EXPLORATORY PROJECT

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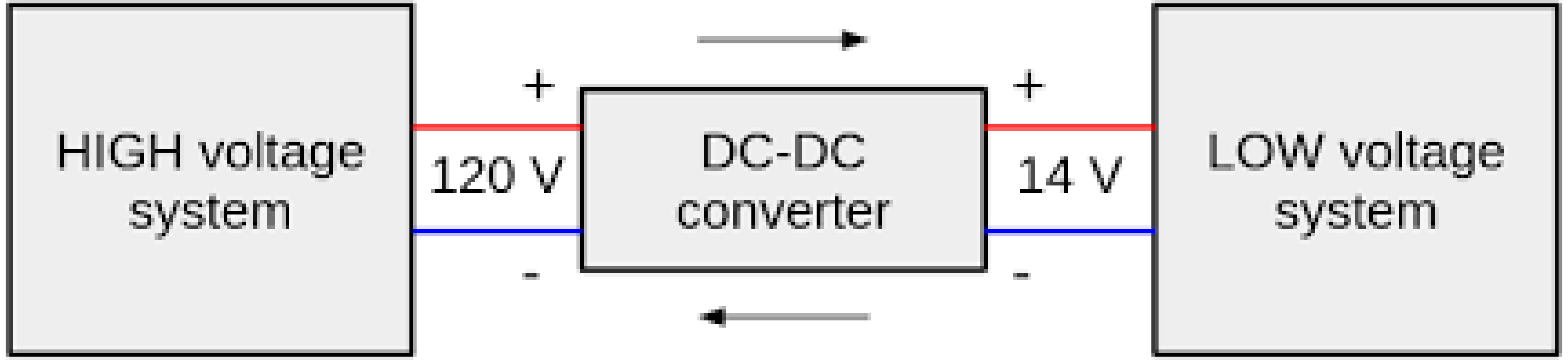
PROBLEM STATEMENT

TO IMPLEMENT CLOSED LOOP CONTROL FOR A BOOST CONVERTER

DC-DC CONVERTER



Dc-dc converters are power electronic circuits that convert a dc voltage to a different dc voltage level, often providing a regulated output.

These circuits help distribute and manage power properly to provide each power consumer with appropriate voltage or current level.

Three main types of DC-DC converters are:
Step-down or Buck converters
Step-up or Boost converters
Universal or Buck-Boost converter

They also protects highly sensitive sub-circuits from damage.

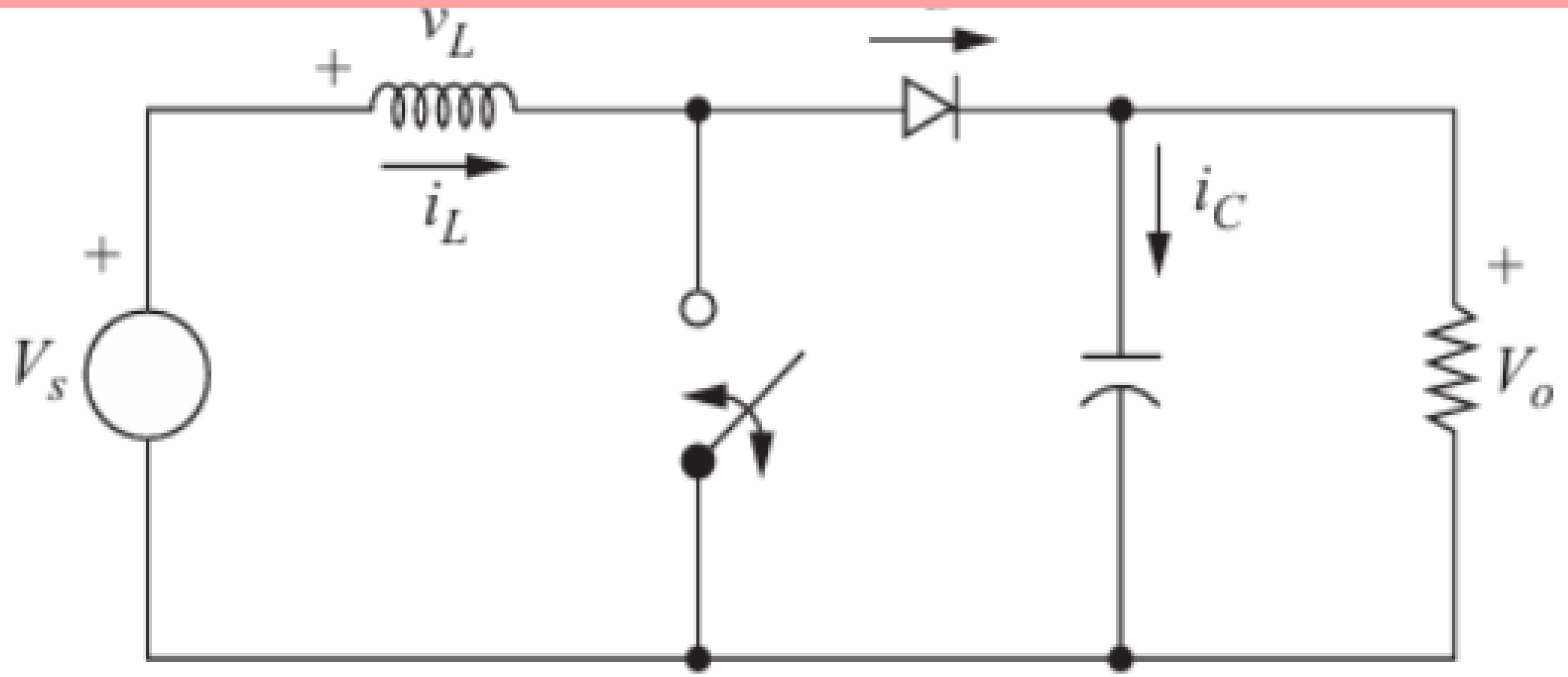
On top of that, in portable devices, they can raise voltage when the batteries are partially lowered or there is not enough room for accomodation of more batteries, making power consumption more efficient.

Since our project focusses on using a Proportional Integral controller for closed loop control of Boost converter, we would be discussing the latter in greater detail.

BOOST CONVERTER

Step-up DC-DC Converters, also called DC-DC boost converters, can produce voltage higher than the input voltage provided. Boost converters are used wherever we cannot provide a high enough input voltage with batteries or there is not enough space for accommodating more batteries.

These converters find applications in hybrid vehicles and lighting systems that use portable lighting devices, energy-saving lamps, etc.



Circuit Diagram for Boost Converter

The **Boost converter** has two modes of operation :

Mode I : Switch is ON, Diode is OFF

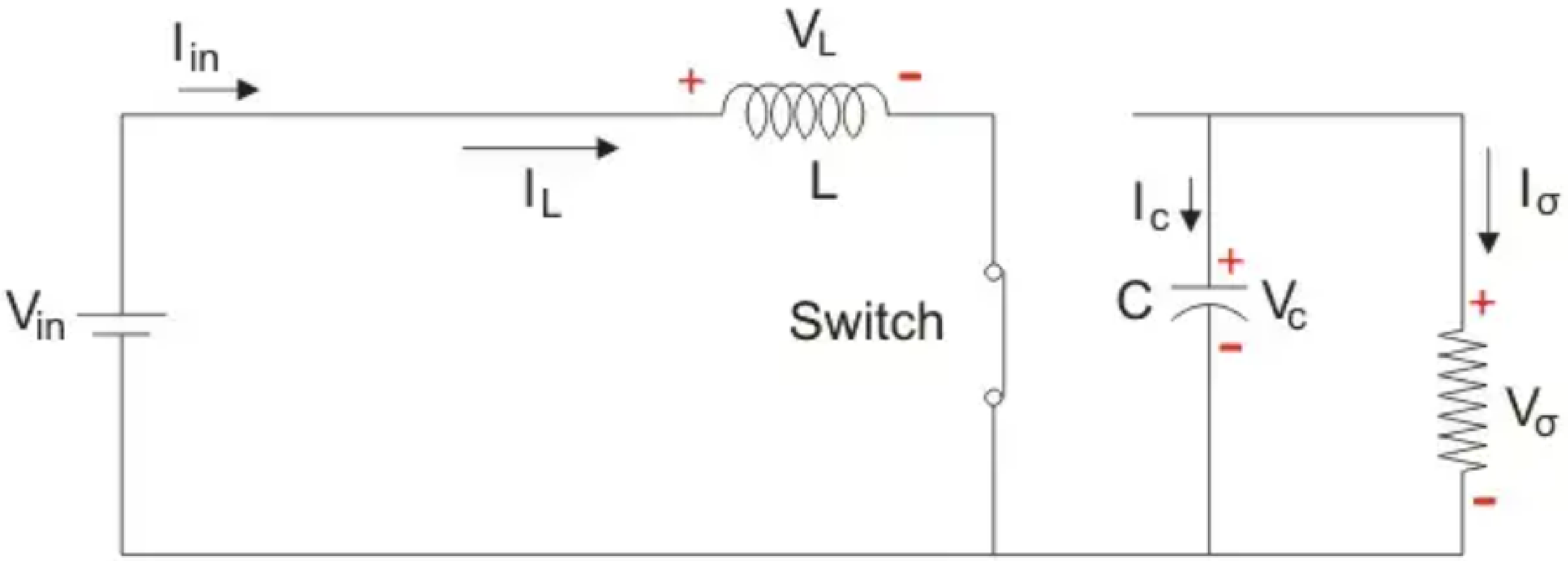
The Switch is ON and therefore represents a short circuit ideally offering zero resistance to the flow of current so when the switch is ON all the current will flow through the switch and back to the DC input source.

the time period, T,

$$T = T_{ON} + T_{OFF}$$

and the switching frequency,

$$f_{switching} = \frac{1}{T}$$



Let us now define another term, the duty cycle,

$$D = \frac{T_{ON}}{T}$$

Let us analyze the Boost converter in steady state operation for this mode using KVL

$$\therefore V_{in} = V_L$$

$$\therefore V_L = L\frac{di_L}{dt} = V_{in}$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_{in}}{L}$$

Since the switch is closed for a time $T_{ON} = D_T$ we can say that $\Delta t = DT$.

$$(\Delta i_L)_{closed} = \left(\frac{V_{in}}{L}\right) DT$$

Mode 2 : Switch is OFF, Diode is ON

operation for Mode II using KVL

$$\therefore V_{in} = V_L + V_o$$

$$\therefore V_L = L\frac{di_L}{dt} = V_{in} - V_o$$

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

Since the switch is open for a time

$T_{OFF} = T - T_{ON} = T - DT = (1-D)T$

we can say that

$\Delta t = (1-D)T$

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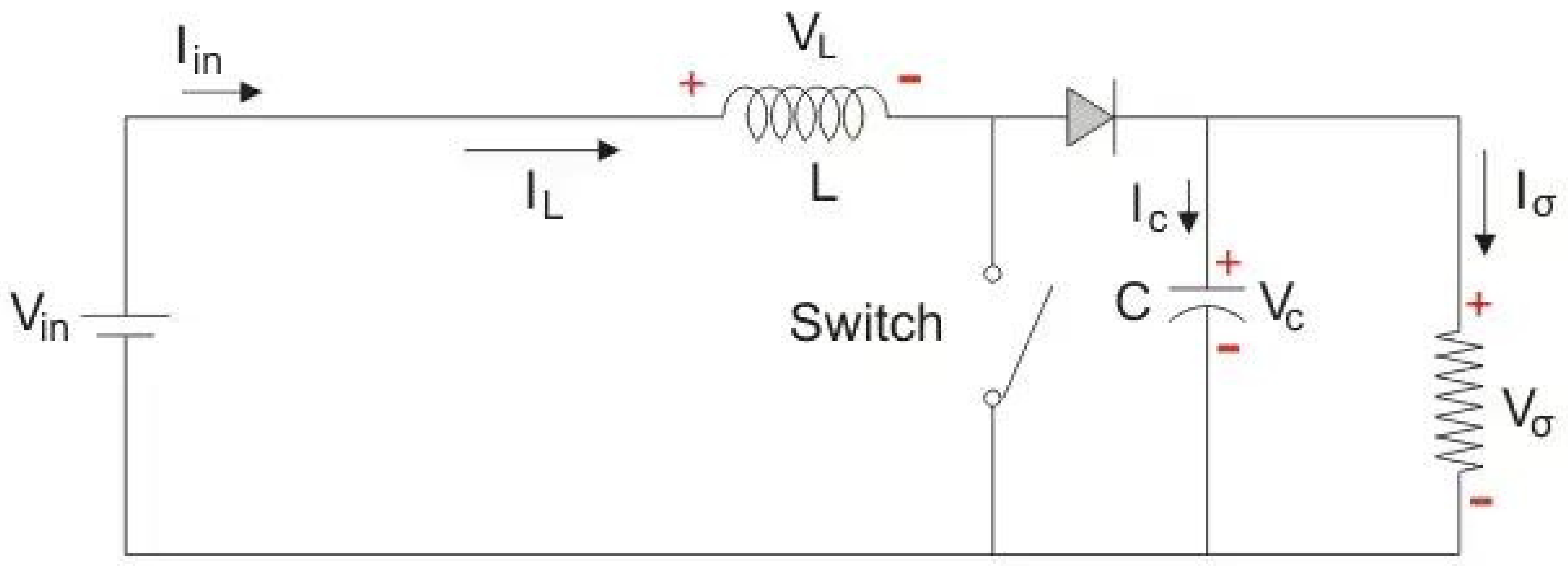

$$(\Delta i_L)_{open} = \left(\frac{V_{in} - V_o}{L}\right)(1-D)T$$

It is already established that the net change of the inductor current over any one complete cycle is zero.

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

$$\left(\frac{V_{in} - V_o}{L}\right)(1-D)T + \left(\frac{-V_o}{L}\right)DT = 0$$

$$\frac{V_o}{V_{in}} = \frac{1}{1-D}$$

Small Signal Analysis of Boost Converter

For the small signal analysis of Boost converter, we take the following assumptions into consideration:

- The switch is closed for time DT and open for (1-D) T, where T is the switching time.
- All components are ideal.
- For the current to be considered constant throughout the operation of the converter, the inductor taken is of large enough value.
- The capacitor is very large, and the output voltage is held constant.

For ON-STATE Condition,

$$V_L = L\frac{di}{dt}$$

$$L\frac{d(i_L+\hat{i_L})}{dt} = (V_s+\hat{V_s})(D+\hat{d}) + \left(1-D-\hat{d}(t)\right)(V_s+\hat{V_s}-V_0-\hat{V_0})$$

$$L\frac{d\hat{i_L}}{dt} = V_s\hat{d}(t) + \hat{V_s}D + (1-D)\hat{V_s} - (1-D)\hat{V_0} - \hat{d}(t)V_s + \hat{d}(t)V_0$$

$$L\frac{d\hat{i_L}}{dt} = \hat{V_s} - (1-D)\hat{V_0} + \hat{d}(t)V_0 \quad \text{——————} \quad \text{(ii-a)}$$

For OFF-STATE CONDITION,

$$C\frac{d(V_0+\hat{V}_0)}{dt} = -\left(\frac{V_0+\hat{V}_0}{R}\right)\left(D+\hat{d}(t)\right) + (I_L+\hat{\imath}_L)\left(1-D-\hat{d}(t)\right)$$

$$-\left(\frac{V_0+\hat{V}_0}{R}\right)\left(1-D-\hat{d}(t)\right)$$

$$= -\left(\frac{V_0+\hat{V}_0}{R}\right) + (I_L+\hat{\imath}_L)\left(1-D-\hat{d}(t)\right)$$

$$= -\frac{V_0}{R} - \frac{\hat{V}_0}{R} + I_L(1-D) - \hat{d}(t)I_L + \hat{\imath}_L(1-D)$$

$$C\frac{d\hat{V}_0}{dt} = -\frac{\hat{V}_0}{R} - \hat{d}(t)I_L + \hat{\imath}_L(1-D) \qquad \text{———————} \quad \text{(ii-b)}$$

From eqs. (ii-a) & (ii-b) Taking Laplace Transform —

$$\hat{\iota}_L(s) = \frac{1}{Ls}\left[\hat{V}_s(s) - (1-D)\hat{V_0}(s) + \hat{d}(s)V_0\right]$$

$$\hat{V}_0(s)\left[Cs + {}^{1}/_{R}\right] = \hat{\iota}_L(s)(1-D) - \hat{d}(s)I_L$$

$$\hat{V}_0(s)\left[Cs + {}^{1}/_{R}\right] = \left[\frac{1}{Ls}\left(V_s(s) - (1-D)\hat{V}_0(s) + \hat{d}(s)V_0\right)\right]\left[(1-D) - \hat{d}(s)I_L\right]$$

Now, Put $\hat{V}_s(s) = 0$

$$\hat{V}_0(s)\left[\frac{1}{R} + Cs + \frac{(1-D)^2}{Ls}\right] = \hat{d}(s)\left[\frac{V_0}{Ls}(1-D) - I_L\right]$$

$$\left.\frac{\hat{V}_0(s)}{\hat{d}(s)}\right|V_{in=0} = \frac{V_0(1-D) - I_L(Ls)}{(1-D)^2 + LCs^2 + \frac{Ls}{R}}$$

DESIGNING PARAMETERS OF OPEN LOOP BOOST CONVERTER

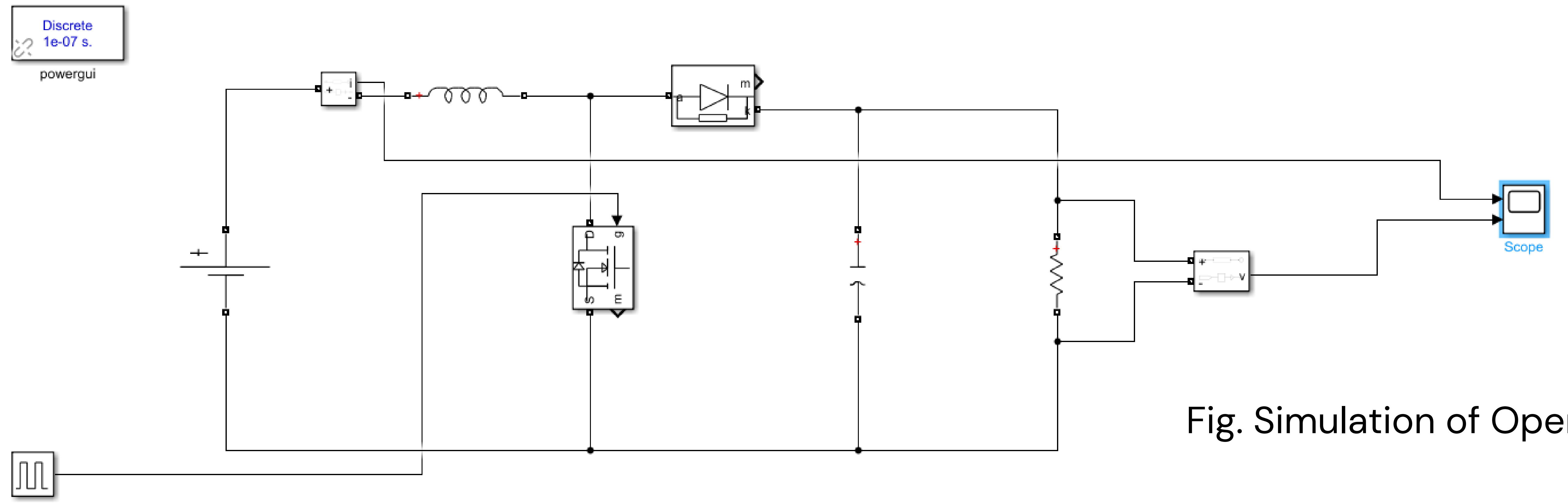

Fig. Simulation of Open Loop Boost Converter

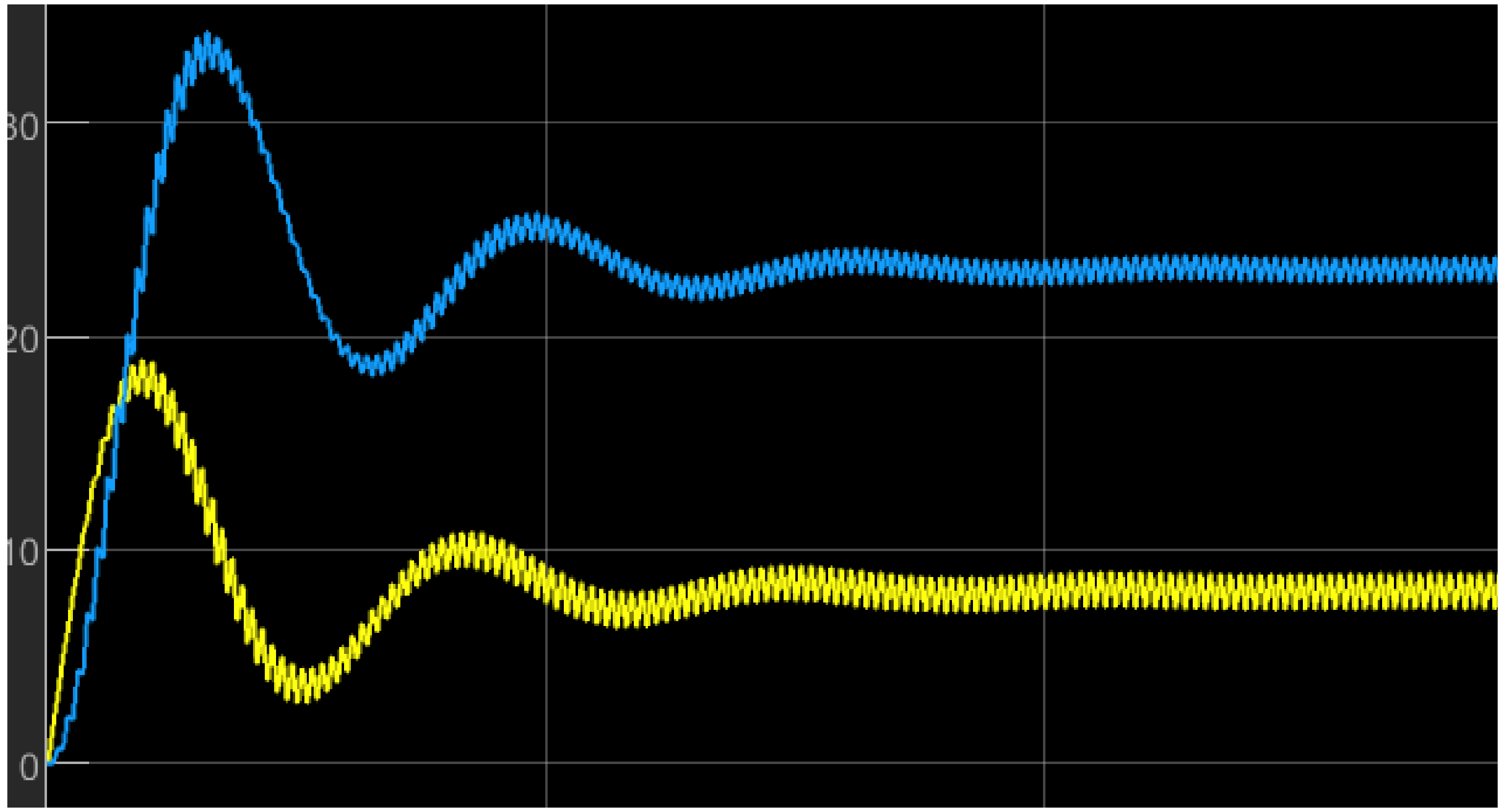

Fig. Output Voltage (blue) and Input Current (yellow)

Input Voltage Vs = 12V
Output Voltage Vo = 24V
Output power Po = 100W
Switching Frequency Fs = 25KHz
Duty cycle D = 50%
Inductance L = 144×10-6 H
Capacitance C = 69.44 ×10-6 F
Resistance R = 5.76 Ω

PROPORTIONAL INTEGRAL CONTROLLER

The use of Proportional Integral controller is made in those industrial applications and control systems where proportional control is necessary to speed up the settling of the output at its steady state value and, further, integral control is required to reduce the steady state error.

The controller is essentially a closed-loop feedback control mechanism that is used to adjust the variable used in the controlling process by manipulating the value of the variable based on the error between the output value and the expected value.

Two terms are used to define the working of a PI controller.
i) Proportional (P)
ii) Integral term (I)

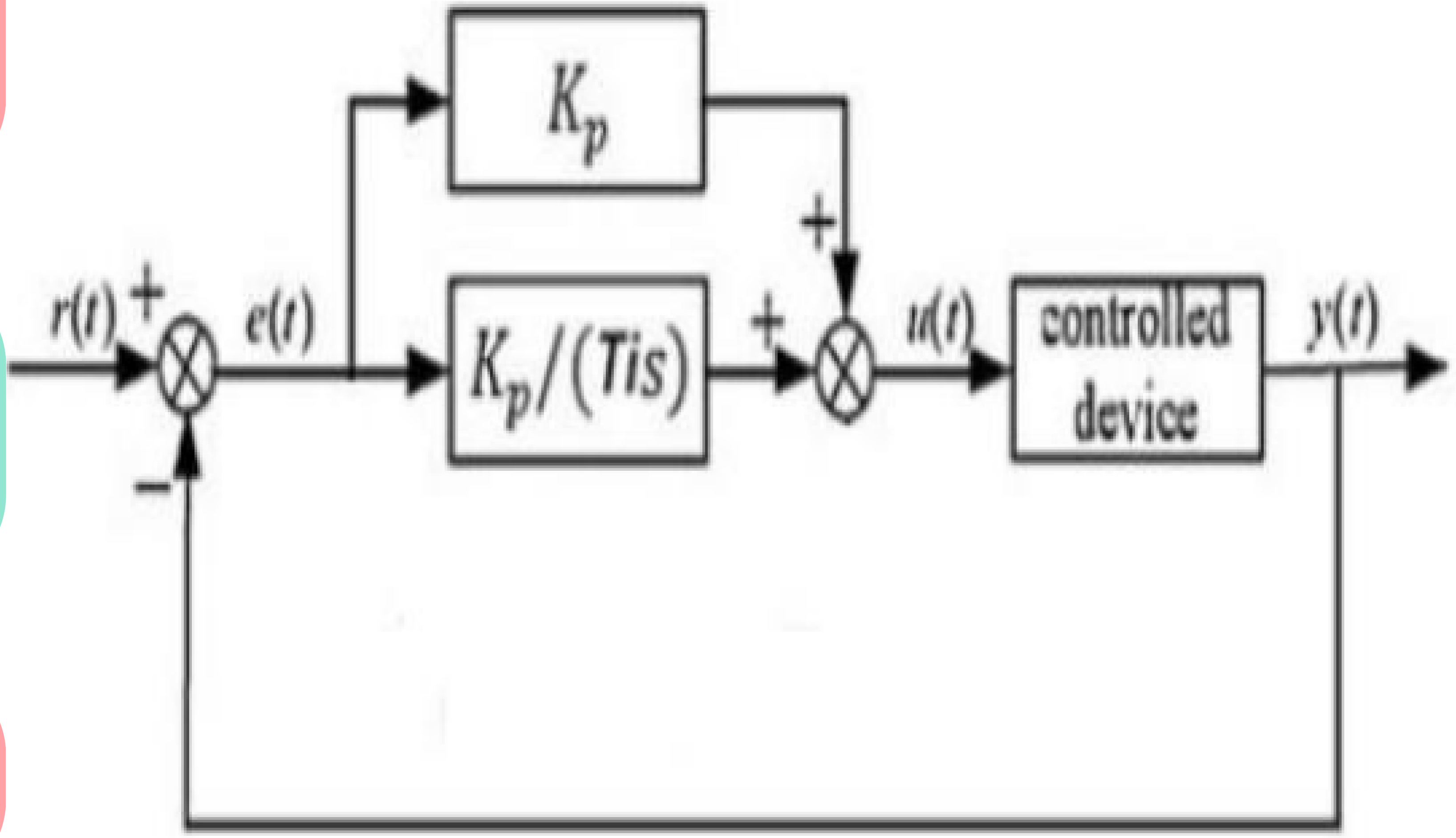

Fig. 3.1. Block Diagram for Proportional Integral Controller

The Proportional controller produces an output which is proportional to the error signal fed back to the controller. There may be a chance of generation of offset. As increase in the gain of the controller keeps on occurring, the system might become unstable. To prevent this from happening, the Integral part of the controller is introduced. It removes the steady state error.

PI CONTROLLER FED BOOST CONVERTER

In the given circuit diagram, we observe that our main components are the PI controller, the Boost converter and the PWM generator.

Any change in the input may lead to changes in the output. To obtain a constant DC voltage as the output, the output generated by the Boost converter is fed to a comparator which compares it with a reference signal. The output given by the comparator is the error signal. The error signal is then given to the PI controller.

The controller generates an output which is compared again with a triangular waveform generated by a pulse width modulation (PWM) generator. The pulses produced thus are used to commute the MOSFET used as the switch i n the Boost converter.

The Proportional Integral controller regulates the output voltage. The PWM generator controls the duty cycle of the MOSFET used. The output voltage is continuously controlled to produce a stable output voltage.

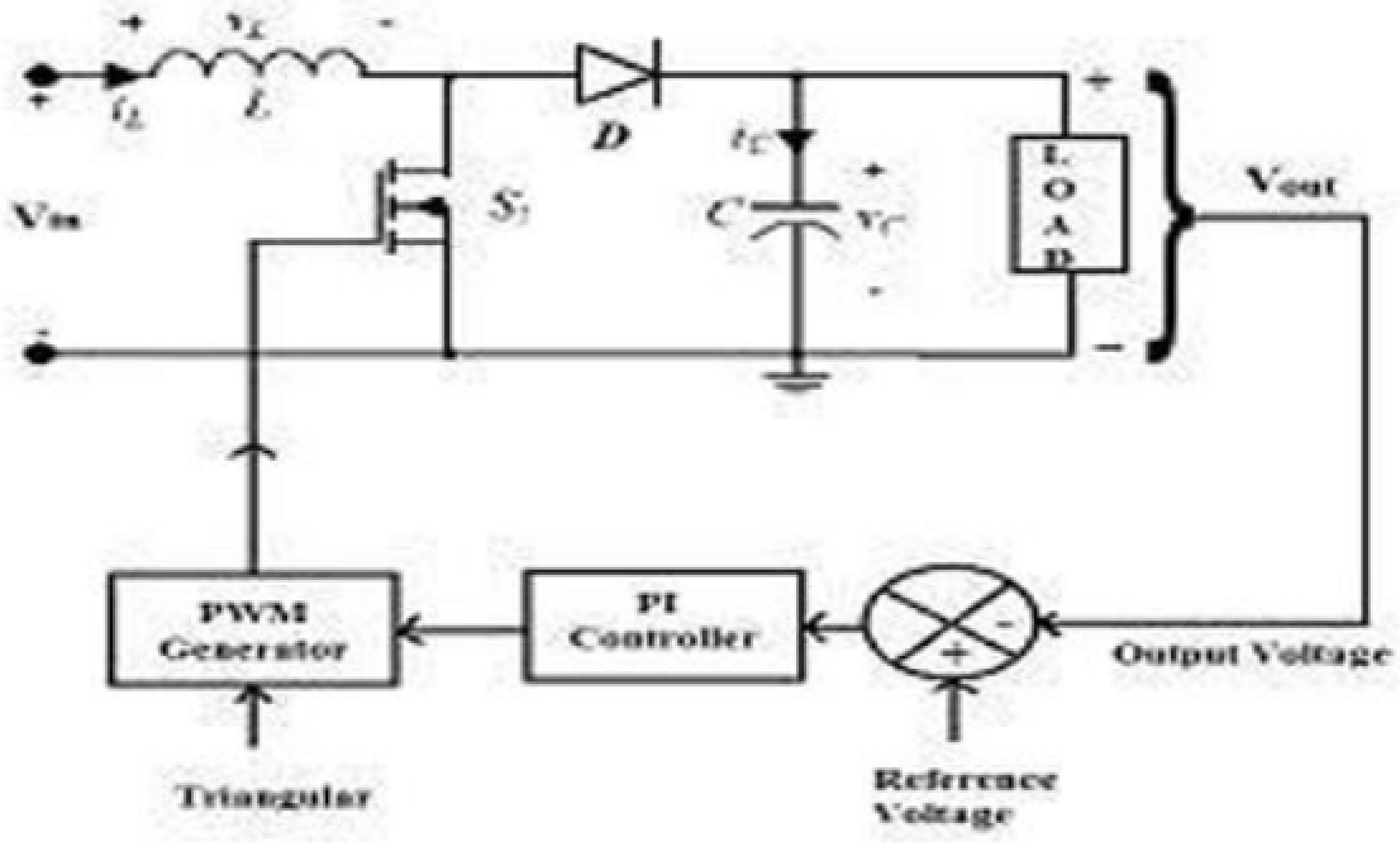

Fig. 3.2. Block Diagram for PI controlled Boost Converter

DESIGNING PARAMETERS OF BOOST CONVERTER WITH PI CONTROLLER

Input Voltage Vs = 12V
Output Voltage Vo = 24V
Output power Po = 100W
Switching Frequency Fs = 25KHz
Duty cycle D = 50%
Inductance L = 144×10-6 H
Capacitance C = 69.44 ×10-6 F
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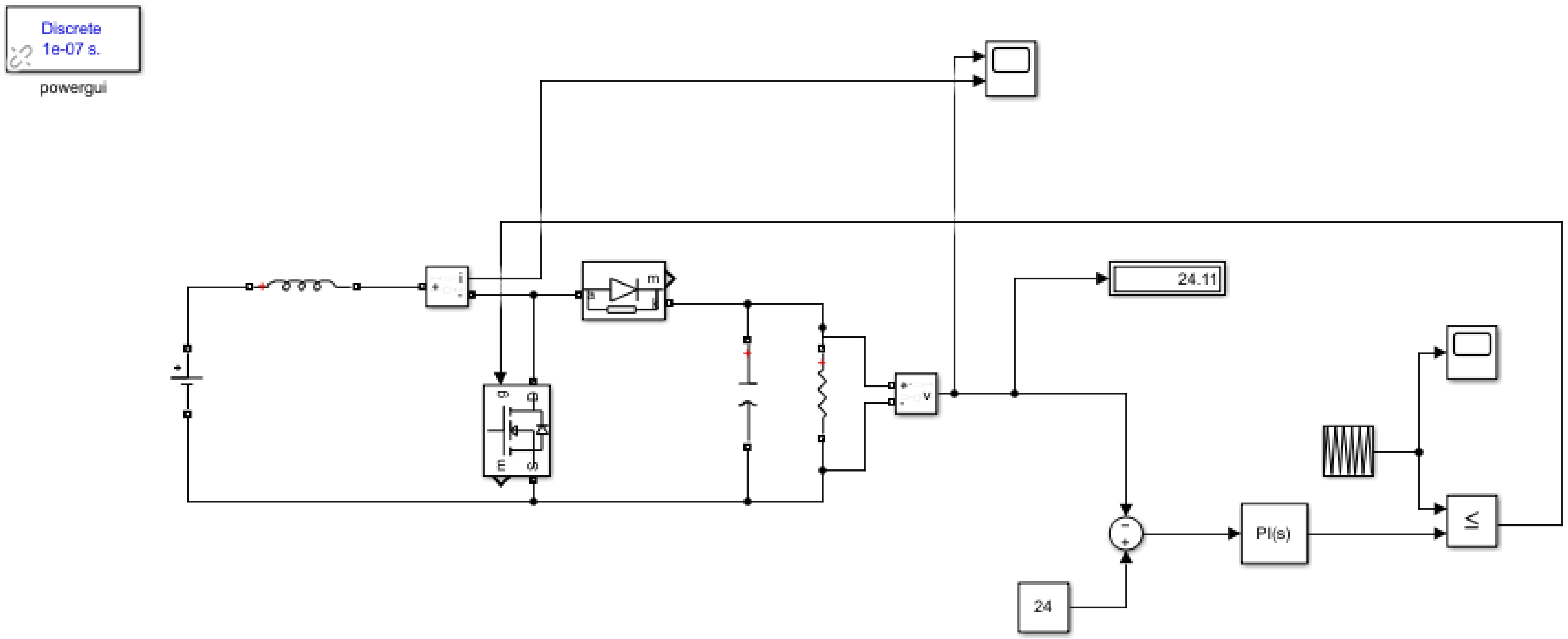

Fig. Simulation of PI controlled Boost Controller

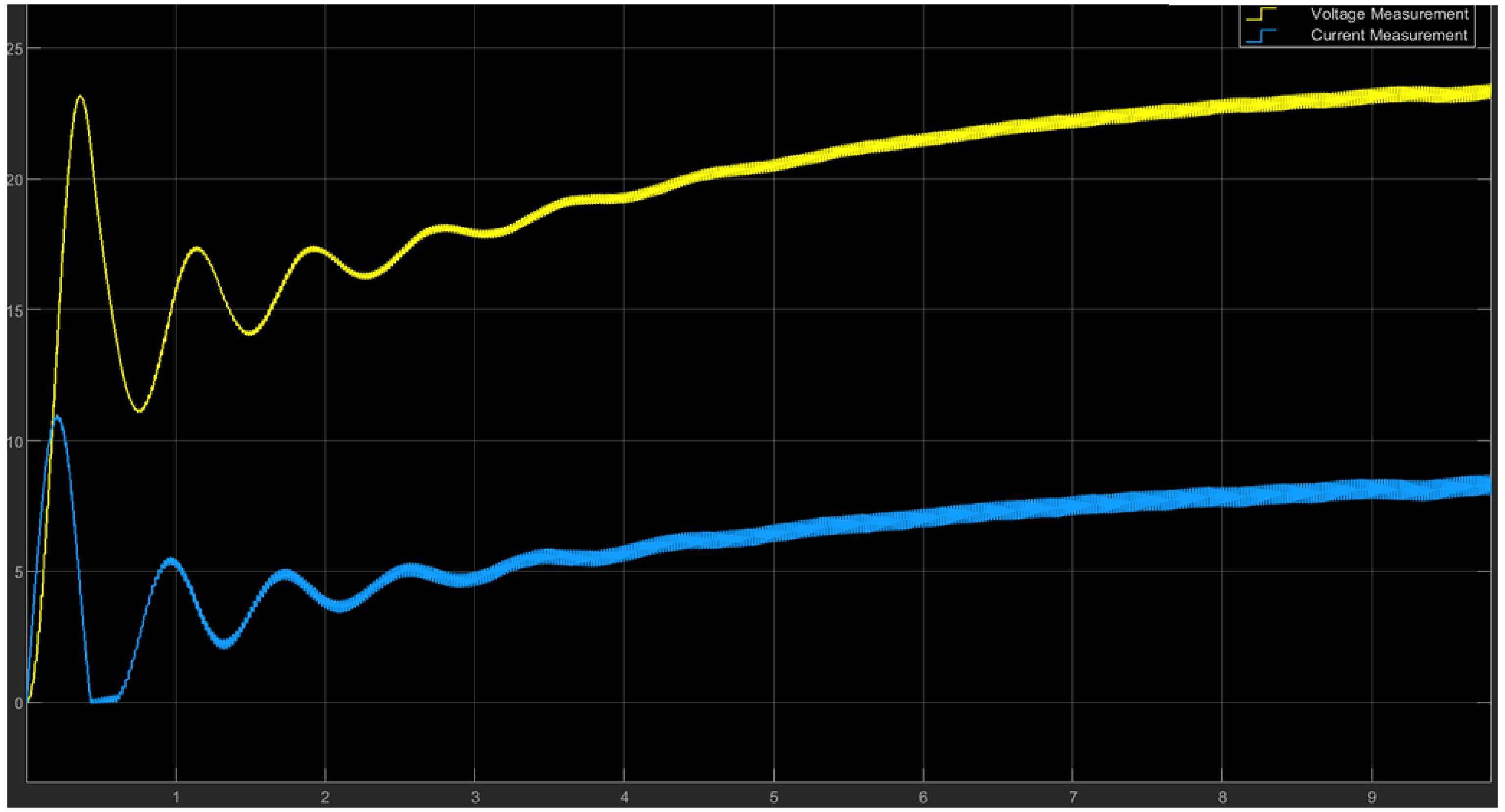

Fig. Output Voltage (yellow) and Input Current (blue)

APPLICATIONS OF BOOST CONVERTER

Boost converters are extensively utilized across various industries and applications due to their efficient voltage stepping capabilities. They are commonly found in:

- **Electric Vehicles:** In electric vehicles, boost converters play a crucial role in elevating the battery voltage to levels suitable for driving the electric motor and other onboard systems.
- **Solar Energy Systems:** Boost converters are essential components in solar power setups. They optimize power output by aligning the panel's voltage with the battery bank's ideal charging voltage.
- **Power Supplies:** Boost converters are integrated into power supplies for electronic gadgets like laptops and smartphones. They efficiently generate the necessary voltage levels for different components within these devices.
- **LED Lighting:** LED lights demand a consistent current for optimal functionality. Boost converters are frequently employed in LED driver circuits to elevate voltage levels, ensuring steady and effective performance.
- **Portable Electronics:** Devices such as portable chargers, power banks, and GPS units rely on boost converters to maintain a stable output 8 voltage while drawing power from lower-voltage battery sources.

THANK YOU