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**SINGLE CHANNEL PULSE-HEIGHT ANALYZER
WITH READOUT**

Bradley E. Martin

Modules for Radiation Detection Systems and related items will be grouped in a series of reports beginning with RFP-2300 through RFP-2325. RFP-2304 represents a continuation in the series.

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GOLDEN, COLORADO 80401

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Product and Health Physics Research
ELECTRONICS GROUP

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SUBJECT DESCRIPTORS

Single Channel Pulse-Height Analyzers
Wound Counting Systems
Gamma Spectrometers
Electronics
Monitoring Systems
Nuclear Instrumentation Bin

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SINGLE CHANNEL PULSE-HEIGHT ANALYZER WITH READOUT

Bradley E. Martin

Abstract. In developing radiation-detection instrumentation at Rocky Flats Division, a system concept using plug-in modules was planned. Losses of operational time due to maintenance are drastically reduced as a malfunctioning module can be replaced within minutes. Versatility is another advantage of the modular concept. A particular module can be used in many different system designs. A significant cost savings in system development can also be realized.

The single channel pulse-height analyzer described is housed in a one-wide Nuclear Instrumentation Bin (NIM-BIN) module. The design uses the latest COS/MOS (complementary symmetry metal-oxide semiconductor) integrated circuits (IC) featuring low power, low cost, and high reliability. The module was developed specifically for isotopic identity in radiation-detection systems.

INTRODUCTION

The single channel analyzer (SCA) with readout module is described. Model 27213-42 was developed for isotopic identification in radiation-detection systems. Low power consumption makes the model ideal for battery-operated instrumentation.

The SCA has importance in determining the level of contamination for a particular isotope. Under the Health Physics monitoring program at Rocky Flats Plant, concerted efforts are directed towards improvements in safety, state-of-the-art applications, and the reduction of operating costs.

DISCUSSION

Description:

Model 27213-42 is a single channel pulse-height analyzer with a scaler and readout located in the same package.

The SCA consists of two integral discriminators that are set to different levels. Signals occurring between these settings produce an output pulse. Those signals above the upper level and below the lower-level settings do not generate any output. The output from the SCA is applied to the scaler which counts up and stores the pulses. The readout is continuously available at the front panel if the display switch remains in the normal position. The display may be left in the *OFF* position and the push-to-read feature be used to conserve power (an advantage in battery-operated systems).

The complete module appears in Figure 1.* Figure 2 is an interior view of the module and shows the three printed circuit boards (PCB): the SCA-PCB, the scaler PCB, and the readout PCB.

The SCA-PCB uses four COS/MOS ICs and one transistor. The power requires +12 volts at 2 milliamperes. The input impedance is 1K ohms ($K = 1000$) and the output impedance is 50 ohms.

The scaler PCB uses six COS/MOS IC decade-divider counters and six bipolar IC-transistor arrays as current boosters for the COS/MOS ICs.

*Illustrations follow at end of text.

The MAN-64A seven-segment light-emitting diode (LED) displays are located on the readout PCB. The readout PCB joins to the scaler PCB at a right angle by a unique connector. The connector eliminates the massive cable harness, common to many such units.

The scaler and readout assembly and the SCA-PCB are mounted to the right-side rails of the module case. All circuitry is accessible for easy maintenance.

The front panel features a *black magic* type display, made of red-translucent plastic. The back side of the panel is painted flat-black, with exception of the LED viewing area. Normally, the panel appears dark, but when the LEDs are illuminated, they show through the plastic and provide a clear, eye-pleasing display.

The rear panel (Figure 3) shows the upper- and lower-level discriminator controls and the SCA input and output receptacles. The NIM-BIN connector routes power and control functions into the module.

Block Diagram:

Figure 4 shows the SCA Model 27213-42. Pin 26 of the NIM-BIN connector supplies 2.5 volts AC to the readout PCB through S1. The switch (S1) provides a continuous display in the normal mode and a momentary display in the push-to-read position.

Pin 27 of the NIM-BIN connector delivers +5 volts DC to the scaler PCB and Pin 16 provides +12 volts DC to the SCA-PCB. The reset from Pin 24 and the enable from Pin 22 are control inputs to the scaler PCB. The SCA-PCB receives signals from the SCA input receptacle and processes them in accordance with the settings of the upper level discriminator (ULD) and the lower level discriminator (LLD). The signals falling between these settings produce an output to Terminal 1 of the scaler PCB and to the SCA output receptacle.

The scaler counts up and stores the output pulses produced by the SCA and the readout displays the number of pulses counted.

Specifications for Pulse-Height Analyzer:

Input Signal Requirements:

Shape	—	Unipolar or Bipolar
Polarity	—	Positive
Amplitude	—	0.5 to 10 volts
Input Impedance	—	1K ohms

Output Signal Characteristics:

Shape	—	Rectangular
Polarity	—	Positive
Amplitude	—	8 volts, open circuit 4 volts, 50-ohm termination
Width	—	1 microsecond
Rise Time	—	30 nanoseconds
Fall Time	—	100 nanoseconds
Output Impedance	—	50 ohms
Power Requirements	—	+12 volts DC at 2 milliamperes

Timing Chart:

Figure 5 shows a timing chart and a logic diagram of the pulse-height SCA. The input signal is applied through the threshold control circuitry to A1, the ULD, and to A2, the LLD. If the input signal exceeds the threshold setting of A2, then A2 produces a two-microsecond pulse.

The pulse is differentiated and the trailing edge is used to trigger A3, the inhibit, and A4, the gate. A one-microsecond output pulse is generated by A4. If the input signal also exceeded the threshold setting of A1, then A1 produces a four-microsecond pulse which couples to A4 as a disable and stops A4 from generating an output. The inhibit circuit, A3, produces an 8-microsecond pulse which keeps A1 and A2 from being retriggered. Transistor Q1 is an emitter-follower circuit that provides a 50-ohm output impedance.

Circuit Analysis:

Figure 6 shows a schematic diagram of the SCA-PCB. The input signal from the jack (J1) is divided-by-four by resistors R1 and R2 and coupled to A2 through the capacitor, C4, and to A1 through C3. The trigger threshold (TT) of A1 is determined by R5, R6, and R-ULD, and the TT of A2 is determined by R3, R4, and R-LLD. Knob pots R-ULD and R-LLD, located on the rear panel, are the adjustable discriminator controls for the unit. Trimpots R3 and R5 (resistors) are set at initial calibration and should not be adjusted except when IC replacement makes recalibration necessary.

Components C7 and R13 determine the two-microsecond pulse width from A2 and C8 and R14 determine the four-microsecond pulse width from A1. The pulse from Pin 11 of A2 is differentiated by C9, R11, and L1. Diode D1 shunts the negative spike to ground and dampens the oscillations caused by L1. The positive pulse representing the trailing edge of the pulse from Pin 11 is used as a trigger for A3 and A4. The pulse from Pin 10 of A1 is coupled to Pin 6 of A4 as a disable.

Circuit A4 functions as a gate. If the trigger is applied without the disable, then A4 produces a one-microsecond pulse at Pin 10. Component C5 and R10 determine the pulse width at Pin 10 of A4. If no trigger is applied or if the trigger and the disable are both applied, then A4 will not generate an output. The inhibit circuit, A3, is triggered by A2. An 8-microsecond output pulse is determined by C6 and R12. This pulse acts as

an inhibit to A1 and A2 and keeps them from being retriggered during the processing of a signal. A 50-ohm output impedance is established by the transistor (Q1), R7, R8, and R9. Proper filtering for COS/MOS circuitry is provided by C1 and C2. Figure 7 is a component layout for SCA-PCB.

Figure 8 shows a schematic diagram of the scaler PCB. Output pulses from the SCA-PCB are applied to Terminal 1. The scaler PCB, 320-01014, is used in other modules. In this application, A1 is not used and a jumper wire is placed between Pin 5 and Pin 6 of the A1 position. This couples the input pulses from R1, D1 to Pin 1 of A2. Approximately three volts are necessary to trigger A2. In order to protect the internal circuitry of A2, R1, and D1, limit the maximum voltage at Pin 1 of A2 to 4.7 volts.

A six-decade ripple counter is formed by A2 through A7 providing a maximum counting range of 999,999. The decade counters used are COS/MOS CD-4033AE ICs, with decoded seven-segment display outputs and zero-blanking. Pin 3 of A2 is the zero-blanking output and it connects to Pin 4 of A3. The zero-blanking function keeps the readout from displaying nonsignificant zeros. Pin 5 of A2 is the carry-out and connects to Pin 1 of A3. It provides one output pulse for every ten input pulses. Only the first decade of counting is shown for simplicity as the other five are typical. Pin 2 of A2 is the enable input and Pin 15 is the reset input.

Since the lamp-test function is performed in conjunction with the reset function, Pin 14 of A2 which is the lamp-test input is connected to the reset input.

The decoded seven-segment outputs from A2 are fed to A8. Similarly, the outputs from A3 are coupled to A9. This is typical for all decades. Integrated circuits A8 through A13 are transistor arrays which provide the necessary drive current for displaying the MAN-64As. The letters A through G represent the MAN-64A segments. Capacitors C1 and C4 provide proper filtering as recommended for COS/MOS circuitry.

Figure 9 shows a component layout for the scaler and readout PC boards. A pin description for the MAN-64A is also given.

OPERATING PROCEDURES

The following requirements and procedures are recommended when using the single channel pulse-height analyzer.

1. Plug SCA module in NIM BIN.
 - a. Power requirements:
 - (1) +12 volts, DC, Pin 16
 - (2) +5 volts, DC, Pin 27
 - (3) 2.5 volts, AC, Pin 26
 - b. Control requirements:
 - (1) Reset, Pin 22 (normally low, zero volts)
 - (2) Enable, Pin 24 (normally high, +5 volts)
2. Connect input signal to the SCA input jack on rear of panel. (Input impedance is 1K ohms.)
3. Turn on NIM-BIN power.
4. Adjust the LLD control to eliminate the signals that occur below the energy band of interest.
5. Adjust the ULD control to eliminate the signals that occur above the energy band of interest.

6. Place the display switch in the *NORMAL* mode for continuous readout or in the *PRESS-TO-READ* mode for momentary readout. (The press-to-read mode conserves power in battery-operated systems.)
7. The SCA is ready for operation.

SERVICING OF MODULE

The chart is included as a troubleshooting guide to assist in the performance of unscheduled maintenance.

Problem	Cause
No SCA output	1. Faulty A3 2. Faulty A2 3. Faulty Q1
No LLD Control	1. Faulty A2
No ULD Control	1. Faulty A1
No lamp test No reset	1. No 2.5 volts, AC 2. No +5 volts, DC 3. Short on reset line (faulty CD-4033AE)
One or more MAN-64A segments do not light with lamp test	1. Burned out segment of MAN-64A 2. Faulty CA3081 3. Faulty CD-4033AE
Does not count during the enable interval	1. Faulty CD-4033AE
Counts continuously when disabled	1. Short on enable line (faulty CD-4033AE)

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FIGURE 1. Front View of Pulse Height Single Channel Analyzer.

FIGURE 2. Interior View of Pulse Height Single Channel Analyzer.

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17700-3

FIGURE 3. Rear View of Pulse Height Single Channel Analyzer.

FIGURE 4. Block Diagram of Single Channel Analyzer Scaler Module.

FIGURE 5. Logic Diagram (a) and Timing Chart (b) for Analyzer.

Legend

- R-ULD, R-LLD – knobpotentiometers
- R3, R5 – trimpotentiometers
- R1, R2, R4 and R6 ... R15 – resistors in ohms (Ω) (K = 1000)
- C1 ... C9 – capacitors [(values as noted in microfarads (μ f) or picofarads (pf))]
- Q1 – transistor
- D1 – diode
- L1 – coil [1 millihenry (mH)]
- LLD – lower level discriminator
- ULD – upper level discriminator
- J1, J2 – jacks
- V – volts
- Vdd, Vss – power supply connections

FIGURE 6. Schematic of Printed Circuit Board for Analyzer.

Legend

- LLD - lower level discriminator
- ULD - upper level discriminator
- A1 ... A4 - integrated circuit multivibrator
- R3, R5 - potentiometers
- R1, R2, R4, and R6 ... R16 - resistors in ohms (Ω) (K = 1000)
- Vdd, Vss - power supply connections
- C1 ... C9 - capacitors
- D1 - diode
- Q1 - transistor
- L1 - coil

COMPONENT LAYOUT

FIGURE 7. Component Layout for Analyzer.

FIGURE 8. Schematic of the Scaler Printed Circuit Board.

FIGURE 9. Component Layout for Scaler and Readout Printed Circuit Boards.