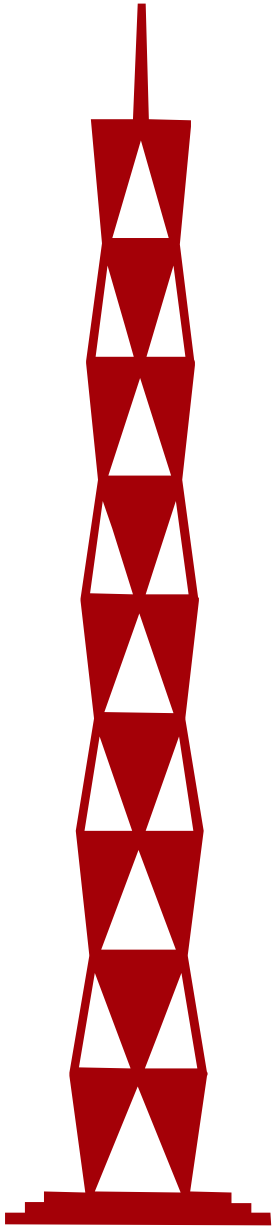


SI100B
Introduction to Information Science and Technology (Part 3: Electrical Engineering)

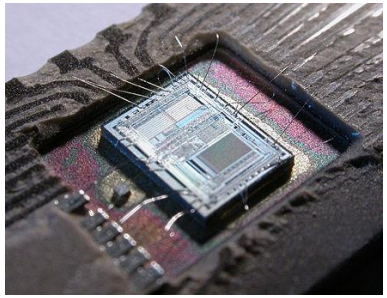
Lecture #7 Power Electronics

Instructor: Haoyu Wang(王浩宇)

Apr. 26th, 2023

The Theme Story

Devices (1)



Circuits (5/5)

Systems (1)

(Figures from Internet)

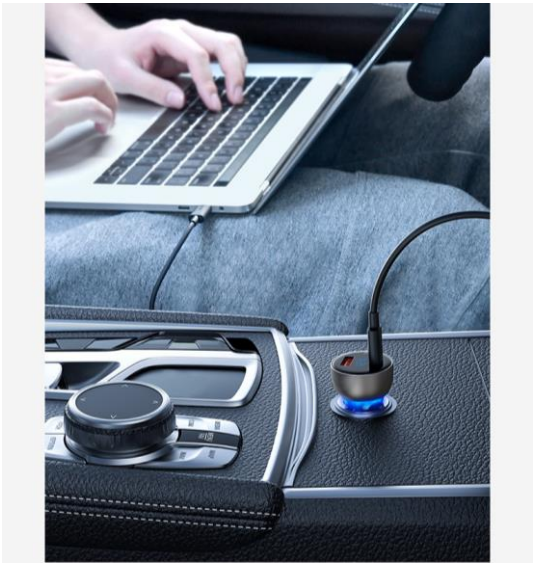
Study Purpose of Lecture #6

- 哲学三问
  - Who are you?
  - Where are you from?
  - Where are you going?

To answer those questions throughout your life

(Figures from Internet)

- In this lecture, we ask
  - What are **power electronics**?
  - How do we **step-up** and **step-down** a dc voltage?
  - How do we model power converters?

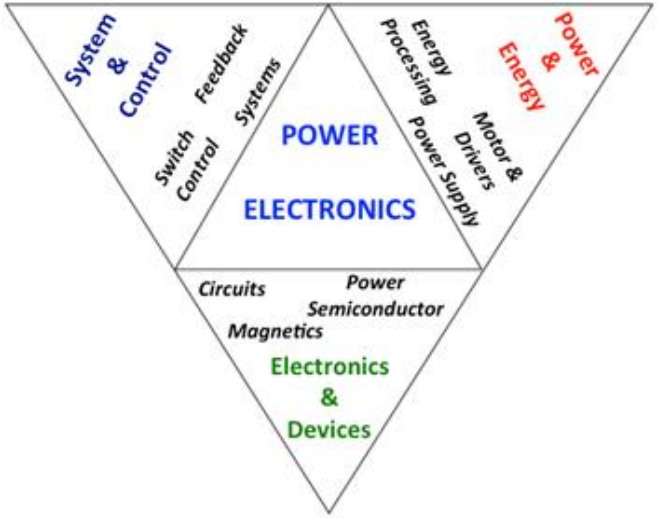


Lecture Outline

- Introduction
- Switched mode power supply
- Buck converter
  - Small ripple approximation
  - Volt-second balance
  - Charge balance
  - Estimating more accurate ripple
- Boost converter
- Closed loop control and negative feedback

Power Electronics

- Power electronics is the application of **solid-state electronics** to the **control** and conversion of **electric power**.
  - Semiconductor functions as switch
  - High frequency
  - Compact size
  - High efficiency
  - Reliable



(Figures from Internet)

UPS

Consumer AC/DC power supply

Telecom & server power

Battery pack & charger

Ubiquitous Power Electronics

上海科技大学 ShanghaiTech University

PEARL 电力电子与再生能源实验室 POWER ELECTRONICS AND RENEWABLE ENERGIES LAB

Electric Vehicle
电动汽车

Data Center
数据中心

Wearable Devices
可穿戴设备

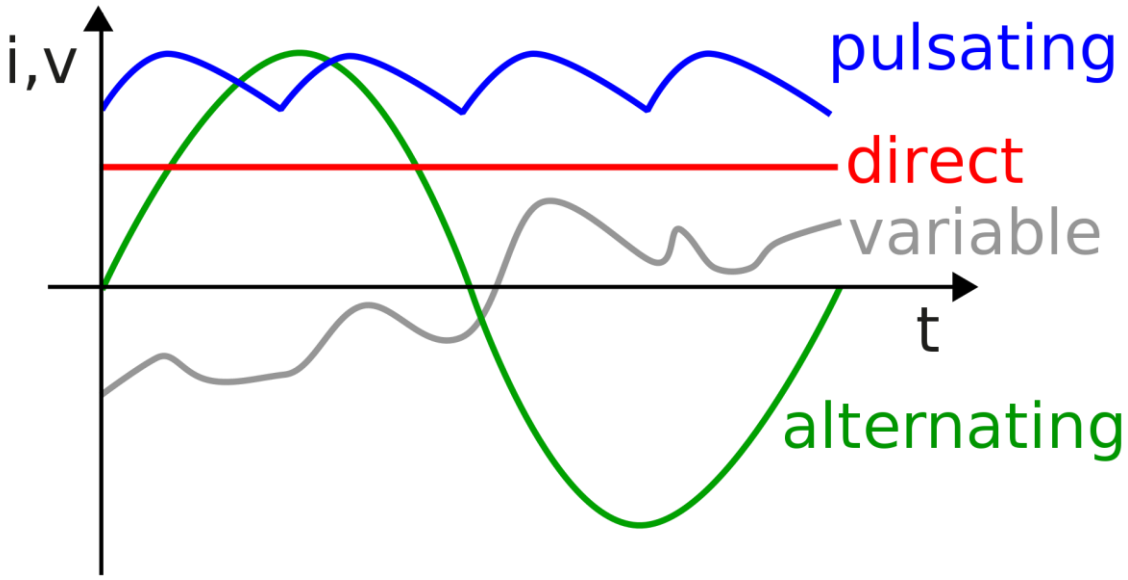
Smart Grid
智能电网

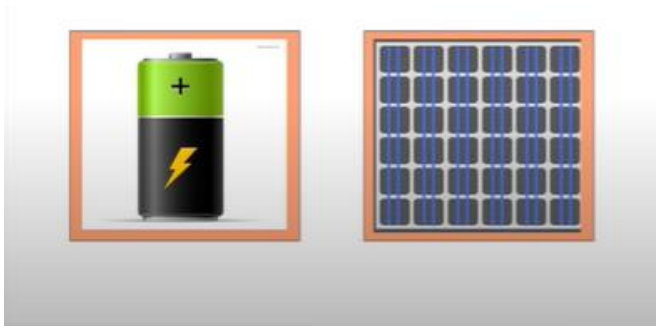
PV Generation
光伏发电

Internet of Things
物联网

- Power electronics is the **enabling** and **transformative** technology
- Evolving towards more **reliable, compact, efficient, low cost**…

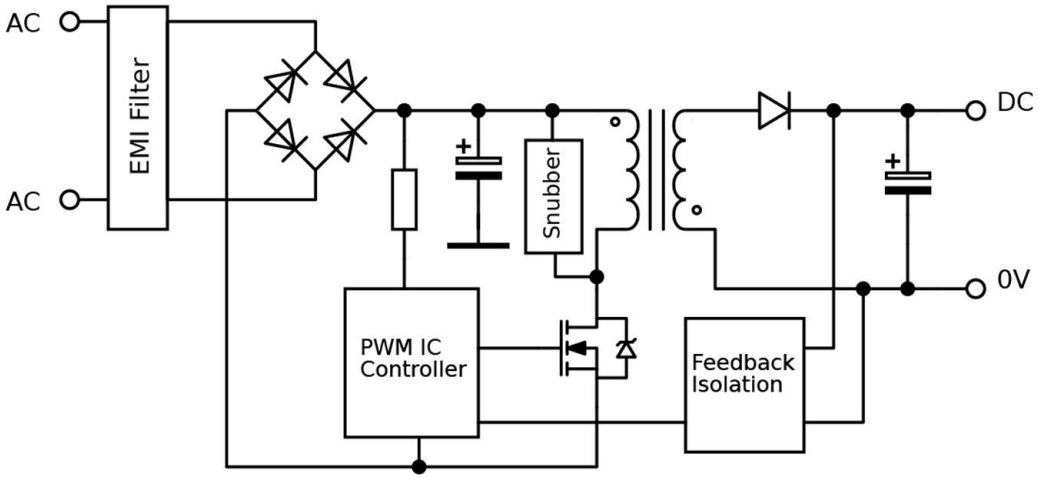
DC vs AC





(Figures from Internet)

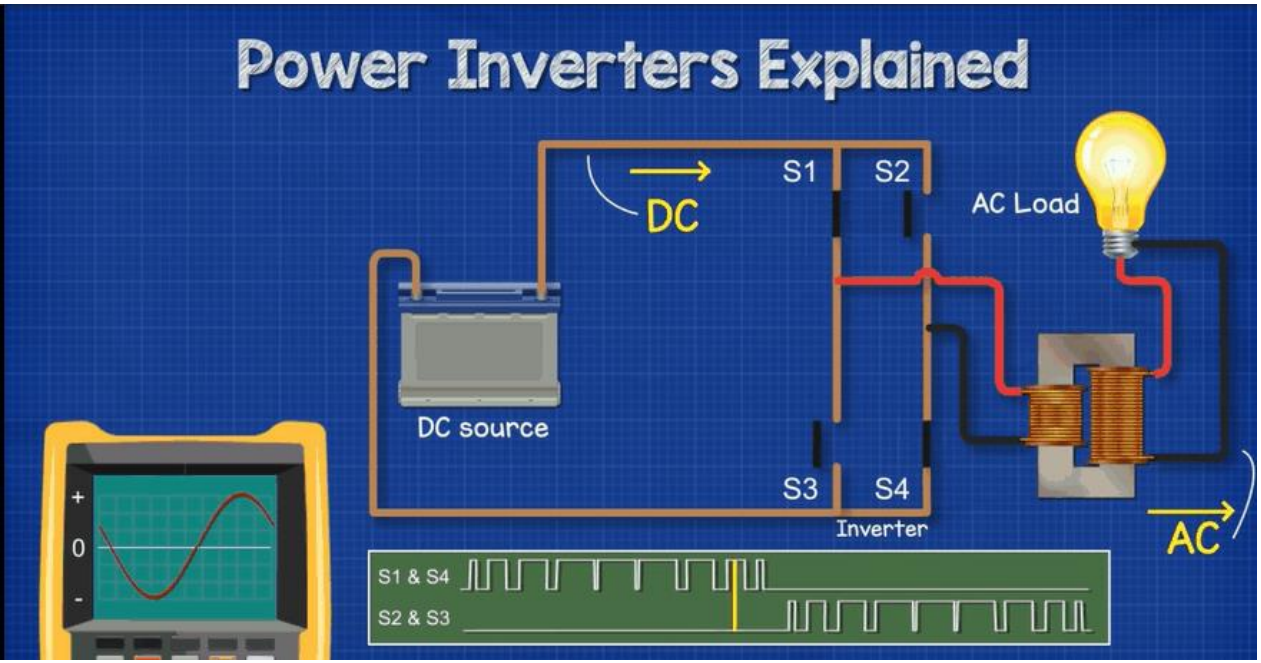
AC/DC Converter



Rectification:
Converting Alternating Current to Direct Current (AC→DC)

(Figures from Internet)

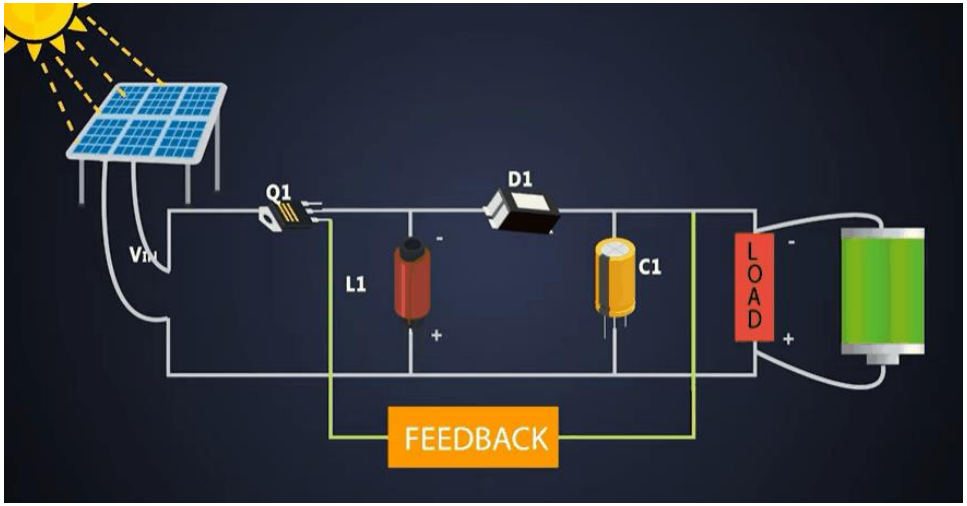
DC/AC Converter



Inverter:
Converting Direct Current to Alternating Current.
(DC→AC)

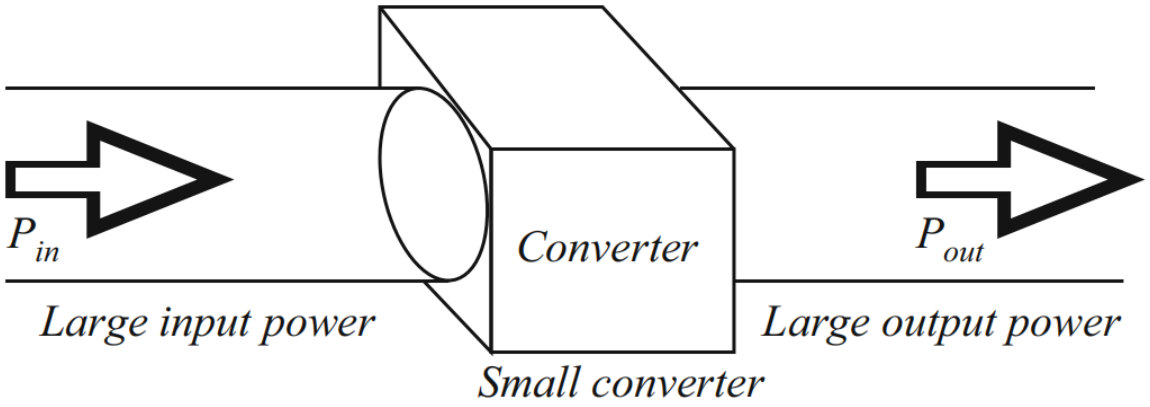
(Figures from Internet)

DC/DC Converter



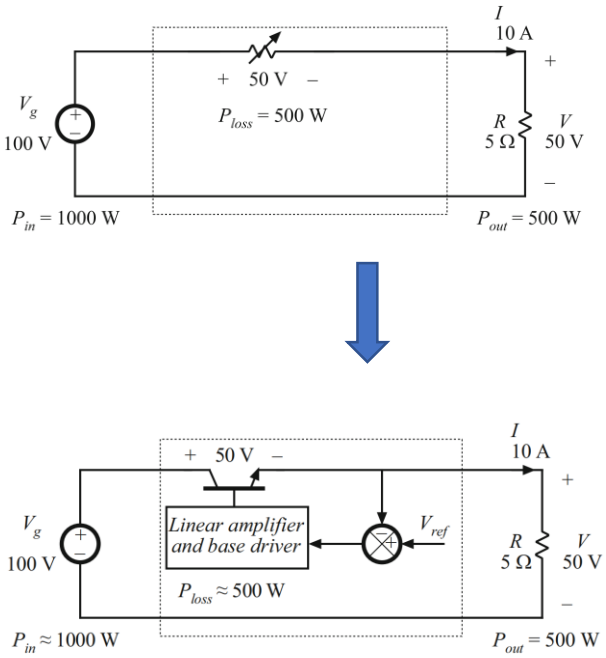
(Figures from Internet)

Power Conversion FOMs



Linear Power Supply

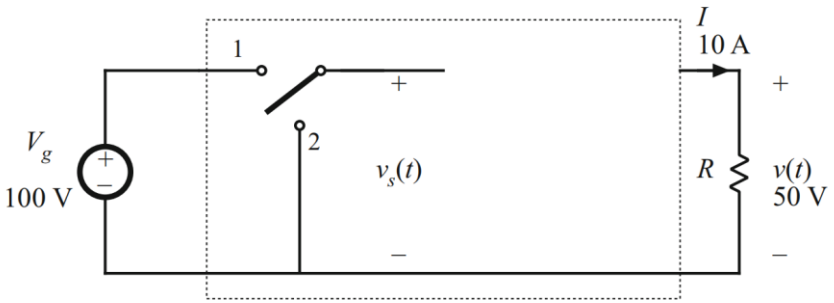
Apple Computer 1



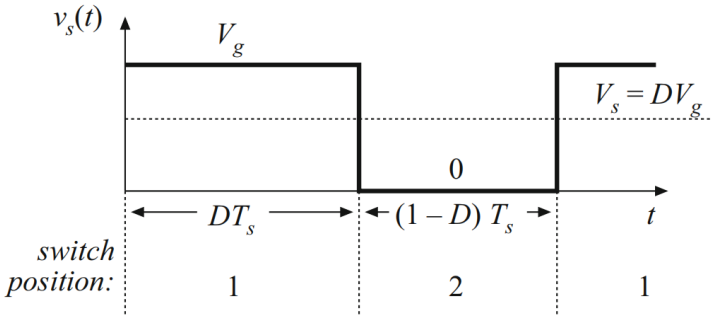
Efficiency: $P_{out}/P_{in} = 50\%$

Switched Mode Power Supply

Apple 140W PD3.1 charger

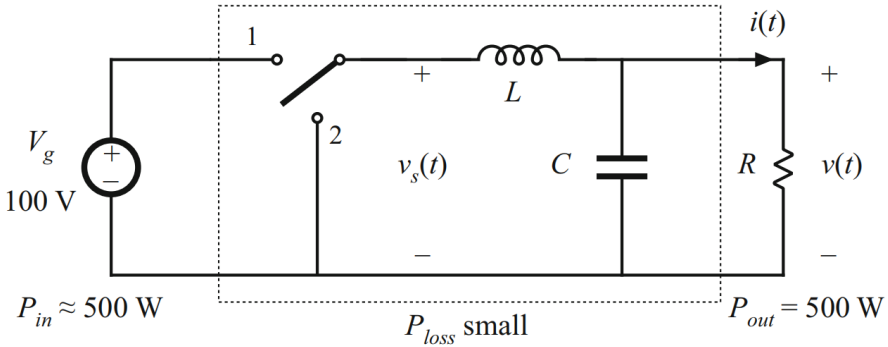


Output voltage $v_s(t)$

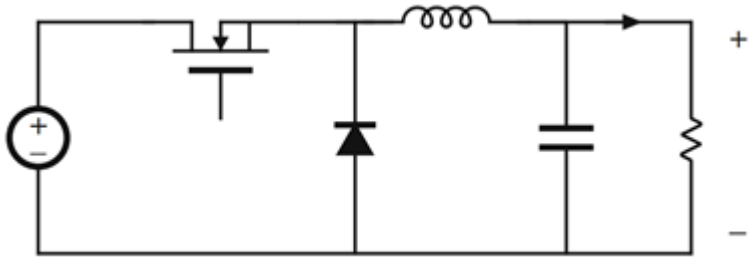


Buck Converter

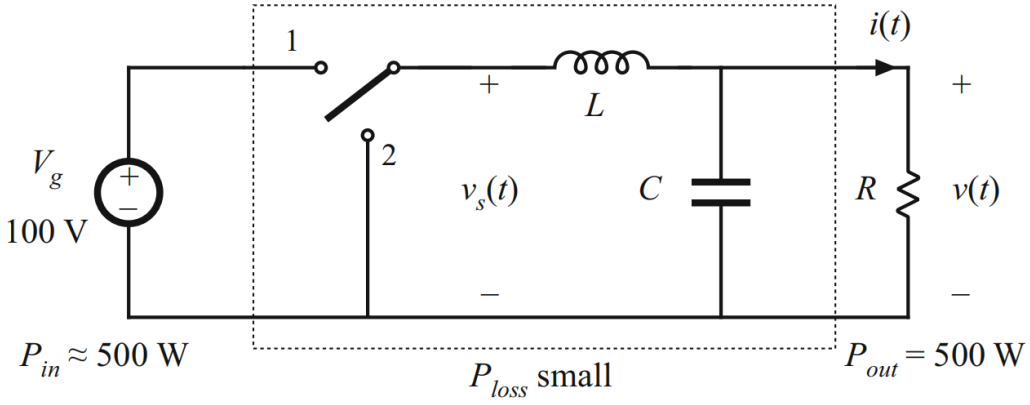
Addition of L-C low-pass filter, for removal of switching harmonics

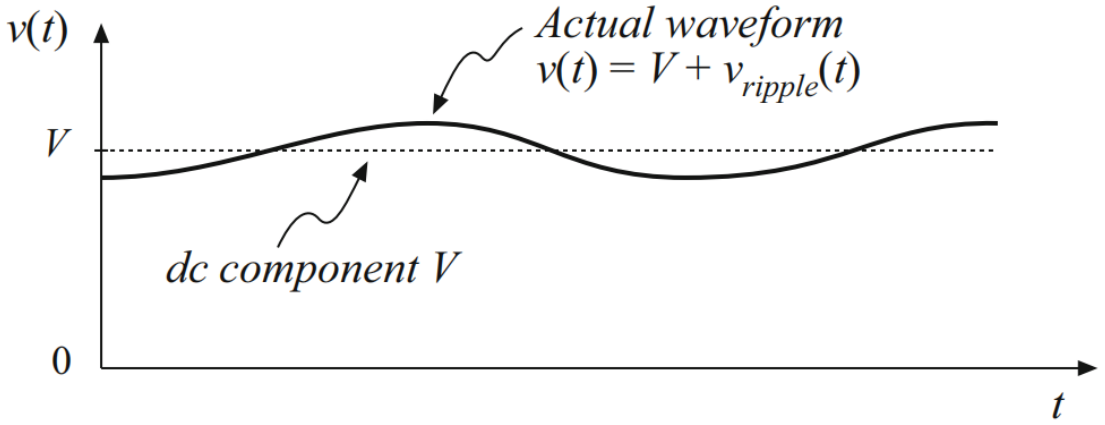


Realization using MOSFET and diode



Small-ripple approximation

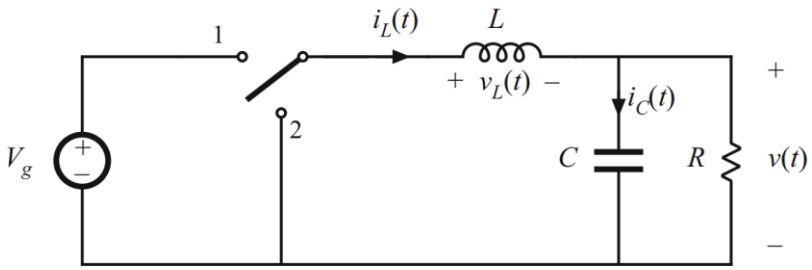




Buck Converter-Mode 1

The devices are assumed to be **ideal**.

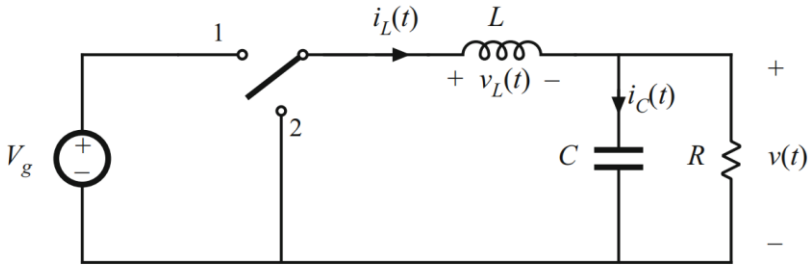
Switch in position 1



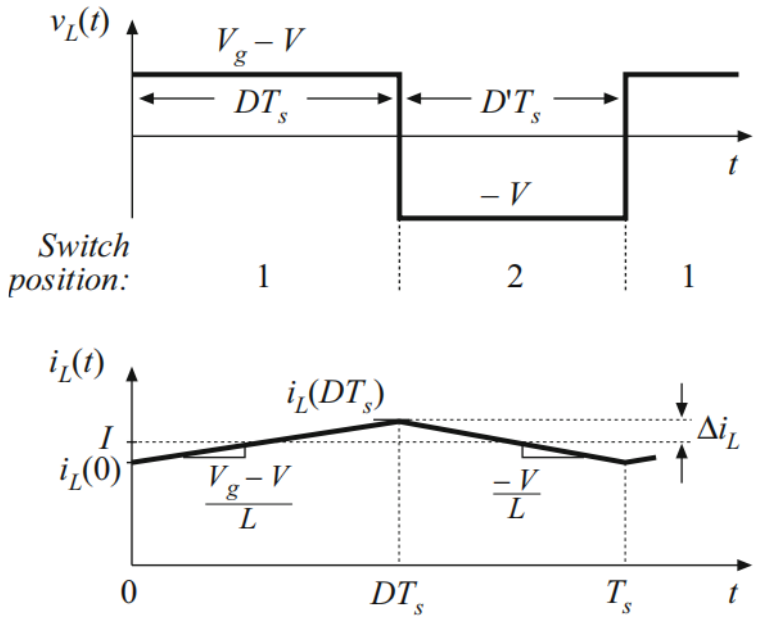
Buck Converter-Mode 2

The devices are assumed to be **ideal**.

Switch in position 2



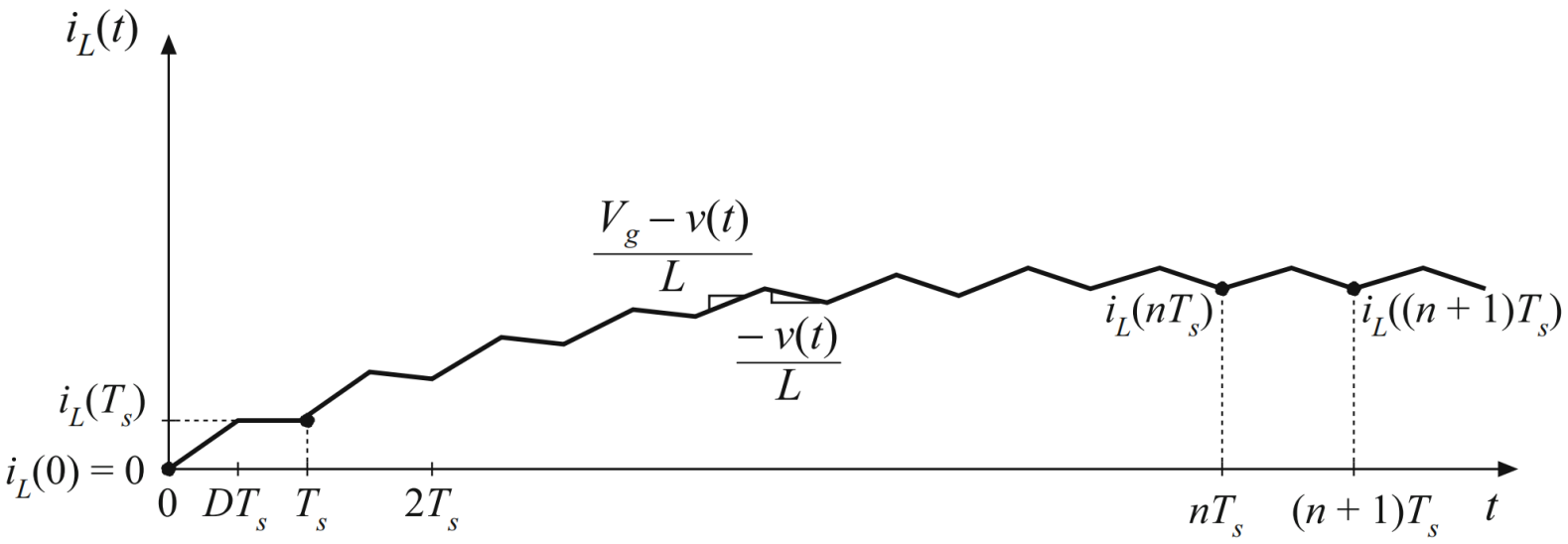
Inductor Voltage and Current



Mode1:

Mode2:

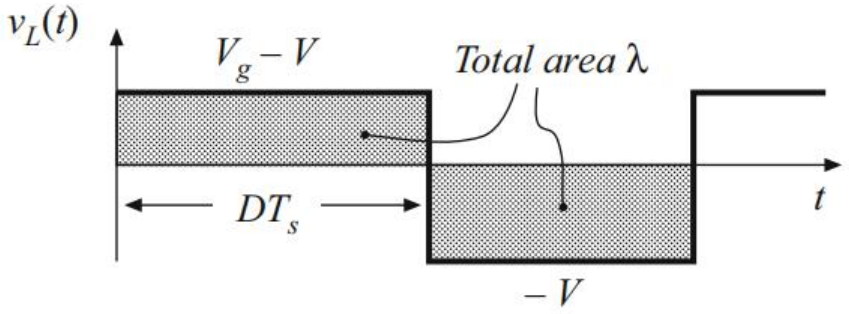
Steady State



Inductor current waveform during converter turn-on transient

Volt-second balance

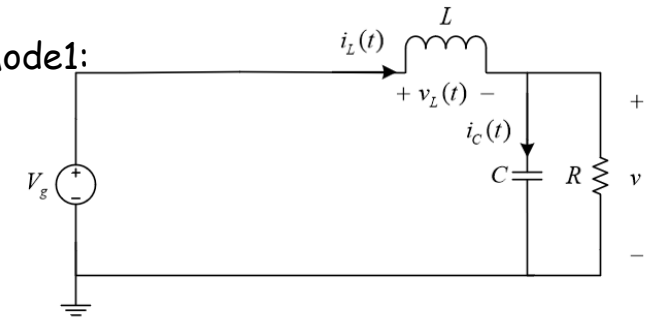
inductor volt-second balance.



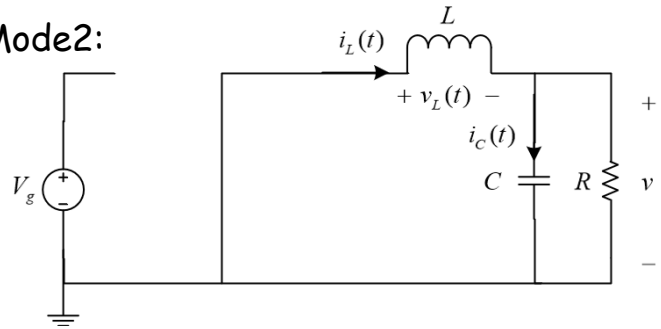
Charge balance

Similarly for capacitors,

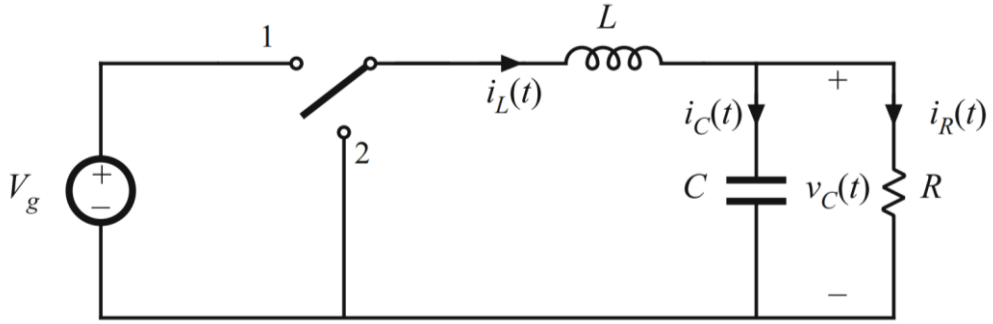
Mode1:

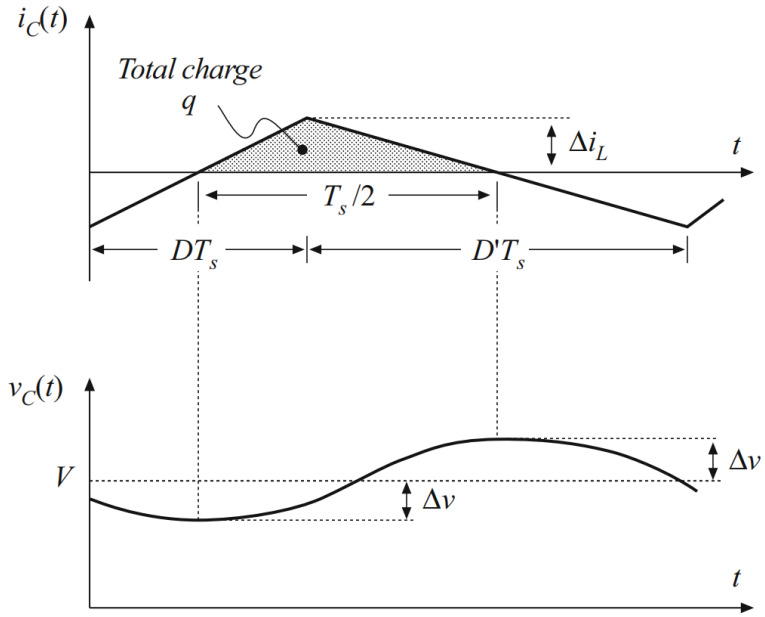


Mode2:



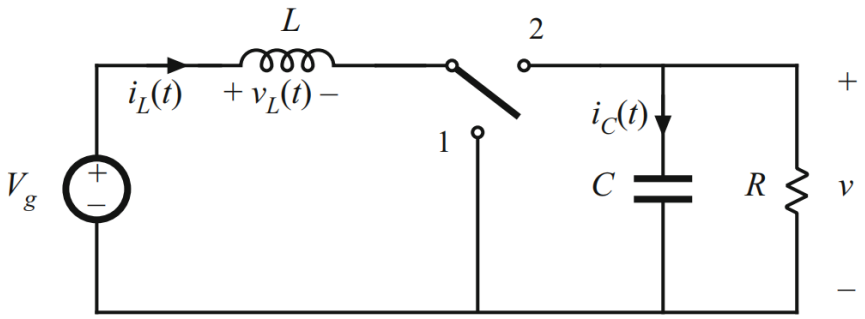
More accurate voltage ripple



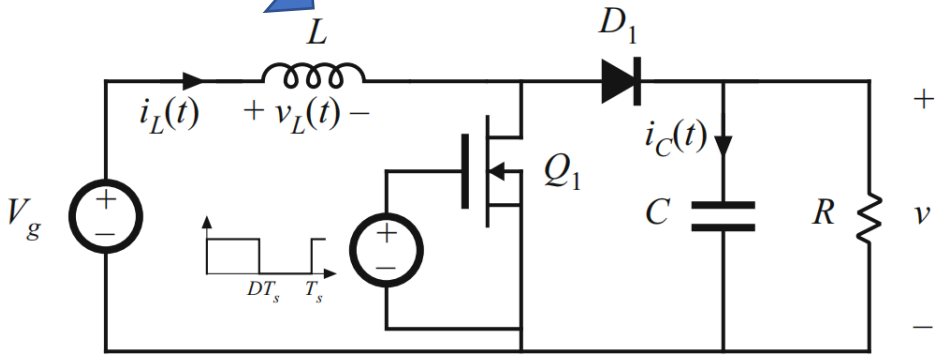


Boost converter

Boost converter(with ideal switch):

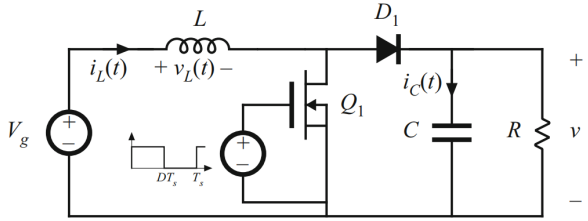


Realization using MOSFET and diode

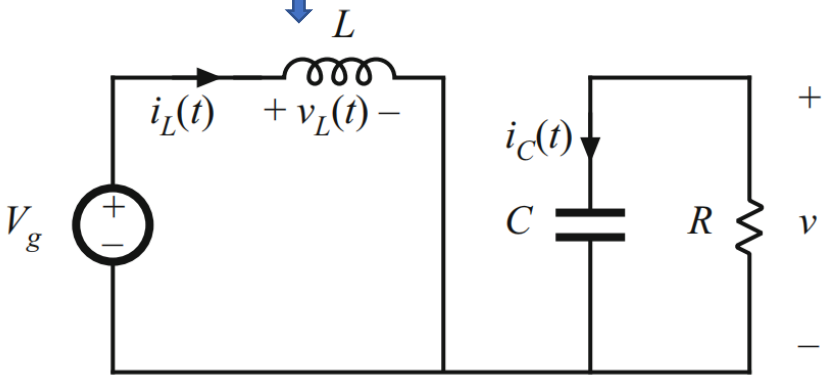


Boost Converter-Mode1

The devices are assumed to be **ideal**.

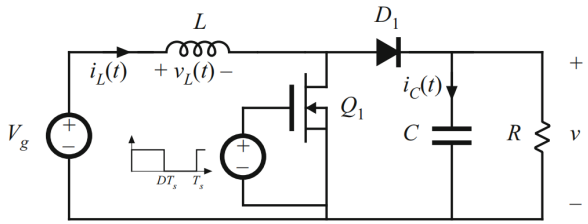


Switch in position 1

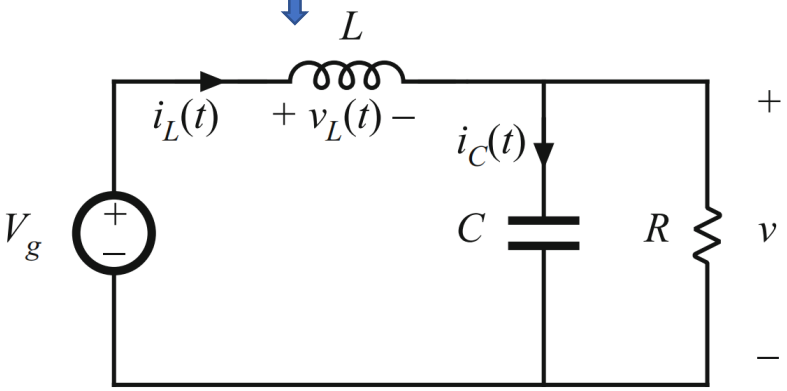


Boost Converter-Mode2

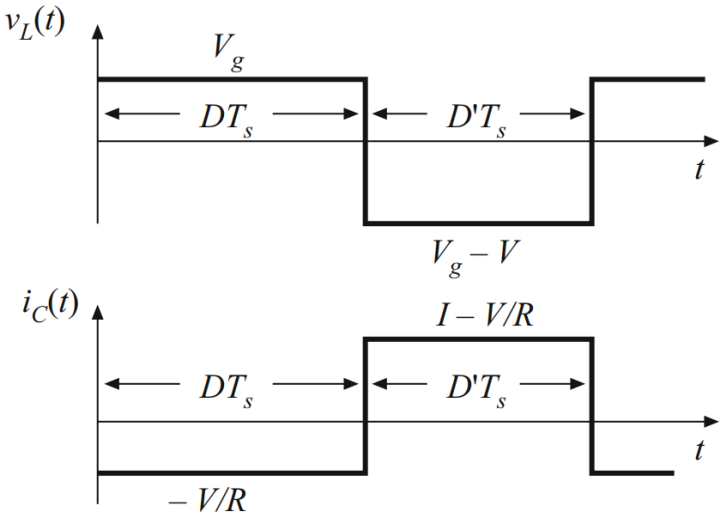
The devices are assumed to be **ideal**.



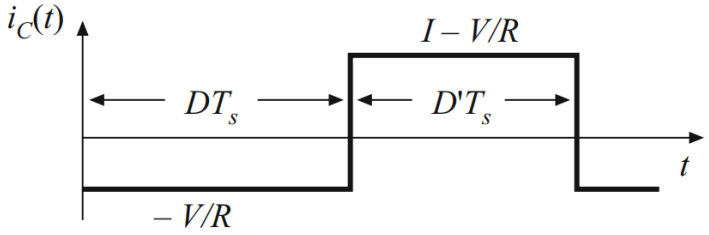
Switch in position 2



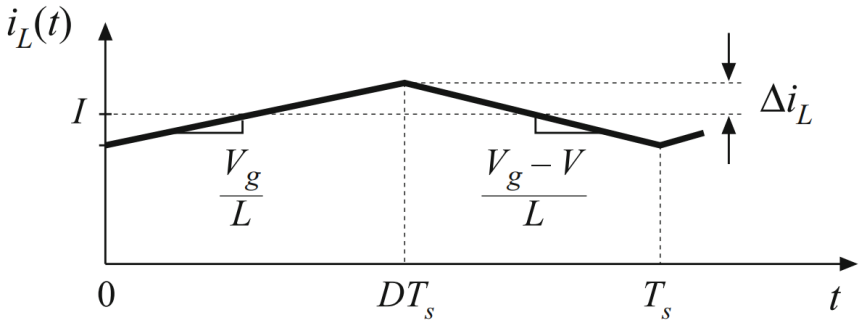
Switching mode analysis-Boost



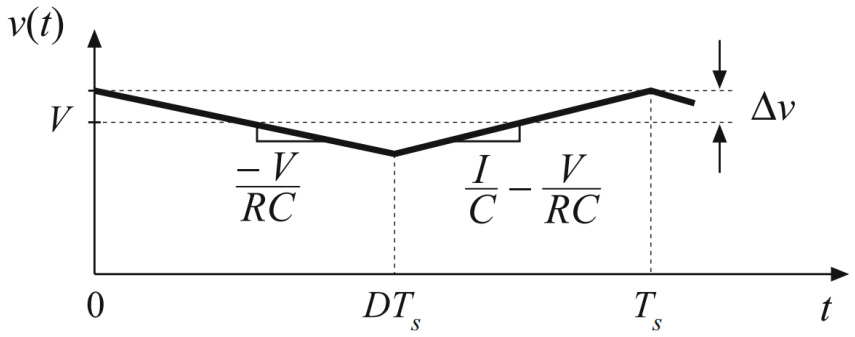
Steady-state analysis



Inductor Current Ripple



Capacitor Voltage Ripple



Closed loop control and negative feedback