CANBERRA

Model 241 Amplifier

User's Manual

9232216C 3/01

Covering the Spectrum
in Nuclear Instrumentation

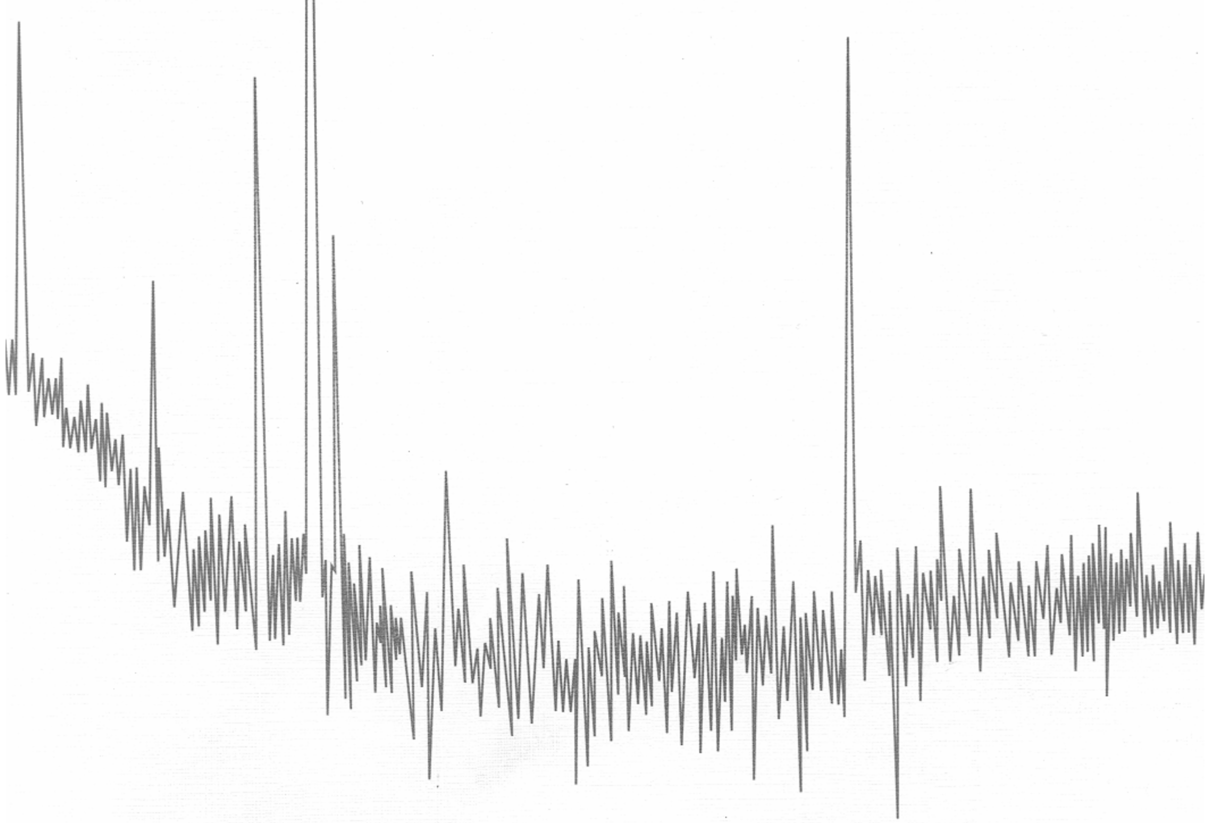

Table of Contents

1. Introduction

The Canberra Model 241 is a high performance, economical spectroscopy amplifier in a single-width NIM module. The low noise and high count rate characteristics of the 241 are ideally suited for semiconductor detectors, proportional counters, and scintillation detectors.

The 241 incorporates four active integration networks that generate very symmetrical, near-Gaussian, unipolar signals. Switch selectable peaking times of 1, 3, and 6 µs (0.5, 1.5, and 3.0 µs shaping times) allow the 241 to match the signal processing requirements of most detectors. The symmetry of the pulse-shaping network optimizes the signal-to-noise ratio while allowing excellent count rate capability.

A gated baseline restorer (BLR) with automatic threshold and restorer rate circuits provides superb high count rate performance without degrading ultimate resolution.

The excellent dc stability of the 241 eliminates spectrum broadening often caused by dc shift of the amplifier output, thus ensuring superior performance.

2. Controls and Connectors

Front Panel

This is a brief description of the 241's front panel control and connectors. For more detailed information, refer to Appendix A, Specifications.

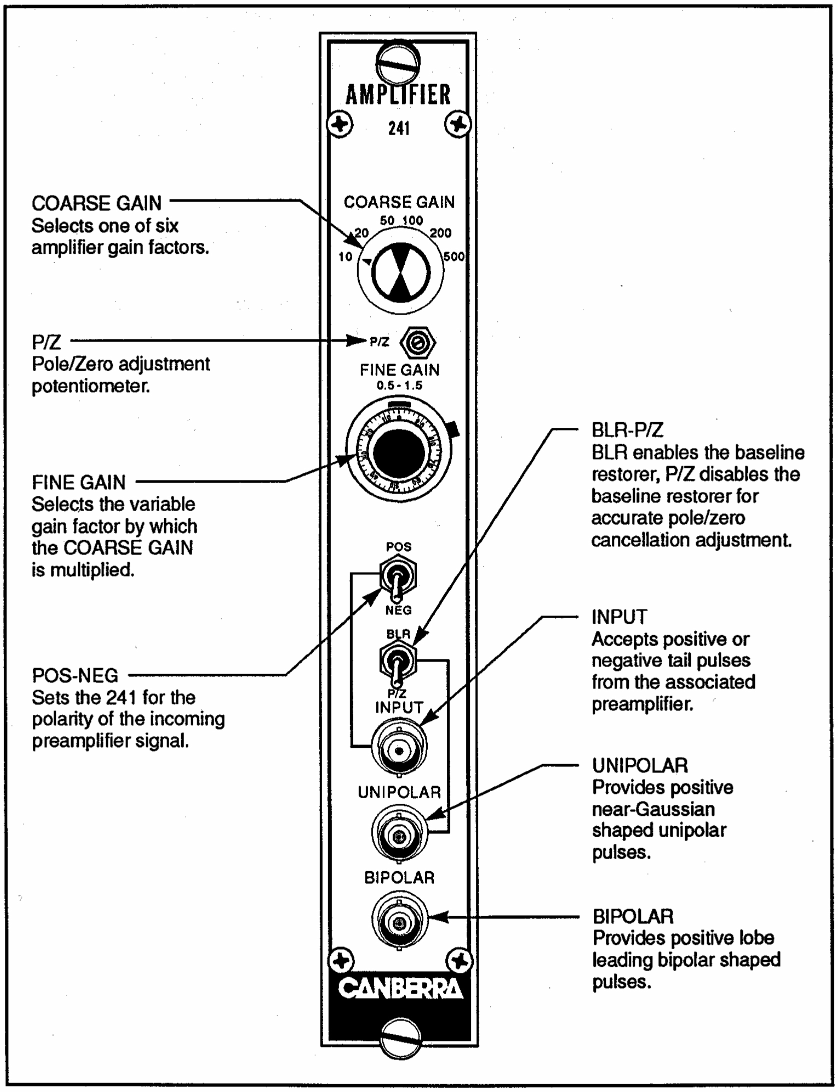

Figure 1 Front Panel

Internal Controls

The internal switches should be set for your specific requirements before applying power to the module.

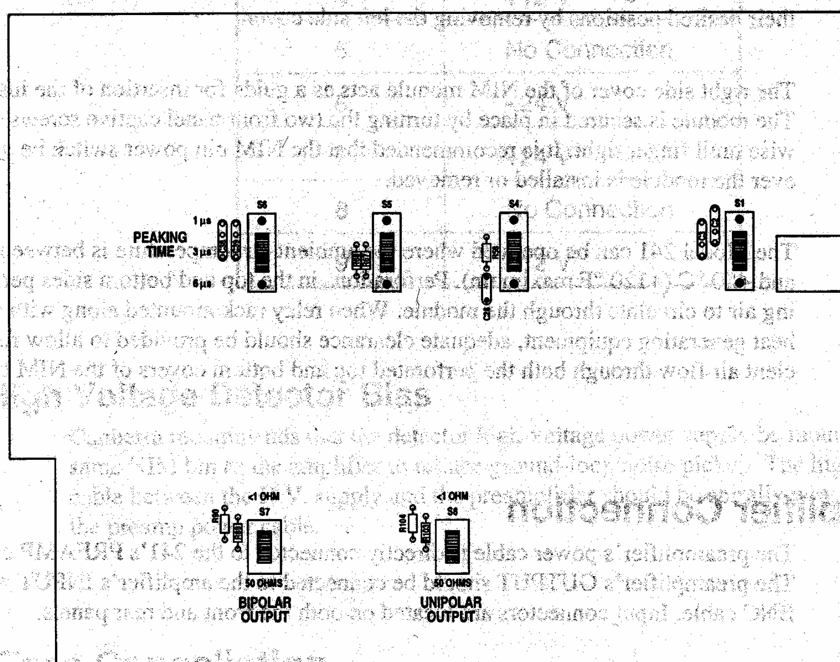

Figure 2 Internal Controls

3. Amplifier Operation

The Canberra Model 2000 Bin and Power Supply, or other bin and power supply systems conforming to the mechanical and electrical standard set by DOE/ER-0457T will accommodate the Model 241.

Before installing the Model 241 in the NIM Bin, the internal controls should be set to their desired positions by removing the left side cover.

The right side cover of the NIM module acts as a guide for insertion of the instrument. The module is secured in place by turning the two front panel captive screws clockwise until finger tight. It is recommended that the NIM bin power switch be *off* whenever the module is installed or removed.

The Model 241 can be operated where the ambient air temperature is between 0 °C and +50 °C (+120 °F maximum). Perforations in the top and bottom sides permit cooling air to circulate through the module. When relay rack mounted along with other heat generating equipment, adequate clearance should be provided to allow for sufficient air flow through both the perforated top and bottom covers of the NIM bin.

Preamplifier Connection

The preamplifier's power cable is directly connected to the 241's PREAMP connector. The preamplifier's OUTPUT should be connected to the amplifier's INPUT with a BNC cable. Input connectors are located on both the front and rear panels.

Note: When using a BNC cable longer than ten feet to connect the preamplifier output to the amplifier input, best results will be obtained when the characteristic impedance of the cable matches the impedance of the preamplifier output. Since all Tennelec preamplifiers have 50 ohms series termination, 50 ohm RG-58 cable should be used.

To minimize electrical noise pickup when external BNC signal and/or high voltage cables are connected between the preamplifier and NIM bin (containing the amplifier and high voltage power supply), the cable lengths should match the preamp power cable length and be spirally wrapped with the preamp power cable.

Note: Tennelec preamplifiers with serial numbers less than 2000 may require an accessory to establish compatibility. Please contact Canberra Customer Service.

Preamplifier Pin Assignment	
Pin	**Description**
1	Power Gnd
2	Signal Gnd
3	No Connection
4	+12 V
5	No Connection
6	–24 V
7	+24 V
8	No Connection
9	–12 V

High Voltage Detector Bias

Canberra recommends that the detector high-voltage power supply be mounted in the same NIM bin as the amplifier to reduce ground-loop noise pickup. The high-voltage cable between the H.V. supply and the preamplifier should be spirally wrapped with the preamp power cable.

Pole/Zero Cancellation

Accurate setting of the pole/zero (P/Z) control is essential for good resolution at high count rates in unipolar operation and for correct operation of the BLR circuit. With bipolar operation, accurate setting is not important regarding resolution, but is important if quick recovery from heavily overloading signals is required.

To set the pole/zero correctly, using a detector and a radioactive source as an input, observe the UNIPOLAR output signals of the amplifier on an oscilloscope with a triggered sweep. The oscilloscope *must* be dc-coupled to the amplifier.

Adjust the amplifier gain so that the highest energy peak produces an amplifier output of approximately 9 volts. Adjust the source strength and or spacing from detector to provide a count rate between 2000 and 10 000 cps. Increase the oscilloscope vertical sensitivity to 100 mV/Div or 50 mV/Div to accurately view the baseline and P/Z adjustment.

Note: Most oscilloscopes will overload for a 10 volt input signal when the vertical sensitivity is set for 50 mV/cm, distorting the signal's recovery to the baseline. Thus the P/Z will be incorrectly adjusted, resulting in a loss of resolution at high count rates. To prevent overloading the scope, Canberra recommends using the Model LB1502 Schottky Clamp Box between the amplifier's output and the scope's input.

Compensation is accomplished by turning the P/Z control for flattest possible baseline (See Figure 3).

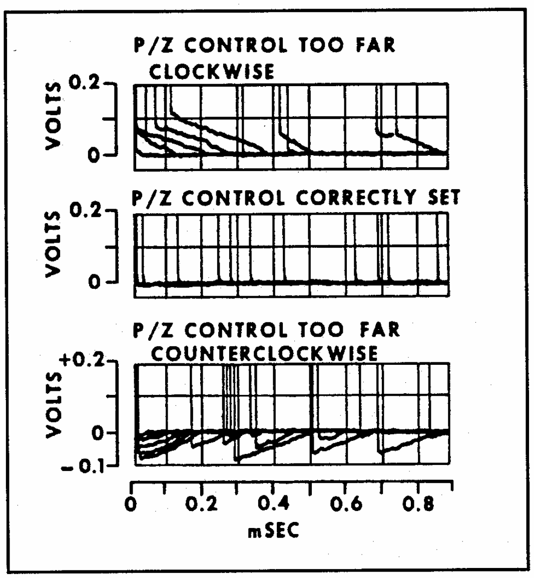

Figure 3 Pole/Zero Control Adjustment

A second method of setting the control is to increase the sweep speed so that the pulse duration occupies approximately 2 cm of sweep. Then, looking at the baseline (which will be fuzzy) about one pulse width from the end of the pulse, adjust the P/Z control for minimum baseline smear.

Amplifier Noise

The typical equivalent noise referred to the input vs. amplifier gain for unipolar shaping is shown in Figure 4 and for bipolar shaping, in Figure 5.

Lowest equivalent input noise results when a high COARSE GAIN and low FINE GAIN are used to produce the same overall gain. For example, with unipolar shaping and a 3 μs peaking time, a COARSE GAIN of 100 and a FINE GAIN of 0.750 result in an overall gain of 75 with an equivalent input noise of 4.8 μV, while a COARSE GAIN of 50 and a FINE GAIN of 1.500, although still producing an overall gain of 75, result in an equivalent input noise of 6.2 μV.

Peaking Time Considerations

The optimum peaking time for a particular system depends on the detector characteristics and counting rate. A general discussion of peaking time requirements is presented below; consult the detector manufacturer for specific shaping requirements.

Setting the Peaking Time

The 241's internal peaking time switches are accesible by removing unit's left side cover; all four switches must be set to the same value.

Gas Proportional Detector

The required peaking time for a gas proportional detector depends on the charge collection time of the detector, which is related to the physical size of the outer electrode and center wire, fill gas and high voltage. Generally, a larger detector will have slower collection time.

Correct pole/zero compensation is not possible with gas proportional detectors because of their charge collection characteristics, resulting in either an undershoot or back porch on the trailing-edge of a unipolar shaped signal. Bipolar shaping is recommended for these detectors because it reduces this effect without degrading detector resolution.

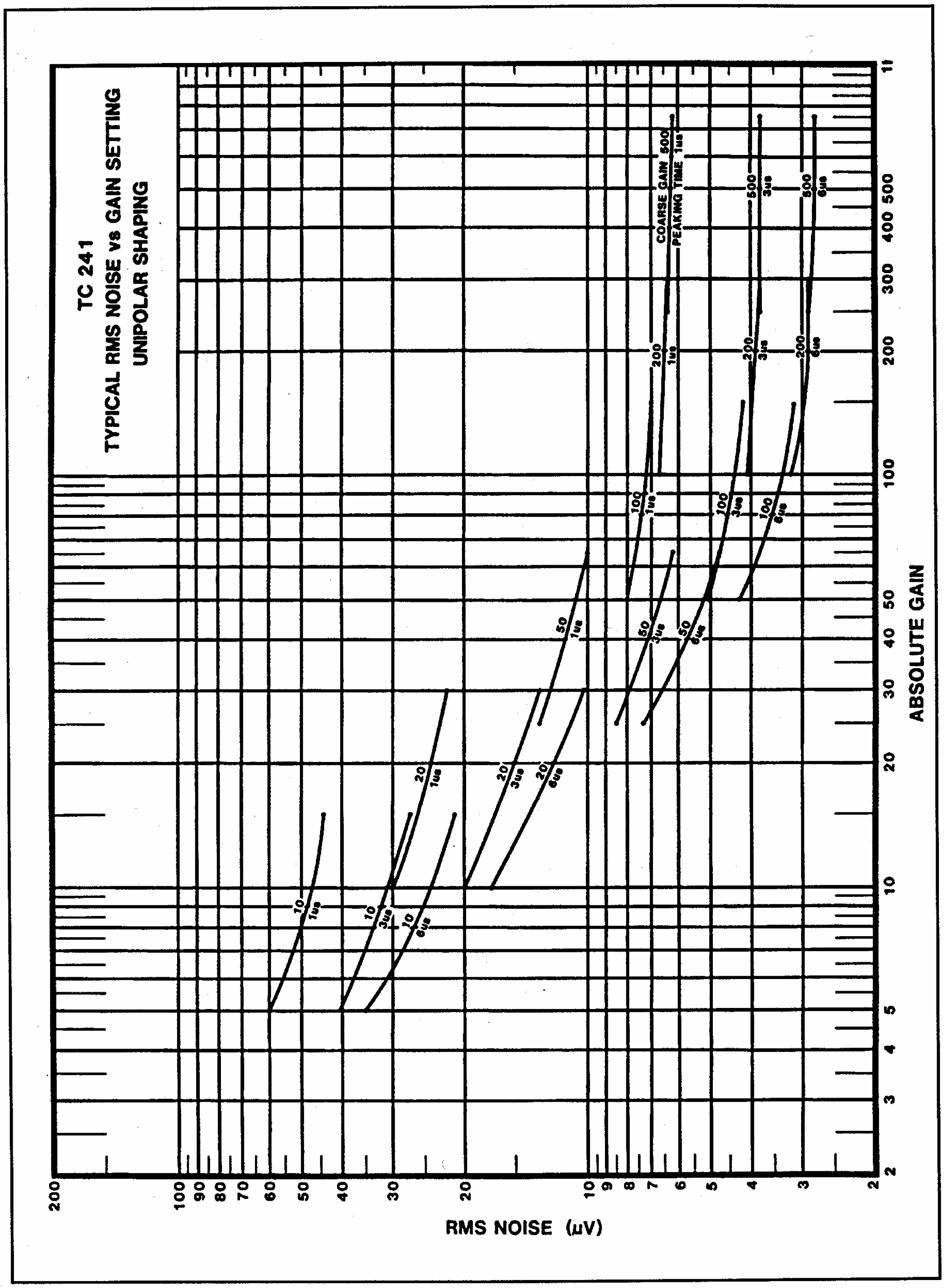

Figure 4 Unipolar Noise vs. Gain and Peaking Time

Peaking Time Considerations

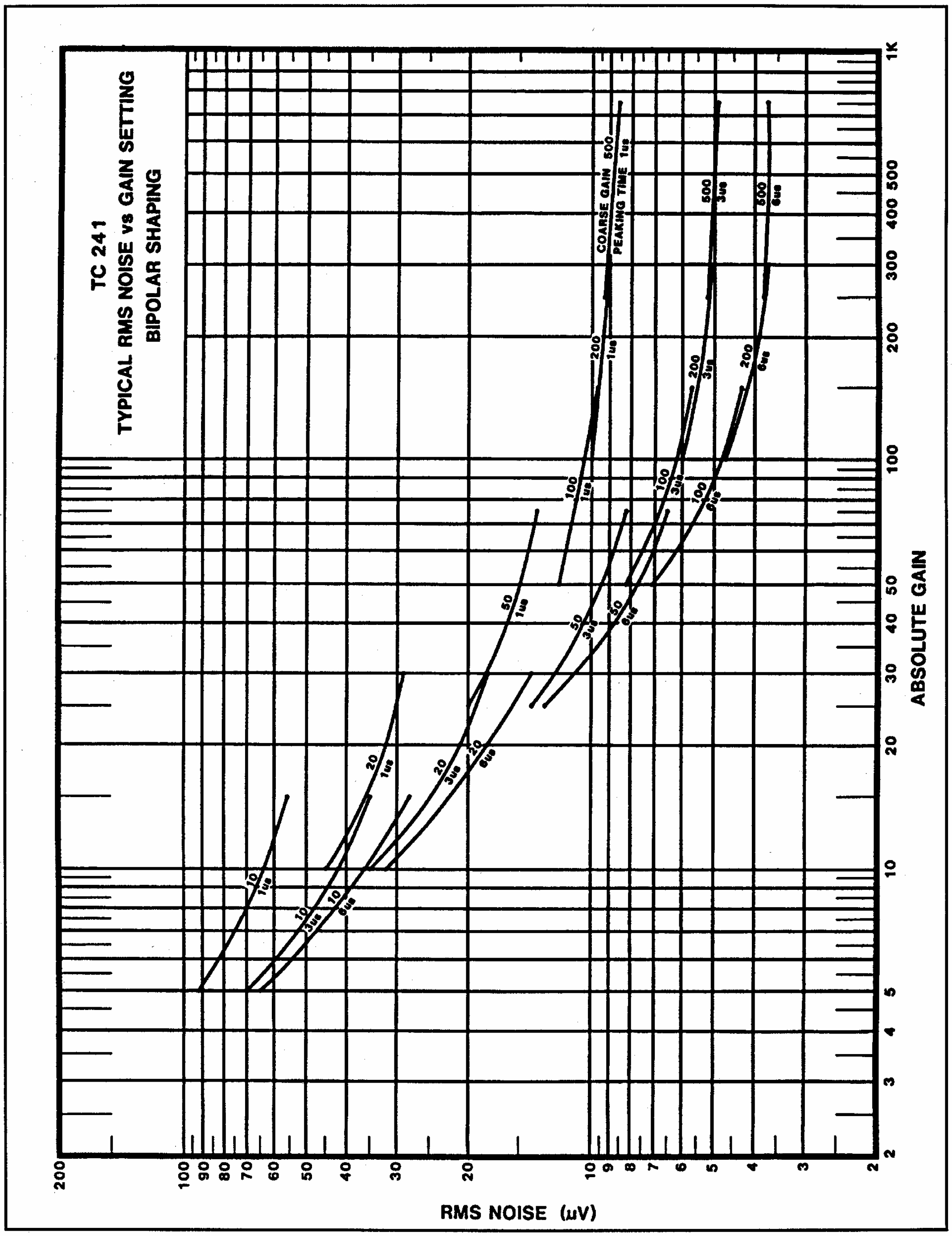

Figure 5 Bipolar Noise vs. Gain and Peaking Time

Germanium Detector

Unipolar shaping and a peaking time of 3 or 6 μs generally will give best results for germanium detectors, depending on the detector size, configuration, and counting rate.

A peaking time of 6 μs is preferred for applications requiring ultimate low-countrate resolution, while 3 μs is preferred at high count rates. Resolution as a function of count rate at 3 and 6 μs peaking times for a typical intrinsic germanium detector is shown in Figure 6. A performance crossover occurs above 80 kcps with 3 μs peaking time providing better resolution.

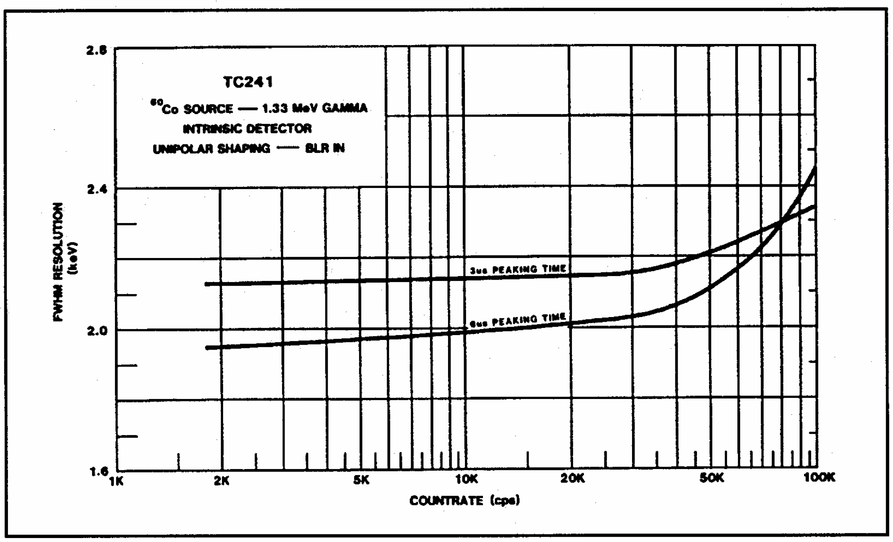

Figure 6 Resolution vs. Count Rate

Scintillation Detector

Scintillation detectors require a peaking time of two to three times the decay time constant of the scintillator (a 1 μs peaking time is about optimum for NaI detectors). Bipolar shaping is preferred because it reduces the effect of overload and detector microphonics without degrading resolution.

Silicon Charged Particle Detector

Unipolar shaping and a peaking time of 1 or 3 μs usually will give best results, depending on the detector capacitance and leakage current. Generally, large area detectors are resolution-limited by their high capacitance, thus benefit from a longer time. Small detectors are resolution-limited by their leakage current, which implies a shorter peaking time.

Output Termination Considerations

The 241 allows individually switchable output terminations of either <1 ohm or 50 ohms for both the UNIPOLAR and BIPOLAR outputs. The 241 is shipped with both OUTPUT IMPEDANCE switches in the 50 ohm position.

Series 50-ohm termination is recommended for applications and is required for long cable lengths and or high noise environments. In extreme situations, both series termination and shunt termination at the receiving end may be required, which will reduce the signal amplitude at the receiving end of the cable by 50% of the non-shunt-termination value. An in-line 50 ohm terminator or BNC Tee and 50 ohm terminator may be used for shunt termination.

The <1 ohm termination is useful when driving several instruments from the same amplifier output connector. The output signal amplitude will be relatively independent of the load impedance, which is not the case with series 50 ohm termination. However, the amplifier may oscillate when driven into overload or for long cable lengths.

Changing the Output Termination

The 241's two output termination switches, one for the Unipolar Output and one for the Bipolar Output, are accesible by removing the unit's left side cover.

Preventive Maintenance

Preventive maintenance is not required for this unit.

When needed, the front panel of the unit may be cleaned. Remove power from the unit before cleaning. Use only a soft cloth dampened with warm water and make sure the unit is fully dry before restoring power. Because of access holes in the NIM wrap, DO NOT use any liquids to clean the wrap, side or rear panels.

4. Circuit Description

The 241 Amplifier consist of three gain stages, two active-filter stages, two output driver stages, and an active baseline restorer (BLR) with automatic threshold and restorer rate circuits. The overall transfer function of the amplifier synthesizes an e^{-3t} $\sin^{4t}$ time response resulting in a pseudo-Gaussian pulse shape.

Transistors Q1 through Q6 form a low-noise input op-amp stage with switch selectable gains of 20, 10, 4, or 2. Diodes D1 and D2 provide input protection, while diodes D3 through D7 provide biasing and overload limiting.

Input-polarity selection and additional gain is provided by IC1. Diode D8 provides overload limiting.

Fine-gain adjustment and additional switch selectable gain is provided by IC2. Diode D9 provides overload limiting.

IC3 and IC4 form a four-pole active integrator.

The signal from the integrators is differentiated, then buffered by IC5 and transistors Q8 and Q9 to provide a high-current BIPOLAR output. Diodes D13 and D14 provide overload limiting.

The integrated signal is directly applied to IC6 and transistors Q10 and Q11 to provide a high-current UNIPOLAR output. Diodes D20 and D21 provide overload limiting.

Baseline restoration of the UNIPOLAR output is provided by transconductance amplifier IC7. Capacitor C51 functions as an output level memory. IC9 and IC10 form a peak detector for the negative noise excursions at the UNIPOLAR output, which determines the BLR gate threshold. IC8 and transistor Q13 gate the restorer current whenever the UNIPOLAR output exceeds the BLR gate threshold. An additional, exponentially decaying restoration current is provided when switch S9 is in the BLR position. This additional current is disabled with switch S9 in the P/Z position for accurate pole/zero cancellation adjustment.

A. Specifications

Inputs

INPUT – Accepts either positive or negative pulses with rise times less than the selected peaking time and decay times of 35 μs to ∞; Z_{in} = 1000 Ω; dc coupled; protected to +25 V max; front and rear-panel BNC connectors.

Outputs

UNIPOLAR – Full scale range is 0 to +10 V (+11.5 V max.); Z_{out} <1 Ω or 50 Ω, switch selectable; dc-restored and short-circuit protected; front and rear-panel BNC connectors.

BIPOLAR – Full scale range is 0 to +10 V (+11.5 V max.); Z_{out} <1 Ω or 50 Ω, switch selectable; short-circuit protected; front and rear-panel BNC connectors.

Front Panel Controls

COARSE GAIN – Six-position rotary switch selects gain factors from 10 to 500 in a 1-2-5 sequence.

FINE GAIN – Ten-turn precision potentiometer with linear calibration from 500 to 1500 corresponding to multipliers of 0.5 and 1.5, respectively; extends the total gain range from 5 to 750.

POLE-ZERO – Multi-turn screwdriver adjustable control for cancellation of preamplifier decay times from 35 μs to ∞.

POS-NEG – Two-position toggle switch selects the polarity of the incoming signals.

BLR-P/Z – Two-position toggle switch; BLR enables the baseline restorer; P/Z disables the baseline restorer for accurate pole/zero cancellation adjustment.

Internal Controls

PEAKING TIME – Four individual three position slide switches select unipolar peaking times of 1, 3, or 6 μs. Bipolar peaking time equals 0.78 of selected unipolar peaking time.

OUTPUT IMPEDANCE – Individual two-position slide switches select an Z_{out} <1 Ω or 50 Ω for either the UNIPOLAR or BIPOLAR outputs.

Performance

PULSE SHAPING – Active shaping networks produce near-Gaussian shaped unipolar pulses with selectable peaking times (Tp) of 1, 3, or 6 μs (0.5, 1.5, or 3.0 μs shaping time). The unipolar pulse width is equal to 2.8 times the selected peaking time. The bipolar pulse zero crossover is delayed from the prompt unipolar peak by 0.32 times the selected peaking time.

GAIN RANGE – Continuously variable from X5 to X750.

INTEGRAL NONLINEARITY – ≤±0.05% over 0 to +10 V output range for 3 μs peaking time.

NOISE – Less than 3.0 μV referred to the input for 6 μs peaking time, unipolar shaping, and maximum gain; typically less than 3.2 μV for gain greater than 100. Bipolar typically less than 5.0 μV for gain greater than 100.

TEMPERATURE COEFFICIENTS – UNIpolar: Gain ≤±0.01%/°C; dc level ≤±10 μV/°C; BIpolar: Gain ≤±0.01%/°C; dc level ≤±30 μV/°C.

WALK – ≤±3 ns over a 50:1 dynamic range for 3 μs peaking time.

OVERLOAD RECOVERY – Unipolar output recovers to within 2% of rated output from X300 overload in less than 2.5 non-overloaded pulse widths at maximum gain. Bipolar output recovers to within 2% of rated output from X300 overload in less than 2.0 non-overloaded pulse widths at maximum gain.

SPECTRUM BROADENING – Unipolar FWHM typically changes less than 10% for a ^{60}Co 1.33 MeV gamma line at 85% of rated output, 3 μs peaking time and incoming rate from 1 to 100 kcps.*

SPECTRUM SHIFT – Unipolar peak position typically shifts less than 0.02% for a ^{60}Co 1.33 MeV gamma line at 85% of rated output, 3 μs peaking time and incoming rate from 1 to 100 kcps.*

*These results may not be reproducible if measurements are made with a detector which exhibits a large number of slow rise-time signals.

Power Requirements

+24 V – 40 mA	+12 V – 65 mA
–24 V – 30 mA	–12 V – 75 mA

Physical

SIZE – Standard single-wide NIM module 3.43 x 22.13 cm (1.35 x 8.71 in.) per DOE/ER-0457T.

NET WEIGHT – 1.1 kg (2.5 lb).

SHIPPING WEIGHT – 2.3 kg (5.0 lb).

Environmental

OPERATING TEMPERATURE – 0 to 50 °C.

OPERATING HUMIDITY – 0 to 80% relative, non-condensing.

Tested to the environmental conditions specified by EN 61010, Installation Category I, Pollution Degree 2.

B. Installation Considerations

This unit complies with all applicable European Union requirements.

Compliance testing was performed with application configurations commonly used for this module; i.e. a CE compliant NIM Bin and Power Supply with additional CE compliant application-specific NIM were racked in a floor cabinet to support the module under test.

During the design and assembly of the module, reasonable precautions were taken by the manufacturer to minimize the effects of RFI and EMC on the system. However, care should be taken to maintain full compliance. These considerations include:

- A rack or tabletop enclosure fully closed on all sides with rear door access
- Single point external cable access
- Blank panels to cover open front panel Bin area
- Compliant grounding and safety precautions for any internal power distribution
- The use of CE compliant accessories such as fans, UPS, etc.

Any repairs or maintenance should be performed by a qualified Canberra service representative. Failure to use exact replacement components, or failure to reassemble the unit as delivered, may affect the unit's compliance with the specified EU requirements.