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HIGH POWER AC/DC VARIABLE R

DYNAMIC ELECTRICAL LOAD SIMULATOR

FINAL REPORT

Program Period:

28 June 1973 to 18 October 1974

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS, 77058

Contract Number NAS 9-13524

AVSD-0292-74-RR

18 October 1974

Prepared by

AVCO GOVERNMENT PRODUCTS GROUP
Systems Division
201 Lowell Street
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Line Item 2

ABSTRACT

This is the final report of the high power AC/DC variable R dynamic electrical load simulator program conducted for the National Aeronautics and Space Administration (NASA) by Avco Corporation's Systems Division (Avco/SD) under Contract NAS 9-13524. Under the program, which covered the period 28 June 1973 to 18 October 1974, two simulators, along with an operating and maintenance manual, were delivered to NASA's Johnson Space Center.

The objective of the program was to extend the design of Avco/SD's previously developed basic variable R load simulator to increase its power dissipation and transient handling capabilities, and to provide for simulation of AC as well as DC loads. The delivered units satisfy all design requirements, and provide NASA with a high power AC/DC simulation capability uniquely suited to the simulation of complex load responses. A study to identify means of dynamically simulating AC loads operating at less than unity power factor was also conducted. To permit effective application of the large number of variable R simulators presently available at NASA, Avco recommends development of techniques for simultaneously controlling a quantity of variable R simulators. Avco also recommends development of a variable R capable of simulating AC loads of less than unity power factor.

In addition to presenting conclusions and recommendations and pertinent background information, the report covers program accomplishments; summarizes study results; describes the simulator basic circuits, transfer characteristic, protective features, assembly, and specifications; indicates the results of simulator evaluation, including burn-in and acceptance testing; provides acceptance test data; and summarizes the monthly progress reports.

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1.0 INTRODUCTION

This document is the final report of the High Power AC/DC Variable R Dynamic Electrical Load Simulator program conducted by Avco Corporation's Systems Division (Avco/SD) for the National Aeronautics and Space Administration (NASA) under Contract Number NAS-9-13524

This program was preceded by a three-phase development program that started in 1970 with an investigation of means of interrogating and simulating electrical loads on the power lines of manned spacecraft. Subsequent phases were undertaken to develop hardware and software capable of implementing the techniques recommended in the Phase 1 study. Under a recent contract (Reference 1) a modular, high-power variable R simulator capable of continuous operation at 1500 watts was developed.

The objective of the current program was to extend the design of the basic variable R simulator developed in the earlier phases to increase its power dissipation and transient handling capabilities, and to provide for simulation of AC as well as DC loads.

Two high-power AC/DC variable R simulators meeting all design requirements were manufactured and delivered to NASA's Johnson Space Center (JSC) along with an operating and maintenance manual.

1.1 BACKGROUND

The design and development of electrical power distribution/conditioning systems is highly dependent on the characteristics of the power sources and the loads. Their influence becomes progressively more significant as the operational functions of the total integrated system become more critical, such as exemplified in complex spacecraft systems. During past manned spacecraft programs (from Project Mercury through Apollo), in order to meet projected schedules it was necessary to evaluate system performance using load simulators which, at best, could only duplicate the steady-state load conditions. Subsequent vehicle testing and flight experience has consistently uncovered system operational problems caused by the transient (or dynamic) characteristics of the various loads reflected back into the system. Identification of the problem at this point in the program resulted in costly work-around and/or corrective action. Recognizing this, a multi-phase program was undertaken to investigate concepts for providing more realistic loads, and to develop prototype hardware and software capable of implementing and evaluating these concepts.

The Phase 1 study program was undertaken to investigate various concepts and techniques for identifying and simulating both the steady-state and dynamic characteristics of electrical loads for use during integrated system test and evaluation. These investigations showed that it is feasible to design and develop interrogation and simulation equipment to perform the desired functions.

A second phase was undertaken to develop hardware capable of providing this simulation. During these activities, actual spacecraft loads were interrogated by stimulating the loads with their normal input voltage and measuring the resulting input voltage and current time-histories. Using an existing computer program with some modifications, general network models consisting of resistance (R), inductance (L), and capacitance (C) elements were optimized by an iterative process of selecting element values and comparing the time domain response of the model with those obtained from the real equipment during the interrogation. A general-purpose simulator was developed with the capability of realizing a variety of models comprised of R, L, and C elements where element values were discretely variable. The different models, each corresponding to real spacecraft equipment, are set up manually for each case by suitable switching and patching. The models are capable of duplicating the dynamic and steady-state response of real loads at full power.

Also developed during the Phase 2 program was a variable resistance (variable R) device with the capability of reproducing a resistance-time curve upon application of a suitable, externally provided control signal. In practice, the current/voltage time-history of an article of hardware is obtained during the interrogation process and this data is then processed and stored. In operation, this signal is retrieved from storage and applied as the control input to the variable R. The output resistance of the variable R, connected to the power source normally used to operate the real equipment, is then made to vary as a function of this control. Thus, the power input current is caused to vary just as the input current to the real equipment.

During the third phase, the optimization software developed during the earlier phases was documented and delivered along with a detailed software manual. Data acquisition hardware used in the interrogation process to acquire the voltage and current time-histories of the equipment to be simulated was also provided during this phase.

For details regarding these earlier programs, see the final reports (References 2, 3, and 4 for the phase 1, 2, and 3 programs, respectively).

The current program was undertaken for the following-listed purposes:

- To conduct a study of means of simulating AC loads of less than unity power factor.
- To modify the design of the basic variable R to permit simulation of AC loads as well as DC loads.
- To extend the design of the basic variable R to permit operation at 500 watts, continuous, and to provide transient handling capability.
- To manufacture and deliver to NASA two high-power AC/DC variable R simulators along with an operating and maintenance manual.

1.2 DEFINITIONS

The terms interrogation and simulation are used in this report. A definition of these terms follows.

Interrogation:--The quantitative determination of those parameters of a device that describe its dynamic and steady-state electrical response on the power lines to a specified application of voltage.

Simulation:--The duplication on the power lines of the dynamic and steady-state response of an electrical load.

1.3 REPORT ORGANIZATION

The final report is organized as follows:

1. INTRODUCTION

   Provides background information, defines key terms, indicates the way the report is organized, and lists pertinent contractual publications.

2. CONCLUSIONS AND RECOMMENDATIONS

   Presents conclusions drawn from the program and recommendations for future action.

3. PROGRAM ACCOMPLISHMENTS

Describes program accomplishments in the following-listed areas:

- Study
- Hardware design, development, and manufacture
- Hardware test and burn-in
- Hardware delivery and demonstration
- Operating and maintenance manual preparation and submission

4. STUDY

Summarizes results of a study conducted to identify means of dynamically simulating AC electrical loads operating at less than unity power factor.

5. HIGH POWER AC/DC VARIABLE R DESCRIPTION

Describes the high power AC/DC variable R, including the basic circuits, transfer characteristic, protective features, its assembly, and specifications.

6. HIGH POWER AC/DC VARIABLE R EVALUATION

Summarizes the evaluation of the high power AC/DC variable R, covering the results of burn-in, acceptance, and demonstration testing.

7. REFERENCES

Lists appropriate references.

1.4 PUBLICATIONS

Avco Systems Division documents published under this contract are listed in Table 1-I. For summaries of the monthly progress reports, see Appendix A.

TABLE 1-I

AVCO SYSTEMS DIVISION DOCUMENTS

PUBLISHED UNDER CONTRACT NAS 9-13524

1. High Power AC/DC Variable R Dynamic Electrical Load Simulator, First Monthly Progress Report, for the period 28 June to 31 July 1973; Avco Systems Division, AVSD-0248-73-CR, 8 August 1973.

2. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Second Monthly Progress Report, for the period 1 August to 31 August 1973; Avco Systems Division, AVSD-0275-73-CR, 7 September 1973.

3. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Third Monthly Progress Report, for the period 1 September to 30 September 1973; Avco Systems Division, AVSD-0310-73-CR, 10 October 1973.

4. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Fourth Monthly Progress Report, for the period 1 October to 31 October 1973; Avco Systems Division, AVSD-0323-73-CR, 5 November 1973.

5. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Fifth Monthly Progress Report, for the period 1 November to 30 November 1973; Avco Systems Division, AVSD-0337-73-CR, 5 December 1973.

6. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Sixth Monthly Progress Report, for the period 1 December to 31 December 1973; Avco Systems Division, AVSD-0003-74-CR, 4 January 1974.

7. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Seventh Monthly Progress Report, for the period 1 January to 31 January 1974; Avco Systems Division, AVSD-0033-74-CR, 5 February 1974.

8. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Eighth Monthly Progress Report, for the period 1 February to 28 February 1974; Avco Systems Division, AVSD-0057-74-CR, 5 March 1974.

9. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Ninth Monthly Progress Report, for the period 1 March to 31 March 1974; Avco Systems Division, AVSD-0093-74-CR, 8 April 1974.

10. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Tenth Monthly Progress Report, for the period 1 April to 30 April 1974; Avco Systems Division, AVSD-0131-74-CR, 6 May 1974.

TABLE 1-I (Concluded)

AVCO SYSTEMS DIVISION DOCUMENTS

PUBLISHED UNDER CONTRACT NAS 9-13524

11. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Eleventh Monthly Progress Report, for the period 1 May to 31 May 1974; Avco Systems Division, AVSD-0160-74-CR, 10 June 1974.

12. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Twelfth Monthly Progress Report, for the period 1 June to 30 June 1974; Avco Systems Division, AVSD-0179-74-CR, 9 July 1974.

13. Operating and Maintenance Manual, Model AC-DC-500 Variable R Dynamic Electrical Load Simulator; Avco Systems Division, ESDM-F420-74-242, 30 August 1974.

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

The high power AC/DC variable R dynamic electrical load simulators developed under this program satisfy all design requirements and provide NASA with a capability for actively simulating unity-power-factor AC loads as well as DC loads. A study of means of simulating AC loads of less than unity power factor has concluded that such devices are feasible, and has described a conceptual design based on using the unity-power-factor variable R as the load dissipative element.

Two high power AC/DC variable R simulators were delivered to NASA's Johnson Space Center.

2.2 RECOMMENDATIONS

The program described in this report provided hardware suitable for simulating complex load responses of a variety of AC- and DC-operated electrical equipment at high power. The availability of the two simulators delivered under this program, coupled with the availability of 20 previously delivered units--2 low-power simulators and the equivalent of 18 medium power simulators (six modular high-power units each consisting of three simulators)--gives NASA the equivalent of 22 variable R simulators. Effective use of this number of variable R simulators requires more flexible control techniques than those currently available. It is recommended, therefore, that control systems capable of simultaneously controlling a number of variable R's be developed.

In addition, it is recommended that development of a variable R simulator capable of simulating AC loads of less than unity power factor be pursued.

3.0 PROGRAM ACCOMPLISHMENTS

The objectives of this program were: (1) to study means of simulating AC loads of less than unity power factor, and (2) to design, develop, manufacture, and deliver two unity-power-factor AC/DC variable R simulators. The two units were to be set up at NASA JSC and their operation demonstrated. In addition, an operating and maintenance manual was to be supplied.

Each of these tasks has been completed, as described in Paragraphs 3.1 through 3.5, below.

3.1 STUDY

Early in the program a study was conducted to identify and investigate means of actively simulating AC loads of less than unity power factor. The study concluded that such devices are feasible, and provided a conceptual design for a device that used a unity-power-factor AC variable R as the load-dissipative element.

Section 4.0 summarizes the study and the resultant recommendations.

3.2 HARDWARE DESIGN, DEVELOPMENT, AND MANUFACTURE

As noted in Section 1.0 INTRODUCTION, the fundamental concepts of the high-power AC/DC variable R simulator are based on work completed previously under the Phase 1 study (NASA Contract NAS 9-10429), and the Phase 2 and Phase 3 hardware and software development programs (NASA Contracts NAS 9-12016 and NAS 9-12913).

To extend the design to satisfy requirements for the AC/DC variable R, three areas of the basic variable R required considerable re-design, as distinct from over-all upgrading of the basic approach. These areas were:

1. The control circuits--to provide for control of the AC voltage source.
2. The power output stage--to provide means for operating with an AC voltage source and for dissipating additional power.
3. The overload protection circuits--to provide transient overload capabilities.

These circuits, along with other simulator circuits, are described in Section 5.0.

The high-power AC/DC variable R hardware developed under this program has been designated Model AC-DC-500.

3.3 HARDWARE TEST AND BURN-IN

All hardware was calibrated to the transfer characteristic, thoroughly tested, and subjected to an 80-hour burn-in prior to being delivered. Details of these activities are provided in Section 6.0

3.4 HARDWARE DELIVERY AND DEMONSTRATION

The simulators were delivered to NASA's Lyndon B. Johnson Space Center where Avco personnel unpacked them, set them up, and then demonstrated their operation.

3.5 OPERATING AND MAINTENANCE MANUAL

An operating and maintenance manual for the AC-DC-500 variable R simulator (Reference 5) provides complete operating instructions along with circuit descriptions, schematic diagrams, safety and maintenance instructions, and specifications.

4.0 STUDY

4.1 SUMMARY

Early in the program a study was conducted to identify means of dynamically simulating AC electrical loads operating at a less-than-unity power factor. Such simulation devices would be required to reproduce the transient and steady-state characteristics of a variety of electrical loads at high power. These requirements suggest the use of either multiple fixed networks whose transfer functions approximate those of the real loads, or a variable network whose transfer function can be varied in response to a suitable control signal.

A literature search failed to produce evidence of any prior development work in this area. However, there are a number of references to impedance conversion in the literature. Although the use of such impedance conversion devices as varactor diodes, saturable reactors, resonant circuits, impedance multipliers, gyrators, etc. has been investigated, dynamic simulation concepts based on such devices were not considered suitable because they are not capable of high power operation, or are highly non-linear, or have only a limited range. For a summary of findings regarding these approaches, see Appendix A of the third monthly progress report (Reference 6) for this program.

In the absence of any significant prior development work, the variable R simulator described in the final reports of earlier load simulator contracts (References 2, 3, and 4) was reviewed to determine whether it could be adapted to meet the requirements of simulators operating at a less-than-unity power factor. A concept for extending the basic design of the simulator in this direction is described in Paragraph 4.2, below.

4.2 AC/DC VARIABLE R SIMULATOR WITH POWER FACTOR CAPABILITIES

Consider the circuit shown in Figure 4-1. A voltage, V_1, applied at the input will be forced to appear at V_2. The current, I_1, is given by

$$I_1 = V_2/R$$

and

$$V_2 = V_1$$

This circuit is a very effective voltage-controlled current sink capable of serving as the basis for the power dissipation stage of the load simulator.

A current sink of itself, however, maintains a constant current. On the other hand, the current into a true impedance would be a function of the voltage applied to it. Therefore, a multiplier was added to the basic current sink circuit, as shown in Figure 4-2. This cuases the current sink to exhibit resistance characteristics. The input signal for the voltage-controlled current sink is applied to one input of the multiplier and a portion of the load voltage is applied to the other input. If the scale factors are chosen properly, the output voltage of the multiplier will be the same as the input voltage on multiplier terminal 1 when the load voltage is at its nominal value.

If the load voltage changes to one-half its nominal value, the output voltage of the multiplier will be one-half the value on terminal 1, etc. If the multiplier output is then applied to the input of the voltage-controlled current sink, the result, insofar as the load supply is concerned, is a true

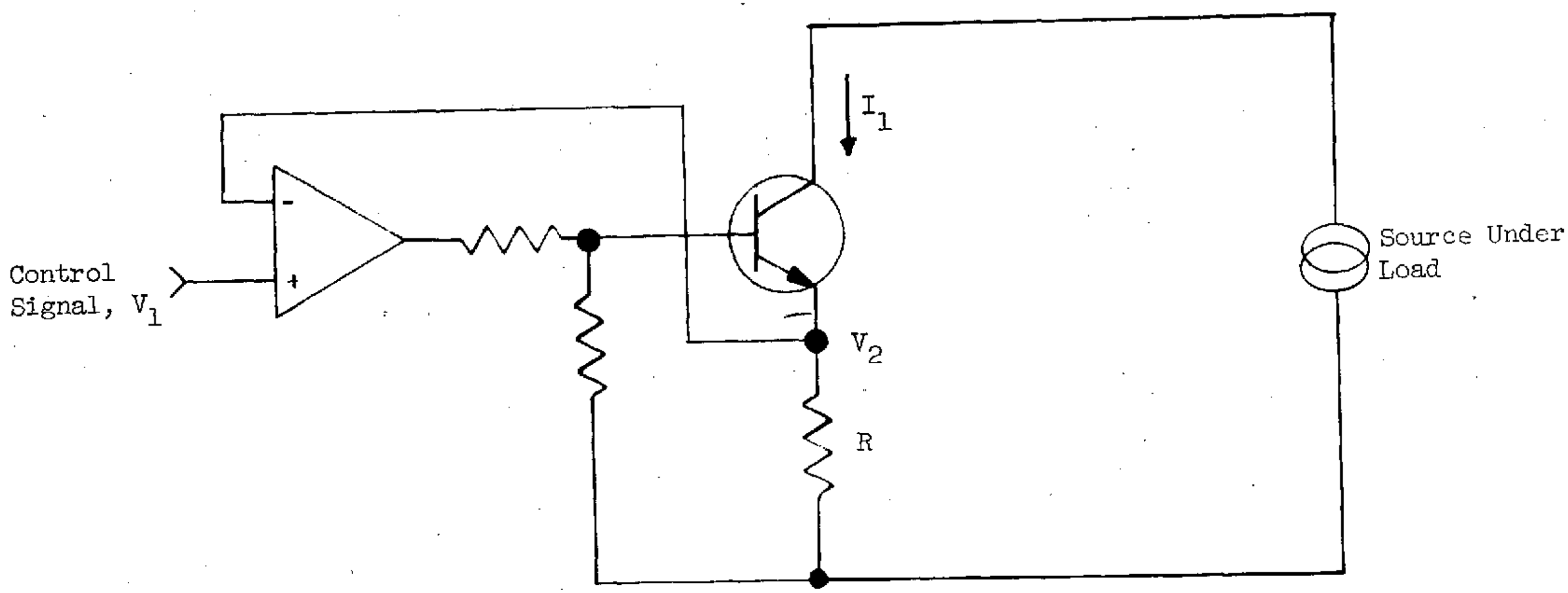

FIGURE 4-1 Schematic Diagram, Voltage-Controlled Current Sink

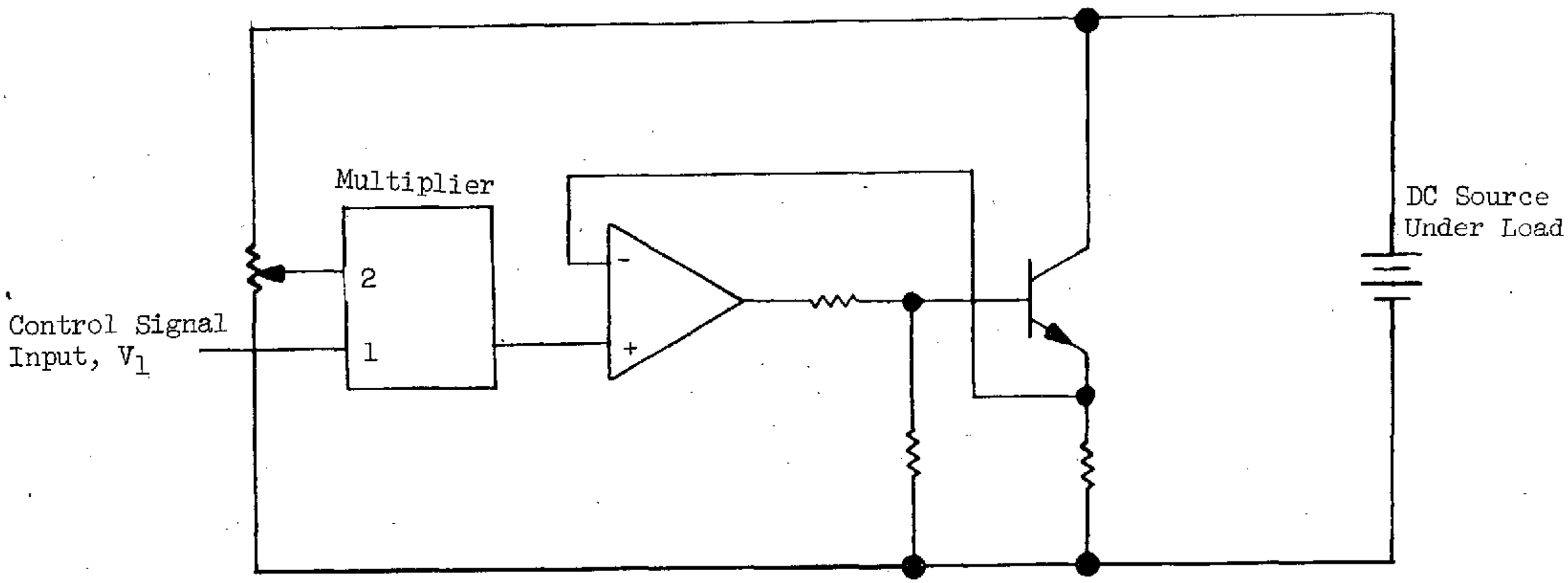

FIGURE 4-2 Schematic Diagram, DC Variable R Simulator

resistance. Thus, the fundamental requirements of a DC load simulator have been satisfied. For a complete description of such a simulator, see References 1, 2, 3, and 4.

The next logical step in load simulation technology was to expand the DC device into one capable of simulating AC loads with phase shift. The power stage for a simple AC simulator is shown in Figure 4-3. Complementary transistors are used to provide a voltage-controlled current sink that will handle both positive and negative currents. When the requirements for phase shift are considered, the power stage must not only be capable of sinking current, but must also be capable of furnishing current to the supply. Figure 4-4 (b) shows one cycle of a sinusoidal voltage and current waveform with approximately 60° of phase shift. During Interval 1 the current is positive. The voltage, however, is positive only during Interval 1A, and is negative during Interval 1B. This reverse polarity during Interval 1B means that: (1) the NPN stage of Figure 4-3 will not conduct during Interval 1B, and (2) the PNP stage will not conduct during Interval 2B. If a voltage, E_1, is placed in series with the NPN stage, and another voltage, E_2, is placed in series with the PNP stage, as shown in Figure 4-5, the waveforms shown in Figure 4-4 (b) result. Thus, the voltage, $V_1(t)$, across the NPN stage is always positive when the current is positive, and the voltage, $V_2(t)$, across the PNP stage is always negative when the current is negative, and both stages will conduct in a normal manner. Diodes CR1 and CR2 decouple each power stage when the polarity is opposite, thereby preventing the transistors from becoming reverse biased.

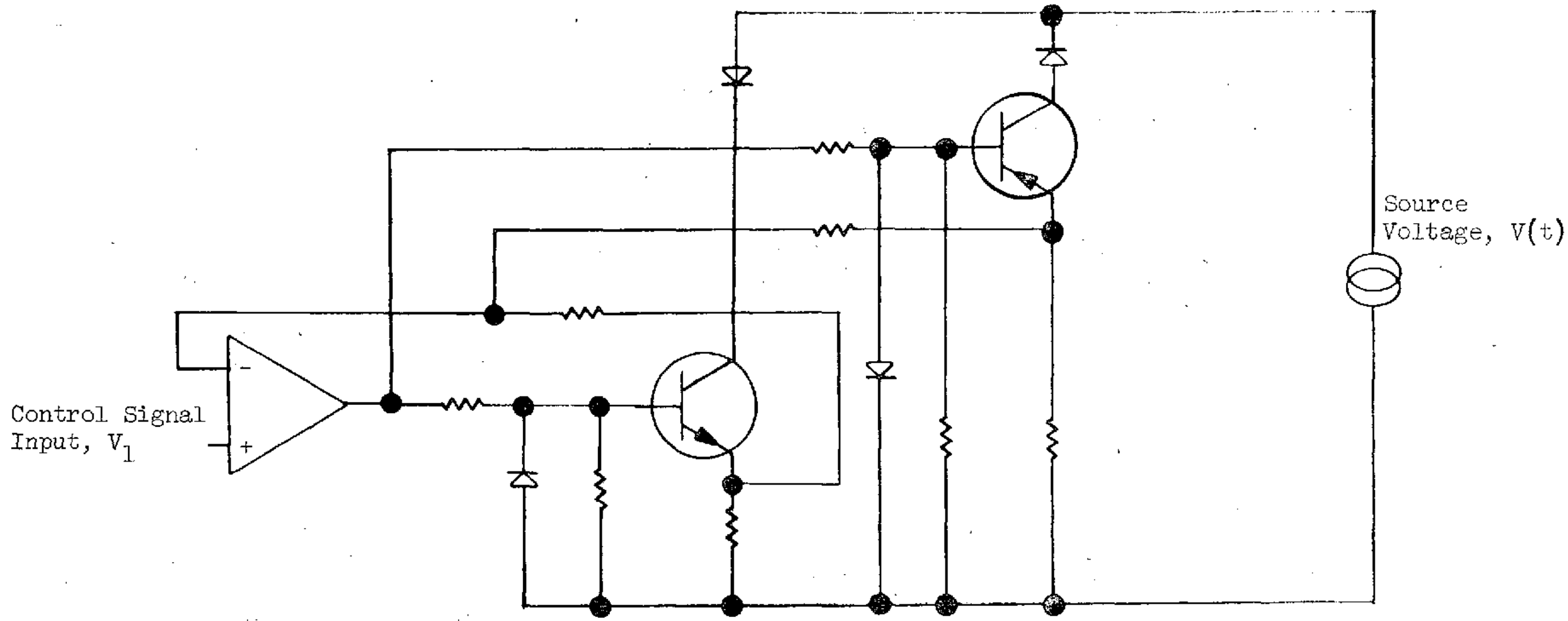

FIGURE 4-3 Schematic Diagram, Complementary Voltage-Controlled Current Sink

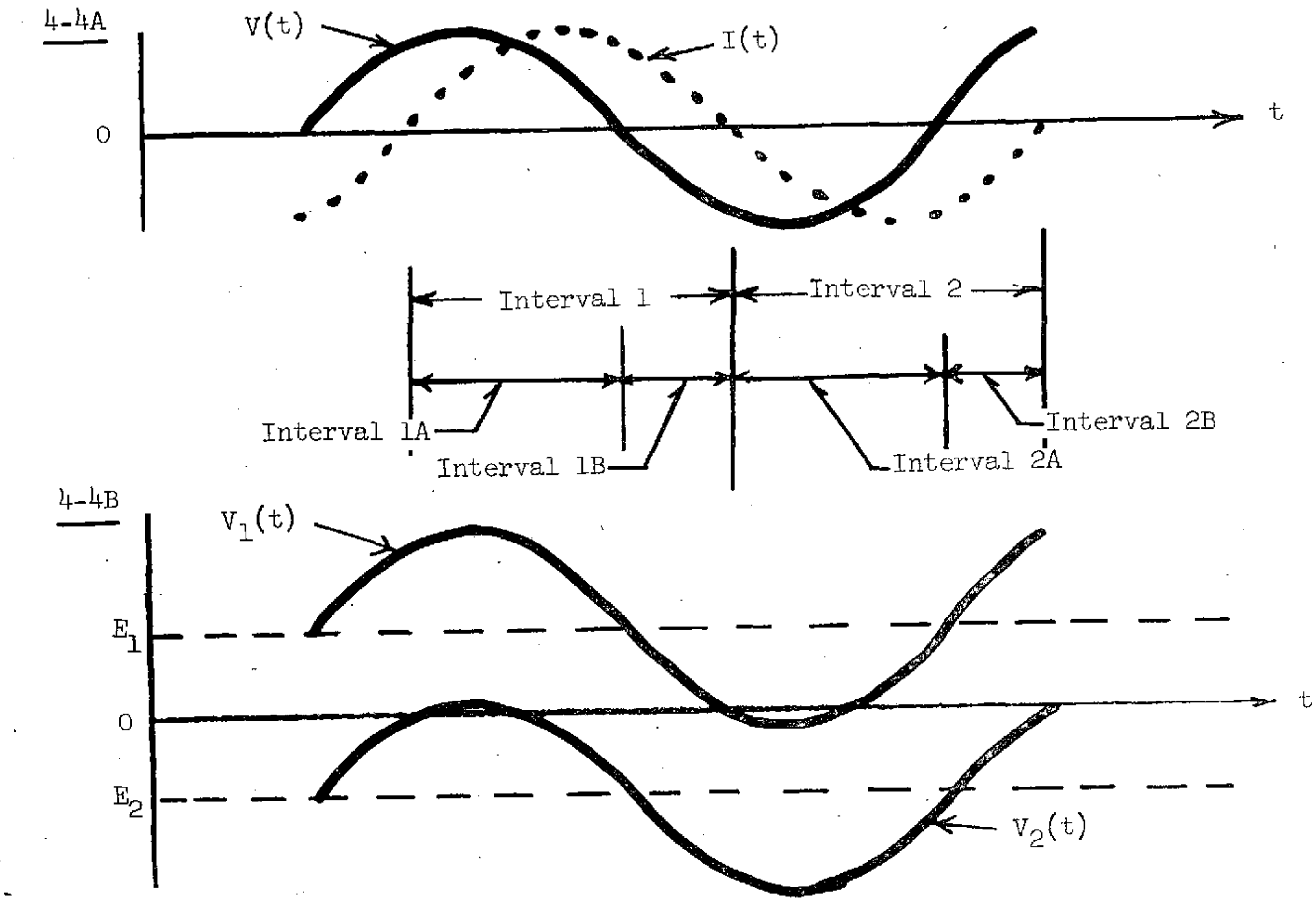

FIGURE 4-4 AC Voltage and Current Waveforms

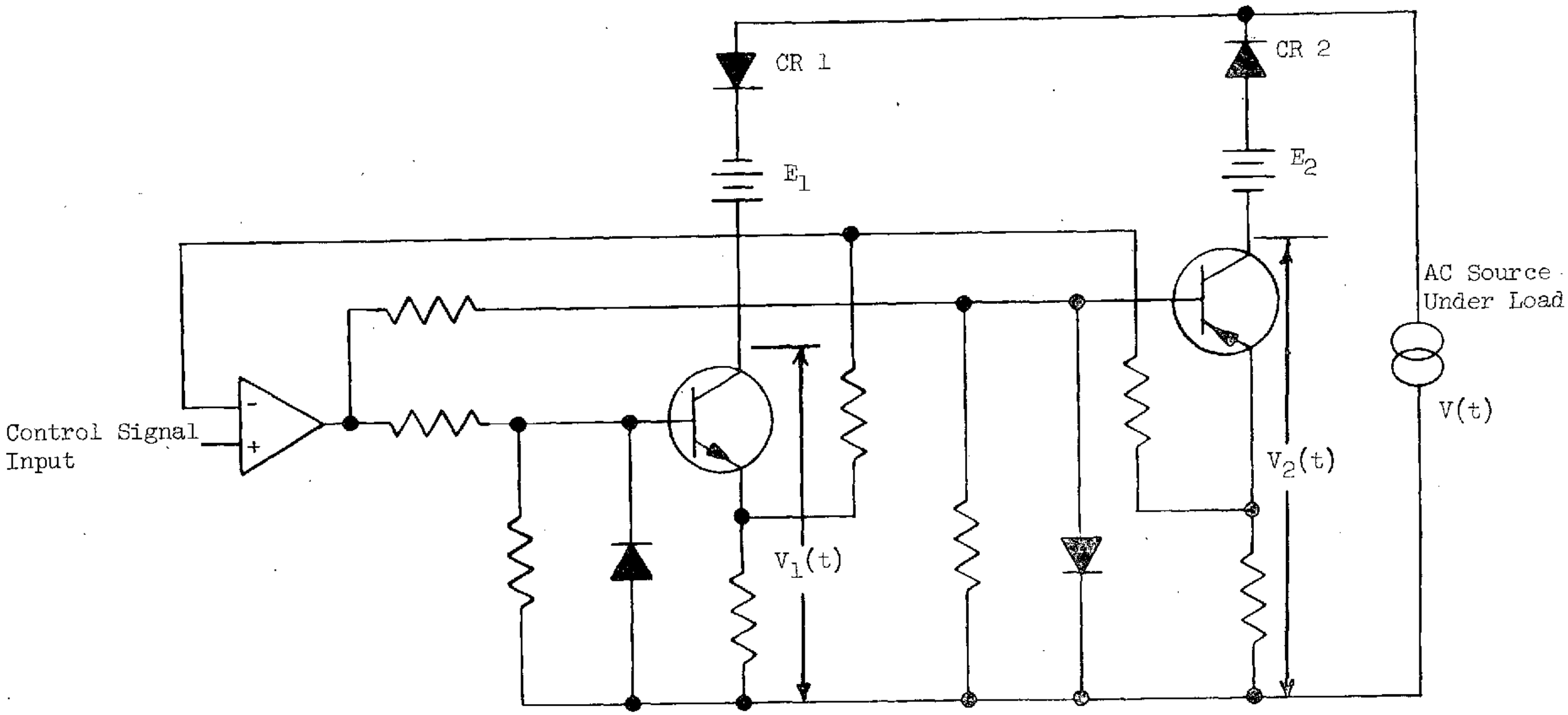

FIGURE 4-5 Complementary Voltage-Controlled Current Sink with Bias

The magnitudes of E_1 and E_2 are the same, and are given by the expression

$$E_1, E_2 = \left| Ep \sin \theta \right|$$

where

Ep = peak value of $V(t)$

θ = maximum phase shift that will be allowed

Actually, the magnitudes of E_1 and E_2 must be slightly larger than their calculated value to compensate for the drop across the sampling resistor, the diodes, and the power transistors.

The addition of a multiplier and a full-wave rectifier, as shown in Figure 4-6, satisfies the requirement that the output current follow the output voltage in the AC case in a manner such as that described above for the DC case. A voltage proportional to current is applied to one input of the multiplier; the output of the full-wave rectifier (FWR) is applied to the other input of the multiplier. The output of the multiplier is identical in form to the signal applied to multiplier input 1, and its amplitude is proportional to the product of input 1 and the peak value of V(t). The output of the multiplier is then used as the input signal for the voltage-controlled current sink.

The control circuit for an AC/DC variable R with phase shift capability requires use of a load interrogator: (1) to determine the power line characteristics of the device to be simulated, and (2) to extract from these characteristics the necessary amplitude and phase data. The power line voltage and

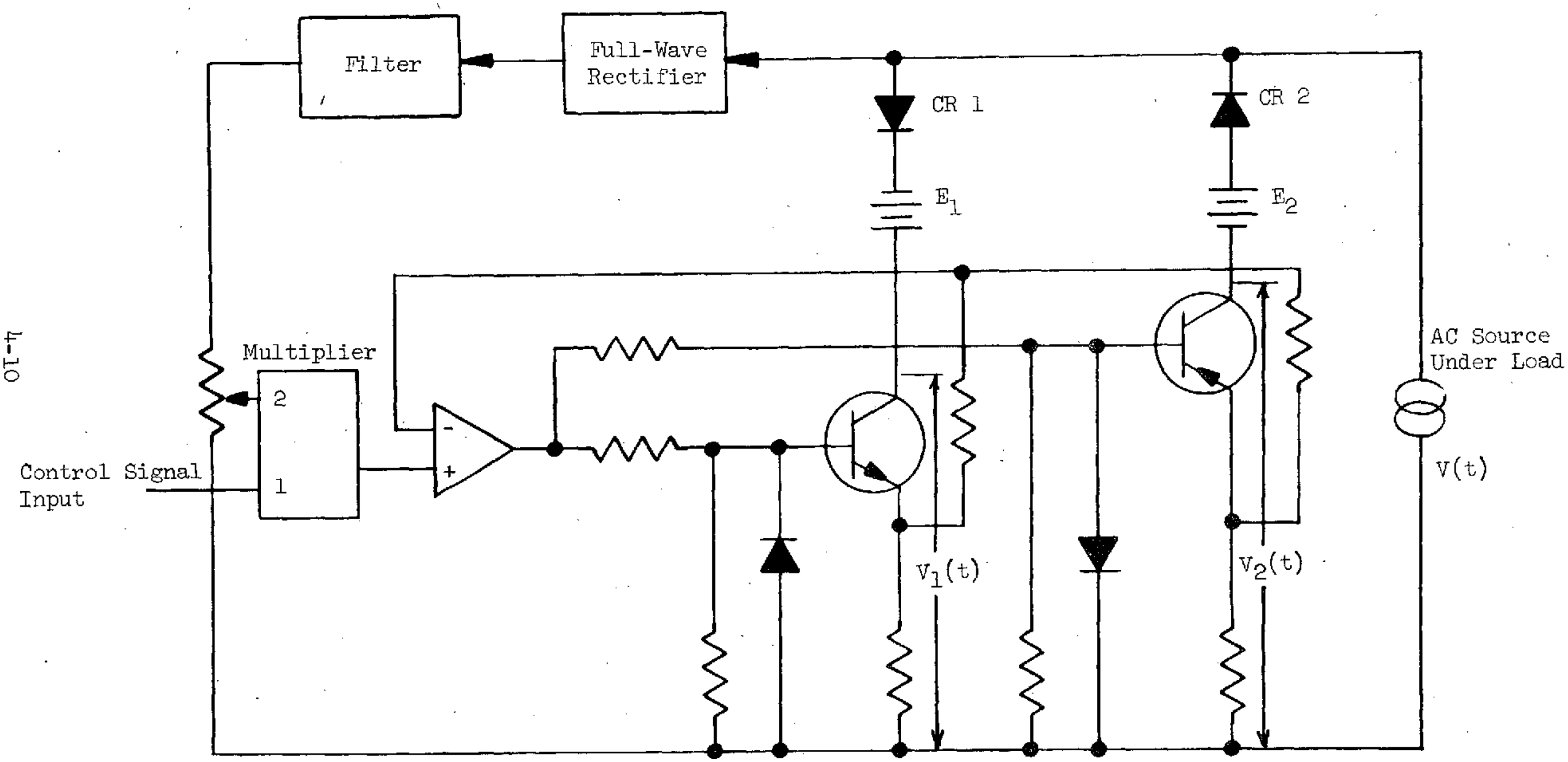

FIGURE 4-6 AC/DC Variable R Simulator with Power Factor Capability

current characteristics may be obtained by the data acquisition system developed under Contract NAS 9-12913 (see Reference 4). The analog current data would be processed via an analog-to-digital (A/D) converter into a series of 7-bit digital words. Each word would described a single point on the sampled waveform, and a total of 64 words would be used to describe one complete cycle. Thus, at a frequency of 400 Hz the time between samples would be 39 microseconds--an interval adequate to assure a 50-microsecond transient response time.

Figure 4-7 is a block diagram of the interrogator system. The oscillator is phase-locked to the voltage source so that its output will track minor variations in source frequency. The oscillator provides the basis for the clock signal used to control the A/D converter and the data buffer unit (DBU). A zero-crossing detector provides an output pulse to the DBU at each positive zero-crossing of the voltage waveform of the supply, as indicated in Figure 4-8. This provides means for identifying the start of each cycle, with the cycle being defined on the basis of the voltage waveform.

The DBU provides short-term storage and signal conditioning for the tape transport. The data format would include a key code, which identifies the start of each voltage cycle, followed by the 64 seven-bit words used to describe the current waveform during each cycle. The tape transport would require a minimum of 7 tracks and, at a character density of 556 characters per inch, would require a speed of greater than 50 inches per second (ips). All of these requirements are within the capabilities of standard, off-the-shelf hardware.

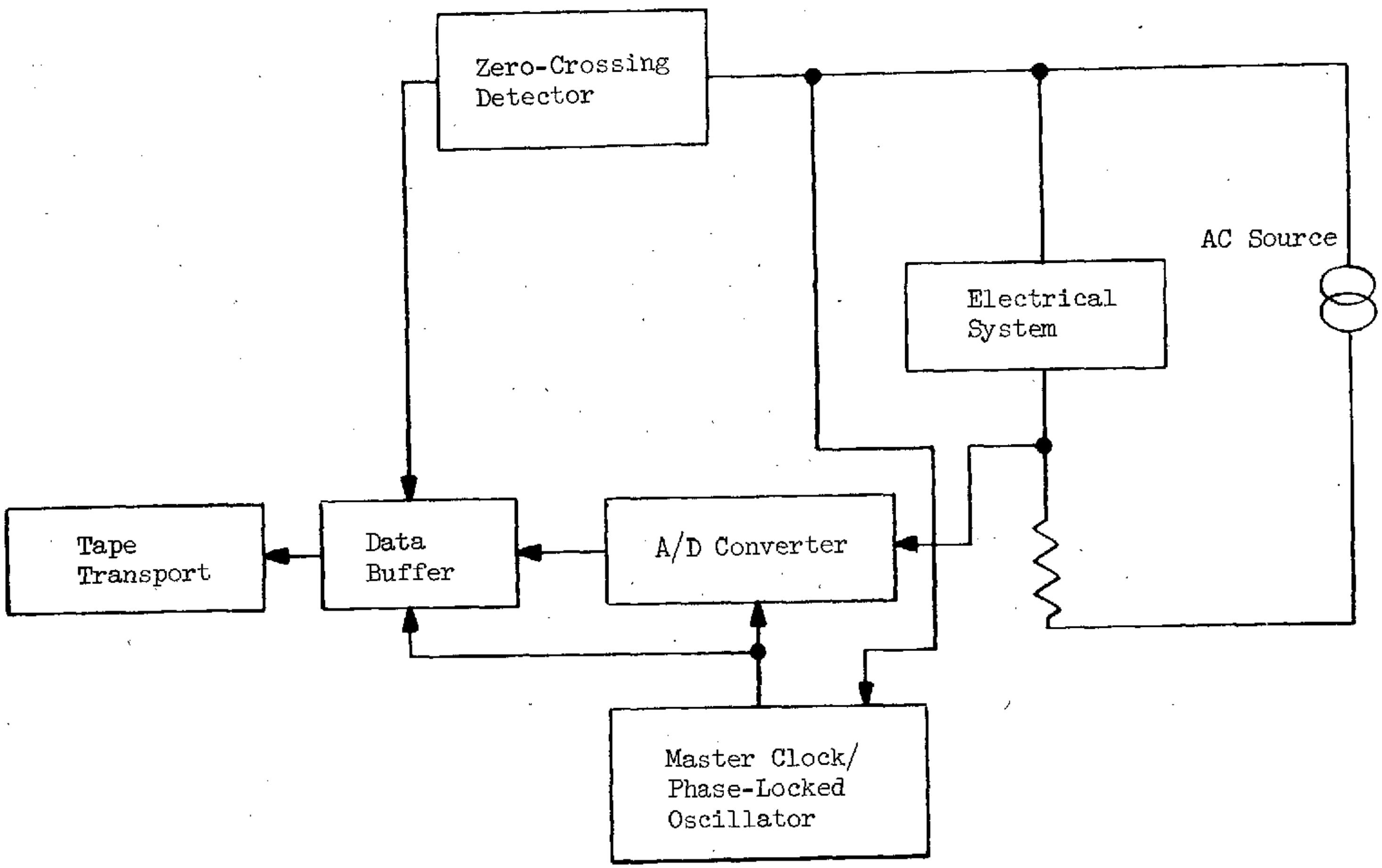

FIGURE 4-7 Block Diagram, Load Interrogation System

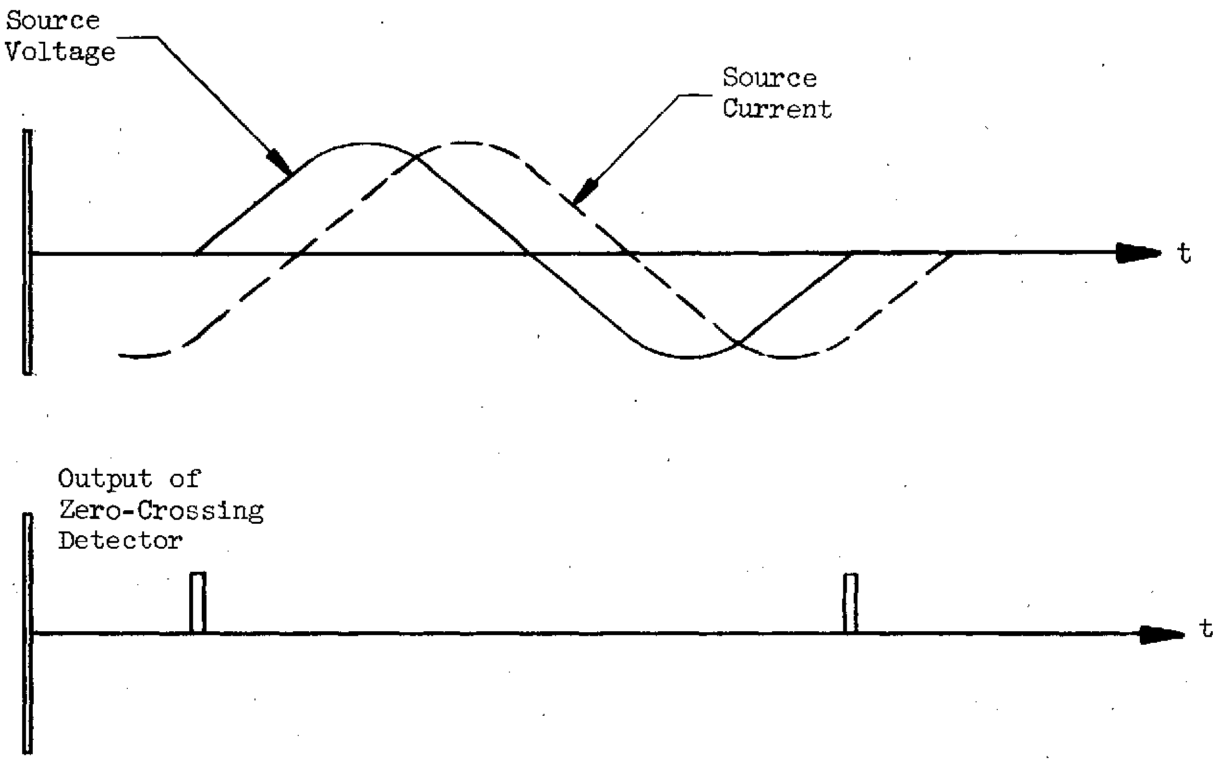

FIGURE 4-8 Voltage and Current Waveforms for Load Interrogator

The load simulator must be capable of accepting digital data from the tape transport and converting it to analog form such that the correct phase relationship is preserved. Figure 4-9 is a block diagram of a power stage that incorporates the controls necessary to meet these requirements. The digital data is loaded from the tape transport into one of two memories. While the data is being loaded into one memory, data is being retrieved from the other memory unit at a rate determined by a phase-locked oscillator. The data is extracted from memory one cycle at a time, with each cycle being called for at the beginning of each voltage cycle of the voltage source being loaded. The data leaving the memory unit is converted to analog form by a digital-to-analog (D/A) converter, and then applied as a control signal to the voltage-controlled current sink.

The zero-crossing detector provides a pulse to the controller whenever the source voltage experiences a positive-going zero crossing. This pulse causes the control unit to start extracting the next cycle of data at a data rate controlled by the phase-locked oscillator.

The system concept described above provides the following features:

- The ability to simulate high-power loads
- The ability to operate on both AC and DC supplies
- The ability to track and reproduce high-frequency transients.
- The ability to synchronize a control signal derived at one frequency with a voltage source operating at a different frequency.

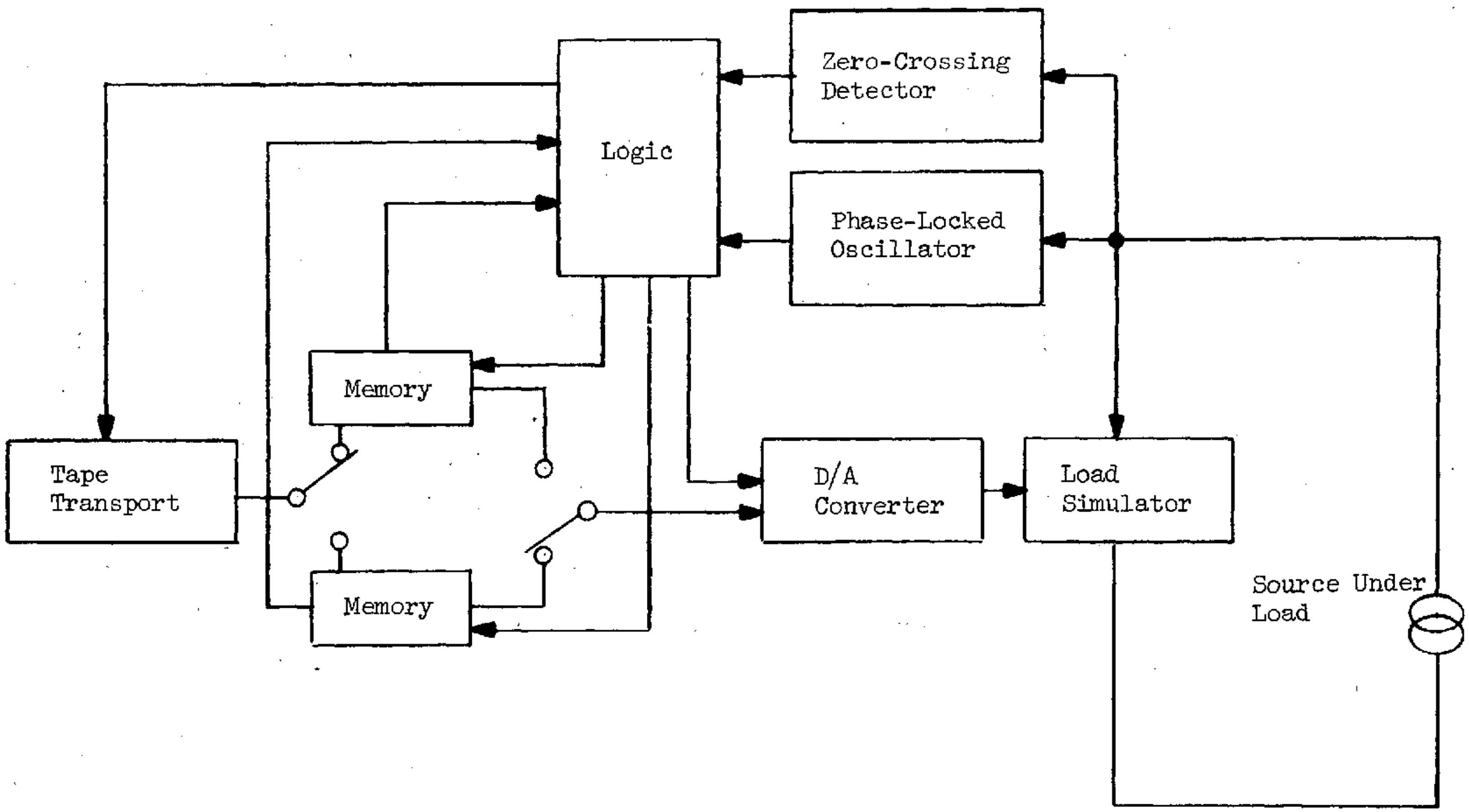

FIGURE 4-9 Block Diagram, Load Simulator with Digital Interface Controls

The Model AC-DC-500 variable R simulator developed under this contract (see Section 5.0 for a description) has been provided with features that will facilitate its use in evaluating the phase shift simulator concept described above. These features include provisions for connection of the bias supplies, careful selection of the power stage transistors, and others.

5.0 DESCRIPTION

The Model AC-DC-500 Variable R Dynamic Electrical Load Simulator provides means for simulating the dynamic and steady-state response of electrical loads on the power lines. Figures 5-1 and 5-2 show front and rear views, respectively, of the simulator.

The variable R can be used to simulate equipment response to application of voltage on the power lines by first interrogating the equipment and computing the input current/voltage ratio, and then using this ratio (conductance analog) as the control signal. The variable R may also be controlled by signals derived from function generators and other such devices.

The variable R simulator is essentially an electronic circuit whose output resistance can be made to vary as a function of a control voltage. It is shown in simplified block diagram form in Figure 5-3. The AC-DC-500 Variable R can be operated in either of two modes (AC or DC), as follows.

> AC Mode:--In the AC mode the variable R will respond to control signals over a frequency range of DC to 10 kHz at current levels as high as 4 amperes (rms), continuous, with AC voltage inputs of 30 to 130 volts (rms) at frequencies from 50 to 440 Hz. The maximum power dissipation is 500 watts, continuous. The unit is capable of operating with transient overloads of up to 10 amperes, peak, for up to 20 milliseconds in duration at a 5 percent duty cycle.

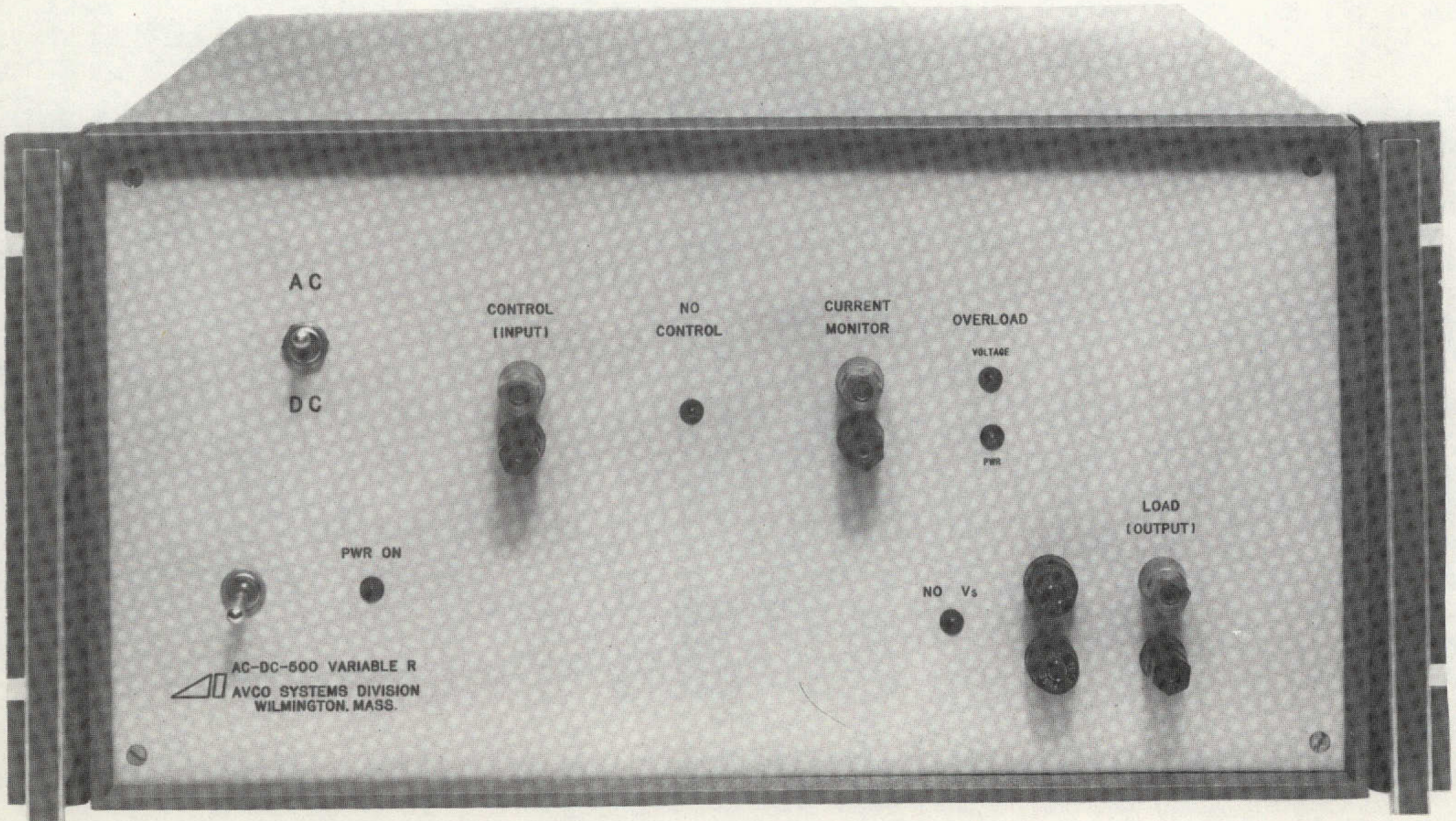

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FIGURE 5-1 Front View, Model AC-DC-500 Variable R Dynamic Electrical Load Simulator

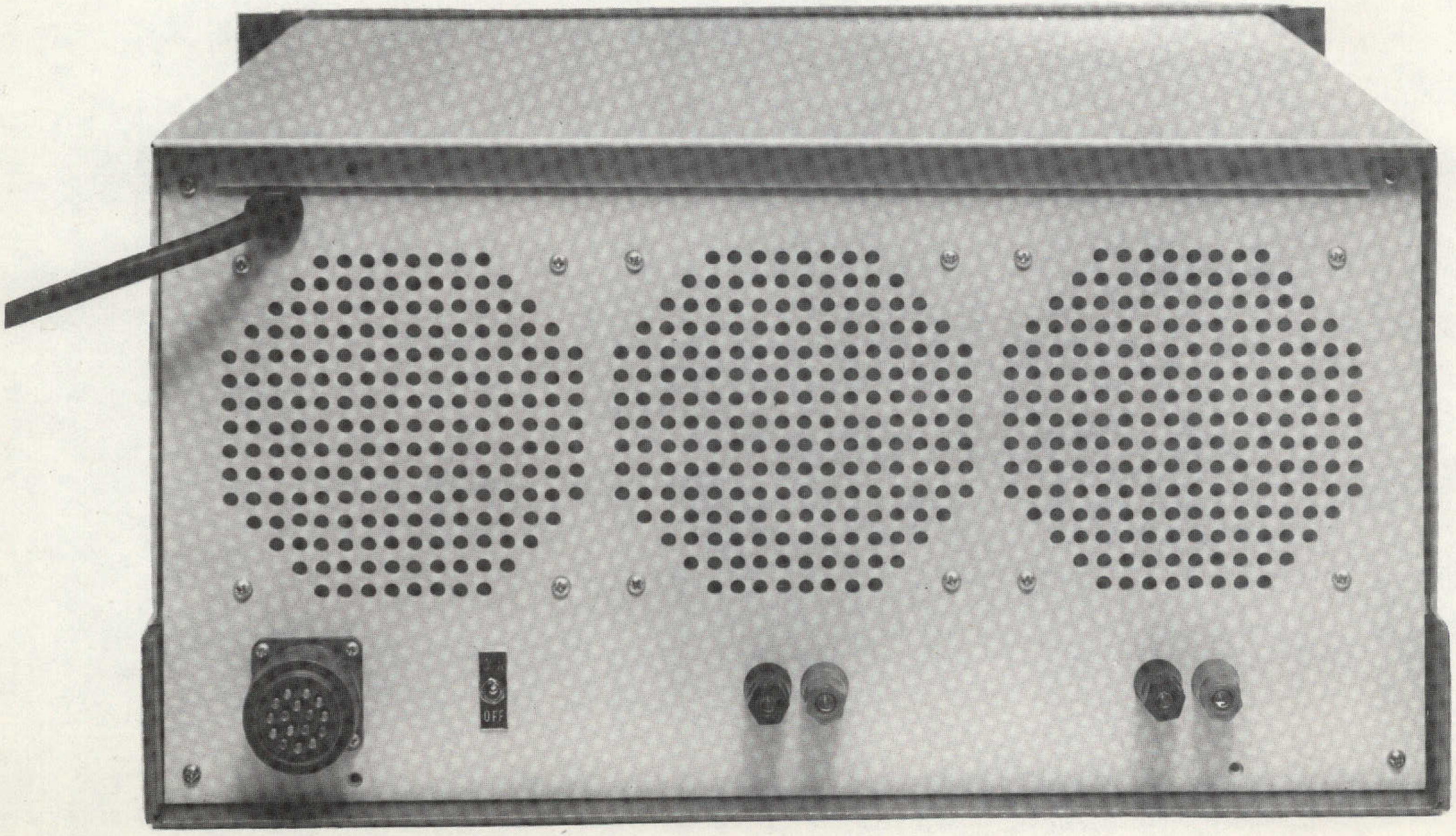

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FIGURE 5-2 Rear View, Model AC-DC-500 Variable R
Dynamic Electrical Load Simulator

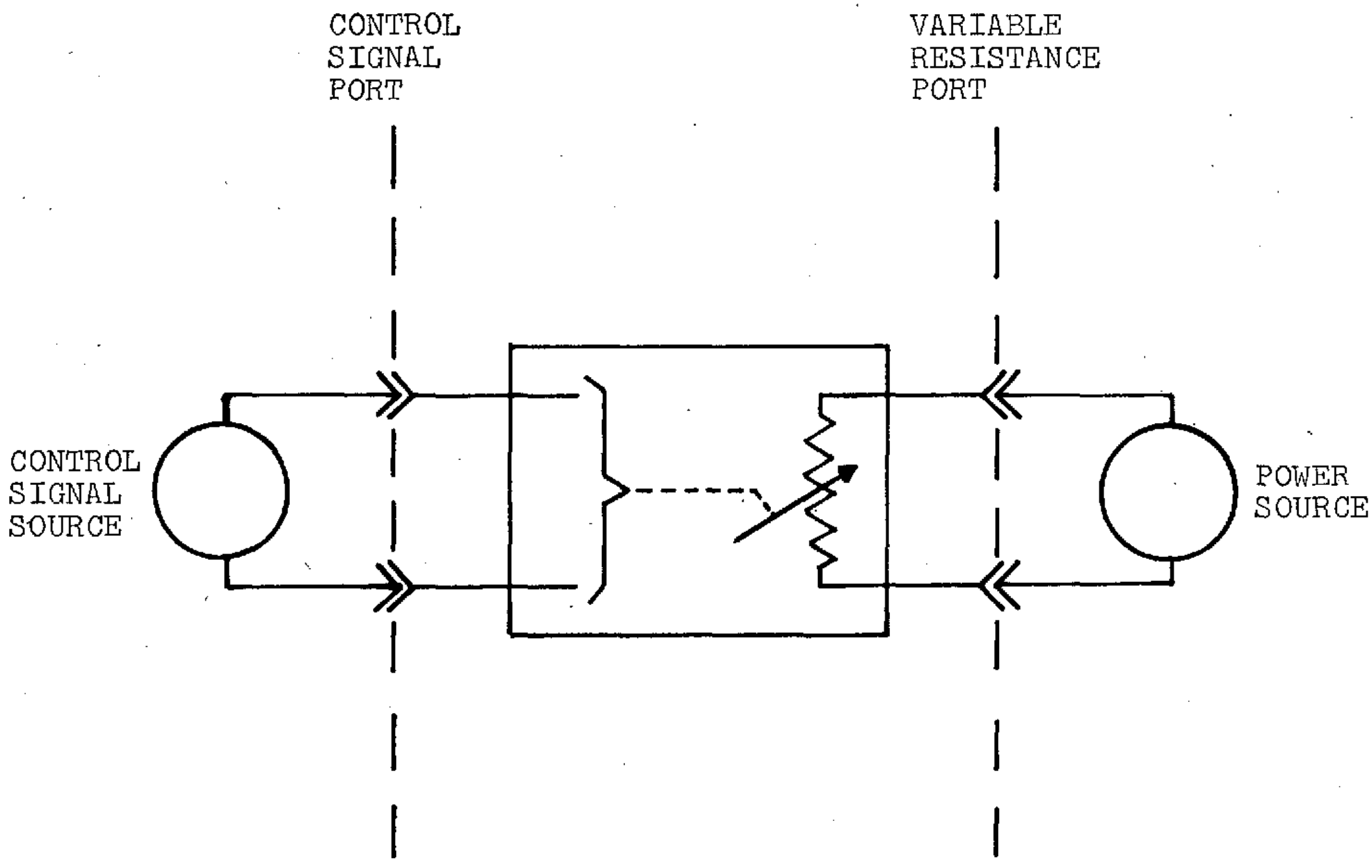

FIGURE 5-3 Variable R Concept - Simplified Diagram

DC Mode:--In the DC mode the variable R will respond to control signals over a frequency range of DC to 10 kHz at load current levels as high as 16 amperes, continuous, with positive, non-zero-crossing, load voltage inputs of 20 to 60 volts. The maximum power dissipation is 500 watts, continuous. The unit is capable of operating with transient overloads of up to 40 amperes (1200 watts) for up to 20 milliseconds in duration at a 5 percent duty cycle.

For a block diagram of the Model AC-DC-500 Variable R, see Figure 5-4.

The Model AC-DC-500 Variable R is housed in an attractive desk-top cabinet with integral cooling. Four rubber-covered feet provide sufficient clearance for circulation of cooling air and also permit stacking of the units. All controls, indicators, and connectors (except for a Remote connector, an Override switch, and two sets of terminals) are located on the front panel. The multi-pin Remote connector, the Override toggle switch (used to override the output relay), and the two sets of binding-post-type terminals (provided for future expansion of the variable R's capabilities) are on the rear panel.

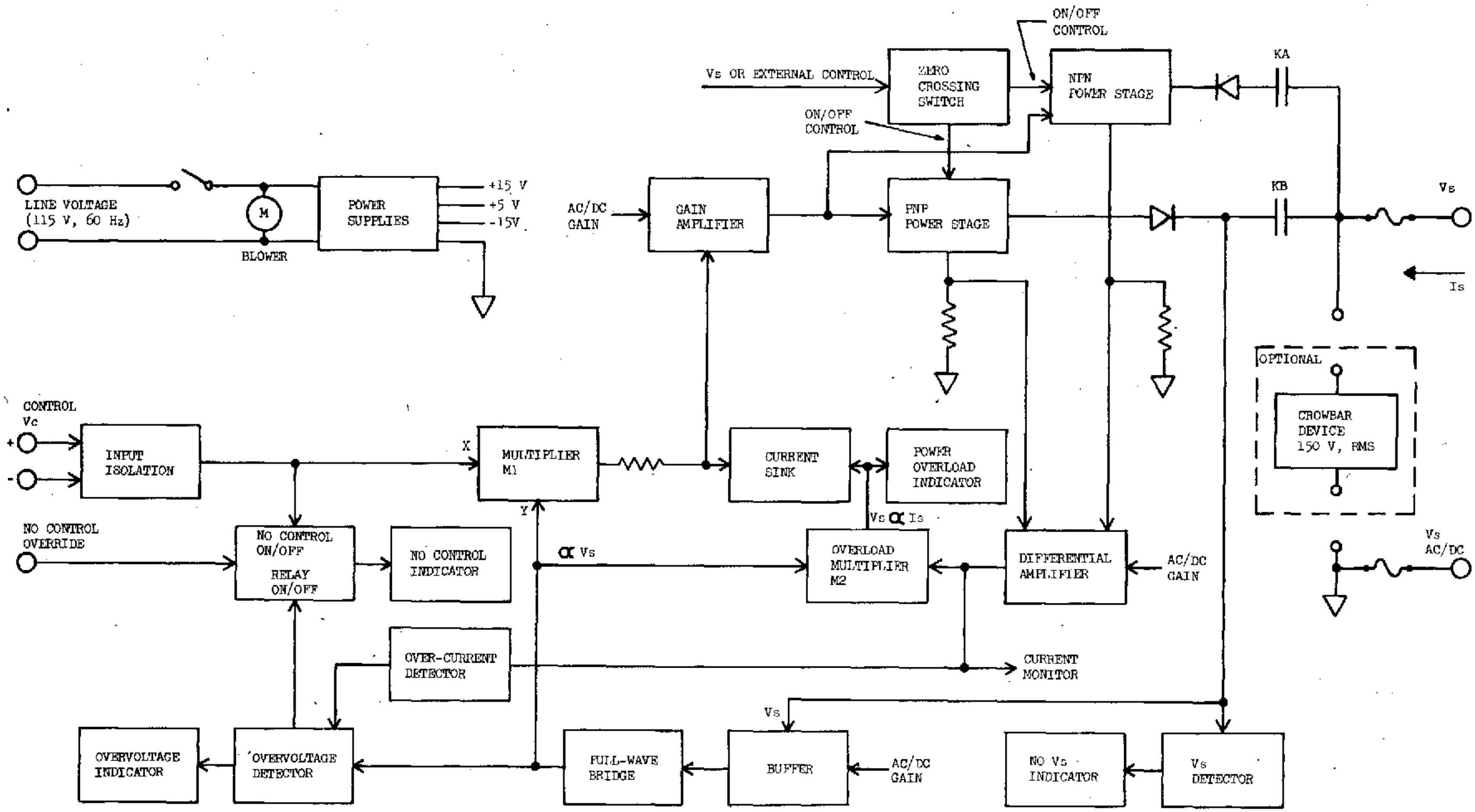

FIGURE 5-4 Block Diagram, Model AC-DC-500 Variable R Dynamic Electrical Load Simulator

5.1 CIRCUIT DESCRIPTION

The AC-DC-500 Variable R consists of an electronic circuit board assembly containing all control and regulation electronics, monitor circuits, and protective circuits; four printed circuit board assemblies for eight power drivers (four NPN and four PNP); interface provisions; and a power supply. Figures 5-5 and 5-6 are schematic diagrams of the AC-DC-500 Variable R. The following paragraphs describe various features of the variable R circuits*.

Input Isolation

The control voltage, Vc, inputs are applied to inverting amplifier stages A13 and A14. A13 inverts the signal on the positive (+) input, and then the signal is summed in amplifier A14, giving unity gain for the differential signal, Vc. The output of amplifier A14 is applied to the X input of multiplier M1. Rejection of the common mode signals (signals from circuit ground to the positive (+) and negative (-) inputs) is based mainly on the match between the resistors chosen for this application.

Multiplier, M1

The X input to the multiplier, M1, is obtained from the input isolation stage. The Y input to M1 is controlled by the adjustable input from the full-wave rectifier circuit (A16 - A22). The multiplier output is proportional to the product of the X and Y inputs, and provides the drive to the power stage. This feature makes the variable R load current (Is) sensitive to the load voltage (Vs) and, therefore, provides a true resistance.

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* The various component reference designations used in the following circuit descriptions correspond directly to those used on typical corresponding circuits shown in the over-all schematic diagrams (Figures 5-5 and 5-6).

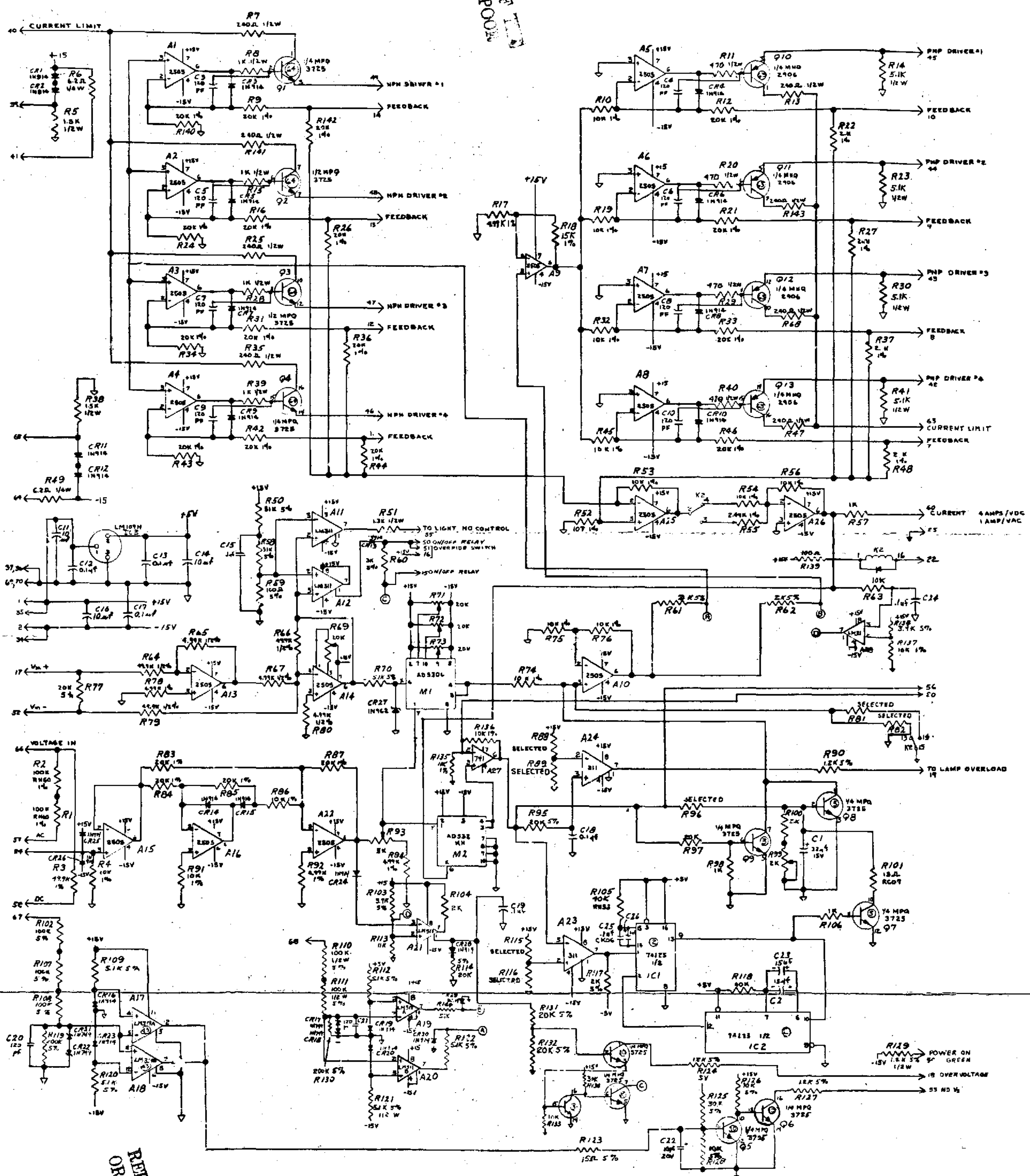


FIGURE 5-5 Schematic Diagram, Control Logic, Model AC-DC-500 Variable R Dynamic Electrical Load Simulator (Avco Drawing 631712)

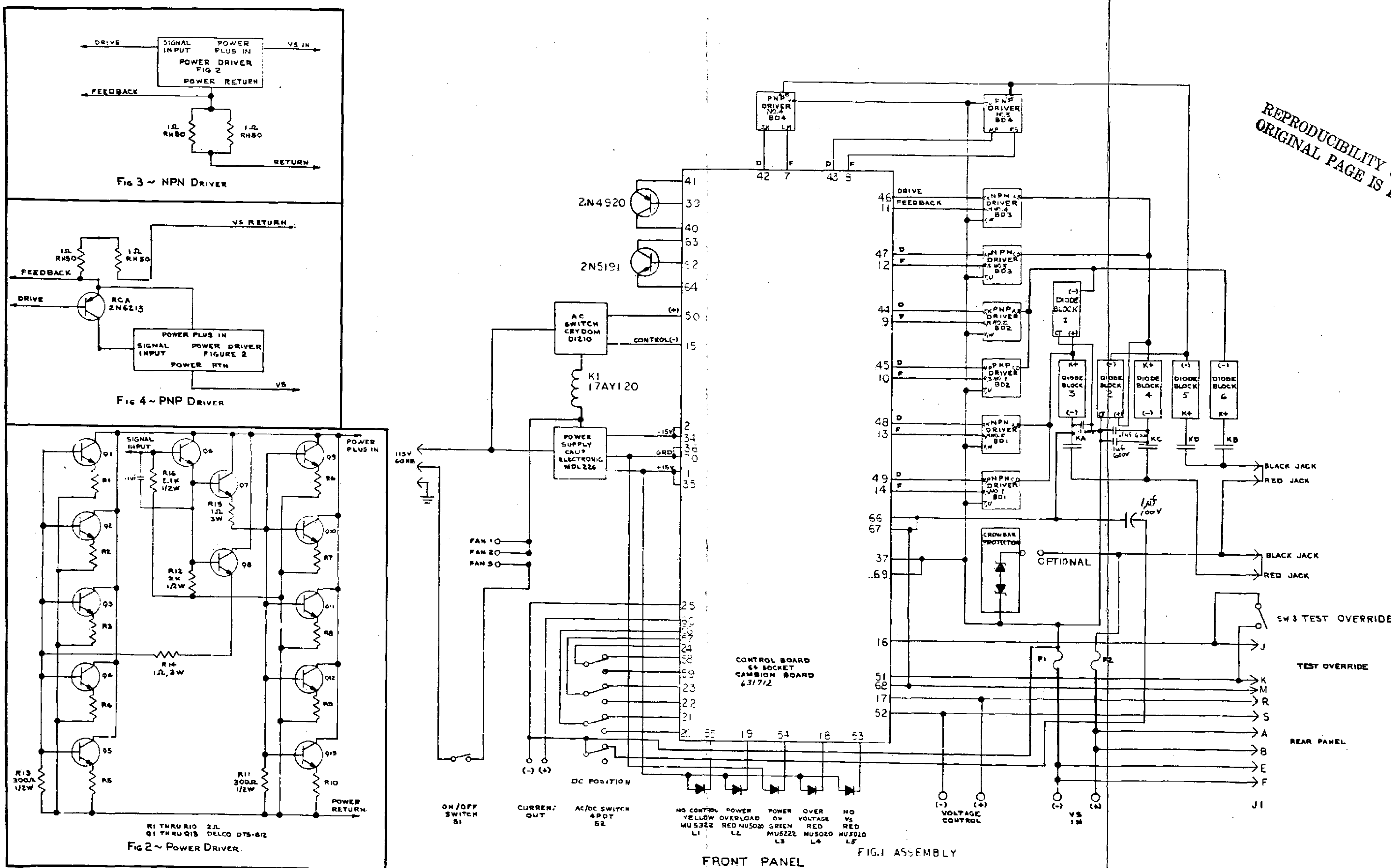


FIGURE 5-6 Schematic Diagram, Model AC-DC-500 Variable R Dynamic Electrical Load Simulator (Avco Drawing 631711)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Input Voltage Conditioner

Either of two load voltage divider circuits is selectable via the AC DC Mode Selector Switch. When this switch is set at the AC position the divider consists of

$$\frac{R4}{R1 + R2 + R4}$$

and when it is set at the DC position the divider consists of

$$\frac{R4}{R3 + R4}$$

The output of the divider circuits is fed into an isolation amplifier, A15, whose output, in turn, is used to drive the full-wave rectifier circuits.

Full-Wave Rectifier

The full-wave rectifier (FWR) consists essentially of two operational amplifier stages arranged in the configuration shown in Figure 5-7. The FWR is necessary to provide positive voltage inputs to the multiplier, M1, for both positive and negative values of the load voltage, Vs.

Operation of this circuit may best be understood by following the signal path for both the negative and the positive inputs. The circuit components referred to in the following description are those shown in Figure 5-7, the schematic diagram of the full-wave rectifier.

Negative Input Signal:--When a negative signal is applied to the input terminals the output of amplifier A16 is clamped to +0.7 volts by diode CR14, and is disconnected from the summing point of amplifier A22

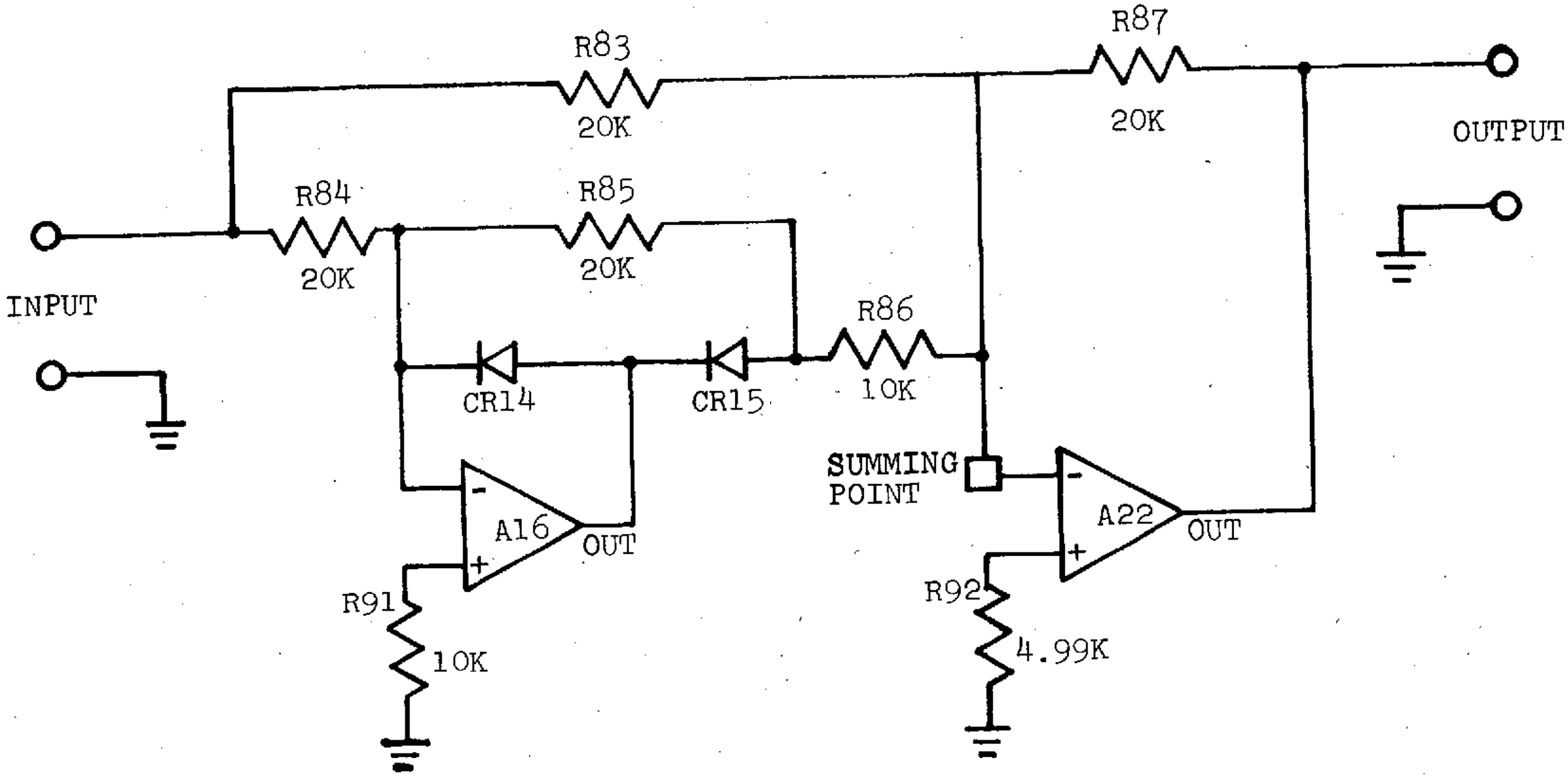


FIGURE 5-7 Schematic Diagram, Full Wave Rectifier
(Absolute Value Circuit)

by a reverse-biased diode, CR15. Since the inverting input to amplifier A16 is maintained at zero volts by the feed-back diode, CR14, the only input to amplifier A22 is that provided via resistor R83. Thus, amplifier A22 functions as a single-input, unity-gain, inverting amplifier, and negative signals at the input terminals of the FWR appear as positive signals (of the same amplitude) at the output terminals of the FWR. The gain of the FWR for negative input signals, $G_{FWR\,(-)}$, is, therefore,

$$G_{FWR\,(-)} = - R87/R83$$

<u>Positive Input Signal</u>:--When a positive signal is applied to the input terminals amplifier A16 functions as an inverting amplifier, driving the summing point of amplifier A22 through resistor R86. The input signal is also applied to the A22 summing point through resistor R83. The A22 summing point, then, has two inputs. These, after being added and inverted in A22, appear at that amplifier's output terminals. The gain of the FWR for positive input signals, $G_{FWR\,(+)}$, is, therefore,

$$\begin{aligned} G_{FWR\,(+)} &= G_{A22\,(R83)} + G_{A16\ A22\,(R86)} \\ &= -\left(\frac{R87}{R83}\right) + \left[\left(-\frac{R85}{R84}\right)\left(-\frac{R87}{R86}\right)\right] \\ &= -\frac{R87}{R83} + \frac{R85\ R87}{R84\ R86} \end{aligned}$$

Multiplier Gain Selector Amplifier, A10

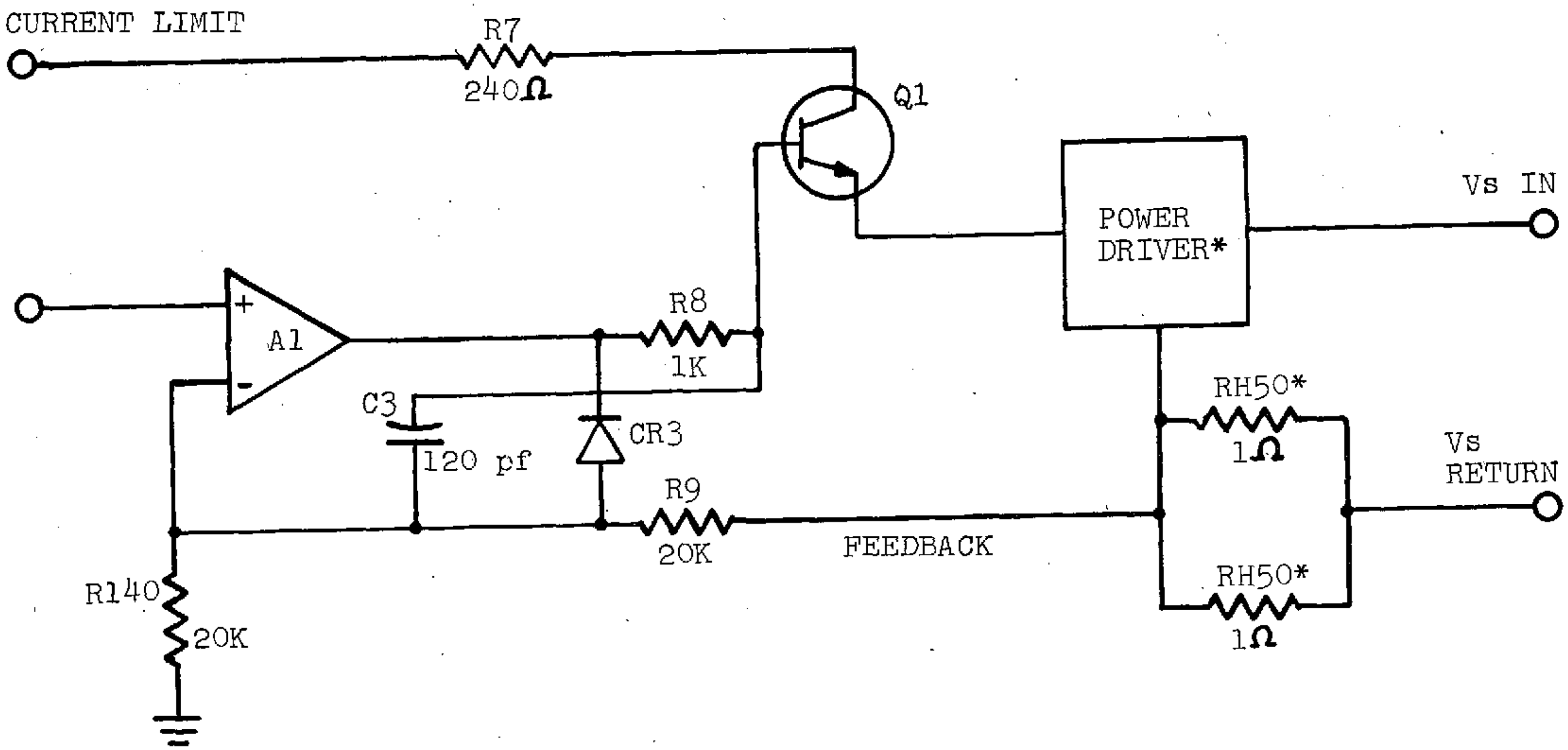
The variable R provides a separate system gain for each mode (AC and DC) to assure optimum dynamic range for each mode. Amplifier A10, in conjunction with the AC DC Mode Selector Switch, provides the means for selecting the gain. The output of A10 is buffered by two 2 Kohm resistors (R61 and R62) to provide capability for ON/OFF strobing of the output stage by the zero crossing detector.

NPN Power Stage

The variable R contains four NPN power stages mounted, 2 to a board, on two fiberglass circuit boards. The NPN stages, which operate in conjunction with appropriate power drivers (see Figure 5-6), are used for all positive load voltage inputs. Each NPN power stage consists essentially of an operational amplifier driver and a driver transistor. The power stage, which operates from the 15-volt supply, controls the power driver associated with it. The control current is monitored via two parallel 1-ohm resistors (RH50) that provide feedback to the amplifier. Figure 5-8 is a schematic diagram on an NPN power stage.

PNP Power Stage

The variable R contains four PNP power stages mounted, 2 to a board, on two fiberglass circuit boards. The PNP stages, which operate in conjunction with appropriate power drivers (see Figure 5-6), are used for all negative load voltage inputs. Each PNP power stage consists essentially of an operational amplifier driver and a driver transistor. The latter is a high-voltage type unit. The power stage, which operates from the 15-volt supply, controls the power driver associated with it. The control current is monitored via two 1-ohm resistors (RH50) connected in series with the load current to provide feedback to the amplifier. Figure 5-9 is a schematic diagram of a PNP power stage.



* REFERENCE DRAWING
NUMBER 631711

FIGURE 5-8 Schematic Diagram, Typical NPN Power Stage

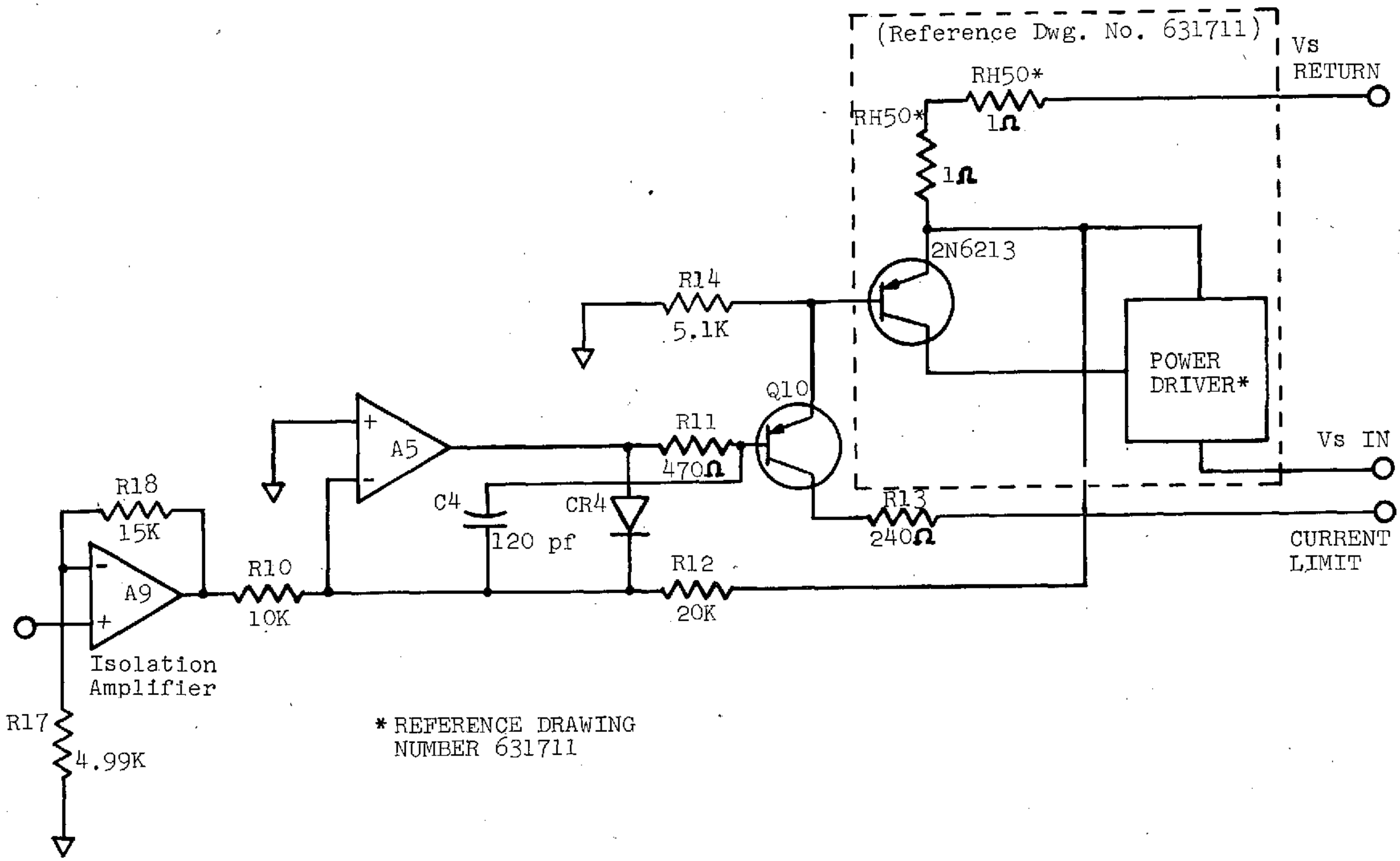


FIGURE 5-9 Schematic Diagram, Typical PNP Power Stage

Differential Current Monitor

The differential output current monitor consists basically of amplifiers A25 and A26. A25 is a differential driver that receives positive input signals from the NPN power stages and negative input signals from the PNP power stages. The gain of amplifier A26, selectable by the AC DC Mode Selector Switch, provides separate transfer characteristics for AC and DC operation. The current monitor's calibration is such that it provides approximately 4 amperes per volt for DC operation, and one ampere per volt for AC operation. The current monitor output is unipolar for both AC and DC operation.

No Load Voltage Monitor

A red lamp (L5) is used to indicate when the voltage applied to the LOAD (OUTPUT) terminals is less than a pre-established level. It lights when the voltage at these terminals is less than 5 volts, peak. The monitor used in conjunction with the indicator lamp consists basically of comparators A17 and A18.

Crossover Detector

The crossover detector activates either the NPN or the PNP power stages according to the polarity of the input voltage. Comparators A19 and A20 detect input voltages greater than 5 volts and then turn on the power stages (NPN or PNP) appropriate to the polarity of the input voltage detected.

5.2 TRANSFER CHARACTERISTICS

The variable R provides two different transfer characteristics--one for AC operation and the other for DC operation.

The source current, Is, is given by the following expression

$$Is = (G1\ Vc)\ (K1)\ (G2)\ (G3)\ (G4)\ (K2\ Vs)$$

where

G1	=	Gain of A13 - A14 isolation stage
Vc	=	Control voltage
K1	=	Multiplier constant (~1/10), 1/volts
G2	=	Gain of A10
G3	-	Gain of power stage, amperes/volts
G4	=	Gain of full-wave rectifier
K2	-	Gain of load voltage multiplier (= 1/6 for DC, = 1/21 for AC)
Vs	=	Source voltage

Transfer characteristic curves for AC and DC operation are shown in Figures 5-10 and 5-11, respectively.

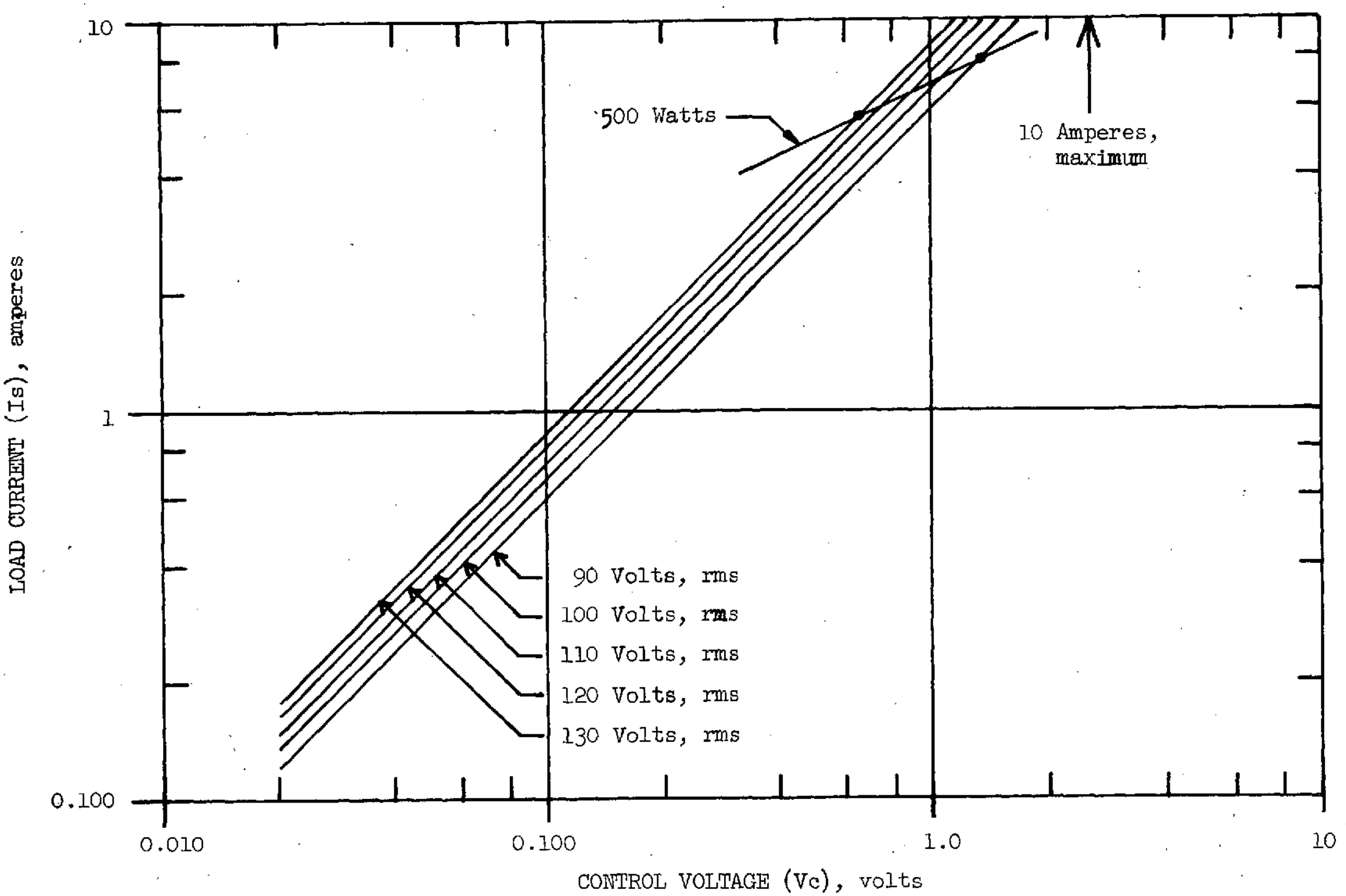


FIGURE 5-10 Transfer Characteristic, AC Mode Operation, Model AC-DC-500 Variable R Dynamic Electrical Load Simulator

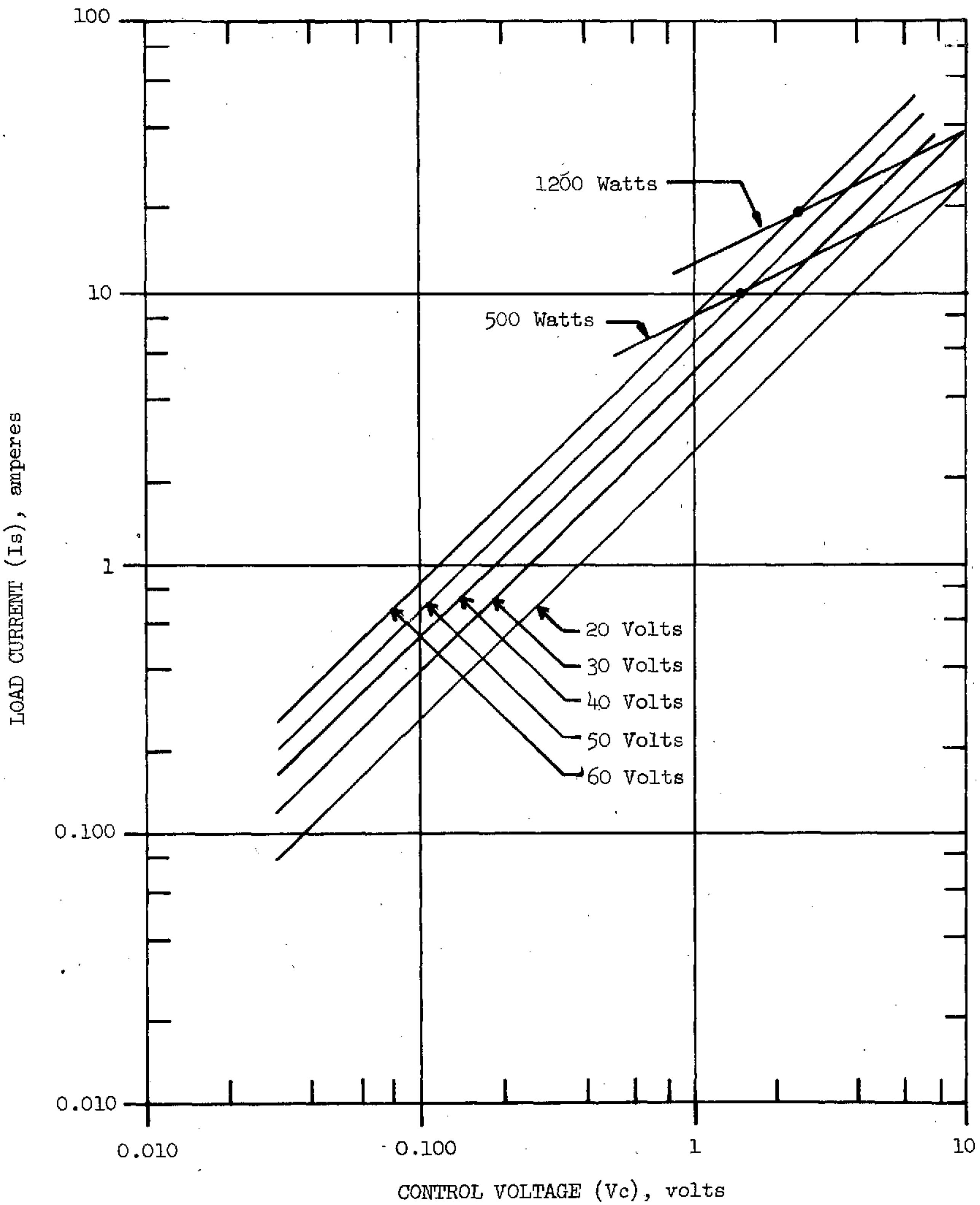


FIGURE 5-11 Transfer Characteristic, DC Mode Operation, Model AC-DC-500 Variable R Dynamic Electrical Load Simulator

5.3 PROTECTIVE FEATURES

The Model AC-DC-500 Variable R incorporates the following features for protection against overloads and other abnormal conditions.

5.3.1 Over-Voltage Protection

Over-voltage protection is provided by comparator A21. The comparator senses the over-voltage condition and locks the source voltage off. This releases the ON/OFF relay, thereby opening the circuit from the load terminals, and lights a red lamp, L4, to indicate that an over-voltage conditions exists. In addition to the protection provided via opening of the relay, the variable R can also be protected against fast transients by an optional crowbar device. The device is rated at 150 volts, rms, and is capable of accommodating 150 amperes. The crowbar device can be connected if desired. Sustained operation of this device would cause the input protection fuses to open.

5.3.2 Power Overload Protection

Multiplier M2 performs a product function whereby the load current (Is) and load voltage (Vc) are sensed and used to drive M2 to provide an output proportional to the output power (Vs Is). The output of M2, amplified by A27, is used to drive a threshold detector, Q8, to limit the drive to the power stages. Any Vs Is product exceeding the threshold value will prevent further drive to the power stages, thereby limiting power. The power limit is set at 500 watts, maximum. A separate threshold detector comparator, A24, is used to drive a red lamp, L2, to indicate existence of a power overload condition.

5.3.3 Peak Power Overload Protection

A third threshold detector circuit (transistor Q9) is employed as a peak power limiter. It limits the peak power to 1200 watts.

A duty cycling limiting circuit in the DC power limiter: (1) prevents the DC limiter from limiting the peak power handling capability for short pulses, and (2) imposes on the simulator a duty cycle of approximately 5 percent should the overload exceed 1200 watts for 20 milliseconds. It should be noted that the DC limit will take effect after the low-pass filter capacitor, C1, becomes charged to the threshold value of the DC limiter. C1 is periodically discharged when the timing circuit (R118, C2, C23, and monostable multivibrator, MSMV, IC2) times out, allowing the comparator to discharge the DC limit capacitor, C1.

If an over-power condition persists, the operating sequence is as follows:

1. The peak power limiter, Q9, limits peak power.
2. The DC limiter turns on after the pulse width of the control signal reaches 20 milliseconds for 1200 watts power--and for pulse widths greater than 20 milliseconds for reduced power dissipation. (Generally, the lower the power to be dissipated, the wider the pulse that can be tolerated.)
3. At the same time that the peak power occurs, the timing circuit (R118, C2, C23, and IC2) starts timing. Approximately 400 milliseconds later it allows another peak power pulse to occur by discharging the DC limiter and starting the cycle over again.

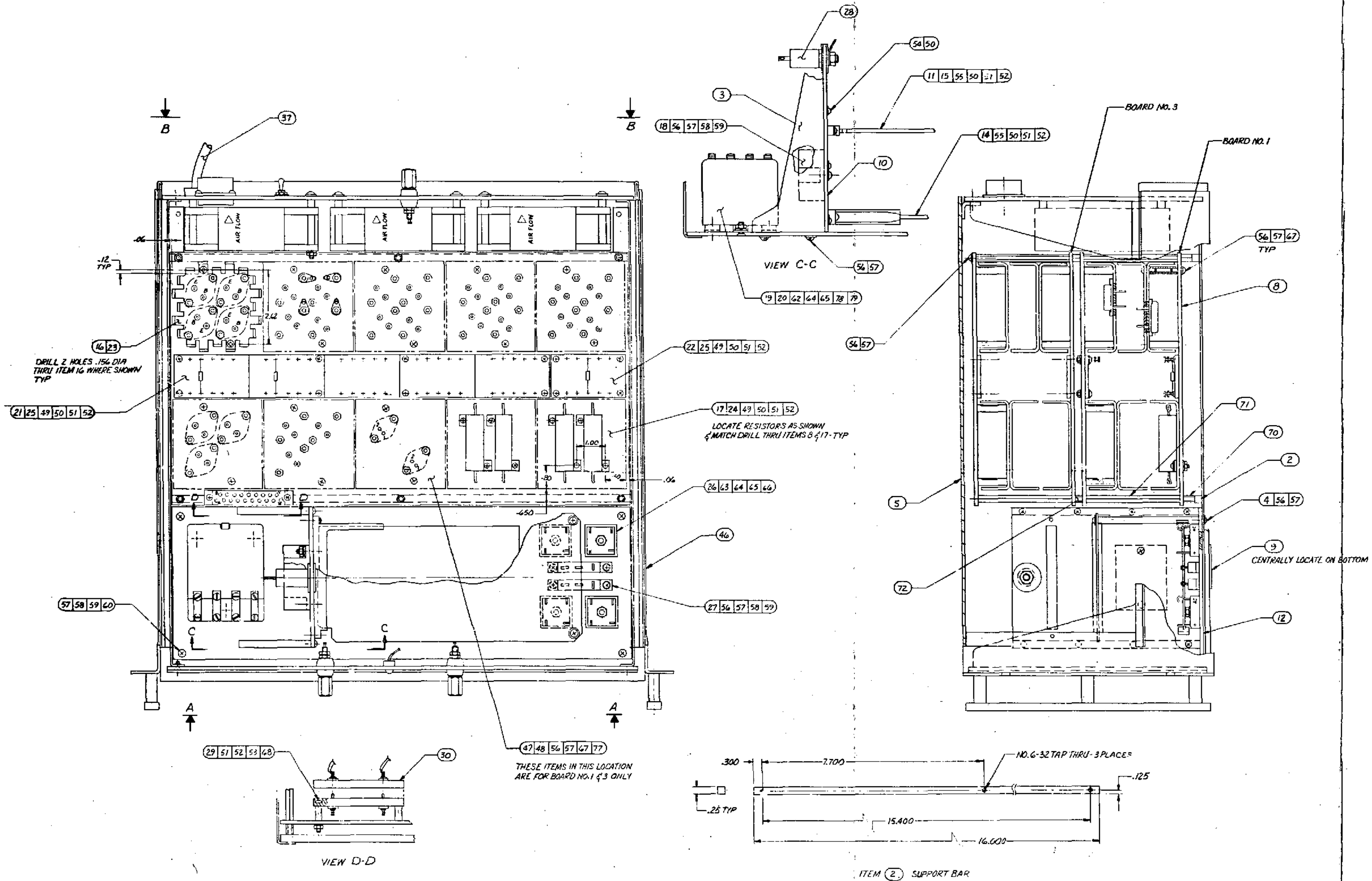
5.3.4 Over-Current Protection

A comparator, A28, on the output of the current monitor is used to detect any peak currents in excess of 44 amperes DC or 11 amperes AC. The output of the comparator actuates the over-voltage protection circuit; releases the ON/OFF relay, thereby opening the circuit from the load terminals; and lights the red over-voltage lamp, L4, to indicate that an over-current condition exists. The LOAD input terminals (and the loads connected to them) are protected with fuses that will open: (1) if the crowbar device operates (if this optional device is connected), or (2) if there is a component failure that causes sustained excessive source (load) current.

5.4 ASSEMBLY

The Model AC-DC-500 Variable R is housed in a standard, instrument-type, desk-top enclosure with provisions for mounting in a standard 19-inch-relay-rack-type console. The unit measures approximately 19 inches wide, by 8-3/4 inches high, by 18 inches deep. The control electronics, protective components, and monitor circuits are located on wire-wrap circuit boards. The 15-volt power supply is located on a separate circuit board. Figures 5-12 and 5-13 show the assembly of the Model AC-DC-500 Variable R. Figure 5-6 shows the interconnecting wiring. Figure 5-14 indicates the internal arrangement of the components. Figure 5-15 is a photograph of the printed circuit assembly.

The power drivers are mounted on fiberglass boards with appropriate heat sinks for power dissipation. Two such boards are used for the four NPN (positive) power driver assemblies; two others for the four PNP (negative) power driver assemblies. These variable R power assemblies, which operate in conjunction with the power stages described in Paragraph 5.1, above, are cooled by three fans located at the rear of the assembly.



QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL OR NOTE	SPECIFICATION	ZONE	ITEM NO.
3		NO. 16415	CORD		ROTRON		81
12		NO. 8427	SPACER		H.H. SMITH		80
AR		C-01-511	TERMINAL		SCOTCH		79
AR		B-01-512	TERMINAL		SCOTCH		78
4		NO. 4066	INSULATOR		THERMALLOY		77
AR		NO. 16 & NO. 18 AWG	WIRE		MIL-W-16878/4		76
AR		AWG 18 THRU AWG 26	INSULATION TUBING				75
AR		AWG 16 UNINSUL	BUS WIRE				74
AR		NO. 20140	BRONZE PAINT		FED-STD 595		73
6			STANDOFF				72
12			STANDOFF				71
6			STANDOFF				70
12		NO. 8501	SPACER		H.H. SMITH		69
8		NO. 8483	SPACER		H.H. SMITH		68
60		NO. 8848	SPACER		H.H. SMITH		67
4		NO. 8-32 UNC-2A x 5/16 LG	SCREW FL HD 100°				66
7		NO. 8-32 UNC-2B	NUT				65
7		NO 8	WASHER, LOCK				64
4		NO. 8	WASHER, FLAT				63
3		NO. 8-32 UNC-2A x 3/4 LG	SCREW FL HD, 100°				62
4		NO. 6-32 UNC-2A x 2 1/4 LG	SCREW, RD HD, PHILLIPS				61
12		NO. 6-32 UNC-2A x 3/4 LG	SCREW, RD HD, PHILLIPS				60
22		NO. 6-32 UNC-2B	NUT				59
22		NO. 6	WASHER, LOCK				58
152		NO. 6	WASHER, FLAT				57
136		NO. 6-32 UNC-2A x 1/2 LG	SCREW, RD HD, PHILLIPS				56
4		NO. 4-40 UNC-2A x 3/16 LG	SCREW, RD HD, PHILLIPS				55
8		NO. 4-40 UNC-2A x 5/16 LG	SCREW, RD HD, PHILLIPS				54
8		NO. 4-40 UNC-2A x 1.0 LG	SCREW, RD HD, PHILLIPS				53
96		NO. 4-40 UNC-2B	NUT				52
96		NO. 4	WASHER, LOCK				51
96		NO. 4	WASHER, FLAT				50
84		NO. 4-40 UNC-2A x 1/4 LG	SCREW, RD HD, PHILLIPS				49
4		2N6213	TRANSISTOR		RCA		48
2		HP3-T066-11CB	HEAT SINK		IERC		47
1		K-081716R	ENCLOSURE		OPTIMA 17 ENCLOSURE SCIENTIFIC ATLANTA		46
2			FUSE	20 AMP	BUSSMANN		45
2		HKP	FUSEHOLDER		BUSSMANN		44
3		MV 5020	DIODE-LIGHT EMIT	RED	MONSANTO		43
1		MV 5322	DIODE-LIGHT EMIT	YELLOW	MONSANTO		42
1		MV 5222	DIODE-LIGHT EMIT	GREEN	MONSANTO		41
1		82606	SWITCH DPST		ARROW HART		40
1		7561K4	SWITCH DPST		CUTLER HAMMER		39
1		R-6 BLACK	S/R BUSHING		RICHLOCK		38
1		616-3 COND 18 AWG	POWER CORD		ALPHA		37
1		SP-3	SWITCH PLATE		ALCOSWITCH		36
1		JMT 123	SWITCH SPDT		C-B-T INSTR		35
1		PT02P-20-16S	CONNECTOR		BENDIX		34
3		747	FAN		ROTRON		33
5		DF 30 BC	BINDING POST		SUPERIOR ELECT		32
5		DF 30 RC	BINDING POST		SUPERIOR ELECT		31
4		MS 14-19	CONNECTOR		DALE		30
4		MP 14-19	CONNECTOR		DALE		29
1		LVC-1LD	CROWBAR		MCS ELECTRONICS		28
2		681D	BRIDGE		UNITRODE		27
4		679	BRIDGE		UNITRODE		26
			RESISTOR				25
16		RH50, 30W, 1Ω, 1%	RESISTOR				24
104		DTS 812	TRANSISTOR		DELCO ELECT DIV		23
4		-13	TERMINAL BOARD	MAKE FROM NO. 15236 FROM KEYSTONE ELECT			22
4		15236	TERMINAL BOARD		KEYSTONE ELECT		21
1		350203	ENCLOSURE		POTTER BRUMFIELD		20
1		PM17DY24	RELAY		POTTER BRUMFIELD		19
1		D1210	RELAY		INTERNATL RECTIFIER		18
8		HP3-000-CB	HEAT SINK		IERC		17
48		HP3-T03-11CB	HEAT SINK		IERC		16
1		706-7029-01-00-00	CARD CONNECTOR		CAMBION		15
1		NO. 226	POWER SUPPLY		CALIF ELECT		14
REF		631711	SCHEMATIC DIAGRAM				13
1		631720-1	INSULATOR BOARD				12
1		631719-1	COMPONENT BD ASSY				11
1		631718-1	SUPPORT PLATE				10
2		631717-1	PLATE IDENT				9
2		631716-1	HEAT SINK BOARD NO 1				8
1		631715-1	REAR PANEL				7
1		631714-1	SUB PANEL				6
1		-11	COVER	MAKE FROM COVER SUPPLIED WITH ITEM 46	OPTIMA 17 ENCLOSURE SCIENTIFIC ATLANTA		5
2		-9	STANDOFF	MAKE FROM NO. 8354	H.H. SMITH		4
2		-7	SUPPORT BRACKET	AL 6061-T6 .25T [illegible]	(3)		3
2		-5	SUPPORT BAR	AL 6061 T6	QQ-A-250/11 (5)		2
1		-3	DRESS PANEL	MAKE FROM [illegible]	OPTIMA 17 ENCLOSURE SCIENTIFIC ATLANTA		1
-1	← NEXT NO						

LIST OF PARTS

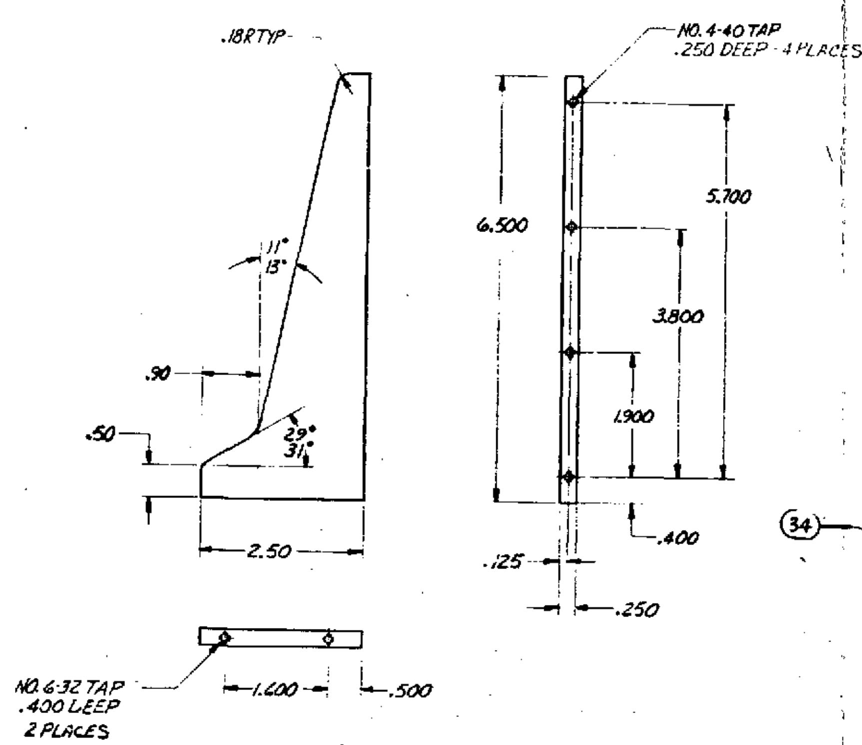
FIGURE 5-12 Assembly, Model AC-DC-500 Variable R
Dynamic Electrical Load Simulator
(Avco Drawing 631713, Part 1)

FOLDOUT FRAME 1

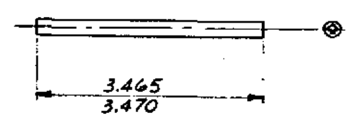
FOLDOUT FRAME 2

NOTES

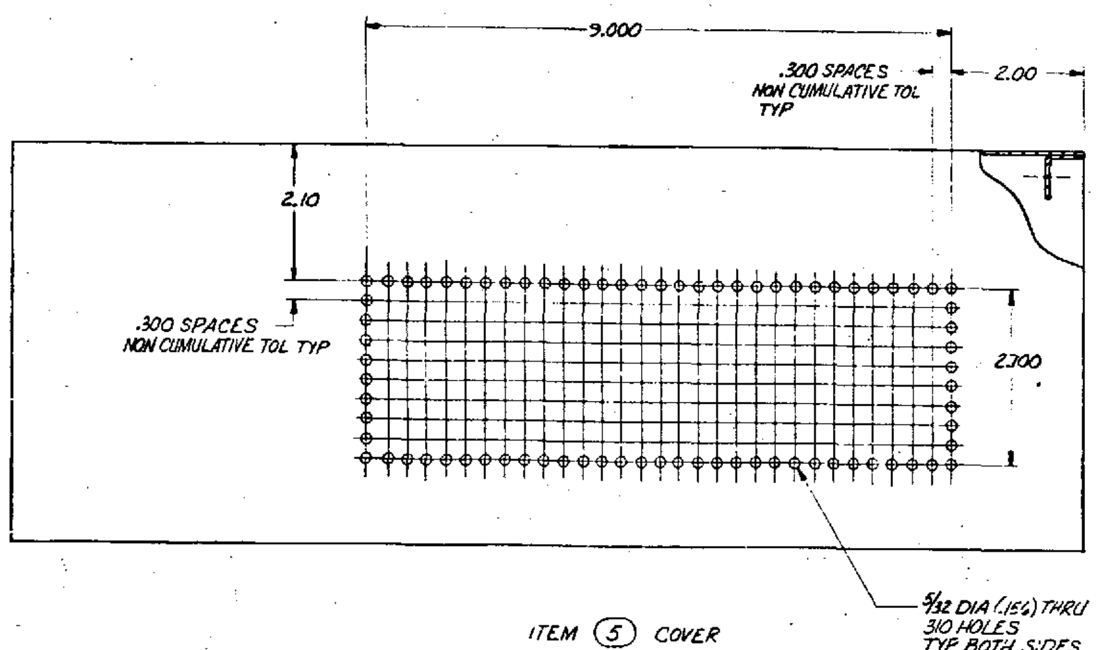
1. PAINT BRONZE COLOR NO. 20140 PER FED-STD-595
2. ALL HARDWARE OF THE SAME BASIC IDENTIFICATION MAY BE INTERCHANGED ONE INCREMENT LARGER OR SMALLER THAN THAT SPECIFIED
3. FINISH: COMMERCIAL ALODINE



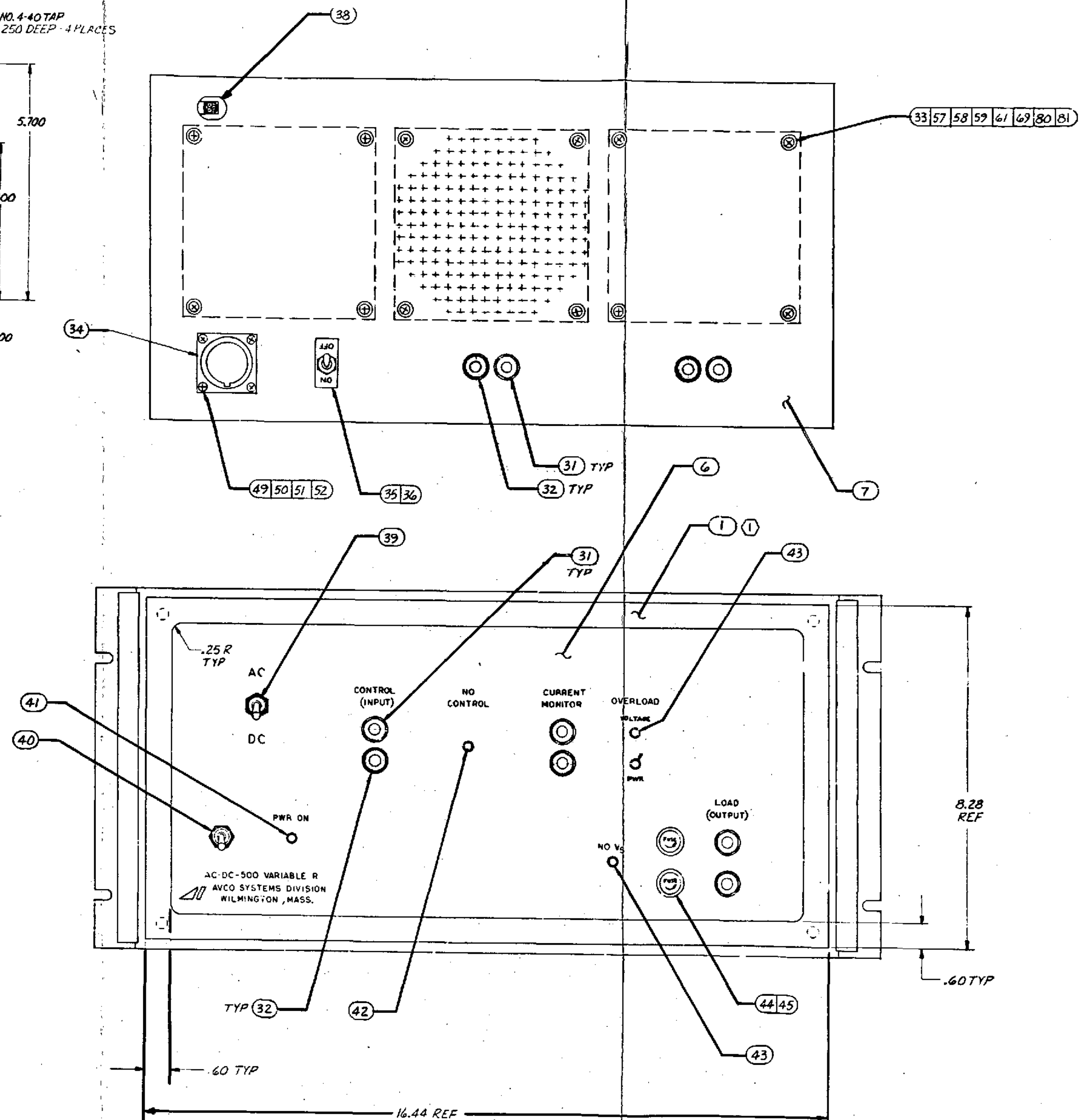
ITEM (3) SUPPORT BRACKET (3)



ITEM (4) STANDOFF



ITEM (5) COVER



FOLDOUT FRAME 1

FIGURE 5-13 Assembly, Model AC-DC-500 Variable R Dynamic Electrical Load Simulator (Avco Drawing 631713, Part 2)

FOLDOUT FRAME 2

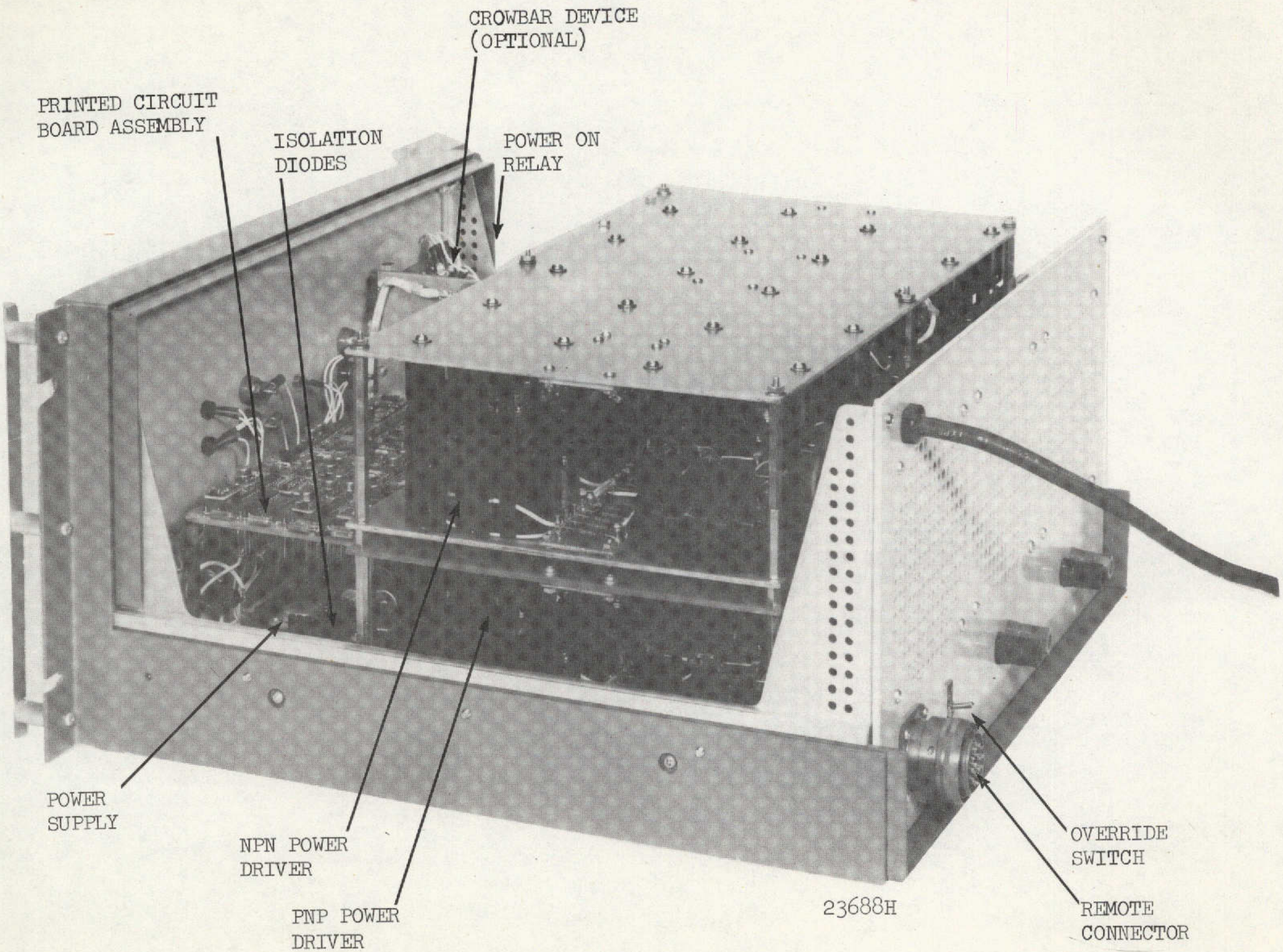
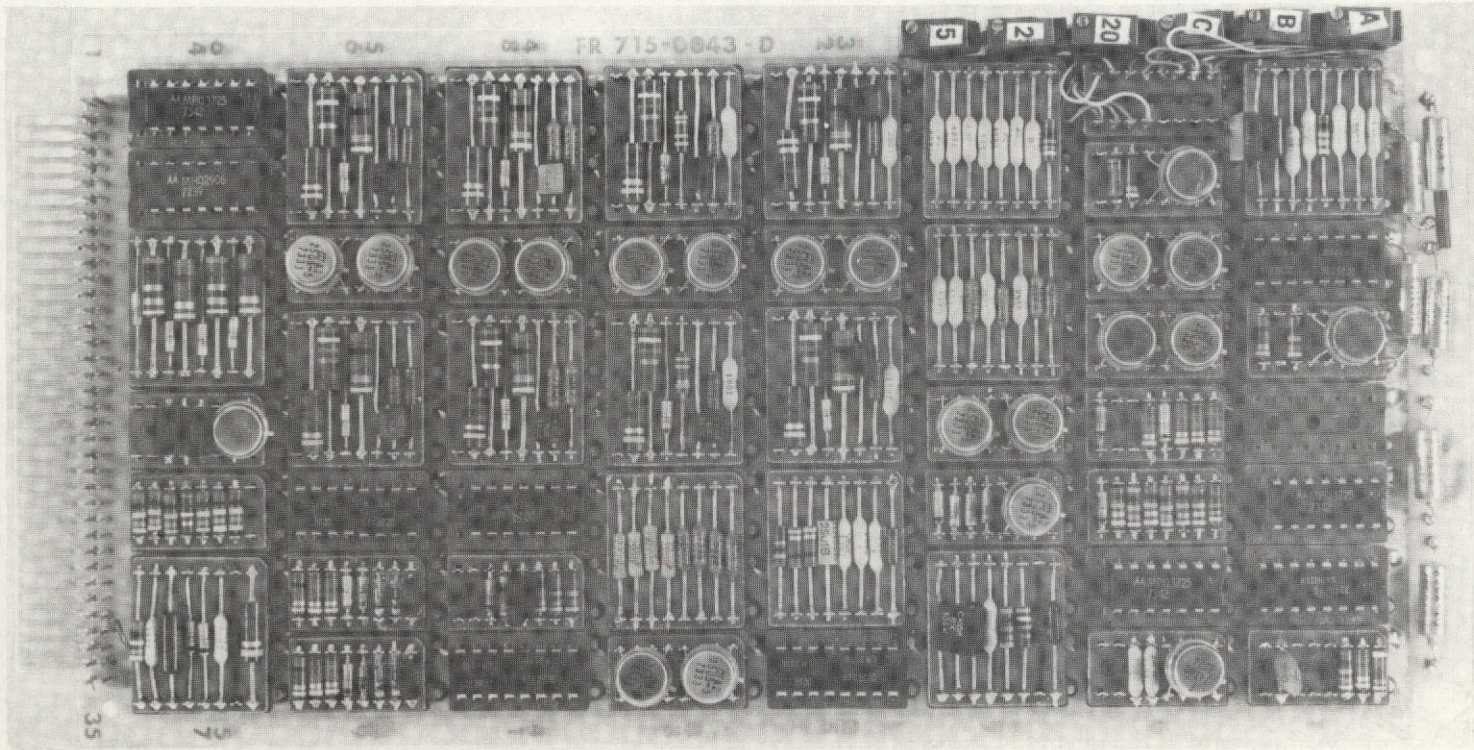


FIGURE 5-14 Internal Arrangement, Model AC-DC-500
Variable R Dynamic Electrical Load Simulator



23688I

FIGURE 5-15 Printed Circuit Assembly, Model AC-DC-500
Variable R Dynamic Electrical Load Simulator

5.5 SPECIFICATIONS

5.5.1 Electrical

DC Mode:

Load Voltage	+20 VDC to +60 VDC
Load Current	
Continuous	Up to 16 amperes
Transient	Up to 40 amperes, peak, for 20 milliseconds, maximum, at a 5 percent duty cycle
Power Dissipation (Continuous)	Up to 500 watts
Transient Response	Less than 50 microseconds
Control Voltage	+0.1 to +10 volts, DC to 10 kHz

AC Mode:

Load Voltage	30 to 130 volts, rms, 50 to 440 Hz, single-phase
Load Current	
Continuous	Up to 4 amperes, rms
Transient	Up to 10 amperes, peak, for 20 milliseconds, maximum, at a 5 percent duty cycle
Power Dissipation (Continuous)	Up to 500 watts, rms
Transient Response	Less than 50 microseconds
Control Voltage	+0.1 to +10 volts, DC to 10 kHz

5.5.2 General

Power Requirements	115 volts, 60 Hz, single-phase
Size	19" W x 8-3/4" H x 18" D
Environment	Laboratory ambient (temperature 25° C, nominal)

6.0 HIGH POWER AC/DC VARIABLE R EVALUATION

Performance evaluation tests were conducted on the high power AC/DC variable R simulator circuits to: (1) assess their ability to satisfy design objectives, and (2) determine the effectiveness of the various protective features. Both burn-in and acceptance tests were carried out on each deliverable unit. In addition, demonstration testing was conducted at NASA JSC. The following paragraphs of this section briefly summarize the burn-in and acceptance tests and describe the results of the demonstration testing.

6.1 BURN-IN TESTS

Each unit was subjected to a minimum of 80 hours of burn-in testing at greater than 80 percent of rated load. The testing was carried out in two steps--static burn-in and transient burn-in.

During static burn-in a control voltage input adjusted to yield a load current of 4.1 amperes at a load voltage of 115 volts, 60 Hz, was applied to each simulator. In general, burn-in testing on a unit was conducted in 6- to 8-hour time segments until a cumulative time of greater than 80 hours was reached.

Transient burn-in testing was conducted at a load voltage setting of 30 volts, DC. A pulse generator was used to provide a train of pulses at a duty cycle of 10 percent to the control terminals. A minimum of 100 pulses was applied to each unit. The pulse width was set at 10 milliseconds to maintain the load energy at a level consistent with the capabilities of the power sources available.

6.2 ACCEPTANCE TESTS

Acceptance tests were conducted on each unit prior to its delivery. These tests determined the static transfer characteristic, verified the operating levels of the protective circuits, and verified other performance features.

6.2.1 Static Transfer Characteristics

The static transfer characteristics of both units were determined at load voltages of 20, 30, 50, and 60 volts, DC, and at 110 volts, 60 Hz. In addition, the static transfer characteristic at 115 volts, 400 Hz was determined on Unit 1. Data taken during these tests was provided with the units, and is shown in Appendix B of this report.

6.2.2 Protective Circuits

The protective circuits of the Model AC-DC-500 Variable R were adjusted to the following-listed levels:

Over Power	500 to 550 watts
No Control	20 to 40 millivolts
Over Voltage	
DC	65 volts
AC	220 volts, peak
Over Current	
DC	44 amperes
AC	11 amperes, peak
No Vs	3 volts, peak

6.2.3 Other Performance Features

In addition to the tests just described, the frequency response and AC transient capabilities were determined for Unit 1. The frequency response was determined in the DC mode with a sinusoidal control input riding on a DC level to maintain operation above the zero level. The data is provided in Appendix B.

Transient operation in the AC mode was verified by applying a train of 10-millisecond pulses to the control input with a 115 volt, 60 Hz source connected to the load terminals.

6.3 DEMONSTRATION TESTING

Testing was conducted at NASA JSC for the purpose of demonstrating variable R performance for customer acceptance.

A significant test conducted as part of this series was operation of the units with the Space Shuttle power system simulator. During this testing, and while operating in the DC mode, an oscillation of the power line voltage could be initiated and maintained under certain peak pulse operating conditions. This condition was corrected by introduction of additional capacitance across the load voltage lines. This capacitance (1 microfarad) was installed such that it is switched into the circuit--via the AC/DC Mode Switch--in the DC mode only. AC operation did not require any such measures.

7.0 REFERENCES

1. Modular, High Power, Variable R Dynamic Electrical Load Simulator, Final Report; Avco Systems Division, AVSD-0170-74-RR, 24 June 1974.

2. A Study of Dynamic Load Simulators for Electrical Systems Test Facility, Final Report; Avco Systems Division, AVSD-0364-70-RR, 17 August 1970.

3. Dynamic Load Simulator, Final Report; Avco Systems Division, AVSD-0076-72-RR, 23 June 1972.

4. Dynamic Electrical Load Simulator, Final Report; Avco Systems Division, AVSD-0166-73-RR, 22 June 1973.

5. Operating and Maintenance Manual, Model AC-DC-500 Variable R Dynamic Electrical Load Simulator; Avco Systems Division, ESDM-F420-74-242, 30 August 1974.

6. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Third Monthly Progress Report for the Period 1 September 1973 to 30 September 1973; Avco Systems Division, AVSD-0310-73-CR, 10 October 1973.

APPENDIX A

SUMMARY - PROGRESS REPORTS

This appendix summarizes the twelve monthly progress reports published by Avco Systems Division under the High Power AC/DC Variable R Dynamic Electrical Load Simulator Program, NASA contract NAS 9-13524.

APPENDIX A

SUMMARY - PROGRESS REPORTS

1. High Power AC/DC Variable R Dynamic Electrical Load Simulator, First Monthly Progress Report, for the period 28 June to 31 July 1973; Avco Systems Division, AVSD-0248-73-CR, 8 August 1973.

   SUMMARY

   Describes Avco's efforts in the two following-listed areas of concentration:

   1. Development of a program schedule.
   2. Initiation of a literature search.

2. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Second Monthly Progress Report, for the period 1 August to 31 August 1973; Avco Systems Division, AVSD-0275-73-CR, 7 September 1973.

   SUMMARY

   Covers efforts in the following-listed areas:

   1. Conduct of a literature search.
   2. Development of design approaches.
   3. Conduct of a progress review meeting.

3. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Third Monthly Progress Report, for the period 1 September to 30 September 1973; Avco Systems Division, AVSD-0310-73-CR, 10 October 1973.

   Describes efforts in:

   1. Completion of the literature search.
   2. Identification of design approaches.

4. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Fourth Monthly Progress Report, for the period 1 October to 31 October 1973; Avco Systems Division, AVSD-0323-73-CR, 5 November 1973.

SUMMARY

Describes efforts in the areas of:

1. Completion of study activities.

2. Conduct of a study review.

5. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Fifth Monthly Progress Report, for the period 1 November to 30 November 1973; Avco Systems Division, AVSD-0337-73-CR, 5 December 1973.

SUMMARY

Describes initiation of procurement of long-lead-time hardware items.

6. High Power, AC/DC Variable R Dynamic Electrical Load Simulator, Sixth Monthly Progress Report, for the period 1 December to 31 December 1973; Avco Systems Division, AVSD-0003-74-CR, 4 January 1974.

SUMMARY

Covers preparation of a preliminary circuit design for the unity power factor AC/DC variable R.

7. High Power, AC/DC Variable R Dynamic Electrical Load Simulator, Seventh Monthly Progress Report, for the period 1 January to 31 January 1974; Avco Systems Division, AVSD-0033-74-CR, 5 February 1974.

SUMMARY

Describes efforts in the areas of:

1. Drawing preparation.

2. Long-lead-time item procurement

8. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Eighth Monthly Progress Report, for the period 1 February to 28 February 1974; Avco Systems Division, AVSD-0057-74-CR, 5 March 1974.

SUMMARY

Describes activities in the areas of:

1. Conduct of a design review.

2. Preparation for simulator production.

9. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Ninth Monthly Progress Report, for the period 1 March to 31 March 1974; Avco Systems Division, AVSD-0093-74-CR, 8 April 1974.

SUMMARY

Describes initiation of production of the deliverable simulators.

10. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Tenth Monthly Progress Report, for the period 1 April to 30 April 1974; Avco Systems Division, AVSD-0131-74-CR, 6 May 1974.

SUMMARY

Covers efforts in the two following-listed areas:

1. Completing assembly of the first unit.

2. Continuing production of the second unit.

11. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Eleventh Monthly Progress Report, for the period 1 May to 31 May 1974; Avco Systems Division, AVSD-0160-74-CR, 10 June 1974.

SUMMARY

Describes completion of burn-in testing of the first unit, and completing production of the second unit.

12. High Power AC/DC Variable R Dynamic Electrical Load Simulator, Twelfth Monthly Progress Report, for the period 1 June to 30 June 1974; Avco Systems Division, AVSD-0179-74-CR, 9 July 1974.

SUMMARY

Covers completion of burn-in testing of the second unit.

APPENDIX B

ACCEPTANCE TEST DATA

APPENDIX B

ACCEPTANCE TEST DATA

This appendix presents acceptance test data for the two Model AC-DC-500 Variable R Dynamic Electrical Load Simulators delivered to NASA under Contract NAS 9-13524.

The data includes:

1. For each unit, a plot showing the measured transfer characteristic (control voltage, Vc, versus load current, Is) for load voltages (Vs) of 20, 30, 50, and 60 volts, DC, and for 110 volts, 60 Hz, AC.

2. For Unit 1 a plot showing the measured transfer characteristic for a load voltage (Vs) of 115 volts, 400 Hz.

3. For each unit, a tabulation of static transfer characteristic data from which the above plots were developed.

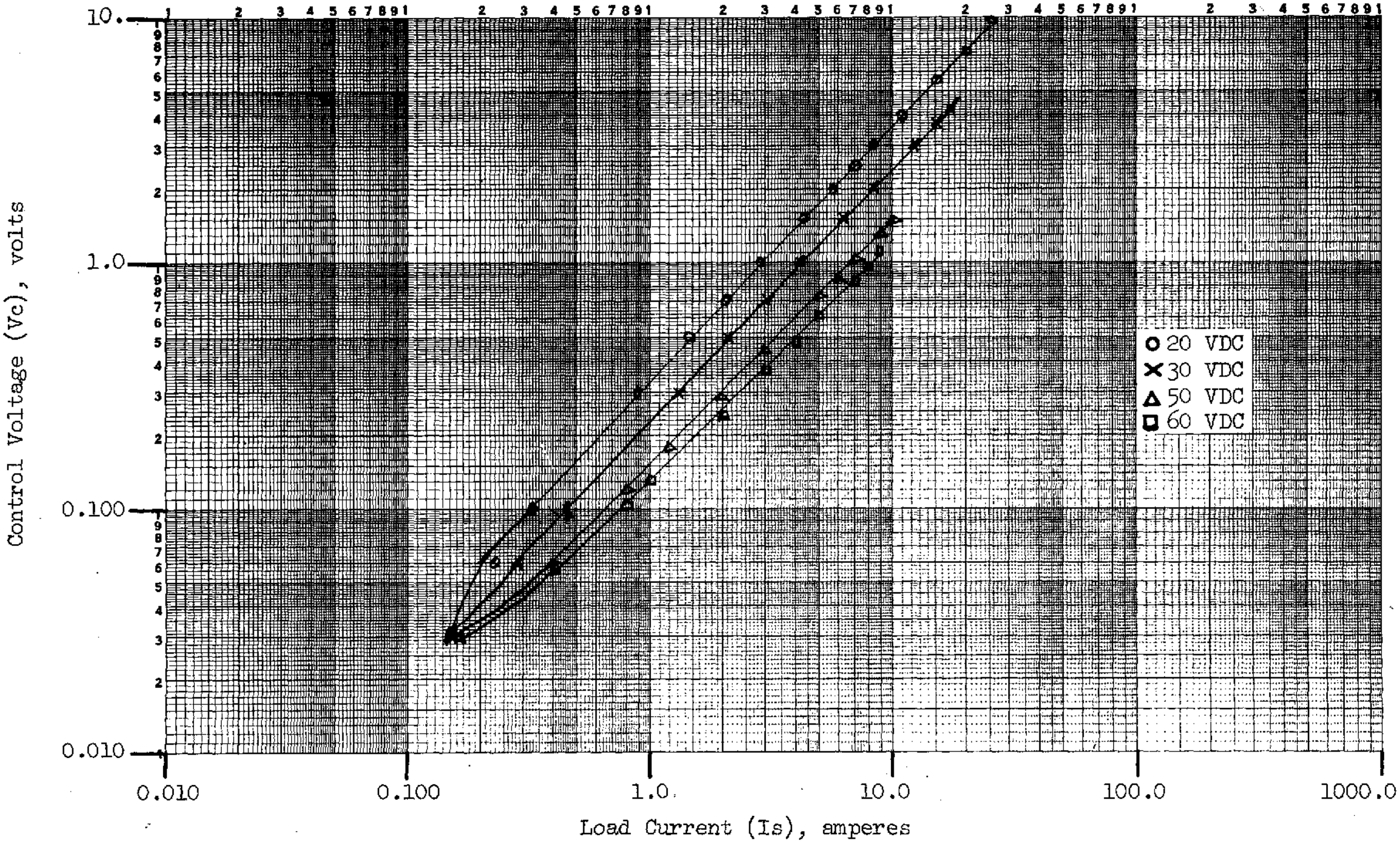


FIGURE B-1 Static Transfer Characteristic, Unit 1; Load Voltages (Vs) = 20, 30, 50, and 60 Volts, DC

TABLE B-I

Static Transfer Characteristic Data, Unit 1
Load Voltages (Vs) = 20, 30, 50, and 60 Volts, DC

LOAD VOLTAGE, Vs

20 Volts, DC		30 Volts, DC		50 Volts, DC		60 Volts, DC	
Control Voltage (Vc) volts	Load Current (Is) amperes	Control Voltage (Vc) volts	Load Current (Is) amperes	Control Voltage (Vc) volts	Load Current (Is) amperes	Control Voltage (Vc) volts	Load Current (Is) amperes
0.03	0.15	0.03	0.15	0.03	0.150	0.03	0.160
0.06	0.23	0.06	0.29	0.06	0.400	0.057	0.400
0.1	0.32	0.1	0.46	0.120	0.800	0.105	0.800
0.3	0.90	0.3	1.3	0.180	1.2	0.130	1.0
0.5	1.46	0.5	2.1	0.290	2.0	0.243	2.0
0.7	2.02	0.7	3.0	0.440	3.0	0.365	3.0
1.0	2.85	1.0	4.2	0.580	4.0	0.485	4.0
1.5	4.30	1.5	6.3	0.730	5.0	0.605	5.0
2.0	5.70	2.0	8.3	0.870	6.0	0.735	6.0
2.5	7.00	2.5	10.3	1.020	7.0	0.855	7.0
3.0	8.40	3.0	12.3	1.170	8.0	0.981	8.0
3.5	9.70	3.5	14.3	1.32	9.0	1.111	8.8
4.0	11.00	3.7	15.0	1.49	10.0		
4.5	12.40	3.96	16.0				
4.8	13.20	4.18	16.8				
5.5	15.00	4.24	17.0				
7.10	20.00						
9.7	25.00						

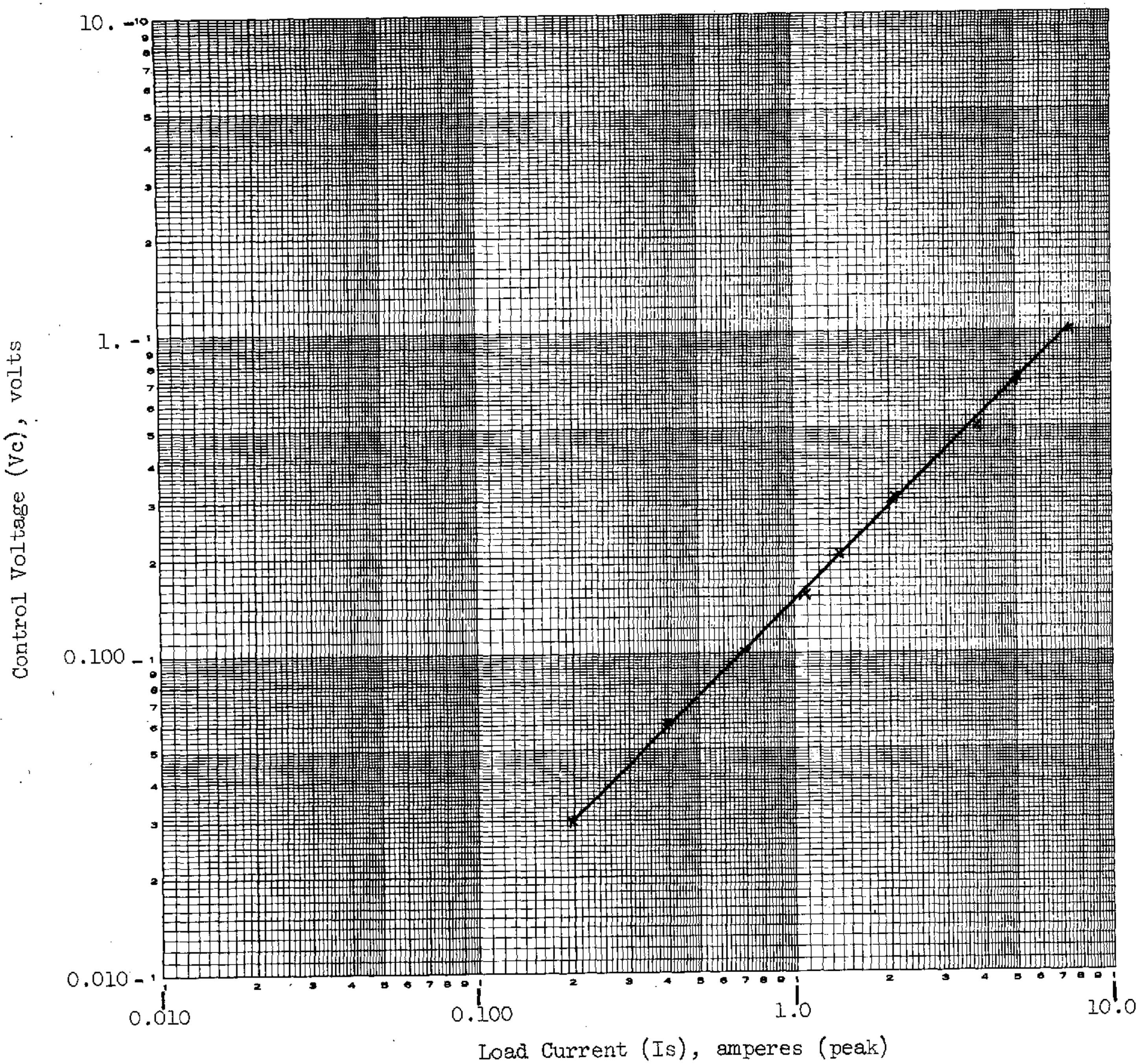


FIGURE B-2 Static Transfer Characteristic, Unit 1: Load Voltage (Vs) = 110 Volts (rms), 60 Hz, AC

TABLE B-II

Static Transfer Characteritic Data, Unit 1
Load Voltage (Vs) = 110 Volts (rms), 60 Hz, AC

Control Voltage (Vc)	Load Current (Is) *		
		Positive Cycle	Negative Cycle
volts	amperes (rms)	amperes (peak)	amperes (peak)
0.030	0.140	0.20	0.15
0.060	0.310	0.40	0.35
0.100	0.530	0.70	0.68
0.150	0.810	1.10	1.10
0.200	1.080	1.40	1.50
0.300	1.63	2.10	2.20
0.500	2.70	3.80	3.80
0.700	3.95	5.00	5.05
1.000	5.53	7.50	7.50

* Across 0.1 ohm.

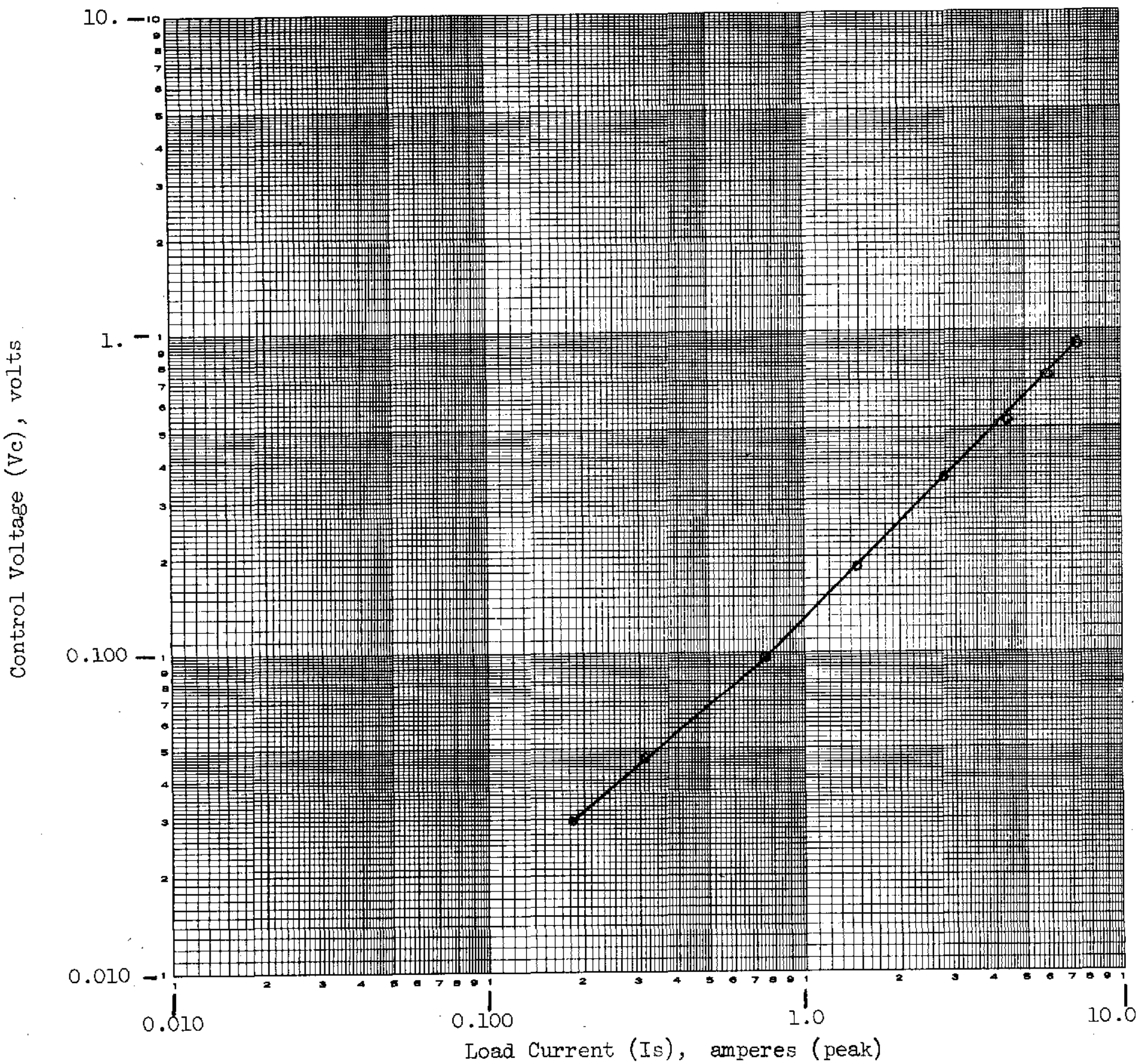


FIGURE B-3 Static Transfer Characteristic, Unit 1; Load Voltage (Vs) = 115 Volts (rms), 400 Hz, AC

TABLE B-III

Static Transfer Characteristic Data, Unit 1
Load Voltage (Vs) = 115 Volts (rms), 400 Hz, AC

Control Voltage (Vc)	Load Current (Is)		
		Positive Cycle	Negative Cycle
volts	amperes (rms)	amperes (peak)	amperes (peak)
0.	0.090	- -	- -
0.030	0.105	0.190	0.090
0.047	0.20	0.320	0.250
0.099	0.50	0.780	0.700
0.187	1.0	1.50	1.50
0.360	2.0	2.90	2.90
0.530	3.0	4.50	4.50
0.730	4.0	6.10	6.10
0.920	5.0	7.50	7.50

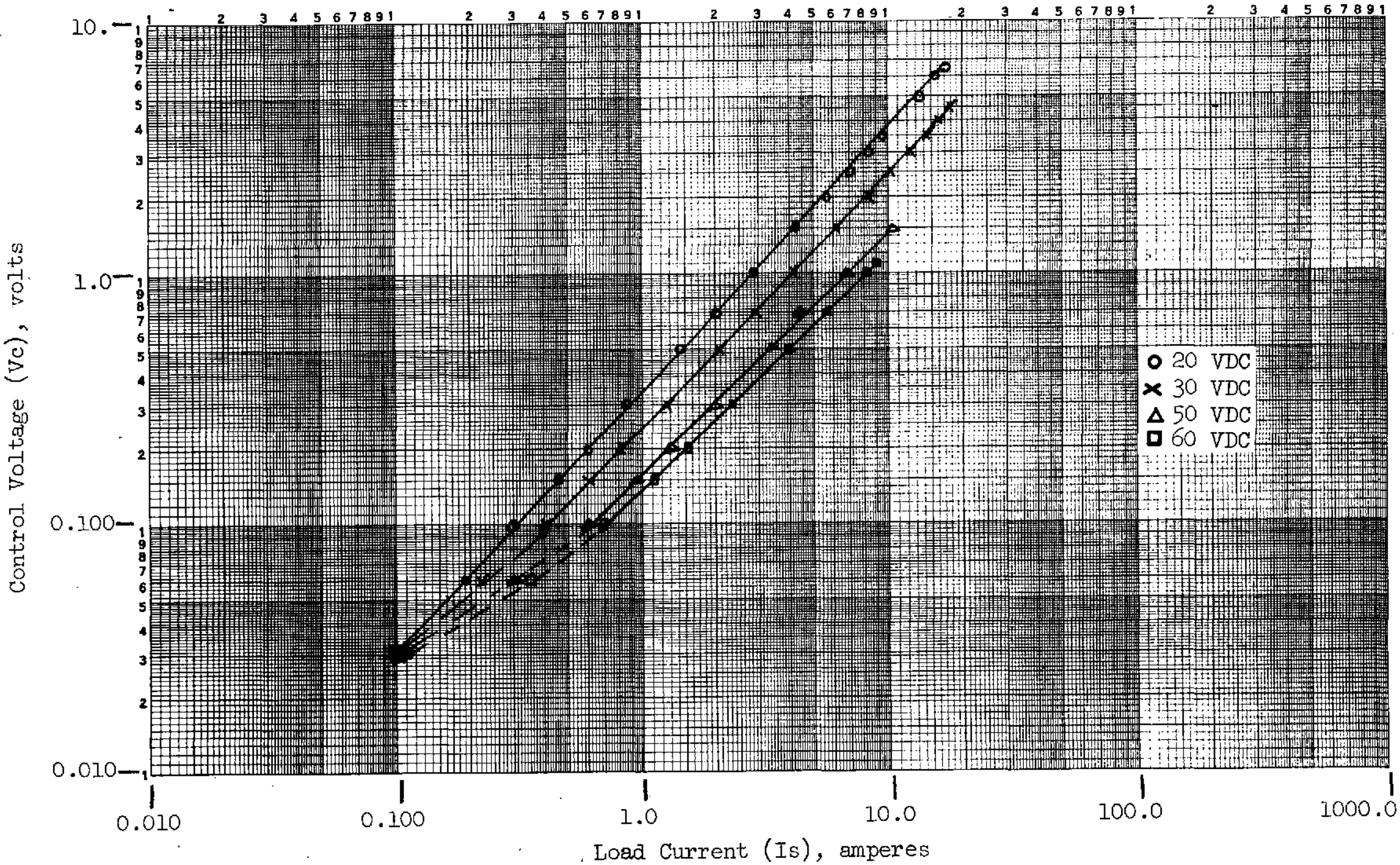


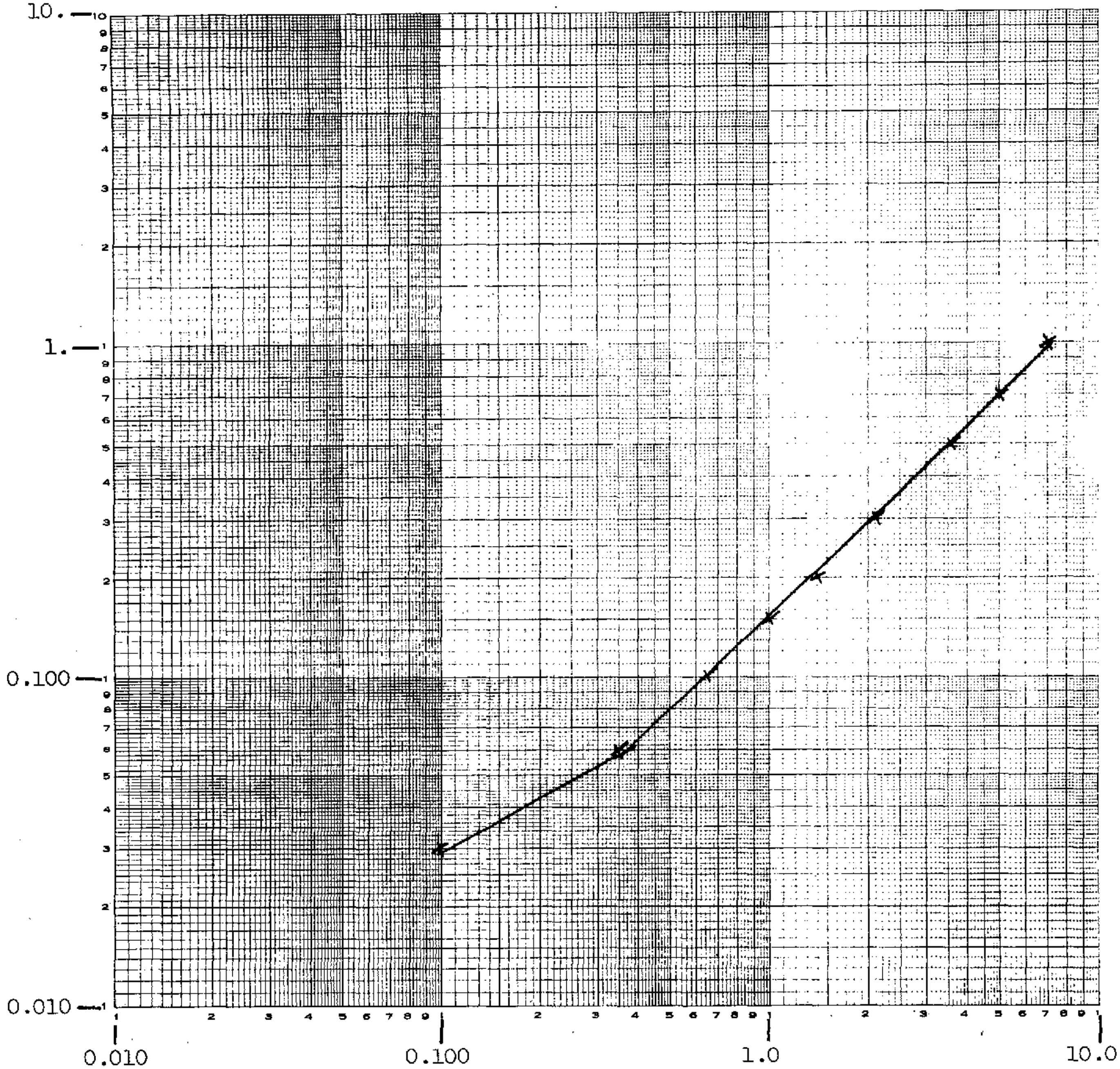
FIGURE B-4 Static Transfer Characteristic, Unit 2; Load Voltage = 20, 30, 50, and 60 Volts, DC

TABLE B-IV

Static Transfer Characteristic Data, Unit 2
Load Voltages (Vs) - 20, 30, 50, and 60 Volts, DC

LOAD VOLTAGE, Vs

20 Volts, DC		30 Volts, DC		50 Volts, DC		60 Volts, DC	
Control Voltage (Vc)	Load Current (Is)	Control Voltage (Vc)	Load Current (Is)	Control Voltage (Vc)	Load Current (Is)	Control Voltage (Vc)	Load Current (Is)
volts	amperes	volts	amperes	volts	amperes	volts	amperes
0.03	0.10	0.03	0.10	0.03	0.10	0.03	0.10
0.06	0.19	0.06	0.22	0.06	0.30	0.06	0.35
0.1	0.30	0.10	0.4	0.10	0.60	0.10	0.70
0.15	0.45	0.15	0.6	0.15	0.95	0.15	1.11
0.2	0.60	0.20	0.82	0.20	1.30	0.20	1.53
0.3	0.86	0.30	1.25	0.30	2.00	0.3	2.35
0.5	1.44	0.50	2.09	0.50	3.36	0.5	4.00
0.7	2.0	0.70	2.9	0.70	4.75	0.7	5.70
1.0	2.82	1.0	4.15	1.0	6.80	1.0	8.20
1.5	4.20	1.5	6.2	1.5	10.50	1.1	9.00
2.0	5.60	2.0	8.25				
2.5	7.00	2.5	10.2				
3.0	8.26	3.0	12.2				
3.5	9.60	3.5	14.18				
4.0	10.8	4.0	16				
4.4	12.05	4.5	17.9				
5.0	13.4						
5.5	14.6						
6.0	15.8						
6.5	17						



Load Current (Is), amperes (peak)

FIGURE B-5 Static Transfer Characteristic, Unit 2: Load Voltage (Vc) = 110 Volts (rms), 60 Hz, AC

TABLE B-V

Static Transfer Characteristic Data, Unit 2
Load Voltage (Vs) = 110 Volts (rms), 60 Hz, AC

Control Voltage (Vc)	Load Current (Is)*		
		Positive Cycle	Negative Cycle
volts	amperes (rms)	amperes (peak)	amperes (peak)
0.03	0.100	0.100	0.100
0.06	0.265	0.350	0.350
0.10	0.490	0.650	0.600
0.15	0.758	1.00	0.950
0.20	1.04	1.40	1.40
0.30	1.51	2.10	2.10
0.50	2.70	3.60	3.60
0.70	3.70	5.00	5.00
1.00	5.30	7.00	7.00

* Across 0.1 ohm.