HOMEWORK SET 10

Issues: November 8, 2004 Due: November 15, 2004

Problem 1.

(a)

Use graphical method to derive the v_o vs. v_i transfer characteristic of the following "voltage-limiter circuit".

Hint: Draw the i_a vs. v_a driving-point characteristic by series-parallel graphical method, and then eliminate the common currents i_a and i_3 of the driving-point characteristic of the zener-diode resistor parallel combination via the grpahical elimination method.

(b)

Sketch the output waveform $v_o(t)$ when the circuit is driven by a 10-volt sinusoidal voltage, i.e., $v_i = 10 \sin t$.

Hint: Use the transfer characteristic from (a).

(c)

Repeat (b) for a 20-volt sinusoidal voltage. Why is this circuit called a voltage lomiter ?

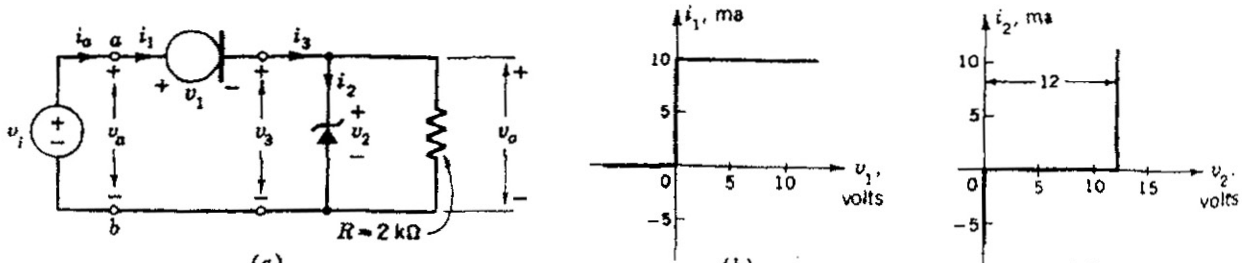


Figure 1

Problem 2.

(*a*) Assuming the nonlinear ideal op-amp model with $E_{sat} = 15$ V, derive and sketch the driving-point characteristic for the one-port shown in Fig. 2.

(*b*) Connect a linear resistor R_1 across the one-port, and find the maximum value of the resistance for which the one-port functions as an independent current source.

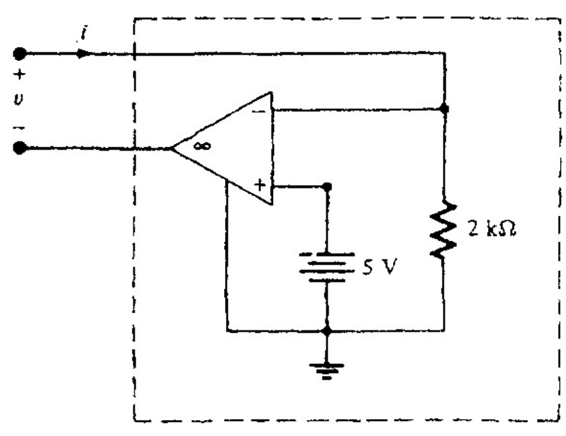


Figure 2

Problem 3.

Using the nonlinear ideal op-amp model, derive and sketch the driving-point characteristic for the circuit shown in Fig. 3 .

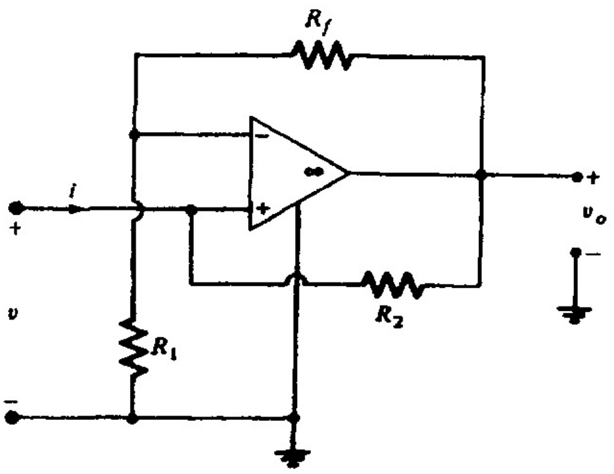


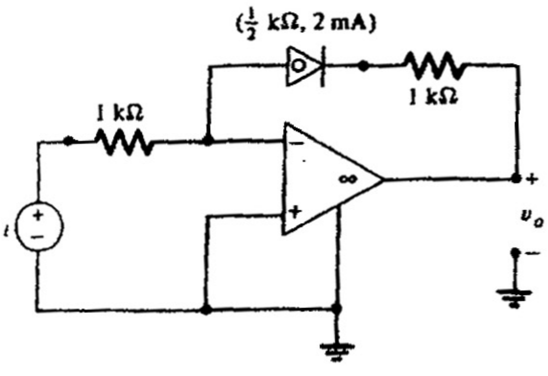
Figure 3

Problem 4.

Repeat Prob. 3 for the v_o vs. v transfer characteristic.

Problem 5.

Assuming the op amp is operating in the linear region, find sketch the v_o vs. v_i transfer characteristic for the circuit shown in Fig. 4



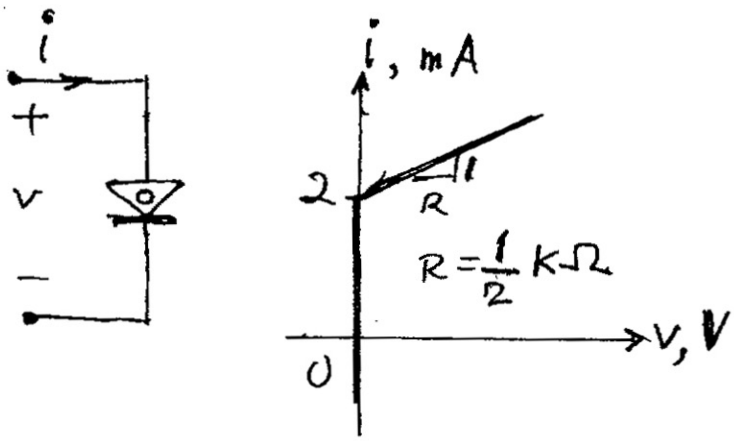


Figure 4

Problem 6.

This ptoblem reviews the ubiquitous phenomenon of synchronization and frequency division presented in the lectures but with numeric rather than symbolic parameters, as specified in the next page.

(a) Assuming $v_S(t) = 0$ and $v_C(0) = 0$, sketch the natural oscilation waveforms of $v_C(t)$ and $i(t)$ for $t \geq 0$. Specify all relevant parameters, including the natural period of oscillation T and the peak value, as well as the two cimplementary time intervals T_1 and T_2 corresponding to each regime of "relaxation" oscilation. What is the natural frequency f of the oscillator , i.e., when there is no forcing trigger signal $v_S(t)$?

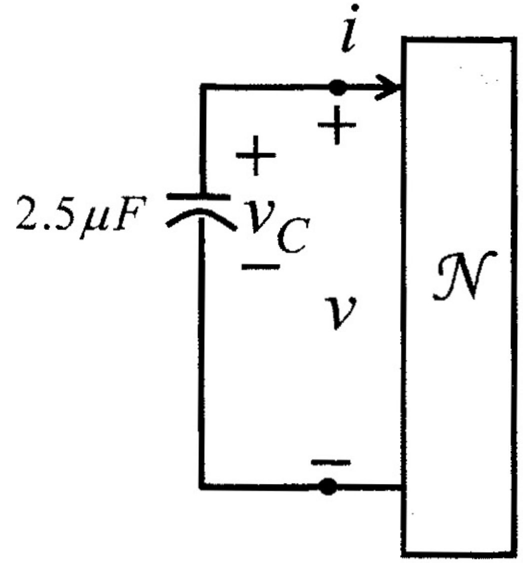
(b) Assuming a periodic trigger signal of period T_S and frequency $f_S = 1/T_S$ is applied at $t = T_1'$ with $v_C(0) = 0$, calculate the minimum value of T_1' necessary to initiate a premature jump in the current waveform i(t). The value T_1' is said to be minimum if an infinitesimally smaller value would not give rise to a jump in i(t).

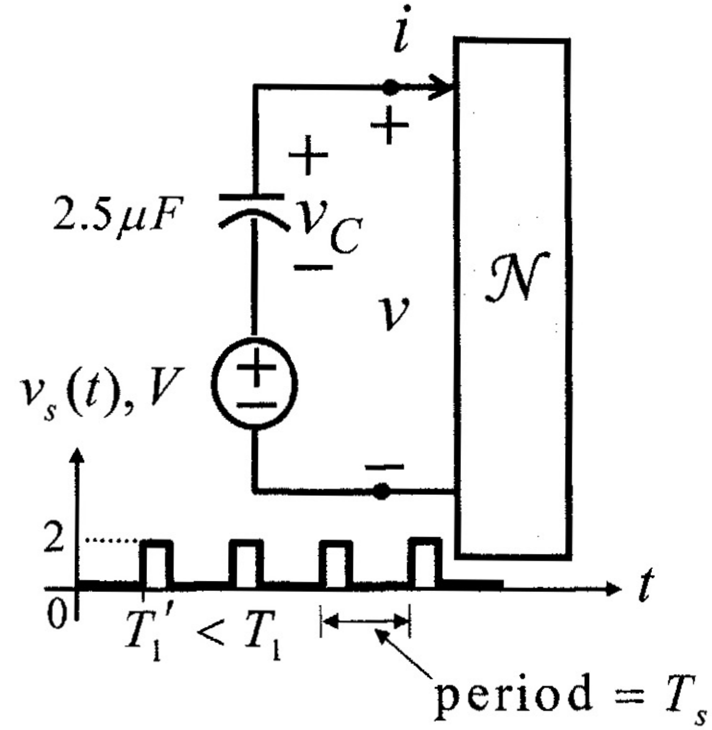
(c) For the minimal T_1' calculated from (b), calculate the corresponding "discharge" time T_2' and the new oscillation period $T' = T_1' + T_2'$ and new oscillation frequency $f' = 1/T'$.

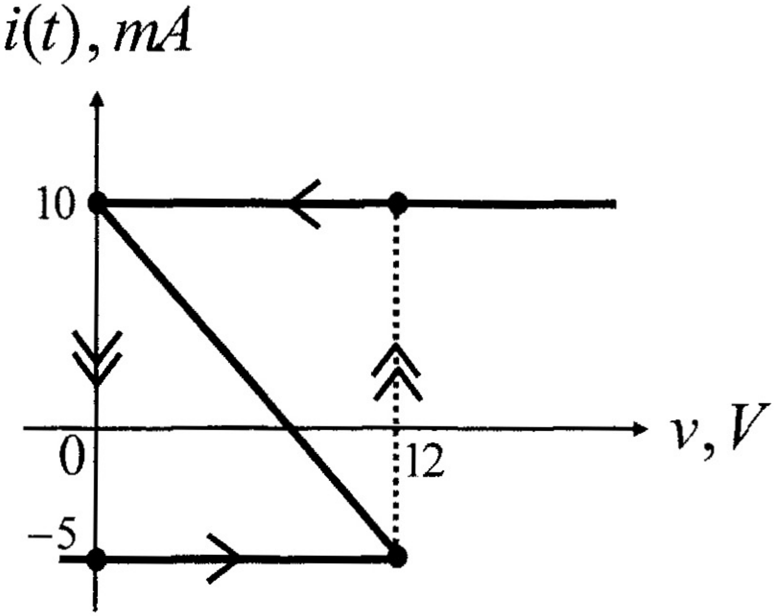
(d) It is possible to force the oscillator frequency f' to synchronize with the periodic pulse triggering signal $v_S(t)$ from (b) but with frequency $f_S = 2f'$. Sketch the waveform of $v_S(t)$ and $v_C(t)$ and align their time axis for comparison purposes. Explain why the oscilator in this case jumps only after every 2 pulses, thereby achieving a frequency division of the input trigger signal by a factor of 2 .

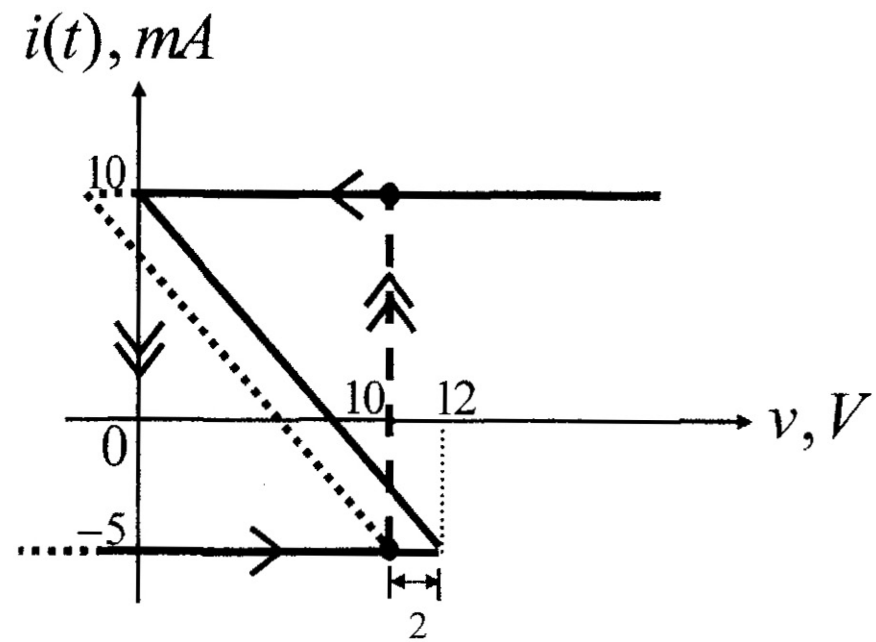
(e) Repeat (d) for $f_S = 3f'$ and explain why the oscillator in this case jumps only after every 3 pulses, thereby achieving frequency division by a factor of 3..

Note: The circuit when driven by a trigger periodic signal is called a frequency divider because the output (oscillator) no longer oscilate at its natural frequency $f = 1/T$, but at $f' = (1/3)f_S$.


i
+
+
2.5μF
v_C
−
v
𝒩
−


i
+
+
2.5μF
v_C
−
v
𝒩
$v_s(t), V$
−
2
0
t
$T_1' < T_1$
period = T_s


i(t), mA
10
0
−5
12
v, V


i(t), mA
10
0
−5
10
12
2
v, V