EEAP 243
Lab 7

Lab Work:
Questions Due:

MORE REAL OPERATIONAL AMPLIFIERS

READING ASSIGNMENT: Horowitz, pgs. 80, 95, 99-100, 279-286.

Abstract:
The performance of non-inverting and instrumentation amplifiers will be examined.

Part I: Non-inverting amplifier

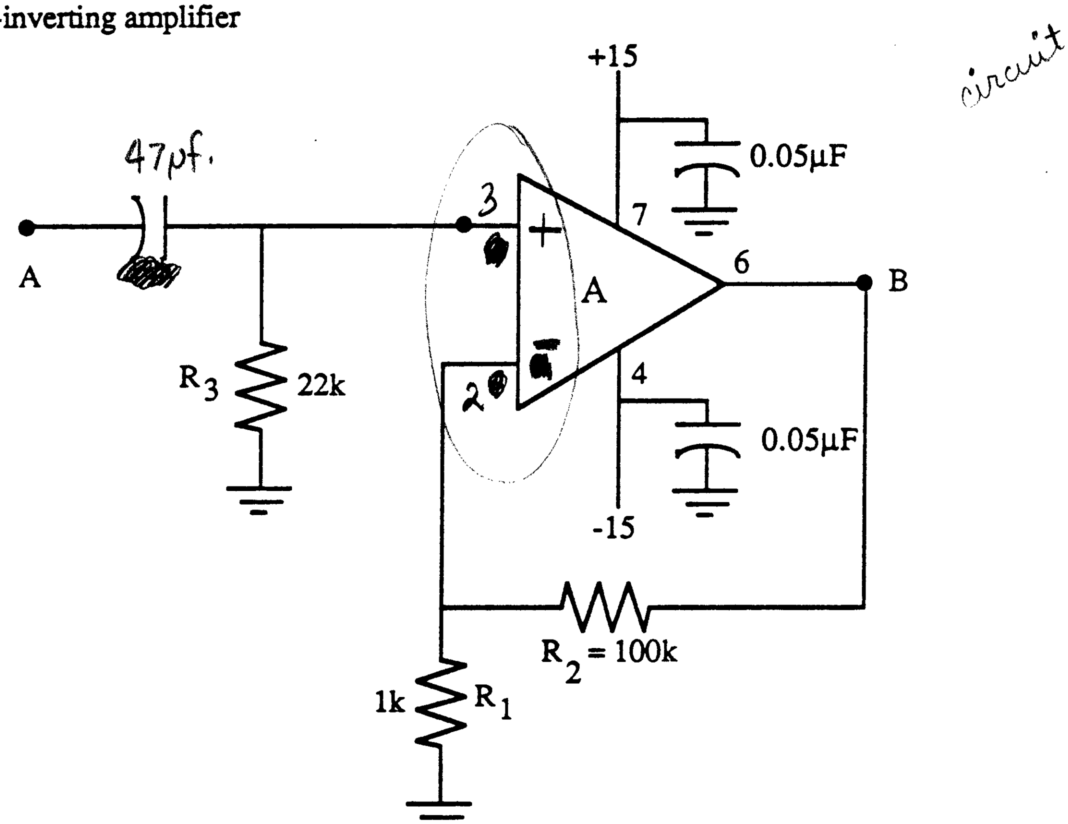


Figure 1

Up to this point, you have only built inverting amplifiers. The non-inverting amplifier configuration is also often useful.

(1) Set the generator to produce a 0.2 V_{p-p} sine wave at 1 KHz with +1 V DC offset.
(2) Build the circuit of Fig. 1 connecting the signal generator to point A.
(3) Record the waveforms at points A and B in Table 7.1 and make note of the phase difference between them.
(4) Vary the generator's DC offset and observe what happens.
(5) Remove resistor R_3, vary the DC offset, and observe what happens.

Part II: Instrumentation amplifier

One of the most useful amplifiers configurations in the real world is the instrumentation amplifier. Imagine that you are using a sensor to, for example, measure temperature or blood pressure. This sensor will typically have two output leads which you will run for some distance to a high gain amplifier to get the signal you need for analysis, control, etc. The problem is that long wires and single-ended inputs are very susceptible to picking up noise from external electromagnetic fields. Consider what you say when you connected a test probe to your scope and simply placed it on the table top. Any real-world circuit must deal with similar noise problems.

To understand the basic principle of an instrument amplifier consider the circuit of Figure 2. The basic requirement of an instrument amplifier is to amplify the signal voltage (E_S) while rejecting the common mode noise voltage (E_{CM}). In actual applications, E_S is often on the order of millivolts while E_{CM} can be on the order of volts. The gain of the circuit shown above is given by

$$E_{OUT} = (E_A - E_B)\frac{R_3}{R_1}$$

provided that $R_1=R_2$ and $R_3=R_4$. In fact, it is very critical that $R_1=R_2$ and $R_3=R$, otherwise, the amplifier will not reject E_{CM}. R_{S1} and R_{S2} are simply the output impedance of E_S.

Practical instrumentation amplifiers use circuits similar to Figure 3. The amplifiers A_1 and A_2 increase the input impedance. Basically, A_1 and A_2 are connected as voltage followers, i.e. ×1 voltage amplifiers.

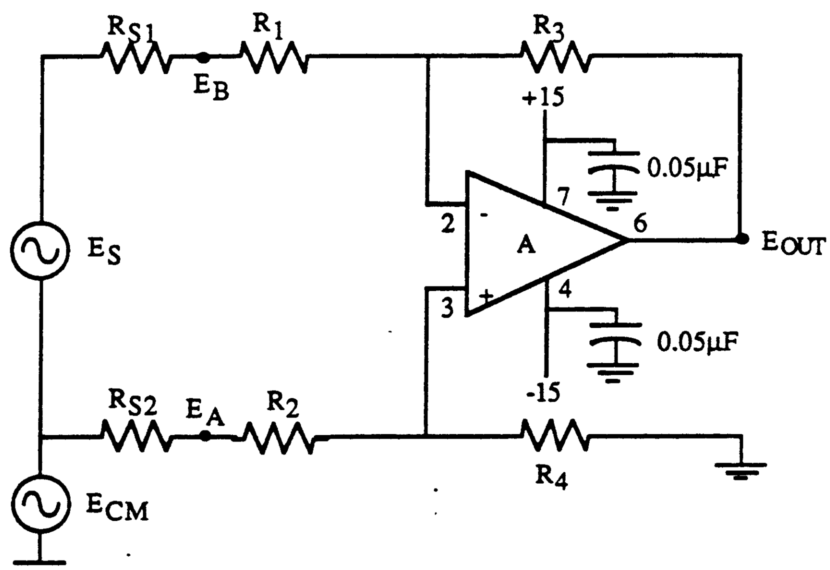


Figure 2 - Basic Instrumentation Amplifier

(1) Build the circuit of Fig.3. Use 1k resistors for R_1 and R_2, a 100k resistor for R_3, and 2.2k resistors for R_5 and R_6. R_7 is a 10k pot. R4 is a 100k pot. Use LM741's for A_1 and A_2. Use a LF357 for A_3. All capacitors unless otherwise shown are 0.05 µF bypass capacitors.

(2) Measure R_1, R_2 and R_3 with your DMM. Record the values in Table 7.2. Calculate

$$R_2 \times \frac{R_3}{R_1}$$

Connect your DMM between the wiper and one of the resistance connections of R_4 and adjust R_4 to equal the value you calculated above as accurately as you can. Connect R_4 into your circuit–DO NOT EVER CHANGE THE VALUE OF R4 unless specifically told to do so. Be careful that you connect R_4 so that the resistance the circuit sees is the same resistance you measured with the DMM.

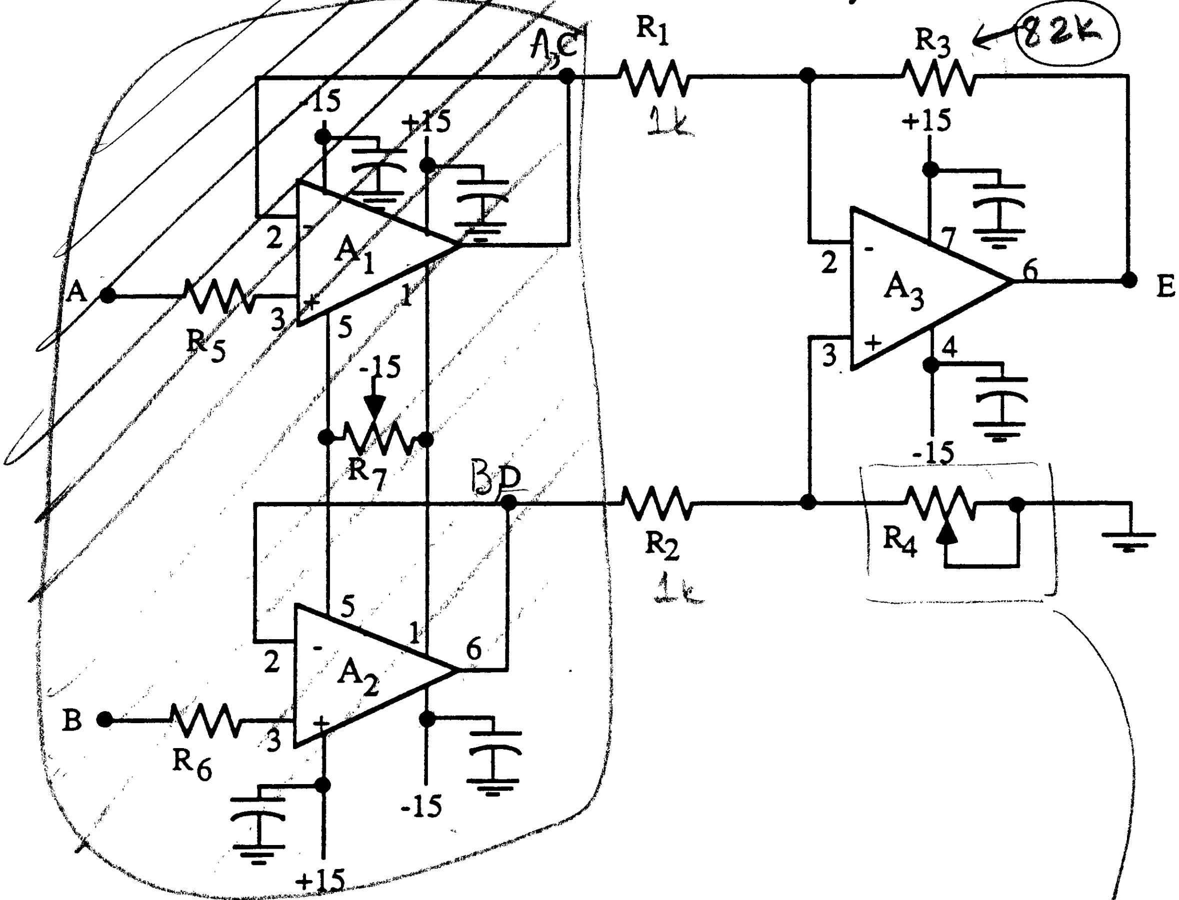
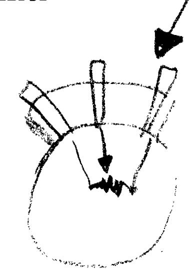
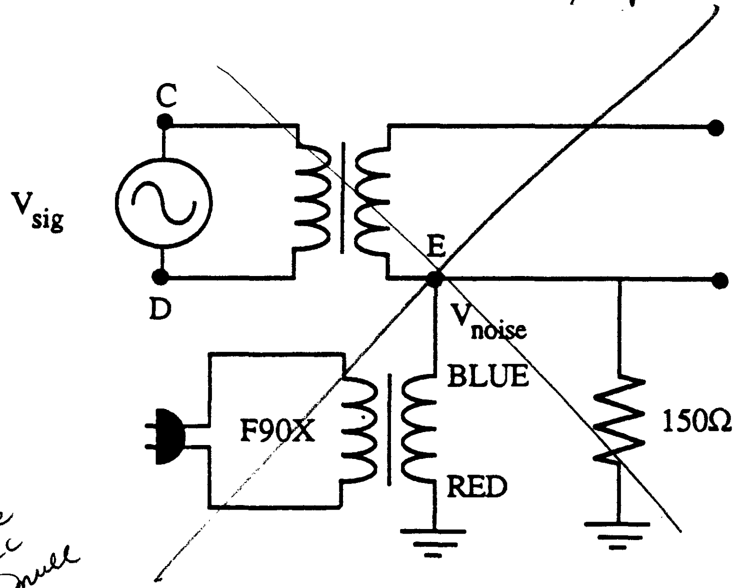


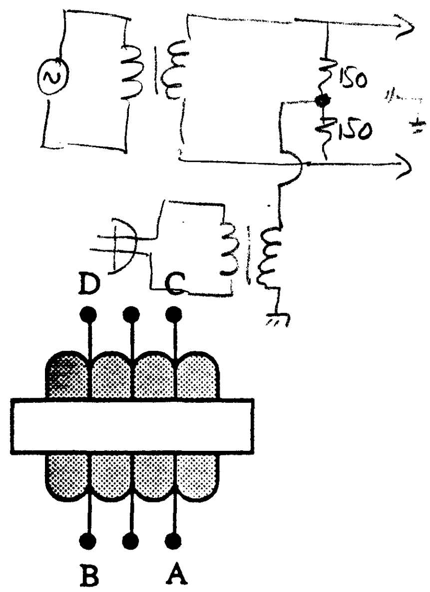
Figure 3 - Practical Instrumentation Amplifier

diagram of potentiometer



replace





Top view of audio transformer

Figure 4 - Differential and Common Mode signal circuit.

instead use common ac waveform to null amplifier

(3) Connect your DMM to point E. Connect points A and B with a jumper. Adjust R_7 until your output voltage is exactly zero. Your amplifier is now ready to test.

(4) Build the signal producing circuit shown in Figure 4 on your protoboard. The points labeled A and B will connect to the correspondingly labeled points of your instrumentation amplifier. Do NOT disassemble your instrumentation amplifier circuit. The upper transformer is your audio transformer. The second transformer is your familiar power transformer. The function of the audio transformer is to allow the signal generator output to be added in series to the output of the power transformer. Do NOT plug the power transformer in yet.

(5) Connect the signal generator output to point C. The other side of the transformer primary should be connected to your station COM. Adjust the signal generator output to $0.2V_{p\text{-}p}$, 0 volts DC at 1 KHz. Connect point A of your signal circuit to point A of your instrumentation amplifier. Connect point B of your signal circuit to point B of your instrumentation amplifier.

(6) Connect your scope CH1 input to point A, connect the scope CH2 input to point B and record the waveform you see in Table 7.3. The signals will look almost identical. Set your scope mode to ADD and the INV CH2 switch ~~out~~ IN. You should now see the signal corresponding to "A-B", the differential signal which the amplifier will see. Vary the generator output–your signal on the scope should follow the change in generator output.Measure and record in Table 7.4 the peak-peak voltage of the "differential" signal you see between points A and B. This is the input signal to your amplifier.

(7) Disconnect the output of your signal generator from point C. Plug in the power transformer. You are now inserting a signal in series with points A and B–a common mode signal. ~~Record the value of any 60Hz signal you see between A and B.~~ record these in Table 7.4

What signal? confusing

(8) Unplug the power transformer. Reconnect the signal generator to point A.

(9) Remove the CH1 probe from point A. Reconnect it to point E. Change the mode switch to CH1. You are now looking at the amplifier output. Record the peak-peak ac voltage in Table 7.5.

(10) Disconnect the signal generator from point C. Plug in the power transformer. Record any 60Hz output voltage (peak-peak) you see at point E in Table 7.5.

Questions:

1. (a) What is the overall gain (B/A) of the circuit of Figure 1?
   (b) Did the signal generator output voltage (point A) change when you connected it to the circuit?
   (c) What is the input resistance of the amplifier circuit (the resistance looking to the right of point A)?
   (d) What is the purpose of the 47 μF capacitor?
   (e) Why is R_3 needed?
2. (a) What is the differential gain of your instrumentation amplifier?
   (b) What is the common mode (60Hz) gain?
   (c) The common mode rejection ratio (CMRR) is defined to be

$$CMRR = \frac{A}{-A_{CM}}$$

   where A_{CM} is the common mode gain and A is the differential gain. Calculate the CMRR for your instrumentation amplifier.
   (d) Explain the function of the two transformers in the signal circuit of Figure 4.
3. Show that the CMRR of the instrumentation amplifier is dependent upon how well matched the RATIO's R3/R1 and R4/R2 are.

EEAP 243 LAB 7 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

Assume that A is connected to B, E is connected to F, G is connected to H, and that J is connected to L in Fig. 7.1. What will happen to the DC voltage at point I if we increase/decrease the resistance of $R_S/R_B/R_E/R_{L3}$?

It will increase / decrease / stay the same.

Question #2

Assume that A is connected to B, E is connected to F, G is connected to H, and that J is connected to L in Fig. 7.1. What will happen to the AC voltage at point J if we increase/decrease the resistance of $R_S/R_B/R_E/R_{L3}$?

It will increase / decrease / stay the same.

EEAP 243

NAMES: ____

Lab 7 Data

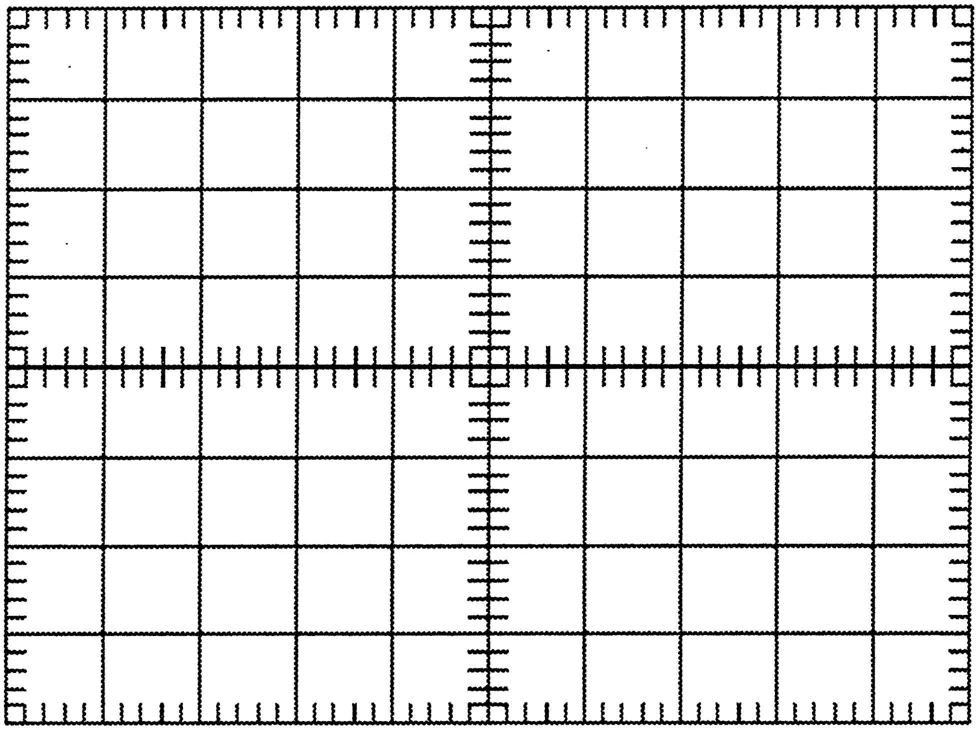


Table 7.1

R_1	____________
R_2	____________
R_3	____________

Table 7.2 instrumentation amp gain resistor measurements

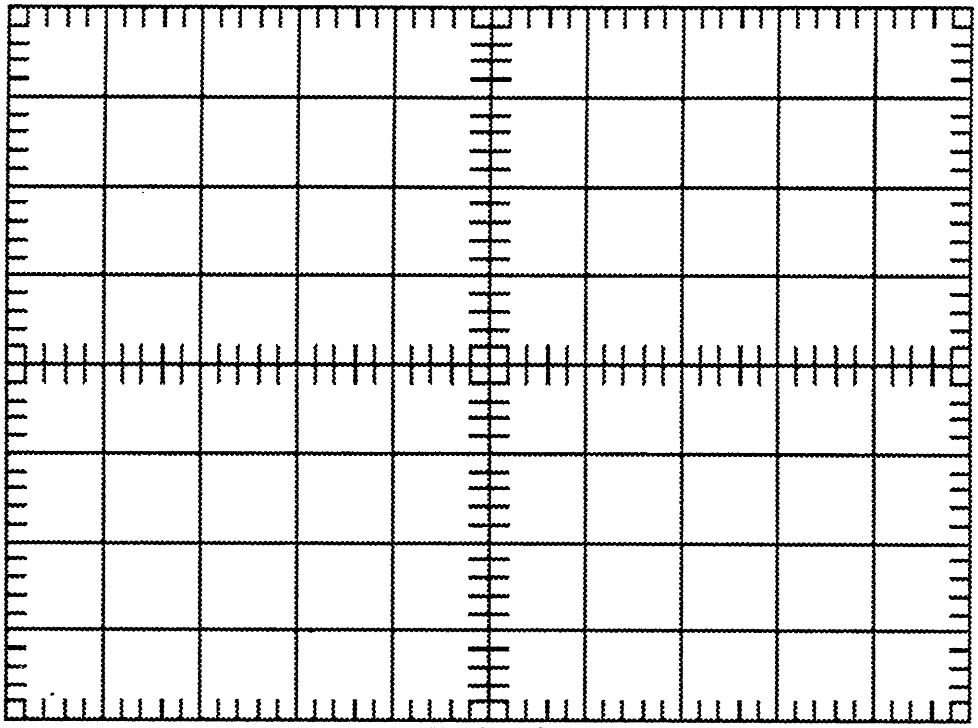


Table 7.3

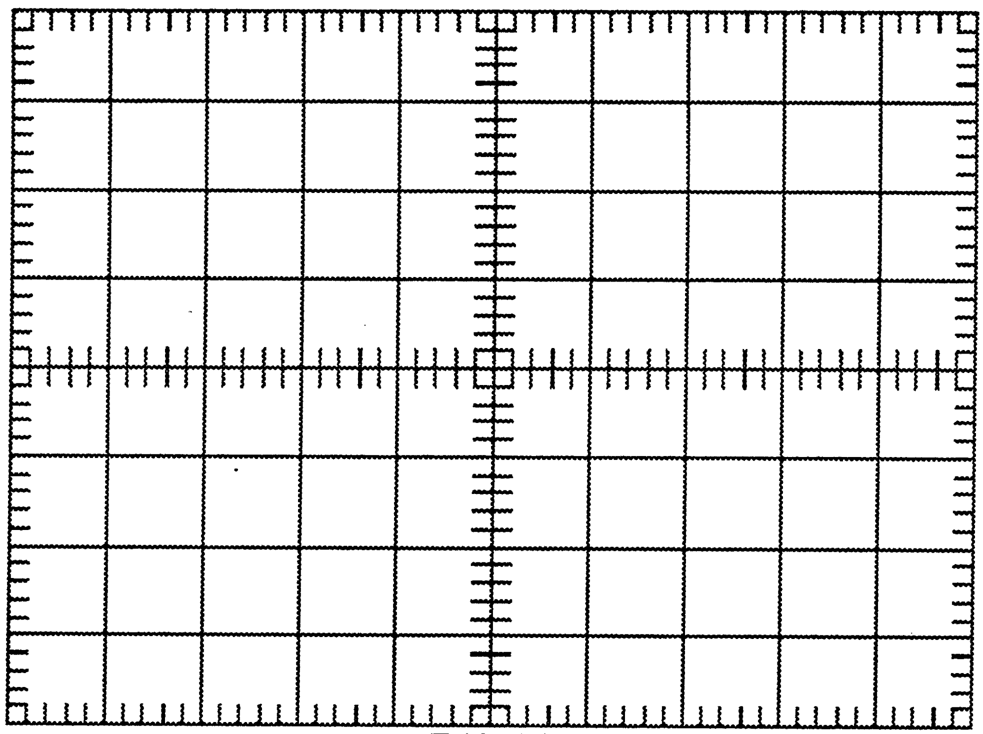


Table 7.4

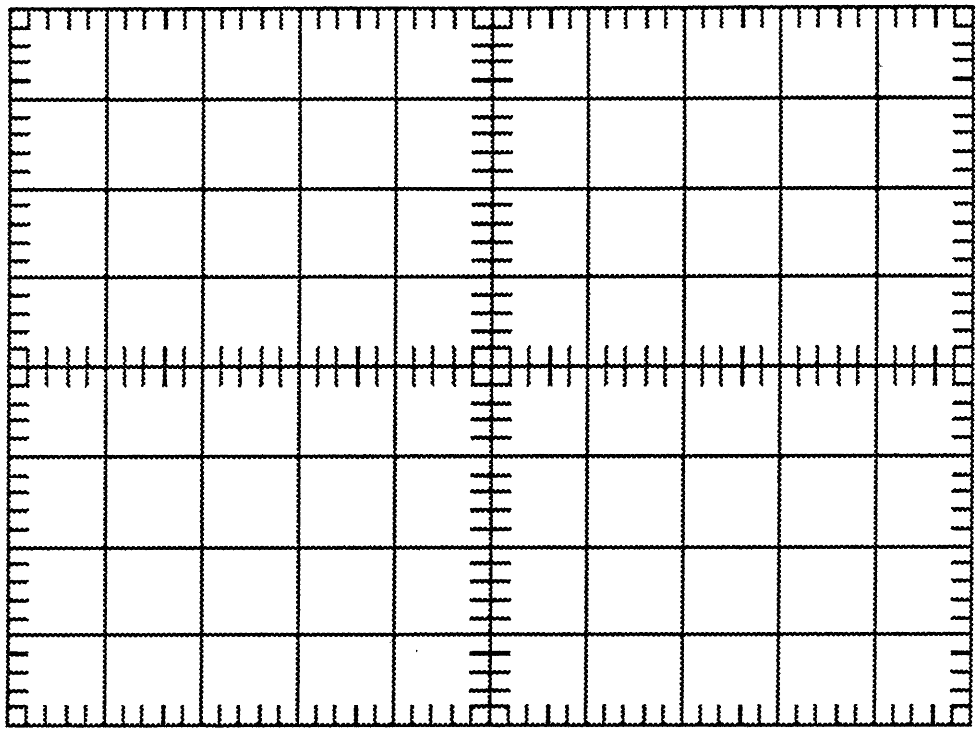


Table 7.5