**Introduction to Photonics**
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Lab Demonstration Semiconductor Detectors

Hello, welcome to the lab session of introduction to photonics. I am the TA of Introduction to Photonics myself Bhagat Indra Prasad. So today I will be demonstrating here some 2-3 modules about optical detectors. So in the theory class it was discussed that what are optical detectors semiconductor optical detectors, what are the different types, its characteristics, etc? And what I will be having today is 3 main aims which means characterize one PIN photo detector and then an avalanche photo detector then I will realize transimpedance amplifier circuit, a simple transimpedance amplifier circuit.

Talking about the photo detectors one important parameter which we need to understand properly is the responsivity. So the main aim today is how the responsivity varies for silicon photo detector and while looking for the avalanche photo detector how it will vary. So there are some fundamental differences and we have a module here which will let you to evaluate the responsivity and we can look into one by one closely enough.

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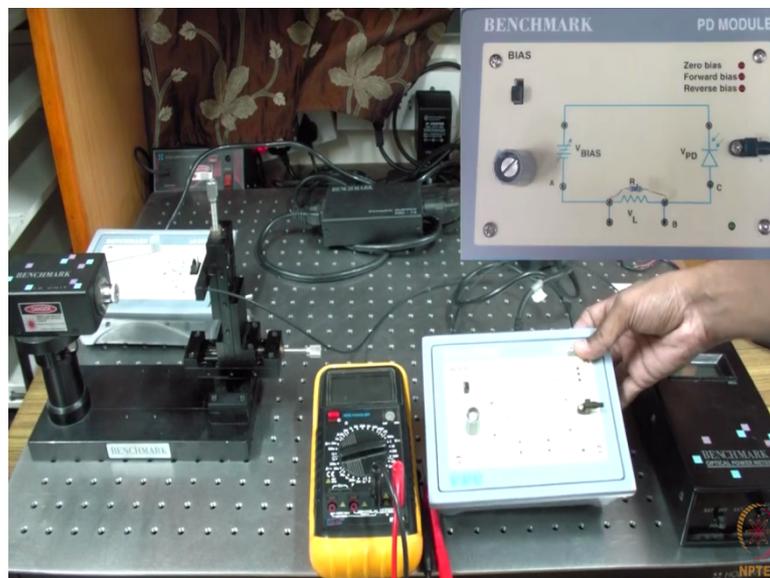
Okay so what we have here is a photodiode module and you can see the circuit diagram what is his designed for and this module is mainly to characterise the photodiode as such. And the light source used is a normal laser diode of 650 nanometre which can generate a power of 3 millivolts and then this area this light launching module has been already introduced in another experiment which is taken which is explained by Freddie which is the fibre coupling

light coupling into the fibre mount. So this is nothing but a laser source and we can couple the light through this transition stage where the fibre is mounted. So the fibre which I am using here is a plastic through from which the light is traverse and we can connect the other end of the fibre to the photodiode module.

And what I have here is a normal power meter when I can measure , how much light I coupled through the fibre and that power need to be noted. We know that the responsivity is nothing but the ratio of incident photo current generated to the incident power and for that for measuring that we need to understand how much photo current is generated and how much power is falling on it. So the power meter will help you to measure the power and the photo current can be generated using this particular module. So in you can see in this particular module that this is a normal photodiode module which uses a silicon PIN photodiode in which there is a bias switch where it should be biased using a reverse bias voltage and the bias voltage can be controlled using this potential meter.

There is a resister connected at this point RN which where you connect a non-resistance. So here I put already a 10 kilo Ohms resistance and a using a multimeter available here I can measure the voltage between this resistance. So knowing the voltage and the resistance we can measure how much current is flowing through this circuit that is how we will get the current value and the divide by power will give the responsivity. So let me demonstrate this thing by switching on the laser diode and how much power is falling on the power metal.

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So I will do the alignment which exactly explained in the other experiment where coupling into the fibre, so let me do that 1st and we will show you how much power is falling on it. Okay so the laser diode is switched ON, looking on all the precautions like it starts from minimum and I increase the power to such a way that it will reach above the threshold and now the light you can see it is emitting from that and that laser light is focused using the convex lens assembly and I aligned this fibre tip during this transition stage to this lasting fibre attached to it. And this fibre light is taken to the power meter okay and you can see this power meter the other end of the fibre is connected.

And according to the suggestions given by the manual of this particular module, you can vary the light power from -18 dBm to -40 dBm so that is the region where we can vary the incident power. So I align in such a way that I am getting power of -18.4 dBm here, then to say a little more about this particular module now the module is turned on, while turning on you need to ensure that the bias voltage is kept at the minimum by using this potential meter. And even you can increase the bias voltage but the bias voltage needs to be ensured using this multimeter here. So the multimeter I put into the voltmeter and then I use this probe to connect across these two points here and I can check the bias voltage directly on the multimeter.
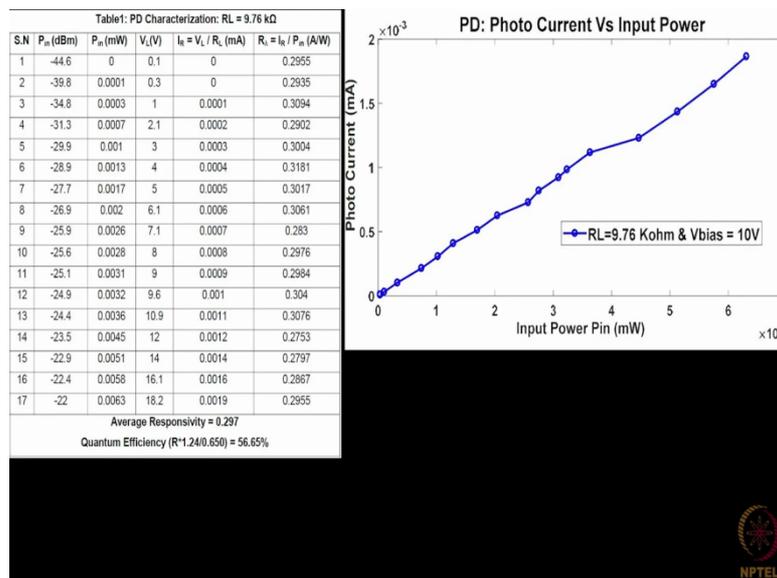
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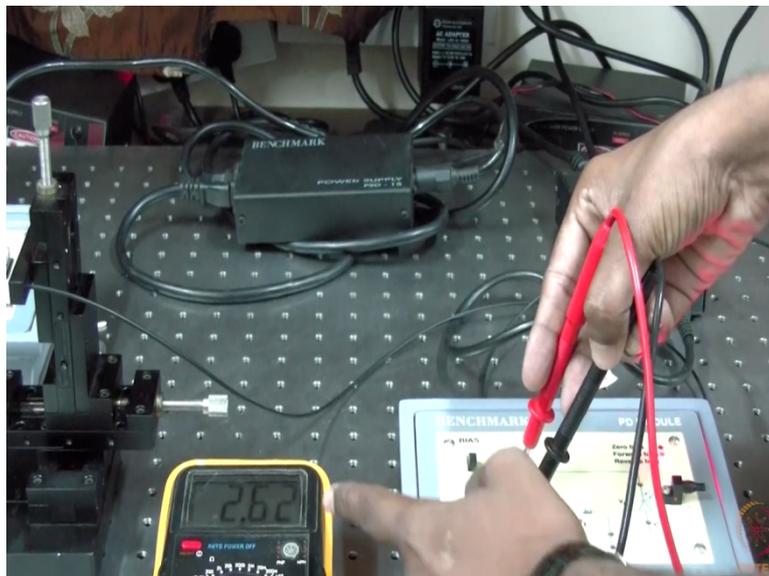
So I will increase the bias voltage from minimum to a maximum constant bias voltage, so I am increasing it you can see how many volts, it is 2.6 volts so I am going to the maximum it can go. Okay so now the potentiometer reach to the maximum, the bias voltage is 9.5 over 9.6 volts which is the reverse bias voltage. Now you can see that this circuit is on and the bias

voltage is across this particular photo detector. I will now coupled the light into this particular module through this hole, so this is how the connection is done and these incident photons will generate some photo current in the circuit which will flow through this particular resistance and we can measure the voltage across the resistance and then being known value of resistance we can measure the current.

So the power value which I measured here should be noted down properly and then the next step is to measure the voltage across these two. Okay so you can see the voltage across the resistors is 31.2 millivolts and this needs to be noted down. Now can avoid the dBm value of power to milliwatt and you need to ensure how much current is flowing through this resister using the non-value of voltage and the resister and you can take the ratio between these two, the current by power input and you will get the responsivity for a particular value value of incident power.
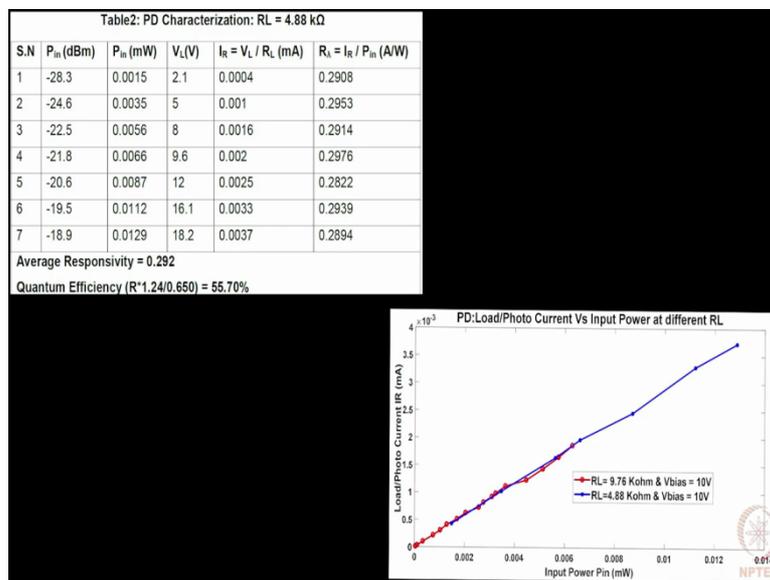
Now you change the incident power like in a step of 5 dBm from -18 to say -40 so -18, -23, -27, like that and you can tabulate these values properly. And you can see the variations, you can calculate at each step the responsivity it is giving and then you can plot the graph between the incident power and the photo current generated and you will get approximately a linear response. And the slope of that thing will be the responsivity value average responsivity value, we can average out responsivity, so for I have the values already which we collected and the values are displayed on the screen and the corresponding graph we obtained is also shown on the screen.

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Table1: PD Characterization: RL = 9.76 kΩ

S.N	P_{in} (dBm)	P_{in} (mW)	V_L (V)	$I_R = V_L / R_L$ (mA)	$R_\lambda = I_R / P_{in}$ (A/W)
1	-44.6	0	0.1	0	0.2955
2	-39.8	0.0001	0.3	0	0.2935
3	-34.8	0.0003	1	0.0001	0.3094
4	-31.3	0.0007	2.1	0.0002	0.2902
5	-29.9	0.001	3	0.0003	0.3004
6	-28.9	0.0013	4	0.0004	0.3181
7	-27.7	0.0017	5	0.0005	0.3017
8	-26.9	0.002	6.1	0.0006	0.3061
9	-25.9	0.0026	7.1	0.0007	0.283
10	-25.6	0.0028	8	0.0008	0.2976
11	-25.1	0.0031	9	0.0009	0.2984
12	-24.9	0.0032	9.6	0.001	0.304
13	-24.4	0.0036	10.9	0.0011	0.3076
14	-23.5	0.0045	12	0.0012	0.2753
15	-22.9	0.0051	14	0.0014	0.2797
16	-22.4	0.0058	16.1	0.0016	0.2867
17	-22	0.0063	18.2	0.0019	0.2955

Average Responsivity = 0.297

Quantum Efficiency (R*1.24/0.650) = 56.65%

PD: Photo Current Vs Input Power

RL=9.76 Kohm & Vbias = 10V

Looking at the screen you can see that the graph is almost linear and when you can go ahead for a different value of resister here and again calculate the do the same, and also you can go for different bias voltage here and again do for the same. More or less in PIN photo detectors, the responsivity will be almost constant even if you increase the voltage because responsivity is the intrinsic characteristic of a material and there is no any phenomena like impact ionisation or something like that happens inside which will generate a different value for responsivity so the value of responsivity will be comparatively low, so the results will be displayed on the screen.

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Table2: PD Characterization: RL = 4.88 kΩ

S.N	P_{in} (dBm)	P_{in} (mW)	V_L(V)	$I_R = V_L / R_L$ (mA)	$R_\lambda = I_R / P_{in}$ (A/W)
1	-28.3	0.0015	2.1	0.0004	0.2908
2	-24.6	0.0035	5	0.001	0.2953
3	-22.5	0.0056	8	0.0016	0.2914
4	-21.8	0.0066	9.6	0.002	0.2976
5	-20.6	0.0087	12	0.0025	0.2822
6	-19.5	0.0112	16.1	0.0033	0.2939
7	-18.9	0.0129	18.2	0.0037	0.2894

Average Responsivity = 0.292

Quantum Efficiency (R*1.24/0.650) = 55.70%

Just to demonstrate how the variation of the input photon power will reflect on the voltage which we measure across this resister, I can show you this multimeter is displaying the voltage across the resister and it will it is a direct measure proportional to the current flowing through it.

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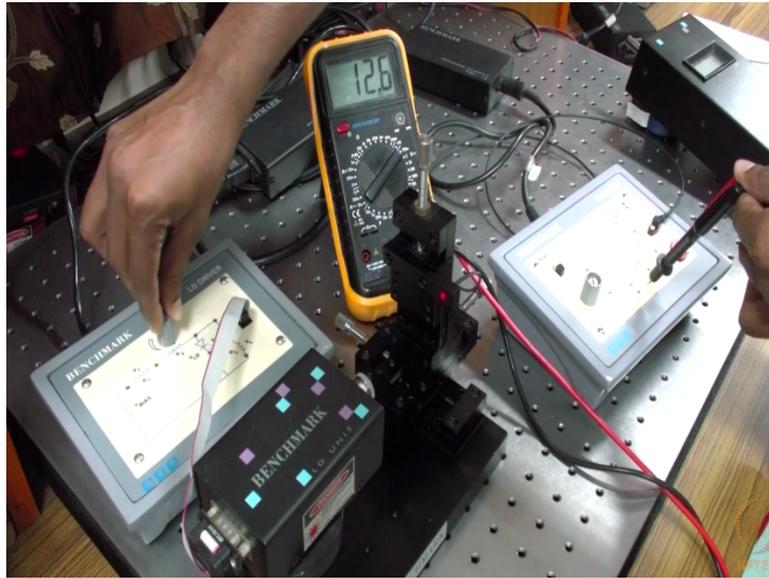
And while increasing the laser power slowly you can see that the voltage across this thing this resister is increasing which is showing that the power has also increased and the power falling on the photo-detector increases and so the current photo current generated is also increasing in a linear manner. So with that we can conclude that looking at the graph that the responsivity would be almost constant and you will get a linear response with the incident power and the photo current generator for photodiode module. Now let me move to the avalanche photodiodes, so I will setup the avalanche photodiode and introduce the module to you.

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Okay so now I have current I have taken the APD module you are and what we have on the desk is this module which looks similar to the PD module but only the difference is we have the APD module with a different character and with a series resistors which will protect for the high current leakages. And the other parameters are same, it should be positioned to reverse bias and we have we are using a different kind of fibre here for the sake of this connector and orange fibre is used, and orange fibre is now and you can see the power coupled to the power meter is -12 dBm.

This particular device is a high-voltage device, so you can vary the voltage into this APD to bias voltage from 0 to 140 volts and that will ensure that this high electric field will be generated across the APD and it will work, it will affect the avalanche effect and impact ionisation will occur and you will get a high current flowing through the output circuit. And resister which is connector gear is now a 1 kilo ohms which is lesser as compared to what we have in the PD module because the output current is comparatively high enough to drop a particular voltage across even a small resister.

So now the voltage is little bit higher so we need to ensure that the connections are made proper, again it should be started using the 0 bias voltage you can control the bias voltage using this potential meter now and rest of the procedure is similar to that of the photodiode module. So we need to note down what is the power incident which is now -12.1 dBm at this case, and once we connect to this APD module then we will vary the reverse bias voltage from in the step of 10 volts from say, 10 volts, 20 volts, up to 140 volts. And we will be at each step we will be measuring the voltage across this resister and we will be tabulating the value, and you can see how the responsivity of the APD module at each case which can be plotted in a graph and the data is taken in such a way and data is shown in the screen.

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Table3: APD Characterization: P_{in} = -11.1 dBm (0.0776mW) & R_L = 985 Ω

S.N	V_{bias} (V)	V_L(V)	$I_R = V_L / R_L$ (mA)	$R_A = I_R / P_{in}$ (A/W)
1	9.83	0.0056	0.0057	0.0732
2	25	0.0074	0.0075	0.0968
3	30.6	0.0094	0.0095	0.1229
4	45	0.0199	0.0202	0.2603
5	50.5	0.0249	0.0253	0.3257
6	60.5	0.0329	0.0334	0.4303
7	70	0.042	0.0426	0.5493
8	75.5	0.052	0.0528	0.6801
9	80.8	0.0565	0.0574	0.7389
10	85.3	0.0692	0.0703	0.905
11	100.6	0.1142	0.1159	1.4936
12	105.5	0.1391	0.1412	1.8192
13	116.3	0.216	0.2193	2.825
14	120.2	0.275	0.2792	3.5966
15	125	0.352	0.3574	4.6037
16	130.7	0.492	0.4995	6.4347
17	135.2	0.61	0.6193	7.978

Table4: APD Characterization: P_{in} = -15.5 dBm (0.0282mW) & RL = 985 Ω

S.N	V_{bias} (V)	V_L(V)	$I_R = V_L / R_L$ (mA)	$R_A = I_R / P_{in}$ (A/W)
1	10.6	0.0043	0.0044	0.1549
2	20.3	0.0048	0.0049	0.1729
3	30.1	0.0064	0.0065	0.2305
4	40.9	0.0114	0.0116	0.4106
5	50.6	0.0182	0.0185	0.6556
6	60.4	0.0241	0.0245	0.8681
7	70.3	0.0309	0.0314	1.1131
8	80.2	0.0404	0.041	1.4553
9	90	0.0541	0.0549	1.9488
10	100.6	0.0783	0.0795	2.8205
11	110.9	0.1143	0.116	4.1173
12	120.9	0.216	0.2193	7.7807
13	130.7	0.446	0.4528	16.0657
14	135.3	0.576	0.5848	20.7485

APD Responsivity vs Reverse Bias Voltage at Constant Input Power

— Pin=0.0776 mW
— Pin=0.0282 mW

Responsivity (A/W) vs Reverse Bias Voltage (V)

NPTEL

And the draft will be obtained and you can see that responsivity increases while the reverse bias increases for a particular incident value of power. The same experiment can be repeated using a different value of power incident and again the voltage can be varied and you can see the trend of responsivity variation by looking at the graph shown in the screen.

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Ok let us see the variation in the APD module while we are giving an input to this module, and while we increasing the photo current. So at this moment I am giving bias voltage of 100 volts which is comparatively little higher voltage which ensures this APD to go to the reverse bias area and also the avalanche effect will be happening. So this is a test value which I will

1st show the voltage drop across this resistor and you can see the current through this resistor will be increasing if I change the photon or the power of the light if I increase it then you will see the change in current. So I am slowly increasing the power here and you can see the voltage across that resister is increasing year in a considerable amount soldier can see it is going say 135 up to 135 millivolts.

So now, which shows that the responsivity is working as a linear nature while we increase the input light power. So now let us change the bias voltage here in this particular module, so let me connect to this bias measuring area which is comparatively high value here of the moment so I am reducing it to a lower value 1st the value which you can measure. This is the minimum value, we can go to even zeros, let us see the nature of increment from 20 volts higher voltage. So again you come to measure the voltage across the resister and let me move to the earlier position in the multi-meter such that you can see the variation and let increase the reverse bias voltage here.

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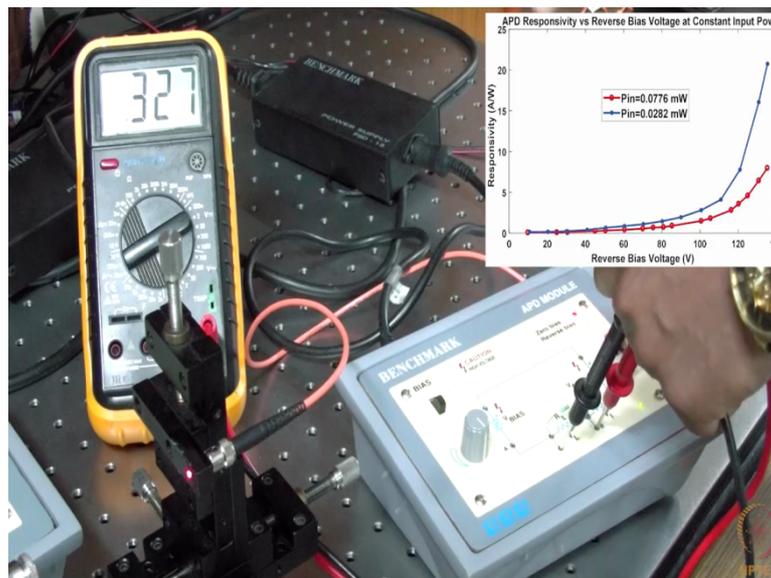
So you can again see it will been craving slowly and while I am going to higher value of bias voltage it will increase vary considerably and you can see it is going to 100, even 200 millivolts, it went to the next level in the multimeter and you can see the maximum I am going to 140 volts and you will be even reaching at a 0.7 volts drop across this resister. So you can see at the last area towards the 100+ area the increment is quite faster, and while we plotting with the data, the data is shown in the screen and if you are plotting and if you are plotting the curve you will see the curve as you see and you can see towards the end after 80 volts bias voltage the response will be shooting up, the photo current generated will be

shooting up, which means that avalanche effect will be much prominent after that and you will see big increment and after that.

So the same set of data can be repeated with a different value of input power also and you can see the trench of the output, the responsivity will be again going high after a particular value of bias voltage. So that bias voltage is nothing but the threshold field which will be applied across the APD which will cause the impact ionisation to happen and it will generate high current comparing to normal PD module and that is the result as you see it is varying in incremental way towards the higher voltages.

Okay now let us see realisation of transimpedance amplifier circuits for driving a photo detector. So all the other module components are like getting from a particular place and we are demonstrating those are designed to completely say how to characterise these particular devices and all, but this time I am going to realise circuit on a breadboard with very discrete components and the basis of this particular configuration of transimpedance amplifier is that the photo current generated by any photo detector will not be sufficiently enough to drive a resistor circuit. If you just connect a resister across a photodiode and when the light falls on it, you cannot ensure that this current will drive will create enough substantial amount of voltage across this particular resistance.

So there is a problem of loading effect and it will in turn load the photo detector back and that will reduce the amount of photo current generated. In order to overcome this particular problem we need something called as transimpedance amplifier configuration which will essentially create impedance matching circuit and with a small current you can bribe comparatively bigger voltage at the output of this configuration and you can take it out. While we are going for realising a particular circuit, the main constraint is the availability of that component.

So the earlier experiment demonstration which we had in this course are mostly revolving around some ready-made modules and characterising components, but this particular circuit you can even realise in your own lab on your home because the components I am showing here is available mostly in any electrical circuits lab in your institute or you can buy this discrete components from a nearby electrical shop.

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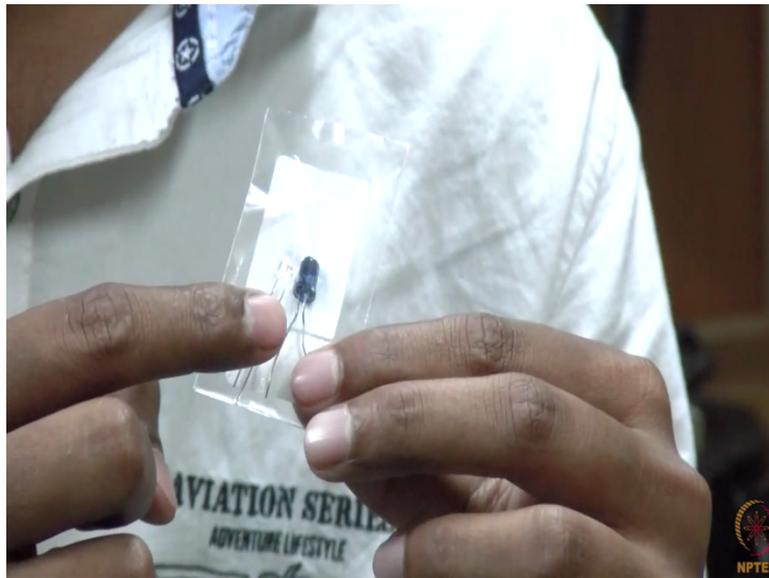
So what I have here is a transmitter and receiver which is nothing but an IRLED and IR photo detector. So in this thing the white colour one or the colourless one is the photo detector and other one is the IRLED. Please keep in mind that while you are illuminating this particular LED, you will not see any light as you see the red LED or green LED like that. You can just switch on your camera on your mobile and just to look at this LED and you can see it will be flowing in a violet colour or red colour in the camera because your eye is not capable to see the IR rays but some of the camera models does have the capability to see IR.

So you can just illuminate so please keep in mind that it is not a long distance transceiver circuit which I am going to realise here. So what I will do is just illuminate the IR LED with sinusoid signal and realise the important part which we are concentrating is the realisation of the transimpedance amplifier on the receiver end. The circuit which I am going to realise is shown on the screen and whatever you are saying there one side is for the illumination where I am connecting a 10 kilo ohms resister in series with the LED. And then the receiver side we are having this photo detector and this detector is connected to one end to the ground so there is no reverse bias is given for this particular circuit so it is working as a photo voltaic mode.
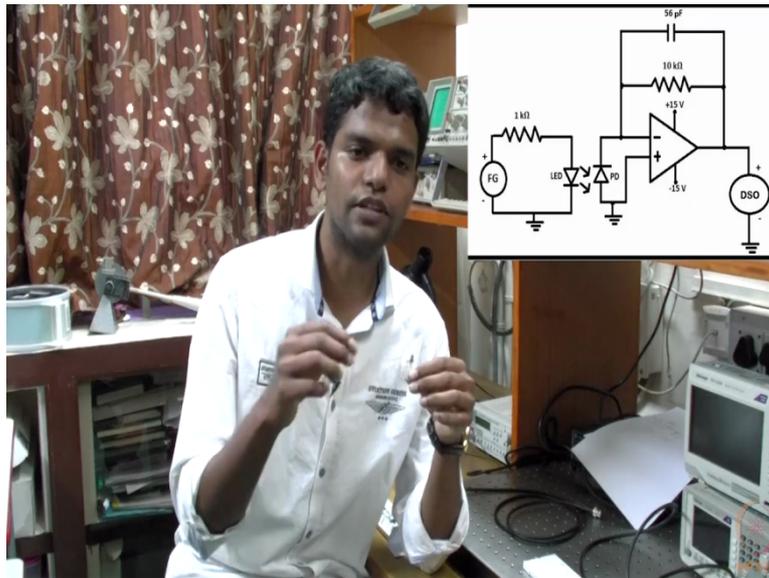
So when light is falling on this particular photo detector, this op-amp configuration which you see in the figure will help to drive the output resistance which we will be connecting at pin number 6 of the op-amp. So this op-amp is a normal op-amp which is commonly available 741 op-amp which will need a dual power supply of +15 and -15 and ground to operate. And the input is given at the inverting terminal as you see in the figure on Pin 2 and the non-inverting terminal at pin 3 is grounded and output is taken from pin 6. And you can see feedback resistor which I am using is 10 kilo ohms, parallel to that there is a 56 pico farads capacitor which essentially reduces the noise of the circuit so let us realise this particular circuit on the breadboard.
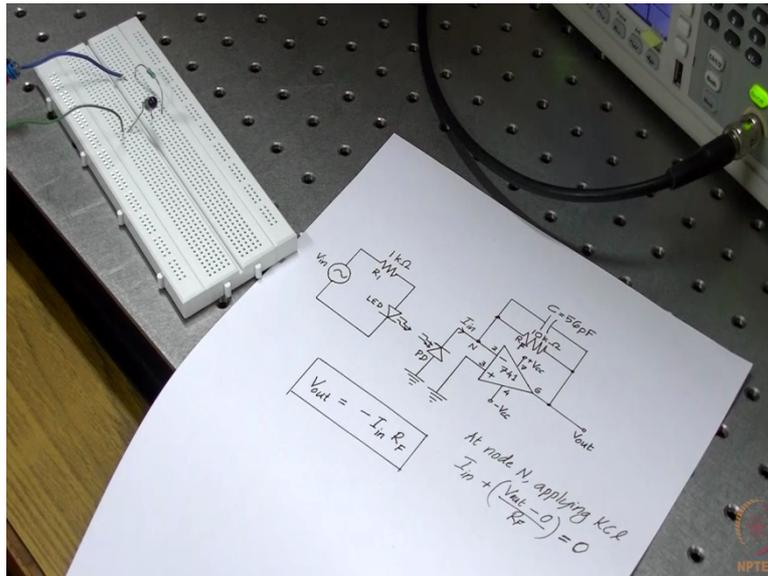
Here what I realise iis the transmitter side, so I just connected the 1 kilo ohm resistor in series with this particular IR LED and I said signal from the signal generator which is Sinusoid signal which varies from 1 volt to 9 volts. And the point is, the frequency is very low, I kept the frequency as 5 hertz such that we can see with a camera. So you might be noticing if you see normally you cannot see any blinking in this LED but actually this LED blinks.

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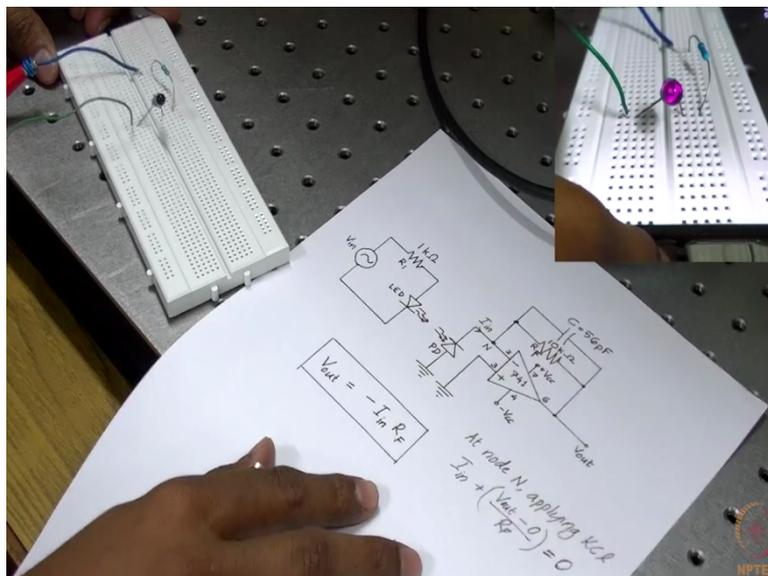
You can see that LED blinks seeing through a camera in the inset video now running on. Coming into the circuit, the circuit has as shown in the figure, if we apply a KCL on node and which is on the point 2, since the non-inverting terminal pin 3 is grounded op-amp will be making the pin 2 inverting terminal as a virtual ground, so no current ideally will follow

through that through that pin 2 into the op-amp, so all the current that is driven by the photo detector will flow through this feedback resistor.

So you can say if you are applying Kirchhoff's Current Law in that particular point, you can write I in the photo current generated plus V out - 0 which is the virtual ground voltage divided by R off is equal to 0, which will yield equation V out is equal to minus of I in times R off which means the impedance factor over the gain. You cannot call it to the gain but the factor of multiplication of current will be nothing but the feedback resistor which we have connected from pin 6 to pin 2. So I will now realise this circuit in this breadboard and you need to keep in mind that the design of this circuit completely depends on the nature of LED and the nature of photo detector that you will be getting from the shop.

So there is no constraint and all, if you have the datasheet you can go for the much perfect design but what pair which I am having now that are sweeter and receiver side, this circuit is sufficient enough to show some response. So let me realise this complete circuit in this breadboard and we can see the output how it is varying.

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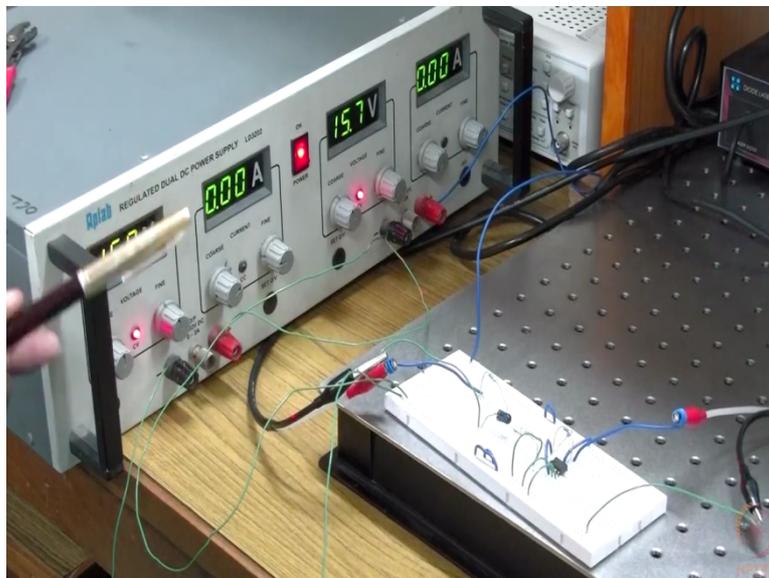
So I have realised the circuit here in this particular breadboard and we need to understand how to get the power supply for those who are not much familiar with the op-amp circuit. We need the power supply at point which is plus VCC, minus VCC and zero ground, the ground is very important here. If you just take a 30 volts and then taking plus VCC and minus VCC and not the ground, you need not be seeing any stable output at the output pin. So for an op-amp configuration circuit realisation we need 3 power lines which I generated using this

power supply here and that he wires coming into this particular breadboard. So this is a breadboard which we use to connect all the discrete components and then realise the complete circuit.

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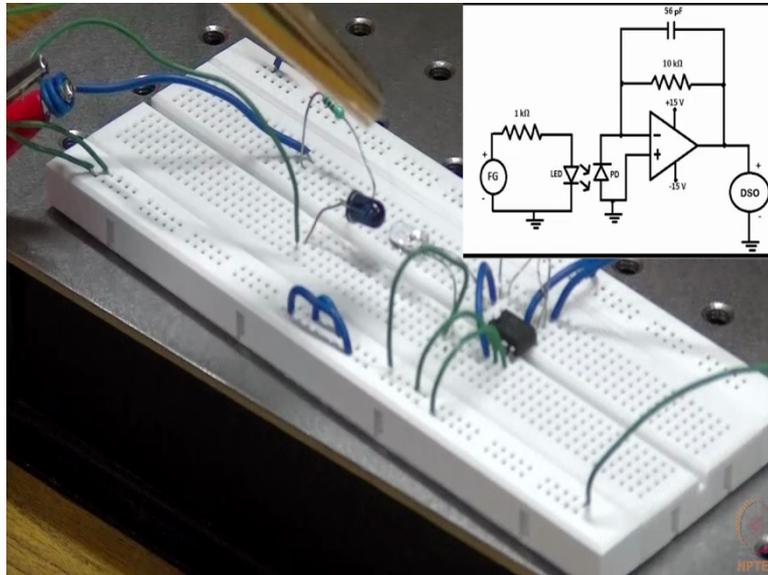
So how I will realise the plus VCC and minus VCC and ground is that you take 2 independent power supply and maintain 15 volts between these 2, and just connect like you connect it to batteries in series, likewise the positive and the negative of the 2 power supplies are short using a particular wire. And this one power supply will maintain +15 through that shorted point and the other power supply will maintain -15 to that short point, so you can take essentially + 15 through this blue wire to the top of this breadboard which is taken from the from the power supply one end, and the ground is connected using this green wire to the 2nd last line of this breadboard, and -15 I connected through the other power supply to the last line of the breadboard.

This breadboard has a centre partition so in order to carry the complete bottom line at the ground and minus VCC, I used these 2 blue wires here to take over the continuity. Likewise in the top also I connected the blue wire to make the continuity, so essentially this breadboard has now plus VCC at top line, ground at the 2nd last line and minus VCC which is -15 volt at the bottom line. So what we have here is this part of the circuit that resistor and the LED, these are nothing but the transmitter side. And the receiver side as per the circuit diagram shown in the inset in the screen, receiver side is also realised. So please note that the photo detector should be placed in such a way that it should be coming head to head with the LED such that maximum power is transmitted.

So this is not a complete realisation that you can communicate but what we have under study is that ability of the transimpedance amplifier and the frequency response of that thing. So hold that realisation part this is the simplest implementation with the locally available transmitter-receiver LED photo detector modules ok. So as per the circuit diagram as I have connected the photodiode and receiver at the pin 2, so the pin 2 is taken to this particular point using this blue wire so you can see this is nothing but op-amp this black chip and the pin is counted from the bottom left so 1, 2 the 2nd pin is taken to this particular point.

And pin 6 and pin 2, I am connecting to this resistor which is 10 kilo and this capacitor which is 56 farad in parallel to them in parallel, so you have a parallel feedback resistor and capacitor between pin 2 and pin 6. And from pin 2 you are connecting this photodiode and it should be connecting in this polarity as shown in the circuit diagram. And the photodiode, the other end of the photodiode is grounded and essentially this op-amp needs power supply so I am connecting the power supply plus VCC to the pin number 7, minus VCC to pin number 4 and the positive terminal non-inverting terminal is grounded, so this is a circuit diagram.

And through this input side I am feeding the required signal to that which is having for this particular LED which I am giving a positive voltage with an offset such that it will be always blinking. If you are giving a sinusoid without any offset which is average around 0 when the positive half cycle comes then only the LED will blink that is why I give an offset to ensure that you will see the full sinusoid swing on the light output coming out from the LED and that same is assumed to be captured using this photo detector. So we can vary the, what we will do is we will show that the light coupling is happening here and I will be giving a test signal to this input port and you can see the output through the DSO connected okay.

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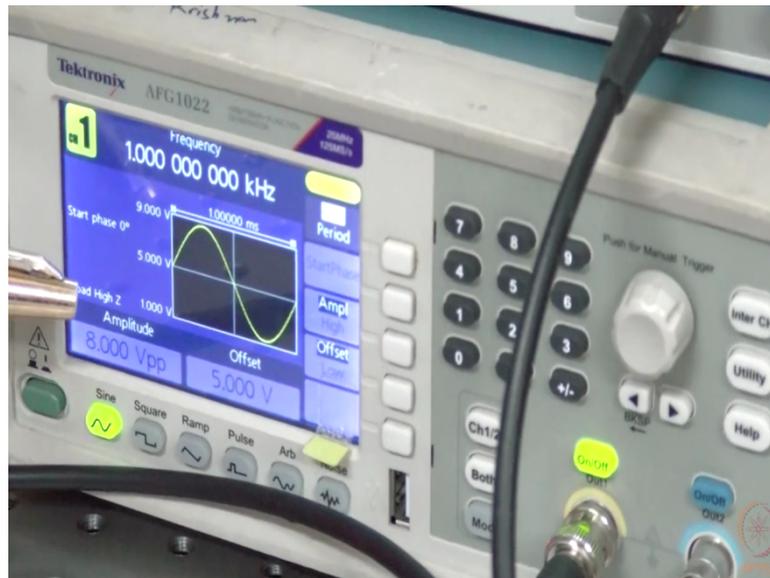
So let slowly move to the result part, the bottom side whatever is shown in this figure, in this signal generator I am giving a 1 kilo hertz signal with a V PP is 8 volts and with an offset of 5 volts, so it will be singing from at 0.5 it will be going four point up and four point down which means 1 volts to 9 volts as shown in this figure (Rand then this is a sinusoid which has a period of 1 kilo hertz.

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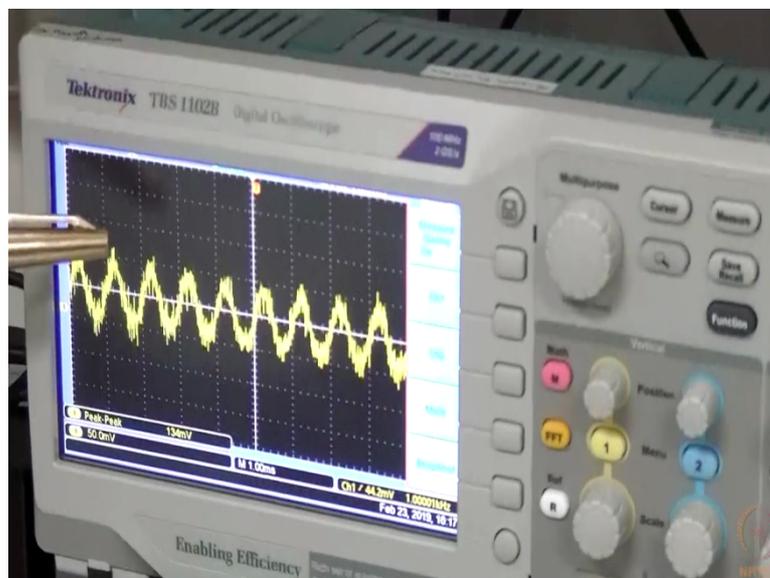
And whatever you are seeing in the DSO is nothing but the output we are connecting from pin 6. So you can see it is a very noisy response that you are seeing that is because of the noise considerations this photo detector is not that good and costly and efficient, and also the circuit of op-amp capacitor and the improper connections and the thermal excitations, so

different kinds of noise effects can happen, so all that together will give very good amount of noise. But I can show you when we increase the frequency here to 2 kilo hertz, you can see the frequency is changing at the output which means the light is coupled from the LED to the photo detector.

Okay so now what is the important constraint while we are designing a receiver circuit is, how much bandwidth it can work on, so then only we can decide how many channels you can transmit and all those criteria. So what I will do, I will start varying the frequency from minimal value to the top value and what we need to observe here is how the amplitude of the signal varies. So you can see the peak to be approximately here is approximately 150 milliwatts, let us see how the frequency response or how the output of the output of the photo detector after the transimpedance amplifier will be varying while increasing the frequency.

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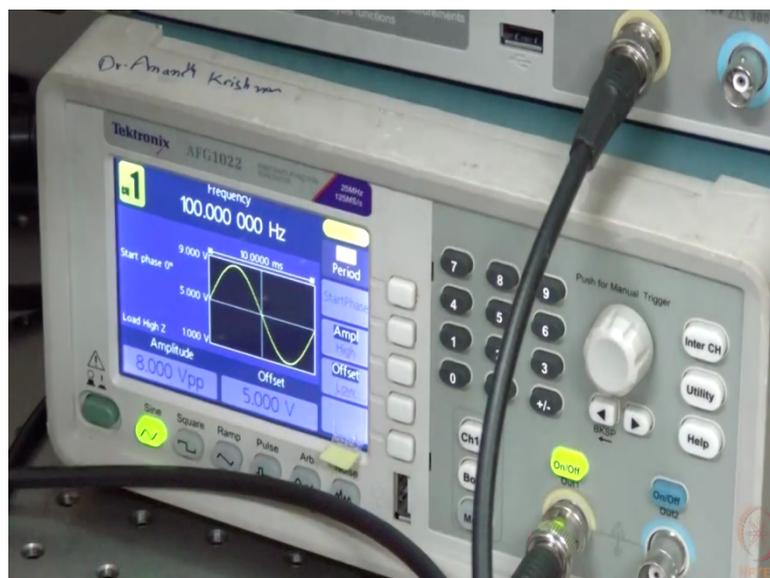
Now let me reduce the frequency to say 10 hertz… So now I have reduced the frequency now it is very changing the scale, so this is nothing but 10 hertz signal. You can see the peak to peak average value will be 2 units here which mean 100 millivolts approximately, so because of the noise I cannot exactly figure out how much value it is we can do an approximation here, it is 100 millivolts. And I am increasing the frequency in logarithmic scale such that all we need to notice is how the value is reducing ok. So I am increasing it further, so you can see that the peak to peak is not reducing much till 100 hertz so if I make the scale right so this is nothing but 100 hertz.
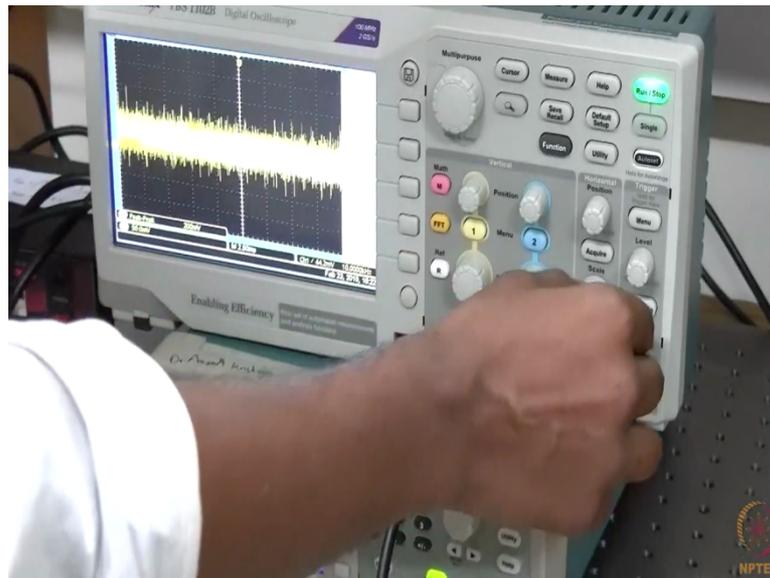
Now I am moving into the different scale, I am implementing in a logarithmic way such that it will go to higher value quicker so what I will do is I will change the, increment frequency to 100, 200, 300, et cetera, so you can see this is reducing. So till up to 1 kilo hertz we can see the average peak to peak is not much reducing, it is around 150 millivolts, it is a reduced value here compared to earlier but you cannot comparatively see that much. But my point is, if you increase to kilo hertz level let us see how it will reduce. So I am going to increase in kilo hertz level and say till 10 kilo hertz it is now reduced to little lower value, you can avoid the noise effect that is happening and this peak to peak value is not correct because of the spikes of the noise in adding on it so you can see the main shape of the sinusoid has reduced a bit.

So the next step I am going to again increment in that scale say in 10 kilo hertz increment ok. So you can essentially see the value is further reducing, peak to peak value is further reducing. So slowly it will reduce and you can go to a point like the peak to peak value reduce to the half value of the beginning beginning peak to peak value. So what will essentially happen is that you cannot comparatively say this particular system has this much frequency bandwidth or this much amount of frequency range you can transmit using this LED transceiver circuit which is nothing but the transmitter and receiver combination.

So this is we cannot confidently tell okay this is the bandwidth of one particular element, this is a bandwidth of the particular system as a whole. So the limitations may start from even the photo detector or from the 741 op-amp or even the circuit configuration, but it is essentially

you will get a feel that this particular signal will be the peak to peak value of the particular signal will be reducing when we are increasing the frequency. So you can see somewhere around 200, 300, the value will be much more reducing here so you can come the point okay where the half power half of the V PP peak to peak voltage swing will be appearing and you can approximately say okay this is the bandwidth of this particular system.

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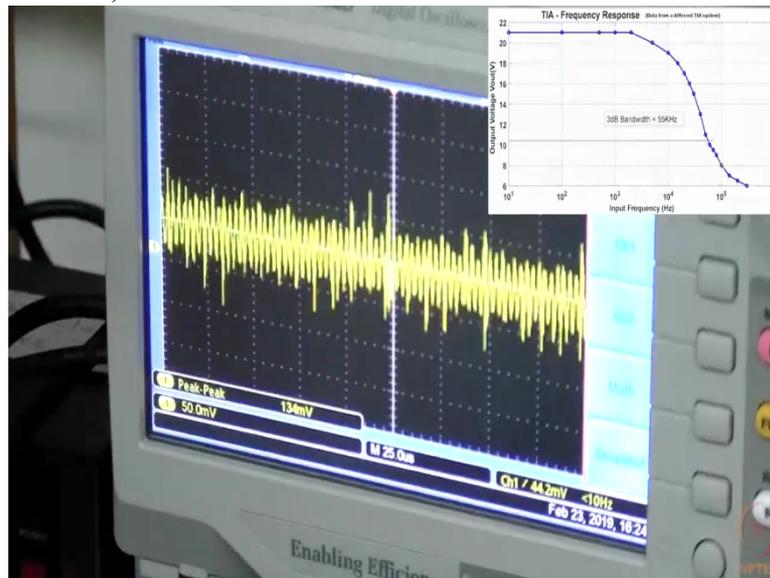
So I have connected a set of data and the data is shown here in the screen and the graph it is also shown on the screen, and you can see the bandwidth of the particular system from the graph directly. So what we take from this particular session is that light transceiver circuit can be realised easily using a using a locally available transceiver IR LED transmitter receiver module ok. Why IR because IR is giving the less noise effect, if you are going for a visible transmitter and receiver and then because of this ambience light you cannot see the pure sinusoidal well enough. So you can play with the frequency effect and frequency and even the wave shape and the response of that.

So if you are giving a square symbol and you can say you can calculate the bandwidth from the response of the square signal also. And there are different other studies that can be done by finding assignment of this particular circuit but in our simplest way the circuit can be easily realised in a breadboard in a simple electric circuit lab, all we need is a signal generator and a DSO and this breadboard and some discrete components which is easily available. And transceiver circuit, transimpedance amplifier circuit has been realised and we can study the bandwidth response of this particular circuit.

Okay so good in this session we have gone through different kind of optical detectors, so we studied what is the fundamental difference between photo detector PIN photo detector and avalanche photodiode detector using this module. So we characterised using giving different light power input and also in the APD module we see how the response for the current photo current generated is incrementing very rapidly while we are going for higher bias voltages reverse bias voltages. So essentially the main factor plays here is nothing but the multiplication factor or the avalanche effect in the APD while the photodiode gives you the linear response in most of the cases.

If you consider the usage of these 2 modules there are different factors involved like noise factor, the response time, the amount of current generated, those things are suitably chosen for a particular application and some cases you can use APD and then some other cases you can use the PD modules . So this choice between these 2 are clearly explained in the theory session, also in the session we have realised transimpedance amplifier circuit using a photodiode and the circuit is made from commercially available low-cost IR LED and the receiver.

So the transimpedance amplifier circuit has also realised and we observed the trend of frequency response of that particular circuit. So altogether we have essentially covered the semiconductors detectors that we have in this particular course explained. And for detailed analyses and theory, you can refer to the theory session and this will essentially give the hands on idea of how this particular circuit will work on. So that concludes this particular session, I want to thank you Freddy and Akshay here for helping me out to shoot this video, hope you enjoy this session thank you.