Design of Power Electronics Converters
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Lecture 69
Lab Demo of Hardware Design

Welcome to the course on Design of Electronic Converters. In this course, we learned about the analysis of power electronic converters from the perspective of designing it. So, we took simple examples of buck converter and H bridge converter to understand how to analyze them. Further, we also looked into power semiconductor devices, how do you select them, how do you read the datasheet, and what are the important specifications that you should be looking for in the datasheet of power semiconductor devices.

We also discussed drivers, a circuit, so what are the different types of driver circuits, how do you use them for driving the transistor like your MOSFETs and IGBTs. Then now, we also saw snubbers, what is the role of snubbers, how do snubbers protect the devices and how they also affect the turn on and turn off process of the devices.

Then, we looked into thermal design that means, how do you select the heat sinks, how do you do the calculations, the heating calculation, the power dissipation calculations and using it how do you choose a heat sink and in the datasheet of a heat sink, what are things that you should be looking for. Then, we also discussed magnetics design, we saw how to design an inductor and a transformer simple examples and demos were also shown to you of practically designing an inductor and a transformer.

Then, we discussed the problem of electromagnetic interference in power electronic converters. We saw that what are the solutions that power electronic engineer can use to avoid the problem of electromagnetic interference. And then we also saw various concepts related to hardware designing, what are the different components, miscellaneous components that are used in power converter, what are the different sections of power converters. Then, how to design PCBs what are the precautions that you should be taking while routing PCBs.

Now, having done all these things, let us look into a practical demonstration of designing a buck converter. So, in the further in this video, you will see how a power converted is practically designed, its hardware is designed and how is it is tested.

Hello, my name is Paban Bujor Barua. I work here at the Department of Electronics and Electrical Engineering, IIT Guwahati as technical officer. In this video, we will see the various components and equipments that we use while designing and testing of power electronic converters. So, let us start with the oscilloscope.

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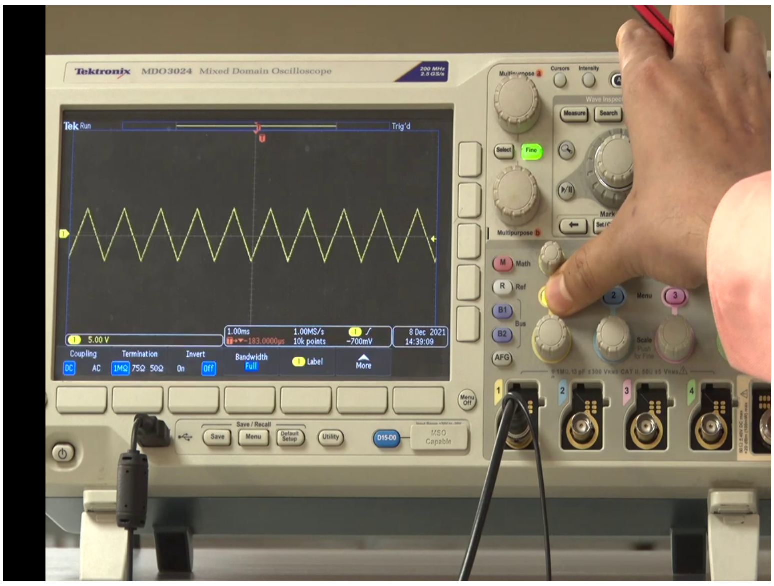

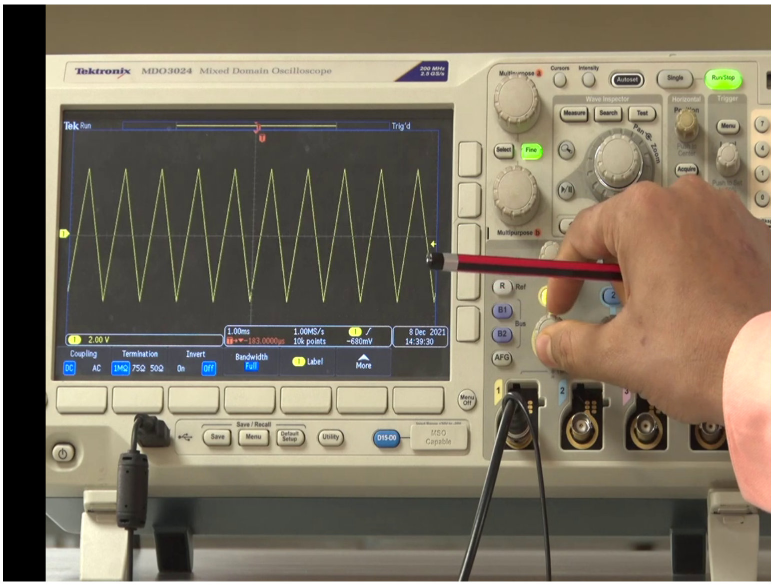

This is a four channel of oscilloscope, we can view four types of currents or voltage waveforms simultaneously by giving inputs to these BNC plugs. These here are channel selector buttons. For example, let us select channel 1. We can see that there is a triangular waveform that is visible in channel 1. This waveform has been given as input from all function generator, the peak to peak value of this function is 10 volts. This knob here is used to set volts per division. As you can see, currently the volts per division is set at 2 volts.

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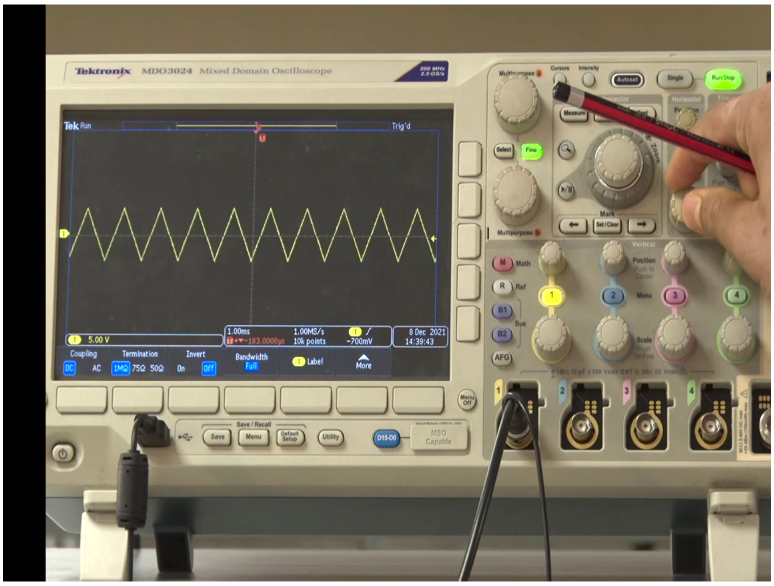

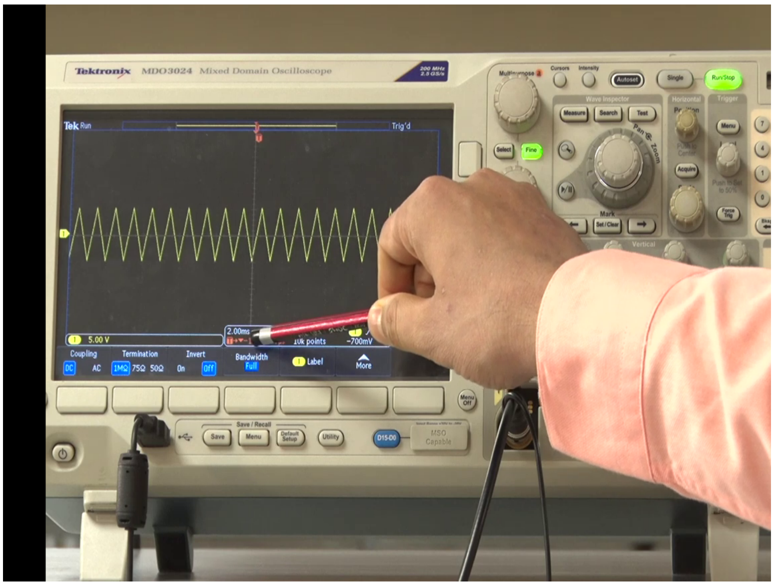

Further, this knob can be used to set time per division scale. Currently, the time per division scale is set at 2 milliseconds per division.

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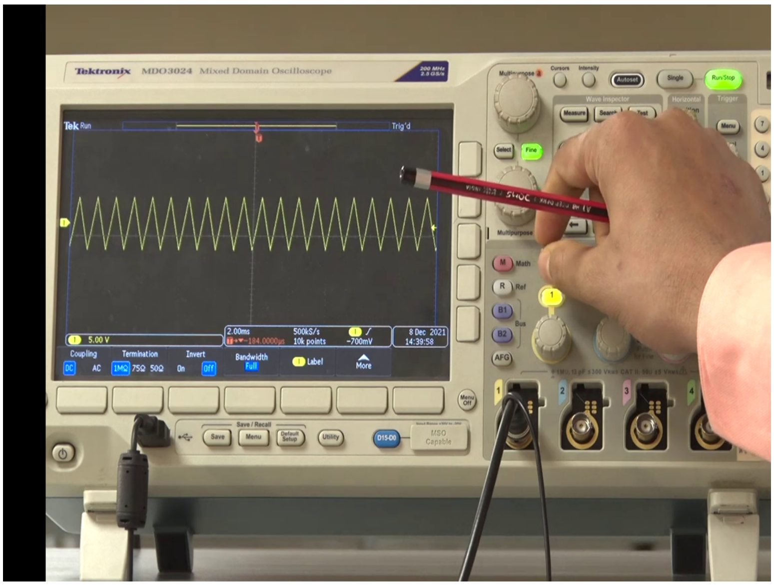

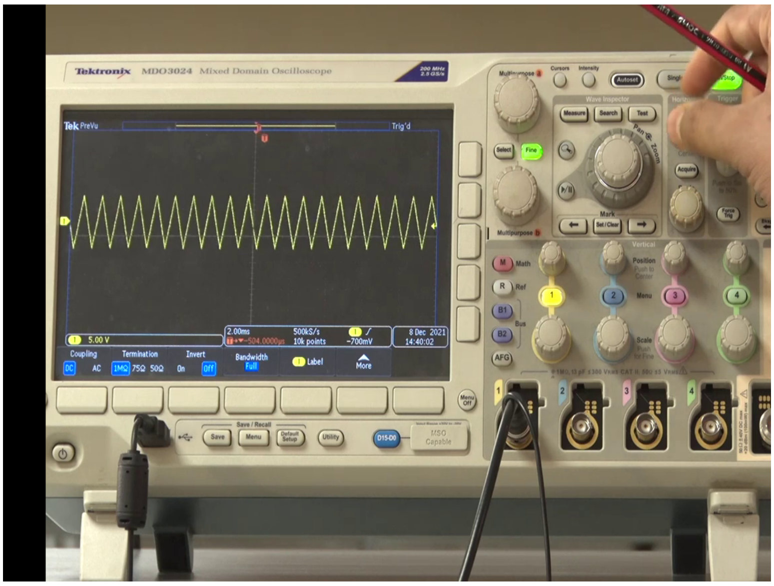

Further, this knob can be used to adjust the vertical scale reference and this knob can be used to adjust the horizontal reference.

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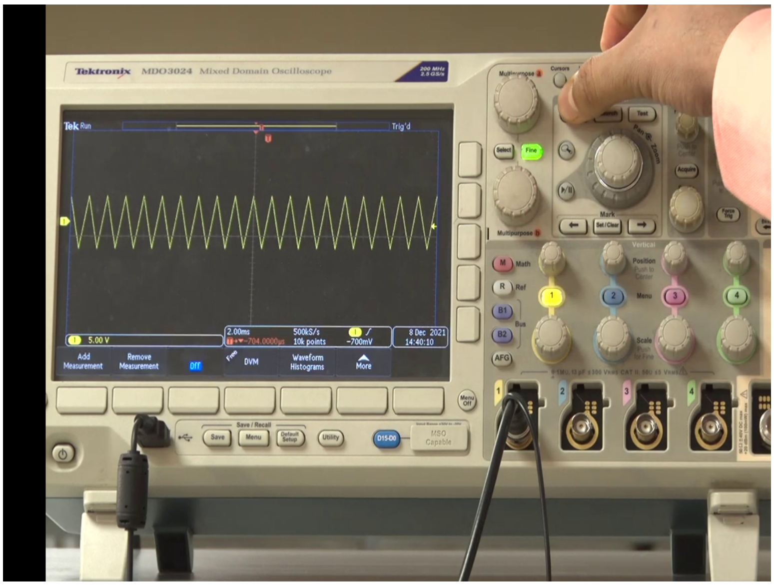

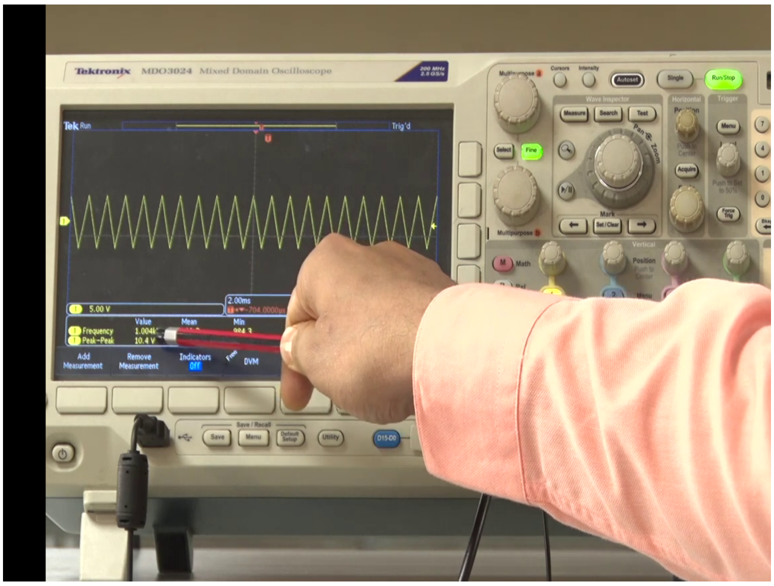

Also, the various data about this waveform can be viewed using the measure button. For example, We can see the frequency of this waveform as well as the peak to peak value you see the frequency of this waveform is around 1 kilo hertz and peak to peak value is 10.4 volts.

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Let us now see our function generator this function generator can be used to generate functions of various frequencies, amplitude, offset and phase. Currently, this function generator is generating a triangular waveform of 1 kilohertz and with amplitude 5 volts, if we want to change the function, we select this button.

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Suppose, we now select a sinusoidal wave the frequency that we have selected is of 10 kilohertz and the amplitude is 5 volts. So, now, we will see whether this frequency can be viewed in the oscilloscope.

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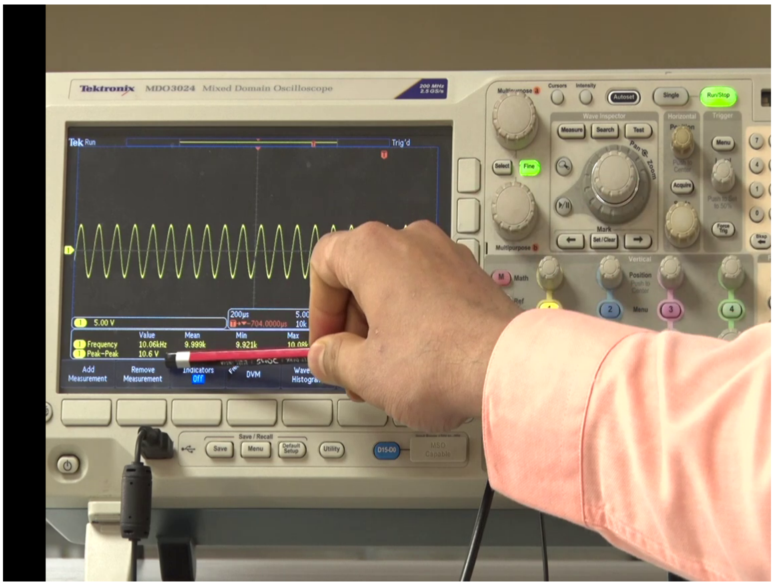

As you can see, the frequency of this waveform is 10 kilohertz as we have set in the function generator also the peak to peak value is 10.6 volts, which is the value that we have set a 5 volts amplitude in our function generator. Next, we will see the dc voltage source that we use in our labs.

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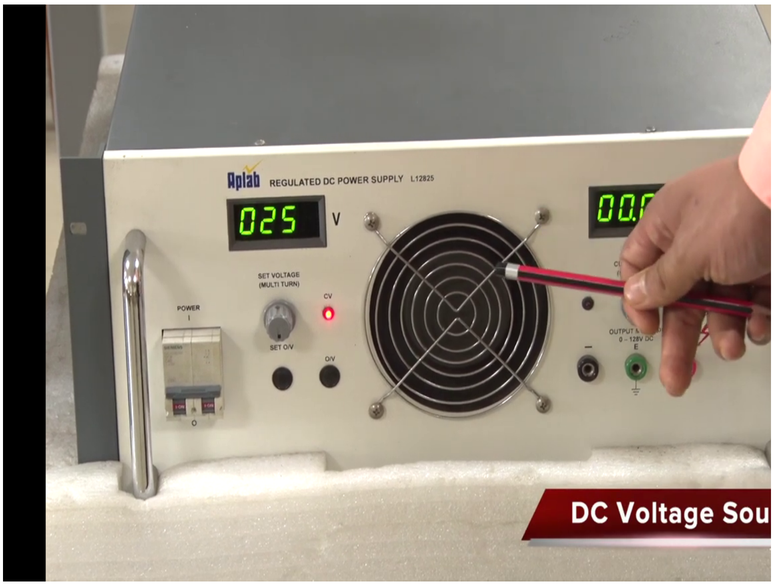

This here is a DC voltage source, this voltage source can provide a voltage of maximum 128 volts and 25 amperes current this knob here can be used to set the required voltage. Also, the current that is coming out of this voltage source can be set to a predefined limit so, that it does not damage our devices. Now, let us see the various components and the probes that we use in our labs.

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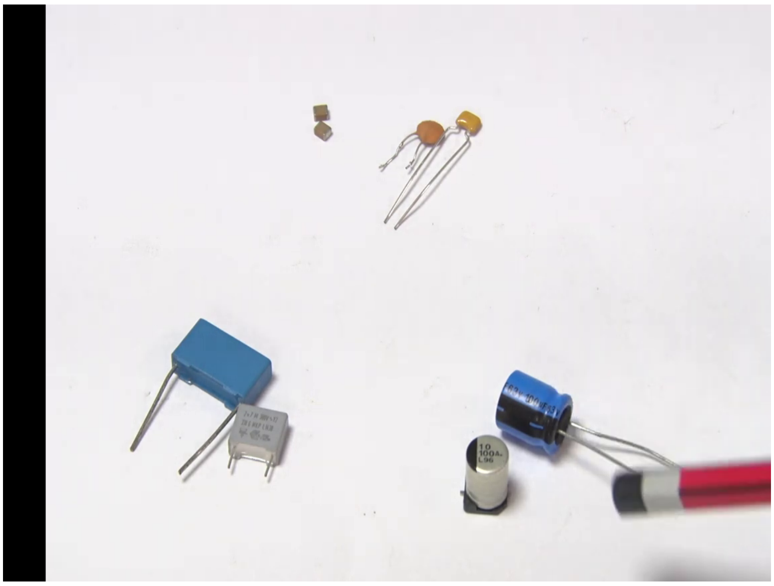

These here are capacitors these are film type capacitors, while these are ceramic capacitors, these smaller capacitors are SMD ceramic capacitors and these are through hole ceramic capacitors. These are electrolytic capacitors, while this one is an SMD electrolytic capacitor This is through hole electrolytic capacitor applying wrong polarity on electrolytic capacitors might damage them. So, proper care should be taken regarding the same.

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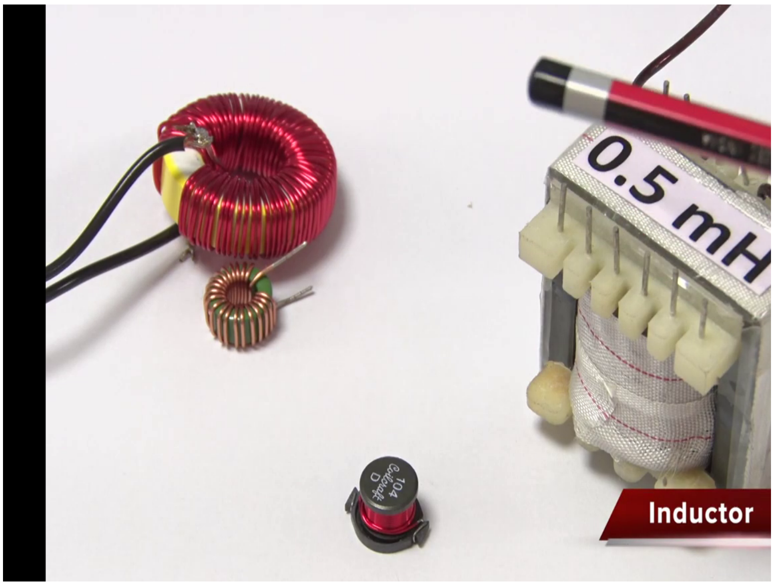

These here are inductors. These are through hole toroidal inductors. This is an SMD type of inductor while this is an EE core type of inductor.

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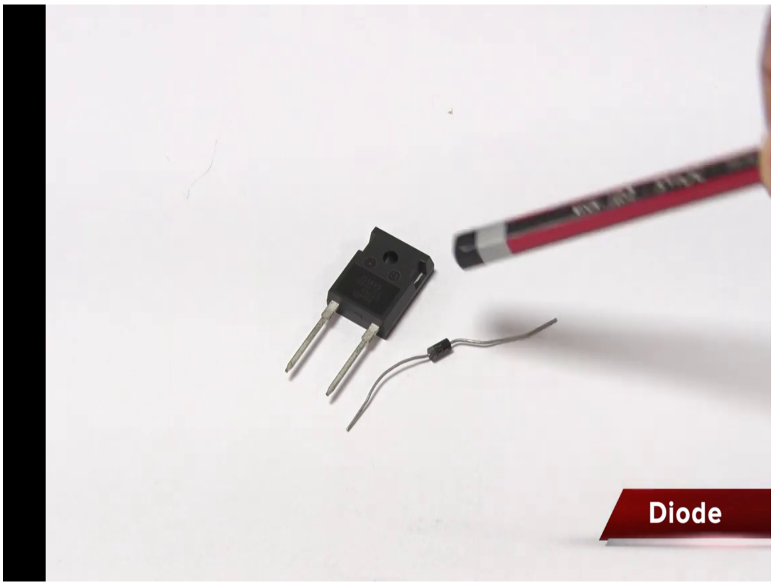

These are examples of diodes. This is a power diode which can handle much higher power rating.

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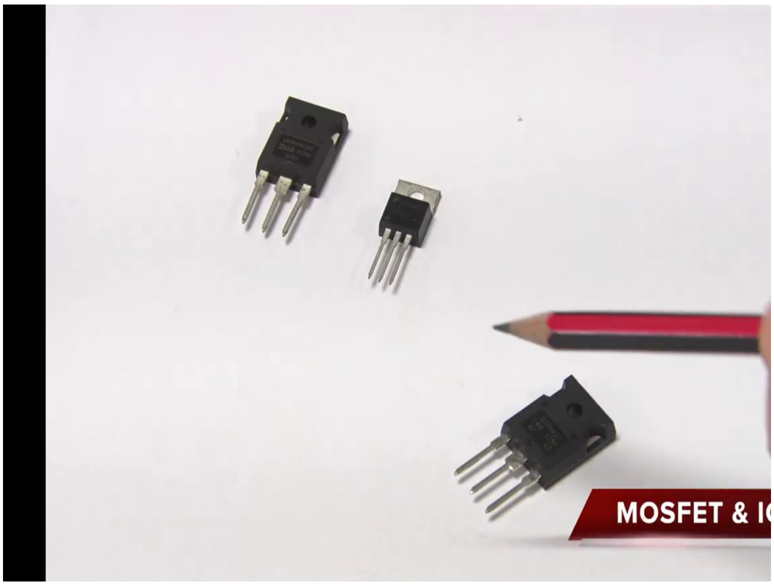

This here is an IGBT, the leftmost pin is the gate pin while the middle pin is the collector and this pin is the ammeter. This here is in power MOSFET where this leftmost pin is the gate pin, this middle pin is the drain pin and the rightmost pin is this source pin.

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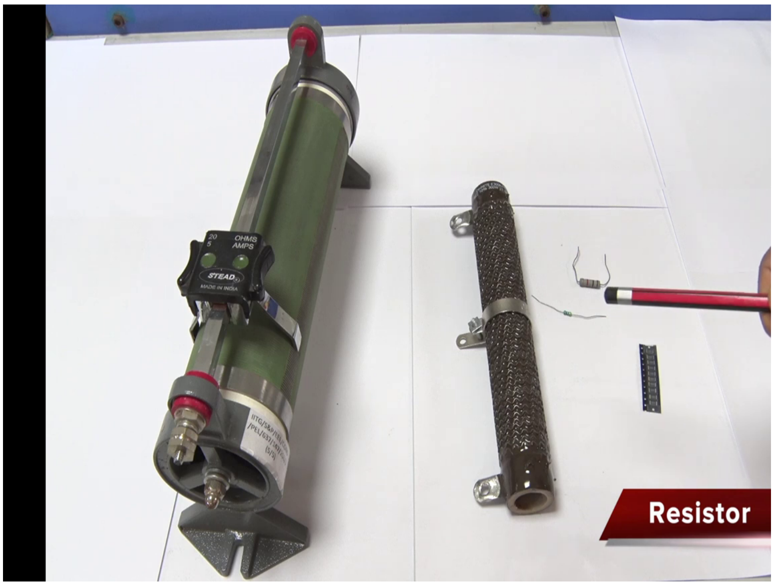

These are various types of resistors that we use in our circuits. These here are through hole resistors while these are SMD resistors this here is a 300 watt wire wound resistor. While this is a rheostat, which is a variable resistor.

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These are various heat sinks that we use in our circuits. These heat sinks are used for through hole components, while these heat sinks are used for SMD components.

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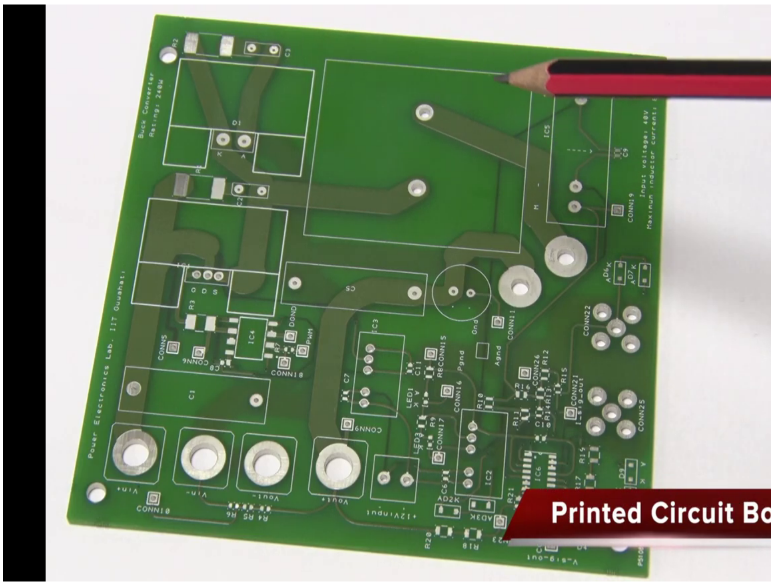

This here is an example of PCB, this is a four layer PCB. So, there are multiple layers of copper which is sandwiched between insulator material. These holes are used for fixing through hole components. While these are used for fixing SMD components. This here, you can see are wires, wires are used to connect different layers of copper to each other.

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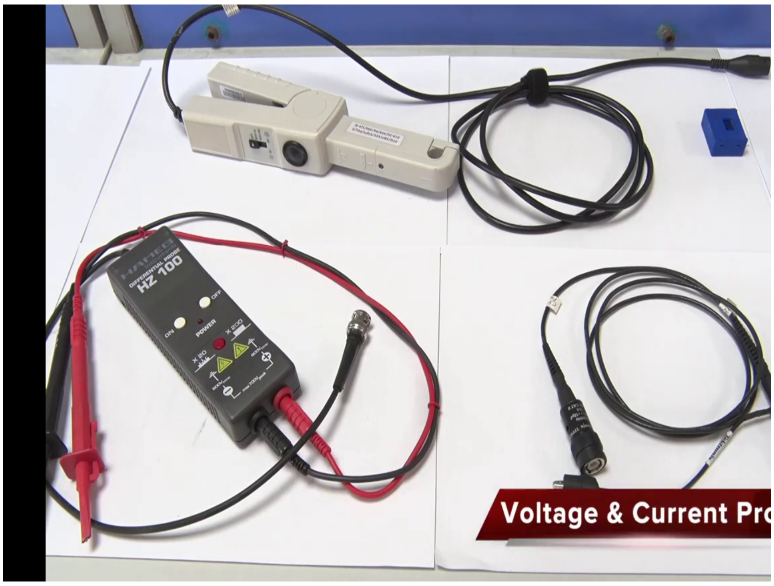

These are the various types of probes that we use to measure voltages and currents in our oscilloscope. These are passive voltage probes while these are differential voltage probes. This here is a clamp type current probe, which works on the principle of hall effect. This is another current sensor which works on the basis of hall effect and can be fixed on the PCB.

In the remaining part of this view video, I will be making a buck converter that has been designed in this lab. Thereafter, we will be testing its various section part by part.

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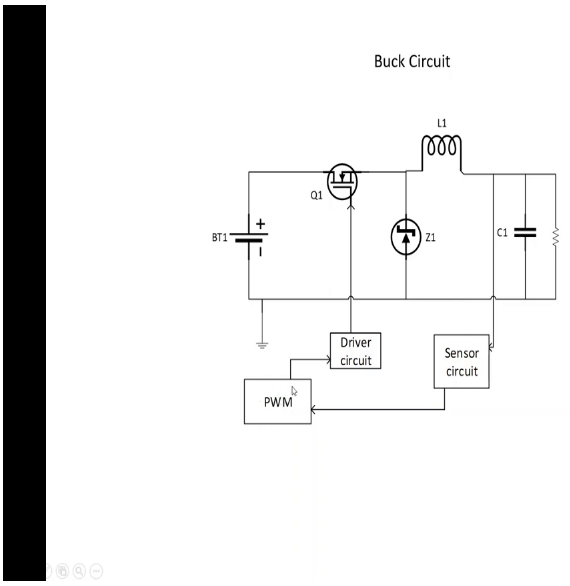

Let us now see the block diagram of the buck converter that we are designing. Here we can see that this is the buck inductor, this is the buck capacitor, the MOSFET the input voltage supply and this is the load resistance, here this Schottky diode that we have used for the buck circuit.

Now, the sensor circuit will sense the inductor current and the output voltage. These these inputs are then set to the sensor circuit, which thereafter sets input voltage waveforms the PWM generator, the PWM generator then provides PWM pulses of appropriate duty cycle to a driver circuit.

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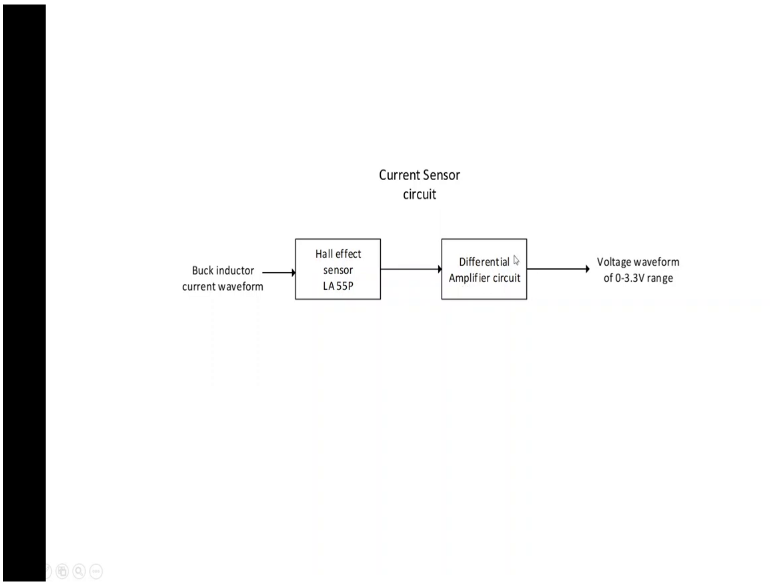

The current sensor circuit consists of a hall effect sensor here we have used an LA55P, the buck inductor current waveform is set to the hall effect sensor which there after gives an input to differential amplifier circuit. This differential amplifier circuit provides a proportional waveform in the range of 0 to 3.3 volts.

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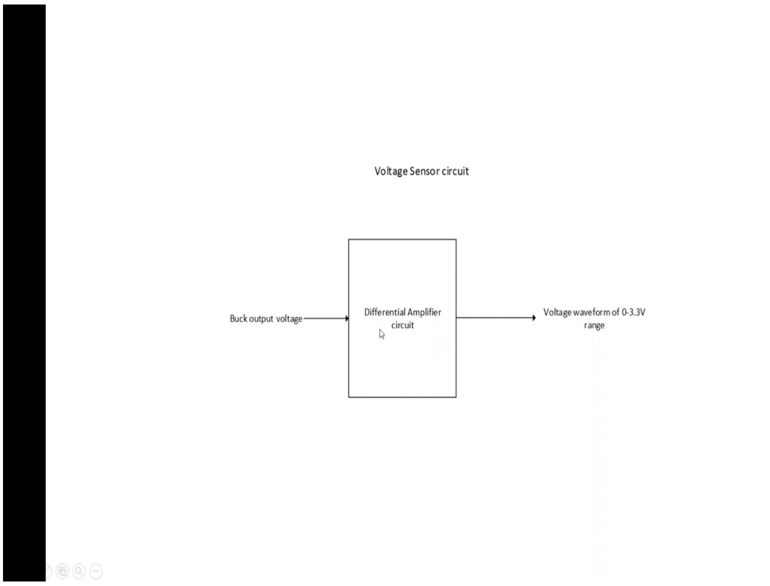

The voltage sensor circuit that we have used here uses the buck output voltage as the input to its differential amplifier circuit. This differential amplifier circuit again provides a voltage waveform it is similar in nature to this input but is in the range of 0 to 3.3 volts.

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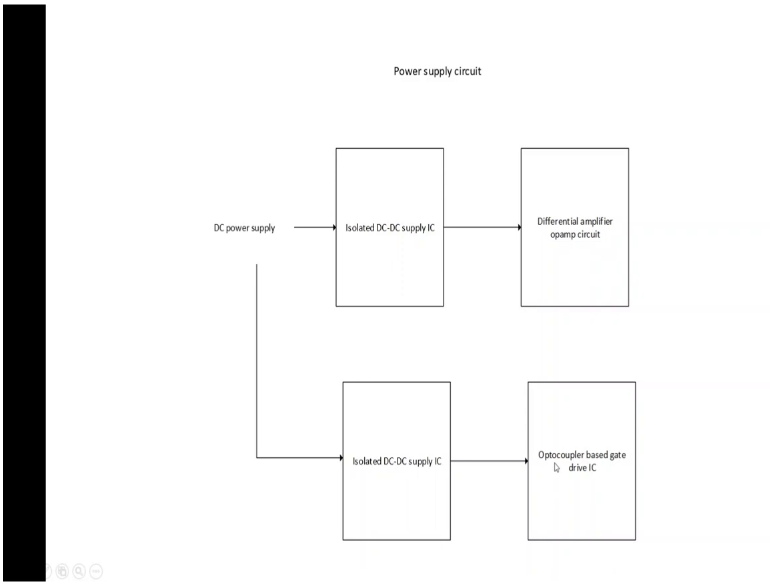

The power supply unit consists of two isolated DC-DC supply ICs. These ICs are supplied by an external power supply. The one of the isolated DC supply provides power to the differential amplifier open circuit while the other provides power to the optocoupler waste heat devices. Let us start with the soldering of a few components on our PCB.

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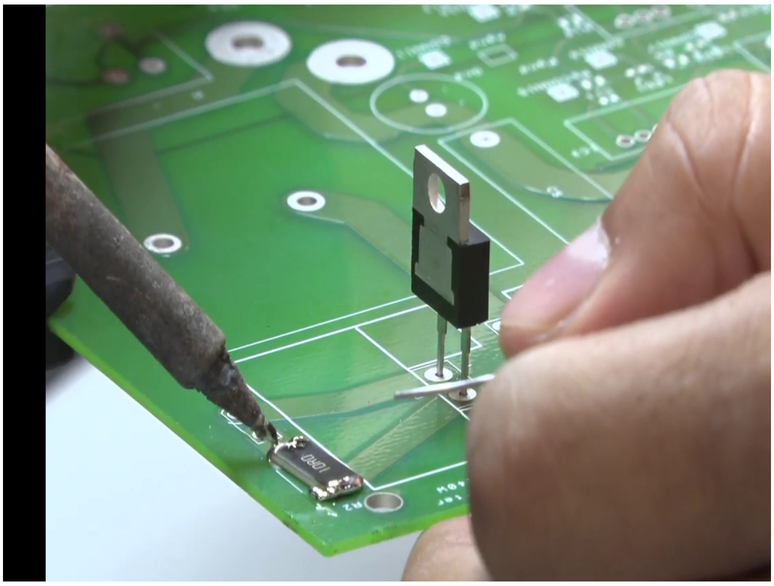

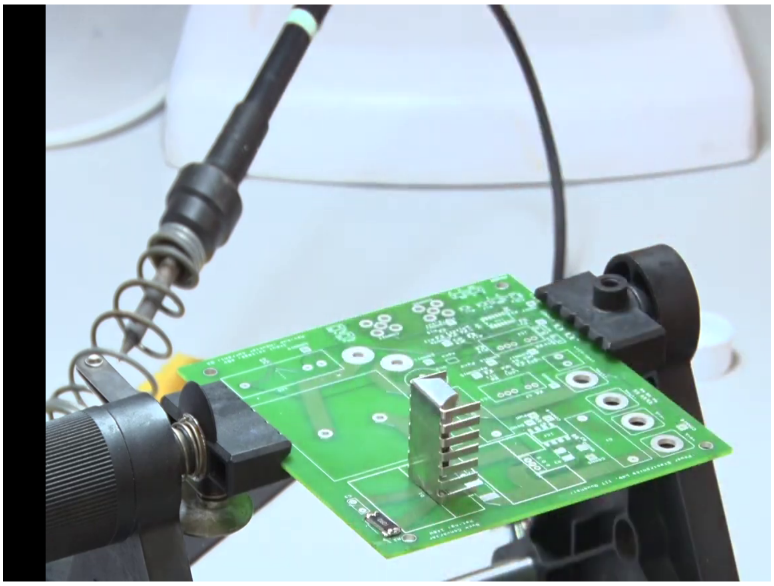

We would now be soldering a through hole device to our PCB. Now, we will be soldering our assembly device on the PCB. Next, we will solder components of the power section and the driver section, we have now soldered the components for the driver and the power section.

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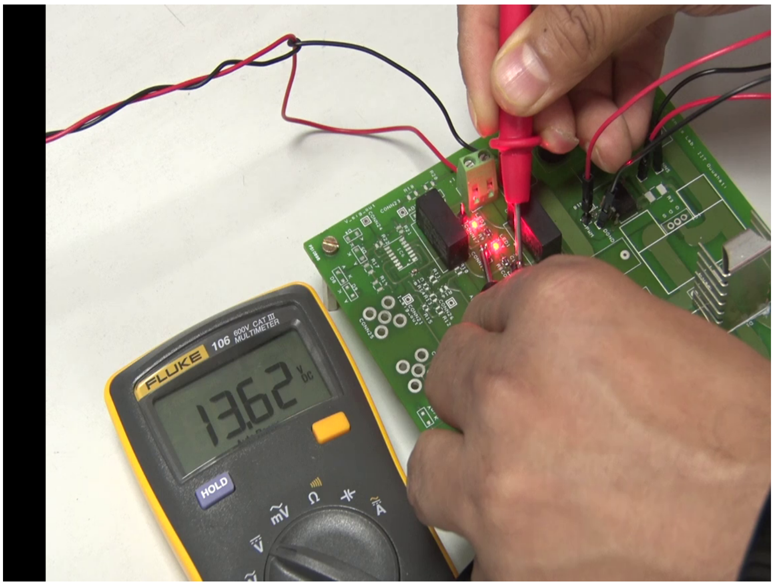

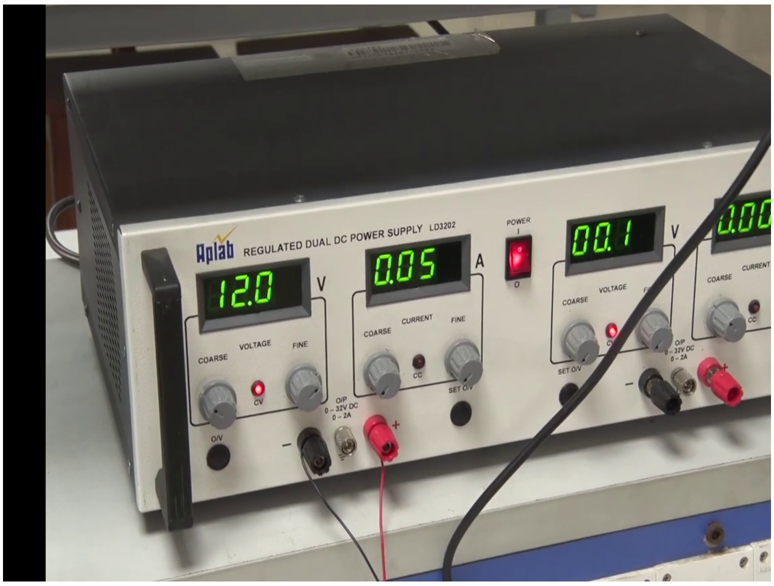

These here are isolated power supply ICs which will be providing power to the open section as well as one of them will be used to drive the MOSFET we will first check the outputs of this ICs, we shall be providing a voltage of 12 volts as input to these ICs. And we are viewing the voltage output of this IC across these two pins. We see that we get a voltage output of 13.6 volts. While we get a voltage output of minus 13.6 volts across these two pins. So, these isolated DC supply ICs are working properly.

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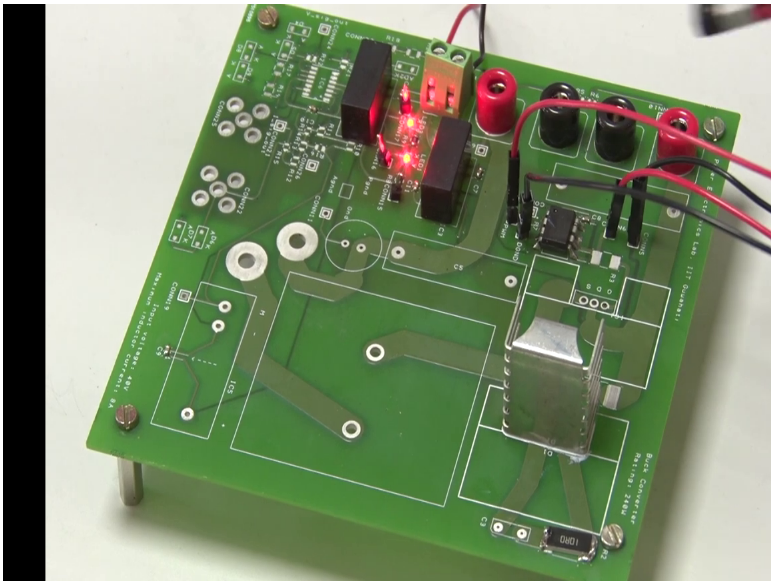

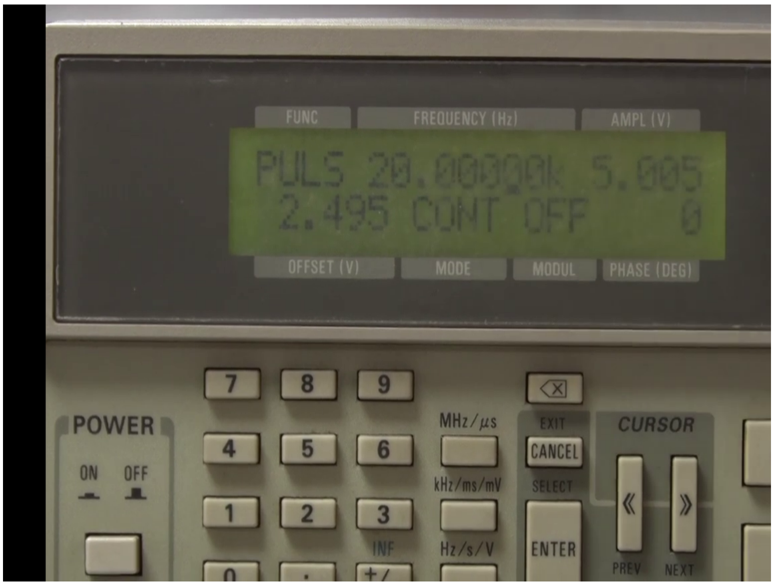

Now, we shall be checking the output of this optocoupler IC we shall provide an input signal from our function generator and then see whether we are getting a proper output or not. Now, to test our gate drive IC we will be providing a pulse waveform of 20 kilohertz using our function generator.

This waveform is been given as input to our optocoupler gate drive IC that waveform will be viewed in a oscilloscope and the output from this gate drive IC will also be viewed in our oscilloscope.

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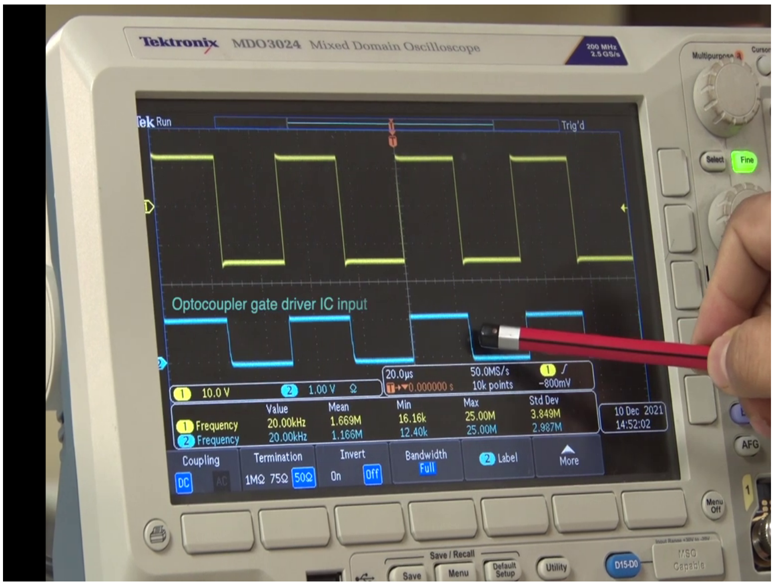

Both these waveforms are fed in channel 1 and channel 2 of our oscilloscope. So, here we can see that these two waveforms are visible on the oscilloscope. This first waveform is the waveform that has been given as input to our optocoupler gate drive IC, while the second waveform is a waveform that we get as output from optocoupler IC, so, our gate drive IC is working properly.

Now, we have soldered the various components of the voltage sensing circuit and the current sensing circuit. We shall now be testing the circuits one by one.

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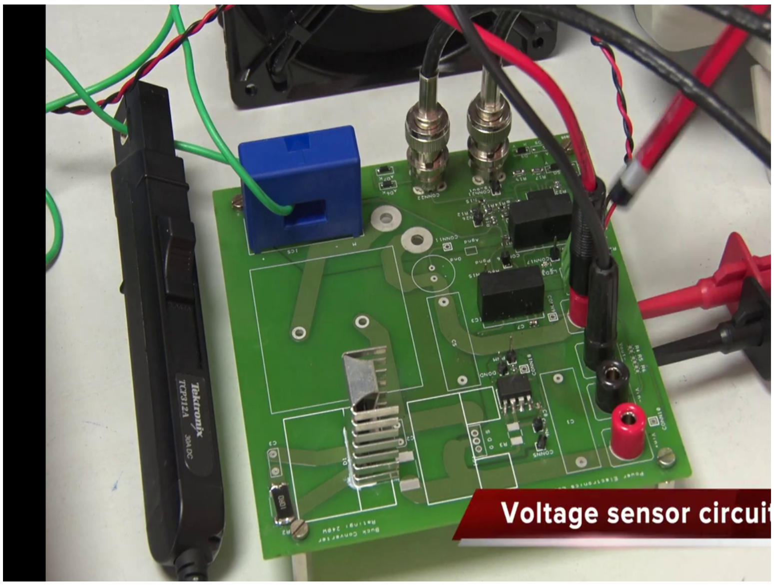

As we are yet to fix the various components of the buck main circuit. So, to test the voltage sensing part, we will be providing an external voltage from the DC power supply to this banana connectors, we shall now be sensing the voltage input that we are giving to a voltage sensing part in these banana connectors using these differential probes, also the output for voltage sensor part is taken from this BNC plugs.

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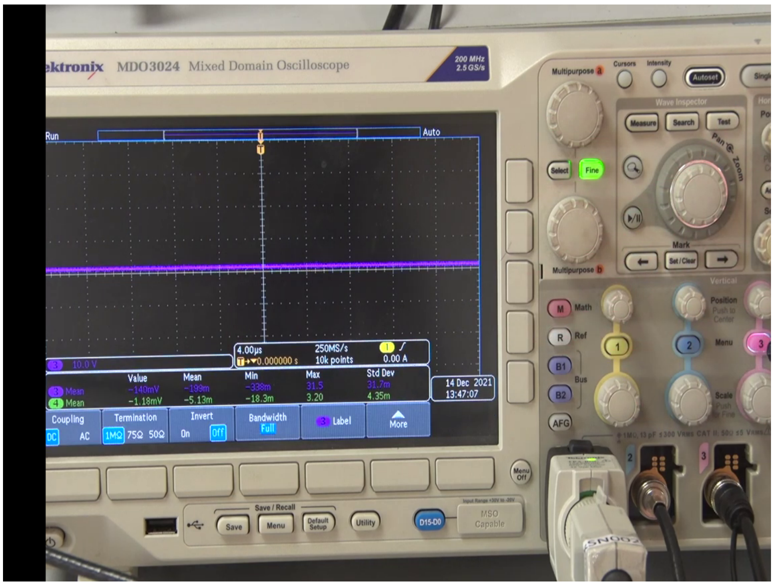

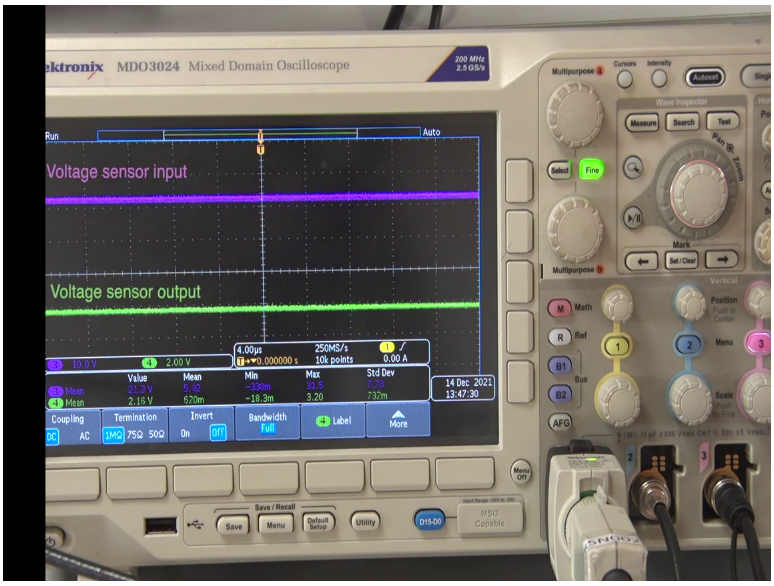

So in this oscilloscope, the channel 3 is the voltage that we are giving as input to the voltage sensing part and this channel 4 is the voltage that we are giving as output from our voltage sensing part. Now, as we increase the voltage input, we see that the corresponding output for voltage sensor is also increasing. So, we can see that for a voltage input of 21.9 volts, we are getting a voltage of 2.22 volts as the output. Our main goal is that the voltage input that we are giving should give a voltage output in the range of 0 to 3.3 volts.

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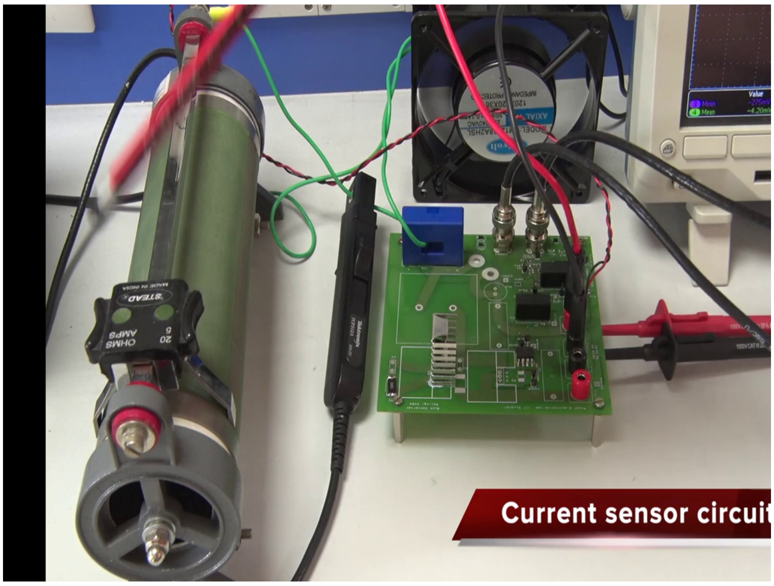

Now, to test the current sensing part, we shall be flowing the current through an external load which is supplied power by our DC voltage source. This current data is flowing through this load is measured by this current probe that we are viewing in the oscilloscope. Also the output from our current sensor is taken from this BNC plug and is viewed in the oscilloscope.

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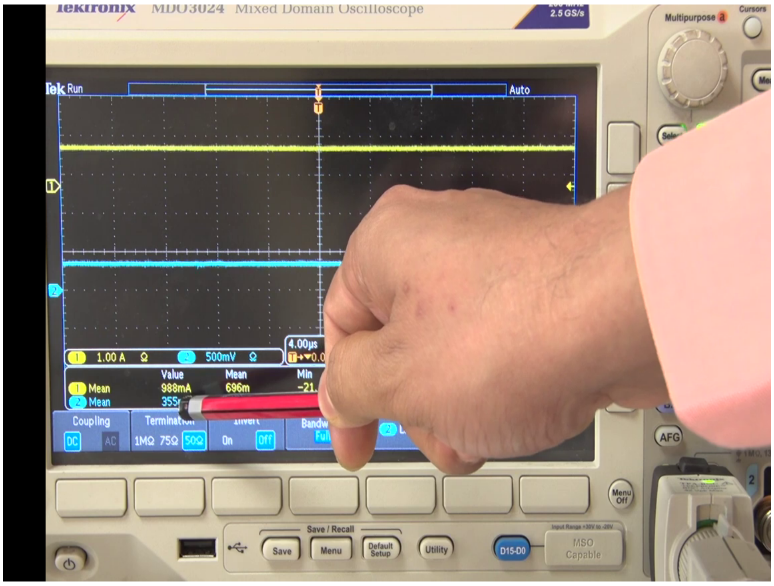

So, the channel 1 here is the current that is flowing to the input for LM sensor. While this channel to hear that we will be doing the oscilloscope is the output for our current sensor part. We now see that as the current is an increase in the circuit, we get an increase in the output of a current sensor also for a current of around 1 ampere flowing through the circuit, we get an output of around 350 millivolt as output in our current sensing part. So, we can see that for various changes in our current input, we are getting corresponding changes in our current sensing part output.

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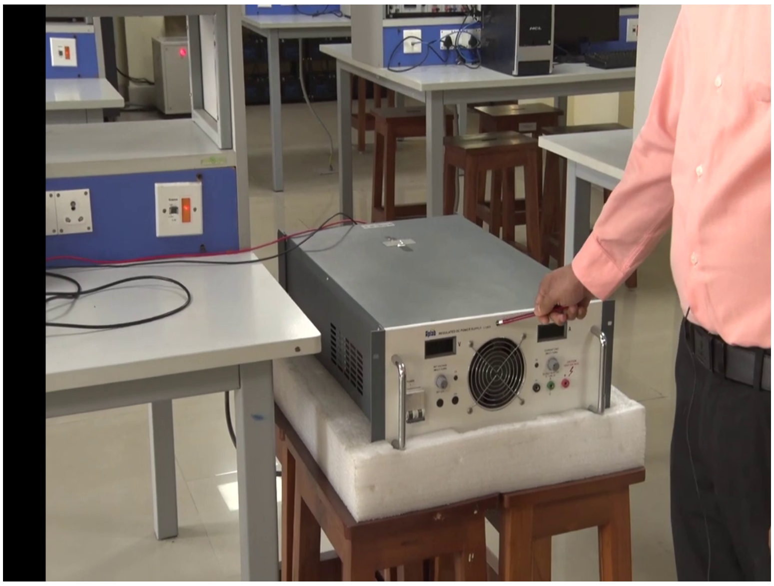

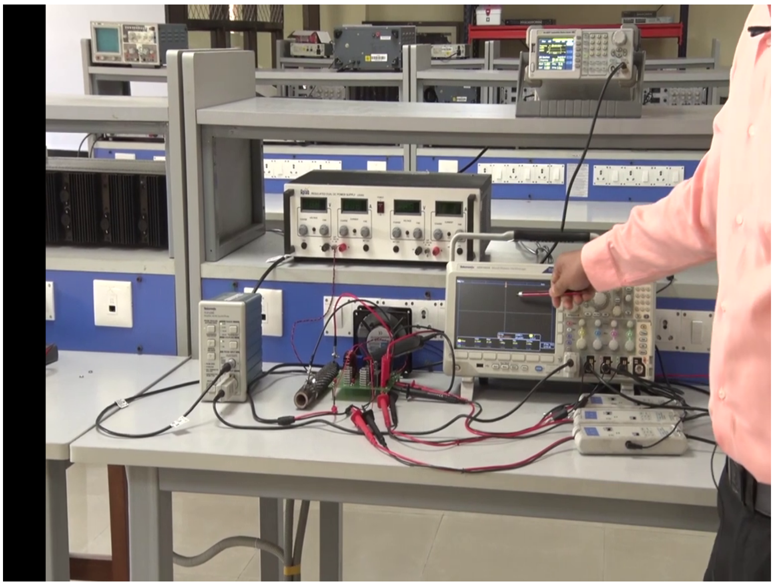

We have now soldered all the components of the buck converter and shall be testing it under load. The voltage input supply to the buck converter will be provided using this DC power supply. Also the opamp as well as the optocoupler gate drive IC will be supplied power using this DC supply. The various current and voltage waveforms from this buck converter shall be viewed in this oscilloscope. And the PWM pulse shall be provided using this function generator.

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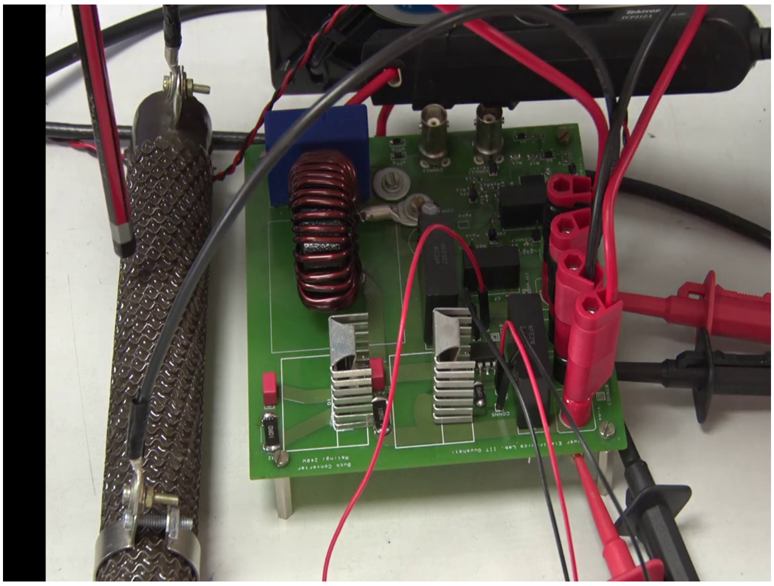

We will be viewing the voltage input by these differential probes that are placed across these banana connectors. Also, the voltage output can be viewed from these banana connectors using these differential probes. The current that is flowing through the inductor is viewed in the oscilloscope using this clamp type current probe and the PWM pulses that we are providing in the optocoupler gate drive IC are seen by this pins, this here is the load which we will be placing across the output of the buck converter.

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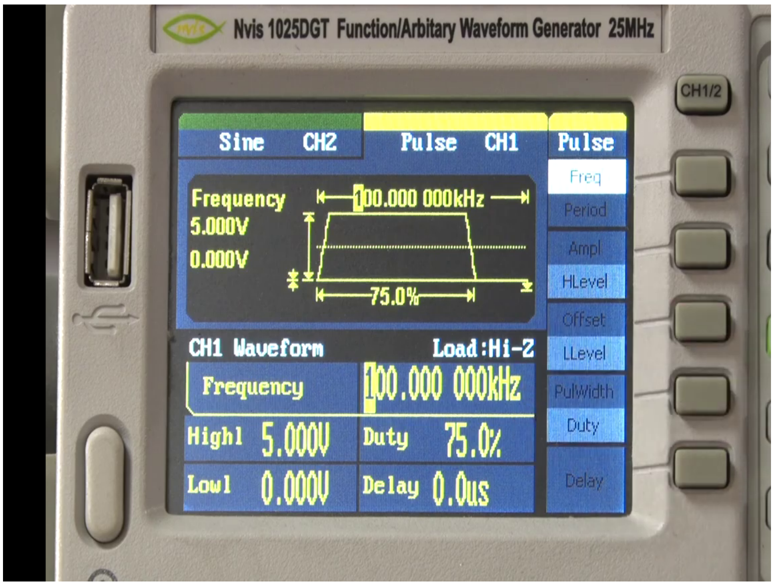

Using this function generator, we will be providing the PWM pulse that is required in optocoupler gate drive IC here we are giving a frequency of 100 kilohertz with a pulse amplitude of 5 volts and duty ratio of 75 percent.

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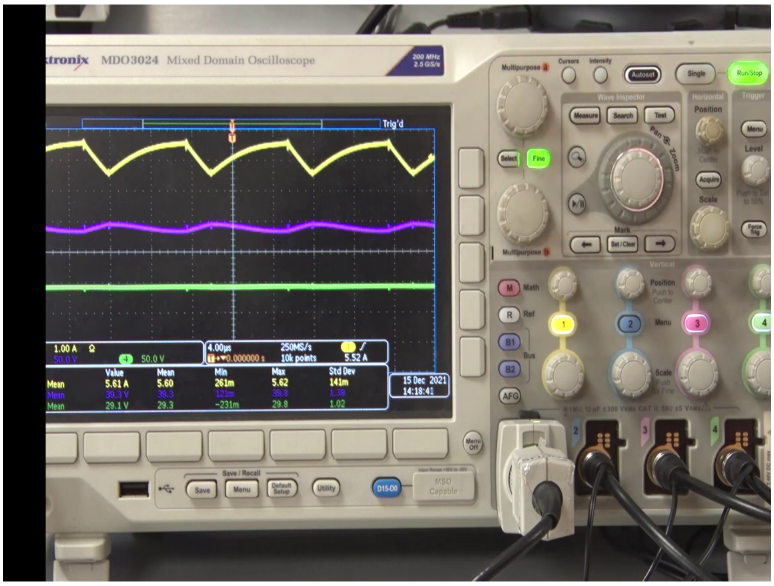

Now in this oscilloscope, this channel 1 will show us the current that is flowing to the inductor of the buck converter, this channel 2 will show us the PWM pulse that is given as input to the optocoupler gate drive IC, this channel 3 will show us the voltage input to the buck converter, and this channel 4 will show us the voltage output of the buck converter.

Now, let us start the circuit. Now, this here is the PWM pulse that is coming out of the optocoupler gate drive IC. We shall now view the voltage output the voltage input and the current that is flowing through the buck converter. Now, this here is the inductor current waveform of the buck converter the mean value of the inductor current is 5.61 amperes, this voltage waveform is the buck input voltage waveform, its mean value is 39.4 volts and this waveform is the buck output waveform output voltage waveform its value is 29.5 volts.

So, the power output that we are getting from this buck converter is around 160 watts. So, in this video we have seen the testing and operation of a buck converter. Thank you.