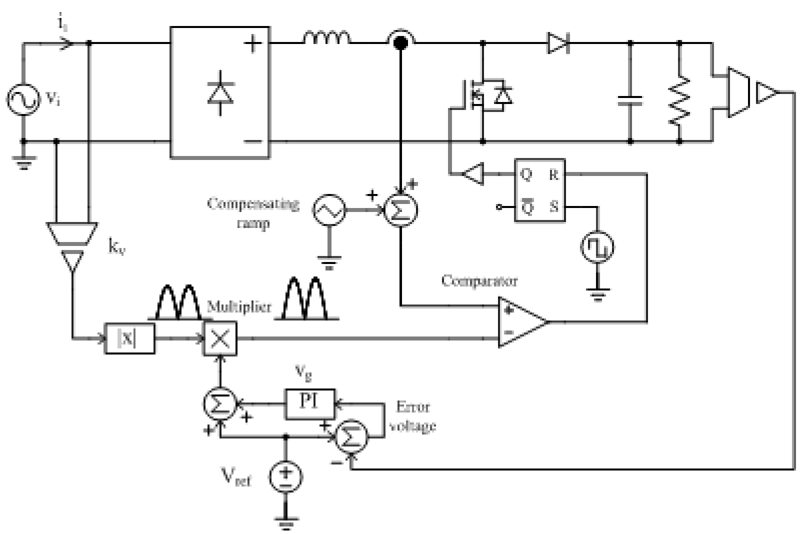
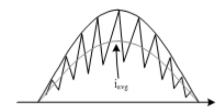
Chapter 13

Applications of switching converters





Power factor correction

- **Review of basic concepts**

$$S = V_{rms}\ I_{rms}$$

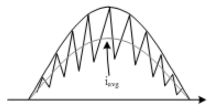
$$P = Re(S) = V_{rms}\, I_{rms}\, cos(\varphi)$$

$$PF = \frac{P}{S}.$$

$$i(t) = i_1(t) + \sum_{h \neq 1} i_h(t)$$

$$I_{rms} = \sqrt{\sum_{h=1} I_h^2}$$

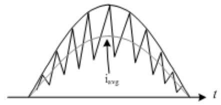
$$PF = \frac{P}{S} = \frac{V\ I_1\, cos(\varphi)}{V\ I} = \frac{I_1}{I}\, cos(\varphi)$$

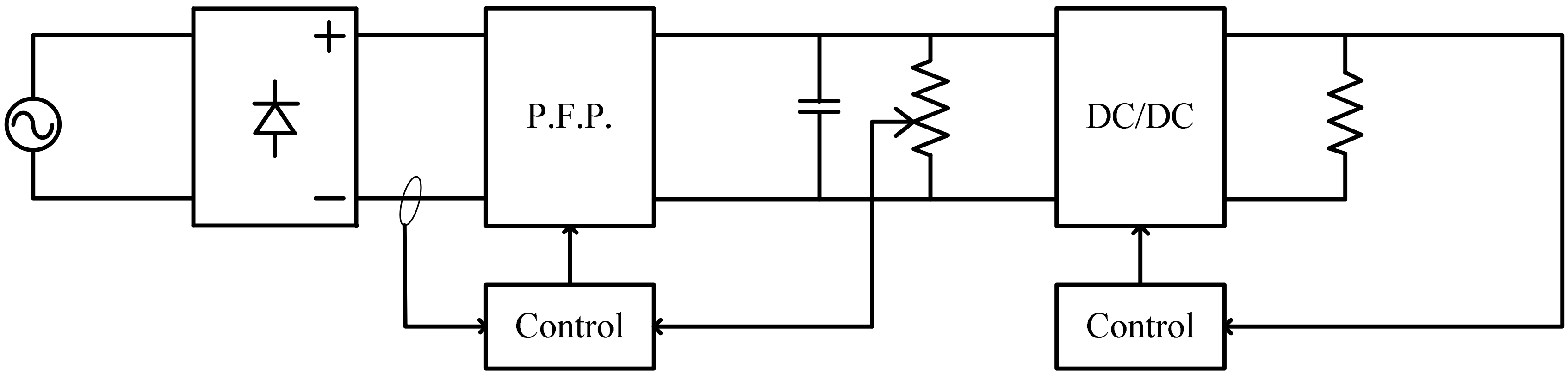


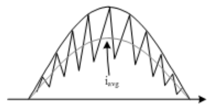
Principle of power factor correction

The main goal of a power factor correction (PFC) circuits is to force the load to draw a quasi-sinusoidal current from the AC power line to be in phase with the line voltage; thus, behaving as a resistive load or a controlled current source to the AC mains.

Block diagram of a typical AC-DC converter with a power factor pre-regulator



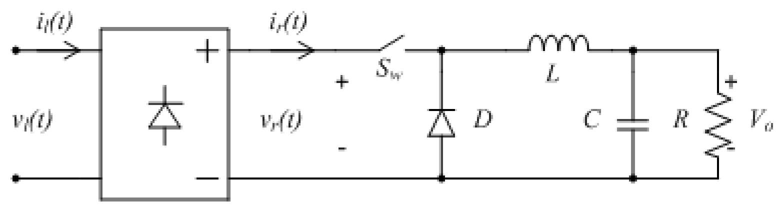




Self-power factor correction properties of switching converters

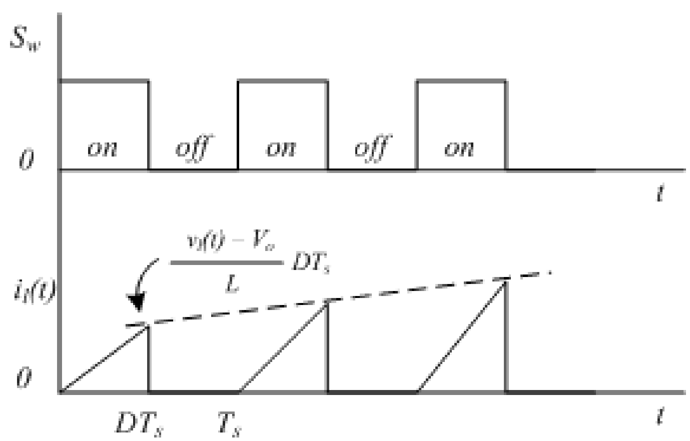
- Switching converters exhibit self-power factor correction characteristics when operating in their discontinuous mode

Buck converter

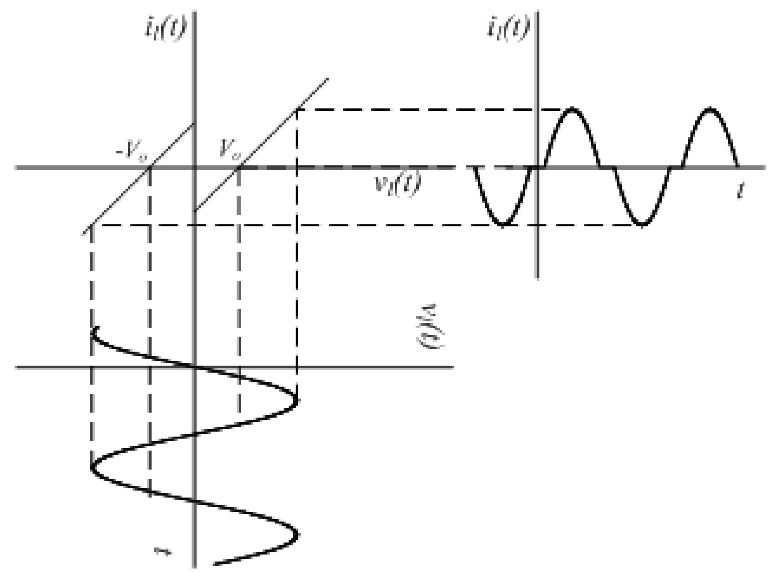


a) Buck converter.

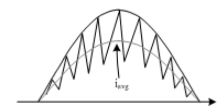
$$i_{l,avg}(t) = \frac{1}{T_s}\left[\frac{1}{2} D\,T_s \frac{v_l(t) V_o}{L} D\,T_s\right] = \frac{D^2\,T_s}{2L} v_l(t) - \frac{D^2\,T_s}{2L} V_o$$



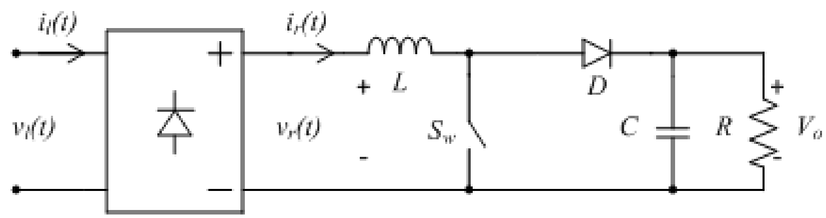
b) Input current.



c) Input V-I characteristic.

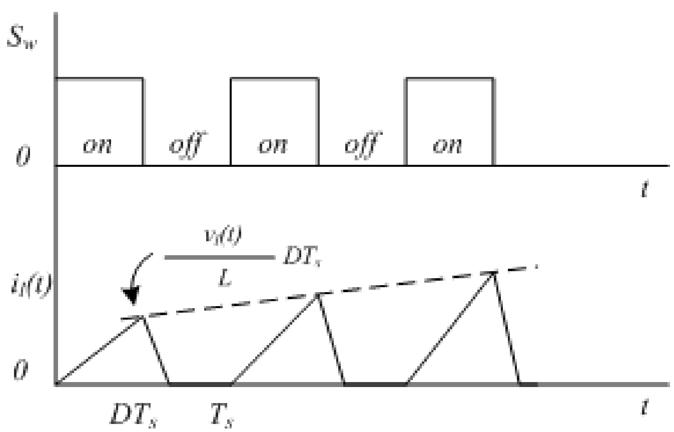


Boost converter

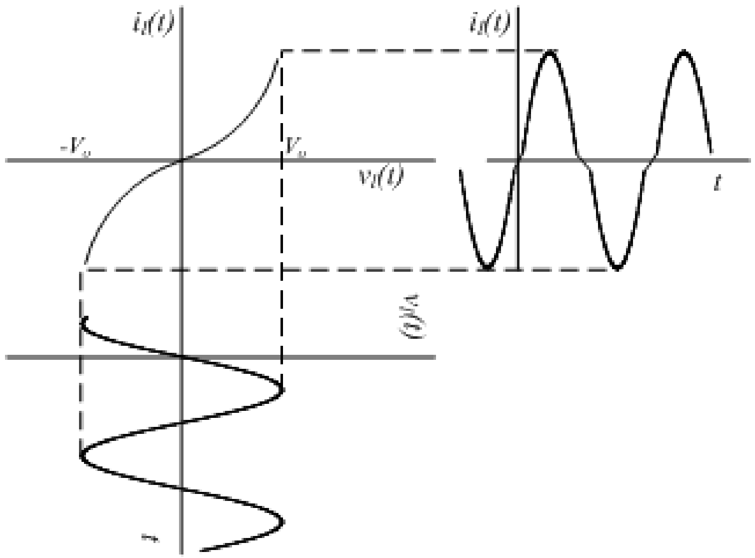


a) Boost converter.

$$i_{l,avg}(t) = \frac{1}{T_s}\left[\frac{1}{2}(D + D_1)\,T_s\frac{v_l(t)}{L}D\,T_s\right] = \frac{D^2\,T_s}{2L}\,\frac{v_l(t)\,V_o}{V_o - v_l(t)}$$

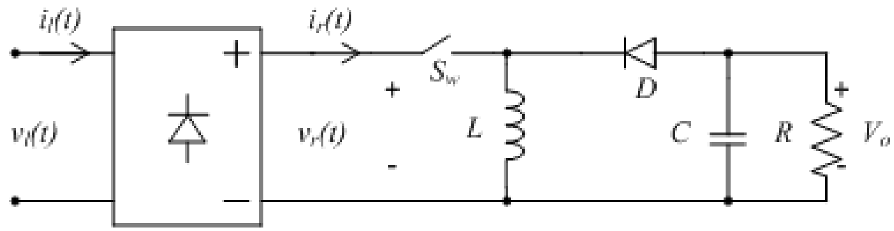


b) Input current.



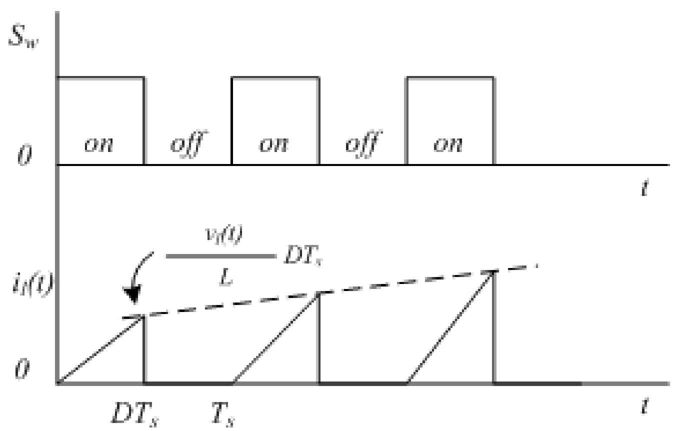
c) Input V-I characteristic.

Buck-boost converter

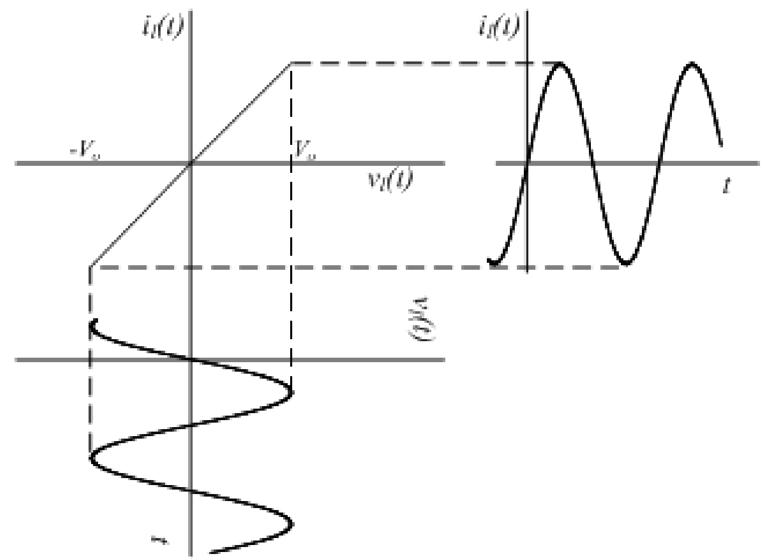


a) Buck-boost converter.

$$i_{l,avg}(t) = \frac{D^2\,T_s}{2L} v_l(t)$$

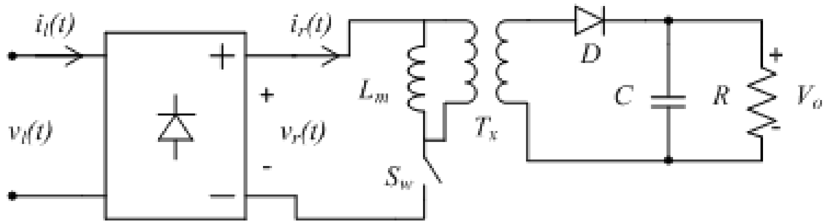


b) Input current.



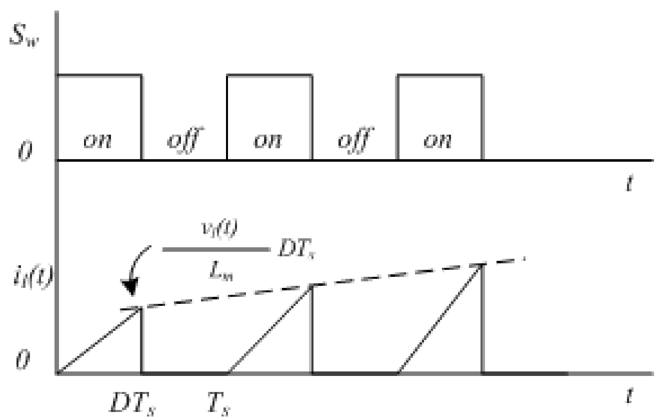
c) Input V-I characteristic.

Flyback converter

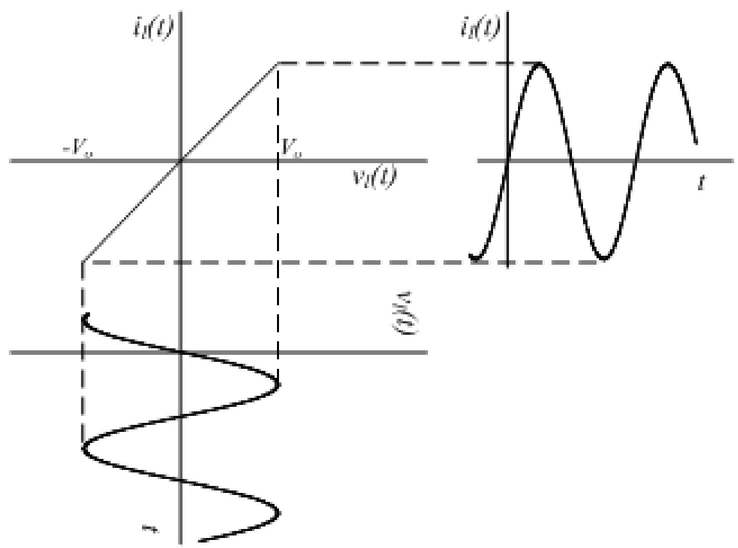


a) Flyback converter.

$$i_{l,avg}(t) = \frac{D^2\,T_s}{2\,L_m} v_l(t)$$

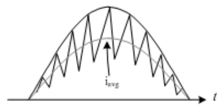


b) Input current.



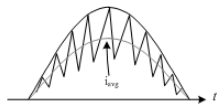
c) Input V-I characteristic.

Control techniques for power factor correctors



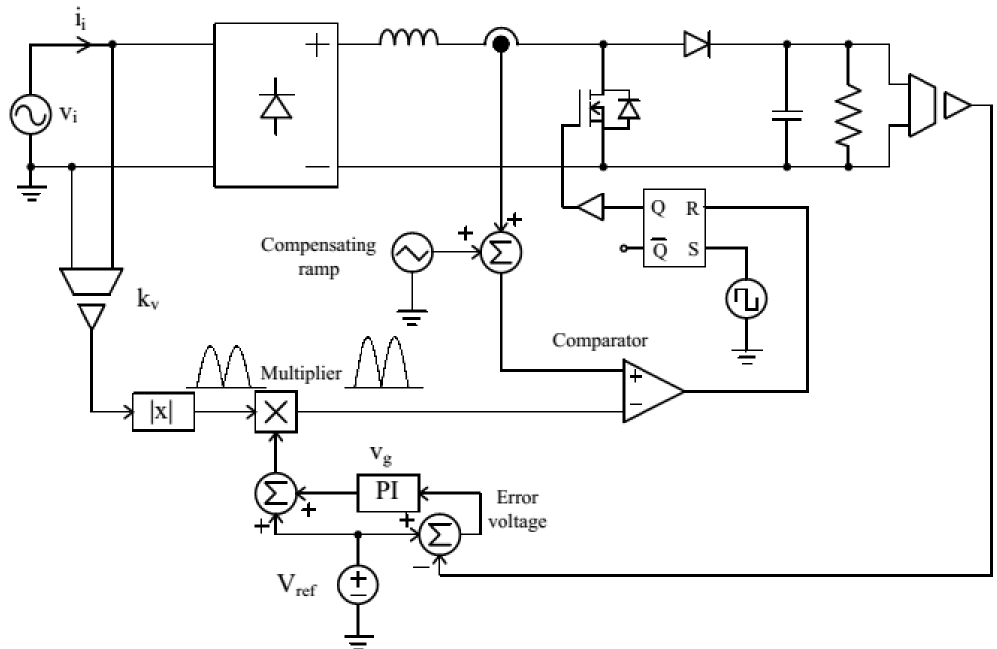
- Continuous conduction mode (CCM)
- Discontinuous conduction mode (DCM)
- Boundary conduction mode (BCM)

Control techniques for power factor correctors

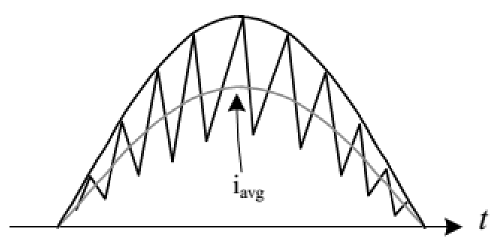


- Peak current mode control (PCM)
- Average current mode control
- Hysteresis control

Peak current mode control (PCM)

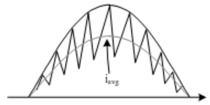


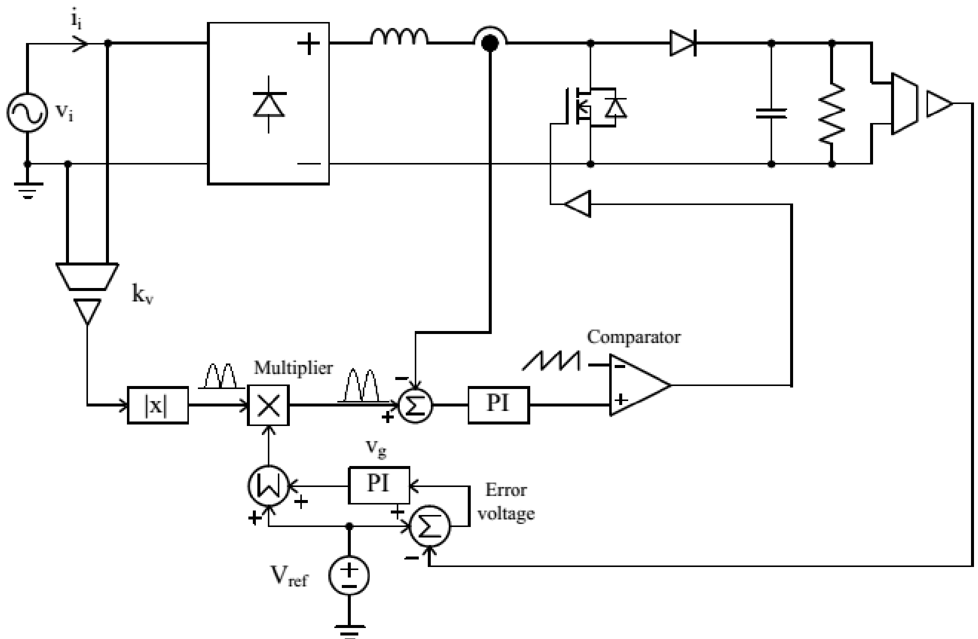
a) Schematic diagram.



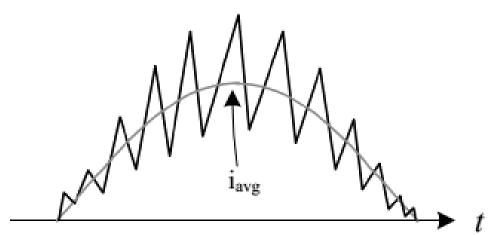
b) Current waveform.

Average current mode control



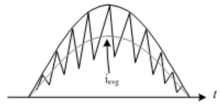


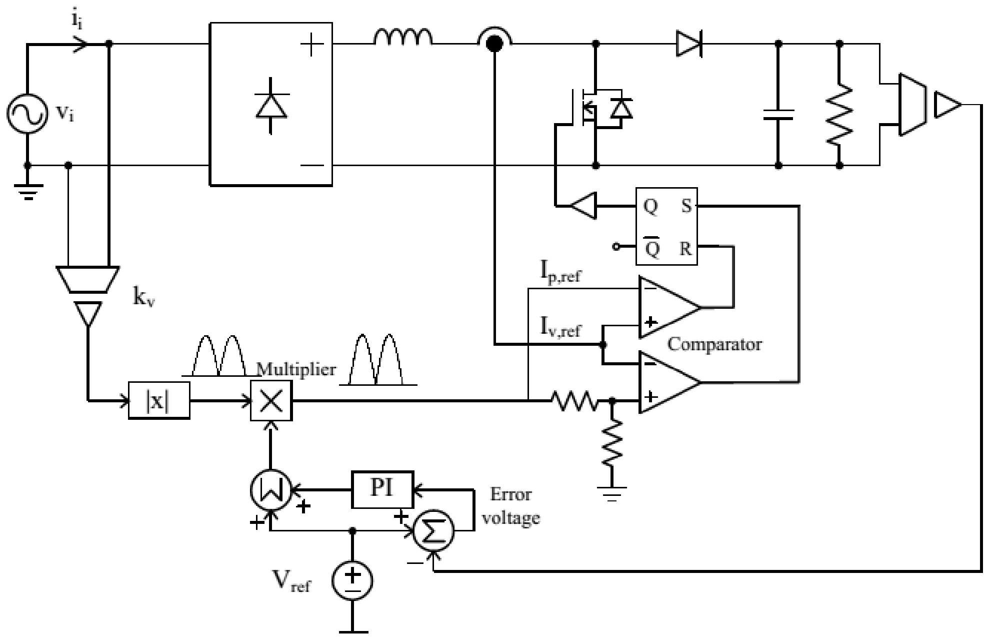
a) Schematic diagram.



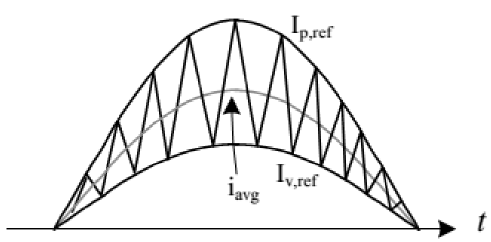
b) Current waveform.

Hysteresis control



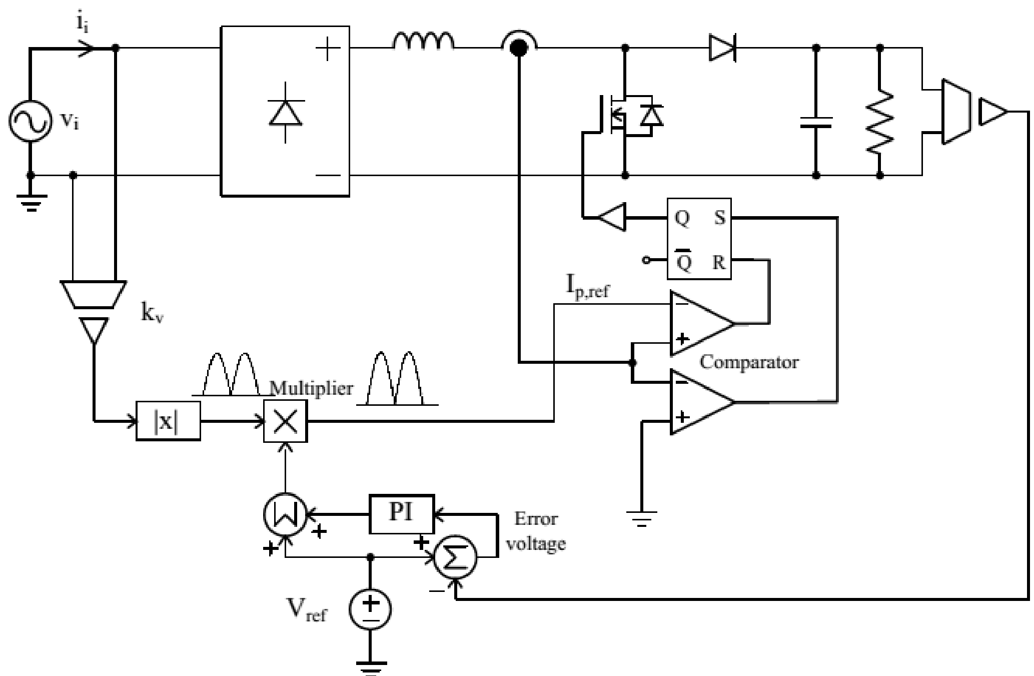


a) Schematic diagram.

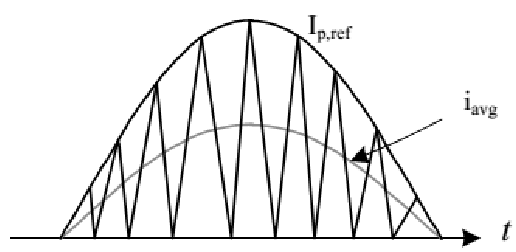


b) Current waveform.

Borderline or boundary control

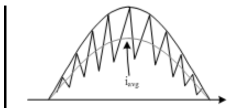


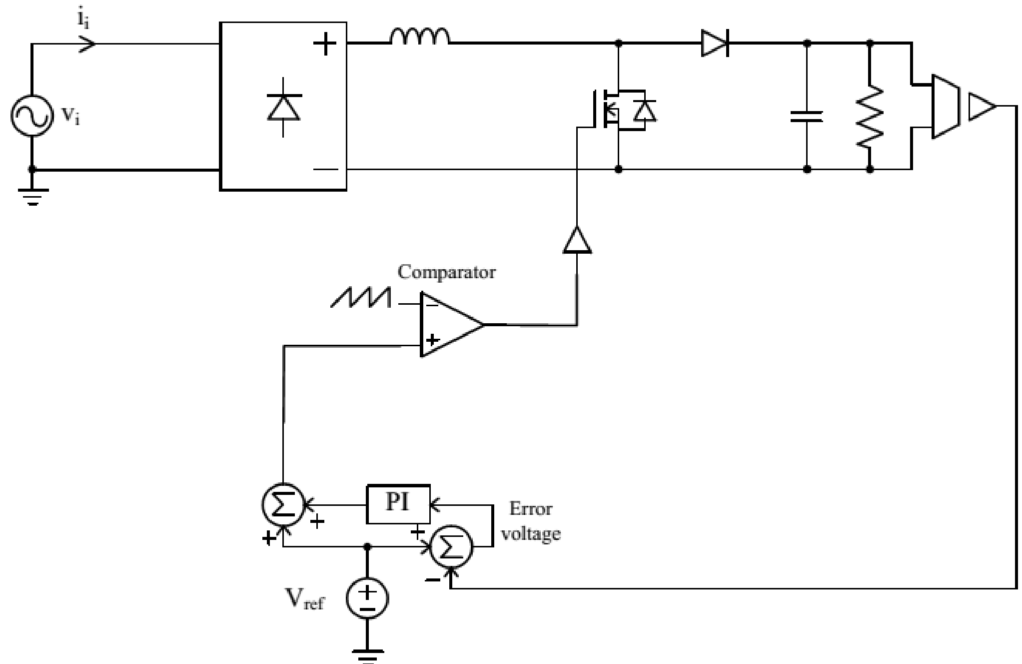
a) Schematic diagram.



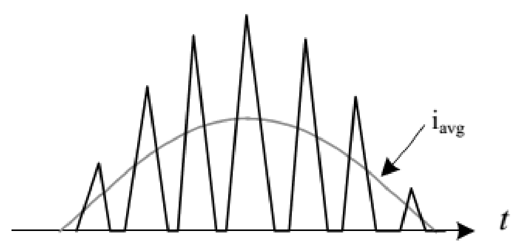
b) Current waveform.

Discontinuous current PWM control



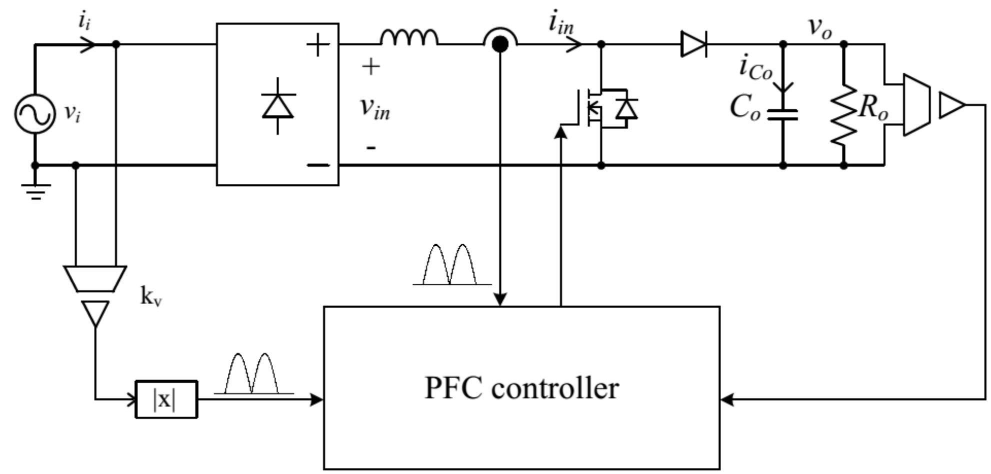


a) Schematic diagram.

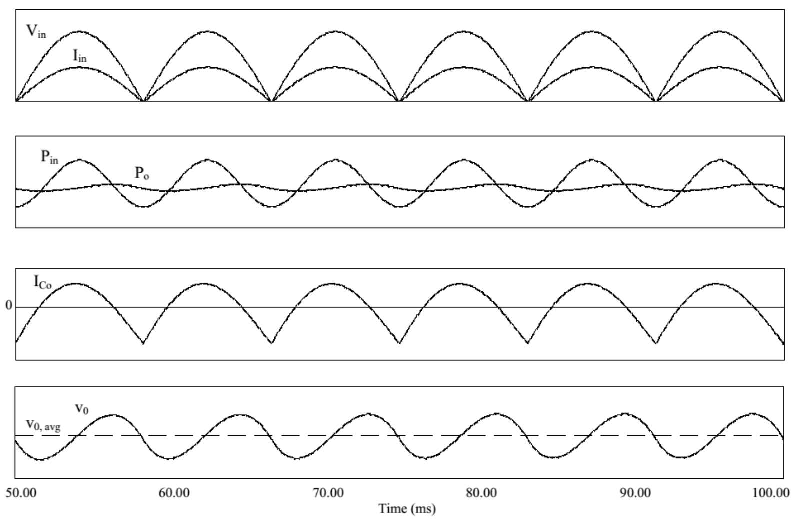


b) Current waveform.

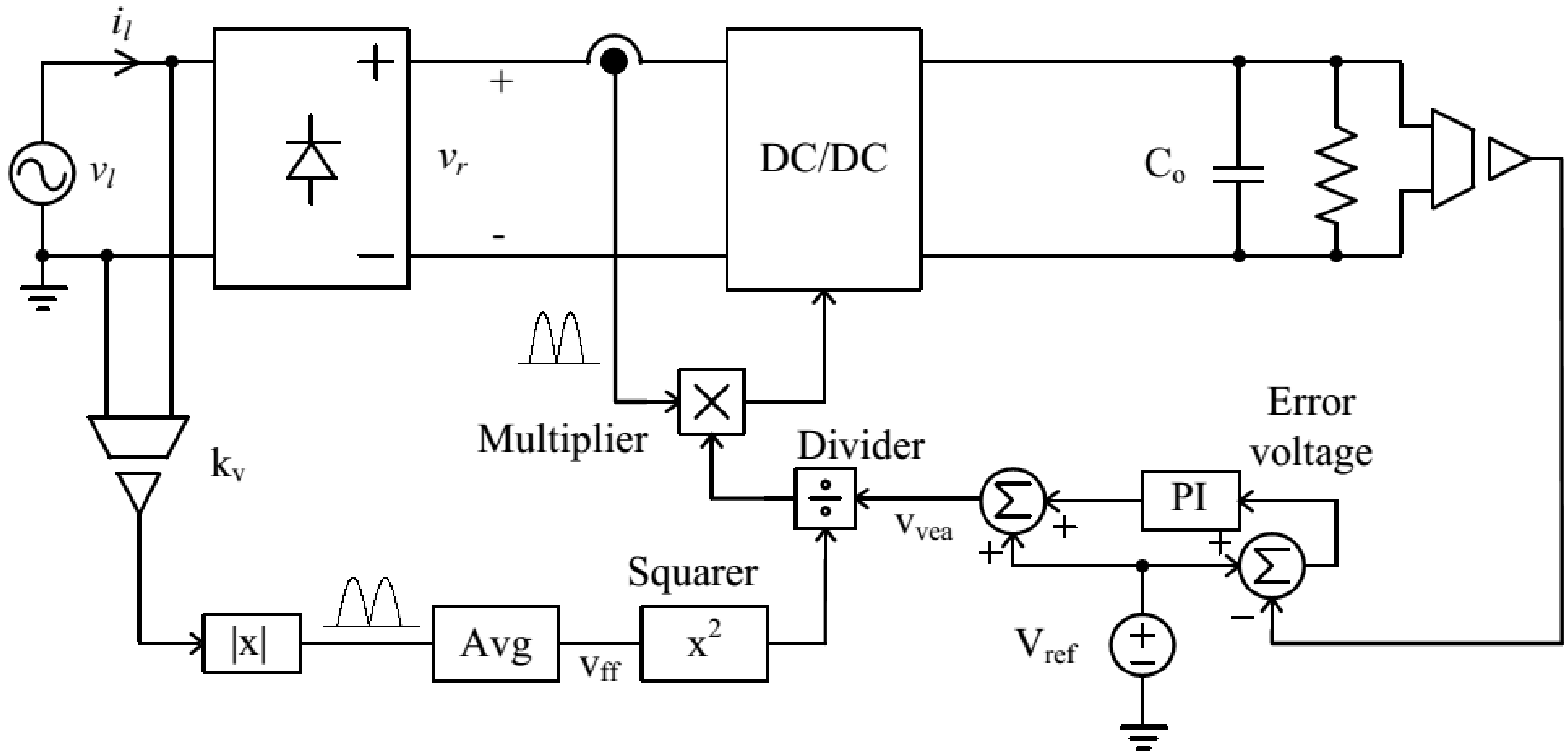
Power factorcorrection circuits

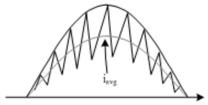


Basic boost-based PFC circuit



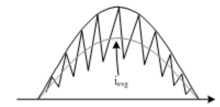
A practical AC-DC converter with power factor correction





Low noise DC-DC converters

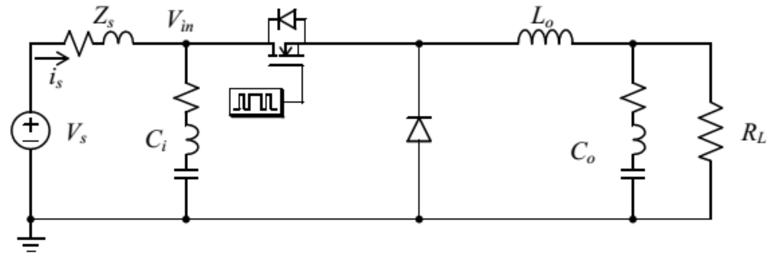
- Linear power supplies produce low EMI but have low power efficiency
- Switched mode power supplies have higher power efficiency but produce EMI
- Low noise switching power supplies use several techniques to reduce the conducted and radiated EMI while achieving acceptable power efficiency



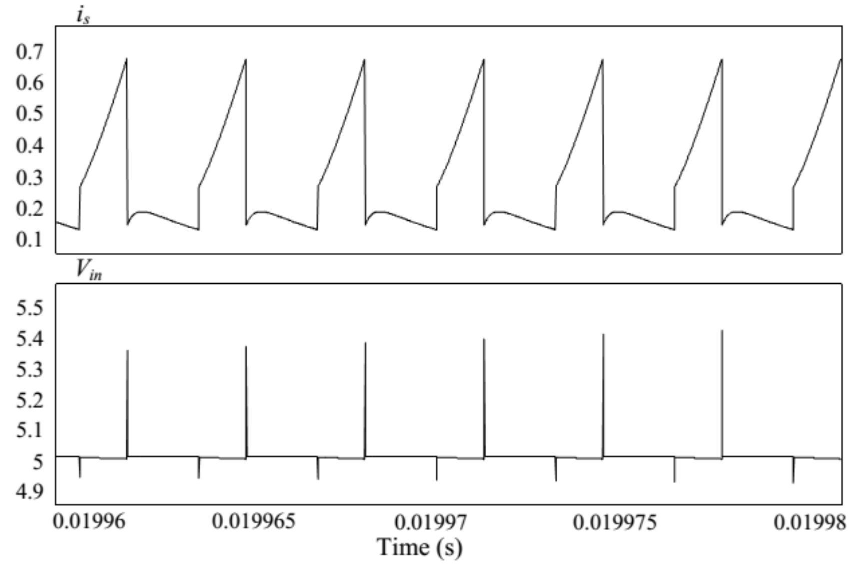
Techniques to reduce EMI

- Capacitive coupling
- Inductive coupling
- Input filtering
- Output Filtering
- Slew rate limiting

Buck converter with practical input and output capacitors

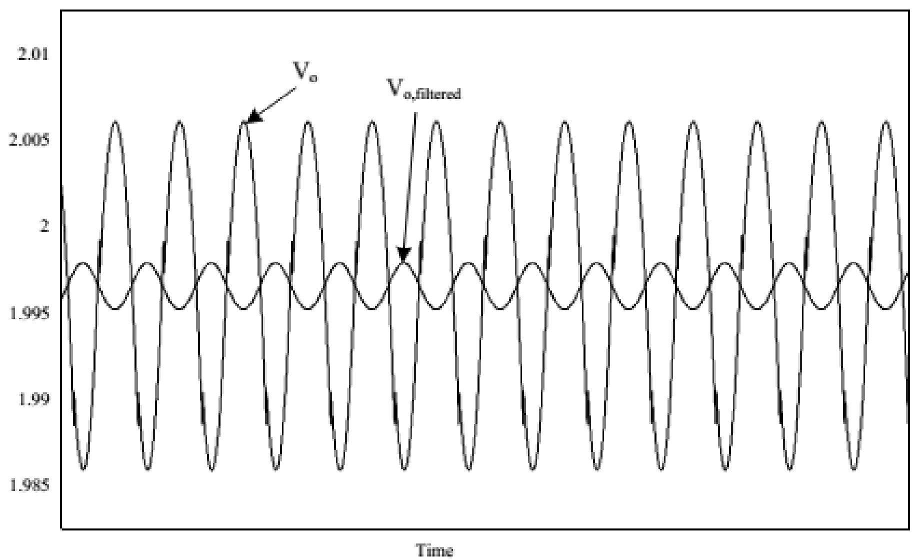


a) Schematic diagram.

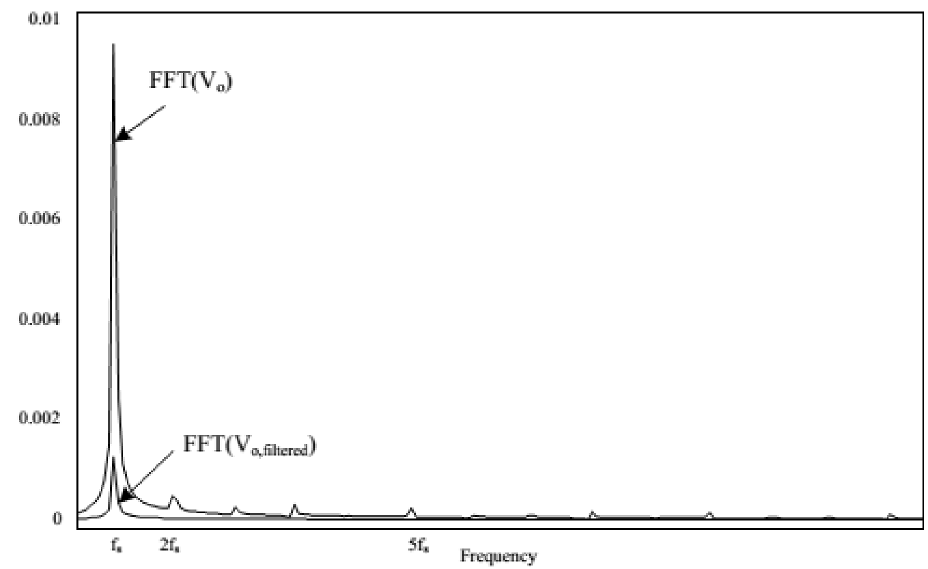


b) Input waveforms.

Comparison of performance between one and two output filters

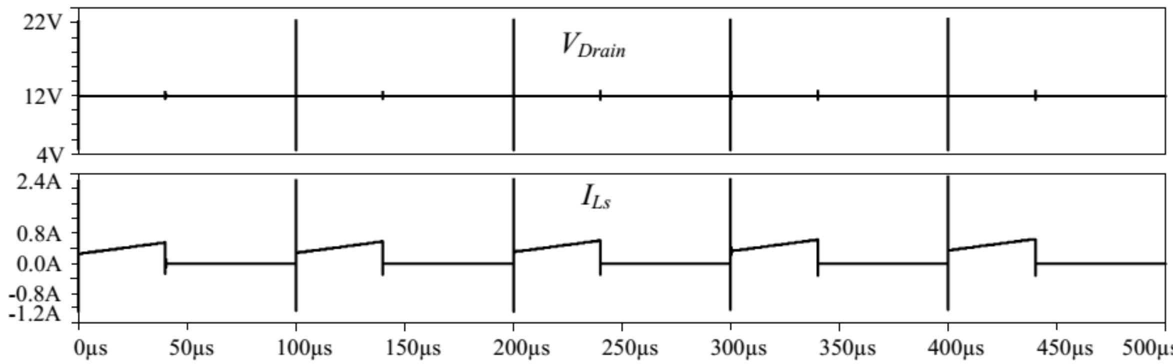


a) Waveforms.

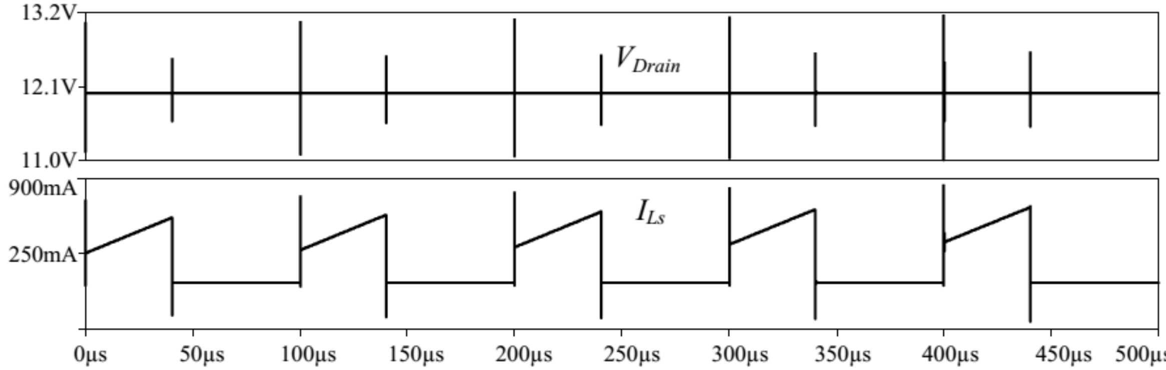


b) Frequency spectrum.

Comparison of voltage waveforms with and without slew rate limitation



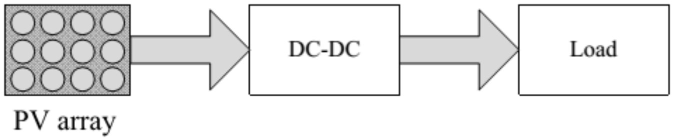
a) 10-ns rise time.



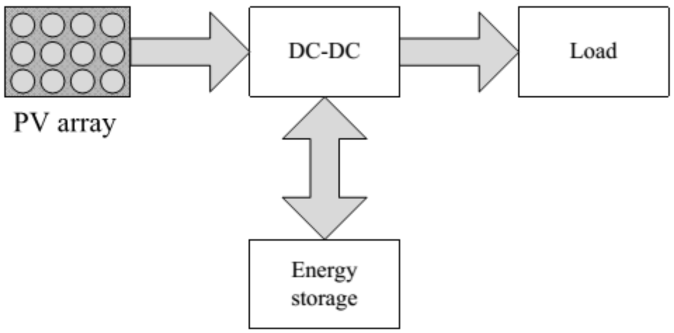
b) 100-ns rise time.

Switching converters for solar cells

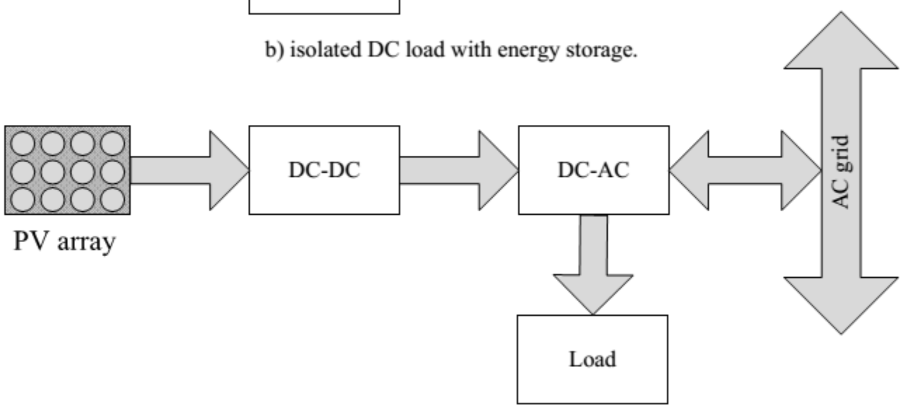
Typical configurations of PV systems



a) Isolated DC load.

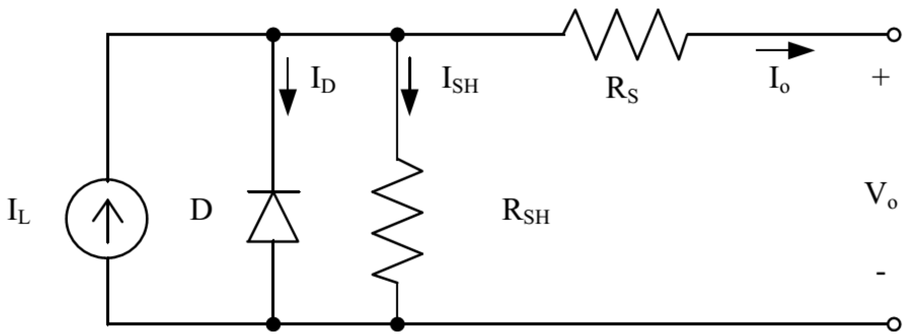


b) isolated DC load with energy storage.



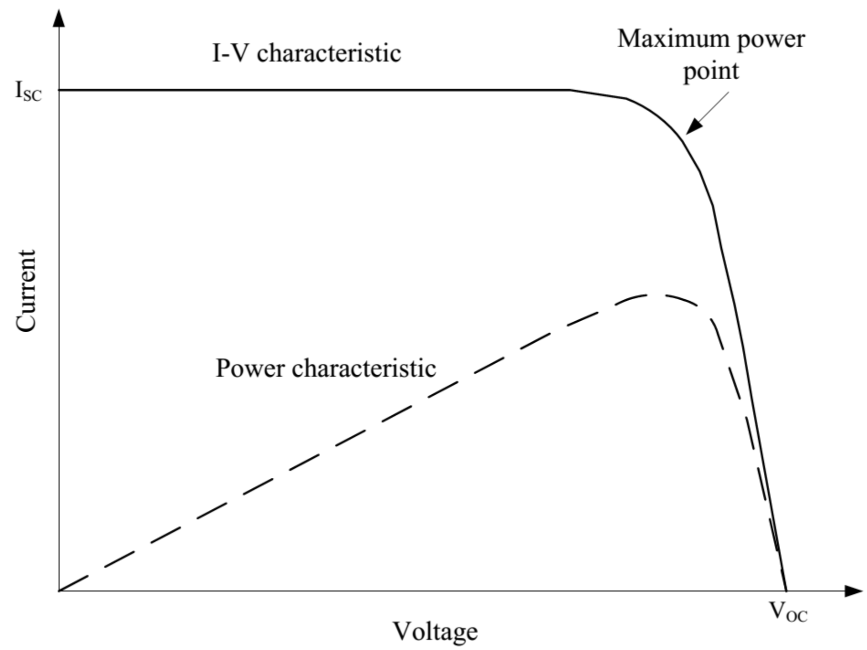
c) Grid connected AC load.

Solar cell model

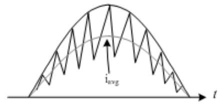


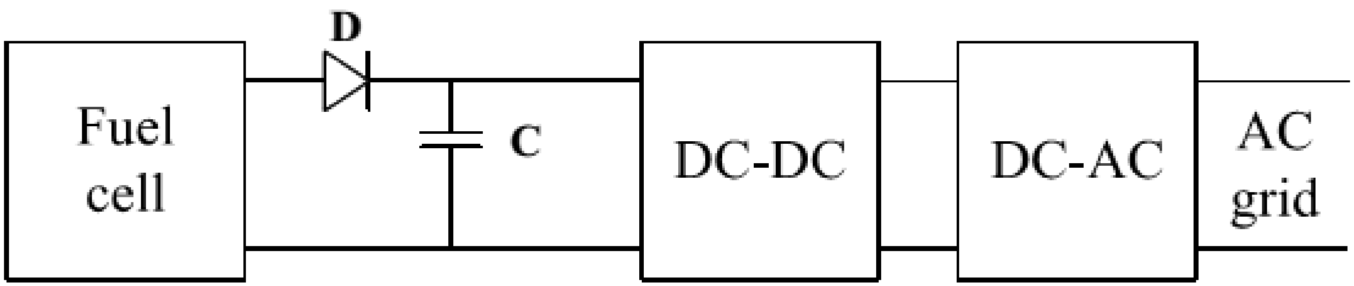
Equivalent circuit of a solar cell

I-V and power curves of a solar cell



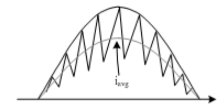
Switching converters for fuel cells

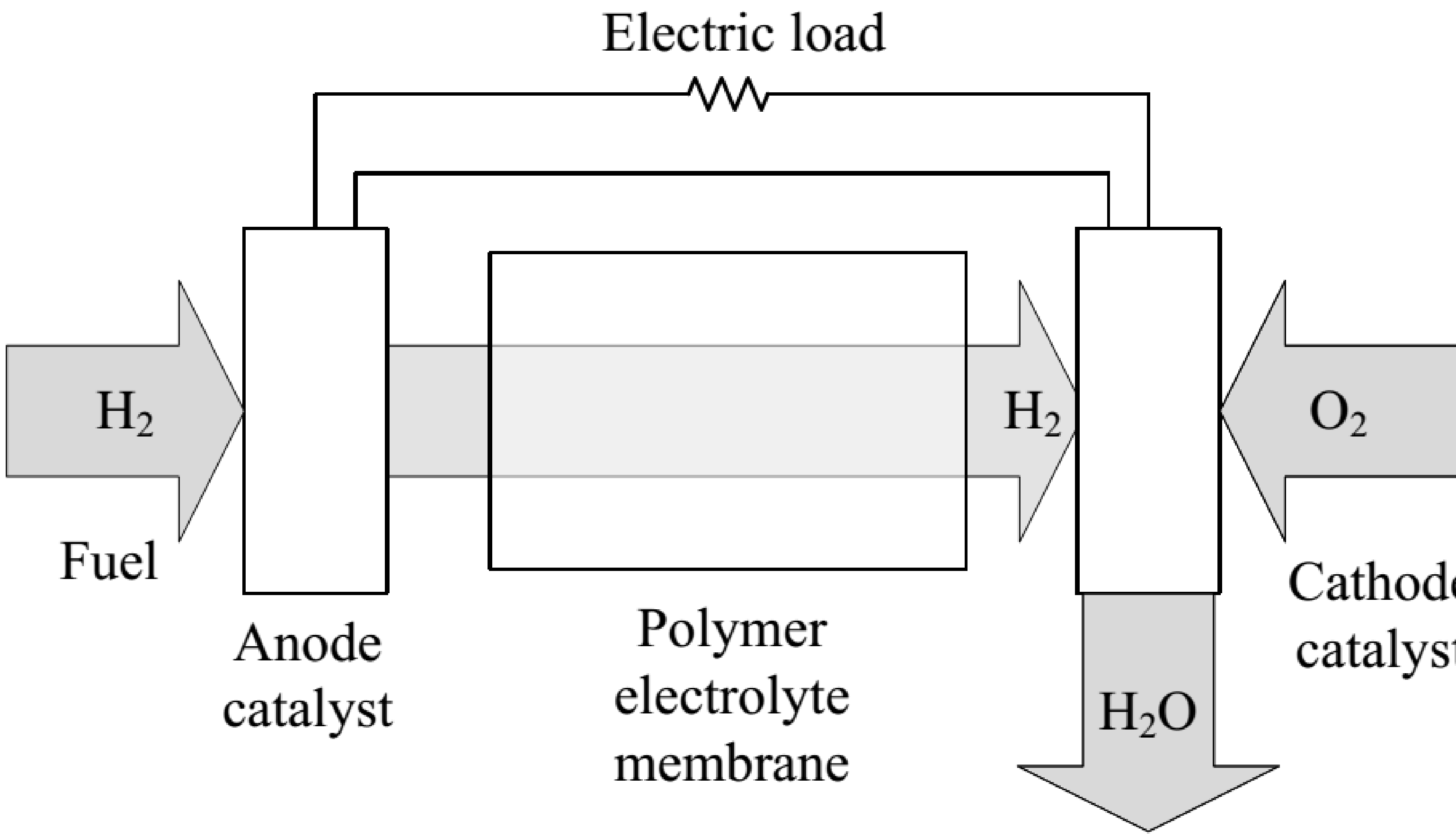




Block diagram representation of a fuel cell system

Switching converters for fuel cells

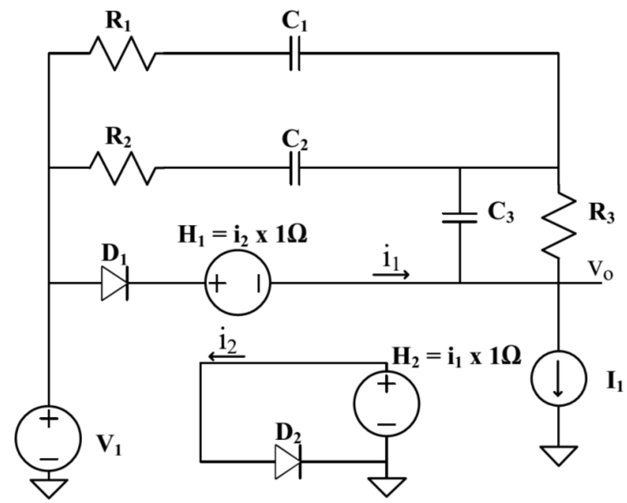


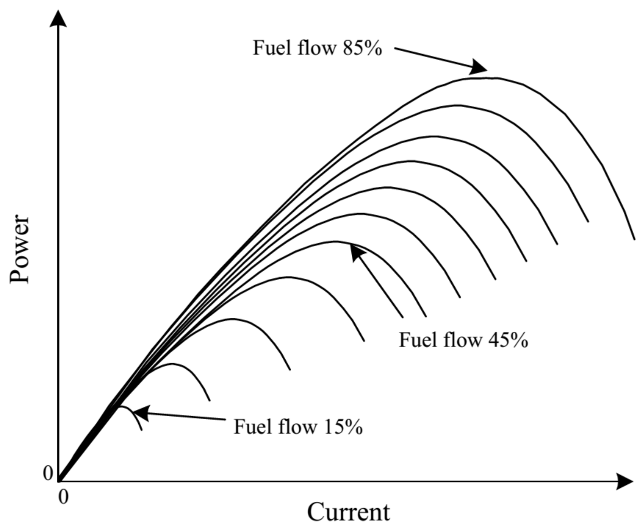


Block diagram of a fuel cell

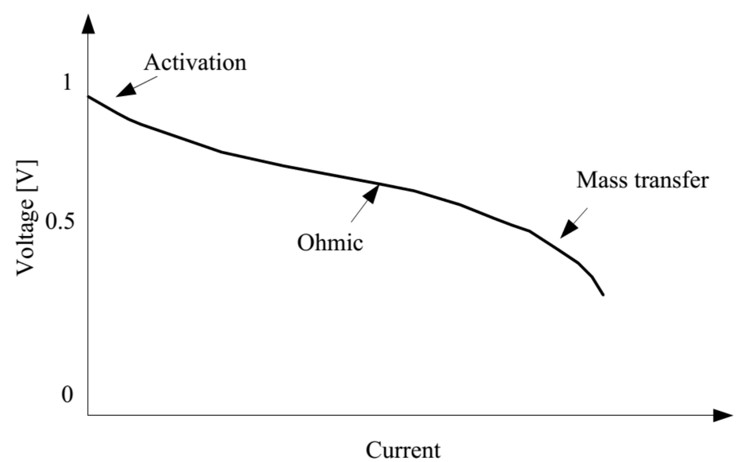
Switching converters for fuel cells

Equivalent circuit of a fuel cell



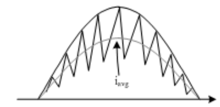


Power-current characteristic of a fuel cell

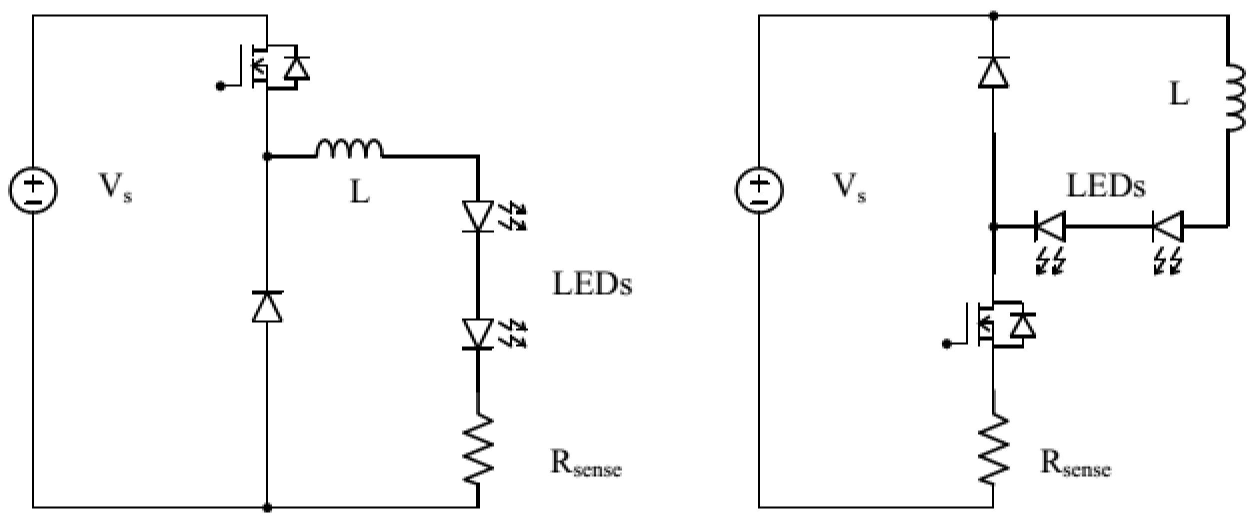


Voltage-current characteristic of a fuel cell

Switching converters for LED drivers



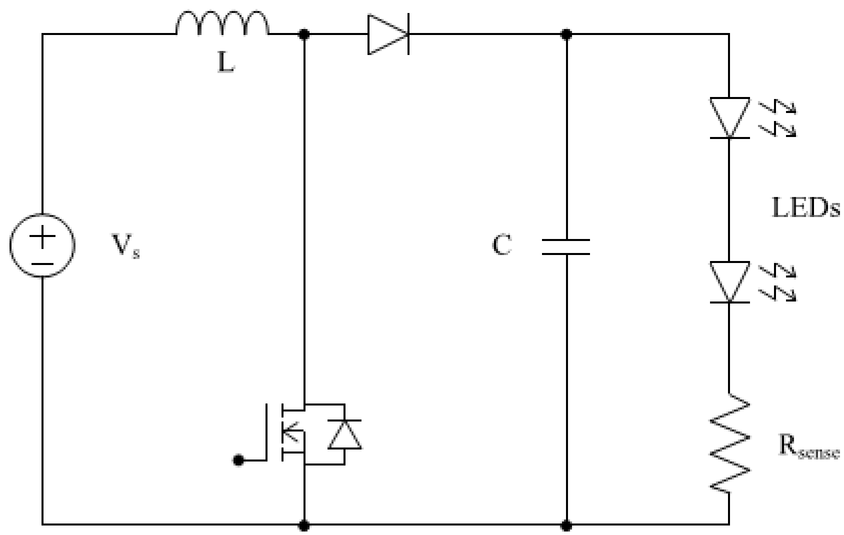
Buck-based LED drivers



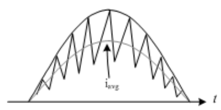
a) b)

Switching converters for LED drivers

Boost-based LED drivers



Switching converters for LED drivers



Cuk-based LED drivers