PHOTOMULTIPLIER TUBE BASE Model 2007

0985

Operator's Manual

Canberra Industries, Inc., One State Street, Meriden, CT 06450 Tel. (203) 238-2351 TWX: 710-461-0192 Cable: CANBERRA

Table of Contents

Section 1. Introduction

The Canberra Model 2007 Tube Base provides the high voltage divider network for correctly biasing essentially all 10 stage photomultiplier tubes (PMTs) used for nuclear spectroscopy. This network is intended for use with a positive high voltage for tubes which operate with their photocathodes near ground potential. The network includes a focus control for adjusting the detector resolution performance, and a gain trim control for matching outputs of several detectors when used in arrays.

Designed to be compatible with the Canberra Model 802 series Scintillation Detectors (or equivalent), the tube base connects directly to the pins of the PMT, providing a compact integrally mounted assembly.

The pulse outputs from the anode and dynode of the PMT, are coupled through high voltage blocking capacitors to rear panel BNC connectors for interfacing with an external preamplifier such as the Canberra Model 2005 or 2005E.

An option of particular interest to some users is a socketed 51 ohm resistor for use in timing experiments. This shunt resistor properly source terminates either or both outputs into any coaxial cable with a characteristic impedance of 50 ohm, which is itself properly terminated. This eliminates the possibility of line reflections interfering with results. The unit is shipped with the terminating resistor removed.

Section 2. Specifications

2.1 INPUTS

HIGH VOLTAGE—PMT bias voltage. Range 0 to +2000 V dc. Anode and dynode series resistors, 10M ohms. Bias network total resistance: 6.66M ohms to 7.16M ohms, depending on the position of the GAIN control.

2.2 OUTPUTS

ANODE OUTPUT—Provide negative polarity output from anode pin of PMT. Series high voltage blocking capacitor 0.01 μF.

DYNODE OUTPUT—Provides positive polarity output from last dynode of PMT. Series high-voltage blocking capacitor: 0.01 μF.

2.3 CONNECTOR TYPES

HIGH VOLTAGE—SHV

ANODE OUTPUT, DYNODE OUTPUT—BNC

TUBE SOCKET—14 pin (Cinch Jones 3M-14 or equivalent)

2.4 CONTROLS

FOCUS—Single turn screwdriver access potentiometer to adjust voltage at grid of PMT. Range 72 to 145 V per 1000 V dc of high voltage input.

GAIN—Single turn screwdriver access rheostat to adjust anode bias. Adjustment range 92% to 100% of applied high voltage.

2.5 POWER REQUIREMENTS

HIGH VOLTAGE—PMT bias network requires 150 μA dc per 1000 V dc applied.

2.6 PHYSICAL

SIZE—Diameter 5.8 cm (2.3 in.) Length 7.6 cm (3.0 in.)

NET WEIGHT—0.3 kg (0.75 lb)

Section 3.
Controls and Connectors

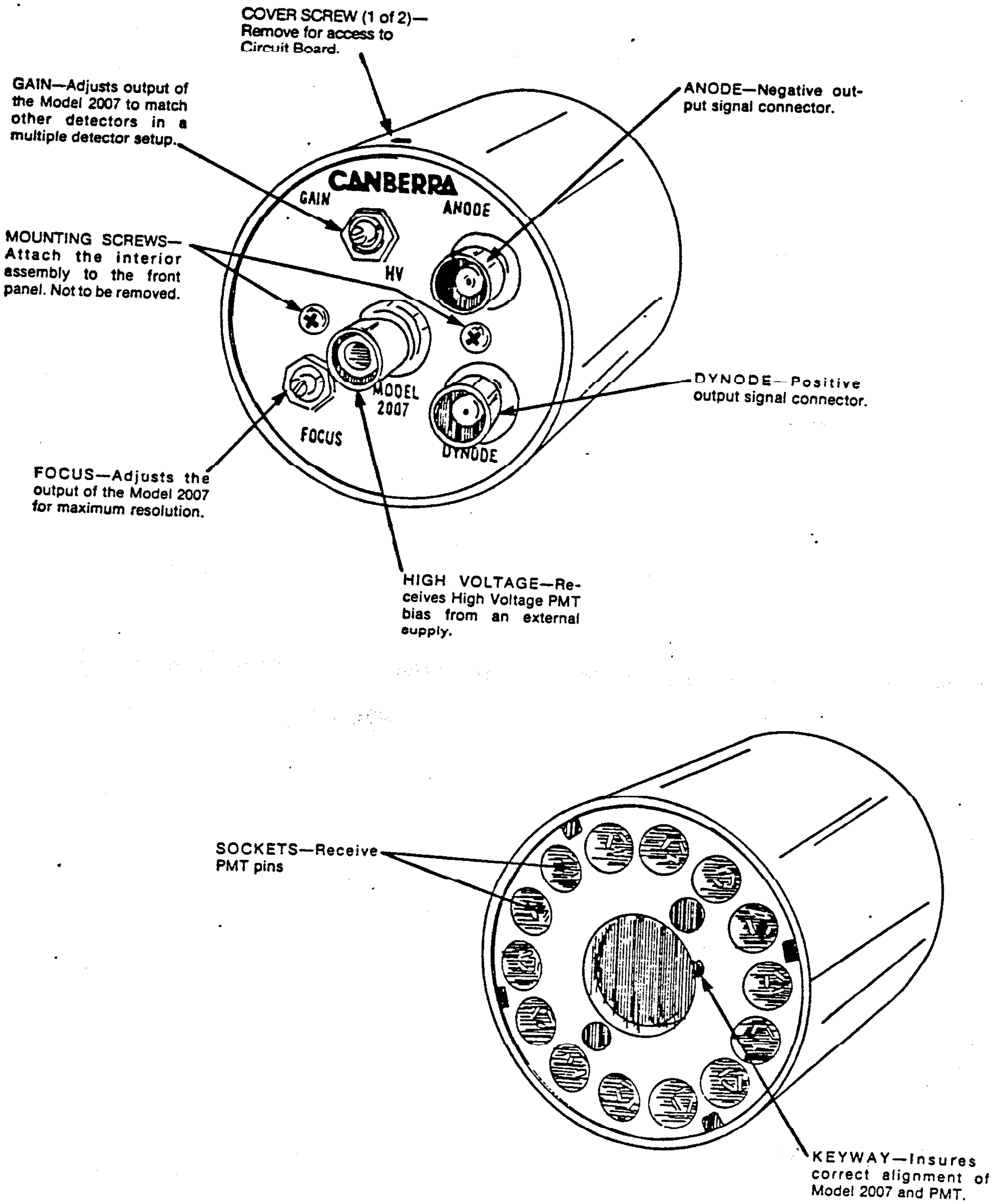
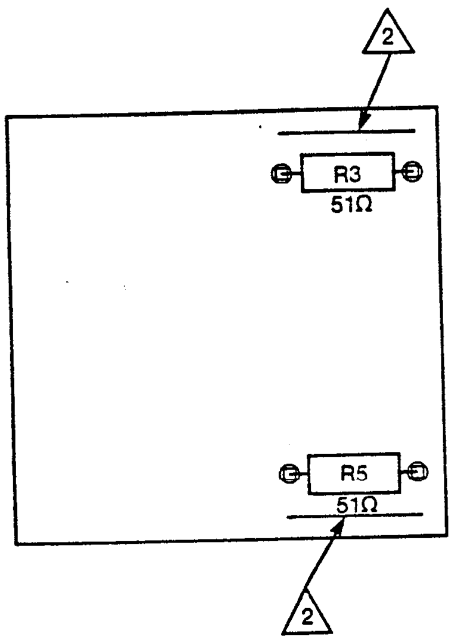


Figure 3-1
Front and Rear Panels

3.1 INSTALLATION OF THE TIMING RESISTORS

To install the Timing Resistors, remove the two small Phillips head screws, one on each side of the cylindrical tube wall near the front panel (see figure 3-1). Slide the interior section out of the cylinder and look on the circuit board for the resistor sockets. See figure 3-2 below.

Insert one resistor in each socket and press down firmly until the resistor is well seated. Reassemble the unit by reversing the diassembly procedure. Be certain that the two cover retaining screws are tightened securely.



NOTES:

1. ⊖ INDICATES AMP SOCKETS
2. △2 #22 BUS WIRE

Figure 3-2
Model 2007 CIRCUIT BOARD

Section 4. Installation

4.1 GENERAL

The 2007 is intended to provide a convenient package for interfacing with the photomultiplier tube (PMT). As specific mounting details differ significantly between the many applications, only the following general considerations can be offered.

4.2 DETECTOR MOUNTING

The tube base is intended to mount coaxially with the Canberra Model 802 series scintillation detectors simply by mating the PMT pins into the tube socket. The scintillator should be handled with care in mating, and protected from shock.

4.3 PRECAUTIONS

Consistent with good operating practice for the PMT, the high voltage full bias should not be applied immediately; it should be raised and lowered over a period of several seconds. Steady state dissipation in the PMT bias network has been minimized, in order to prevent degradation of background "dark" currents due to local heating. Heat sinking for the tube base is not necessary.

4.4 TIMING APPLICATIONS

For those users who wish to avail themselves of the excellent time response of scintillation detectors, a provision is made for source terminating either or both outputs into any coaxial cable with a characteristic impedance of 50 ohms, which is itself properly terminated. This eliminates the possibility of line reflections interfering with results. To exercise this option, insert the resistors included with the unit into the sockets provided on the printed circuit board. See Figure 3-2.

Section 5.
Operating Instructions

5.1 GENERAL

The purpose of this section is to familiarize the user with a typical setup incorporating the Model 2007 Photomultiplier Tube Base. Since the system configuration may vary from user to user, explicit operating instructions cannot be given. However, the following discussion of a typical configuration will give the user sufficient familiarity with the Model 2007 to permit its proper use in any system.

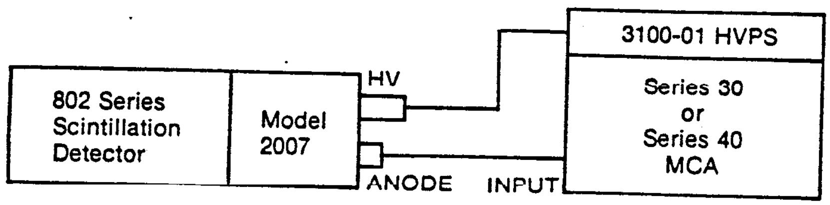


Figure 5-1
Model 2007 in Series 30/40 MCA system

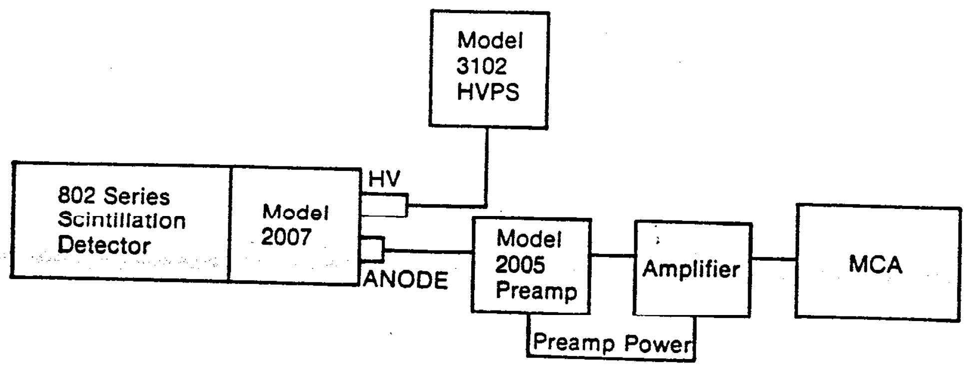


Figure 5-2
Model 2007 in other MCA systems

5.2 SETUP

Connect the Model 2007 to the Photomultiplier Tube (PMT). Be certain to align the key on the PMT with the keyway on the Model 2007 before attempting to insert the PMT pins into the Model 2007 tube base socket.

Using a small screwdriver, turn the Model 2007 GAIN control to its extreme clockwise position, which will provide the highest possible gain, and adjust the FOCUS control to about mid-range.

Connect a high voltage cable between the Model 2007 HV connector and the High Voltage Power Supply. Connect a signal cable between the Model 2007 ANODE connector and the preamplifier. This will provide a negative going signal to the preamp. If a positive signal is desired at the preamp, connect the signal cable to the DYNODE connector instead.

Connect the preamp's OUTPUT to the amplifier's INPUT and the preamp power cable between the amplifier and the preamp. Connect the amplifier's OUTPUT to the MCA's ADC input.

If the PMT is being used with Canberra's Series 30 MCA, connect the signal cable from the Model 2007 ANODE connector directly to the MCA's INPUT connector, with the INPUT LEVEL switch set to LOW. (Figure 5-1).

If the PMT is being used with Canberra's Series 40 MCA, Connect the signal cable from the Model 2007 ANODE connector directly to the MCA's AMP INput connector, with the adjacent ADC IN switch in the AMP position. The Series 40 must be set for a charge sensitive input; see Appendix A of the Series 40 Operator's Manual.

5.3 THE GAIN CONTROL

The GAIN control is used to match the gain of two or more PMTs in a multiple detector system. If a single PMT is being used, the control should be left in the extreme clockwise position.

To match the gain of several PMTs, it is necessary to know the gain of the each detector. Collect several thousand counts in a peak of ^{137}Cs (*for instance*) and record the number of the peak channel. Repeat for each PMT.

Place the MCA's cursor in the lowest recorded channel found in the preceding paragraph and adjust the GAIN controls of each PMT in turn so that all will collect the peak in that same peak channel.

5.4 THE FOCUS CONTROL

The FOCUS control is used to obtain the best possible resolution with a given PMT. Resolution is defined as the ability of the detector to differentiate between two peaks that are close together in energy. It follows therefore, that the narrower the peak the better the peak separation and thus the better the resolution.

By checking the resolution several times with slight adjustments of the FOCUS control each time, the point of best resolution can be found.

5.5 RESOLUTION

The full width of the peak at half of its maximum value (FWHM) is used to determine the resolution by:

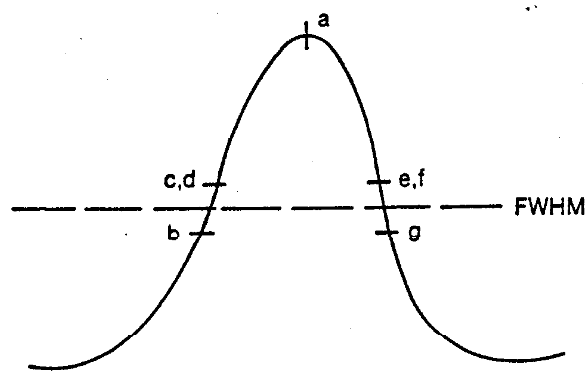
Resolution = FWHM / Peak Position

where Peak Position and FWHM are expressed in channels. The performance of a scintillation detector is usually specified in terms of its resolution for the 662 keV peak of ^{137}Cesium.

To determine the resolution, collect a peak of 10 000 counts of ^{137}Cs. Half maximum of the peak would be 5 000 counts, but it is unlikely that there will be a channel that contains exactly 5 000 counts. Therefore, it is necessary to interpolate the data.

It will be necessary to record the following information:

a. The peak channel. That is, the channel with 10 000 counts.
b. The counts in the channel just below FWHM on the left side of the peak. Counts 5 000.
c. The counts in the channel at or just above FWHM on the left side of the peak. Counts ≥5 000.
d. The number of the channel at or just above FWHM on the left side of the peak.
e. The number of the channel at or just above FWHM on the right side of the peak.
f. The counts in the channel at or just above FWHM on the right side of the peak. Counts ≥5 000.
g. The counts in the channel just below FWHM on the right side of the peak. Counts 5 000.



Using the information gathered above, apply the following formula:

$$\frac{e\text{-}d + \frac{b}{c} + \frac{f}{g}}{a} = \text{resolution expressed as a decimal fraction}$$

The resolution will be in the range of 0.06 to 0.09 (6 to 9%) for a Canberra Series 802 Scintillation Detector.

By adjusting the FOCUS control slightly to one side or the other of mid-range and doing another resolution check, it will be apparent that the resolution has been improved (the number is smaller) or has been degraded (the number is larger).

By doing several sucessive approximations, it will become apparent where the best resolution can be found. The FOCUS control can be left in that position as long as the same PMT and Model 2007 are associated. It would be helpful however, to check for best resolution from time to time to be sure that there is no change with time.

Section 6.
Theory of Operation

6.1 CIRCUIT DESCRIPTION

The bias network chosen for the PMT provides the best performance for nuclear applications. Capacitors C4 and C5, located between the anode and upper two dynodes, bypass large signal current occuring under moderately high pulse amplitude conditions. RV2 permits independent control of PMT grid potential for optimization of resolution, while RV1 allows PMT gain to be adjusted by modifying the potential applied at the high end of the bias network.

C1 and C2 capacitively couple the anode and dynode respectively to J1 and J2. R4 and R6 discharge C1 and C2 with a nominal time constant of 100 msec when ANODE and DYNODE outputs are unterminated. With socketed resistors R3 and R5 in place, the fall time constant is changed to less than 5 µs, and both outputs are properly source terminated into any coaxial cable with a characteristic impedance of 50 ohms, which is itself properly terminated. The high voltage input is filtered by C3.

6.2 INITIAL SETUP AND CHECKOUT

1. Set the tube base on a non-conductive work surface. Turn the GAIN control fully CW. Turn the FOCUS control fully CCW.

2. Connect a high voltage power supply to the HIGH VOLTAGE connector, and set the voltage to 100 V dc.

3. Using a dc voltmeter (DVM) with a rated accuracy to 0.1% and a 10M ohm input impedance, measure the potential, with respect to chassis ground (pin 14), of each pin in the Model 2007 socket. The range of acceptable potentials is given below in dc volts.

PIN	Volts dc	PIN	Volts dc
1	13 - 15.4	8	63.1 - 69.7
2	20.7 - 22.9	9	72.2 - 79.9
3	27.4 - 30.2	10	80.8 - 91.6
4	33.7 - 37.3	11	89.8 - 99.2
5	40.5 - 44.7	12	no connection
6	47.4 - 52.4	13	7.6 - 8.4
7	54.8 - 60.6	14	ground

4. Turn the FOCUS control fully CW. Pin 13 should now be 14 to 15.4 V. Turn the GAIN control fully CCW. Pin 10 should now be 70.9 to 82.7 V. Reduce the high voltage to zero and turn it OFF.

5. Mate the tube base with the detector. Turn on the high voltage and adjust it for the recommended potential specified for the detector.

6. Connect the ANODE output to one channel of an oscilloscope and the DYNODE output to the other channel.

7. Present a appropriate source to the detector and, using a convenient time base and channel sensitivity, observe the two traces on the scope. Note that the ANODE output provides a negative-going tail pulse and the DYNODE output provides a positive-going tail pulse.

PHOTOMULTIPLIER TUBE BASE-PREAMPLIFIER Model 2007P

0985

Operator's Manual

Canberra Industries, Inc., One State Street, Meriden, CT 06450 Tel. (203) 238-2351 TWX: 710-461-0192 Cable: CANBERRA

Table of Contents

Section 1. Introduction

1.1 INTRODUCTION

The Canberra Model 2007P Tube Base-Preamplifier provides the high voltage divider network for correctly biasing essentially all 10-stage photomultiplier tubes (PMT) used for nuclear spectroscopy. This network is intended for use with a positive high voltage for tubes which operate with their photocathodes near ground potential. The network includes a focus control for adjusting the detector resolution performance, and a gain trim control for matching outputs of several detectors when used in arrays.

Designed to be compatible with the Canberra Model 802 series Scintillation Detectors (or equivalent), the tube base connects directly to the pins of the PMT, providing a compact integrally mounted assembly.

The Canberra Model 2007P Tube Base-Preamplifier also contains a low noise charge-sensitive preamplifier. The preamplifier recovers the charge pulse at the anode pin of the PMT directly and converts it to a positive voltage pulse output. The peak amplitude of each output pulse is linearly proportional to the total charge output of the PMT during each amplified photo event. The pulse is set to decay at a nominal 50 μsec time constant, and interfaces directly with any of Canberra's spectroscopy amplifiers.

The Model 2007P includes a diode protection network on the preamplifier input to prevent damage to the circuitry from the inadvertent sudden application or removal of PMT bias voltage. A test input is also provided to aid system testing, gain calibration, or troubleshooting. Preamplifier power is usually derived from the associated pulse shaping amplifier. A ten-foot long power cable in supplied with the Model 2007P.

Section 2. Specifications

2.1 INPUTS

DETECTOR—The preamplifier is internally connected to pin 11 of the Tube Base socket (PMT anode).

TEST INPUT—Accepts a positive - or negative - polarity tail pulse from a test-pulse generator. Charge coupled at 30 picocoulombs per volt to preamplifier input. Voltage gain to output is 130 mV/V nominal. Input impedance is ≈ 93 ohms.

HV INPUT—PMT bias-voltage range, 0 to + 2000 V dc. Anode series resistance 1M ohms. Bias network total resistance: 6.66 M ohms to 7.16 M ohms, depending on the position of the GAIN control.

2.2 OUTPUTS

ENERGY OUTPUT—Provides unipolar positive pulses linearly proportional in peak amplitude to charge delivered at PMT anode.

Decay time constant 50 microseconds nominal. Rise time less than 20 nanoseconds. Delivers up to 10 V peak. Output impedance ≈ 93 ohms, series connected; direct coupled.

2.3 PERFORMANCE

INTEGRAL NON-LINEARITY—less than ± 0.04% for up to 10 volt output.

GAIN DRIFT—Less than ± 0.01%/°C (± 100 ppm/°C).

NOISE—Less than 1×10^{-16} coulombs rms referred to input.

CHARGE SENSITIVITY—4.5 mV/picocoulomb

2.4 CONNECTOR TYPES

HIGH VOLTAGE—SHV

ENERGY OUTPUT, TEST INPUT—BNC

TUBE SOCKET—14-pin (Cinch Jones 3M-14 or equivalent)

POWER—Amphenol 17-20090

2.5 CONTROLS

FOCUS—Single-turn screwdriver adjusted potentiometer to adjust voltage at grid of PMT. Range 72 to 145 V per 1000 V dc of high voltage input.

GAIN—Single-turn screwdriver adjusted rheostat to adjust anode bias. Adjustment range: 92% to 100% of applied high voltage.

2.6 POWER REQUIREMENTS

HIGH VOLTAGE—Bias network requires 150 μA per 1000 V dc

± 12 V dc—15 mA dc nominal

2.7 PHYSICAL

SIZE—Diameter 5.8 cm (2.3 in.)

LENGTH—7.6 cm (3.0 in.)

NET WEIGHT—0.7 kg (1.5 lb.)

Section 3. Installation

3.1 GENERAL
The Model 2007P is intended to provide a convenient package for interfacing with the photomultiplier tube (PMT). As specific mounting details differ significantly between applications, only the following general considerations can be offered.

3.2 DETECTOR MOUNTING
The tube base preamp is intended to mount coaxially with the Model 802 series scintillation detectors simply by mating the PMT pins into the tube socket. The scintillator should, of course, be handled with care in mating, and protected from shock.

3.3 PRECAUTIONS
Consistent with good operating practice for the PMT, the high voltage full bias should not be applied immediately: it should be raised and lowered over several seconds. The Model 2007P is diode protected for occasional faults and for high-voltage arcing. A primary consideration here will be the instantaneous noise current in the PMT, which may take a considerable time to settle.

Steady state dissipation in the PMT bias network has been minimized, in order to prevent degradation of background "dark" currents due to local heating. Hence no particular care need be expended in providing any heat sinking for the tube base.

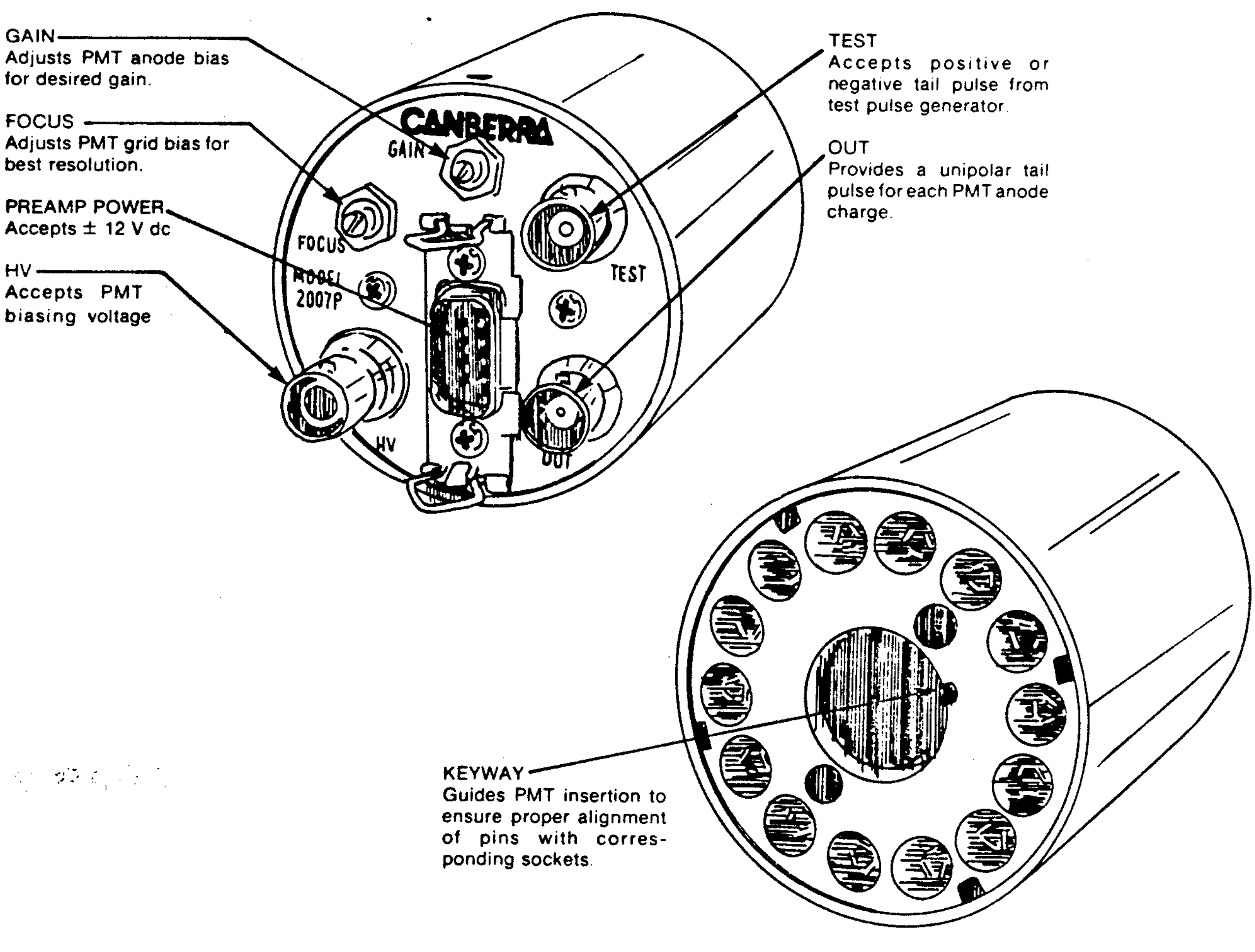


Figure 2-1
Model 2007P
Front and Rear Panels

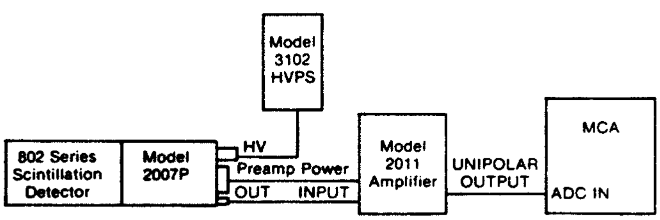
Section 4.
Operating Instructions

4.1 GENERAL
The purpose of this section is to familiarize the user with a typical setup incorporating the Model 2007P Photomultiplier Tube Base/Preamplifier. The following discussion of a typical configuration will give the user sufficient familiarity with the Model 2007P to permit its proper use in any system.

4.2 SETUP
Connect the Model 2007P to the Photomultiplier Tube (PMT). Be certain to align the key on the PMT with the keyway on the Model 2007P before attempting to insert the PMT pins into the tube base socket. See the rear panel photograph (Figure 2-1) for the location of the keyway.

Using a small screwdriver, turn the Model 2007P GAIN control to its extreme clockwise position, which will provide the highest possible gain, and adjust the FOCUS control to about mid-range.

Connect a high-voltage cable between the Model 2007P HV connector and the High Voltage Power Supply. Connect a signal cable between the Model 2007P OUT connector and the amplifier's input. Connect the preamplifier power cable between the preamp power (9-pin) connectors on the Model 2007P and the amplifier. Note that for a PMT, the amplifier must be capable of 0.5μ sec shaping.



Model 2007P in a Typical System
Figure 4-1

4.3 THE GAIN CONTROL
The GAIN control is used to match the gain of two or more PMTs in a multiple detector system. If a single PMT is being used, the control should be left in the extreme clockwise position.

To match the gain of several PMTs, it is necessary to know the gain of the each detector. Collect several thousand counts in a peak of ^{137}Cs (for instance) and record the number of the peak channel. Repeat for each PMT.

Place the MCA's cursor in the lowest recorded channel found in the preceding paragraph and adjust the GAIN controls of each PMT in turn so that all will collect the peak in that same peak channel.

4.4 THE FOCUS CONTROL
The FOCUS control is used to obtain the best possible resolution with a given PMT. Resolution is defined as the ability of the detector to differentiate between two peaks that are close together in energy. Thus the narrower the peak the better the peak separation and the better the resolution.

Start with the FOCUS control set about the middle of its range. By checking the resolution several times with a slight adjustment of the FOCUS control each time, the point of best resolution can be found.

4.5 RESOLUTION
The full width of the peak at half of its maximum value (FWHM) is used to determine the resolution by:

$$\text{Resolution} = \frac{\text{FWHM}}{\text{Peak Position}}$$

where Peak Position and FWHM are expressed in channels. The performance of a scintillation detector is usually specified in terms of its resolution for the 662 keV peak of ^{137}Cesium.

To determine the resolution, collect a peak of 10 000 counts of ^{137}Cs. Half maximum of the peak would be 5 000 counts, but it is unlikely that there will be a channel that contains exactly 5 000 counts. Therefore, it is necessary to interpolate the data.

Record the following information:

a. The peak channel . That is, the channel with 10 000 counts.
b. The counts in the channel just below FWHM on the left side of the peak. Counts $< 5\ 000$.
c. The counts in the channel at or just above FWHM on the left side of the peak. Counts $\geq 5\ 000$.
d. The number of the channel at or just above FWHM on the left side of the peak.
e. The number of the channel at or just above FWHM on the right side of the peak.
f. The counts in the channel at or just above FWHM on the right side of the peak. Counts $\geq 5\ 000$.
g. The counts in the channel just below FWHM on the right side of the peak. Counts $< 5\ 000$.

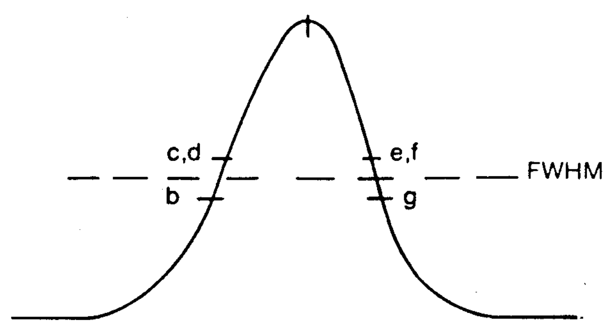


Figure 4-2

Using the information gathered above, apply the following formula:

$$\frac{e-d + \frac{b}{c} + \frac{f}{g}}{a} = \text{resolution expressed as a decimal fraction.}$$

The resolution will be in the range of 0.06 to 0.09 (6% to 9%) for a Canberra Series 802 Scintillation Detector.

By adjusting the FOCUS control slightly to one side or the other of mid-range and doing another resolution check, it will be apparent that the resolution has been improved (the number is smaller) or has been degraded (the number is larger).

By doing several successive approximations, the best resolution will be found. The FOCUS control can be left in that position as long as the same PMT and Model 2007P are associated. It would be helpful however, to check for best resolution from time to time to be sure that there is no change with time.

Section 5. Theory of Operation

5.1 GENERAL

The Model 2007P essentially consists of two functionally separate sesctions. The voltage divider provides the photomultiplier tube (PMT) with the proper operating potentials and the *preamplifier* converts the charge output of the PMT into a proportional voltage.

Specifically, the bias network chosen for the PMT provides the nominal distribution of accelerating potentials between dynode sections that has found to yield the best performance for nuclear applications. Capacitors C9 and C10, provided between the anode and upper two dynodes, bypass large signal current occuring under moderately high pulse amplitude conditions. RV3 permits independent control of PMT grid potential for optimization of resolution, while RV2 permits PMT gain to be adjusted by modifying the potential applied at the top of the divider string.

The preamplifier section functions as an operational integrator with Q1 in the common source configuration providing a high open loop gain by virtue of the ac bootstrap action furnished by C5. Q1 also allows a high input impedance by virtue of its gate input, while Q2 provides current gain and low output impedance. The loop is then closed by the integrating *capacitor* C3, with R5 providing dc stability in addition to facilitating the discharge of C3. RV1 enables the adjustment of output dc offset at the same time allowing the gate of Q1 to be biased slightly negative.

The sensitivity of the preamp to charge may be calculated by noting that all charge transferred from the PMT anode through C2 collects on C3, creating a potential difference across C3 according to the relation,

Q=CV or V/Q = 1/C3
For the 2007P since C3 = 220 pF,
V/Q = 1/220 pF = 4.5 mV/pC

Filtering of the HV input is provided by C8 while standard LC decoupling of the low voltage supply lines is employed to minimize problems caused by noise pickup in the power cable.

5.2 EQUIPMENT REQUIRED FOR CHECKOUT

1. Calibrated dual trace Oscilloscope (scope), rated dc-100 MHz minimum, with vertical sensitivity of at least 50 mV/cm and a time base sweep of at least 20 ns/cm.
2. Reference Pulser with a rise time less than 20 nsec (Canberra Model 1407 or equivalent).
3. High Voltage Power Supply (HVPS).
4. DC Voltmeter (DVM) with rated accuracy to 0.1% with a 10M ohm input impedance.
5. Model 2000 NIM Bin and Power Supply, or equivalent.
6. Preamplifier power source with Preamp Power Connector. Note that all Canberra amplifiers are equipped with preamp power connectors.
7. Shielded coaxial cable, RG-62, BNC-BNC as required, lengths as short as practicable, herein referred to as "coax".
8. Shielded coaxial cable, RG-59, SHV-SHV as required, lengths as short as practicable, herein referred to as "HV coax".

5.3 INITIAL SETUP FOR CHECKOUT

1. Model 2007P:

GAIN	fully CW
FOCUS	fully CCW

2. Model 1407 Pulser:

RISE TIME	MIN
FALL TIME	400 μsec
ATTENUATION	X2
LINE/OFF/90Hz	90 Hz
NORMALIZE	fully CW
POS/NEG	NEG

3. Oscilloscope

CHANNEL 1	1 V/cm
CHANNEL 2	50 mV/cm
DISPLAY	ALT,EXT TRIG
SLOPE	(-)
TIME BASE	20 μsec/cm

.4 CHECKOUT PROCEDURE

1. Connect the preamp power cable from the 2007P to the source of preamp power.
2. Using a length of coax, connect the OUTPUT of the 2007P to channel 2 of the scope.
3. Apply power to the 2007P and verify the dc level on the scope channel 2 trace is 0 ± 50 mV.
4. Connect the 1407 NORMAL output to the scope external trigger input and the 1407 ATTEN output to the scope channel 1 input using suitable coax lengths.
5. Adjust the 1407 PULSE HEIGHT control for a -5V signal on the channel 1 trace.
6. Remove the cable from the Scope channel 1 input and connect it to the 2007P TEST input.
7. Move the cable from the scope channel 2 input to channel 1 input and set the channel 1 range to 0.2 V/cm.
8. Verify the signal on the channel 1 trace to be > + 1 volt.
9. Adjust the 1407 PULSE HEIGHT control for a 1 V signal on the channel 1 trace.
10. Verify the slow *fall* time from 1 V peak to 360 mV to be between 35 and 65 μsec.
11. Expand the scope time base to 10 nsec/cm and verify the fast rise time from the 10 - 90% levels to be < 20 nsec.
12. Disconnect all coax from the 2007P and using HV coax connect the HVPS to the HV connector on the 2007P.
13. Make sure the 2007P is resting on a nonconductive surface and increase HVPS to + 100 V dc.
14. Use the DVM to measure the potential, with respect to chassis ground (pin 14), of each pin in the 2007P socket. The range of acceptable potentials is given below in dc volts.

PIN		PIN	
1	13 - 15.4	8	63.1 - 69.7
2	20.7 - 22.9	9	72.2 - 79.9
3	27.4 - 30.2	10	80.8 - 91.6
4	33.7 - 37.3	11	89.8 - 99.2
5	40.5 - 44.7	12	no connection
6	47.4 - 52.4	13	7.6 - 8.4
7	54.8 - 60.6	14	ground

15. Turn the FOCUS control to CW. Pin 13 should now be 14 to 15.4 V. Turn GAIN control to CCW. Pin 10 should now be 70.9 to 82.7 V. Reduce HVPS to zero and turn OFF.

This warranty covers Canberra equipment shipped to customers within the United States. For equipment shipped outside the United States, a similar warranty is provided by Canberra's local representative.

DOMESTIC WARRANTY

Equipment manufactured by Canberra's Instruments Division, Detector Products Division, and Nuclear Data Systems Division is warranted against defects in materials and workmanship for one year from the date of shipment. This warranty does not cover damage caused by improper use of the equipment.

If defects are discovered within 30 days of the time you receive the equipment, Canberra will pay transportation costs both ways. After the first 30 days, you will have to pay the transportation costs.

Canberra's software media are warranted to be free from defects for 90 days from the date of shipment.

This is the only warranty provided by Canberra; there are no other warranties, expressed or implied. All warranties of merchantability and fitness for an intended purpose are excluded. Canberra shall have no liability for any special, indirect or consequential damages caused by failure of any equipment manufactured by Canberra.

EXCLUSIONS

This warranty does not cover equipment which has been modified without Canberra's written permission or which has been subjected to unusual physical or electrical stress as determined by Canberra's Service Personnel.

Canberra is under no obligation to provide warranty service if adjustment, repair, or parts replacement is required because of damage caused by other than ordinary use or if the equipment is serviced or repaired or if attempts are made to service or repair equipment by other than Canberra personnel without the prior approval of Canberra.

This warranty does not cover detector damage caused by abuse, neutrons, or heavy charged particles. Damage from these causes is readily identifiable, as described in the manual accompanying each detector.

Equipment provided by Canberra from other manufacturers will carry the warranties provided by those manufacturers unless this equipment is specifically covered under a separate service contract.

SHIPPING DAMAGE

Examine shipments carefully when you receive them for evidence of damage caused in transit. If damage is found, notify Canberra and the carrier immediately. Keep all packages, materials and documents, including your freight bill, invoice and packing list. Although Canberra is not responsible for damage sustained in transit, we will be glad to help you in processing your claim.

OUT OF WARRANTY REPAIRS

Any Canberra equipment which is no longer covered by warranty may be returned to Canberra freight prepaid for repair. After the equipment is repaired, it will pass through our normal pre-shipment checkout procedure.

RETURNING EQUIPMENT

Before returning equipment other than detectors for repair you must contact your Regional Service Center or one of our factories for instructions.

For detector repair, contact the Canberra Detector Division in our Meriden, Connecticut factory for instructions.

> If you are going to return the equipment to the factory, you must call first to get an Authorized Return Number (ARN).
>
> Any shipment received without an ARN will not be processed or repaired until you contact us with the necessary information.

When you call us, we will be glad to suggest the best way for you to ship the equipment and will expedite the shipment in case it is lost or delayed in transit. Giving you shipping advice does not make us responsible in any way for the equipment while it is in transit.

Please pack your equipment carefully so it won't be damaged in shipment. The original shipping material is best for this purpose, but if you don't have it, Canberra will be glad to provide a suitable container for a fee.

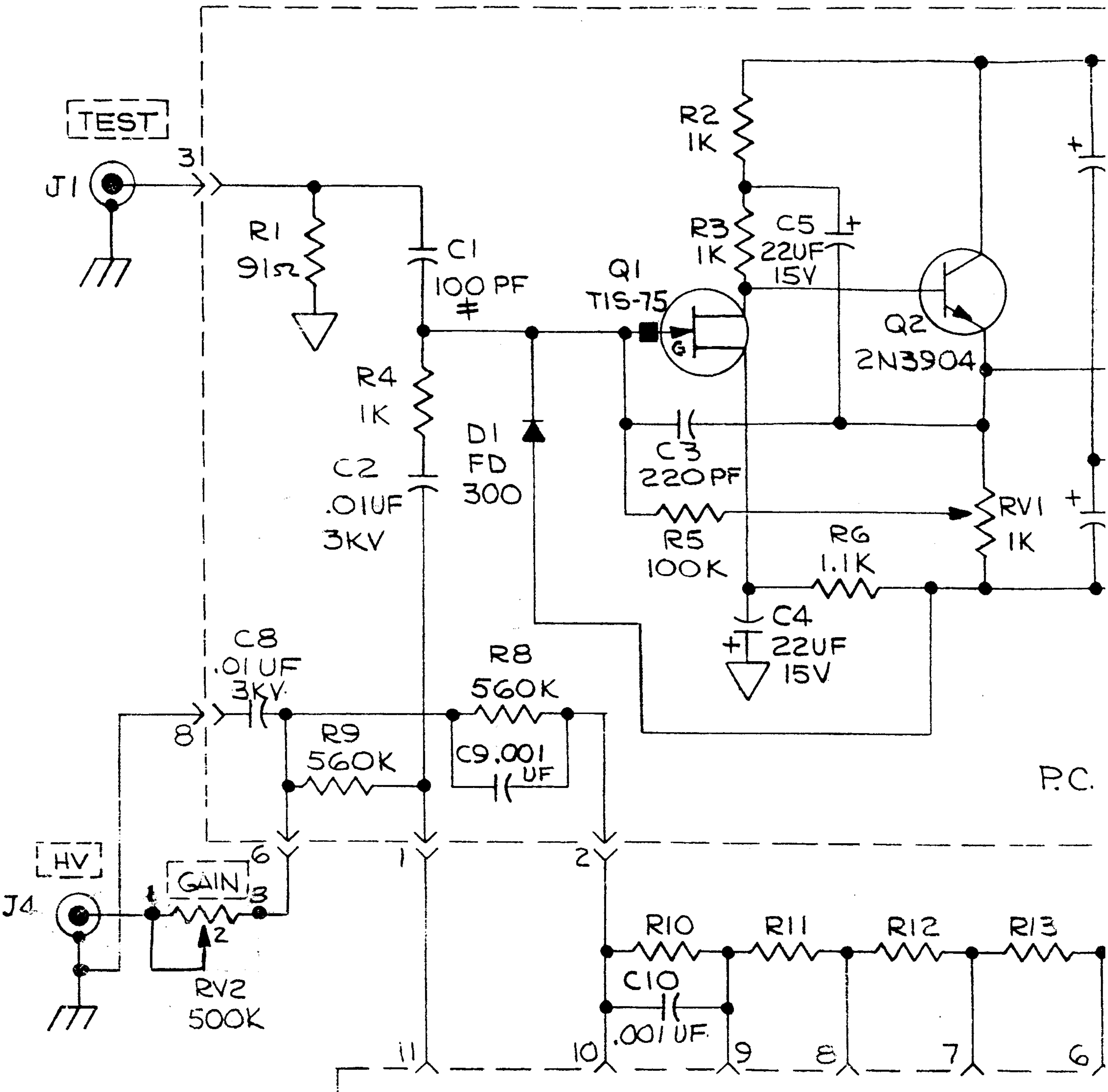
SERVICE OPTIONS

Canberra has a comprehensive Service Program which provides several options for your equipment maintenance needs:

- On-site Maintenance Agreements for system users who require the highest level of service.
- Extended Warranty Agreements for customers who need a rapid response, low cost, fixed fee repair service.
- Essential Software Service Agreements designed to assist users who want continuous technical assistance or software updates as they occur.
- Standard return-to-factory service options.
- A full line of quality replacement parts for customers who elect to maintain their own equipment.
- A Field Communications Center to provide over-the-phone technical assistance.

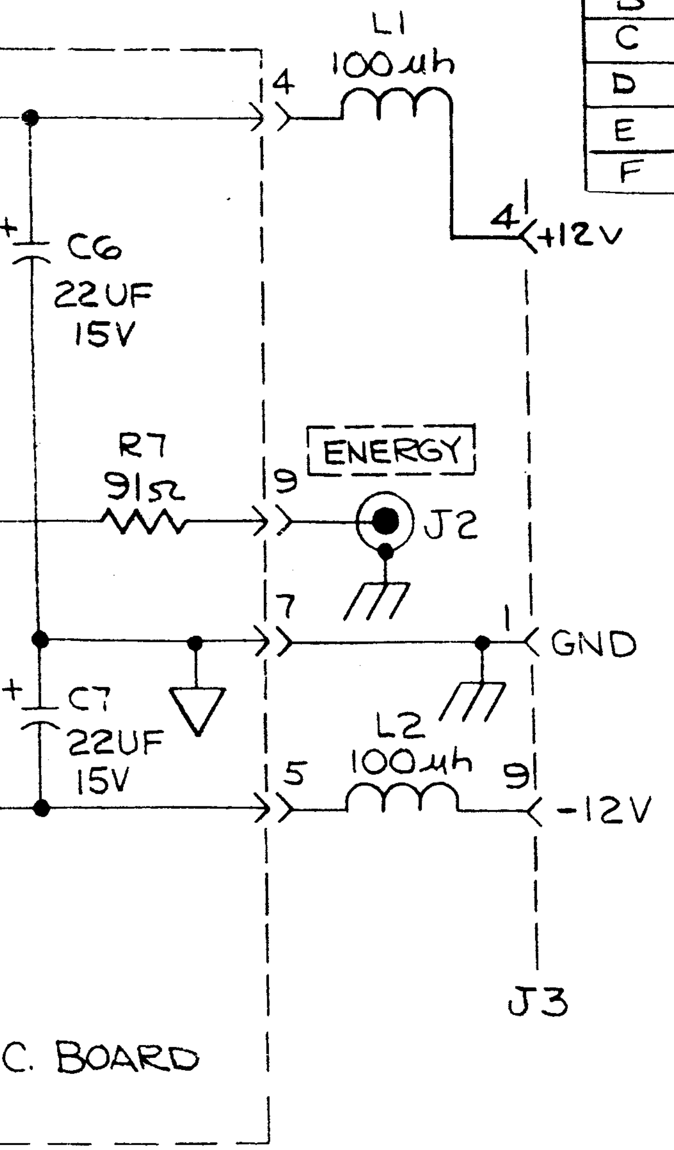
For further information on these service options, please contact any of Canberra's Regional Service Centers.

In addition to our factory-based support services, Canberra's Regional Service Centers are strategically located throughout the world to provide fast and efficient service.



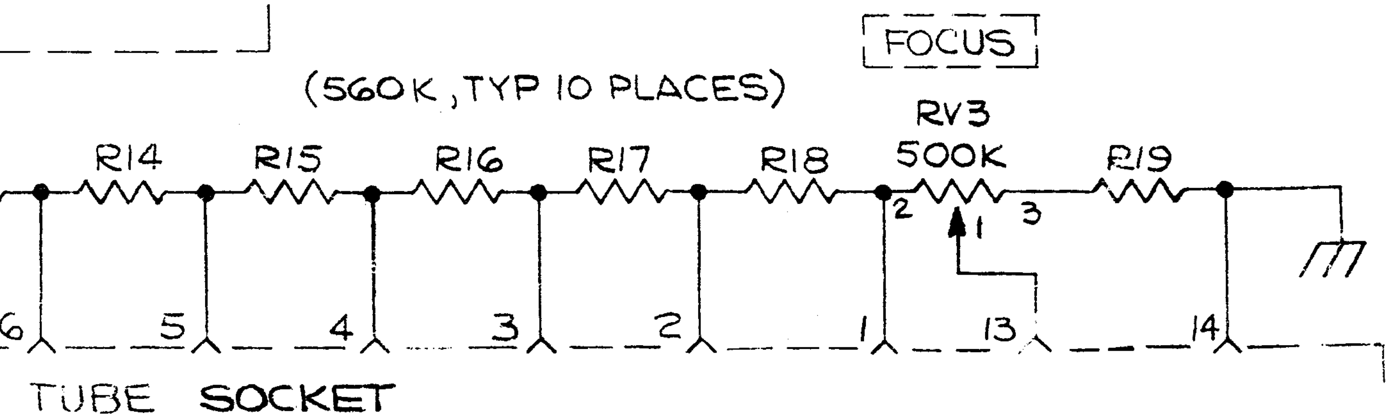
LAST COMPONENT REF. DESIGNATION	
CAPACITORS	C10
DIODES	D1
RESISTORS	R19
CONNECTORS	J4
VARIABLE RESISTORS	RV3
TRANSISTORS	Q2
INDUCTOR	L2

REV	CHANGE	ECN	BY	DATE	APPD
B	REDRAWN & INIT. RELEASE	2049	DRW	12-78	
C	SEE ECN	2060	JH	12-78	
D	REV WIRING ON RV2 SEE ECN	2088	ZP	1-24-78	
E	SEE ECN	2194	AM	4-10-79	
F	AR 13002	4418	SAS	2-10-86	
G	REV. C9 & C10 NOW MONO CAP.	5142	HMC	7-21-88	
H	REVISED (AR 14080)	5364	RJB	4-19-89	
J	ADD FERRITE BEAD / DELETE MONO-CO CO	5397	RA	6-28-89	



NOTES:

1. THERE ARE NO FOUR WAY TIES ON THIS SCHEMATIC.
2. UNMARKED RESISTORS ARE ¼W, 5%.
3. [ ] INDICATES REAR PANEL COMPONENT LOCATION.
4. ■ INDICATES FERRITE BEAD ICN 20300080



DRAWN D. WEST	DATE 12-18-78	SCHEMATIC MODEL 2007P	CANBERRA	
CHKD R.W.L.	12/21/78			
APPD MECH				
APPD ELEC GH	12/21/78		DRAWING NO B-17403	REV J
NEXT ASSY PARTS LIST A-17405		SCALE —	DO NOT TEMPLATE DRAWING	SHT 1 OF 1

USED ON

PHOTOMULTIPLIER TUBE BASE-PREAMPLIFIER Model 2007P

0985

Operator's Manual

Canberra Industries, Inc., One State Street, Meriden, CT 06450 Tel. (203) 238-2351 TWX: 710-461-0192 Cable: CANBERRA

Table of Contents

Section 1.
Introduction

1.1 INTRODUCTION

The Canberra Model 2007P Tube Base-Preamplifier provides the high voltage divider network for correctly biasing essentially all 10-stage photomultiplier tubes (PMT) used for nuclear spectroscopy. This network is intended for use with a positive high voltage for tubes which operate with their photocathodes near ground potential. The network includes a focus control for adjusting the detector resolution performance, and a gain trim control for matching outputs of several detectors when used in arrays.

Designed to be compatible with the Canberra Model 802 series Scintillation Detectors (or equivalent), the tube base connects directly to the pins of the PMT, providing a compact integrally mounted assembly.

The Canberra Model 2007P Tube Base-Preamplifier also contains a low noise charge-sensitive preamplifier. The preamplifier recovers the charge pulse at the anode pin of the PMT directly and converts it to a positive voltage pulse output. The peak amplitude of each output pulse is linearly proportional to the total charge output of the PMT during each amplified photo event. The pulse is set to decay at a nominal 50 μsec time constant, and interfaces directly with any of Canberra's spectroscopy amplifiers.

The Model 2007P includes a diode protection network on the preamplifier input to prevent damage to the circuitry from the inadvertent sudden application or removal of PMT bias voltage. A test input is also provided to aid system testing, gain calibration, or troubleshooting. Preamplifier power is usually derived from the associated pulse shaping amplifier. A ten-foot long power cable in supplied with the Model 2007P.

Section 2.
Specifications

2.1 INPUTS

DETECTOR—The preamplifier is internally connected to pin 11 of the Tube Base socket (PMT anode).

TEST INPUT—Accepts a positive - or negative - polarity tail pulse from a test-pulse generator. Charge coupled at 30 picocoulombs per volt to preamplifier input. Voltage gain to output is 130 mV/V nominal. Input impedance is ≈ 93 ohms.

HV INPUT—PMT bias-voltage range, 0 to + 2000 V dc. Anode series resistance 1M ohms. Bias network total resistance: 6.66 M ohms to 7.16 M ohms, depending on the position of the GAIN control.

2.2 OUTPUTS

ENERGY OUTPUT—Provides unipolar positive pulses linearly proportional in peak amplitude to charge delivered at PMT anode.

Decay time constant 50 microseconds nominal. Rise time less than 20 nanoseconds. Delivers up to 10 V peak. Output impedance ≈ 93 ohms, series connected; direct coupled.

2.3 PERFORMANCE

INTEGRAL NON-LINEARITY—less than ± 0.04% for up to 10 volt output.

GAIN DRIFT—Less than ± 0.01%/°C (± 100 ppm/°C).

NOISE—Less than 1 x 10^{-16} coulombs rms referred to input.

CHARGE SENSITIVITY—4.5 mV/picocoulomb

2.4 CONNECTOR TYPES

HIGH VOLTAGE—SHV

ENERGY OUTPUT, TEST INPUT—BNC

TUBE SOCKET—14-pin (Cinch Jones 3M-14 or equivalent)

POWER—Amphenol 17-20090

2.5 CONTROLS

FOCUS—Single-turn screwdriver adjusted potentiometer to adjust voltage at grid of PMT. Range 72 to 145 V per 1000 V dc of high voltage input.

GAIN—Single-turn screwdriver adjusted rheostat to adjust anode bias. Adjustment range: 92% to 100% of applied high voltage.

2.6 POWER REQUIREMENTS

HIGH VOLTAGE—Bias network requires 150 μA per 1000 V dc

± 12 V dc—15 mA dc nominal

2.7 PHYSICAL

SIZE—Diameter 5.8 cm (2.3 in.)

LENGTH—7.6 cm (3.0 in.)

NET WEIGHT—0.7 kg (1.5 lb.)

Section 3. Installation

3.1 GENERAL

The Model 2007P is intended to provide a convenient package for interfacing with the photomultiplier tube (PMT). As specific mounting details differ significantly between applications, only the following general considerations can be offered.

3.2 DETECTOR MOUNTING

The tube base preamp is intended to mount coaxially with the Model 802 series scintillation detectors simply by mating the PMT pins into the tube socket. The scintillator should, of course, be handled with care in mating, and protected from shock.

3.3 PRECAUTIONS

Consistent with good operating practice for the PMT, the high voltage full bias should not be applied immediately: it should be raised and lowered over several seconds. The Model 2007P is diode protected for occasional faults and for high-voltage arcing. A primary consideration here will be the instantaneous noise current in the PMT, which may take a considerable time to settle.

Steady state dissipation in the PMT bias network has been minimized, in order to prevent degradation of background "dark" currents due to local heating. Hence no particular care need be expended in providing any heat sinking for the tube base.

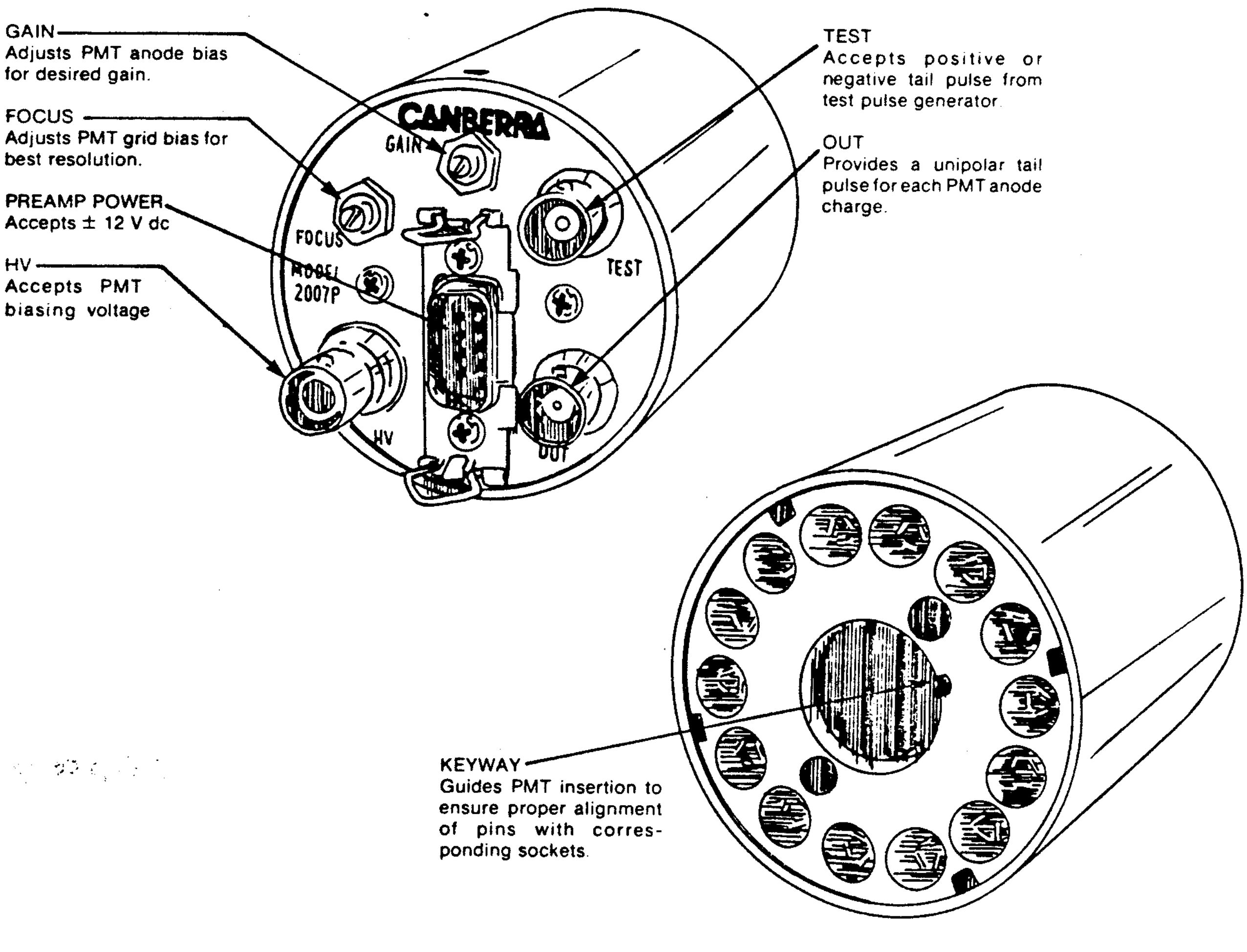


Figure 2-1
Model 2007P
Front and Rear Panels

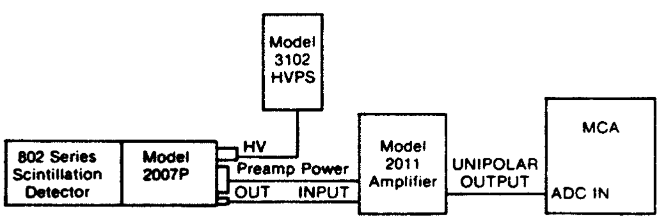
Section 4.
Operating Instructions

4.1 GENERAL
The purpose of this section is to familiarize the user with a typical setup incorporating the Model 2007P Photomultiplier Tube Base/Preamplifier. The following discussion of a typical configuration will give the user sufficient familiarity with the Model 2007P to permit its proper use in any system.

4.2 SETUP
Connect the Model 2007P to the Photomultiplier Tube (PMT). Be certain to align the key on the PMT with the keyway on the Model 2007P before attempting to insert the PMT pins into the tube base socket. See the rear panel photograph (Figure 2-1) for the location of the keyway.

Using a small screwdriver, turn the Model 2007P GAIN control to its extreme clockwise position, which will provide the highest possible gain, and adjust the FOCUS control to about mid-range.

Connect a high-voltage cable between the Model 2007P HV connector and the High Voltage Power Supply. Connect a signal cable between the Model 2007P OUT connector and the amplifier's input. Connect the preamplifier power cable between the preamp power (9-pin) connectors on the Model 2007P and the amplifier. Note that for a PMT, the amplifier must be capable of 0.5μ sec shaping.



Model 2007P in a Typical System
Figure 4-1

4.3 THE GAIN CONTROL
The GAIN control is used to match the gain of two or more PMTs in a multiple detector system. If a single PMT is being used, the control should be left in the extreme clockwise position.

To match the gain of several PMTs, it is necessary to know the gain of the each detector. Collect several thousand counts in a peak of ^{137}Cs (for instance) and record the number of the peak channel. Repeat for each PMT.

Place the MCA's cursor in the lowest recorded channel found in the preceding paragraph and adjust the GAIN controls of each PMT in turn so that all will collect the peak in that same peak channel.

4.4 THE FOCUS CONTROL
The FOCUS control is used to obtain the best possible resolution with a given PMT. Resolution is defined as the ability of the detector to differentiate between two peaks that are close together in energy. Thus the narrower the peak the better the peak separation and the better the resolution.

Start with the FOCUS control set about the middle of its range. By checking the resolution several times with a slight adjustment of the FOCUS control each time, the point of best resolution can be found.

4.5 RESOLUTION
The full width of the peak at half of its maximum value (FWHM) is used to determine the resolution by:

$$\text{Resolution} = \frac{\text{FWHM}}{\text{Peak Position}}$$

where Peak Position and FWHM are expressed in channels. The performance of a scintillation detector is usually specified in terms of its resolution for the 662 keV peak of ^{137}Cesium.

To determine the resolution, collect a peak of 10 000 counts of ^{137}Cs. Half maximum of the peak would be 5 000 counts, but it is unlikely that there will be a channel that contains exactly 5 000 counts. Therefore, it is necessary to interpolate the data.

Record the following information:

a. The peak channel. That is, the channel with 10 000 counts.
b. The counts in the channel just below FWHM on the left side of the peak. Counts $<$ 5 000.
c. The counts in the channel at or just above FWHM on the left side of the peak. Counts $\geq$ 5 000.
d. The number of the channel at or just above FWHM on the left side of the peak.
e. The number of the channel at or just above FWHM on the right side of the peak.
f. The counts in the channel at or just above FWHM on the right side of the peak. Counts $\geq$ 5 000.
g. The counts in the channel just below FWHM on the right side of the peak. Counts $<$ 5 000.

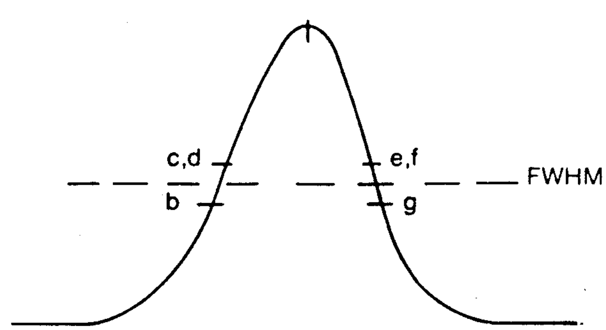


Figure 4-2

Using the information gathered above, apply the following formula:

$$\frac{e\text{-}d + \frac{b}{c} + \frac{f}{g}}{a} = \text{resolution expressed as a decimal fraction.}$$

The resolution will be in the range of 0.06 to 0.09 (6% to 9%) for a Canberra Series 802 Scintillation Detector.

By adjusting the FOCUS control slightly to one side or the other of mid-range and doing another resolution check, it will be apparent that the resolution has been improved (the number is smaller) or has been degraded (the number is larger).

By doing several successive approximations, the best resolution will be found. The FOCUS control can be left in that position as long as the same PMT and Model 2007P are associated. It would be helpful however, to check for best resolution from time to time to be sure that there is no change with time.

Section 5. Theory of Operation

5.1 GENERAL

The Model 2007P essentially consists of two functionally separate sesctions. The voltage divider provides the photomultiplier tube (PMT) with the proper operating potentials and the *preamplifier* converts the charge output of the PMT into a proportional voltage.

Specifically, the bias network chosen for the PMT provides the nominal distribution of accelerating potentials between dynode sections that has found to yield the best performance for nuclear applications. Capacitors C9 and C10, provided between the anode and upper two dynodes, bypass large signal current occuring under moderately high pulse amplitude conditions. RV3 permits independent control of PMT grid potential for optimization of resolution, while RV2 permits PMT gain to be adjusted by modifying the potential applied at the top of the divider string.

The preamplifier section functions as an operational integrator with Q1 in the common source configuration providing a high open loop gain by virtue of the ac bootstrap action furnished by C5. Q1 also allows a high input impedance by virtue of its gate input, while Q2 provides current gain and low output impedance. The loop is then closed by the integrating capacitor C3, with R5 providing dc stability in addition to facilitating the discharge of C3. RV1 enables the adjustment of output dc offset at the same time allowing the gate of Q1 to be biased slightly negative.

The sensitivity of the preamp to charge may be calculated by noting that all charge transferred from the PMT anode through C2 collects on C3, creating a potential difference across C3 according to the relation,

Q=CV or V/Q = 1/C3
For the 2007P since C3 = 220 pF,
V/Q = 1/220 pF = 4.5 mV/pC

Filtering of the HV input is provided by C8 while standard LC decoupling of the low voltage supply lines is employed to minimize problems caused by noise pickup in the power cable.

5.2 EQUIPMENT REQUIRED FOR CHECKOUT

1. Calibrated dual trace Oscilloscope (scope), rated dc-100 MHz minimum, with vertical sensitivity of at least 50 mV/cm and a time base sweep of at least 20 ns/cm.
2. Reference Pulser with a rise time less than 20 nsec (Canberra Model 1407 or equivalent).
3. High Voltage Power Supply (HVPS).
4. DC Voltmeter (DVM) with rated accuracy to 0.1% with a 10M ohm input impedance.
5. Model 2000 NIM Bin and Power Supply, or equivalent.
6. Preamplifier power source with Preamp Power Connector. Note that all Canberra amplifiers are equipped with preamp power connectors.
7. Shielded coaxial cable, RG-62, BNC-BNC as required, lengths as short as practicable, herein referred to as "coax".
8. Shielded coaxial cable, RG-59, SHV-SHV as required, lengths as short as practicable, herein referred to as "HV coax".

5.3 INITIAL SETUP FOR CHECKOUT

1. Model 2007P:

GAIN	fully CW
FOCUS	fully CCW

2. Model 1407 Pulser:

RISE TIME	MIN
FALL TIME	400 μsec
ATTENUATION	X2
LINE/OFF/90Hz	90 Hz
NORMALIZE	fully CW
POS/NEG	NEG

3. Oscilloscope

CHANNEL 1	1 V/cm
CHANNEL 2	50 mV/cm
DISPLAY	ALT,EXT TRIG
SLOPE	(-)
TIME BASE	20 μsec/cm

.4 CHECKOUT PROCEDURE

1. Connect the preamp power cable from the 2007P to the source of preamp power.
2. Using a length of coax, connect the OUTPUT of the 2007P to channel 2 of the scope.
3. Apply power to the 2007P and verify the dc level on the scope channel 2 trace is 0 ± 50 mV.
4. Connect the 1407 NORMAL output to the scope external trigger input and the 1407 ATTEN output to the scope channel 1 input using suitable coax lengths.
5. Adjust the 1407 PULSE HEIGHT control for a -5V signal on the channel 1 trace.
6. Remove the cable from the Scope channel 1 input and connect it to the 2007P TEST input.
7. Move the cable from the scope channel 2 input to channel 1 input and set the channel 1 range to 0.2 V/cm.
8. Verify the signal on the channel 1 trace to be > + 1 volt.
9. Adjust the 1407 PULSE HEIGHT control for a 1 V signal on the channel 1 trace.
10. Verify the slow *fall* time from 1 V peak to 360 mV to be between 35 and 65 μsec.
11. Expand the scope time base to 10 nsec/cm and verify the fast rise time from the 10 - 90% levels to be < 20 nsec.
12. Disconnect all coax from the 2007P and using HV coax connect the HVPS to the HV connector on the 2007P.
13. Make sure the 2007P is resting on a nonconductive surface and increase HVPS to + 100 V dc.
14. Use the DVM to measure the potential, with respect to chassis ground (pin 14), of each pin in the 2007P socket. The range of acceptable potentials is given below in dc volts.

PIN		PIN	
1	13 - 15.4	8	63.1 - 69.7
2	20.7 - 22.9	9	72.2 - 79.9
3	27.4 - 30.2	10	80.8 - 91.6
4	33.7 - 37.3	11	89.8 - 99.2
5	40.5 - 44.7	12	no connection
6	47.4 - 52.4	13	7.6 - 8.4
7	54.8 - 60.6	14	ground

15. Turn the FOCUS control to CW. Pin 13 should now be 14 to 15.4 V. Turn GAIN control to CCW. Pin 10 should now be 70.9 to 82.7 V. Reduce HVPS to zero and turn OFF.

This warranty covers Canberra equipment shipped to customers within the United States. For equipment shipped outside the United States, a similar warranty is provided by Canberra's local representative.

DOMESTIC WARRANTY

Equipment manufactured by Canberra's Instruments Division, Detector Products Division, and Nuclear Data Systems Division is warranted against defects in materials and workmanship for one year from the date of shipment. This warranty does not cover damage caused by improper use of the equipment.

If defects are discovered within 30 days of the time you receive the equipment, Canberra will pay transportation costs both ways. After the first 30 days, you will have to pay the transportation costs.

Canberra's software media are warranted to be free from defects for 90 days from the date of shipment.

This is the only warranty provided by Canberra; there are no other warranties, expressed or implied. All warranties of merchantability and fitness for an intended purpose are excluded. Canberra shall have no liability for any special, indirect or consequential damages caused by failure of any equipment manufactured by Canberra.

EXCLUSIONS

This warranty does not cover equipment which has been modified without Canberra's written permission or which has been subjected to unusual physical or electrical stress as determined by Canberra's Service Personnel.

Canberra is under no obligation to provide warranty service if adjustment, repair, or parts replacement is required because of damage caused by other than ordinary use or if the equipment is serviced or repaired or if attempts are made to service or repair equipment by other than Canberra personnel without the prior approval of Canberra.

This warranty does not cover detector damage caused by abuse, neutrons, or heavy charged particles. Damage from these causes is readily identifiable, as described in the manual accompanying each detector.

Equipment provided by Canberra from other manufacturers will carry the warranties provided by those manufacturers unless this equipment is specifically covered under a separate service contract.

SHIPPING DAMAGE

Examine shipments carefully when you receive them for evidence of damage caused in transit. If damage is found, notify Canberra and the carrier immediately. Keep all packages, materials and documents, including your freight bill, invoice and packing list. Although Canberra is not responsible for damage sustained in transit, we will be glad to help you in processing your claim.

OUT OF WARRANTY REPAIRS

Any Canberra equipment which is no longer covered by warranty may be returned to Canberra freight prepaid for repair. After the equipment is repaired, it will pass through our normal pre-shipment checkout procedure.

RETURNING EQUIPMENT

Before returning equipment other than detectors for repair you must contact your Regional Service Center or one of our factories for instructions.

For detector repair, contact the Canberra Detector Division in our Meriden, Connecticut factory for instructions.

> If you are going to return the equipment to the factory, you must call first to get an Authorized Return Number (ARN).
>
> Any shipment received without an ARN will not be processed or repaired until you contact us with the necessary information.

When you call us, we will be glad to suggest the best way for you to ship the equipment and will expedite the shipment in case it is lost or delayed in transit. Giving you shipping advice does not make us responsible in any way for the equipment while it is in transit.

Please pack your equipment carefully so it won't be damaged in shipment. The original shipping material is best for this purpose, but if you don't have it, Canberra will be glad to provide a suitable container for a fee.

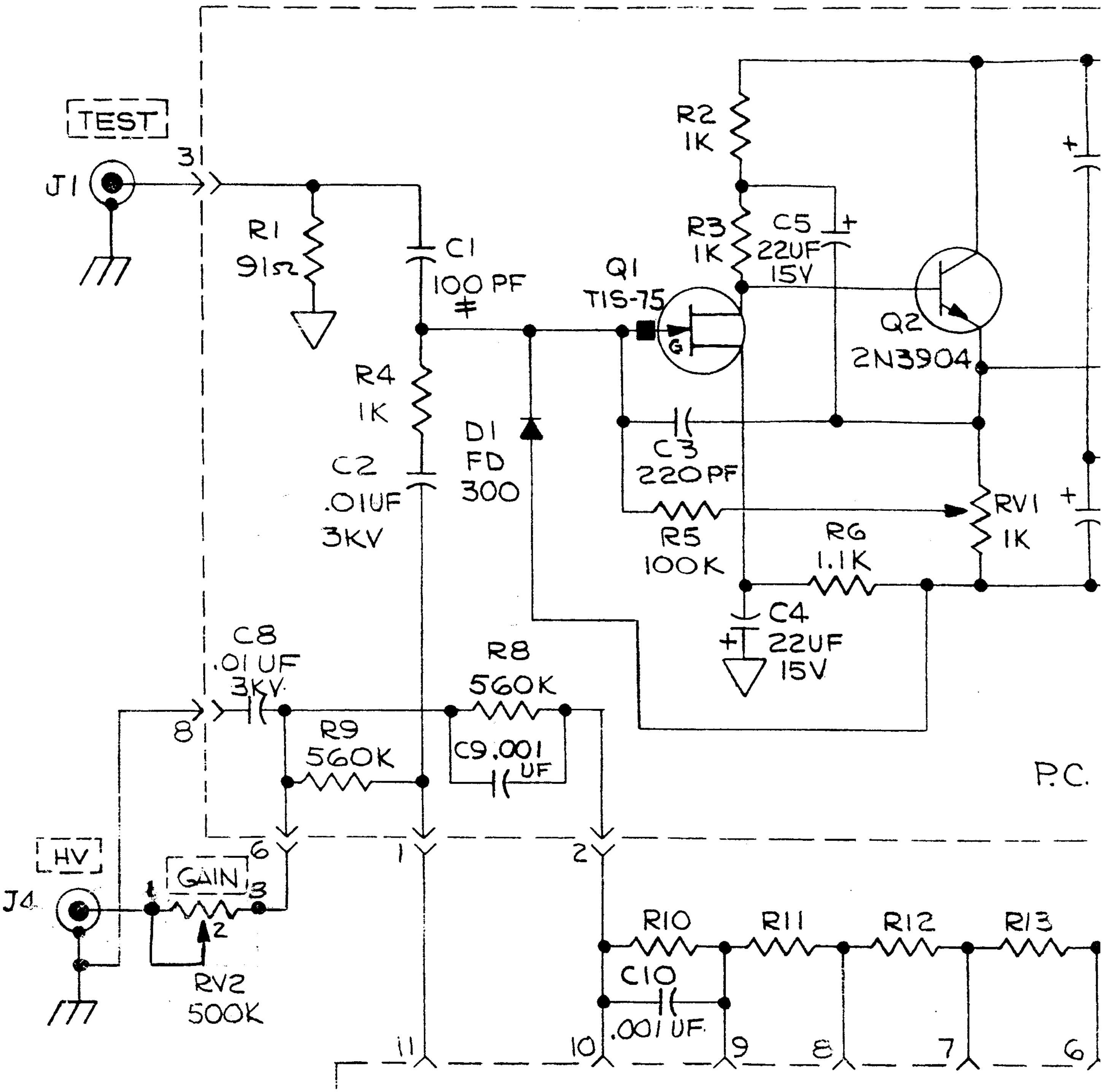
SERVICE OPTIONS

Canberra has a comprehensive Service Program which provides several options for your equipment maintenance needs:

- On-site Maintenance Agreements for system users who require the highest level of service.
- Extended Warranty Agreements for customers who need a rapid response, low cost, fixed fee repair service.
- Essential Software Service Agreements designed to assist users who want continuous technical assistance or software updates as they occur.
- Standard return-to-factory service options.
- A full line of quality replacement parts for customers who elect to maintain their own equipment.
- A Field Communications Center to provide over-the-phone technical assistance.

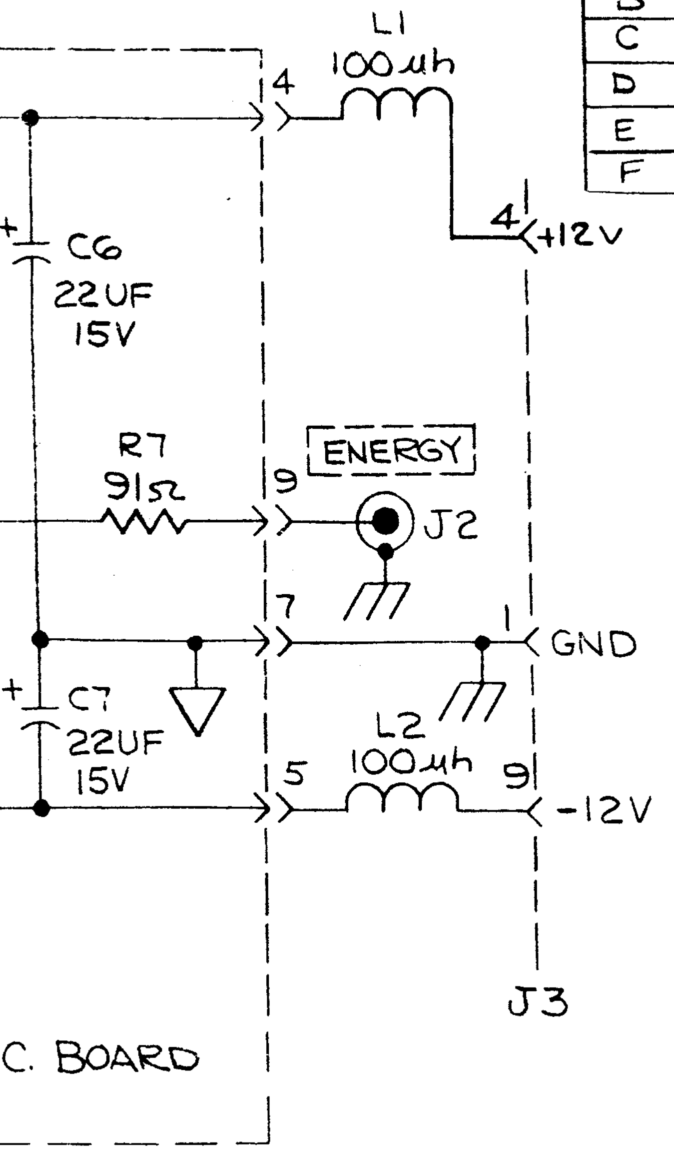
For further information on these service options, please contact any of Canberra's Regional Service Centers.

In addition to our factory-based support services, Canberra's Regional Service Centers are strategically located throughout the world to provide fast and efficient service.



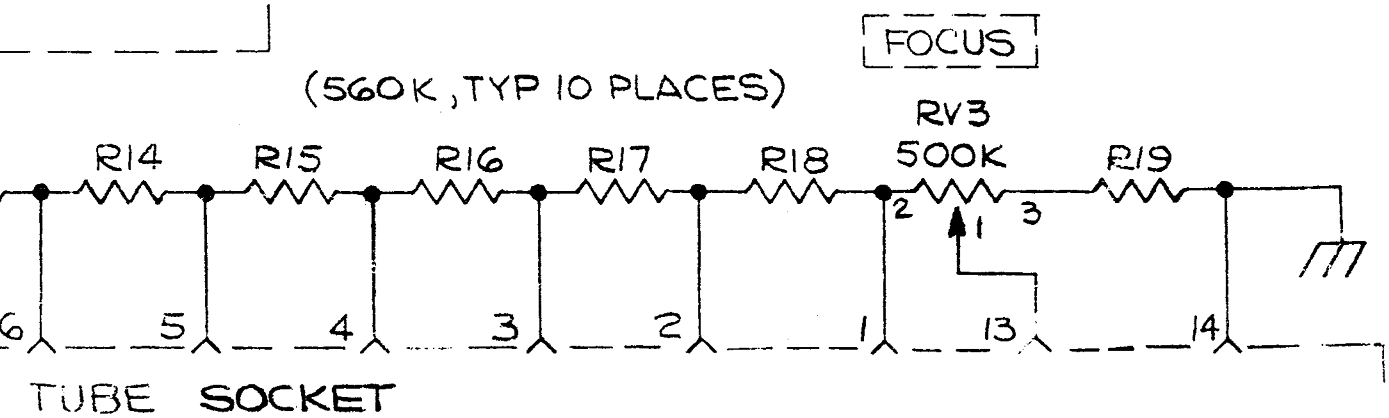
LAST COMPONENT REF. DESIGNATION	
CAPACITORS	C10
DIODES	D1
RESISTORS	R19
CONNECTORS	J4
VARIABLE RESISTORS	RV3
TRANSISTORS	Q2
INDUCTOR	L2

REV	CHANGE	ECN	BY	DATE	APPD
B	REDRAWN & INIT. RELEASE	2049	DRW	12-78	
C	SEE ECN	2060	JH	12-78	
D	REV WIRING ON RV2 SEE ECN	2088	ZP	1-24-78	
E	SEE ECN	2194	AM	4-10-79	
F	AR 13002	4418	GAS	2-10-86	
G	REV. C9 & C10 NOW MONO CAP.	5142	HMC	7-21-88	
H	REVISED (AR14080)	5364	RJB	4-19-89	
J	ADD FERRITE BEAD / DELETE MONO-CO CO	5397	RA	6-28-89	



NOTES:

1. THERE ARE NO FOUR WAY TIES ON THIS SCHEMATIC.
2. UNMARKED RESISTORS ARE ¼W, 5%.
3. [ ] INDICATES REAR PANEL COMPONENT LOCATION.
4. ■ INDICATES FERRITE BEAD ICN 20300080



DRAWN D. WEST	DATE 12-18-78	SCHEMATIC MODEL 2007P	CANBERRA	
CHKD R.W.L.	12/21/78			
APPD MECH				
APPD ELEC GH	12/21/78		DRAWING NO B-17403	REV J
NEXT ASSY PARTS LIST A-17405		SCALE —		
USED ON		DO NOT TEMPLATE DRAWING	SHT 1 OF 1	