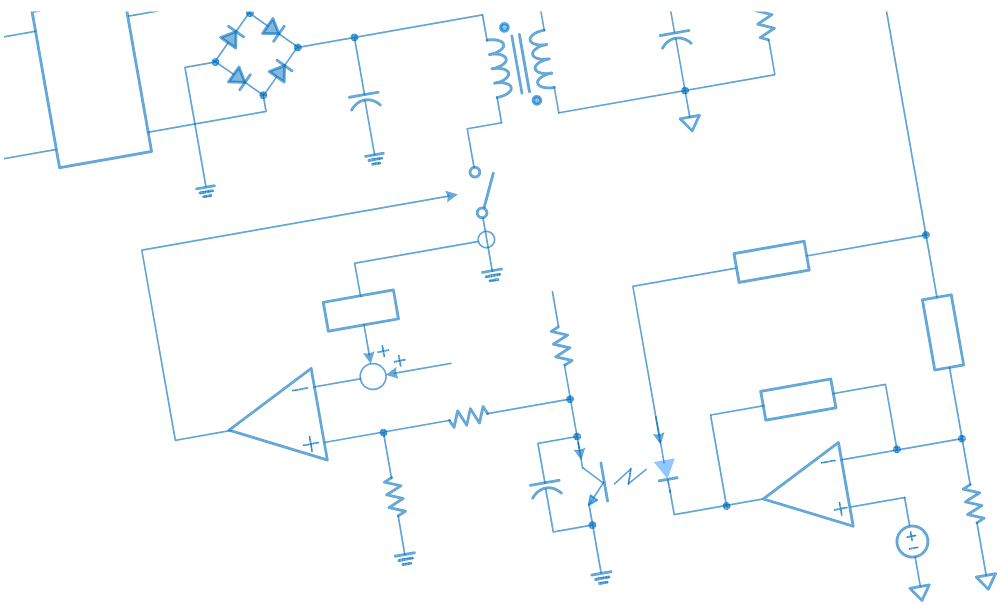
POWER ELECTRONICS with
PULSEWIDTH MODULATED DC-TO-DC POWER CONVERSION

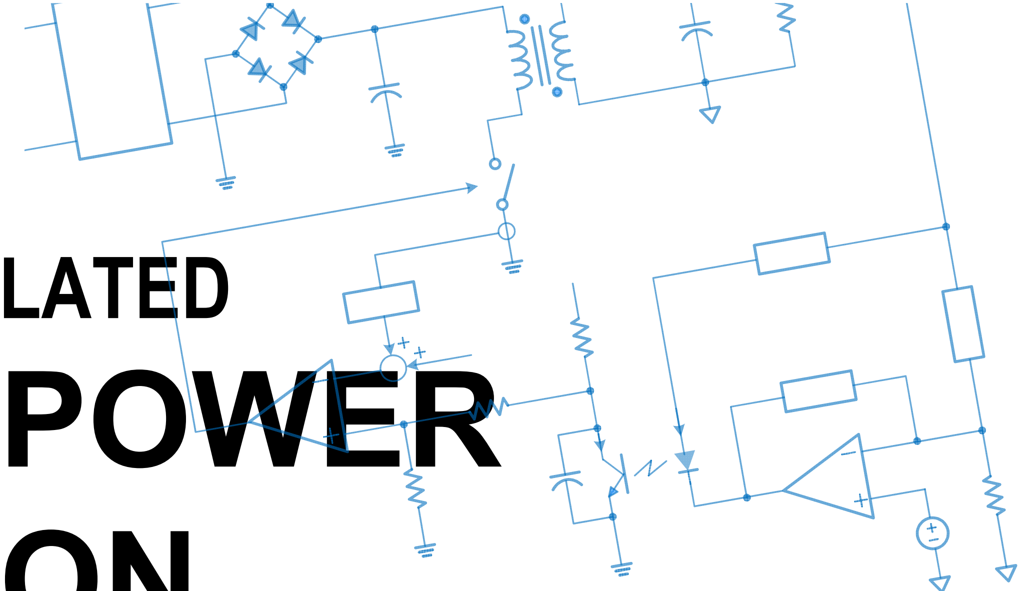


POWER ELECTRONICS

- General Information
  Office: IT3-314 Office Hour: Fri 9:00-12:00 AM Email: bchoi@ee.knu.ac.kr
  Home Page: **http:// smpc.knu.ac.kr**
  OCW Site: http://bkict-ocw.knu.ac.kr
- Course Objective: As an introductory course in power electronics, the class will address basic principles, analysis techniques, and applications of modern power electronics with a strong emphasis on switchmode dc-to-dc power conversions. The students would learn methods of solving various power electronics problems using their knowledge about electronics, circuit theories, and control theories.
- Text: *Byungcho Choi*, "Fundamentals of PWM Power Conversion, 2^{nd} Ed., Guardian Book Publishing
- Grading Policy:
  Midterm Test: 45 %, Final Exam: 45 %,
  Class Activities: 10 %

Tentative Course Outline

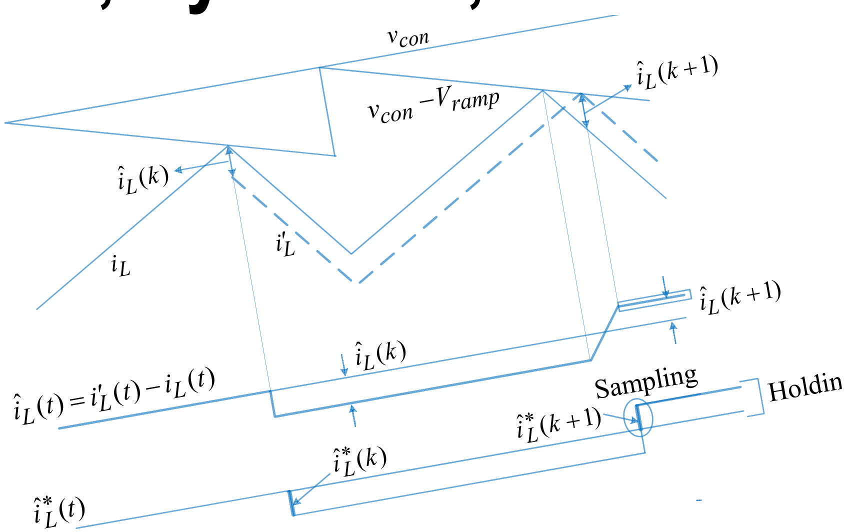
Topic	Major Contents	Weeks
Chapter 1: PWM Dc-to-Dc Power Conversion **Chapter 2: Power Stage Components**	• Introduction to PWM dc-to-dc power conversion • Semiconductor switches and switching circuits • Energy storage/transfer devices and switching circuits • Switch circuits in practice	2 weeks
Chapter 3: Buck Converter	• Basic principles of buck converter • Time-domain analysis of buck converter • Discontinuous-conduction mode of operation • Closed-loop control of buck converter	2 weeks
Chapter 4: Dc-to-Dc Power Converter Circuits	• Boost converter • Buck/boost converter • Flyback converter • Isolated converter topologies	2 weeks
Midterm Test		
Chapter 5: Modeling PWM Dc-to-Dc Converters **Chapter 6: Power Stage Transfer Functions**	• Averaging power stage dynamics • Linearizing averaged power stage dynamics • Bode plot for transfer functions • Power stage dynamics of three basic converters	3 weeks
Chapter 7: Dynamic Performance of PWM Dc-to-Dc Converters **Chapter 8: Closed-Loop Perform ance and Feedback Design**	•Frequency-domain performance of dc-to-dc converters •Time-domain performance of dc-to-dc converters • Stability of dc-to-dc converters • Compensation design and closed-loop analysis	4 weeks
Final Exam		



PULSEWIDTH MODULATED

DC-TO-DC POWER CONVERSION

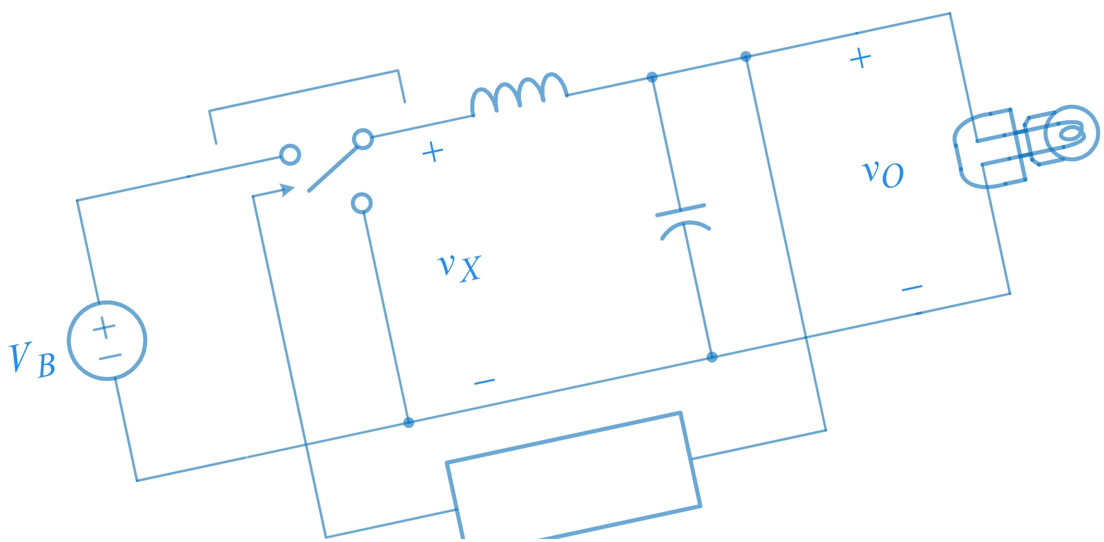
Circuits, Dynamics, and Control Designs



Contents in Brief

Chapter 1

PWM Dc-to-Dc Power Conversion



Pulsewidth Modulated Dc-to-Dc Power Conversion. By Byungcho Choi

Chapter Outline

1) PWM Dc-to-Dc Power Conversion

    Dc-to-Dc Power Conversion

    PWM Technique

2) Dc-to-Dc Power Conversion System

3) Features and Issues of PWM Dc-to-Dc Converter

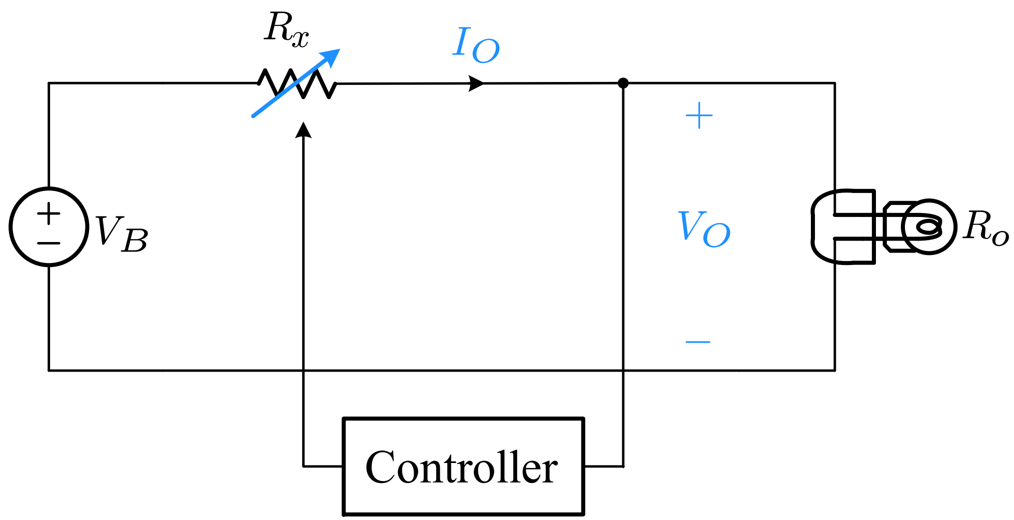
Electric Bulb Drive Circuit

- Energy source and load

  Source: battery with variable output voltage ($V_B = 18\ \text{V} - 30\ \text{V}$)

  Load: $12\ \text{V}$ electric bulb ($V_O = 12\ \text{V}$)

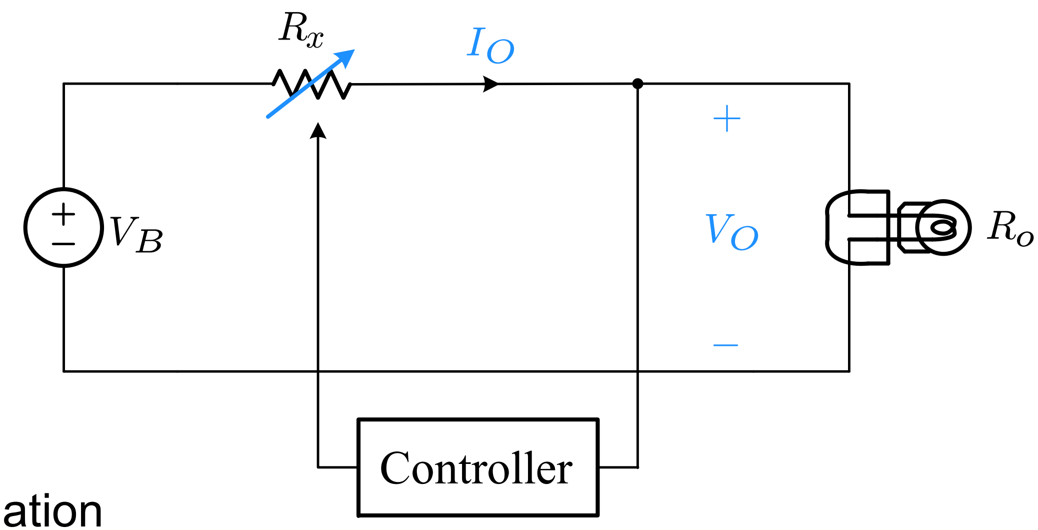
- Conventional resistive solution



Control law: $V_O = \dfrac{R_o}{R_x + R_o} V_B = 12\ \text{V}$

Ohmic loss at R_x: $P_{loss} = P_{in} - P_{out} = I_O V_B - I_O V_O$
$= I_O(V_B - V_O)$

Problem of Resistive Solution



- Efficiency evaluation

  Assumptions

  Battery voltage: $V_B = 30\ \mathrm{V}$

  Bulb: 60 W power at $12\ \mathrm{V}$ voltage level $\Rightarrow$ $V_O = 12\ \mathrm{V}$ and $I_O = 60/12 = 5\ \mathrm{A}$

  $$P_{loss} = I_O(V_B - V_O) = 5(30-12) = 90\ \mathrm{W}$$

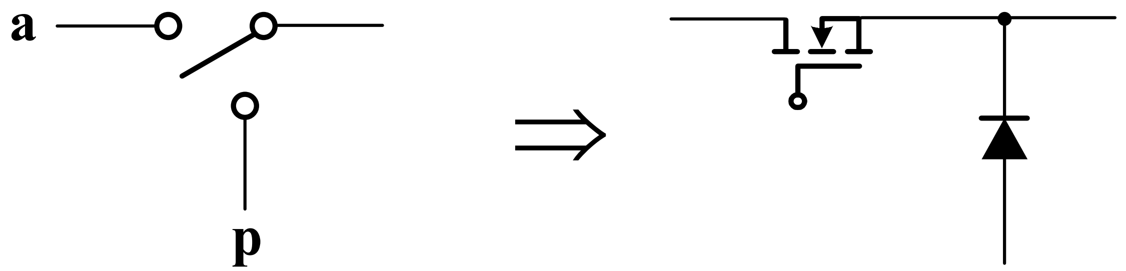
  Efficiency: $\eta = \dfrac{P_{out}}{P_{in}} = \dfrac{P_{out}}{P_{out} + P_{loss}} = \dfrac{60}{60+90} = 0.4$

- Consequence of poor efficiency

  Heat generation $\Rightarrow$ Requirement of cooling system

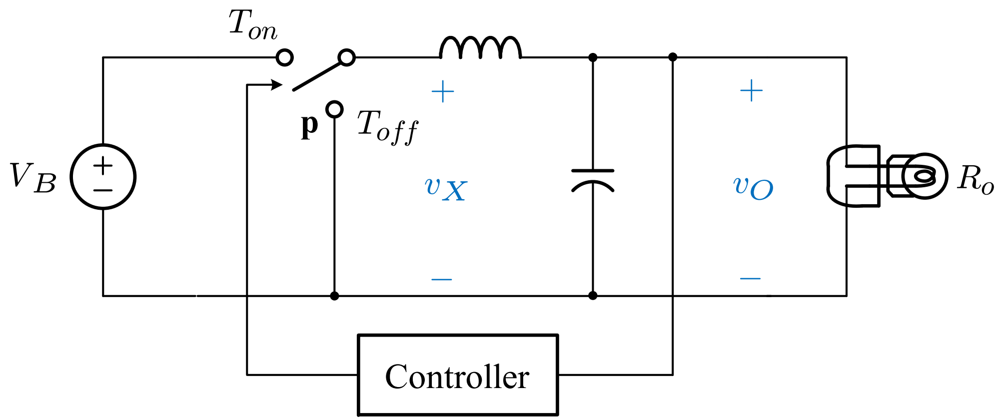
  $\Rightarrow$ Increase in weight and size of bulb drive circuit

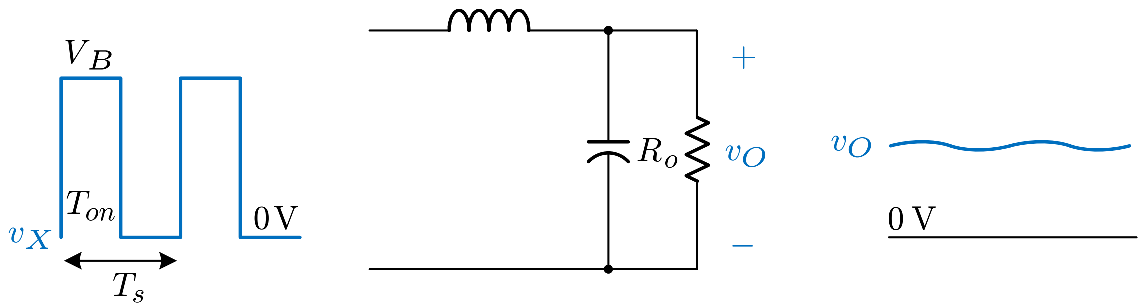
SPDT Switch



- Single-pole double-throw (SPDT) switch contains one pole which is always connected to one of the two contacts: the throw a and the throw p.
- SPDT switch is usually implemented using MOSFET-diode pair.

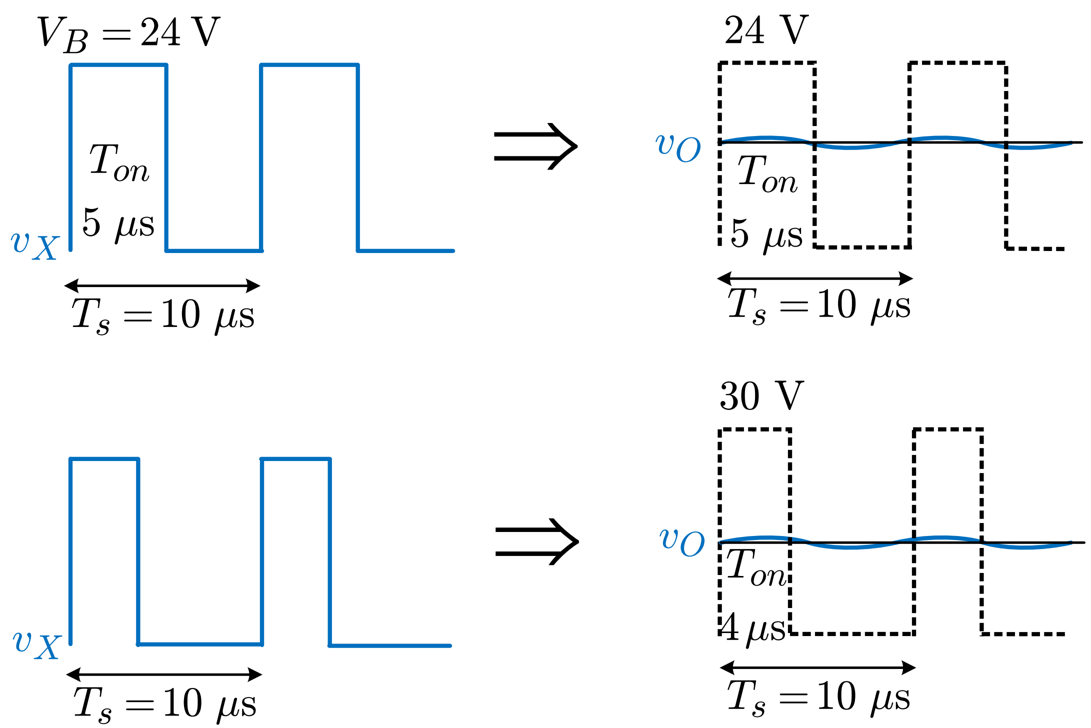
Dc-to-Dc Power Conversion as Alternative Solution





- Two steps in dc-to-dc power conversion
  - i) conversion of dc voltage into a pulse waveform
  - ii) filtering of the pulse waveform into another dc voltage
- Control law: $v_O(t) \approx V_O = \text{average}\{v_X(t)\} = \bar{v}_X(t) = \dfrac{T_{on}}{T_s} V_B = 12\,\text{V}$
- No power loss in circuit $\Rightarrow$ $\eta = 100\ \%$

Pulsewidth Modulation for Output Voltage Regulation



- Control law: $\dfrac{T_{on}}{T_s} V_B = \dfrac{T'_{on}}{T_s} V'_B = 12\ \text{V}$

- Output remains constant in spite of input voltage variation

  $\Rightarrow$ Output voltage regulation using pulsewidth modulation (PWM) scheme

PWM Dc-to-Dc Converter

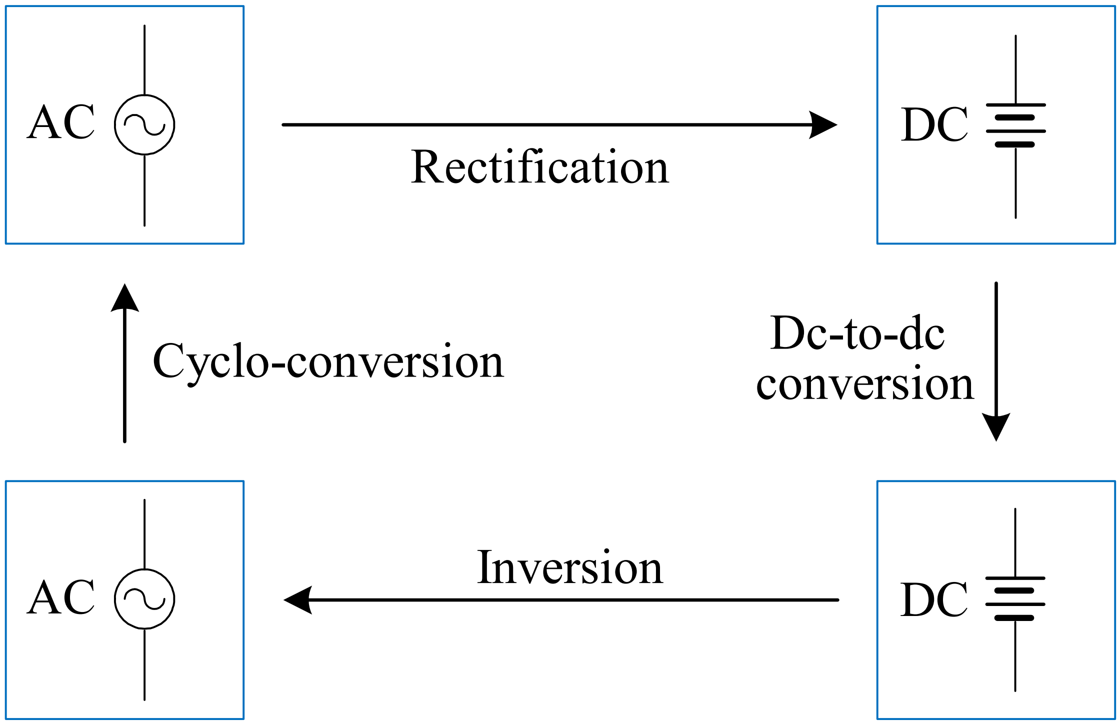
- Power conversion: changing electrical energy/power from one form to another form using electric devices

- Power electronics: electronic engineering that deals with all types of power conversions *while questing the maximum possible conversion efficiency*

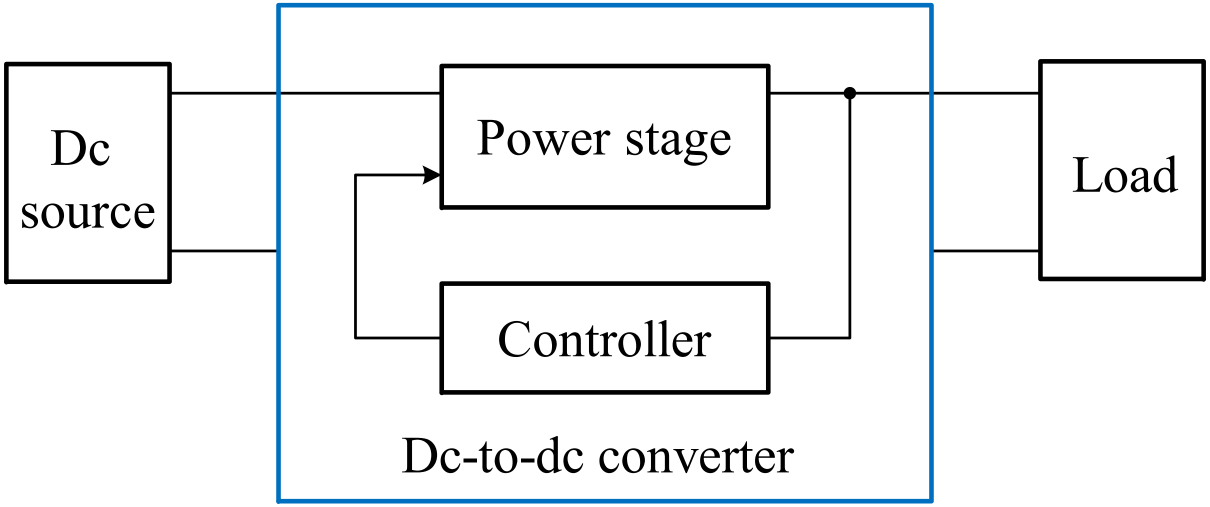
- Dc-to-dc power conversion: process of changing the voltage level of a dc source to another value

- PWM dc-to-dc power converter: dc-to-dc conversion circuit operating under the PWM technique

Classification of Power Conversion



Dc-to-Dc Power Conversion System



- Dc source with non-ideal characteristics

  Standalone dc source: variation in source voltages

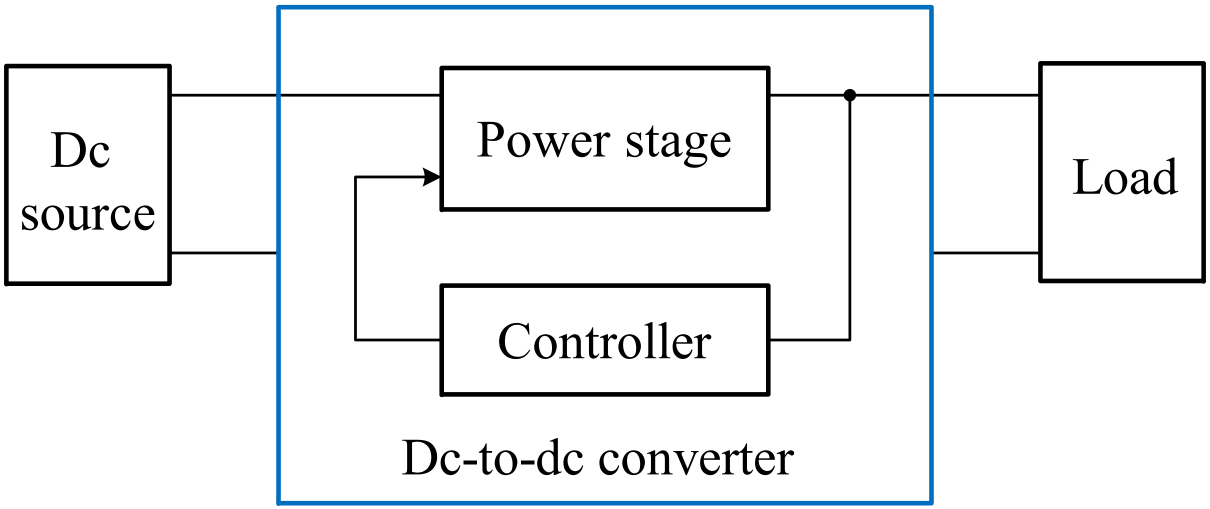
  Rectified ac source: ac ripple and noise compenents

- Load as a dynamic current sink with general impedance characteristics

  Electric equipmemt: non-resistive load impedance characteristics

  Digital logic system: dynamic changes in load current

Dc-to-Dc Power Conversion System



- Dc-to-dc converter as a voltage source

  Functions of dc-to-dc converter: power conversion and energy flow control

- Components of dc-to-dc converter

  Power stage: semiconductor switches – MOSFETs and diodes
  energy storage/transfer decives – inductors, capacitors,
  and transformers

  Controller: ICs and discrete components

Features and Issues of PWM Dc-to-Dc Converter

- Power stage components
  - Semiconductor devices: high-frequency switching operations
  - Inductors and capacitors: periodic voltage/current excitations
  - Transformers: periodic voltage/current excitations
- Power stage configurations
  - Accommodation of input voltage and load current requirements
  - Very large or small voltage conversion ratio
  - Galvanic isolation between source and load
- Dynamic modeling and analysis
  - Closed-loop feedback control for output regulation
  - Stability and dynamic performance
  - Dynamic modeling to embrace conventional analysis techniques
- Dynamic performance and control design
  - Dynamic performance: stability, transfer functions, and transient responses
  - Feedback control design for optimal dynamic performance