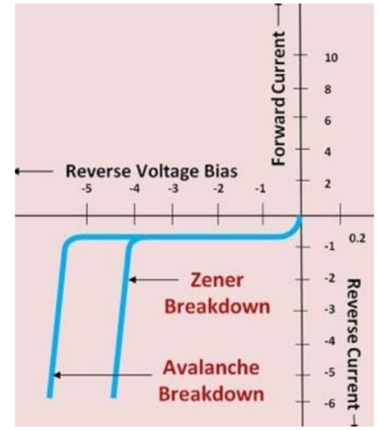
EEE-2103: Electronic Devices and Circuits

Dept. of Computer Science and Engineering
University of Dhaka

Prof. Sazzad M.S. Imran, PhD
Dept. of Electrical and Electronic Engineering
sazzadmsi.webnode.com

Zener Diode Voltage Regulators



Regulator circuit with no load:

Zener diode application = dc voltage regulator

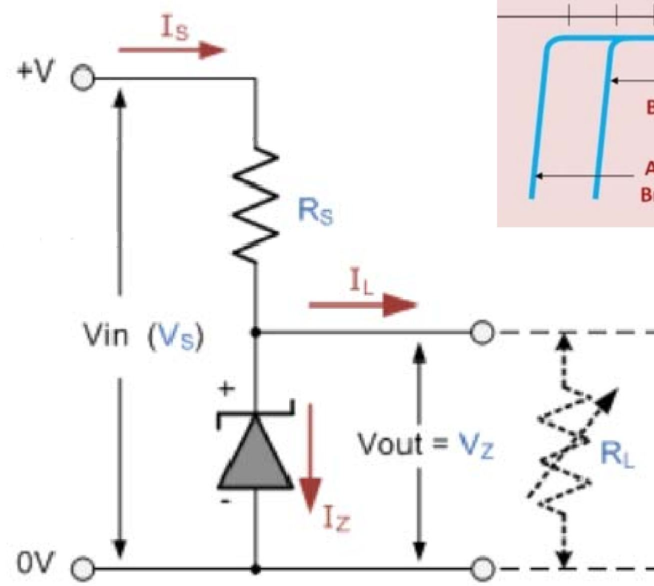
Reference voltage source →

supplies very low current to output

R_S limits Zener diode current

$$I_Z = \frac{V_S - V_Z}{R_S}$$

$I_Z >\approx I_{ZK}$ and $I_L << I_Z$



Loaded regulator:

Zener diode regulator supplies load current I_L

$$I_S = I_L + I_Z$$

$I_Z >\approx I_{Z(min)}$ to keep diode in reverse breakdown

$I_S < I_{Z(max)}$

Circuit current equation →

$$I_Z + I_L = \frac{V_S - V_Z}{R_S}$$

Zener Diode Voltage Regulators

Problem-12:

A 9 V reference source is to use a series-connected Zener diode and resistor connected to a 30 V supply. Select suitable components, and calculate the circuit current when the supply voltage drops to 27 V. Assume that a 9.1 V Zener diode has knee current of 20 mA.

Assume, $I_Z \approx I_{ZK} = 20$ mA

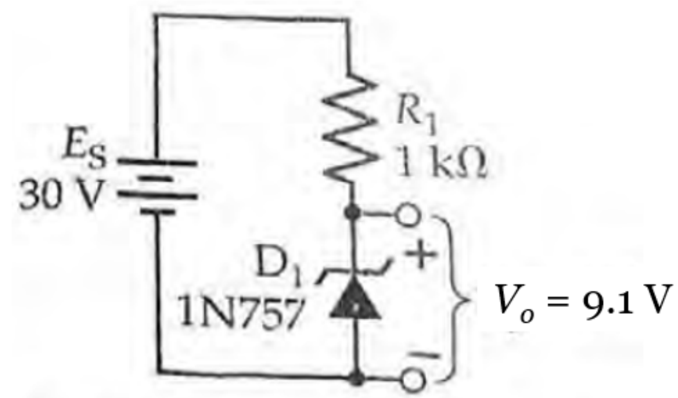
When $E_S = 30$ V

$R_1 = (E_S - V_Z)/I_Z = (30-9.1)/20\times10^{-3} = 1.05\ \text{k}\Omega \approx 1\ \text{k}\Omega$

$P_{R1} = I_1^2 R_1 = (20\times10^{-3})^2\times1\times10^3 = 0.4$ W

When $E_S = 27$ V

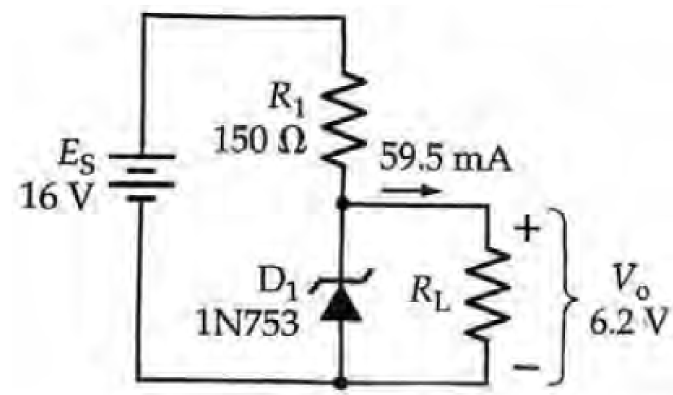
$I_Z = (E_S - V_Z)/R_1 = (27-9.1)/1\times10^3 = 17.9$ mA



Zener Diode Voltage Regulators

Problem-13:

Design a 6 V dc reference source to operate a 16 V supply as shown in Fig. 13. The circuit is to use a low-power Zener diode and is to produce the maximum possible load current. Calculate the maximum load current that can be taken from the circuit. Assume that for the Zener diode V_Z = 6.2 V, $I_{Z(min)}$ = 5 mA and P_D = 400 mW.



$I_{Z(max)} = P_D/V_Z = 400\times10^{-3}/6.2 = 64.5$ mA

$I_{L(max)} + I_{Z(min)} = 64.5$ mA

$R_1 = (E_S - V_Z)/I_{Z(max)} = (16 - 6.2)/64.5\times10^{-3}$

$= 152\ \Omega$ (use 150 Ω standard value)

$P_{R1} = I_1^2R_1 = (64.5\times10^{-3})^2\times150 = 0.62$ W

Select $I_{Z(min)} = 5$ mA

$I_{L(max)} = I_{Z(max)} - I_{Z(min)} = 64.5\times10^{-3} - 5\times10^{-3} = 59.5$ mA

Zener Diode Voltage Regulators

Regulator performance:

Performance parameters →

1) source and load effects
2) line and load regulations
3) ripple rejection ratio = ratio of output to input ripple amplitude

ac equivalent circuit →

replace Zener diode with its dynamic impedance Z_Z

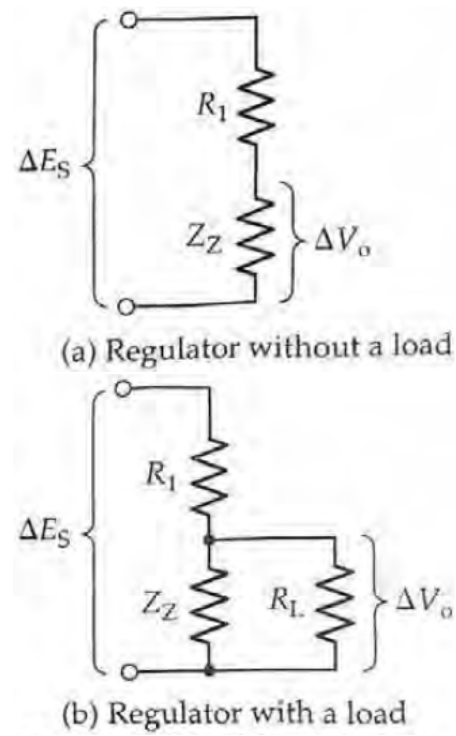
simple voltage divider circuit

1) Source effect

When E_S changes by ΔE_S →

without load, $\Delta V_0 = \frac{\Delta E_S \times Z_Z}{R_1 + Z_Z}$

with load, $\Delta V_0 = \frac{\Delta E_S \times (Z_Z \| R_L)}{R_1 + (Z_Z \| R_L)}$



Zener Diode Voltage Regulators

Regulator performance:

2) Load effect

Assuming R_S = 0, from regulator Thevenin equivalent circuit

$R_o = R_1 \, || \, Z_Z$

$\Delta V_o = \Delta I_L(R_1 \, || \, Z_Z)$

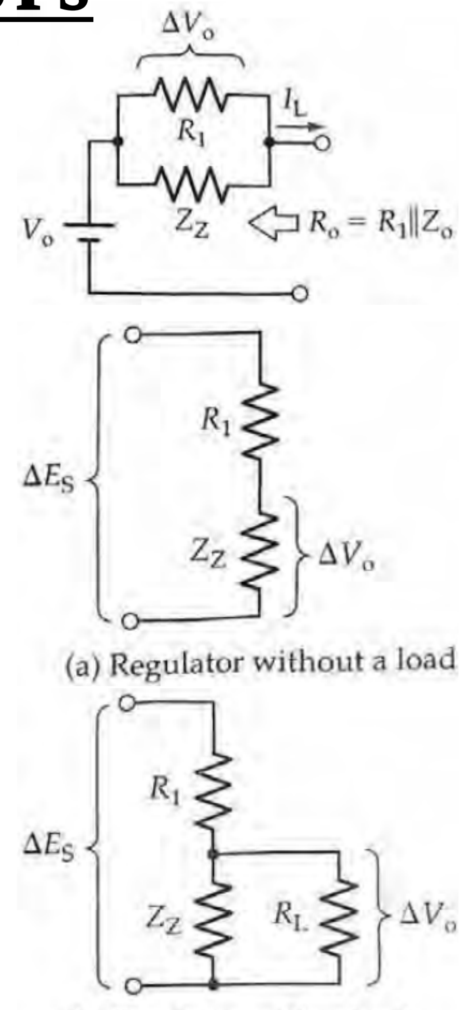
3) Ripple rejection ration

without load, $\frac{V_{ro}}{V_{ri}} = \frac{Z_Z}{R_1+Z_Z}$

with load, $\frac{V_{ro}}{V_{ri}} = \frac{Z_Z \| R_L}{R_1+(Z_Z \| R_L)}$

V_{ro} = output ripple amplitude

V_{ri} = input ripple amplitude



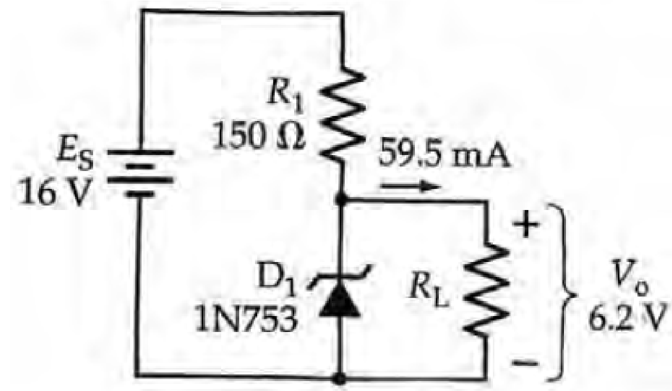
(a) Regulator without a load

(b) Regulator with a load

Zener Diode Voltage Regulators

Problem-14:

Calculate line regulation, load regulation, and ripple rejection ratio for the voltage regulator in Fig. 14. Assume that dynamic resistance of the diode is Z_Z = 7 Ω and there is 10% change in the voltage source.



Source effect:

ΔE_S = 10% of E_S = 16×10/100 = 1.6 V

$R_L = V_o/I_L$ = 6.2/59.5×10^{-3} = 104 Ω

$\Delta V_0 = \frac{\Delta E_S \times (Z_Z \| R_L)}{R_1 + (Z_Z \| R_L)} = \frac{1.6 \times (7 \| 104)}{150 + (7 \| 104)}$ = 67 mV

Line regulation = (ΔV_o for 10% change in E_S)×100%/V_o

= 67×10^{-3}×100/6.2 = 1.08%

Load effect:

$\Delta V_o = \Delta I_L(Z_Z||R_1)$ = 59.5×10^{-3}×(7||150) = 398 mV

Load regulation = (ΔV_o for $\Delta I_{L(max)}$)×100%/V_o = 398×10^{-3}×100/6.2 = 6.4%

Ripple rejection, $\frac{V_{ro}}{V_{ri}} = \frac{Z_Z \| R_L}{R_1 + (Z_Z \| R_L)} = \frac{7 \| 104}{150 + (7 \| 104)}$ = 4.19×10^{-2}