INDIAN INSTITUTE OF SCIENCE, BANGALORE

NPTEL

NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

Course Title
Electronic Modules for Industrial Applications using Op-Amps

By
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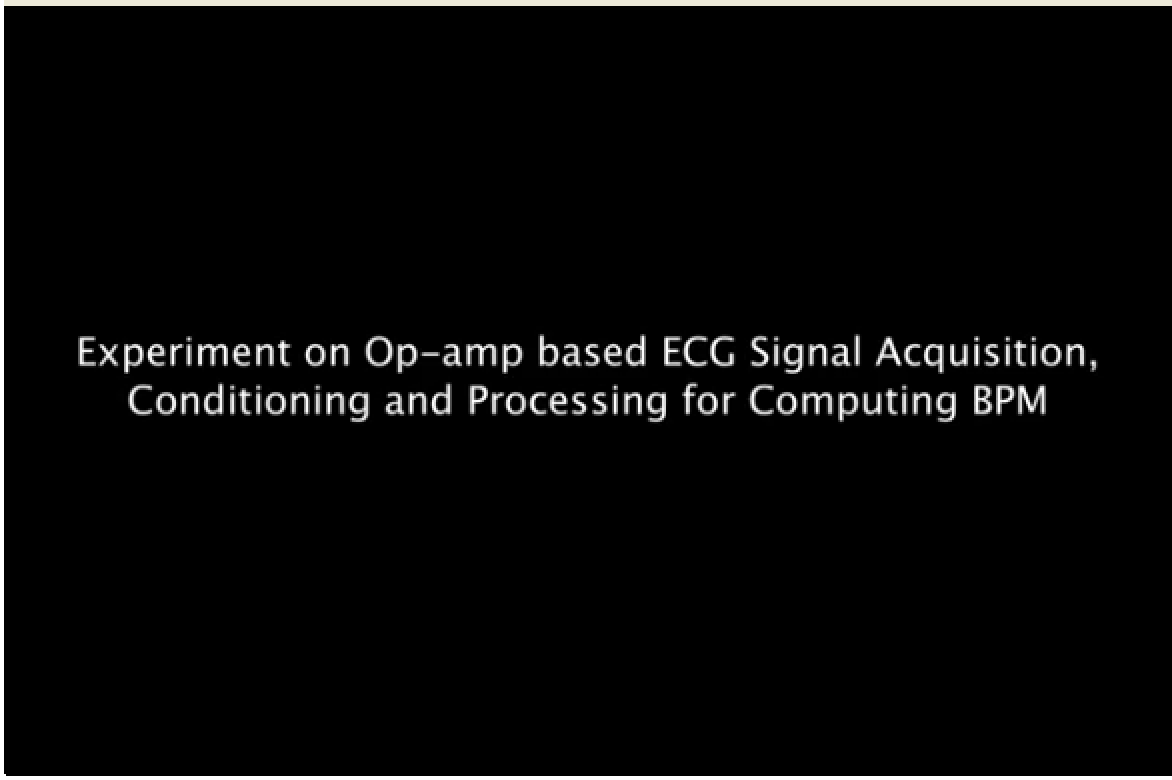

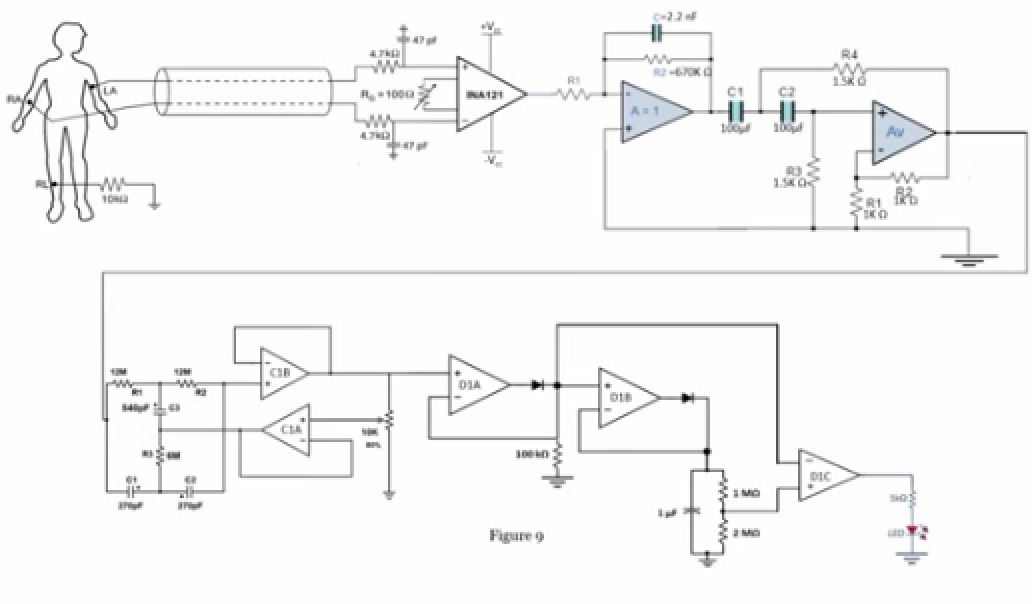

Figure 9

Till now we have seen the subsystem level of each and every that design the part, now what we are going to see is that once we interface and connect our electrodes to the specific person to acquire our ECG signal, how the processing will be done, right, everything we'll see.

Now we will compare the signals, the outputs at you know at this point as well as at this point, (Refer Slide Time: 01:08)

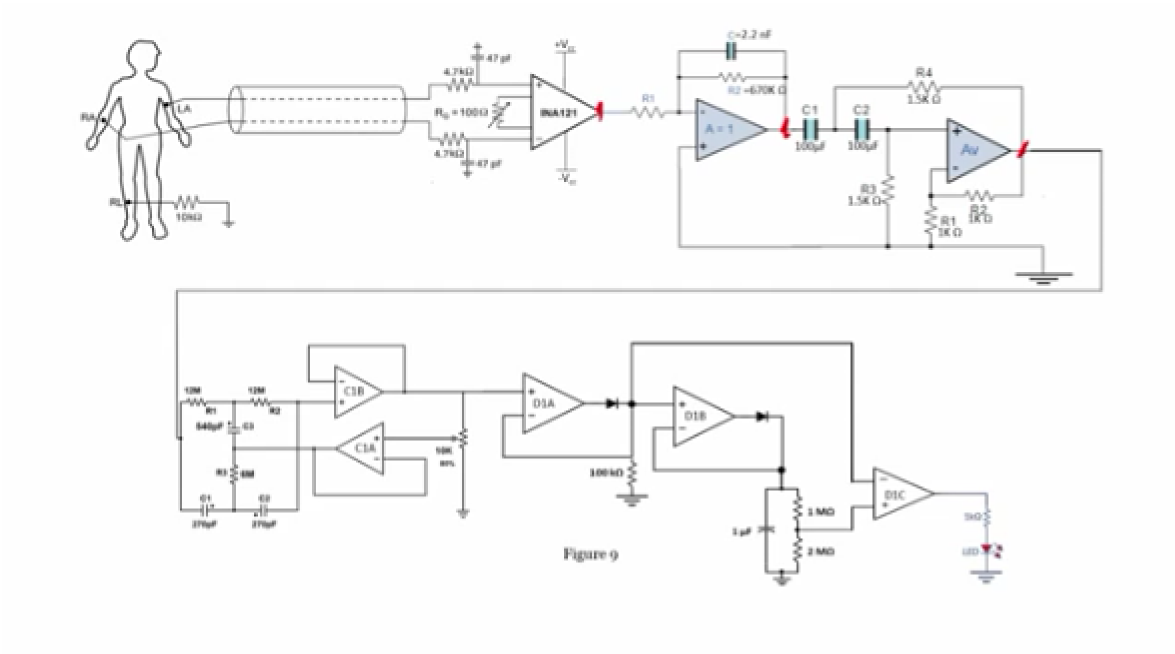

Figure 9

right, we will see how accurate, how good ECG signals that we get at this two outputs too, as well as at this point too, so in order to acquire the signal from the person or from the subject the thing is that we have to connect 3 different adaptors, if you recall we told that one electrode, one voltage source will be from right arm to the right leg, right, so another voltage source will be from left arm to the right leg, right, so this is one particular voltage source.

This is another particular voltage source, and the signal strength or the signal amplitude of the, from this particular source as well as this particular source will be almost equal to the same, that's a reason we required to have a higher CMRR operational amplifier, and since we have to do the difference between the two voltage source as we require to use some difference between the outputs,
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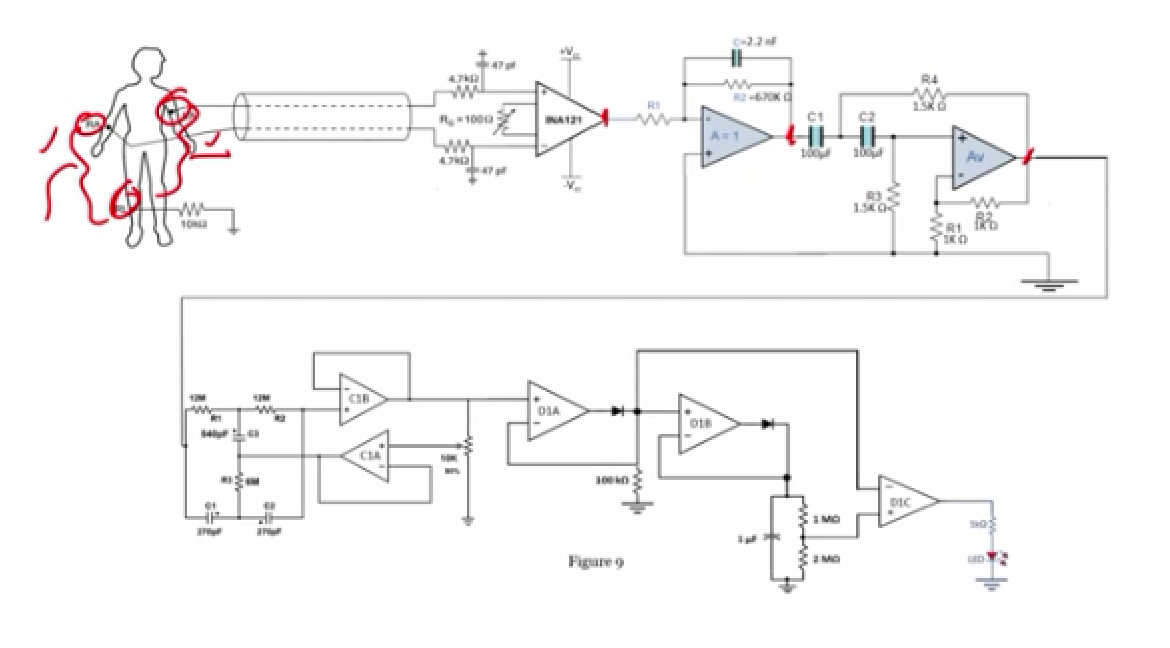

Figure 9

so in order to perform, in order to perform the difference either we have to go with a differential amplifier or we will be going with an instrumentational amplifier, right, but differential amplifier cannot be used in this application because the input given to the system, the output that we get from the subject will be all off common mode signal and we required to have a higher CMRR value, so differential amplifier will always you know affect from CMRR that is one thing, and the input impedance of our instrumentational amplifier is higher compared to the differential amplifier, so that’s a reason we will be going with instrumentational amplifier, but the instrumentational amplifier that I am using here is INA128 so you can look into the data sheet in order to understand the detail architecture, detail specifications of the instrumentational amplifier of INA128 so that even you will get to understand about the working the gain setting, the resistance value that we choose and why we have chosen, right, everything we can see from the data sheet.

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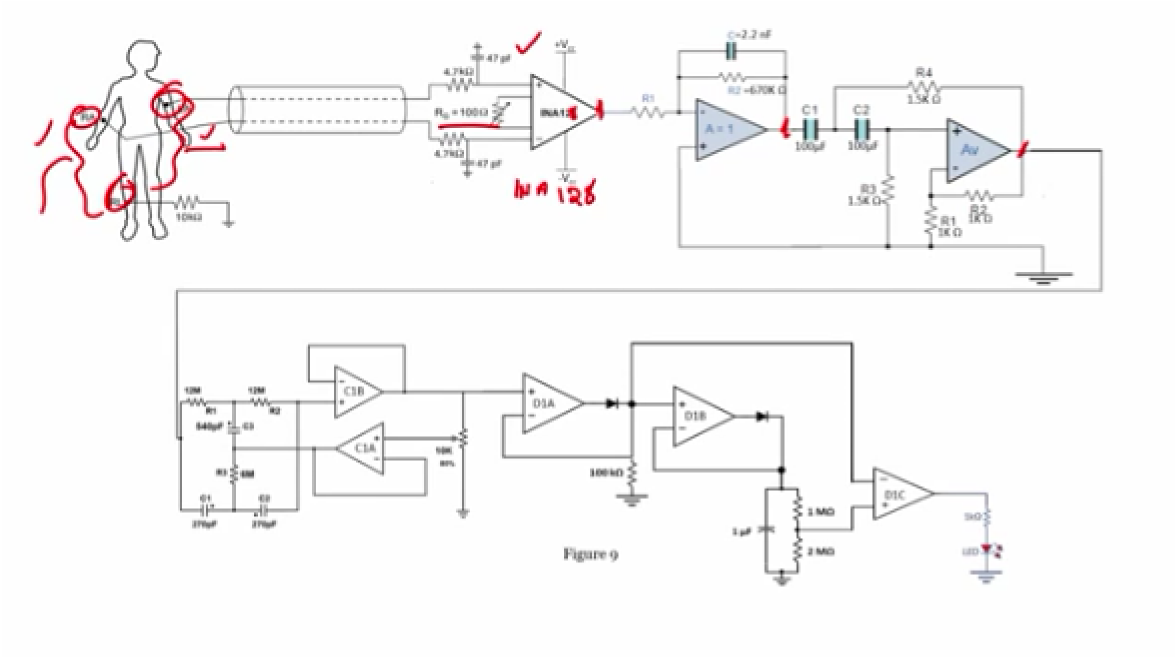

Figure 9

Now when we see the output at this particular point since it is not a processing signal, only the amplifications says that we have done we can see amplified version of ECG signal, but as if you recall our the discussion, so initially we have discussed as well as professor discussed in the class that the raw ECG signal will always prone to lot of interference due to so many noise, due to other signals, so those are nothing but our power line interference, baseline mandarin, right motion artifacts, all those things will be observed at this point, right, so we will try to see you know the effect of the baseline mandarin in the system, so if you recall so the baseline and mandarin is nothing but the signal will be always wandering with respect to this baseline, right, this is due to because of the respiratory,

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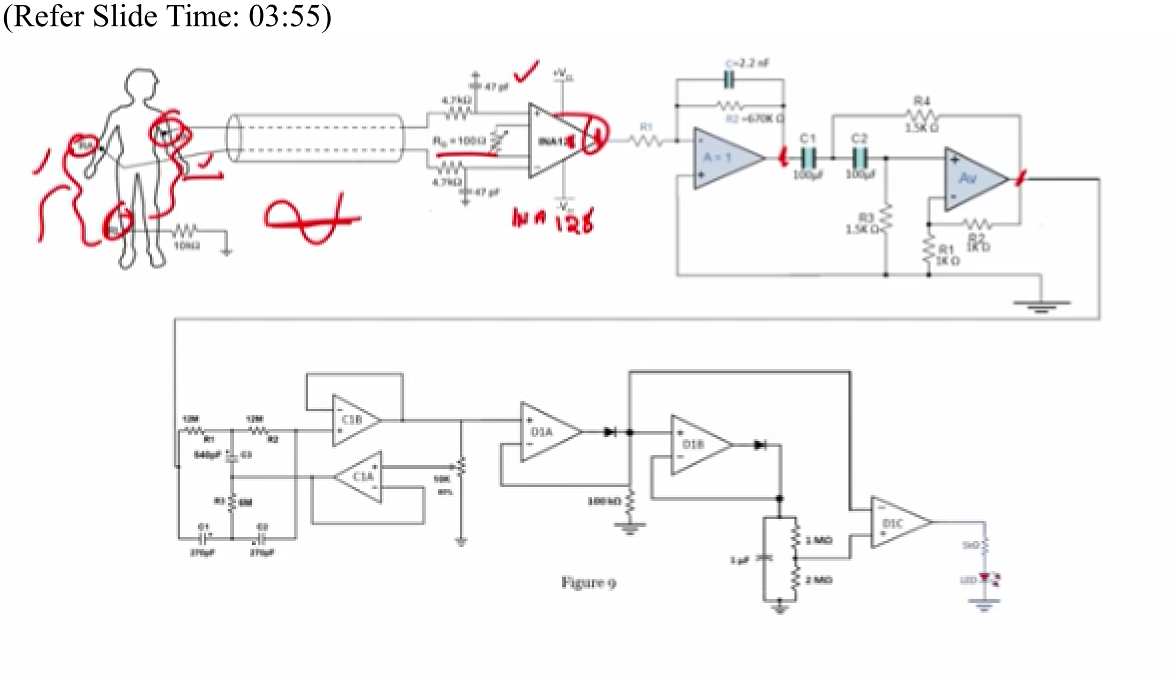

Figure 9

so during the respiration of our breath because of that it creates some kind of a noise into the system so that will be somewhere around lesser than 0.5H, so since we are using high pass filter, so after passing through the high pass filter so we can see the complete removal of our baseline mandarin.

And even motion artifacts will also be in the same range, so completely will be eliminated when we pass through this particular system, when we pass through this particular system then we also have some odd multiples of our power line interference so which is greater than 100 hertz so by using our low pass filter we are completely eliminating it, and notch filter to remove our 50 hertz signal.

And we will also see, since we have also seen in the practical as well as theoretically, as well as a simulation version how exactly this works, right, so we will only show till this point because this requires some more you know computational requirement in order to do verification, since we are using DSO, digital signal oscilloscope,
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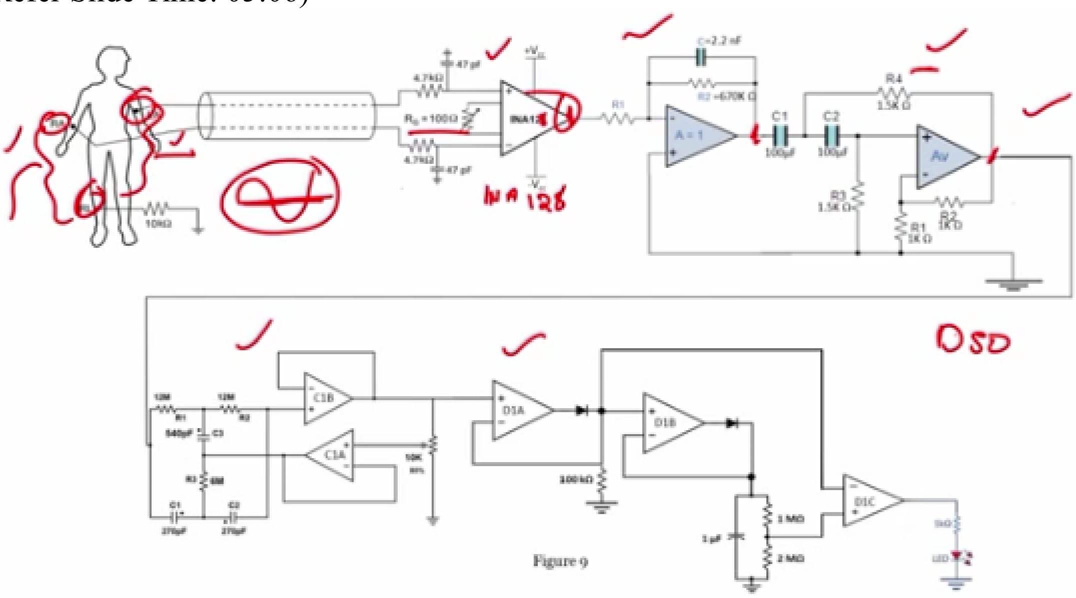

Figure 9

since the whatever the signal are nothing but will be stored in terms of our digital outputs, even by using our DSO at this particular point we can easily analyze the BPM of the subject that we are connecting it there, and subject that we are connecting to the input of our amplifier.

Now we’ll try to see the outputs at each and every point, so starting from the output at instrumentational amplifier at this point, then connecting the output of the instrumentational amplifier to low pass filter and check the output at this point, connect the output of the low pass filter to the high pass filter check the output at this point,
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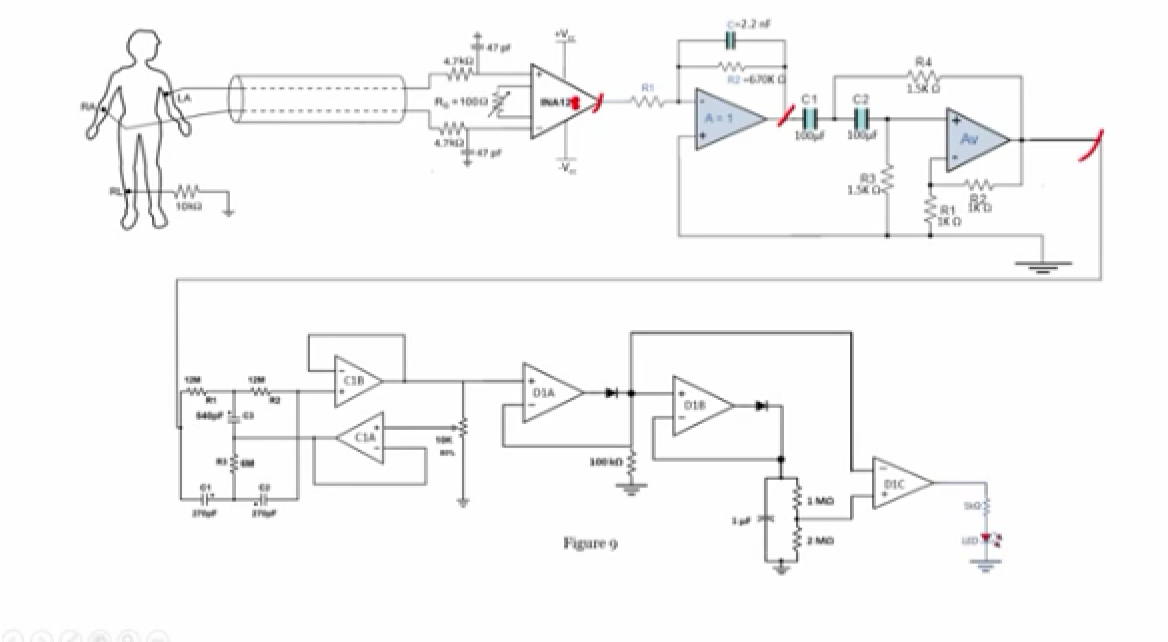

Figure 9

and we will see how much difference in the amplified version as well as the elimination of a noise in the pre-processing stage, everything we can observe at this point too.

So in order to connect the electronic circuit to the subject we required to have some electrodes, so we are going to use some ECG patch electrode, switch are available in the market, so these are let me take out the ECG patch electrodes, so these are our ECG patch electrodes, so these are our ECG patch electrodes if you see that, right,

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so this ECG patch electrodes will have a metal contact on top of it and these are not reusable, use and throw, once we use it we have to throw it out, disposable ECG electrodes, so we will be placing one at right arm, one at left arm, other one at right leg because the reference is are right leg, so when we see we have already connected, we have already connected to the person, so one we have connected to the right arm, other one we have connected to the left arm,

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so it has a stickiness inside, as well as silica gel too, so here at the back side we can see that silica gel is to just to remove the impudence, to decrease the impudence value and this is at right leg position, so this access our reference, right.

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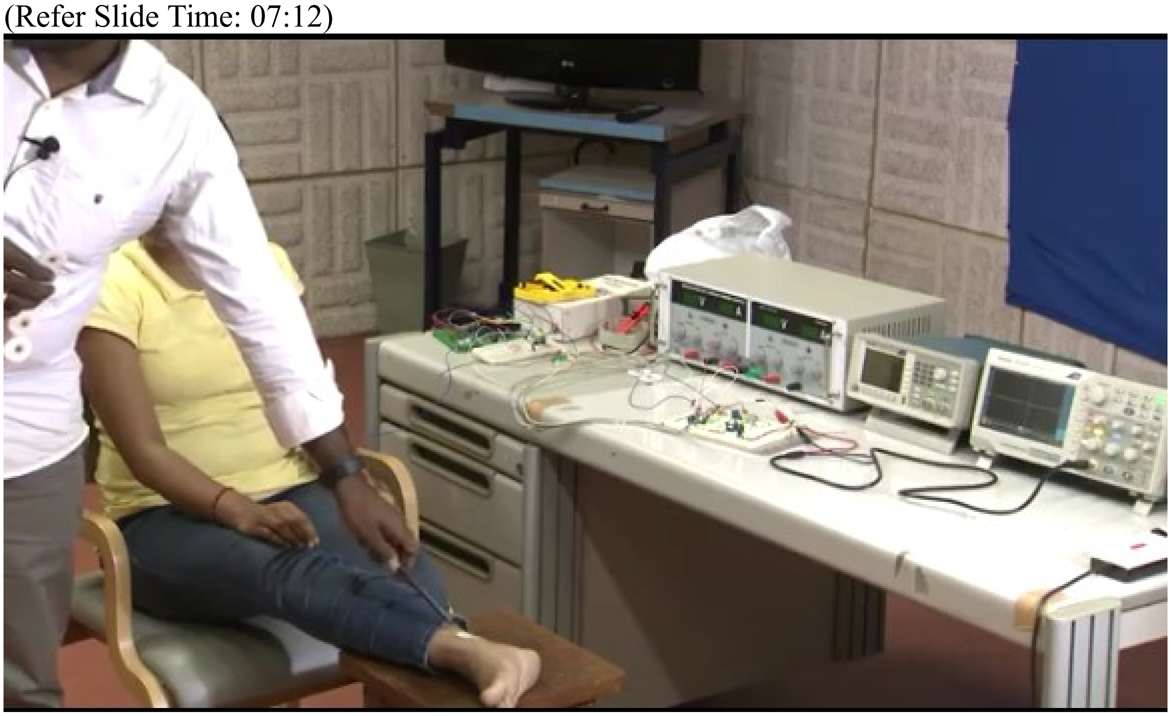

Now we will take ECG connectors, so I'm using some ECG connectors, so these are our ECG connectors, sorry, right, so 3 ECG connectors we have taking it, so what I'll do is that one I'll connect it to the reference point I'll connect it to the leg, whereas one I'll connect it to the right one, other one I'll connect it to the left arm,

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so I just made the connections, even in the circuitry, so at this point one we will connect it to the positive terminal, right, other one connect it to the negative terminal,

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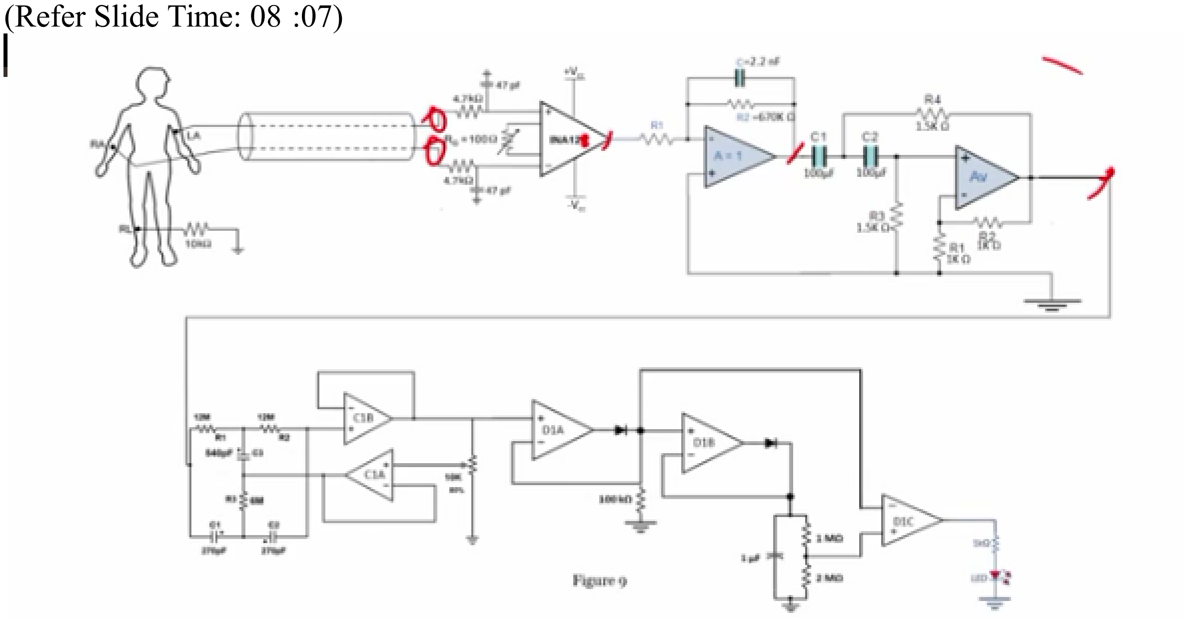

Figure 9

so when it comes to the breadboard when you see the breadboard, so what I have done is the outputs of the ECG signal, right, through the leaps connect it to the inputs of both here, the inputs of the both instrumentational amplifier, and this particular blue colour trimmer port

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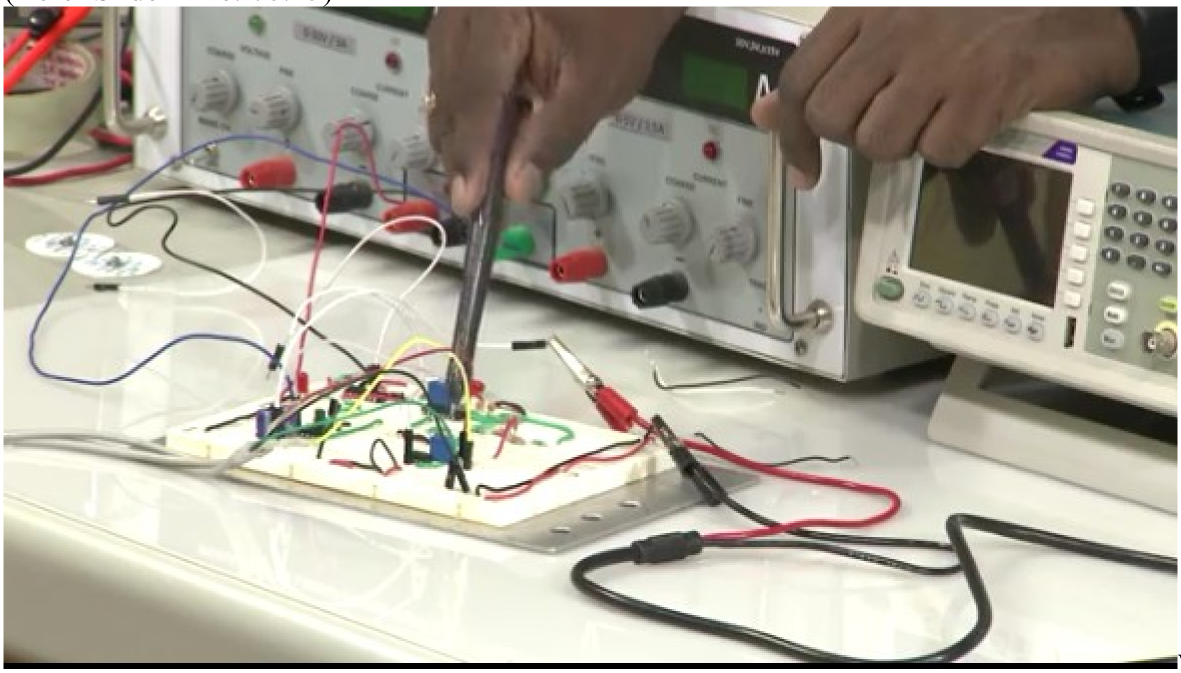

whi
ch is of 200 ohms port we are using and set it at 100 ohms so that the gain, the gain will be as per the datasheet you can calculate the gain of the system, based upon the resistance that we have used somewhere around 500 to 1000 gain we are using it, so let me switch on the power supply and we will see how exactly the signal will look like, so what I'll do is that I'll connect, so since our interest is to see the signal at the output of instrumentational amplifier so I'll connect the output only to the instrumentational amplifier and remaining connections I'll remove, so I'm connecting it to the output of instrumentational amplifier.

Now when I look into the oscilloscope how the exact signal will be, we can see some signal we are getting it, but there is some offset, so here we can see this is our ground point, but there is some offset, right,

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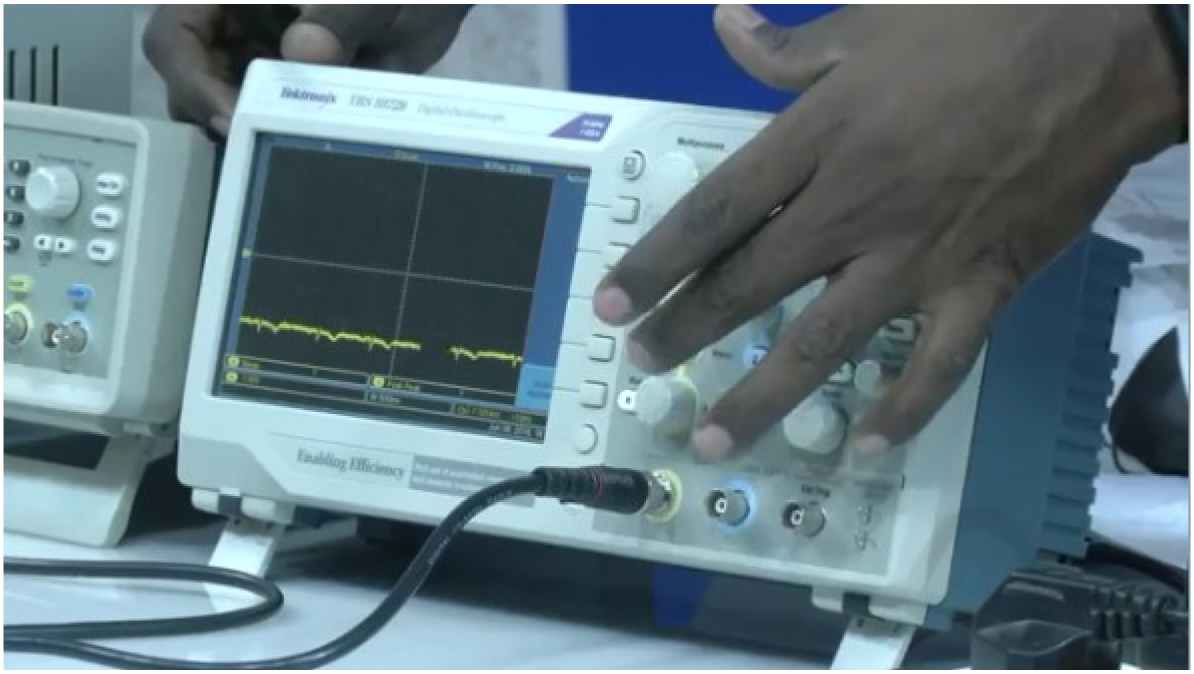

and when I increase the time duration, time scale, we can even see some kind of wandering, right, so observe? Started increasing the value, again starts decreasing,
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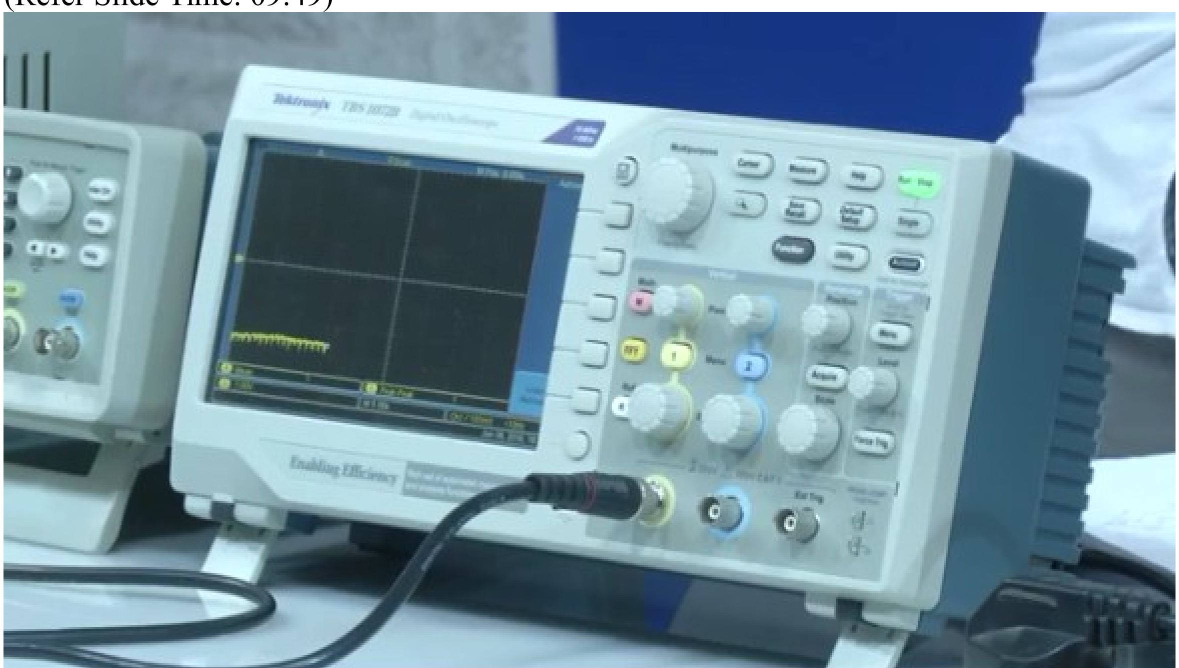

again starts increasing, so like that it's a wandering, so it is may not be clear in this way, but if I connect it to the low pass filter, so what I will do is that the output of the amplifier, I'll connect it to the low-pass filter, so low-pass filter and the output of the low-pass filter will be connected to the oscilloscope.

Now when I see the signal in our oscilloscope, right, there is some shift from positive to negative, now what I'll do is that just let me auto scale once, right, and let me zoom, I'll change the time duration to somewhere around 10 seconds, right, so we can see the wandering, we can clearly observe this, so some part of the noise has been completely filtered when we pass through the low-pass filter, so what I'll do is that I'll slightly shift the signal to down, little bit down, and I'll increase the time duration, right now one box is completely 1 volt, I'll change to 500 for the increase of the amplitude, keep it down, so suppose if I zoom it, time duration if I increase one thing it is clear that we are getting some peaks and the pattern is also looks similar to that of your ECG, isn't it?

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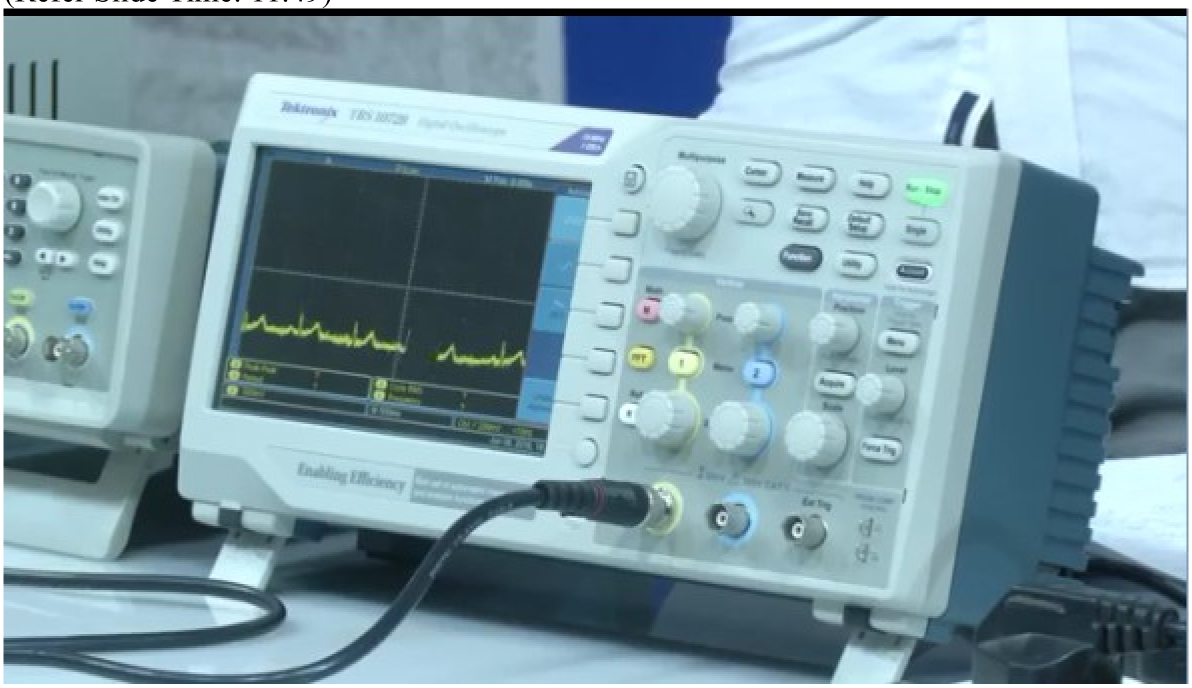

See here, the QRS, Q R S, and P, Q, R, S somewhere or here T and U, so T and U is very hard to visualize using this particular the patch electrodes, but if you have rather than 3 lead electrodes if you go with the 12 lead electrodes even that signal it is you know, the pattern will be easy to recognize using that particular 12 lead electrodes, but we have some offset as well as we also have some kind of wandering, wandering in the signal, so in order to understand the wandering, so I changed the time duration to somewhere around 50 seconds, it's too high so I'll take to 25 seconds, so in order to finish one box it takes 25 seconds, so 50 seconds to 2 boxes, 75 seconds, approximately 1 minute to 2 minutes if I wait I can easy to understand how the signal will be looks like, but here it is clear that it is started wandering, right, so you can see sometime it is at the peak, sometime at the negative, right,

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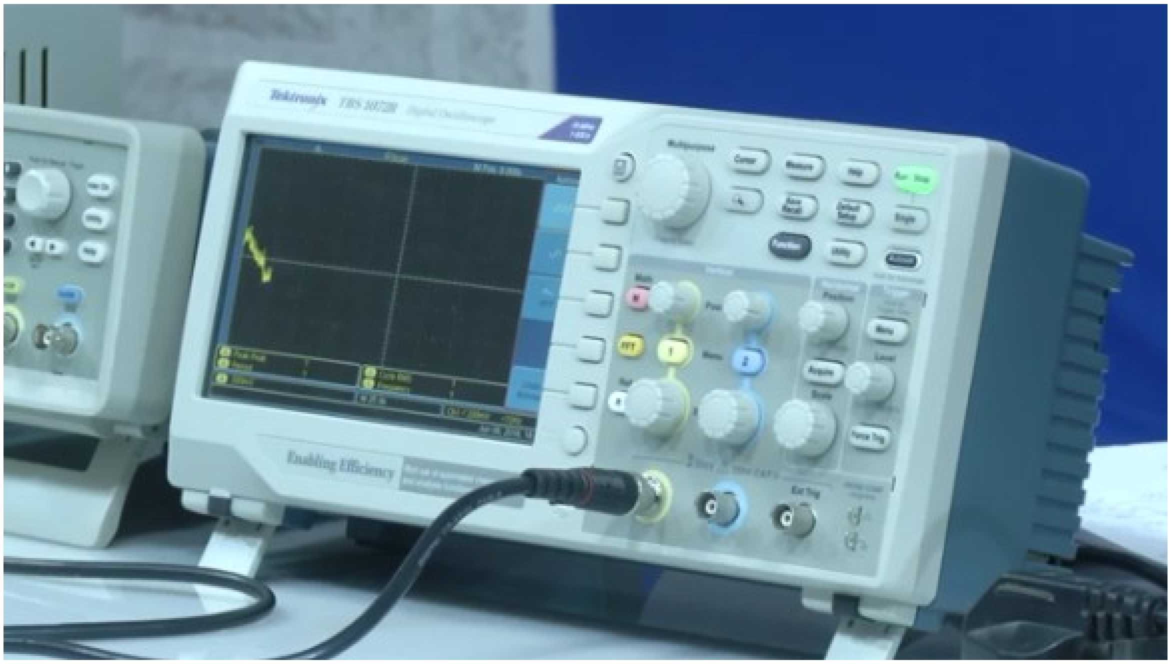

this is because of our respiration rate or even because of our motion artifacts too, so basically because of the respiration while taking the recording this creates some wandering in the system, right.

In order to remove this noise, so we have to pass through high pass filter, since we have not pass through the high pass filter we can only see the signals which are always wandered with respect to the baseline.

Now what I'll do is that in order to even remove that as a motion artifacts when we are moving there will be always noise generated into our system too, so if you want to remove everything what we have to do is that, we have to pass through the high-pass filter too, so now I'll connect the output of the low-pass filter to the high pass filter, so I'll remove this connection, connect it to the high-pass filter, then the output, so output pin is somewhere around first pin here, so this is our output I'm connecting it here, when I look into the signal at oscilloscope, the offset is removed and you can see there is some sudden jump down,

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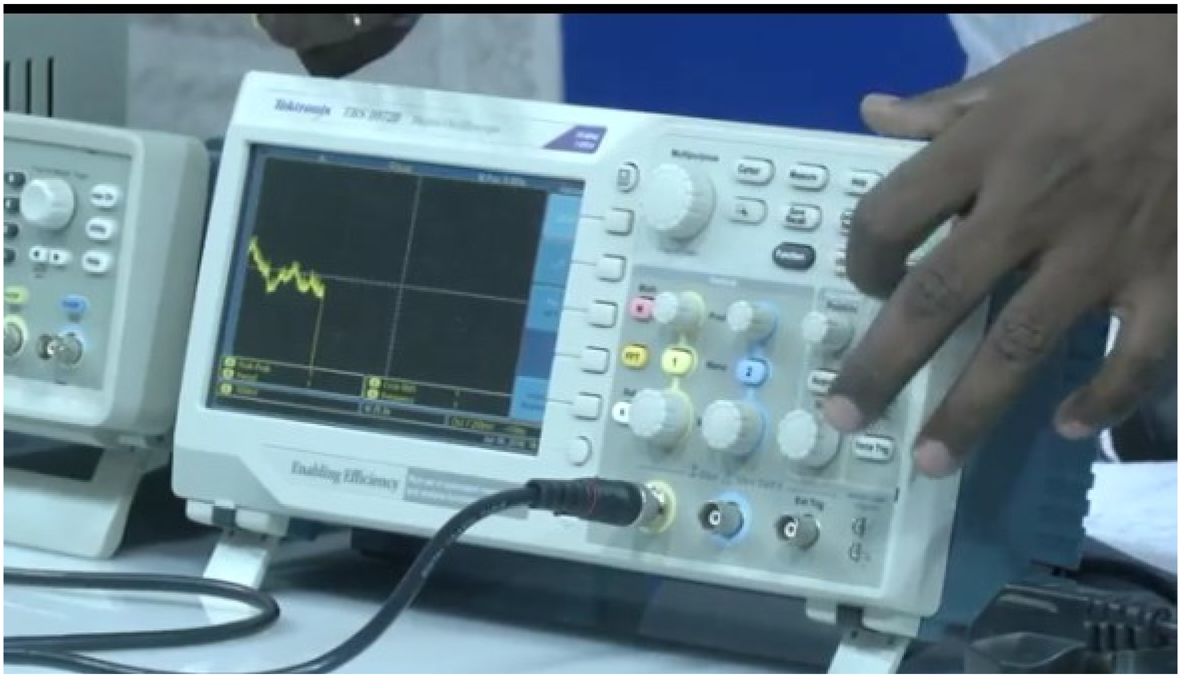

so to see that what I'll do is that first I'll auto-set it and I'll change the right, I'll change my the time duration, time scale to somewhere around 1 second or 2 seconds, and the box line, the amplitude see the high pass filter whatever we design have the gain of 2, so that's a reason we can see the amplitude signal, so I'll put it somewhere around 1 volt or 500 milli, then, right,

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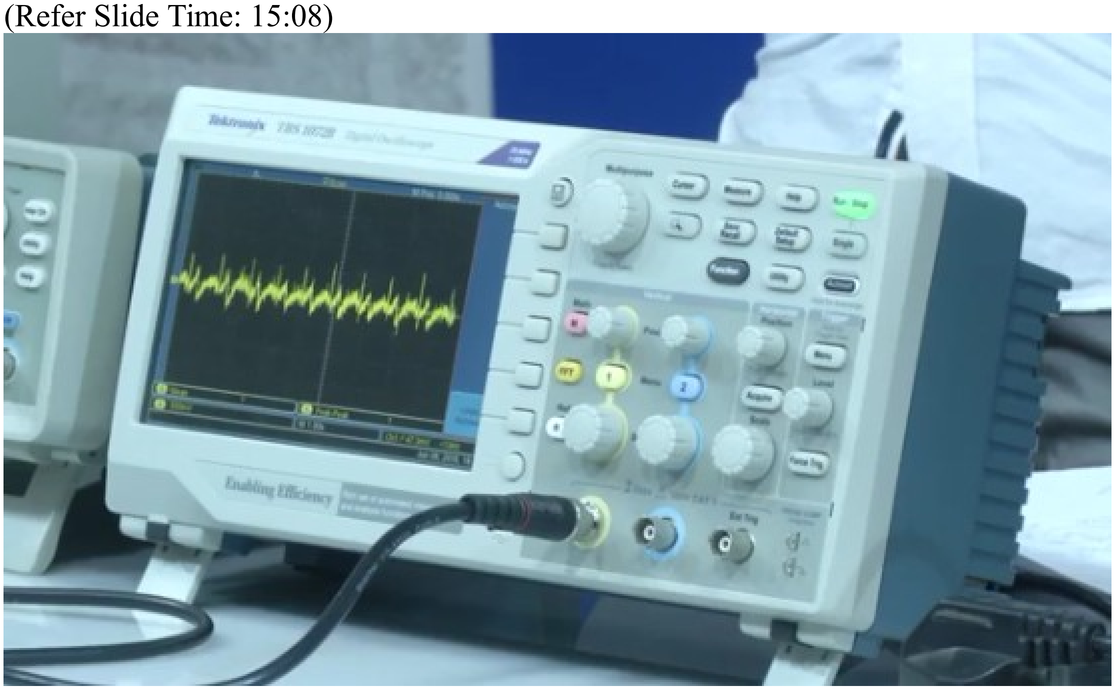

so when we look into the signal it's a continuously recording it, when you look into the signal so we have different peaks right, so here it is easy to understand QRS peak very easily, QRS and the amplitude of the QRS is more compared to the other peaks, isn't it?

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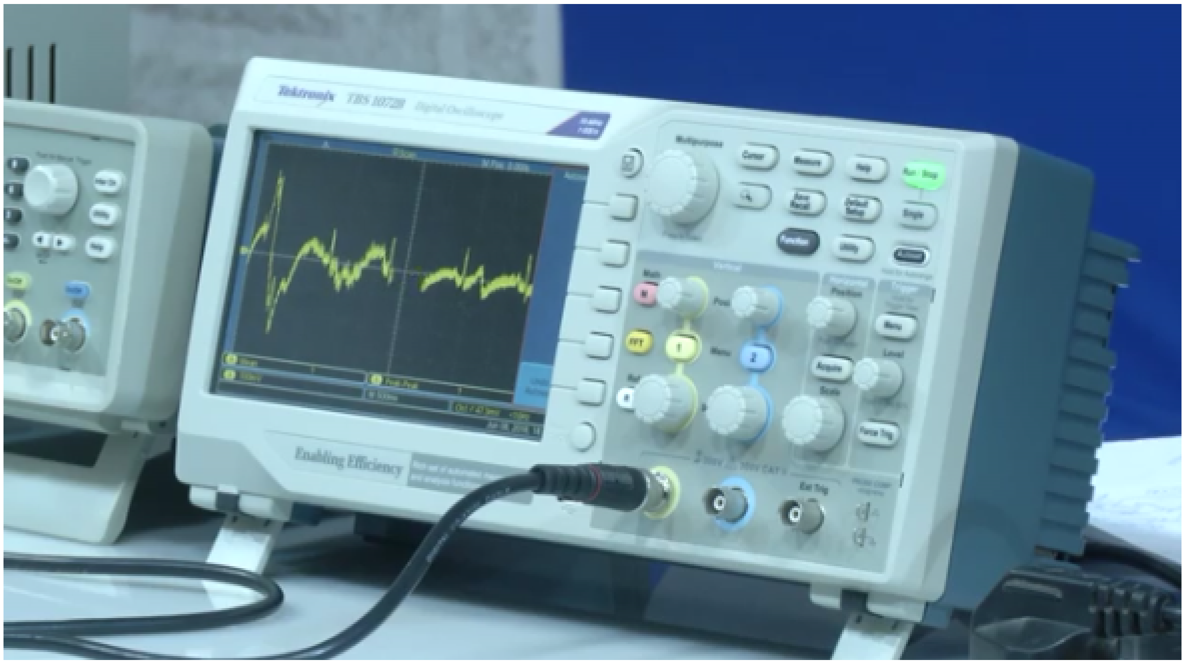

Right, when we observe it is clear that the QRS peak it is easy to visualize using our system, right, clear?

Now how do we understand our BPM in this, so if I want to understand I have to calculate how many number of such peaks we are getting per particular time duration, so to set that what I will do is that since it is our digital oscilloscope we can easily visualize one box is corresponds to how many seconds, so we will see how many number of boxes we have and we will take how many, we will calculate how many number of peaks that we are getting, that is one way, another way is if I put a cursor, if I find the frequency between one peak to the other peak, so if I know the time duration 1 divided by time duration and automatically you get the frequency that gives me what rate that peaks are even obtaining, so what I will do is that either to both the ways we can go ahead, so first thing I will see what is the box that I have set, so let me change it to 1 second, I have set it to 2.5 seconds, so that’s why you can see very you know shortening of the signal but so if I want to, if it looks really not perfect what I’ll do is that I’ll change duration to one second, right, so here we can easily, so one box is one second and total we have, total 9 boxes, 1, 2, 3, 4, 5, 6, 7, 8, 9,
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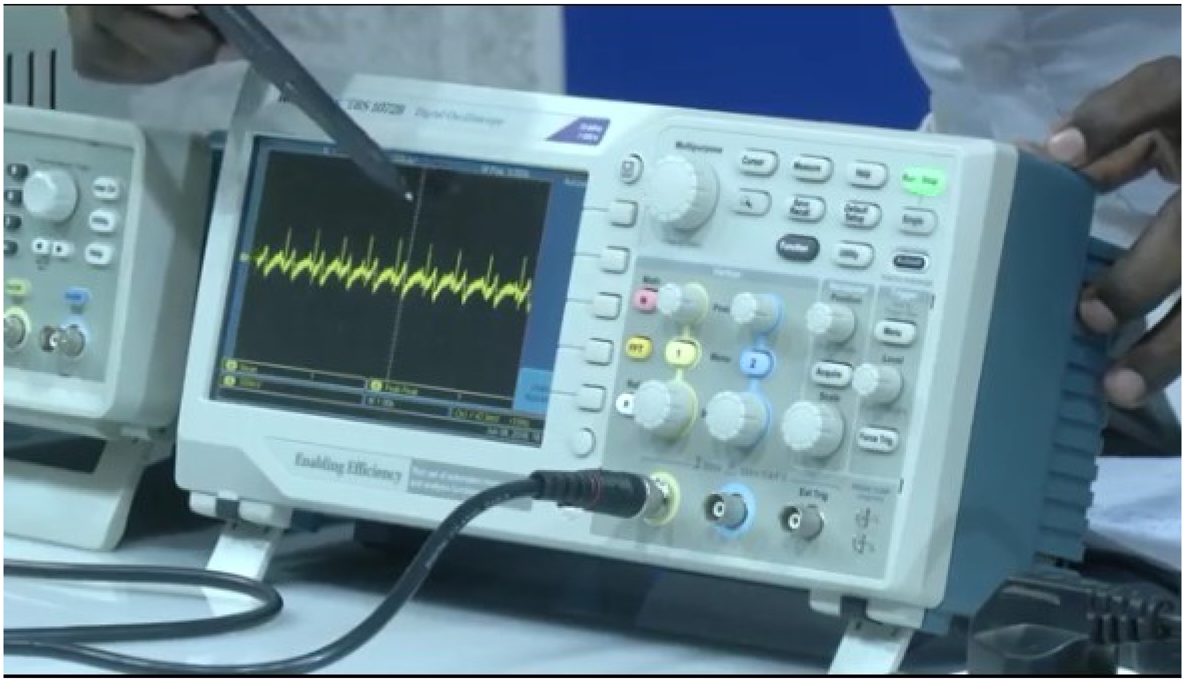

so total we have 9 boxes and we will see how many number of peaks that we are getting it.

So in order to understand how many number of peaks that we are getting, let me stop at this point, okay, let me run for one more time and I'll stop it, I'm stopping at this point, now if I calculate 1, 2, 3, 4, 5, 6, 7, 8, 9, so 9 peaks 9 heads, 9 peaks and for 9 seconds, so we have a total of 9 second scale, 9 heads, 60 so the frequency is somewhere around 60, so if you want to find out accurately what we can also do is that rather than taking to 1 second I'll take it as 2.5 seconds let me see, so total 9 boxes, 2.5 x 9,

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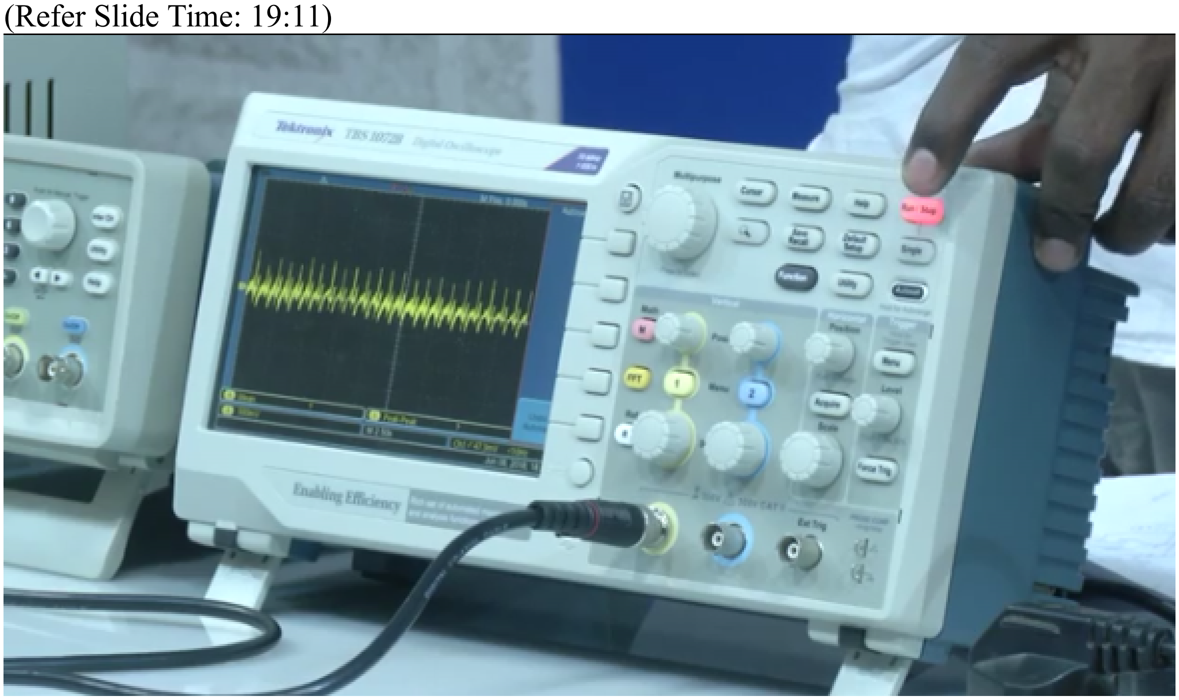

so 2.5 x 9 is somewhere around 22.5, so total is of 22.5 seconds, and how many number of peaks we have? 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, so total we have 24 peaks in a time duration of 22.5 seconds, I need per minute meaning 60 seconds, so 60 seconds how many peaks? 60 x 29, 24 sorry, 60 into whatever, how many number of peaks? 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, so 24 peaks divided by 22.5, so we are getting somewhere around 64 BPM, so the average BPM of the subject that we have here is of 64 BPM which is a normal rate, sorry 64 BPM which is also a normal rate.

So now it is clear that when we pass a signal through amplifier, it amplifies but it also, it cannot remove anything, but after passing the signal through our pre-processing stage, our filtering and everything we have seen very pure you know like meaning, we have seen the signals which are you know the filtered output which is, which was removed by our high-pass as well as low-pass filtering, so once we connect the signals to the other stages even we can see you know, the peak detection as we have already seen in our practical and experiment of that particular system, and we can also record, we can also visualize the output, peak outputs by using our peak detectors and we can also set a threshold using our you know resistor divider circuits, then since we also have the comparator it will compare and gives a high peaks too, since the frequency is really higher it is very hard to visualize with our LED that we have connected there in the circuit board, but once if it is like, if you connect it to the CRO even we can see the pulses too.

But since we already have oscilloscope here rather than doing all the analog, since we have also shown how the working of the operational amplifiers in theoretical and the subsystem level, as well as then practical session why don't we take, why don't we understand how digitally we can do it, so in order to understand how the digitally we do it generally we'll take a microprocessor and microcontroller, so we will connect in the same way, we required to have an amplification as well as either we can go with digital filtering or our analog filtering, the way that we used it, once the pre-processing and amplifications stage, amplification pre-processing stage is done we can pass the signal to our digital you know system, so in this case we are using DSO or we can also go with our microprocessor or microcontroller, once we acquire we'll get a digital data, and that is a filtered digital data.

So once we do the, you know processing in the processor, how do we have to do the processing? If you recall what we have discussed when we are designing our subsystem, first step is to find out the peak value, how do you calculate the peak value? So I'll compare the first value with the next value as well as preceding value and the next value, if this particular value is greater than this value and this value I can say this value is peak, right, if you see the peak will be something like this, the peak value will be always higher compared to the next value, either in the right direction or the left direction, right, so since our interest was only towards our positive side, I can pass through you know rectifier circuit or half-wave rectifier circuit so that only the peak signals of positive peaks can only be pass through that, and by using a capacitor I can charge it to the peak value, right, so whichever the voltage that we are getting QRS peak amplitude that we are getting by passing through the capacitor even I can pass it.

After passing it by using a resistor I can set a threshold, now when we set a threshold right, the way that we have calculated a frequency right we can see how many signals, how many peaks that we are getting after passing through the thresholds, if I can count those many number of peaks by writing an algorithm, right, my problem is solved, now that is one way or if I see the time duration, so we have seen in frequency domain, sorry we can calculate manually.

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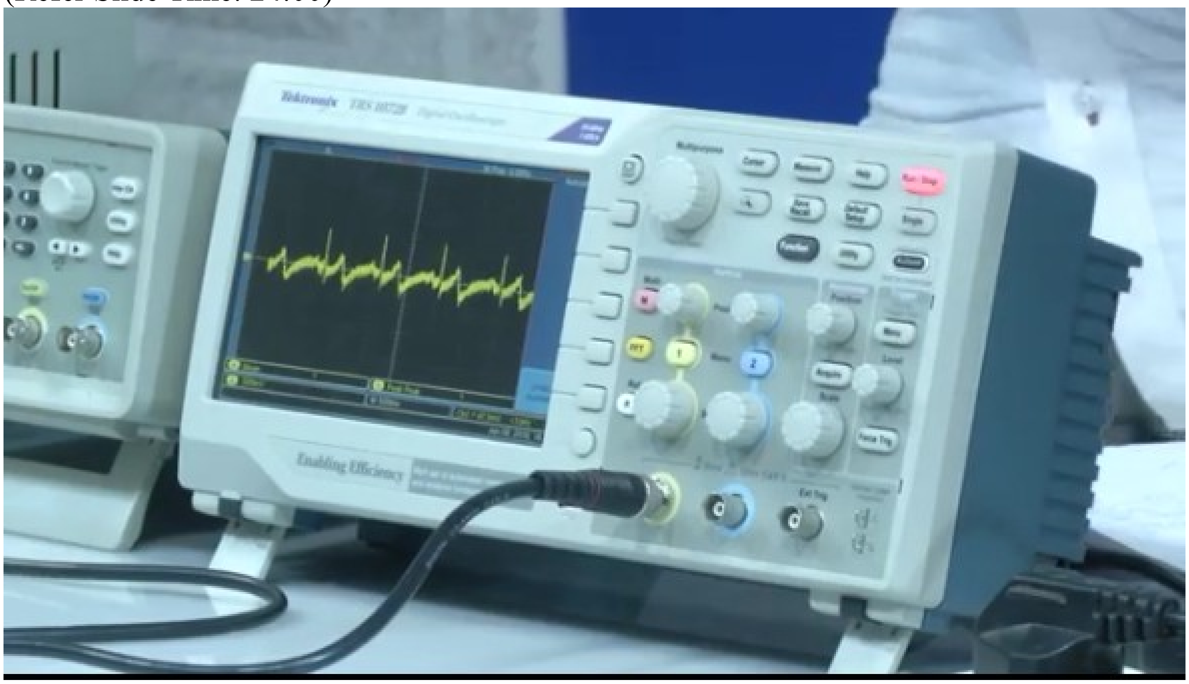

Why don't I see in frequency domain? So in order to understand that what I will do is that I'll take the cursor, I'll take 2 cursors, so one, so I need a time duration cursors, so one I'll connect it at one peak, so right now I'm at connected at this particular peak value, you can see that,

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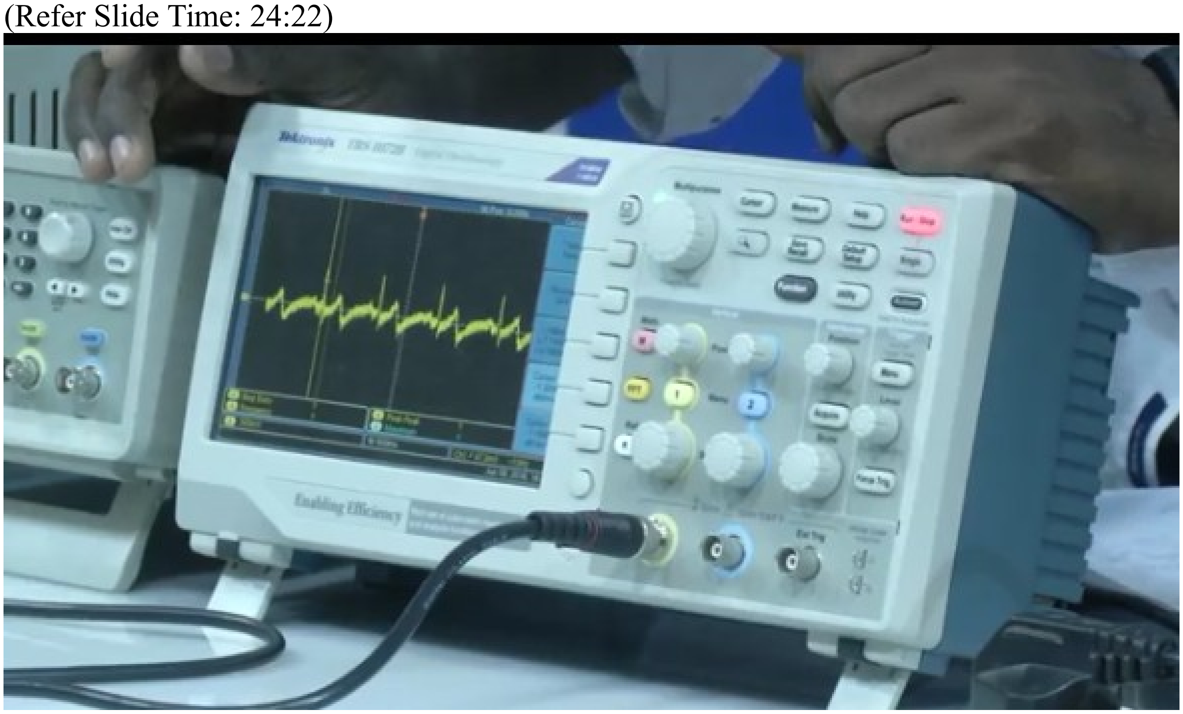

I’ll take one more cursor, cursor 2 and I’ll connect it another peak, right, so one I have connected at this peak, other one I have connected this peak,
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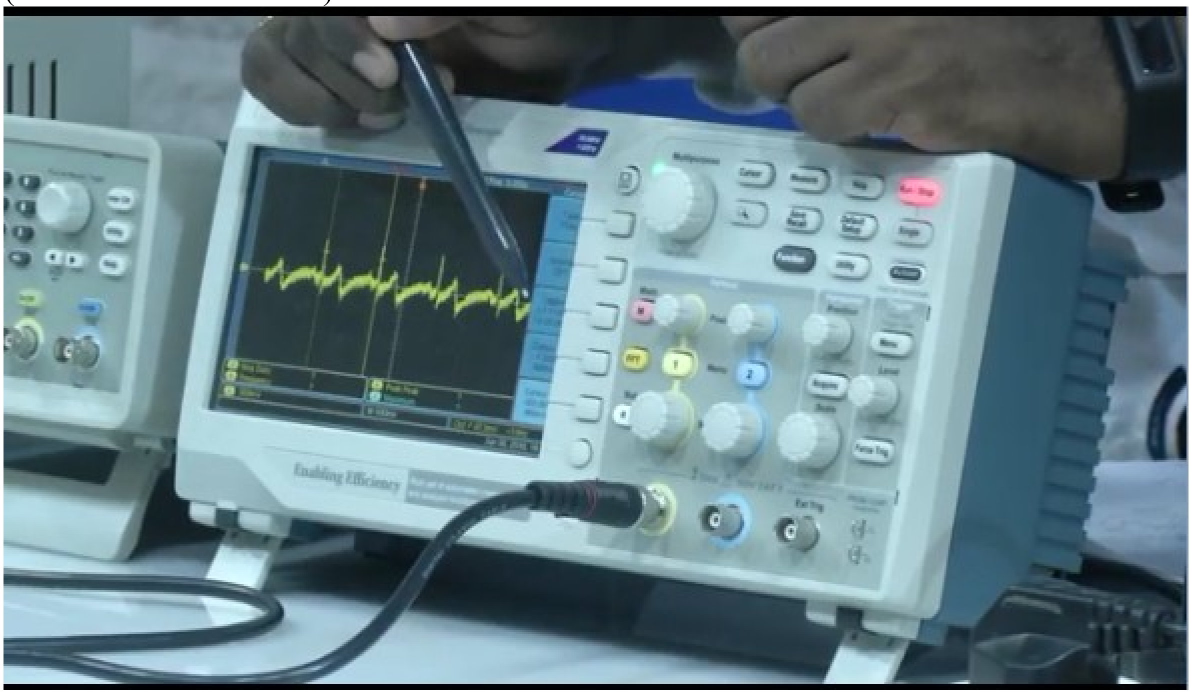

now when I see delta V, sorry delta frequency, so we are getting somewhere around 900 milliseconds, the time duration between the first signal to another signal is somewhere around 900 milliseconds, okay, which is cursor 1, source 1, cursor 1 okay, cursor 2 okay, now okay, I’ll take this two peaks one is this peak, good, then I’ll take cursor 1, I’ll take at this point, right,
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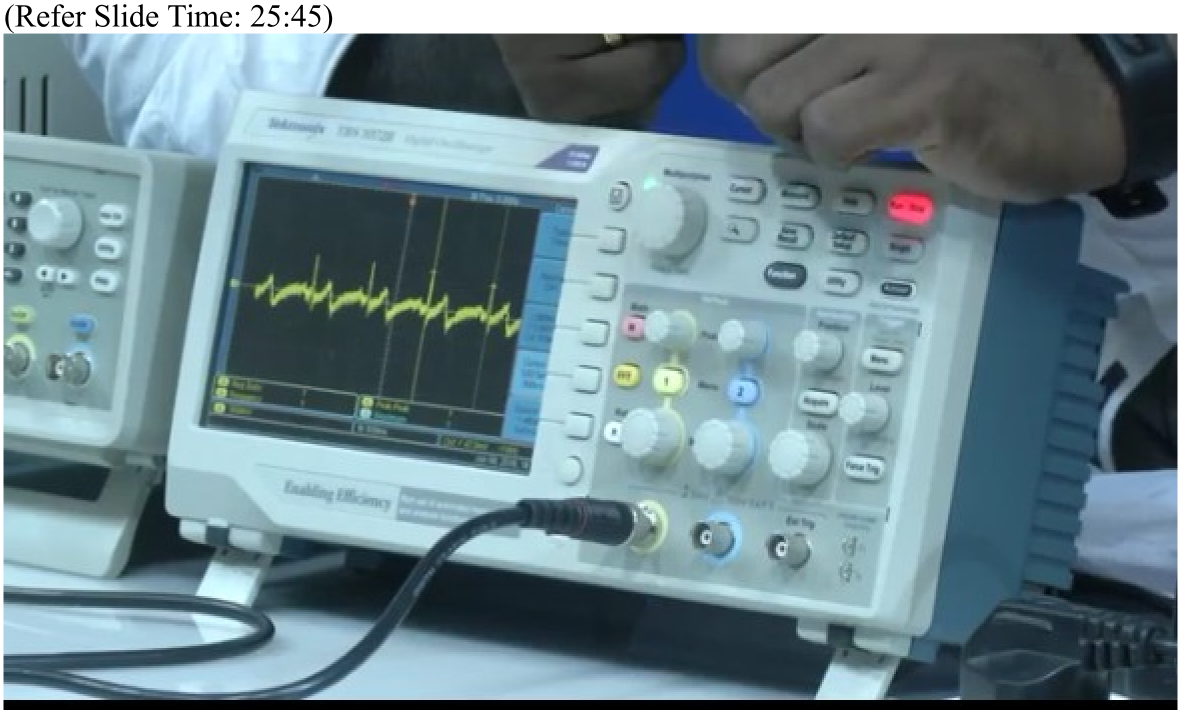

so when I see the time duration between this two peaks is 960 milliseconds, so when we calculate 1 divided 960 milliseconds it will be somewhere around 1H, so even here we can see the cursor somewhere around 1.042 hedges, so 1.042 hedges is approximately when we calculate it is 64, 1.02 or we can also say that since we know the frequency which is of 1.042 hedges I want to know the time duration of each thing, so it is of 900, right, the distance between both the things is 960 milliseconds, so I need for 60 second, how many number of 62, so when we calculate it we get somewhere around 62 pulses, 62 pulses in one minute, right.

So even you can do the digitally the logic that we have seen or even we can calculate with our thing, so but the whole idea is that by using our analog circuitry we can even acquire the ECG signal, we can even do the signal conditioning and the processing to some extent, of course we can also make it very pure signal, but we require the complexity of the system will be too huge, so in order to build first order and second order system we will be taking so many resistors, capacitors as well as you know op-amps, if you go with an higher order filters more number of op-amps and more number of circuitry so that to have a better role of we have to always go with an higher order filters, so that the results will be really good, right, so in this way we can see that the acquisition as well as condition of a signal, so we will stop at this point, I hope it is clear and thank you very much.