Op-Amp Practical Applications: Design, Simulation and Implementation

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Lecture - 37
Experiment on EGG Signal Acquistion, Conditioning and Processing of PQRS wave to Compute BPM using Op-Amps

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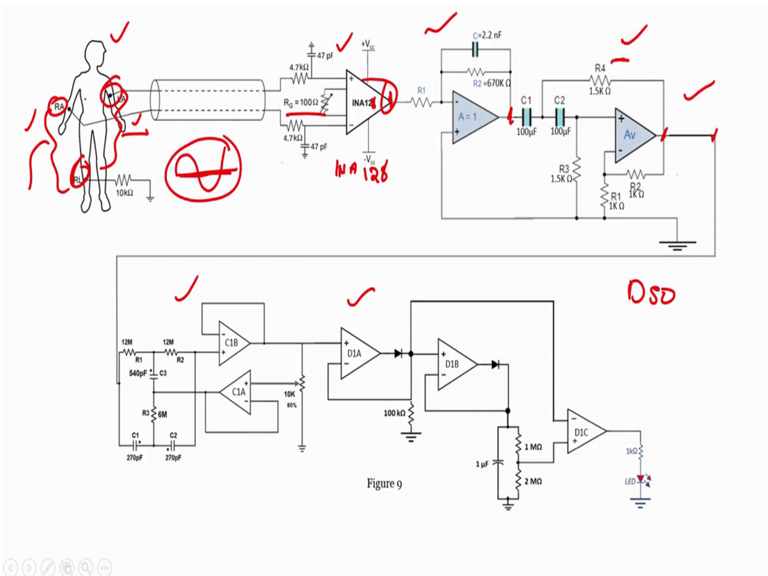

Till now we have seen the subsystem level of each and every the designed part. Now, what you are going to see is that once we interface, once we interface and connector electrodes to the specific person to acquire our ECG signal how the processing will be done? Right, everything we will see. Now, you will compare the signals the output at you know this point as well as at this point right we will see how accurate, how good the ECG signals that we get at this 2 outputs too as well as at this point 2.

So, in order to acquire a signal from the person or from the subject the thing is that we have to connect 3 different electrodes. If you recall you told that 1 electron 1 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 the this particular source as well as this particular source will be almost equal to the same. That is a reason we required to have a higher CMRR operational amplifier. And since we have to do the difference between the 2 voltage sources we required to use some difference between the outputs.

So, in order to perform in order to perform the difference either we have to go with the differential amplifier or we will be going with an instrumentation 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 of common mode signal and we required to have a higher CMRR value.

So, differential amplifier will always you know effect from CMRR that is one thing and the input impedance of our instrumentation amplifier is higher compared to the difference amplifier. So, that is a reason we will be going with instrumentation amplifier, but the instrumentation amplifier that I am using here is INA 128.

So, you can look into the data sheet in order to understand the detail architecture detailed specifications of the instrumentation amplifier of INA 128. So, that even you will get 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.

Now, when we see the output at this particular point since it is not a processes signal only the amplification state that we have done. We can see rye ECG amplified version of ECG signal, but, as you if you recall our the discussion. So, initially we have discussed as well as professor discuss in the class that the rye ECG signal will always prone to lot of interference due to so, many noise due to other signals.

So, those are nothing, but a power line interference, baseline wandering right, motion artefacts all those things will be observed at this point right. So, we will try to see you know the effect of the baseline wandering the system so, if we recall.

So, the baseline and wandering is nothing, but the signal will be always wandering with respect to this baseline right this is due to because of the respiratory. So, during the respiration of our breath because of that it create some kind of a noise into the system. So, that will be somewhere around lesser than 0.5 hertz. 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 wandering.

And even motion artefact will also be in the same range so, completely will be eliminated when we pass through this particular system in a pass through this particular system. Then we also have some odd multiples of our power line interference so, which is greater than 100 Hz. So, by using a low pass filter we are completely eliminating it or notch filter to remove are 58 signal.

And we will also see since we also seem in a practical as well as theoretically as well as 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 verifications.

Since, we are using DSO digital signal oscilloscope since what are the signal or nothing, but will be stored in terms of our digital outputs. Even by using DSO at this particular point we can easily analyse the BPM of the subject that we are conducting it and subject that we are connecting to the input of our amplifier. Now, now we will try to see.

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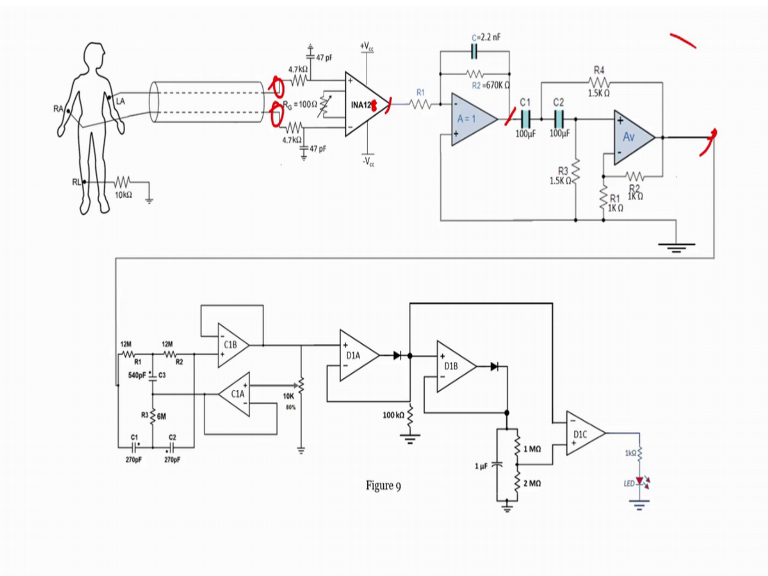

Figure 9

The outputs at each and every point so, starting from the output at instrumentation amplifier, at this point then connecting the output of the instrumentation 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. And we will see how much difference in the amplified version as well as the elimination of a noise in the preprocessing stage. Everything we can observe at this point 2.

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 electrodes which are available in the market. So, these are let me take out the ECG patch electrodes. So, these are our ECG patch electrodes.

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So, these are our ECG patch electrodes, if you see that right. So, this is ECG patch electrodes will have a metal contact on top of it and these are not reusable, use and through. Once we use it we have 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 references are the right leg. So, when we see we have already connected.

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You have already connected to the person. So, one we have connected to the right arm, other one we have connected to the left arm. So, it has stickiness inside as well as silica gel to. So, here the back side we can see the silica gel is to just to remove the impedance to decrease the impedance value and this is the at right leg position. So, this access our reference right.

Now, we will take ECG connectors some using some ECG connectors. So, these are our ECG connectors sorry right. So, 3 ECG connectors we have taking it. So, what I will do is that one I will connect it to the reference point I will connect it to the leg. Whereas, one I will connect to the right one, other one I will connected to the left arm.

So, I just made the connections, even in the circuitry. So, at this point one we will connected to the positive terminal right, other one connected to the negative terminal. So, when it comes to the breadboard when you see the breadboard.

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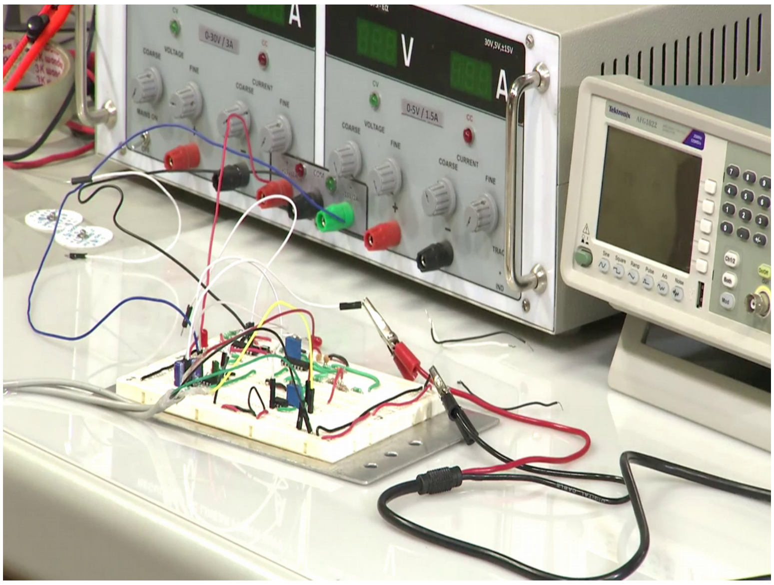

So, what I have done is the outputs of the ECG signal right through the leads connected to the inputs of both, here the inputs of the both instrumentation amplifier. And this particular blue colour trimmer pot which is of 200 ohms pot we are using and set it at 100 ohms. So, that the gain will be as per the data sheet we can calculate the gain of the system based upon the resistance that we have used, somewhere around 500 to 100 1000 gain we are using it.

So, let me switch on the power supply and we will see what how exactly the signal will look like. So, what I will do is that I will connect. So, since our interest is to see the signal at the output of an instrumentation amplifier. So, I will connect the output only to the instrumentation amplifier and remaining connections I will remove. So, I am connecting it to the output of instrumentation amplifier.

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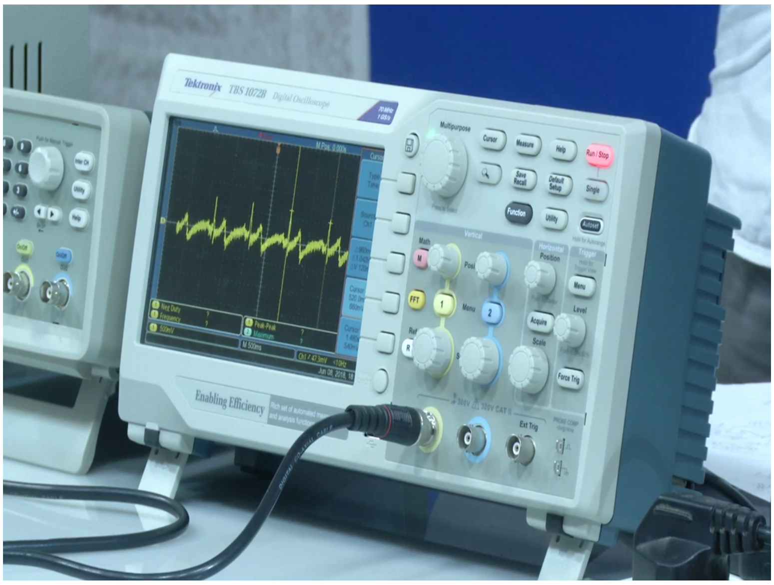

Now, when I look into the oscilloscope how the exact signal will be? We can see some signal we are getting it, but there is some offset. So, here we can see this is a ground point, but there is some offset right. And when I increase the time duration, time scale we can even see some kind of wandering right.

So, observe started increasing the value again starts decreasing, again it starts increasing so, like that it is a wandering. So, this may not be clear in this way, but if I connected to the low pass filter. So, what I will do is that the output of the amplifier I will connected to the low pass filter. It is a low pass filter and the output of the low pass filter will be connected to the oscilloscope.

Now, when I see the signal in the function in our oscilloscope right, there is some shift from positive to negative. Now, what I will do is that just let me auto scale once right and let me zoom I am I will change the time duration to somewhere around 10 seconds right.

So, we can see the wandering, we can clearly observe. So, some part of the noise has been completely filtered when we pass through the low pass filter. So, what I will do is that I will change slightly shift the signal to down little bit down. And I will increase the time duration, right now one box is completely 1 volt I will change to 500 for the increase of amplitude, keep it down.

So, suppose if I zoom it, time duration of increase one thing it is clear that we are getting some peaks and the pattern is also look similar to that of your ECG, isn't it? See here the q r s, q r s, q r s, q r s and p, q, r, s somewhere here t and u. So, t and u is very have to do visualize using this particular the patch electrodes.

But, if you have rather than 3, 3 lead electrodes, if you go with a 12 lead electrodes even that signal it is you know, it is the pattern will be easy to recognise using that particular polydisperse. But, we have some offset as well as we also have some kind of wandering in the signal. So, in order to understand the wandering.

So, I change the time duration to somewhere around 50 seconds. So, high so, I will take to 25 seconds. So, in order to finish 1 box it takes 25 seconds. So, 50 seconds to 2 boxes, 75 seconds, approximately 1 minute to 2 minutes of a 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, we can see some time it is at the peak, sometime at the negative right this is because of our respiration rate or even because of our motion artefacts to.

So, basically because of the respiration while taking the recording this create 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 base line.

Now, what I will do that in order to even remove that as well as the motion artefacts when you are moving there will be always noise generated into our system to. So, if we want to remove everything what we have to do is that we have to pass through the high pass filter to.

So, now I will connect the output of the low pass filter to the high pass filter. So, I remove this connection connected to the high pass filter, then the output so, output pin is somewhere around first pin here. So, this is our output I am 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.

So, to see that what I will do is that first I will auto set it and I will change the right I will change my time duration time scale to somewhere around the 1 second or 2 seconds. And the box the box the amplitude see the high pass filter whatever we designed have the peak the gain of 2. So, that is a reason we can see the amplitude signal. So, I will put it somewhere around 1 volt or 500 milli then right.

So, when we look into the signal it is a continuously recording it, when you look into the signal. So, we have different peaks right. So, here it is easy to understand q r s peak very easily q r s, q r s and the amplitude of the q r s is more compared to the other peaks, isn’t it? Right, when we observe it is clear that the q r s peaks it is easy to visualise using our system right clear.

Now, how do you understand our BPM in this? So, if you want to understand I have to calculate how many number of such peaks we are getting per particular time duration. So, to said that what I will do is that since it is a digital oscilloscope we can easily visualise 1 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 the how many number of peaks that we are getting that is way. Another way is if you put a cursor, if a find the frequency between 1 peak to the other peak. So, if I know the time duration 1 divided by time duration and automatic you get the frequency that gives me the what rate that peaks are even obtaining.

So, what I will do is that either 2 both ways we can go ahead. So, first thing I will see what is a box that I have set so, let me change it to one second I have set it to 2.5 seconds. So, that is 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 will do is that I will change I will change duration to 1 second right.

So, here we can easily so, 1 box is 1 second and total we have total 9 boxes 1, 2, 3, 4, 5, 6, 7, 8, 9. 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 let me run for one more time and I will stop it, I am 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 seconds scale, 9 heads 60. So, the frequency is somewhere 60. So, if I want to find out accurately what we can also do is that rather than taking to 1 second I will take it as 2.5 seconds let me see it. So total 9 boxes, 2.5 into 9 so, 2.5 into 9 is 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 into 29 24 sorry 60 into whatever how many number 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 20 64 BPM which is the normal rate sorry 64 BPM which is also a normal rate.

So, now it is clear that when we pass the 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 filtered output which was removed by our high pass as well as low pass filtering.

So, once we connect the signals to other stages even we can see you know the peak detection as you 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 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 the high peaks to. Since, the frequency is really higher it is very hard to visualise with our LED that we have connected then in the circuit board, but, once if it is like if we connect it to the CRO we even we can see the pulses to. But, since we already have oscilloscope here rather than doing all the analogue. Since, we have also shown how the working of the operational amplifier in theoretical and the subsystem level as well as then practical session, why do not we take, why do not we understand how digitally we can do it.

So, in order to understand how digitally we do it generally we will take a microprocessor and microcontroller. So, we will connect in the same way we required to have an application as well as either we can go with the digital filtering or our analogue filtering the way that we uses it. Once the pre processing and amplification stage amplification pre processing stage is then 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 will 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 we recall what we have discussed when we are designing our sub system first step is to find out the peak value.

How do we calculate the peak value? So, I will 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 value 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 though that and by using a capacitor I can charge it to the peak value right. So, whichever the voltage that we are getting Q R S peak amplitude that we are getting by passing through the capacitor even I can pass it. After passing it by using a resistor I set a threshold.

Now, when we set a threshold right the way that we have calculated frequency right, we can see how many signals, how many peaks that we are 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 it manually why do not I see in frequency domain. So, in order to understand that what I will do is that I will take a cursor, I will take 2 cursors so, one so, I need the time duration cursors.

So, one I will connected at 1 peak so, right now I am at connected at this particular peak value you can see that I will take one more cursor, cursor 2 and I will connect at another peak right. So, one I have connected at this peak other one I have connected at this peak. Now, when I see delta V sorry delta frequency.

So, we are getting somewhere around 900 milli seconds. The time duration between the first signal to another signal is somewhere around 900 milli second which is cursor 1, source 1 cursor 1 cursor 2. No, I will take these 2 peaks, 1 is this peak good then I will take cursor 1 I will take at this point right.

So, when I see the time duration between these two peaks is 960 milliseconds. So, when we calculate 1 divided by 960 milliseconds will be somewhere around 1 hertz. So, I even here we can see in the cursor somewhere around 1.042 Hertz's. So, 1.042 Hertz's 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 Hertz's 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 seconds, how many number of 62? So, when we calculate it we get somewhere around 62 pulses in 1 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 analogue circuitry we can even acquired 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 to use.

So, in order excuse me 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 filter 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.