

# Instruction Manual



**Model PB-5**  
Precision Pulse Generator

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## WARRANTY

Berkeley Nucleonics Corporation warrants all instruments, including component parts, to be free from defects in material and workmanship, under normal use and service for a period of one year. If repairs are required during the warranty period, contact the factory for component replacement or shipping instructions. Include serial number of the instrument. This warranty is void if the unit is repaired or altered by other than those authorized by Berkeley Nucleonics Corporation.

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# SECTION 1

## OPERATIONS

### 1.1 INTRODUCTION

The PB-5 sets a new standard for nuclear pulse generators. It offers full digital controllability with a built-in ramp generator. It provides tail and flat top pulses with excellent integral linearity and extremely low amplitude change with temperature. The PB-5 is capable of testing the stability, linearity and resolution of the most demanding spectroscopy circuits and instrumentation. It is the successor to the industry standard PB-4.

The PB-5 programmable precision pulse generator is menu-driven utilizing a 16-bit Microcontroller. The front panel consists of a LCD display, keypad, and a spinner knob for selection of parameters and fine adjustments. A precision 16-bit DAC in conjunction with a 10-bit 'trim' DAC is used to obtain excellent linearity and resolution over the 0 to 10-volt range. When driving 50-ohm loads the output range is 0 to 5 volts (without affecting stability, linearity, or pulse shape). Temperature compensation is performed with an algorithm in software allowing precision (16-bit) settings and repeatability within +/- 5 ppm/deg C. Digital control is either manual or by RS-232 interface. Menu selections, such as saving/recalling pre-programmed configurations, provide many new features not previously available. The PB-5 will not require a separate ramp generator for linearity tests since it produces a digitally controlled linear ramp that will accurately test large multi-channel analyzers.

### 1.2 PRINCIPLES OF OPERATION

The block diagram is shown in Figure 1. A microcontroller ( $\mu\text{C}$ ) and its flash memory control the PB-5. The  $\mu\text{C}$  receives external input commands from the keypad, spinner selector knob, RS-232 I/O port, and temperature sensor readings. The  $\mu\text{C}$  then converts these inputs to various codes that in turn drive the selected functions. When the unit is turned off the  $\mu\text{C}$  stores the last settings of the pulser so that these settings can be recovered upon powering up the unit. It has the capability of storing an additional nine pulse settings for recall at any time. The amplitude is generated by a 16-bit serial DAC. The pulse is created by an electronic switch within the Pulse Amplitude circuitry. Next the pulse is shaped and fed to the Attenuator control which has a 50-ohm series terminated output. The pulse parameters are shown to the user on a LCD display. These parameters are set by the keypad or by the spinner knob (optical encoder). The spinner has a push switch for enabling and selecting the user values. The spinner performs the same functions as the keypad but it is much easier to use. The keypad on the other hand allows a precise setting to be entered (e.g., amplitude 1.256750 volts for precision and repeatability).

The External Pulse Input passes through a limiter circuit and an adjustable level discriminator. The Input discriminator is controlled by a 10-bit serial DAC.

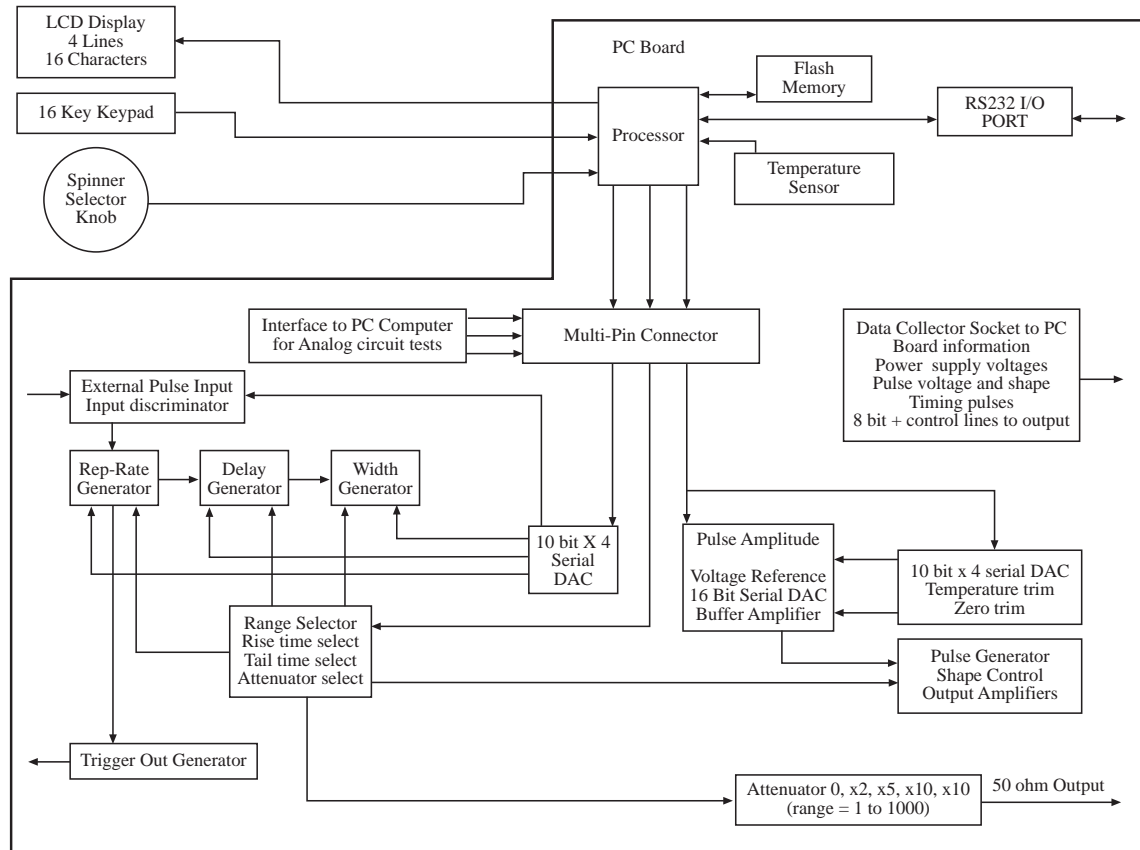


FIGURE 1. Block Diagram of Model PB-5 Precision Pulse Generator

The Trigger Out Generator provides a pulse synchronized with the beginning of the rep-rate generator or the External Pulse Input. This provides synchronization with the target instrument.

The pulse Rep-Rate, Delay, and Width Generators are controlled by the Range Selector and the associated 10-bit DAC voltage. The pulse rise and fall times are selected via the  $\mu$ C selector bus, providing shape control to the output amplifiers.

Temperature Sensor information is sent to the  $\mu$ C which in turn operates the Temperature Trim DAC. Very fine adjustments (error corrections) are made to the amplitude every 5 minutes. When in the Ramp mode, corrections are made only between ramp cycles.

The RS-232 I/O port provides connection to a computer from a remote location. All the functions can be remotely controlled by a standard terminal or a PC operating in the HyperTerminal mode.

The pulse amplitude is set by a 16-bit DAC referenced to an accurate voltage source. A high-gain, low-drift amplifier buffers this voltage source. The output zero level is set by a zero trim-DAC controlling the buffer amplifier. During factory calibration the instrument is set so that the 0-10 volt range can be adjusted within the precision specified (150  $\mu$ Volts). The output attenuator has ten selections that produce attenuation factors from 1 to 1000.

Factory testing and calibration is provided via an external tester. A multi-pin connector separates the  $\mu\text{C}$  from the analog circuits. Normally they are connected together by this multi-pin plug. When the plug is removed a cable can be inserted from an external tester which provides the functions of the  $\mu\text{C}$ . In conjunction with this mode of operation a test socket, connected to vital circuit points, collects data that can be used by an external test computer. The tester can automatically find the calibration points to be placed in the  $\mu\text{C}$  memory.

### 1.3 FUNCTION OF CONTROLS AND CONNECTORS

The spinner knob is an optical encoder capable of slow or fast adjustments. Fine adjustments are made when the knob is rotated slowly. When the knob is rotated fast the parameter will change rapidly. Push the knob to make selections from the menu, rotate to desired value, and push again to select the value. To operate from the keypad, use the up/down keys and press the ENTER key to select.

The menu is easy to use since there are only two levels. To return to the main menu use the key on the keypad so marked, or push the spinner knob when in main menu position. One can use a combination of key pad and spinner knob or operate entirely with the spinner.

The ENTER key will allow sequential step selection of rise time, fall time, and attenuation. These are discrete values and therefore not entered with a specific value on the key pad (can also be selected with the spinner). Pulse amplitude is adjustable in increments of about  $150\ \mu\text{V}$  (better than 1 part in 64,000). Since this amplitude adjustment is very fine it will take many turns of the spinner knob to cover the zero to 10-volt range (even with fast rotation). Therefore, when covering a large amplitude range it may be expedient to enter the number with the keypad and then make any fine adjustments with the spinner.

The CLAMP mode is not a baseline restorer. Rather it allows long tail pulses to maintain the same amplitude as rep-rates exceed the duty cycle necessary for full exponential decay to the baseline. This is accomplished by clamping the tail to the baseline prior to the next pulse. This may be useful in some applications where the long tail must be preserved. For optimum performance in this mode the delay must be set greater than  $3.0\ \mu\text{s}$  (see Section 1.5.4).

Three BNC connectors are located on the front panel. The PULSE OUT is reverse terminated in 50 ohms and provides 0-10 volts out (0-5 volts into 50 ohms). The EXT TRIG is used in conjunction with the menu to trigger the pulser at a given threshold and frequency up to 500 kHz. The TRIG OUT can be used to trigger a scope, another pulser, or system under test.

When remote operation is desired connect a null modem RS-232 cable to a PC running HyperTerminal. From the main menu set the PB-5 to remote operation. The

HyperTerminal settings are as follows (use PROPERTIES from the file menu to enter values):

Flow control:	None	Data bits:	8
Emulation:	VT 100	Parity:	None

#### 1.4 MENU SELECTIONS

Figure 2. shows the two level menu employed by the PB-5. The menu is selected by using the up/down keys on the keypad and pressing enter or by using the spinner/switch knob. Operating solely by the spinner is most convenient since rotating and depressing the push switch, all in one motion, makes the menu selection easy. There are only two levels of menu selection - the main menu and the sub menu. There are 6 selections on the main menu: TRIGGER MODE, PULSE SETTINGS, RAMP SETTINGS, SCALE V/keV, SAVE/RECALL, and OPERATING MODE. The sub menu for each of these selections is shown separately in Figure 2. Four lines of information are displayed on the LCD at all times (represented by the dotted line in figure 2). The remaining items are viewed by scrolling up or down. The examples shown represent the maximum number of significant digits used in determining the parameter. For example, amplitude accuracy is given to 6 significant digits regardless of the decimal place (0.00001, 1.00000, 10.0000). It should be noted that the least significant digit for amplitude might not give the same number with both the spinner knob and the keypad. Both methods of setting amplitude are accurate to at least one part in 64000, but if repeatability is desired the keypad should be used. (In the case of the spinner knob the  $\mu$ C calculates the amplitude for every position and with the same accuracy as the keypad.)

Sub menu items are described in more detail directly below each sub menu. For example, discrete numbers for all rise time, fall time, and attenuation values are shown below the sub menu for the pulse settings. Note that many menu settings can be volts or keV. If using an isotope line for calibration in keV, the instrument will calculate equivalent volts so that value limits will not be exceeded. When the tail pulse is selected, rise time and pulse width are removed from the sub menu. This is because rise time is fixed at 50 ns and width is automatically set to minimum value in this mode. This insures the best accuracy and repeatability when using a tail pulse. If there are circumstances that require different rise times, special tail pulses can be created in the flat-top mode (simply reduce the width to the minimum setting). The last item in the sub menu allows one to return to the main menu. Alternatively, the key marked "main menu" on the keypad will also allow a quick return to the main menu.

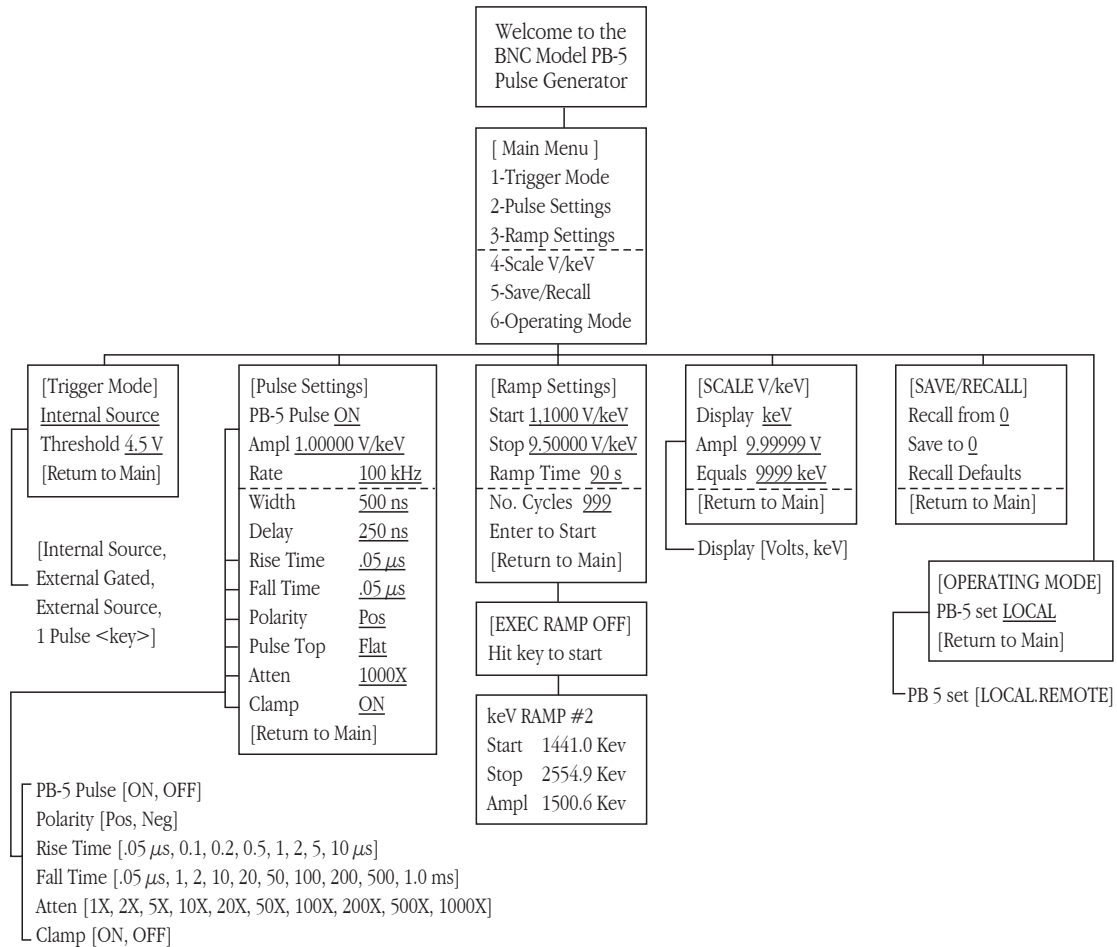


FIGURE 2. Model PB-5 Menu

## 1.5 OPTIMUM PERFORMANCE

To achieve optimum performance of the model PB-5 several factors should be considered as follows:

### 1.5.1 NIM Power Supply

It is important that the NIM power supply meet all regulation, long term stability, and ripple specified by the manufacturer. For high performance, the Berkeley Nucleonics' Portanim, Model AP-3, is recommended to power the PB-5.

### 1.5.2 Amplitude Settings

When the pulse amplitude is set near zero volts it is common to have switching transients and clock pulse feed-through occur in the order of 10 mV. In order to minimize these transient effects it is important to set the amplitude high (~ 10 volts) and switch in attenuation to obtain low-level pulses. It is common practice to use attenuation to obtain low noise performance for low-level pulses. It is also preferable to use attenuation to preserve pulse shape at low amplitudes. This is especially true when preserving a minimum flat top width on low-amplitude tail pulses. If attenuation is not used for low-amplitude tail pulses

the flat top portion will become longer as amplitude decreases. Since some amount of flat top is desirable this may not be a problem especially when using long tail pulses. However, low-level pulses below one or two volts can have up to 700 ns flat top when attenuation is not used.

### 1.5.3 Linearity Measurements

In order to achieve the best statistical distribution and low drift, it is best to use the fastest ramp time (90 seconds) and the maximum number of cycles (999). This combination is convenient for long runs (about 25 hours). Depending upon the frequency of the PB-5 and the number of channels under test, the ramp can be restarted the following day and repeated for the number of days necessary to achieve the required statistical accuracy (see Section 1.7).

### 1.5.4 CLAMP Mode

The amplitude of long exponential tail pulses may decrease with increasing rep-rates. This happens when the duty cycle exceeds the time requirements for full baseline recovery prior to the next pulse. To maintain the pulse amplitude activate the CLAMP Mode. To optimize performance in this mode the DELAY must be set greater than 3.0  $\mu$ s.

## 1.6 TESTING A PREAMPLIFIER

Select PULSE SETTINGS from the main menu and select PULSE TOP TAIL from the sub menu. The rise time will automatically be 50 ns and the tail time should be set long compared to the decay time of the preamplifier (tail time is typically set to 500  $\mu$ s or more). Sometimes an experimenter may be concerned about using this pulse for the test signal of a charge-sensitive preamplifier especially when solid-state detectors have shorter rise times. However, the 50 ns pulse rise time is perfectly satisfactory for use in testing linearity, stability, and resolution of the preamplifier. The following comments are provided to clarify this matter.

It can be shown that the amount of injected charge from the pulser into a preamplifier is given by  $Q = CV$ , where  $C$  is the coupling capacitance and  $V$  is the pulse amplitude. The only restraint is that  $C$  be much smaller than the input capacitance of the preamplifier. As long as the rise time of the injected pulse is much shorter than the decay time-constant of the preamplifier, essentially all the charge will be collected. A corollary of this is that the test pulser rise time need not be as short as the detector pulse to simulate the same charge. These conditions are fulfilled by the Model PB-5 which provides a rise time of 50 ns compared with the usual preamplifier decay time-constant of 50  $\mu$ s or more.

## 1.7 MEASURING DIFFERENTIAL LINEARITY IN A MCA

The model PB-5 has a built in ramp generator for measuring the differential linearity of a multichannel analyzer (MCA).

Differential nonlinearity (DNL) in a MCA describes the change in relative width of one



or more channels with respect to the average width of all the channels. DNL can be determined by manually setting a pulse amplitude to both edges of each channel and calculating the width of each channel individually. This method is subject to error since it is difficult to accurately find the edges of each channel particularly due to system noise. DNL may be more conveniently and quickly determined by using the sliding pulser method, where a constant frequency pulse is swept in amplitude at a constant rate. When the channel widths are identical, the pulses will fall in each channel for an equal length of time and the number of counts accumulated in each channel will be equal. The MCA display for zero DNL would then be a horizontal straight line.

DNL measurements on a MCA are typically made as follows:

- 1) Connect the pulse generator OUTPUT to the analyzer input.
- 2) Set the pulse top to FLAT, rise time to 50 ns, pulse width to 1  $\mu$ s, fall time to 0.5  $\mu$ s, polarity to positive (for most commercial MCAs), and the frequency to 50 kHz or more (depending upon the amount of MCA dead time and the time required to test a large number of channels).
- 3) Select RAMP SETTINGS from the main menu and set the start/stop to cover the required number of channels (a small or large number of channels can be effectively tested in volts or keV).
- 4) To lessen the possibility of drift set the ramp time to its minimum setting (90 seconds). To assure adequate statistical data set the number of ramp cycles appropriately (999, when testing a large number of channels). A 24-hour test can be conveniently run with a 0 to 10-volt ramp (see Section 1.5.3).
- 5) Clear the memory in the MCA and place the analyzer in the acquire mode.
- 6) Select ENTER TO START from the ramp menu to execute the ramp. The ramp is executed by any one of three ways: Pushing the spinner knob, pushing the ENTER key, or pushing any of the numbered keys. The ramp is stopped by repeating any of these three choices. The changing amplitude value can be observed on the LCD during the ramp.
- 7) When sufficient counts have been accumulated for the statistical accuracy desired, stop the ramp by any of the three methods above. Alternatively, let the program stop the ramp.

The amount of noise in the system and whether it is statistical or non-statistical, will affect the time required to smooth out irregularities in the DNL display. The maximum error of the DNL measurement will be inversely proportional to the square root of the number of counts accumulated in each channel plus the error in the sliding pulse train. The accuracy of the sliding pulse train is better than  $\pm 150 \mu$ volts ( $< 1$  part in 64,000). Therefore, the contribution to DNL from the pulser will be minimal when testing analyzers up to 8K channels.

The DNL of the analyzer may be computed by:

$$\text{DNL} = 100 \{ 1 - N_x/N_{av} \} \%$$

Where  $N_x$  = number of counts in channel  $x$

And  $N_{av}$  = average number of counts in all channels

Nx is generally taken as the worst case deviation from the average. Occasionally there is a "dropped" channel or an odd-even effect. This type of analyzer defect is easily observed with the PB-5 DNL test but this type of anomaly should not be used for the calculation of DNL.

## **SECTION 2**

### **RS-232 COMMANDS**

A PC can control all parameters of the model PB-5. The following commands will allow full operation of the pulser including the RAMP mode. This is convenient when remote operation of the PB-5 is required (see last paragraph of Section 1.3 for information on configuring the PC). This full set of commands can be conveniently displayed by typing "help".

```
set trigger mode internal
set trigger mode external
set trigger mode gated
set trigger mode one pulse
trigger one pulse
set threshold 3.5
set power on 1/0
set amplitude 10.000
set rep rate 10000
set width 25000
set delay 10000
set rise time 10000
set fall time 10000
set tail pulse 1/0
set polarity positive 1/0
set attenuation 1000
set display kev 1/0
set equivalent kev 1000
clamp baseline 0/1
set ramp startv 2.0
set ramp stopv 10.0
set ramp starteV 100.0
set ramp stopeV 1000.0
```

set ramp time 100  
 set ramp cycles 10  
 execute ramp  
 recall factory defaults  
 help

Values given for time in the above examples are in nanoseconds

## SECTION 3

### SPECIFICATIONS

Rep Rate:	2.0 Hz to 500 kHz
Width:	100 ns to 1 ms, continuously variable
Delay:	250 ns to 10 ms
Rise Time:	0.05 $\mu$ s to 10 $\mu$ s (10%-90%) in 8 steps
Decay Time:	0.5 $\mu$ s to 1.0 ms (100%-37%) in 11 steps
Amplitude:	0.0 to 10.0 V (0 to 5 V into 50 ohms) Scaleable in energy units (keV)
Resolution:	155 $\mu$ V
Jitter:	$\pm$ 10 ppm
Attenuation:	0, 2, 5, 10, 20, 50, 100, 200, 500, 1000
Integral non-linearity:	$\pm$ 15 ppm
Temperature stability:	$\pm$ 5 ppm per $^{\circ}$ C from 20 $^{\circ}$ C to 45 $^{\circ}$ C
Pulse Type:	Flat-top or tail pulse – In flat-top mode, both rise time and decay time are adjustable. In tail mode, rise time is fixed at 50 ns and decay time is adjustable.
Polarity:	Positive/Negative
Ext. Trigger:	0 to 500 kHz, +100 mV to +10 volts Threshold is adjustable from +100 mV to +3.5 V in 0.1 V steps
Trigger Out:	+5 V unterminated, +2.2 V into 50 ohms, width 200 ns
Modes:	Single pulse via a front panel pushbutton Internal Rep Rate External Trigger External Gate with the same pulse requirements as Ext Trig. Internal Ramp-adjustable start and stop points: adjustable ramp period 30-900 S, selectable number of ramp cycles, ramp in keV or volts. Clamped baseline option to bring the baseline to zero prior to the next pulse.
Stored Settings:	Up to 9 complete configurations with recall. Also stores parameters upon shutdown for recall when powered on.
Remote:	RS232 at 9600 baud.

Power Required:    +24 V        170 mA  
                         - 24 V        150 mA  
                         +12 V        450 mA  
                         - 12 V        5 mA

Mechanical:        Triple-width AEC NIM module 4.05" wide x 8.70" high in  
                         accordance with TID-20893 (Rev 3.)

Weight:              3 lbs. Net, 6 lbs. Shipping

Portable Power  
Supply Available:    See BNC Model AP-3 Portable NIM Power Supply