Name ____________________

Date ____________________

Instructor ____________________

EXPERIMENT

6

Clamping Circuits

OBJECTIVE

To calculate, draw, and measure the output voltage of clampers.

EQUIPMENT REQUIRED

Instruments

Oscilloscope
DMM

Components

Resistors

(1) 100-Ω
(1) 1-kΩ
(1) 100-kΩ

Diode

(1) Silicon

Capacitor

(1) 1-μF

Supplies

(1) 1.5-V D cell and holder
Function generator

EQUIPMENT ISSUED

Item	*Laboratory serial no.*
Oscilloscope	
DMM	
Function generator	

RÉSUMÉ OF THEORY

Clampers are designed to "clamp" an alternating input signal to a specific level without altering the peak-to-peak characteristics of the waveform. Clampers are easily distinguished from clippers in that they include a capacitive element. A typical clamper will include a capacitor, diode, and resistor with some also having a DC battery. The best approach to the analysis of clampers is to use a step-by-step approach. The first step should be an examination of the network for that part of the input signal that forward biases the diode. Choosing this part of the input signal will save time and probably avoid some unnecessary confusion. With the diode forward biased the voltage across the capacitor and across the output terminals can be determined. For the rest of the analysis it is then assumed that the capacitor will hold on to the charge and voltage level established during this interval of the input signal. The next part of the input signal can then be analyzed to determine the effect of the stored voltage across the capacitor and the open-circuit state of the diode.

The analysis of a clamper can be quickly checked by simply noting whether the peak-to-peak voltage of the output signal is the same as the peak-to-peak voltage of the applied signal. This check is not sufficient to be sure the entire analysis was correct but it is a characteristic of clampers that must be satisfied.

PROCEDURE

Part 1. Threshold Voltage

Determine the threshold voltage for the silicon diode using the diode-checking capability of the DMM or a curve tracer. If either approach is unavailable assume $V_T = 0.7$ V.

$V_T =$ ________

Part 2. Clampers (R, C, Diode Combination)

a. Construct the network of Fig. 6.1 and record the measured value of R.

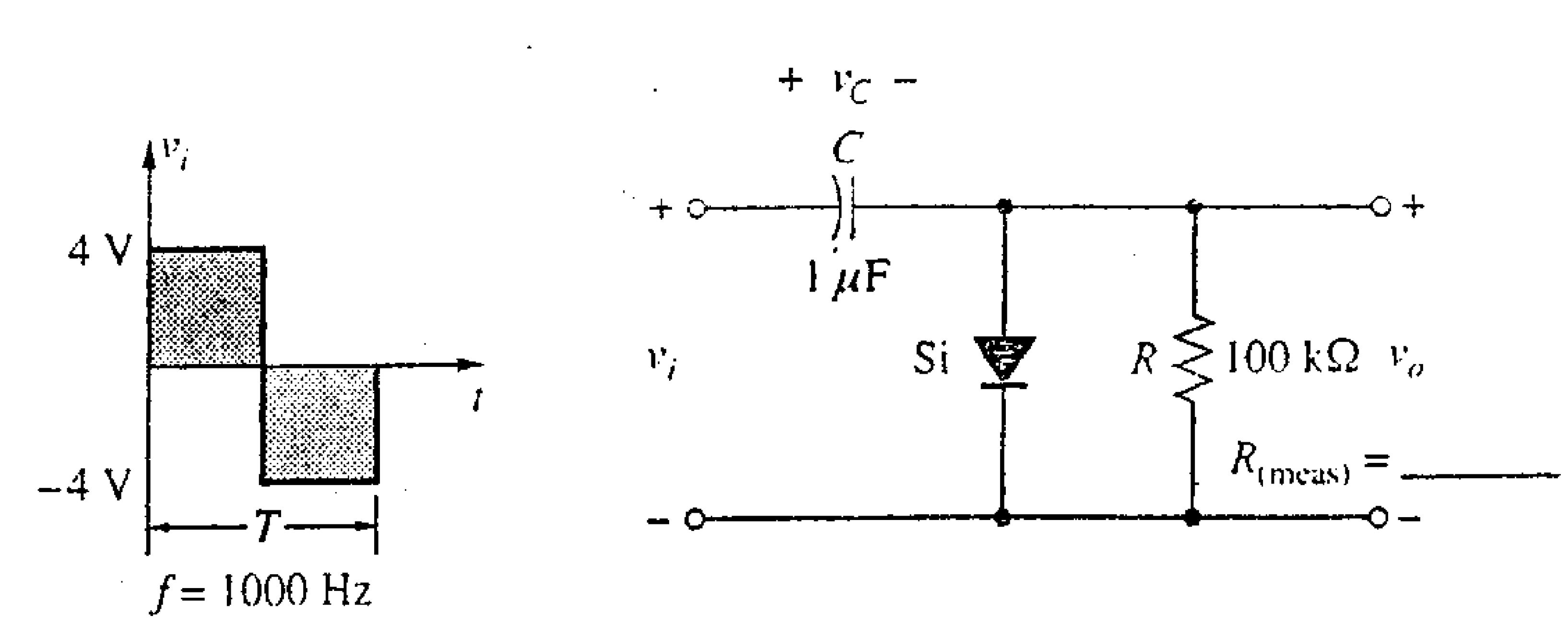

Figure 6-1

b. Using the value of V_T from Part 1 calculate V_C and V_o for the interval of v_i that causes the diode to be in the "on" state.

V_C (calculated) = ____________

V_o (calculated) = ____________.

c. Using the results of Part 2(**b**) calculate the level of V_o after v_i switches to the other level and turns the diode "off."

V_o (calculated) = ____________

d. Using the results of Parts 2(**b**) and 2(**c**) sketch the expected waveform for V_o in Fig. 6.2 for one full cycle of V_i. Use the horizontal center axis as the V_o = 0 V line. Record the chosen vertical and horizontal sensitivities below:

Sketch of V_o from calculated results:

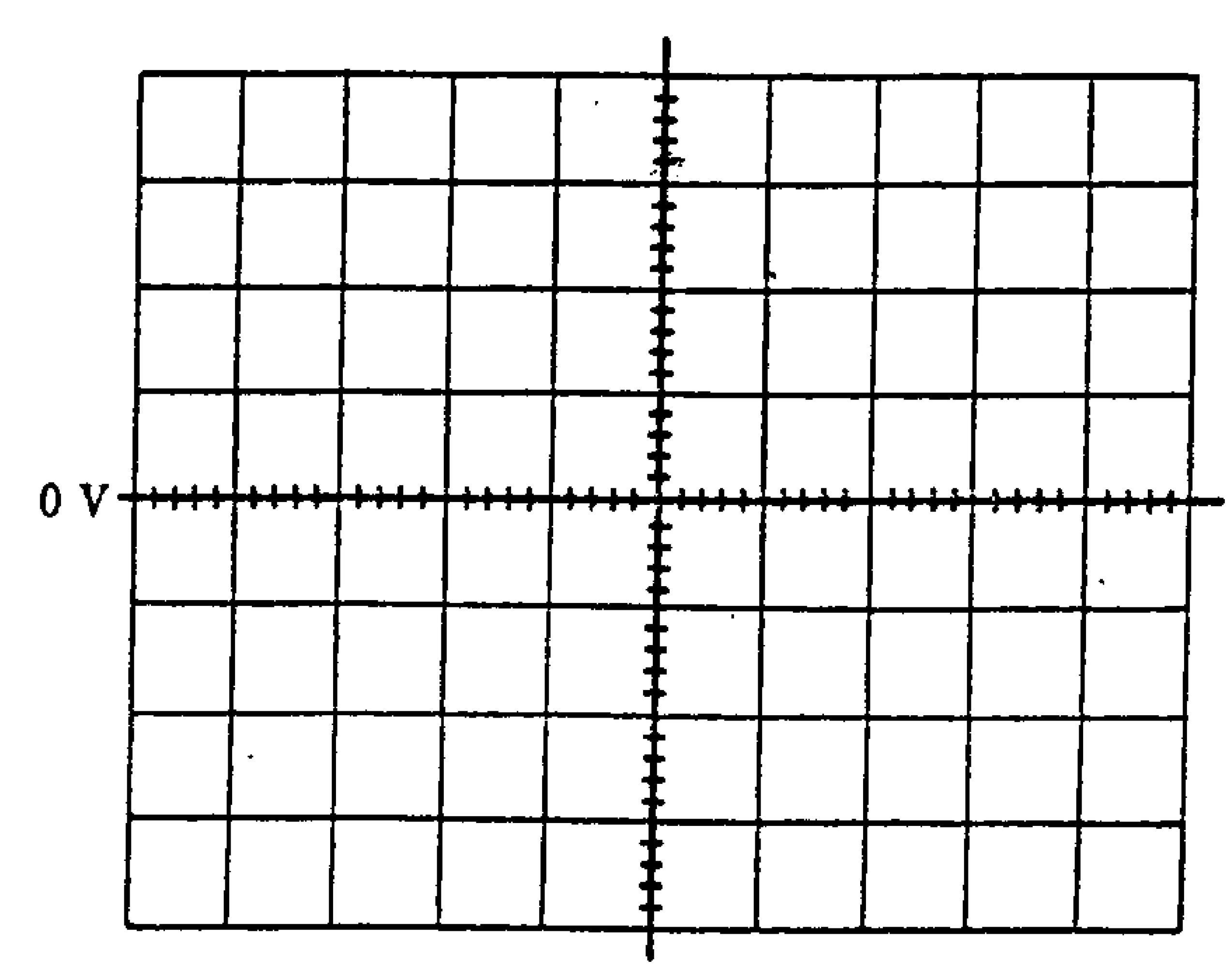

Figure 6-2

Vertical sensitivity = ____________

Horizontal sensitivity = ____________

e. Using the sensitivities of Part 2(b) use the oscilloscope to view the output waveform v_o. Be sure to preset the V_o = 0 V line on the screen using the GND position of the coupling switch (and the DC position to view the waveform). Record the resulting waveform on Fig. 6.3.

How does the waveform of Fig. 6.3 compare with the expected waveform of Fig. 6.2?

Sketch of V_o from measured results:

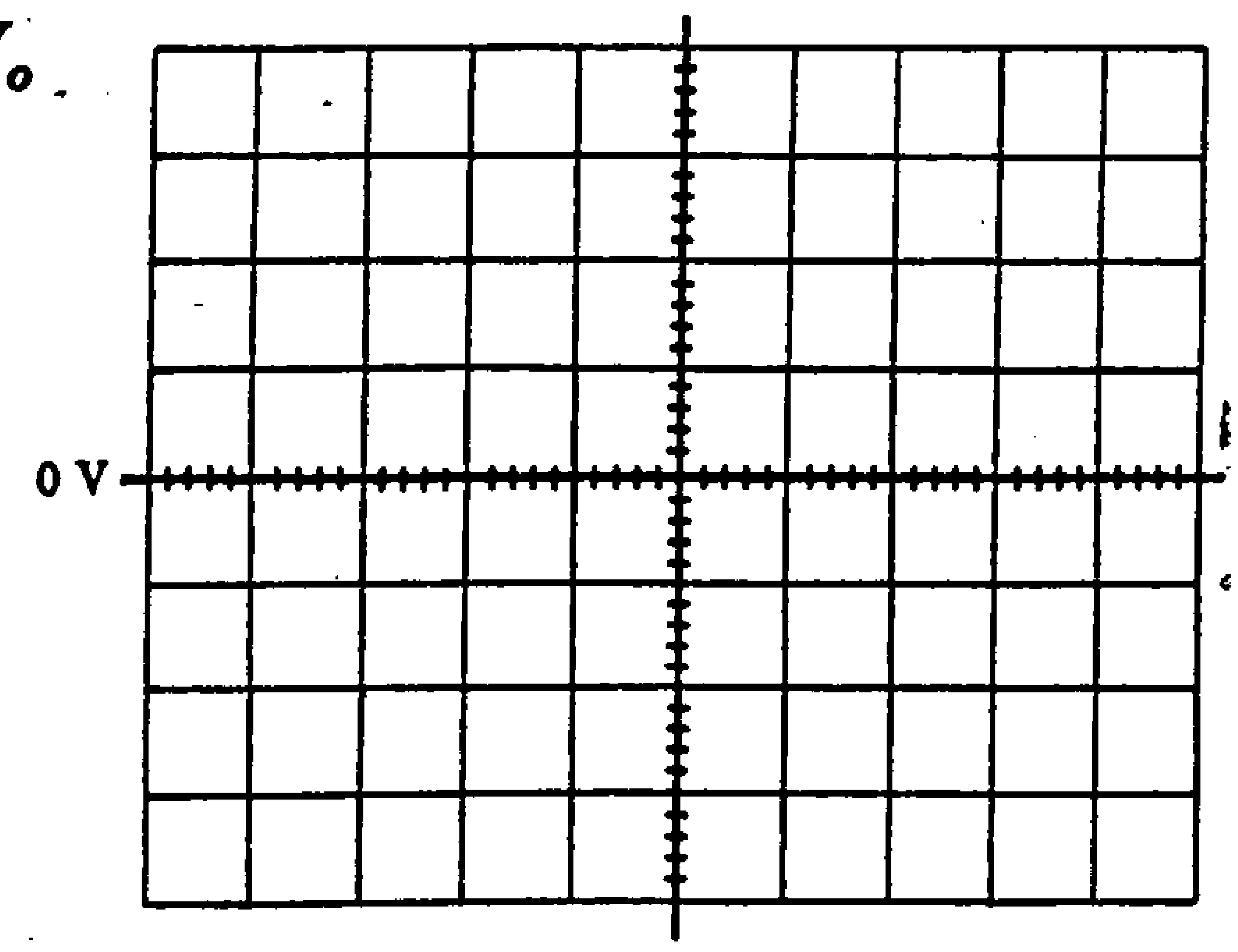

Figure 6-3

f. Reverse the diode of Fig. 6.1 and using the value of V_T from Part 1 determine the levels of V_C and V_o for the interval of v_i that causes the diode to be in the "on" state.

V_C (calculated) = __________

V_o (calculated) = __________

g. Using the results of Part 2(f) calculate the level of V_o after v_i switches to the other level and turns the diode "off."

V_o (calculated) = __________

h. Using the results of Parts 2(f) and 2(g) sketch the expected waveform for v_o on Fig. 6.4. Use the horizontal axis as the v_o = 0 V line. Record the chosen vertical and horizontal sensitivities below:

Sketch of V_o from calculated response:

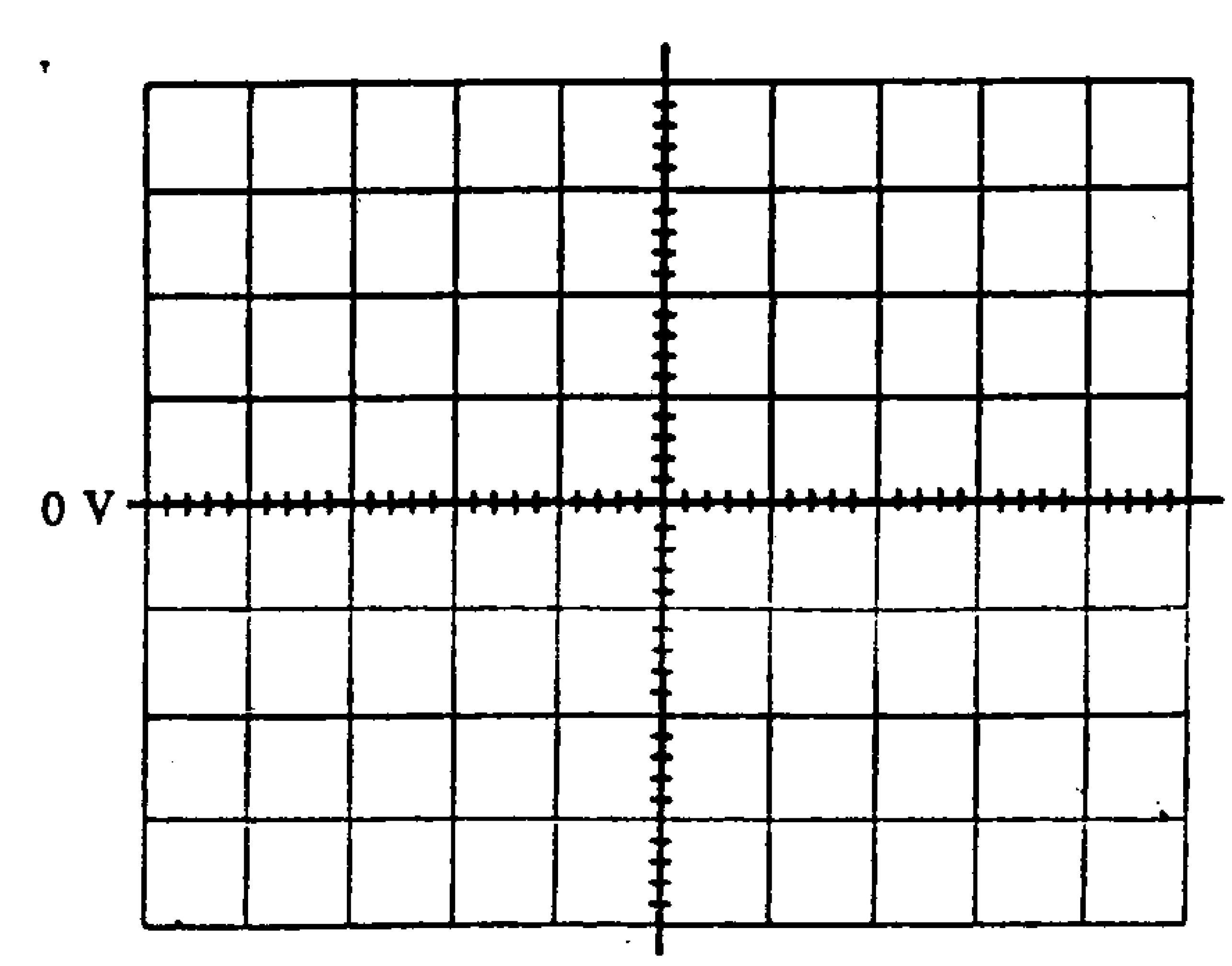

Figure 6-4

Vertical sensitivity = __________

Horizontal sensitivity = __________

i. Using the sensitivities of Part 2(h) use the oscilloscope to view the output waveform v_o. Be sure to preset the V_o = 0 V line on the screen using the GND position of the coupling switch (and the DC position to view the waveform). Record the resulting waveform on Fig. 6.5.

Sketch of V_o from measured results:

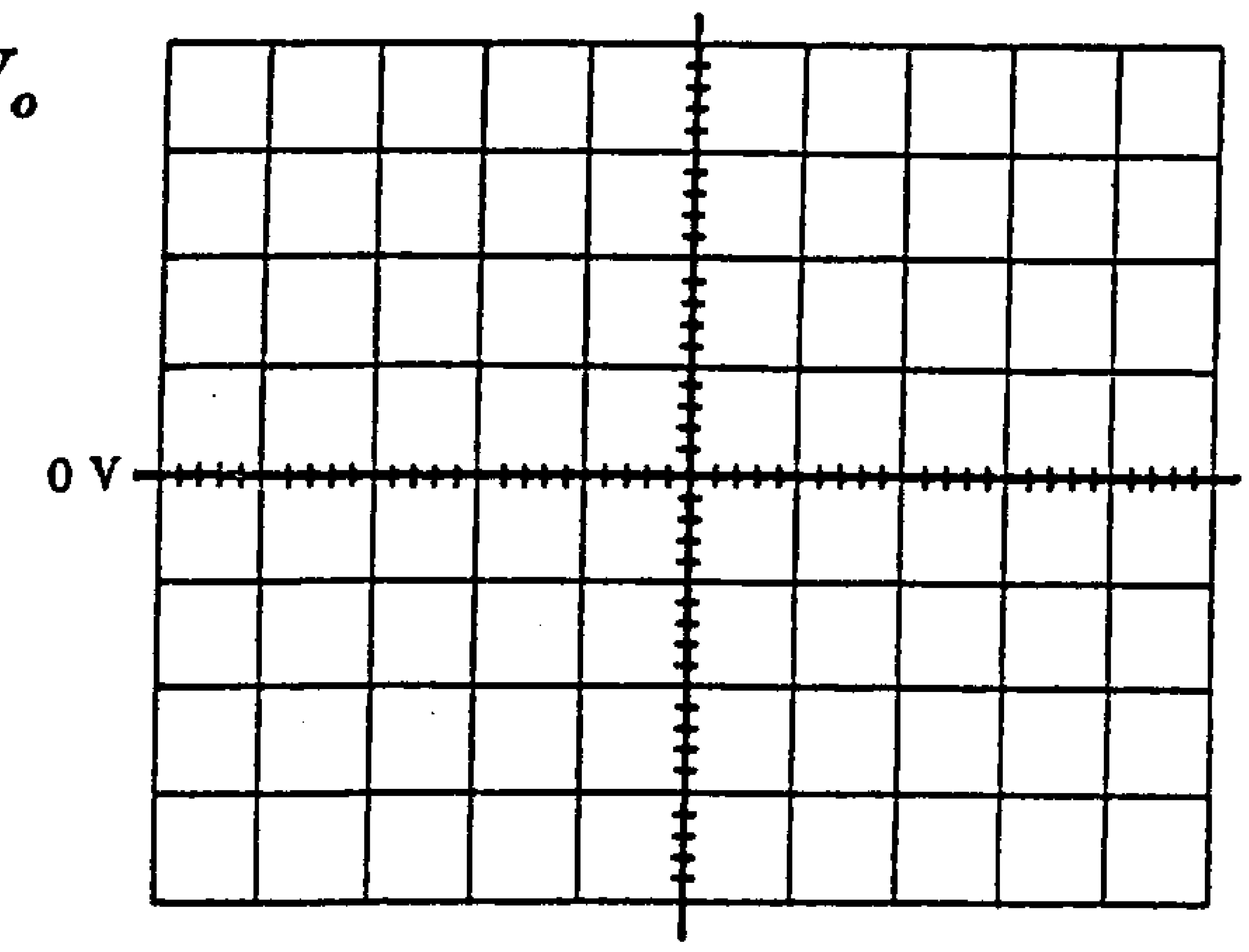

Figure 6-5

How does the waveform of Fig. 6.5 compare with the expected waveform of Fig. 6.4?

Part 3. Clampers with a DC Battery

a. Construct the network of Fig. 6.6 and record the measured values of R and E.

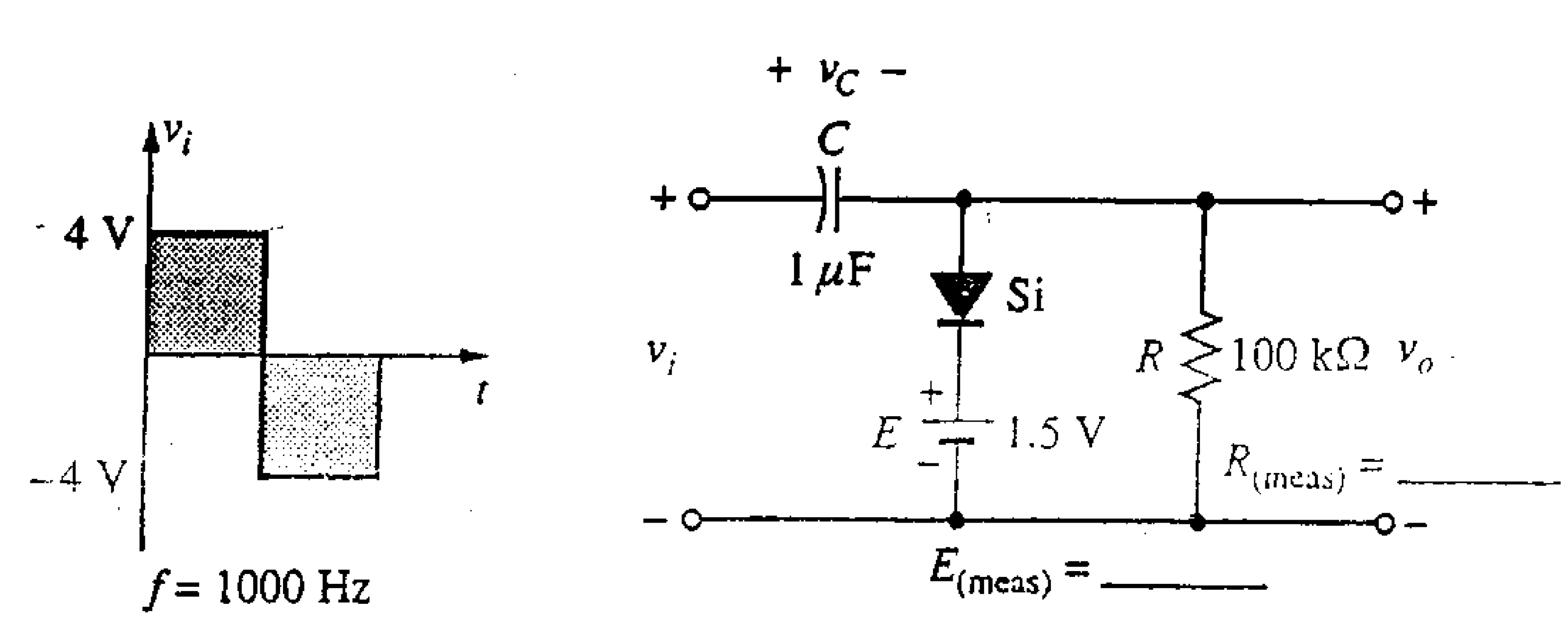

Figure 6-6

b. Using the value of V_T from Part 1 calculate V_C and v_o for that interval of v_i that causes the diode to be in the "on" state.

V_C (calculated) = __________

V_o (calculated) = __________

c. Using the results of Part 3(**b**) calculate the level of v_o after v_i switches to the other level and turns the diode "off."

V_o (calculated) = __________

d. Using the results of Parts 3(**b**) and 3(**c**) sketch the expected waveform for v_o on Fig. 6.7. Use the horizontal center axis as the V_o = 0 V line. Record the chosen vertical and horizontal sensitivities below:

Sketch of V_o from calculated results:

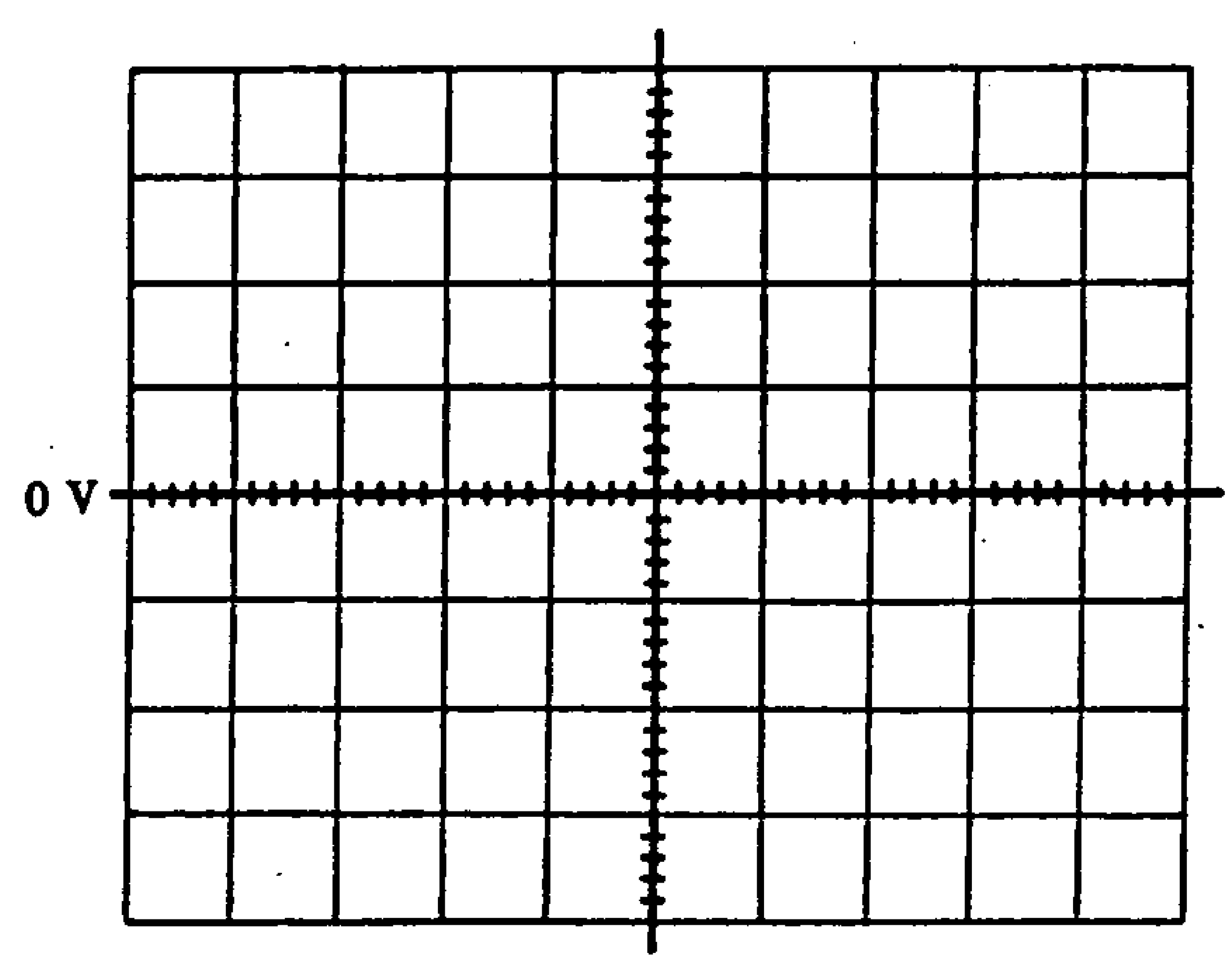

Figure 6-7

Vertical sensitivity = __________

Horizontal sensitivity = __________

e. Using the sensitivities of Part 3(**d**) use the oscilloscope to view the output waveform v_o. Be sure to preset the V_o = 0 V line on the screen using the GND position of the coupling switch (and the DC position to view the waveform). Record the resulting waveform on Fig. 6.8.

How does the waveform of Fig. 6.8 compare with the expected waveform of Fig. 6.7?

Sketch of V_o from measured results:

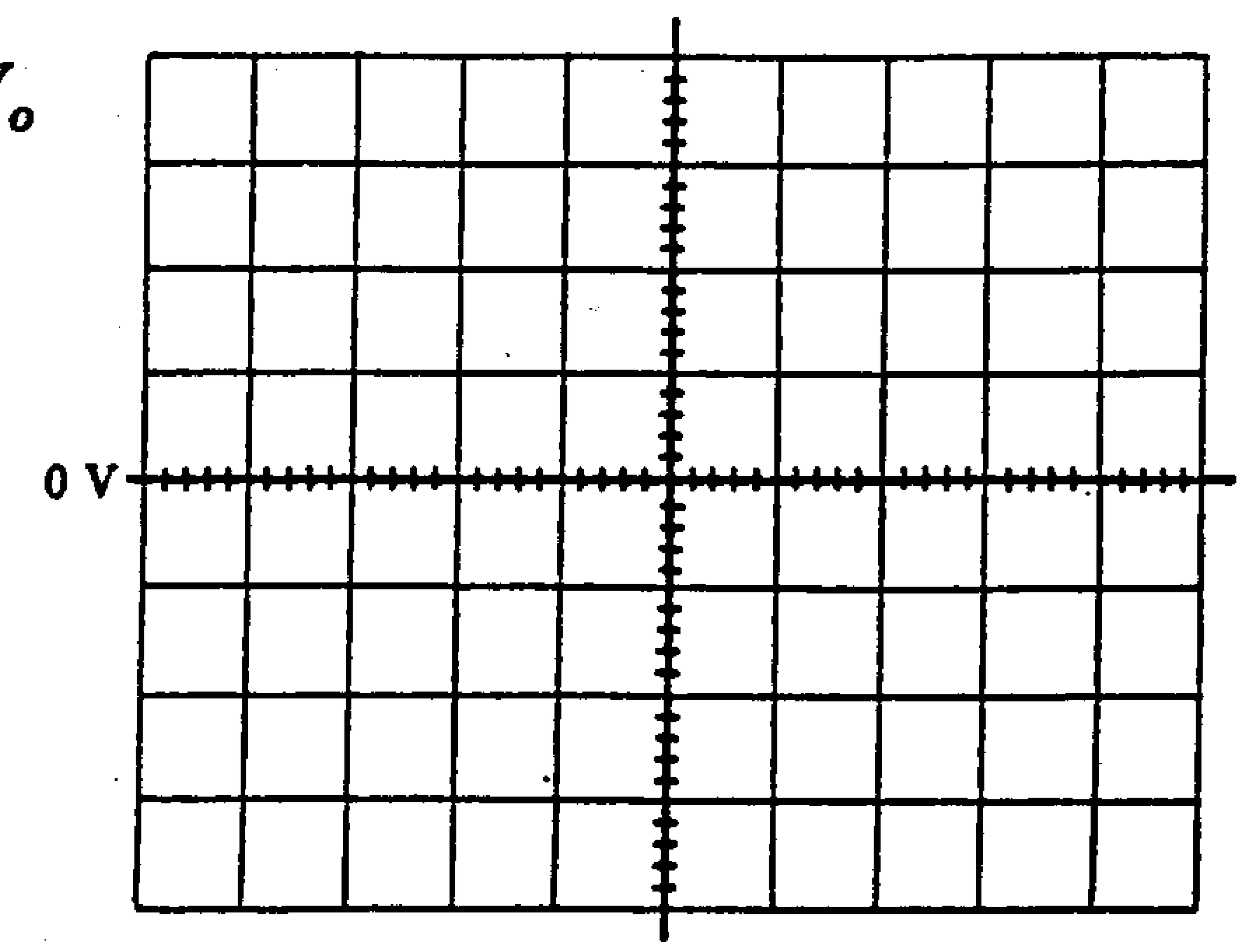

Figure 6-8

f. Reverse the diode of Fig. 6.6 and using the value of V_T from Part 1 calculate the levels of V_C and V_o for that interval of the input voltage v_i that causes the diode to be in the "on" state.

V_C (calculated) = ________

V_o (calculated) = ________

g. Using the results of Part 3(**f**) calculate the level of V_o after v_i switches to the other level and turns the diode "off."

V_o (calculated) = ________

h. Using the results of Parts 3(**f**) and 3(**g**) sketch the expected waveform for v_o on Fig. 6.9. Use the horizontal center axis as the V_o = 0 V line. Record the chosen vertical and horizontal sensitivities below:

Sketch of V_o from calculated results:

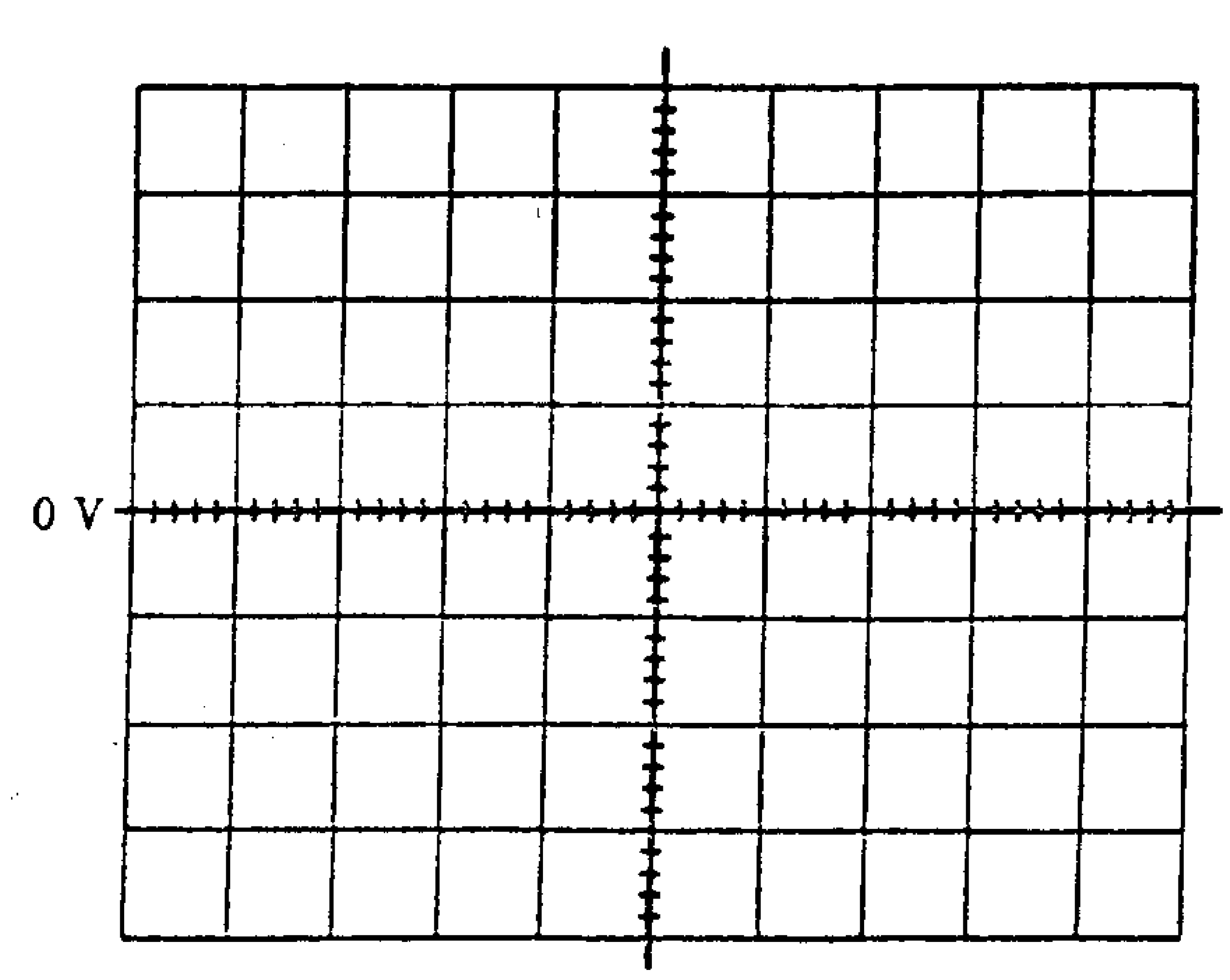

Figure 6-9

Vertical sensitivity = __________
Horizontal sensitivity = __________

i. Using the sensitivities of Part 3(**h**) use the oscilloscope to view the output waveform v_o. Be sure to preset the V_o = 0 V line on the screen using the GND position of the coupling switch (and the DC position to view the waveform). Record the resulting waveform on Fig. 6.10.

Sketch of V_o from measured results:

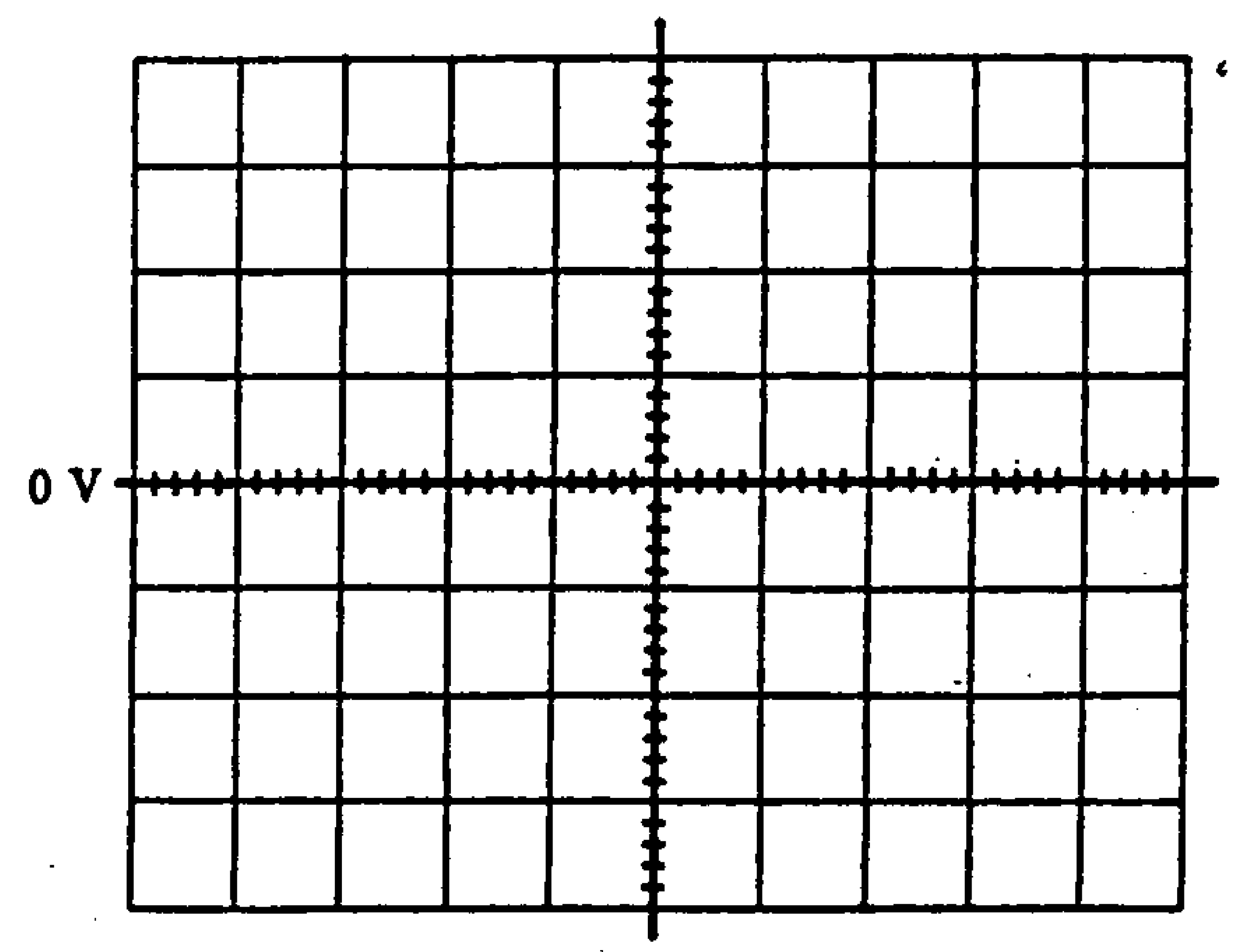

Figure 6-10

How does the waveform of Fig. 6.10 compare with the expected waveform of Fig. 6.9?

Part 4. Clampers (Sinusoidal Input)

a. Reconstruct the network of Fig. 6.1 but change the input signal to an 8 $V_{p\text{-}p}$ sinusoidal signal with the same frequency (1000 Hz).

b. Using the results of Parts 1 and 2 and any other analysis technique at your disposal, sketch the expected output waveform for v_o on Fig. 6.11. In particular find v_o when v_i is its positive and negative peak value and when v_i = 0 V. Record the chosen vertical and horizontal sensitivities below:

Sketch of V_o from calculated results:

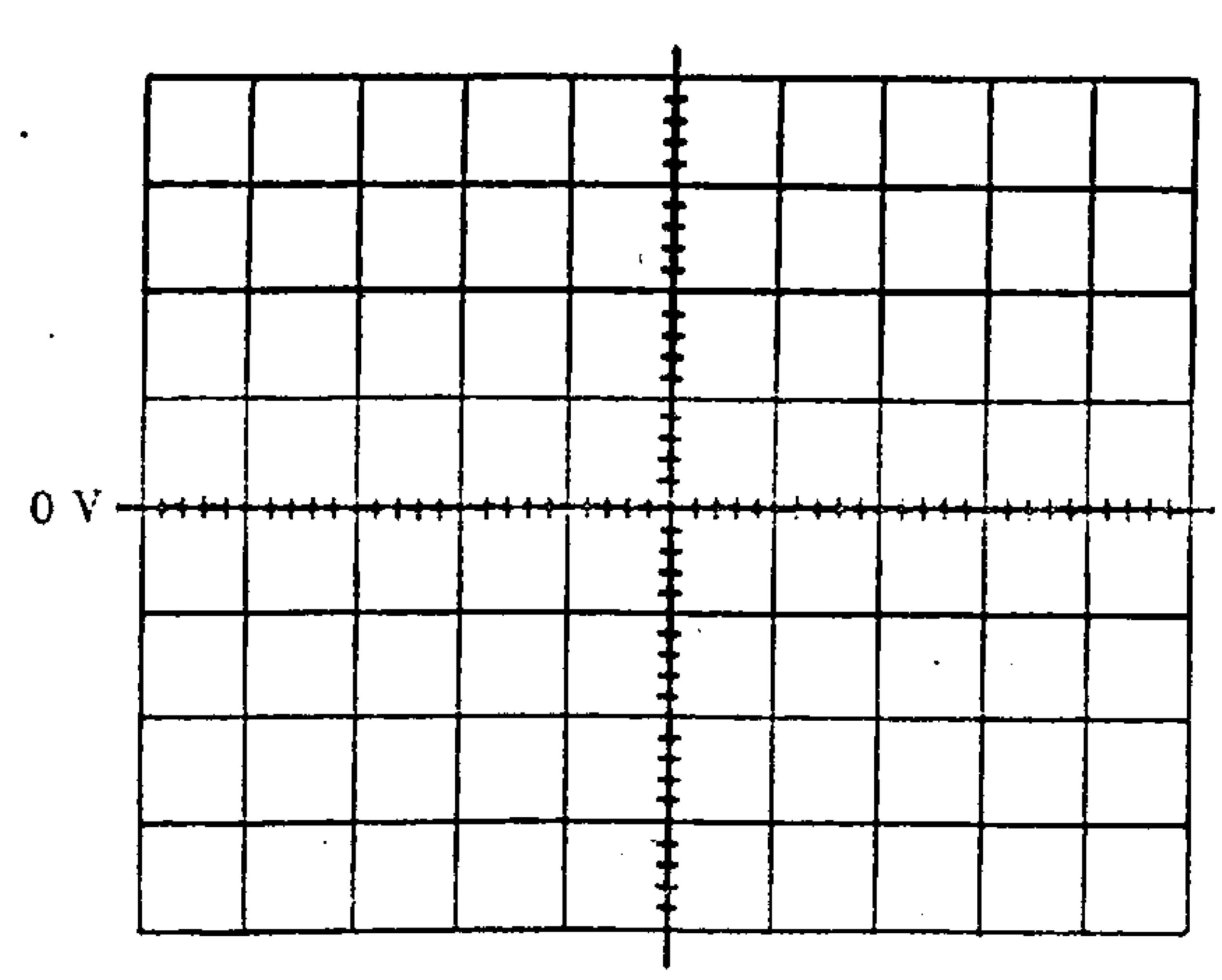

Figure 6-11

V_o (calculated) when $V_i = +4$ V is ________
V_o (calculated) when $V_i = -4$ V is ________
V_o (calculated) when $V_i = 0$ V is ________
Vertical sensitivity = ________
Horizontal sensitivity = ________

c. Using the sensitivities of Part 4(b) use the oscilloscope to view the output waveform v_o. Be sure to preset the $V_o = 0$ V line on the screen using the GND position of the coupling switch (and the DC position to view the waveform). Record the resulting waveform on Fig. 6.12.

Sketch of V_o from measured results:

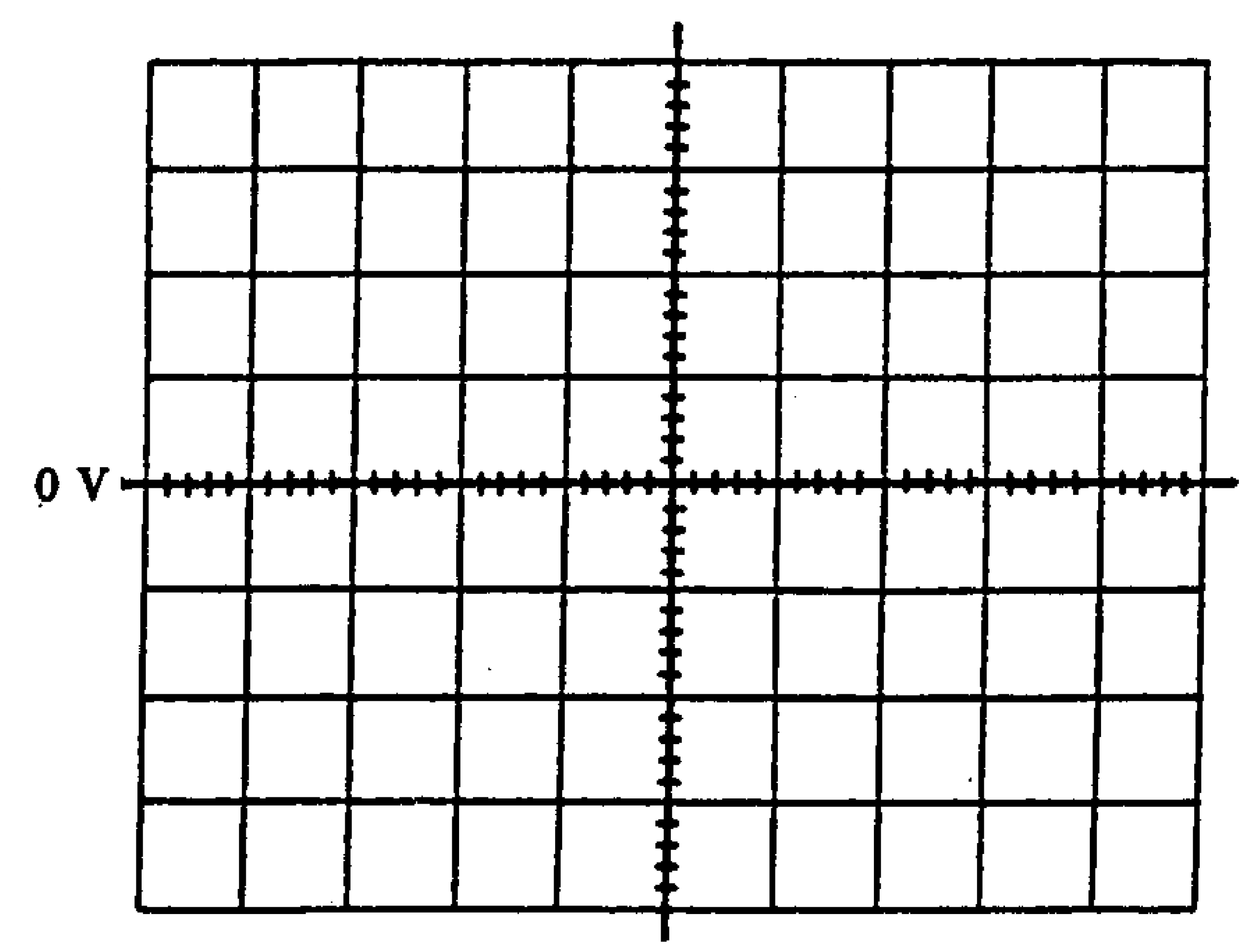

Figure 6-12

How does the waveform of Fig. 6.12 compare with the expected waveform of Fig. 6.11?

Part 5. Clampers (Effect of *R*)

a. Determine the time constant ($\tau = RC$) for the network of Fig. 6.1 for that interval of the input signal that causes the diode to assume the "off" state and be approximated by an open circuit.

τ (calculated) = ________

b. Calculate the period of the applied signal. Determine half the period to correspond with the time interval that the diode is in the "off" state during the first cycle of the applied signal.

T (calculated) = ________
$T/2$ (calculated) = ________

c. The discharge period of an *RC* network is about 5τ. Calculate the time interval established by 5τ using the result of Part 5(**a**) and compare to *T*/2 calculated in Part 5(**b**).

5τ (calculated) = ________

d. For good clamping action, why is it important for the time interval specified by 5τ to be much larger than *T*/2 of the applied signal?

e. Change *R* to 1 kΩ and calculate the new value of 5τ.

5τ (calculated) = ________

f. How does the 5τ calculated in Part 5(**e**) compare to *T*/2 of the applied signal? How would you expect the new value of R to affect the output waveform v_o?

g. Set the input of Fig. 6.1 with R = 1 kΩ and record the resulting waveform on Fig. 6.13. Be sure to preset the V_o = 0 V line in the center of the screen using the GND position of the coupling switch and be sure to use the DC position to view the waveform. Insert the chosen vertical and horizontal sensitivities below:

c. The discharge period of an *RC* network is about 5τ. Calculate the time interval established by 5τ using the result of Part 5(**a**) and compare to *T*/2 calculated in Part 5(**b**).

5τ (calculated) = __________

d. For good clamping action, why is it important for the time interval specified by 5τ to be much larger than *T*/2 of the applied signal?

e. Change *R* to 1 kΩ and calculate the new value of 5τ.

5τ (calculated) = __________

f. How does the 5τ calculated in Part 5(**e**) compare to *T*/2 of the applied signal? How would you expect the new value of R to affect the output waveform v_o?

g. Set the input of Fig. 6.1 with *R* = 1 kΩ and record the resulting waveform on Fig. 6.13. Be sure to preset the V_o = 0 V line in the center of the screen using the GND position of the coupling switch and be sure to use the DC position to view the waveform. Insert the chosen vertical and horizontal sensitivities below:

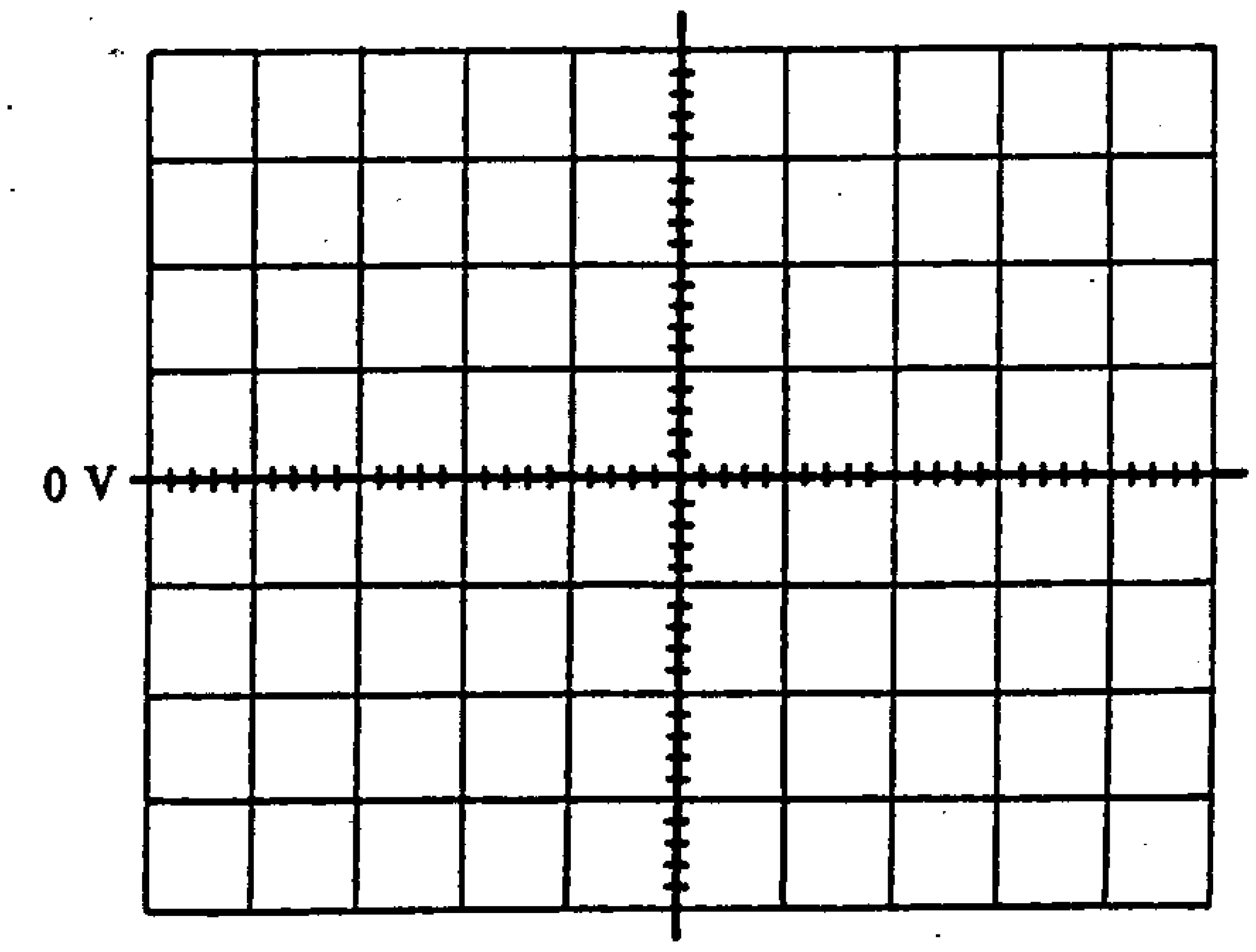

Figure 6-13

Vertical sensitivity = __________
Horizontal sensitivity = __________

h. Comment on the resulting waveform of Fig. 6.13. Is the distortion as you expected? Are you surprised by the positive and negative peaks? Why?

i. Change R to 100 Ω and calculate the new value of 5τ.

5τ (calculated) = __________

j. How does the 5τ calculated in Part 5(**i**) compare to $T/2$ for the applied signal? What effect will the lower value of R have on the waveform of Fig. 6.13?

k. Set the input of Fig. 6.1 with R = 100 Ω and record the resulting waveform on Fig. 6.14. Be sure to preset the V_o = 0 V line using the coupling switch and use the DC position to view the waveform v_o. Insert the chosen vertical and horizontal sensitivities below:

Vertical sensitivity = __________
Horizontal sensitivity = __________

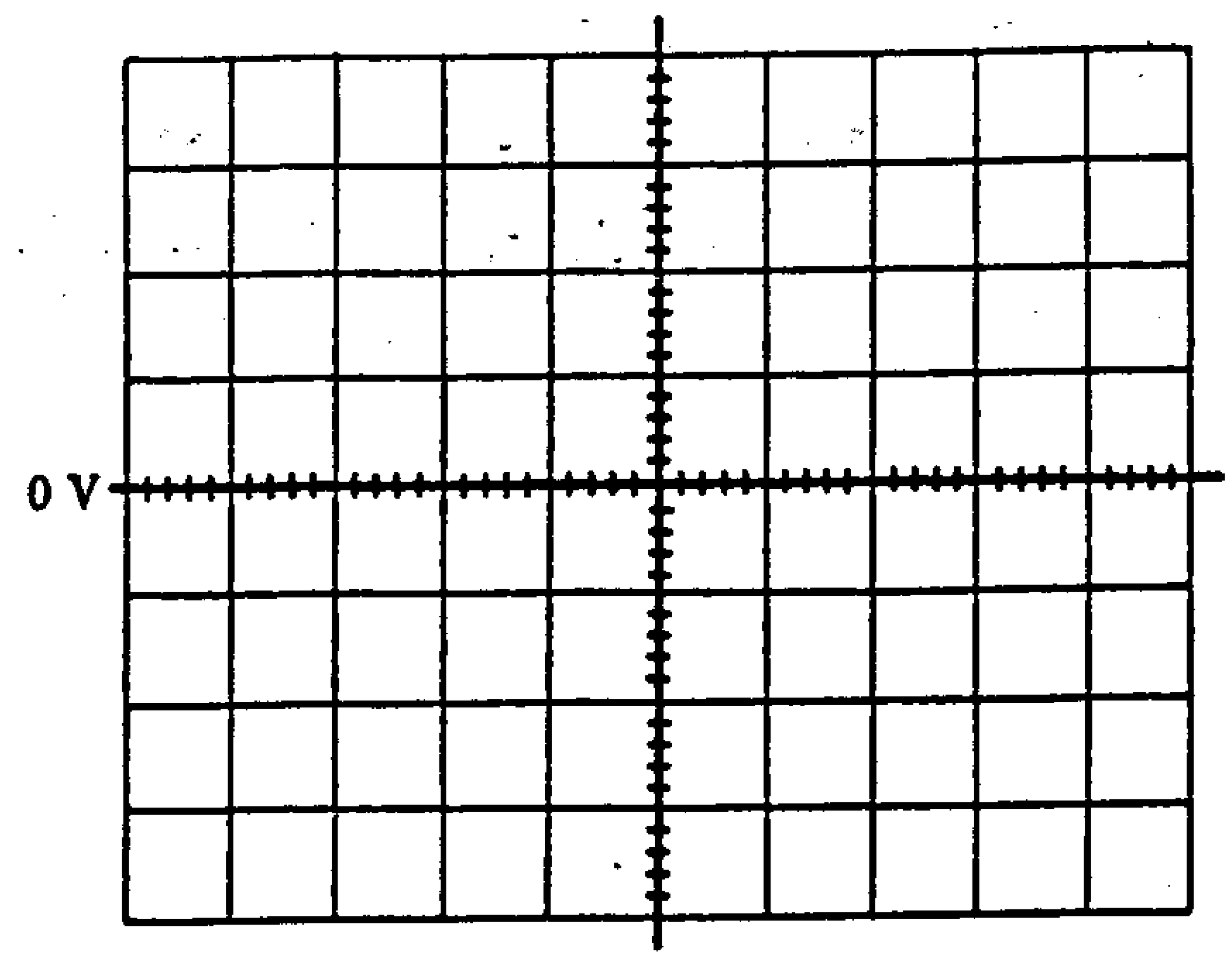

Figure 6-14

l. Comment on the resulting waveform of Fig. 6.14. Compare it to the waveform of Fig. 6.13 and the properly clamped waveform of Fig. 6.3.

m. Based on the results of Parts 5(**a**) through 5(**l**) establish a relationship between 5τ and the period of the waveform (*T*) that will ensure that the output waveform has the same characteristics as the input. Note that the requested relationship is between 5τ and *T* and not *T*/2.

Part 6. Computer Exercise

a. Construct the network of Fig. 6.1 using PSpice Windows. Obtain the voltages V_C and V_o. Compare them to the results of Part 2.

b. Repeat the analysis of Part 5(**a**) but with $R = 1\ \text{k}\Omega$. Comment on the resulting shape of the v_o curve.

c. Repeat the analysis of Part 5(**a**) but with $R = 100\ \Omega$. Comment on the resulting shape of the v_o curve.