



OPERATING AND SERVICE MANUAL

(HP PART NO. 00463-90001)

MODEL 463A  
PRECISION AC AMPLIFIER

SERIALS PREFIXED: 738-

Appendix C, Manual Backdating  
Changes adapts this manual to  
Serials Prefixed: 624-, 738-00240  
and below, 738-00280 and below

79-42  
T.E. MAINT.

Copyright Hewlett-Packard Company 1968  
P.O. Box 301, Loveland, Colorado, 80537 U.S.A.

TABLE OF CONTENTS

Section	Page
I GENERAL INFORMATION . . . . .	1-3
1-1. Introduction . . . . .	1-3
1-3. Description . . . . .	1-3
1-7. Applications . . . . .	1-3
1-9. Accessory Equipment Supplied . . . . .	1-3
1-11. Instrument Identification . . . . .	1-3

Section	Page
II INSTALLATION . . . . .	2-1
2-1. Introduction . . . . .	2-1
2-3. Initial Inspection . . . . .	2-1
2-5. Power Requirements . . . . .	2-1
2-7. Grounding Requirements . . . . .	2-1
2-10. Installation . . . . .	2-1
2-12. Bench Mounting . . . . .	2-1
2-14. Rack Mounting . . . . .	2-1
2-16. Repackaging for Shipment . . . . .	2-1

Section	Page
III OPERATING INSTRUCTIONS . . . . .	3-1
3-1. Introduction . . . . .	3-1
3-3. Description of Controls . . . . .	3-1
3-5. Operational Instructions . . . . .	3-1
3-6. Turn On Procedure . . . . .	3-1
3-8. Front Panel Zero Adjustment . . . . .	3-1
3-10. Selection of Input Terminal . . . . .	3-1
3-12. Selection of Gain . . . . .	3-1
3-14. Operation of Reset Button . . . . .	3-1
3-16. Capacitive Drive Capability . . . . .	3-1
3-18. Applications . . . . .	3-2
3-20. Low Level Precision Measurements . . . . .	3-2
3-22. High Voltage Oscillators and Function Generators . . . . .	3-2
3-26. Low Level AC Measurements . . . . .	3-2
3-29. Calibrating Voltmeters and Attenuators . . . . .	3-3

Section	Page
IV THEORY OF OPERATION . . . . .	4-1
4-1. Introduction . . . . .	4-1
4-5. General Description . . . . .	4-1
4-14. Outstanding Features . . . . .	4-1
4-17. Detailed Description . . . . .	4-1
4-19. Preamplifier . . . . .	4-2
4-22. Shaper Amplifier . . . . .	4-2
4-24. Driver Amplifier . . . . .	4-2
4-26. Power Amplifier . . . . .	4-2
4-30. Load Protection at Turn-On and Off . . . . .	4-2
4-32. Power Supply . . . . .	4-2
4-42. Shield and Ground Connections . . . . .	4-3

Section	Page
V MAINTENANCE . . . . .	5-1
5-1. Introduction . . . . .	5-1
5-3. Test Equipment . . . . .	5-1
5-5. Performance Checks . . . . .	5-1
5-7. Front Panel Zero . . . . .	5-2
5-9. Overload Protection Check . . . . .	5-2
5-12. DC Gain Check . . . . .	5-3
5-14. 1000 DC Gain Check . . . . .	5-3
5-16. 100 DC Gain Check . . . . .	5-3
5-18. 10 DC Gain Check . . . . .	5-3
5-20. AC Gain Accuracy Check . . . . .	5-3
5-22. Alternate Method for Gain Accuracy 10 kHz to 100 kHz, 10 Gain Range . . . . .	5-5
5-26. Phase Angle of Output Check . . . . .	5-6
5-32. Output Impedance Check . . . . .	5-7
5-34. Input Impedance Check . . . . .	5-8
5-36. Noise Check . . . . .	5-8
5-38. Maximum Output Voltage and Current Check . . . . .	5-9
5-40. Square Wave Rise Time . . . . .	5-9
5-42. Distortion Check . . . . .	5-9
5-44. Adjustment and Calibration Procedures . . . . .	5-11
5-46. Cover Removal . . . . .	5-11
5-48. Power Supply Voltage Adjustment . . . . .	5-12
5-50. Overload Protection Adjustment . . . . .	5-12
5-51. Internal Zero Adjustment . . . . .	5-13
5-53. AC Calibration Procedure . . . . .	5-13
5-55. Troubleshooting . . . . .	5-14
5-56. Introduction . . . . .	5-14
5-60. Servicing Etched Circuit Boards . . . . .	5-14
5-63. Troubleshooting Tree . . . . .	5-15

Section	Page
VI SCHEMATICS . . . . .	6-1
6-1. Introduction . . . . .	6-1
6-3. Schematic Diagrams . . . . .	6-1
6-6. Component Location Diagrams . . . . .	6-1

Section	Page
VII REPLACEABLE PARTS . . . . .	7-1
7-1. Introduction . . . . .	7-1
7-4. Ordering Information . . . . .	7-1
7-6. Non-Listed Parts . . . . .	7-1

Appendix
A CODE LIST OF MANUFACTURERS
B SALES AND SERVICE OFFICES
C MANUAL BACKDATING CHANGES

LIST OF TABLES

Number	Page
1-1. Specifications . . . . .	1-1
1-2. Equipment Supplied . . . . .	1-3
3-1. Model 453A Capacitive Drive . . . . .	3-2
3-2. Combined Accuracy of -hp- Model 463A and Holt 6A Transfer Voltmeter . . . . .	3-2
3-3. -hp- Models 463A, 3440A/3445A Combined Accuracy . . . . .	3-3
3-4. -hp- Models 463A and 741B Combined Accuracy . . . . .	3-3

Number	Page
5-1. Required Test Equipment . . . . .	5-0
5-2. Parts and Diagram for 10:1 Output Divider . . . . .	5-6
5-3. Distortion Check . . . . .	5-10
5-4. AC Gain Accuracy Adjustments . . . . .	5-14
6-1. DC Voltage Chart on Pins of PC Board . . . . .	
7-1. Replaceable Parts . . . . .	7-2

## LIST OF ILLUSTRATIONS

Number		Page	Number		Page
1-1.	Model 463A Precision AC Amplifier . . .	1-1	5-7.	Distortion Check on the 10 GAIN range .	5-10
3-1.	Front and Rear Panel Controls. . . . .	3-0	5-7a.	DC Linearity Check (10 GAIN Range) . .	5-11
3-2.	Low Level Precision Thermal Transfer Measurements . . . . .	3-3	5-8.	Model 463A Adjustment Location . . . .	5-12
4-1.	463A Block Diagram . . . . .	4-0	5-9.	Troubleshooting Tree . . . . .	5-14
4-2.	Power Supply Block Diagram and the External Load Protective Circuit. . . .	4-0	6-1.	Chassis and A6S1 Component Location .	6-2
5-1.	Overload Protection Check . . . . .	5-2	6-2.	A1 Component Location . . . . .	6-3
5-2.	DC Gain Accuracy Check . . . . .	5-3	6-3.	Preamplifier and Shaper Schematic . .	6-3
5-3.	AC Gain Accuracy Check . . . . .	5-4	6-4.	S1 Contact Location . . . . .	6-4
5-4.	AC Accuracy Check with 1 kHz as Reference . . . . .	5-5	6-5.	A2 Component Location . . . . .	6-5/6-6
5-5.	Output Impedance Check . . . . .	5-7	6-6.	A3 Component Location . . . . .	6-5/6-6
5-6.	AC and DC Input Impedance Check . . .	5-8	6-7.	Driver and Power Amplifier Schematic . . . . .	6-5/6-6
			6-8.	A4 Component Location . . . . .	6-7/6-8
			6-9.	Power Supply Schematic . . . . .	6-7/6-8

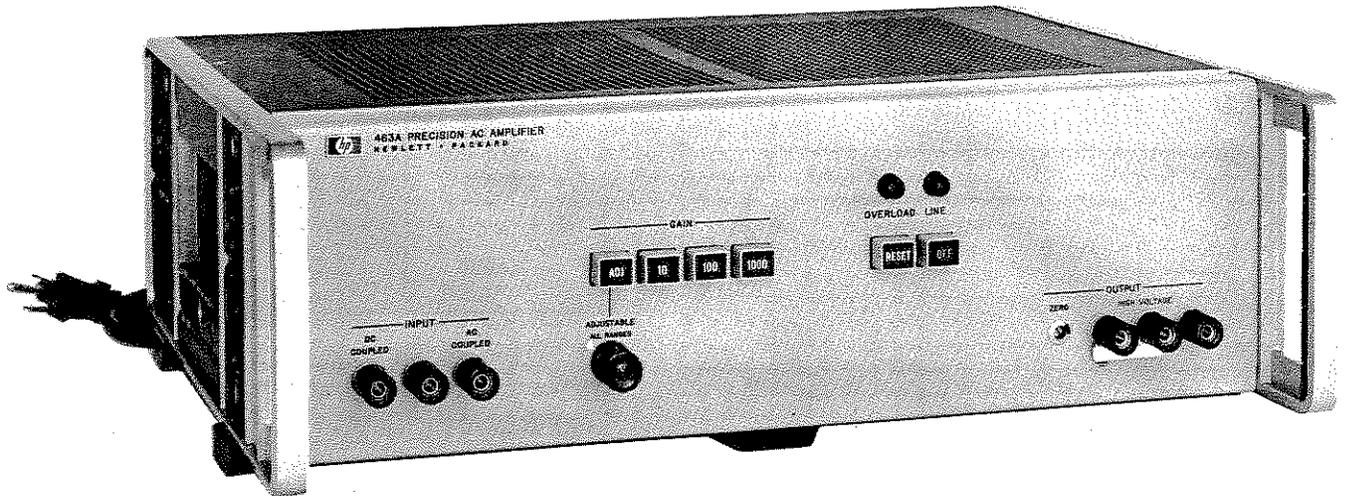


Figure 1-1. Model 463A Precision AC Amplifier

Table 1-1. Specifications

**FIXED GAIN (DC COUPLED)**

**X10 Range**

Accuracy: DC to 10 Hz, <math>\lt; \pm 0.3\%</math>  
 10 Hz to 10 kHz, <math>\lt; \pm 0.01\%</math>  
 10 kHz to 100 kHz, <math>\lt; \pm 0.1\%</math>

Distortion (100 V Output, Full Load):  
 10 Hz to 10 kHz, <math>\lt; 0.01\%</math>  
 10 kHz to 100 kHz, <math>\lt; 0.1\%</math>

**X100 Range**

Accuracy: DC to 10 Hz, <math>\lt; \pm 3\%</math>  
 10 Hz to 20 kHz, <math>\lt; \pm 0.1\%</math>  
 20 kHz to 100 kHz, <math>\lt; \pm 1.0\%</math>

Distortion (100 V Output, Full Load)  
 10 Hz to 10 kHz, <math>\lt; 0.03\%</math>  
 10 kHz to 100 kHz, <math>\lt; 0.1\%</math>

**X1000 Range**

Accuracy: DC to 10 Hz, <math>\lt; \pm 30\%</math>  
 10 Hz to 20 kHz, <math>\lt; \pm 0.3\%</math>  
 20 kHz to 100 kHz, <math>\lt; \pm 3.0\%</math>

Distortion (100 V Output, Full Load):  
 10 Hz to 10 kHz, <math>\lt; 0.1\%</math>  
 10 kHz to 100 kHz, <math>\lt; 0.5\%</math>

**FIXED GAIN (AC COUPLED)**

Identical to dc coupled except coupling capacitor causes a 0.01% error (25 Hz) to a 3-dB error (0.35 Hz).

**ADJUSTABLE GAIN (AC OR DC COUPLED)**

Gain may be adjusted from 0 to 100% of the fixed gain range. Distortion characteristics identical with fixed gain range.

**TEMPERATURE COEFFICIENT (FIXED GAIN)**

Frequency	X10	GAIN X100	X1000
10 Hz to 10 kHz	10 ppm/°C**	50 ppm/°C**	100 ppm/°C**
10 kHz to 100 kHz	50 ppm/°C**	250 ppm/°C**	500 ppm/°C**

\* Includes temperature coefficient and short term stability

\*\* Deviation from calibration temperature

**INPUT CHARACTERISTICS**

Input Impedance:

Fixed gain: 1 MΩ (±5%), <math>\lt; 35\text{ pF}</math>

Adjustable gain: 50 kΩ, <math>\lt; 200\text{ pF}</math>

Maximum Input Voltage: protected to ±150 volts.  
 AC Coupling capacitor ±500 volts peak.

Noise (rms referred to input):

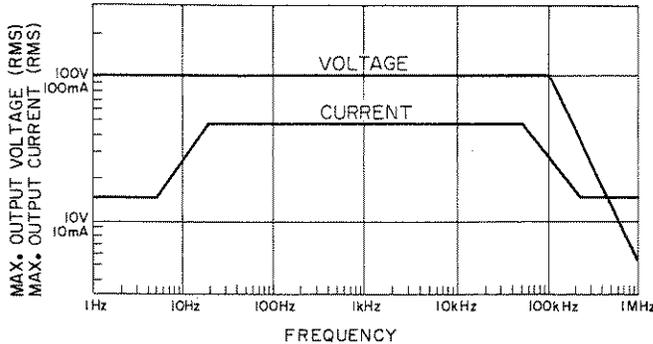
GAIN RANGE	<math>\lt; 1\text{ k SOURCE}</math>	> 1 k SOURCE*
X10	1.5 mV	1.5 mV
X100	150 μV	300 μV
X1000	50 μV	200 μV

\* with input shielded

Table 1-1. Specifications (Cont'd)

OUTPUT CHARACTERISTICS

Maximum Output: DC: 100 volts, 20 mA  
AC: refer to curve below



LOAD CAPABILITY

Maximum Output Power: 5 watts continuous

Current Limit (Nominal): < 20 Hz, 30 mA peak  
> 20 Hz, 90 mA peak

Minimum Resistance, All Ranges: 100 Ω

Maximum Capacitance: capacitance drive capability of 463A is increased by adding a resistor in series with the output as indicated below.

GAIN RANGE	SERIES RESISTANCE	MAXIMUM CAPACITANCE
X10	0	300 pF
	600 Ω	No Limit
X100	0	1000 pF
	50 Ω	No Limit
X1000	0	5000 pF
	50 Ω	No Limit

OUTPUT IMPEDANCE

GAIN RANGE	OUTPUT IMPEDANCE (OHMS)	
	DC to 10 kHz	10 kHz to 100 kHz
X10	.05	.5
X100	.2	2.
X1000	2.	20.

SQUARE WAVE RESPONSE (FIXED GAIN)

X10: 40 V p-p, 0.5 μs rise time  
X100: 80 V p-p, 1 μs rise time  
X1000: 200 V p-p, 2 μs rise time

PHASE SHIFT (FIXED GAIN) IN DEGREES

GAIN RANGE	PHASE SHIFT (FIXED GAIN) IN DEGREES	
	< 1 kHz	> 1 kHz
X10	.1	.1 + 7 ( $\frac{f}{10^5}$ )
X100	.2	.2 + 20 ( $\frac{f}{10^5}$ )
X1000	1.0	1 + 50 ( $\frac{f}{10^5}$ )

LONG TERM STABILITY (FIXED GAIN)

FREQUENCY	X10	GAIN X100	X1000
10 Hz to 10 kHz	0.003%/mo or 0.01%/yr	0.03%/mo or 0.1%/yr	0.3%/mo or 1%/yr
10 kHz to 100 kHz	0.03%/mo	0.3%/mo	3%/mo

DC ZERO STABILITY

Short Term: (23°C ± 1°C)	
GAIN Range	V/hr (output)
X10	0.05
X100	0.5
X1000	5.0

Temperature Coefficient:

DC Coupled < 10 kΩ source: ±400 μV/°C referred to input.

DC Coupled > 10 kΩ source or AC Coupled: ±4 mV/°C referred to input.

GENERAL

Input/Output Terminals:

Front Panel: 3/4" spaced banana terminals for input, output, and chassis.

Rear Panel: BNC terminals for input and output. Recessed three-terminal power line connector. Amplifier common may be floated 500 V dc above chassis.

Temperature Range: 0 to +50°C.

Power: 115 or 230 V ±10%, 50 to 1000 Hz, approximately 50 W at full load.

## SECTION I

### GENERAL INFORMATION

#### 1-1. INTRODUCTION.

1-2. This section contains general information concerning the -hp- Model 463A Precision AC Amplifier (Figure 1-1). Included are its specifications (Table 1-1), general description, outstanding features, accessory equipment supplied, instrument identification and some of the major applications.

#### 1-3. DESCRIPTION.

1-4. The solid-state -hp- Model 463A Precision AC Amplifier was primarily designed as a wide band ac amplifier with a bandwidth from 10 Hz to 100 kHz. Since it is directly coupled throughout the amplifier, this 463A can also be used as a dc amplifier with different accuracy specifications. The output of the 463A is rated at 5 watts continuous and is protected for a nominal overload, indicated by a front panel OVERLOAD light. It has an output capability of 100 V rms with an output impedance of 50 m $\Omega$  to 20  $\Omega$  depending on the gain and frequency selection. This Precision Amplifier has a direct coupled input and an ac, capacitive coupled input, each with a high input impedance. The input is protected up to  $\pm 150$  V and the common terminal can be floated 500 V above chassis.

1-5. The -hp- Model 463A Precision Amplifier has three ranges of voltage amplification: 10, 100 and 1000. The output of all three of these ranges may be adjusted from zero to a maximum indicated on the depressed fixed gain button. This is accomplished by also depressing the ADJ button of the switch and positioning the ADJUSTABLE ALL RANGES control.

1-6. This Precision Amplifier has a gain accuracy of 0.01% from 10 Hz to 10 kHz on the X10 range. The accuracy decreases with higher gain and at the highest and lowest frequencies (see Table 1-1 for specifications). The low distortion, low noise and long-term stability make this instrument a desirable multi-purpose laboratory amplifier.

#### 1-7. APPLICATIONS.

1-8. The features of this amplifier listed under specifications and described in this section make it applicable to the following uses:

- a. Precision ac wideband voltage amplification.
- b. Isolation amplifier for Thermocouple transfer measurements.
- c. Preamplifier for low level precision voltage measurements.
- d. Amplify oscillator outputs.
- e. Sensitive bridge measurements.
- f. Precision voltmeter calibration systems.
- g. Attenuator calibration (as much as 110 dB). (See Section III for detailed applications).

#### 1-9. ACCESSORY EQUIPMENT SUPPLIED.

1-10. The additional equipment supplied with this instrument are listed in Table 1-2.

Table 1-2. Equipment Supplied

-hp- Part No.	Description
8830-0032	Extractor-PC Board (included in rack mount kit)
00463-84401	Kit, Rack Mount
2110-0019	Fuse, 0.4A S.B. (230 V operation)
8120-0078	Power Cord, detachable
00463-90001	Manual, Operating and Service

#### 1-11. INSTRUMENT IDENTIFICATION.

1-12. Hewlett-Packard uses a two-section, eight-digit serial number to identify instruments (e.g., 000-00000). The serial number is located on the rear panel of the instrument. The first three digits are the serial prefix, and the last five digits refer to a specific instrument. If the first three digits of your instrument serial number do not appear on the title page of this manual, there are differences between the manual and your instrument which are described in change sheets included with the manual. The "Manual Changes" loose leaf change sheet contains errata and changes in instruments with a larger serial prefix or serial number than that on the title page of the manual. If the change sheet is missing, the information can be supplied by your nearest Hewlett-Packard field office. The backdating sheet for previous serial prefixes is located in the appendix of the manual.

## SECTION II INSTALLATION

### 2-1. INTRODUCTION.

2-2. This section contains information and instructions necessary for the installation and shipping of the -hp- Model 463A Precision Amplifier. Included are initial inspection procedures, power and grounding requirements, installation information and instructions for repackaging for shipment.

### 2-3. INITIAL INSPECTION.

2-4. This instrument was carefully inspected both mechanically and electrically before shipment. It should be physically free of marks or scratches and in perfect electrical order upon receipt. To confirm this, the instrument should be inspected for physical damage in transit. If the instrument was damaged in transit, file a claim with the carrier. Test the electrical performance of the instrument using the procedure outlined in Paragraph 5-5. If there is damage or deficiency, see the warranty on the inside front cover of this manual.

### 2-5. POWER REQUIREMENTS.

2-6. The Model 463A can be operated from any source of 115 or 230 V ( $\pm 10\%$ ), at 50 to 1000 Hz. With the instrument disconnected from the ac power source, move the slide switch (located on the rear panel) until the desired line voltage appears on the switch. Power dissipation is approximately 50 W at full load.

### 2-7. GROUNDING REQUIREMENTS.

2-8. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. This instrument is equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable three-prong connector is the ground wire.

2-9. To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to ground.

### 2-10. INSTALLATION.

2-11. The Model 463A is fully transistorized; therefore, no special cooling is required. However, the instrument should not be operated where the ambient temperature exceeds  $50^{\circ}\text{C}$  ( $122^{\circ}\text{F}$ ) or the relative humidity exceeds 95%.

### 2-12. BENCH MOUNTING.

2-13. The Model 463A is shipped with plastic feet and tilt stand in place, ready for use as a bench instrument.

### 2-14. RACK MOUNTING.

2-15. The Model 463A may be rack mounted by using the Rack Mount Kit (-hp- Part No. 00463-84401). Instructions for the conversion are included with the kit. The bottom cover of the 463A must be removed before removing the plastic feet. Lay the instrument on its top and remove two screws from the bottom cover. Slide cover toward the rear of the instrument and lift. To remove feet, depress button and move foot toward center of instrument and lift. Replace bottom cover by reversing the removal procedure. When mounted in a rack using the rack mount kit, additional support at the rear of the instrument should be provided if vibration or similar stress is likely. The rack mount is an EIA standard width of 19 inches.

### 2-16. REPACKAGING FOR SHIPMENT.

2-17. The following paragraphs contain a general guide for repackaging of the instrument for shipment. Refer to Paragraph 2-19 if the original container is to be used; 2-20 if it is not. If you have any questions, contact your local -hp- Sales and Service Office. (See Appendix B for office locations.)

2-18. If the instrument is to be shipped to Hewlett-Packard for service or repair, attach a tag to the instrument identifying the owner and indicating the service or repair to be accomplished; include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model number, serial number, and serial number prefix.

2-19. If original container is to be used, proceed as follows:

- a. Place instrument in original container if available. If original container is not available, one can be purchased from your nearest -hp- Sales and Service Office.
- b. Ensure that container is well sealed with strong tape or metal bands.

2-20. If original container is not to be used, proceed as follows:

- a. Wrap instrument in heavy paper or plastic before placing in an inner container.
- b. Place packing material around all sides of instrument and protect panel face with cardboard strips.
- c. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.
- d. Mark shipping container with "DELICATE INSTRUMENT," "FRAGILE," etc.

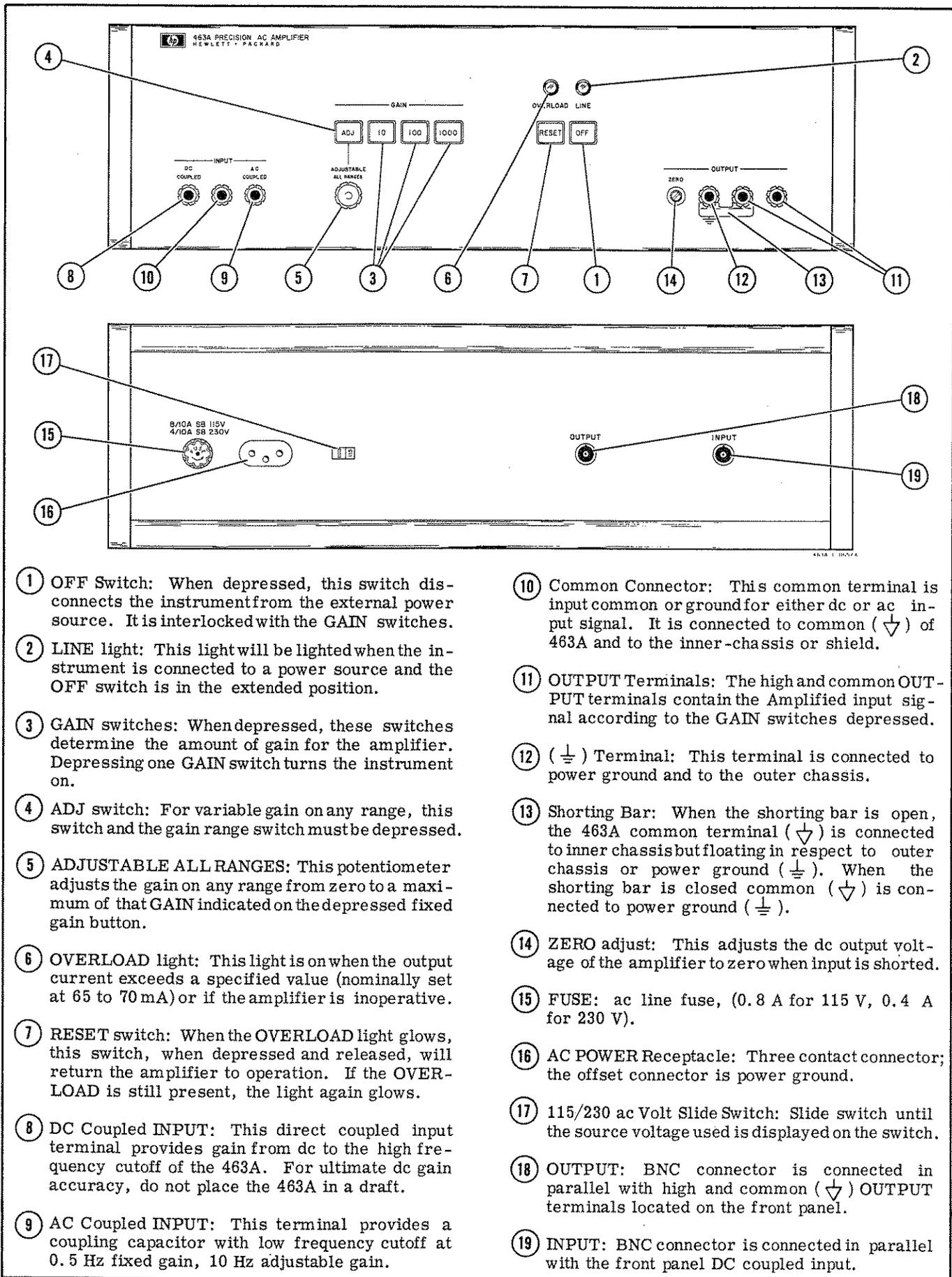


Figure 3-1. Front and Rear Panel Controls

## SECTION III

### OPERATING INSTRUCTIONS

#### 3-1. INTRODUCTION.

3-2. This section contains instructions for the operation of the -hp- Model 463A Precision Amplifier. It includes Figure 3-1. Front and Rear Panel Controls, Indicators and Connectors, a Turn On procedure, output zero adjustment procedure and procedures for specific applications.

#### 3-3. DESCRIPTION OF CONTROLS.

3-4. Figure 3-1 shows the front and rear panels of the 463A with the description and function of the controls, indicators and connectors. The components on the front and rear panel are numerically keyed to the description.

#### 3-5. OPERATIONAL INSTRUCTIONS.

##### 3-6. TURN ON PROCEDURE.

3-7. Before connecting the 463A to a power source, position the 115 V/230 V slide switch for an indication of the source voltage to be used.



IF THE 230 V AC SOURCE IS USED, REPLACE THE 0.8 A FUSE WITH THE 0.4 A FUSE ENCLOSED WITH THE INSTRUMENT.

- a. Connect the detachable power cable to the ac power receptacle, located on the rear panel, and to the power source.
- b. If the OFF button is depressed, it can be released by pressing the X10, X100 or X1000 GAIN button.

#### NOTE

The three GAIN buttons and the OFF button are interlocked so that only one is depressed at a time. The 463A is turned on when the OFF button is in the extended position.

- c. To insure maximum stabilization, allow instrument to warm up for two hours with shield covers in place.

#### 3-8. FRONT PANEL ZERO ADJUSTMENT.

3-9. Zero the 463A, using the following procedure, each time the GAIN range is changed and before using the instrument.

- a. Short the direct coupled INPUT to the common terminals.
- b. Connect the OUTPUT of the 463A to the input of a dc voltmeter.
- c. Place the dc voltmeter on the range to be used.
- d. Adjust front panel ZERO screwdriver adjust to zero  $\pm$  the tolerances listed below:

10 GAIN range . . .  $\pm$  1 mV

100 GAIN range . . .  $\pm$  10 mV

1000 GAIN range . . .  $\pm$  200 mV

#### 3-10. SELECTION OF INPUT TERMINAL.

3-11. The DC Coupled INPUT terminal must be used for a dc voltage or a frequency of 1 Hz or less. When used as a dc amplifier for maximum accuracy and minimum dc zero drift, the 463A must have covers in place and not be in a draft. AC Coupled INPUT with fixed gain is (-3 dB at 0.5 Hz); adjustable gain is -3 dB at 10 Hz. The ac coupling capacitor will block dc voltage, if this is desired, and the capacitor is protected up to an input of  $\pm$  500 volts peak. The dc coupled input is protected up to  $\pm$  150 volts. The Common terminal may be floated 500 Vdc above chassis with the output grounding strap open.

#### 3-12. SELECTION OF GAIN.

3-13. The gain of the Amplifier may be 10, 100, 1000 fixed gain or variable gain up to a maximum of any of these fixed ranges. If the OFF button is depressed, the amplifier will be turned on by depressing the desired fixed gain button. If a gain other than the fixed gain is desired, the ADJ button must be pressed in addition to the desired fixed gain button. The desirable output voltage is obtained by adjusting the variable gain control. This is a ten-turn potentiometer with high resolution.

#### 3-14. OPERATION OF RESET BUTTON.

3-15. When the OVERLOAD light glows, it indicates an external current overload or a defect in the Amplifier causing an internal current overload. Under these circumstances, depress the RESET button and hold depressed for approximately one (1) second. If the OVERLOAD light glows again when RESET is released, disconnect the load and depress RESET again.

#### 3-16. CAPACITIVE DRIVE CAPABILITY.

3-17. The capacitive drive capability of the 463A is increased by adding a resistor in series with the output as indicated on following page.

Table 3-1. Model 463A Capacitive Drive

RANGE	SERIES RESISTANCE	MAXIMUM CAPACITANCE
X10	0	300 pF
X10	600 $\Omega$	No limit
X100	0	1000 pF
X100	50 $\Omega$	No limit
X1000	0	5000 pF
X1000	50 $\Omega$	No limit

**3-18. APPLICATIONS.**

3-19. The following paragraphs list some of the applications for the 463A. These include making low level precision measurements, producing high voltage from solid-state oscillators and function generators, combining the 463A with digital and differential voltmeters to measure low level ac signals, and using the 463A to enhance calibration systems for voltmeters and attenuators.

**3-20. LOW LEVEL PRECISION MEASUREMENTS.**

3-21. Because of the low distortion, good gain accuracy and high output levels, the 463A Amplifier enhances the specifications of many existing instruments. In the paragraphs following, some of the combined specifications are indicated for the 463A used with available instruments. Probably one of the most interesting applications is using the 463A with commercially available thermal transfer voltmeters or with a thermocouple utilizing the circuitry indicated in Figure 3-2 where the input to the 463A would be the signal to be measured. The thermal transfer method is one of the most accurate ac measuring devices available. The problem associated with this method is the input impedance which is approximately 200  $\Omega$  per volt. This low input impedance, of course, causes errors because of loading the circuit involved. By utilizing the 463A as a preamplifier or isolation amplifier with the thermal transfer voltmeter, a high input impedance can be achieved. Indicated in Table 3-2 are accuracies that can be achieved in ac to dc transfer measurements by using the 463A with commercially available transfer voltmeters or NBS calibrated thermocouples.

Table 3-2. Combined Accuracy of -hp- Model 463A and Holt 6A Transfer Voltmeter

463A Gain	Measurement Level	$\pm$ % Reading* (ac-dc difference) Frequency				
		10 Hz	10 kHz	20 kHz	50 kHz	100 kHz
X10	10 V	0.02	0.12	0.12	0.30	
X10	1 V	0.015	0.11	0.11	0.15	
X10	100 mV	0.026	0.12	0.12	0.16	
X100	10 mV	0.12	0.12	1.0	1.1	
X1000	1 mV	0.43	0.43	3.1	3.2	

\* Noise of the 463A is added at lower levels.

**3-22. HIGH VOLTAGE OSCILLATORS AND FUNCTION GENERATORS.**

3-23. Since most solid-state oscillators do not have high-level output signals, the 463A can be used as a post-amplifier. Because of its low distortion, using it in this fashion introduces very little distortion to the high voltage output signal. Since the 463A Precision Amplifier is direct coupled and has a low frequency response, it can be used with a low frequency oscillator or function generator. For instance, used with the 203A, an output of 100 V rms with less than 0.07% distortion can be achieved from 0.005 Hz to 10 kHz. The 203A may also be used with two 463A's to generate a 200 volt rms balanced output. By connecting one 463A to the reference phase sine wave output and the other 463A to the variable phase sine wave output, set at 180 degrees, the amplitudes can be adjusted to produce a balanced 200 volt rms signal from the two outputs of the 463A having the output grounds connected together.

3-24. The OUTPUT of the 3300A Function Generator can be connected to the DC (direct coupled) INPUT of the 463A Precision Amplifier to form a high voltage, low frequency function generator. The combined specifications are as follows:

Frequency Range	0.01 Hz to 100 kHz
OUTPUT	100 V rms sine wave 280 V p-p triangular wave 40 V p-p square wave with < 0.75 $\mu$ s risetime

3-25. These high voltage, low frequency, low distortion signals may be used to provide power for servo loops, for medical experiments and for geophysical measurements. The sensitivity requirement on the null detector is decreased by having up to 100 volts rms available.

**3-26. LOW LEVEL AC MEASUREMENTS.**

3-27. The Model 463A Precision Amplifier may be used to amplify a low level ac signal so that it may be measured by a 3440 Digital Voltmeter with a 3445A

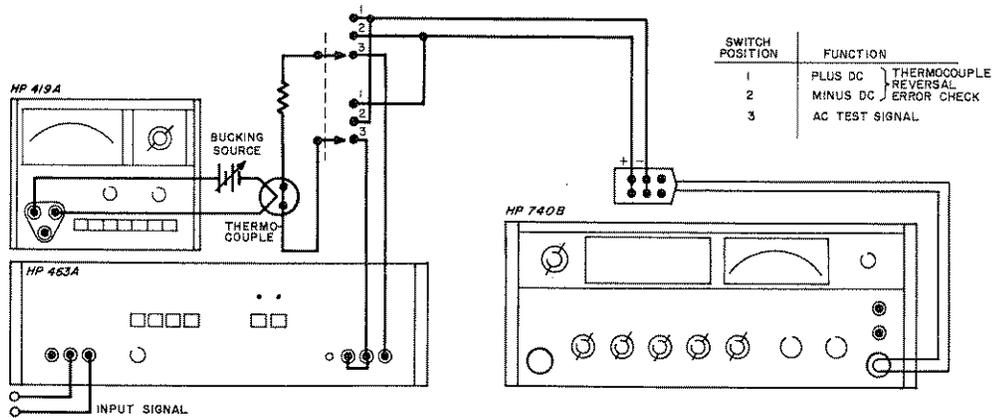


Figure 3-2. Low Level Precision Thermal Transfer Measurements

Table 3-3. -hp- Models 463A, 3440A/3445A Combined Accuracy

463A GAIN	3440A F.S. SENSITIVITY*	Combined Accuracy ± (% Reading + % Full Scale + 2 Counts)				
		50 Hz	10 kHz	20 kHz	50 kHz	100 kHz
X10	1 V	0.11	0.2	0.1 + 0.1	linearly de-rate (% of full scale) from 50 kHz to 100 kHz	$\left\{ \begin{array}{l} 0.1 + 0.3 \\ 1.0 + 0.3 \\ 3.0 + 0.3 \end{array} \right.$
X100	100 mV	0.2	0.2	1.0 + 0.1		
X1000	10 mV	0.4	0.4	3.0 + 0.1		

\* With the 3445A on 10 Volt Range

AC-DC Range Unit. The Combined Accuracy Specifications are as shown above.

3-28. The Model 463A Precision Amplifier may be used to amplify a low level signal so that it can be measured by the Model 741B. Table 3-4 shows the Combined Accuracy Specifications for the two instruments.

3-29. CALIBRATING VOLTMETERS AND ATTENUATORS.

3-30. The 463A can be used to increase the range of calibration systems for both voltmeters and attenuators. When used as a post-amplifier with the E02-738BR Voltmeter Calibration System, the output of the 652A oscillator can be increased up to 100 volts

rms from 10 Hz to 100 kHz. Attenuators may be calibrated for as much as 110 dB by using both the input and the output of the 463A Amplifier. Since some measuring instruments are degraded in accuracy at very low levels, it is more desirable to accurately amplify the unknown and measure it at a higher level. The accuracy at the input of the 463A will depend on the accuracy of the measuring instrument, at the higher level, plus the accuracy of the amplifier. Noise and distortion introduced in the amplifier also affect accuracy. The 463A is advantageous in this application because of its low noise and distortion and its precision gain accuracy over a broad frequency band.

3-31. As can be seen from these examples, the 463A can be used in a variety of applications from the most critical in accuracy and distortion to the general purpose high gain applications.

Table 3-4. -hp- Models 463A and 741B Combined Accuracy

463A GAIN	741B F.S. SENSITIVITY*	Combined Accuracy** ± (% Reading + 0.01% Full Scale)									
		20 Hz	30 Hz	50 Hz	100 Hz	400 Hz	5 kHz	10 kHz	20 kHz	50 kHz	100 kHz
X10		0.21	0.16	0.11	0.05	0.03	0.05	0.2	0.2	0.3	
X100		0.3	0.25	0.2	0.14	0.12	0.14	0.2	1.1	1.2	
X1000		0.5	0.45	0.4	0.34	0.32	0.34	0.4	3.1	3.2	

\* With 741B on 1 V range

\*\* 463A noise contributes error as: % error =  $25 \left( \frac{en}{es} \right)^2$  where  $\frac{en}{es}$  is noise to signal ratio

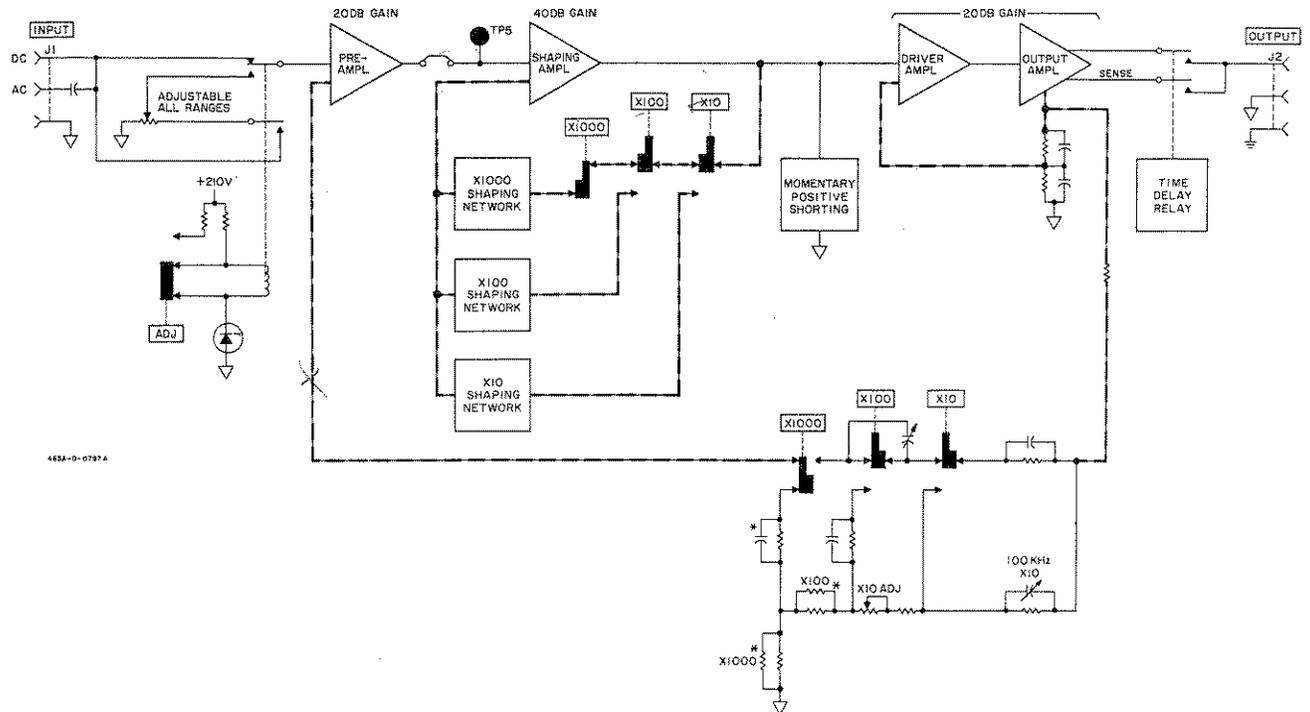


Figure 4-1. 463A Block Diagram

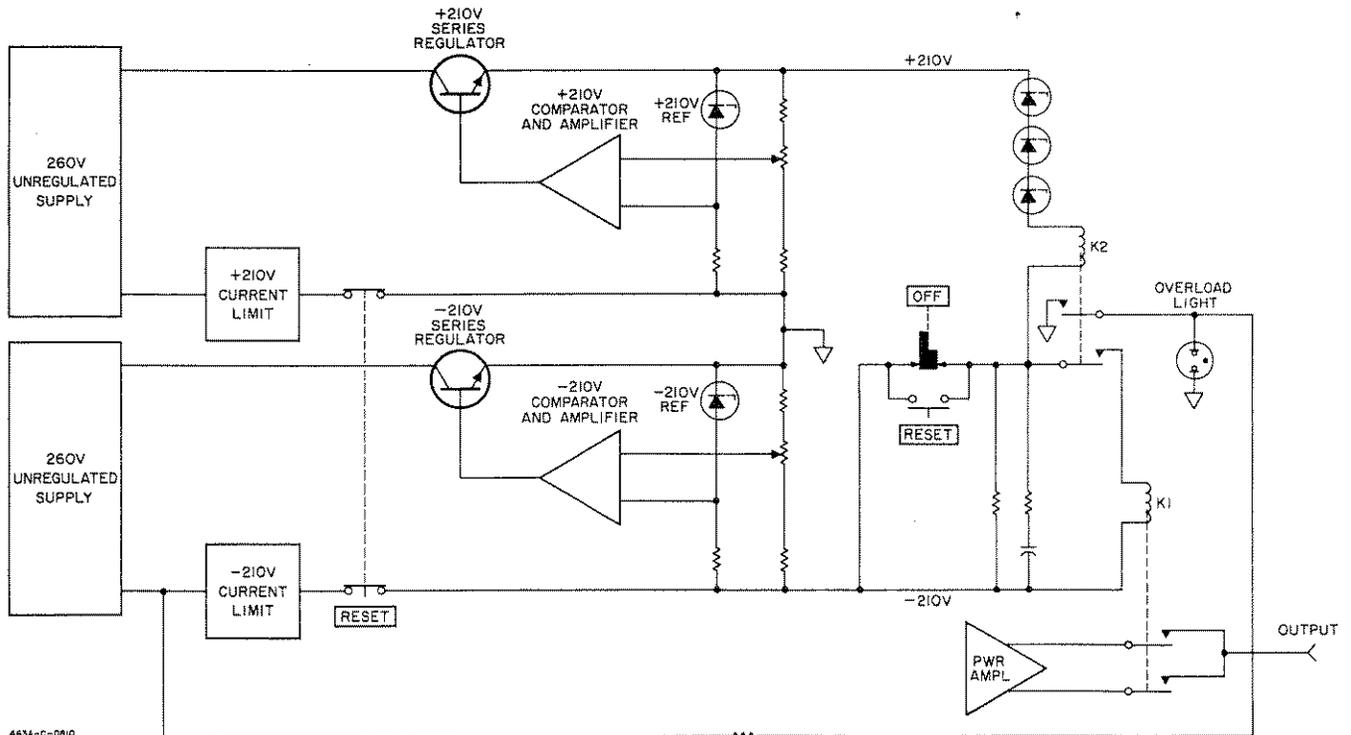


Figure 4-2. Power Supply Block Diagram and the External Load Protective Circuit

## SECTION IV

### THEORY OF OPERATION

#### 4-1. INTRODUCTION.

4-2. Section IV contains information relating to the theory of operation of the Model 463A. Block Diagrams are given in Figures 4-1 and 4-2 to which the general description is referenced. The detailed description is referenced to Figures 6-3 and 6-7, Amplifier Schematics, or Figure 6-9, Power Supply Schematic. The general description is given first followed by the detailed description.

4-3. The Model 463A is usable for amplifying frequencies from dc to 100 kHz. The accuracy and frequency response for a gain of 10 is greater than  $\pm 0.01\%$  for frequencies from 10 Hz to 10 kHz. The distortion for this frequency range and gain is less than -80 dB or 0.01%. The 463A has excellent ac gain stability making it reliable for long term measurements.

4-4. The amplifier provides three fixed gain ranges, 10, 100, 1000, with an adjustable control for all ranges. The front panel ZERO control adjusts the output to zero with the dc input shorted.

#### 4-5. GENERAL DESCRIPTION.

4-6. The Model 463A has the following assemblies: Preamplifier and Shaping Amplifier (A1), Driver Amplifier (A2), Output Amplifier (A3), Power Supply and Current Limiting (A4) and the Switch Assembly (A6). These assemblies are interconnected by a main board assembly (A5).

4-7. The input signal is either sent directly to the preamplifier, through a capacitor to the preamplifier or, if the adjustable switch is depressed, it is sent to an adjustable gain potentiometer where a portion or all of the input signal can be sent to the preamplifier.

4-8. This input and the feedback signal from the output (attenuated according to the gain button depressed) are compared by the dual differential preamplifier. The exceptional gain accuracy and low distortion of the amplifier is dependent on this input differential preamplifier. The 20 dB differential amplifier actually is the summing junction of the overall feedback loop. This summing junction has very good common-mode rejection, low distortion characteristics and good dc characteristics as it is a direct-coupled amplifier.

4-9. Following the preamplifier is a 40 dB shaping amplifier. This section, in addition to giving 40 dB of forward gain, changes its high frequency gain characteristics on the different gain ranges in order to maintain a wide bandwidth on all ranges.

4-10. The next stage is a 20 dB output power amplifier. Primarily this amplifier was designed for the

high voltage swing necessary for 100 V rms output. This was accomplished by stacking five high voltage transistors so they share the swing in output voltage. The push-pull emitter follower output, using six stacked transistors, has high current capabilities with low distortion.

4-11. Both the shaping amplifier and the output amplifier are feedback amplifiers within themselves. This internal feedback gives the high gain accuracy and the low distortion characteristics of each stage. The overall feedback loop of the amplifier is closed through a precision feedback attenuator. This attenuator is especially designed for good high frequency characteristics, low temperature coefficient and good long term stability. This attenuator in the overall feedback loop determines the overall gain of the 463A amplifier.

4-12. The 463A always maintains a forward loop gain of 80 dB while the feedback varies from -20 dB to -60 dB, depending on gain range selection. Thus, the highest gain range has the lowest feedback or loop gain of the amplifier. For this reason, the best characteristics are obtained on the low gain range where the highest loop gain is employed.

4-13. The adjustable gain of the amplifier is accomplished by simply switching in a multiturn high resolution potentiometer. The input to the amplifier is then taken from the tap of this potentiometer.

#### 4-14. OUTSTANDING FEATURES.

4-15. The 463A is protected for an input voltage of  $\pm 150$  volts. The common terminal may be floated  $\pm 500$  volts above chassis ground. The gain switching device provides for a momentary shorting to ground during change of gain range which prevents an erratic output at this time.

4-16. Two major features were added to the basic amplifier to provide protection to both the amplifier itself and external equipment used with the amplifier. One is the time delay circuitry at the output terminals. This circuitry prevents the output signal from appearing at the output terminals until the power supplies are stabilized at turn-on and overload resets of the instrument. Also provided is the current limit circuitry shown in the power supply diagram. These current limits are set to open the power supplies in the event too much current is drawn at the output terminals or if an internal short within the amplifier occurs; thus, protection is provided at the output terminals and within the amplifier itself.

#### 4-17. DETAILED DESCRIPTION.

4-18. Two inputs are provided on the front panel; a dc coupled input and an ac capacitive coupled in-

put; both use the same common terminal. These inputs are connected directly to the preamplifier through the nonenergized contacts of A5K1 or they are connected through the energized contacts to the adjustable gain potentiometer and the wiper arm is connected to the preamplifier. The input impedance changes with the adjustable gain. See Table 1-1 for specifications. The output on the front panel consists of three terminals with a grounding strap. When the grounding strap is open the circuit common or inner chassis ground is floating in respect to outer chassis or power line ground. When the grounding strap is closed, inner chassis is connected to outer chassis and power-line ground. Located on the rear panel are a dc coupled input and a floating output which are BNC connectors. Both are connected in parallel with the respective connectors on the front panel.

#### 4-19. PREAMPLIFIER.

4-20. The Amplifier input signal or a portion of it selected by the adjustable gain control is applied to a Darlington differential amplifier along with a feedback signal from the Amplifier's output. This differential amplifier is connected to another differential amplifier for minimizing errors due to junctions and variations in components.

4-21. The collector of A1Q1 is bootstrapped by A1CR4 and the emitter is bootstrapped by A1CR5 for high input impedance. A1R9 adjusts a DC zero output reading with open dc coupled input terminal while R2 front panel ZERO ADJ provides a zero output signal with the dc coupled input terminals shorted. A1R11 is an adjustment for common mode rejection of the input differential amplifier A1Q1-Q6, and A1R26 provides an adjustment for an internal zero at base of A1Q6 with the dc coupled input shorted. A1CR1, A1CR2 and A1R1 provide an input protective device. The single ended output of the preamplifier is taken from the collector of A1Q7.

#### 4-22. SHAPER AMPLIFIER.

4-23. The shaper differential amplifier A1Q9 and A1Q10 compares the output signal from the preamplifier and the signal from the shaper network, determined by the GAIN switch depressed. This output is applied to the base of A1Q11 and thence through A1Q12, 13 and 14, through the GAIN switches to the Driver Amplifier. A portion of each GAIN switch shorts the input of the Driver Amplifier to circuit ground during change of fixed GAIN. This prevents transients on the Amplifier output due to GAIN switching.

#### 4-24. DRIVER AMPLIFIER.

4-25. The output signal from the shaper amplifier and the feedback from the power amplifier is compared in the two stage differential amplifier A2Q1 through A2Q4. The potentiometer A2R6 adjusts the Amplifier OUTPUT to zero without an input to the base of A2Q1 (pin 18 of A5J2). The dc output from A2Q2 is made 175 volts more negative by A2CR1 through A2CR6 to provide for high voltage gain in the succeeding amplifier stage. The output of the differential amplifier is applied through A2Q5, emitter follower, to the voltage

amplifier A2Q6 through A2Q10. These high voltage transistors are stacked to divide the high voltage swing of the output which is rated, for a sine wave, at 280 volts peak-to-peak. The bias or voltage level for these stacked transistors are proportioned by a voltage divider A5R10 through A5R27.

#### 4-26. POWER AMPLIFIER.

4-27. The voltage amplifier outputs are interlinked to the Power Amplifier, which also uses stacked transistors (A3Q1 through A3Q6). This power amplifier is a push-pull emitter follower circuit used for high current capabilities with low distortion. A portion of the output of the emitter follower is fed back to the base of A2Q4 driver differential amplifier for stability of the output amplifier.

4-28. The overall feedback loop of the 463A amplifier is closed through a precision feedback attenuator. This precision attenuator is made up of four wire-wound resistors (A6S1R8 through A6S1R11) especially designed for good high frequency characteristics, low temperature coefficient and excellent long-term stability. These characteristics of the attenuator determine the overall gain characteristics of the 463A amplifier. Variable resistors and capacitors or factory selected values are located in the attenuator feedback path for each gain range. These are adjusted components for the extreme accuracy and frequency response of the 463A on each individual gain range.

4-29. The output of the power amplifier is connected to the front panel output terminals through the contact points of A3K1. The amplifier output is sensed at the front panel output terminals for low output impedance.

#### 4-30. LOAD PROTECTION AT TURN-ON AND OFF.

4-31. The external load, connected to the 463A is protected during turn-on and turn-off procedure from current surges and voltage transients. When relay A3K1 is de-energized, the relay contact points disconnect the output terminal from the amplifier. When the 463A is turned on or the reset switch is pressed, A3K1 is energized, instantly closing the circuit to the coil of A3K2 and preventing the OVERLOAD light from glowing. A3K2 does not energize for 400 ms or less due to the time constant for charging A5C1. At the end of this time, the relay is energized connecting the Amplifier to the output terminal. When the instrument is turned off, both relays de-energize instantaneously.

#### 4-32. POWER SUPPLY.

4-33. The Model 463A power supply consists of two identical sections. One section regulates the +210 volts and the other section regulates the -210 volts. Each section has an adjustable current limit control and a RESET switch (ganged in one switch).

4-34. The primary power can be used from a 115 volt or 230 volt ac source. The source slide switch connects the two primary coils in series for 115 volts and in parallel for the 230 volt source. The fuse, F1 inserted in the instrument when shipped is a 0.8 A

slow-blow used for 115 volts source. If the instrument is used from a 230 volt source, this fuse must be changed to 0.4 A slow-blow. L1 and L2 are used in the power input to suppress R. F. signals which are passed to ground through C1 and C2. When the primary power is connected to the instrument, the line light, connected through S1R17, glows.

#### 4-35. +210 V AND -210 V REGULATOR CIRCUITS.

4-36. In this explanation the +210 V Regulator component designators will be used as both circuits are identical. Figure 4-2 shows the power supply block diagram and the external load protective circuits.

4-37. The differential amplifier (A4Q5 and the Darlington configuration A4Q6 and A4Q7) senses a minute variation in the +210 volt output through a voltage divider adjusted by A4R16. The output of the differential amplifier is applied to the base of A4Q4 which is a current source for the series regulator transistor A5Q1 (see Figure 6-9).

4-38. The -210 volt regulator has the series transistor between the most positive portion of the circuit and common ground. An additional voltage -211 volts, is taken from pin 13 of J4 for the overload light.

#### 4-39. CURRENT LIMIT CONTROL CIRCUITS.

4-40. When the external current load increases beyond a set value or if the internal circuit is defective and the power supply draws too much current, the power is disconnected automatically and the OVERLOAD light glows. Pressing and releasing the RESET switch restores the circuit to operation if the overload is removed.

4-41. Transistor A4Q1 senses the current drawn from the power supply and applies a potential to the base of the Darlington configuration A4Q2 and Q3. The more current drawn the more positive the voltage becomes at the base of A4Q1. The cutoff point is adjusted by A5R28. When A4Q1 turns on, A4Q2 and Q3 are turned off and the power supply is disconnected from the amplifier and the overload light glows. Because of the positive feedback due to R8 and CR1, the circuit remains in this condition until the RESET switch is pressed and released.

#### 4-42. SHIELD AND GROUND CONNECTIONS.

4-43. Circuit ground  $\nabla$  is connected to the inner chassis or shield. Power ground  $\perp$  is connected to the outer chassis or case of the instrument. The only way these two grounds are connected is by closing the grounding strap on the front panel OUTPUT terminals. If it is desirable to float the circuit output above power ground, this ground strap must be open.

**NOTES**

use banana type leads for test setup,  
coax cable is not suitable because it is  $50\Omega$

Table 5-1. Required Test Equipment

TEST EQUIPMENT	REQUIRED CHARACTERISTICS	SUGGESTED MODEL
Square Wave, triangular Function Generator	Frequency: .01 Hz to 10 kHz Output Voltage: 10 volts p-p	-hp- Model 3300A Function Generator with plug-in
Oscillator	Frequency: 10 Hz to 100 kHz Output Voltage: 6 volts rms open circuit	-hp- Model 651A/B Test Oscillator
DC Standard/AC Differential Voltmeter	Standard Output: 10 volts AC Differential Voltmeter Resolution: 10 $\mu$ V	-hp- Model 741B AC-DC Differential Voltmeter/DC Standard
DC Null Voltmeter	Resolution: 100 $\mu$ V Accuracy: $\pm 2\%$ of end scale $\pm 0.1 \mu$ V	-hp- Model 419A DC Null Voltmeter
DC Differential Voltmeter	$\Delta$ Voltmeter ranges: 1 V to 100 V Resolution: 5 digits Accuracy: 0.02%	-hp- Model 741B AC-DC Differential Voltmeter/DC Standard
AC Voltmeter	Battery operated Resolution: 0.001 volt rms	-hp- Model 403A/B AC Voltmeter
AC Inductive Divider	Accuracy: 10:1 ratio 10 ppm 100:1 ratio 100 ppm 1000:1 ratio 1000 ppm Input Voltage: 100 volts	ESI Model DT72A Dekatron
AC Metal Film Resistance Divider	Accuracy of metal film resistors Wattage: 1/2 W	Build from parts listed in Paragraph 5-23.
Distortion Analyzer	Frequency: 1 kHz to 100 kHz Distortion: -70 dB below fundamental	-hp- Model 333A/334A Distortion Analyzer
Amplifier/DC Source	Range: 10 GAIN Frequency: 10 Hz to 100 kHz	-hp- Model 467A Power Amplifier
Oscilloscope	Sensitivity Horizontal: 1 $\mu$ sec/cm 0.05 volt/cm to 20 volts/cm with 10:1 probe Frequency: 10 Hz to 100 Hz Dual Trace	-hp- Model 175A Oscilloscope with -hp- Model 1750B plug-in
Variable Line Transformer	115 Vac power source Voltage Output: 103.5 volts to 127.5 volts Power: 100 W  230 Vac power source Voltage Output: 206 volts to 256 volts Power: 100 W	Superior V116T  Superior V216