Figure 1-1. DC Power Supply, Model 6516A
SECTION III
OPERATING INSTRUCTIONS

3-1 TURN-ON CHECK OUT PROCEDURE

3-2 The following procedure describes the use of the front panel controls and indicators illustrated in Figure 3-1 and insures that the power supply is operational.

![Figure 3-1. Front Panel Controls and Indicators](image)

- a. Push ON/OFF switch—Indicator (1); indicator should light.
- b. Set METER switch (2) to VOLTS position (6110A only).
- c. Adjust voltage thumbwheel switches for desired output voltage as indicated on meter.
- d. Attach a multimeter to the output and set the voltage decadal control to at least 200 volts. Check that the current indication on the multimeter does not exceed 7.5mA.
- e. Remove meter and connect load to output terminals.

3-3 OPERATION

3-4 The power supply can be operated as a single unit (normal operation) or in parallel. No provisions for remote programming or remote sensing have been made due to their limited use and insulation problems at 3,000Vdc. For safety, insure that the power supply chassis is grounded (either via power cord or by other means). The operator can ground either output terminal or operate the power supply up to 1,000 volts dc off ground (floating). It is not recommended that the power supply be floated above 300 volts rms at low audio frequencies (less than 500Hz).

WARNING
Serious injury to personnel can occur if the power supply chassis is ungrounded. The warranty is void if the chassis is ungrounded during operation.

NOTE
This supply emits a ticking sound which is characteristic of normal operation. It in no way indicates that the power supply is malfunctioning.

3-5 CURRENT LIMIT PROVISIONS

3-6 The current limiting feature is designed to protect the power supply and the load. It is factory adjusted by selecting resistor R20 so that the short-circuit output current will not exceed approximately 8mA.

3-7 OPERATION OF SUPPLY BEYOND RATED OUTPUT

3-8 The shaded area on the front panel meter face indicates the amount of output voltage that is available in excess of the normal rated output. Although the supply can be operated in this shaded region without being damaged, it cannot be guaranteed to meet all its performance specifications. However, if the line voltage is maintained above 115Vac, the power supply will probably operate within its specifications.

3-9 LOAD CONNECTION

3-10 Output terminals are provided on the front panel of the power supply; mating connectors are UG-932 and cable type is RG-59/U. The positive or negative output terminal may be grounded by shorting the center pin and case of the applicable UG-931/U jack; or both output terminals ungrounded (floating operation). Floating operation is permitted to 1,000 volts dc off ground; neither output terminal should exceed 4,000 volts dc. The best ripple-free results are obtained when one output jack is grounded and the load is connected to the other output jack by the appropriate cable and connector.

WARNING
To avoid injury to personnel due to arcing, turn off the power supply before connecting or disconnecting the load connectors.
3-11 Each load should be connected to the power supply output terminals using separate pairs of connecting wires. This will minimize mutual coupling effects between loads and will retain full advantage of the low output impedance of the power supply. Each pair of connecting wires should be as short as possible to reduce noise pickup. In addition, a 0.1 to 1.0 μf capacitor should be connected between one terminal and the chassis, if the supply is floated off of ground.

3-12 If load considerations require that the output power distribution terminals be remotely located from the power supply, then the power supply output terminals should be connected to the remote distribution terminals via a pair of shielded wires and each load connected separately to the remote distribution terminals. A 0.1 to 1.0 μf capacitor should be connected across the remote distribution terminals to reduce high frequency coupling and noise.

3-13 OUTPUT CAPACITANCE

3-14 An internal capacitor, across the output terminals of the power supply, helps to supply high current pulses of short duration during constant voltage operation. Any capacitance added externally will improve the pulse current capability, but will decrease the safety provided by the current limiting circuit. A high current pulse may damage load components before the average output current is large enough to cause the current limiting circuit to operate.

3-15 REVERSE CURRENT LOADING

3-16 Active loads connected to the power supply may actually deliver a reverse current to the power supply during a portion of its operating cycle. An external source cannot be allowed to pump current into the supply without loss of regulation and possible damage to the output capacitor. To avoid these effects, it is necessary to preload the supply with a "dummy" load so that the power supply delivers current through the entire operating cycle of the load device.

3-17 REVERSE VOLTAGE LOADING

3-18 A diode is connected across the output terminals. Under normal operating conditions, the diode is reverse biased (anode connected to negative terminal). If a reverse voltage is applied to the output terminals (positive voltage applied to negative terminal), the diode will conduct, shunting current across the output terminals and limiting voltage to the forward voltage drop of the diode. This diode protects the series transistors and the output electrolytic capacitors.
Figure 4-1. Overall Block Diagram
SECTION IV
PRINCIPLES OF OPERATION

4-1 OVERALL BLOCK DIAGRAM DISCUSSION
(Figure 4-1)

4-2 Models 6110A and 6516A, as illustrated in Figure 4-1, are constant voltage/current limited power supplies that utilize a "piggy-back" regulator design. This design extends the usefulness of the series regulating transistors rated for approximately 30 volts to short-circuit-proof power supplies rated for 3,000 volts. The basic technique consists of placing the well-regulated low-voltage "piggy-back" supply in series with a less well-regulated high voltage doubler. Notice, however, that the amplified error signal from the voltage input circuit is dependent upon the total output voltage—not just the output of the "piggy-back" supply alone. Thus, the well-regulated "piggy-back" supply continuously compensates for any ripple, load regulation, or line regulation deficiencies of the high voltage doubler, and adjusts the voltage across the series regulator so that the total output voltage remains constant despite disturbances in the high voltage doubler.

4-3 For purposes of discussion the voltage values of Model 6110A are used in the following paragraphs, however, the theory pertains equally well to both Models 6110A and 6516A. The "piggy-back" supply develops 200 volts, and the high voltage doubler supply is capable of providing a maximum of 3200 volts. With 30 volts normally dropped across the series regulator, the maximum output of this supply is 3370 volts; 170 volts from the "piggy-back" supply and 3200 volts from the high voltage doubler. Thus, the series regulator of the "piggy-back" supply has a voltage range for accomplishing the dynamic changes necessary to compensate for the variations of the power source. Short-circuit protection for the series regulator in the "piggy-back" supply is provided by the protection diode, which provides a discharge path from the positive side of the power supply to the positive side of the high voltage doubler shunting the short circuit current around the series regulator. Whenever the load resistance decreases to a value such that +S becomes greater than -200 volts, the protection diode conducts. This prevents the output terminals of the "piggy-back" supply from ever reversing polarity, and the series regulator will never be called upon to withstand a voltage strain greater than 200 volts from its own rectifier.

4-4 The ac input line voltage is raised to the proper level and coupled to the "piggy-back" supply. This supply converts the ac input to raw dc which is fed to the positive terminal via the series regulator and current sampling resistor network. The regulator, part of the feedback loop, is made to alter its conduction to maintain a constant output voltage or limit the output current. Voltage developed across the current sampling resistor is the input to the current limiting circuit. If the output current that passes through the sampling network exceeds a certain predetermined level, the current limiting circuit applies a feedback signal to the series regulator which alters the regulator's conduction so that the output current does not exceed the predetermined limit.

4-5 The voltage input circuit obtains its input by sampling the output voltage of the supply at the voltage control. Any changes in output voltage are detected in the constant voltage input circuit, amplified by the error amplifier and driver, and applied to the series regulator in the correct phase and amplitude to counteract the change in output voltage. The reference regulator circuit provides stable reference voltages which are used by the constant voltage input circuit and the current limiting circuit for comparison purposes.

4-6 The high voltage control circuit monitors the voltage across the "piggy-back" supply, and alters the conduction of transformer T1 so that the output of the high voltage doubler can be varied between 0 and 3.2 kilovolts. For instance, if the high voltage control is adjusted for an output voltage in excess of the voltage supplied by the "piggy-back" supply, the input to the high voltage control circuit becomes more negative. The high voltage control circuit opens the control winding, and all the energy appearing at the ac input of transformer T1 is coupled to the secondary which is connected to the high voltage doubler. The result is that the output voltage of the high voltage doubler increases. If the voltage control is adjusted for an output which is less than the "piggy-back" supply, the input to the high voltage control circuit becomes less negative. The control winding of transformer T1 becomes shorted impeding the transfer of energy from the ac input to the secondary which is connected to the high voltage doubler. Thus, the output voltage of the high voltage doubler decreases.

4-7 In Model 6110A, an oven houses the temperature sensitive components in the supply to provide a low temperature coefficient which results in excellent stability. The oven control circuit maintains the oven temperature at 65°C.
Figure 4-2. Simplified Schematic Diagram

4-8 SIMPLIFIED SCHEMATIC DISCUSSION
(Figure 4-2)

4-9 The regulating feedback loop, consisting of the thumbwheel switch assembly (programming resi­ditors), voltage input circuit, driver and error amplifier, series regulator, and high voltage control circuit, function continuously to maintain the output voltage constant during constant voltage operation and the output current at a safe limit during current limit operation.

4-10 The voltage input circuit amplifier, Q16 detects an error voltage that is proportional to the difference between the voltage across its program­ming resistors (thumbwheel switch assembly) and the dc output voltage. The error signal is ampli­fied by Q10 and applied to the series regulator. The series regulator increases or decreases the output current as required to maintain a constant dc output voltage that is equal to the programmed voltage. The high voltage control circuit, transformer T1, and the high voltage doubler maintain the voltage across the series regulator within a limited range. When the voltage across the series regulator falls below a predetermined level, Q17 turns on, forward biasing diodes CR3 and CR4. SCR's CR7 and CR40 begin firing on each cycle, and the voltage across C27 and C28 decays. When the voltage across the series regulator rises above a predetermined level, Q17 turns off, reverse biasing diodes CR3 and CR4. SCR's CR7 and CR40 stop firing and the voltage across C27 and C28 rises.
4-11 The current limit circuit protects the load and the series regulator against excessive currents. If the external load resistance is decreased to a point where the load current exceeds the value selected by resistor R70, the positive voltage on the collector of Q10 forward biases CR31. Thus, the collector of Q10 is clamped and the output current is maintained at a constant safe maximum. Any further decreases in load resistance cause the output voltage to decrease proportionally.

4-12 DETAILED CIRCUIT ANALYSIS (Refer to overall schematic at rear of manual)

4-13 SERIES REGULATOR

4-14 The series regulator consists of transistor stage Q11. The regulator serves as a series control element by altering its conduction so that the output voltage and current limit is never exceeded. The conduction of Q11 is controlled by the feedback voltage obtained from driver Q10.

4-15 CONSTANT VOLTAGE INPUT CIRCUIT

4-16 This circuit consists of voltage decade control R200 through R224 and amplifier Q16.

4-17 The constant voltage input circuit continuously compares a fixed reference voltage with a portion of the output voltage and, if a difference exists, produces an error voltage whose amplitude and phase is proportional to the difference. The error output is fed back to the series regulator, through the error and driver amplifiers. The error voltage changes the conduction of the series regulator which, in turn, alters the output voltage so that the difference between the two input voltages applied to the differential amplifier is reduced to zero. The above action maintains the output voltage constant.

4-18 The base of Q16 is connected to the junction of the programming resistors and the current pull-out resistor, R18, through a current limiting resistor R19. Diode CR5 limits voltage excursions on the base of Q16. R19 limits the current through the programming resistors under the condition of rapid voltage turn-down. Capacitors C4 shunts the programming resistors to increase the high frequency gain of the amplifier. The programming current is determined primarily by the reference voltage and the pull-out resistor, R18.

4-19 Negative feedback is coupled from the output to the input of Q16 by network R20 and C20. This feedback provides high frequency roll-off in the loop gain to stabilize the feedback loop.

4-20 DRIVER AMPLIFIER

4-21 The driver amplifier circuit raises the level of the error signal from the constant voltage input circuit to a sufficient level to drive the series regulator.

4-22 CURRENT LIMIT CIRCUIT

4-23 The output current flows through R23 producing a voltage drop of 1.8 volts for 7 milliamps output current. The positive voltage appearing on R23 is connected to the emitter of Q10. When the output current reaches 7 milliamps diode CR8 is forward biased and the base of Q10 is clamped so that the conduction of Q10 is limited. The value of resistor R70 determines the level at which the output current will be limited. This value is normally selected for 7 milliamps output current.

4-24 HIGH VOLTAGE CONTROL AND DOUBLER CIRCUITS

4-25 This circuit controls the voltage output of the high voltage doubler as a function of the voltage across the series regulator and resistor R54. When the voltage across the series regulator rises to a predetermined value, CR39 becomes forward biased and Q17 conducts. Diodes CR3 and CR4 are forward biased and on alternate half-cycles SCR's CR7 and CR40 fire, shorting the control winding of transformer T1. This action decreases the voltage on the secondary of T1 thus reducing the charge on capacitors C27 and C28. This, in turn, reduces the voltage drop across the series regulator.

4-26 When the voltage drop across the series regulator decreases to a predetermined amount, diode CR39 becomes reverse biased and Q17 turns off. This action reverse biases diodes CR3 and CR4 and the SCR's cease firing on alternate half-cycles. The output of the high voltage doubler rises until Q17 again begins to conduct.

4-27 Diodes CR3 and CR4 form an OR-gate that prevents the interaction of SCR's CR7 and CR40. For example, when CR7 fires a positive pulse appears on its gate, back biasing CR3 and preventing this positive pulse from tripping CR40. Two RFI filters in the control winding of transformer T1 prevent spikes from being transferred to the high voltage doubler and the ac input line. These filters consist of C29, R61, C26, R74 and L2. Diode CR39 protects the base of transistor Q7 from the negative output voltage of the "piggy-back" supply. This voltage can go as far negative as -215 volts.
PROTECTION CIRCUIT

This circuit prevents the high voltage doubler from exceeding approximately 4kV which might occur if the feedback loop were to malfunction. Diodes CR37 and CR38 are connected directly across the control winding and rectify (monitor) the voltage across this winding. The rectified voltage charges capacitor C24, and when it exceeds a predetermined level, neon tube VR3 fires. The resulting positive going voltage turns on Q17 which in turn shorts the control winding of transformer T1, thus, reducing the output of the high voltage doubler. Overvoltage control R71 determines the level at which VR3 will fire and, therefore, controls the maximum output voltage of the high voltage doubler.

REFERENCE REGULATOR

This circuit supplies regulated dc bias voltages to the voltage input circuit and +15V programming voltage to the voltage control circuit. Diodes CR22 through CR25 and capacitor C16 rectify and filter the 43 Vac developed across the secondary of T2. The 56 Vdc is regulated by transistor Q12 which is controlled by Q13 and VR1. The +15V programming voltage is developed by constant current amplifier Q14-Q15 which is connected to the -40V reference voltage. Resistors R51 and R52 are selected to provide precisely the correct programming current. Procedures for selecting these resistors are included in the adjustment and calibration paragraphs in Section V, Maintenance.
HIGH VOLTAGE CONTROL CIRCUIT WAVEFORMS

NORMAL WAVEFORMS

140V- 115VAC INPUT
SCR Firing 3000V/6MA OUTPUT
MUST BE >0V TP(I) TO (+)
0V 20V/CM
10MS/CM

100V-

140V-

TP(36) TO (+)
20V/CM
10MS/CM

TYPICAL TROUBLES

>5V TP(36) TO (+)
0V 5V/CM
10MS/CM

NOTE: ALL WAVEFORMS ARE DC COUPLED.
MANUAL CHANGES
Model 6516A DC Power Supply
Manual HP Part No. 06516-90001

Make all corrections in the manual according to errata below, then check the following table for your power supply serial number and enter any listed change(s) in the manual.

<table>
<thead>
<tr>
<th>SERIAL MAKE</th>
<th>Changes</th>
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<tbody>
<tr>
<td>Prefix</td>
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<tr>
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<td>0811 - 0960</td>
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<td>1661 - 1760</td>
</tr>
<tr>
<td>7C</td>
<td>1761 - up</td>
</tr>
</tbody>
</table>

CHANGE 4:
In the replaceable parts list, make the following change:
S1: Change to HP Part No. 3101-1248.

CHANGE 5:
In the replaceable parts list, make the following change:
S1: Change to HP Part 3101-1244.

CHANGE 6:
In the replaceable parts list, make the following change:
S1: Change to HP Part No. 3101-1248.

CHANGE 1:
On the replaceable parts table, make the following changes:
Change C19 to 300Vdc, 39D206F300FJ4, Sprague, Part No. 0180-2256.
Under Option "05", change T2 to Part No. 5080-7129.
Under Options "18" and "05 and18", change T2 to Part No. 5080-7130.

CHANGE 2:
On replaceable parts table, make the following change:
T2: Bias Transformer, Part No. 5080-7129.
Under Option 18: Delete T2.

CHANGE 3:
In the Replaceable Parts Table, change transistor Q11 to RCA 2N4240, Part No. 1854-0311.

ERRATA:
Substitute the following for Paragraph 4-23:
4-23 The output current flows through resistor R23, producing a voltage drop of 1.8 volts at an output current of 7 milliamperes. This voltage appears at the emitter of Q11. When the output current flowing through Q11 reaches 7 milliamperes, diode CR31 becomes forward biased, clamping the base of Q11 and limiting its conduction. The value of R70 thus determines the level at which the output current will be limited; this value is factory selected to limit the output current at the above mentioned 7 milliamperes.

10-12-70