ORTEC®

Experiment 1
Introduction to Electronic Signal Analysis in Nuclear Radiation Measurements

Equipment Required:

- 480 Pulser
- 113 Scintillation Preamplifier
- 4001A/4002D NIM Bin and Power Supply
- 575A Spectroscopy Amplifier
- 996 Timer and Counter
- 551 Timing Single-Channel Analyzer
- Coaxial Cables and Adapters:
  - o C-27 100-Ω Terminator, BNC Male Plug
  - o Two C-29 BNC Tee Connectors
  - o Two C-24-8 8-ft. (2.4 m) 93-Ω RG-62A/U Coaxial Cable with BNC plugs
  - o Three C-24-4 4-ft. (1.2 m) 93-Ω RG-62A/U Coaxial Cables with BNC plugs
  - o Two C-24-1 1-ft. (30 cm) 93-Ω RG-62A/U Coaxial Cables with BNC plugs
- Oscilloscope with Bandwidth ≥150 MHz, e.g., Tektronix TDS 3032C or equivalent
- Small, flat-blade screwdriver for tuning screwdriver-adjustable controls

Purpose

All Experiments in Nuclear Science require that some combination of detectors and electronic instrument modules[1] be interconnected and adjusted to measure the desired information. The purpose of this experiment is to familiarize the student with the basic instrumentation and techniques used in checking for proper system arrangement and response.

Electronic Circuits

The first part of this experiment facilitates familiarity with an oscilloscope. The oscilloscope is an indispensible diagnostic tool for observing the input and output pulses for the various modules in the system to determine whether the pulse shapes, amplitudes, and timing are correct with respect to the rest of the equipment.

Next is an introduction to a pulse generator, which is an instrument that simulates the pulses originating in a nuclear radiation detector. Typically, it is employed to furnish pulses with controlled characteristics to the input of the system. The pulse generator is used for calibration, timing alignment, and certain test operations. Nuclear radiation interacting with the detector produces pulses that are randomly distributed in time and amplitude, and that randomness sometimes makes it difficult to set-up the electronics. On the contrary, the pulse generator produces periodic pulses at a known frequency and a precisely-controlled amplitude. That predictability facilitates the energy calibration and timing alignment processes during initial adjustment of a system. Used together, the oscilloscope and the 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 experiments can be completed as required. It is important to gain as much familiarity as possible with these two instruments to make execution of the rest of the experiments more productive.

The system 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 signal processing chain, which constitutes 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 AN34 Library under the heading, Linear and Logic Signal Standards in ORTEC NIM Instruments. Briefly, a logic module is a device that generates an output pulse of fixed amplitude[2], if specific logic criteria are met at its input(s). 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 example of a logic module. A linear

[1]The modular electronics used in Experiments for Nuclear Science is typically referred to as NIM (Nuclear Instrumentation Modules), and they are designed to conform to the NIM Standard. See reference 2.

[2]Typically the "amplitude" of a pulse refers to the maximum height of the pulse above the baseline between pulses for a positive-polarity pulse, or the maximum excursion below baseline for a negative-polarity pulse. The amplitude is measured as a voltage. For bipolar pulses, the amplitude is measured on the leading lobe (leading phase). The "amplitude" is sometimes referred to as the "pulse height."

module is one in which the output linear signal contains proportional information, such as the energy of an incident particle that has been absorbed in a detector. Typically, the amplitude of the pulse is linearly proportional to the energy of the detected particle. Some modules combine both linear and logic signal functions.

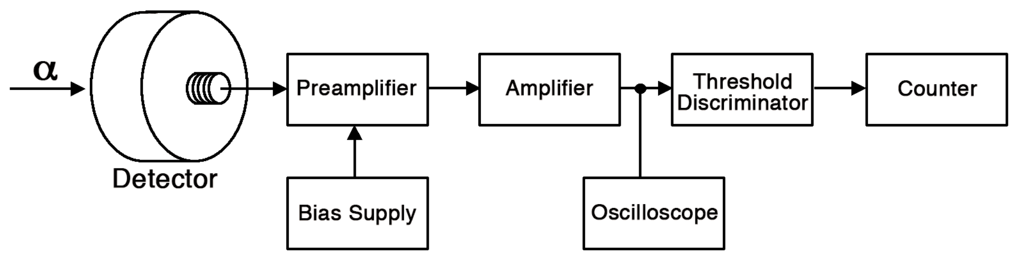

Fig. 1.1. Block Diagram for Alpha-Particle Measurements.

Measurement of alpha particle energies with a charged particle detector illustrates the use of both linear and logic modules. Fig. 1.1 shows a simplified block diagram for this process. Alpha particles from the radioactive source interact in the detector to produce pulses whose amplitudes are proportional to the energies of the alpha particles. The preamplifier collects these pulses and delivers them to the amplifier. The amplifier increases the voltage amplitude of each pulse by a predetermined gain factor, and provides some pulse shaping.

Let us assume that the alpha particles have an energy[3] of 5 MeV, and that the output of the preamplifier is a series of pulses, each with the same 0.5-V amplitude. Furthermore, assume that the gain of the amplifier is set at 10. Consequently, 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, the output pulses from the preamplifier would increase to 0.6 V, and those from the amplifier would become 6 V. In this example, the linear signal of interest is the output of the amplifier, and it contains information regarding the energy of the alpha particle that originated the pulse. In other words, the pulse amplitude at the output of the amplifier is proportional to the energy of the alpha particle.

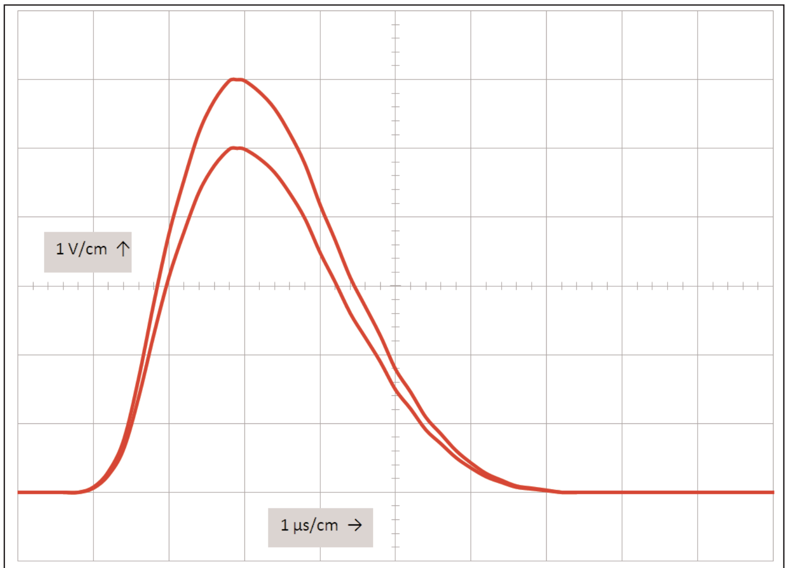

Fig. 1.2. Typical Linear Amplifier Output: 5.0-Volt and 6.0-Volt Pulses from 5-MeV and 6 MeV Alpha Particles.

Fig. 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. The horizontal axis is time (1 μs/cm, or 1 μs per major division) and the vertical axis is Voltage (1 V/cm, or 1 V per major division).

Each time a 5-MeV particle strikes the detector, a 5-V pulse is produced, and every time a 6-MeV particle strikes the detector a 6-V pulse is produced at the amplifier output. Therefore, in addition to the pulse-height information, the number of linear pulses can also determine how many events of a given pulse height occurred per unit time. If the discriminator is set at 5.5 V for the amplifier output in Fig. 1.2, the discriminator generates logic 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 guides the student on how to operate the oscilloscope and the ORTEC 480 Pulser to observe the direct and attenuated outputs from the pulser. The procedures in Experiment 1.2 comprise three parts:

(1) how to inject the 480 output signal 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 the logic output from an integral discriminator with the oscilloscope, and

(3) how to use a single-channel analyzer to replace the function of the integral discriminator.

[3]Energy is usually measured in eV, keV or MeV. One electron-Volt (1 eV) is the kinetic energy acquired by an electron that falls through a potential difference of 1 Volt (1 V) in a vacuum. 1 keV = 1,000 eV. 1 MeV = 1,000 keV.

The Oscilloscope

Most oscilloscopes in nuclear laboratories have a plethora of knobs and adjustments for performing the various functions for which they were designed. Fortunately, only a limited number of these controls are necessary for observing input and output pulses from the modules, or for making simple timing adjustments. One can perform virtually all the necessary operations once proficiency with these commonly-used knobs is attained.

The particular model of oscilloscope supplied for this experiment may differ from the model shown in Fig. 1.3. However, the display and the functions of the various controls tend to be generic among all oscilloscopes. The laboratory instructor will be able to explain any differences from the example described here.

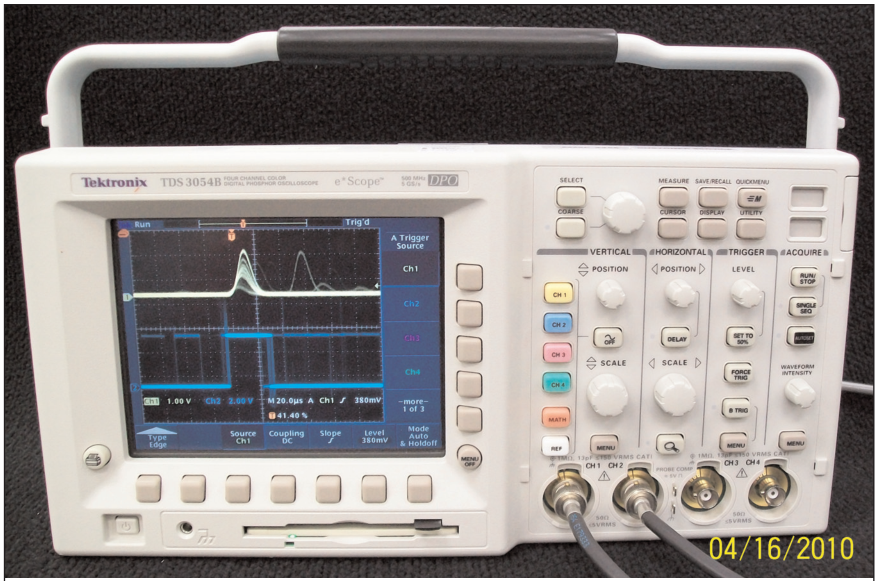

Figure 1.3. The Tektronix Model TDS 3054B Digital Sampling Oscilloscope.

The most important control to locate first is the power on/off button. In Fig. 1.3, that button is located in the lower left corner of the front panel. Turn the power on. The most prominent feature is the display that shows the signals captured by the oscilloscope. In Fig. 1.3, the yellow traces in the display are from the linear output of a pulse-shaping amplifier that is processing gamma-rays from a Cs137 radioisotope. The 662-keV gamma-rays are being detected by a high-purity Ge detector. The blue traces are the logic pulses from the BUSY output of the amplifier.

The inputs and controls that affect that display are described next.

Inputs

The oscilloscope in Fig. 1.3 accommodates up to 4 inputs (CH1, CH2, CH3, and CH4)[4] for simultaneous capture and display. (The oscilloscope provided with Experiment 1 may offer fewer inputs.) These inputs are BNC connectors spaced across the bottom right of the front panel. For most of the measurements in the series of Experiments in Nuclear Science, the outputs on the electronic modules will be provided on BNC connectors, and those signals will be fed to the BNC connectors on the oscilloscope using RG-62A/U 93-Ω coaxial cables, as illustrated on inputs CH1 and CH2 in Fig. 1.3. A menu option described later permits selecting the input impedance to be either 1 M Ω or 50 Ω. Normally, this should be selected to be 1 MΩ.

Vertical Controls

The column of yellow, blue, pink and white buttons to the right of the display permits selection of the input that will be displayed. Normally, CH1 is selected and the signal is connected to the CH1 input. In Fig 1.3, both inputs CH1 and CH2 have been selected for simultaneous display. The ~/OFF pushbutton to the right of the colored column of buttons can be used to disable the display of a particular input.

The two knobs to the right of the column of colored buttons enable shifting the signal up or down in the display (POSITION), and choosing the sensitivity of the vertical scale (SCALE). Pushing the grey MENU button will add the menu displayed on the right side and the bottom of the screen, as illustrated in Fig. 1.4.

The buttons adjacent to the menu blocks on the screen allow manipulation and selection of the options in the menus. Selecting a main menu option with any of the 7 buttons across the bottom of the screen pulls up a dependent sub-menu for the 5 buttons along the side of the screen. For example, the Coupling option has been selected with the extreme left button on the bottom. Subsequently, the DC option was selected with the top button and the 1-MΩ input impedance was selected with the lowest button on the side of the display.

To find out where the ground reference is in the display, push the 3rd programmable button from the top, the one opposite the GND block in the Coupling sub-menu. This can be useful for finding the location of zero volts in the vertical display. Normally, one would choose the DC coupling option offered by the top soft button. Although the AC coupling option can be convenient in a few cases

[4]The labels CH1, CH2, CH3 and CH4 imply Channel 1, Channel 2, Channel 3 and Channel 4.

where a small AC signal must be observed riding on a large DC level. The input impedance should be toggled to the 1 MΩ option for virtually all usage.

Via the bottom row of programmable buttons, select Invert Off, Bandwidth Full and Probe Setup 1X.

Across the bottom of the active region of the display, note that the currently selected vertical scales for CH1 and CH2 are displayed in Volts per major division (a.k.a., Volts per cm). Also, the horizontal time scale is listed (20.0 µs per major division), and the " ∫ " shape to the right of Ch1 indicates that the triggering is derived from CH1 on the rising edge of the pulse at a threshold of 380 mV.

If at any time it is desirable to hide the menu on the right side and bottom of the screen, the round MENU OFF button can be pushed at the lower right corner of the display.

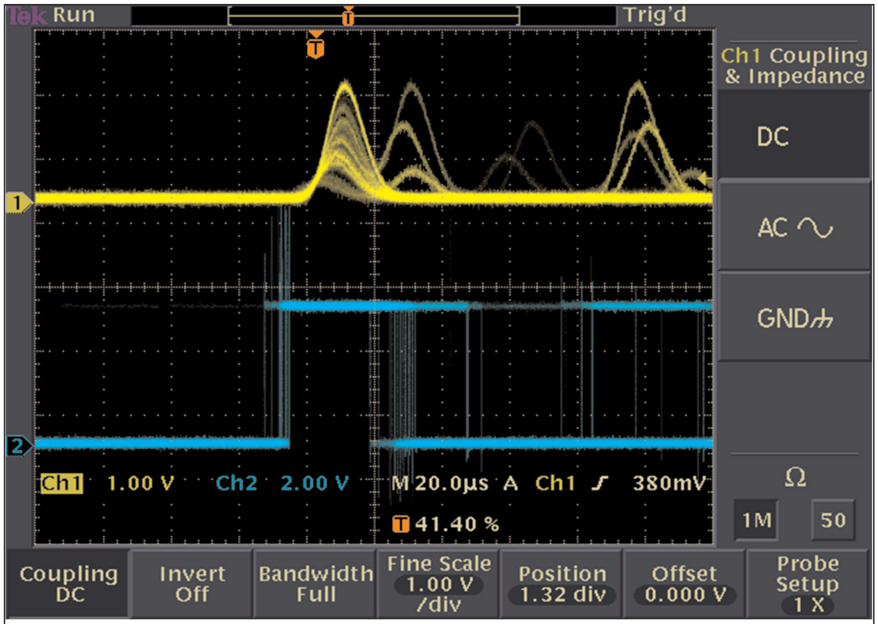

Fig. 1.4. The Vertical Scale Menu (Bottom) and the Coupling Sub-menu (Side) for Input CH1.

Horizontal Controls

Returning to the control knobs on the right side of the oscilloscope, consider the column of controls under the HORIZONTAL label. The small round knob adjusts the horizontal position of the signal in the display, while the large round knob selects the sensitivity of the horizontal time scale (ns, µs, ms and seconds).

Trigger Controls

The oscilloscope must be told which signals to capture and display, and when to recognize the arrival of those signals. That function is achieved via the controls under the TRIGGER heading to the right of the HORIZONTAL controls. Pushing the trigger MENU button will display the menu shown in Fig. 1.5.

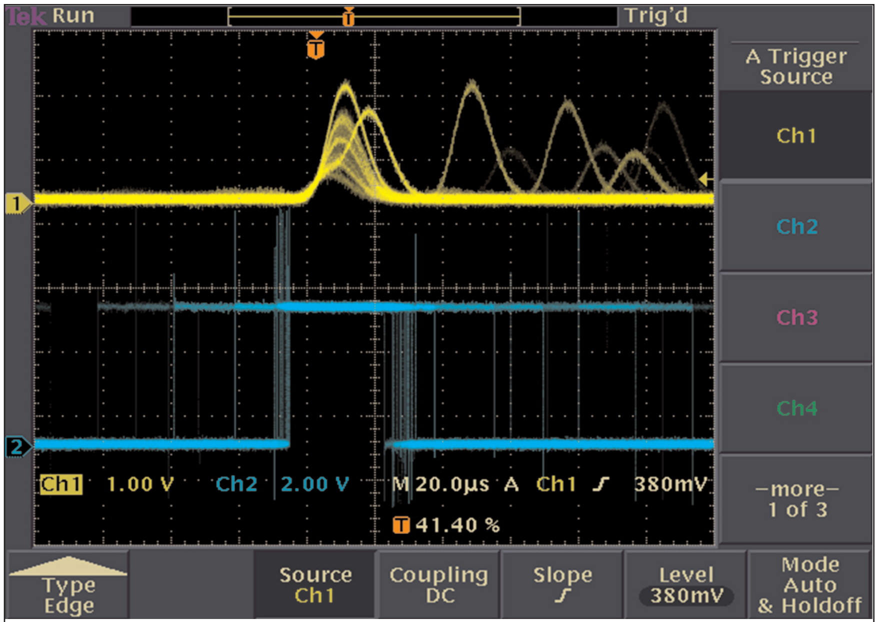

Fig. 1.5. The Trigger Menu (Bottom) and Source Sub-menu (Side).

Using the programmable buttons on the bottom and side of the display, chose the Edge triggering Type. Under the Triggering Mode, the Auto option can be useful for initially finding the signals. However, the Normal mode is recommended, because it provides more precise selection of the pulsed signals encountered in nuclear instrumentation. Select the input to be used for triggering. Normally, this will be CH1. In the displayed example, the operator has chosen to trigger on the rising edge of the pulse arriving in Ch1 when the pulse rises through the 380-mV threshold. That triggering threshold is adjusted by the round LEVEL knob under the TRIGGER group of controls. When triggering on a linear signal the LEVEL is typically lowered until the oscilloscope triggers on the noise in the input. Then the LEVEL is raise slightly above the noise until the pulses can be observed to be reliably displayed. When triggering on logic pulses, the LEVEL can be set half way between the upper and lower limits of the pulses.

Under the Coupling menu, select DC. For the Slope menu, choose the rising edge (∫ -shape) for positive signals or the falling edge (\ -shape) for negative signals.

Acquisition Controls

The column of ACQUIRE controls on the extreme right side of the oscilloscope allows a choice of continuously capturing signals or the acquisition of a single signal. Normally, this is operated in the continuous mode. The round knob permits adjustment of the display intensity. Pushing the Acquire MENU button will offer access to the acquisition features via the programmable buttons bordering the display. The AUTOSET pushbutton automatically sets up the oscilloscope to trigger on the CH1 signal and display it with appropriate vertical and horizontal scales. This can be used to find a signal quickly, so that subsequent adjustments can be made to optimize the view.

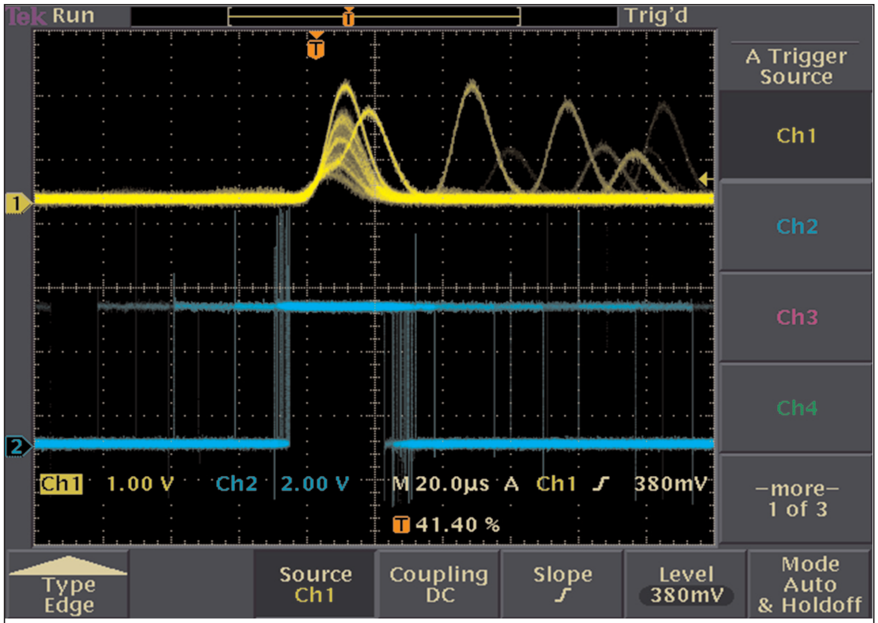

Fig. 1.6. The Quick Menu.

Quick Menu

Pushing the QUICKMENU button near the top right of the oscilloscope reveals the menu in Fig. 1.6. This offers access to the more commonly used functions. The Cursors can be turned off or on at the discretion of the operator. When turned on, the general-purpose knob near the top of the control panel can be used to position the cursors. The SELECT button to the left of this knob chooses the function controlled by the knob. The COARSE button can be pushed to make the knob cover a wider range more quickly. This COARSE button can also be used to modify the sensitivity of any of the knobs on the control panel. Selecting some of the menu functions from other menu buttons will require a numerical input. The general-purpose knob can be used to select the values for those entries.

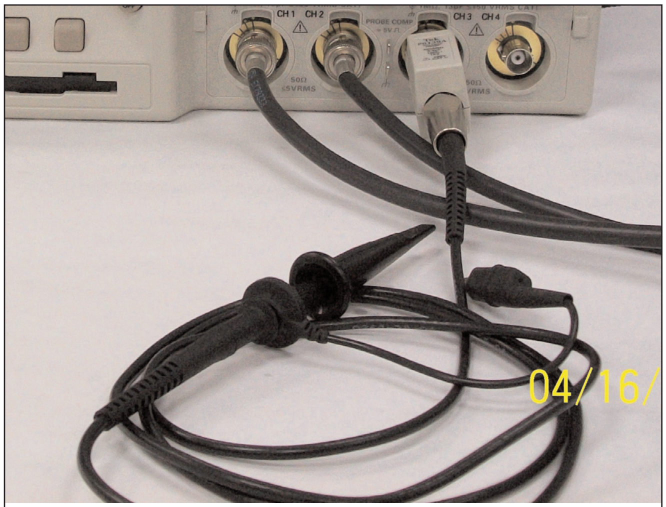

Fig. 1.7. The X10 Probe Connected to Input CH3.

The X10 Probe

Figure 1.7 shows the X10 probe connected to the Channel 3 Input (CH3) of the oscilloscope. This particular probe is useful for examining signals at sensitive points in an electronic circuit, because it has a high input impedance (10 MΩ) that causes minimal perturbation of the circuit. The probe achieves that high input impedance by inserting a 9-MΩ resistor between the measurement tip and the 1-MΩ input impedance of the front-panel oscilloscope input. That attenuates the measured signal by a factor of 10. So, perhaps a more appropriate name would be a 1/10 probe.

Place two fingers in front of the flange closest to the tip. Position the thumb behind the other flange, and squeeze to expose the metal hook at the end of the tip. This hook can be placed over a bare wire in the circuit, and the flanges released to leave the probe securely attached to the desired monitoring point in the circuit. A ground wire and alligator clip is attached near the rearmost flange. Connect this clip to a convenient grounding point in the circuit to establish the proper ground reference.

Sometimes, the hook is inconvenient, and what is needed is a sharp pin on the end of the probe to contact the desired measurement point. Grasp the flange closest to the end of the probe tip and pull the plastic hook enclosure off of the probe. This will expose a tip with the desired sharp pin. This pin is convenient for inserting into the center conductor of a BNC connector on the output of an instrument. Again, make sure the ground clip is attached to a good ground reference on that same module. To return to the hook function, simply push the plastic hook tip back onto the probe.

Some probes offer the option of replacing the tip featuring the sharp pin with a tip that has a much larger diameter pin, similar to the pin diameter found on the probes accompanying a voltmeter. This type of probe tip is convenient for insertion into the test points found on the front panels of Nuclear Instrumentation Modules (NIM).

Frequency Compensation: Because the resistive impedances in the X10 probe are so large, stray capacitance across the 9-MΩ resistor can distort the frequency response of the probe when coupled to the input capacitance of the connector on the oscilloscope. The X10 probe incorporates an extra capacitor that can be adjusted to make the high-frequency response of the parasitic, capacitive attenuator match the low-frequency response of the primary, resistive divider. In the model shown in Fig, 1.7, this calibration is achieved via a screwdriver adjustment in the probe's grey box next to the CH3 input. To make the adjustment, connect the probe hook to the PROBE COMP metal loop between the CH2 and CH3 inputs, and connect the ground clip to the ground loop just below that calibration signal loop. Push the AUTOSET button above the WAVEFORM INTENSITY knob on the extreme right side of the oscilloscope control panel. This will cause a 5-V, 1-kHz square wave to be displayed on the oscilloscope. Rotate the screwdriver control on the probe clockwise or counterclockwise until an ideal square wave is achieved with no undershoot or overshoot on the rising and falling edges. Ideally, this adjustment should be made again if the probe is moved to a different input, because the input capacitance can be slightly different.

Further Oscilloscope Details

There are additional sophisticated features offered by the oscilloscope. But, being familiar with the above basic controls should be sufficient for exploring the series of Experiments in Nuclear Science. The instruction manual for the oscilloscope can be consulted for further explanations of the controls. There may be a hard copy of that manual with the oscilloscope, or you may need to search the Internet for an on-line version of the manual by manufacturer and model number.

Table 1.1 lists suggested settings for starting the measurement. Deviations from these settings can be implemented to optimize the viewing and measurement.

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 480 Pulser is cabled directly to the oscilloscope input and the X1 probe setup will be used. For Experiments 1.2 and 1.3, the X10 probe furnished with the oscilloscope can be used for the circuit test connections. If that option is chosen, the X10 probe setup should be used. On some oscilloscopes, attaching the probe to the input automatically selects the correct sensitivity factor.

Table 1.1. Typical Oscilloscope Settings

Parameter	Typical Initial Setting
Input	CH1 for a single input; CH1 and CH2 for two inputs
Input Impedance	1 MΩ
Input Coupling	DC
Probe Setup	1X without probe. (Use 10X with 10X probe.)
Offset	0.00 V, then adjust for optimum viewing
Position	0.00 Divisions, then adjust for optimum viewing
Vertical (Fine) Scale	5 V/division, then adjust for optimum viewing of the pulse shape
Bandwidth	Full
Invert	Off
A Trigger Source	CH1
Mode	Normal (Auto used to initally find the signal)
Triggering Type	Edge
Slope	∫ (rising edge)
Coupling	DC
Level	Adjust for reliable triggering
Acquisition	Run; continuous sweeps
Acquire Mode	Sample
Acquire Fast Trigger	Normal
Cursor	Off
Waveform Intensity	Adjust for optimum viewing
Horizontal Scale	5 µs/division, then adjust for optimum viewing of the pulse shape

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 pulser will be fed into the test pulse input of the preamplifier. Typically, the pulser is turned on when the system must be calibrated. It is turned off when the nuclear radiation is being measured, because its exponential decay can perturb the baseline for the nuclear radiation pulses. The pulser may also be fed directly into an amplifier.

The pulser 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 by a front panel dial and will usually be employed 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 continuously varied from 0 to ~5 V via the pulse-height and calibration controls and the attenuator switches. The output polarity is selectable on the front panel. As is true for all NIM modules, the 480 Pulser must be installed in a NIM Bin and Power Supply, and the power supply must be turned on to provide the operating power to 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 the power off before inserting or removing any instrument module.

For this experiment and all succeeding experiments, keep the coaxial cables as short as is practical when interconnecting signals from the various parts of the measurement system. The exception to this guideline is when connecting the output of the preamplifier to the amplifier input, the pulser output to the test input on the preamplifier, and the high voltage bias supply to the preamplifier. Preamplifiers are designed for possible remote location from the supporting electronics in the bin and power supply.

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 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 Test Input on the preamplifier.
3. Find the 100-Ω terminator that is chained to the front panel of the 480 pulser, and connect that terminator to the ATTENuated OUTPUT of the pulser. This simulates the 100-Ω load that is normally driven by the attenuated output.
4. Set the 480 Calibrate and Pulse-Height controls fully clockwise, and select a positive output polarity. Set the oscilloscope parameters as listed in Table 1.1. Change the oscilloscope vertical scale to 1 V per major division and the horizontal scale to 100 µs per major division.
5. Trigger the oscilloscope by adjusting the Triggering Level control. If the trace will not trigger, re-check 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. 1.8. Note that in Fig. 1.8 the maximum amplitude appears at the beginning and is ~5 V. It may be necessary to adjust the Vertical and Horizontal Position controls to properly position the signal trace in the display.

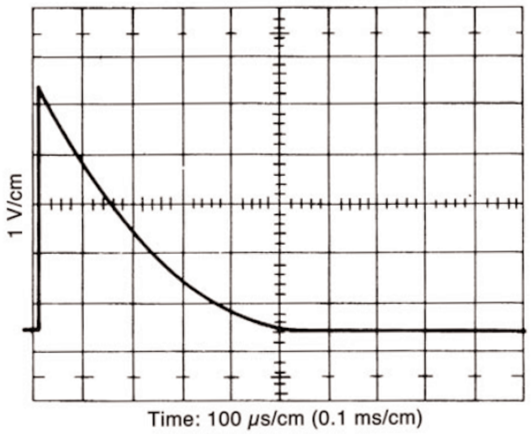

Fig. 1.8. Typical Pulse Generator Output.

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 ordinates can be changed by changing the Vertical Scale control referenced in Table 1.1. When this is changed, it may be necessary to readjust the triggering controls. The time per major division can be changed by adjusting the Horizontal Scale.

b. Set the Vertical Scale to 2 V per major division, and the Horizontal Scale to 0.2 ms per major division, and make a plot on centimeter graph paper of the picture observed.

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6. Now change the cable connection on the pulser to the ATTENuated OUTPUT, and transfer the chained 100 Ω terminator to the Direct 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 pulser is a 10-turn potentiometer with a dual-dial. There are 100 division marks for each turn of the dial for a total of 1000 divisions on the dial. The settings on the PULSE-HEIGHT dial can be represented as a ratio. For example, 90% of full clockwise would be 900/1000, etc.

EXERCISES

c. In Table 1.2, record the maximum voltage values observed on the oscilloscope for the pulse-height settings. The Vertical Scale will have to be changed to be able to make an accurate reading from the display as the pulse height is reduced by the dial setting.

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

Table 1.2

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

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7. Return the PULSE-HEIGHT dial to 1000/1000. Set the top attenuator switch on the 480 Pulser at X2. The amplitude of the pulse should decrease by a factor of 2.

   Try various combinations of these attenuator switches, and observe the output. When the output signals are attenuated, it will be necessary to change the oscilloscope Vertical Scale, and readjust the oscilloscope triggering controls 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

Set up the electronics shown in Fig 1.9 as follows:

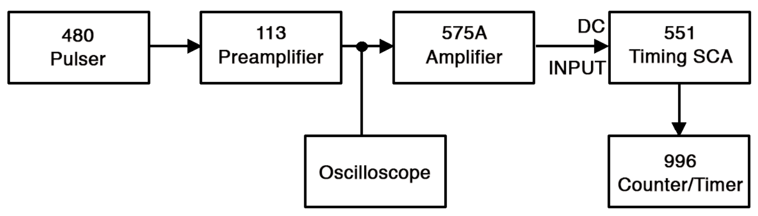

Fig. 1.9. Typical Counting System with Pulser Input.

1. Install the 480, 575A, and 996 in the bin and power supply.
2. Connect the power cable for the 113 Preamplifier to the PREAMP POWER connector in the rear of the 575A Amplifier.
3. Connect the ATTENuated OUTPUT of the 480 to the TEST PULSE input connector on the 113 Preamplifier. (Connections are always made with 93-Ω RG-62A/U coaxial cable and BNC connectors unless otherwise specified). The 100-Ω terminator is no longer required on the receiving end of this cable, because the 100-Ω termination is provided internally at the preamplifier test input.
4. Place the chained 100-Ω terminator on the DIRECT OUTPUT of the 480 Pulser.
5. Connect the OUTPUT of the 113 Preamplifier to the CH1 input of the oscilloscope. Do not use a 100-Ω termination at the oscilloscope input. The preamplifier incorporates a 93-Ω resistor in series with its output to provide series termination of the coaxial cable at the signal source.
6. Connect the stem of a BNC tee to the DC INPUT of the 551 Timing SCA. Using a 30-cm (1-ft.) coaxial cable, connect the 575A UNIpolar OUTput to one arm of the tee. The 551 will be set up as an integral discriminator.

Make the following control settings:

1. Set the INPUT CAPacitance of the 113 at 100 pF.
2. Set the 575A for a NEGative input.

3. Confirm that the three shaping time jumpers accessible through the side panel of the 575A are all set to 1 μs.
4. Set the 551 mode switch at INTegral, Lower-Level at 50/1000, and the rear toggle switches to INTernal STROBE and LL REF. This combination allows the 551 to operate as a threshold discriminator. On the front panel, set the Delay toggle switch to 0.1 – 1.1 μsec, and turn the DELAY dial counterclockwise to zero.

Procedure

1. Using the 480 ATTENuated OUTPUT, set its parameters as follows: PULSE HEIGHT, 1000/1000; CALibrate, fully clockwise; Output, NEGative. Other adjustments will be made later.
2. Adjust the 480 ATTENUATOR switches and CALibrate control so that the output pulses from the preamplifier have a pulse height ~0.1 V.
3. Trigger the oscilloscope by the methods shown in Experiment 1.1.
4. Now, connect the 113 Preamplifier OUTPUT to the 575A Amplifier INPUT.
5. Connect the second arm of the BNC tee on the 551 Timing SCA DC INPUT to the oscilloscope CH1 Input. Confirm that this routes the UNIpolar OUTput of the 575A Amplifier via the tee to the oscilloscope CH1 Input. Adjust the amplifier gain controls until the output pulses have an amplitude of 8.5 V. The oscilloscope parameters should be the same as those in Table 1.1 except that the Vertical Scale should be 2 V per major division, and the Horizontal Scale should be 1 μs per major division. The correct output pulse should look like the signal shown in Fig. 1.10.
6. With all other settings the same, connect the oscilloscope CH1 Input to the 575A BIpolar OUTput. The correct output pulse should look like the signal shown in Fig. 1.11. (Re-trigger the oscilloscope if necessary).
7. Reconnect the oscilloscope CH1 input to the other side of the tee on the 551 input. The oscilloscope should be viewing the UNIpolar OUTput of the 575A Amplifier.
8. Set the oscilloscope vertical scale for CH1 to 5 V per major division. Adjust the triggering level on the oscilloscope as low as possible, while still achieving reliable triggering. Shift the amplifier output signal to the upper half of the display, as shown in Fig. 1.4. This may require readjustment of the trigger level.

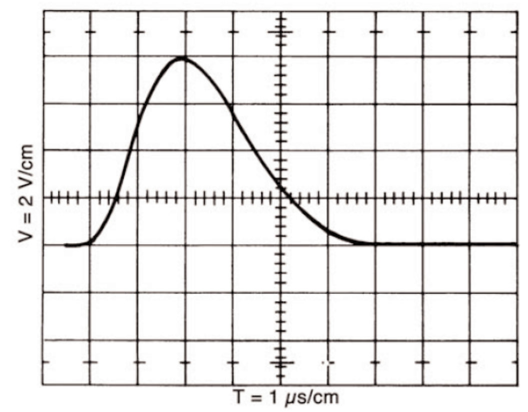

Fig. 1.10. Correct Unipolar Amplifier Output Signal.

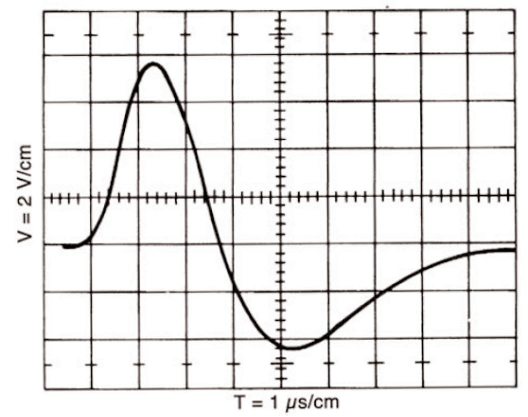

Fig. 1.11. Correct Amplifier Bipolar Output Signal.

Determining Logic Criteria

1. Place a BNC tee on the POSitive INput connector of the 996 Timer/Counter. Connect one side of the tee to the 551 Timing SCA POSitive OUTput using a 30-cm (1-ft.) 93-Ω coaxial cable. Connect the other side of the tee to the CH2 input of the oscilloscope via a 93-Ω coaxial cable.
2. Using the colored buttons on the oscilloscope add the CH2 signal to the display, while still triggering on the CH1 signal and displaying the amplifier pulse. A 5-V logic pulse should be observed on the oscilloscope display. Adjust the CH2 vertical scale and vertical position to position the SCA output logic pulse similar to what is shown in Fig. 1.4.

EXERCISES

a. QUESTION: What is the width of the SCA output logic pulse?

b. QUESTION: What is the position of the logic pulse relative to the amplifier pulse, measured in μs from the beginning of the amplifier pulse, and also from the point of maximum amplitude on the amplifier pulse?

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3. On the 996 Timer/Counter, push the TIME BASE button repeatedly to select the 0.01-MINute time base. Push the DISPLAY pushbutton to select PRESET. Under the PRESET buttons use the SELect and ADVance buttons to set M=3, N=0 and P=2. This selects a preset time limit of 30 minutes for counting.

4. On the 996 Timer/Counter press the COUNT button. The 996 should begin counting the 551 output pulses. If the 996 does not count the pulses, it may be necessary to adjust the positive input THRESHold. Turn the screwdriver adjustment clockwise or counterclockwise to achieve reliable counting. The screwdriver adjustment operates a 25-turn potentiometer to set the POSitive INput threshold between +100 mV and +9.5 V. The nominally desirable +1.6-V threshold can be accomplished by turning the potentiometer counterclockwise until it clicks, followed by turning the control clockwise 4 turns. Note that the COUNT and STOP pushbuttons on the 996 are used to start and stop the counting function. The RESET button is used to clear the contents of the counter.

EXERCISES

c. Now, increase the setting of the 551 LOWER-LEVEL control until the counter just stops counting. Record the control setting on the first line of Table 1.3.

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

e. Decrease the 551 LOWER-LEVEL control until the counter just barely starts to count. Record this setting in Table 1.3, and repeat the process for the other settings in Table1.3.

f. 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 to NORmal. This changes its function from an integral discriminator to a single-channel analyzer. Instead of the POSitive OUTput, connect the LL OUT (Lower Level Output) on the rear panel of the 551 to the tee on the 996 Counter POSitive INput.

EXERCISES

a. Use the LOWER-LEVEL control of the 551 to adjust the discriminator levels for various settings of the 480 PULSE-HEIGHT control, and fill in Table 1.4 per the methodology used for Table 1.3. With this connection, the 551 operates the same as it did in the Integral mode. That happens because the LL OUT generates an output logic pulse every time the linear input pulse exceeds the lower level threshold, regardless of the setting of the front-panel mode switch. Readjustment of the CH1 Vertical Scale and Triggering Level may be necessary to observe the lower amplitude pulses.

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.

c. QUESTION: What is the width of the LL OUT pulse?

d. QUESTION: What is the relative position in time of the LL OUT logic pulse compared to the amplifier pulse?

Table 1.4

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

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2. Move the output connection of the 551 from LL OUT to either the SCA OUTput connector on the rear panel or the POSitive OUTput connector on the front panel. (Output pulses are identical through these two connectors.) This connects the SCA output to the 996 counter input.

3. Set the SCA in the WINdow (differential) mode via the front-panel switch. Set the Lower-Level control at 100/1000 and the Window (Upper-Level) control at 100/1000.

EXERCISES

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

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

g. Repeat steps e and f for the settings listed in Table 1.5.

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

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

j. QUESTION: What is the width of the SCA OUT logic pulse?

k. QUESTION: What is the position in time of the SCA OUT pulse relative to the point of maximum amplitude on the amplifier pulse?

l. QUESTION: Why is the relative time position of the logic pulse different for the LL OUT and the SCA OUT? For answers, consult Reference 3 on Single-Channel Analyzers/Introduction.

Table 1.5

Lower Level	Window or Upper Level	ΔE Upper	ΔE Lower
100/1000	100/1000		
100/1000	300/1000		
100/1000	600/1000		
100/1000	800/1000		

Table 1.6

Lower Level	Window or Upper Level	ΔE Upper	ΔE Lower
200/1000	100/1000		
200/1000	300/1000		
200/1000	600/1000		
200/1000	800/1000		

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4. Place the toggle switch on the 551 in the NORmal position. With the switch in this position, the 551 front-panel Upper-Level and Lower-Level controls are independently variable from 1 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 551 SCA output. With this in mind, complete the last Exercise.

Table 1.7

Lower Level	Window or Upper Level	ΔE Upper	ΔE Lower
200/1000	100/1000		
200/1000	300/1000		
200/1000	600/1000		
200/1000	800/1000		

EXERCISE

l. With the setting from step 4., Repeat the measurements for Table 1.7 with the Lower Level set at 200/1000 as in Table 1.6.

m. Do the results in Table 1.7 support or conflict with the statements in step 4.?

References

1. For additional information on oscilloscopes and sources of instruction manuals, consult the Tektronix web site at www.tek.com, the LeCroy site at www.lecroy.com/oscilloscope/, or the website for the manufacturer of the particular oscilloscope supplied for Experiment 1.
2. For additional information on the NIM Standard, go to www.ortec-online.com, select SOLUTIONS, PRODUCT CATEGORIES, and MODULAR ELECTRONICS INSTRUMENTS. Information on the NIM Standard is accessible from the OVERVIEW page.
3. Further information on how nuclear electronics works can be found in the Introduction sections for the NIM products accessible via the route in reference 2.
4. Information on how nuclear radiation detectors work can be found at the site in reference 2 by selecting SOLUTIONS, PRODUCT CATEGORIES and RADIATION DETECTORS.