Digital Switching
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Lecture – 1

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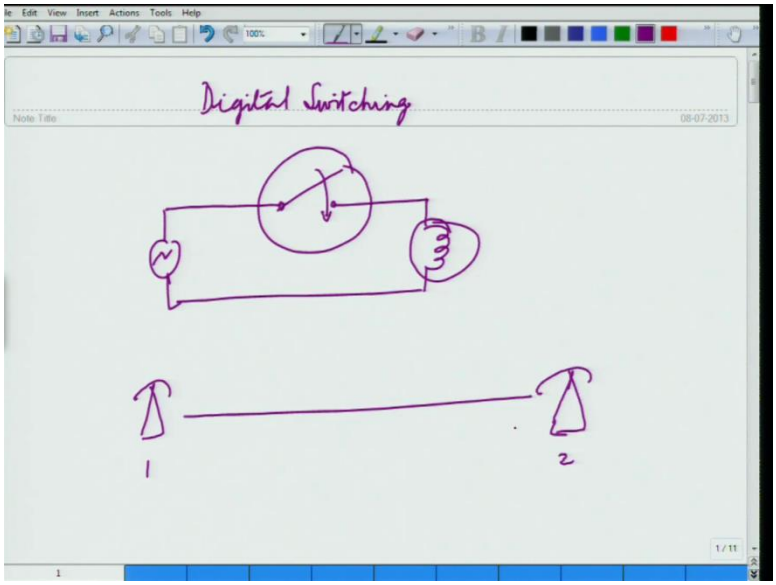

So, welcome to the lecture series on digital switching systems, this is the first course. So, I will be introducing, what you are going to cover in the whole course? And then how I will be actually producing. So, basically the idea is, what we understand from digital switching is; it has to do something with the switching. Switching basically is an action, where either there is going to be a path deciding the most basic way of understanding, most of the people understand only this way, that usually they will use a switch. To for example, switch on their lamp and their usually will be a power source and they will switch on or off.

So, this is what basically the switch, but we need to talk about digital switch and basically switching functionality is what is more important how it is implemented either different issue. So, what we are talking about is not switching in the sense of electricity, but switching in the sense of communication. So, usually what will happen is in the how why we required actually a switching, let us come to that.

So, essentially it is the communication requirement. So, usually, what will people do for communication? There will be a transmitter, so I am putting up a telephone here. And

telephone on the other end and user 1 wants to talk to user 1 they can actually lay line, and they can start working on this. So, this is the point to point communication link, which gets created between them and they will communicate. So, they can just lift the handset they need to have some power source or to actually analyze both the phones. And that is all they communication happens whenever they want, but there only two uses, but this kind of communication system will actually not work.

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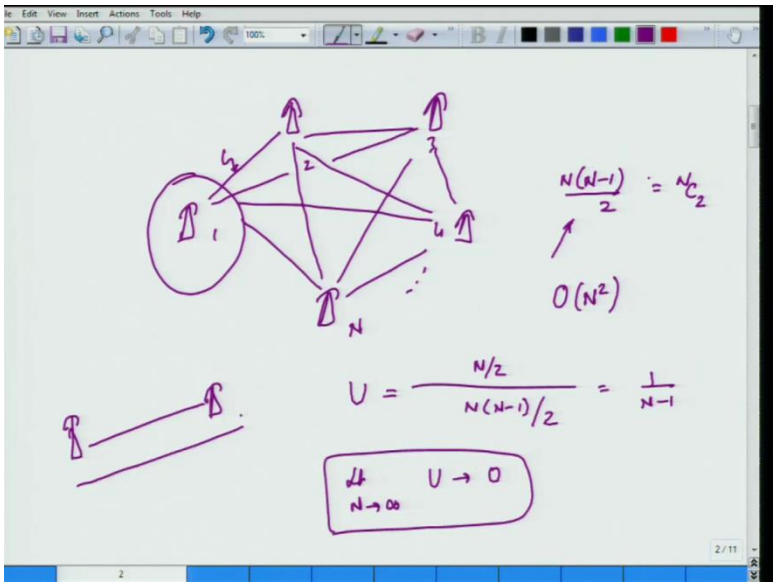

So, usually, what we desire is; we are going to have instead of this, you would like to communicate not with one person, but everybody whom I know. So, if I actually know lot of people. So, in general they can be 1, 2, 3, 4 and N. So, if I still want to create same kind of communication mechanism, it is a basically long distance telecommunication thing.

Then, what I need? I need to lay my wires all the way to every user, which I know, but this is true only for 1, same is going to be true for node 2, same is going to be true for node 3, and same is going to be true for node 4, and so on. So, usually what you will require is N into N minus 1, this is which is by 2 which is N c 2 bidirectional links. Bidirectional actually means, where the information or voice can flow in both the directions. Now, a such a scenario actually happens the number of wires, which are required you can actually observe is, I am going to have a complexity of o N square.

Now, this is not acceptable because, has my number of users in the communication network are increasing. Numbers of links which are required are going to be too high, and now what will be the utility of basically of each link, if we take a case where by only a user talks to only one another user, hence a 1 to 1 communication. In general total N by 2 communications can happen at any point of time. So, what you will figure out is that there only N square communications happening. And I have invested money on N into N minus 1 by 2 links.

So, N by two basically is the number of communications. So, utilization is basically number of links, which are utilized divided by total number of links. So, I will be using N by 2 links and I have total number of links, which is these many, so this will be the maximum utilization facto, r which you can actually have in such a scenario. And once you solve this will turn out to be 1 divided by N minus 1.

So, this is the utility when everybody every user is talking all the time. It is that kind of situation now, when this happens, what you will find that? As m N grows in limit when m goes to infinity, when number of users becomes very large my utilization will go to 0. Now, this is not acceptable because, each cable which you are going to lay will cost you something, and its utilizations is going to be low. So, the cost per unit of call is going to be very high. But, if you carefully observe the cost is because you are laying, so many cables and user using only one of them at any point of time.

Now, this is a full mesh network actually which have created. A switching is happening here it is done by users. So, if I as a user I would like to talk to say 1 wants to talk 2, he will be now switching off basically there will be a some person sitting in here, which will be having a handset in a microphone they have to be connected to onto this particular line.

So, other lines will not be used, and tomorrow after some time for example, if we decides that I am not going to talk to node 2, but I want to talk to 3 he will stop he will take out this handset and microphone from line 1. And then, will connect to line 2. So, he is doing switching in that sense actually. So, this all switching functionality are happening at the user end not in the network. Network is purely passive, end sense of switching actually now, question is my utilization also becomes almost 0 as I am grows very large. So, my cost becomes very prohibitive actually.

So, this kind of communication systems cannot be built. So, only kings or top bureaucrats can actually afford a, hot line running all the time dedicatedly for them, they are nothing but dedicated hot lines been created between all possible peers of users in the whole community. So, that is what actually is happening.

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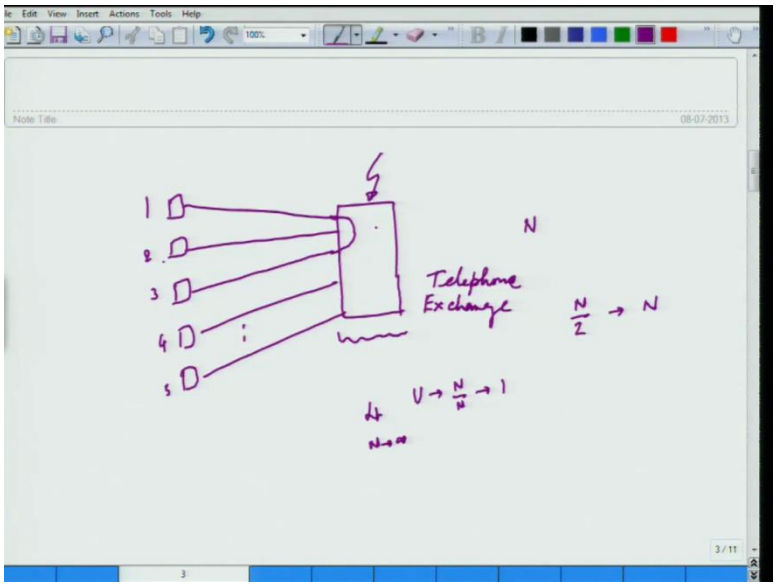

So, there it will be a better situation I can create. I probably can ask, what I can do is the better option is, let me create a central switch. Now, there actually switch functionality will come, and let every user gets connected to this. So, I am connecting all users to this thing. Now, how many links I need to actually lay for N users in this case? It is not going to be N c 2, what I require is only N links. Only problem is, I need a mechanism whereby a 1 wants to talk to 2, he should be able to tell this box, and it should be able to create a path between 1 and 2.

Next time for example, if this guy 1 decides to talk to somebody else, say 3. So, a path can be created in this fashion. So, I am now creating switching functionality is been implemented by this box. And that is what we mean by a switch. And when we represent or my voice signals or data whatever is been transported between users, in digital formats, I will call it a digital switching system.

Now, in general in common sense term this is also known as exchange. Telephone exchange is what the word which lot of people are aware of. So, this commonly it is not called as a switch is a technical term, but telephone exchange is, what people commonly

know of this particular system. So, this is basically exchange is nothing, but a building where why you put all these kind of switch is there, with all power supply everything all user gets connected.

Now, if all users share will talk all the time, all 24 hours then, what will happen? What you will find is that; you will have, what N by two possible communications N links will be consumed, and their only N links. So, utilization will be N by N which will be going to 1 in limit when m goes to infinity. For that matter for whatever be the value of N, it will always be going to be 1, in worst case scenario. Utilization is not 0 it is independent of N, now that is a very good thing.

Once it is independent of n. So, my cost is going to be very low of course, you can see I am not using a number of links is not N into N minus 1 which is o N square, but it is o N now. So, this system will work wonderfully well we have to still figure out how the switch will get implemented. Because, now important thing is that the node has to talk to this switch, this switch has to understand the logic or whatever link or whatever destination, which one would like to connect in earlier case. One simply decides that, I am going to connect to 2 hour I am going to connect to 1, and as per that its makes a decision.

So, there is some intelligence, which needs to set in this box. Now, there is another problem actually, we I have been assuming that all links are been used 24 hours, all most all the time somebody is busy on the equipment he is talking. So, I am taken example of voice communication, but this true even for data. Now, if you are now going to work talk only for say half an hour a day. So, remaining 23 and half hours the line is empty and is specially if for example, line is very long.

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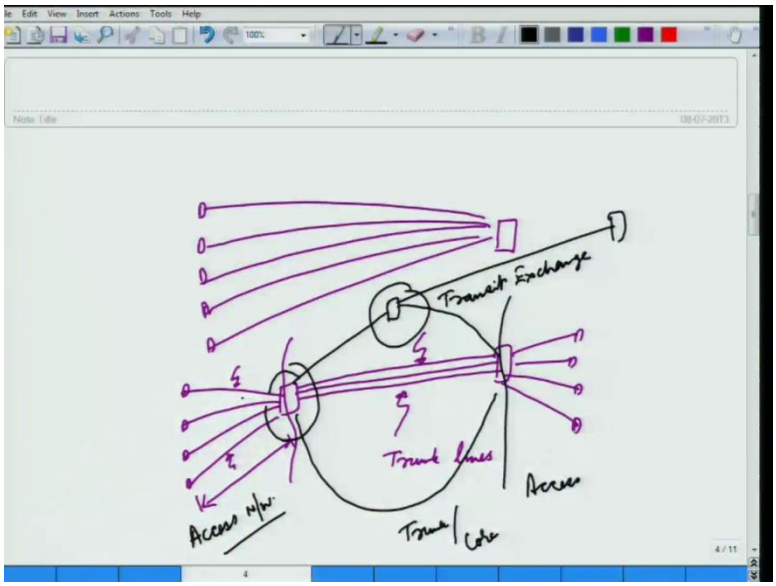

Say for example, I am in the capital city of Delhi; we have a central exchange or central switch. And all users all across India are connected to that place, and I have got dedicated wires. So, think of number of wires which you have to lay is going to be huge, and the cost of each wire is going to be also quite large. Because, it is about 450 kilometers from here from Kanpur, if I have to lay from Kanpur 450 kilometer, from Bombay 1300 and so…

So, this going to be a costly affair, and you are going to use only for 1 by 24, 1 by 48 hours, for my 48 of the day, only that much fraction of the day will be using it. So, can I actually take care of even this. So, idea came what we can do is, we can create a smaller switch within a city, and let all users get connected to this. And when they want communicate; I have to ensure that this length is as small as possible.

So, that my cost of this digging, because the utilization of these lines are very small, they are connecting directly to the users. So, there cost has to be as well as possible. So, length has to be kept as small. Now, I can create another city, another exchange of similar kind, and I can connect the users there. Now, I can connect few lines in between these 2 cities. So, what will happen is; these are known as trunk lines, and I keep then and few number not a very large number.

So, I did not actually lay very thick cable, and what will happen is; whenever a call this even if this guys are talking only for half an hour a day. I can keep these lines busy for

because, everybody is not talking all the time. So, people will talk different times of the day. So, I can probably make the utilization of these lines to be very high. I can make them to be say busy for say 14 hours in a day or 16 hours in a day kind of thing. So, the per unit call the cost is going to be lower for a trunk line in this case.

So, now the thumb rule in any network design, actually perceive from here is, that in any network, whichever is the costly link your utilization factor has to be high, as high as possible. So, usually we keep them about 0.8 to 0.9 roughly in between that range. Because, this is the number of calls which are been made simultaneously will they will they keep on fluctuating, sometime there will be too many people calling sometimes less.

But the average you would like to keep round about 0.85 or 0.9 a roughly in between that and remaining is for taking care of if suddenly the large burst of calls will coming, for that peer, but that actually reduces the cost. So, wherever the cost is high reduce the length to reduce the cost. So, here utilization is low, cost is high and hence forth, we keep the length less.

Now, this actually creates kind of a network, in general the most of the telecommunication networks or data networks are created in such fashion. And these kinds of things where users are connected this particular portion, is known as access network actually. This is access network and of course, then you will have this is also going to be access networks.

And the part which is their in between this is known as trunk network, trunk or core that is a word which is been used depending on whether it is a voice or whether it is a data. I will actually then again we will basically merge everything in to data network ultimately. Now, in between it is also possible that, I might connect to anywhere exchange, something like this.

So, there is no users connected to this one, but it is permitting the calls to go through it is using like interconnect, we call it a transit exchange actually. So, now we at least understand that, what is the switch functionality? Switch functionality is in this box, and we need to understand, how this gets designed actually? How we can implement this?

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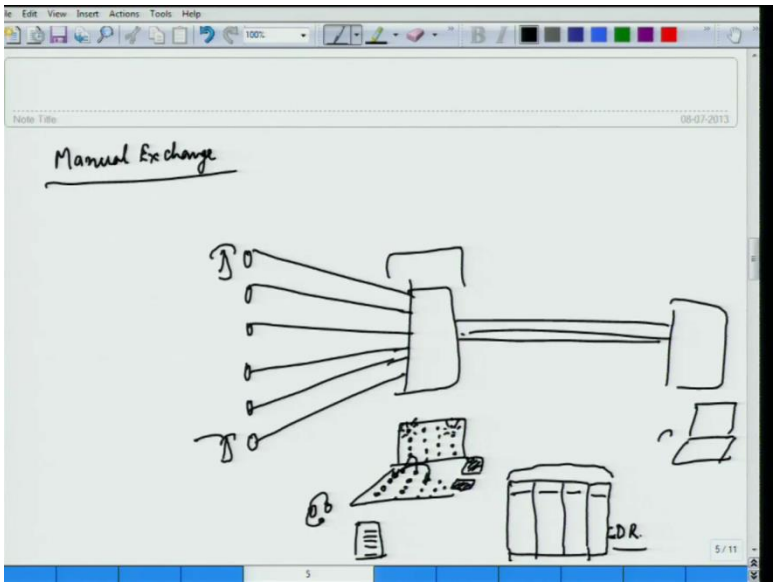

So, in earlier days, how we used to do it? So in earlier days this we used to have something called manual telephony. I think this is not being used currently not being practiced anymore most of them are now automatic fully automatic exchanges. In fact, now we are moving over to voice over I p systems, instead of manual exchanges. So, manual exchange is what typically very simple these are all analog there is no digital thing here, a simple voice is being captured, and is being transmit.

So, usually in this case a person… So, I have given these telephone instruments set the various houses, they are connected to an exchange, subscriber exchange we call it or a access network. Then, there is a backbone or trunk there can be other exchange is now, each exchange there will be a person sitting there, a human being. So, earlier days this is what how the telephone he actually started, automatic exchange came much later actually.

So, a simple thing is the protocol, which can be followed here is you lift up your hand set, and that hand set once you lift there will be a board here sitting hence, somebody will be sitting there at pins or jags, which are connecting to your wires. ((Refer Time: 16:34)) users and for making a connection, you have to create a jumper wire or you have to put in take a wire, and put your pins into this slots, and which will make the connection.

So, that is how it can be done, and usually there will be a display here, depending on whether you have lifted the handset or not. And there will be users, there will be an operator which will be operating this particular thing. So, whenever you will you lift the hand set the circuit will get completed and a light will glow here. So, once the light glows, operator will see the light and of course, if operator is not their nobody is going put through your call.

Once he sees he or she actually sees the light, he has to put in an earphone which is maintained by this person along with the microphone. So, this guy will then actually put his jumper into your port. So, that now he or she can listen to you, and you can and she can also talk to you. Now, once she greets you, this light is being glowing, and she knows that you have she will talk to you.

And she will ask you after greeting that which particular number you would like to connect to. And you will tell the number now, remember whatever the steps I am telling are exactly followed even in current day telephone. So, this basically if gives the frame work of how the protocol is going to be build, and once you tell the number, this lady will probably will have a music generator or some something.

So, that music generator will be connected to you, and this particular thing will be taken off. And she will note down the number on which you would like to make the call, and she will search the directory that on which particular port that number is connected. If that number is not in the same exchange it is in the next exchange, she has to talk to the person, who is there in the next exchange.

Same protocol and then, she will tell this is a number which her subscriber needs to be connected to. So, in this case I am actually assuming that the other subscriber is in the same exchange. So, she will pick up the other person, she will find out there is some body there is already there on that exchange. So, there will be another box.

So, meanwhile remember the music is been played back to this guy. So, this is like a search tone, which we actually see. So, this music been played to this guy, for the next person once she knows that this is the person whom to call has to be, who is the other person to whom the call has to be made actually made.

She will use another, what we call ringing generator. So, this ringing current has to be applied from here on to that particular jacket, this is destination ringing current will be applied here, which in turn calls the phone here to ring. Ringing current usually is a not in the audio band this is actually the current power, which is been modulated which will cause the ringing of the phone.

So, phone will start ringing at this end, and once, the user comes here and he will see still there is a current; he will lift up the handset. The moment he lift up the handsets the light will glow here corresponding to that person, and once the light glows the operator has to now take this particular ringing current out. So, that now there is no ringing here, and then she will put her own jack here, in this case. So, this particular thing will be taken off.

So, her own jack will be put now, she can talk to the destination, she will tell that this is the guy who want to make a call to you, would like to take up the call. And once, this person agrees, that he would like to take up the call. She will actually have a record driverster we call it a call detail recorder nowadays c d r.

And the c d r she will make an entry that, who was the person, who met the, who initiated the call? Who is the person to whom the call has to be made? At what time the call was made? And then, there is a call closing time she will actually enter at the end of the call. And what she will do is, one of the both people agree, she will just put a jumper wire she will take out her own jumper and then, she will connect a jumper wire between the two people. And once the call is through, these light will remain both glowed up because, there hand sets are lifted, because this is being driven by the d c current.

Circuit which is gets completed when you lift the handset. And they will talk, they will keep on talking, and once there talk is over, anyone of them can put back the handset. Once, that hand set is put back this lady will actually observe the light is off, and that point of time she will note down the time, when the call was off call was actually completed. And once, the one of the light is off she will take out all the jumpers, and these guy will simply put their handset back on the cradle.

And the call will get completed. Now, this is exactly is still now a days the phone call, does get completed in the same fashion, except now, complication will come if there is going to be another operator sitting here another console board which is sitting. So, if the

call has to be through a trunk route. So, it will easily takes more time because, the user will tell the operator, operator will take the till the next operator. And this operator will also keep this operator on hold, and then and so on.

And each operator will keep their own c d r at their end, and as per that they will start doing which will charging from each other. So, based on this essentially then the bill has to be generated at the end of it. Now, this is a very cumbersome process, but this is how the telephone he actually started it became popular. But, remember the human cost involved is pretty high, and their chances of mistake there is a chances of making a mistake in call recording and then now as per generating the bills.

Now, this was the most elementary switch, which we can talk about. This known as manual switch our manual exchange is initial difference, I think some places if everything else fail this will always where a kind of thing. So, this still use as a backup, especially in defense organizations, but I think nowadays most of them have moved on to packets switch base systems. Now, another important thing, which I would like to tell here, is that; what I am talking about is a circuit is a circuit switch.

So, this circuit switch technically means I am creating a path from source to destination, as it is intact throughout and once a path has been created the information or voice just simply flows. So, currently as of now it is circuit switching, I will tell at some point of time, where we will move over to packet switching, later on because once we complete all the theory of even the circuit switching then, it will become much more clear. I still distillation has not started in this case it is ((Refer Time: 24:02)).

Now, this manual telephony is problems because, operator can always listen to what you are talking to other person. So, you have to either talk in code words, if you talking to the person if you want to maintain secrecy otherwise; information can leak. So, there was a A B Strowger actually, I think was the person who realized this, and he is started working on automatic exchanges.

He said, I think this man will operators need to be removed and we should have fully automated system, and he lend it of something called Strowger exchanges. And he it was purely an electromechanical system, and it was built with very simple devices. So, one of the elementary thing for example, it simply uses a ratchet wheel. So, A B Strowger actually build up, an automatic exchange, which was purely electromechanical thing.

And basically it uses electromagnets for creating mechanical motion, and thus creating contexts between, electrical contexts between, the input and IO ports input and outputs ports, and thus creating switch a basically voice path.

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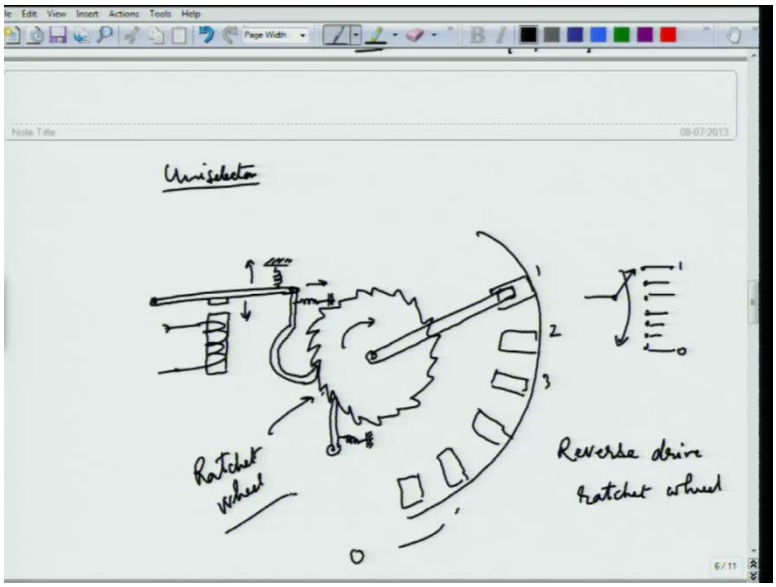

So, it uses basically two kinds of elements one is uniselector. And In fact, there is all whole lot of a logic, which got a embedded using a relays actually for implementing this kind of system. So, our flip flops which were actually used, but the basic switching elements for uniselector and two motion selectors. I am just showing that how would it have been look like.

So, unimotion selector usually will consist of a inch, which will be like this and this is this can rotate around this part. So, there is a spring connected to this, and there is a hook, which is there this is again connected to the spring and this is the hard surface. So, it is always trying to pull this thing upward, and this is being tried to pull towards this side. And then there is an electromagnet, which is here and whenever you actually supply current to this, this will actually come down, and then it will go up once, the pulse is over. So, with every pulse there is a motion of this particular bar coming down and going back up. And as a result and there is a ratchet wheel, which is being used on this side.

So, every time this motions this pulse happen, this wheel actually moves by 1 teeth in this particular direction. Because, when it comes down it will engage with the next teeth

because, of these two springs and it goes back in the return this wheel is going to rotate. And this can be used to create now, the central there is a current which is coming, and this is wiper electro this is going to make a electrical contact. And I actually have on this circle many points, where every time it rotates it keeps on moving here.

So, I need to have mechanism to take it back to the 0 position. So, usually it will come from 1, 2, 3, until 0, and come back to, and home situation, when there is no connection. So, these are like outgoing port. So, usually it will be like 1 input it is a switch of this kind now. So, it will have 1 2 0. So, total 10 outgoing ports, and this can rotate and connect to any one of them.

So, this was the uniselector, which was actually used. And this wheel actually should not go back, when it is this electromagnetic is working there is an always stint, which is put. So, there is a very simple drawing this, what was the uniselector? Which was invented by him? And he builds up what is known as Strowger exchanges. And this is a reverse drive type of ratchet wheel, we call it reverse drive because, when the pulse is switched of that time there is a reverse thing, when its going back at that time the ratchet wheel will move, reverse drive type ratchet wheel is mechanism.

There other mechanism which also people have built, and this is what is known as ratchet wheel actually, what you are seeing here. So, this was the 1 element which was built. And secondly, what he built was a uniselctor that is what he designed. So, the other 1 was, actually two motions selector, it required 2 electromagnets to actually work.

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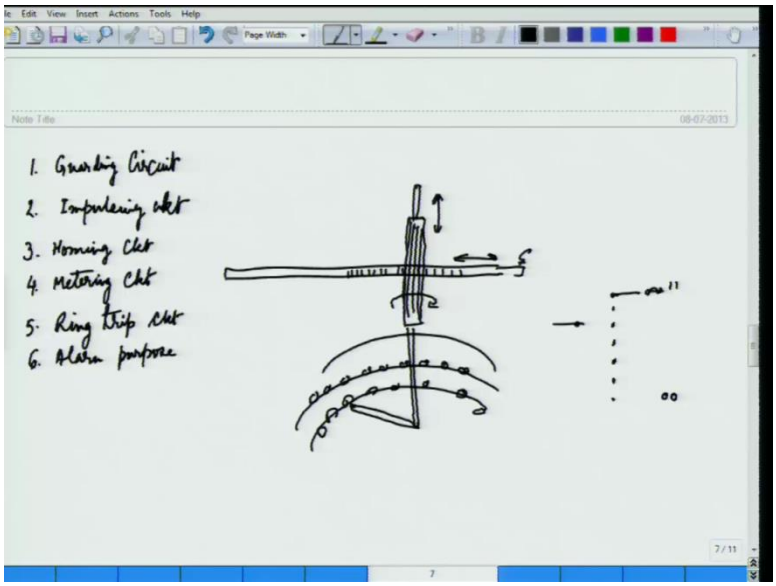

So, 1 was a straight bar which is going to have gears on this. So, as this bar moves, and then of course this is also a gear drive. So, this can move upward and down ward, this vertical motion is happens because of another electromagnet depending on the pulse, and this motion happens because of this bar. So, it will turn into rotation of this thing, and I can then connect a wiper, and these are the connection points in one plane, similarly another plane, and so on.

So, you can actually, usually have this, actually means this will move into these are like 10 points being there in the 1 plane, and there will be 10 such planes. So, total 1900 actually outgoing points, and 1 in coming point which will be there. This was used to work in 2 dimensions using 2 electromagnetic, basically you require pulse is for driving this kind of thing. So, this will work from 0 0 technically I call it 11200, that is way because 1 is always what the start 0 actually means 10 pulses.

And of course, there many control circuits which build using relays, and these are integrated with these kinds of things. He also now started something, what we call a concept of common control switch is with this. In this case, the control circuitry usually is going to be common, which is going to be then used for different uniselector in to motion selector say different point of time, depending on requirement it is not all the time.

So, common control switch were actually a slightly complex, but the amount of hardware required is going to be small. Now, remember all these are mechanical components; their failure is going to be pretty high, and as a result there maintain cost is also very high. So, using less amount of hardware always make sense, also direct control switches are also built, where the control circuitry was directly integrated part of uniselctor two motion selector.

But, they were actually having a problem because of the lot of failures which were happening in the exchange. And of course, here also for the first time now, the different kind of circuits came up. Now, which we can I can just actually mention, what was circuit which were built of course, with voice over I p coming in most of this will not be required.

So, various circuits which built, were like this. So, one was a guarding circuit. So, in this case, what happens that? Whenever you are actually trying to set up a call you actually, use a one particular uniselector, and call is still not through,, but you have made the connection. So, at that point of time you have to make, you have to actually set this status of that uniselectro to be busy,, but nobody no other calls should be actually try to again try to capture it in use it for some other call.

So, only when it is freed up, then only it should be. So, basically maintain the status of each uniselctor into motion selector. So, it was basically purpose was for that purpose second, was the impulsing circuit. So, idea here is again remember, the electromagnets are been used to drive both the systems. So, whenever you have to norm move at this particular arm, on to anyone of the connection points you need to give certain amount of power.

So, when you are giving a signal the power is going to be small, it is only signaling pulses. And you have to now convert into drive current, and we call impulsing circuit, which will generate this much of power or drive current, so that these electromagnets can move these arms to appropriate point.

So, basically it is like a power amplifier, then similarly we have a homing circuit which was built which is required. So, once you have made a call, and call is over. This actually should come back to its home position, all either uniselector or a two motion selector both have to come to their 11 position or there is a home position before 11 where it they

should come. And then, again you can give the pulse is depending on which number, you have to connect you want to connect the incoming port to which particular out going port you want to connect to basically based on that based on that you will give the number of pulses.

So, that for putting all these things back to home position after a call is over, we require a homing circuit. Now, this is another innovation, in the manual telephony the lady was actually writing on a register, the source destination the call is start time, and call end time, so that the bills can be generated.

Here the bills were generated using a metering system. So, usually these things, which were the way it was used is, you are having kind of a pulsing system. So, maybe say every 6 second there is going to be 1 clock pulse, which will be there or every second there is a clock pulse. And whenever the call is through, at that point of time, this timing the clock thing is also fed to a counter, and there is one counter for every user actually, sitting in the exchange.

So, these counters are nothing, but kind of dial, so like meters. So, whenever call is through this meter will start counting, and based on total count in the whole month the bill actually can be generated. And if there is a long distance call, you might probably will connect a faster clock to the meter, if it is a short call short distance call you will be connecting a slower clock to the meter actually.

So, that was the metering circuit. Then, there was a ring trip these are conventionally used now. So, ring trip circuit is whenever you are actually applying ringing current, the bar is ringing of the destination user. And it is a powerful current, which can actually a transfer power to the bell. So, that the sound can be very large, and people can listen that there is a call coming in, the moment he lifts the handset this information will come back in form of electric circuit getting completed back to the exchange.

And that time this ring trip circuit will actually get activated. And the ring generator ring tone generator will be disconnected from the subscriber. Earlier; it was the operator, which was doing it now, it has to be done through the particular circuit. And then of course, alarm circuits were built this was for administration purposes. So, for certain kind of faults the alarm will start beating, and then at least the maintenance guys will figure out that there is a flow in the system, they can come and rectify it.

So, this actually improves the maintenance, this kind of system were not very… They actually have been used for a long time, but there were lot of this mechanical problem, dirt, oxidation of the contacts, and then of course, is a mechanical thing maintenance is going to be pretty tricky. People have to be well trained for doing the maintenance thing then this need to be improving.

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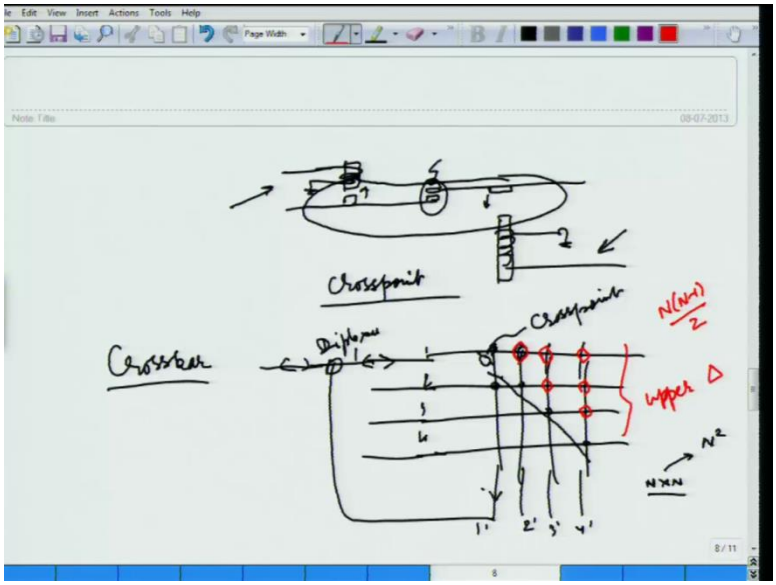

So, ultimately again the invention being made to take care of this particular thing, and people came up with an idea of something in the capsule, and saying totally doing away with electromechanical things. So, there is no motion, there is no pulse, there are no gears. So, they will not gears will not get damaged over time, and you will not replace them, you did not do this all kind of machine maintenance will not be required.

So, ultimately idea came there let there be a glass bulb, which is sealed and I can put and inert gas is there is no oxidation problem also. So, connection quality will also be good. And I can now actually have 2 simple wires and whenever they actually just snap, they will connect to the each other the connection is on otherwise it is off, but how to control it? So, then you can put the electromagnets similarly, you can put electromagnet here. In fact, I have done it incorrectly. I will just rectify the figure. So, this particular part will be in the glass. This particular thing, so this how to electromagnet will be outside the actually the glass bulb.

So, whenever you will actually put this electromagnet as well as this electromagnet. So, this will be pulled downward, this will be pulled upward, and there will be going to be a connection which will be snapped in. And the moment any one of the electromagnet is switched off, the connection will be broken, and voice communication cannot take place.

And we call this thing as a cross point, this is a cross point, this a electromagnetic thing is still. And this cross point now can be used to build up the basically the switching module, and this particular switching system module, which was built is known as crossbar. So, how you can actually make the connections with this? That is the question. So, very simple thing this for example, there are 4 users which are connecting in here 4 users which are connected so.

Technically, I have I am not splitting; these are not bidirectional lines these are unidirectional lines. So, signal comes in signal goes out, both are for user 1. So, I will connect them together, and I will use something called diplexer. So, it converts bidirectional in to 2 unidirectional things. So, 1 is where the signal enters 1 where signal goes out. So, this will I will be doing for all other users. So, I can call them 1 prime, 2 prime, 3 prime, 4 prime and 1, 2, 3, 4.

And now, I can connect them, and that is why we call it a cross bar. Because, there many bars they have been crossed with each other. And at this point between these 2 elements I am going to put, this cross point, which I have talked about, and this is the cross point. So, N by N switch. So, N users connected to N users I require, and N square cross points now that is the only problem here, this can be reduced by using only upper triangle or lower triangle.

Because, I can connect 1 to 1 through this of course, this will never happen. But, 1 to 2 connections can be made through this cross point as well as from, this cross point. And if it is unidirectional I require both the cross points to be operated, and if it is bidirectional for example, this link can be bidirectional, because this is nothing, but mechanically I am connecting the wires.

Signal will travel in both ways. So, I only need to operate only one of these two. So, it all depends on this. So, most of the time these electromechanical systems, are going to be electromagnetic systems are going to be nothing, but bidirectional elements input output. So, I did not use lower half, I need to only use… So, 1 to 1 connection, I will never make

because that is not required because, the same user. So, I will be only using these elements first building up the complete switch, these known as upper triangle actually.

So, this actually, means N into N minus 1 by 2 cross points will be requires in this case, N is 4. So, 4 into 3 divided by 2 which is 6, and you can see I require 6 cross points here, to build up the cross bar, if all ports are bidirectional ports. Now, question is, how to operate at how to set up the path? That is an issue. So, I can stop now, and then probably we can discuss how the algorithm is going to be worked out for operation of this particular switch, so that we will see in the next class.