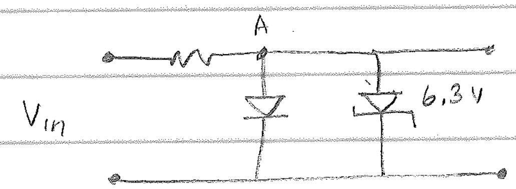
Homework 7 Solutions

3.2) a)

Use simplified diode model



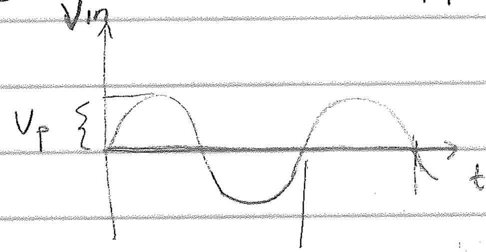
Clipper circuit

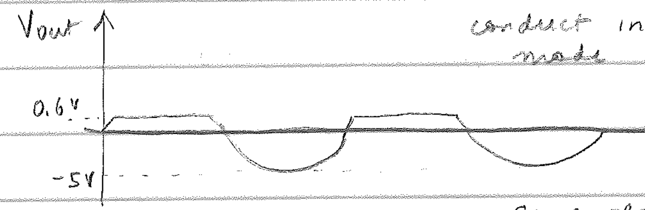
If $V_A = V_{out} > 0.6\,V$ the normal diode conducts, $V_A = V_{pn} = 0.6\,V$

The Zener does not conduct in breakdown mode

$f = 100\,Hz$

$V_p = 5\,V$



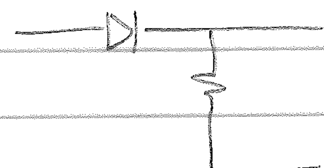


same period T

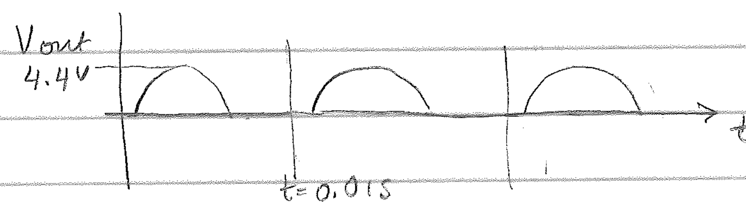
T = 0.01 s

For $V_A < 0.6\,V$, output follows input

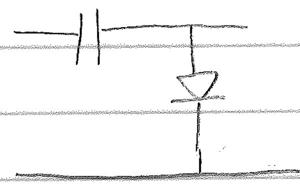
b)



This is a half-wave rectifier, diode conducts and $V_{out} = V_{in} - 0.6\,V$ for $V_{out} > 0.6\,V$



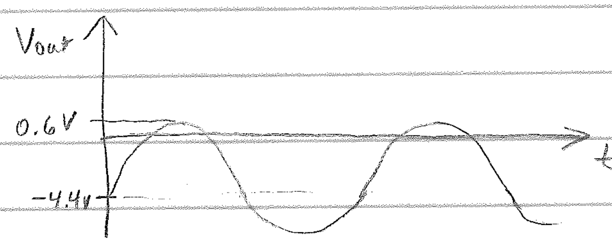
c)



This is a clamp.

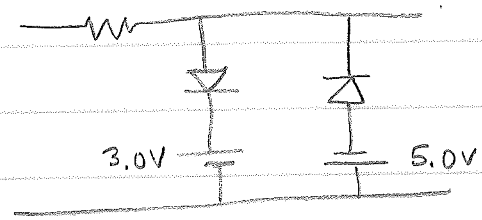
Output is shifted down by $V_p - 0.6\,V = 4.4\,V$

(assume capacitor has a large value)

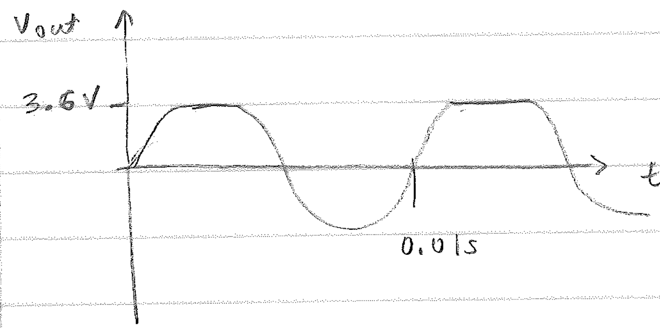


same period T

d)

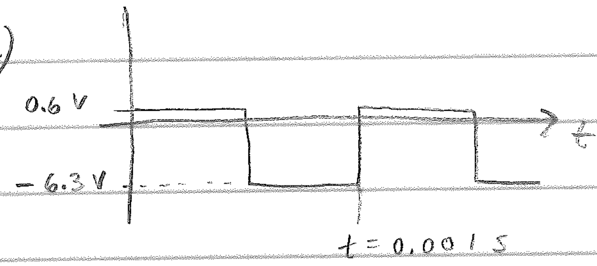


Another clipper,
except output cannot
be more positive than
3.0 V + 0.6 V
or more negative than
- 5.0 - 0.6 V
this signal always has
> -5V, so never gets
negatively clipped



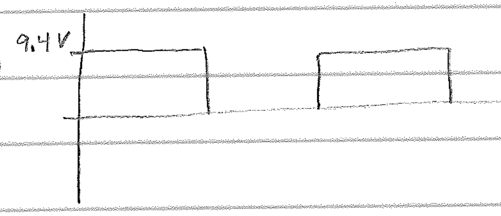
3.3) Same explanations as for problem 3.2 apply, except that input $V_p = 10\,V$, and output period follows the input with $T = 0.001\,s$ period (and it's a square wave)

a)



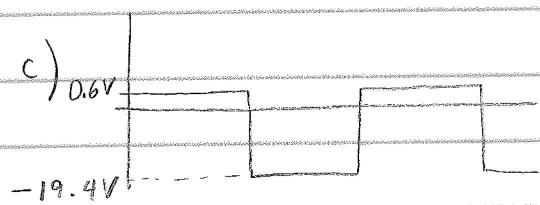
clipper
Here the zener limits the negative swing

b)



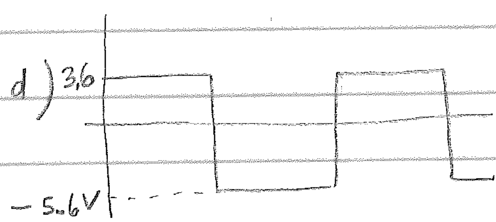
Conducts only on positive side

c)



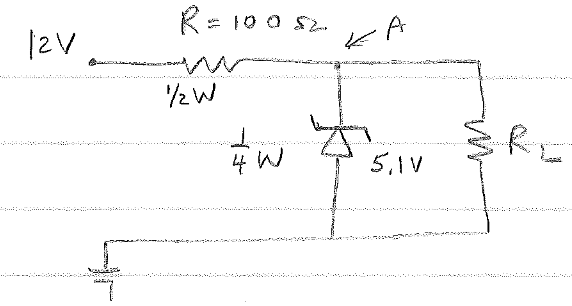
clamp
shifts down by
$V_p - 0.6 = 9.4\,V$

d)



clamp, limits to $+3.6\,V$, $-5.6\,V$

3, 5)



a) What happens if R_L is shorted?

$V_A = 0$,

Power through R is $P = \frac{V^2}{R} = \frac{12^2}{100} = 1.44\ W$

The resistor is only rated for 0.5 W so sadly, it burns out

b) What happens if R_L is removed?

All the current must flow through the zener

$V_A = 5.1\ V$

$I = \frac{12V - V_A}{R} = 0.069\ A$

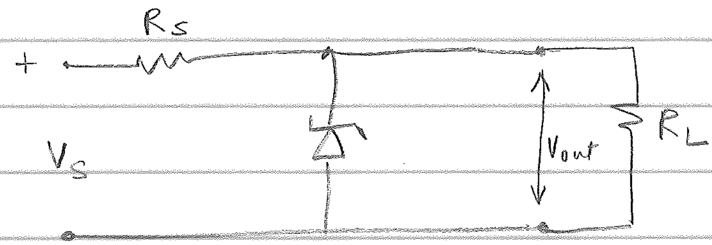
$P_R = I^2 R = (0.069)^2 (100) = 0.48\ W$ resistor survives

$P_Z = IV = (0.069)(5.6) = 0.35\ W$

which exceeds the zener power rating

So bad news for the zener.

3.6) Zener diode voltage regulator



$R_S = 1500\,\Omega$

$V_S = 150\,V$

a) Want: range of R_L over which V_{out} = constant

Zener breaks down @ $100\,V = V_Z$

I_{max} through Zener $= 100\,mA$

Want the Zener in breakdown mode, in which case we have $V_{out} = 100\,V$

Breakpoint at $V_{out} = V_S \dfrac{R_L}{R_L + R_S}$ (voltage divider)

$$> V_Z = 100\,V$$

$\Rightarrow$ Breakpoint for $\dfrac{R_L}{R_L + R_S} = \dfrac{V_Z}{V_S}$

$$R_L\left(1 - \frac{V_Z}{V_S}\right) = \frac{V_Z}{V_S} R_S$$

$$R_L = R_S\left(\frac{V_Z}{V_S}\right)\left(\frac{V_S}{V_S - V_Z}\right) = R_S\left(\frac{V_Z}{V_S - V_Z}\right)$$

$$\Rightarrow R_L > 1500\,\Omega\left(\frac{100}{50}\right) = \underline{\underline{3\,k\Omega}}$$

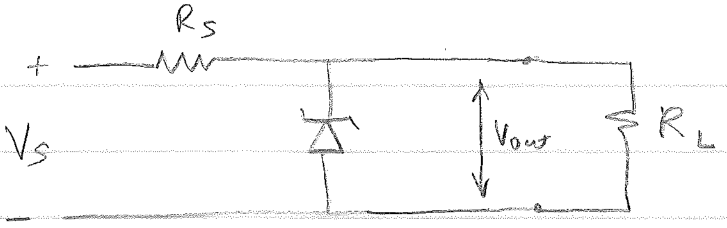
So we get constant V_Z for $\boxed{R_L > 3\,k\Omega}$

b) For $R_L = 10\,k\Omega$, solve $\dfrac{R_L}{R_L + R_S} = \dfrac{V_Z}{V_S} \Rightarrow V_S = V_Z \dfrac{(R_L + R_S)}{R_L}$

$$V_S = 100\left(\frac{1500 + 10^4}{10^4}\right)$$

$$\boxed{V_S > 115\,V}$$

3.7)



$V_S = 30\text{ V}$

$R_S = 300\ \Omega$

$V_Z = 15\text{ V}$

Vary R_L to vary I_L

Want V_{out} vs I_L

Same expressions as in the previous problem apply

$$R_L > R_S\left(\frac{V_Z}{V_S - V_Z}\right)$$ gives minimum R_L for regulation

$$R_L > 300\left(\frac{15}{30-15}\right) = 300\ \Omega$$

At this R_L, $I_L = \dfrac{15\text{ V}}{R_L} = 50\text{ mA}$

For larger R_L, I_L is smaller, so for 50 mA or less, voltage is regulated to $V_{out} = V_Z$

For $R_L < 300\ \Omega$, I_L is larger and zener not conducting

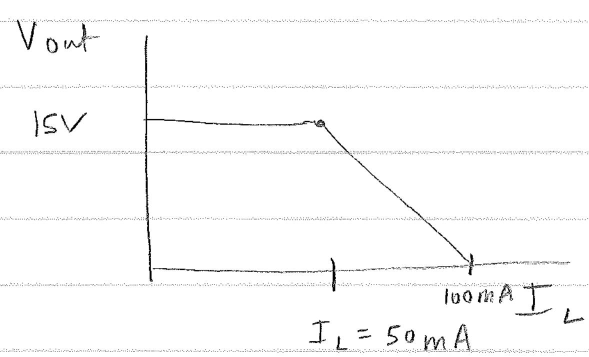
$$I_L = \frac{V_S}{R_S + R_L} \Rightarrow (R_S + R_L) I_L = V_S$$

$$I_L R_L = V_S - I_L R_S$$

$$V_{out} = I_L R_L$$

$$V_{out} = V_S - I_L R_S$$

so V_{out} vs I_L is straight line with slope $-R_S$.



$V_{out} = 0$ at

$$I_L = V_S / R_L = \frac{30\text{ V}}{300} = 100\text{ mA}$$