EXPERIMENT 1K: BASIC PULSE ELECTRONICS

The purpose of this experiment is to acquaint the student with some of the fundamental instruments and methods used in amplifying, shaping, analyzing, and counting pulses produced by nuclear radiation detectors. You may want to refer to Experiment 1 in the ORTEC Laboratory Manual AN-34; this is very similar.

Equipment

NIM minibin and power supply
NIM instrument modules:
pulse generator
ORTEC M/485 linear amplifier
ORTEC M/420A timing single-channel analyzer
counter/timer or count-rate meter
Tektronix M/2213A 60 MHz oscilloscope
ORTEC M/113 preamplifier

Introductory

Nuclear detectors respond to individual events - the arrival of individual particles or photons - and most kinds of detectors respond by creating a pulse of current in an electronic circuit. In many kinds, the amplitude of the pulse from the detector is significant, in that it is proportional to the energy, or perhaps some other property, of the particle that triggered the detector pulse. As a result, a great many electronic instruments have been developed for counting, sizing, timing, amplifying, analyzing, and otherwise massaging the pulses from nuclear radiation detectors. In this experiment you'll get acquainted with two essential instruments: the linear amplifier and the single-channel analyzer.

A. The Oscilloscope and the Pulse Generator

The oscilloscope you'll use here is a Tektronix model 2213A or something very similar. The front panel of an M/2213A is shown in Figure 1 on the next page.

The pulse generator you'll use operates installed in a "NIM (Nuclear Instrument Module) bin"; the bin supplies its power. Other instrument modules that you'll use work in the same way. The bin can accommodate any of these modules, in any configuration, and supply power to them. Always turn OFF the bin power before inserting or removing any instrument module.

1. Install the pulse generator module in the NIM bin. Connect a coaxial cable from the direct output of the pulse generator to the Y input of the oscilloscope. A terminator plug should be connected to the other (attenuated) output. Turn on the power to the NIM bin.

2. Set the pulse-height control on the pulse generator to its maximum value, and the output polarity to +.

3. On the oscilloscope, set the V/div control (13) to 1 and the variable volts/div (15) knob fully clockwise, for a vertical deflection sensitivity of 1.0 volt per cm. Set the input coupling switch (14) to AC. Set the sec/div

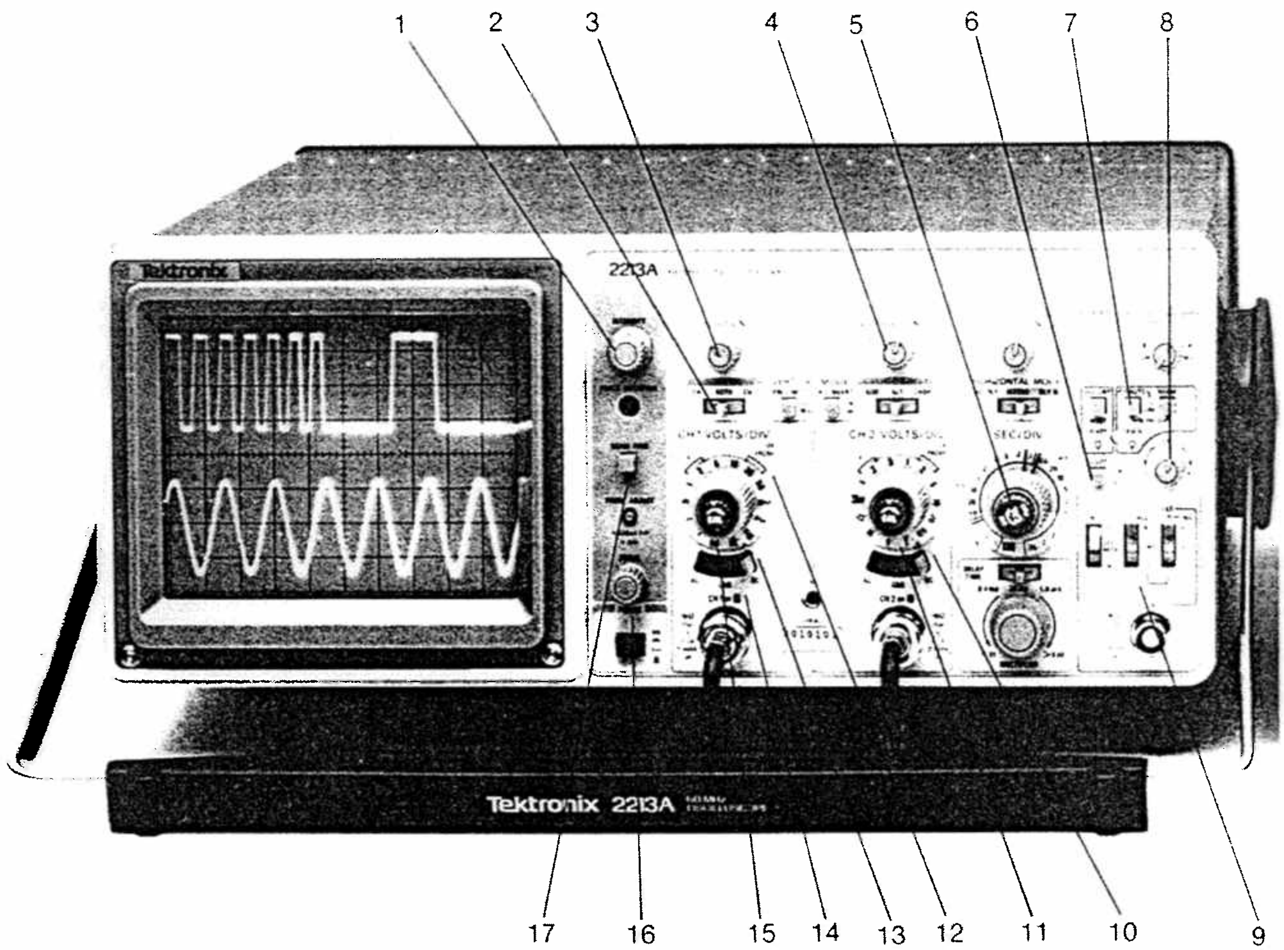

Figure 1 Tektronix M/2213A Oscilloscope — Front Panel

switch (5) to 0.1 ms, providing a horizontal sweep rate of 0.1 milliseconds (100 microseconds) per cm. Set the triggering slope switch (7) to + and the triggering level (8) to midscale. Change the triggering mode control (7) from automatic to normal.

4. Turn on the pulser. If you hear a faint buzzing noise, that's normal! Adjust the triggering level on the oscilloscope (8) until you see a display like that in Figure 2. Adjust the position controls until the baseline of the trace is on the grid line 3 cm below midscale, and the rise is along the left-hand edge of the scale. (The rise is very fast and nearly invisible. See if you can expand the scale enough to estimate the rise time; it will be less than 1 μsec. Then return the horizontal scale to 100 μsec/cm.)

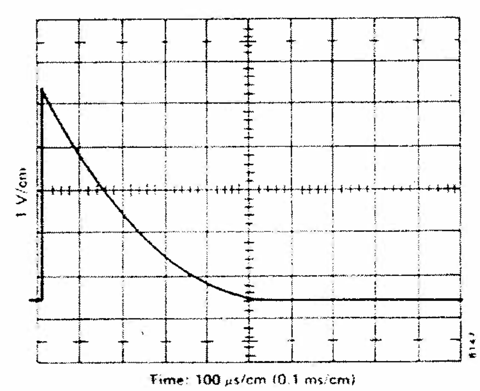

Figure 2 Pulse generator output

5. Note the approximate amplitude and duration of the pulse. Using the grid lines on the scope face as a guide, sketch the trace you observe quantitatively in

your notebook.

6. Mess around with all the controls until you have a clear idea of what they do. Note that (5) and (13) are your basic control over the scale of the display.

7. Now change the cable connection on the pulser to the attenuated output. All attenuation switches should be at X1. Leave the pulse height control set at maximum. (This control is a 10-turn pot with a dual dial. Read the digit in the window, then a decimal point, then the 100-division dial reading. Maximum setting is 10.00.)

8. Make a table like the one at the right, recording the amplitude (the maximum voltage) of the oscilloscope trace for each of the indicated settings on the pulse-height dial. You may have to adjust the triggering controls to keep the trace on the scope, but don't change the vertical scale setting. Make a graph of pulse amplitude vs pulseheight dial setting. It should be a straight line, to within your experimental error. Is it?

pulser setting	amplitude on scope
10.00	
9.00	
8.00	
etc.	

9. Set the pulse-height dial back to 10.00, and set the first attenuator switch on the pulser to X2. Read the amplitude of the oscilloscope trace, and use the graph you just drew to read the equivalent pulser setting. It should be around 5.0; the function of the attenuator switch is to reduce the pulser signal by exactly one half. Try various combinations of the attenuator switches to see what they do. (It may be necessary to readjust the vertical scale and triggering level controls on the oscilloscope.)

B. Using the Pulser as Input to a Typical Counting System

A linear amplifier is a circuit that produces an output pulse whose amplitude is directly proportional to (but usually much larger than) that of the input pulse. The amplifier is linear only in the sense that this proportionality holds; the duration, shape, etc. of the input pulse need not be preserved.

A single-channel analyzer is a circuit that produces an output logic pulse if and only if the input pulse amplitude is within fixed, settable limits. By a "logic" pulse we mean a pulse of a standard shape and size that is either generated or is not: yes or no, on or off, a binary logic value. The output logic pulse, when there is one, is unrelated to the shape, amplitude, or duration of the input pulse. Used together, the two circuits can be employed to measure the distribution of pulse heights coming from a detector — in a word, the pulse-height spectrum.

1. Turn off the power to the NIM bin. Install the ORTEC model 485 linear amplifier, the model 420A timing single-channel analyzer, and a counter-timer in the bin, and connect them as shown in Figure 3 on the next page. The junctions are made using a BNC "T" connector. The M/113 preamplifier is a separate unit, but its power is drawn from the bin via a connector on the back of the linear amplifier module.

2. Set the 485 for a positive input and a unipolar output. Set the attenuator switches on the pulser for a total attenuation of about 50X. With the pulse-height dial set at 10.00, this should produce pulses (from the pulser) of the order of 0.1 V amplitude.

3. The oscilloscope is now displaying the output pulses from the M/485 linear amplifier. Set the amplifier gain to something on the order of 40 or 50 (note that the gain setting is the product of the coarse and fine switch settings), and adjust the scale and triggering controls until you get a display that looks

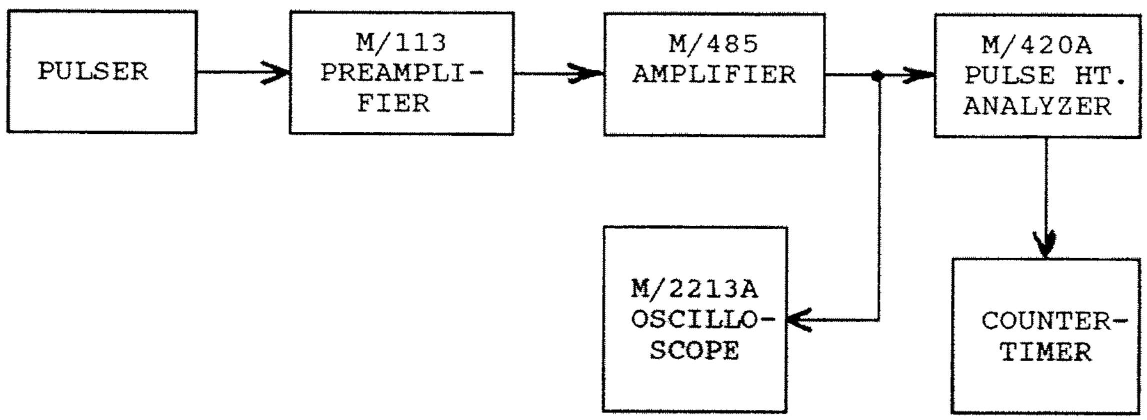

Figure 3 Typical Counting System With Pulser Input

something like that in Figure 4. Now adjust the amplifier gain until the output pulses, as closely as you can tell, have an amplitude of 8.00 V.

4. Leaving all other settings the same, switch the 485 output to bipolar. The output pulse should look something like that in Figure 5 (you may have to adjust the oscilloscope triggering).

5. Return the amplifier output switch to unipolar. Now double the gain setting on the amplifier. You <u>won't</u> see the pulse of Figure 4, increased to 16 V high. What is happening instead? Now set the gain back where it was. The pulse on the display should be that of Figure 4 again.

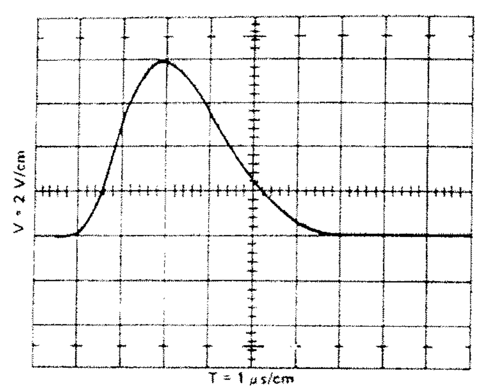

Figure 4 Unipolar Output Pulse

6. Set the pulse-height dial on the pulser to 5.00. Record the amplitude of the pulse on the oscilloscope display. Now double the gain setting on the amplifier, and again record the output pulse amplitude.

7. Vary the amplifier gain and pulser output controls until your data clearly demonstrate the functions and limitations of the amplifier module.

8. Return all the controls to their initial settings. If necessary, trim the 485 gain until the output pulse amplitude is, as closely as you can tell, 8.00 V. Now set the pulse generator dial to 9.00, and record the amplitude of the amplifier output pulse as precisely as you can. Continue taking data in this way until you can plot a graph of amplifier output pulse height vs. pulser setting. If your amplifier is linear, this should be a straight line. Is it?

C. Pulse Height Measurement

1. The single-channel analyzer has three 10-turn controls; the middle one is labelled "E". Set this to 0.50 V. Set the left-hand switch to UNIPOLAR and the righthand one to INT. What you have now is a circuit that will send an output pulse to the counter if and only if the pulse coming into it has an amplitude greater than the setting on the "E" dial.

2. Set the pulser and amplifier controls back to the point at which the amplifier output has an amplitude of 8.0 V. Start the scaler; it should be counting here at about 60 counts/second. The scaler is being used here just as an indicator that you are getting counts out of the SCA.

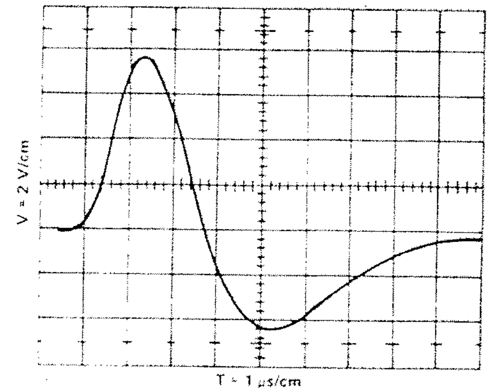

Figure 5 Bipolar Output Pulse

3. Turn up the E dial on the SCA until the scaler just stops counting. Record the E dial setting. Now decrease the pulse-height dial on the pulser to 9.00. Measure and record the amplitude of the pulses on the oscilloscope. Decrease the E dial on the SCA until the scaler <u>just</u> starts counting again, and record this E dial value, and you have found the pulse height (on the oscilloscope screen) that corresponds to a setting of 9.00 on the E dial of the SCA. Continue taking data in this way until you have spanned the whole range of the pulser dial.

pulse height on scope	cutoff E dial setting
8.0 V	
7.5 V	
7.0 V	
etc.	

4. This illustrated the function of the E dial. If the pulse coming into the SCA has an amplitude larger than the setting of the E dial, an output pulse is generated; if not, not. Ideally, the ratio of E dial cutoff setting to critical pulse height should be 1.00; what is it for your data? Is your SCA functioning as it should?

5. Connect the positive output of the single channel analyzer to input channel 2 on the oscilloscope, switch the scope to channel 2, and adjust the channel 2 controls ((10), (11) in Figure 1) to see the SCA output pulse. It will look something like Figure 6. Adjust the pulse-height setting on the pulser and/or the amplifier gain, and notice that the size of the input does not affect the logic pulse from the SCA.

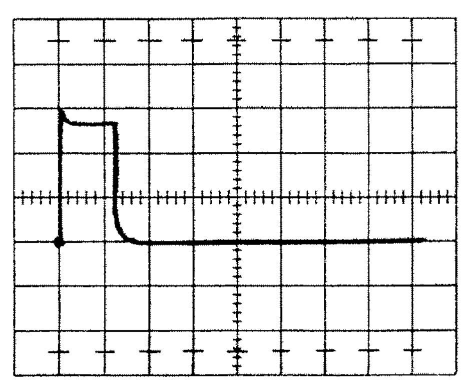

Figure 6 SCA Logic Pulse

6. In the mode in which we've been using the single-channel analyzer, it functions as a <u>discriminator</u> circuit: it gives an output if the input signal is bigger than a set level; if not, not. If the righthand switch is set to DIFF, on the other hand, the analyzer will give an output pulse if and only if the input pulse is within a certain range of amplitude, from E to E+ΔE. Now set this switch to DIFF.

7. Set the oscilloscope back to channel 1 so that you are looking at the pulses being input to the SCA. Set the pulse-height dial on the pulser to 1.00, the E

dial to 2.00, and the ΔE dial on the SCA to 1.00. Increase the pulse-height dial until the scaler just begins to count, and record the dial setting and pulse height on the scope. Continue to increase the pulser dial until the counting stops again, and record this value also. The analyzer is responding to input pulse heights only in the range you have just measured. How well does the difference between the two pulse heights correspond to the setting of the ΔE dial?

8. Reset the E dial to a different baseline value, leaving the ΔE dial at 1.00, and repeat the measurement above. If the analyzer is functioning properly, you should get a different range of pulse heights, but a range of the same width.

9. Repeat this measurement for several other E and ΔE settings. If the analyzer is functioning properly, it should give an output pulse when the pulse input to it has a height greater than "E" but less than "E+ΔE". Is this what you observe?

10. Change the amplifier and SCA switches to use BIPOLAR pulses from the 485. Repeat enough of the measurements above to determine whether the functions are any different for bipolar pulses.

D. Single-Channel Analyzer Timing

Set the oscilloscope to display both input channels, triggered by channel 1. Set the instruments back to UNIPOLAR pulses. Adjust the controls on the various instruments until you see both the amplifier output pulses and the SCA output pulses on the scope. Diddle with this arrangement until you have a good sense of how to answer the following questions.

1. How is the time delay between SCA input and output pulses affected by the size of the input pulse, and by the SCA settings?

2. Do the answers to question 1 change if you operate on bipolar, rather than unipolar, amplifier pulses?