LAB # 05

Analyzing Buck Converter Design Using PV Array

Objective:

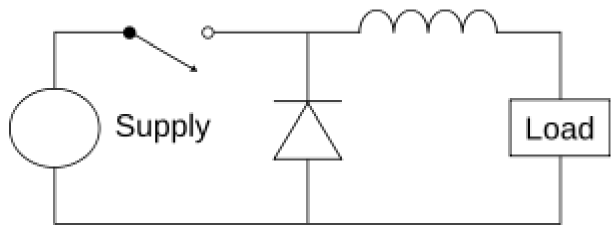
- To understand the working principle of buck converter
- To learn how to calculate values of D (duty cycle), L (inductor) and C (capacitor) for buck converter
- To analyze the working of buck converter with PV array
- To observe input output characteristics (power, voltage & current) of buck converter by varying its duty cycle

Component required:

- PV Array
- Inductor
- Capacitors
- Constants
- PWM Generator
- IGBT (insulated Gate bipolar transistor)
- Diode
- Current Measurements
- Voltage Measurements
- Scope
- Display

Related Theory:

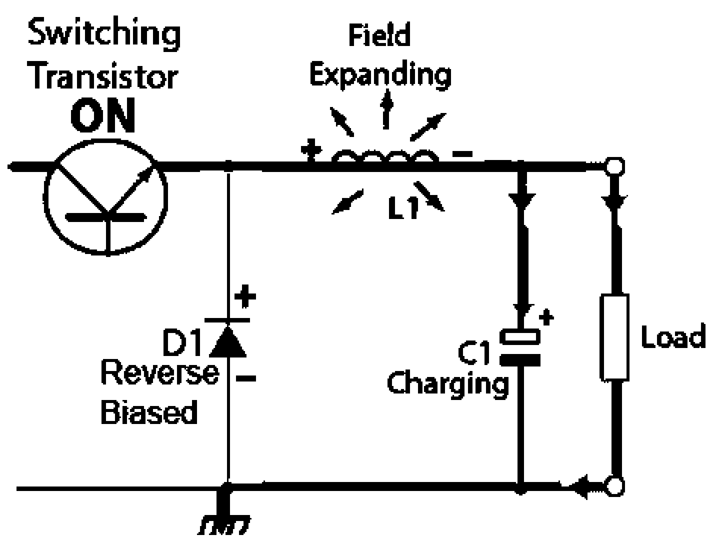
A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another.
It is a type of electric power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission).
A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).



Operation:

Transistor Switch 'on' Period:

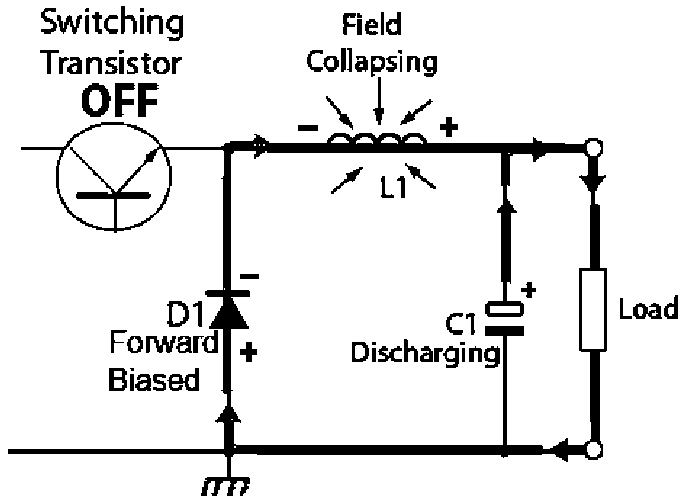
When the switching transistor is switched on, it is supplying the load with current. Initially current flow to the load is restricted as energy is also being stored in L1; therefore, the current in the load and the charge on C1 builds up gradually during the 'on' period. Notice that throughout the on period, there will be a large positive voltage on D1 cathode and so the diode will be reverse biased and therefore play no part in the action.



Transistor Switch 'off' Period:

When the transistor switches off, as shown in figure below, the energy stored in the magnetic field around L1 is released back into the circuit. The voltage across the inductor (the back e.m.f.) is now in reverse polarity to the voltage across L1 during the 'on' period, and sufficient stored energy is available in the collapsing magnetic field to keep current flowing for at least part of the time the transistor switch is open.

The back e.m.f. from L1 now causes current to flow around the circuit via the load and D1, which is now forward biased. Once the inductor has returned a large part of its stored energy to the circuit and the load voltage begins to fall, the charge stored in C1 becomes the main source of current, keeping current flowing through the load until the next ‘on’ period begins.



Equations:

- For duty cycle D

$$D = \frac{v_o}{v_s}$$

- For finding L, we use following equation:

$$L_{min} \geq \frac{(1-D)R}{2f}$$

$$L = 1.25\, L_{min}$$

- For finding the value of C, we use:

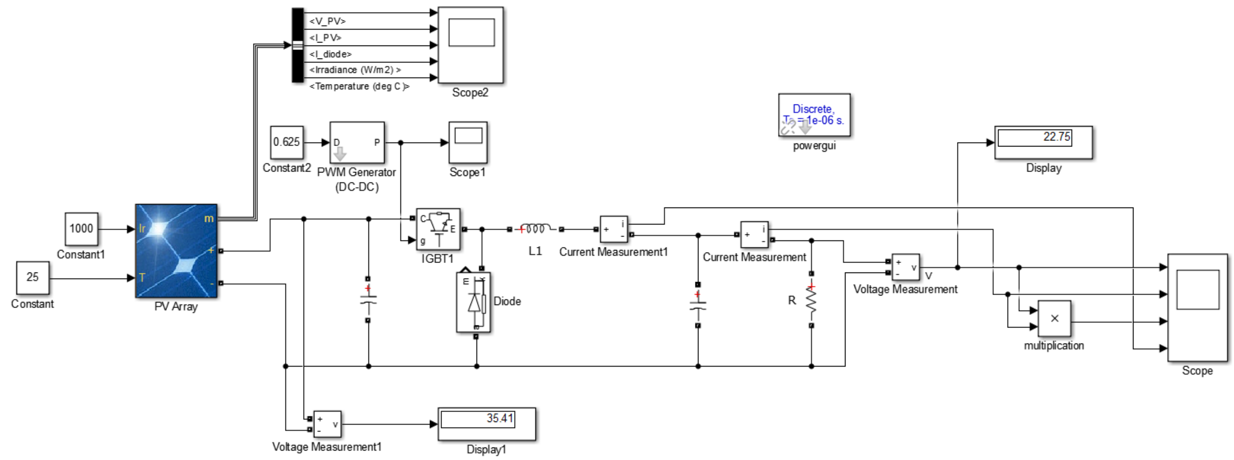
$$C = \frac{(1-D)}{8\, L\, (\frac{\Delta v_o}{v_o})\, f^2}$$

Buck Converter Design Calculations:

Design a buck converter to produce an output voltage of 22V across a 10Ω load resistor. The output voltage ripple must not exceed 0.5 percent. The dc supply from PV array is 35V. Design for continuous inductor current. Specify the duty ratio, the switching frequency, the values of the inductor and capacitor. Assume ideal components.

Solution:

Simulation diagram:



Scope Output of Different Parameter of PV Array:

PWM Scope Output:

Output Waveforms of P_o, V_o and I_o:

Conclusion and Comments: