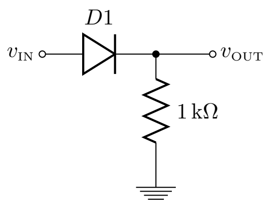
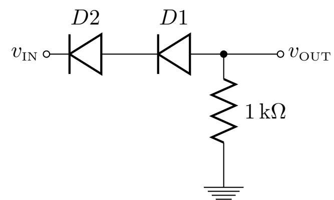
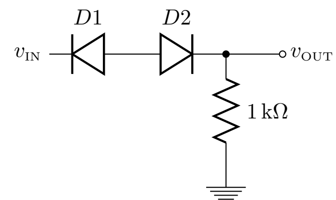
Problem 1. In each of the ideal-diode circuits shown below, v_{IN} is a 1 kHz sinusoid with zero-to-peak amplitude 10 V. For each circuit, sketch the output waveform and state the values of the maximum and minimum output voltages. For this problem, use the ideal switch model of the diode.



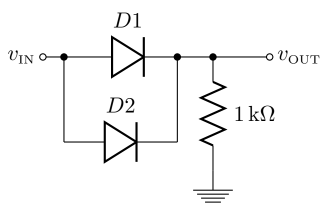
(A)



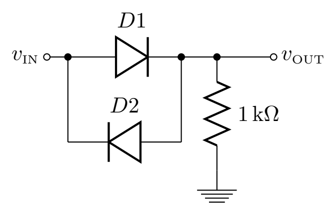
(B)



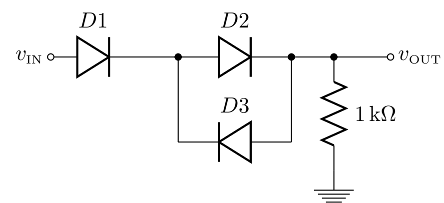
(C)



(D)



(E)



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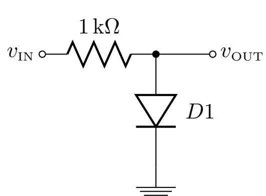
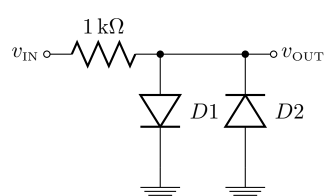
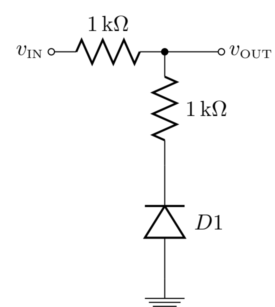


(G)

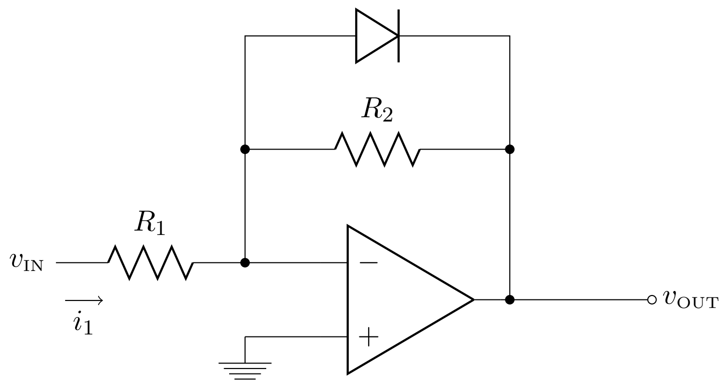


(H)



(I)

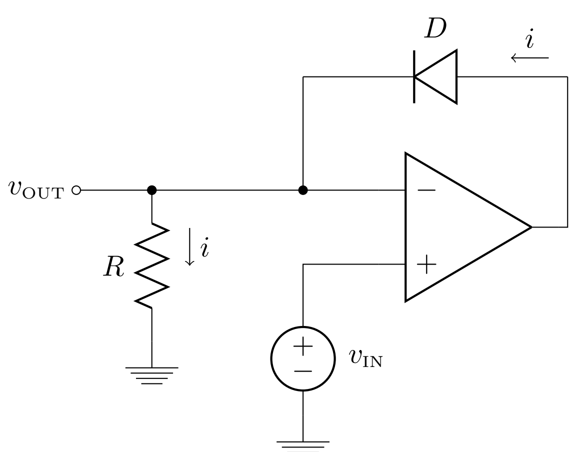
Problem 2. The circuit shown below uses a diode in the feedback path of the op amp. For each question, use only the **ideal switch model** to analyze the circuit's behavior (i.e. ignore the diode's 0.7V forward drop). Assume that $R_1 = 1\text{k}\Omega$, $R_2 = 4\text{k}\Omega$, and the op amp is ideal.



(A) Suppose $v_{\text{IN}} = 2\text{V}$. What direction is the current i_1 passing through R_1? Is the diode ON or OFF? What is v_{OUT}?

(B) Suppose $v_{\text{IN}} = -2\text{V}$. What direction is the current i_1 passing through R_1? Is the diode ON or OFF? What is v_{OUT}?

Problem 3. The circuit shown below uses a diode in the feedback path of the op amp. For each question, use only the **ideal switch model** to analyze the circuit's behavior (i.e. ignore the diode's 0.7V forward drop). Assume that $R = 1\text{k}\Omega$, and the op amp is ideal.

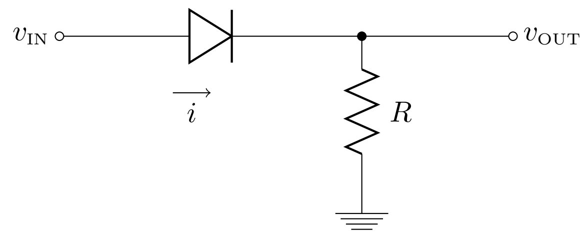


(A) Suppose $v_{\text{IN}} = 2\text{V}$. What direction is the current i passing through R? Is the diode ON or OFF? What is v_{OUT}?

(B) Suppose $v_{\text{IN}} = -2\text{V}$. What direction is the current i passing through R_1? Is the diode ON or OFF? What is v_{OUT}?

(C) Explain why v_{OUT} can never be less than 0V.

Problem 4. A half-wave rectifier circuit is shown below. You may assume that $R = 1\text{k}\Omega$ and the diode D has a 0.7V forward drop when its forward current equals 1mA.

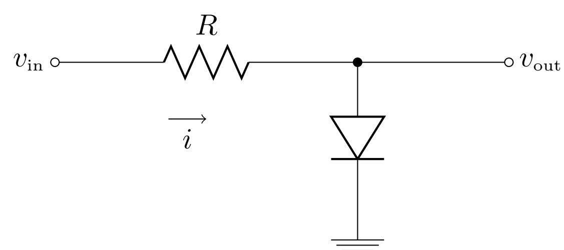


(A) Using the **iterative analysis procedure**, solve a precise solution for i and v_{OUT} for the case when $v_{\text{IN}} = 2\text{V}$. Show your results at each iteration, and state the number of iterations required to reach three significant digits of precision.

(B) Using the **small-signal model**, solve an approximate solution for i and v_{OUT} for the case when $v_{\text{IN}} = 2\text{V}$. How close is the small-signal result compared to the iterative method, and compared to the constant voltage drop method?

(C) Repeat the iterative and small-signal solutions for the case when $v_{\text{IN}} = 0.5\text{V}$. How do they compare in this case?

Problem 5. A 0.7V regulator circuit is shown below. You may assume that $R = 1\text{k}\Omega$ and the diode has a 0.7V forward drop at 1mA.



(A) Suppose v_{IN} has a sinusoidal "ripple" such that its maximum and minimum values are

$$v_{\text{IN}}(\text{max}) = 3.5\text{V}$$
$$v_{\text{IN}}(\text{min}) = 3.0\text{V}$$

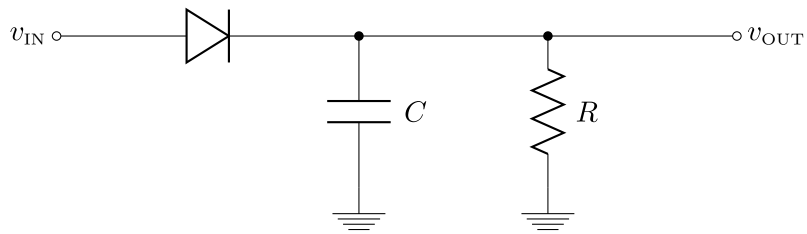
Using the small-signal procedure, estimate the maximum and minimum values that will appear at v_{OUT}. Calculate your answer with mV precision.

(B) Calculate the **line regulation**, defined as the ratio

$$LR = \frac{v_{\text{OUT}}(\text{max}) - v_{\text{OUT}}(\text{min})}{v_{\text{IN}}(\text{max}) - v_{\text{IN}}(\text{min})}$$

Give your result in mV/ V.

Problem 6. The peak rectifier circuit shown below is used to convert a 1kHz AC signal into a DC signal. The input signal has a zero-to-peak amplitude of 15V. The input signal also has a frequency $f = 1\text{kHz}$ and period $T = 1\text{ms}$. The resistor and capacitor values are $C = 10\mu\text{F}$ and $R = 10\text{k}\Omega$, respectively. The diode has a 0.7V forward drop when its forward current is 1mA.

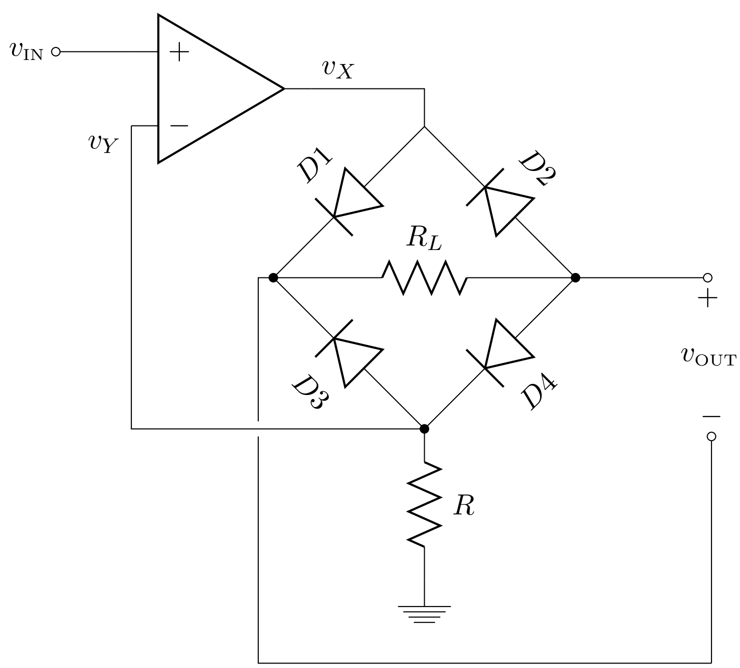


(A) Assuming that v_{OUT} charges all the way up to +15V during the positive cycle of v_{IN}, calculate the **ripple amplitude** V_r that happens during the period when the diode is OFF. Note that, since $RC \gg T$, if the diode switches OFF at some time t_0 then we may approximate v_{OUT} as

$$v_{\text{OUT}} \approx 15\text{V} - \frac{t - t_0}{RC}$$

(B) Calculate the ripple amplitude when f is increased to 10kHz.

Problem 7. The half-wave precision rectifier circuit suffers from three problems: First, when the diode is off, the feedback loop becomes an open-circuit and the op amp is driven to a rail voltage. Second, when the diode turns on again, the op amp must slew back from the rail, which delays its response. Third, only half of the waveform is rectified. The circuit shown below rectifies (ehem) these problems. Study the circuit and answer the following questions.



(A) First, let $v_{\text{IN}} = 0\,\text{V}$ and suppose has a (very large) open-loop gain A but is otherwise ideal. Using the ideal switch model, predict the voltages that will appear at v_X, v_Y and v_{OUT}.

(B) Now let $v_{\text{IN}} = 100\,\text{mV}$. Using the ideal switch model for the diodes, predict which diodes will be on and which will be off, and **report the state (ON/OFF) for each diode**. Is the op amp's negative feedback loop closed? Predict the value at v_Y, v_X and v_{OUT}.

(C) Now let $v_{\text{IN}} = -100\,\text{mV}$. Again using the ideal switch model, predict which diodes will be on and which will be off, and report the state for each diode. Is the op amp's negative feedback loop closed? Predict the value at v_Y, v_X and v_{OUT}.

(D) If you use the diode's full exponential model instead of the ideal switch model, how will your results change for the last two sub-problems? You may state your answer symbolically, in terms of the diodes' unknown forward voltage drop, v_D.