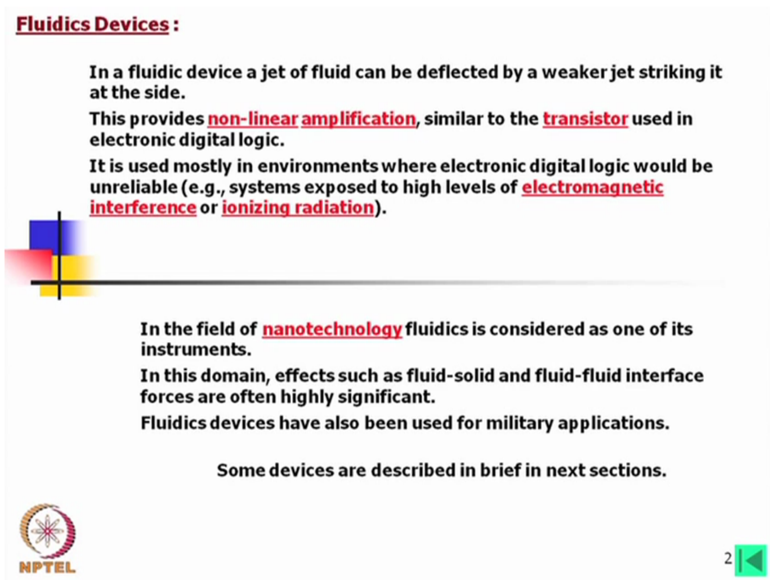
Fundamentals of Industrial Oil Hydraulics and Pneumatics
By Professor R. Maiti
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur
Lecture 27
Module 07
Basic Devices, Symbols and Circuits

Welcome to today's lecture, this is lecture number 27 under model 7, this means fluidics and fluid logic and the lecture is on Basic devices, symbols and circuits.

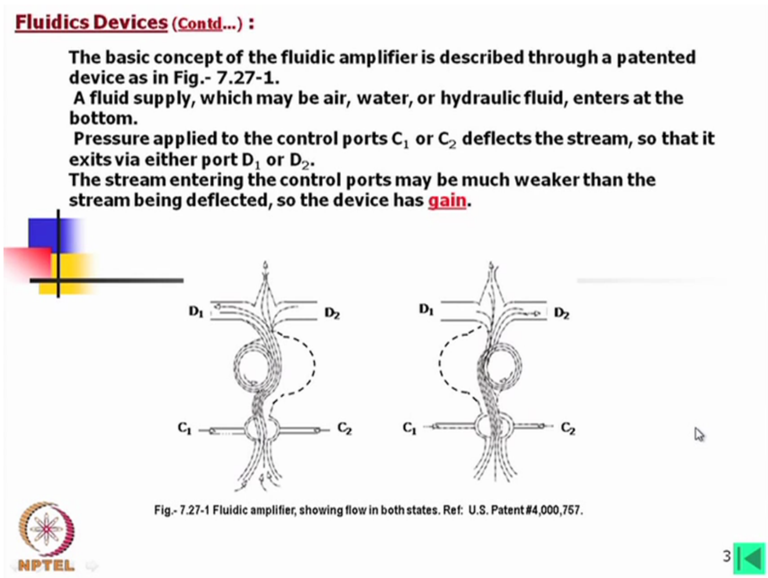
(Refer Slide Time: 0:43)



In a fluidic device, a jet of fluid can be deflected by weaker jet striking it at the side, this means that fluidic devices already I have told that there is no moving component except the fluid is moving inside so imagine a fluid flowing in a direction and that is being disturbed by another slow from the transverse direction or direction at an angle. This provides non-linear amplification, it is similar to transistor used in electronic digital logic. It is used mostly in environments where electronic digital logic would be unreliable that is system exposed to high levels of electromagnetic interference, ionising radiation, et cetera.

In the field of nanotechnology, fluidic is considered as one of its instruments I would say in other words, the word nanotechnology is used for various fields, in case of medical science involved with fluid flowing nowadays it is the fluidic is finding its way that it can be utilised in better ways than any other devices. In this domain, effects such as fluid-solid and fluid-fluid interface forces are often highly significant. Fluidic devices have also been used for military applications, some devices are described in brief in this lecture.

(Refer Slide Time: 3:28)

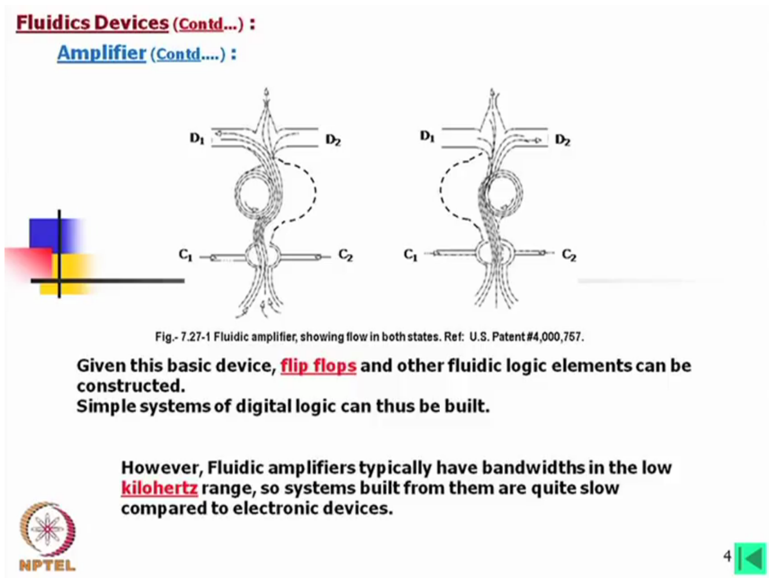


Now basic concept of fluid amplifier is described through a device as shown in this figure. Now if you look into this figure that from the bottom something is flowing through this body, this is basically you can imagine a cavity between 2 plates, 2 bodies there is a cavity inside. Now what is there, there is a main flow it is flowing like this, now there are at this zone there are 2 inputs, you should call this is input, this is some disturbing jet. Now it is like that when C 1 is being actuated, then flow is moving like this, when C 2 is being actuated the flow is going like this and it is going through the D 2 and it is going, in case of C 1 it will go via D 1.

If we consider the pressure, pressure in this direction usually these devices are of low pressure, even if for the main flow. And the disturbing flow is even of much less pressure but it is the fluid mechanics in which with this disturbance basically which are normally nominal flow will be disturbed and it will move in a particular direction. For that what we need that we need to have some pressure range in these 2 flow as well as shape of this body. A fluid supply which may be air, water, or hydraulic fluid, I have described that is entering at the bottom, and then pressure applied through this control port C 1 and C 2 to have the flow in D 1 and D 2 direction.

The stream entering the control ports may be much weaker which I have described than the stream being deflected so the device has gain. This means that we normally by this small force we are deflecting a relatively larger force and that we are getting output through this larger force so therefore we should call as gain in terms of the gain used in both electrical fluid and any control field.

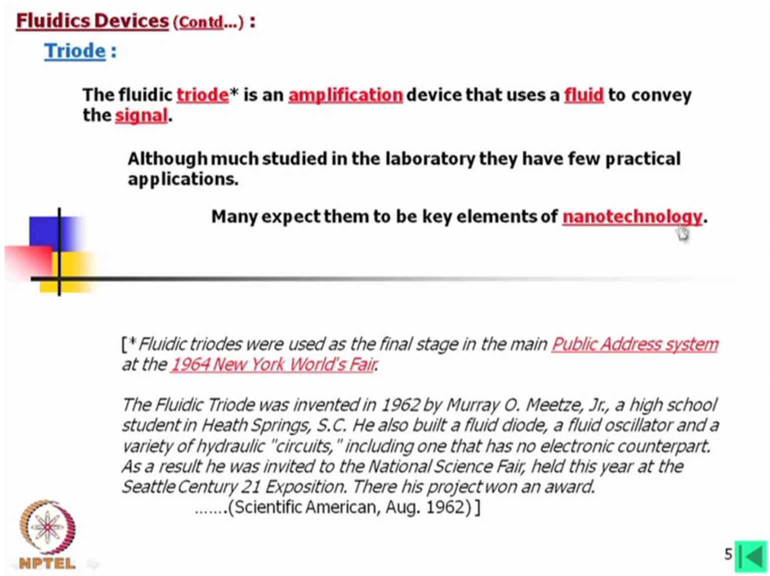
(Refer Slide Time: 6:47)



Now with this basic device, the flip-flops and other fluidic logic elements also can be constructed, basic principle remains same. Simple systems of digital logic can thus be built, this means we have already learned about the digital logic, now with this we can make the device which are called Gates different types of Gates and with these gates we can build the logic and we can construct also physical circuits.

However, fluidic amplifiers typically have bandwidth in the low kilohertz range, so systems built from them are quite slow compared to electronic devices that we have to remember, the response will be slow in this case. However, say for example in many medical instruments these fluidic devices are used where it is not required like a computer calculation but we require much accuracy, safety and Hazard free operation.

(Refer Slide Time: 8:18)



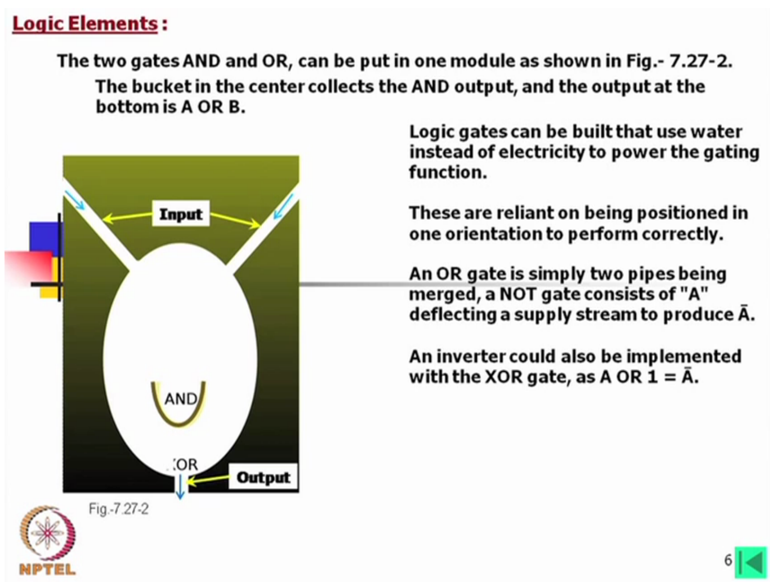
Now, basic device when 1st it was developed then basic was the triode, sorry this amplifier and then the fluidic triode is an amplification device and that used a fluid to convey the signal. Now if we look into this history, then the fluidic triodes were used as the final stage in the main public address system in the year 1964 New York World's Fair, the name of the fair is 1964 New York World's Fair. Now surprisingly, this fluid triode was invented just 2 years earlier to this fair by a boy who is Murray Meetze Junior, he was a high school student but he invented this fluidic triode.

Obviously, it is not electronic device, it was some this whether you can say mechanical part along with the fluid part and he built a fluid diode, a fluid oscillator and a variety of hydraulic circuits including one that has no electronic counterparts as yet there is no electro… That went with fluidic we can make many devices and which may not be available with electronics on the other hand, there are many things electronics also which cannot be achieved by fluidics. Now he was invited in this National Science Fair and he was also awarded for his project.

Now although much studied in laboratory then onwards have been done but there are really few practical applications because to make a particularly to make a circuit, although these fluidic devices are very small may not be very big but in comparison to electronic components it is big. However, at the time when the fluidic was developed, the fluidic components were developed that time there was not much progress in electronic devices so fluidic devices were initially was being used for automation and other control system. However, those were not very quite, we have too many such devices when they are connected together, the shape was very large, et cetera.

And so it was in many cases it was found that that it may not be feasible to use such devices for making a control circuit or logical circuit. Many expect them to be key elements of nanotechnology, nowadays it is found that which did not find its application in general industrial applications or other devices but it is expected that those will be now will be used in nanotechnology.

(Refer Slide Time: 12:14)



Now this is a very simple system is shown, imagine a pocket like this, it has 3 holes which is like tube and at the middle position there is a bucket, let us consider it is in the vertical position. You can imagine that a plate is machined like this, 2 plates are machined like this and they are put together in reverse way that means the other plate is the mirror image of this and that is put together. So this means that this is one passage, this is another passage, this is a cavity inside, this is another passage to go out and there is some sort of bucket is placed there. Now what we can do, let us we can put a ball, diameter is very close to the diameter of the tube not very small neither it is very tight.

So one ball you can it can come through this passage, another ball can come through this passage. Now forget about the probability, what may happen these 2 balls will fall in this bucket or it will fall outside and then through this passage only one ball can go. Now if one suppose you have sent only one ball so this will go out then there will be some function will be performed that one output is there or this ball has come through this then the performance will be there. Or if the 2 balls come through and one by one it is coming out, still the performance will be there, if nothing is coming out now performance here.

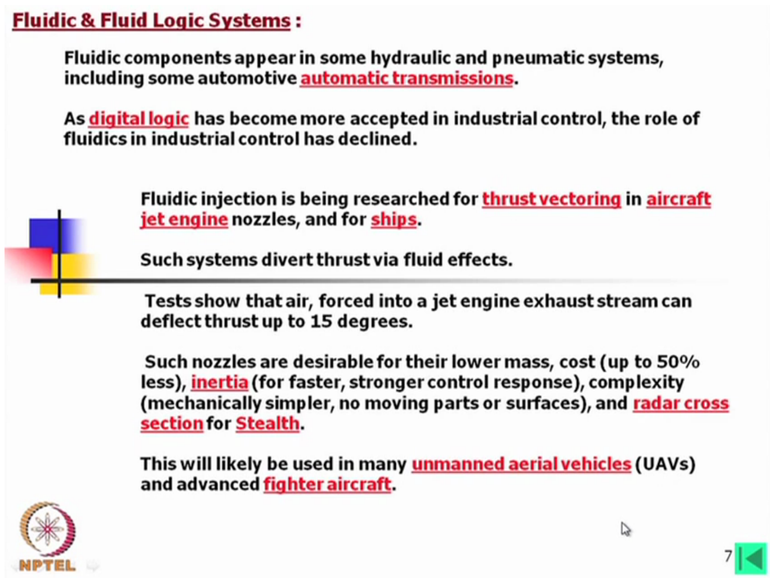
On the other hand, if these 2 balls instead of coming over here they take this bucket or that means these 2 balls fall inside this bucket then there will be another function. Now this is just to understand when these 2 together coming then one function and if anyone of them coming through this then another function is being performed. So this is basically to understand what is OR function and what is AND function. This is described what I have already told you, now logic gates can be built that use water instead of electricity to power the gating function, this means in this case case the function itself is performed by the fluid flow, this indicates that you may need to amplify this power.

In case of electronic, by electrical devices the power is directly taken from the electrical source that means whatever is being used for the control that can be magnified that can be amplified and can be used for the power. In this case also we can verify those but we have to use the source has water or other fluid say air. These are reliant on being positioned in the orientation to perform correctly, this means that you have to make sure that the orientations are correct and you have to construct devices accordingly. In case of electrical devices you can say electric flow is through wire you can put in direction, but in case of fluidic devices you have to care careful about this path except where the flexible path can be used flexible tube can be used for example.

An OR gate is simply two pipes being merged, a NOT gate consists of “A” deflecting supply stream to produce A bar. Now here, instead of going in too much detail definition of this gates, there is a NOT function, NOT function is simply remember because there will be NOR function also. Now NOT function is that simply one function we are reversing, that inverse of that function.

Suppose A in OR function A means 1, through some input there is a signal output is 1, now you if you would like to make it not 1 then simply you disturb that, not allow to go through that, that means what was going to be output as 1, you are diverging that then you call inverse of that NOT of that. This means we are this output could be A, now by applying a disturbance we are getting the output A bar not A that is designated by A bar, so which is called NOT gate. An inverter could also be implemented with the OR gate this is XOR not X OR, as A OR 1 = A bar okay.

(Refer Slide Time: 18:33)

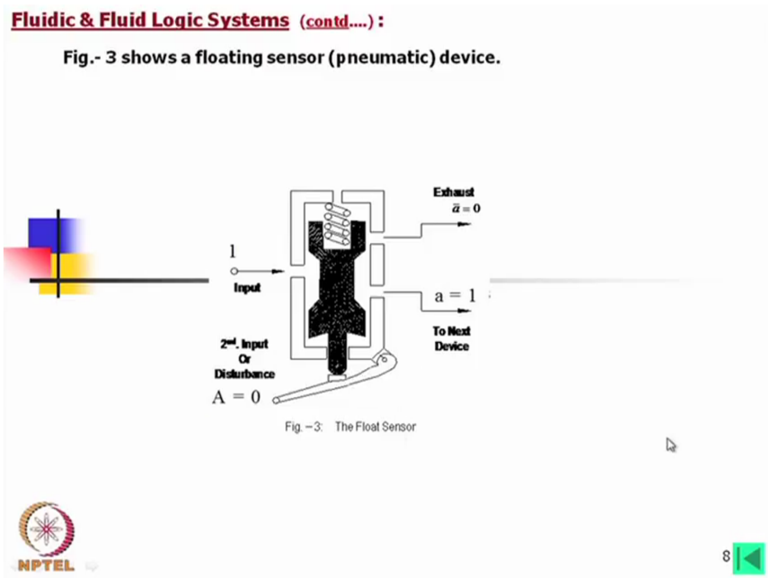


The fluidic components appear in some hydraulic and pneumatic systems including some automotive for automatic transmissions, this is just an information. As digital logic has become more accepted in industrial control, the role of fluidic in industrial control has declined that means digital logic means electronics logic nowadays available so you may not find much applications of fluidics in industrial control. Fluidic injection is being researched for thrust vectoring in aircraft jet engine nozzles and for ships, only the fluidic principle is being used for fluid injection in case of engines jet engines mainly ships and aircraft.

And this is because of that their function is more efficient for less consumption of the fluid sorry less consumption of the fuel to increase the efficiency, such systems divert thrust via fluid effects that means again as I mentioned that we are diverging a thrust by simply we can disturb disturbance fluid which is of much less pressure. Tests show that air forced into a jet engine exhaust stream can deflect thrust up to 15 degrees, so this is just an information so a small jet of very low pressure can divert a thrust into 15 degrees, this means that the thrust is coming, if you can divert that that will have better impact on the impaler which will get more power output.

Such nozzles are desirable for their lower mass, cost (up to 50 percent less), inertia (for faster, stronger control response), complexity (mechanically simpler, no moving parts or surfaces), and radar cross-section and Stealth. Now this is also used in unmanned aerial vehicles that is UAVs and also advanced fighter aircraft.

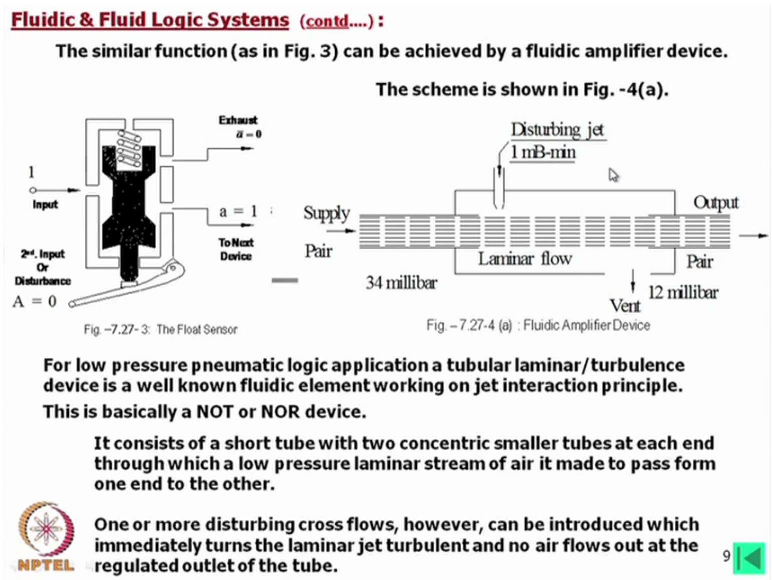
(Refer Slide Time: 21:37)



Now we shall discuss about a device, now in this device this is pneumatic device, also the similar fluidic fluid device or hydraulic device can be made but this describes precisely a logic gate. Now look at this, this is the input, input means as I told a flow that not very high-pressure not very high-pressure, this flow is there. Now this flow is going through this and then going out in normal conditions when the liver at this position. So if this flow is there then there is a flow output so what we put, input 1, output a is also 1, now this is being used to perform some performance so it is going to the next device.

Now here I would say that in this case the fluidic devices as I told that it should we have laminar flow even if for the mainstream? In this case, this disturbance not buy the jet but this disturbance is or you can call it 2nd input that we are moving this lever, while we are moving this lever then this is being closed this fluid is going out that is it is going out to exhaust. If we consider the output here then it is reverse of the output here so it is A bar which is equal to 0, it is NOT A. This means that by operating this ON-OFF, ON-OFF, et cetera we are getting that at either the flow is going to next device or the flow is going to exhaust so device is not being operated. So if this is called the this is basically used in to use as a flow say for example, water level control in a tank, etc.

(Refer Slide Time: 24:25)



Now the similar functions can be achieved by a fluidic amplifier device also, how? Now in this case let us consider this is a large tube and it is blocked here, small piece of large tube large diameter tube it is blocked here. Now what is having, imagine this is a cylindrical body this may be square also rectangular body or square cross-section body but let us imagine this is a circular one. Now here there is a small hole okay, now in that small hole again a nozzle type small pipe is inserted through which again one flow can enter into this. Now in this case there is no physical connection between this hole to this hole, simply than as a hole and this side it may be a tube like this or may not be tube but the flow we can consider that supply of this is Air, P is the pressure and A is the Air not Pair.

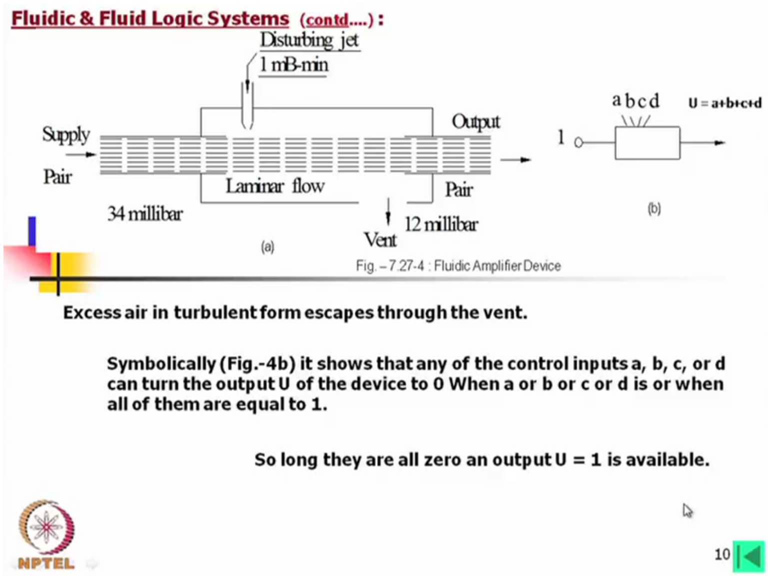
Now this flow is a laminar flow, it is like that if this flow is allowed through this hole, straightaway it will go here, you can imagine that as if it is going through a tube it is like that. Now when this flow is initiated that means this flow is given then it will be disturbed and it will go through another larger hole, it will go out and it will not this flow will not come in this way so it will not go to next device and the work will not be performed. So this is a basically a hydraulic device, this is not a logic device not fluidic device because air is the moving part, in that case there is no moving part except the fluid is moving and the function is same. Now if you look into this pressure, here 34 Milibar you can imagine that 34 Milibar, 1 bar = 0.1 mega pascal and Milibar means you can imagine this is divided by 10 to the power 3.

34 Milibar only and whereas this disturbance is 1 Milibar minimum of course, it can be slightly higher but you need at least 1 Milibar. And when this disturbance is on this fluid, you can see that it is being bent at 12 Milibar, this pressure is not there. Now as I told this if you would like to use this air source to drive something say for example, in that case it needs amplification. Say suppose we need say at least say 340 Milibar say that means we have to amplify 10 times that is different issue, but 340 Milibar air we cannot pass through this to have this performance, this is usually low pressure.

Now for low pressure pneumatic logic application, a tubular laminar or turbulence device is a well-known fluidic element working on jet interaction principle, this is basically a NOT or NOR device. It consists of a short tube with 2 concentric smaller tubes which I have described and this flow is laminar. Now we can have one or more disturbing jet that means in that case say for example, this work I mean this will be disturbed either one input or maybe either of the 1 either one of the all the disturbance jet are there or maybe 2-3 jets at a time.

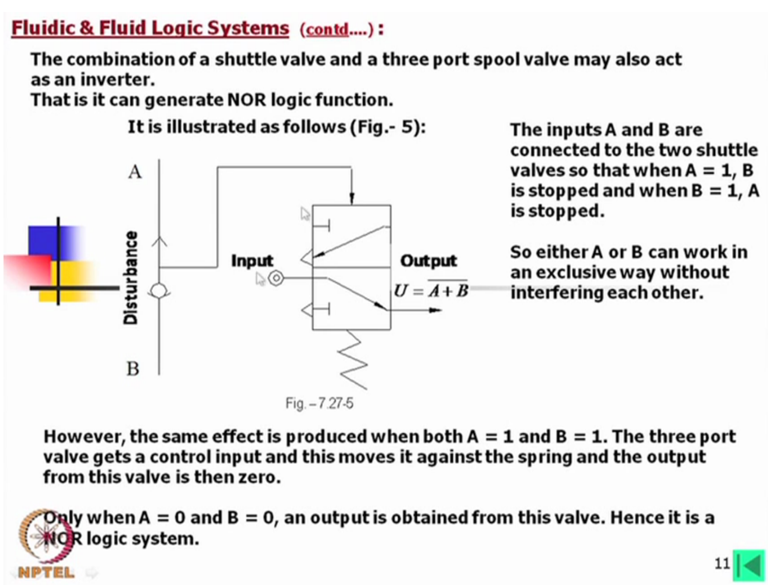
So this means that this is a in a system it is like that, if one disturbance is there this will not be performed, if 2-3 disturbance at a time also there, there will be no performance. Only this will be performed, it will go to the next device, there is no disturbance so we can make this device multiple input and single output.

(Refer Slide Time: 30:23)



Say this is again I have shown this and the symbol for multiple input it is like that, this symbol is used for this device. Symbolically it shows that any of the control inputs a, b, c or d can turn the output U of the device to 0 when a or b or c or d is or when all of them are equal to 1. This thing I think here we can put 1, this means that a, b, c, d any of them is 1 or all of them 1 okay. So long they are all 0 an output U = 1 is available that means only then if they are 0 only then there will be this jet will be will go to the next device and the performance will be achieved, so this is basically a NOR device.

(Refer Slide Time: 31:54)



The combination of a shuttle valve and a 3 port spool valve may also act as an inverter this I will show, that is it can generate NOR logic function, how? Now what we have used? We have used a shuttle valve here and then we have used another 3-port spool valve. The inputs A and B, this is A and this is B, there are 2 inputs connected to shuttle valves or in other words say you can call this is a shuttle valve 2 ends of the shuttle valves so that A = 1, B is stopped and when B is equal to 1, A is stopped. That means when the flow is coming through this, it can go this direction this will be stopped or when the flow is coming from B, A will be stopped and flow is going in the direction, either A or B this will be operated okay.

If the flow from both side is coming, this will be operated also because this valve will be in the intermediate position but there will be passage to go here, so this is basically OR function so either A or B can work in an exclusive way without interfering each other. However, the same effect is produced when both A = 1 and B = 1, the 3 port valve gets a control input and this moves it against the spring and the output from this valve is then 0. This means that if you look into this valve, what is there?

This indicates looking into this symbol this indicates that there is an ample flow and it is going out okay. But when there is an actuation then this will come to this position and the flow will be stopped so if these are present then there is no function no output, functions means no output. So that means that either A or B or from both of them reverse of that, if A is there, no output, if B is there, no output, if A and B both are there, no output. So symbolically sorry this in equation form we will write like this, A = A OR B this is + OR B and inverse of that A + B bar okay.

So this at this point I would like to tell you that actually to remember all such things we need a practice because we are habituated with normal algebra General algebra and this is following Boolean algebra. And say suppose if it would follow the general algebra, in that case we could have remember easily but as you see this function is something different, we need a practice. Only when A = 0 and B = 0, an output is obtained from this valve hence it is a NOR logic system.

(Refer Slide Time: 35:56)

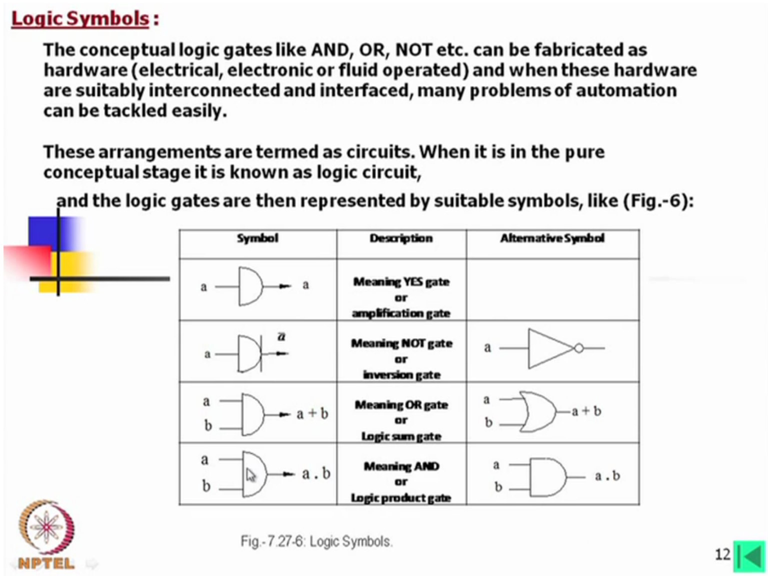


Fig.-7.27-6: Logic Symbols.

The conceptual logic gates like AND, OR, NOT, etc can be fabricated as hardware Electrical, electronic or fluid operated and when these hardware are suitably interconnected and interfaced, many problems of automation can be tackled easily. These arrangements are termed as circuits, if such devices are put in sequence with a proper connection between them and we achieve a desire performance then we call it circuit and we call it logic circuit.

Now let us see the logic gates and their symbols, now this symbol is like this, it is like a D capital D and look at this symbol carefully, one simple line is coming this side from left to right and then this is the line with an arrow, this we should consider as output whereas, this is input. Now what it is doing, meaning YES gate or amplification gate, now there are little confusing that YES means a flow is coming in and that flow is going out, now why we should call it an amplification? May not be it is amplified, the same input is going out even there might have some loss also pressure drop also, but why we should call amplification gate? Amplification gate mean we call it whenever this is not being disturbed and going out, we should call this is amplification.

Now here we find that the same D but there is a vertical bar, in that case A is input and then this will be output is reverse of a okay. And that means if A is 1, say let us consider in that case 1 and 0, suppose if you consider 1 means there is a flow and 0 means there is no flow then suddenly inverse of no flow must be flow is there, so it is normally not possible you cannot think of we have not given flow at all, how it can come the output. But usually this device is like that, there will be flow if this flow is not being passed through this only then this is not a think in this way because we are no discussing the internal details of this okay.

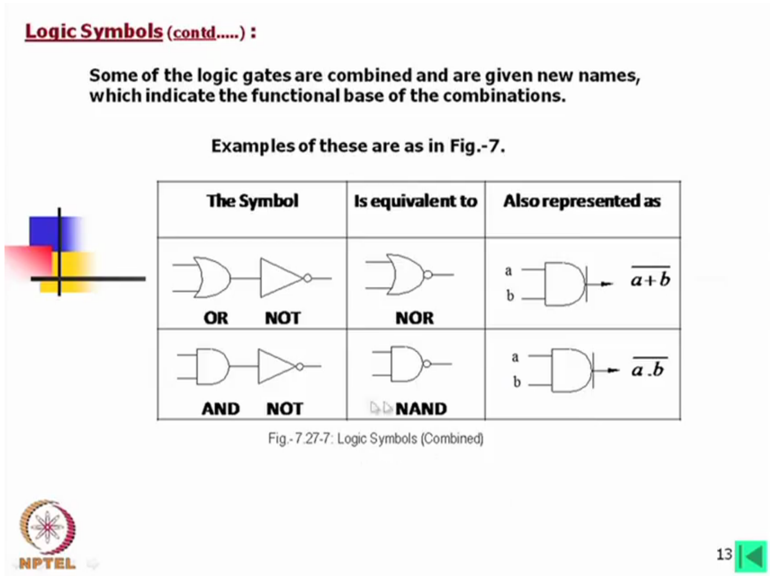
Now next one so it is called inverse gate and in this case the 1st one has no alternative symbol is used, but mostly you will find in electrical circuits this type of symbols are used, this is called bubbled, a bubble is used so it is NOT. But we can also because this is basically we will call logic circuit say for example we would like to achieve some performance, in that case what we should do, we should first make the logic circuits then we will think of whether we should go for fluidic device or electronic device, so you may find also in fluidic device also this type of circuits sometimes are being used.

Now next you look at this, here input is 2 double input and then output is a + b, this = means OR, a OR b that means if there is a signal at a then the output is there, if there is signal at b then there is a output, both a and b are there, there will be output but if a is not there, b is not there then only this will be 0 no signal, so this is this represents OR gate or we call it logic sum gate, it has also an alternative symbol which is like this okay, usually with this sign there is no arrow is used.

And remember, usually with all these symbols, this a, b, a + b , etc are written that means is you do not write this a, b, a + b then may be in some cases it might be difficult to understand what is the actual device is because in many cases they look alike, not many cases in some cases I would say look alike. Say in this case you see these 2 look alike, but this is for a dot b that means meaning AND gate, what is AND gate?

Suppose a is there, b is not there then this like a general algebra in that case this output will be 0, b is there, a is not there then is also output is 0, only if a and b both are there then there will be output, so there is a distinct difference between this and this, this is OR gate, this is AND gate, this is logic sum, this is logic product. And in this case you will find that alternative symbol has difference, this device and this device has difference so even if these are not written, still you can understand but in this case you have to write to understand this device. And also observe, here D and this is this also looks like capital D but that is a difference, this is this half circle = straight-line, where, this is normally semicircle or even less.

(Refer Slide Time: 43:58)

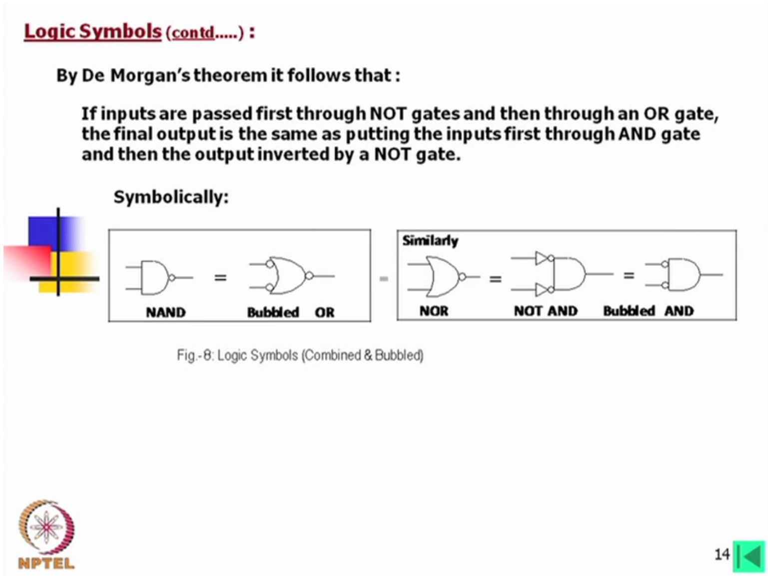


Some of the logic gates are combined and are given new names, which indicate the functional base of combinations. That means we have seen OR gate, AND gate, NOT gate, et cetera, NOR gate also is there, now combining OR and NOT we can make a NOR gate we are coming to that. Now here some are shown, let us see these symbols, this is OR, we have used the alternative symbol here OR gate and there is a NOT gate, combining this we are getting NOR. Now NOR gate is while we are presenting the NOR gate we have taken this part and we have taken this bubble, the intermediate portion is eliminated, this means that OR and NOT, NOR gate.

But remember, in this device 1st performance will be OR and then NOT of OR, do not be confused. It is not like that you can put in another sequence to get NOR device, you have to put in this sequence. Physically, you can put OR device and NOT device and get NOR and but the NOR also can be made separately as we have seen earlier, now this is also represented as like this okay. Usually with this symbol you will find a, b, a + b bar is is given.

Take another one, in this case we have put AND and NOT, now this is called NAND but this is not very popular one NAND, the same way and alternative is this, if you look into these 2 these 2 are again only device looks alike, only symbol looks alike but the when we put a + b bar or a dot b bar that indicates the 2 different devices, this is NOR, this is NAND okay, so these are combining the symbols.

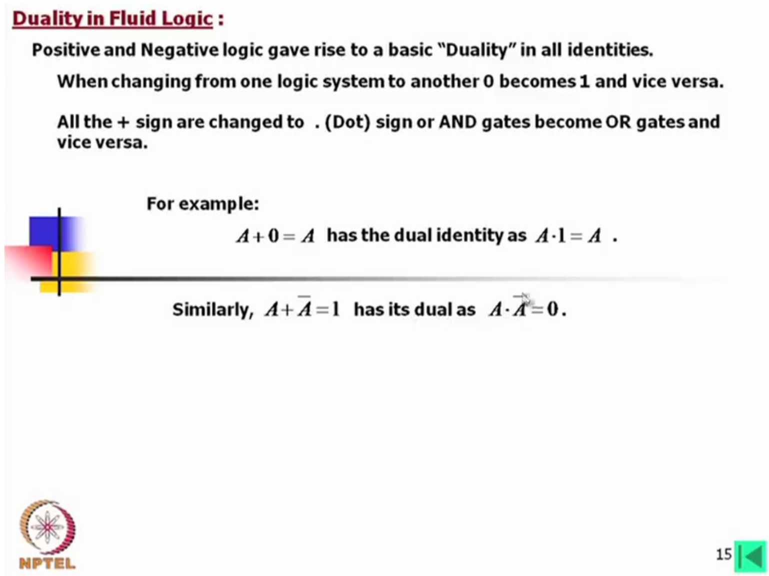
(Refer Slide Time: 46:31)



Now another interesting part is that by De Morgan's theorem what we have learned earlier it follows that. If inputs are passed 1st through NOT gates remember first we are sending through NOT gate and input and then through an OR gate the final output is the same as putting the inputs 1st through AND gate and then output inverted by NOT gate. Look at this, earlier I told that we if we put NOT and OR, we will not get NOR, to get a NOR, OR and then NOT. But if you put NOT and then OR, what actually you will get, you will get first AND and then NOT, this means that you may think of NAND, you are getting NOT OR = NAND so this using De Morgan's theorem we have already learned and symbolically NAND is equal to bubbled OR, say this this output we have written here NAND and this can be given bubbled OR.

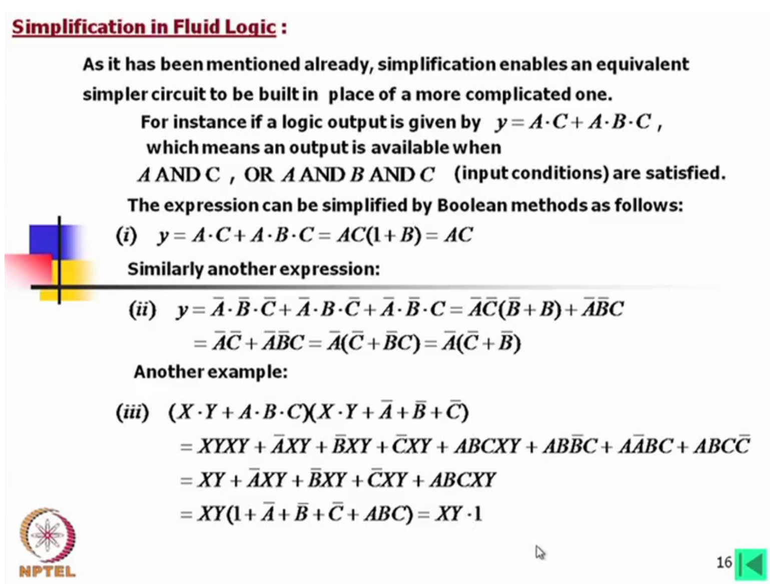
What it is? Input are NOT this input are NOT and then output is OR, this is OR connection so we get bubbled OR. Look at the symbols and this is 1 De Morgan's theorem and also if you take NOR then NOT AND what we do the reverse way NOT AND then OR so we get NOR sorry NOT and AND we get NOR okay just remember this. If you put OR and NOT, you will get NOR, NOT for both inputs and OR you will get NAND and vice versa.

(Refer Slide Time: 49:12)



Positive and negative logic gave rise to basic 'Duality" in all identities. When changing from one logic system to another, 0 becomes 1 and vice versa, so these are termed as duality so just seeing this line sentence you may not have feeling immediately but if you read it, if you learn it, you will have this feeling. All the + sign are changed to "Dot" sign or AND gates become OR gates and vice versa, from this it is called duality. For example, A + 0 = 0 has the dual identity A dot 1 = A, similarly A+ A bar = 1 has its dual as A dot A bar = 0.

(Refer Slide Time: 50:20)



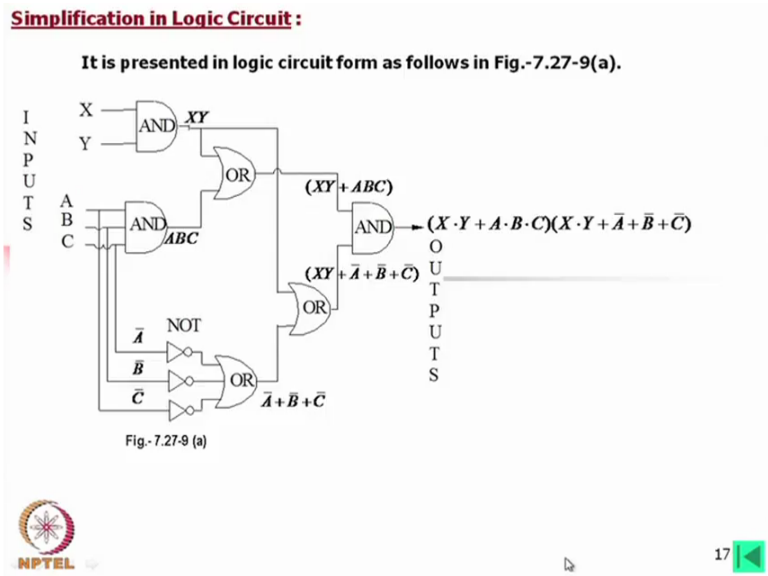
As it has been mentioned already, simplification enables an equivalent simpler circuit to be built in place of more complicated one, we have learned about simplification earlier, here is something also will be shown. For instance if a logic output is given by y = A dot C + A dot B dot C that means A AND C then A AND B AND C which means an output is available when A AND C or A AND B AND C the input conditions are satisfied. The expression can be simplified by Boolean methods as follows; now you see this how we are simplifying this, y is equal to simply you can while you are simplifying you just remember this thing, then writing this equation you may omit this Dot, AC + ABC simply write it AC + ABC no harm.

Then this you can take the like an ordinary algebra you can take AC common so this becomes 1 + B okay. Now 1 + B is OR in Boolean algebra and then as there is 1 that means always there is a positive output then B whatever it may be, whether it is 0 or 1 it will be always 1 so this means that this simplification is Boolean algebra, you can make simplified to AC okay. Similarly, another expression if you consider y = A bar dot B bar dot C bar + A dot B C bar + A bar dot B bar Dot C that also can be simplified in this form, how? You take A bar C bar common here, then in that case you will find that B bar + B is coming over there + here A bar B bar C.

Now this is again this is always supposed this is 1 this is 1 then this is 0 and if this is 0 then this is 1 that means this part is always 1 so this becomes A bar C bar and this becomes A bar B bar C bar and that is equal to again A bar C bar B bar C and finally we get only A bar then C bar B bar C sorry B bar because if suppose C = 1 then C bar will be 0 and whatever the B bar that will be the value there and similarly if you analyse this one, these 2 will give the same result okay. So this again as I told you it is not easy to grasp immediately, you need a practice you have to just 2-3 times you have to see this how this simplification is done.

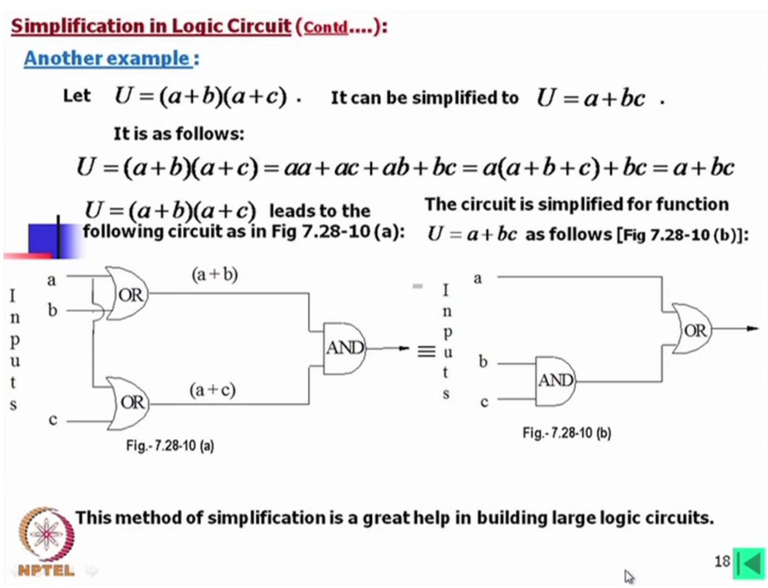
Another example is that X dot Y + A dot B dot C dot into X Y + A bar + B bar + C bar okay. Now this 1st you follow the ordinary algebra, as I told that you can write XY + ABC and XY + A bar + B bar + C bar does not matter, but remember these 3 items are separate items, ABC not a single item there are 3 items. Remembering this you can write down this equation then you will arrive into this and finally you will find this 1 that means these functions these are you can see so many inputs 1, 2, 3, 4, 5, 5 inputs are there and their NOT functions are there that can be simply achieved by XY two inputs AND function so this is becoming XY.

(Refer Slide Time: 55:32)



Now this can be proved by this logic circuit, I shall discuss this logic circuit later and this can be simply represented by this one okay, so I think we shall continue in the next lecture this one.

(Refer Slide Time: 55:51)



Similarly, if we take another example that will have also the same that 1st we simplify this U = a + b into a + c is simply can be represented by a + bc that means put an input a and then for bc there is an AND gate and then finally you pass through a OR gate okay. And this circuit as you see that this circuit can be simplified as follows, in that case you see a, b, say if you have to make this function full function in a circuit, this will be the circuit okay, a + b through an OR gate, c through an OR gate and a also the same OR gate so we are getting this output then these 2 are this AND gate.

Instead of that use a OR gate here, directly put a there, b and c through AND gate and then you are getting the output , so these 3 devices simplified into 2 devices, this one is not required. Such simplification is required in logic circuits arriving into a simpler circuit, so we shall discuss in next lecture.