INSTRUCTION MANUAL
109PC
PREAMPLIFIER

Serial No. ____________________

Purchaser ____________________

Date Issued ____________________

ORTEC

AN EG&G COMPANY

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LIST OF FIGURES AND ILLUSTRATIONS

A NEW STANDARD TWO-YEAR WARRANTY FOR ORTEC ELECTRONIC INSTRUMENTS

ORTEC warrants its nuclear instrument products to be free from defects in workmanship and materials, other than vacuum tubes and semiconductors, for a period of twenty-four months from date of shipment, provided that the equipment has been used in a proper manner and not subjected to abuse. Repairs or replacement, at ORTEC option, will be made without charge at the ORTEC factory. Shipping expense will be to the account of the customer except in cases of defects discovered upon initial operation. Warranties of vacuum tubes and semiconductors, as made by their manufacturers, will be extended to our customers only to the extent of the manufacturers' liability to ORTEC. Specially selected vacuum tubes or semiconductors cannot be warranted. ORTEC reserves the right to modify the design of its products without incurring responsibility for modification of previously manufactured units. Since installation conditions are beyond our control, ORTEC does not assume any risks or liabilities associated with methods of installation other than specified in the instructions, or installation results.

QUALITY CONTROL

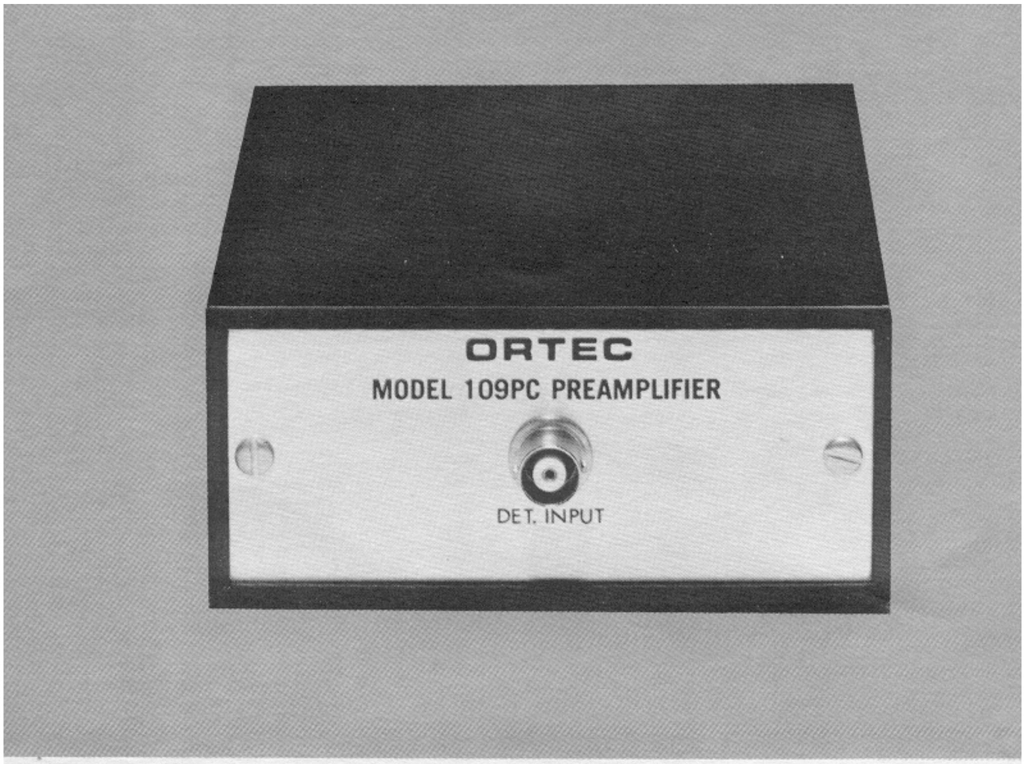
Before being approved for shipment, each ORTEC instrument must pass a stringent set of quality control tests designed to expose any flaws in materials or workmanship. Permanent records of these tests are maintained for use in warranty repair and as a source of statistical information for design improvements.

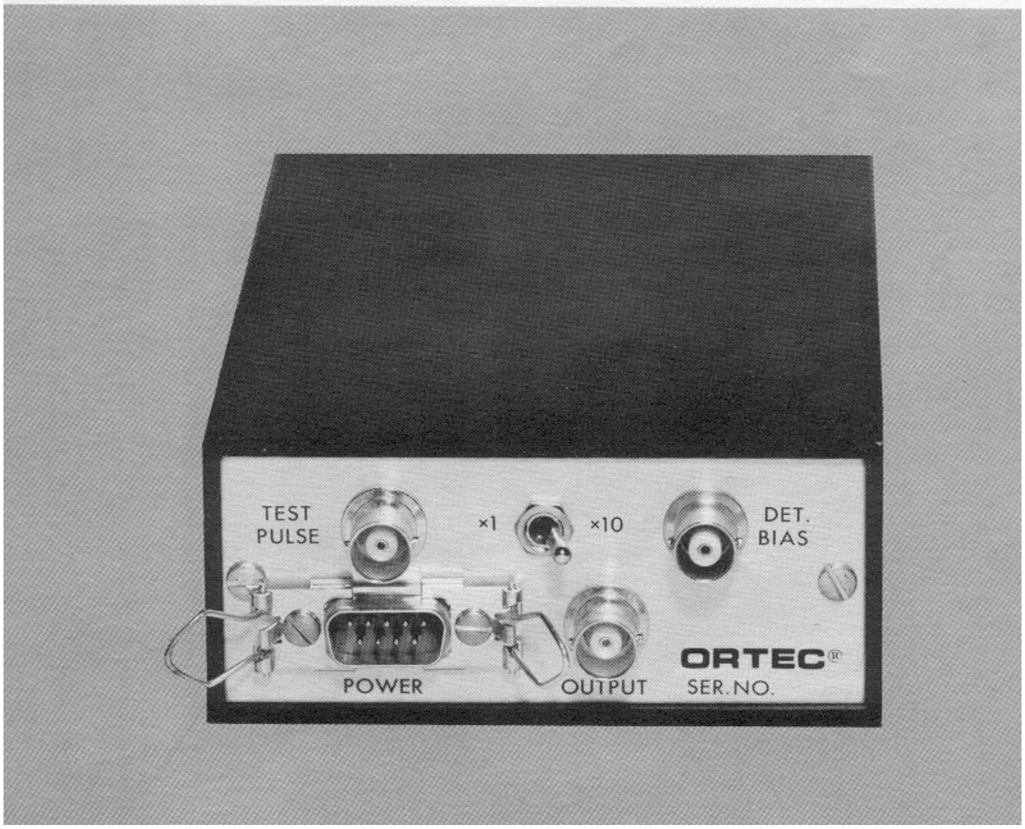
REPAIR SERVICE

ORTEC instruments not in warranty may be returned to the factory for repairs or checkout at modest expense to the customer. Standard procedure requires that returned instruments pass the same quality control tests as those used for new production instruments. Please contact the factory for instructions before shipping equipment.

DAMAGE IN TRANSIT

Shipments should be examined immediately upon receipt for evidence of external or concealed damage. The carrier making delivery should be notified immediately of any such damage, since the carrier is normally liable for damage in shipment. Packing materials, waybills, and other such documentation should be preserved in order to establish claims. After such notification to the carrier, please notify ORTEC of the circumstances so that we may assist in damage claims and in providing replacement equipment if necessary.


ORTEC
MODEL 109PC PREAMPLIFIER
DET. INPUT


TEST
PULSE
×1
×10
DET.
BIAS
POWER
OUTPUT
ORTEC®
SER. NO.

WARNING

DETECTOR BIAS VOLTAGE MUST BE REDUCED TO ZERO FOR 20 SECONDS BEFORE CONNECTING PREAMP TO DETECTOR TO PREVENT FIELD EFFECT TRANSISTOR BLOWOUT.

NOTICE

The 109PC is supplied with a built-in protection circuit which prevents destruction of the input FET. This circuit causes a degradation in the performance of the unit to approximately 505 electrons rms at 0 pF external capacitance and degrades the slope to approximately 27 electrons/pF. The 109PC is shipped with the protection circuit IN.

This protection circuit can be added simply by moving the <u>plug-in jumper</u> from OUT to IN. The jumper is located on the printed board next to Q1.

WARRANTY IS VOIDED WITHOUT THE PROTECTION CIRCUITRY UNLESS THE FOLLOWING PRECAUTIONS ARE TAKEN.

1. DO NOT connect a detector, cable, capacitor, or other capacitive device or low impedance to the DET. INPUT connector, shown in the Front View on page ii of this manual, unless the detector bias circuitry is COMPLETELY DISCHARGED. (Refer to explanation below.)

2. Discharge the detector bias circuitry before making ANY connections to the DET. INPUT connector.

To discharge the detector bias circuitry requires that a low impedance (short circuit preferably) be connected across the DET. BIAS connector, shown in the Rear View on page ii, for at least 20 SECONDS.

The input transistor will be destroyed if the DET. INPUT connector is shorted, i.e., by connecting a detector, cable, capacitor, or other capacitive device such as a voltmeter probe, etc., while the detector bias components are charged. A short circuit, short-term or continuous, will cause the applied bias voltage (stored on C3) to be coupled via C3 directly to the input transistor, causing catastrophic breakdown. If this happens, the only recourse is to replace Q1 and perhaps Q2 also, depending on the failure mode of Q1.

If a variable bias supply is used, merely turning down the voltage control to zero and leaving it for at least 20 SECONDS will suffice, since the bias circuitry can discharge itself through the output impedance of the bias supply.

Sometimes it is necessary to simply disconnect the bias supply, such as when using batteries for bias. This situation leaves no discharge path, so a path must be provided by placing a short circuit or low impedance across the DET. BIAS connector on the rear panel of the unit.

DO NOT SHORT the DET. INPUT connector on the front panel.

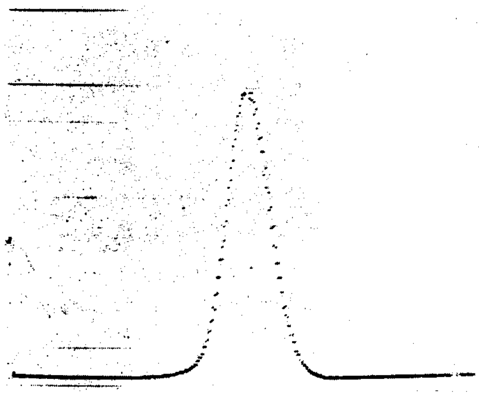
ORTEC 109PC
PROPORTIONAL COUNTER PREAMPLIFIER

1. DESCRIPTION

The ORTEC 109PC is an all-transistor preamplifier using a field-effect transistor in the input stage. It is designed for use with proportional counters in applications such as soft X-ray or low energy gamma spectrometry where resolution approaching the theoretical limit is desired. The gain provided by the 109PC allows operation of the counter at substantially lower voltages, thus reducing peak position shifts and peak broadening due to space charge effects in the tube and simultaneously extending tube life. Significant resolution improvement is also possible due to the extremely low noise contribution of this specially designed transistor circuit as compared to the usual cathode follower or White cathode follower circuits. Figure 1.1 shows typical spectra obtained with the 109PC and standard ORTEC electronics, illustrating the improved counter stability and resolution at lower operating voltages.

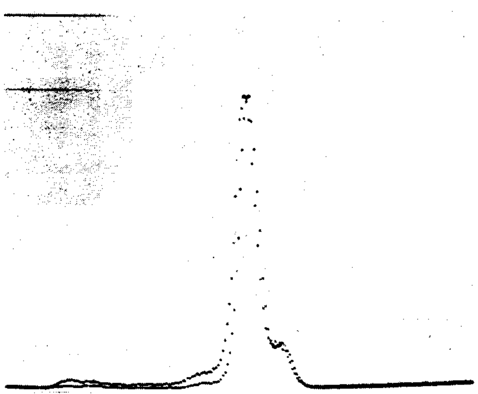
A TEST PULSE connector with built-in charge terminator is provided for use with a pulse generator such as the ORTEC 204 or 419 to simultate the detector signal. This allows a check of system performance while an experiment is in progress.

The 109PC will accommodate up to 5000V bias on the proportional counter. A 50μsec differentiation time constant in the preamp reduces pulse pile-up in the following amplifier. No other pulse shaping is provided in the preamplifier. The 109PC should be followed by a shaping type main amplifier such as the ORTEC 410, 435A, 440A, or 485.

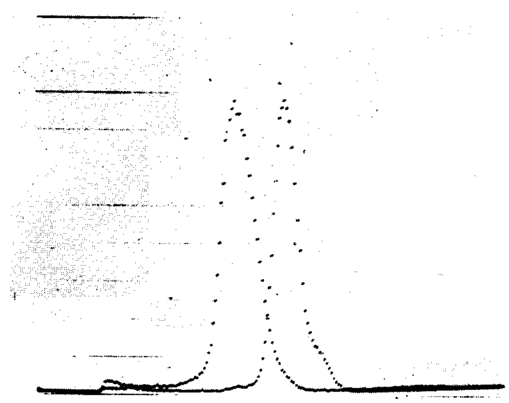


5.9 keV Mμ Kα @ 1700V

5.9 keV Mμ Kα @ 2300V



22.15 Ag Kα @ 1700V
24.95 Ag Kβ



22.15 Ag Kα @ 2300V
24.95 Ag Kβ

GAIN CHANGE IN PROPORTIONAL COUNTERS
AT HIGH COUNTING RATES

Overlapped spectra taken at counting rates of 250 CPS and 20,000 CPS for two different energies at two values of detector bias.[1] Note reduction in gain at high rates with high detector bias. The high gain and low noise of the 109PC allows operation at the lower voltage with excellent energy resolution.

[1] Detector was 2 inch cylindrical detector, 90% Xenon-10% Methane. Fill gas at 76 cm Hg pressure.

Figure 1.1

2. SPECIFICATIONS

OUTPUT PULSE SHAPE: Approximately 20 nsec rise time (10% to 90%), in X1 gain position; 50μsec fall time constant

OUTPUT PULSE POLARITY: Positive with negative input pulse and vice versa

INTEGRAL NONLINEARITY: ≤0.1% for 0-5V output span with internal series termination

TEMPERATURE COEFFICIENT: ±0.01%/°C

DETECTOR BIAS ISOLATION: 5000V dc

GAIN: Reducible to one-tenth by OUTPUT gain switch

DETECTOR LOAD RESISTOR: 22 megohms

OUTPUT AMPLITUDE: 0-7V

OUTPUT IMPEDANCE: Adjustable from 50 to 150 ohms (shipped at 100 ohms)

CHARGE SENSITIVITY: 3.38×10^{12} volts/coulomb (0.54×10^{-6} volts/electron) in X10 gain position

NOISE: Increases with increasing input capacitance. Typical performance values are given in the following table.

NOISE REFERRED TO INPUT

INPUT CAPACITANCE, pF	PROTECTION "OUT"			PROTECTION "IN"		
	rms Electrons		Risetime in nsec	rms Electrons		Risetime in nsec
	2μsec	1μsec		2μsec	1μsec	
0	361	323	15	505	482	25
5	386	354	20	579	486	31
10	412	403	28	682	690	38
15	444	450	42	793	741	43
20	471	494	50	902	791	45
35	588	575	78	1317	997	64
50	720	658	125	1722	1226	83
100	1210	1015	220	3180	2070	175
200	2141	1730	375	5820	3795	385

OUTPUT AND TEST PULSE CONNECTORS: BNC

DETECTOR INPUT CONNECTOR: MHV (5000V)

DETECTOR BIAS CONNECTOR: MHV (5000V)

POWER REQUIRED: +24V dc at 18mA; -24V dc at 18mA. Supplied from ORTEC 410, 435A, or 440A main amplifier or 115 preamp power supply.

NET WEIGHT: 1.5 pounds (0.68 kg)

DIMENSIONS: 1.75 x 4 x 6 inches (4.45 x 10.2 x 15.3 cm)

3. INSTALLATION INSTRUCTIONS

3.1 Connection to Detector

A direct connection with shielded coaxial cable should be made between the detector and the input MHV connector labeled DET. INPUT on the front panel.

The performance of the 109PC Preamplifier, like that of all other such low-noise nuclear amplifiers, is degraded as the capacity at the input of the amplifier increases. For this reason, it is important that the length of coaxial cable used between the amplifier and the detector be kept at the minimum necessary. Also, it is preferable to use 93- or 100-ohm impedance cable rather than 75- or 50-ohm cable, since the capacity per foot is less for the higher-impedance cable. Type RG-62/U cable has 93-ohm impedance and a 13.5 pF per foot capacity; therefore, it is recommended. Type UG-932/U connectors fit both this cable and the MHV input connector.

Once the input cable installation has been made, the electronic noise performance of the 109PC can be predicted by calculating the cable capacity from the above information, adding the capacity expected from the detector, and referring to the table of typical performance versus input capacity (section 2).

3.2 Connection To A Shaping Main Amplifier

The 109PC can be used to drive long 93-ohm line to a shaping main amplifier and is designed to be directly compatible with the ORTEC transistor main amplifiers. It can be used with any shaping main amplifier if a power supply is used to power the 109PC.

3.3 Input Power

Power for the 109PC is supplied through the POWER connector on the rear of the chassis. Power may be supplied by a single 45-volt battery with a tap at 22.5 volts (the tap is used as ground, providing +22.5V and -22.5V; current drain is 18mA), or any well-filtered ±24V power supply such as the ORTEC 115 Preamplifier Power Supply.

If the 109PC is used with ORTEC transistor main amplifiers, power for the preamplifier will automatically be supplied to the preamplifier from the main amplifier through the interconnecting cable supplied with the 109PC.

3.4 Test Pulse

A voltage test pulse can be inserted at the TEST PULSE connector on the rear of the 109PC without the use of an external charge terminator, since the 109PC has a built-in charge terminator. The shape of this voltage pulse must have a fast rise (less than 10^{-8} seconds) followed by a slow exponential decay back to the baseline (2 to 4 x 10^{-4} seconds). The input amplitude can be set at any desired level with the knowledge that 1.6 mV amplitude at the TEST PULSE connector is equal to approximately 10^{4} electrons or 1.6 x 10^{-15} coulombs in the proportional counter.

Also, the test pulse can be inserted into the DET. INPUT connector simultaneously with an operating detector by using an external charge terminator, provided the charge terminator will withstand the detector bias voltage.

4. OPERATING INSTRUCTIONS

4.1 Detector Bias

Apply detector bias through the 109PC Preamplifier at the high-voltage DET. BIAS connector on the rear panel. Supply this bias out to the detector through the signal cable, connected to DET. INPUT.

4.2 Linear Output

The output of the 109PC is a "step" of voltage of 3.4V/picocoulomb with the gain switch in the X10 position, or .34V/picoulomb in the X1 position (silicon detector equivalents). The dynamic range of the output is 7 volts, either polarity, when the output is "sending-end" terminated. "Receiving-end" termination will result in a 3.5 volt dynamic range, but this may be preferable to sending-end termination. The integral nonlinearity in the 109PC is specified at not greater than 0.1 percent over the 0 to 5V range.

5. CIRCUIT DESCRIPTION (See Schematic Diagram 109PC-0000-S1)

5.1 Charge-Sensitive Loop

The charge-sensitive loop consists of five transistors acting as an operational amplifier with capacitive feedback. Transistors Q1 and Q2 operate in cascode and drive Q3, Q4, and Q5 in a low impedance driver configuration for low output impedance and fast rise time. The rise time of the charge-sensitive loop output increases as the external input (detector) capacitance is increased (see section 2).

5.2 Voltage Amplifier

The voltage amplifier is designed for fast rise time (20 nanoseconds) so as to faithfully reproduce the pulse from the charge-sensitive loop.

5.2.1 Pole-Zero Cancellation Network

The decay time constant of the output signal from the preamplifier is determined by C12 and the parallel combination of R17, R18, and R42. It is accurately set at 50 microsecond. R42 C12 is a 400 microsecond time constant in the proper configuration to provide a "zero" type frequency response which cancels out the 400 microsecond "pole" generated by the charge-sensitive loop feedback time constant. The purpose of this "Pole-Zero Cancellation" is to obtain a pulse response which has a step rise with a single 50 microsecond decay time constant back to the baseline without appreciable undershoot. This will allow accurate pole-zero cancellation in the shaping amplifier.

5.3 Cable Driver

The cable driver consists of Q8, Q9, Q10, and Q11 operating in a complementary Darlington connection. This circuit gives extremely good linearity and an output impedance of a few ohms. However, 51 ohms is inserted in series with each circuit, so that the minimum output impedance (R35 at 0Ω) is 51 ohms. The maximum output impedance is 150 ohms (R35 at 100Ω), so that cables in the range of 50 to 150 ohms can be series (sending-end) terminated.

6. MAINTENANCE INSTRUCTIONS

6.1 Testing Performance

As ordinarily used in a counting or spectroscopy system, the 109PC is one part of a series system involving the source of particles to be analyzed, the detector, the 109PC, the main amplifier, and the pulse height analyzer. In situations where proper results are not being obtained and tests for proper performance of the 109PC and the other components are indicated, it is important to realize that rapid and logical testing is possible only when the individual components are separated from the series system. In proving the performance of the 109PC, this consists of removing it from the system and dealing with it alone, by providing a known electrical input signal and testing for proper output signal with an oscilloscope.

6.1.1 Use a voltage pulse in the TEST PULSE jack, as outlined in section 3.4, or use a pulse with a charge terminator at the DET. INPUT jack.

The polarity of the test pulse signal should be in agreement with the expected signal input polarity from a detector.

6.1.2 If a suitable input signal has been obtained for the 109PC as outlined in the preceding section, the performance of the instrument may be checked by observing the pulse waveform at the OUTPUT jack. If an input signal of 1.6 mV has been obtained as described above, one can expect an output pulse amplitude of about 5.4 mV with the gain switch in the X10 position, and 0.54 mV with the gain switch in the X1 position.

6.1.3 The noise contribution of the preamplifier may be verified by two basic methods. In either case, the normal capacity of the detector and associated cables should be replaced by a capacitor of equal value connected to the DET. INPUT jack. This is necessary because the noise contribution of the preamplifier is dependent upon input capacity, as can be seen from the noise specifications given in section 2. The only meaningful statement of the noise level of the preamplifier is one that relates to the spread caused by the noise in actual spectra. This can be measured and expressed in terms of rms electrons after passing through the preamplifier and main amplifier system. The noise performance referenced in section 2 is stated in these terms, and verification methods will be described. If desired, the preamplifier can be tested with no external capacity on the DET. INPUT jack, in which case the noise width should be approximately that shown for zero external capacity. In any case, the input jack and capacitors, when used, should be completely shielded electrically. A wrapping of aluminum foil around the input jack will suffice for testing at zero capacity.

The preamplifier must be tested in conjunction with an associated main amplifier that provides the required pulse shaping. The typical noise performance given in section 2 is based on main amplifier pulse shaping consisting of equal RC differentiation and integration of 2-microsecond time constant. For comparison to these tabulated values, it is preferable to test the preamplifier under identical pulse shaping conditions. It is also important to ensure that the noise level of the input stage of the associated main amplifier does not contribute materially to the total noise. This is usually no problem provided input attenuators, if any, on the main amplifier are set for minimum attenuation.

If a multichannel pulse height analyzer is used following the main amplifier, testing of the noise performance can be accomplished merely by using a calibrated test pulse generator with charge terminator, as outlined in section 6.1.1. With only the charge terminator connected to the DET. INPUT jack, the spread of the pulser peak thus analyzed will be due only to the electronic noise contribution of the preamplifier and main amplifier. The analyzer can be calibrated in terms of keV per channel by observing two different pulser peaks of known energy, and the fwhm of a peak can be taken directly from the analyzer readout.

It is also possible to determine the noise performance of the 109PC preamplifier by the use of a wide-bandwidth rms ac voltmeter such as the Hewlett-Packard 400D, reading the main amplifier output noise level and correlating with the expected pulse amplitude per keV of input signal under the same conditions. Again, a calibrated test pulse generator is required for an accurate measurement.

In this method, the preamplifier and main amplifier are set up as they would be used normally, but with a dummy capacitor (or no capacity) on the DET. INPUT jack, and with the ac voltmeter connected to the amplifier output. The noise voltage indicated by the meter, designated E_{rms}, is read and noted. Then, a test pulse of known energy, E_{in} (in keV), is applied to the input jack, and the amplitude of the resulting output pulse, E_{out}, is measured in volts with an oscilloscope. The noise spread can then be calculated from the formula

$$\mathrm{ENC} = \frac{314\ (E_{rms})\ (E_{in})}{E_{out}} = \text{Electrons rms}$$

where E_{rms} is output noise in volts on the 400D meter, E_{in} is the input signal in keV particle energy, E_{out} is the output signal in volts corresponding to the above signal.

The noise performance of the preamplifier, as measured by the above methods, should not differ significantly from that given in the specifications in section 2.

6.1.4 When testing the preamplifier and detector, if the noise performance of the preamplifier has been verified as outlined in the preceding section, or is otherwise not suspect, a detector may be tested to some extent by duplicating the noise performance tests with the detector connected in place, and with normal operating bias applied. The resulting combined noise measurement, made either with an analyzer or by the voltmeter method, indicates the sum in quadrature of the separate noise sources of the amplifier and the detector. In other words, the total noise is given by $(N_{tot})^2 = (N_{det})^2 + (N_{ampl})^2$.

Each quantity is expressed in electrons rms. The quantity N_{det} is known as the "noise width" of the detector. By use of the above equation, with a knowledge of the noise of the preamplifier, the noise width of the detector can be determined. The most useful application of determining the noise width of a detector is in the occasional monitoring of this quantity to verify that the detector characteristics have not undergone any significant change during use.

6.2 Suggestions For Troubleshooting

In situations where the 109PC is suspected of a malfunction, it is important to isolate the 109PC and test it alone, not in a system involving other units such as a source of particles to be analyzed, the detector, the 109PC, a main amplifier and subsequent scalers and/or analyzers. Such logical isolation and individual testing of components will be the most productive approach.

6.2.1 Charge-Sensitive Loop

The function of the 109PC is simple and lends itself to relatively easy scrutiny. The charge-sensitive loop performs a charge-to-voltage conversion on the input signal. It has an output signal that manifests itself as a fast rise (≈40 nanoseconds at 0 pF external capacitance) step of voltage whose height is determined by the input charge, followed by a 400-microsecond decay back to the baseline. This signal can be observed at the emitter of Q4 while impressing a signal, as described in section 3.4. The amplitude of this signal should be 1 volt/picocoulomb input signal.

6.2.2 Voltage Amplifier

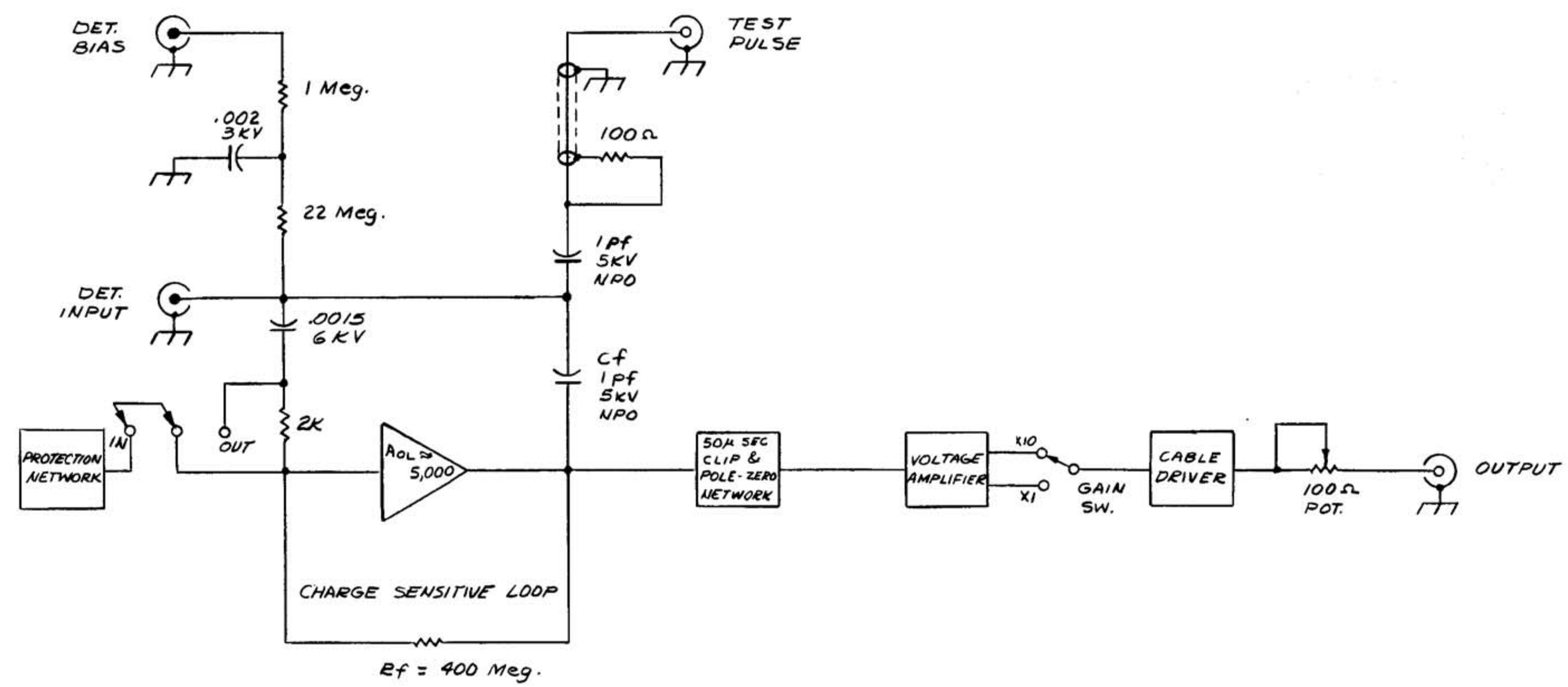
To reduce pulse pileup in the voltage amplifier and subsequent stages, the output signal from Q4 is differentiated with a 50 microsecond time constant by C12. Transistors Q6 and Q7 provide voltage amplification of 0.34 or 3.4 for the X1 or X10 gain switch positions, respectively. Accordingly, the output signal at the S1 wiper arm should be a fast rise with 50 microsecond time constant decay, with amplitude either 0.34 or 3.4 times greater than that at the Q4 emitter.

6.2.3 Cable Driver

The cable driver, consisting of Q8 through Q11, is simply an impedance converter, and the output signal should look exactly like the input signal. No gain is obtained in the cable driver.

TYPICAL VOLTAGES

LOCATION		VOLTAGE
Jct. R15 & C9		22.0
Jct. R28 & C16		22.7
Jct. R29 & C15		- 22.7
Jct. R16 & C11		- 21.9
Q1	S	- 5.7
	Jct. R38 & Dz1	- 5.8
	D	
Q2	E	- 0.5
	B	0
	C	
Q3	E	10.7
	B	11.4
	C	17.1
Q4	E	10.1
	B (E of Q3)	
	C	22.0
Q5	E	- 14.2
	B	- 13.6
	C (Jct. of R8 & Dz1)	
Q6	E	1.3
	B	1.9
	C	10.8
Q7	E	11.4
	B (C of Q6)	
	C	- 0.7
Q8	E	10.8
	B	11.3
	C	24.0
Q9	E	10.2
	B (E of Q8)	
	C	24.0
Q10	E	- 10.3
	B	- 10.9
	C	- 24.0
Q11	E	- 9.6
	B (E of Q10)	
	C	- 24.0



REV.	ECN. NO.	DATE	BY	APPD.
C	109PC-8	10-11	JDW	
B	REDRAWN 109PC-4	2-9-67	JDW	
A	109PC-2	12-8-66	JDW	

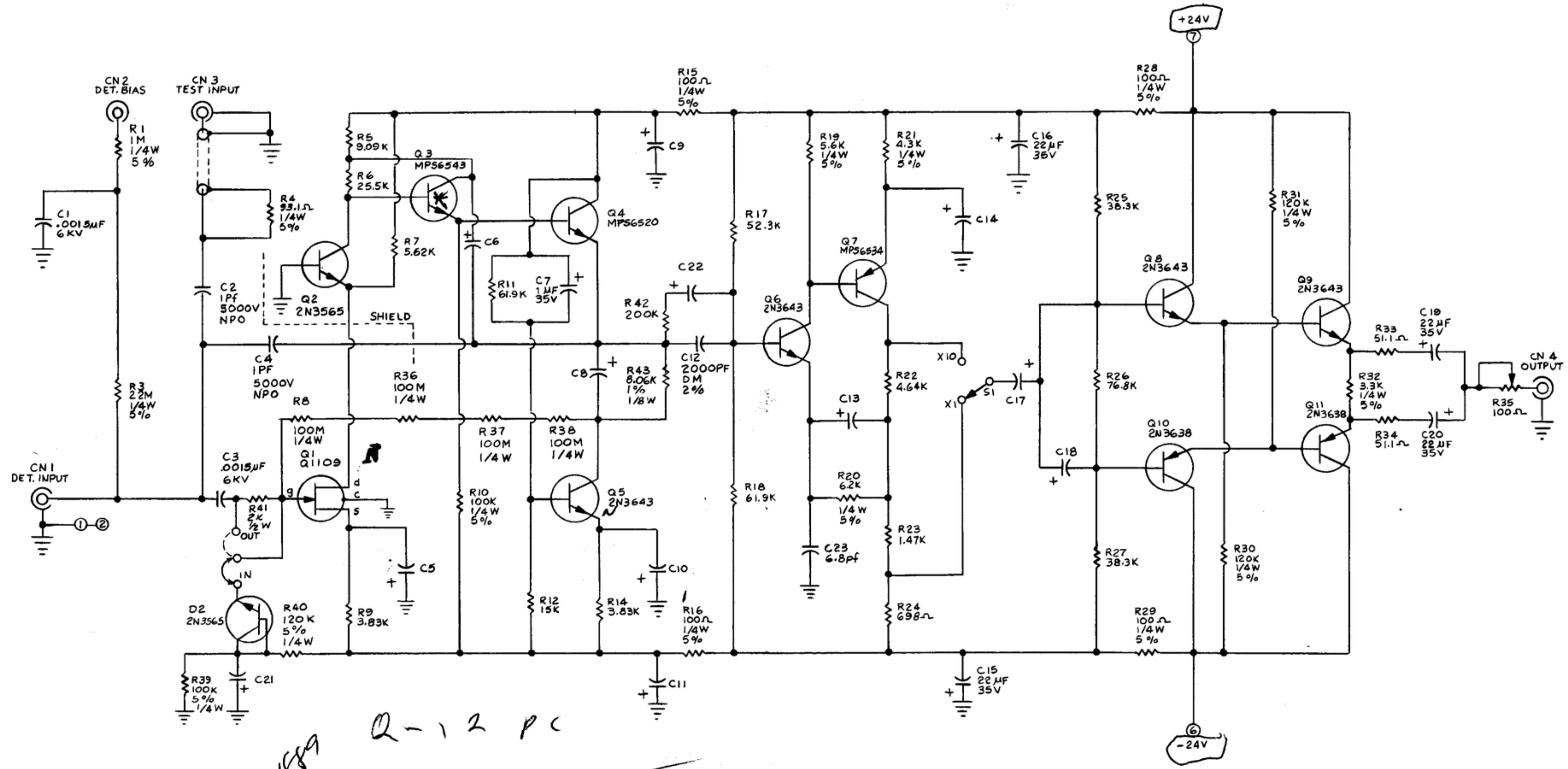
REVISIONS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES
FRACTION ±
DECIMALS ±
ANGLES ±
SURFACE FINISH √ RMS
APPLIED PRACTICES

ORTEC
OAK RIDGE TECHNICAL ENTERPRISES CORPORATION
OAK RIDGE TENNESSEE

TITLE
BLOCK DIAGRAM
MODEL 109PC PREAMPLIFIER

DRAFTSMAN JDWEBB DATE 2-9-67	ENG. APPROVAL J.B. [signature]	RESP. ENG. J.B. Ayers
CHECKED DATE	MFG. APPROVAL	DRAWING NO.
SCALE ~	DWG. ISSUED JDW DATE 2-9-67	109 PC-0000-B1



Q-12 PC

SFB-1889
2N3819
FET-47802

The transistor types installed in your instrument may differ from those shown in the schematic diagram. In such cases, necessary replacments can be made with either the type shown in the diagram or the type actually used in the instrument.

NOTES:
1. ALL RESISTORS ARE METAL FILM, 1/8W, 1%, UNLESS OTHERWISE SPECIFIED.
2. ALL CAPACITORS ARE 6.8µF, 35V TANTALUM, UNLESS OTHERWISE SPECIFIED.
3. NUMBERS ① ② ⑥ ⑦ GO TO AMPHENOL CONNECTOR 17-20090.
4. C 21, R39, R40, R41 NOT USED.

REV	ECN NO.	DATE	BY
A	109PC-2	12-8-66	JDW
B	109PC-3	12-20-66	JDW
C	109PC-4	2-8-67	JDW
D	109PC-5	4-9-68	JDW
E	109PC-7	8-27-68	JDW

REVISIONS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES
FRACTIONS ±1/64 DECIMALS XX ±.01 XXX ±.005 ANGLES ±0°30' FINISH √ RMS
MATERIAL
APPLIED PRACTICES

ORTEC INCORPORATED
100 MIDLAND ROAD, OAK RIDGE, TENNESSEE 37830

TITLE: SCHEMATIC - MODEL 109 PC PREAMPLIFIER

DRAFTSMAN	DATE	RESPONSIBLE ENGINEER	REFERENCE
D. WEBB	4-9-68	J. AYERS	
CHECKED	DATE	ENG. APPROVAL	STOCK NO.
	4-9-68		
SCALE		MFG. APPROVAL / DATE	DRAWING NO.
~		4-9-68	109PC-0000-S1
DWG. ISSUED	DATE	RELEASED FOR MFG. / DATE	
	4-18-68		