INSTRUCTION MANUAL
433
SUM-INVERT AMPLIFIER

Serial No. ______________________

Purchaser ______________________

Date Issued ______________________

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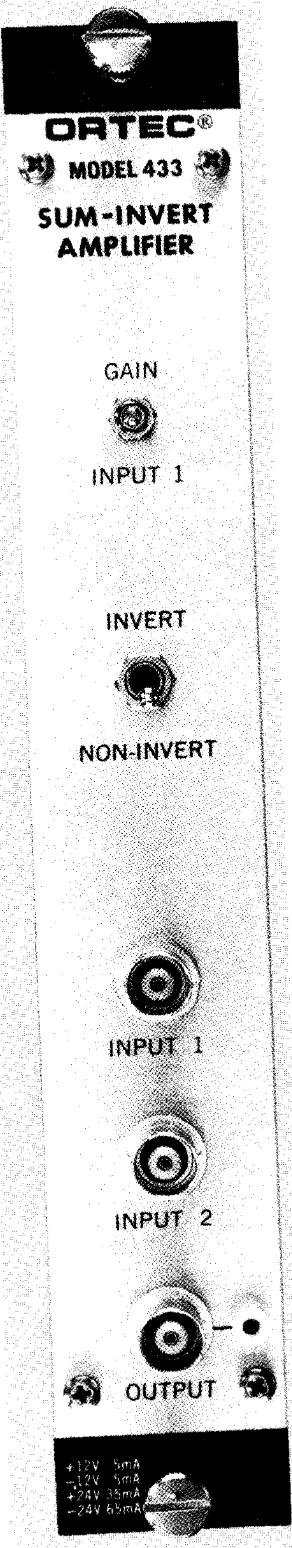

ORTEC®
MODEL 433
SUM-INVERT
AMPLIFIER
GAIN
INPUT 1
INVERT
NON-INVERT
INPUT 1
INPUT 2
OUTPUT
+12V 5mA
-12V 5mA
+24V 35mA
-24V 65mA

ORTEC 433
SUM-INVERT AMPLIFIER

1. DESCRIPTION

1.1 General Description

The 433 Sum-Invert Amplifier is a dual-purpose amplifier that provides a summation of as many as four signals and line drive capability, with or without inversion. It is one of the ORTEC 400 Series of Modular Nuclear Instruments designed to meet the recommended interchangeability standards outlined in AEC Report TID-20893 (Rev.). The 433 is a single width module (1.35 inches wide). It receives necessary operating power from the ORTEC 401A/402A Modular System Bin and Power Supply through the rear panel power connector.

1.2 Description of Basic Functions

The 433 has four summing inputs that allow the algebraic summation of any of four signals that are present on the four input connectors. The incoming signals are fed in parallel into the virtual ground input of an operational amplifier. This minimizes the interaction of one input signal onto the other input. There is no internal pulse shaping in the amplifier; i.e., it is a wideband amplifier, and therefore the output pulse will be a faithful reproduction of the input. The amplifier has a flat frequency response (3db) from 200 Hz to 7.5 MHz. The output may be either the direct sum or the inverted sum of the input signals.

2. SPECIFICATIONS

INPUT SIGNAL	0 to 10V rated span, 12 volts maximum, positive or negative, unipolar or bipolar
INPUT IMPEDANCE	1000 ohms
VOLTAGE GAIN	Unity on each input; tolerance ⩽±4% Input 1 adjustable ±25%
SUMMING INPUTS	Four total (two front panel and two rear panel)
FUNCTION SELECTION	Invert/Non-Invert by front panel switch
BANDWIDTH	Within 3 db from 200 Hz to 7.5 MHz (T_r ⩽46 nsec)
OUTPUT	0 to 10V rated output, positive or negative, unipolar or bipolar
OUTPUT IMPEDANCE	⩽1 ohm
TOTAL INPUT NOISE WITHIN THE BANDWIDTH	⩽60 μV rms
INPUT NOISE (Shaped with 1.0 μsec integrate and differentiate time constants)	⩽20 μV rms
LINEARITY	Integral nonlinearity ⩽0.05% from 0.2 volts to 10 volts
TEMPERATURE STABILITY	The gain shift of the amplifier is ⩽0.015% per °C
POWER REQUIREMENTS	+24V 40mA, -24V 68.5mA +12V 2mA, -12V 2mA
SIZE	Standard single width module (1.35 inches wide) per TID-20893 (Rev.)

3. INSTALLATION

3.1 General Installation Considerations

The 433, used in conjunction with a 401A/402A Bin and Power Supply, is intended for rack mounting. It is necessary to ensure that vacuum tube equipment operating in the same rack with the 433 has sufficient cooling air circulating to prevent any localized heating of the all-transistor circuitry used throughout the module. The temperature of equipment mounted in racks can easily exceed the recommended maximum unless precautions are taken. The 433 should not be subjected to temperatures in excess of 120°F (50°C).

3.2 Connection to Power – Modular System Bin, ORTEC 401A/402A

The 433 contains no internal power supply; therefore, it must obtain power from a Nuclear Standard Bin and Power Supply such as the ORTEC 401A/402A. The bin power supply should be turned off when inserting or removing modules. The ORTEC 400 Series is designed so that it is not possible to overload the bin power supply with a full complement of modules in the bin; however, this may not be true when the bin contains modules other than those of ORTEC design, and in such instances the power supply voltage should be checked after the insertion of modules. The ORTEC 401A/402A has test points on the power supply control panel to monitor the dc voltages. When using the 433 outside the 401A/402A Bin and Power Supply, be sure that the jumper cable used properly accounts for the power supply grounding circuits set forth in the recommended AEC standards of TID-20893 (Rev.). Both high quality and power return ground connections are provided to ensure proper reference feedback into the power supply, and these must be preserved in remote cable installations. Be careful to avoid ground loops when the module is not physically in the bin.

3.3 Signal Connections to the 433 Inputs

The 433 inputs are compatible with all linear output signals of the ORTEC 400 Series modular electronic instruments. The signal range of the input is from 0 to 10 volts. The input pulse shape can be as wide as the typical preamplifier output, i.e., a time constant of 50 microseconds, or as narrow as 200 nanoseconds.

The input connector should be terminated in the characteristic impedance of the connecting coaxial cable when cable lengths exceed approximately 10 feet. The input impedance of each input is approximately 1000 ohms.

It is recommended that RG-62/U or RG-63/U coaxial cable be used due to the relatively higher impedance (93 ohms and 125 ohms, respectively). If 50-ohm coaxial cable must be used, be sure that the driving source can drive terminated 50-ohm cable. Normally, nonlinearity of a system will vary directly with the amount of power being driven; therefore, quite often the best method of linearly driving 50-ohm coaxial cable which needs to be terminated is that of series drive. For example, a series resistance of 50 ohms is placed between the driving source and the coaxial line, for sources whose driving impedance is less than 2 ohms. When the line is terminated at the receiving end the output signal will be divided and only half of it will appear at the receiving end; however, the receiving end may be left open-circuited, causing voltage doubling to take place, and the cable is terminated back at the driving impedance end. In this case, the driven power is very low.

3.4 Linear Output Signal Connections and Terminating Impedance Considerations

The source impedance of the 0-10 volt standard linear outputs of most 400 Series modules is approximately 1 ohm. Interconnection of linear signals is, thus, non-critical since the input impedance of circuits to be driven is not important in determining the actual signal span, e.g., 0-10 volts, delivered to the following circuit. Paralleling several loads on a single output is therefore permissible while preserving the 0-10 volt signal span. Short lengths of interconnecting coaxial cable (up to approximately 4 feet) need not be terminated. However, if a cable longer than approximately 4 feet is necessary on a linear output, it should be terminated in a resistive load equal to the cable impedance. Since the output impedance is not purely resistive, and is slightly different for each individual module, when a certain given length of coaxial cable is connected and is not terminated in the characteristic impedance of the cable oscillations will generally be observed. These oscillations can be suppressed for any length of cable by properly terminating the cable either in series at the sending end or in shunt at the receiving end of the line. To properly terminate the cable at the receiving end, it may be necessary to consider the input impedance of the driven circuit, choosing an additional parallel resistor to make the combination produce the desired termination resistance. Series terminating the cable at the sending end may be preferable in some cases where receiving end terminating is not desirable or possible. When series terminating at the sending end, full signal span, i.e., amplitude, is obtained at the receiving end only when it is essentially unloaded, or loaded with an impedance many times that of the cable. This may be accomplished by inserting a series resistor equal to the characteristic impedance of the cable internally in the module between the actual amplifier output on the etched board and the output connector. Remember that this impedance is in series with the input impedance of the load being driven, and in the case where the driven load is 900 ohms, a decrease in the signal span of approximately 10% will occur for a 93-ohm transmission line. A more serious loss occurs when the driven load is 93 ohms and the transmission system is 93 ohms. In this case, a 50% loss will occur.

BNC connectors with internal terminators are available from a number of connector manufacturers in nominal values of 50, 100, and 1000 ohms. ORTEC stocks in limited quantity both the 50 and 100 ohm BNC terminators. The BNC terminators are quite convenient to use in conjunction with a BNC tee for terminating at the receiving end of the cable.

4. OPERATING INSTRUCTIONS

4.1 Typical Operating Considerations

The 433 is typically used in a linear system after the main pulse shaping amplifier; however, it may be used as a summing amplifier prior to pulse shaping in the main amplifier, if so desired. The connotation of SUMMING AMPLIFIER is true only in case of time coincidence of arrival of input pulses. If the input signals do not arrive within a time coincidence period given by the width of the input signals, then the inputs may be thought of as a linear fan-in. There are many applications for the unit as a summing amplifier and as a linear fan-in unit. The 433 is directly compatible with and can be driven from any of the ORTEC 400 Series linear output signals. It can be used to sum the outputs from preamplifiers, either the shaping or nonshaping type. Unless the charge conversion gain of the preamplifier is quite high, some degradation in signal-to-noise ratio may be expected when summing preamplifier outputs, since the noise from each input must be summed in quadrature.

4.2 Gain Variation

One consideration when summing preamplifier outputs is matching gains in respect to preamplifier channels. The 433 has one input with built-in provision for trimming the gain. The gain of input 1 may be trimmed by adjustment of R39. The gain of the other inputs may be changed by changing resistor values as given in Section 6.2 of this manual, or by replacing a given resistor with a variable potentiometer at each input.

5. CIRCUIT DESCRIPTION

5.1 General Description

The circuit of the 433 consists essentially of two amplifier sections. In the INVERT mode, only one amplifier section is used. This amplifier, composed of Q4, Q5, Q6, and Q7 and the associated components, forms a gain of one inverting line driver and current amplifier. In the NON-INVERT mode, Q1, Q2, Q3, and the associated components form an inverting amplifier with a gain of 0.5. The output of this amplifier is then fed to the second stage of amplification previously described. In the NON-INVERT mode of operation, the second stage has a gain of 2. For example, in the INVERT mode, the gain from input 4 to the output is given by R22/R4; however, for the NON-INVERT mode the gain is given by (R5/R4) (R22/R6). In either case, the total gain is 1.

5.2 Circuit Details

For the NON-INVERT mode, the base of Q1 is a virtual ground, and therefore a summing point for all inputs. Q1 and Q2 form what is characteristically called the npn-pnp pair feedback loop. Q3 forms a current source for the output of Q2. The base of Q4 is again a virtual ground. The second loop is composed of Q4 and Q6, with Q7 being an emitter-follower to aid the driving a bipolar signal onto the low impedance output. Q8 serves as a short-circuit protection to prevent burning out Q7 and Q6 when the output is accidentically shorted. Q8 can supply large peak currents from the collector capacitor, C14; these currents can flow directly through Q8 and Q7 and thence into the load.

In the event of a short circuit on the output, the absolute magnitude of the current that can be supplied through Q7 and Q8 from C11 is less than that required to destroy either Q7 or Q8. C11 charges back to the quiescent voltage through R28 in the absence of any input pulse.

6. MAINTENANCE

6.1 Testing Performance of the Sum-Invert Amplifier

6.1.1 Introduction

The following paragraphs are intended as aids in the installation and checkout of the 433. These instructions present information on front panel controls, waveforms at test points and output connectors.

6.1.2 Test Equipment

The following, or equivalent, test equipment is needed:

1. ORTEC 419 Precision Pulse Generator
2. Tektronix Model 580 Series Oscilloscope
3. 100-ohm BNC terminators
4. High-impedance dc voltmeter
5. ORTEC 410 Linear Amplifier
6. Schematic and block diagrams for the 433 Sum-Invert Amplifier

6.1.3 Prelminary Procedures

1. Visually check the module for possible damage due to shipment.
2. Connect ac Power to the Modular System Bin and Power Supply, ORTEC 401A/402A. Turn power off.
3. Plug the module into the bin and check for proper mechanical alignment.
4. Switch on the ac power and check the dc power supply voltages at the test points on the 402A Power Supply control panel.

6.1.4 Sum-Invert Amplifier

There are no internal adjustments to be made on the 433; therefore, testing is simply a matter of observation of input and output waveforms.

1. Feed the output of the 419 Precision Pulse Generator into the input of the 410 Amplifier.
2. Set the 410 Amplifier controls as follows:

INPUT ATTENUATOR	– 1	1st DIFFERENTIATION (outer concentric control)	– .5
COARSE GAIN	– 3		
INTEGRATION	– .5	2nd DIFFERENTIATION (inner concentric control)	– .5
INPUT POLARITY	– NEG		
FINE GAIN	– 1.5		

3. Feed the BIPOLAR OUPUT of the 410 to the Summing INPUT 1 of the 433 through RG-62/U cable, and terminate the cable at the input of the 433 with a 100-ohm terminator.

4. Adjust the 419 Pulse Generator for an output of 500mV from the 410.

5. The output of the 433 should be 500mV and should come out promptly with respect to the input signal.

6. Move the input signal and terminator from the Summing INPUT 1, and connect it to Summing INPUT 2.

7. Again, the output should be 500mV and prompt with respect to the input. Repeat steps 5 and 6 for input 3 and 4. Raise the amplitude of the signal from the 410 to check the output under high signal conditions. The amplifier should saturate at approximately 11 volts.

6.2 Changing the Amplifier Gain

Since the amplifier is composed of two loops, one of which is bypassed in the INVERT mode, the changing of the gain for any input except number 1 is complicated to some extent. First of all, the values of the feedback resistors, given on the block diagram as R_f, should not be changed because they directly affect the dc bias condition of the circuits. Therefore, all gain changes should be made by means of the input resistors R3, R4, R37, and R35. The gain equations are given on the block diagram (Drawing 433-0101-B). The following example shows the calculation of the values of resistance needed to reduce the gain on a given input, e.g., input 4, from a gain of 1 to a gain of 0.5. For the INVERT mode, the gain is given by R22/R4; therefore R4 should be changed to 2940 ohms. Since a resistance value of 2940 ohms is not a standard value, one should probably choose 2870 ohms, which is a standard value, and will give a gain of slightly greater than 0.5. This will, of course, make the gain 0.5 in the NON-INVERT mode as well. The same procedure may be applied to each input. The input resistor to be changed may be replaced by a shorting type potentiometer if one wishes to continuously vary the gain on a given input.

6.3 Suggestions for Troubleshooting

In situations where the 433 is suspected of malfunction, it is essential to verify such malfunction in terms of simple pulse generator pulses at the input and output. In consideration of this, the 433 must be disconnected from its position in any system, and routine diagnostic analysis performed with a test pulse generator and an oscilloscope. It is imperative that testing not be performed with a source and detector until the Sum-Invert Amplifier performs satisfactorily with the test pulse generator. The testing instructions given in Section 6.1 of this manual and the circuit descriptions in Section 5 should provide assistance in locating and repairing the malfunction. The guide plate and shield cover can be removed completely from the module to permit oscilloscope and voltmeter observation with a minimal chance of accidentally short-circuiting portions of the etched board. Table 6.1 is also presented here as a typical set of dc voltage measurements against which any unit can be tested. The 433 may be returned to ORTEC for repair service at nominal cost at any time. Standard procedure requires that each repaired instrument receives the same extensive quality control tests that a new instrument receives.

6.4 Tabulated Test Point Voltages on Etched Board

The following voltages indicate the dc voltages measured on the etched circuit board. In some intancess the circuit will perform satisfactorily even though, due to component variations, there may be some voltages that measure outside the given limits; therefore, the voltages given here should not be taken as absolute values, but rather are intended to serve as an aid in troubleshooting.

Table 6.1

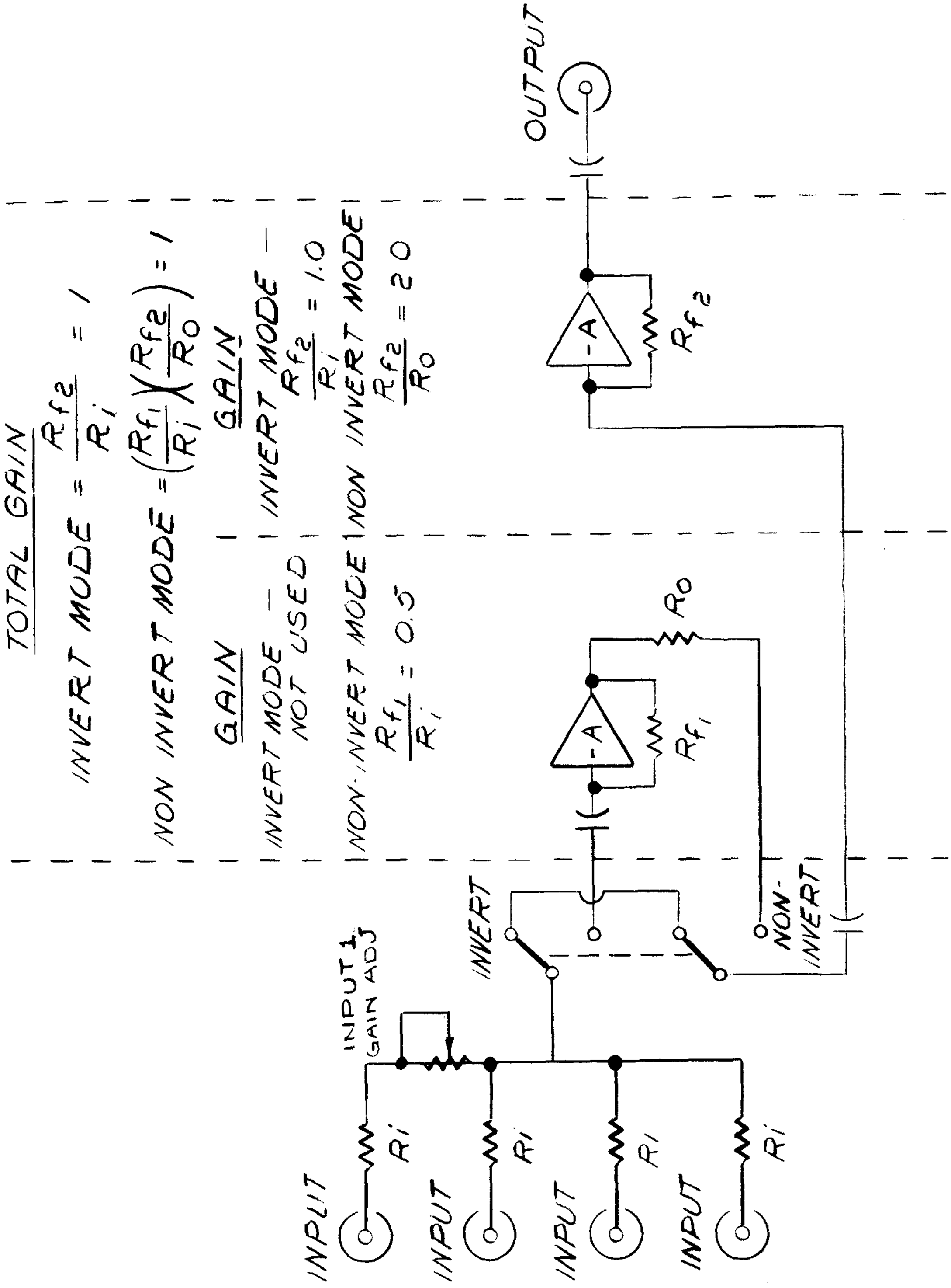
Typical DC Voltages

1. All voltages are measured to ground with a vtvm having input impedance of 10 megohms or greater.

2. Voltages are dc values with no input pulses.

Location	Typical DC Voltages
+24 Bus	+ 22.8
+12 Bus	+ 12.0
-12 Bus	- 12.0
-24 Bus	- 22.6
Q1c	- 7.7
Q2e	- 8.3
Q3b	- 17.8
Q4b	- 11.5
Q4e	- 12.1
Q4c	- 0.7
Q5b	- 12.8
Q6e	- 0.1
Q7c *	+ 14.2
Q8b *	+ 13.9

*Q8b must never be more than 0.5V more positive than Q7c.



REV.	ECN. NO.	DATE	BY	APPD.
A	433-4	6/24/66	HW	

REVISIONS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES

TOLERANCES
FRACTION ± ______
DECIMALS ± ______
ANGLES ± ______
SURFACE FINISH ✓ RMS
APPLIED PRACTICES

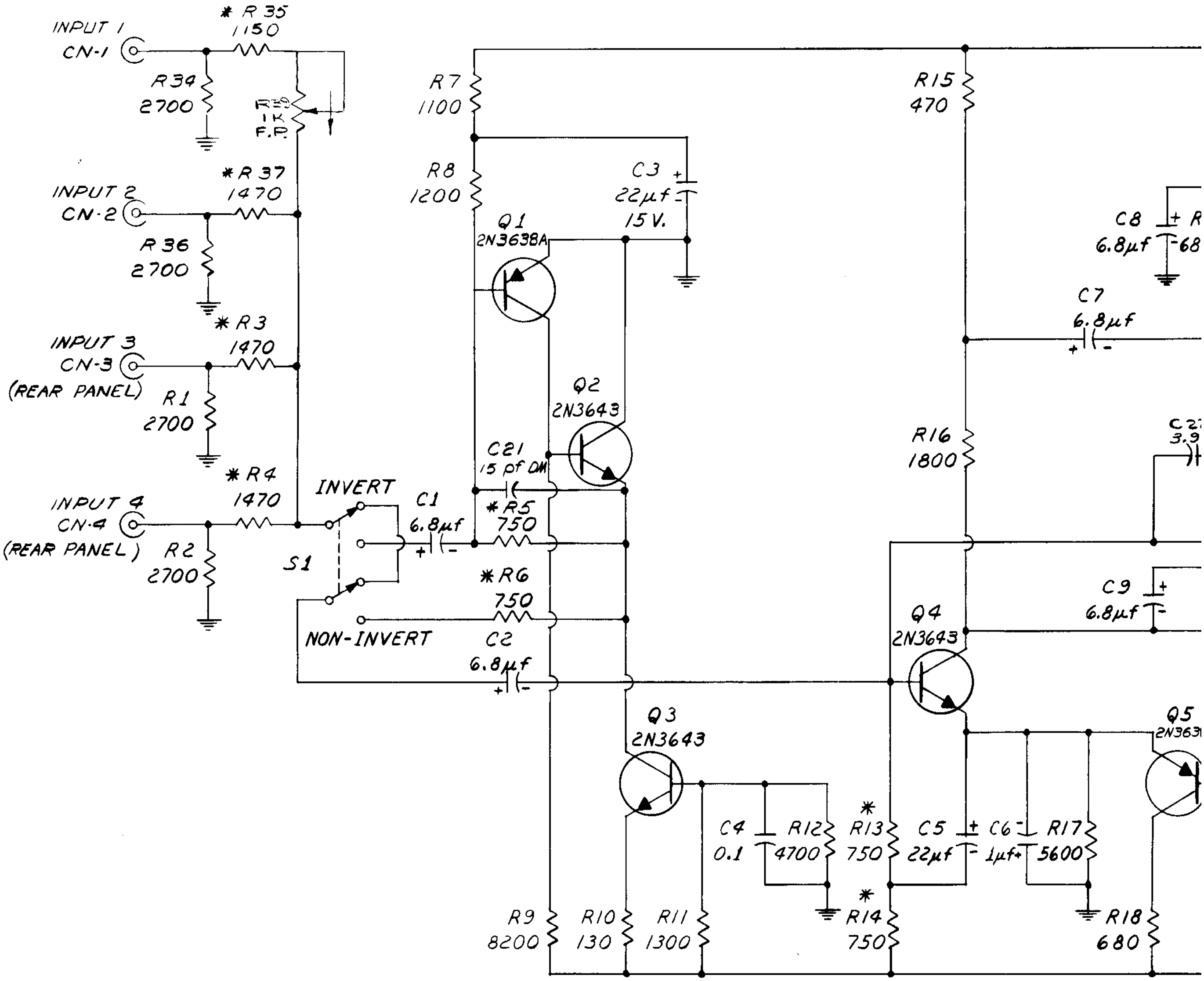
ORTEC

OAK RIDGE TECHNICAL ENTERPRISES CORPORATION
OAK RIDGE TENNESSEE

TITLE
SUM/INVERT AMPLIFIER BLOCK DIAG.

DRAFTSMAN	DATE	ENG. APPROVAL	RESP. ENG.
[signature]	3-9-66	C.W.	C.W. WILLIAMS
CHECKED	DATE	MFG. APPROVAL	DRAWING NO.
			433-0101-B1
SCALE		DWG. ISSUED [signature] DATE 3-9-66	
~			

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

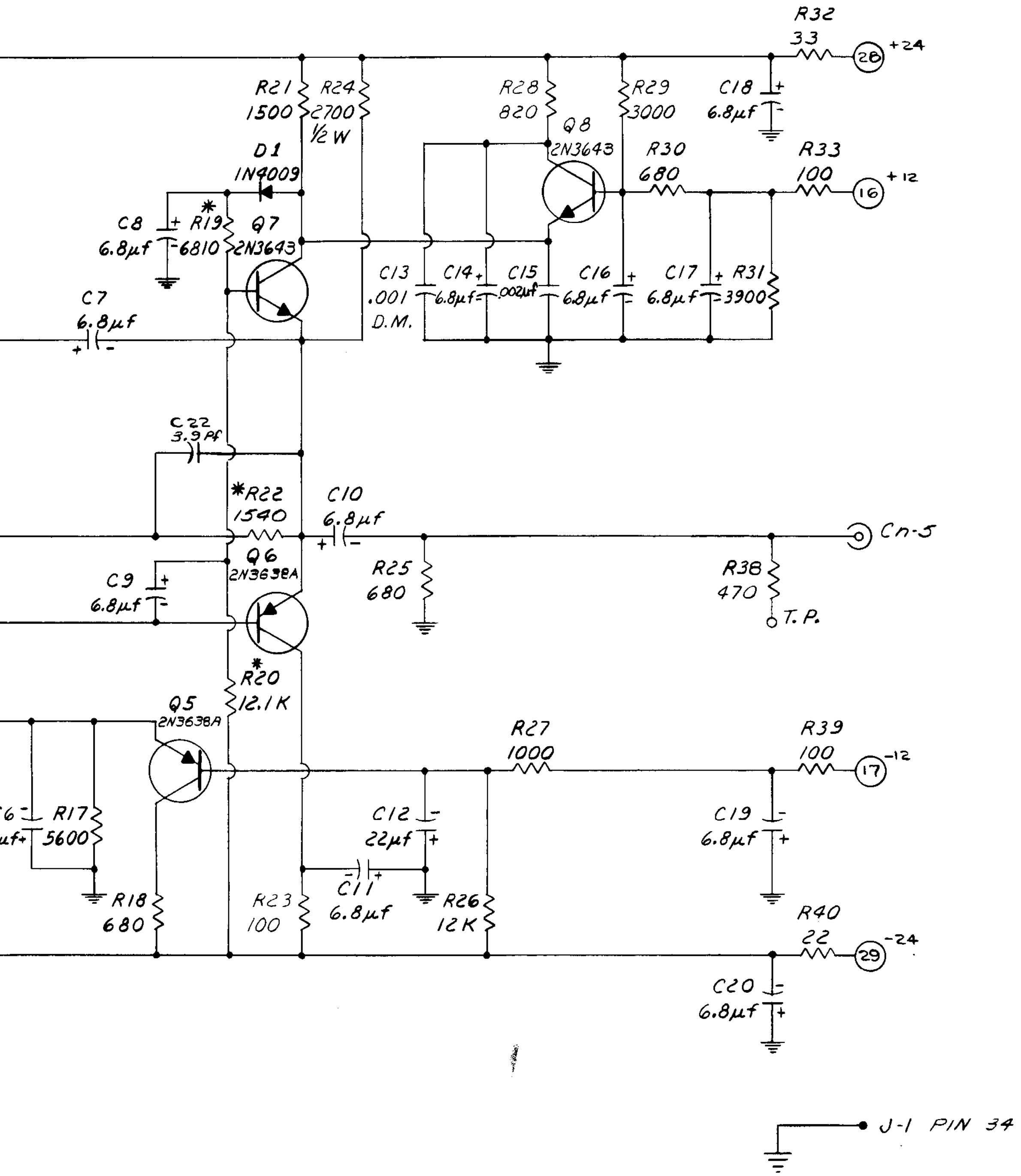


NOTE-

*1. Resistors marked with an asterisk are 1% Metal Film, CEA-TO.

2-20-67	E	ECI
11-19-66	D	EC
5-3-66	C	ECN
3-15-66	A	ECN
DATE	NO.	

DESIGN
C.W. Williams



DATE	NO.	REVISION	BY
2-20-67	E	ECN 433-8	JDW
11-19-66	D	ECN 433-6	JDW
5-3-66	C	ECN 433-4	
3-15-66	A	ECN 433-1	JDW

OAK RIDGE TECHNICAL ENTERPRISES CORP.
OAK RIDGE, TENN.

SUM / INVERT AMPLIFIER SCHEMATIC

DESIGN	DRAWN	DATE	RESP. ENGR.	APPR.	SCALE	DRAWING NO.
C.W. Williams	E.C. Keith	12-11-65	C. Williams	C. H.	~	433-0101-S1