Electronic Systems for Cancer Diagnosis
Dr. Hardik J. Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture – 36
Basic building blocks of Electronic System: Signal Conditioning Circuits

Hi, welcome to this module and this module is continuation with the last module. In which we have seen what are the basic building blocks for signal conditioning circuits, right.

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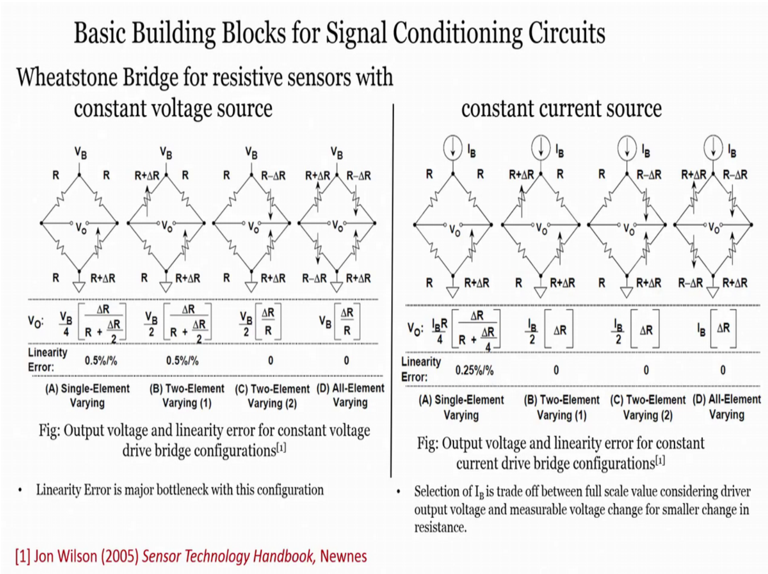

So, in last module what we have seen is how we can use Wheatstone bridge for resistive sensors with constant voltage source and constant current source. And what are different type of resistive sensors, that we can use and what a kind of elements we can vary either we can have a one variable resistor or we can have two; in a two different ways or we can have all four resistors in a varying condition right and we have seen the advantages of both.

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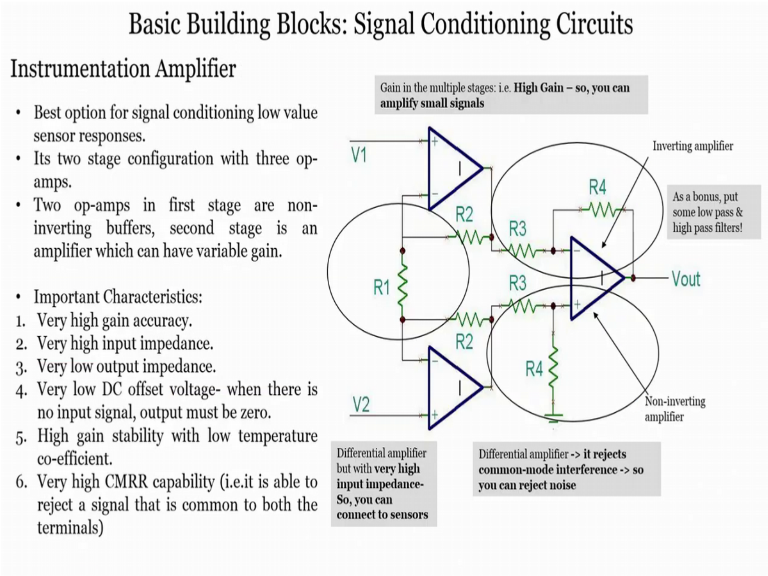

So, let us see a very important amplifier and that is used for lot of signal conditioning circuit and that is your instrumentation amplifier. Now, the instrument amplifier has several advantages, some of the important characteristics are it has a very high gain accuracy; extremely high input impedance, low output impedance, low DC offset voltage, when there is no signal, input output should be 0 right, and then high gain stability with low temperature co-efficient as well as it has extremely high CMRR.

Now you know, what is CMRR right, we have seen CMMR is given by ratio of CMRR is common mode rejection ratio is a Ad differential gain by common mode gain right, mode of Ad by A CM. The, we want A CM to be extremely low, we want a differential gain to be extremely high right. So, that we can faithfully replicate the signal and we can have the gain only from the difference of this signal, thus CMRR should be extremely high.

So, this particular instrument amplifier has advantage that, it has a very high CMRR ok. Now you can also understand that, what is advantage? So, that it can reject the common signals to both the terminals. So, this instrument amplifier is the best option for signal conditioning for low value, since the responses, it is two stage configuration with three operational amplifier you can see here right, one, two and three; there are three operational amplifiers that are used right and you can see further that this amplifier as well as this amplifier are nothing but the inverting buffers right. And non-inverting buffers because the signals are blind to the non terminal as you can see here and in this particular case. While the second stage is a amplifier which has a variable gain right; this is a amplifier with a variable gain, is nothing but a differential amplifier, is differential amplifier right.

Now, gain in multiple stage is that is high gain. So, you can amplify small signals that is the advantage, second is that as a bonus we can put some low pass and high pass filters. If you want to the differential amplifier, which is this amplifier here, it rejects common more interference; so, you can reject the noise, further the differential amplifier with very high input impedance so you can connect to the sensors right. We have seen the; if you know the little bit about operation amplifier in the loading effect, then you will understand and appreciate why we are using a very high input impedance amplifier sensor in the circuits.

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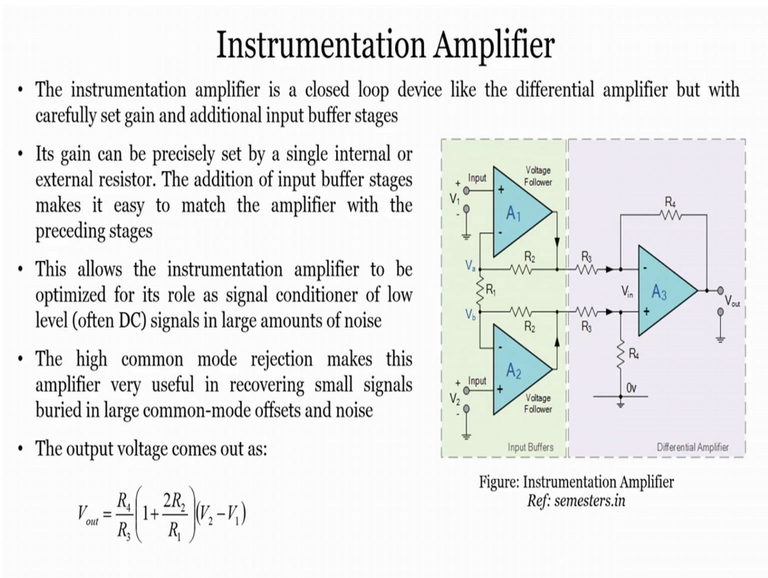

So, in continuing this particular amplifier, if we see further the instrument amplifier is a closed loop device like the differential amplifier, but with a carefully set gain and additional input buffer stages right. If you see this one, it is what? Differential amplifier; what is there what is the difference here that you have the buffer at the input and you also have the carefully set gain.

Now the gain can be precisely set by a single internal or external register right, and another thing is that the addition of input buffer stages makes it easy to match the amplifier with the preceding stages. If you want to match this amplifier, if you have the voltage for over here and here, then it is easy to connect the preceding stages, this is before this particular instrument amplifier circuit. So, you can easily connect sensors to it, you can easily connect (Refer Time: 04:45) circuits to it and so on and so forth.

The further, this allows instrumentation amplifier to be optimized for its role as a signal conditioner of a low level, that is often as a DC signals in large amount of noise, the high common mode rejection makes this amplifier very useful in recovering small signals, because most of the sensors that you use the output is generally extremely small and a small signals you need to catch it and you have to reject the common mode signals.

So, when you want to catch a small signals and you want to amplify it further, so, if the sensor is not is sensitive, but it is not that sensitive and it will show a enough change in resistance, if it is a resistive sensor then instrument amplifier can play a very important role because you can catch the small signal and amplify it further. And additional advantage of instrument amplifier over deficient wafer is that because there are two buffers the input, you can easily match with the preceding stage.

So, that things are comes as a handy when you are actually designing signal conditioning circuit. Further if you can see the voltage, the voltage is given by V out equals to R 4 by R 3 2 1 plus 2 R 2 by R 1 and the difference of the voltage V 2 and V 1, this is difference of signal at the input stages.

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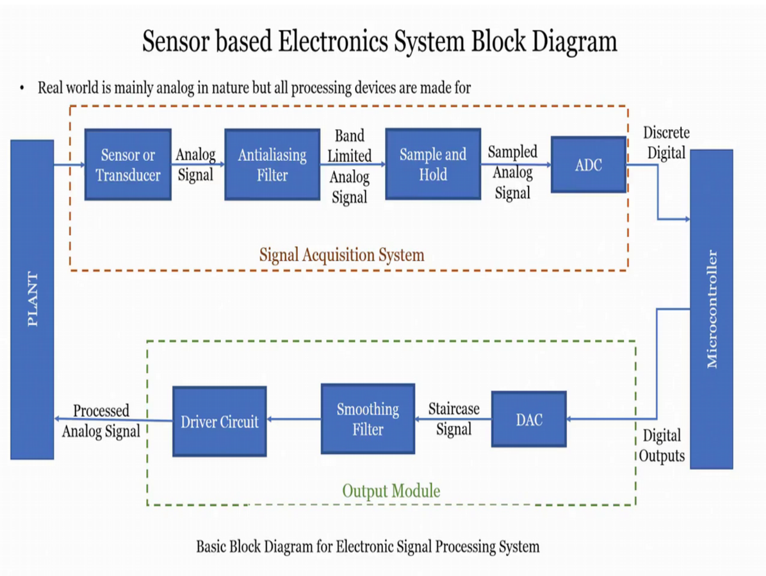

So, if I want to use now, let us take a few examples. Let us the first example is the sensor based electron system for real world; that means, if you have a if you have a plant right and you want to we want to control the it says a signal equation system as well as the feedback system you can see that the if it is contains a sensor or transducer right, and what exactly this does? It converts it to a discrete signal, and a discrete signal can be given back to proceed analog signals; say like a feedback system right.

So, suppose you want to measure a temperature or you want to measure the let us say the motor parameters. For example, if the motor is having too much vibration it is dying. So, that vibration can be uses important parameter to understand the lifetime of a motor. The temperature of the motor can also be used as a life time for understanding the lifetime of the motor. For example, if the temperature increases too much then you can say that there is fault in the system. Thus, if you want to have a feedback system in the real time, then you can use this kind of signal acquisition system with output module.

So, let us see that what kind of sensor. For example, if we take the temperature is one of the parameter right, then you have a thermistor and these; so, you can say here is a sensor or transducer say first block then what is the signal? It is analog signal. So, you need to have the filtering as antialiasing filter at the second block then you have a band limiter analog signal.

Now, you can use sample and hold circuit to convert the signal and then you can sample this signal into the ADC and then finally, with a discrete signal you can now control that mega-controller.

Now, depending on what is the temperature if you want to maintain right, you can switch off the plant or you can change the that particular parameter by giving a feedback. So now, the feedback is digital output; digital outputs are converted to analog domain there is a smoothening filter and then you have a driver circuit and so that to proceed the analog signal.

So now, what you are doing is in a way you are converting the analog signal to digital signal and feeding into controller and then taking the digital signal from the controller, and feeding it back to the plant; so, converting back to the analog. So, this is how the electronic model works when you take this signal acquisition and the output module.

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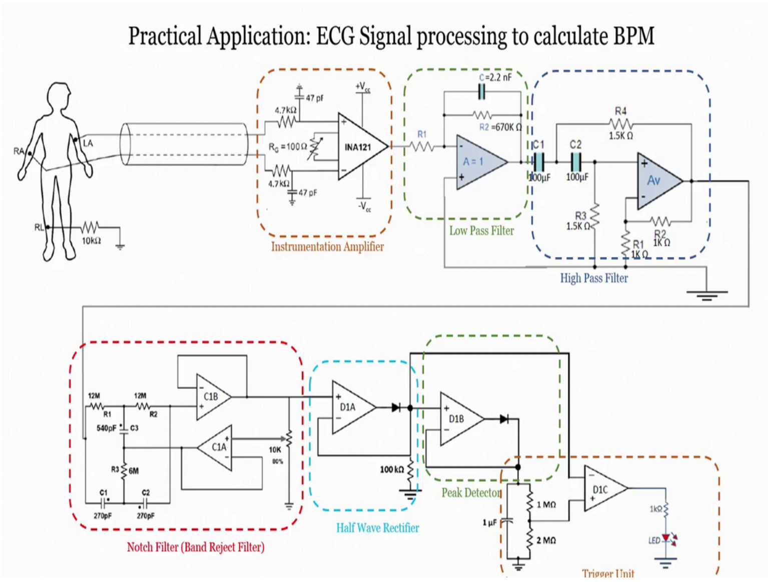

Now, let us see a very interesting example which is your ECG signal to calculate bits per minute ok. Now, why we are learning ECG? We are learning ECG because we want to understand that for functioning of the heart right. So, the point is how can we design a signal conditioning circuit for measuring this ECG signal, one of course is the bits per minute, what is the heart rate right.

So for doing that; what we have to learn? We have to learn instrumental amplifier, we want to learn high pass filter, low pass filter, we want to learn the notch filter, we to learn the halfway rectifier, we have to understand what the triggering unit and then bringing all together we can understand, how the signal conditioning circuit for a ECG would work ok.

So, let us see each circuit in detail and then we will talk about the and how to bring all the circuit together to form the entire signal conditioning circuit. Let us see, how to develop a electronic module for designing or for measuring the ECG signal. Now, ECG we know is used for monitoring the health of the heart. So, how whether heart is working properly or not; so, ECG is one of the extremely useful signal to understand the functioning of heart.

Now, when you are talking about functioning of heart, we are also talking about the how many bits per minute the heart is pumping right. So, to understand or to develop such a module we need to understand, how can we now use, what we have learned in the previous module different amplifiers, different filters right, half way rectifier and a triggering circuit, so as to integrate all those components together and form a signal conditioning circuit for the ECG.

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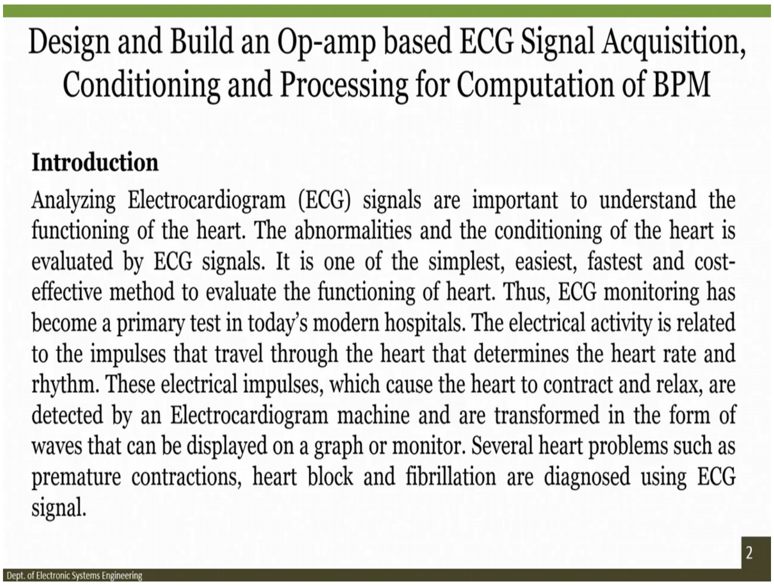

So, let us see the first point and that is the how to design the, this particular system. So the first thing, let us understand the introduction and introduction about ECG is Analyzing Electrocardiogram which is also called ECG is not an important to understand the functioning of the heart, but also to understand the abnormalities and the conditioning of the heart is evaluated using ECG signal.

Now, the it is one of the simplest, fastest, easiest, cost effective method to evaluate the functioning of the heart and thus, ECG monitoring has become a primary test in today's modern hospitals.

The electrical activity is related to the impulses that travel to the heart and that determines the heart rate and the rhythm right. So, this is important point for us because we want to understand how can we measure this electrical activity. And these electrical impulses, causes the heart to contact and relax are detected by nothing but the ECG machine and are transform into form of the waves that can be displayed on a graph or a monitor right. So, several heart problems such as premature contractions, heart block, and fibrillation are diagnosed using ECG signal.

We will understand, what exactly fibrillation means, what is the difference been in a different kind of fibrillation, we will in particularly focus on atrial fibrillation and a sensors that can help to make the (Refer Time: 11:54) smarter for performing the ablation. So, we will talk about this particular heart disease at the end of this module, but first let us understand that how can we design this signal conditioning circuit.

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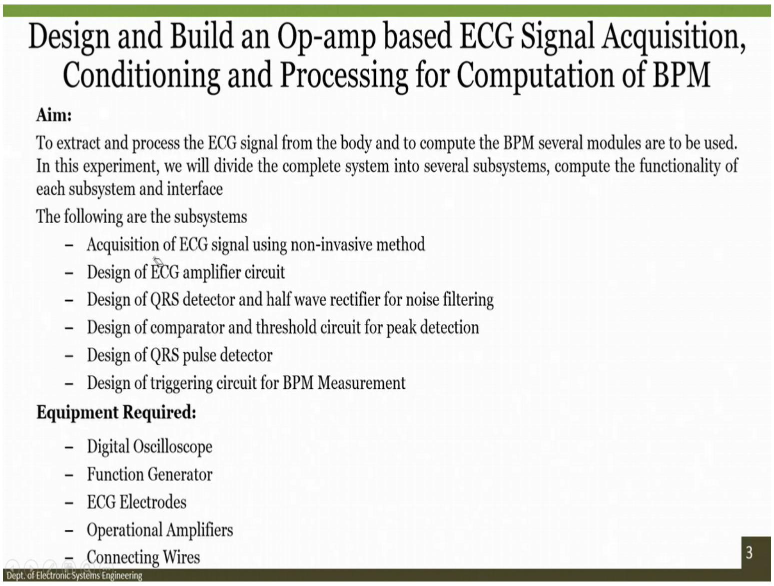

So, the aim of this particular experiment you can say because why I am saying experiment, because we will also see in reality, how can we design electronic conditioning system which is consisting of acquisition, conditioning and processing in the real time ok. So, we will see as a part of the experiment. So, let us see the aim. Aim is to extract and process the ECG signal from the body and to compute BPM several modules are to be used. In this experiment, we will divide the complete system into several sub system, compute the functionality of each system. So, the following are the subsystems, so, first one is the acquisition of ECG signals using non-invasive method right; this is the first one that we need we will see.

The second system that we will see is, how to design a ECG amplifier circuit, the third system that we will look at is the designing of QRS and half wave rectifier for noise filtering, and then we will go for how to understand; how to design a comparator and threshold circuit for P detection, followed by QRS pulse detector, followed by triggering circuit for BPM measurement. And then the equipment that we require to understand this

ECG signals in the laboratory would be a digital oscilloscope functional related, we require the ECG electrodes and operation amplifiers as well as connecting wires right.

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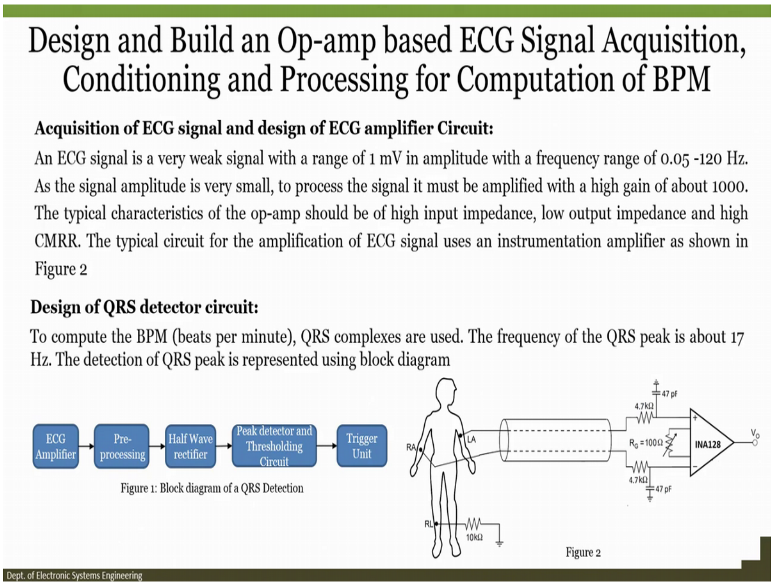

So, let us see the first one; and the first one would be acquisition of ECG signals and design of the ECG amplifier circuit. So, here you can see that an ECG signal is a very weak signal with a range of just 1 milli volt in amplitude with a frequency range of 0.05 to 120 Hertz right. So, this is a very important point for us because we have to amplify this signal which is extremely low. As a signal amplitude is very small to process a signal it must be amplified with a high gain of about 1000 right.

The typical characteristics of the op-amp should be high input impedance, low output impedance, high CMRR; we know that these are kind of idle characteristics. They are infinite input impedance, 0 output impedance and extremely high infinite CMRR, but the practical op-amps would have high input impedance, low output impedance and high CMRR. So, the typical circuit for the amplification of ECG signals uses instrument amplifier which is shown in figure 2, this is the typical circuit ok.

We will see in detail how it is done; for now, let us understand the block diagram of the QRS detection. So, for a QRS detection we have to understand that we have the ECG amplifier which will be followed by pre-processing and then half a rectifier, pre detector and finally the trigger unit right. So, these are the steps in the case of the QRS detection ok.

Then, we will move further and further is that, we had to design a QRS detector circuit. So, to compute bits per minute QRS complexes are used the frequency of QRS is about 17 Hertz, the detection of QRS is depended using the block diagram which we have just discussed.

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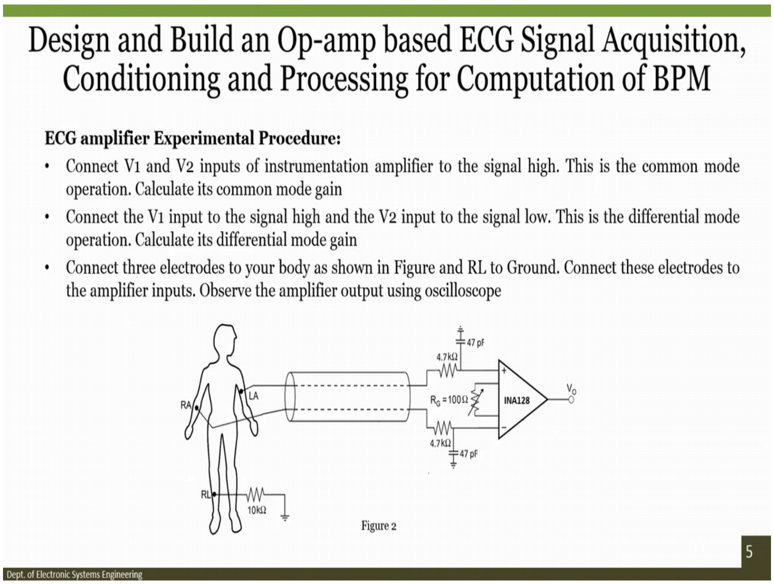

So let us now see, how can we developed ECG amplifier for the QRS signals as well as the BPM. So the first one is, you have to connect the V 1 and V 2 which is the inputs to the instrument amplifier to the signal high, this is the common node common mode operation and we had to calculate its common mode gain. The second process is we have to connect to V 1 to the input signal high and V 2 to the signal low, so that this is a differential mode operation and you calculate the differential mode gain.

Finally, we connect all three electrodes to the body as shown here RA, LA and RL to the and we can see that RL is connected to the ground through 10 kilo ohm resistor and then connect these electrodes to amplifier inputs and observe the amplifier output at the oscilloscope.

Now, whatever I am saying it will become little bit difficult for you to understand directly, but when we go for the experiment then we will understand in detail how this is done in reality.

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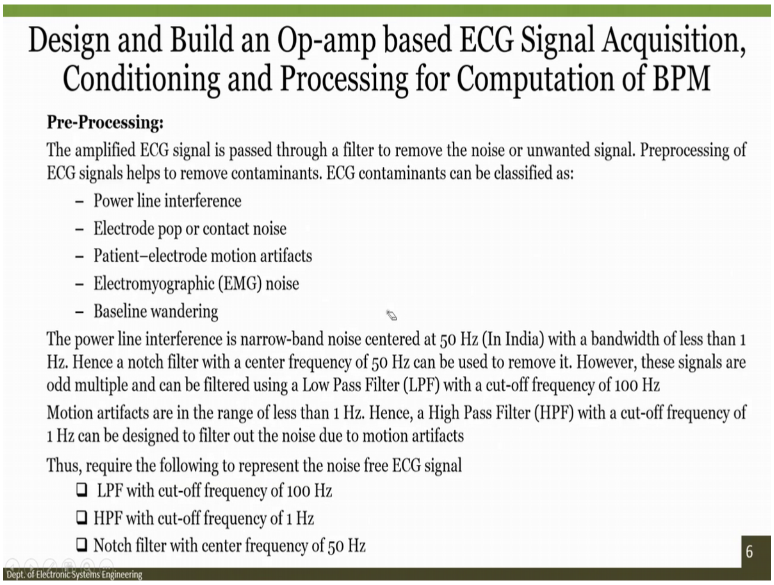

So, the pre-processing which is a important part. How we are performing that experiments or how we are developing the system for the pre processing? The amplifier is a signal is processed through a filter to remove the noise or unwanted signal. A pre-processing of ECG signals helps to remove contaminants all right; so, we had to pre process the signal before for the next stage.

So, and then ECG console; so, what actually contaminants in ECG signals are? The contaminants in ECG signals are that we have electrode pop or contact noise, we also have baseline wandering, we have EMG noise where which is also called electromyograph, and then we have patient electrode motion artifacts right because if you connect the electrodes, the patient is moving then there is a motion artifact, we have to take care of that right.

We had to take out the EMG, EMG comes from the muscles right; the signal coming from the muscle. If I moving my muscles, then there is a signal that is generated on the muscles which can be measured with the help of electromyograph, ok. And then we have power line interference that is a extra thing that will come into effect, we have contact noise, we have electrode pop. So, all these things will contribute in the contaminants for measuring the during the measurement of the ECG signal right.

So now for our country the power line noise comes is a narrowband noise around 50 Hertz and with a bandwidth of less than 1 Hertz. So, we can use a notch filter at a frequency of 50 Hertz right. Then you have seen different filters and in this the notch filter; if you can design for 50 Hertz you know right, what is notch filter, it is a band reject filter. Now, if it is just single frequency it looks like a notch that is why we say notch filter; so, if we can design a noise filter for 50 Hertz frequency then the power line interference will be taken care of.

So, let us see here what I was saying is that there are several contaminants we have just seen 1, 2, 3, 4 and 5 and then the power lines interference in narrowband noise around 50 Hertz, we have talked about it, notch filter we can develop a center of 50 hertz. However, these signals are on multiple and can be filter using a low pass filter with a cut off frequency of about 100 Hertz right. Since these are the odd multiple we can use the cutoff frequency 100 Hertz and see this is below 100 Hertz, we can use a low pass filter. The motion artifacts which are the another contaminants and the range of less than 1 Hertz hence, high pass filter the cutoff frequency of 1 Hertz can be designed to filter out the noise due to motion artifacts. So, what we require? We require a low pass filter with cutoff frequency of 100 Hertz, we require high pass filter with a cut off frequency of 1 Hertz and finally, we require or notch filter with the center frequency of 50 Hertz. So, these are the requirements for pre-processing.

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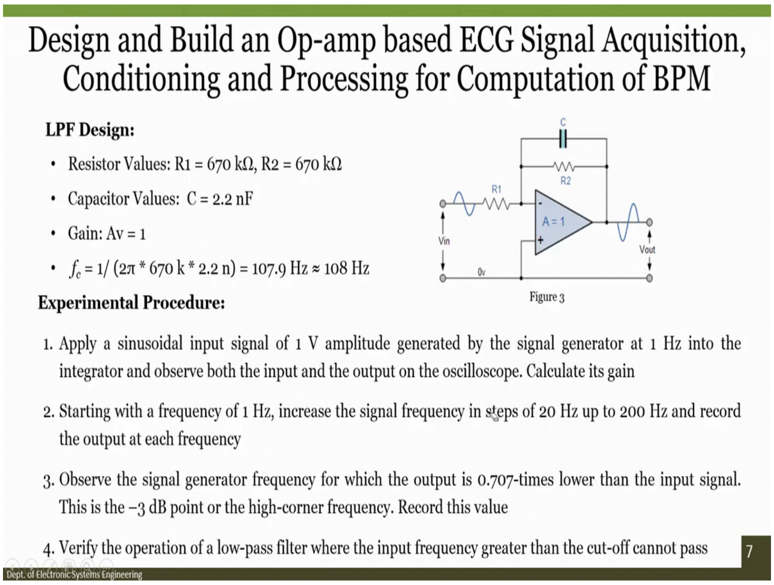

Now, let us see how can we design each of this filters; so, we start with the low pass filter. So, you can see here in the circuit right, the circuit is of low pass filter and if we keep a value of R1 and R2 as 670 kilo ohm and capacitors values as 2.2 nano Farad, then we have a gain of 1 and our frequency will be 1 by 2 pi RC. So, f c equals 1 by 2 pi RC and that will give us close to 108 Hertz, this is our low pass filter design. For the experimental procedure, what we can do? We can apply a sinusoidal signal of 1 Volts, amplitude generated by signal generator at 1 Hertz into the integrator and observe the output input and output on the oscilloscopes, we can also calculate the gain.

Second one is that with a frequency of 1 Hertz increase the signal frequency in steps of 20 Hertz up to 200 Hertz and record the output of each frequency, this is actually the experiment procedure. Finally, we can also go for observing the signal generator frequency for which the output is 0.707 times lower than the input signal which is your minus 3 dB point and finally, you can have the; we can we have to verify the operation of a low pass filter by the input frequency greater than the cut off frequency should not pass right. So, this is how you should perform the experiment like I said we will perform the experiment for the ECG in detail.

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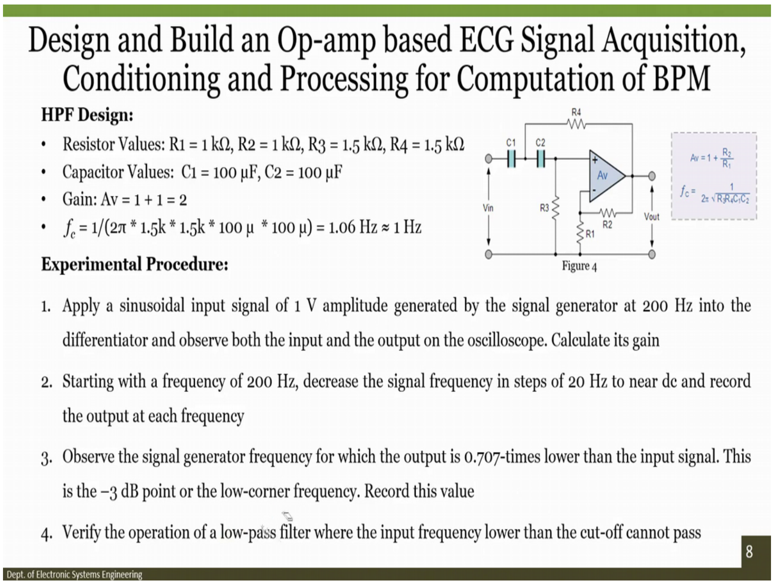

Now let us understand the second part which is your High Pass Filter Design. Now, in the high pass filter design, what we are working on? We are working on designing a high pass filter right which you can see here, and here you if we have resistors value of R1 R2 equals to 1 kilo ohm and R3 R4 equals to 1.5 kilo ohm, where C1 equals to 100 microfarad and C2 also equals to 100 microfarad, then we know the fc which is the cut off frequency value will be nothing but 1 by 2 pi under root of R1 R2 C1 C2. Since R1 equals to R2 and C1 equals to C2 you can have or you can in this case is like R 3 R 4 C 1 C 2.

So, if you have these values then what will be the fc? fc would be nothing but 1 by 2 pi under root of R square C square, which is nothing but 1 by 2 pi RC right. So, this is what we are using here and that is why it is 1 by 2 pi RC and what we get is close to 1 Hertz, your gain is nothing but 1 plus R2 by R1.

So, this is the formula. For experimental procedure, we will apply the input voltage which is sine wave of 1 volt amplitude and generated by at 200 Hertz into the differentiator and observe the input and the output at the oscilloscope and we calculate the gain.

Second one is starting with a frequency of 200 Hertz, we decrease the signal frequency in step of 20 Hertz to near dc and record the output at each frequency. Finally, we will observe the signal generator for the frequency for which the output is 0.707 times or you can say minus 3 dB point or the low-corner frequency. And, we will verify the operation of a high pass filter, cannot low pass filter where the input frequency lower than the cut off frequency should not pass.

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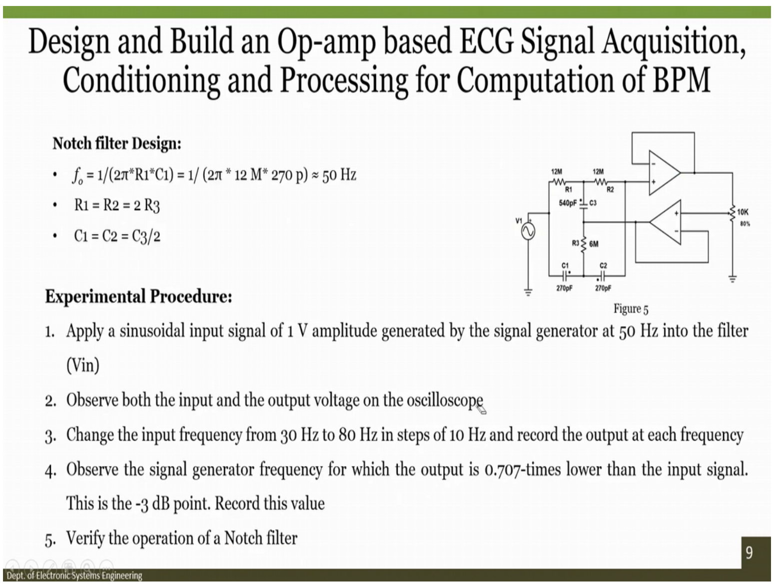

Now, how can you design notch filter? Notch filter is very easy to design. We have seen in the earlier modules here what we have is f o equals to 1 by 2 pi R1 into C1 which is 1 by 2 pi RC, we perhaps see the values, which are already given here and you can design the notch filter right. Now here, if you want to perform the experiment what you have to do? You have to apply the 1 volt amplitude generated by signal generator at 50 Hertz into the filter and observe the input and output voltages on the oscilloscope, then we can change the frequency from 30 Hertz to 80 Hertz, in a step of 10 Hertz and I got the output at each frequency, what we want? We that 50 Hertz should not pass through the filter (Refer Time: 23:47) frequency can pass through, we can observe the signal generator frequency for which the output is again 0.707 times lower than the input signal or you can say it is a minus 3 dB point and finally, we can verify the operation of a notch filter. This is how the filters are designed.

So, what if you see go and go back what we had to do? We had to design a low pass filter, high pass filter in a notch filter. So, that is what we have done here.

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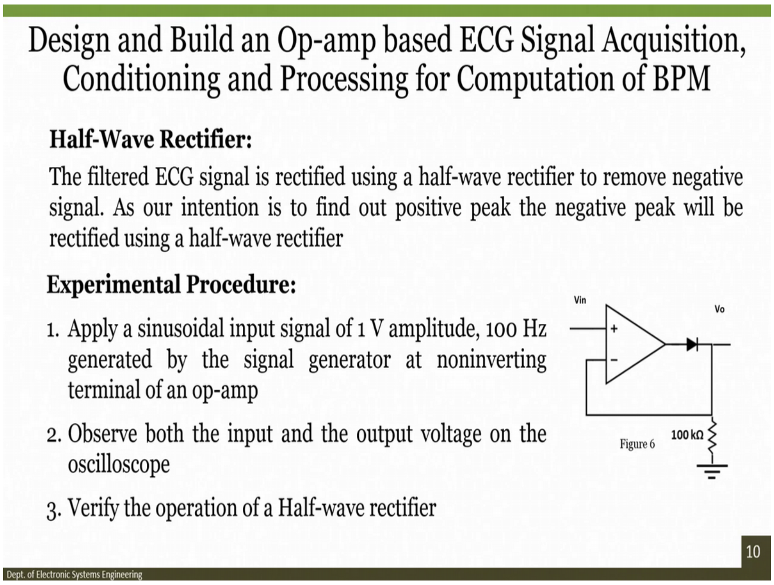

Then, let us understand the next stage; so we are now understanding the half-wave rectifier. Now in the case of half way rectifier, the filtered is ECG signal is rectified using a half-wave rectifier to remove the negative signals right. We do not require negative signals. As our intention is only to find out the positive peak the negative peak will be rectified using a half-wave rectifier.

So, what is the experimental procedure? Experimental procedure is apply a sine wave input signal of 1 volt, in the input V in at 100 Hertz generated by signal generator at the non-inverting terminal which is right over here. Then, we have to observe both input voltage and the output voltage on the oscilloscope.

Next one would be we will verify the operation of a half-wave rectifier. Half-wave rectifier is very easy to design which is right over here; so, it is very extremely simple design right.

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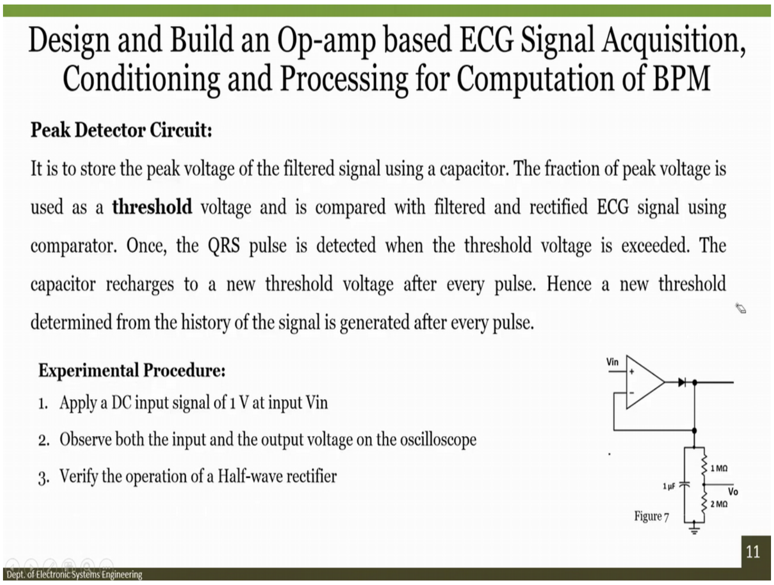

Now, let us go for the next one. The next one is nothing but a peak detector circuit. So, for peak detector circuit what is a circuit how circuit will look like, circuit look like the one shown here and how it is going to help us, because it is used to store the peak of the filter signal using the capacitor right. The fraction of the peak voltage is used as a threshold voltage is compared with the filtered, and rectified ECG signal using the comparator right, this your this one.

Ones the QRS pulse is detected, when threshold voltage is exceeded, the capacitor recharges to a new threshold value. So, this is the threshold voltage. If it exceeds the earlier one, the capacitor will recharge to a new value right after every pulse and the new threshold determined from the history of signal is generated after every pulse. The output voltage you can measure right occurrence this particular circuit. And, if you want to verify the circuit using experiments, then what you have to do? You would apply a DC input signal of 1 volt at Vin, observe input and output voltage on the oscilloscope and you have to verify the operation of a half-wave rectifier.

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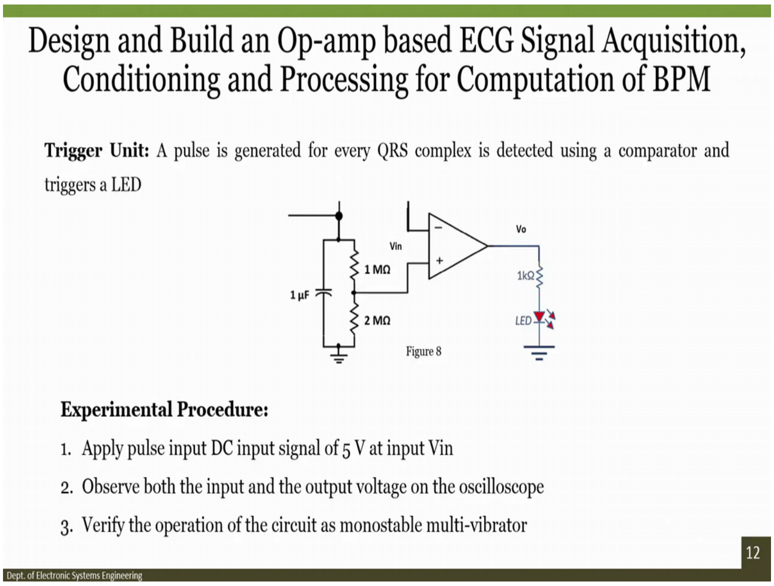

Now, if we see; so, you can also so, in case of a signal you can also apply the sine wave and look at the operation. It is not just like every time you have to go for DC you can also increase the frequency and you can see what happens at the input and what happens at the output for the same circuit, but at the different for the different signal.

Finally, if we understand trigger unit then it is becomes very important because trigger unit is nothing but the pulse is generated for every QRS complex that we know and it is detected using the comparator and triggers the LED which is right over here. So, every time the QRS complex is detected, we there is a comparator here and whenever there is a high, this will the LED will glow; whether is a low the LED will not glow because it is a comparator circuit you will know the functioning of a comparator. If the if it is a non-inverting signal is higher than the inverting signal, the comparator output will be higher, if the inverting signal is higher than non-inverting signal then the output will be lower. And based on that, the LED will glow or it will not glow or you can drive or we cannot drive the LED depending on the signal at the output.

For the experiment procedure, we can apply a input DC a pulse input DC a signal of 5 volts at the input voltage V in. You can observe the input and output voltage on the oscilloscope and finally, we can verify the operation on circuit as a monostable multi vibrator right.

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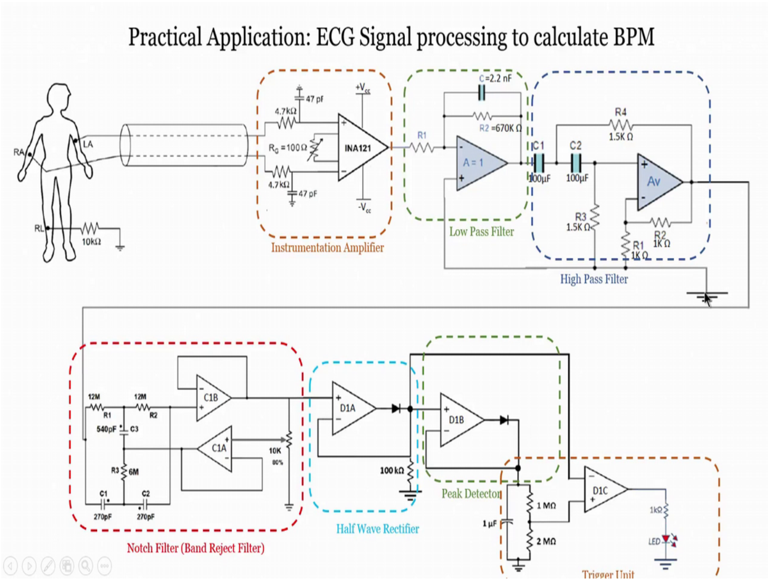

So, what you observe here? You observe a very interesting application what we have just understood is that there is a instrument amplifier, there are filters and then there is a comparator and there is a triggering circuit. So, when we connect this LED's to the instrument amplifier right, then what will happen? Instrument amplifier will pick up the signal and because of its high CMRR the common mode signals are rejected and the differential signal is amplified and further fed to the low pass filter right.

Now we know, for low pass filter we have designed a filter which can filter out anything above 100 Hertz and then we have a high pass filter that is for anything for the 1 Hertz frequency. Then we have a notch filter that is for the 50 Hertz frequency then we have a half-wave rectifier because we are interested only in the positive signals of the QRS. And then we have a peak detector, where for every QRS signals we it will detect a peak and finally, we have a LED. So, that LED will help us to understand how many bits per minute this QRS signals are generating and that will help us to understand the count the number of bits right.

So now what do you guys see? You guys see that, the integrating all the circuits together will form a signal conditioning unit right; this is how the ECG would work right. In the next module we will see two different aspects, one is how can we design a force sensing unit right and what kind of signal conditioning circuit we have to use to understand the force from the catheter.

Now we will see in the next module, but for this module just understand that, if you know the each block in detail you can integrate those blocks and you could use for practical applications such as ECG right. So, till then I will see you in the next class and you just look at the look at this particular video, if you have any questions feel free to ask us in the forum right. So, take care and bye I will see you in the next class, bye.