DP - 112

Instrumentation

A VERSATILE LABORATORY SERVO - AMPLIFIER

by

L. M. Johnson

Instrument Development Division

March 1955

E. I. du Pont de Nemours & Co.
Explosives Department — Atomic Energy Division
Technical Division — Savannah River Laboratory

UNCLASSIFIED

DP - 112

INSTRUMENTATION

A VERSATILE LABORATORY SERVO-AMPLIFIER

by

L. M. Johnson
Instrument Development Division

March 1955

E. I. du Pont de Nemours & Co.
Explosives Department - Atomic Energy Division
Technical Division - Savannah River Laboratory

Printed for
The United States Atomic Energy Commission
Contract AT(07-2)-1

UNCLASSIFIED

INTERNAL DISTRIBUTION

No. of Copies		
(5)	AEC, SROO	Augusta, Ga.
(1)	R. M. Evans - B. H. Mackey	Wilmington AED
(1)	J. E. Cole - M. H. Smith - J. B. Tinker	"
(1)	W. C. Kay - H. Worthington	"
(1)	D. F. Babcock	"
(1)	S. I. Winde	Engineering Department
(1)	J. D. Ellett	Savannah River Plant
(1)	W. P. Overbeck	"
(1)	T. C. Evans	"
(1)	J. D. Cist	"
(1)	H. J. Bowman - W. M. Sloan	"
(1)	W. S. Church	"
(1)	A. A. Johnson	"
(1)	P. S. Shane	"
(1)	M. M. Mann	"
(1)	R. H. Dietz	"
(1)	PRD File	"
(1)	M. H. Wahl - C. W. J. Wende	Savannah River Laboratory
(1)	J. W. Croach - L. M. Arnett	"
(1)	J. N. Wilson	"
(1)	L. Cathey	"
(1)	L. M. Johnson	"
(15)	TIS File	"
(1)	TIS File Record Copy	"

EX-1176-AX

DU PONT
REG. U.S. PAT. OFF.
ESTABLISHED 1802

E. I. DU PONT DE NEMOURS & COMPANY
INCORPORATED
SAVANNAH RIVER PLANT
AIKEN, SOUTH CAROLINA
(TEL. & TEL. ADDRESS, AUGUSTA, GA.)

EXPLOSIVES DEPARTMENT
ATOMIC ENERGY DIVISION

June 27, 1956

To: Recipients of DP-112, "A Versatile Laboratory Servo-Amplifier", by L. M. Johnson.

CORRECTION NOTICE

The gain of the servo-amplifier described in the subject report has been determined to be higher than was originally reported. This higher gain is sufficient to cause the amplifier to develop a regenerative feedback resulting in oscillation. Subsequent modification of the amplifier has eliminated this feedback, and the report should be corrected according to the attached diagram.

The driver stage should be converted to a push-pull cathode follower by deleting R25, R26, and R27 and then adding resistors J and K as shown. This conversion reduces the overall gain, as the gain of a cathode follower is always less than unity.

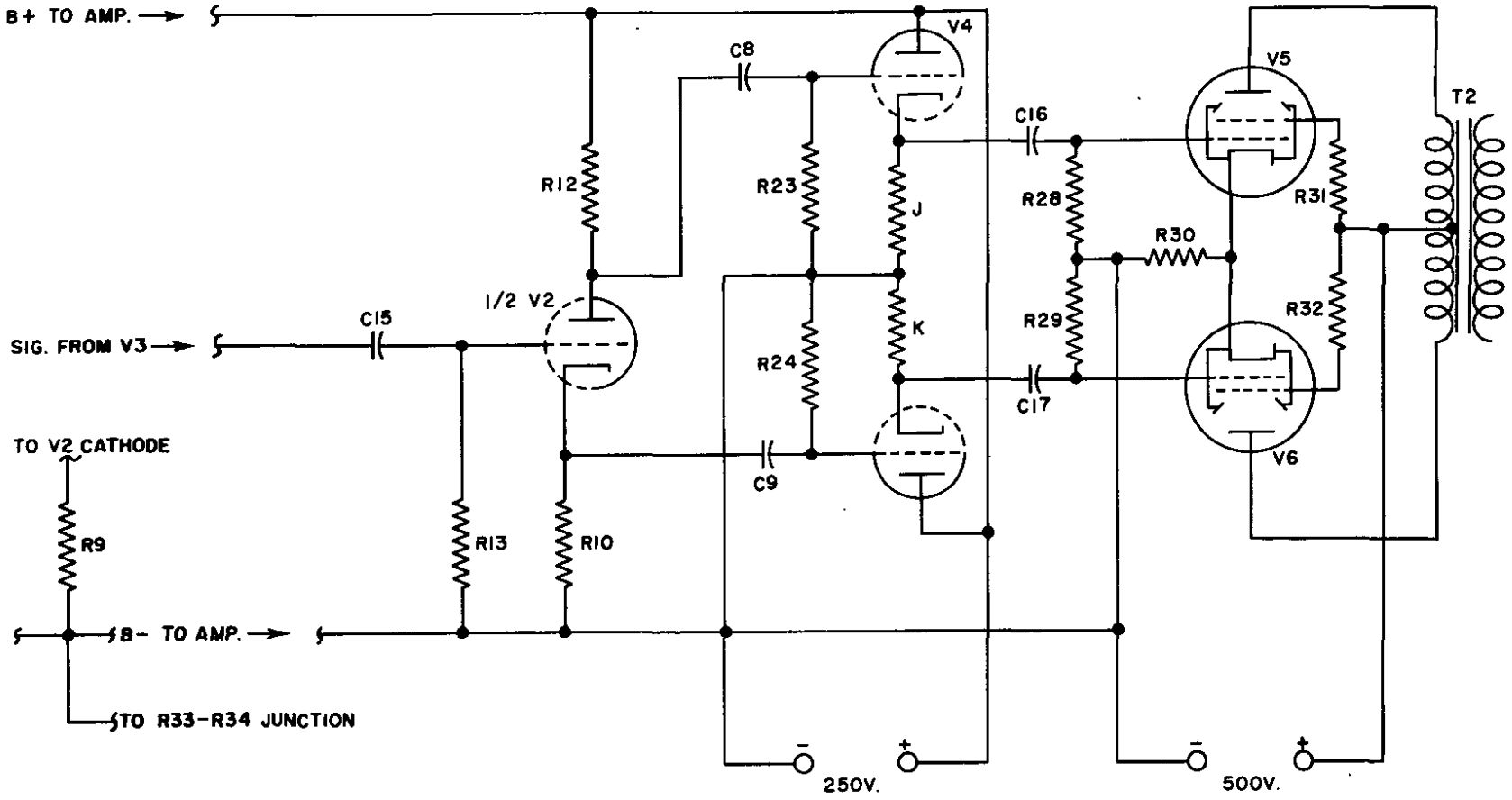
The original diagram shows R9, R33, and R34 disconnected from B⁻. This connection should be made as shown. Coupling capacitor C9 is identical to C8 instead of 25 mfd as listed on page 10.

In the event that the G. E. transformer listed for T3 is not obtainable, a Stancor A-8103 is an excellent substitute.

TECHNICAL DIVISION
SAVANNAH RIVER LABORATORY

J. N. Wilson, Research Manager
Instrument Development Division

WJW/eef



PARTS LIST CORRECTIONS
DELETE R25, R26 & R27
ADD J = 75K-2W., K = 75K-2W.
CHANGE C9 = .47 MFD. -200V.

REFERENCE DP-112: CORRECTIONS TO DIAGRAM, PAGE 9, & MATERIAL LIST, PAGE 10.

ABSTRACT

A versatile amplifier was developed for use as a laboratory instrument in the design of various electrical servo systems.

External Distribution according to
TID-4500, 9th Edition

TABLE OF CONTENTS

	Page
INTRODUCTION	4
SUMMARY	4
DISCUSSION	5
Input Circuit	5
Carrier and Signal Control	5
Output Circuit	5
Power Requirements	6
General	6
BIBLIOGRAPHY	7

LIST OF FIGURES

Figure 1.	Photograph, Front Panel	8
Figure 2.	Circuit Diagram of Amplifier	9
Figure 3.	Photograph, Rear of Chassis	11

A VERSATILE LABORATORY SERVO-AMPLIFIER

INTRODUCTION

Control and remote manipulation systems often involve electrical servo systems which require various types of amplifiers. Since commercial amplifiers are usually packaged units that are difficult to adjust and modify, a need existed for a general-purpose servo-amplifier which had variable characteristics and could be modified with a minimum of effort. This report covers the development of such an amplifier.

SUMMARY

A flexible servo-amplifier was developed with the following characteristics:

A. The servo-amplifier employs a carrier frequency of 60 cps,
B. The amplifier will accept either AC or DC signals and has a maximum gain of 10^6 with microvolt signals, or 10^3 with millivolt signals. The input impedance is 250,000 ohms.
C. The error signal may be limited internally to any preset level. The variable feedback may be obtained internally or externally. The carrier phase may be shifted through 150 degrees.

DISCUSSION

The servo motors most used in SRL control systems are two-phase AC (60 cps) control motors requiring a rated voltage input of 115 volts and a power input of 5 to 20 watts. Error detectors or transducers may supply either an AC or a DC signal. The amplifier designed to be used with these components is shown in Figure 2.

INPUT CIRCUIT

The amplifier accepts either AC or DC signals; the proper input terminals (Figures 1 and 2) are connected into the circuit by the AC/DC switch (SW 1). The AC is fed directly to the first amplifier stage while the DC is fed to a 60 cps chopper before going to the first stage. The μv/mv switch (SW 2) selects the proper input for signals in the upper microvolt or millivolt range. The maximum gain with the microvolt input is 10^6 and that with the millivolt input is 1000. The input impedance for both ranges is approximately 250,000 ohms. A continuous variation in gain on either range is obtained by the gain control potentiometer, R_7.

CARRIER AND SIGNAL CONTROL

A limiter circuit, which is connected to the input of the third amplifier stage, prevents the error signal from exceeding a preset level. The limiting action is accomplished by biasing a pair of diodes to the preset level; signals above that level are conducted to ground. The limiter is switched out of the circuit by Switch 3 (Figures 1 and 2).

A stabilizing and damping characteristic is supplied by a potentiometer, R_{16}, which is connected to the output of the third amplifier stage and feeds back part of the output voltage to the cathode of the same stage. The amount of feedback is selected by setting the knob on the front panel. Input terminals for resistive and tachometric feedback (not presently used in the circuit) are located on the front panel.

Also connected to the output of the third stage is a phase shifting circuit. By varying potentiometer R_{13}, the 60 cps carrier phase may be shifted a total of 150 degrees.

OUTPUT CIRCUIT

The push-pull output stage is connected directly to the primary of the output transformer. The twelve secondary leads from the transformer are connected to banana jacks at one side of the amplifier chassis (Figure 3). Various output impedances are easily obtained by selecting different output windings according to the following table:

Output Impedance Ohms	Connect To	Join Together
50	8 and 10	8 and 9, 10 and 11
125 (or 150)	7 and 10	7 and 9, 10 and 12
200 (or 250)	8 and 11	9 and 10
333	7 and 11	9 and 10
500 (or 600)	7 and 12	9 and 10

The power output leads (Figure 3) are connected to banana jacks on the front panel (Figure 1) providing a convenient outlet for the motor power. Voltage and current supplied to the motor are read directly from the voltmeter and ammeter on the front panel (Figure 1).

POWER REQUIREMENTS

The servo-amplifier is designed for use with laboratory power supplies such as the Hewlett-Packard Model 712A or the Sorenson Model 500BB. The power requirements are: 6.3 volts AC at 4 amps; 250 volts DC at 70 ma; and 360 volts DC at 120 ma. Power is supplied to the rear of the amplifier chassis through banana jacks, as shown in Figure 3.

GENERAL

To facilitate changes and additions in the circuitry, all the resistors and capacitors are mounted on two resistor boards, which are placed back-to-back and are mounted in the center of the underside of the chassis. The resistors and capacitors are numbered as indicated on the circuit diagram for easy identification.

L. M. Johnson

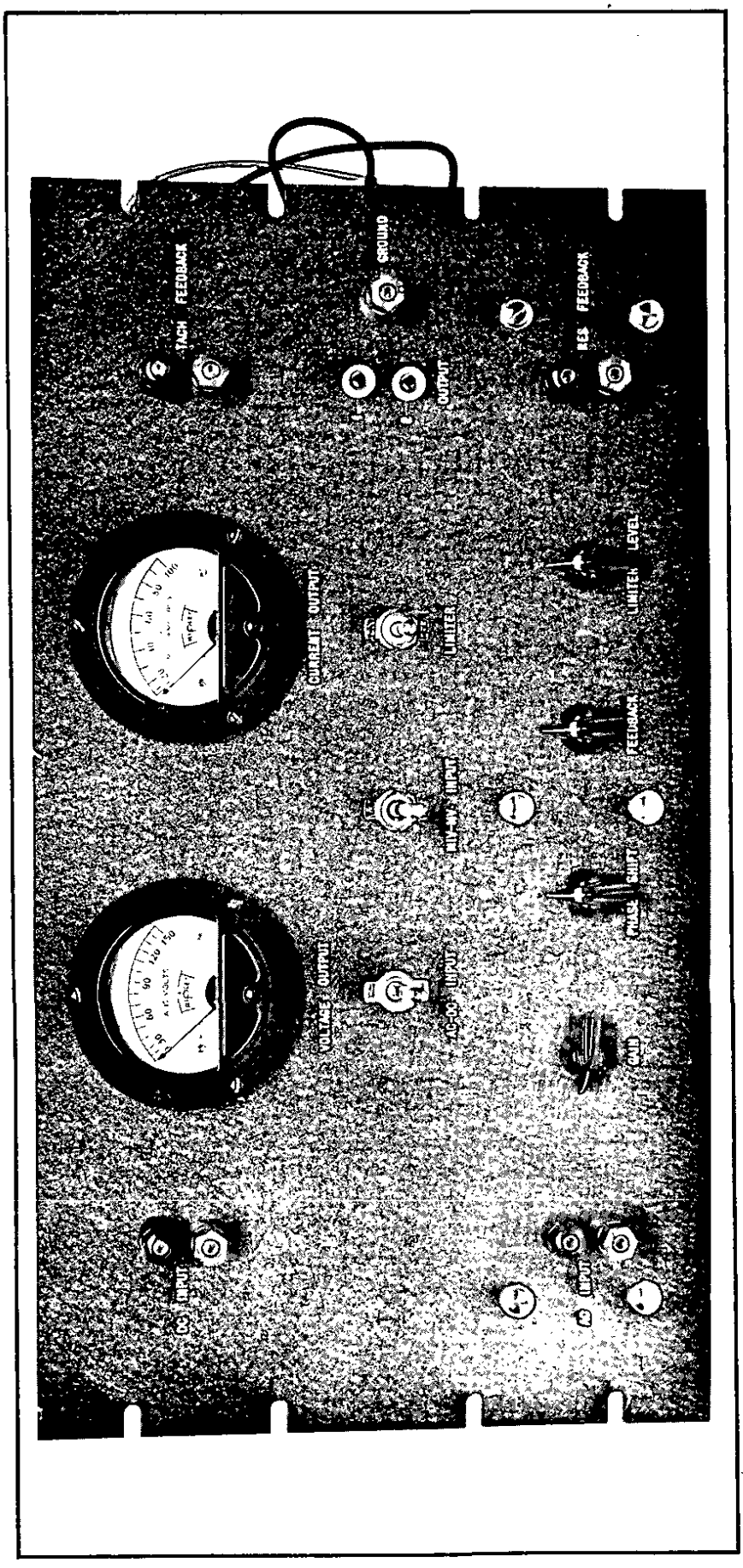
L. M. Johnson
Instrument Development Division

BIBLIOGRAPHY

1. Eastman, A. V, Fundamentals of Vacuum Tubes. Third Edition. New York: McGraw-Hill Book Co., Inc. (1949).

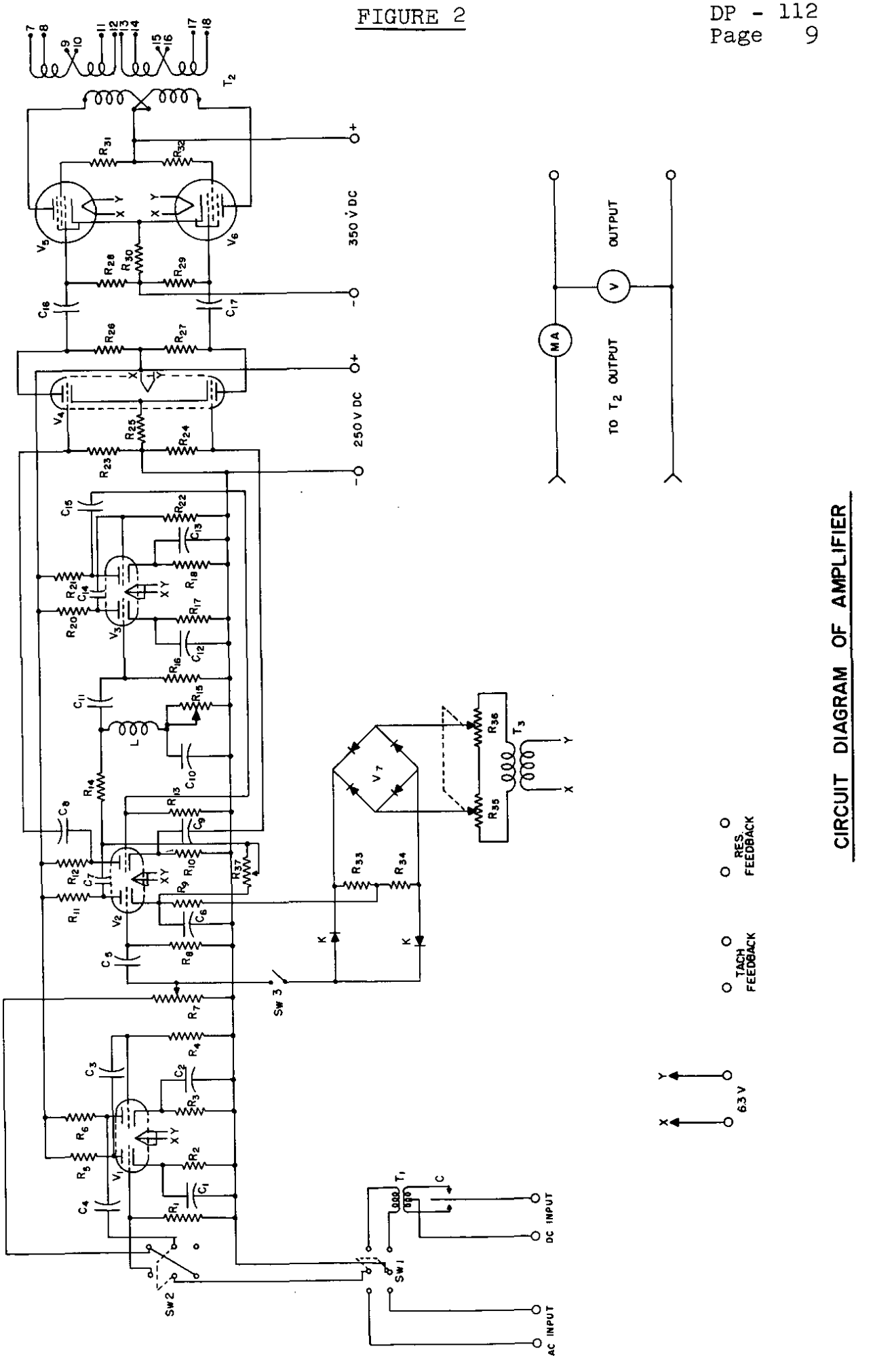
2. Terman, F. E. Radio Engineering. Third Edition. New York: McGraw-Hill Book Co., Inc. (1947).

FIGURE 1



PHOTOGRAPH, FRONT PANEL

FIGURE 2



CIRCUIT DIAGRAM OF AMPLIFIER

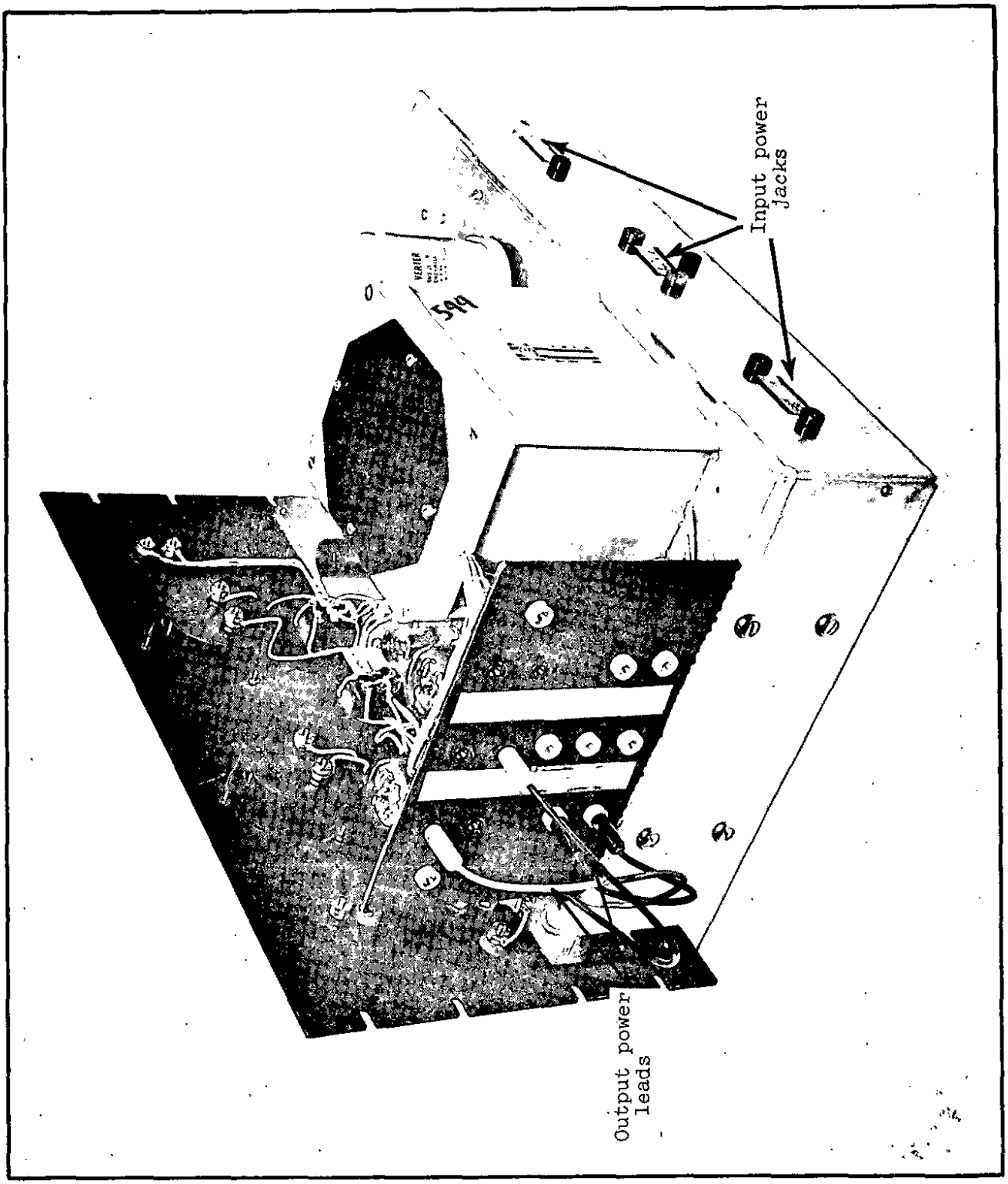
LIST OF MATERIALS FOR SERVO-AMPLIFIER

C-chopper - Brown Instrument Div. converter No. 354210-1
K-diodes - germanium diodes IN34A
- input & feedback terminal posts - Superior Electric Co. DF 30 RC & DF 30 BC
SW1 - Carling No. 2 GM-63 (DPDT center off)
SW2 - Cutler Hammer No. 8370 K7 (DPDT)
SW3 - Cutler Hammer No. 7501 K13 (SPST)
- power supply & output jacks - H. H. Smith No. 219
- output power lead plugs - H. H. Smith No. 213
V - Triplett, model 331-S, 0-500 voltmeter
MA - Triplett, model 331-S, 0-100 milliammeter
T_1 - Brown Instrument Div. input transformer No. 355567

T_2 - UTC LS 6L4
T_3 - G.E. 3587
V_1 - 12AX7
V_2 - 12AU7
V_3 - 12AU7
V_4 - 6SN7
V_5 - 6L6
V_6 - 6L6
V_7 - 1N40
L - thordarson T20C53 choke
R_1 - 200K-1/2
R_2 - 1.3K-1
R_3 - 2K-1
R_4 - 200K-1/2
R_5 - 270K-1
R_6 - 180K-1
R_7 - 0.5M pot
R_8 - 100K-1/2
R_9 - 2K-1
R_{10} - 6.2K-1
R_{11} - 47K-1
R_{12} - 6.2K-1
R_{13} - 100K-1/2
R_{14} - 200K-1
R_{15} - 250K pot
R_{16} - 100K-1/2
R_{17} - 1.4K-1
R_{18} - 1.4K-1
R_{20} - 47K-2
R_{21} - 200K-1
R_{22} - 200K-1/2
R_{23} - 270K-1/2
R_{24} - 270K-1/2
R_{25} - 2.4K-1
R_{26} - 75K-1
R_{27} - 75K-1
R_{28} - 100K-1/2
R_{29} - 100K-1/2
R_{30} - 250-5
R_{31} - 39K-1
R_{32} - 39K-1
R_{33} - 1K-1
R_{34} - 1K-1
R_{35} - 10K pot
R_{36} - 10K pot
R_{37} - 1.0M pot
C_1 - 25 mfd. 25V
C_2 - 25 mfd. 25V
C_3 - .47 mfd. 200V
C_4 - .47 mfd. 200V
C_5 - .47 mfd. 200V
C_6 - 25 mfd. 25V
C_7 - .47 mfd. 200V
C_8 - .47 mfd. 200V
C_9 - 25 mfd. 200V
C_{10} - .147 mfd. 400V
C_{11} - .47 mfd. 400V
C_{12} - 25 mfd. 25V
C_{13} - 25 mfd. 25V
C_{14} - .47 mfd. 200V
C_{15} - .47 mfd. 200V
C_{16} - .47 mfd. 200V
C_{17} - .47 mfd. 200V

* Resistor values given as: ohms - watt rating

FIGURE 3



PHOTOGRAPH, REAR OF CHASSIS