EXPERIMENT 1

Basic Identifications in Electronic Measurement Systems

EQUIPMENT NEEDED FROM EG&G ORTEC

480 Pulser
113 Scintillation Preamplifier
575A Amplifier
551 Timing Single-Channel Analyzer
875 Counter
Bin and Power Supply
ORC-1 Cable Set
Tektronix 2213A Oscilloscope or equivalent

Purpose

All of the experiments described in this manual require that some combination of electronic instrument modules be interconnected and adjusted to provide the desired information. The purpose of this experiment is to familiarize the student with the basic techniques to use in checking for proper system arrangement and responses.

Electronic Circuits

The first part of this experiment provides familiarity with the oscilloscope. This is the instrument that is used for observing the input and output pulses for the various modules in the system to determine whether the waveshapes, amplitudes, and timing are correct with respect to the rest of the equipment.

Next is an introduction to a pulse generator. This is an instrument that simulates the pulses that would originate in a nuclear radiation detector and furnishes the pulses with the known characteristics into the input of the system. The pulse generator is used for calibration, timing, and certain test operations. Used together, the oscilloscope and pulse generator can assure the student that the electronics have been set up according to the block diagrams that accompany each experiment so that the series of exercises can be completed as required.

The system that is used in this experiment includes a group of modules that are basic to many experiments: a preamplifier, an amplifier, a threshold discriminator, a single-channel analyzer (SCA), a counter, and an oscilloscope. Each module provides a necessary function in the overall system, which, in this combination, is a simple counting system.

These electronic modules are divided into two general types, logic and linear. A more complete discussion of these devices is included in the Appendix, "Linear and Logic Signal Standards in EG&G ORTEC NIM Instruments." Briefly, a logic module is a device that generates an output pulse of fixed amplitude if its logic criteria are met. The simplest example of a logic device is a threshold discriminator, which gives an output pulse (always with the same amplitude) every time it receives an input pulse that has an amplitude greater than the threshold level. The SCA is another good example of a logic module. A linear module is one in which the output linear signal contains information such as the energy of an incident particle that has been absorbed in a detector.

Measurement of the energies of alpha particles with a surface barrier detector illustrates the use of both linear and logic modules. A simplified electronic block diagram for this measurement is shown in Fig. 1.1.

The alpha particles from the source produce pulses from the detector whose magnitudes are proportional to the energies of the alpha particles. The preamplifier and amplifier simply (at least for this discussion) amplify each pulse by an adjusted gain factor and provide some pulse shaping.

Let us assume that the alpha particles have an energy of 5 MeV and that the output of the preamplifier is a series of

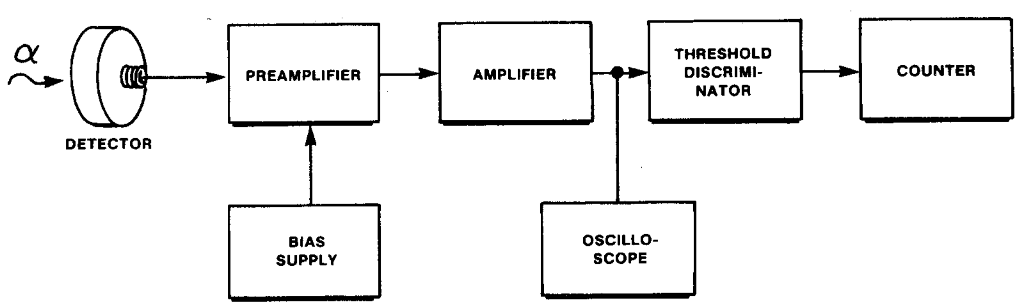

Fig. 1.1. Block Diagram for Alpha-Particle Measurements.

0.5-V pulses. Let us further assume that the gain of the amplifier is set at 10. Then the output pulses from the amplifier will have an amplitude of 5 V. If everything is left the same except that the 5-MeV alpha source is replaced with a 6-MeV alpha source, then the output pulses from the preamplifier would be 0.6 V and those from the amplifier would be 6 V. In this example the linear signal is the output of the amplifier and it contains information with regard to the energy of the alpha particle that originated the pulse. That is, the output of the amplifier is proportional to the energy of the alpha particle.

Figure 1.2 shows how the output of the amplifier might look on an oscilloscope with both 5- and 6-MeV alphas impinging on the detector.

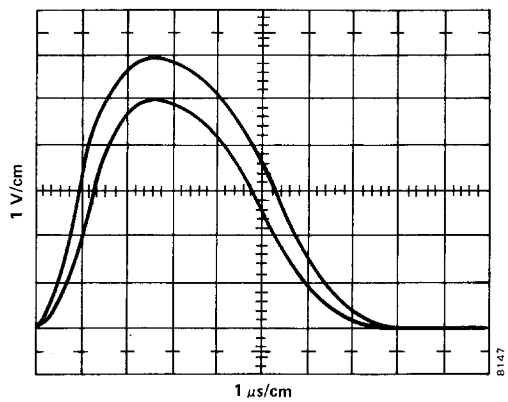

Fig. 1.2. Typical Amplifier Output.

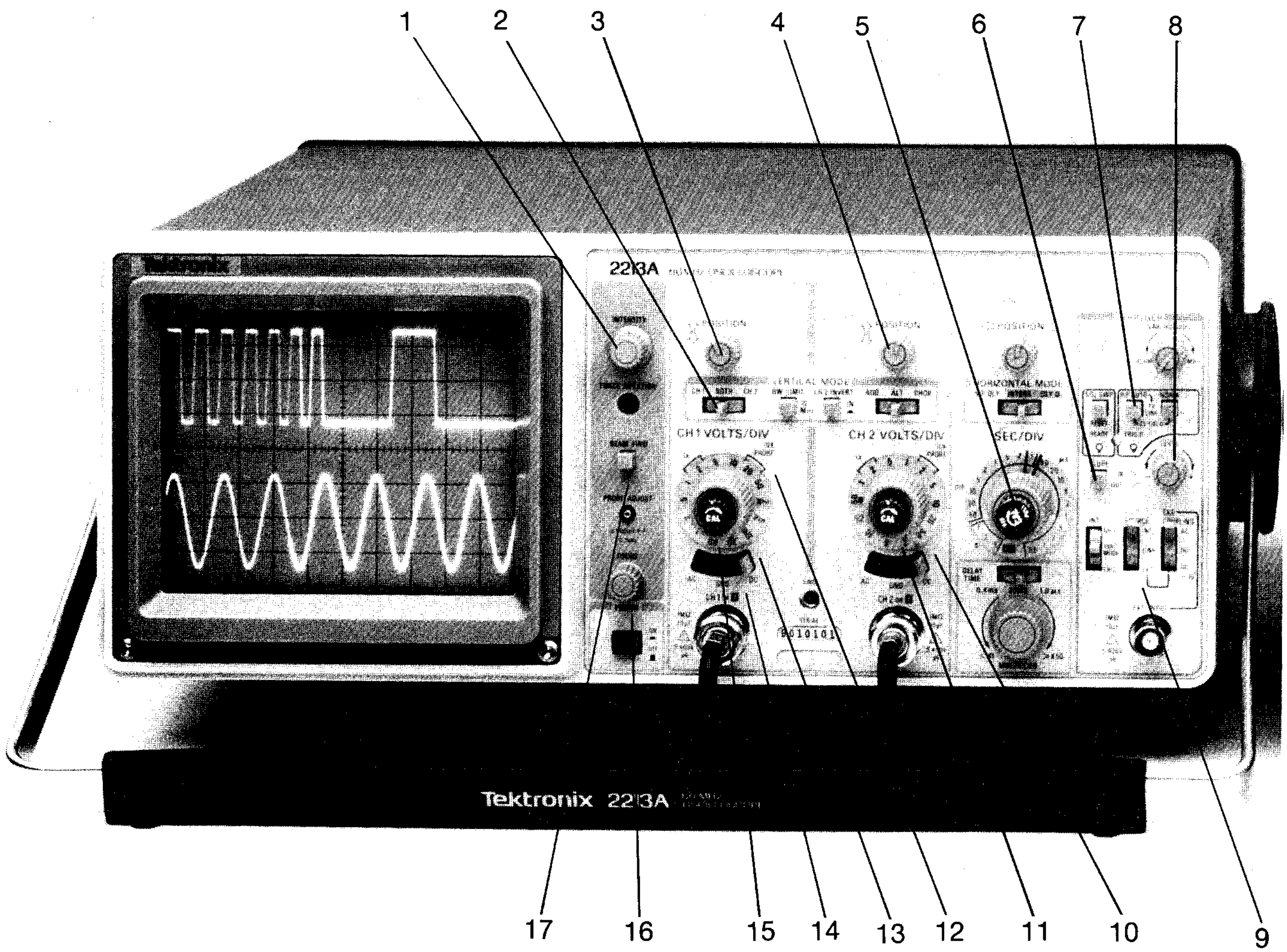

Fig. 1.3. Tektronix 2213A Oscilloscope Front Panel.
(Courtesy of Tektronix, Incorporated.)

Each time a 5-MeV alpha particle strikes the detector, a 5-V pulse is produced, etc. Therefore, in addition to the pulse-height information, the number of linear signals can also tell how many events of a given pulse height occurred per unit time. If the discriminator level is set at 5.1 V for the amplifier output in Fig. 1.2, the discriminator gives logic output pulses for only the 6-MeV alphas. These logic pulses are then fed into the counter and counted. Other examples of linear and logic arrangements are given later.

The procedure outlined in Experiment 1.1 tells the student how to operate the oscilloscope and the EG&G ORTEC 480 Pulser to observe the direct and attenuated outputs from the 480. The procedures in Experiment 1.2 consist of three parts: (1) how to apply the output signal from the 480 into the linear portion of the measurement system (the preamplifier and amplifier) and observe the linear shaping of these modules in the system; (2) how to determine whether the logic criteria have been met by observing with the oscilloscope the logic output from an integral discriminator; and (3) how to use a single-channel analyzer to replace the function of the integral discriminator.

The Oscilloscope

Most oscilloscopes in nuclear laboratories have about 30 knobs and adjustments for performing the various functions for which they were designed. Fortunately, only about 10 of these parameters are necessary for observing input and output pulses from modules or for making simple timing adjustments. In other words, you can perform virtually all the necessary operations if you can become proficient with these 10 knobs.

Since most laboratories have an oscilloscope similar to a Tektronix 2213A, this brief discussion will be concerned with these types. Familiarity with the operation of a Tektronix oscilloscope makes it quite easy to learn the functions of any other oscilloscope. For reference, Fig. 1.3 shows the details of the front panel of a Tektronix 2213A oscilloscope.

In this experiment, only one of the two channels will be used, and the settings in Table 1.1 are basic adjustments that will be adequate to operate the oscilloscope. In Experiment 1.1, the output from the pulse generator is cabled directly to the oscilloscope input and the amplification factors shown for

Table 1.1. Oscilloscope Parameters.
(Keyed to Fig. 1.3)

1. **Intensity:** mid-scale, and then readjust for desirable level; this control interacts with the Focus adjustment.
2. **Display mode selection:** select CH1 (only) for the vertical deflection.
3. **Vertical Position (Channel 1):** place baseline of trace at 0% mark on graticule, 2.5 cm below the center line.
4. **Vertical Position (Channel 2):** ineffective, channel not used.
5. **Sec/Div:** .1 ms provides a horizontal sensitivity of 100 μs (0.1 milliseconds) per centimeter in the sweep; other available time bases will be appropriate to other applications.
6. **Triggering Slope:** + (Out) elects to trigger on the positive rise of the trigger source pulse.
7. **Triggering Mode:** NORM is appropriate to most laboratory uses; alternate settings are for other applications of this oscilloscope.
8. **Triggering Level:** set at mid-scale and then readjust when input pulses are available.
9. **Triggering Source:** INT starts a sweep on each input pulse through the Channel 1 input circuit; other settings select alternate triggering sources for other applications.
10. **Volts/Div (Channel 2):** ineffective, because the channel is not used.
11. **Variable Volts/Div (Channel 2):** ineffective, channel not used.
12. **Probe selection:** use the X1 window on the knob-skirt if the input is a direct connection, or the X10 window if through the X10 Tektronix probe that is furnished with the instrument.
13. **Volts/Div (Channel 1):** set a 1 for a vertical deflection sensitivity of 1 V/cm.
14. **Input Coupling (both channels):** select AC for this application.
15. **Variable Volts/Div (Channel 1):** full clockwise to use the selected vertical sensitivity; otherwise provides fine attenuation adjustment.
16. **Focus:** mid-scale, and then readjust for pin-point spot of light.
17. **Beam Finder:** push to center the trace if off-scale to determine the direction to adjust both vertical and horizontal position controls.

the X1 Probe are effective. For Experiments 1.2 and 1.3, the probe that is furnished with the oscilloscope is used for the circuit test connections, so the vertical amplification factors shown for the X10 Probe are effective.

If you are using a different oscilloscope, your instructor will give you the necessary modifications of the parameters listed in Table 1.1. Also, additional information and definitions of the parameters are given in the oscilloscope operator's manual.

EXPERIMENT 1.1

Observing the Direct and Attenuated Outputs of the Pulser

Introduction

The 480 Pulser generates output pulses that are used to simulate pulses from nuclear radiation detectors. Normally the output from the pulse generator will be fed into a preamplifier to become the test pulse input. It may also be fed directly into an amplifier.

The pulse generator has two output pulses that occur simultaneously: a direct output and an attenuated output. The direct output has a pulse height or full amplitude that is adjusted with a front panel dial and will usually be used to trigger the oscilloscope with a time = 0 reference. The attenuated output has a pulse height that is a selected fraction of the direct output and is the variable amplitude needed for energy calibration. The amplitude of these outputs can be varied continuously from 0 to about 5 V by the use of the pulse-height and calibration controls and the attenuator switches. The output polarity is selectable on the front panel.

As is true for almost all NIM modules, the 480 Pulser must be installed in a bin and power supply and the power supply must be turned on to provide the operating power requirements of the module. The bin and power supply can accommodate any of these instrument modules in any configuration and supply the appropriate power to all the modules. Always turn off the power before inserting or removing any instrument module.

Procedure

1. Install the 480 Pulser in the bin and power supply and turn on the power.

2. Connect a BNC tee to the input of the oscilloscope, channel 1. Connect a 93 Ω cable with BNC connectors from the direct output of the 480 to one side of the BNC tee, and connect a 100 Ω terminator to the other side of the tee. This is known as receiving-end termination and in this case simulates the input impedance of the preamplifier.

3. Set the 480 Cal (calibrate) and Pulse-Height controls fully clockwise and select a positive output polarity. Set the oscilloscope parameters as listed in Table 1.1.

4. Trigger the oscilloscope by adjusting the Triggering-Level control. If the trace will not trigger, recheck the settings of the parameters in Table 1.1. When the oscilloscope is operating properly, the output should appear approximately as that shown in Fig. 1.4. Note that in Fig. 1.4 the maximum pulse amplitude appears at the beginning and is ~5 V.

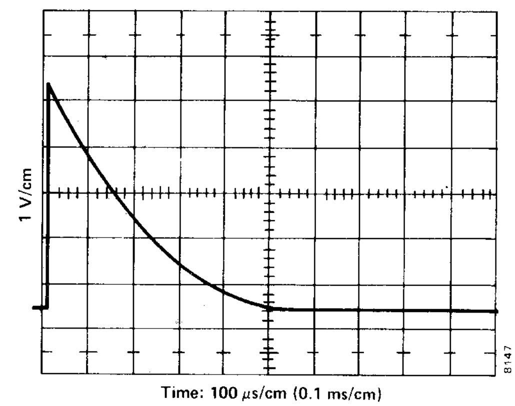

Fig. 1.4. Typical Pulse Generator Output.

EXERCISES

a. Make a plot on centimeter graph paper of the picture that is observed. Note that the picture gives the voltage of the pulse as a function of time. The scale on the ordinate can be changed by changing parameter 13 of Table 1.1. When this is changed, it may be necessary to readjust the triggering controls. The time per centimeter can be changed by adjusting parameter 5.

b. Set parameter 13 at 2 V/cm and parameter 5 at .2 ms/cm and make a plot on centimeter graph paper of the picture that you observe.

5. Now change the cable connection on the pulser to the attenuated output. Set all attenuation switches at X1. Leave the pulse-height and calibration controls fully clockwise. The output pulse on the oscilloscope should show a 5-V amplitude. The pulse-height dial on the 480 Pulser is a 10-turn potentiometer with a duo-dial. There are 100 division marks for each turn of the knob for a total of 1000 divisions on the dial. The settings on the pulse-height dial can then be represented as a ratio. For example, 90% of full clockwise would be 900/1000 etc.

EXERCISES

c. In Table 1.2, record from the oscilloscope the maximum voltage values observed for the pulse-height settings.

d. Make a plot on linear graph paper of pulse-height dial settings vs oscilloscope voltage. Is this a straight line?

6. Return the pulse height dial to 1000/1000. Set the top attenuator switch at X2 on the pulser. The amplitude of the pulse should decrease by a factor of 2.

Table 1.2

Pulse-Height Dial Settings	Voltage Amplitude (Oscilloscope)
1000/1000	
800/1000	
600/1000	
400/1000	
200/1000	

Try various combinations of these attenuator switches and observe the output. It will be necessary to change parameter 13 of Table 1.1 and readjust the oscilloscope triggering controls when the output signals are attenuated in order to observe the pulses with reduced amplitudes. Return the attenuator switches to X1 and readjust the oscilloscope vertical sensitivity. Now with a small screwdriver slowly turn the calibrate control counterclockwise while observing the output pulse. It should linearly attenuate the output voltage as does the pulse-height dial.

EXPERIMENT 1.2

Using the Pulser as the Linear Input to a Typical Counting System

Introduction

To set up the electronics shown in Fig. 1.5:

1. Install the 480, 575A, 551, and 875 in the bin and power supply.

2. Connect the power cable for the 113 to the preamplifier power connector on the rear of the 575A.

3. Connect the attenuated output of the 480 Pulser to the test input connector on the 113 Scintillation Preamplifier (connections are always made with 93 Ω cable and BNC connectors unless otherwise specified). The 100 Ω terminator previously used is no longer required.

4. Use a BNC tee at the 575A Amplifier input and connect the output of the preamplifier to one side of the tee. Connect the oscilloscope to the other side of the tee.

5. Connect the amplifier output to the input of the 551, used as an integral discriminator.

6. Connect the positive output of the 551 to the input of the 875 Counter.

Make the following control settings:

1. Set the input capacity of the 113 Scintillation Preamplifier at 100 pF.

2. Set the 575A for a negative input and unipolar output.

3. Set the 551 mode switch at Integral, Lower Level at 50/1000, and rear panel toggle switch at Internal. This combination makes the 551 operate as a threshold discriminator.

Procedure

Adjusting the Linear Portion of the System

1. Using the 480 attenuated output, set its parameters as follows: pulse height, 1000/1000; calibrate, full clockwise; output, negative. Other adjustments will be made later.

2. Adjust the attenuator switches and the calibrate control of the 480 so that the output pulses from the preamplifier are about 0.1 V. (When using the X10 probe for the oscilloscope, use the X10 probe settings of parameter 13 of Table 1.1.)

3. Trigger the oscilloscope by the methods shown in Experiment 1.1.

4. Now move the oscilloscope cable to the output of the 575A Amplifier and adjust its gain controls until the output pulses have an 8.5-V amplitude. The oscilloscope parameters should be the same as those in Table 1.1 except that parameter 13 should be 2 V/cm and parameter 5 should be 0.1 ms/cm. The correct output pulse should look like the pulse shown in Fig. 1.6.

5. With all other settings the same, switch the 575A output to bipolar. The correct output pulse should look like the pulse shown in Fig. 1.7. (Retrigger oscilloscope if necessary.)

6. Return the switch on the amplifier to unipolar.

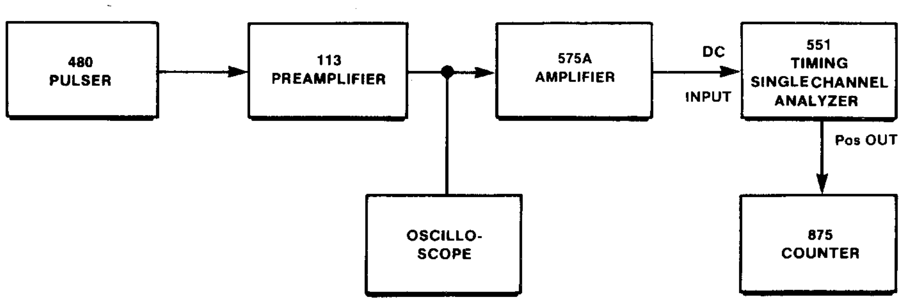

Fig. 1.5. Typical Counting System with Pulser Input.

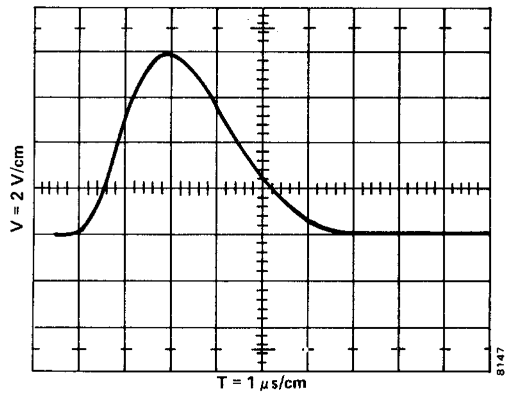

Fig. 1.6. Correct Amplifier Unipolar Output.

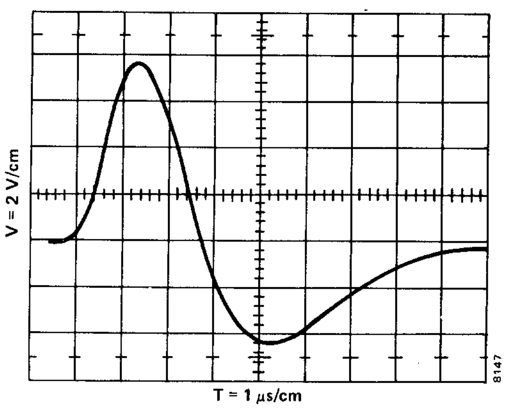

Fig. 1.7. Correct Amplifier Bipolar Output.

Determining Logic Criteria

1. Connect the oscilloscope to the test point for the Pos output of the 551.

2. Trigger the oscilloscope with the same parameters that were used for looking at the amplifier output.

3. A 5-V logic pulse should be observed in the oscilloscope.

4. Set the counter Count/Stop switch at Count. The counter should count the 551 output pulses.

5. Now, increase the setting of the 551 Lower-Level control until the counter just stops counting. Record the control setting for the first line in Table 1.3.

6. On the 480 Pulser, decrease the Pulse-Height control to 800/1000.

EXERCISES

a. Decrease the 551 Lower-Level control until the counter just barely starts to count. Record this setting in Table 1.3, and continue for the other settings in Table 1.3.

b. Make a plot of the data in Table 1.3 on linear graph paper. This should produce a straight line.

Table 1.3

480 Pulse Height	551 Lower Level
1000/1000	
800/1000	
600/1000	
400/1000	
200/1000	

EXPERIMENT 1.3

Using a Single-Channel Analyzer

1. Change the 551 mode switch from Integral to Normal. This changes its function from an integral discriminator to a single-channel analyzer. Connect the LL Out on the rear panel of the 551 to the 875 Counter Input.

2. Use the Lower-Level control of the 551 to adjust the discriminator levels for various settings of the 480 Pulse-Height control. With this connection, the 551 operates the same as it did for Integral mode.

EXERCISES

a. Fill in Table 1.4.

Table 1.4

480 Pulse Height	551 Lower Level
1000/1000	
800/1000	
600/1000	
400/1000	
200/1000	

b. Make a plot of the lower-level settings as a function of pulse height. This will prove that the lower-level portion of the SCA operates the same as the integral discriminator.

3. Move the output connection of the 551 from LL Out to either the SCA Out connector on the rear panel or the Pos Output connector on the front panel; output pulses are identical through these two connectors.

4. Set the 551 front panel toggle switch at Normal and the Upper-Level dial at 1000/1000. The operation of the 551 for this arrangement will be exactly the same as for the use of its LL Out signals, except that the output signals occur slightly later in the trace.

5. Set the SCA in the Window (Differential) mode. Set the

Lower-Level dial at 100/1000 and the Window or Upper-Level dial at 100/1000.

6. Decrease the 480 Pulse-Height control until the counter starts to count. Record this setting in Table 1.5 as ΔE Upper.

Table 1.5

Lower Level	Window or Upper Level	Δ*E* Upper	Δ*E* Lower
100/1000	100/1000		
100/1000	300/1000		
100/1000	600/1000		
100/1000	800/1000		

EXERCISES

c. Continue to decrease the 480 Pulse-Height control until the counter stops counting. Record this value as ΔE Lower in Table 1.5.

d. Make a plot of the Window settings vs ΔE Upper − ΔE Lower on linear graph paper.

e. Repeat these measurements with the Lower Level set at 200/1000 as in Table 1.6.

7. Place the toggle switch on the front panel in the Normal position. With the toggle switch in the Normal position, the Upper-Level and Lower-Level controls on the front panel of the 551 are independently variable from 0 to 10 V. Also in the Normal mode, if the Upper Level is set below the Lower Level, no output will be generated from the SCA output on the 551.

Table 1.6

Lower Level	Window or Upper Level	Δ*E* Upper	Δ*E* Lower
200/1000	100/1000		
200/1000	300/1000		
200/1000	600/1000		
200/1000	800/1000		

With this in mind, complete Exercise f.

EXERCISE

f. Repeat the measurements for Table 1.7 with the Lower Level set at 200/1000 as in Table 1.6.

Table 1.7

Lower Level	Window or Upper Level	Δ*E* Upper	Δ*E* Lower
200/1000	100/1000		
200/1000	300/1000		
200/1000	600/1000		
200/1000	800/1000		