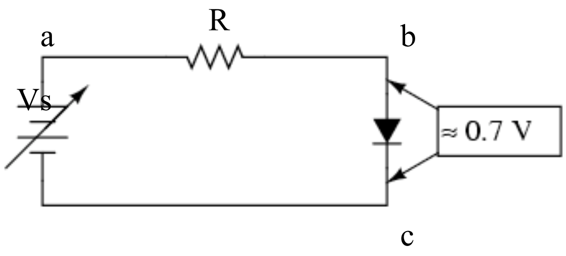
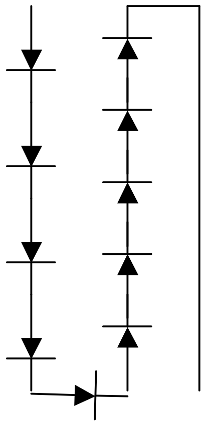
DIODES for Voltage Regulation PHYS321

The Si diode exhibits a ~0.7 voltage drop in the **forward biased case**. The voltage at b is then Vab = 0.7 V. Point b is fixed to 0.7V independent of current!

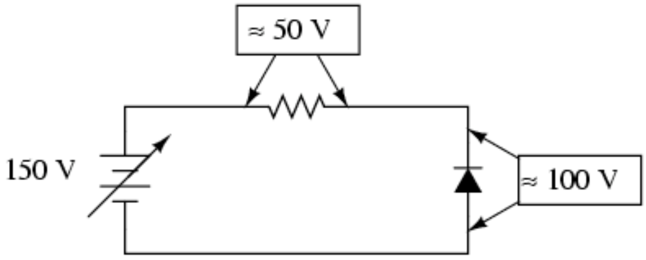
The voltage drop across the resistor is Vba = Vs – 0.7. The current flowing through the resistor is then I = (Va-Vb)/R =(Vs-0.7) /R



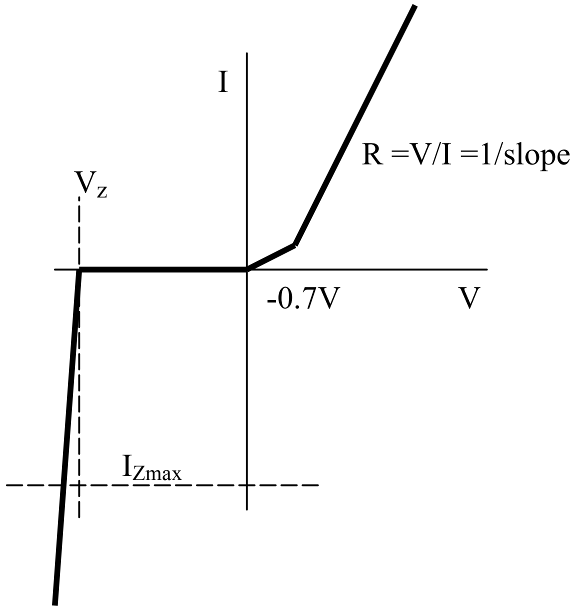


We can add more diodes to the circuit to increase the voltage at point b. If we put 10 diodes in series then Vb = 10 x 0.7 = 7V. The current will drop to I = (Vs-7.0) /R .

Reversing the diode. If we increase the supply voltage (now in the reverse direction) the diode will reach it's breakdown voltage Vb(reak) almost independent of current flow! Vb is usually 4-100V so a more practical regulation device. Zener realized this property and worked on making diodes which provide a sharp and stable breakdown pattern, the **Zener diode**.

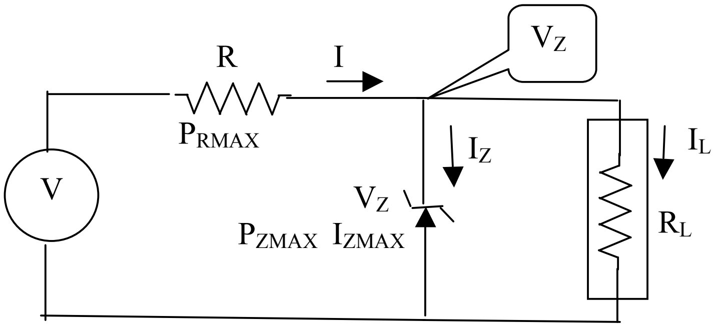


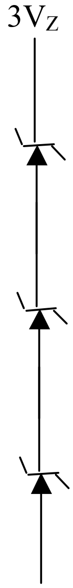
Diode $V_{breakdown}$ = 100 V



ZENER DIODE CIRCUIT w LOAD

Imagine we want to design a circuit which keeps the voltage across the load constant. We can use a Zener diode in lower current applications,





1) $V < V_Z$ $\quad V = V_R + V_L$ (not interesting)

2) $V > V_Z$ $\quad V = V_R + V_Z$ $\quad (V_Z = V_R)$

$$V - V_Z = V_R = I R = (I_Z + I_L) R \sim (0.2\, I_{ZMAX} + I_L)\, R$$

$$I = 0.2\, I_{ZMAX} + I_L$$

Choose:
$R = (V - V_Z) / (0.2\, I_{ZMAX} + I_L)$

Check the power rating on the resistor is not exceeded.
$P_R = I^2 R$

Check the power rating on the Zener diode is not exceeded.
$P_R = I_Z V_Z = (I - I_L) V_Z < P_{ZMAX}$

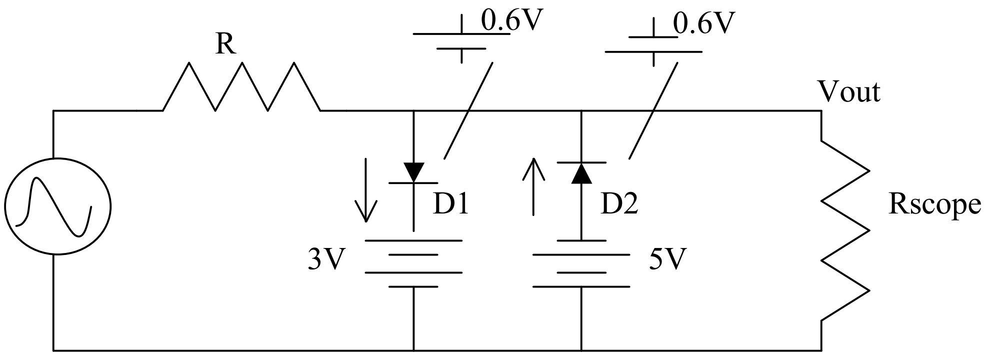
EXAMPLE
With V=7V design a 5.1V power source capable of supplying I_L=10ma.

1) Choose a zener diode with $(V_Z = 5.1V \;\; I_{ZMAX} = 50mA)$

2) $R = 1.9V/20mA = 95\Omega$
$P_R = (0.020A)^2 \; 95\Omega = 38\,mW$ (Can use 100Ω 1/4W)

3) $P_Z = I_Z V_Z = (0.010A)(5.1V) = 5.1mW = 1/5 \; I_{ZMAX} V_Z$

Analysis of a Diode Clipper Circuit



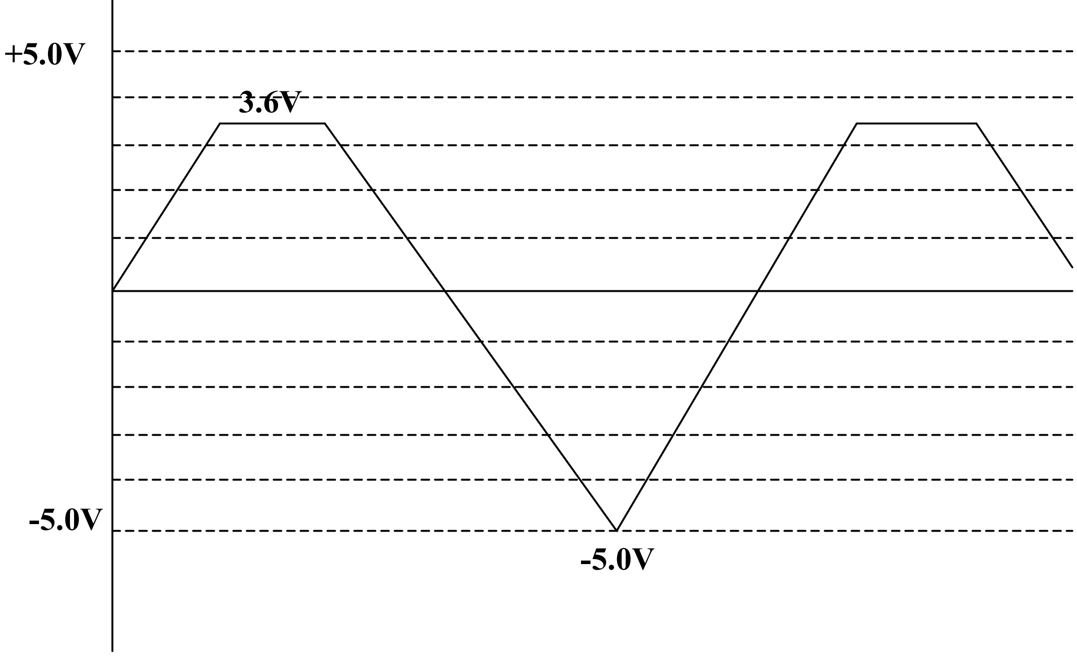
Both diodes are reversed biased by the batteries in the circuit. Until the input voltage exceeds the battery voltage + 0.6V diode drop in both cases no current will flow through the diodes D1 or D2. All the current flows through Rscope! The scope will see the input voltage rise and fall during this period (Rscope >> R).

Vout = Vin (Rscope/(Rscope + R) ≅ Vin *-voltage divider*

On the positive half-cycle when +|Vin| > 3V + 0.6V the diode conducts and all current flows through D1, none though D2. (A small amount through Rscope!) The diode
is now like the 0.6V battery depicted above.

On the negative half-cycle D2 conducts when -|Vin| < 5V + 0.6V or Vin < -5.6V. This condition is never reached and the negative input signal is seen on the scope unclipped!

Figure-1 Clipped Sawtooth Wave



Cockroft Walton Voltage Multipliers

The classic multistage diode/capacitor voltage multipler, popularized by Cockroft and Walton, is probably the most popular means of generating high voltages at low currents at low cost. It is used in virtually every television set made to generate the 20-30 kV second anode accelerating voltage from a transformer putting out 10-15 kV pulses. It has the advantage of requiring relatively low cost components and being easy to insulate. It also inherently produces a series of stepped voltages which is useful in some forms of particle accelerators, and for biasing photomultipler tube dynodes.

The CW multiplier has the disadvantage of having very poor voltage regulation, that is, the voltage drops rapidly as a function the output current. In some applications, this is an advantage. The output V/I characteristic is roughly hyperbolic, so it serves well for charging capacitor banks to high voltages at roughly constant charging power. Furthermore, the ripple on the output, particularly at high loads, is quite high.

It is quite popular for relatively low powered particle accelerators for injecting into another accelerator, particularly for heavy ions. The high ripple means that there is a signficant energy spread in the ion beam, though, and for applications where low ripple is important at megavolt potentials, electrostatic systems like Van de Graaf and Pelletron machines are preferred