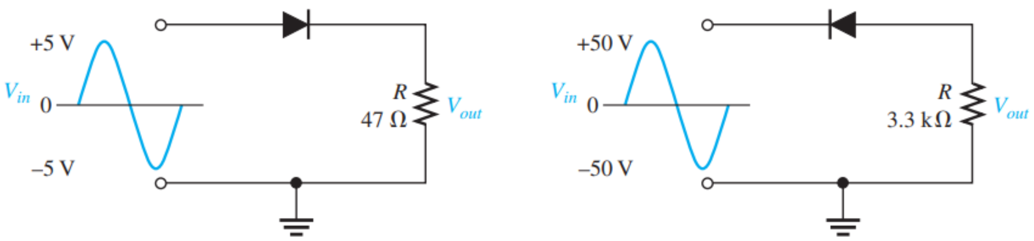
VICTORIA UNIVERSITY OF WELLINGTON TE HERENGA WAKA NEW ZEALAND

XMUT204 Electronic Design

Tutorial 2: Diode Applications

Section A: Half-wave Rectifiers

1. For each circuit in the figures given below:



(a) (b)

a. Draw the output voltage waveform and include the voltage values. [4 marks]

b. What is the peak inverse voltage across each diode? [4 marks]

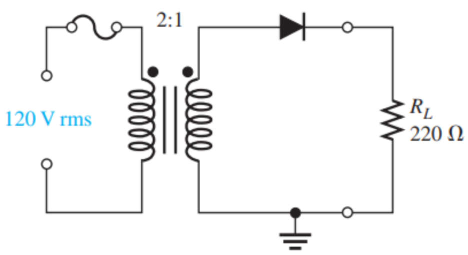
c. Derive the average voltage (V(ave)) of half-wave rectifier. [10 marks]

d. Calculate the average value of half-wave rectified voltage with a peak value of 200 V. [2 marks]

e. What is the peak forward current through each diode? [4 marks]

f. A power-supply transformer has a turn ratio of 5:1. What is the secondary voltage if the primary is connected to a 120 V rms source? [2 marks]

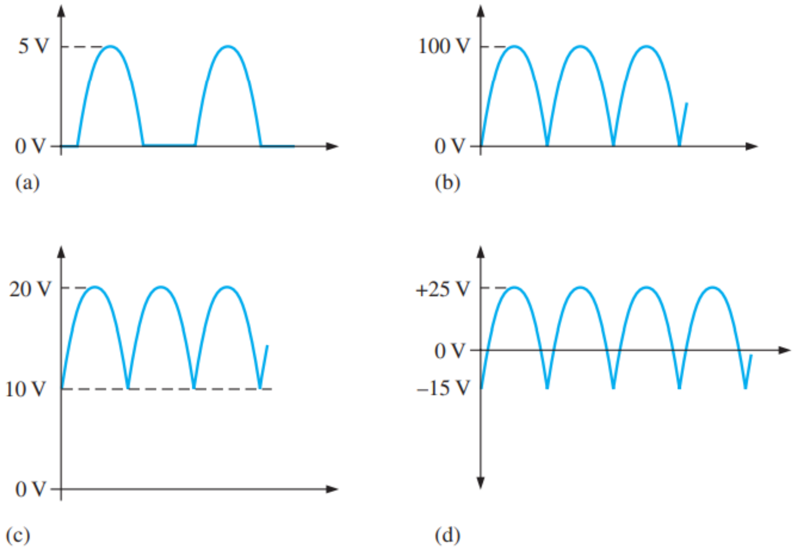
2. Determine the peak and average power delivered to R_L in the figure given below. [8 marks]



Section B: Full-wave Rectifiers

1. In terms of energy transfer, full-wave rectifiers are twice more efficient compared with half-

wave rectifiers.



a. Determine the average voltage ($V(\text{ave})$) of full-wave rectifier. [2 marks]

b. Find the average value of each voltage in the figures given above. [8 marks]

2. Full-wave rectifier circuit can be realised as centre-tap or bridge full-wave rectifier circuit.

   a. Using ideal diode + voltage source model, determine average voltage from the peak voltage in full-wave rectifier circuit. [2 marks]

   b. Using ideal diode model and ideal diode + voltage source model, determine the voltage across the load at the output for centre-tap full wave rectifier circuit. [4 marks]

3. Peak inverse voltage (PIV) is one of the device parameters which is useful for determining rating of the diode during reverse bias condition.

   a. Determine the PIV of centre-tap full-wave rectifier circuit. [6 marks]

   b. Determine the PIV of bridge full-wave rectifier circuit for ideal and ideal + voltage source models. [4 marks]

   c. Compare the PIV of centre-tap full-wave rectifier circuit with the PIV of bridge full-wave rectifier circuit. [4 marks]

4. For a given diode rectifier circuit, derive the following parameters of the circuit:

   a. Ripple voltage (V_r). [12 marks]

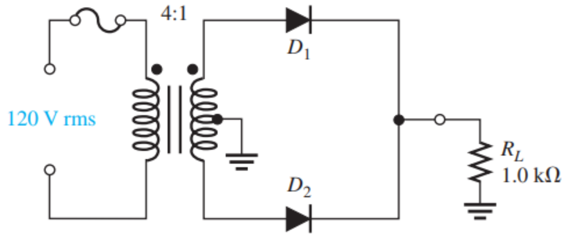
   b. DC voltage (V_{DC}). [6 marks]

5. Show how to connect the diodes in a centre-tapped rectifier in order to produce a negative-

going full-wave voltage across the load resistor. [2 marks]

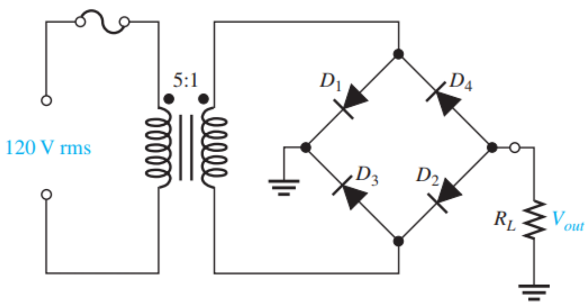
6. Calculate the peak voltage across each half of centre-tapped transformer used in a full-wave rectifier that has an average output voltage of 120 V. [4 marks]

7. Consider the centre-tap full-wave rectifier circuit given in the figure below.



   a. What is the total peak secondary voltage? [2 marks]
   b. Find the peak voltage across each half of the secondary. [2 marks]
   c. Sketch the voltage waveform across R_L. [4 marks]
   d. What is the peak current through each diode? [2 marks]
   e. What is the peak inverse voltage for each diode? [2 marks]

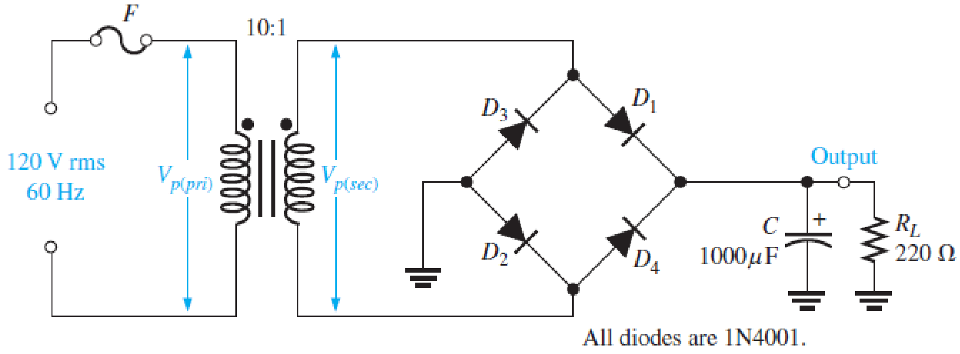
8. Draw the output voltage waveform for the bridge rectifier given in the figure below. Notice that all the diodes are reversed from circuits shown earlier in the lecture. Determine also the peak output voltage of the rectifier circuit. [10 marks]



9. What peak inverse voltage rating is required for diodes in a bridge rectifier that produces an average output voltage of 50 V? [4 marks]

10. The rms output voltage of a bridge rectifier is 20 V. What is the peak inverse voltage across the diodes? [4 marks]

11. Determine the following circuit parameters for the filtered bridge rectifier with a load as indicated in the figure given below.



a. Peak primary voltage. [2 marks]

b. Peak secondary voltage [2 marks]

c. Unfiltered peak full-wave rectified voltage. [2 marks]

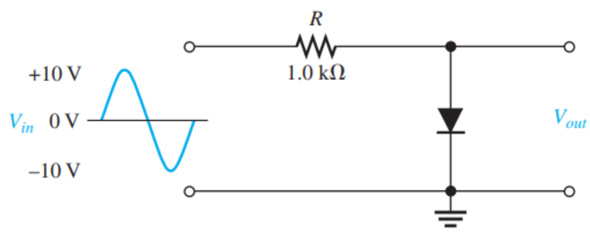
d. Peak-to-peak ripple voltage at the output. [2 marks]

e. Approximate dc value of the output voltage. [2 marks]

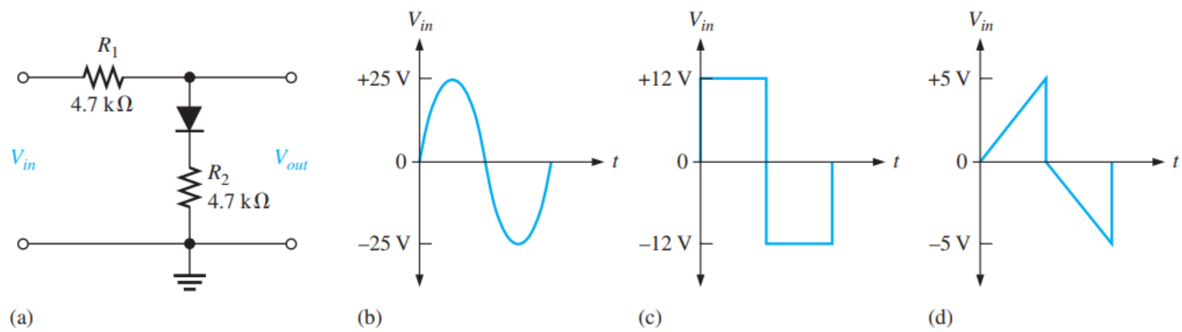
f. Ripple factor (in percentage). [2 marks]

Section C: Diode Limiters and Clampers

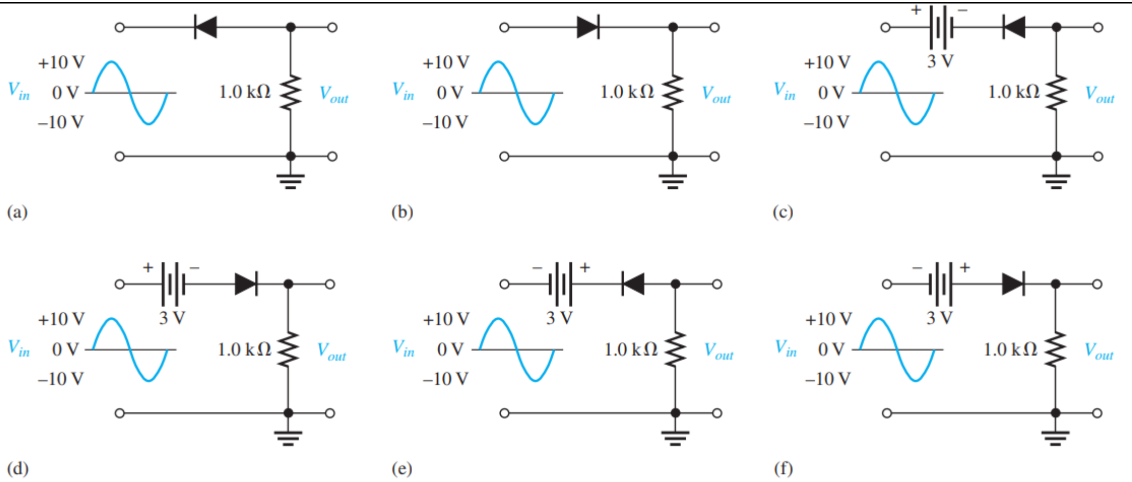
1. Determine the output waveform for the circuit given in the figure below. [4 marks]



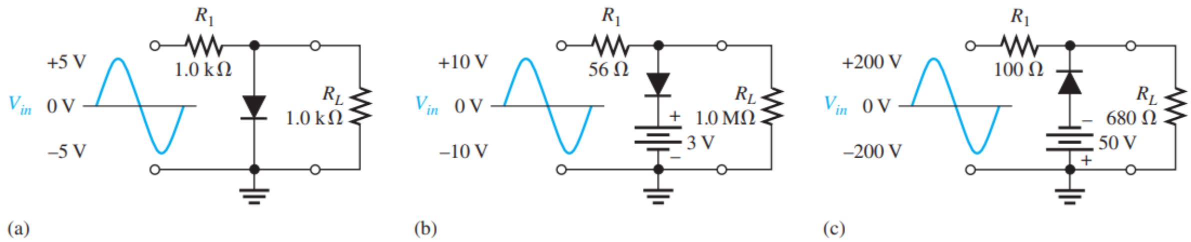
2. Determine the output voltage for the circuit in (a) for each input voltage in (b), (c), and (d). [6 marks]



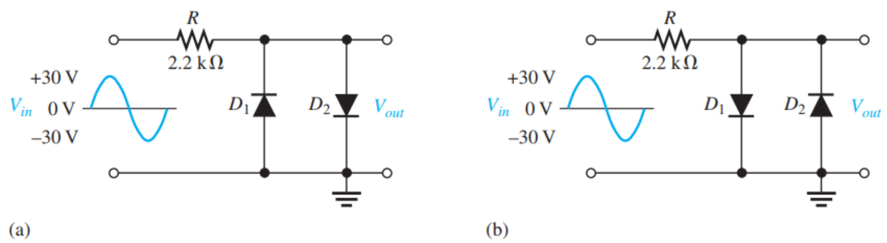
3. Determine the output voltage waveform for each circuit in the figure given below. [12 marks]



4. Determine the R_L voltage waveform for each circuit in the figure below. [6 marks]



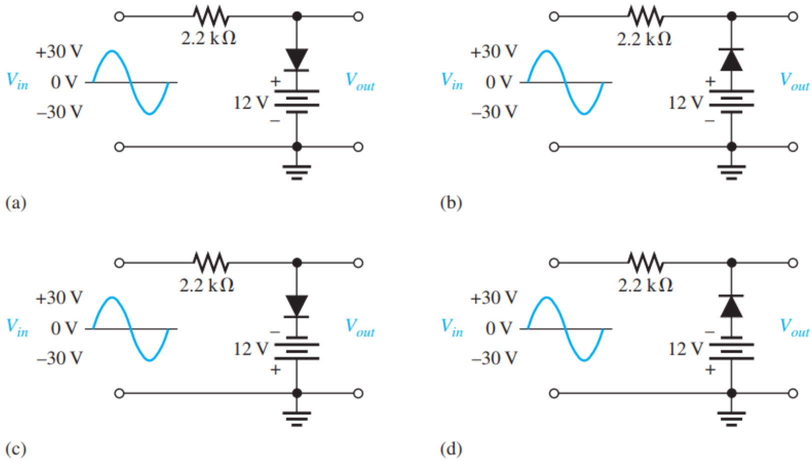
5. For each circuit in the figure below, determine:



a. The output voltage waveform. [4 marks]

b. The peak forward current through each diode. [4 marks]

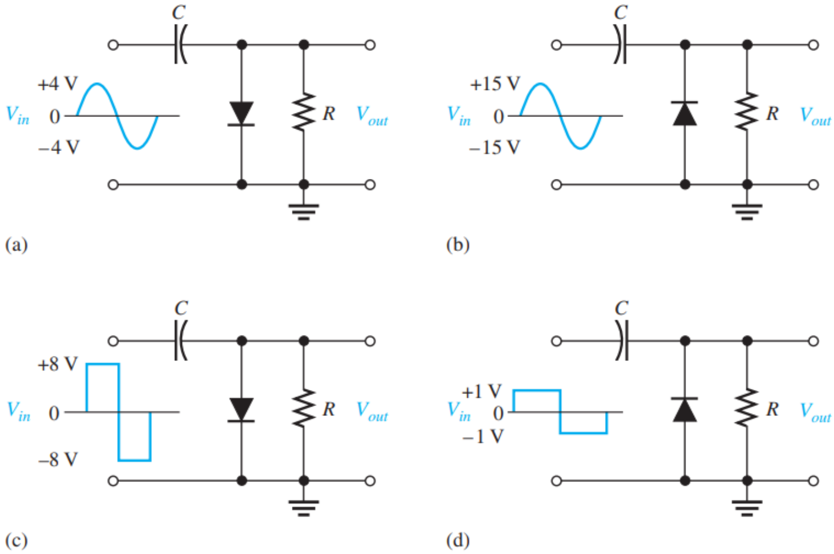
6. For each of the circuit given below, determine:



a. The peak forward current through each diode. [8 marks]

b. The output voltage waveform for each circuit. [8 marks]

7. For each circuit given in the figure below:



a. Describe the output waveform of each circuit. Assume the RC time constant is much greater than the period of the input. [8 marks]

b. Repeat (a) with the diodes turned around. [8 marks]

Appendix 1 – Datasheet of 1N4148 Diode

FAIRCHILD SEMICONDUCTOR®

1N/FDLL 914/A/B / 916/A/B / 4148 / 4448

Small Signal Diode

Absolute Maximum Ratings*

T_A = 25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{RRM}	Maximum Repetitive Reverse Voltage	100	V
$I_{F(AV)}$	Average Rectified Forward Current	200	mA
I_{FSM}	Non-repetitive Peak Forward Surge Current Pulse Width = 1.0 second Pulse Width = 1.0 microsecond	 1.0 4.0	 A A
T_{stg}	Storage Temperature Range	-65 to +200	°C
T_J	Operating Junction Temperature	175	°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:
1) These ratings are based on a maximum junction temperature of 200 degrees C.
2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Thermal Characteristics

Symbol	Characteristic	Max	Units
		1N/FDLL 914/A/B / 4148 / 4448	
P_D	Power Dissipation	500	mW
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	300	°C/W

Electrical Characteristics T_A = 25°C unless otherwise noted

Symbol	Parameter		Test Conditions	Min	Max	Units
V_R	Breakdown Voltage		I_R = 100 µA	100		V
			I_R = 5.0 µA	75		V
V_F	Forward Voltage	**1N914B/4448**	I_F = 5.0 mA	620	720	mV
		1N916B	I_F = 5.0 mA	630	730	mV
		1N914/916/4148	I_F = 10 mA		1.0	V
		1N914A/916A	I_F = 20 mA		1.0	V
		1N916B	I_F = 20 mA		1.0	V
		1N914B/4448	I_F = 100 mA		1.0	V
I_R	Reverse Current		V_R = 20 V		25	nA
			V_R = 20 V, T_A = 150°C		50	µA
			V_R = 75 V		5.0	µA
C_T	Total Capacitance					
		1N916A/B/4448	V_R = 0, f = 1.0 MHz		2.0	pF
		1N914A/B/4148	V_R = 0, f = 1.0 MHz		4.0	pF
t_{rr}	Reverse Recovery Time		I_F = 10 mA, V_R = 6.0 V (60mA), I_{rr} = 1.0 mA, R_L = 100Ω		4.0	ns

Appendix 2 - Key Formulas

Parameter	Formulae
Potential across the depletion region	$V_o = V_T \ln\left(\frac{N_A N_B}{n_i^2}\right)$
Potential energy (PE) in the depletion region	$PE = eV_o$
Forward current, ideal diode model	$I_F = \frac{V_{bias}}{R_{limit}}$
Forward current, practical diode model	$I_F = \frac{V_{bias} - V_F}{R_{limit}}$
Half-wave average value	$V_{avg} = \frac{V_p}{\pi}$
Peak half-wave rectifier output (silicon)	$V_{p(out)} = V_{p(in)} - 0.7\ \text{V}$
Peak inverse voltage, half-wave rectifier	$PIV = V_{p(in)}$
Full-wave average value	$V_{avg} = \frac{2V_p}{\pi}$
Center-tapped full-wave output	$V_{out} = \frac{V_{sec}}{2} - 0.7\ \text{V}$
Peak inverse voltage, center-tapped rectifier	$PIV = 2V_{p(out)} + 0.7\ \text{V}$
Bridge full-wave output	$V_{p(out)} = V_{p(sec)} - 1.4\ \text{V}$
Peak inverse voltage, bridge rectifier	$PIV = V_{p(out)} + 0.7\ \text{V}$
Line regulation	$\text{Line Regulation} = \left(\frac{\Delta V_{out}}{\Delta V_{in}}\right) \times 100\%$
Load regulation	$\text{Load Regulation} = \left(\frac{V_{NL} - V_{FL}}{V_{FL}}\right) \times 100\%$