glow you connect it to ground.

Then this resistance will determine the total current that is flowing ok. So, in the worst case, when all the 8 segments are glowing then this current will be divided into means among these 8 segments. So, in total you should allow 40 milliamperes of current to flow through this resistance accordingly, you should choose the value of the resistance ok. So, like this you can select the value of the resistance to be used ok.

(Refer Slide Time: 07:49)



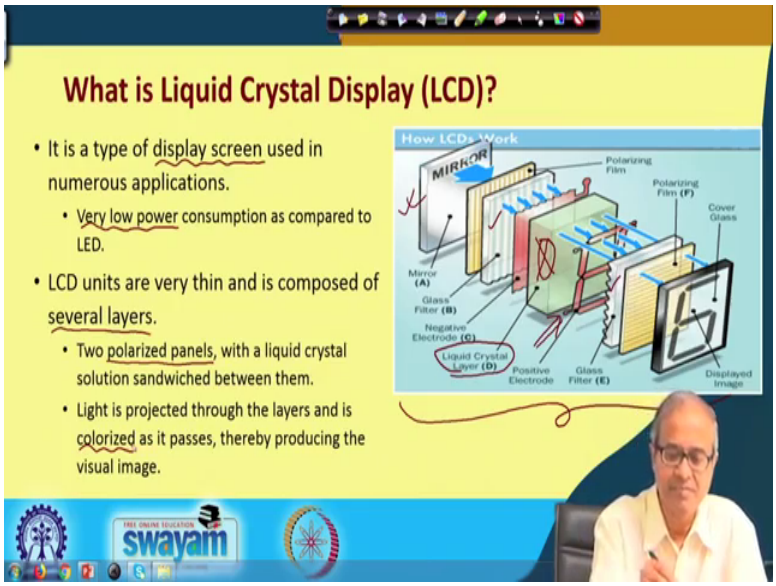
Now, a typical interface like you see when you have a display unit like this let us assume that I have a common anode display common anode means my common terminal is connected to 5 volts, I have connected 5 volts to it and to glow a segment the corresponding segment pin has to be connected to ground 0 volts ok.

So, let us say if I want to display the character 0. So, what is 0? 0 will look like this. So, all these segments other than G will be glowing. So, only G will be connected to high Vcc that will not glow and all other segments will be connected to ground, they will be glowing. Similarly, let us say when you want to display 5, the character 5 is like this ok. So, this segments B and E will not be glowing. So, you see B and E you connect to Vcc all others to ground.

Similarly, for the character F which is like this here B, C and D are not glowing. So, BCD you are connecting to Vcc like this. So, depending on which of the segment lines, you are setting to 0 or 1, you can display any arbitrary combination of segments as per your requirement right. Now the point to note is that, if we have a common cathode display then you have to do just the reverse instead of 5 volts, you will be connecting ground to the common terminal and to display a particular character. Let Us say 0, you will be connecting this to Vcc 5 volts and G will be connected to ground just the reverse.

So, this segments that you want to glow, you will have to connect a high voltage to those if it is common cathode just the convention will be reversed fine.

(Refer Slide Time: 09:55)



So, this is how you can just interface a 7 segment LED display unit to the microcontroller. So, I have told you the basic way of interfacing, how to do it. Now let us come to liquid crystal display unit, which has become so very popular today. So, in so, many display devices, we see this LCD display units some of the characteristics first. This LCD display units are used as the display screen in numerous applications starting from many of our mobile phones our laptop screens touch screens many control appliances everywhere, you see that there is LCD screen that is provided as an output device.

Some of the older kind of LCD screen cannot display color those are called monochrome schemes, they can display only black and some background, but the more sophisticated

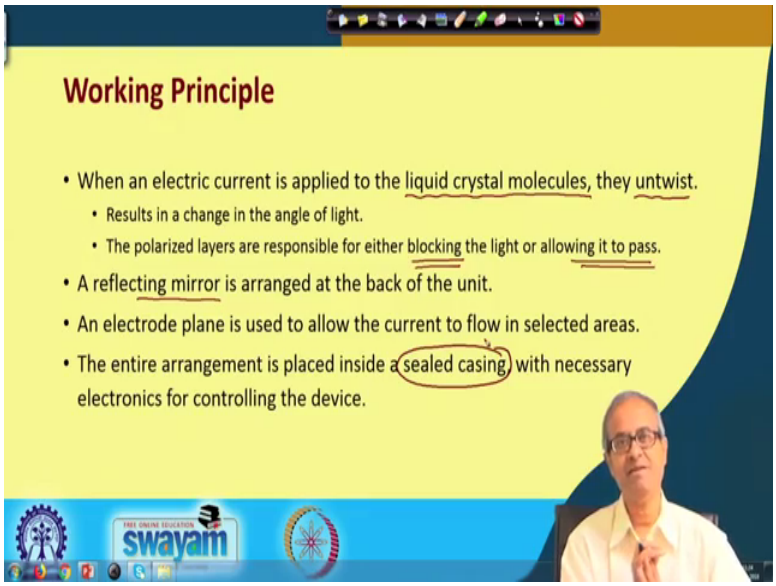
ones they can also display color ok. Now the main advantage of this LCD screens is that they consume very low power as compared to LEDs like LEDs as I told you to glow every LED, you need of the order of 5 milliampere of power, but in contrast for LCD the current requirement is of the order of micro ampere very very small and the way LCD units are manufactured they are also very thin in terms of form factor like the LCD, TV's you must have seen they are so, thin in structure as compared to the older TV's which were so bulky.

Now, means I am not going into the details of how LCDs constructed just to tell you that LCD has a number of layers inside it, they are all sandwiched together. So, the central thing is a layer, which is shown here in the middle, this is a liquid crystal layer, there is a special material which is called liquid crystal depending on a voltage applied. So, it either allows light to pass through or it blocks light is typically polarized and there are some glasses on both sides, this is a glass layer, there is a glass layer, the liquid crystal is sandwiched between them. And let us assume that it is a 7 segment display unit of LCD, you are considering then there will be an electrode, which will be here which will be in the shape of a 7 segment display, this individual electrodes can be applied a current and activated.

Depending on the applied current, there will be some polarization of the light that will be flowing through it and depending on the polarization some light will be blocked and some light will pass through there is a mirror in the backside, which reflects the light. So, that it is visible in the screen and also for good intensity there is often an LED black backplane, where there is a some kind of a you can say illumination in the back side. So, that the display vehicle becomes very clear and prominent this is how internally LCD works ok.

So here, I mentioned it very briefly it consists of several layers, there are 2 polarized panels with a liquid crystal solution sandwiched between them as I have shown and light is projected, when light flows through the layers for a color LCD, they are colorized they are polarized in some way, which represent colors ok. It is a very sophisticated kind of engineering that is done so that light comes out with particular color properties, for a monochrome displays so, either you pass a light or block a light ok.

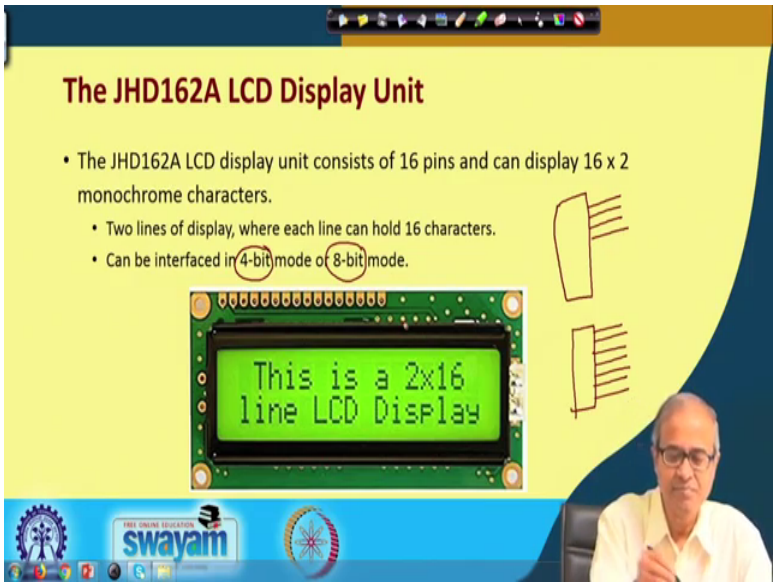
(Refer Slide Time: 14:05)



Then, when some electric current is passed through one of the electrodes; so, this electric current will get or will influence the liquid crystal molecules, what will happen? They will change their orientation depending on the change in orientation, the polarized light will either flow or a not flow through them ok. This will result in a change in angle of light. So, you can either block the beam of light passing through a particular segment or you can allow it to pass, in this way a segment is either glowing or a not glowing.

So, you are not directly passing a current through the liquid crystal right, indirectly it is happening and as I said there is a reflecting mirror at the end, electrode plane and the whole arrangement is placed inside a sealed casing, when you see an LCD display unit, you see everything in a nicely packaged case very thin, all these layers are they are engineered and put inside that sleek frame ok.

(Refer Slide Time: 15:19)



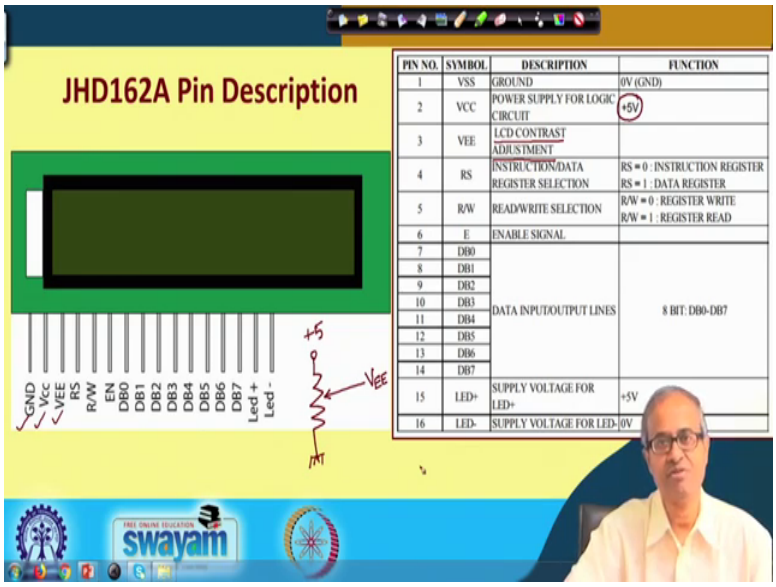
Now, let us consider one particular LCD device that we shall be showing as part of our demonstration session, this is a very convenient output device, which can be used to display alphanumeric characters. Alphanumeric means not only the numbers, but also alphabetic characters abcdefgh everything. Now this is a particular device, the part number is JHD162A and this is the picture of it, this is how it looks, this you can see on one side there are some connected pins, a total 16 pins are provided and this display unit can display 2 lines of characters, 16 characters each at a given time.

So, 16 by 2 display unit and the way this display unit is interfaced or connected with a microcontroller or any other device, there are 2 different modes you can either have a 4 bit mode or you can have an 8 bit mode, in 4 bit mode what is happening? In this display unit, you connect only 4 data lines with the microcontroller and in the 8 bit mode, you will be connecting 8 data lines to the microcontroller. Here, among the 16 pins 8 of them are data lines. So, naturally if you connect all 8 of them to the microcontroller, it is easier to send the data right because, all characters you know they are typically encoded in some character code like a ASCII, their 8 bit code or something like that 7 bit or 8 bit.

So, you have to output 8 bits, but on the flip side you have to connect 8 wires. So, the number of wires becomes more that is why this device also provides with an alternative of 4 bit mode, where you connect only 4 bits of data lines to the microcontroller and the microcontroller will be sending the 8 bit data in 2 cycles, 4 bits and then the other 4 bits,

this will be handled automatically by the drivers. So, if you are using a driver that supports 4 bit mode, you need not have to worry about it, you connect to only 4 lines and the driver will take care of the rest fine.

(Refer Slide Time: 17:53)



So, let us look at the pin description, there are 16 pins I told you. So, on the right the pins and their brief descriptions are mentioned. So, let us see the first 2 are ground and power supply typically, the ground is connected to ground and power supply is connected to 5 volts power supply because, this is a display unit that works with a 5 volt power supply. The third input this VEE, this you can see this is LCD contrast adjustment, these are input by applying a voltage you can adjust the contrast level of the display.

So, how you connected to it? The way you connect is like this, you use a variable resistance called a potentiometer, on one side you can connect 5 volts, on the other side you connect ground and this is a potentiometer, this tapping point can be changed either by rotating a knob or there is screw by rotating a screw and the middle point the tap point this, you connect to VEE. So, by suitably adjusting the potentiometer, you can apply any voltage between 0 and 5 volts to VEE and depending on your suitability, your viewing angle, you can adjust the contrast accordingly ok.

This is one thing and then there is a pin called RS, RS stands for register select. Now, when you are sending some data or instruction to the display unit, it can be either the data you want to display or you see it is not only a data sometimes, you are telling the

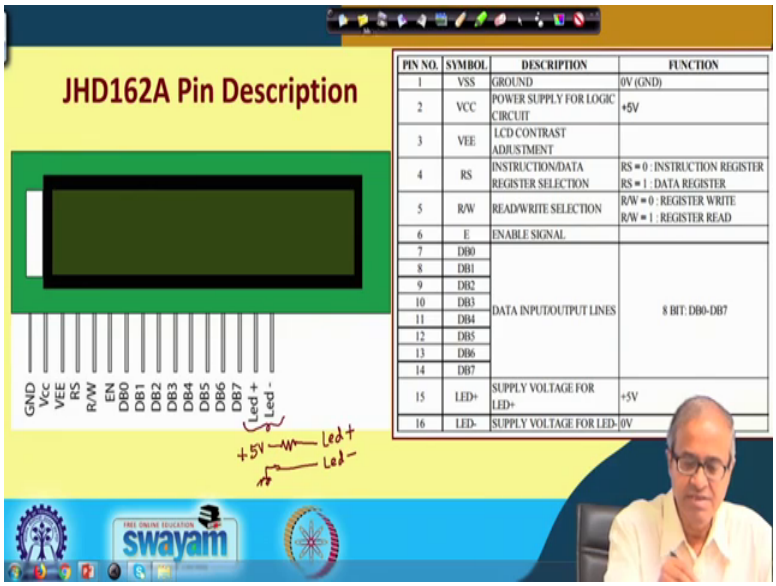
display unit that look we want to display the characters in 8 bit mode or 16 bit mode. So, some instructions can also be written to this display unit. So, it can be either instruction or data this RS actually tells you, what you are actually writing.

So, when you are interfacing with to the microcontroller, sometimes microcontroller will be sending an instruction, sometimes it will be sending a data. So, this RS pin has to be connected to some data line of the microcontroller. So, that it can change it to 0 or 1 as per the requirement ok. The next pin is a read or write pin, this tells you whether you are writing a data to the LCD unit or you are reading some status information from the LCD unit. So, if it is 0, it means write, if it is 1 it means read.

Now, in our interfacing application, we would only be writing, we would not be reading the status. So, for our purpose what you can do? We can directly connect it to ground you can make it 0. So that, it is always in the register write mode the next pin is an enable signal, you see this is enable this enable signal will activate this display unit. So, whenever you are enabling it only then it will be working. So, typically this enable pin is also connected to the microcontroller so that whenever, it wants to send the data, it enables it and then it writes the data ok.

So, if it is 1, it is enabled, if it is 0, it is not enabled. Then comes the 8 data lines DB 0 2 DB 7 ok, these are the 8 data lines. So, when you are interfacing in the 8 bit mode, you will be connecting 8 lines from the microcontroller port to these 8 pins, but when you are using the 4 bit mode then you need to connect only 4 of these lines D 4, DB 5, DB 6 and DB 7, you only connect the high order 4 lines to the microcontroller and as I said the microcontroller will be outputting the data in 2 cycles, 4 bits at a time ok.

(Refer Slide Time: 22:33)

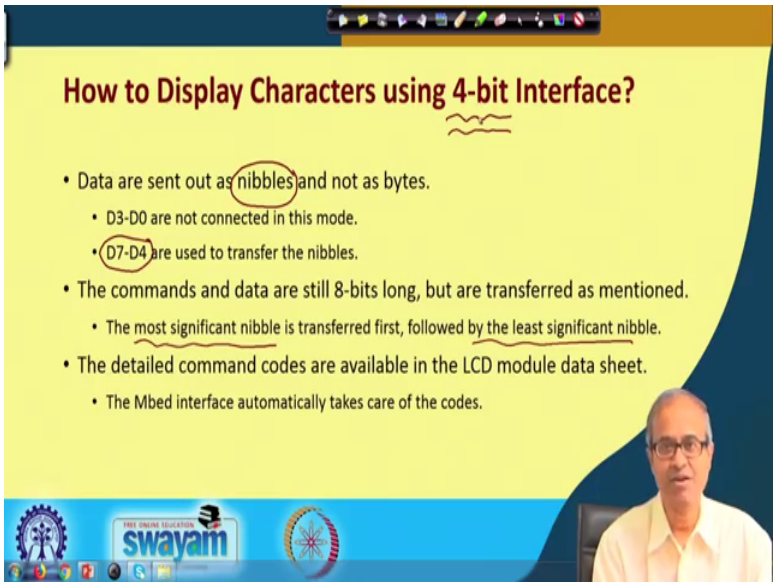


PIN NO.	SYMBOL	DESCRIPTION	FUNCTION
1	VSS	GROUND	0V (GND)
2	VCC	POWER SUPPLY FOR LOGIC CIRCUIT	+5V
3	VEE	LCD CONTRAST ADJUSTMENT	
4	RS	INSTRUCTION/DATA REGISTER SELECTION	RS = 0 : INSTRUCTION REGISTER RS = 1 : DATA REGISTER
5	R/W	READ/WRITE SELECTION	R/W = 0 : REGISTER WRITE R/W = 1 : REGISTER READ
6	E	ENABLE SIGNAL	
7	DB0	DATA INPUT/OUTPUT LINES	8 BIT: DB0-DB7
8	DB1		
9	DB2		
10	DB3		
11	DB4		
12	DB5		
13	DB6		
14	DB7		
15	LED+	SUPPLY VOLTAGE FOR LED+	+5V
16	LED-	SUPPLY VOLTAGE FOR LED-	0V

And the last 2 pins this LED plus and LED minus, these are used to control I told you that there is an LED backplane in typical LCD displays, which controls the brightness level. So, you can connect a voltage across LED plus and LED minus to make the display bright typically, what you do with 5 volts, you can connect a resistance, you can connect it to the LED plus input and the other input you are connecting to LED minus, this you can ground, this is how you can connect ok.

So, this tells you the different pins and exactly how you can connect this pins; that means, this display unit to a microcontroller ok.

(Refer Slide Time: 23:31)

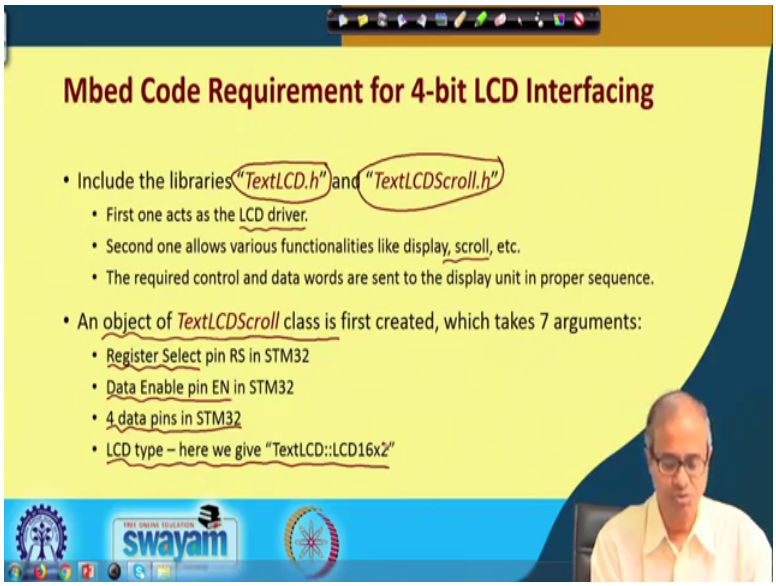


And now talking about the interfacing issue; so, in our experiments because of simplicity, we shall be using the 4 bit mode because, only 4 data lines have to be connected otherwise 8 wires have to be connected ok. Now, I told you in the 4 bit node data are written into the display device, 4 bits at a time, 4 bit is called a nibble byte is 8 bits. So, data are sent as nibbles.

So, only as I told you D 7 to D 4 DB 7 to DB 4, they are connected to the microcontroller via these lines the data are sent so, but the commands and data that are actually to be written they are still 8 bit wide, but they will be written in 2 cycles, 4 bits and 4 bits. First the higher order 4 bit is sent, first the lower order 4 bits are sent after that that is how it works. Now, these display units the way we shall be showing you the demonstrations, for example with the STM 32 board, we will be using a programming environment called Mbed.

This Mbed programming environment allows us to develop our application in C and it provides with a host of library functions and drivers, which you can use ok. Now in that library function that we will be using automatically, this 4 bit interfacing will be taken care of and while writing the program, we need not have to worry about anything, the driver will automatically take care of; that means, writing the high order 4 bit, first low order 4 bit next and so on and so forth, when to write instruction, when to write data those will be taken care of by the driver ok.

(Refer Slide Time: 25:31)



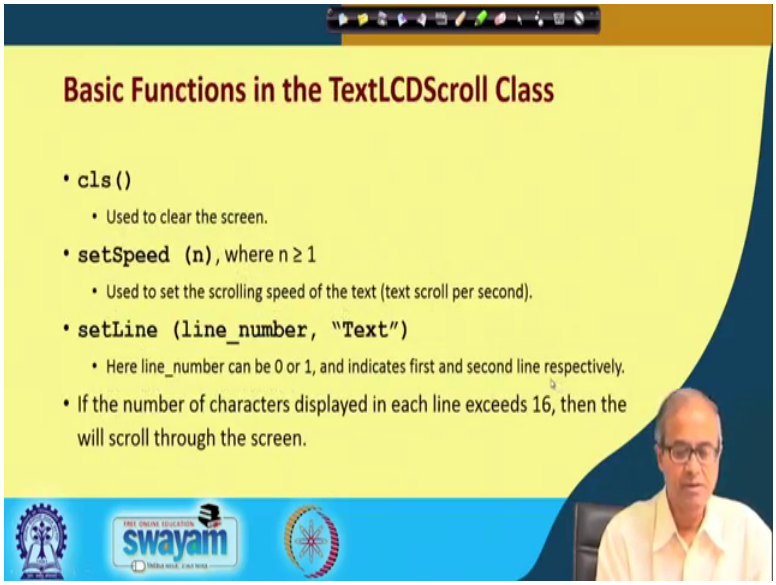
So for this Mbed coding, we shall be using these 2 libraries text LCD and text LCD scroll ok, this we shall be seeing a small example, the first library is actually the LCD driver, it is responsible for sending the low level data and the instruction has 4 bits at a time and the second one allows you with scrolling features in the display, if you are trying to display a more than 16 characters in a row, the display will automatically scroll from left to right that scrolling is automatically supported by this driver ok.

Now the way, we write the program, I shall show an example we first create an object of this LCD text LCD scroll class, it will create an object which will indicate that LCD unit, this is an object oriented programming concept ok. Now when you specify this object 7 arguments have to be specified because, you see with this LCD you have to make some connections with the microcontroller, these 7 things are required to make the connections, what are the things?

First you have to connect the register select input. So, I told you have to select whether it is the instruction or a data then data enable, you have to enable the display unit then the 4 data lines, this makes it 6 and lastly LCD type here, we have to specify what kind of LCD display unit is there? You see there are other display unit like there are some display unit, which is 16 by 4, there are 4 lines, but their display unit that we are interfacing here consists of only 2 lines.

So, we also specify what kind of display unit you are using as part of the parameters, when you are creating an object of the type text LCD scroll ok.

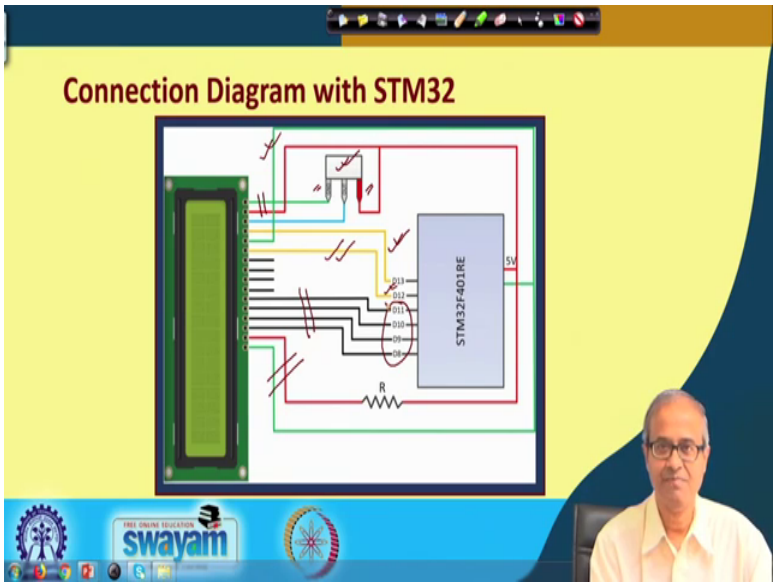
(Refer Slide Time: 27:47)



So, the different functions that are supported by this text LCD scroll class are cls means? clear the screen, the screen is cleared, it is made blank. Set speed n, where n is an integer greater than or equal to 1, it means when you are scrolling this screen, what will be the speed of scrolling? 1 means 1 character per second, 2 means 2 characters per second, 3 means first of 3 characters per second, you can control the speed of scrolling.

And set line is a function, where you can tell what text you want to display and in which line number line number can be either 0 or 1, 0 means the first line, 1 means the second line and as I said earlier, if the text you are trying to display on a line is greater than 16 then automatically the text will start to scroll all right.

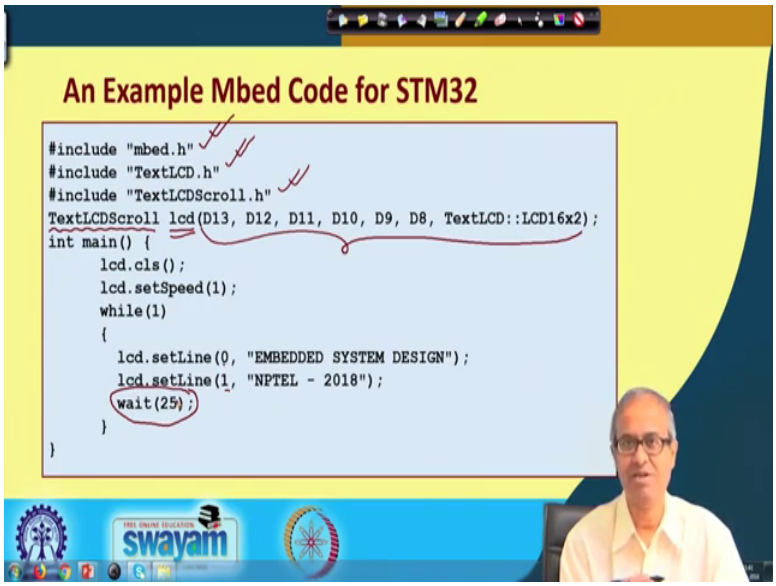
(Refer Slide Time: 28:53)



So here, I am showing a very typical interface with the STM microcontroller to this board you see here I am connecting the LED plus and LED minus connections. Here, the first 2 are the power supply and ground you see here, I am using a potentiometer on one side, I am connecting ground on one side, I am connecting 5 volt the middle point, I am connecting to the VEE terminal that is the contrast control.

Then, we have the registers select this yellow line, which is connected to one of the microcontroller pins then the read write bar is permanently connected to ground, because we are only writing then here we have the enable. Enable is also connected to one of the microcontroller lines, because microcontroller has to enable it then the low order 4 4 data lines are not connected only the high order 4 lines are connected and they are connected to some microcontroller pins ok. This is how you make the connection microcontroller to the display unit right.

(Refer Slide Time: 30:11)



And I am showing a sample Mbed code. This is a sample Mbed code to display a some character, you see at the beginning you have to include some headers because, you are using the Mbed programming environment; mbed dot h is mandatory. You have to include this and these are the 2 additional libraries, you are using in l text LCD and text LCD scroll as I told you have to create an object of type text LCD scroll, you give a name LCD is the name, you can give any other name, if you want and these are the 7 things you specify.

Here you specify which pins you are connecting to first one is the register select; that means, you are telling you are connecting register select to your STM, STM 32 D 13 pin then next one is your enable, you are connecting or enable to the STM 32 D 12 pin then the 4 data lines, you are connecting to D 11, D 10, D 9, D 8 and then the last one says what kind of display unit is this? And in the main program, you see it is very simple, we are calling this clear function cls function first.

We have to give the name of this object LCD dot name of the function this is how you call. So, the display is cleared then dot set speed 1, I am setting a speed of scrolling a one character per second then in a loop, while 1 means it is an infinite loop we are displaying something on first line, something on second line, we are displaying embedded system design, which is more than 16 character. So, there will there will be slow scrolling, 1

character per second, second line NPTEL 2018, this is fixed less than 16 this will not scroll.

And here, just this is not required actually, I am waiting for 25 seconds, I am repeating it well this will get repeated anyway whether or not you give this wait 25. This is how you can interface and program an LCD by connecting with the STM 32 micro controller ok. This will give you an idea, how to do it. So, with this we come to the end of this lecture. So, we shall be continuing by talking about some other sensors and means actuators output devices in the next lectures.

Thank you.