CANBERRA INDUSTRIES
STURRUP NUCLEAR DIVISION

Instruction Manual

SPECTROSCOPY AMPLIFIERS

MODELS [illegible]

Canberra 1400 Series of Modular Nuclear Instruments

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SPECTROSCOPY AMPLIFIERS

MODELS 1416, 1417, 1418

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WARRANTY FOR CANBERRA NUCLEAR INSTRUMENTS

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WARRANTY

This equipment is warranteed by Canberra to be free from defects in materials and workmanship for a period of twelve months from date of shipment, provided that the equipment has been used in a proper manner as detailed in this instruction manual. Repairs or replacement, at Canberra's option, will be made without charge at the Canberra plant during this warranty period. Except for the case of defects discovered upon initial operation, shipping expense to Canberra is to be paid by the customer; shipping expense to return the repaired equipment will be paid by Canberra.

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REPAIRS

Any Canberra instrument no longer in its warranty period may be returned, freight prepaid, to our factory for repair and realignment. All such work will be done at the least possible expense to the customer. All equipment thus repaired or realigned will pass through our normal preshipment checkout procedure and will meet or surpass its original specifications when returned. Return shipping expense will, in this case, also be charged to the customer.

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SHORT-FORM INSTRUCTIONS

You have just received what Canberra Industries believes to be the finest nuclear pulse amplifier ever produced, as of June 1, 1967. We are confident that you will obtain the best system resolution you have ever obtained, with this amplifier. If you wish to try the amplifier immediately in a live system, follow the instructions below:

1. Connect the preamp output to the input connector (appropriately selected as determined by the preamp output, for the Model 1417)

2. Set the controls as follows, in the order specified:

. Fine Gain	9.0, or near maximum for 1418
. Coarse Gain	maximum possible before saturation of spectral peak of interest
. Shaping	2 microseconds (factory preset on Model 1416)
. Input	93 ohms (Model 1417 only)
. Input Polarity	as determined by input (Model 1416 and 1418 only)
. Mode	UNIPOLAR
. Count Rate	HIGH
Fine Gain	Readjust <u>slightly</u> if desired, <u>not</u> below 70% of maximum

3. Observe the output on an oscilloscope; adjust the Pole/Zero control until the pulse neither undershoots nor returns to the baseline with the preamp time constant (check Section 4.1.5 if uncertain as to the setting)

4. Switch the Count Rate control to LOW

5. These are probably the optimum settings; the most critical (which should be explored for better resolution) are the Shaping, the Mode if high count rates are present, and the Count Rate control; try different combinations of these controls to ascertain the best settings for your particular system.

6. Take data and compare to the best you have previously obtained

7. After satisfying yourself on the question of resolution, turn to Section 3.0 and follow the familiarization procedure listed there

MODELS 1416, 1417, 1418 SPECTROSCOPY AMPLIFIERS

1.0 GENERAL

1.1 Description

The three Canberra Spectroscopy Amplifiers share a common fundamental design, and differ only in the number of possible features which are included in each.

All three amplifiers feature :

- adjustable Pole/Zero cancellation
- active element pulse shaping
- linear integrated circuit construction
- switch selectable count rate performance optimization
- differential input for common mode noise rejection (optional with the 1418 as the Model 1418A)
- ultra-low noise contribution
- highly linear gain response
- constant gain regardless of output mode selected

Thus, for relatively straight-forward nuclear counting, coincidence, or spectroscopy applications, identical performance will be obtained from the three versions.

1.1.1 In addition to the features shared by all three versions of the Canberra Spectroscopy Amplifier, the Canberra Model 1416 Spectroscopy Amplifier offers the following additional features:

- adjustable pulse shaping time constants for optimum spectrum resolution and minimum amplifier resolving time
- ten-turn fine gain control
- differential input for common mode noise rejection as a standard feature
- prompt and delayed outputs

1.1.2 In addition to the features common to Models 1416 and 1418, the Canberra Model 1417 offers the following additional features:

- front panel adjustable pulse shaping time constants for optimum spectrum resolution and minimum amplifier resolving time
- front panel input impedance selection of 1000 or 93 ohms
- front panel output DC level adjustment trimmers

1.2 Applications

The three Canberra Spectroscopy Amplifiers have two principal applications. Because of their near-optimum Gaussian pulse shaping, extremely low noise contribution, and highly stable linear design, the Spectroscopy Amplifiers offer unmatched performance as the main shaping amplifier in a high resolution gamma spectroscopy system, in combination with a cooled Ge (Li) detector, low noise FET input preamplifier, and biased post amplifier.

And, they are ideally suited for fast coincidence and other zero crossing applications, as they offer extremely low crossover jitter and excellent overload performance.

The usefulness and application of the Canberra Spectroscopy Amplifier is enhanced by the following unique design features not found in comparable amplifiers: front panel count rate optimization, front panel Pole/Zero adjustment, only a single AC coupling in the design, easily accessible output DC level adjustments, and ultra-low noise design (less than 5 microvolts referred to the input at 2 microsecond unipolar shaping).

2.0 SPECIFICATIONS

2.1 Performance

- Linearity: better than $\pm$0.075% integral from 0.3 to 10 volts output into 100 ohms; typically $\pm$0.04% integral
- Shaping: selectable unipolar or bipolar time constants of 0.25, 0.5, 1, 2, and 4 microseconds, Model 1417; 0.5, 1, 2 microseconds, Model 1416 internally selectable; choice of 0.5, 1, or 2 microseconds, Model 1418 not adjustable; near-Gaussian pulse shape

- Gain Stability: better than $\pm0.01\%$ per $^{\circ}C$, better than $\pm0.01\%$ over 24 hours at constant temperature; typically $\pm0.04\%/^{\circ}C$

- Gain Constancy: constant amplifier gain for unipolar or bipolar shaping to within 1%; constant gain for different time constants to within 3% (Model 1416 and 1417)

- Overload Recovery: recovery to within 2% of baseline from 1000X overload within two non-overloaded pulse widths, at full gain for any bipolar shaping time constants

- DC Level Stability: better than $2mV/^{\circ}C$ (0 to $50^{\circ}C$), better than 10mV over 24 hours at constant temperature

- Count Rate Stability: less than 0.25% gain change (Cesium 137 peak) in presence of 50KHz pulser input

- Crossover Walk: less than ±4 nanoseconds over 20:1 dynamic range (0.5 volts to 10.0 volts) including contribution of Canberra Model 1435 Timing SCA; less than ±8 nanoseconds over 50:1 dynamic range

- Noise: less than 7 microvolts referred to the input, at full gain and 1 microsecond unipolar shaping, less than 5 microvolts at 2 microsecond unipolar shaping, less than 10 microvolts at 1 microsecond bipolar shaping

- Gain: maximum gain 2000; adjustable via front panel controls over 1920:1 range; 192:1 range for Model 1418

- Common Mode Rejection: better than 250:1 between common mode inputs for any input polarity (common mode inputs optional on Model 1418)

2.2 Controls, Inputs, Outputs

2.2.1 Controls

- Coarse Gain: front panel rotary switch, 64:1 range in six binary steps

- Fine Gain: front panel ten-turn non-inductive Helipot (single-turn potentiometer on Model 1418), 3:1 range, allowing maximum accuracy and resettability

- Pole/Zero: front panel twenty-two turn screwdriver adjustment potentiometer to optimize amplifier baseline recovery and overload performance for the preamplifier time constant and the main amplifier pulse shaping chosen

- Input Mode: front panel rotary switch to select 1000 ohms, 93 ohm, or ÷ 10 input attenuation (Model 1417 only); ÷ 10 position is 93 ohms

- Output Mode: front panel toggle switch, UNIPOLAR and BIPOLAR positions affecting PROMPT OUT only

- Count Rate: front panel toggle switch, LOW and HIGH positions; LOW position introduces 20 microsecond second differentiation to minimize low frequency and 60 Hz noise where required by noisy preamplifiers or inferior grounding conditions

- Shaping: front panel rotary switch to select shaping time constants of 0.25, 0.5, 1.0, 2.0, or 4.0 microseconds (while maintaining near-Gaussian pulse shaping) - Model 1417 only; internal choice of 0.5, 1, 2 for Model 1416

- DC Levels: two front or side panel screwdriver adjustments to set PROMPT and DELAYED OUT DC levels to zero volts (Model 1418 has PROMPT output only)

- Common Mode Rejection Balance: rear panel screwdriver adjustment to obtain optimum common mode rejection when utilizing COMMON MODE input capability (Common Mode inputs optional on Model 1418)

2.2.2 Inputs

- Common Mode Inputs: front panel BNC connectors (rear panel on Models 1416 and 1418A), one of which accepts the input signal, the other of which may accept the noise and cable pickup signals from a second input cable (which is in all other respects identical to the primary input cable) for subtraction from the input signal to be processed; input impedances 1000 ohms or 93 ohms as selected, DC coupled; terminate unused input on Model 1417 in 100 ohms

- Input Specifications: positive or negative tail pulse from associated preamplifier, 0 to 6 volts before input saturation, 12 volts maximum; 0 to 500 nanosecond rise time, 30 to 1000 microsecond fall time

2.2.3 Outputs

- Prompt Out: unipolar or bipolar (as switch-selected), positive 0 to 10 volt linear pulses, 11 volts saturation unterminated; pulse shape near-Gaussian, time constants as selected on front panel; output impedance less than 1 ohm, DC coupled; labelled A OUT on Model 1416, OUTPUT on Model 1418

- Delayed Out: unipolar, positive 0 to 10 volt pulses, 11 volts saturation unterminated; pulse shape the same as unipolar PROMPT OUT regardless of PROMPT OUT shaping; delayed from PROMPT OUT by 2.5 microseconds; output impedance less than 1 ohm, DC coupled; Models 1416 and 1417 only; labelled B OUT on Model 1416

3.0 INITIAL INSTALLATION

3.1 Initial Setup

- Insert the amplifier into an AEC compatible bin such as the Canberra Model 1400

- Connect a tail pulse generator with an output rise time less than 250 nanoseconds and fall time greater than 30 microseconds to the input connector of the amplifier (front panel of Models 1416 and 1418), or to the appropriate input connector (POS or NEG) of the Model 1417 with the unused input terminated by the 100 ohm BNC cap provided; the output of the pulse generator should ideally be variable from 5mV to 6 volts, and must not in any case be greater than 6 volts for proper amplifier functioning

- Connect the PROMPT OUTPUT of the Model 1417 (A OUT on Model 1416, OUTPUT on Model 1418) to an oscilloscope set for 2v/cm and 0.5 microsec/cm

- Obtain a pulser output of +20mV

- Set the amplifier controls to:

- Coarse Gain	16
- Fine Gain	10.0 (fully clockwise on Model 1418)
- Shaping	2 (Models 1416 and 1417 only)
- Input	1000 ohms (Model 1417 only)
- Mode	Unipolar
- Count Rate	High
- Input	÷ 1 (Model 1416 only)
- Input	POS (Models 1416 and 1418 only)

3.2 Initial Checkout (all models)

- Observe the output on the oscilloscope; it should appear approximately as shown below:

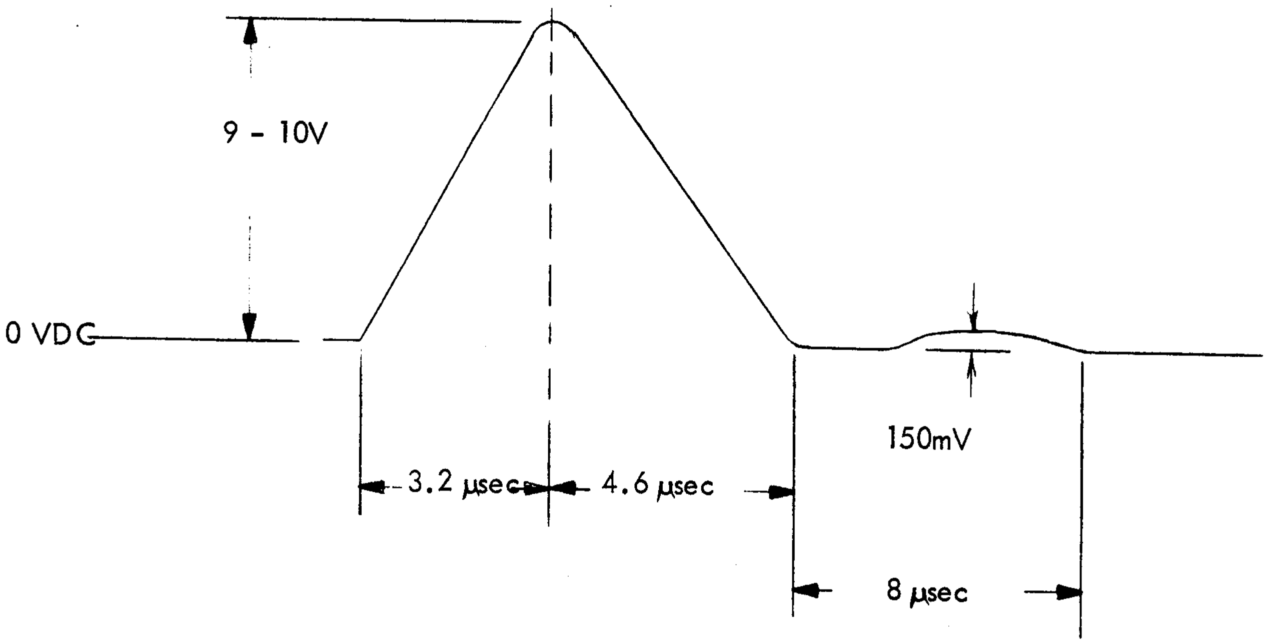


Figure 3-1

- Turn the Coarse Gain control to 8 and to 4; observe the pulse decrease in amplitude by factors of 2

- Rotate the Fine Gain control counter-clockwise and observe the pulse decrease in amplitude over a 3:1 range; be sure to read Section 4.1.2 before using the amplifier in a live system

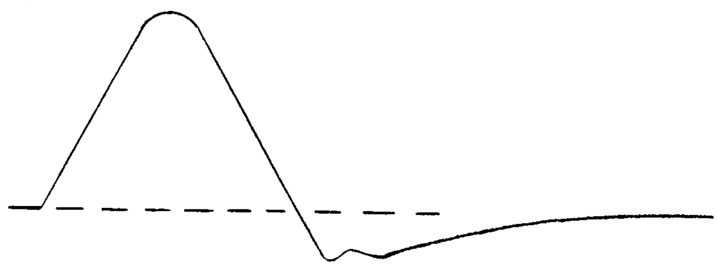
- On the Model 1417, switch the shaping control through the ranges from 0.25 to 4 microseconds and observe the change on the output; this may be done over a 0.5 to 2 microsecond range for the Model 1416 by removing the left side cover and lifting the long green shorting bar from its bottom position (2 microseconds) and placing it successively on its middle (1 microsecond) and top (0.5 microsecond) positions

- Switch to the ÷ 10 input control position (Models 1416 and 1417) and observe the output attenuate by a factor of 10

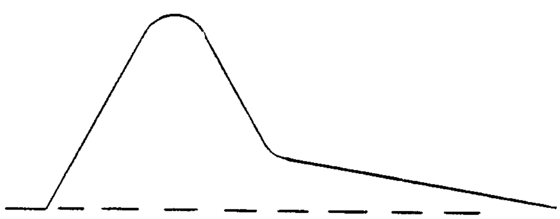
- Return all controls to the initial settings

- Increase the vertical gain on the oscilloscope by a factor of ten, and with a small jewelers screwdriver, rotate the Pole/Zero adjustment about ten turns counter-clockwise then twenty turns clockwise; observe the effect on the output pulse; the optimum setting for the particular fall time constant of the pulser is when the pulse returns to the baseline most rapidly. Sample waveforms are shown below:

Undercompensation:



Overcompensation:



Perfect Compensation:

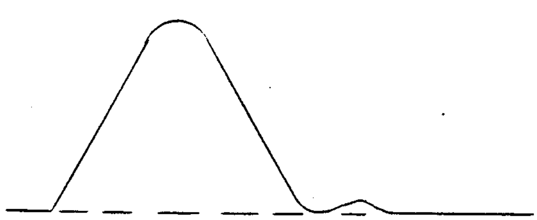


Figure 3-2

- The theoretical explanation for this effect and its impact on system resolution and overload performance is given in Section 4.1.5
- Switch the Mode control to the BIPOLAR position and observe the bipolar output pulse shape:

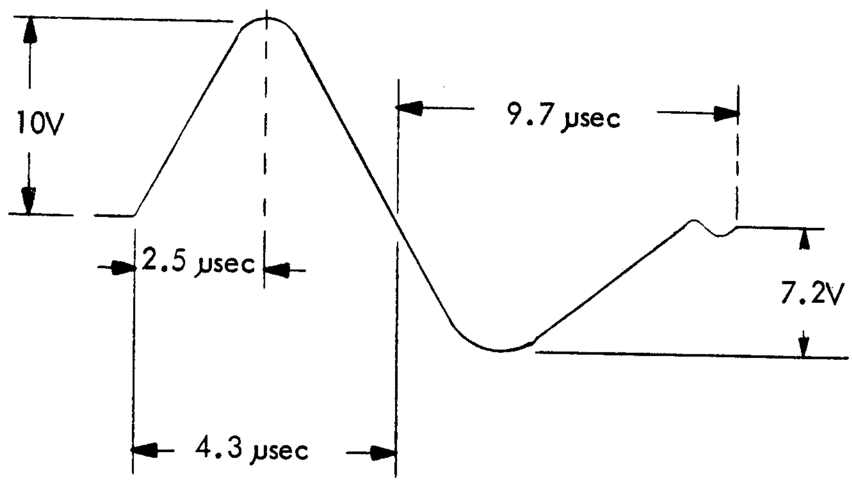


Figure 3-3

- Return to unipolar and switch the Count Rate control to the LOW position; observe the 15 - 20 microsecond second differentiation:

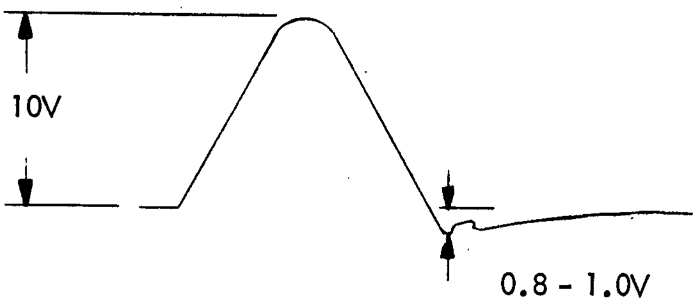


Figure 3-4

- The function of this control is explained in Section 4.1.7

3.3 Additional Familiarization (Models 1416 and 1417)

- Using a BNC "tee" connector feed the input pulse into both Common Mode inputs - on the front panel of the Model 1417, on the rear panel of the Model 1416

- If a Model 1416 is being examined (or a Model 1418A), switch the Common Mode control on the rear panel from the NOR(mal) position to the Common Mode position

- Using a small screwdriver, adjust the Common Mode Trim control on the rear panel, while observing the amplifier output on the oscilloscope; the optimum control setting is when the minimum amplifier baseline to peak output is observed; the application of this control - and of the Common Mode outputs - is described in Section 4.1.9

- Connect the oscilloscope's second channel to the Delayed Output (Model 1417) or the B Out (Model 1416) and observe both outputs simultaneously; be sure the horizontal time base is sufficiently long to observe both the Prompt and the 2.5 - 3.0 microsecond Delayed Outputs; trigger the oscilloscope externally from the unattenuated output of the input pulser

3.4 Testing the Specifications

3.4.1 System Resolution: basically, the procedure to be followed is outlined in the Short-Form instructions preceding the body of this manual. The critical settings which may strongly affect system resolution are:

- Time Constant

- Mode (unipolar or bipolar)

- Count Rate Optimization (high or low)

The optimum settings depend strongly on the characteristics of the individual system: ratio of low frequency to high frequency noise, system hum and ripple and ground loop problems, and the count rate being encountered. Empirical experimentation is far simpler (and probably faster) than any attempt at analytical evaluation of the optimum control settings.

One procedure that is often illuminating is to take a test run with your existing system before beginning the evaluation of your Canberra Spectroscopy Amplifier. This provides an "all other things being equal" benchmark against which the results later obtained may validly be compared.

3.4.2 Linearity: one of the simplest and most accurate tests is to set up the system shown below:

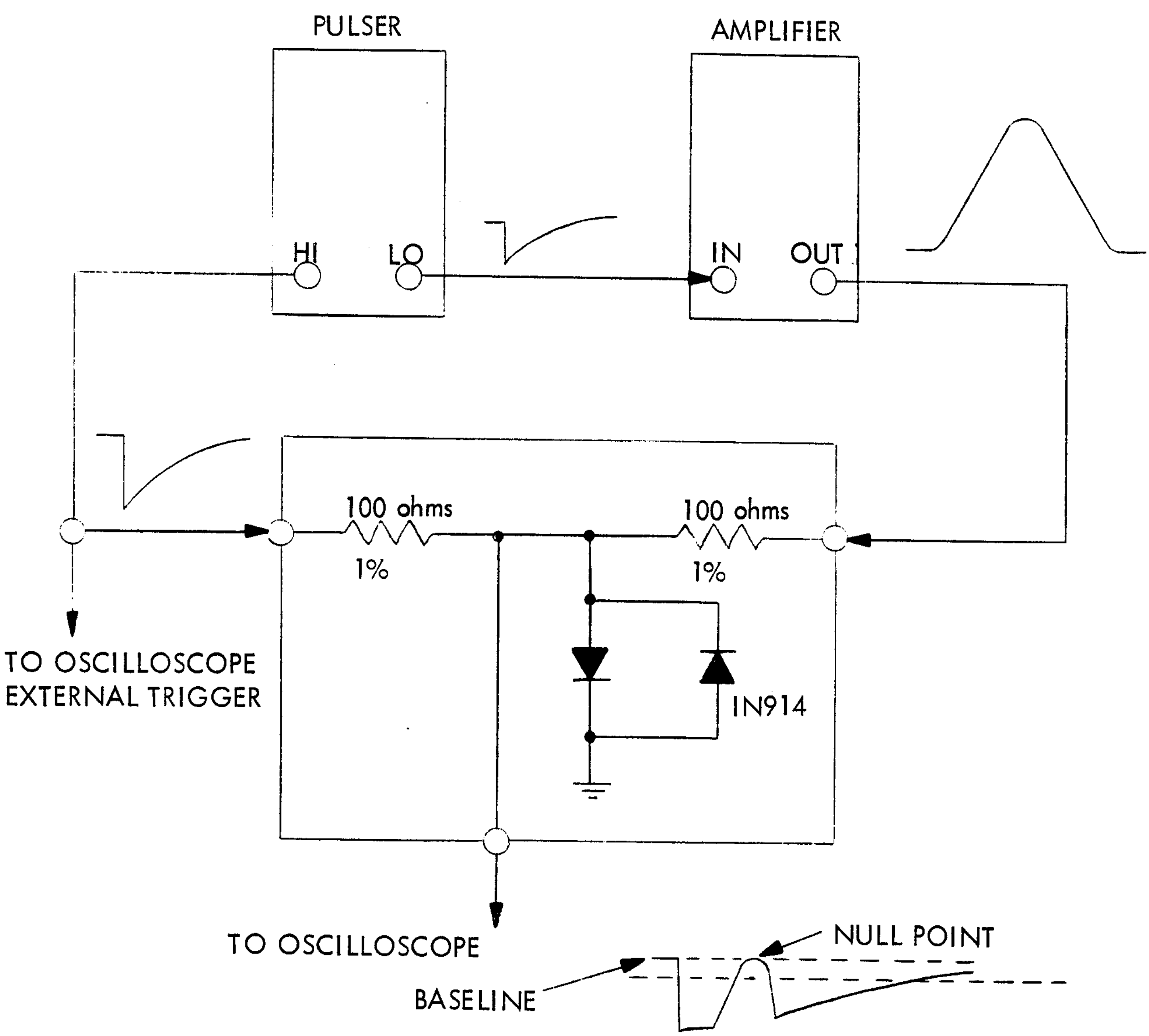


Figure 3-5

This test is performed by adjusting the pulser attenuator and amplifier gain so that with a ten volt high level (Direct) output from the pulser, the output from the amplifier is also exactly ten volts. This may be ascertained by adjusting the attenuator and amplifier gain so that the null point observed on the oscilloscope is at exactly the same level as the baseline with the highest oscilloscope vertical gain.

When this condition is obtained, turn the pulser pulse height control down from ten volts to the lowest level that will still trigger the oscilloscope, and observe the maximum difference between the baseline and the null point. The integral linearity of the amplifier under test is then equal to:

$$\frac{\text{(Maximum deviation) in volts} \times 2 \times 100\%}{\text{10 volts}}$$

The maximum deviation must thus be less than ± 3.75 mV in order to meet the $\pm 0.075\%$ specification.

The test may be explained as follows: integral nonlinearity is the maximum deviation from the straight line plotted on an output vs. input plot from zero output to rated output (10 volts), divided by the rated output, stated as a percentage.

This calculation is performed electronically by the test described above by setting:

Output = (K) (Input)

where K is the pulser attenuation factor (and the gain of the amplifier). As the input is decreased, the amplifier gain should remain constant (output should decrease linearly); whether or not it does is tested by comparing the output to a signal known to decrease linearly with the amplifier input - the pulser Direct Output which is related to the Attenuated Output by a passive attenuator.

The factor of two must be included because the summing network also serves as a voltage divider, decreasing the apparent deviation by a factor of two.

Note that nonlinearity and instability in the pulser output do not enter the question, because both Direct and Attenuated Outputs will be affected identically, save for the negligible effect of the pulser's attenuator instabilities over the short time required for the test.

Instabilities in the baseline level on the 'scope are due to oscilloscope triggering and DC level fluctuations, and need not be of concern in this test.

3.4.3 Gain Stability: this specification is extremely difficult to test without somewhat elaborate test equipment, because of the difficulty of assuring that the measuring instruments are stable and because of the relatively long test periods required.

Temperature stability can most simply be observed by duplicating the test setup of Section 3.4.2, except that the amplifier is placed in a temperature chamber. The effect of temperature excursions may be observed by plotting the deviation between the baseline and null point versus chamber temperature. The calculation is performed as in Section 3.4.2 if the amplifier output is initially ten volts.

Long-term stability tests could also be performed in this fashion if the pulser attenuator resistors and the summing circuit resistors are protected from temperature variations during the test period. This test is extremely tedious, as the oscilloscope does not record any excursions, and only the situation at the moment can be observed. Thus, constant observation is required.

The maximum deviation permitted for temperature is $\pm 0.5 mV/^{\circ}C$; the maximum deviation over 24 hours is ± 0.5 mV at constant temperature and power supply voltages; if the initial amplifier output is ten volts.

3.4.4 Gain Constancy: this test is simply performed by storing a pulser output from the amplifier in an analyzer and switching from unipolar to bipolar shaping; the change in peak position should be less than 1% - if a greater excursion is noted, make sure that the analyzer itself is not pulse shape sensitive by checking the apparent change on an oscilloscope at the maximum vertical sensitivity obtainable which allows the output peak to be observed.

In similar fashion, the gain versus shaping may be observed, although this is of practical significance only for the Model 1417; a shift of 3% or less is specified.

Note that the test setup of 3.4.2 cannot be used unless the pulser output is a square, flat-topped pulse, as the amplifier output peak point occurs at different times for the unipolar and bipolar pulses, destroying the equivalence established with the Direct Output tail pulse.

3.4.5 Overload Recovery: set the amplifier under test to its maximum gain position (gain approximately equal to 2000). Feed in via a very short cable a 5 mV pulser input, so that a ten volt output is obtained. Using the pulser attenuator switches only, increase the pulser output to give 5 volts (a 1000X overload on the amplifier).

Observe a non-overloaded bipolar pulse and record the time it takes to reach 2% of the baseline (basically, into the noise). Repeat with an overloaded bipolar output. The overloaded pulse should reach 2% of the baseline in less than twice the period required for the non-overloaded pulse.

Note: the amplifier Pole/Zero control must be adjusted to match the pulser fall time constant (observed with a Unipolar output with the Count Rate switch in the HIGH position) before this test can be attempted.

3.4.6 DC Level Stability: this specification can most easily be tested with a digital voltmeter when performing the gain stability tests of Section 3.4.3.

3.4.7 Count Rate Stability: this test is rather simply performed by setting up a live system at a moderate count rate (say 1000 counts per second), observing the position of a prominent peak in a multichannel analyzer, and repeating at a higher count rate such as 50,000 counts per second. The shift in the peak position should be less than 0.25% (one channel in 400) over this count rate range.

Since many laboratories do not have energetic enough sources or large enough detectors to reach the requisite count rate, it may be necessary to artifically increase the count rate using a tail pulse generator which has a variable frequency, such as the Berkeley Nucleonics RP-1 or RP-2.

To perform this test, establish the live system with a Cesium 137 peak storing in Channel 350. Then inject pulses into the Test pulse input so that the pulser peak stores in Channel 150. Note that the fall time constant of the pulser output should be as near to that of the preamp as possible, and that the Count Rate switch on the amplifier should be in the HIGH position.

Be sure that the amplifier Pole/Zero adjustment is correct for the preamplifier being used.

Note: the Multichannel Analyzer must be DC coupled and a DC Restorer used at its input to prevent baseline shifts with count rate.

3.4.8 Crossover Walk: obtain a ten volt bipolar output from the amplifier with the gain set at its minimum value. Connect the output to a Canberra Model 1435 Timing SCA with the Baseline control set at its minimum value and the Window Width control at its full range setting. Trigger the 'scope from the pulser and observe one of the

Coincidence Outputs from the Model 1435.

Using the pulser attenuator switches only, reduce the pulser output by a factor of 20; the output of the Timing SCA should shift by less than ±4 nanoseconds. Repeat the test with an output attenuation of 50. The Model 1435 output should shift less than ±8 nanoseconds.

3.4.9 Noise: set the amplifier to maximum gain (about 2000). Measure the noise (no input) signal at the output using a true RMS or average reading voltmeter. If an average reading voltmeter is used, multiply the reading by 1.13 to convert from average to true RMS. The readings obtained should be less than the following values:

Shaping	Output Noise (true RMS)	Noise Referred to Input
1 microsecond UNI	14 millivolts	7 microvolts
2 microsecond UNI	10 millivolts	5 microvolts
1 microsecond BI	20 millivolts	10 microvolts

Be sure that the input(s) are terminated in 100 ohms when making this test.

3.4.10 Gain: set the amplifier to maximum gain and determine the input pulse necessary to obtain a ten-volt output. The input required should be less than 5mV, for a gain of 2000.

3.4.11 Common Mode Rejection: feed the same 5 volt pulse into both front panel inputs of a Model 1417 or rear panel inputs of a Model 1416 or 1418A. Observe the pulser output on an oscilloscope in order to be sure that the amplitude is 5 volts when feeding the amplifier inputs.

Set the amplifier to minimum gain and observe its output on an oscilloscope. Adjust the Common Mode Trim control for minimum output amplitude. This minimum output should be less than 20mV from the baseline to the largest peak.

4.0 MODULE OPERATION

4.1 Control Functions

4.1.1 Coarse Gain: this front panel rotary switch covers a 64:1 range in six binary steps. It is not necessarily always advantageous to obtain all possible gain from the preamplifier at the expense of main amplifier gain in an experimental situation; data should be taken at maximum preamp gain and at minimum preamp gain (after readjusting the Spectroscopy Amplifier gain accordingly) to see which obtains better resolution. Never use the Input Attenuator (÷10) unless absolutely necessary, as this reduces the signal to noise ratio in the amplifier by X10.

4.1.2 Fine Gain: this front panel ten-turn noninductive Helipot (single-turn potentiometer on the Model 1418) covers a 3:1 gain range. As a consequence, the question arises as to which of two equivalent gain conditions - high Fine Gain with Low Coarse Gain, or low Fine Gain with high Coarse Gain - is preferable.

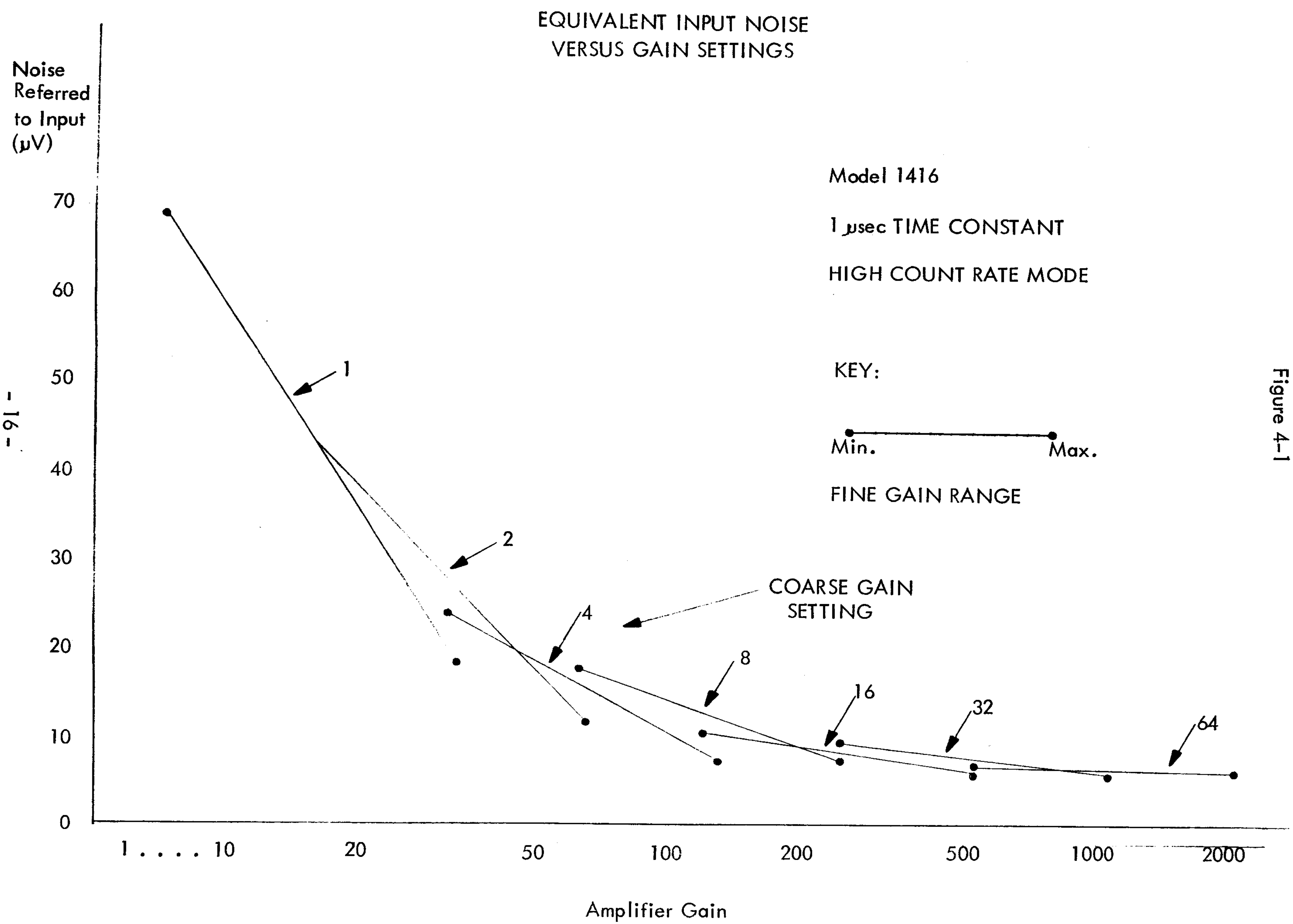
In general, the rule of thumb to use is that the Fine Gain should be set as high as possible, letting the Coarse Gain fall where it may.

Figure 4-1, which is a plot of the amplifier noise referred to the input versus gain control settings, illustrates the reason for this choice. In nearly every case, the higher Fine Gain setting yields the lower amplifier noise. This is especially true at the lower Coarse Gain values, where most practical systems will operate.

Note that the Coarse Gain control is so arranged that the user can not make the error of stumbling into a setting that penalizes him heavily in terms of amplifier noise referred to the input, unless he cannot in fact use any higher gain setting. This has been achieved by having the Coarse Gain control begin to have an effect near the amplifier output, where the least following amplification will magnify and add to amplifier noise after signal attenuation. Its effect then moves in successive steps back toward the input, accepting this increasing penalty only when absolutely required.

4.1.3 Shaping: this front panel rotary switch (Model 1417) or internal jumper control (Model 1416) allows the selection of five equal integration and differentiation nearly-Gaussian time constants of 0.25, 0.5, 1, 2, or 4 microseconds (Model 1417) or three time constants of 0.5, 1, or 2 microseconds (Model 1416). Virtually any time constant larger than 0.2 microseconds may be obtained at the factory. For the appropriate component values for any desired time constant, contact the factory.

4.1.4 Input: this front panel rotary switch permits the user to select an amplifier input impedance of 93 ohms, 1000 ohms, or to attenuate the input signal by a factor of ten while selecting a 93 ohm input



EQUIVALENT INPUT NOISE
VERSUS GAIN SETTINGS
Noise Referred to Input (μV)
70
60
50
40
30
20
10
0
Model 1416
1 μsec TIME CONSTANT
HIGH COUNT RATE MODE
KEY:
Min.
Max.
FINE GAIN RANGE
COARSE GAIN SETTING
1
2
4
8
16
32
64
1 10
20
50
100
200
500
1000
2000
Amplifier Gain

Figure 4-1

impedance (Model 1417). Models 1416 and 1418 have a fixed 1000 ohm input impedance; this control is reduced to an input attenuator of X10 for the Model 1416 and is absent on the Model 1418.

The 93 ohm input impedance is useful when a long 93 ohm cable separates the preamp and amplifier, to prevent spurious oscillations and reflections due to impedance mismatch.

The X10 attenuator should be used only when absolutely necessary, as the amplifier noise referred to the input increases by a factor of ten when this control is used.

4.1.5 Pole/Zero Adjustment: this front panel screwdriver adjustment permits the precise elimination of undershoots on the amplifier pulse after the first differentiation, for all input pulses whose fall time constant exceeds 30 microseconds.

A classical problem in nuclear pulse amplifier design is that nominally singly differentiated pulses actually have two differentiations: the first by the amplifier first differentiation circuitry itself, whose time constant may range from 100 nanoseconds up to 10 microseconds, the second by the preamplifier circuitry, whose fall time constant usually ranges from 40 to 1000 microseconds. Thus, the "singly differentiated" pulse actually appears as:

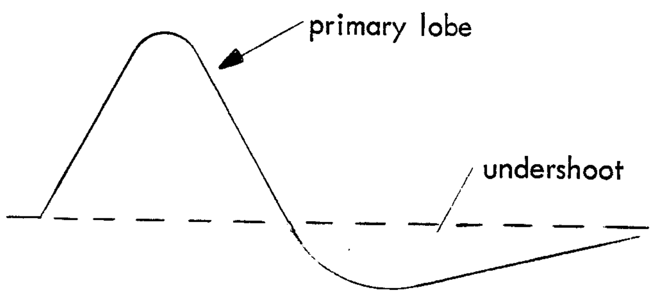


Figure 4-1

where the undershoot has an amplitude roughly equal to the primary pulse times the ratio of the amplifier differentiating time constant to the preamplifier fall time constant. For example, if the preamp fall time constant is 70 microseconds, a one microsecond first differentiated pulse ten volts high will have an undershoot equal to $\frac{(10)\,(1)}{70} = 142\text{mV}$.

This undershoot causes two aggravating effects. Under amplifier overload conditions, if the undershoot saturates the amplifier is blocked not only until the primary lobe recovers, but also until the undershoot recovers (at the much slower rate of the preamp fall time constant).

Second, if the count rate is sufficiently high, succeeding pulses may fall into the undershoot of preceding pulses, subtracting from their apparent pulse height and causing peaks to broaden on the low energy side.

Pole/Zero cancellation compensates for this effect, by artificially adding a Laplace "zero" to cancel the Laplace "pole" due to the preamplifier fall time constant, removing the undershoot caused by the preamplifier.

In its simplest form, the original differentiating network is compensated by the addition of a single resistor.

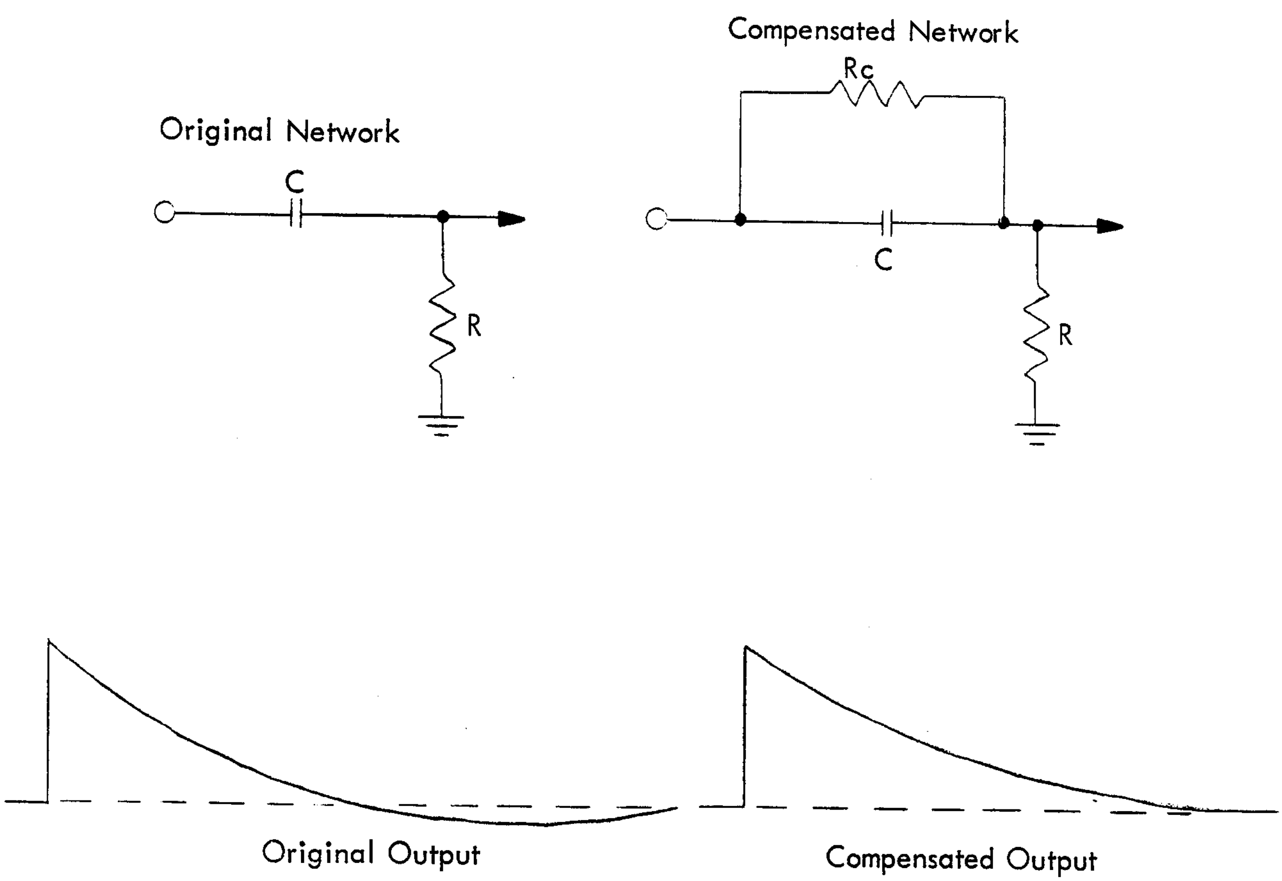


Figure 4-2

This technique is fully effective only if the input pulse to the network is composed of a single exponential fall time constant - thus, problems will be encountered in trying to compensate the fall time constants contained in the more complex pulse arising when a pulse generator with fall time constant T_1 feeds a preamplifier with fall time constant T_2, which in turn feeds the main amplifier. One may compensate for either time constant, but not both simultaneously.

The compensation circuit must in practice be variable, to permit adjustment for the range of fall time constants that may be encountered in the field. In the Canberra Spectroscopy Amplifiers, this compensation range extends from 30 microseconds upward, covering all commercially available preamplifiers.

In the practical case, adjustment is best done live, by observing the unipolar pulses from the amplifier with the detector and preamplifier attached. The amplifier must be placed in the HIGH Count Rate mode. The only difficulty that is encountered is that the system noise obscures the undershoots when the adjustment is reasonably close. One aid is to increase the amplifier gain by X8 or more for the purposes of this adjustment. If low energy tailing is observed on spectral peaks, it may be a sign that the Pole/Zero adjustment is incorrect.

Once adjusted for a given preamplifier, the adjustment need not be changed, and any gain settings, either setting of the Count Rate switch, and unipolar or bipolar output modes, may be selected, with assurance that the adjustment is still correct.

4.1.6 Mode: this front panel toggle switch permits the selection of UNIPOLAR or BIPOLAR outputs. This switch affects the PROMPT OUTPUT (Model 1417) or A OUT (Model 1416) only; the DELAYED or B OUT is always unipolar. On the Model 1418, the single output is affected by this control.

For a one microsecond time constant, the two pulse mode choices are as shown below:

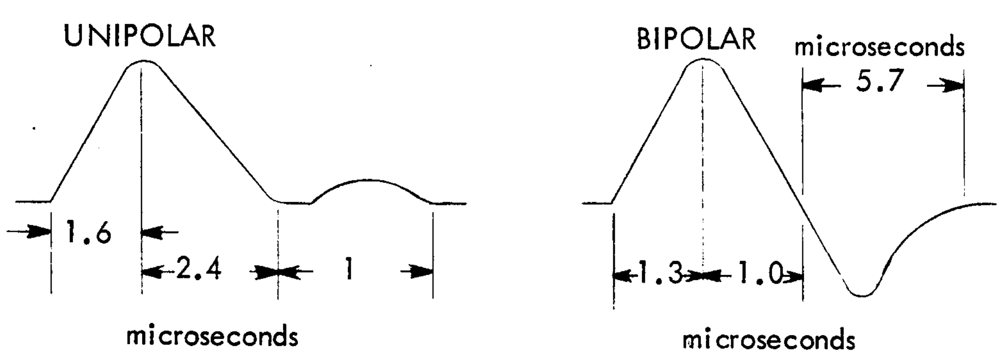


Figure 4-3

4.1.7 Count Rate Optimization: this front panel toggle switch permits the selection of the following two unipolar pulse shapes:

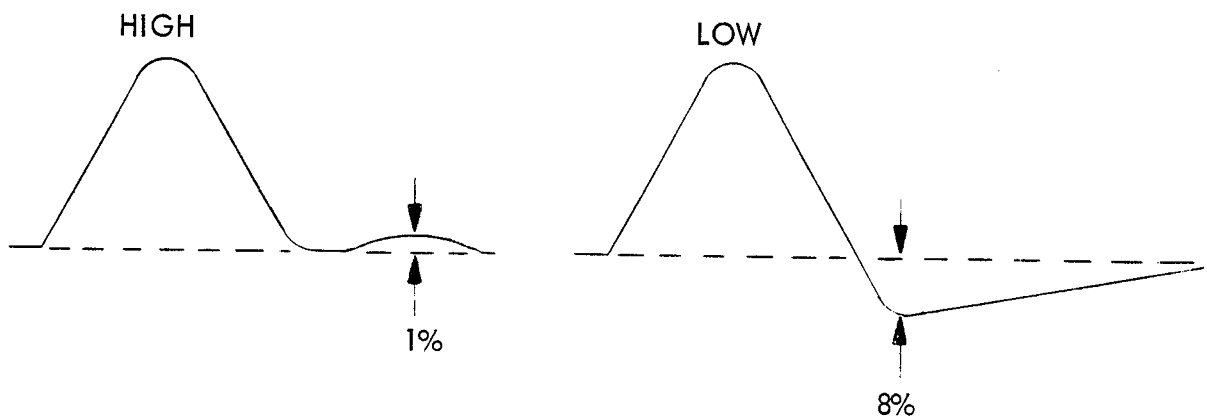


Figure 4-4

Pole/Zero Cancellation, for all its virtues, has the disagreeable result of greatly increasing a main amplifier's response to low frequency hum, ripple, and noise. An artificial second differentiation of long time constant (10 - 25 microseconds) can eliminate this effect, at the cost of introducing an undershoot which may lead to spectral line broadening as described in Section 4.1.5.

Neither of the two alternatives is ideal for all situations. The HIGH choice has the advantage of improved resolution due to the complete elimination of undershoots, at the expense of enhanced low frequency noise response. At high count rates, the first effect may dominate. The LOW choice eliminates hum and ripple, but suffers badly at high count rates.

The Canberra Spectroscopy Amplifiers leave the choice to the user; the better of the two depends upon the character and magnitude of his system noise, and upon the count rates being encountered.

Above 6,000 counts per second or so, the HIGH position is almost always best. Below 1,000 counts per second, the LOW position is probably superior. For count rates between these limits, only empirical investigation can decide.

This control does not affect bipolar outputs, of course.

4.1.8 DC Level Adjustments: two front or side panel screwdriver adjustments to set PROMPT and DELAYED OUT DC levels to zero volts (Model 1418 has PROMPT output only).

4.1.9 Common Mode Selector and Rejection Balance Controls: the Common Mode Selection toggle switch on the rear panel of Models 1416 and 1418A disables the front panel input (C.M. position) and enables the rear panel common mode inputs or, in the NOR(mal) position, disables the common mode inputs. This control is not provided on the Model 1417, as the front panel inputs may be used for common mode or normal input operation (the unused input must be terminated in 100 ohms).

When the common mode input capability is used, the Rejection Balance control should be trimmed for its optimum setting with the system and all cables as they will actually be used, as described in Section 3.4.11.

Common mode inputs are useful when the amplifier is used far from its associated preamplifier (e.g., 50 feet or more), especially in environments high in low frequency and line frequency interference. The theory is straight-foward; if a cable, in all respects identical to the preamp to amplifier cable except it is merely grounded at the preamp end rather than being connected to the preamp, is laid along the path of the true signal cable, both will pick up the same noise while only one will have the true signal. If the output from the bogus cable is inverted and summed with the output from the true cable, the signals common to both (i.e., noise and pick up) will cancel, while the signals appearing on only one (i.e., the true signal) will be unaffected.

The true signal cable is connected to the POS or NEG input (as appropriate), while the bogus cable is connected to the remaining input. Using this technique, noise and pick up may be reduced by more than 250:1.

4.2 Input Requirements

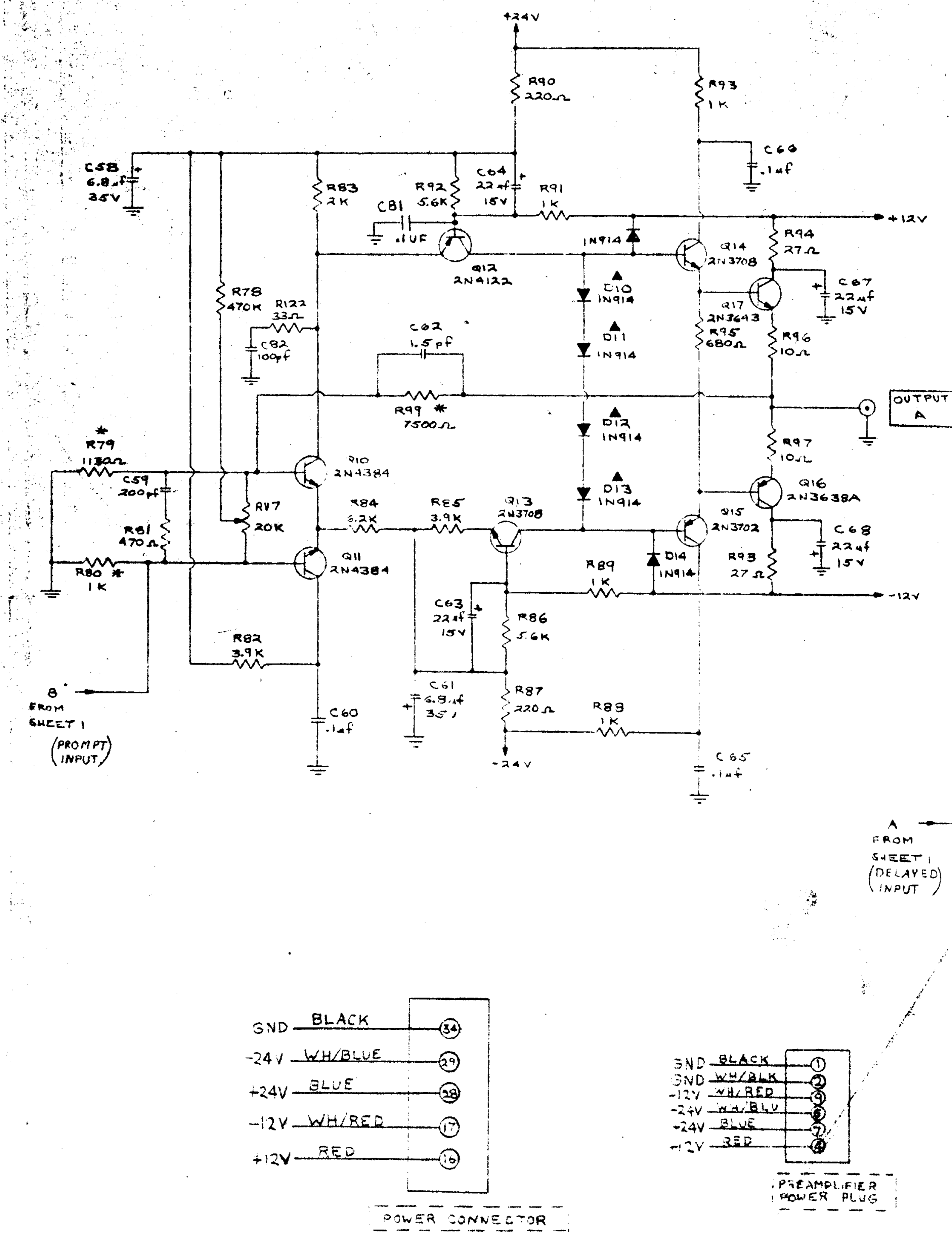
- Common Mode Inputs: front panel BNC connectors (rear panel on Models 1416 and 1418A), one of which accepts the input signal, the other of which may accept the noise and cable pickup signals from a second input cable (which is in all other respects identical to the primary input cable) for subtraction from the input signal to be processed; input impedances 1000 ohms or 93 ohms as selected, DC coupled; terminate unused input on Model 1417 in 100 ohms

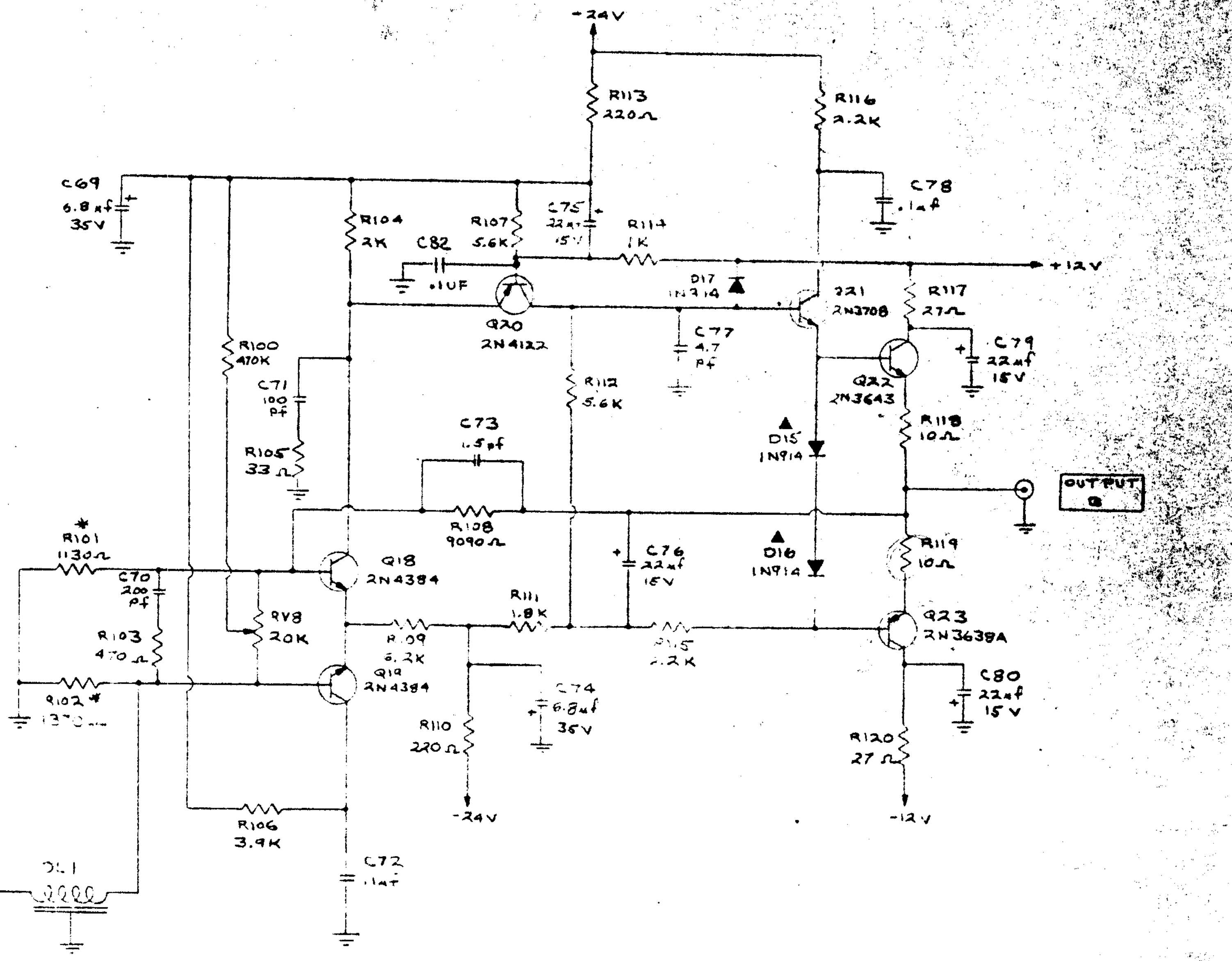
- Input Specifications: positive or negative tail pulse from associated preamplifier, 0 to 6 volts before input saturation, 12 volts maximum; 0 to 500 nanosecond rise time, 30 to 1000 microsecond fall time

4.3 Output Specifications

- Prompt Out: unipolar or bipolar (as switch-selected), positive 0 to 10 volt linear pulses, 11 volts saturation unterminated; pulse shape near-Gaussian, time constants as selected on front panel; output impedance less than 1 ohm, DC coupled; labelled A OUT on Model 1416, OUTPUT on Model 1418

- Delayed Out: unipolar, positive 0 to 10 volt pulses, 11 volts saturation unterminated; pulse shape the same as unipolar PROMPT OUT regardless of PROMPT OUT shaping; delayed from PROMPT OUT by 2.5 microseconds; output impedance less than 1 ohm, DC coupled; Models 1416 and 1417 only; labelled B OUT on Model 1416


+24V
R90
220Ω
R93
1K
C66
.1μf
C58
6.8μf
35V
R83
2K
R92
5.6K
C64
22μf
15V
R91
1K
+12V
C81
.1UF
IN914
Q14
2N3708
R94
27Ω
Q12
2N4122
C67
22μf
15V
R78
470K
R122
33Ω
D10
IN914
Q17
2N3643
C82
100pf
C62
1.5pf
D11
IN914
R95
680Ω
R96
10Ω
OUTPUT
A
R99 *
7500Ω
D12
IN914
R97
10Ω
*
R79
1130Ω
C59
200pf
Q10
2N4384
D13
IN914
Q16
2N3638A
RV7
20K
R84
6.2K
R85
3.9K
Q13
2N3708
Q15
2N3702
C68
22μf
15V
R81
470Ω
Q11
2N4384
D14
IN914
R89
1K
R93
27Ω
R80 *
1K
-12V
C63
22μf
15V
R86
5.6K
R82
3.9K
B
FROM
SHEET 1
(PROMPT
INPUT)
C61
6.8μf
35V
R87
220Ω
R88
1K
C60
.1μf
-24V
C65
.1μf
A
FROM
SHEET 1
(DELAYED
INPUT)
GND BLACK 34
-24V WH/BLUE 29
+24V BLUE 28
-12V WH/RED 17
+12V RED 16
POWER CONNECTOR
GND BLACK 1
GND WH/BLK 2
-12V WH/RED 9
-24V WH/BLU 6
+24V BLUE 7
+12V RED 8
PREAMPLIFIER
POWER PLUG



REVISION	CHANGE	ECN	DATE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMAL ± .005
FRACTIONAL ± 1/64
ANGLE ± 1°

INVENTORY NO.

MATERIAL

TITLE SCHEMATIC DIAGRAM
AMPLIFIER
MODEL 1416

SCALE

APPROVAL

DRAWN 3/6/22/67

CHECKED

APPROVED

SHEET 2 OF 2

CANBERRA IN
50 SILVER ST.
MIDDLETOWN, CONN.

DRAWING NO. D-10417 E

AHKED RESISTORS ARE 1/4 WATT 5%

60C 1% FILM RESISTOR

RN60D 1% FILM RESISTOR

WATT 5% RESISTOR

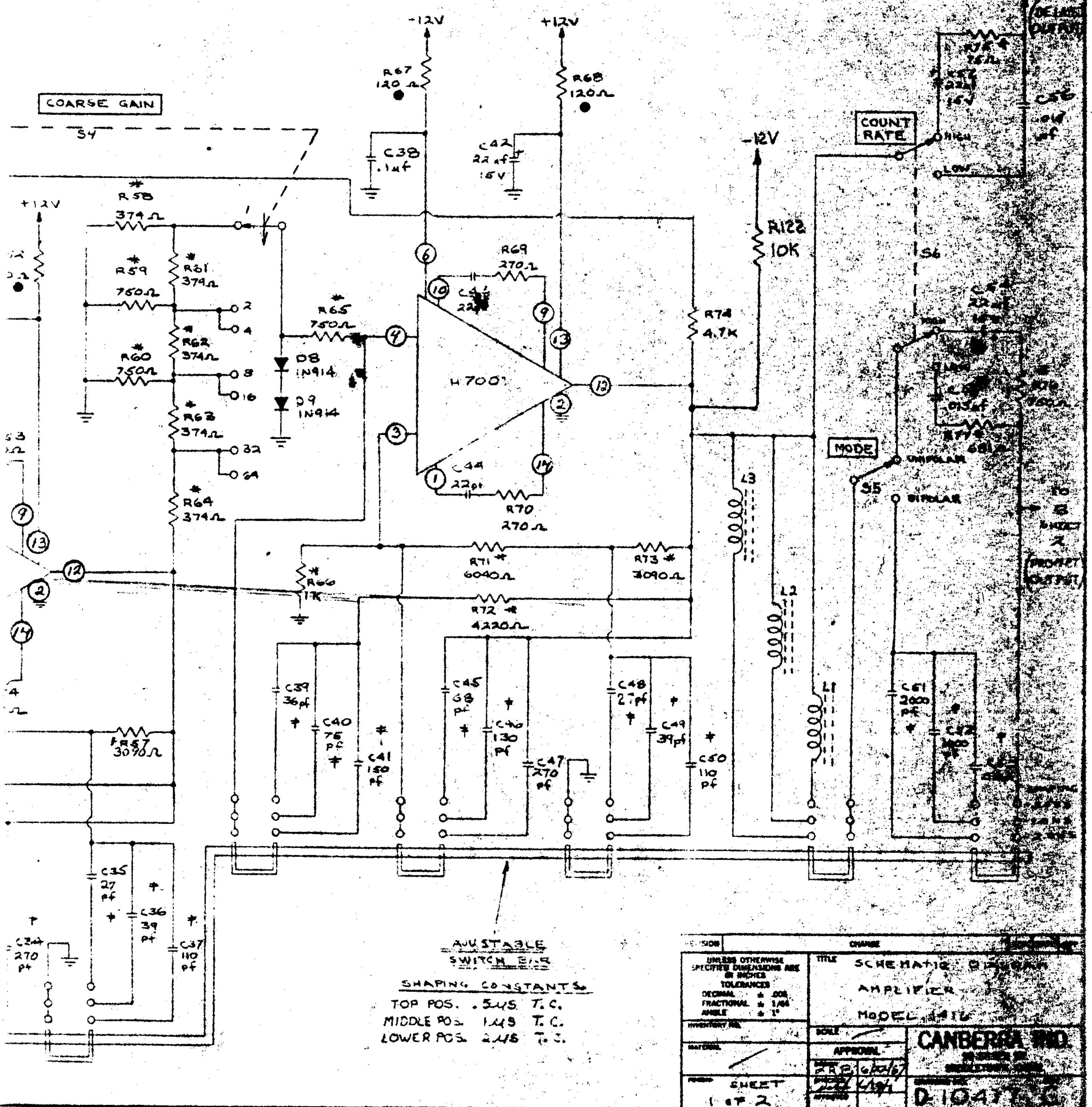
% MICA CAPACITOR

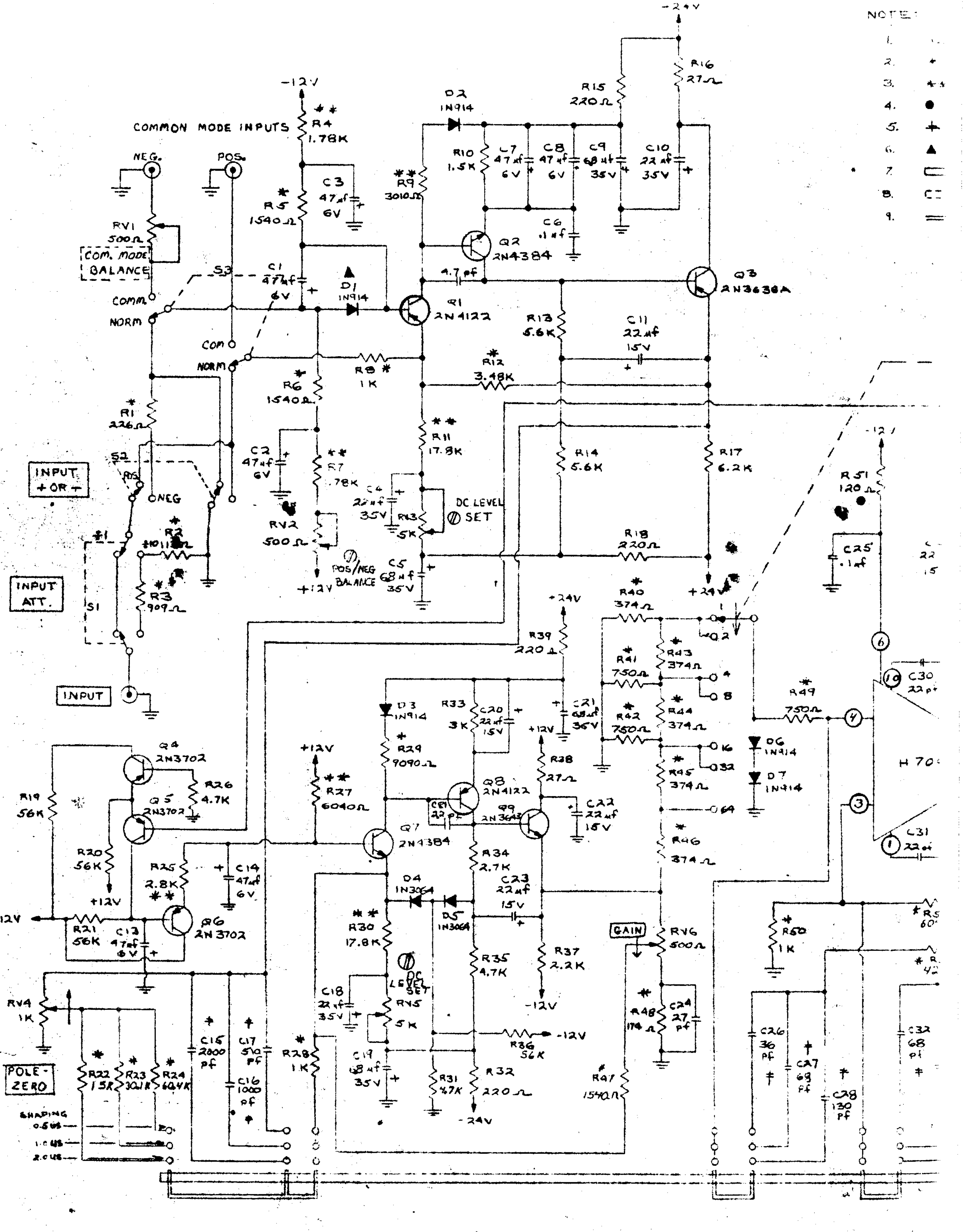
ELECTED IN914 DIODES

= LOCATED ON FRONT PANEL

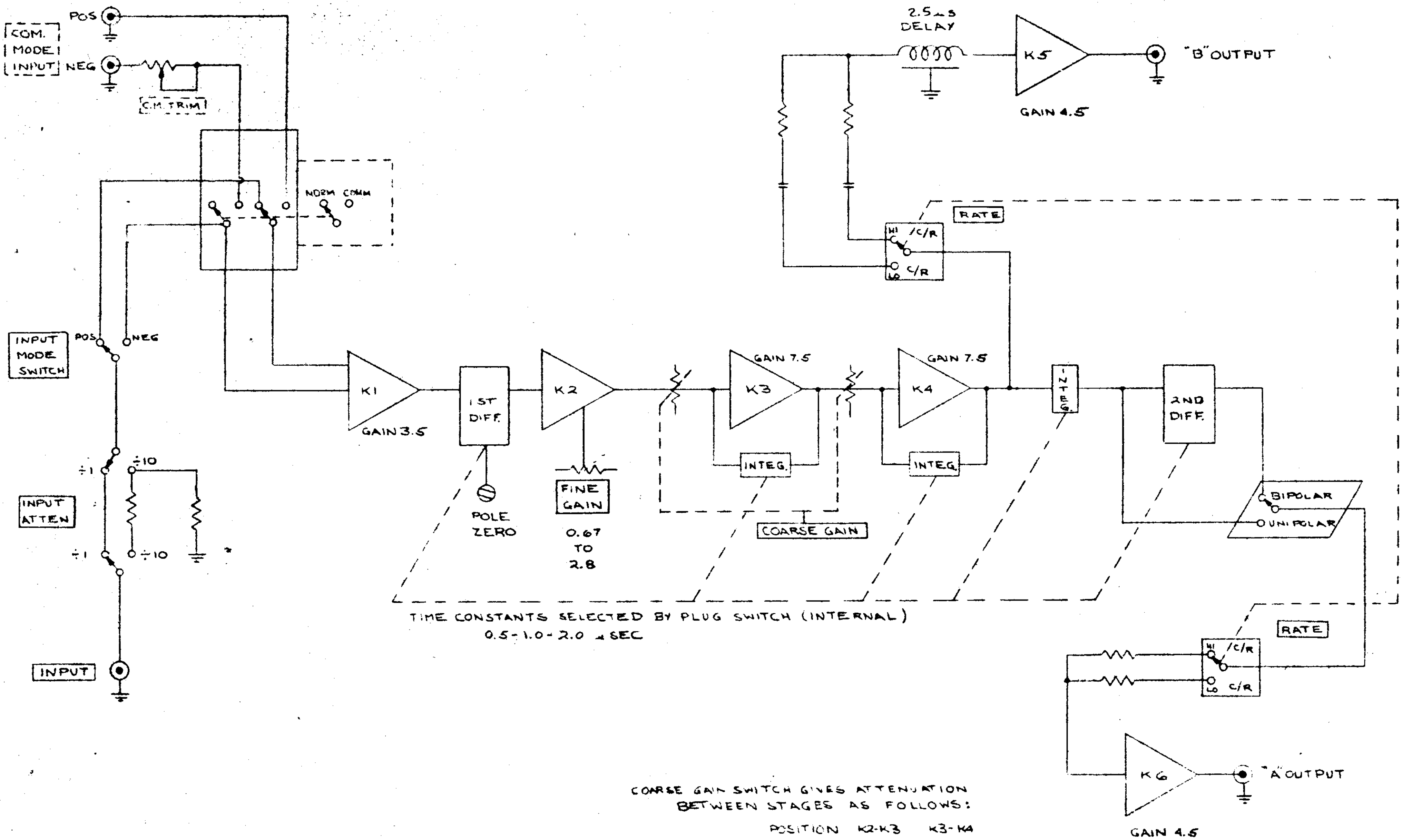
= LOCATED ON REAR PANEL

= = INTERNAL USERS ADJUST





+24V
NOTE:
1.
2.
3.
4.
5.
6.
7.
8.
9.
-12V
COMMON MODE INPUTS
NEG.
POS.
RV1 500Ω
COM. MODE BALANCE
COMM
NORM
COM
NORM
S3
S2
S1
INPUT + OR -
NEG
INPUT ATT.
INPUT
R4 1.78K
R5 1540Ω
C3 47µf 6V
C1 47µf 6V
D1 1N914
D2 1N914
R9 3010Ω
R10 1.5K
C7 47µf 6V
C8 47µf 6V
C9 68µf 35V
C10 22µf 35V
R15 220Ω
R16 27Ω
C6 .1µf
Q2 2N4384
Q1 2N4122
Q3 2N3638A
4.7pf
R13 5.6K
C11 22µf 15V
R12 3.48K
R8 1K
R6 1540Ω
R1 226Ω
R2
R3 909Ω
C2 47µf 6V
R7 1.78K
RV2 500Ω
POS/NEG BALANCE
+12V
R11 17.8K
C4 22µf 35V
R13 5K
DC LEVEL SET
C5 68µf 35V
R14 5.6K
R17 6.2K
R18 220Ω
R51 120Ω
C25 .1µf
R40 374Ω
R39 220Ω
R41 750Ω
R43 374Ω
R42 750Ω
R44 374Ω
R45 374Ω
R46 374Ω
R49 750Ω
D6 1N914
D7 1N914
H 70
C30 22pf
C31 22pf
D3 1N914
R33 3K
C20 22µf 15V
C21 68µf 35V
R29 9090Ω
R28 27Ω
Q8 2N4122
Q9 2N3643
C22 22µf 15V
CB1 22pf
Q7 2N4384
R27 6040Ω
Q4 2N3702
Q5 2N3702
R26 4.7K
R19 56K
R20 56K
R25 2.8K
C14 47µf 6V
Q6 2N3702
R21 56K
C13 47µf 6V
R34 2.7K
C23 22µf 15V
D4 1N3064
D5 1N3064
R30 17.8K
R35 4.7K
R37 2.2K
GAIN
RV6 500Ω
R48 174Ω
C24 27pf
R47 1540Ω
C18 22µf 35V
RV5 5K
DC LEVEL SET
R36 56K
C19 68µf 35V
R31 4.7K
R32 220Ω
-24V
R28 1K
RV4 1K
POLE-ZERO
R22 15K
R23 30.1K
R24 60.4K
C15 2000 pf
C17 510 pf
C16 1000 pf
SHAPING
0.5µs
1.0µs
2.0µs
R50 1K
C26 36 pf
C27 68 pf
C28 130 pf
C32 68 pf



COARSE GAIN SWITCH GIVES ATTENUATION BETWEEN STAGES AS FOLLOWS:

POSITION	K2-K3	K3-K4
64	1.5	1.5
32	3	1.5
16	3.0	3.0
8	6.0	3.0
4	6.0	6.0
2	12.0	6.0
1	12.0	12.0

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: DECIMAL ± .005, FRACTION ± 1/64, ANGLE ± 1°

TITLE: BLOCK DIAGRAM AMPLIFIER MODEL 1416

APPROVAL

STURRUP, INC.
30 SILVER ST.
MIDDLETOWN, CONN.

C-10444