EE Lecture 5: Diode Circuits

MS101 Makerspace

2024-25/II (Spring)

1. Rectifier Circuits

- Half-Wave Rectifier

- Full-wave Rectifier
  – Bridge rectifier circuit

Step-Down Transformer (230 V - 12 V RMS)

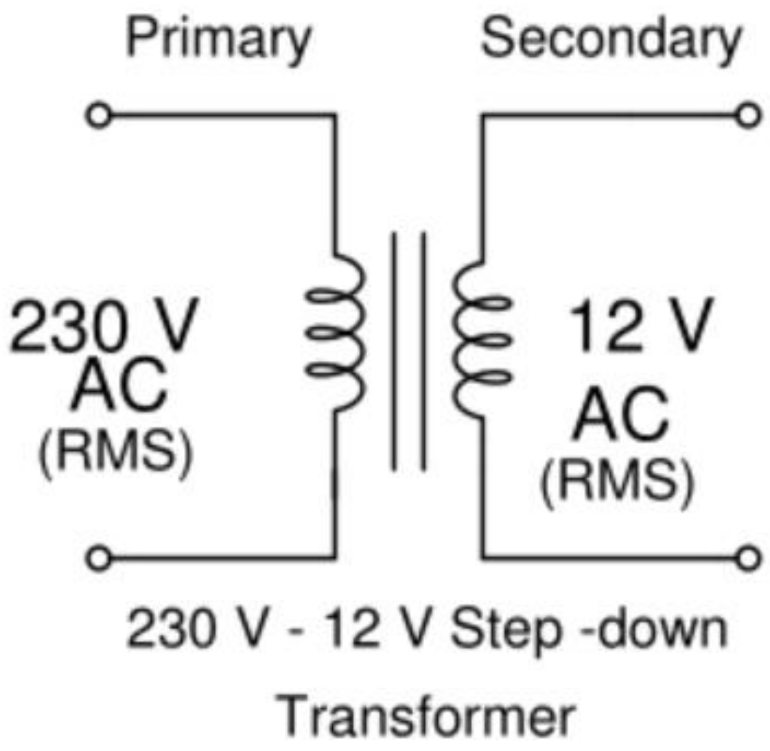
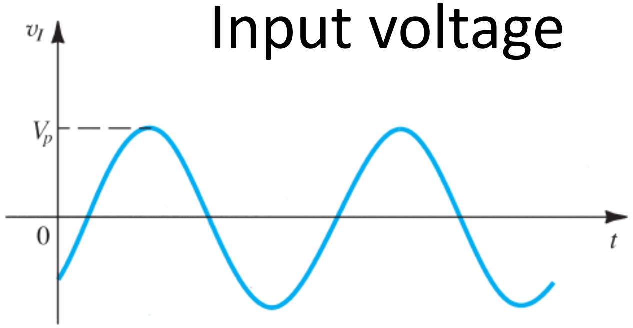


Fig. 1 Step-down Transformer

A) Half-wave Rectifier

Input voltage



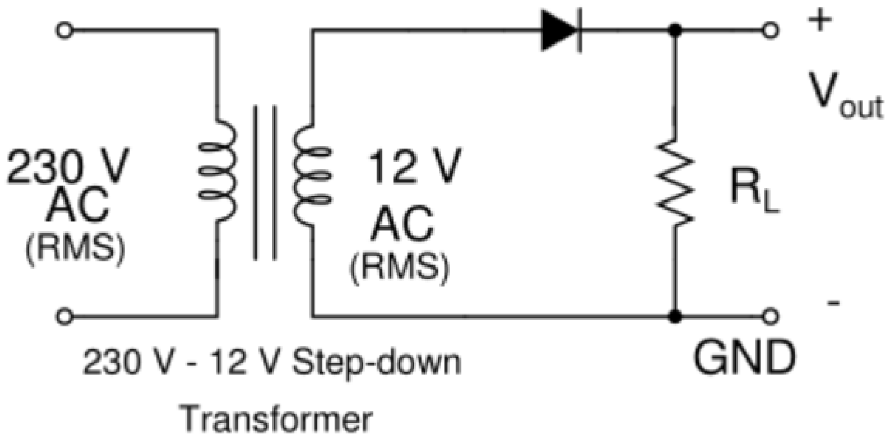
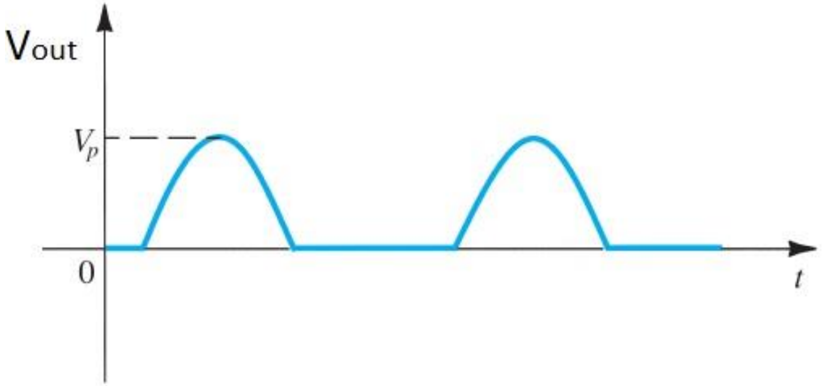


Fig. 2

Output voltage (assuming an ideal diode, i.e. zero voltage drop)



Output voltage (assuming a practical diode with voltage drop)

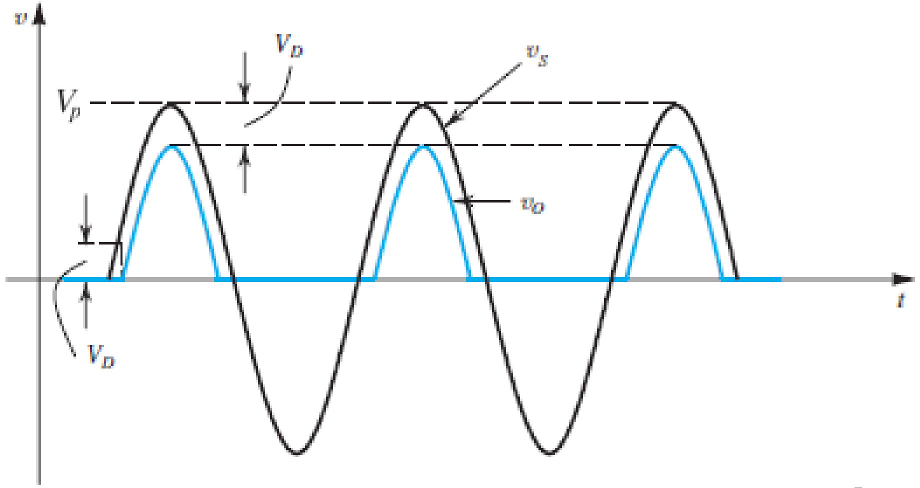


Fig. 3

B) Full-wave (Bridge) Rectifier

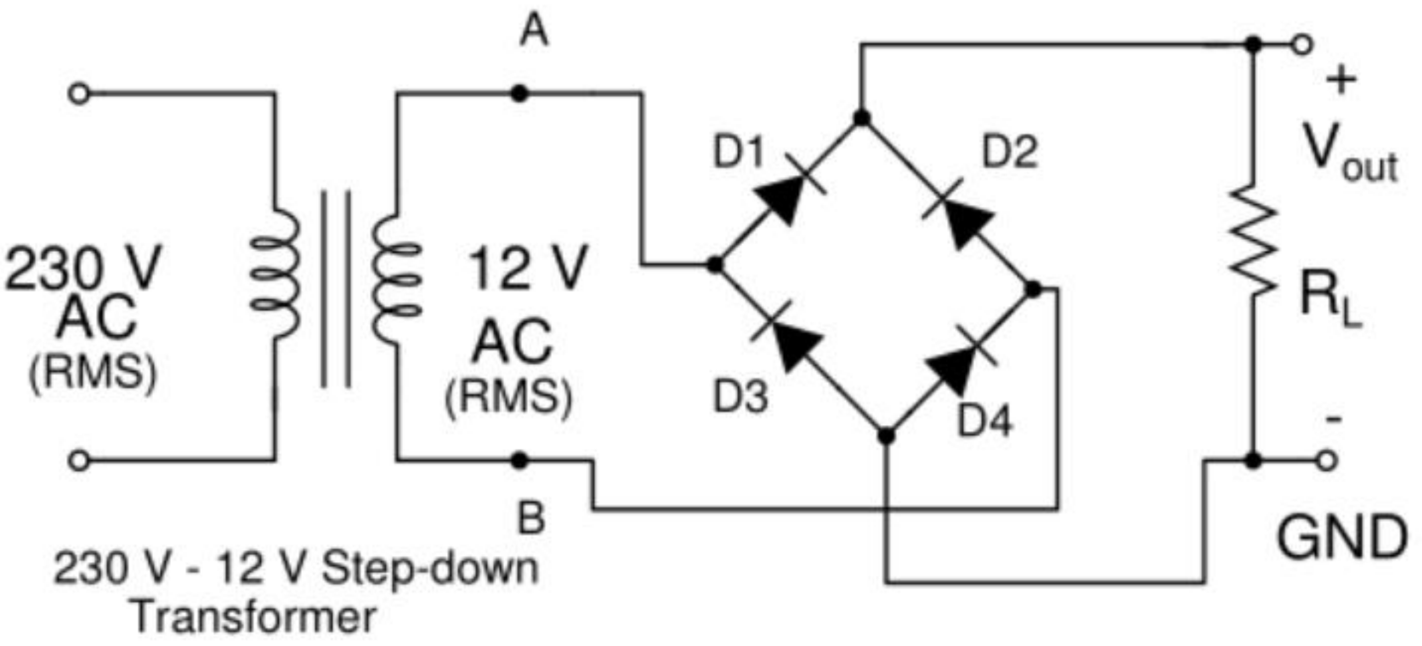
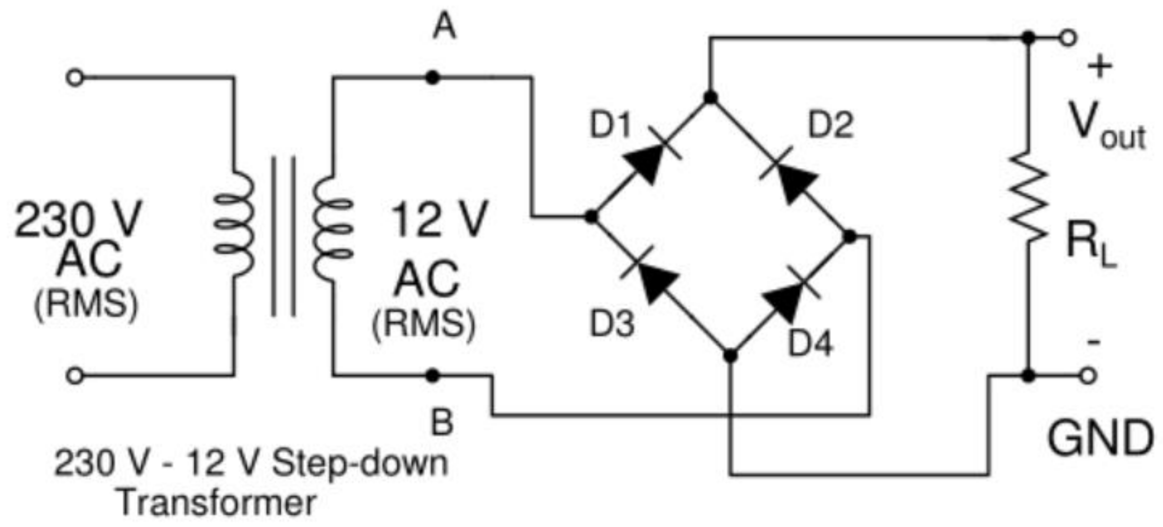


Fig. 4

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



V_D: voltage drop across two diodes (D1&D4, D3& D2)

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

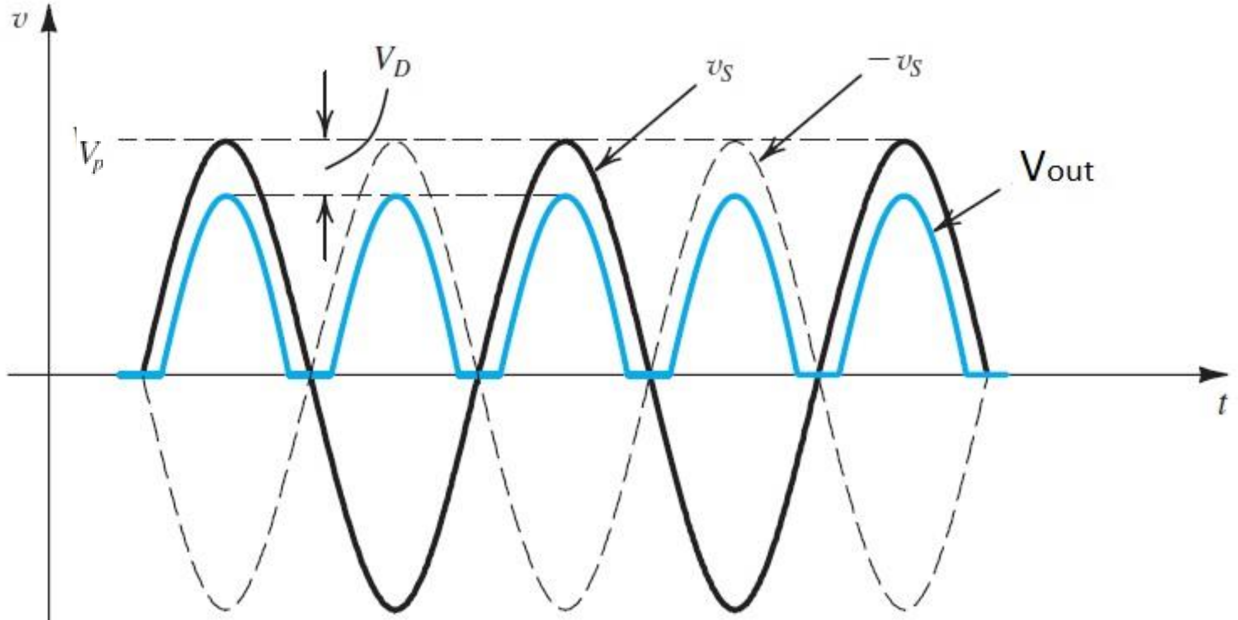


Fig. 5

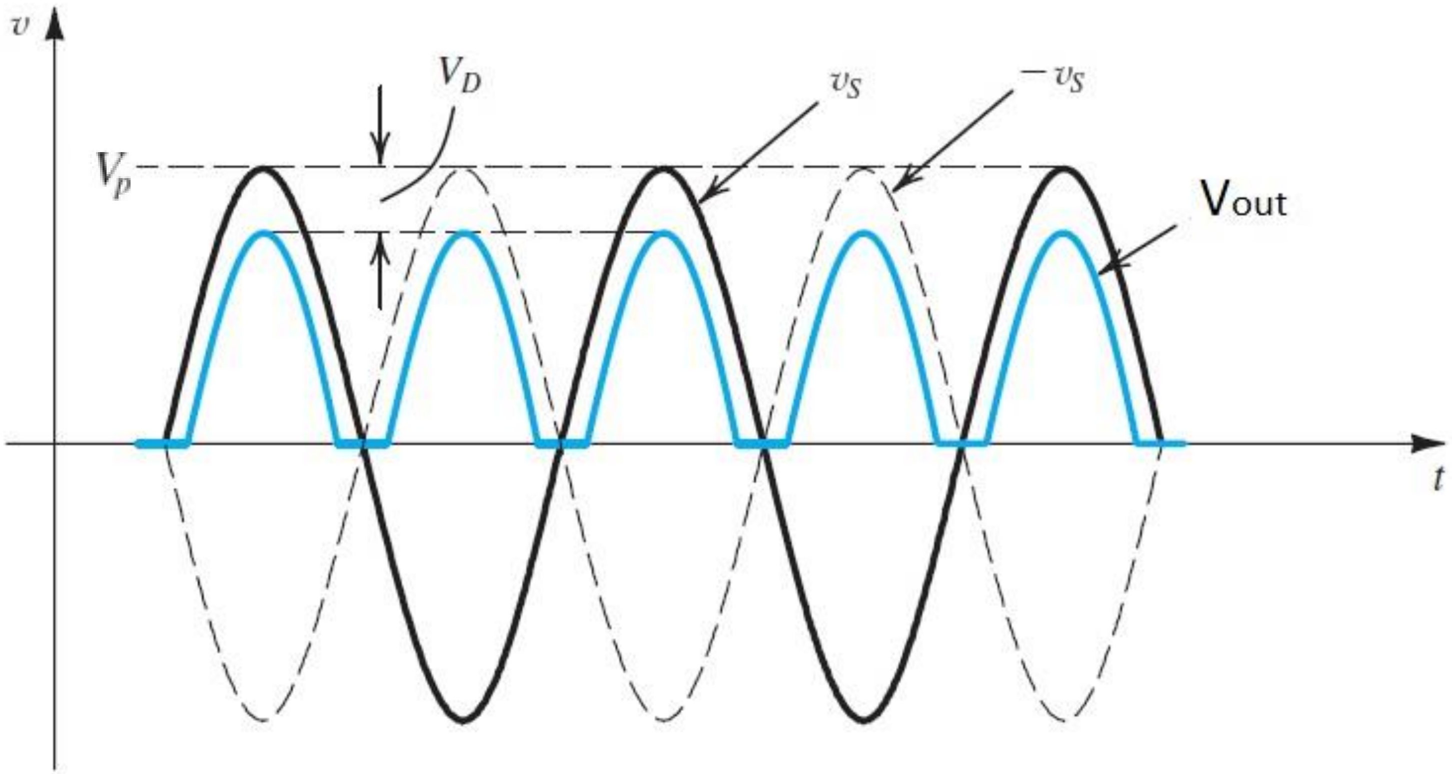


Fig. 6

- Full-wave Rectifier: Input and Output waveforms (considering diode drops)
- Peak output voltage will have the *two diode drops* lower than the input voltage. Typ. diode drop = 2x 0.5 V = 1 V

2. Unregulated Power Supply (Capacitive filter)

- Case A): Half-wave rectifier with a large value capacitor - (>> 10 μF)

- Case B): Full-wave bridge rectifier with a large value capacitor (>> 10 μF)

Unregulated Power Supply
(Using Half-wave Rectifier and a Capacitive filter)

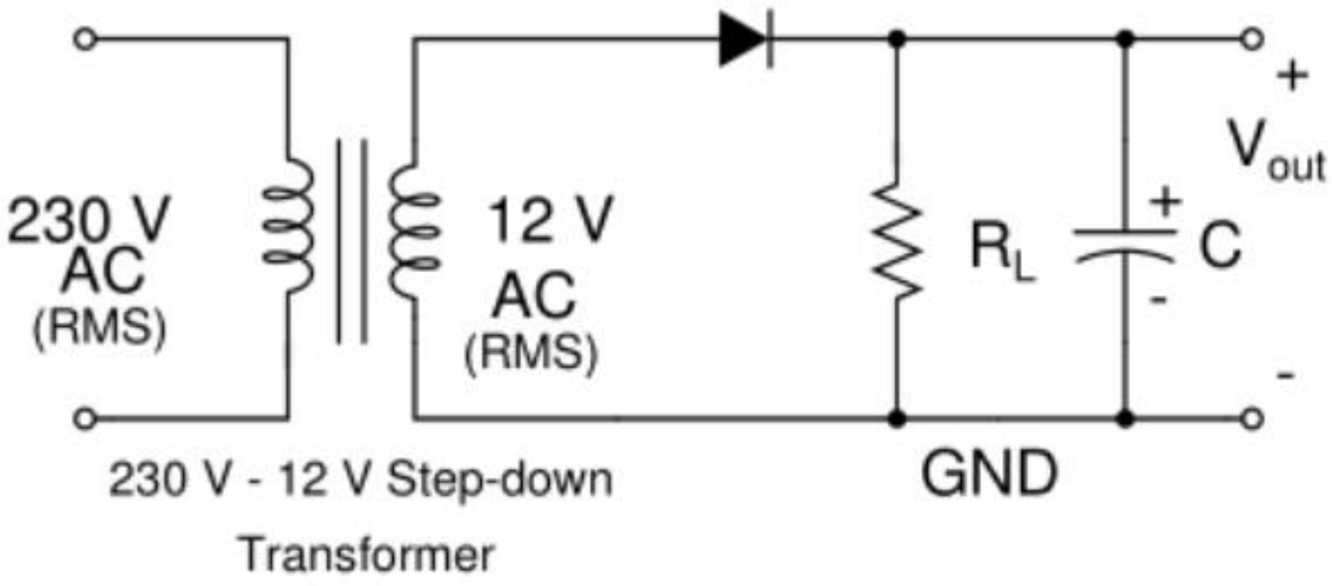


Fig. 7

Note:

- Large value capacitors are usually "electrolytic" type capacitors, with the terminals having + and - polarities and should be connected across a dc voltage with matching terminal polarities.

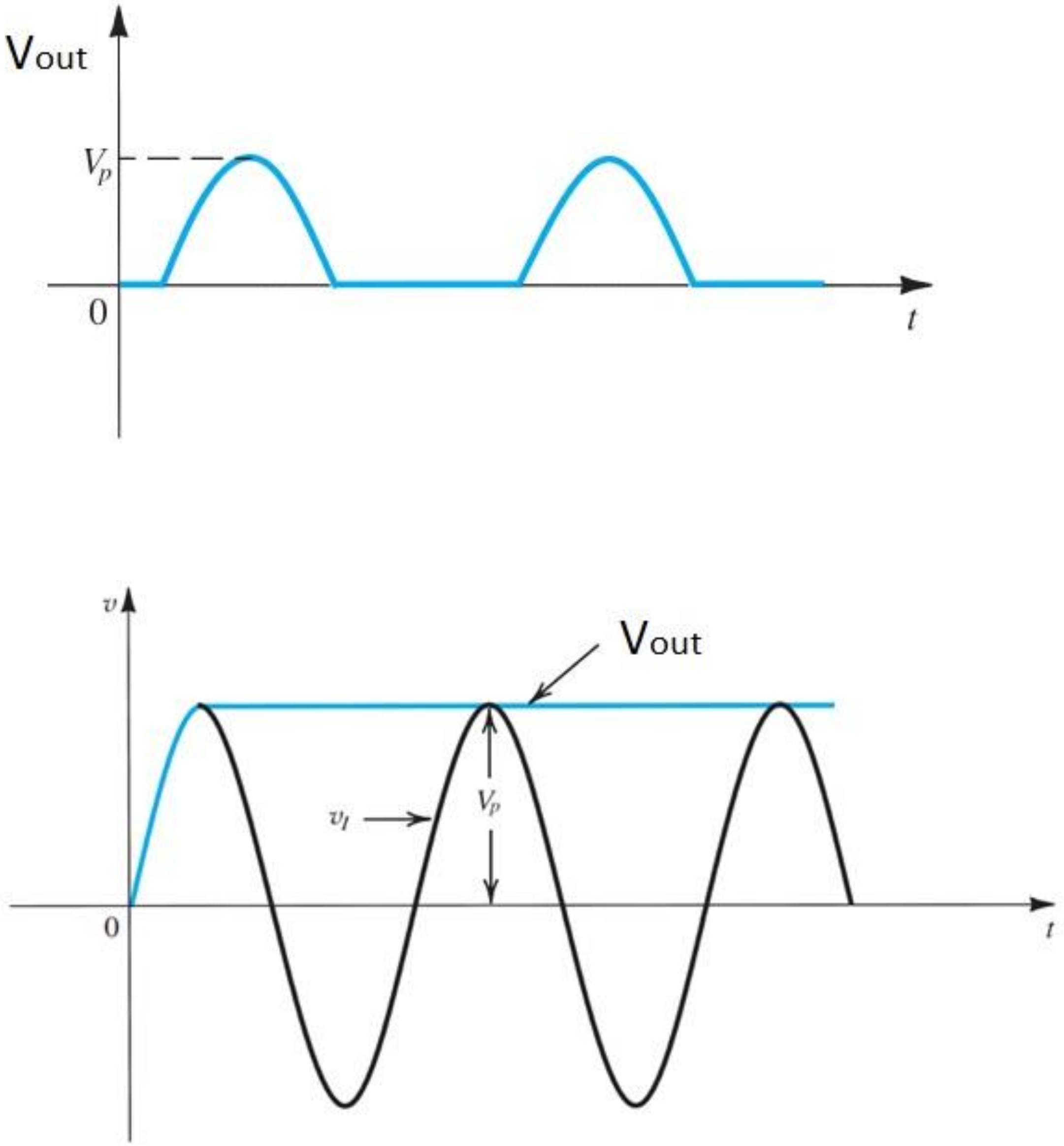
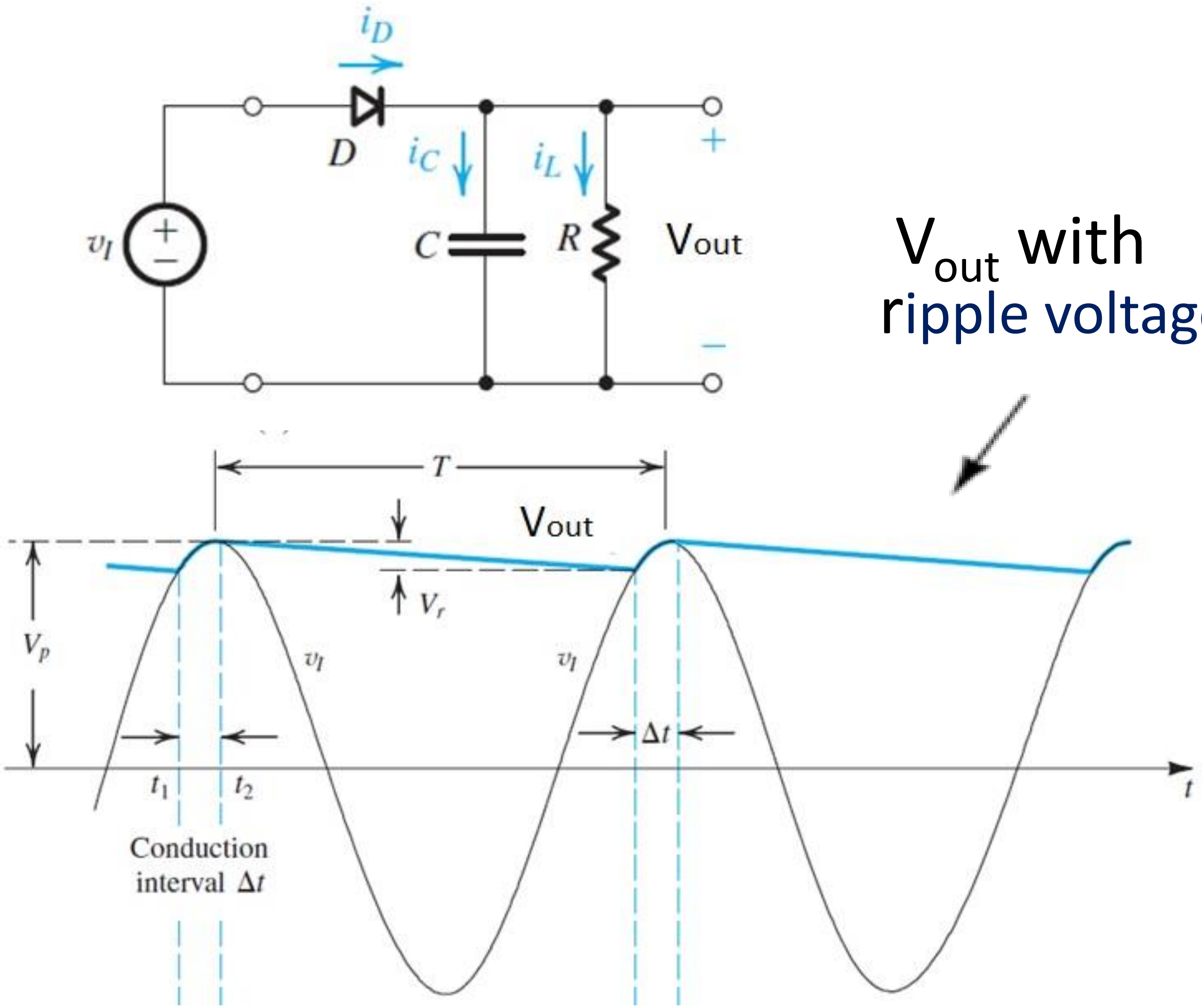


Fig. 8

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



Vout with ripple voltage

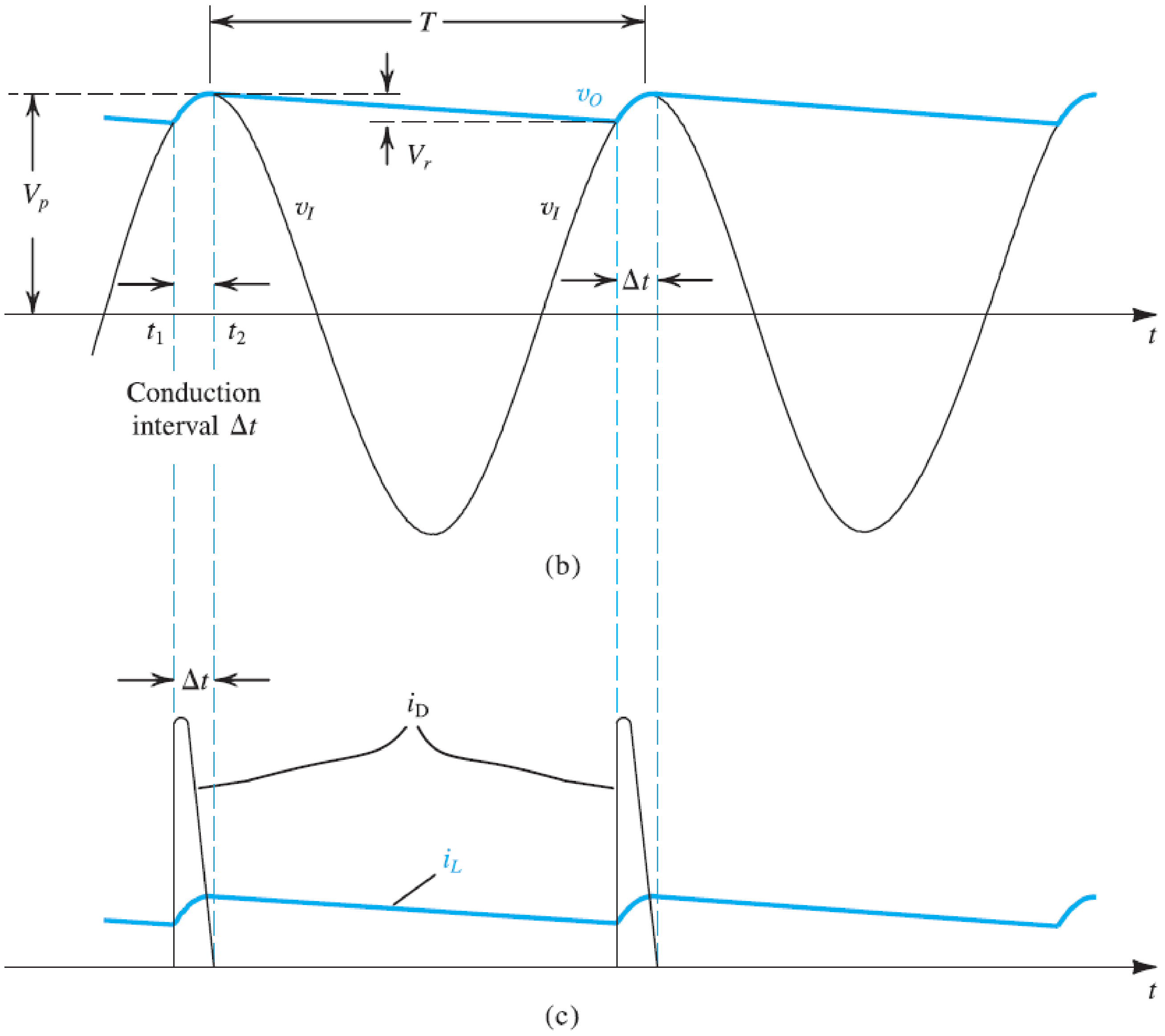
- The half-wave rectifier with C is very seldom used due to its higher ripple voltage

Fig. 9

Operation with C across R_L

- C charges during Δ_t , and discharges during (T- Δ_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 $i_D\uparrow\uparrow$)

Operation with C across R_L



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

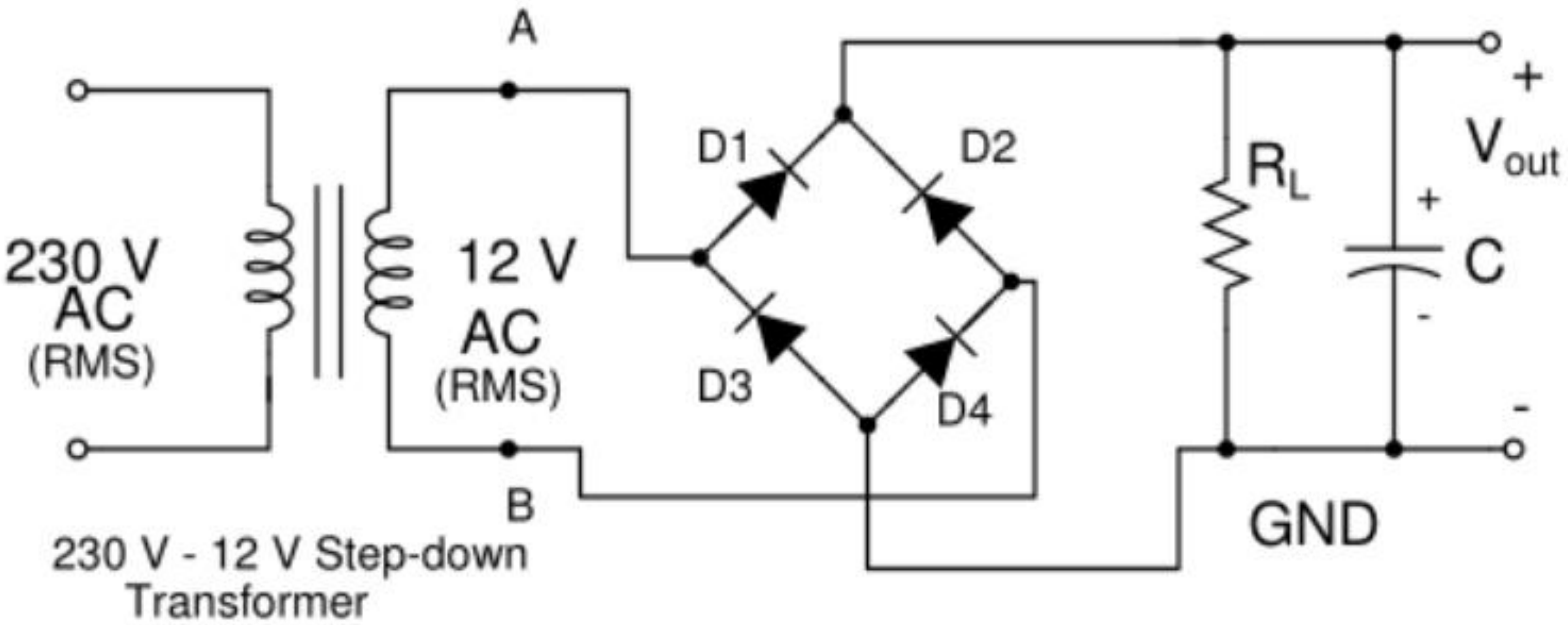
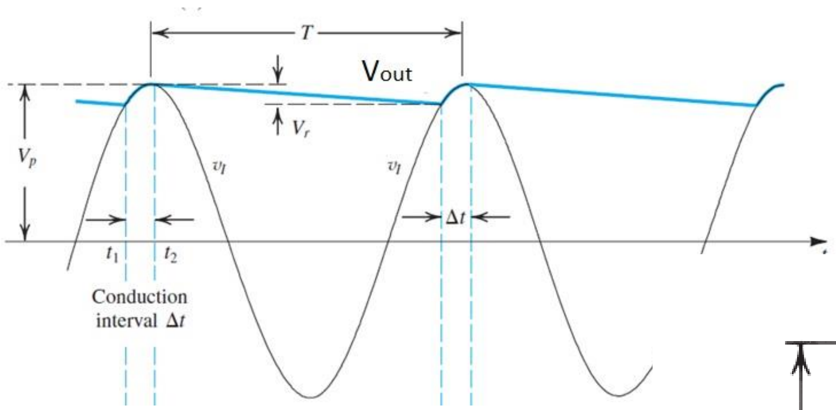


Fig. 10

- 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



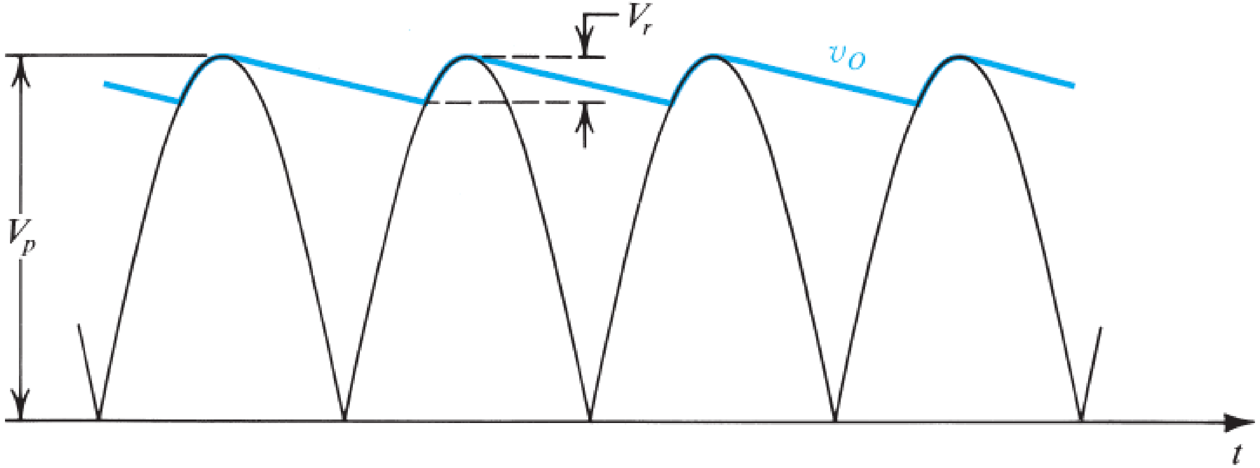


Fig. 11

- 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 Ω, $V_{in(peak)}$ = 17 V)

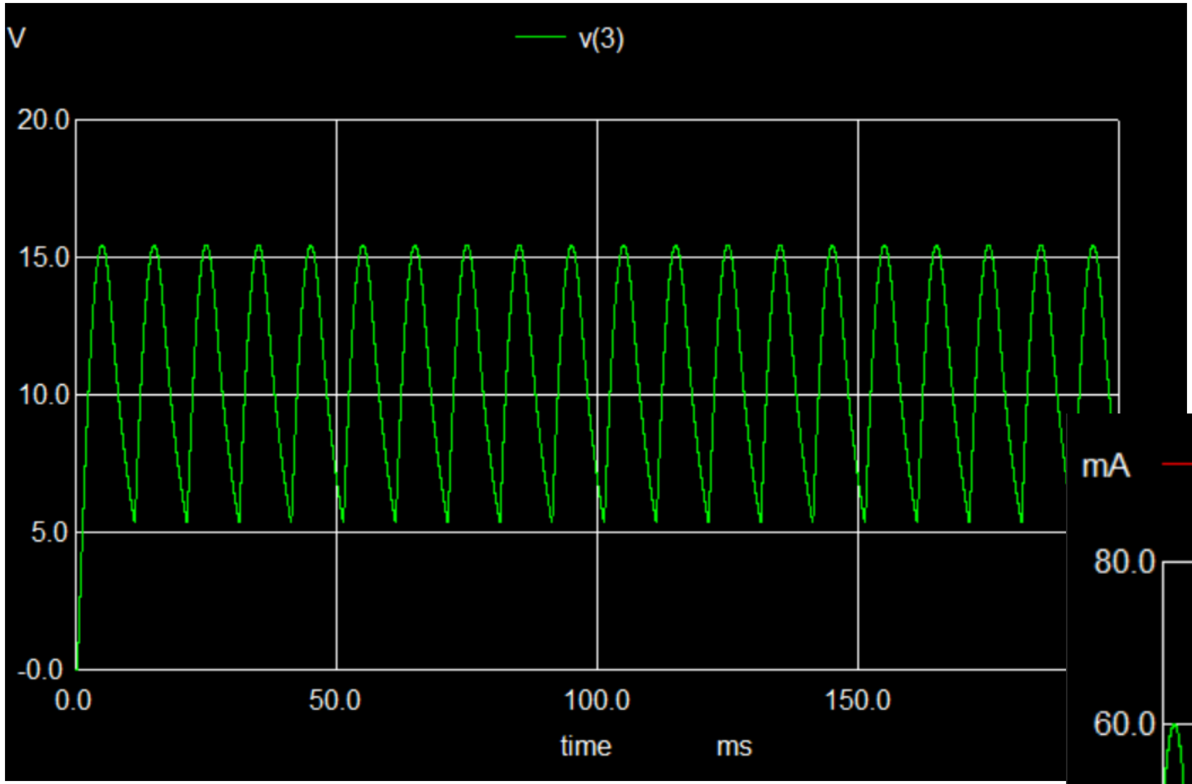
  C = 10 μF

  C = 50 μF

  C = 100 μF

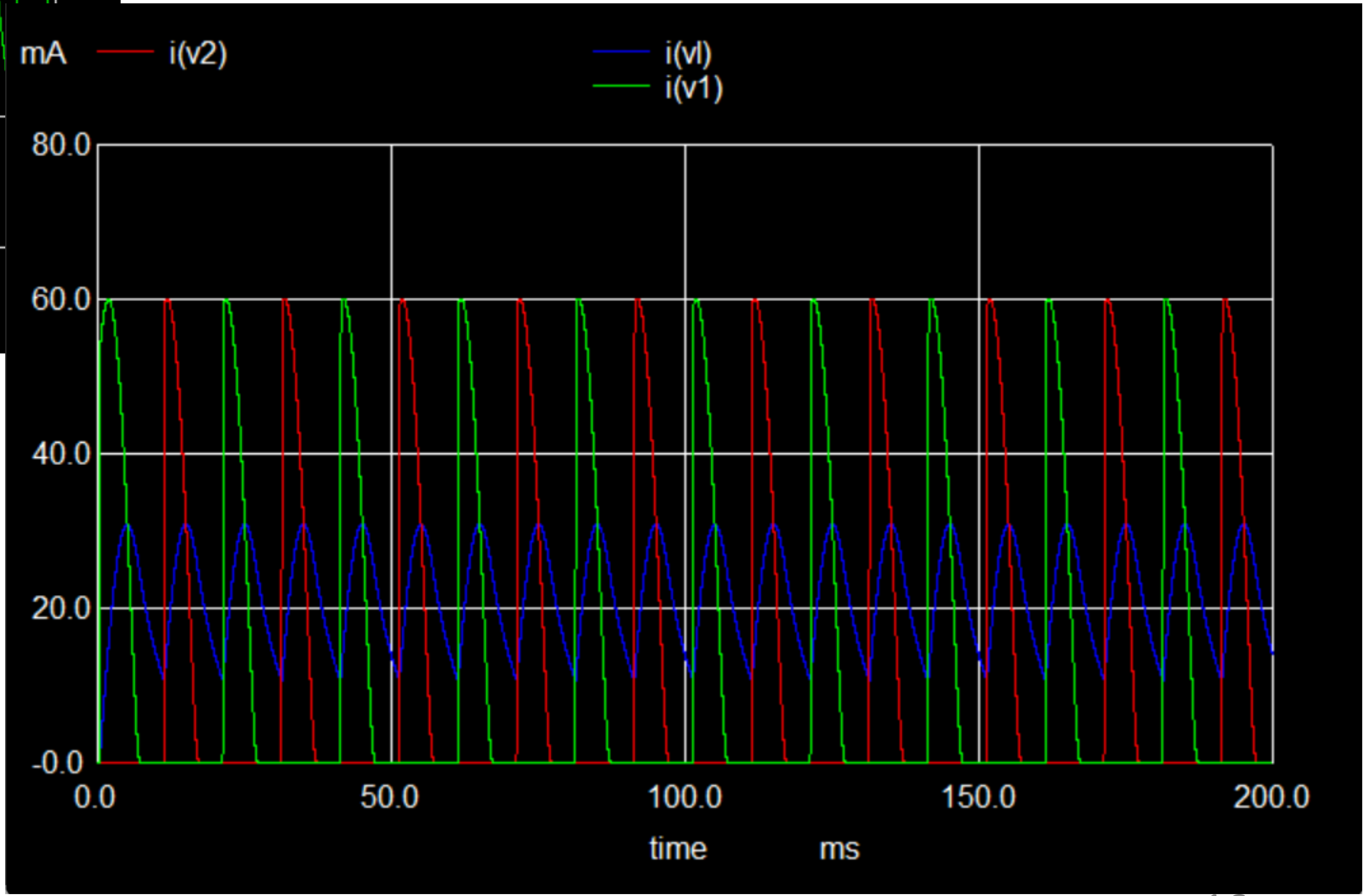
  C = 1000 μF

- V_{in}(peak) = 17 V
- C = 10 μF; R_L = 500 ohms
- $I_L = V_{out(avg)}/R_L \approx 20$ mA
- Peak-to-peak ripple ≈ 10 V



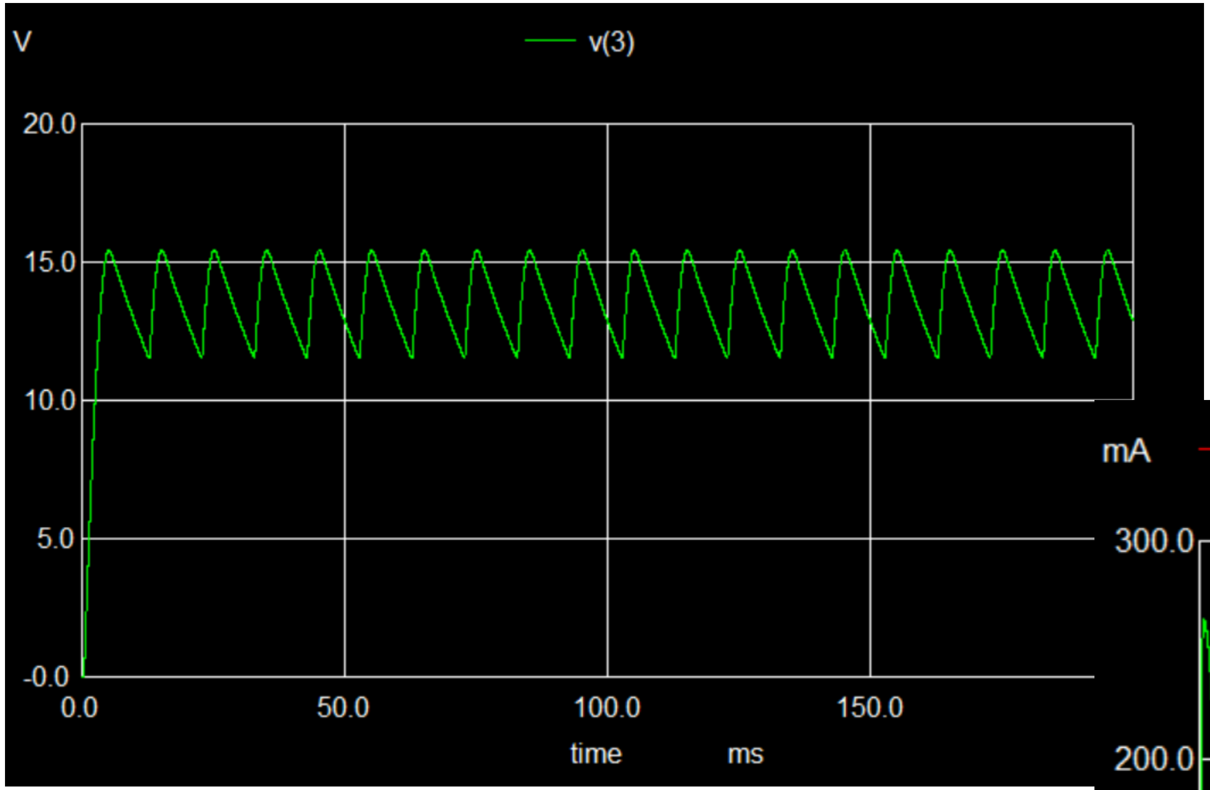
↑
V_{out}

Load current I_L and the Diode currents →



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

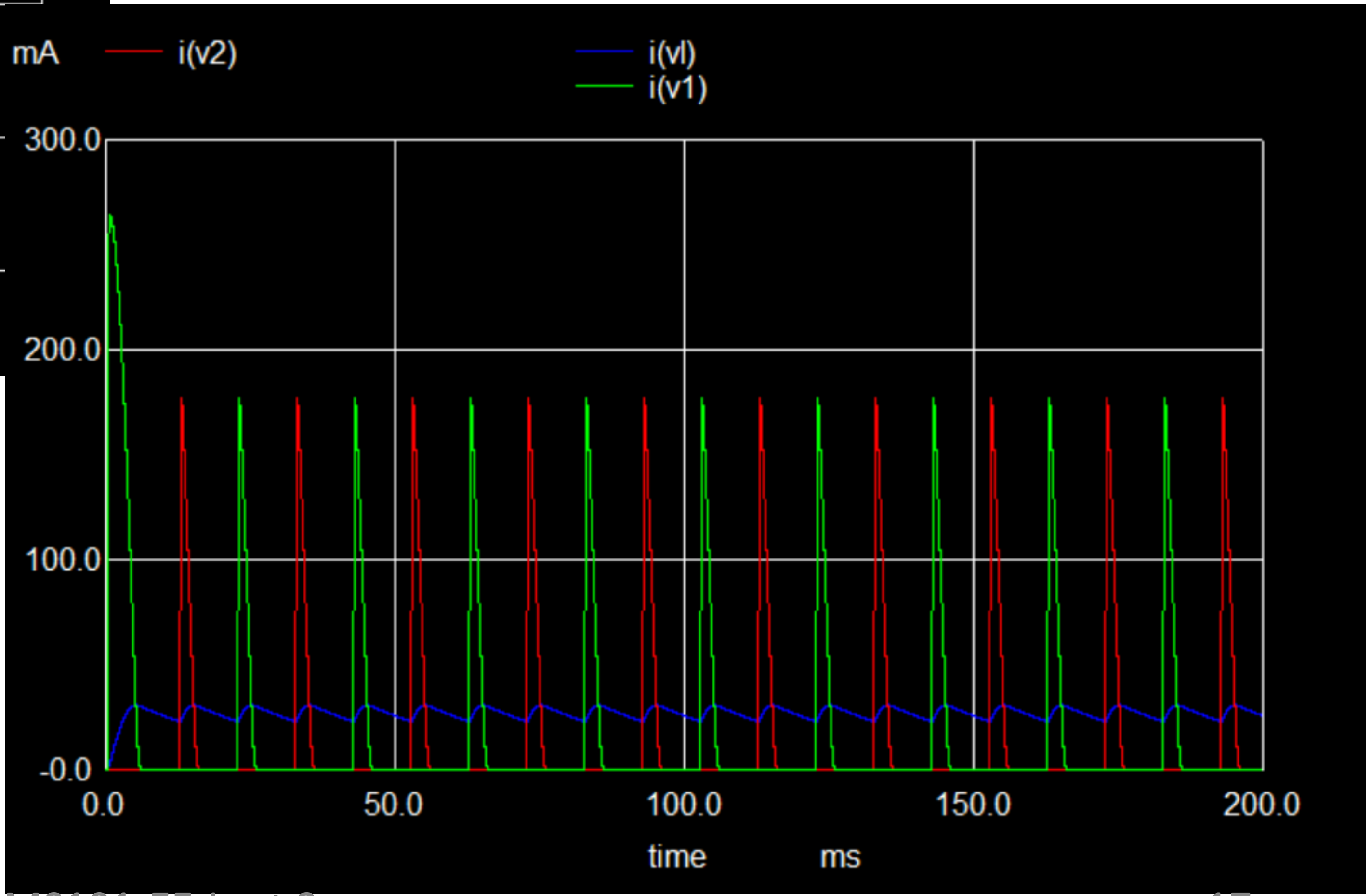
- V_{in}(peak) = 17 V
- C = 50 µF; R_L = 500 ohms
- $I_L = V_{out(avg)}/R_L \approx$ 26 mA
- Peak-to-peak ripple ≈ 3 V



↑

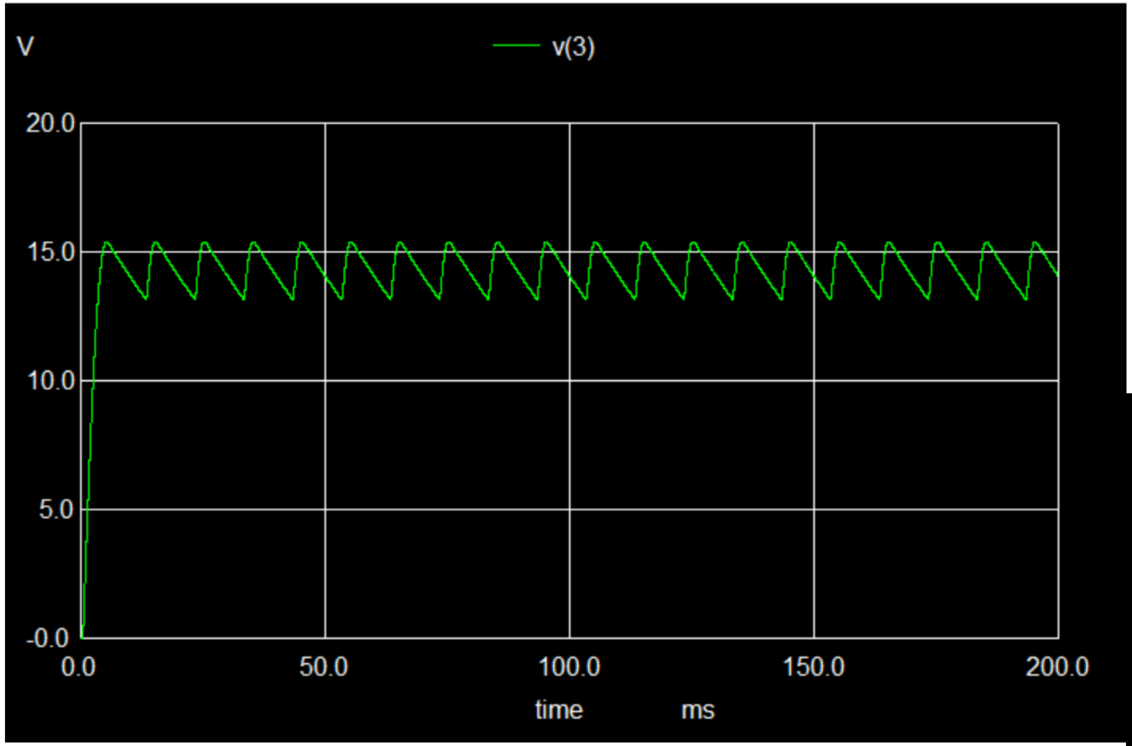
V_{out}

Load current I_L and the Diode currents →



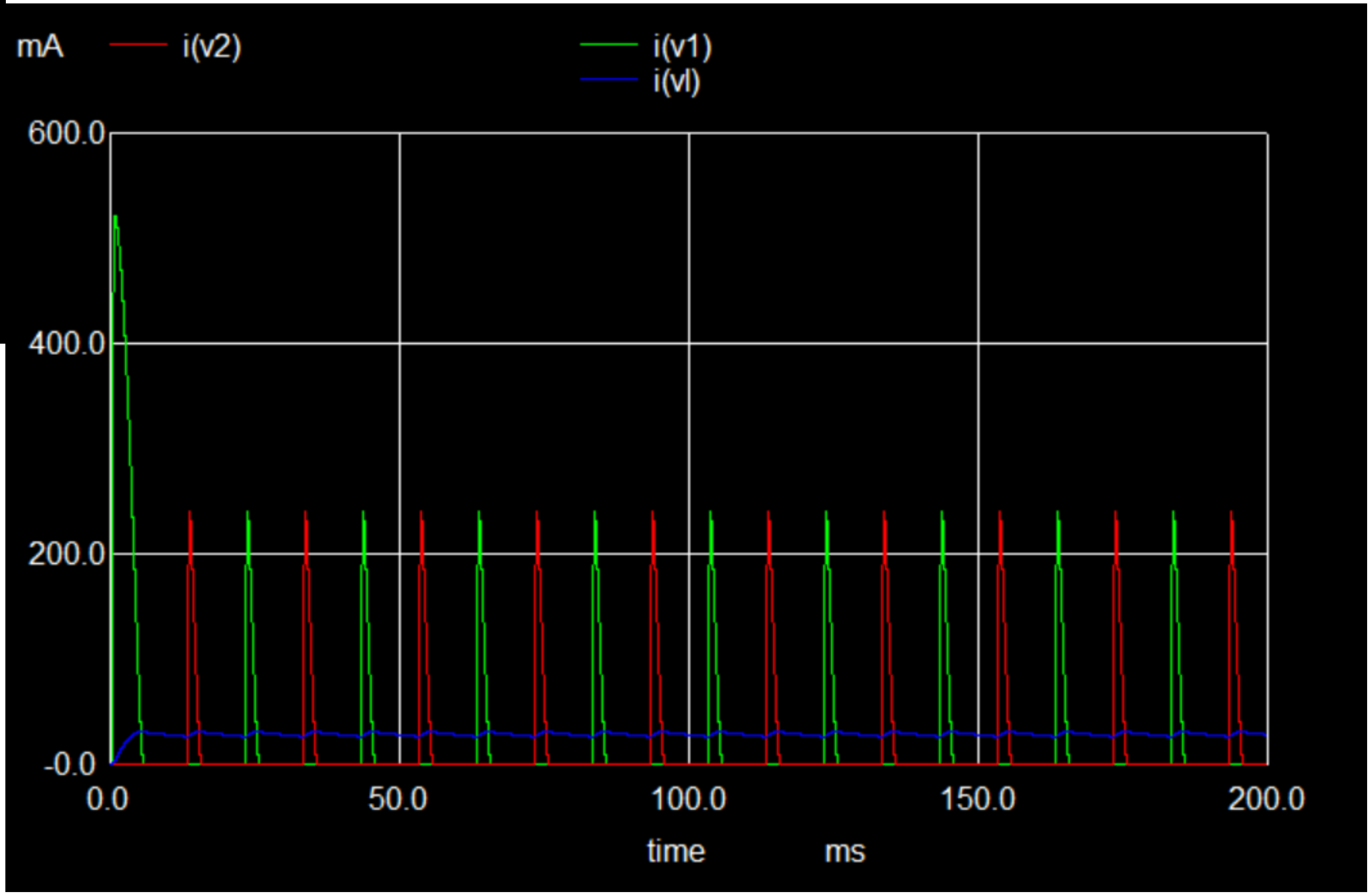
- NGSPICE Simulation - the effect of C on
  - Output ripple voltage
  - Diode currents

- V_{in}(peak) = 17 V
- C = 100 µF ; R_L = 500 ohms
- $I_L = V_{out(avg)}/R_L \approx 28$ mA
- Peak-to-peak ripple ≈ 2 V



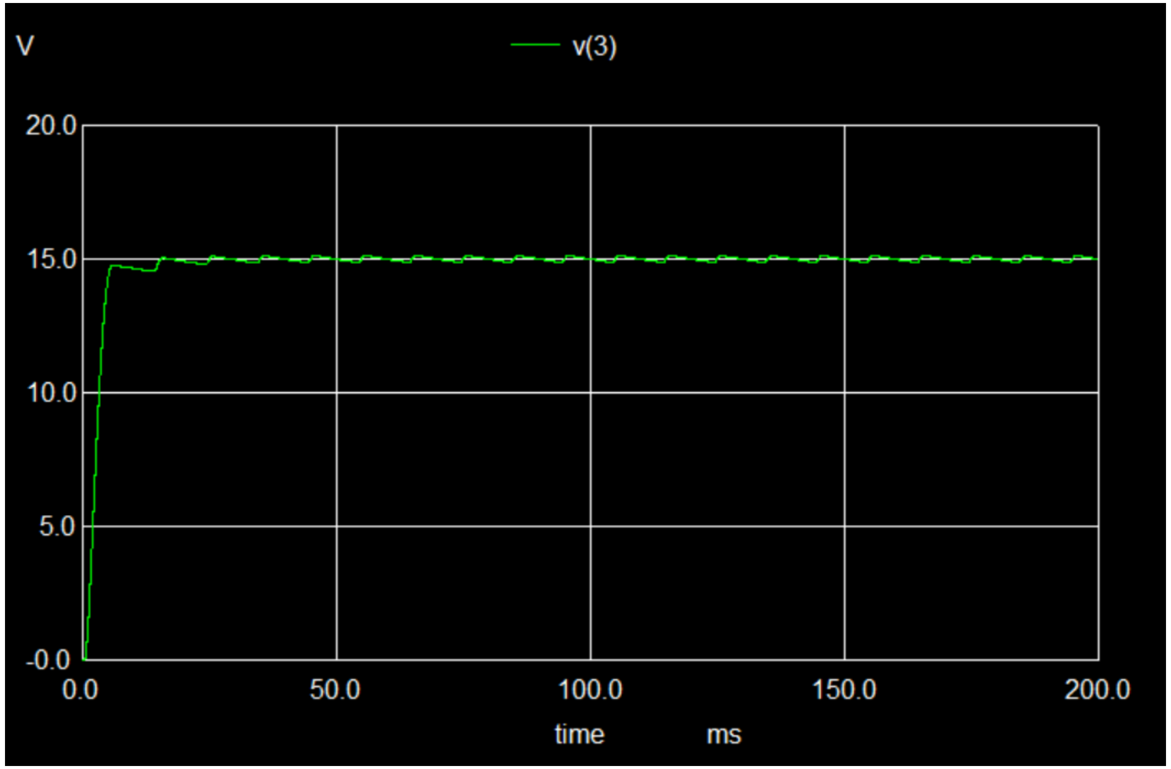
↑ V_{out}

Load current I_L and the Diode currents →



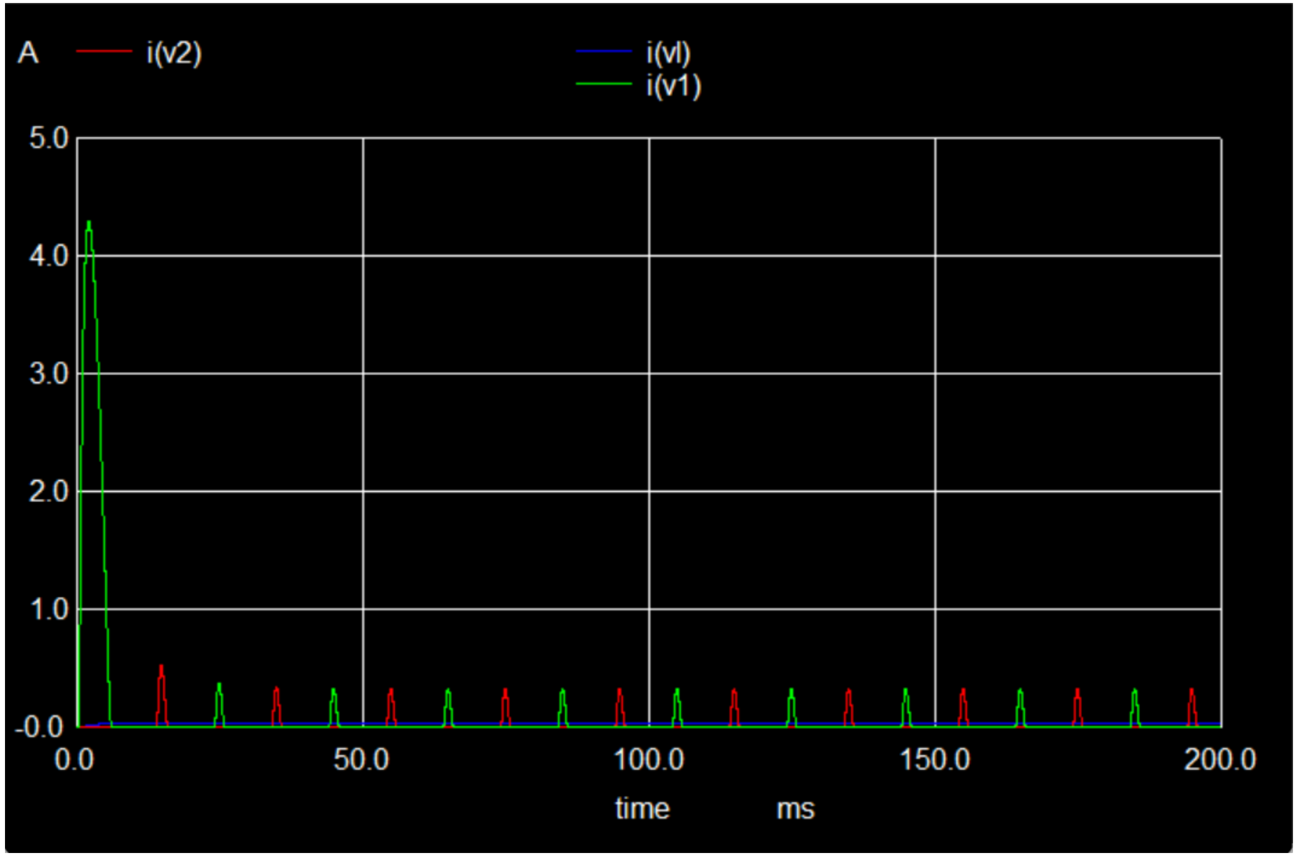
- NGSPICE Simulation - the effect of C on
  - Output ripple voltage
  - Diode currents

- V_{in}(peak) = 17 V
- C = 1,000 μF ; R_L = 500 ohms
- $I_L = V_{out(avg)}/R_L \approx 30$ mA
- Peak-to-peak ripple ≈ 0.3 V



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)

3. 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

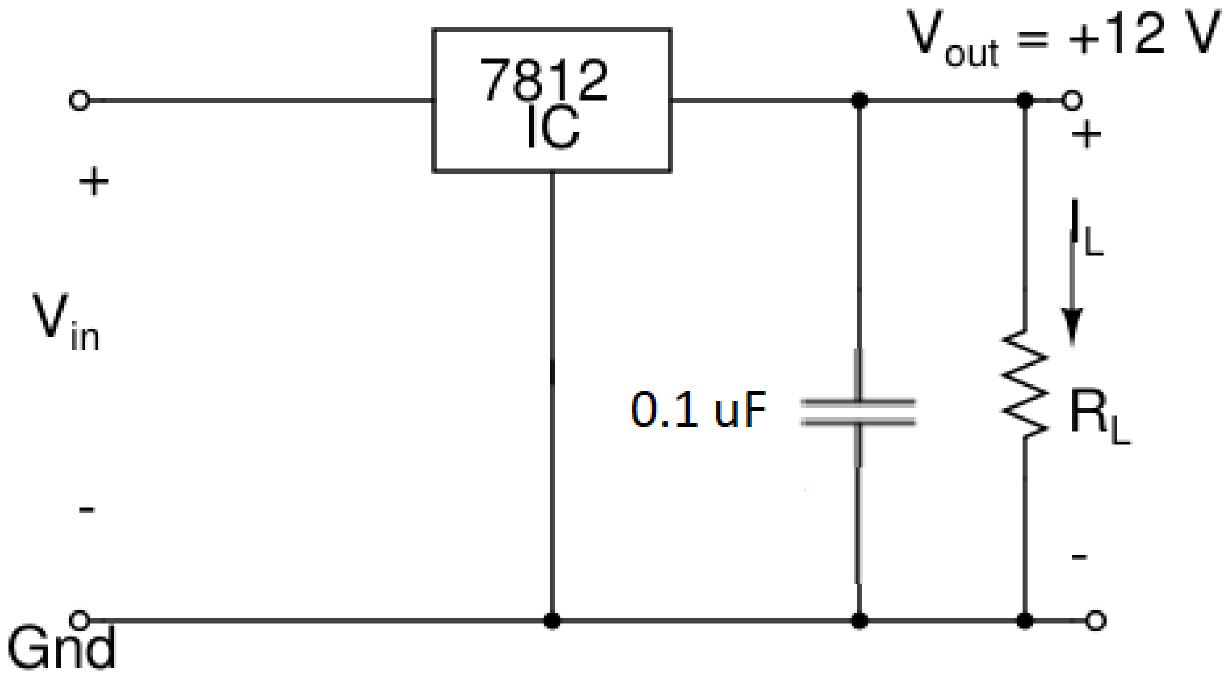
Two solutions

- Solution 1
  - Zener diode regulator circuit (usable for small variations in input voltage & load current)

- Solution 2
  - Voltage Regulator IC

- We will consider only Solution 2

3B: 7812 Three-terminal Voltage Regulator



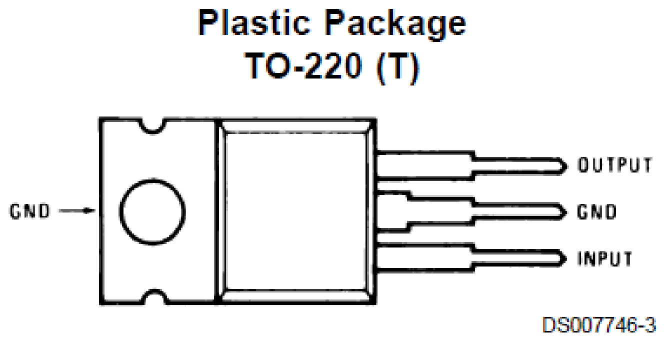


Fig. 12

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

I_L = up to 1 A

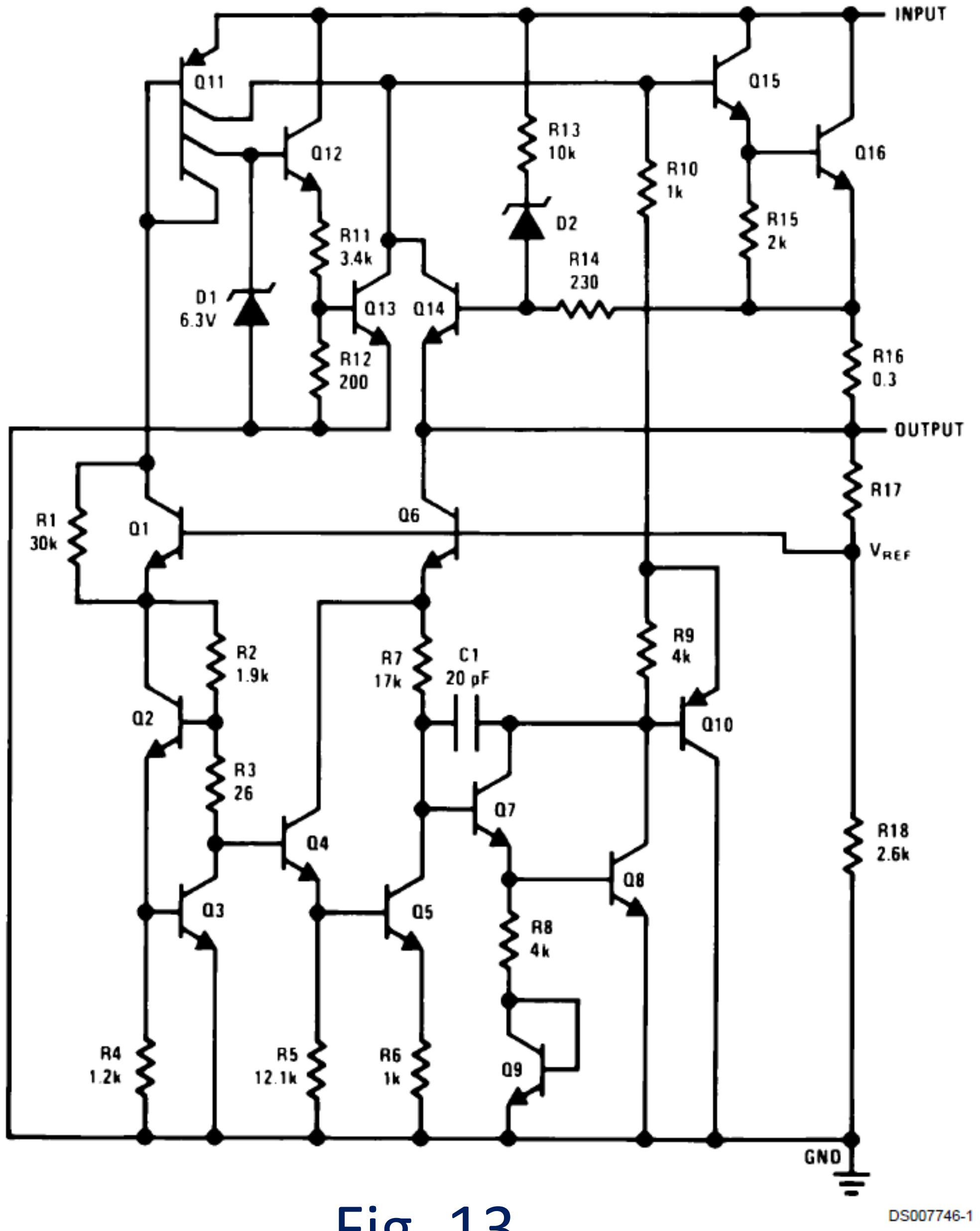


Fig. 13

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

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 μF 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_{out} = 5 V
  2. 7806 : V_{out} = 6 V
  3. 7809 : V_{out} = 9 V

- Negative Voltage Regulator ICs
  1. 7905 : V_{out} = -5 V
  2. 7906 : V_{out} = -6 V
  3. 7909 : V_{out} = -9V
  4. 7912 : V_{out} = -12 V