Op-Amp Practical Applications: Design, Simulation and Implementation
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Lecture – 31
Introduction to ECG Experiment

Hi, welcome to this module. In this module we will understand how to design and build an Op-Amp base ECG signal acquisition conditioning and processing of PQRS wave and a complete BPM. So, how to design such a circuit? Now, we have created a special set of experiments to make you understand how the ECG signals are obtained using electrodes that you can fix on left and right hand, and of course on the feet, and we will talk about the experiments in the experiment section. Let us see the how we can design the circuit first ok.

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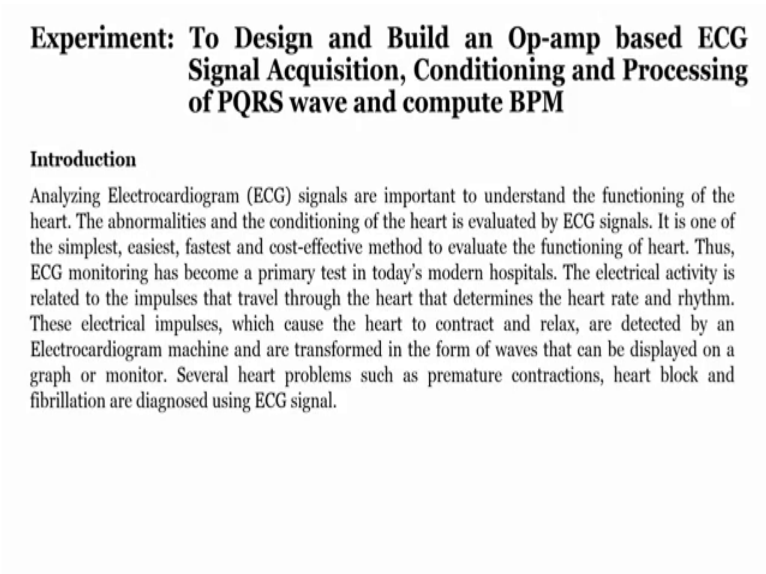

So, if you see the slide our idea is to design and build an operation amplifier based ECG signals right, and for that what we have to understand? First we understand what are the ECG signals so, analyzing electrocardiogram which is ECG signals are important to understand the functioning of the heart. First we need to understand how the heart function right. The abnormalities and the conditioning of the heart is evaluated by ECG signals. It is one of the simplest, easiest, fastest and cost effective method to evaluate the functioning of heart ok.

Thus, ECG monitoring has become a primary test in today's modern hospitals. The electrical activity is related to the impulses that travel through the heart that determines the heart rate and rhythm. Now, we know that in case of heart the electrical signals are the signals that helps the heart to pump evenly. If there is a misfiring of signal all the signals are too high, then there is something called arrhythmia. If there is a misfiring of signal and the heart beats unevenly it is called atrial fibrillation.

So, how to determine whether a person is person hearts; a person heart is working normally or it has a arrhythmia or it has a atrial fibrillation that is a problem with the electrical signals in the heart, right. So, to do that we can measure ECG; so, like I said the electrical activity is related to the impulses that travel through the heart and determines the heart rate and rhythm. And, these electrical impulses which cause the heart to contract and relax are detected by the ECG machine, right. So, several heart problem such as premature contraction hard block fibrillation are the organize using ECG signal. So, thus you can see that ECG signals are very important to understand the functioning of our heart.

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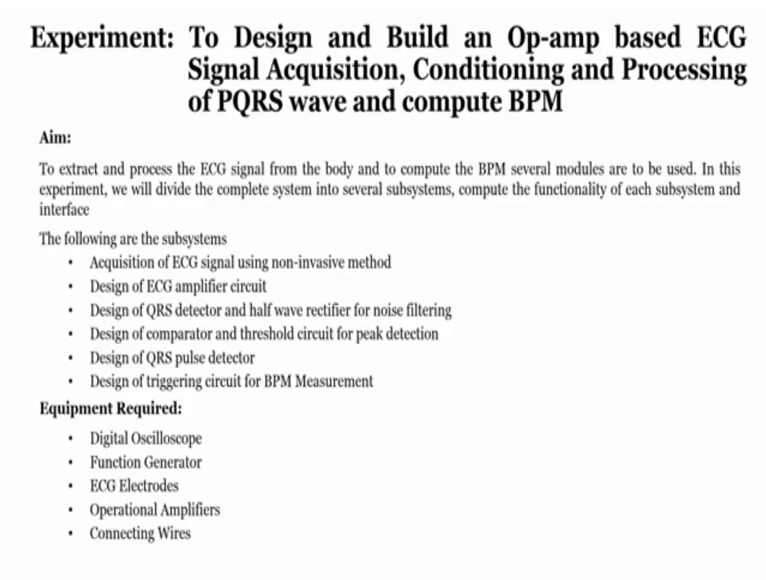

Now, what we want to do? Our aim is to extract n process the ECG signal from the body, and to compute the bits per minute several modules are you to be used. In this experiment we will divide the complete system into several subsystem. So, what are these subsystems?

So, to understand the complete module we will first let us understand the subsystems. First one is acquisition of ECG signal using non invasive method. Second is design of ECG amplifier circuit. Third thing is design of QRS detector and half wave rectifier for noise filtering. Next one is comparator and threshold circuit for peak detection. Next one would be design of QRS pulse detector, and finally, we will design the triggering circuit for BPM measurement.

So, for performing these experiments, what are the equipment required? So, the list of equipment that we require to perform these experiments are; digital oscilloscope, function generator, ECG electrodes, operation amplifier, connecting wires that that is it. And we using these components let us try to make the electronic module.

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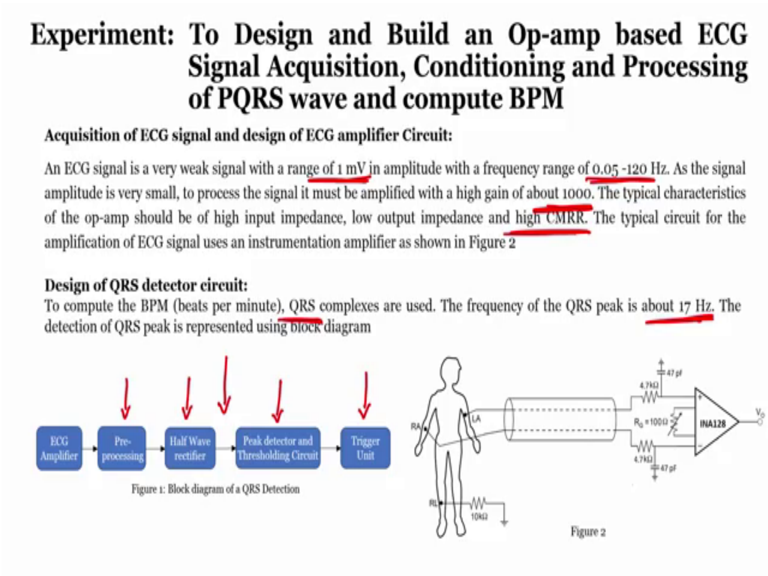

So, let us first understand how to acquire the ECG signal, and how to design ECG amplifier circuit, ok. So, an ECG signal is a very weak signal with a range of 1 millivolt in amplitude, and with the frequency range of 0.05 to 120 hertz. As a signal amplitude is very small to process the signal it was pre amplified with a gain of about 1000. Now what we understand that the ECG signals are very weak, and they range from about 1 millivolt in amplitude. And what is a frequency range? 0.05 to 120 hertz.

So, thus as a signal amplitude is so small, you can see here we require a high gain of about 1000. The typical characteristics of Op-Amp should be high input impedance, low output impedance and high common mode rejection ratio. So, the typical circuit for amplification of ECG signals using an instrumentation amplifier as shown in figure, you can see here we are connecting electrodes to right arm left arm right leg right, and this is connected to your instrumentation amplifier through some copper wires right.

So, to compute the bits per minute QRS complexes are used. And the frequency of QRS peak is about 17 hertz. The detection of QRS is represented using the following diagram. So, you will see here and there is a ECG amplifier, then there is a preprocessing unit followed by a half wave rectifier, followed by peak detector and thresholding circuit followed by a trigger unit right. So, this is a block diagram of your QRS signal.

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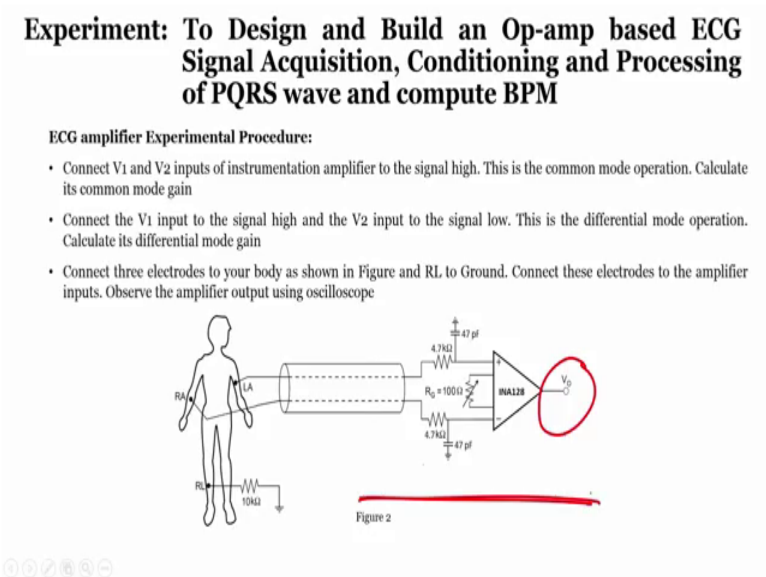

Now, how can you get this signal? So, first you connect V 1 and V 2 of the instrumentation amplifier, right which is your V 1 and V 2, you connect it to the high signal right. And this is common mode operation. Then when you connect to the high signal it is a common mode, if both the modes are same. So, calculate the common mode gain. And now if I connect V 1 to high input signal and V 2 to a low signal, then what we will have? We will have a differential gain.

So, differential mode operation and we can understand the differential mode gain. Now once we do that, with the instrumentation amplifier let us connect the 3 electrodes to our body right, to a person's body here as you can see. And the right leg to the ground and connect this electrode to the amplifier inputs, and observe amplifier output using oscilloscope. So, if you do this and if you connect in this particular fashion, let us observe the output using the oscilloscope. So, we will be doing these experiments in the experimental class. So, you can see how the how the output is changing in the oscilloscope.

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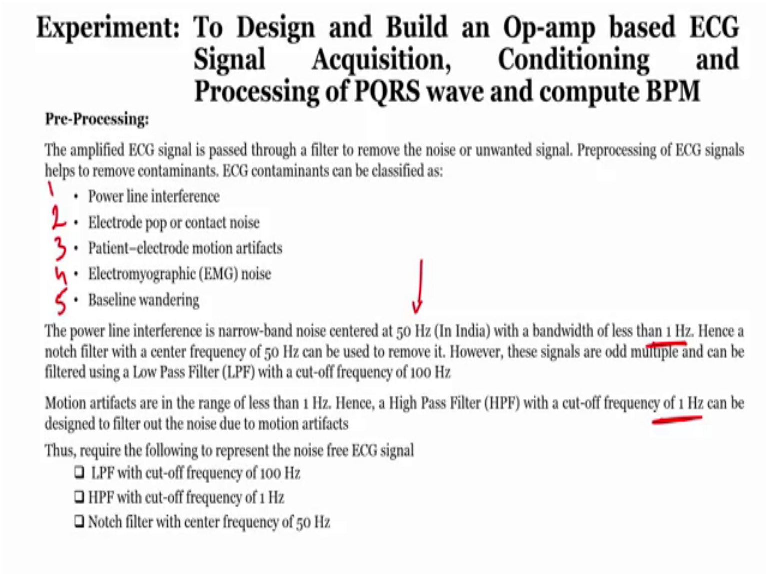

So now what to do with preprocessing circuit, right? You are seen here, that first is our ECG amplifier. And that we already have seen here right, this is our ECG amplifier. Next step is a preprocessing right. So, for preprocessing the amplified ECG signal is passed through a filter to remove the noise or unwanted signal, and preprocessing of ECG signals helps to remove the contaminants. ECG contaminants can be classified as power line interference; right this is one which is power line interference.

Second would be electrode pop or contact noise. Third can be patient electrode motion artifacts. Fourth can be electromyographic noise which is EMG, and finally, would be baseline wandering. So, this 5 are the contaminants we can consider in the ECG, and we have to remove these contaminants. So, the power line interference which is the first one is narrowband noise center around 50 hertz right. We are using 230 volts 50 hertz in India. So, we have designed the module such that we considered 50 hertz.

And power line interference is a narrow band noise centered around 50 hertz with a bandwidth less than 1 hertz, ok. So, hence a notch filter with the center frequency 50 hertz can be used because we have to remove only one particular frequency. So, if you understand notch filter we can use or band reject filter right, it is also called band reject filter. So, we can use this notch filter which can remove 50 hertz noise; however, these signals are or multiple and can be filtered using a low pass filter with a cutoff frequency of 100 hertz. We can also use this.

Now, motion artifacts are in the range of 1 hertz. So, hence a high pass filter with a cutoff frequency of 1 hertz can be used right, to remove the noise due to the motion artifacts. So, what we require then? Then we require a low pass filter with cutoff frequency of 100 hertz, high pass filter with a cutoff frequency of 1 hertz, and notch filter with the centered frequency of 50 hertz. These 3 filters we have to design for preprocessing.

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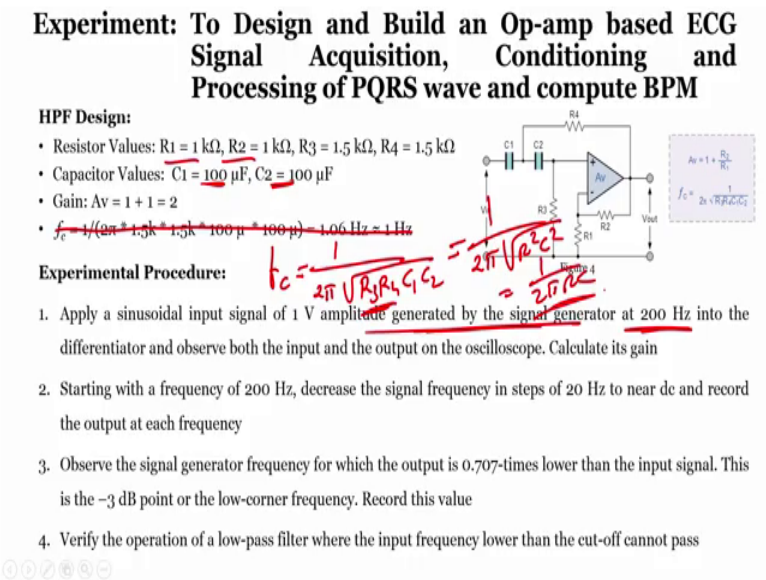

So, let us see first low pass filter. Now low pass filter we have seen in the earlier class also, earlier course also. But let us again look at it. So, here the resistors value if I take R 1 R 2 equals to 670 kilo ohm, and capacity equals to 2.2 nano farad, gain equals to 1, then my f c is close to 108 hertz right. So, there is first thing. Now for this what is experimental procedure? Experimental procedure is given here we have to apply a sinusoidal input voltage of 1 volt right, my signal generator at 1 hertz into an integrator. And observe the output of the, observe both inputs and output at the oscilloscope.

Now, if you know this thing then you can also calculate your gain. Second step would be you can starting with a frequency of 1 hertz, we can increase the signal frequency in step of 20 hertz to 200 hertz, and I count the output at each frequency. That is the second step we can use, right. Third one can be we can observe the signal generator frequency for which the output is 0.707 times lower than the input signal, right.

So, this is our minus 3 dB point or high corner frequency recoded this value. We can record this value where one once we have one single generator frequency for which the output volume value would be 0.07 0.707 times lower than the input signal. Finally, verify the operation of low pass filter; where the input frequency greater than the cutoff cannot pass. So, these are the experimental procedure we have to follow. We will see in the experiment actual experiments so that you understand how this can be done, ok.

Now, let us see how we can design a high pass filter. Here we have a value of R 1 R 2 equals to 1 kilo ohm R 3 1.5 R 4 1.5. So, capacitor value is C 1 equals 100 micro farad C 2 equals to 100 micro farad. If we do that, then we can have x equals to 1 by 2 pi, just ignore this equation because f C equals to 1 by 2 pi under root of R 3 R 4 C 1 C 2. Now, C 1 equals to C 2, right? And R 3 equals to R 4 right. So, we can consider as a equation s 1 by 2 pi R square C square or 1 by 2 pi RC, this is how you have to calculate ok; which is close to 1 hertz. We will see in the experiment. So, do not again worry about this if there is some error do not worry about. It we will rectify it in the experimental portion. So, apply a sinusoidal input signal of 1-volt amplitude generated by signal generator at 20 200 hertz into the differentiator.

You can see here and observe both input and output on the oscilloscope. Again we are calculate the gain, but it very easy to calculate the gain, start with the frequency of 200 hertz, and decrease the signal frequencies type of 20 hertz to near DC and record the output at each frequency. Then we observe the signal generator frequency for which output is 707 times lower than input signal, this is minus 3 dB point. And finally, verify the operation of a low pass filter by input frequency is lower than the cutoff frequency so that cannot pass.

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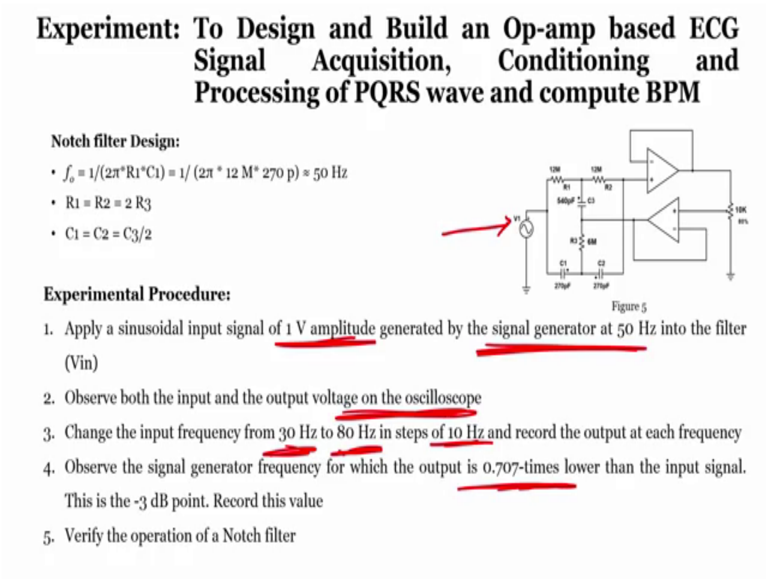

If I want to design a notch filter, what would I do? You of course, know how the notch filter is designed right, we have seen in our earlier course. So, notch filter design is f o equals to 1 by 2 pi R 1 C and we put the value of R 1 and C 1 and we get 50 hertz. Now you see here the value of R 1 and R 2 is extremely high, these reason is that we need to only reject 50 hertz signal while accepting all the other frequencies right. Same way R 1 R 2 equals to 2 times R 3 right and C 1 constant C 2 equals so, C 3 by 2.

If we if we keep this values, then we can design a notch filter which will give us a 50 hertz notch signal. Or we can remove 50 hertz signal. So, for this the experimental procedure is, to apply a sinusoidal input signal of 1-volt amplitude, right generated by signal generated at 50 hertz. Observe input and output voltage on the oscilloscope. Change the input frequency from 30 hertz to 80 hertz in step of 10 hertz right, from 30 hertz to 80 hertz in step of 10 hertz. And record the output at each frequency.

Next would be observe the signal generator frequency for which output is 707 times lower and finally, verify the operation of notch filter. So, this is how we can design low pass high pass and notch filters.

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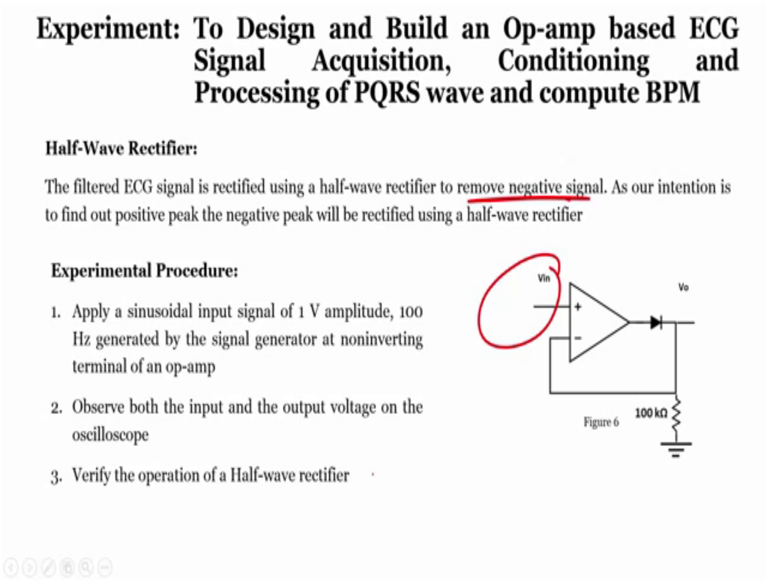

Next process if you if you see the block diagram, the next one would be half wave rectifier, right half wave rectifier. So, we need to now design a half wave rectifier. Half wave rectifier is very simple to design like you can see in the circuit, right. The filter ECG signal is rectified using a half wave rectifier to remove the negative signal if I use this kind of circuit I can remove the negative signal, right.

And our intention is to find out the positive peak and negative peak will be rectified. Using a half wave rectifier to do that the experimental procedure is to apply a (Refer Time: 15:29) input of 1 volts here we apply 1 volts right. And 100 hertz generated by a signal generator at the non-inverting terminal. And observe input and output voltage and verify the operation of a half wave rectifier, very simple circuit.

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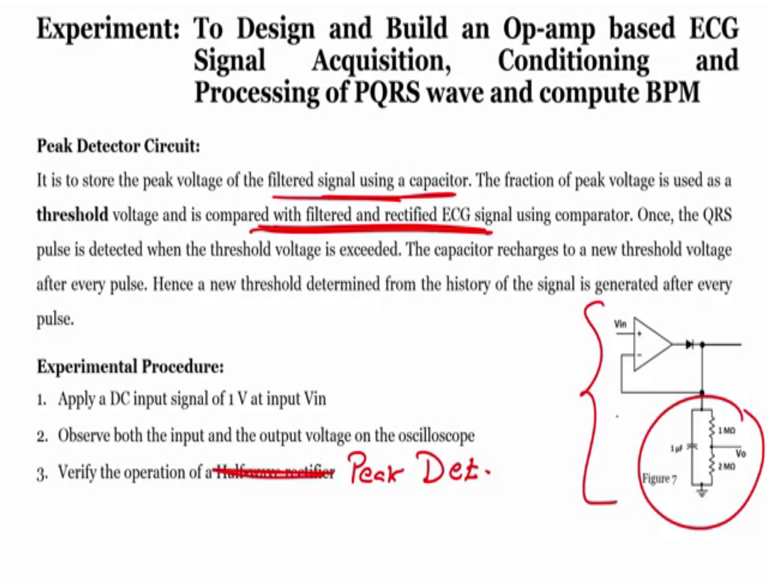

Next circuit is to understand peck detector right peak detector. So, what is the role of peak detector? Peak detector is used to store the peak voltage of the filter signal using a capacitor ok. So, the fraction of peak voltage is used as a threshold voltage and is compared with filtered and rectified ECG signal. Once the QRS pulse is detected, when the threshold voltage is exceeded, the capacitor recharge is here you can see here, right the capacitor recharges to a new threshold voltage after every points. And the new threshold voltage determined from the history of signal is generated after every pulse is very simple the circuit for peak detector is right now shown here.

And if you want to perform the experiments, then we have to apply a DC signal of 1 volts at v in observe input and output and verify the operation of a half wave rectifier followed by or verify a operation of the peak detector not a half wave rectifier, but a peak detector ok, peak detector all right. It is very easy hum. So, half wave rectifier is here, peak detector is here. Now what we will do next?

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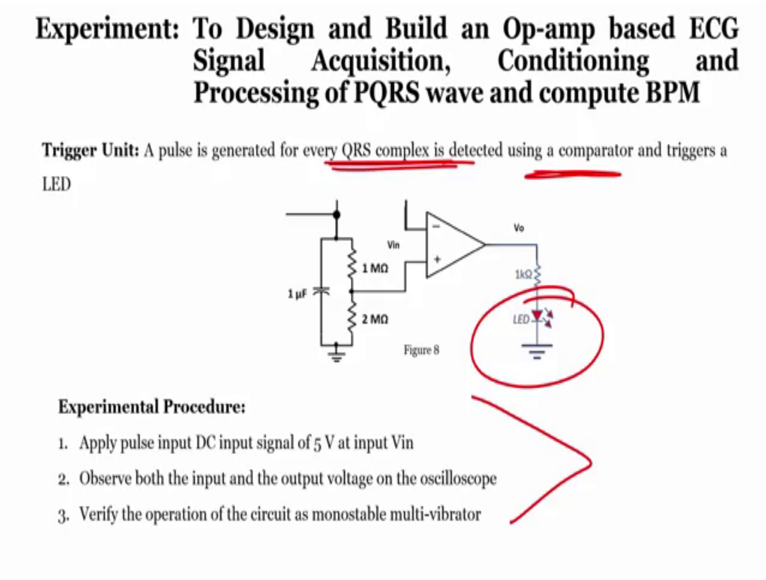

The next is trigger unit right, next is trigger unit. So, in trigger unit a pulse is generated for every QRS complex, and is detected using a comparator, and triggers a led which you can see right over here, right. So, the trigger unit is used to generate a pulse for every QRS complex. An experimental procedure here is to apply pulse input DC signal at of 5 volts. Second is observe both the input and output voltage on the oscilloscope. And third one is verify the operation of circuit as monostable multi vibrator. It is a nothing but a triggering circuit right. So, you can use a monostable multi vibrator. We have seen earlier that a monostable multi vibrator can be used as a triggering circuit for such a application.

Now, since we know that we have designed a low pass filter, high pass filter, amplifiers of starting with a amplifier, then low pass filter high pass filter notch filter, then we have designed a peak detector, then we have designed a trigger circuit right. And if we combine all this thing along with these electrodes, how the circuit will look like?

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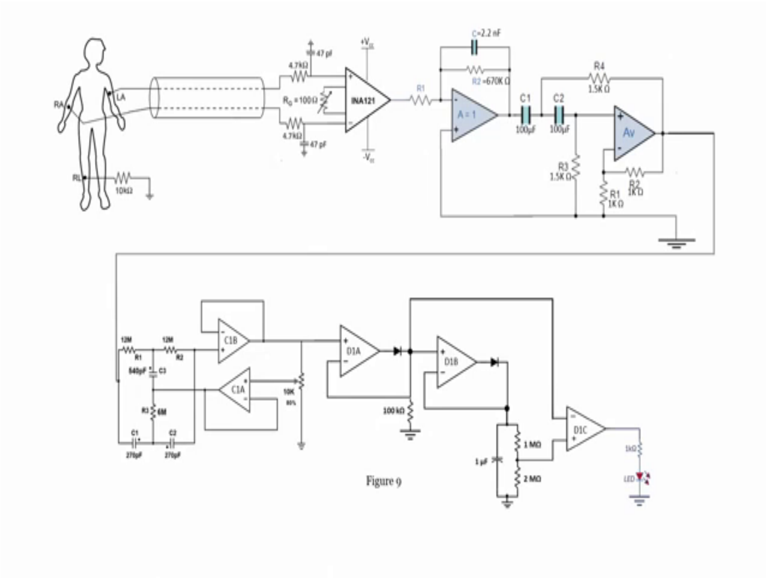

Figure 9

So, if you see this slide now then you can realize, that we have a complete electronic conditioning circuit for measuring and processing ECG signals and finally, measuring the BPM right. So, in your experimental class, we will see the entire circuit how we can design what kind of signals, you can generate at the output of every stage, and we will see how the ECG is measured in a real time, alright guys. So, you just go through the entire slide, and understand the importance of ECG measurement, how to design a electronic conditioning circuit. And, in our next module we will see in the experimental class. So, you can see how the how the output is changing in the oscilloscope.

Now, to do that my TA discuss about the circuit design, and perform simulation. Then, they will discuss about how the circuit operates. We have seen in theory in detail, but we just need to have a quick recall of how circuit operates. So, that I will show you about that circuit operation, and compare it with this simulation. So, simulation we use multi-sim and perform experiments. So, we compare theory with simulation to compare theoretical results with our experimental results.

So, try to read, try to figure it out, right if you have any difficulties, do ask me I will reply to your answer and to your questions and with the suitable answers. So, as to move forward and learn the applications operational amplifier for either ECG or for keeping the temperature constant in case of our plant, in case of our industry or as to just understand how we can create a signal conditioning module as a interfacing tool between a sensor and a display right.

So, till then you take care, I will see you in the next class.