Electronic Systems for Cancer Diagnosis
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Lecture – 43
Experiment on Op-amp based ECG Signal Acquisition, Conditioning and Processing for Computing BPM

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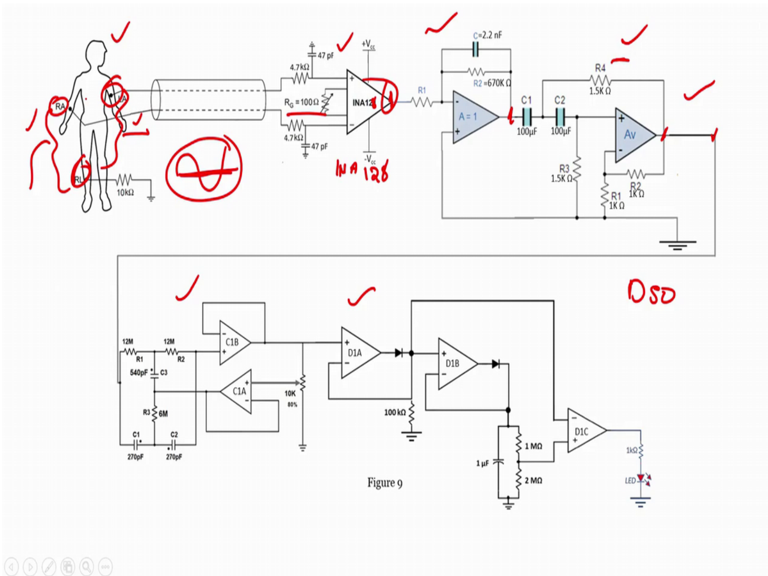

Till now, we have seen the subsystem level of each and every the designed part. Now, what you are going to see is that once we interface; once we interface and connector electrodes to the specific person to acquire our ECG signal, how the processing will be done right; everything we will see. Now, we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

So, in order to acquire the signal from the person or from the subject, the thing is that we have to connect 3 different electrodes. If we 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 a 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 require 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 a 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 differential 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 detailed 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 process signal, only the amplification says that we have done. We can see ECG amplified version of ECG signal.

But, as you if you recall our the discussion. So, initially we have discuss as well as professor discuss in the class that the RA 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, base line wandering right, motion artifacts; all those things will be observe at this point right.

So, we will try to see you know the effect of the base line wandering in the system. So, if you recall, so the base line and wandering is nothing but the signal will be always wandering with respect to this base line 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 a high pass filter. So, after passing through the high pass filter, so we can see the complete removal of our base line wandering and even motion artifacts will also be in the same range. So, completely will be eliminated when we pass through this particular system, when you pass through this particular system; then, we also have some odd multiples of our power line interference. So, which is greater than 100 Hertz's. So, by using our low pass filter, we are completely eliminating it and notch filter to remove our fifty hertz signal and we will also see since we have also seen the in the practical as well as theoretically as well as the 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, since the what are 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 and subject that we are connecting to the input of our amplifier. Now, we will try to see 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 too. So, in order to connect the electronic circuit to the subject, we require to have some electrodes.

So, we are going to use some ECG patch electrode 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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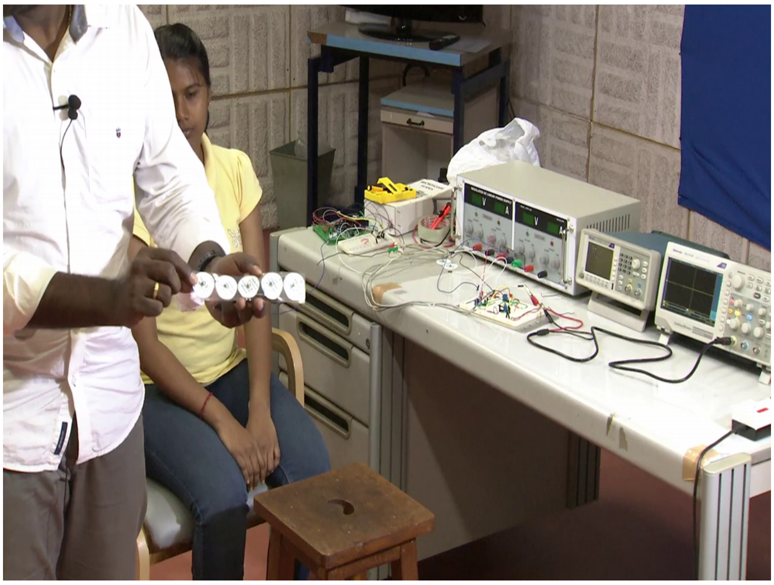

So, these are our ECG patch electrodes if you see that right. So, this is ECG patch electrodes will have a metal contact on top of it and these are not reusable; use and throw. Once we use it, we have to throw it out; disposable ECG electrodes. So, we will be placing one at right arm; one at left arm; other one at right leg because the references are right leg.

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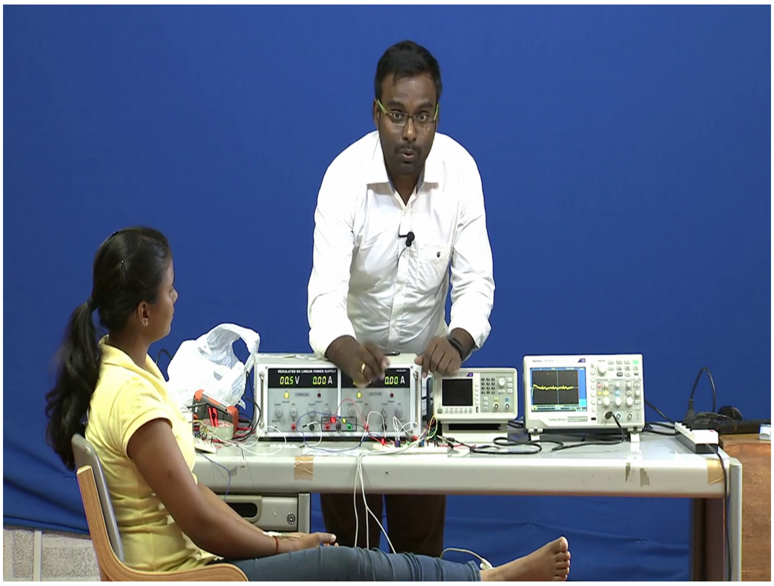

So, when we see we have already connected; we have already connected to the person. So, one we have connected to the right arm other one we have connected to the left arm.

So, it has a stickiness inside as well as silica gel too. So, here at 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 connected to the reference point, I will connected to the leg; whereas, one I will connected 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.

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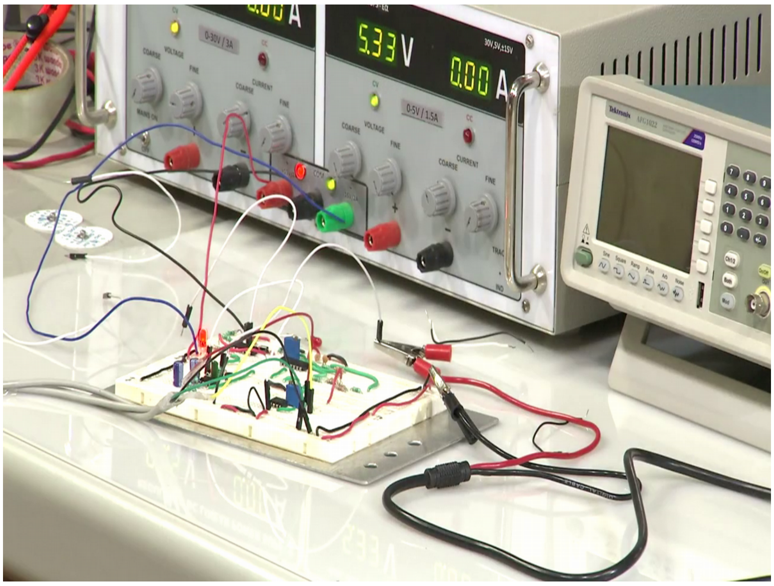

So, when it comes to the breadboard when you see the breadboard. So, what I have done is the outputs of the ECG signal right through the leads connected to the inputs of both. Here, the inputs of the both instrumentation amplifier and this particular blue colour trimmer part which is of 200 Ohm’s part we are using and set it at 100 Ohm’s. So, that the gain, the gain will be as per the data sheet you can calculate the gain of the system based upon the resistant that we have use 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 we 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.

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 and when I increase the time duration, time scale; we can even see some kind of wandering right. It is observed, it started increasing the value again starts decreasing, again starts increasing.

So, like that it is a wandering. So, it is 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. 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 the function in our oscilloscope right, there is some ship 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 of. 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 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 look similar to that of your ECG; is not it? See here; the QRS QRS, QRS, QRS and P-QRS somewhere around here T and U. So, T and U is very hard to do visualize using this particular the patch electrodes. But if you have rather than 3D electrodes if we go with at one lead electrodes even that signal. It is you know it is the pattern will be easy to recognize using that particular to a leader.

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 high change the time duration to somewhere around 50 seconds; it is too 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 weight, 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 some time it is at the peak, some time at the negative right. This is because of our respiration rate or even because of our notion artifacts too.

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 baseline. Now, what I will do is that in order to even remove that as well as a motion artifacts, when you are moving there will be always noise generated into our system too.

So, if I want to remove everything what we have to do is that? We have to pass through the high pass filter too. So, now, I will connect the output of the low pass filter to the high pass filter. So, I will 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 the time duration, time scale to somewhere around the 1 second or 2 seconds and the box length the amplitude see the high pass filter whatever we design have 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 QRS peak very easily. QRS and the amplitude of the QRS is more compared to the other peaks; is not it right. When we observe it is clear that the QRS peaks, 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 said 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, I automatically get the frequency. That gives me that what rate that peaks are even obtaining.

So, what I will do is that either 2 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 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 ok. Let me run for one more time and I will stop it, I am stopping at this point.

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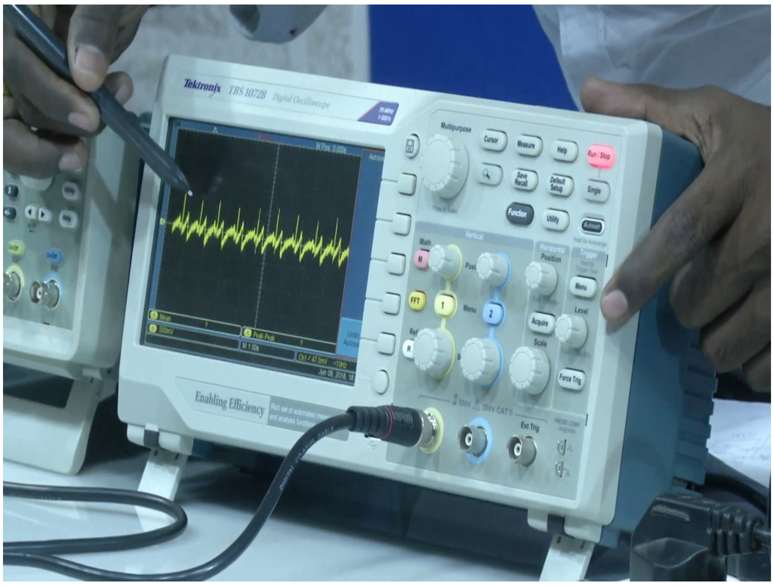

Now, if I calculate 1 2 3 4 5 6 7 8 9. So, 9 peaks 9 Hertz; 9 peaks and for 9 seconds. So, we have a total of 9 second scale 9 Hertz 60. So, the frequency somewhere around 360. So, if I want to find out accurately what we can also do is that rather than taking to 1 second I will take it as 2.5 seconds. Let me see. So, total 9 boxes; 2.5 into 9, so, 2.5 into 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 into 29 24 sorry 60 into whatever how many number of peaks 1 2 3 4 5 6 7 8 9 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 preprocessing stage, our filtering and everything, we have seen very pure you know like meaning we have seen the signals which are you know filtered, 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 an 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 it threshold using our you know resistor divider circuits. Then, since we also have the comparator, it will compare and gives the high peaks too.

Since, the frequency is really higher, it is very hard to visualize with our LED that we have connected; then, in the circuit board, but once if it is like if we connected to the CRO, we even we can see the pulses too. But since we already have oscilloscope here rather than doing all the analogue, we since we have also shown how the working of the operational amplifiers in theoretical and the subsystem level as well as an practical session. Why do not we take; why do not we understand how digitally we can do it? So, in order to understand how the digitally we do it, generally we will take a microprocessor and microcontroller.

So, we will connect in the same way we require to have an application as well as either we can go with the digital filtering or our a analogue filtering the way that we use that. Once the pre processing and amplification stage, amplification preprocessing 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 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 you recall, what we have discussed when we are designing our subsystem. First step to find out the peak value. How do you 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. 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 entrance was only towards our pass two side, I can pass through you know rectifier circuit or half wave rectifier circuit. So, that only the peak signals of the 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 you know 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 of 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 oh sorry we can calculate in manually. Why do not I see; 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 time duration cursors. So, one I will connected a one 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 connected 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; 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.

Now, what I said 360 ok, I will take this two peaks; one is this peak good, then I will take cursor one. I will take at this point all right. So, when I see the time duration between this two peaks is 960 milliseconds. So, when we calculate 1 divided by 960 milliseconds will be somewhere around 1 Hertz. So, even here we can see in the cursor somewhere around 1.042 Hertz. So, 1.042 Hertz 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, 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; I need for 60 seconds. How many number of? 62. So, when we calculate it we get somewhere around 62 the pulses; 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 think. So, but the whole idea is that by using our analogue 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 comp the complexity of the system will be 2 fuse. 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 we 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 within 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 ECG signal. So, we will stop at this point,

And thank you very much.