SILICON SURFACE BARRIER DETECTOR PREAMPLIFIER
Model 2003T and 2003BT

0587

Instruction Manual

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Model 2003T & 2003BT

CONTENTS

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Model 2003T & 2003BT

Section 1

INTRODUCTION

The Canberra Model 2003T charge sensitive FET input preamp is deisgned for optimum performance with Silicon Surface Barrier (SSB) detectors. Operating as a charge to voltage converter, the unit accepts charge carriers produced in the detector during each absorbed nuclear event. The output then provides a voltage in direct proportion to the collected charge at the rate of 0.45V per picocoulomb. This translates to a gain of 20mV per MeV for room temperature silicon detectors.

For typical use with positively biased SSB detectors, the extremely linear energy output provides a positive polarity pulse ideal for energy spectroscopy. The coincident timing output provides a negative polarity fast differentiated pulse ideal for resolution of nuclear events in time.

The high charge rate capability of the design is evidenced by an energy rate capacity of greater than 2 x 10^6 MeV per second when used with silicon detectors. In order to take full advantage of such a high count rate capability, a main amplifier with a correspondingly high count rate ability, such as the Canberra Model 2010, should be used.

The basic operation of the preamplifier is indicated in the functional schematic diagram below. The first stage acts as an operational integrator which produces an output potential proportional to the accumulated charge on the feedback capacitor Cf. The integrator drives the energy output directly. The timing output is derived from the integrator error signal through a pulse shaping network. Such an arrangement allows for the low noise and fast rise times, as indicated in the Specifications Section of this manual.

The noise contribution of the preamplifier is only 2.0 KeV, FWHM, Si with an increase of less than 10 eV for each picofarad of additional source capacitance. To reduce noise injected through the HV input, a decoupling network is utilized for filtering the detector bias voltage.

To reduce the possibility of transmission line reflections when using long lengths of coaxial cable, the energy output is provided with a series resistor, eliminating the necessity of terminating the line at the receiving end. However, as a result of the extremely fast rise time of the timing signal, the timing output must always be terminated at the receiving end in its characteristic impedance (50 ohms).

For those applications utilizing the common lower voltage detectors with vacuum chamber feedthrough connectors or direct detector cabling inside a chamber, the Model 2003BT provides a BNC for the detector input. Necessary power is provided by any Canberra main amplifier through the ten foot compatible cable furnished with the preamp.

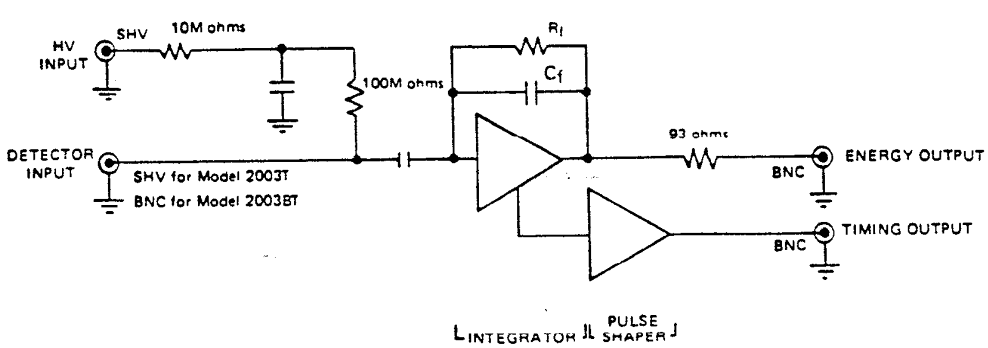


Figure 1-1. Functional Schematic.

Section 2

SPECIFICATIONS

2.1 INPUTS

DETECTOR INPUT	Accepts positive or negative charge pulses from semiconductor detectors, but not limited to silicon surface barrier types.
POWER	Accepts standard NIM supply voltages from associated main amplifier.
HV INPUT	Accepts up to 2000 VDC, (0 to 1000 VDC for the 2003BT), positive or negative, for detector bias. No limit to the rate at which bias may be applied. Series resistance to detector bias point is 110M ohms nominal.
TEST INPUT	Accepts negative polarity tail pulses via BNC connector extension on power cable to simulate or calibrate gain of detector input.

2.2 OUTPUTS

ENERGY OUTPUT	Provides unipolar voltage pulses linearly proportional in peak amplitude to the charge input, inverting. Rise time as in Table 2-1. Decay time constant is nominally 250 μsec, and output swing is ± 10V open circuit. Output impedance is 93 ohms series connected, and DC coupled. Output DC offset is adjustable to zero.
TIMING OUTPUT	(For use with positively biased detectors only.) Provides unipolar fast differentiated voltage pulses non-inverting with respect to the input. Rise time as in Table 2-1 and fall time of 20–40 nsec. DC coupled. Output polarity is negative only. Requires load termination of 50 ohms when in use.

2.3 PERFORMANCE

INTEGRAL NONLINEARITY	Less than ± 0.04% for 0 to ± 10 volt peak output (unterminated).
GAIN DRIFT	Better than ± 0.005%/°C, (± 50 ppm/°C).
CHARGE SENSITIVITY	0.45 V/pC, nominal.
ENERGY SENSITIVITY	20 mV/MeV (Si), nominal.
RESOLUTION	See Table 2-1.
DETECTOR BIAS ISOLATION	± 2000 VDC (± 1000 VDC for the 2003BT) maximum.
DETECTOR BIAS RESISTOR	110 Megohm total.

TABLE 2-1

C source in picofarads	Noise in keV FWHM, Si	Rise Time in Nanoseconds Energy Output	Timing Output
0	< 2.0	< 12	< 3
100	< 3.0	< 14	< 4
500	< 6.5	< 22	< 10
1000	< 9.5	< 28	< 16

NOTE: Noise performance measured using Canberra Model 2010 Spectroscopy Amplifier set at 2 microsecond unipolar near-Gaussian shaping.

2.4 CONNECTOR TYPES AND CABLES

POWER — Amphenol 17-20090.

HV INPUT — SHV

DETECTOR INPUT — SHV for the Model 2003T
BNC for the Model 2003BT

ENERGY OUTPUT — BNC

TIMING OUTPUT — BNC

CABLE — A ten foot power cable with required connectors is supplied with the preamplifier.

2.5 POWER

+24V	- 24V	+12V	- 12V
10 mA	4 mA	30 mA	6 mA

Total power consumption of 750 mW supplied from associated Canberra main amplifier or MCA.

2.6 PHYSICAL

SIZE — 3 x 1.75 x 1.25 inches (7.6 x 4.4 x 3.2 cm).

NET WEIGHT — 8 ounces (0.23 kg).

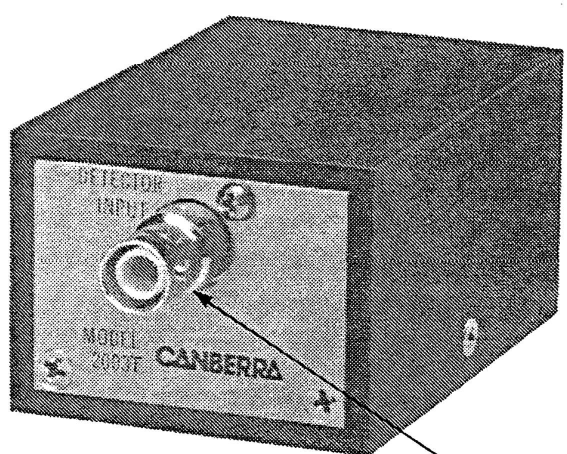
Section 3

CONTROLS AND CONNECTORS

3.1 GENERAL

This section describes the functions of the controls and connectors located on the front and rear panels of the Model 2003T and 2003BT. It is recommenced that this section be read before proceeding with the operation of the preamplifier.

3.2 FRONT PANEL



DETECTOR INPUT
Accepts the positive or negative charge pulse from a charged particle detector. Use the shortest possible connection, as coaxial cable of the type normally found in a laboratory contributes about 13pF input capacitance per foot. Direct connection to the detector will reduce preamplifier noise. A dust cover cap is provided to minimize noise contribution due to accumulated dust and grime on the detector input connector.

Note: Input connector is SHV type for Model 2003T and BNC for Model 2003BT.

Figure 3-1. Front Panel, Model 2003T/2003BT.

3.3 REAR PANEL

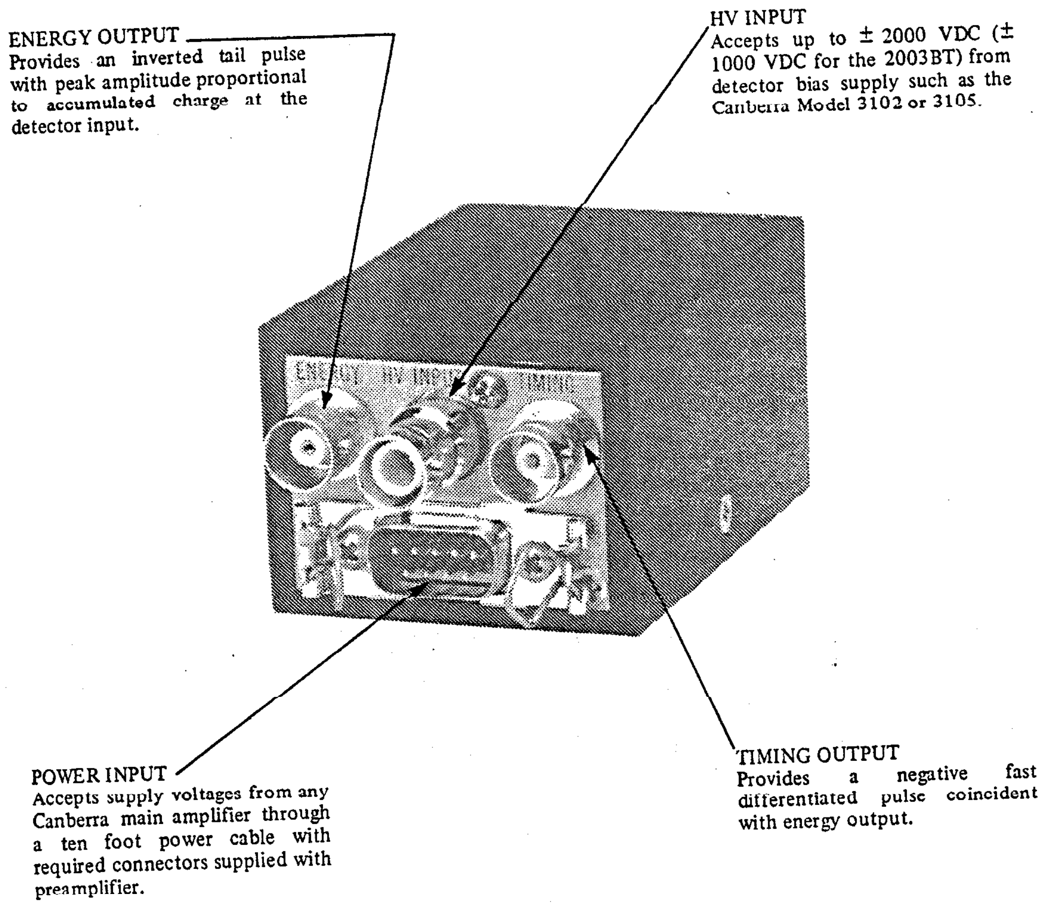


Figure 3-2. Rear Panel, Model 2003T and 2003BT.

3.4 INTERNAL CONTROLS

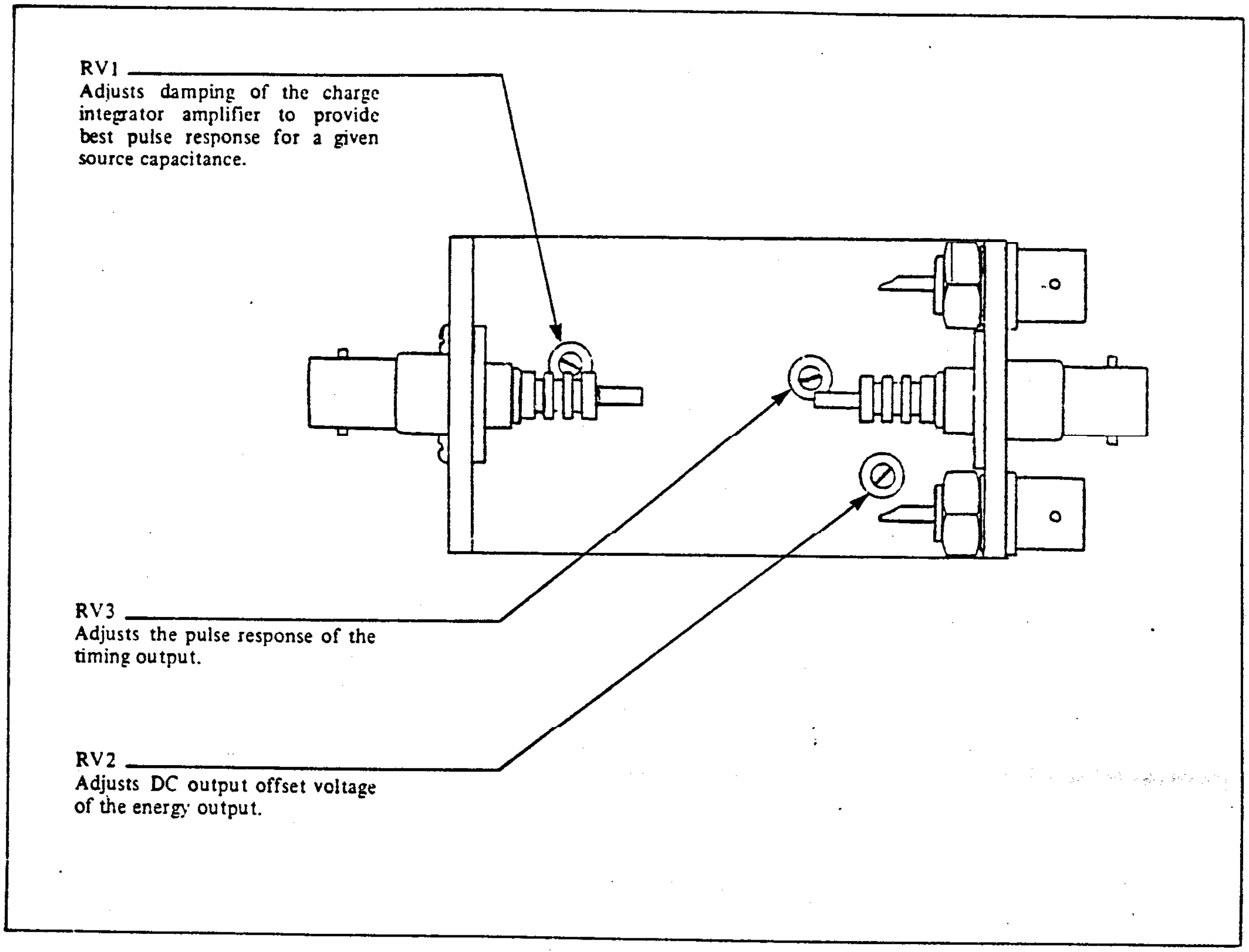


Figure 3-3. Top View, Cover Removed, Model 2003T and 2003BT.

Section 4

INSTALLATION

4.1 NOISE CONSIDERATIONS

The preamplifier components associated with the detector bias (HV) have been scientifically cleaned in an ultrasonic bath using special solvents. This process removes all residues and fingerprints which could cause excessive noise and possible failure of the preamplifier when high voltage is applied. It is strongly recommended that caution be exercised never to touch these components nor have them exposed to the atmosphere without the preamplifier case, for any long duration.

Any capacitance added to the input of the preamplifier will increase the noise contribution and degrade the rise time performance of the Model 2003T or 2003BT. The capacitance should be minimized by using the shortest possible interconnecting cable between the detector and preamplifier. Choose a cable with minimum capacity per unit length such as RG-62A/U, which has an impedance of 93 ohms and 13.5 pF per foot.

The detector load resistance R2 is normally 100 megohms. If silicon surface barrier detectors are used whose leakage current is greater than 1 microamp, the voltage drop across the resistor must be allowed for, or alternatively, the value of R2 reduced to provide an acceptable voltage drop. The latter will cause the 0 pF noise of the preamplifier to increase, but this will usually be insignificant compared to the noise generated in the detector by the increased leakage current. Do not reduce R2 below 10 megohms without contacting the factory.

4.2 DETECTOR BIAS

The Model 2003T or 2003BT Preamplifier HV INPUT accepts up to ± 2000 VDC (± 1000 VDC for the 2003BT) from the detector bias supply (such as Canberra Model 3102 or 3105). Never connect or disconnect the preamplifier from a detector while the high voltage is on. Always wait at least one minute after the detector bias has been reduced to zero before disconnecting the preamplifier from the detector. Maximum stability of the preamplifier is maintained 60-90 seconds after preamplifier power and high voltage is applied.

4.3 OTHER DETECTOR CONSIDERATIONS

While the Model 2003T or 2003BT may be used with both positively and negatively biased detectors in spectroscopy work, it does not yield an acceptable timing output for negatively biased detectors. Since the majority of the detectors available on the market require positive bias, this should present no problem to most users.

However, all users will be affected by the contact resistance inherent in the construction of the semiconductor detector itself, a result of the conductor-to-semiconductor interface. The potential barrier produced by this interface acts as a resistance and tends to degrade the idealized impulse response of the detector by increasing the rise time and decreasing the amplitude of the detector signal output.

Therefore, in applications requiring maximum timing resolution and to realize the full potential of the preamplifier, it would behoove the user to minimize this detector parameter, if possible.

Section 5

OPERATING INSTRUCTIONS

5.1 GENERAL

The purpose of this section is to familiarize the user with the Model 2003T or 2003BT Preamplifier and to check that the unit is operating correctly. Since it is difficult to determine the exact system configuration in which the unit will be used, explicit operating instructions cannot be given. However, if the following procedure is carried out the user will gain sufficient familiarity with the instrument to permit its proper use in the system at hand.

The instructions which follow may be best carried out with the preamplifier on a test bench, separated from the detector. Keep the dust cap secured on the input SHV connector when the DETECTOR INPUT is not in use.

Because the input is charge sensitive, and ultra high impedances are involved, the Preamplifier is inherently somewhat microphonic. For best results, testing should be done with the Preamplifier chassis cushioned on a block of foam rubber, and the cover securely fastened to the frame.

5.2 TEST INPUT

The Model 2003T and 2003BT accommodate a TEST input via a BNC connector extended from the preamplifier power cable at the end used to mate to the preamplifier rear panel. A normally unused pin (J1-8) introduces the externally applied signal (preferably a negative tail pulse of -1 to -5 volt peak amplitude) to a charge injection capacitor to the summing junction of the integrator. The test signal voltage is usually adjusted in amplitude by the user so as to give a reference peak signal in his data spectrum at a convenient location so as to normalize multiple detectors. This input does not provide a resistive terminating impedance.

5.3 INITIAL SETUP

1. Connect the Preamp to a source of low voltage power such as a Canberra Spectroscopy Amplifier using the 10 foot gray cable provided.
2. Using the RG-62/U coax, connect the Preamp ENERGY output to channel 1 of a dual trace Oscilloscope.
3. Connect the negative, attenuated output of a tail pulse generator (such as the Canberra 1407 Reference Pulser) to channel 2 using RG-62/U and a "tee" at the Scope input.
4. The other side of the "tee" should be connected to the Test input BNC connector through a length of RG-62/U coax.
5. Select Scope vertical sensitivities of 50 mV/div. and set the time base to 10 μs/div. Turn Preamp power on.

5.4 INITIAL CHECKOUT

1. Using the Test input BNC provided on the Model 2003T and 2003BT, a detector input of approximately 25 MeV per input volt is simulated. Adjust the Pulser for -100 mV peak input signal and observe a Preamplifier energy output of +50 mV peak (nominal). This is equivalent to a detector input of 2.5 MeV (nominal).
2. Increase the Pulser output to -5 volts. Note the Preamp does not saturate.

3. Set the Scope channel 2 trace for -200 mV peak pulse.

4. Remove the coax from Scope channel 1 input and connect a length of RG-58/U from the TIMING output to Scope channel 1 using a "tee" at the Scope Input. Attach a 50 ohm terminator on the other side of the "tee."

   NOTE: The Model 2003T TIMING output produces a signal with an extremely fast rise time. To avoid impaired performance resulting from transmission line reflections, use only 50 ohm coaxial cable properly terminated.

5. Select a Scope time base of 20 ns/div. Note the TIMING output is inverted with respect to the ENERGY output.

5.5 COMMON OPERATING PROBLEMS

The modern spectrometer is an extremely sensitive, state-of-the-art system. Inexact performance of other than the grossest type is generally due to subtle factors. It is the ability to determine and correct these factors that constitutes the art in the science of spectroscopy instrumentation.

All of the many possible contributors to less than optimum performance cannot be listed here. The purpose of this section is to note the usual causes of loss of resolution, and to suggest curative steps.

Do not expect to diagnose all problems with a detector, a preamplifier, a main amplifier, and a multichannel analyzer. The spectroscopy system records results, it does not necessarily lead to the identification of causes. A good, modern oscilloscope (Tektronix 454, 475, 485) will be needed. Also, a high quality tail pulse generator (Canberra 1407 or equivalent) will be extremely useful.

The simplest test is, of course, to connect your detector, apply bias, present a source, and accumulate a spectrum. Be sure a pulser is not feeding the preamplifier while the spectrum is accumulating, or resolution loss may result. If the results obtained are far different from what is expected, it then becomes necessary to troubleshoot the system.

First observe the amplifier output on an oscilloscope at various time base and amplitude settings. Is the amplifier properly pole/zero cancelled (do the output pulses cause undershoots that persist for longer than two or more main pulse widths)? Set the main amplifier pole/zero cancellation (without DC restoration) to obtain the most rapid, complete baseline recovery.

The next step is to remove all sources and, with the detector still connected and bias applied, present a test pulse to the detector input of the preamplifier using the test input described in Section 5.2. Make sure the pulser polarity is correct. Set the amplitude of the pulser so that its peak occurs near the region of the peak of the source previously used.

Observe the output of the amplifier without DC restoration. Note that the amplifier is not properly pole/zero cancelled for the pulser feeding the preamp (due to the extra time constant of the pulser). This is of no consequence for a pure pulser input. Are the baseline fluctuations of 60 or 120 Hz frequency? A ground loop is indicated. Insert all system line plugs into the same output. Or, are the baseline fluctuations of random frequency between 10 Hz and 15,000 Hz? The area may be too noisy, causing microphonic problems.

If low frequency noise is a serious problem, it may be necessary to use the Low Rate mode of the Canberra main amplifier's built-in DC restorer.

If high frequency noise is observed, is it random or periodic? Periodic noise is a sign of electronics failure; isolate the cause by observing the preamplifier output. Is the same pattern observed, or is the problem in the main amplifier? Random high frequency noise may be detector load resistor or input capacitor breakdown.

Next, accumulate a pulser peak on the analyzer. Calculate its resolution. Repeat, with the detector removed and the input connector of the preamplifier shielded. (Wait five minutes to remove the preamplifier from the detector after removing the detector bias.) You now have three resolution figures available for essentially equal energy peaks; source, pulser and biased detector connected, pulser without detector connected. Denote these by R_S, R_D and R_E, respectively.

If R_E is not less than 2.0 keV for two microsecond unipolar Gaussian shaping time constant, the problem is in the electronics and probably in the preamplifier.

If R_E is acceptable, but R_D is greater than 2.0 keV plus 10 eV/pF detector and connection capacitance, then the problem is either in the detector (microphonics, excess leakage current noise, breakdown due to moisture or grime on the detector output connector), or in the preamplifier (leaky input capacitor, dirty or moist detector load resistor, dirty or moist detector input connector).

If R_E and R_D are acceptable, but the live spectrum (R_S) is not as good as expected, the problem is probably in the detector (bad detector, poor charge collection, insufficient bias) or in the electronics following the preamplifier (count rate too high, improper amplifier pole/zero cancellation, wrong main amplifier time constant, wrong amplifier shaping-bipolar vs. unipolar, improper amplifier shaping for the ADC being used, ADC cannot take the count rate, amplifier or ADC drift).

These many alternatives are not easy to check. Substituting, one-by-one other detectors, preamplifiers, amplifiers, and multichannel analyzers may help pinpoint the problem. Checking the above common problems will aid in spotting the source of trouble.

Going through the steps mentioned above helps to eliminate obvious problems and will provide a good starting point for the final troubleshooting step - Call Canberra: 203-238-2351. With the information collected above, our advice will be far more concise and to the point.

Section 6

THEORY OF OPERATION

6.1 FUNCTIONAL DESCRIPTION

The Model 2003T and 2003BT Silicon Surface Barrier Detector Preamplifier consist of a charge sensitive integrator for converting input charge into an output potential, a pulse circuit for deriving a fast differentiated signal from the integrator and a decoupling network for filtering the detector bias voltage.

6.2 DETAILED CIRCUIT DESCRIPTION

The charge sensitive integrator is implemented as an operational amplifier with Q1 through Q6 functioning collectively to provide a large voltage gain, low output impedance and high input impedance. C3 closes the loop and defines the charge gain of the configuration.

Specifically, the input FET operates at a relatively low drain-to-source voltage and a bias current conducive to high signal gain and low noise. R4 defines this current and in conjunction with R6 and R7 sets the base of Q2 at a potential equal to that at the base of Q3. L1 presents the drain of Q1 with a high impedance for high signal gain with R5 providing damping.

With Q2 and Q3 biased as a differential amplifier, voltage gain is accomplished by using an active current source Q4 as a load to the collector of Q3. At this point dominant pole compensation is employed (RV1 and C5) to roll off the voltage gain uniformly as a function of frequency. Buffer action is provided by Q5, Q6, and R17.

As a result of the finite response time of such a configuration, an error is developed corresponding to the difference between the input and the output. It is this error appearing as a small current change through Q2, which is utilized to derive the timing output signal. This is accomplished by shunting the AC current from Q1 through C10 to the base of Q7. The transistor pair formed by Q7 and Q8 provide the necessary gain to drive 50 ohm coaxial cable, and by virtue of the open loop differential configuration they respond to the error signal in approximately one nanosecond.

Model 2003BT Silicon Surface Barrier Detector Preamplifier

Features

- Low noise design: less than 2.0 keV (Si) at 0 pF
- High energy rate capability: up to 2 x 10^6 MeV per second
- FET input, diode protected
- Independent energy and fast timing outputs
- Fast rise time less than 3 ns at 0 pF
- Small size
- Capable of operating in a vacuum chamber

Description

The Canberra Model 2003BT charge sensitive FET input preamp is designed for optimum performance with Silicon Surface Barrier (SSB) detectors. Operating as a charge to voltage converter, the unit accepts charge carriers produced in the detector during each absorbed nuclear event. The output then provides a voltage in direct proportion to the collected charge at the rate of 0.45 V per pC. This translates to a gain of 20 mV per MeV for room temperature silicon detectors.

For typical use with positively biased SSB detectors, the extremely linear energy output provides a positive polarity pulse ideal for energy spectroscopy. The coincident timing output provides a negative polarity fast differentiated pulse ideal for resolution of nuclear events in time.

The high charge rate capability of the design is evidenced by an energy rate capacity of greater than 2 x 10^6 MeV per second when used with silicon detectors. In order to take full advantage of such a high count rate capability, a main amplifier with a correspondingly high count rate ability, such as the Canberra Model 2025 or Model 2026, should be used.

The basic operation of the preamplifier is indicated in the functional schematic. The first stage acts as an operational integrator which produces an output potential proportional to the accumulated charge on the feedback capacitor C_f. The integrator drives the energy output directly. The timing output is derived from the integrator error signal through a pulse shaping network. Such an arrangement allows for the low noise and fast rise times, as in Table 1. To preserve pulse fidelity the energy output is buffered through a series terminating resistor of 93 Ω.

The preamplifier offers a noise contribution of only 2.0 keV, FWHM, Si, with a rate of increase with increasing input capacitance of ±10 eV per pF. All necessary power is provided by a Canberra main amplifier through the 300 cm (10 ft) compatible cable furnished with the preamp.

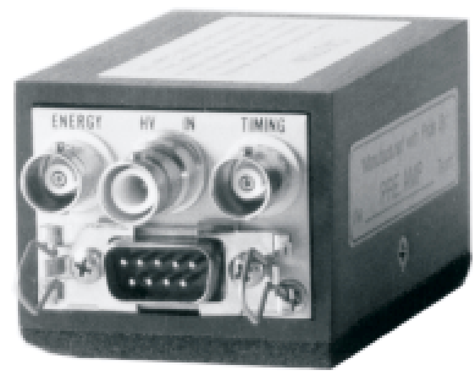
Specifications

INPUTS

DETECTOR INPUT – Accepts charge pulse from semiconductor detectors including SSB types.

HV INPUT – Allows detector biasing up to ±1000 V dc; detector series bias resistance is 110 MΩ.

TEST INPUT – Charge coupled to the preamp input at 1 pC per V; available at the end of the preamp cable.



OUTPUTS

ENERGY OUTPUT – Inverted with a tail pulse time constant of 250 µs and an amplitude of up to ±10 V unterminated; Z_{out} = 93 Ω, direct coupled. Rise time as in Table 1; dc offset adjustable to zero.

TIMING OUTPUT (with positively biased detectors only) – Noninverted, fast differentiated pulse with rise time as in Table 1 and fall time variable. Direct coupled current source output to drive 50 Ω load.

PERFORMANCE

INTEGRAL NONLINEARITY – ≤±0.04% for ±10 V output.

GAIN DRIFT – ≤±0.005% per °C (±50 ppm per °C), 0-50 °C.

DETECTOR BIAS ISOLATION – ±1000 V dc maximum.

NOISE – See Table 1.

CHARGE SENSITIVITY – 0.45 V/pC.

ENERGY SENSITIVITY – 20 mV/MeV (Si).

RISE TIME – See Table 1.

CONNECTORS

POWER – Amphenol 17-20090.

DETECTOR – BNC.

HV INPUT – SHV.

ENERGY AND TIMING OUTPUTS – BNC.

300 cm (10 ft) preamp power cable with required connectors is supplied with the preamplifier.

Phone contact information

Benelux/Denmark (32) 2 481 85 30 • **Canada** 905-660-5373 • **Central Europe** +43 (0)2230 37000 • **France** (33) 1 39 48 57 70 • **Germany** (49) 6142 73820
Japan 81-3-5844-2681 • **Russia** (7-095) 429-6577 • **United Kingdom** (44) 1235 838333 • **United States** (1) 203-238-2351
For other international representative offices, visit our Web Site: ***http://www.canberra.com*** or contact the Canberra U.S.A. office.

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POWER REQUIREMENTS

+24 V dc – 10 mA   +12 V dc – 30 mA
–24 V dc – 4 mA   –12 V dc – 6 mA

PHYSICAL

SIZE – 7.6 x 5.1 x 3.8 cm (3 x 2 x 1.5 in.).
NET WEIGHT – 0.2 kg (0.5 lb).
SHIPPING WEIGHT – 0.9 kg (2 lb).

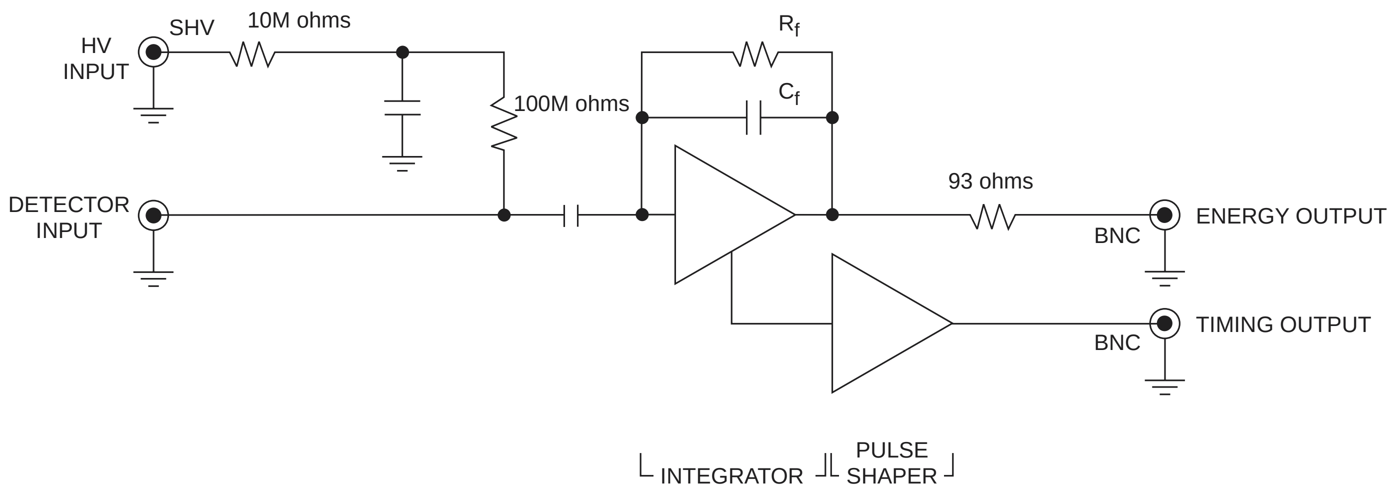
ENVIRONMENTAL

OPERATING TEMPERATURE – 0 to 50 °C.
OPERATING HUMIDITY – 0-80% relative, non-condensing. Tested to the environmental conditions specified by EN 61010, Installation Category I, Pollution Degree 2.

Table 1

C_{source} in Picofarads	Noise in keV FWHM, Si	Rise Time in Nanoseconds	
		Energy Output	Timing Output
0	<2.0	<12	<3
100	<3.0	<14	<5
500	<6.5	<22	<10
1000	<9.5	<28	<16

Noise performance using Canberra Model 2025 Spectroscopy Amplifier set at 2 µs unipolar near-Gaussian shaping.



Functional Schematic

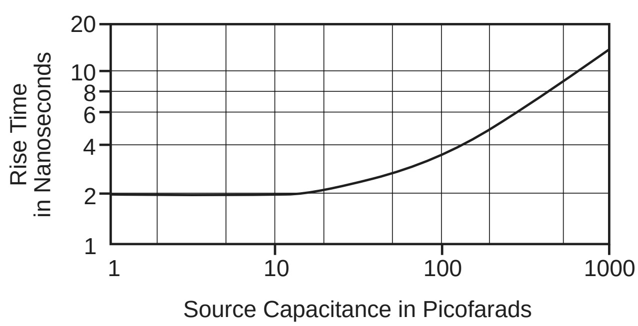


Figure 1 Typical Rise Time vs. Source Capacitance for the Timing Output

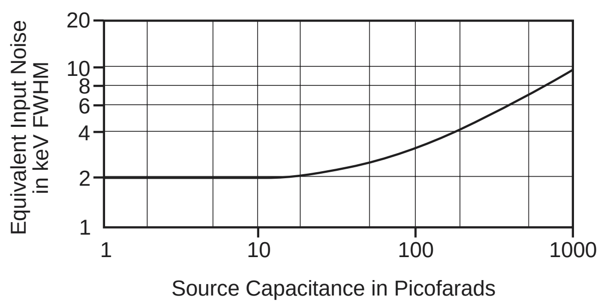
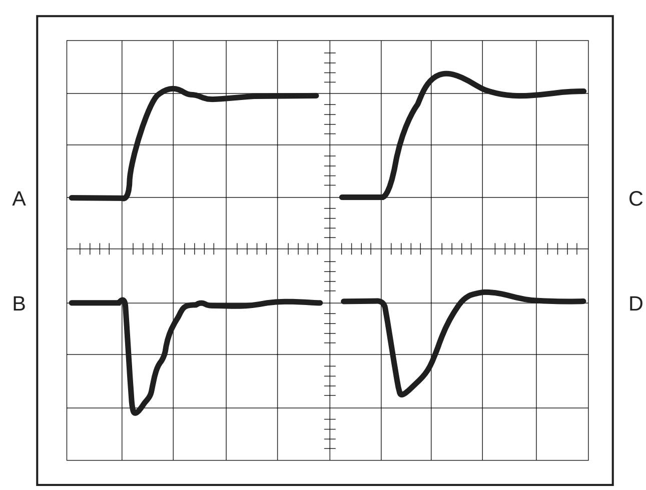


Figure 2 Typical Noise Performance vs. Source Capacitance



Vertical Sensitivity 50 mV/div.
Horizontal Sensitivity 20 ns/div.

Figure 3 Pulse Response
(A) Energy Ouput and (B) Timing Output with C_{source}=10 pF
(C) Energy Ouput and (D) Timing Output with C_{source}=100 pF