EEAP 243
Lab 8

Lab Work:
Questions Due:

NON-LINEAR OP-AMP CIRCUITS

READING ASSIGNMENT: Horowitz, pgs. 124-127., read section 9.07, p. 390-393 also.

Abstract:
This laboratory will examine the principles and operation of non-linear op-amp circuits. The Schmitt trigger exhibits hysteresis and is often used to "square up" analog signals. The comparator is often used to monitor the presence or absence of analog signals. Effectively, these circuits convert analog signals into 0's or 1's. The performance of these circuits in the presence of simulated "noise" will be examined.

As a pre-lab exercise, you should determine the switching points and output voltages for the comparator and Schmitt trigger circuits and the voltage and resistor values needed to modify the Schmitt trigger. Remember to connect $+V_{cc}$ to +15 V and $-V_{cc}$ to -15 V.

Part 1 - The Comparator and Noise

When an op-amp is used without feedback, it is said to be "open-loop". Under these conditions the gain of the amplifier is $A(IN^+ - IN^-)$ where A is on the order of 100,000. For $(IN^+ - IN^-) > +150\ \mu V$, the theoretical output is higher than $+V_{cc}$ and the output will saturate at +15 V. For $(IN^+ - IN^-) < -150\ \mu V$, the theoretical output is lower than $-V_{cc}$ and the output will saturate at -15 V. The region of linear operation is very small and, for the most part, the amplifier's output will saturate at either +15 V or -15 V, depending on which of its inputs is greater. This type of circuit is known as a "comparator" because it compares the two input voltages to see which is greater and produces an output which is one of two states (+15 V or -15 V), depending on the result of the comparison. The circuits used in this part compare the input voltage at the inverting input to a "reference" voltage at the non-inverting input. Other configurations are possible; the reference may be on the inverting input and both the reference and input voltages may be any voltage between $+V_{cc}$ and $-V_{cc}$.

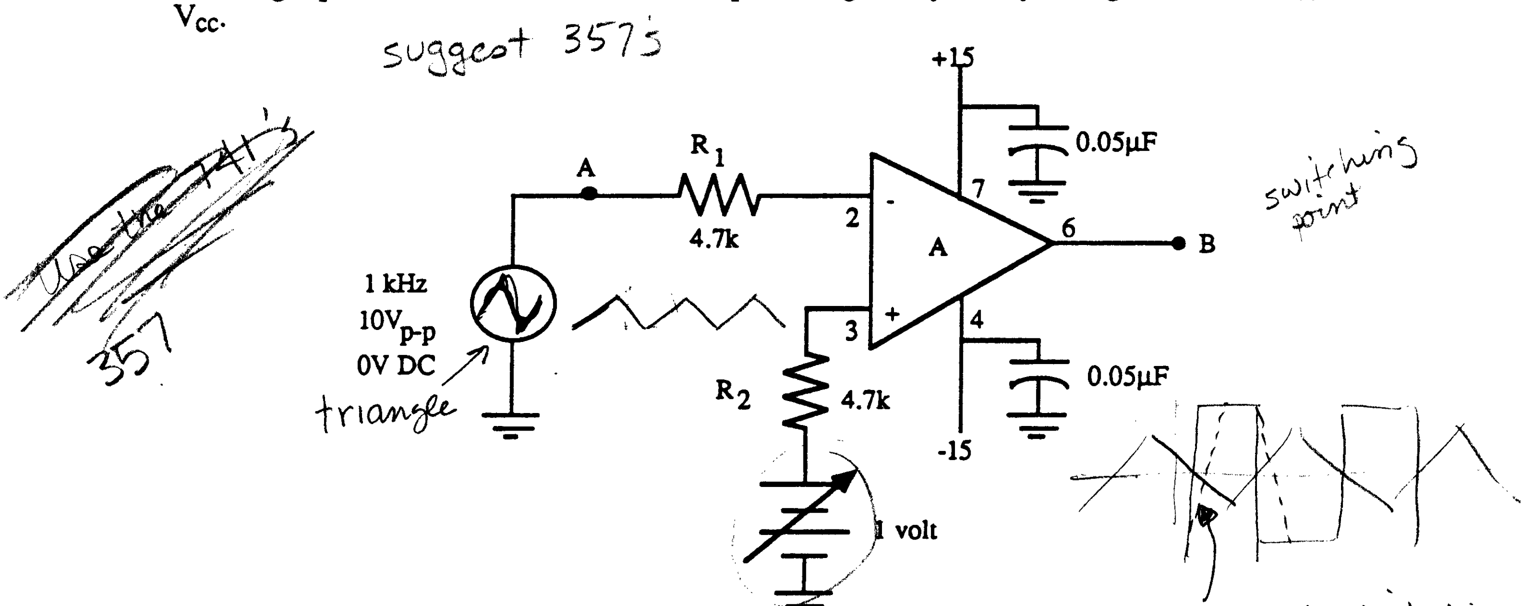


Figure 1 - Comparator circuit

slew rate distortion causes misrepresentation of where switching points

(1) Build the comparator circuit of Fig.1.
(2) Display points A and B simultaneously on the oscilloscope and record each waveform in Table 8.1.
(3) Carefully note the phase difference between A and B and note the two switching points.
(4) Set the DC offset to +3 V. To do this, set the scope channel connected to point A to 2 V/cm. A +3 V DC offset will make the triangle wave jump up 1.5 cm when the mode is switched from AC to DC.
(5) Record the waveforms in Table 8.2 and make note of the phase difference between A and B.
(6) Repeat step 5 for a DC offset of -3 V.

A "noisy" signal can be thought of as the sum of a desired signal and other, unwanted signals. The result is a signal which generally follows the desired one, but which deviates from it. If a noisy signal is fed into a comparator, the noise will cause unwanted changes of state at the output as the desired signal crosses zero volts.

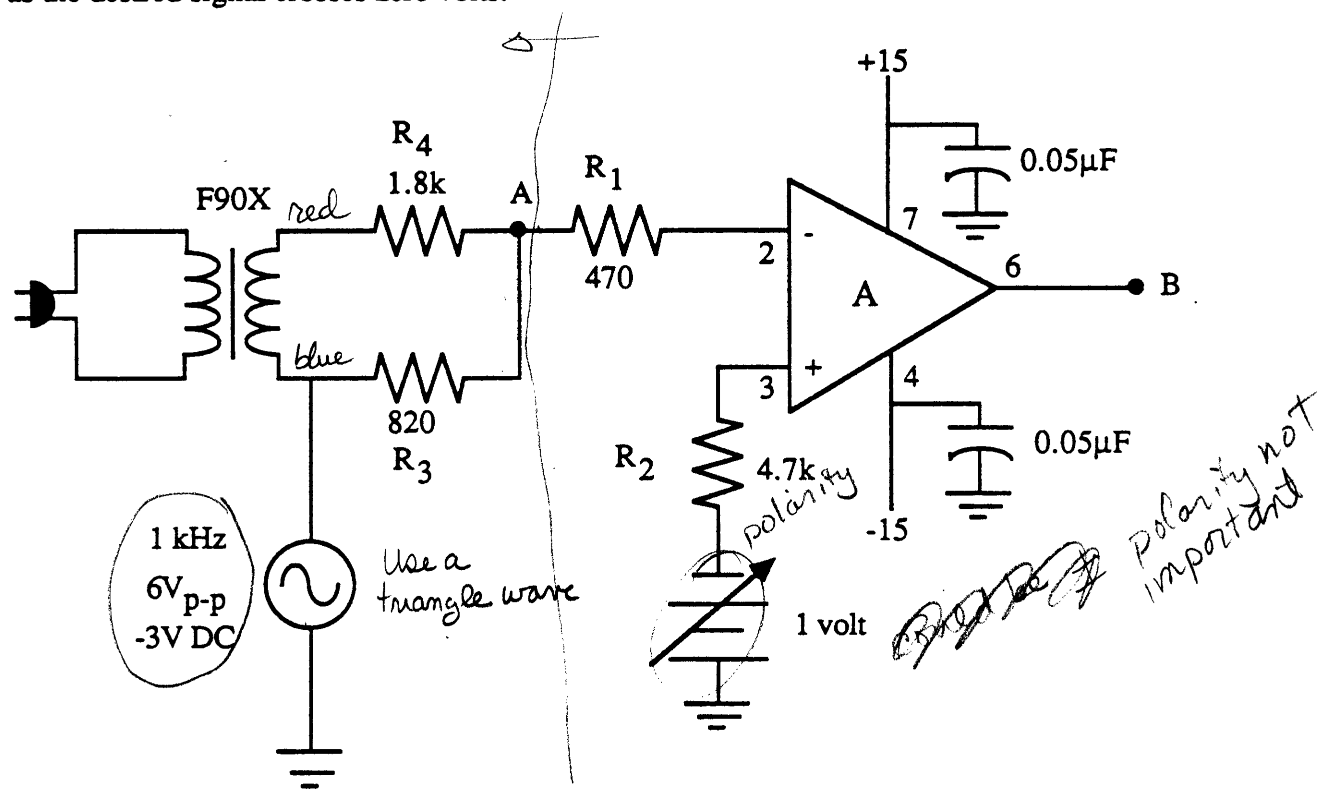


Figure 2 - Signal + "Noise" generator

(1) Disconnect the signal generator from your circuit and adjust its output to that shown in Fig.2.
(2) Build the circuit shown in Fig.2. Plug in the transformer. The transformer produces a sine wave at 60 Hz, which is added to the 1 KHz from the signal generator.
(3) If the composite signal at A is not around 14 V_{p-p} you have not connected the circuit properly.
(4) Display the waveforms at A and B and record them in Table 8.3 making special note of the phase difference between them. It will not be possible to get an absolutely stable trace on the oscilloscope.
(5) Make note of exactly what takes place when the waveform at B changes state.

Part 2 - The Schmitt Trigger and Noise

The amplifiers you built in Lab 6 and 7 used negative feedback - a resistor feeding the output signal back to the inverting input. By using positive feedback - a resistor feeding the output back to the non-inverting input - the two switching points can be moved further apart. Consider the circuit of Fig.3 and assume that the input is zero, that the output is +15 V, and that $R_2 = R_3$. R_2 and R_3 set the voltage at the non-inverting input to +7.5 V, ($IN^+ - IN^-$) > 0, and the output is indeed forced to +15 V. If we raise the input to +7.50015 V, then A($IN^+ - IN^-$) = -15 V and the output switches to -15 V. This changes the voltage at the non-inverting input to -7.5 V which makes ($IN^+ - IN^-$) very negative, maintaining the output at -15 V. The output will stay at -15 V until the input drops to -7.50015 V which will make A($IN^+ - IN^-$) = +15 V, setting the output to +15 V, setting the non-inverting input to +7.5 V. This makes ($IN^+ - IN^-$) very positive, maintaining the output at +15 V. We can summarize the operation of the circuit by saying that, when the input goes above the upper switching point, the output will go negative and stay negative until the input goes below the lower switching point. This characteristic is called "hysteresis" and this type of circuit is called a "Schmitt trigger".

PLEASE CALL A TEACHING ASSISTANT TO CHECK YOUR DATA BEFORE CONTINUING.

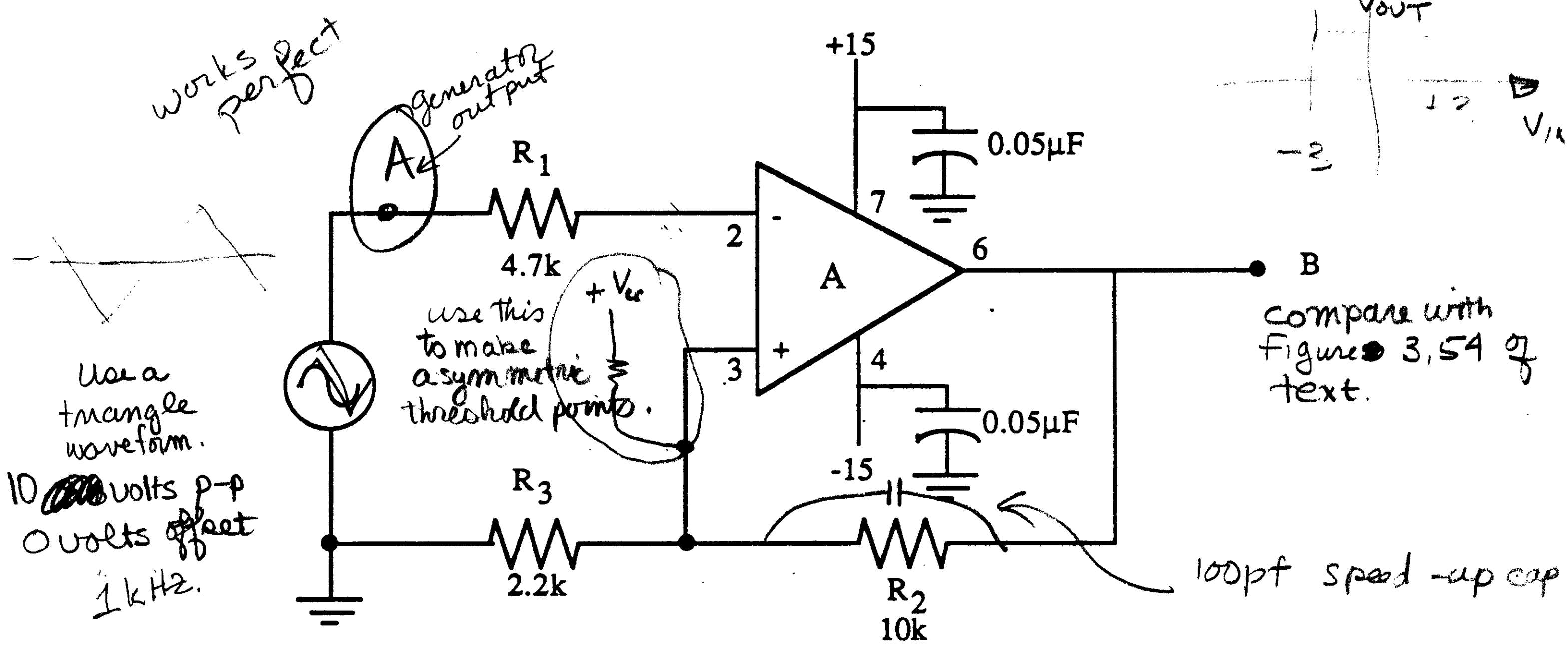
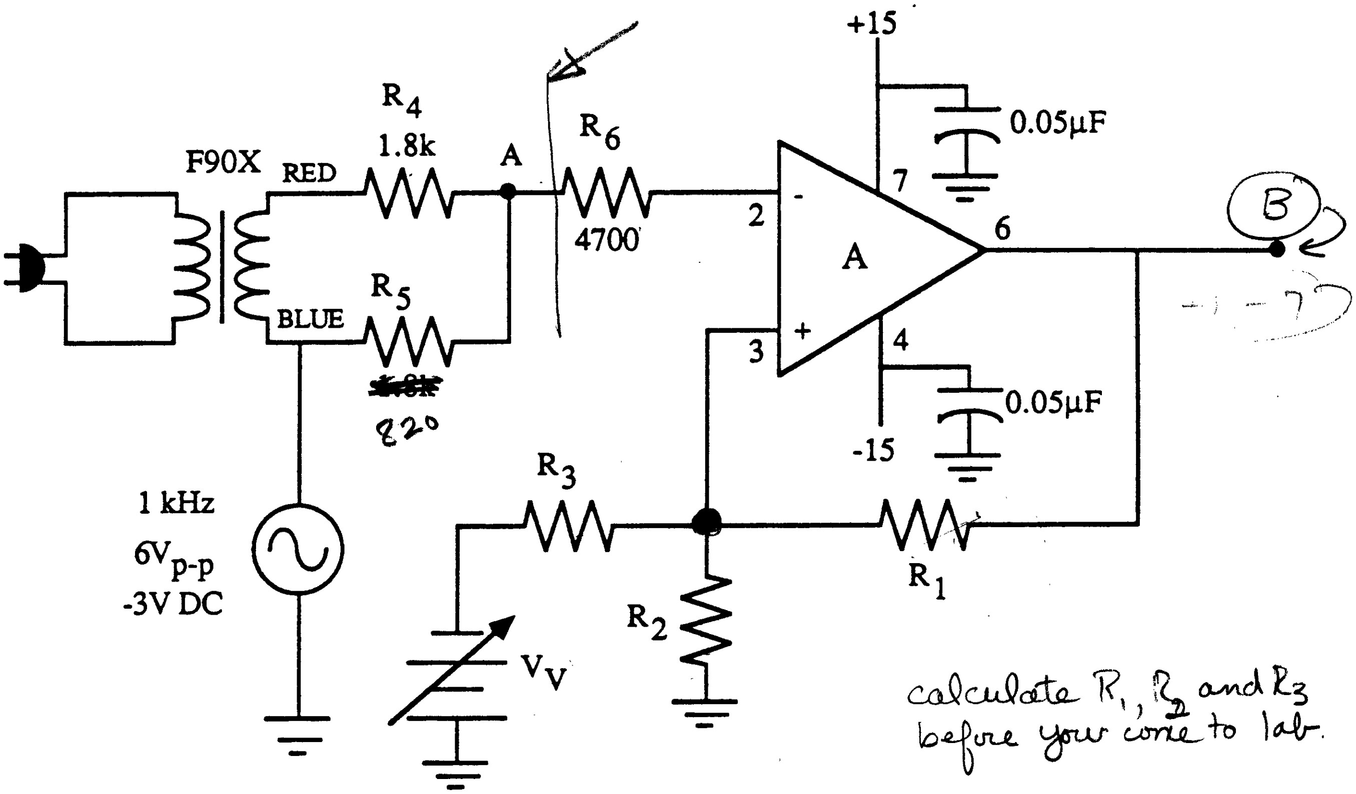


Figure 3 - Schmitt trigger

(1) Build the Schmitt trigger circuit of Fig. 3 with R_2 = 10K and R_3 = 2.2K.
(2) Display points A and B simultaneously on the oscilloscope and record each waveform in Table 8.4., i.e, use two traces
(3) Carefully note their phase difference and the two switching points.
(4) Slowly vary the DC offset between +3 V and -3 V and observe what happens at point B.



calculate R_1, R_2 and R_3 before you come to lab.

Figure 4

The Schmitt trigger can be used to eliminate signal noise.

(1) Disconnect the signal generator from your circuit and set it as shown in Fig. 4.

(2) Build the circuit shown in Fig. 4 and plug in the transformer. Select a variable supply voltage and standard values for R_1, R_2, and R_3 so that the switching points are +1 V and -7 V.

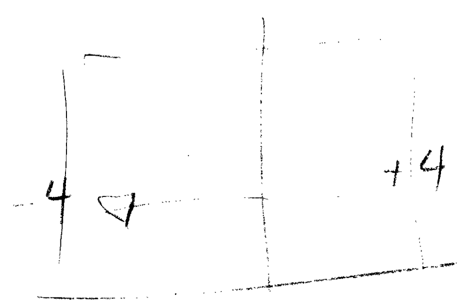
(3) If the composite signal at A is not around 14 $V_{p\text{-}p}$ you have not connected the circuit properly.

(4) Display the waveforms at A and B and record them in Table 8.5 making special note of their phase difference. It will not be possible to get an absolutely stable trace on the oscilloscope.

(5) Make note of exactly what takes place when the waveform at B changes state.

at point A

Use DC coupling for everything in lab



Questions:

1. (a) What are the two switching points for the circuit of Figure 2 ?
   (b) Describe what point B does as the triangle wave goes from its lowest to highest and back to its lowest voltage.
   (c) Explain why the relative phase acts as it does when you change the DC offset.

2. (a) Describe the input waveform at point A in Figure 2,
   (b) Describe why point B changes state several times before stabilizing.
   (c) Why does ~~this sort of comparator~~ the circuit of Figure 2 have problems with a "noisy" signal?

3. (a) Calculate the switching points for the circuit of Figure 3 without using your experimental data.
   (b) What switching points are indicated by the scope?
   (c) Why aren't they the same as your calculated values?
   (d) Explain why the signal at point B acts as it does when you change the DC offset.

4. (a) Show your calculations for R_1, R_2, R_3, and V in Figure 4.
   (b) How is the output different from that seen in [redacted] the circuit of Figure 3?
   (c) Why is a Schmitt trigger better at handling signals which contain undesirable noise?
   (d) Are both R_2 and R_3 really needed?

EEAP 243 LAB 8 EVALUATION

NAME (print)____________________________ CHECKPOINT #1 ___ DATE _____
GRADE _____/_____ CHECKPOINT #2 ___ DATE _____

With respect to the course material, this lab was: (pick one)
___ highly relevant ___ relevant ___ not relevant ___ completely irrelevant

This lab was: (pick one)
___ too long ___ long ___ just right ___ short ___ too short

This lab was: (pick one)
___ too hard ___ hard ___ just right ___ easy ___ too easy

The background material in the lab assignment was: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

The step by step procedures in the lab assignment were: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

Describe any mistakes made in the lab assignment.

Describe anything that just didn't work right.

Describe how this lab could be made better.

QUIZ

NOTE: THE TEACHING ASSISTANT IS TO SELECT BOTH QUESTIONS FROM THE UNDERLINED OPTIONS AT THE SECOND CHECKPOINT

Question #1

What will happen to the DC voltage at point D in Fig. 8.3 if we increase/decrease the resistance of $R_1/R_2/R_3/R_4/R_5$?

It will increase / decrease / stay the same.

Question #2

What will happen to the AC voltage at point D in Fig. 8.3 if we increase/decrease the resistance of $R_1/R_2/R_3/R_4/R_5$?

It will increase / decrease / stay the same.

EEAP 243

NAMES: ____

Lab 8 Data

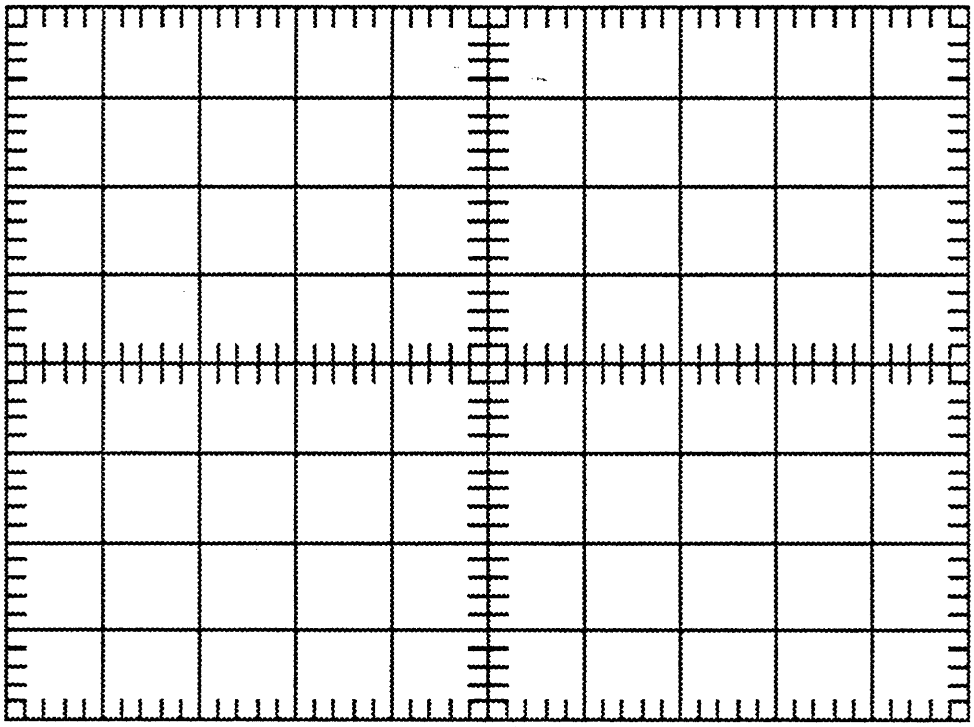


Table 8.1

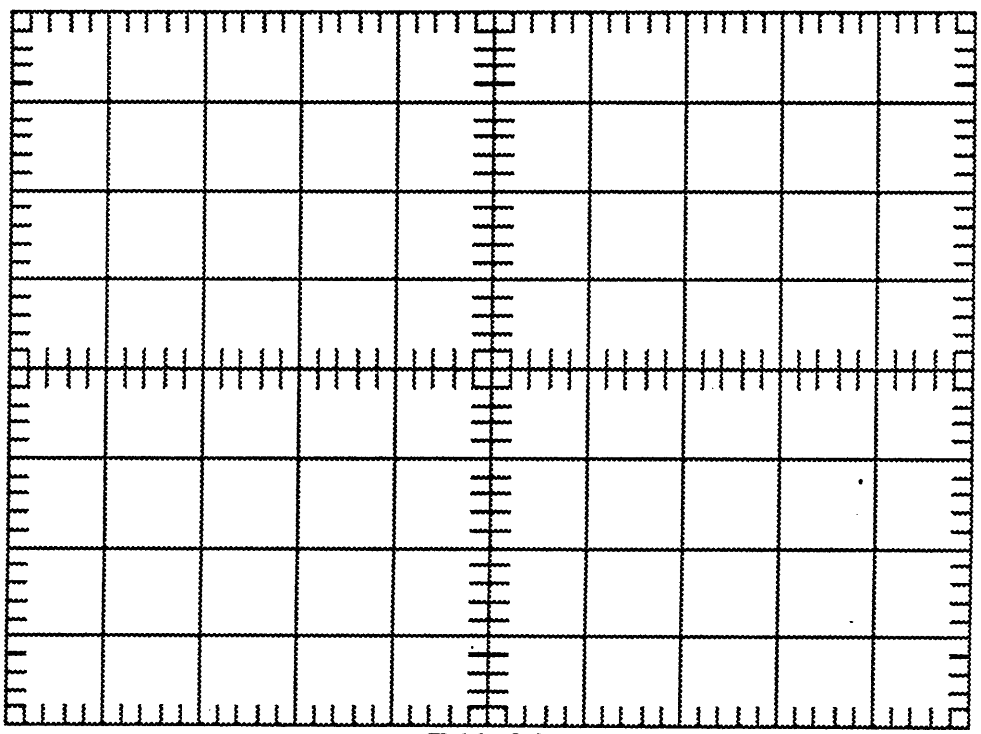


Table 8.2

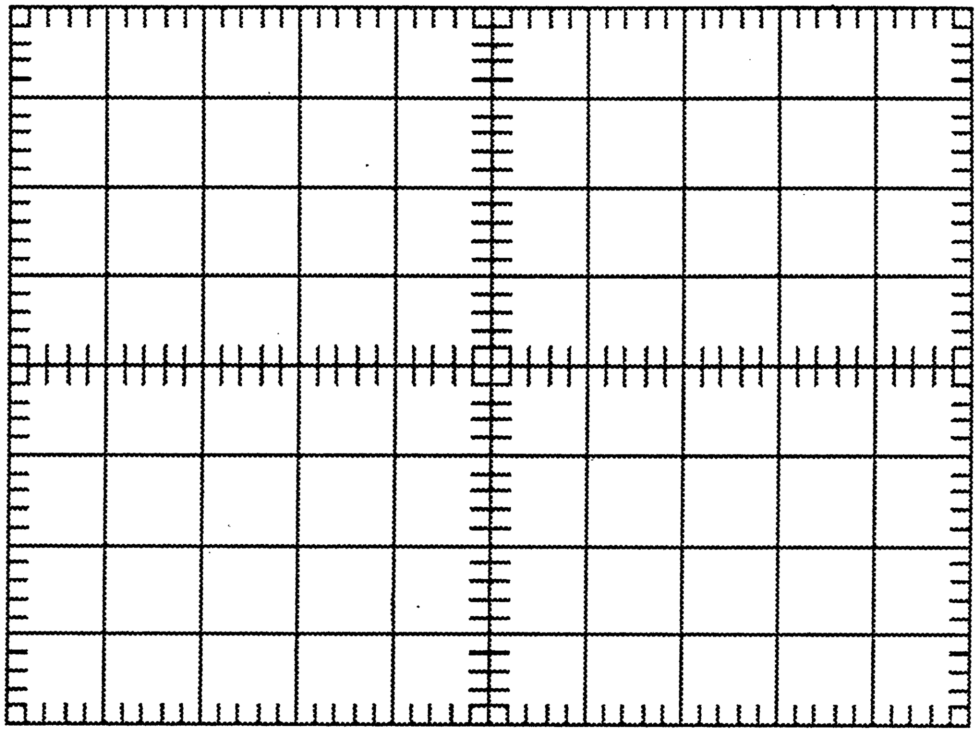


Table 8.3

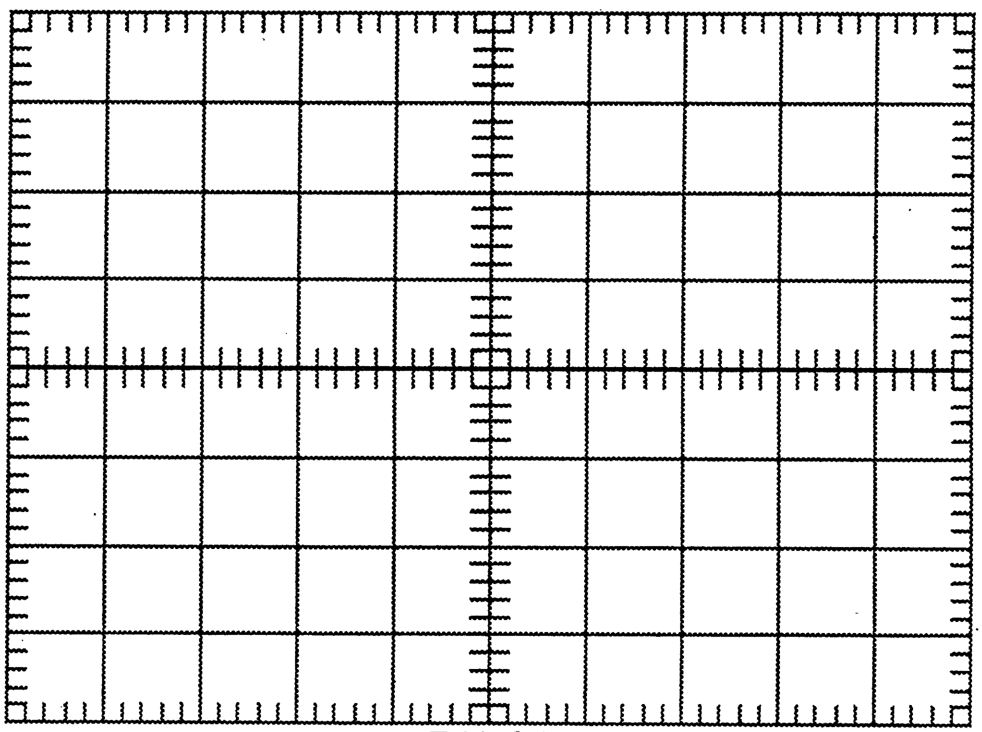


Table 8.4

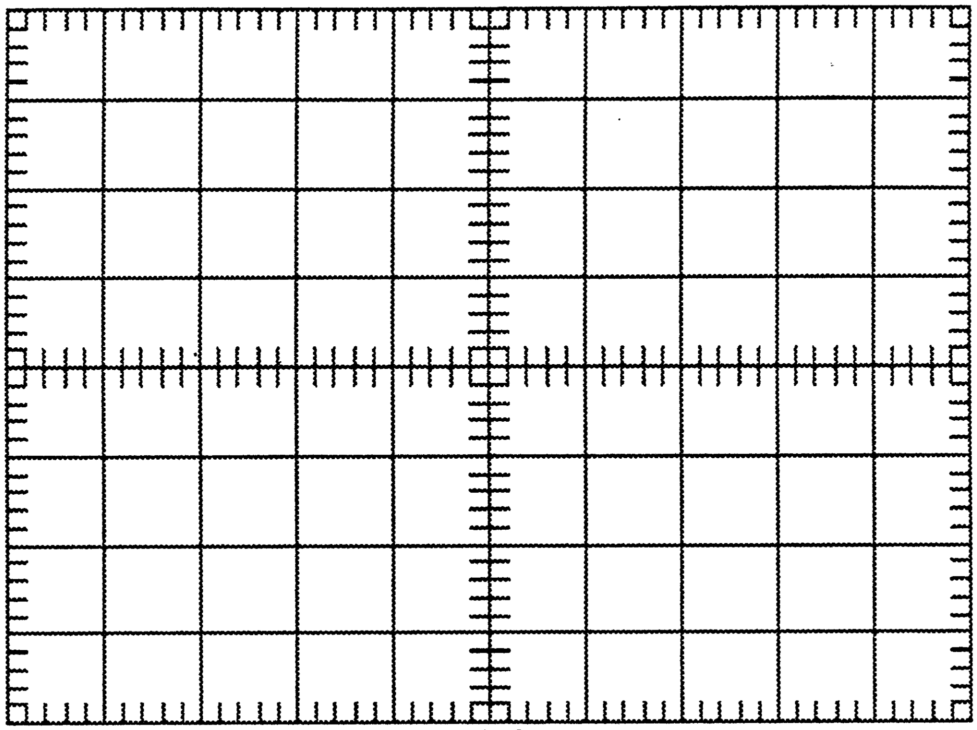


Table 8.5