

EE Lecture 3: Electronic Devices and Circuits-Part B

Makerspace (MS 101)

2023-24/I (Autumn)

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Syllabi for Lect 2 and Lect 3

- **Lect 2 – Electronic Devices**

- Electronic Sub systems:
 - Two-terminal electronic devices (diodes)
 - Two-port networks: 3-pin devices (BJT, MOSFET), Filters, Amplifiers
- *pn* junction diode
- Zener diode,
- LED,
- Photodiode, and
- Solar Cell

- **Lect 3 – Rectifier and Regulator Circuits**

- Part1: Rectifier circuits: Half-wave rectifier, Full-wave rectifier (Bridge rectifier)
- Part 2: Unregulated DC Power Supply
- Part 3: Regulator DC Power Supply (Voltage Regulator: IC based regulated DC Power Supply)

Part 1: Rectifier Circuits

Part 1: Rectifier Circuits

- Half-Wave Rectifier
- Full-wave Rectifier
 - Bridge rectifier circuit

Step Down Transformer (230 V - 12 V RMS)

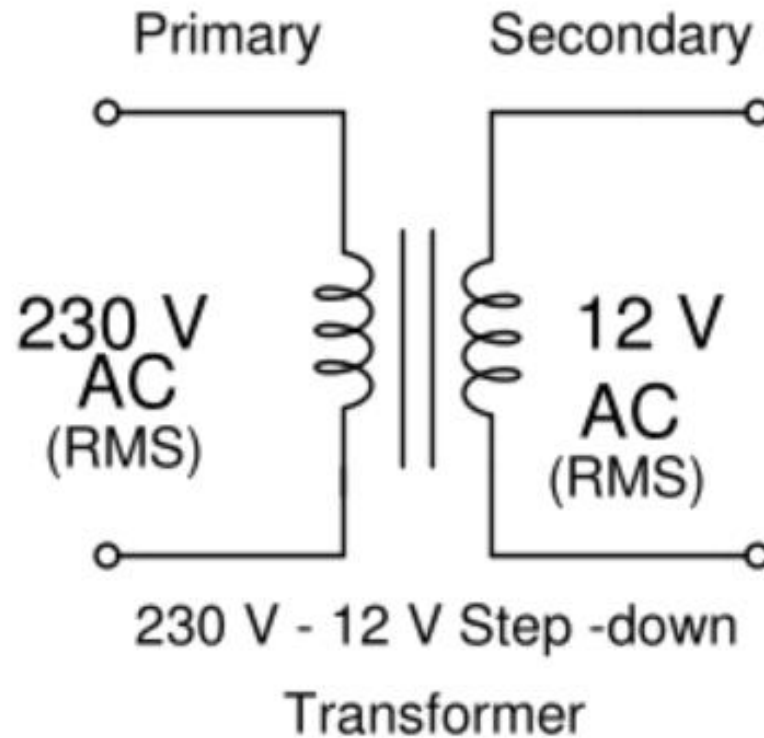


Fig. 1 Step-down Transformer

A) Half-wave Rectifier

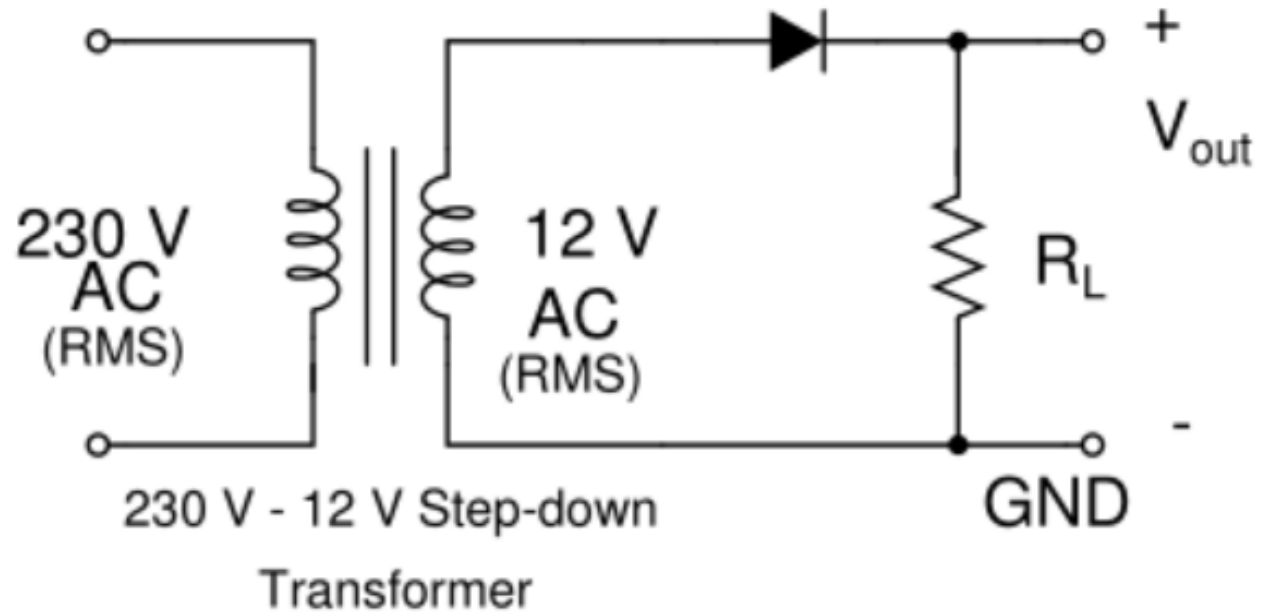
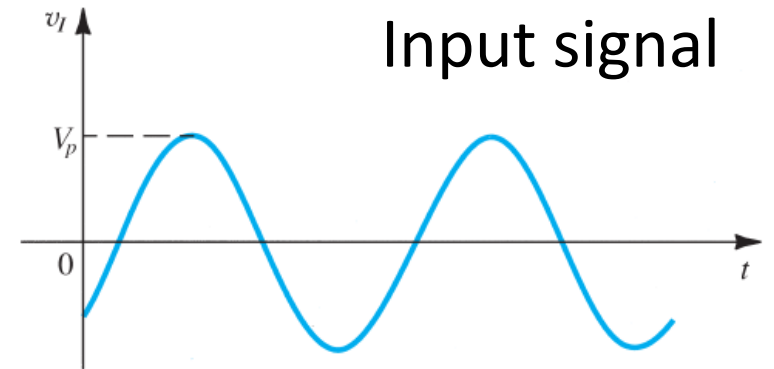


Fig. 2



Half-wave Rectifier Output

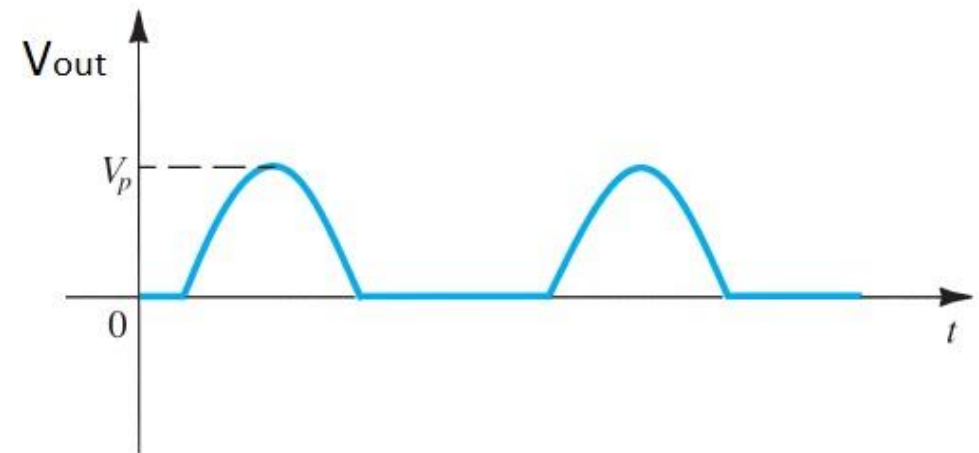


Fig. 3

B) Full-wave (Bridge) Rectifier

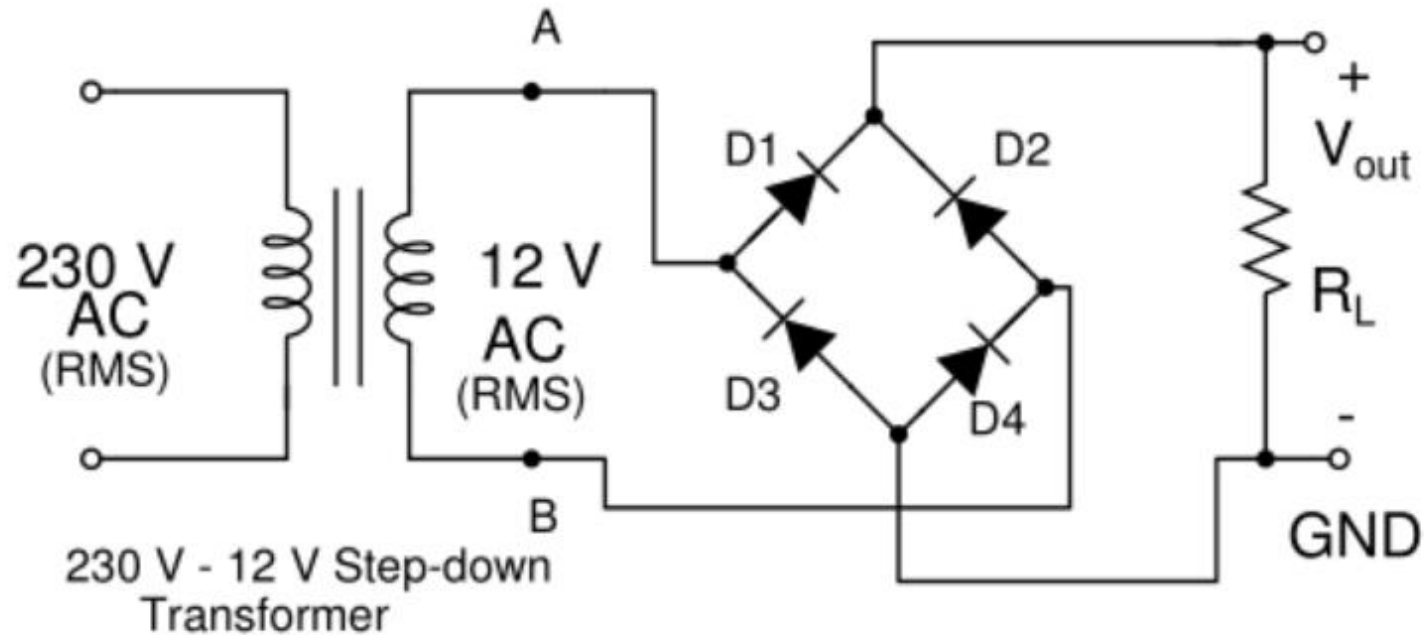
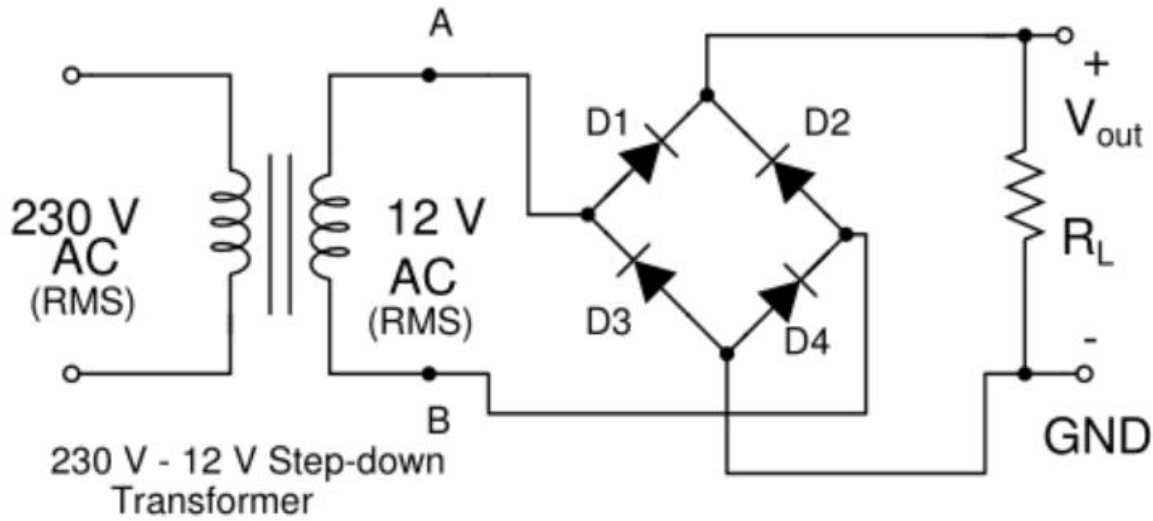


Fig. 4

- Bridge Rectifier: in every half cycle, two diodes will be in the current path



- 1st half cycle (output A is +ve w.r.t. Output B): current path – from output A \rightarrow D1 \rightarrow R_L \rightarrow D4 \rightarrow B; D2 and D3 will not conduct.
- 2nd half cycle (Output B is +ve w.r.t. output A): current path – from B \rightarrow D2 \rightarrow R_L \rightarrow D3 \rightarrow A; D1 and D4 will not conduct.

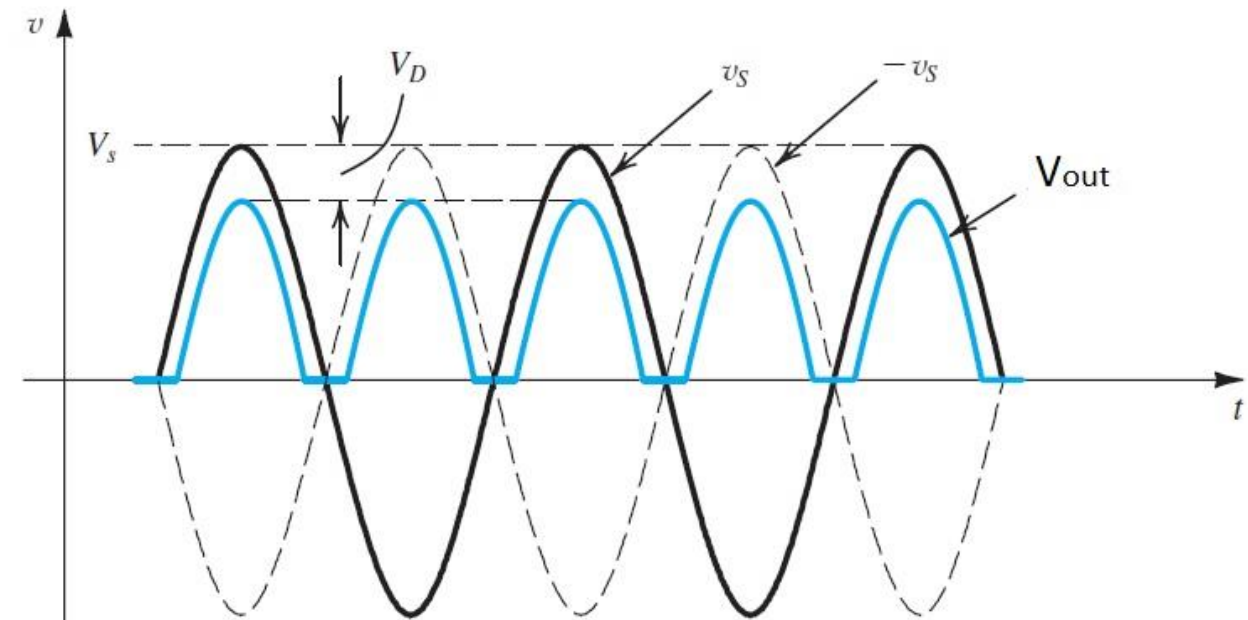


Fig. 5

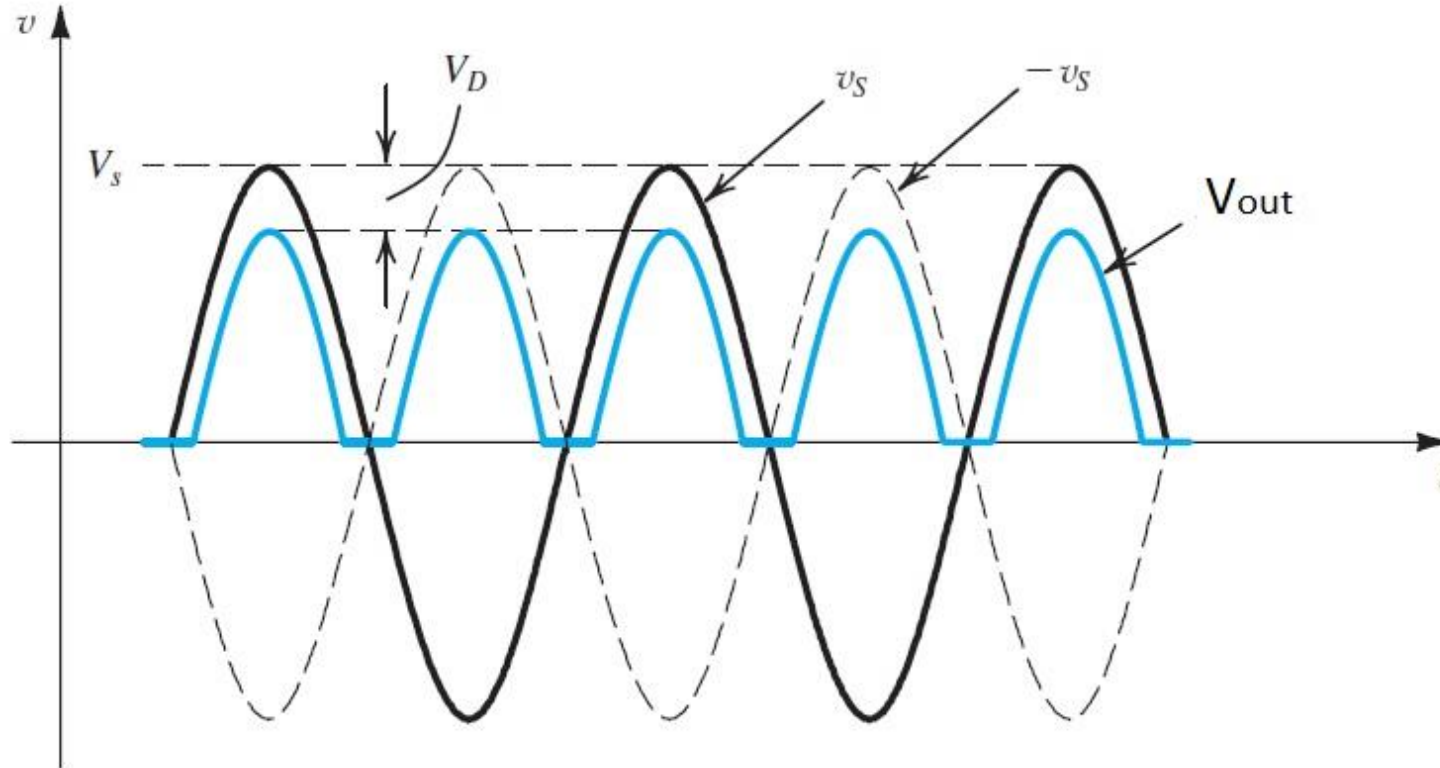


Fig. 6

- Full-wave Rectifier: Input and Output waveforms (considering diode drops)
- Output voltage will have the *two diode drops* lower than the input voltage. Typ. diode drop = 0.6 V

Part 2: Unregulated Power Supply (Capacitive filter)

Unregulated Power Supply (Capacitive filter)

- Case A): Half-wave rectifier with a large value capacitor - ($\gg 10 \mu\text{F}$)
- Case B): Full-wave bridge rectifier with a large value capacitor ($\gg 10 \mu\text{F}$)

Unregulated Power Supply

(Using Half-wave Rectifier and a Capacitive filter)

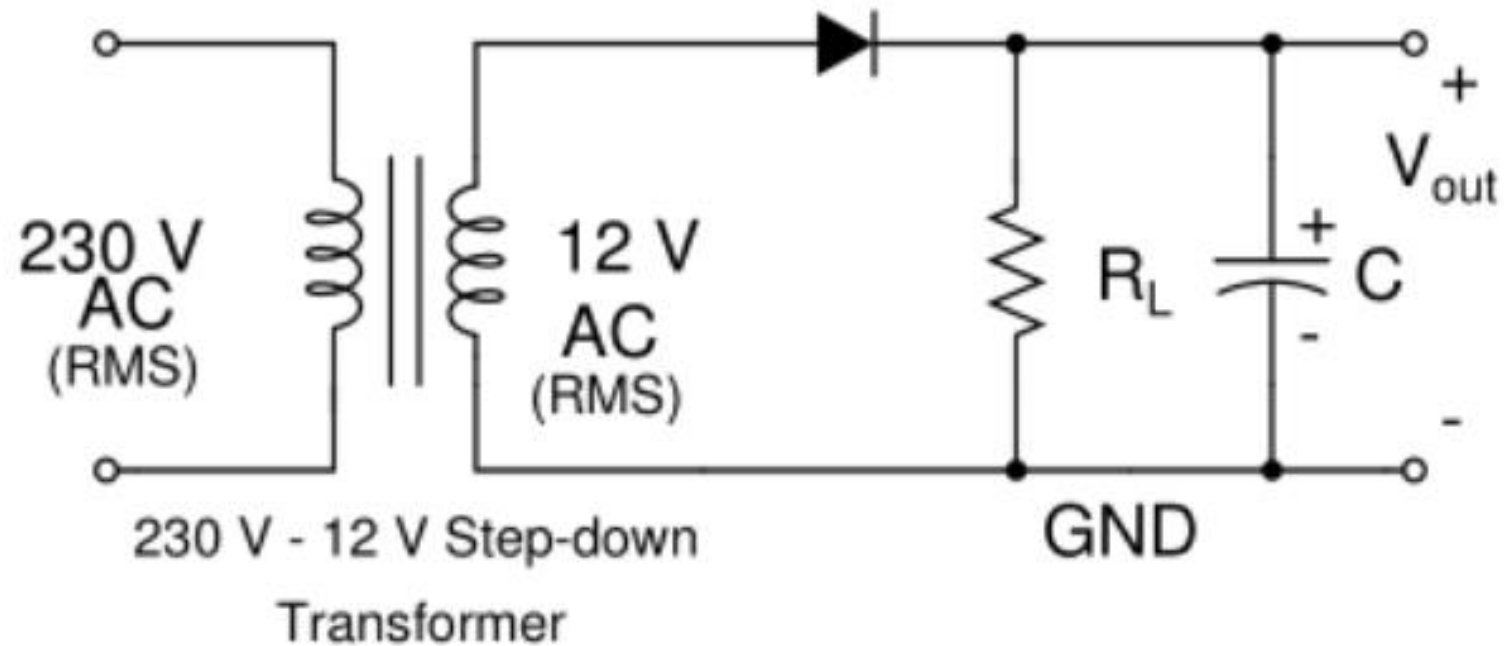
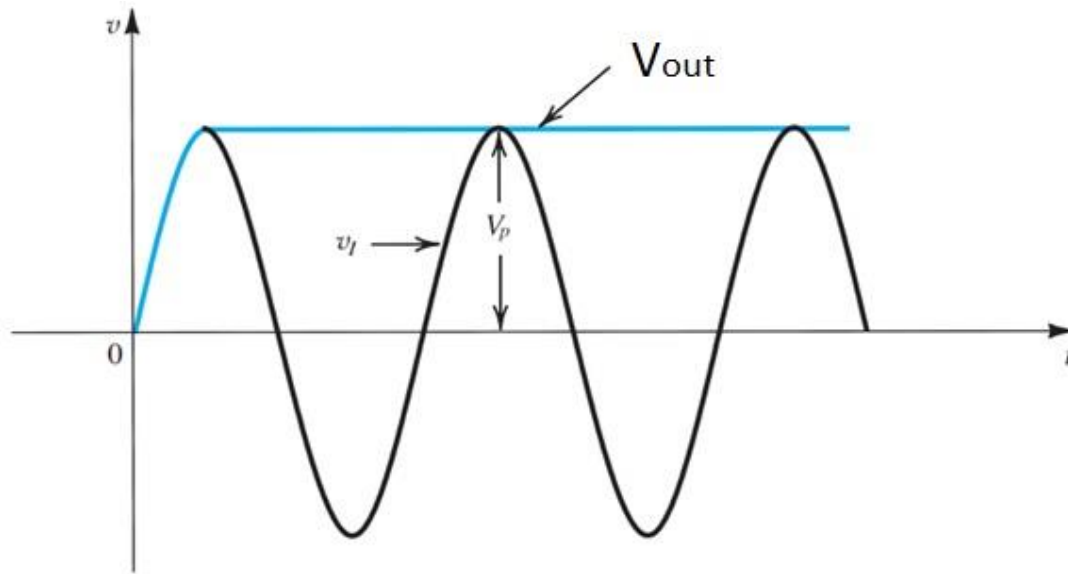
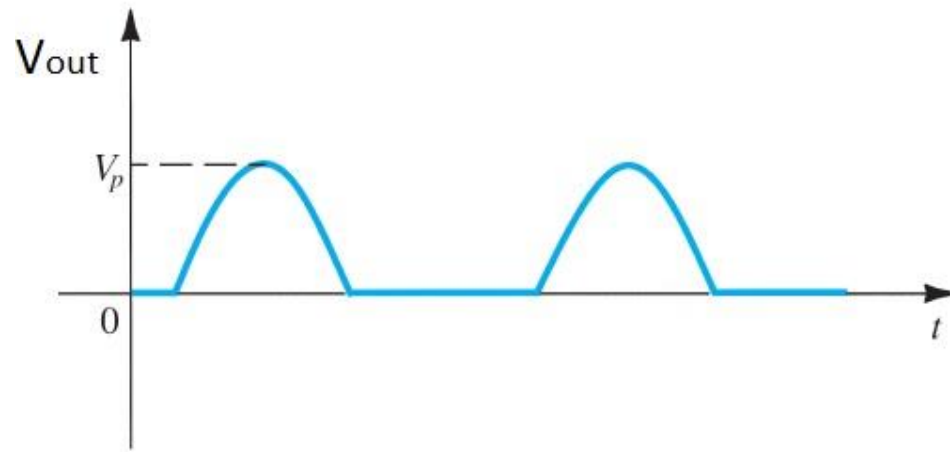
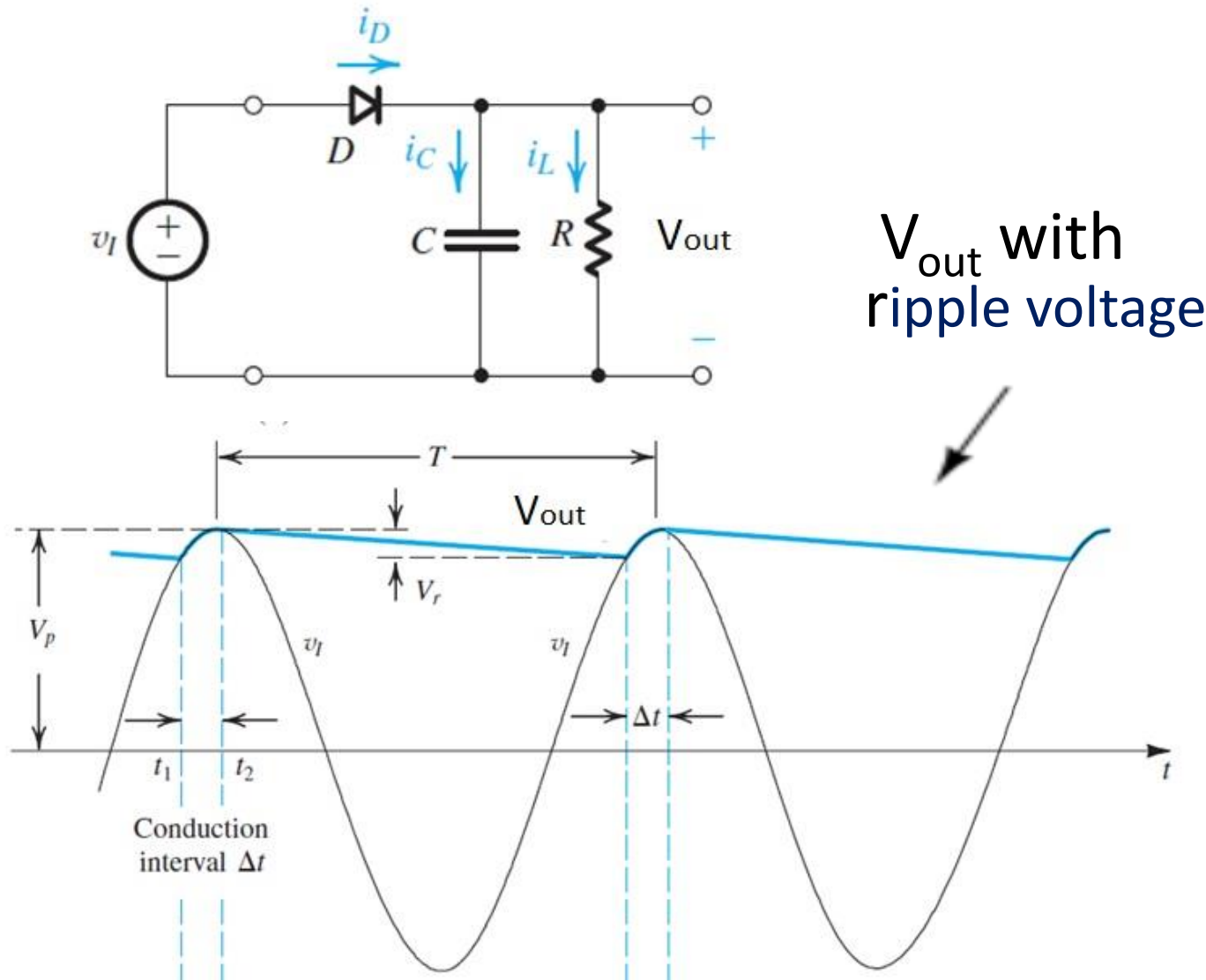


Fig. 7



When there is no load (or open circuit), V_{out} has no ripple (i.e. V_{out} is a constant dc voltage)

Fig. 8



- The half-wave rectifier with C is very seldom used due to its higher ripple voltage

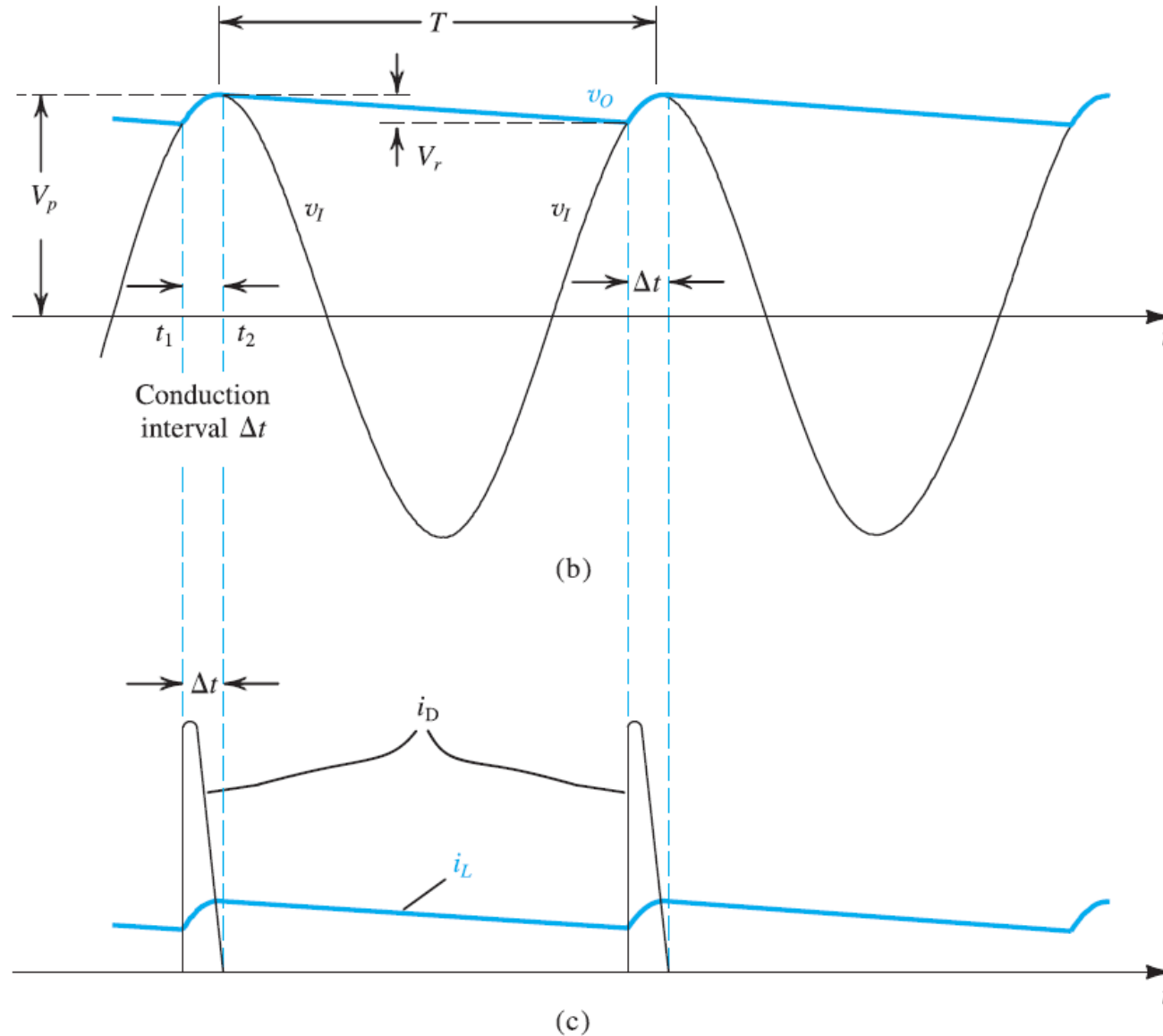
Fig. 9

Operation with C across R_L

- C charges during Δ_t , and discharges during $(T - \Delta_t)$.
- Ripple voltage, V_r increases with i_L (load current).
- Ripple voltage can be decreased by increasing C (not a good solution).
- For a given i_L , as $C \uparrow$, $\Delta_t \downarrow$ (which will make $i_D \uparrow \uparrow$)

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Unregulated Power Supply

(Using Full-wave Bridge Rectifier and a Capacitive filter)

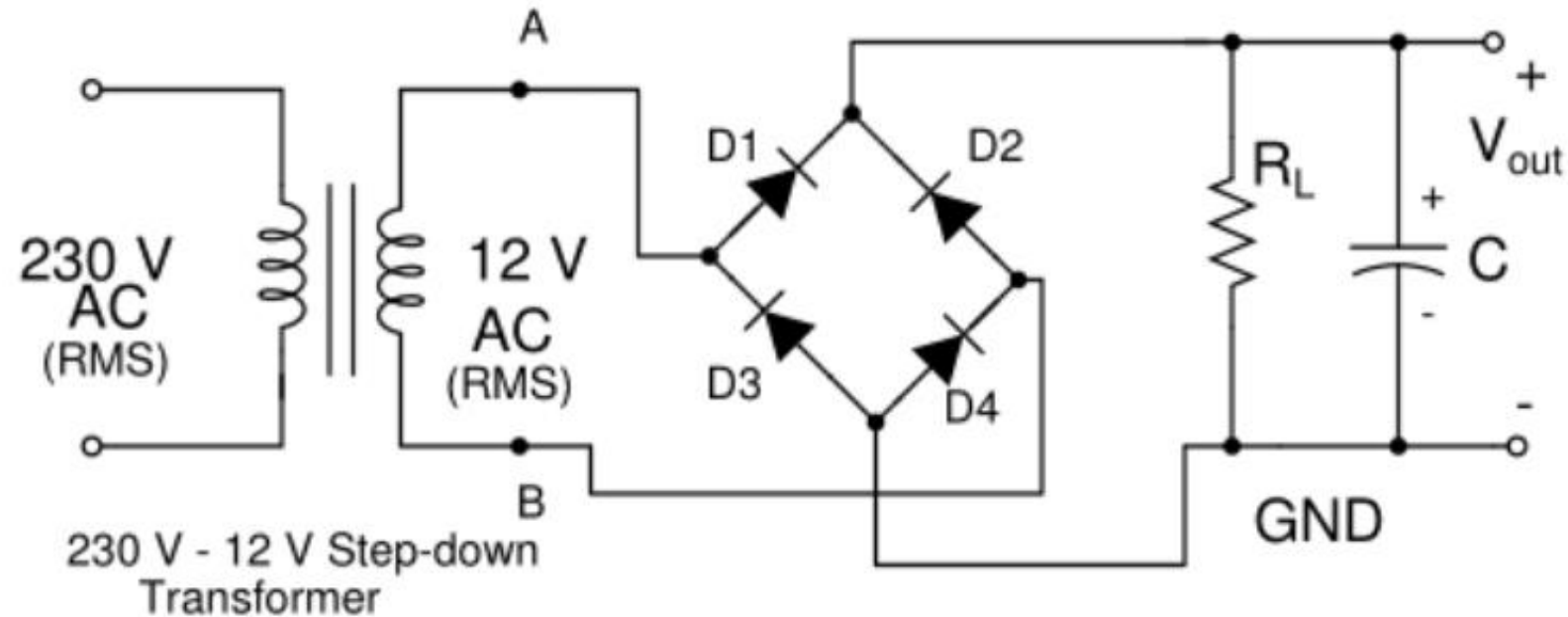


Fig. 10

- Much better than the half-wave (HW) rectifier
 - For the same C and R_L , peak-to-peak ripple voltage gets reduced to half that of HW

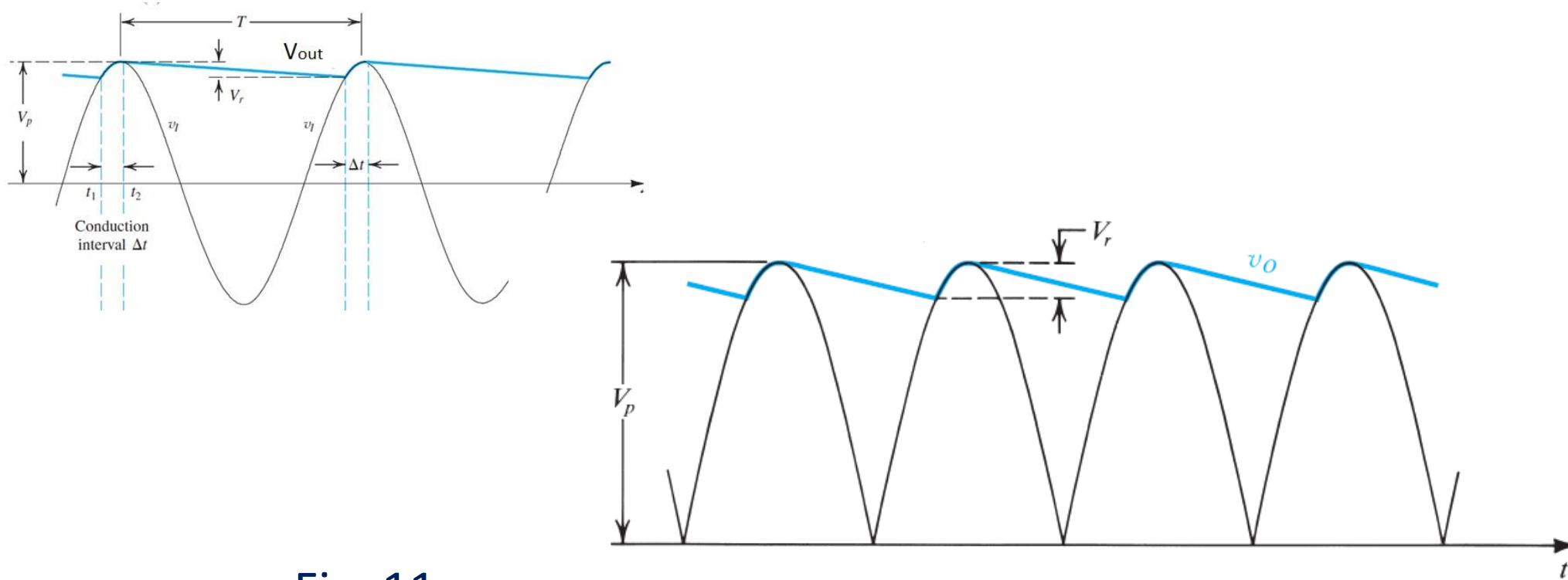
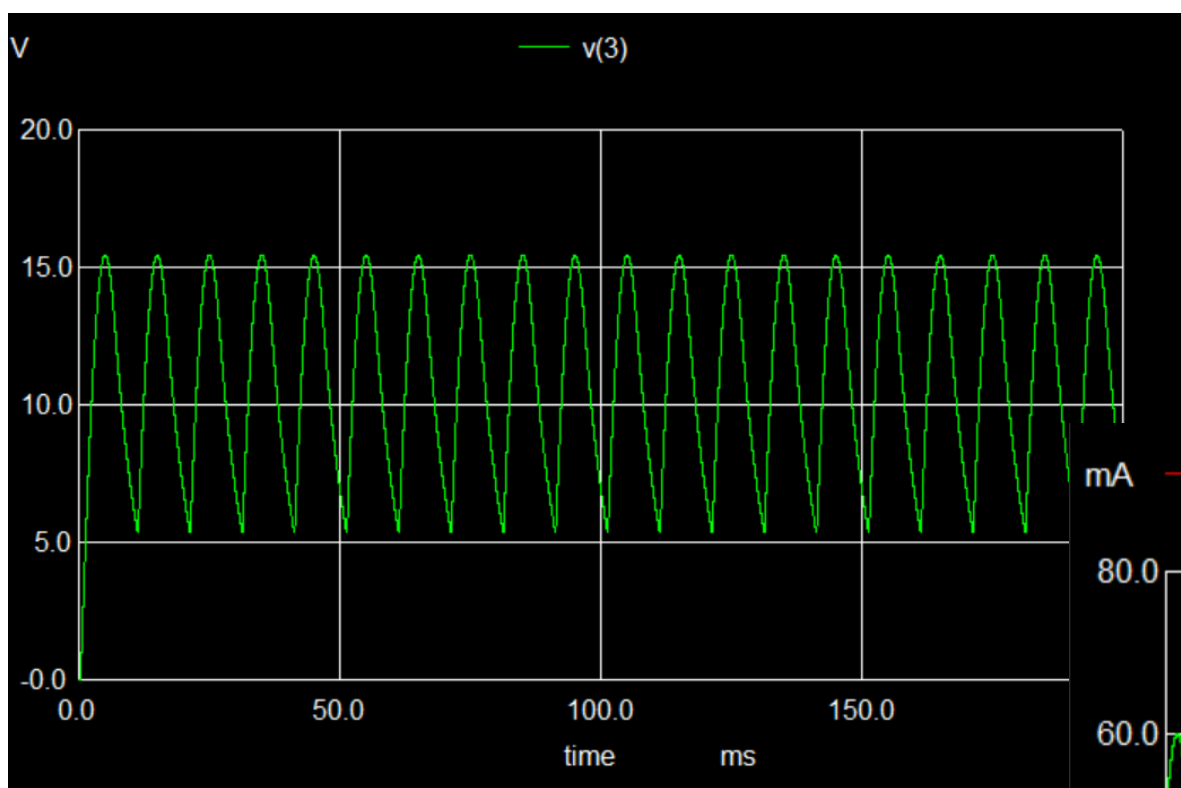


Fig. 11

- Full-wave rectifier output waveform (blue)
- Less Ripple voltage, compared to the Half-wave rectifier circuit
 - Discharge interval for C almost half that of HW case)

NGSPICE Simulation Results (Bridge Rectifier)

- To show the effect of changing C
 - on V_{out}
 - on the diode currents
- Four values of C considered ($R_L = 500 \, \Omega$, $V_{\text{in(peak)}} = 17 \, \text{V}$)
 - $C = 10 \, \mu\text{F}$
 - $C = 50 \, \mu\text{F}$
 - $C = 100 \, \mu\text{F}$
 - $C = 1,000 \, \mu\text{F}$
 - $C = 10,000 \, \mu\text{F}$

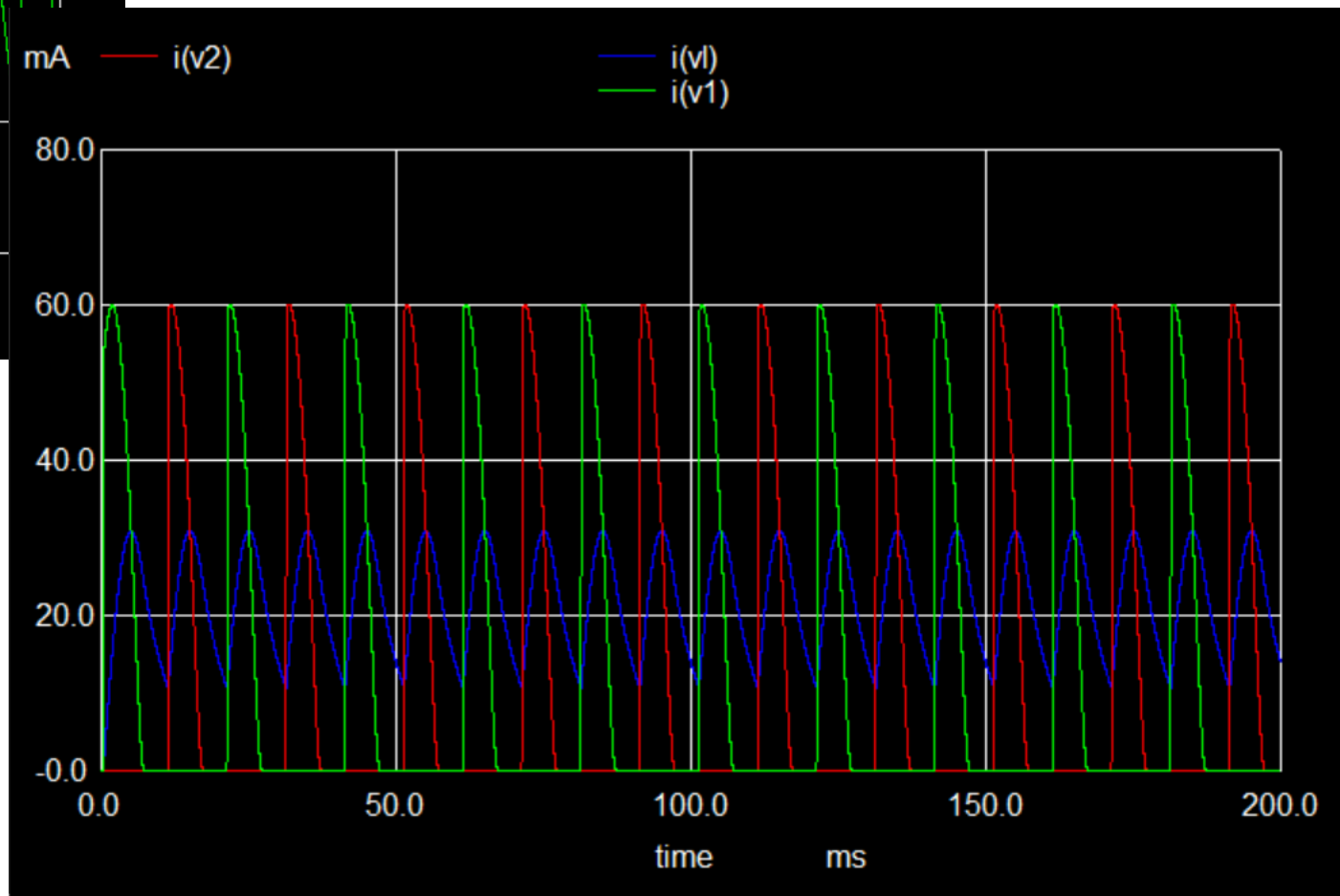


V_{out} ↑

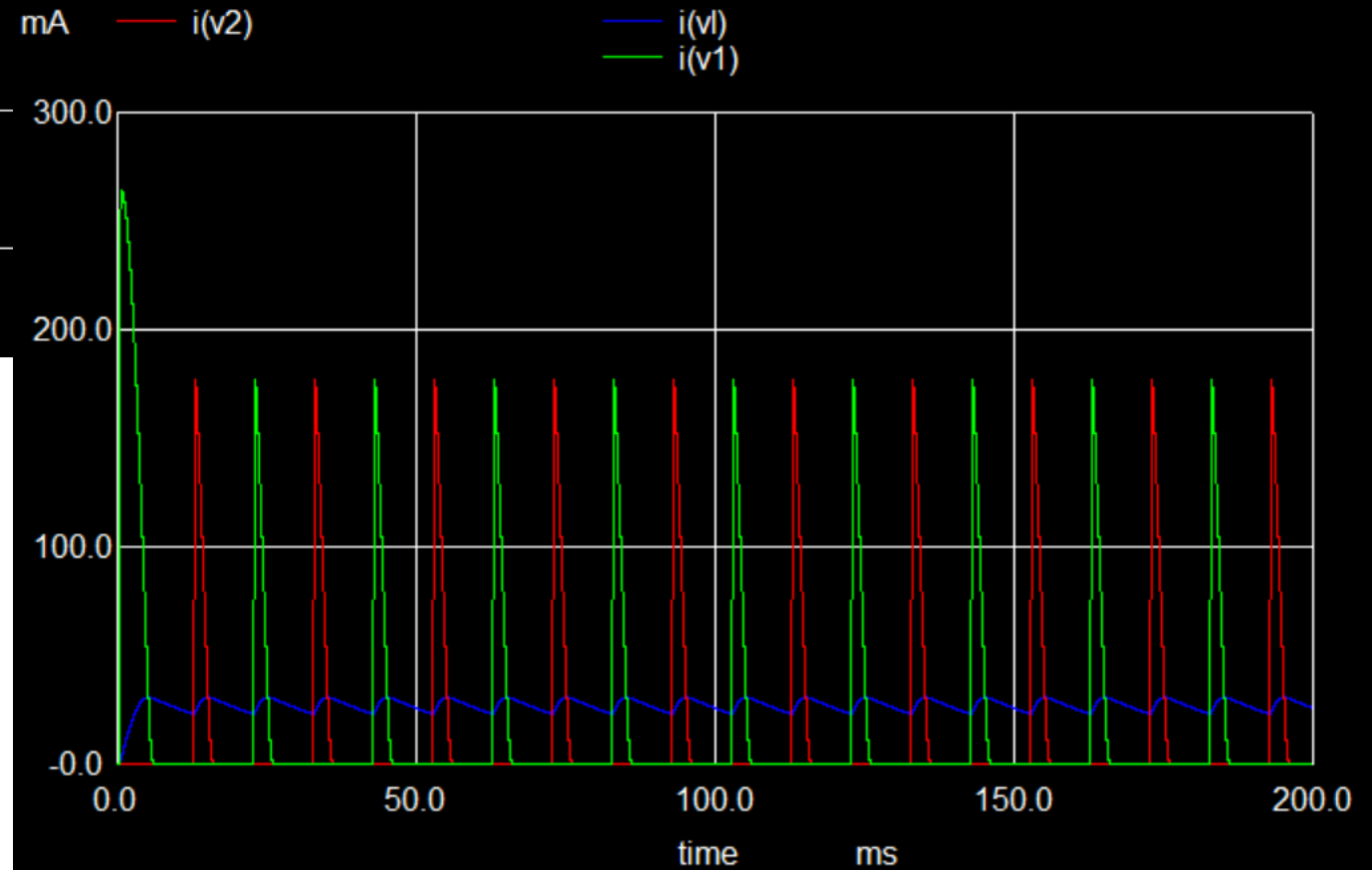
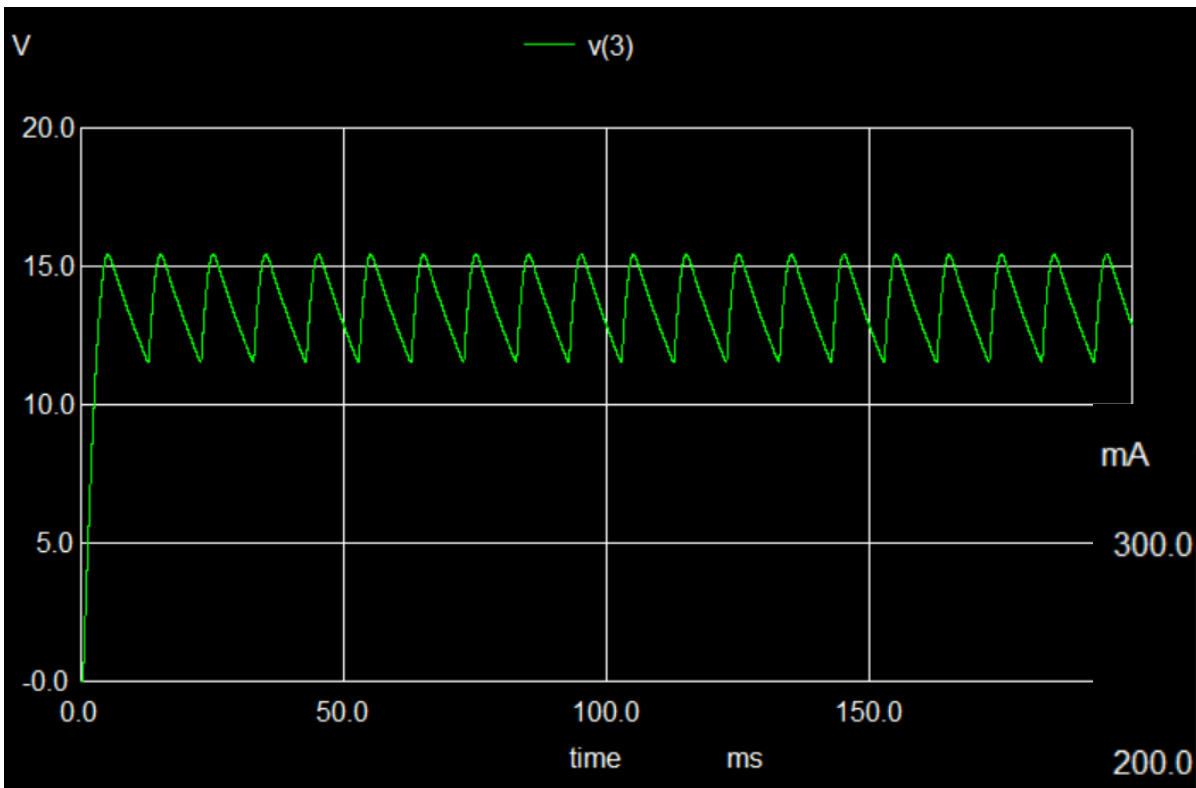
Load current I_L
and the Diode currents →

- NGSPICE Simulation - the effect of C on
 - Output ripple voltage
 - Diode currents

- $V_{in(peak)} = 17 \text{ V}$
- $C = 10 \mu\text{F}$
- $R_L = 500 \text{ ohms}$
- $I_L = V_{out(avg)}/R_L \approx 20 \text{ mA}$



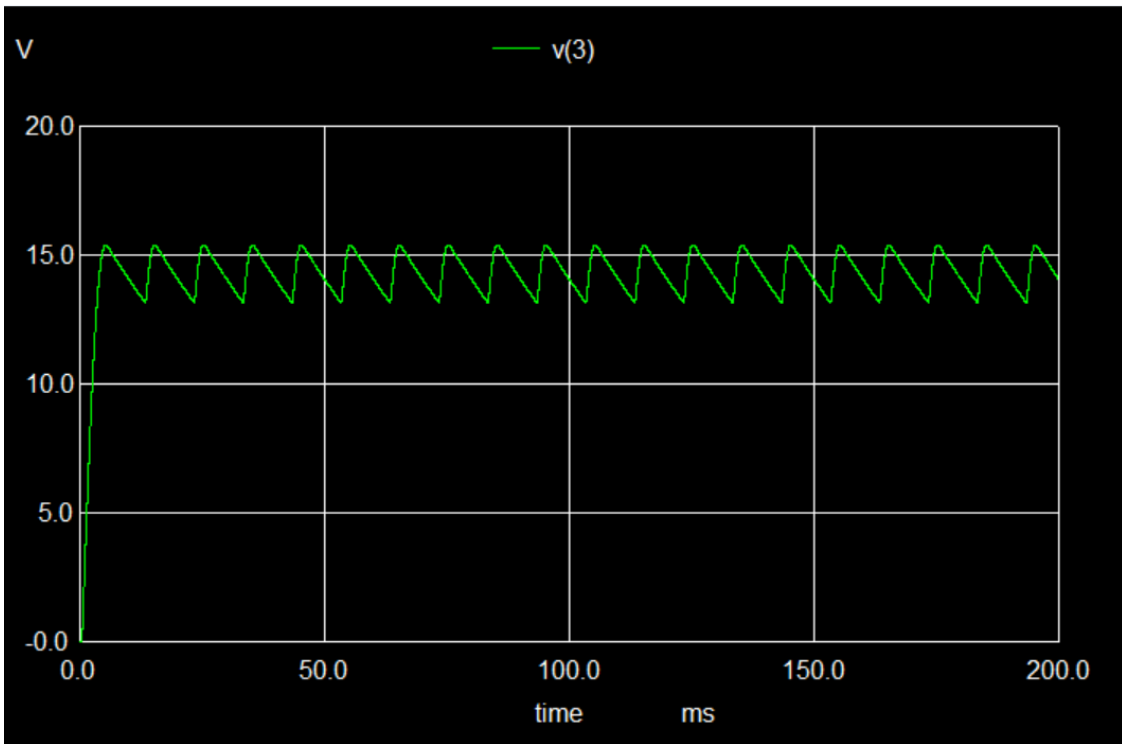
- $V_{in}(\text{peak}) = 17 \text{ V}$
- $C = 50 \mu\text{F}$
- $R_L = 500 \text{ ohms}$
- $I_L = V_{out(\text{avg})}/R_L \approx 26 \text{ mA}$



V_{out} ↑

Load current I_L
and the Diode
currents →

- NGSPICE Simulation - the effect of C on
 - Output ripple voltage
 - Diode currents

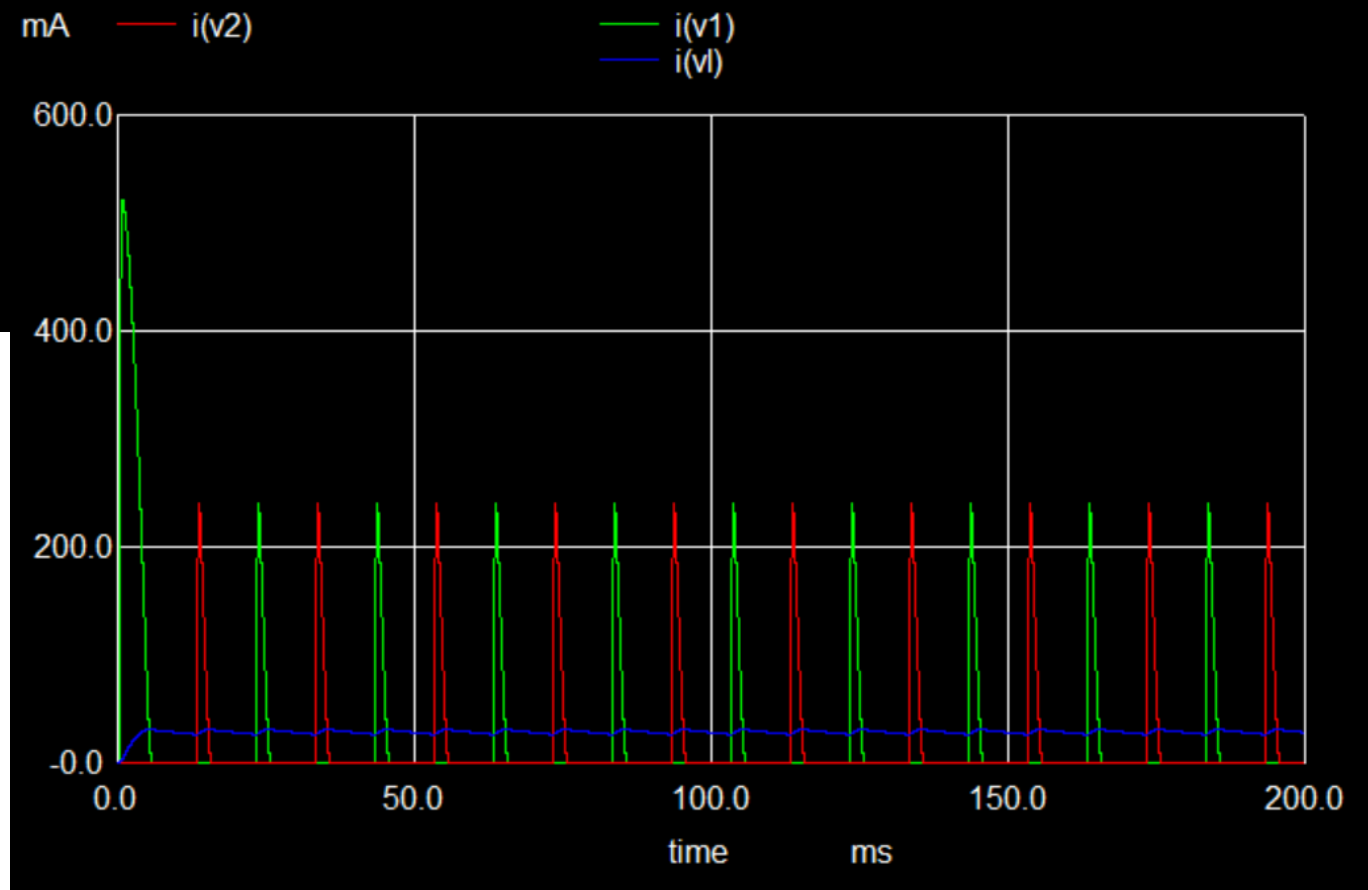


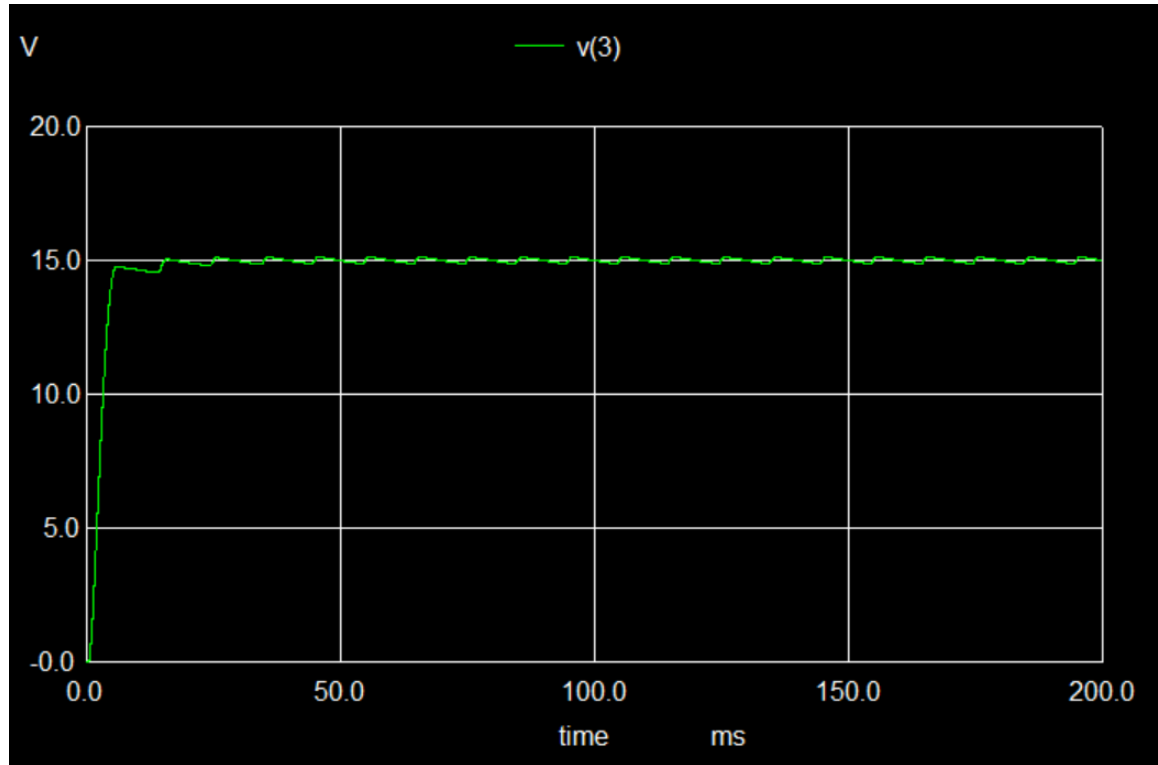
V_{out} ↑

Load current I_L and the Diode currents →

- NGSPICE Simulation - the effect of C on
 - Output ripple voltage
 - Diode currents

- $V_{in(peak)} = 17 \text{ V}$
- $C = 100 \mu\text{F}$
- $R_L = 500 \text{ ohms}$
- $I_L = V_{out(avg)}/R_L \approx 28 \text{ mA}$



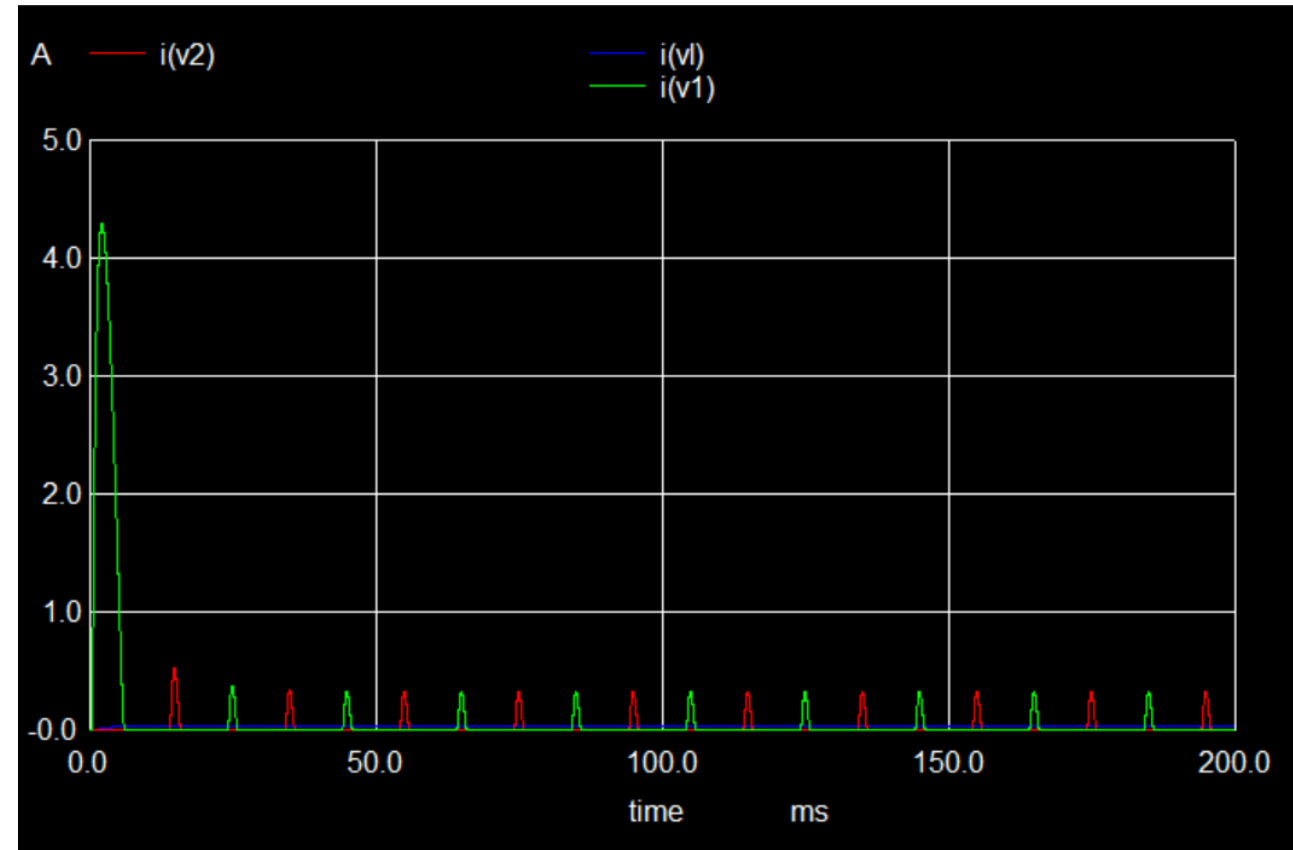


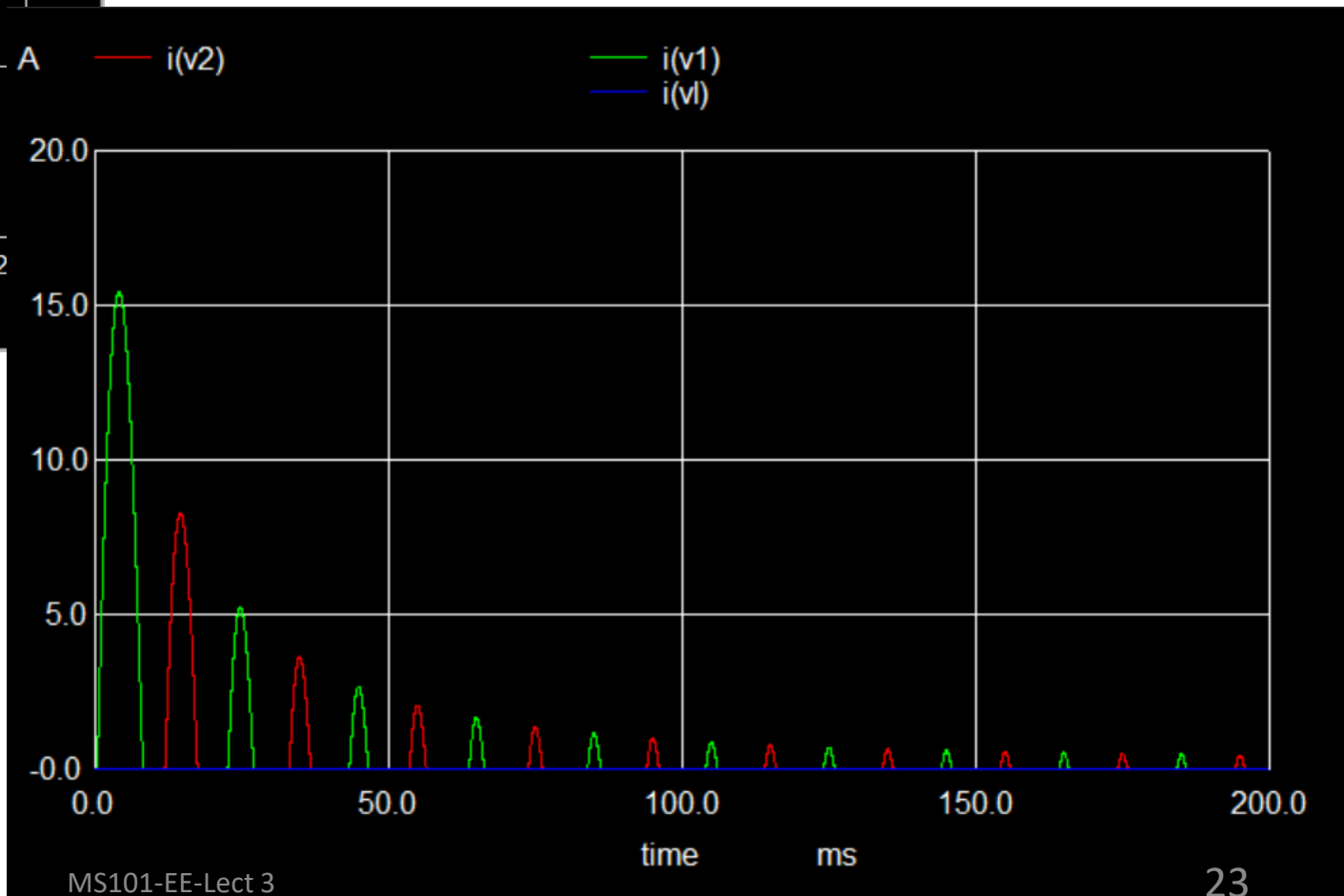
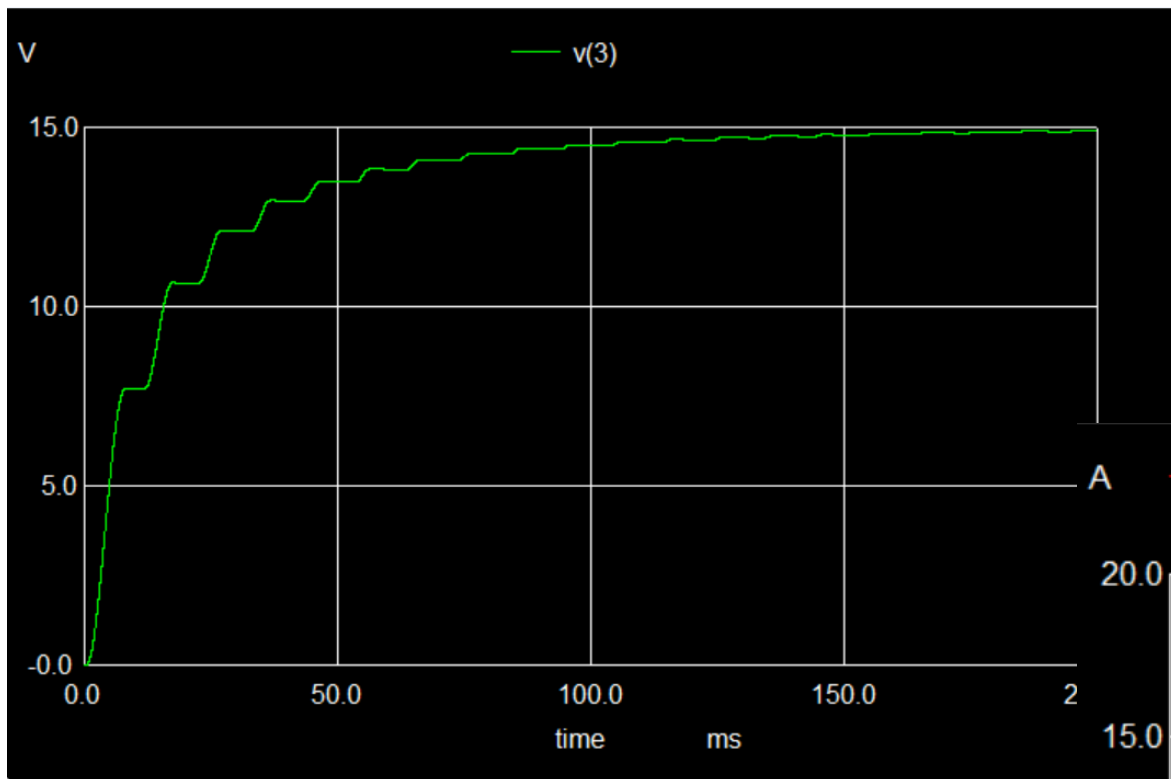
↑
 V_{out}

Load current I_L
and the Diode currents →

- NGSPICE Simulation - the effect of C on
 - Output ripple voltage
 - Diode currents

- $V_{in(peak)} = 17\text{ V}$
- $C = 1,000\text{ }\mu\text{F}$
- $R_L = 500\text{ ohms}$
- $I_L = V_{out(avg)}/R_L \approx 30\text{ mA}$





- $V_{in}(\text{peak}) = 17 \text{ V}$
- $C = 10,000 \mu\text{F}$
- $R_L = 500 \text{ ohms}$
- $I_L = V_{\text{out(avg)}}/R_L \approx 30 \text{ mA}$

V_{out} ↑

Load current I_L and the Diode currents →

- NGSPICE Simulation - the effect of C on
 - Output ripple voltage
 - Diode currents

Problems of Unregulated Power Supply

- Output voltage fluctuates
 - When ac input voltage fluctuates
 - When load current fluctuates
- Ripple voltage increases with load current
 - Ripple voltage for a given load current (i_L) can be reduced only by increasing C
 - Increasing C beyond a certain value can cause diode damages (as the peak diode current will always be many times the average load current)

Part 3: Regulated DC Power Supply

Regulated Power Supply

- **Problems of the unregulated power supply**
 - Output voltage fluctuates with the input voltage (for a given load current) - Line regulation
 - Output voltage fluctuates for load current (for a given input voltage) - Load regulation
- **Regulated Power Supply**
 - Output voltage stays constant (reasonably well):
 - For varying input voltages
 - For varying load currents

Two solutions

- Solution 1
 - Zener diode regulator circuit
- Solution 2
 - Voltage Regulator IC
- We will consider only Solution 2

3B: 7812 Three-terminal Voltage Regulator

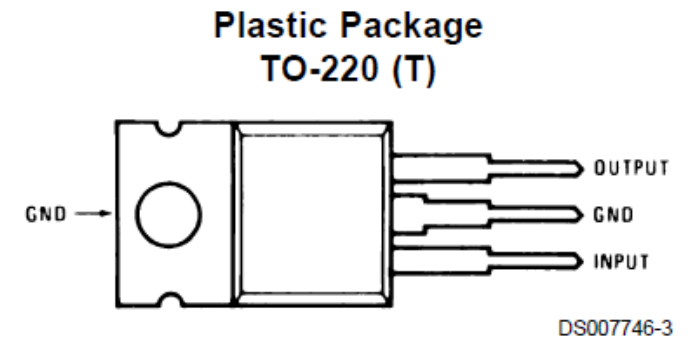
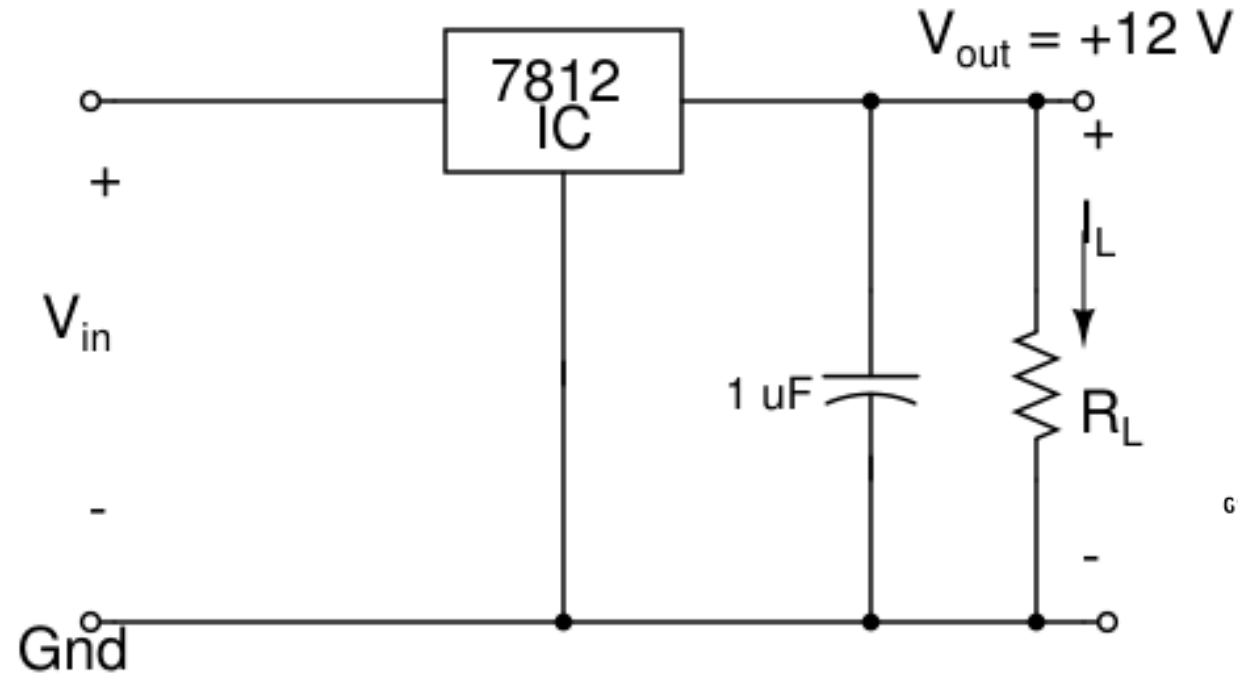


Fig. 12

$V_{in} : +14.5 \text{ to } 30 \text{ V}, V_{out} : 11.5 \text{ to } 12.5 \text{ V}$

$I_L = \text{up to } 1 \text{ A}$

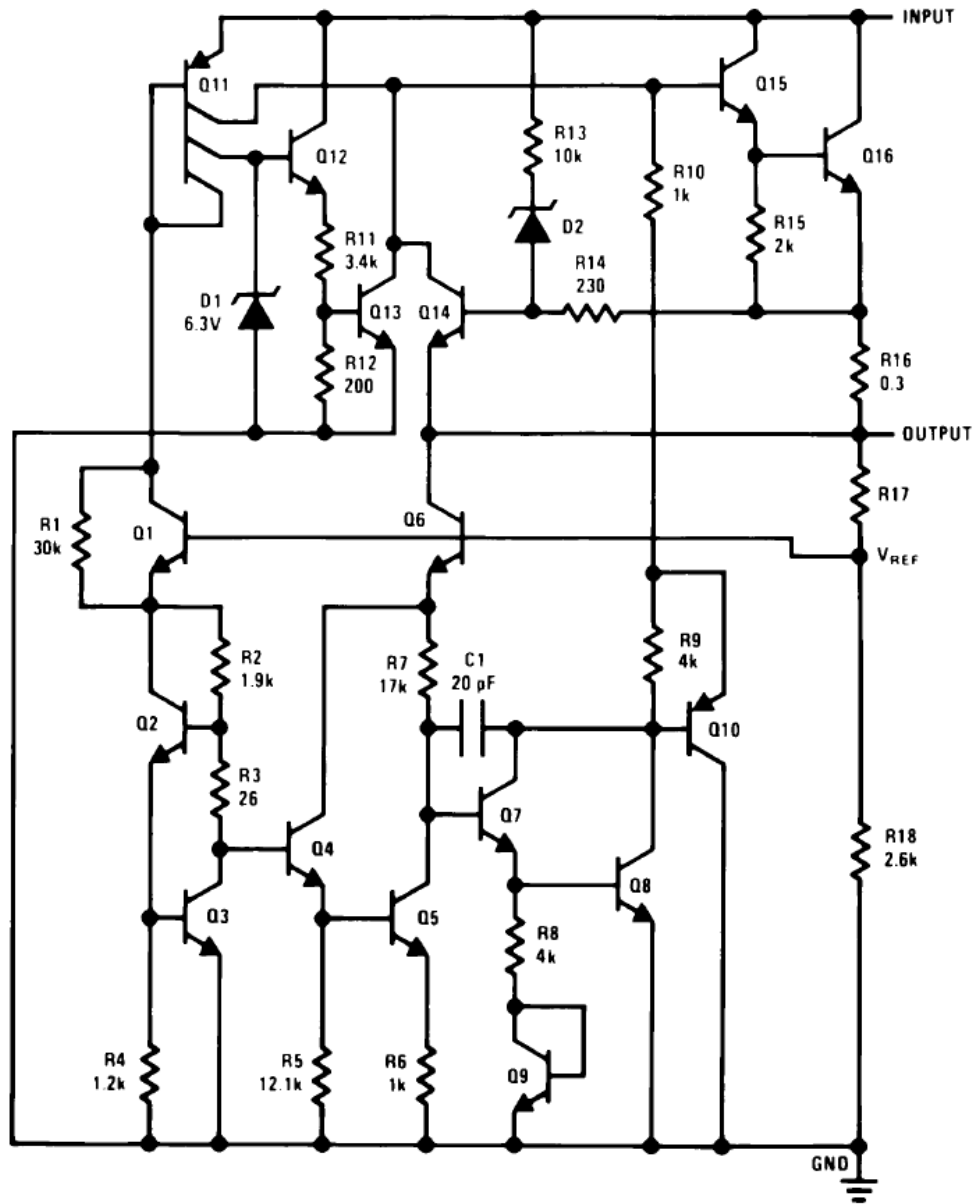


Fig. 13

Major blocks of the 7812 Voltage Regulator IC:

- Series-pass transistor (Q16)
- Stable Zener reference voltage
- Error amplifier
- Short-circuit protection

Source: 7812 Data sheet, National Semiconductor Corp., 2000

DS007746-1

Features of an IC Regulator

- V_{out} will be steady for a large range of V_{in} and I_L values
- Minimum V_{in} to the IC regulator: $V_{out} + 2$ or 3 V (typical)
- A small value of capacitor, typically $1\ \mu\text{F}$ is put at the output for stability (i.e. to prevent oscillations)
 - The regulator IC uses a negative feedback error amplifier circuit, which could result in instability.

Other Popular Three-terminal Voltage Regulator ICs

- Positive Voltage Regulator ICs
 1. 7805 : $V_{\text{out}} = 5 \text{ V}$
 2. 7806 : $V_{\text{out}} = 6 \text{ V}$
 3. 7809 : $V_{\text{out}} = 9 \text{ V}$
- Negative Voltage Regulator ICs
 1. 7905 : $V_{\text{out}} = -5 \text{ V}$
 2. 7906 : $V_{\text{out}} = -6 \text{ V}$
 3. 7909 : $V_{\text{out}} = -9 \text{ V}$
 4. 7912 : $V_{\text{out}} = -12 \text{ V}$