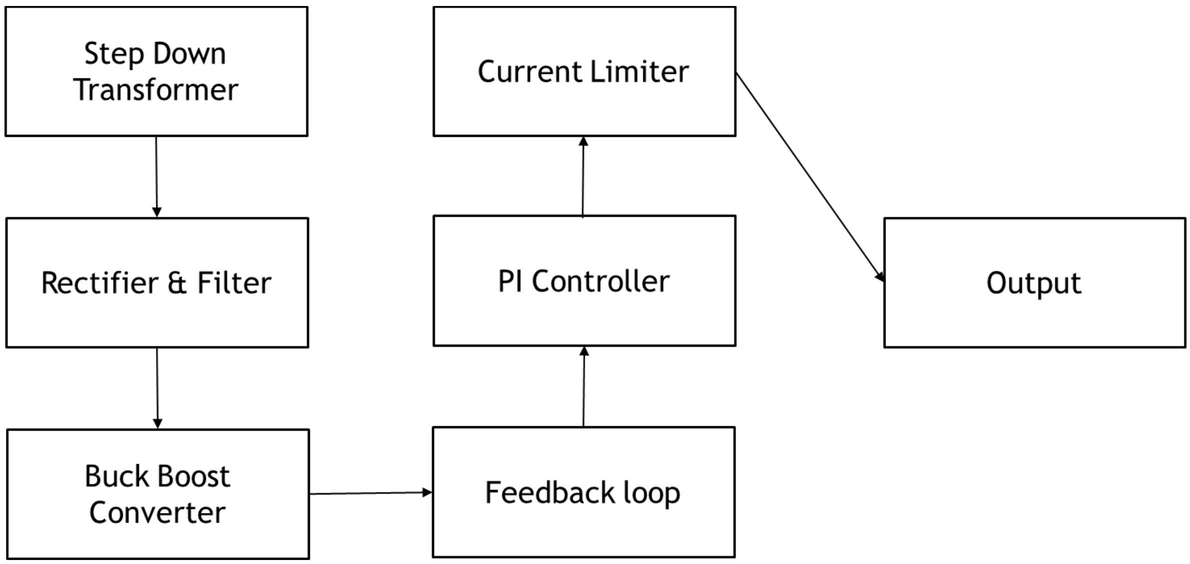
Objective:

The main goal of this project is to produce a Laboratory Variable DC Power Supply. A variable DC power supply is a device where we can easily change the output voltage and also supply enough current to the load. The voltage is regulated irrespective of load & line variation

Every power supply has an input or supply power that it converts to meet the demand from the electrical load using various methods. Even if the load demand current or supply power varies, power supplies are said to be regulated when the output voltage or current is kept constant. To achieve this goal, we will implement and design a complete full circuit.

This is a typical laboratory dc supply which can supply upto 50V & maximum current rating is 30 A.

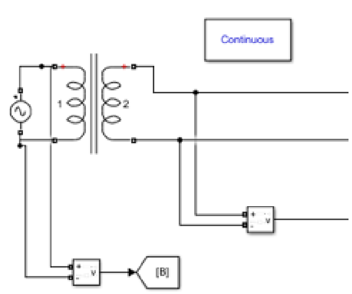
Project Overview:



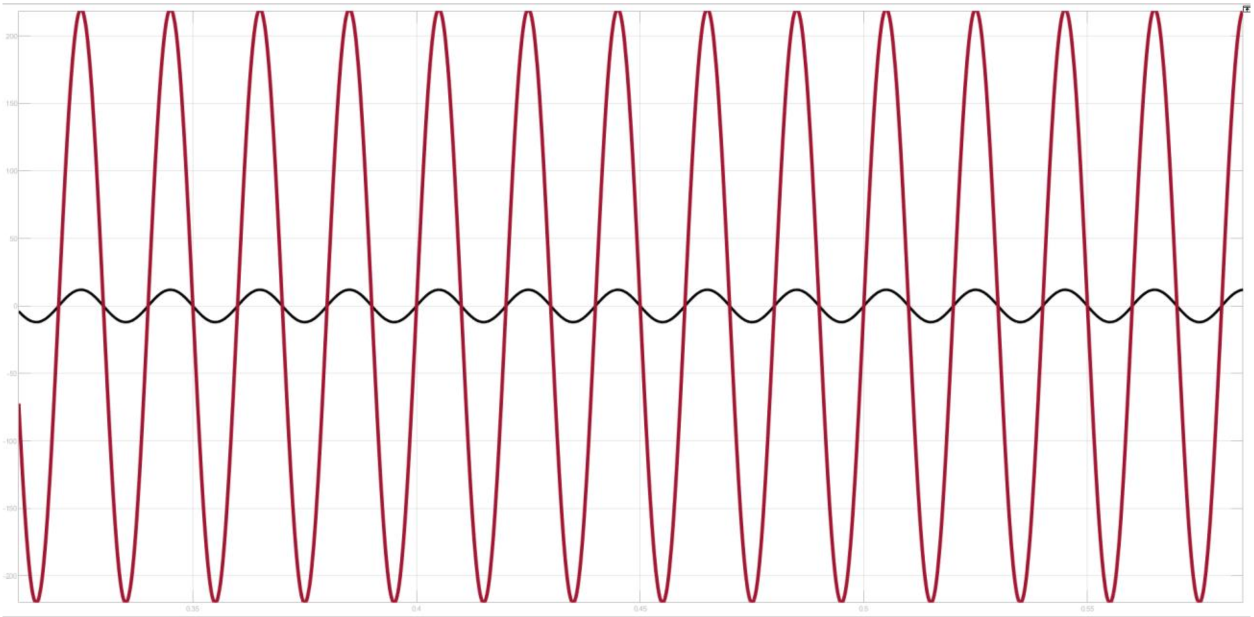
- **Voltage Step-Down:**

A step-down transformer converts high voltage (HV) and low current from the transformer's primary side to low voltage (LV) and high current on the secondary side.

We used a transformer with a 1A current rating and a 12 V output voltage to step down the voltage from 220V to 12 V..



Transformer output:

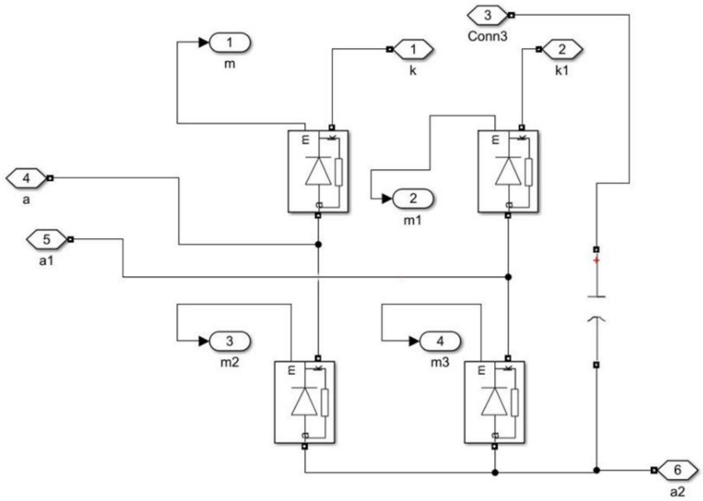


The brown sinusoidal wave shape represents input 220-volt ac transmission line which was in primary side of transformer. The tiny middle BLACK wave shape represents output of transformer which is 12-volt ac.

We used an ideal transformer for Simulink so that we got a perfect 12 volt ac in the output line. But practically transformer losses are present so this transformer losses reduce output voltage from 12-volt ac.

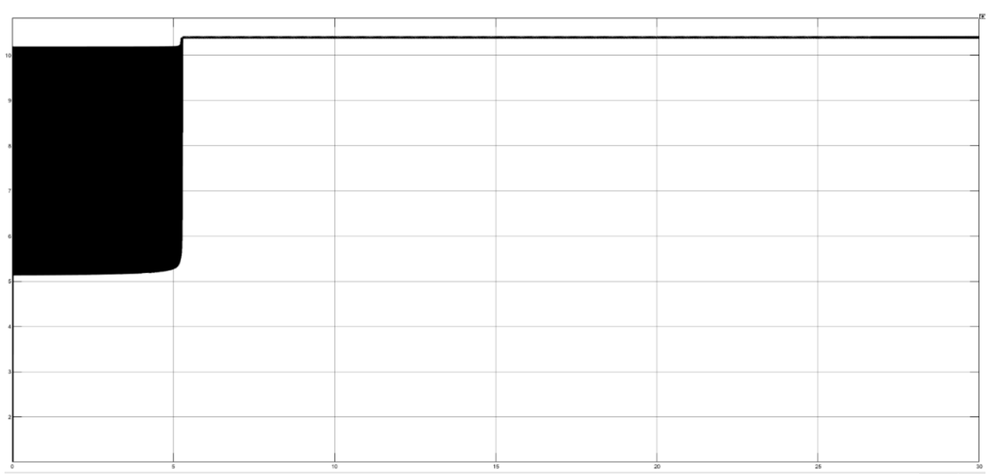
Rectification:

Rectification is the process of turning an alternating current waveform into a direct current waveform, i.e., creating a new signal that has only a single polarity. We used a full wave bridge rectifier to rectify our transformer output voltage.



When an AC signal is applied across the bridge rectifier, during the positive half cycle, terminal A becomes positive while terminal B becomes negative. This results in diodes D1 and D3 to become forward biased while D2 and D4 become reverse biased. During the negative half-cycle, terminal B becomes positive while the terminal A becomes negative. This causes diodes D2 and D4 to become forward biased and diode D1 and D3 to be reverse biased. The capacitor at the full-wave bridger rectifier smooth the pulsating DC and reduce the ripples.

<u>Output of full wave bridge rectifier:</u>



BUCK-BOOST Converter:

The buck-boost converter is a type of DC-to-DC converter (also known as a chopper) with an output voltage magnitude greater than or less than the input voltage magnitude. The output voltage of the magnitude depends on the duty cycle.

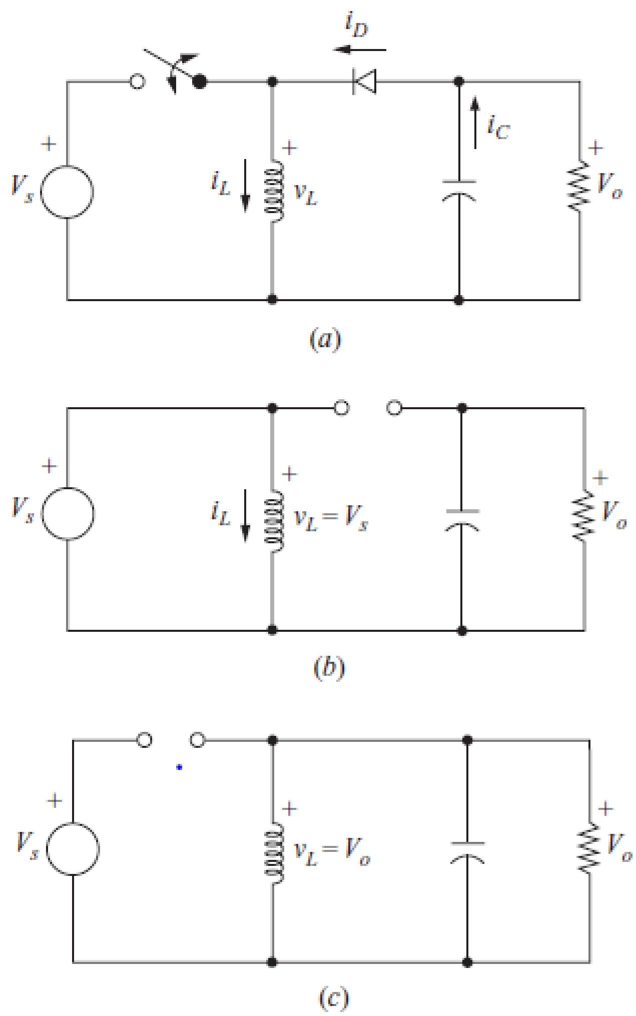


Figure 6-11 Buck-boost converter. (*a*) Circuit; (*b*) Equivalent circuit for the switch closed; (*c*) Equivalent circuit for the switch open.

Analysis for the Switch Closed When the switch is closed, the voltage across the inductor is

$$v_L = V_s = L\frac{di_L}{dt}$$

$$\frac{di_L}{dt} = \frac{V_s}{L}$$

The rate of change of inductor current is a constant, indicating a linearly increasing inductor current. The preceding equation can be expressed as

$$\frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_s}{L}$$

Solving for Δi_L when the switch is closed gives

$$(\Delta i_L)_{\text{closed}} = \frac{V_s DT}{L} \tag{6-45}$$

Analysis for the Switch Open When the switch is open, the current in the inductor cannot change instantaneously, resulting in a forward-biased diode and current into the resistor and capacitor. In this condition, the voltage across the inductor is

$$v_L = V_o = L\frac{di_L}{dt}$$

$$\frac{di_L}{dt} = \frac{V_o}{L}$$

Again, the rate of change of inductor current is constant, and the change in current is

$$\frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1 - D)T} = \frac{V_o}{L}$$

Solving for Δi_L,

$$(\Delta i_L)_{\text{open}} = \frac{V_o(1 - D)T}{L} \tag{6-46}$$

For steady-state operation, the net change in inductor current must be zero over one period. Using Eqs. (6-45) and (6-46),

$$(\Delta i_L)_{\text{closed}} + (\Delta i_L)_{\text{open}} = 0$$

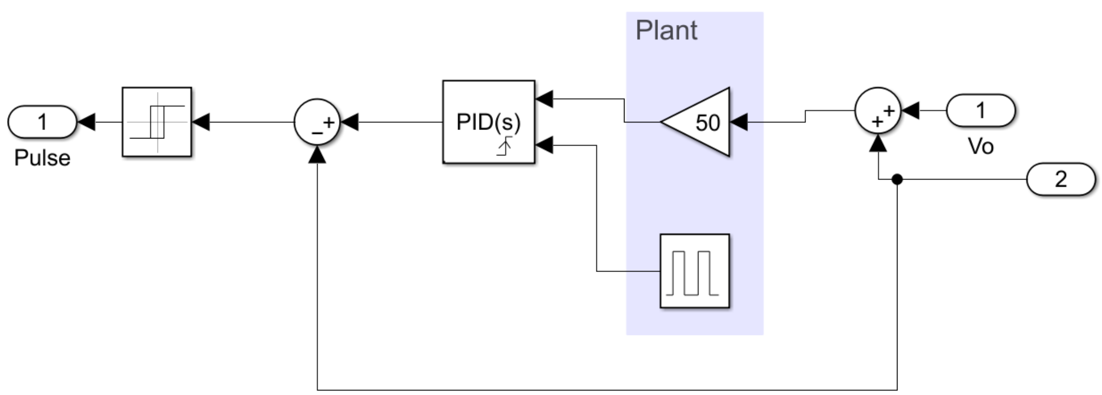
$$\frac{V_s DT}{L} + \frac{V_o(1 - D)T}{L} = 0$$

Solving for V_o,

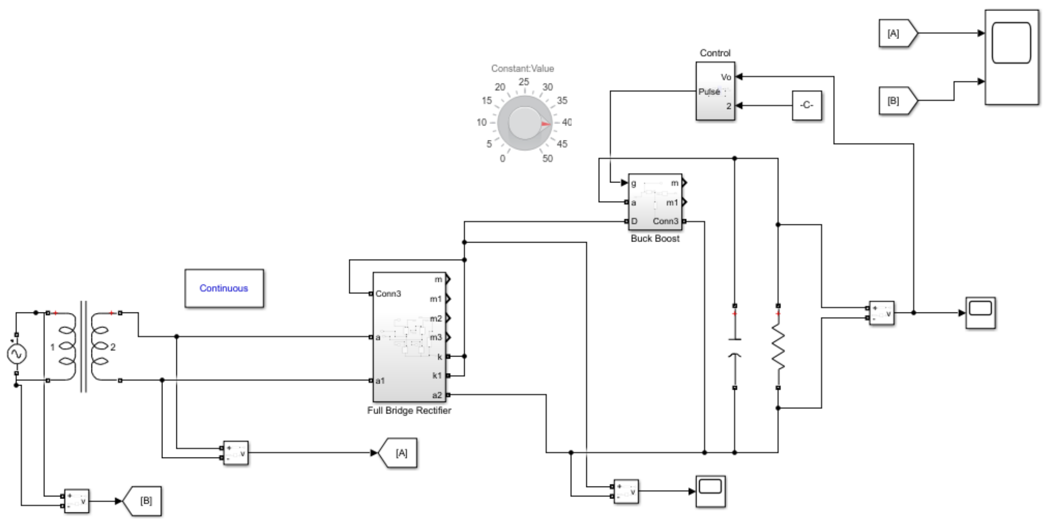
$$\boxed{V_o = -V_s\left(\frac{D}{1-D}\right)} \qquad (6\text{-}47)$$

PID Controller:

The MOSFET used in the buck-boost converter requires a gate signal for switching. The PWM block in SIMULINK provides the gate signal which is connected to a knob to control the duty cycle. The duty cycle is automatically taken care of by the integrator via a feedback path & necessary reference voltage. The relay block allows its output to switch between two values.

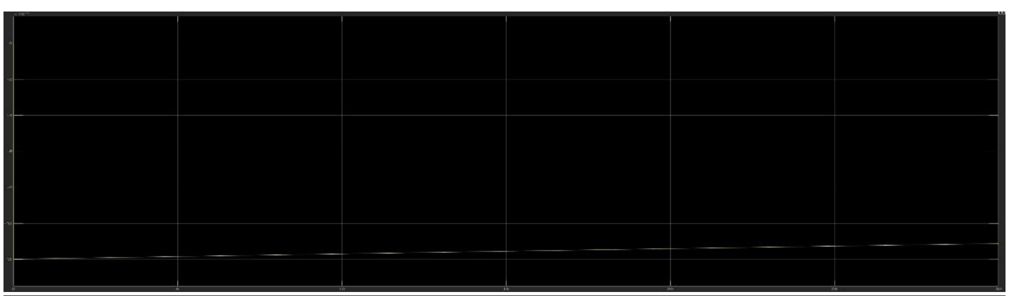


Full circuit diagram for a Laboratory Variable DC Power Supply is:

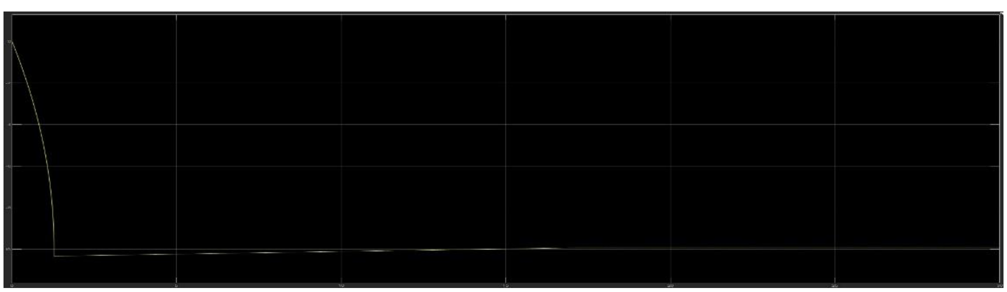


Outputs varying the voltage reference of control knob

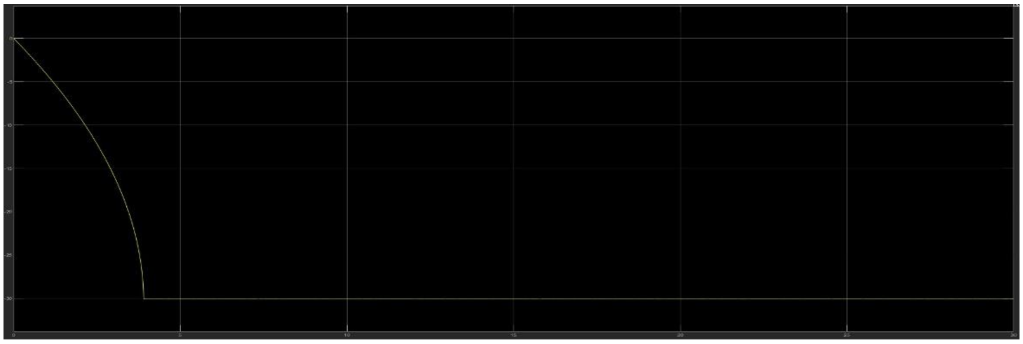
For vref = 0V



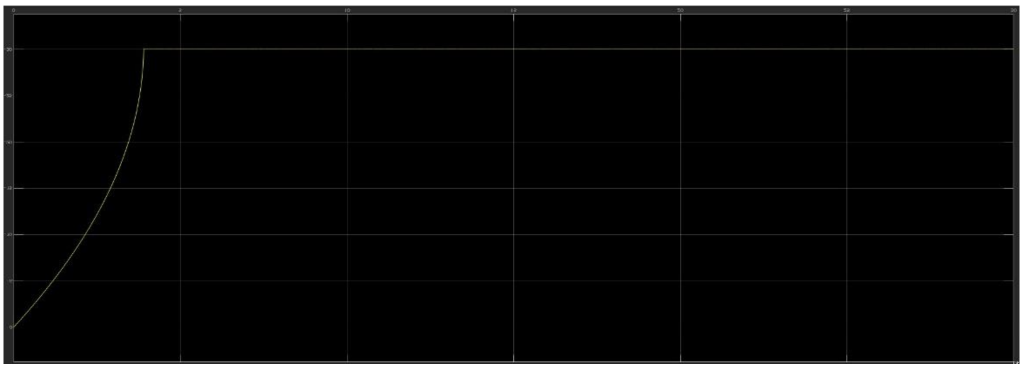
For vref = 10V



For vref = 20V



For vref=30V



Current Limiter:

The current limiting circuit, as the name implies, restricts the current from the regulated power source to a maximum quantity defined by the circuit, preventing serious damage to the both power supply and the circuit being powered.

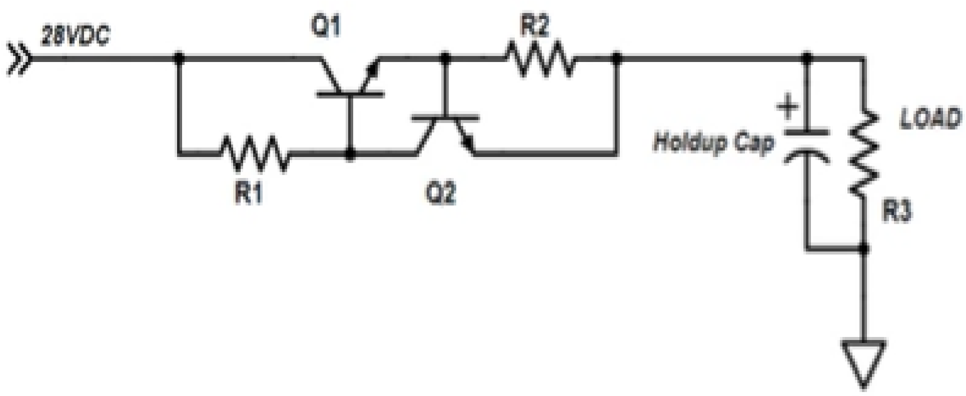


Fig: Current limiting Circuit

The current limiting circuit we used in our project is shown above. This is an active current limiting circuit. To actively limit the current to the holdup capacitors, it will put the holdup capacitor in line with the decoupling capacitor effectively filtering the low frequency current demand noise using the above circuit and its dynamic resistance R2. The holdup capacitance can be changed for a set amount of time as per our need.

Hardware Implementation vs. Simulation:

For simulation and circuit implementation, we used MATLAB Simulink. Due to practical disruptions and various types of external losses, the simulation and hardware implementation results differ.

- The output voltages in hardware would not have been as good as they were in simulation.
- In a hardware implementation, abruptly turning the potentiometer would generate a huge spike in the output current, perhaps causing component overheating.
- A SG3524/555 Timer or comparable ICs would be required to implement the PWM signal.
- If the capacitors are not discharged properly, the output voltages may differ from what is expected.

Limitations:

- No voltage regulating IC's in Simulink
- Integration between simscape & non-simscape elements
- Op-amps and transistors are not available in physical module
- PID couldn't be tuned automatically

Applications

- ▶ Regulation range of output voltage
- ▶ Stability Degree
- ▶ Ripple Voltage control
- ▶ Overcurrent Protection

Further Improvements: Include a CC knob which will imply a variable loading system to supply necessary current to the output.