INSTRUCTION MANUAL

REGULATED DC POWER SUPPLY

PAD8-100L

KIKUSUI ELECTRONICS CORPORATION

Power Requirements of this Product

Power requirements of this product have been changed and the relevant sections of the Operation Manual should be revised accordingly.
(Revision should be applied to items indicated by a check mark ☑.)

☐ Input voltage

The input voltage of this product is ________ VAC,
and the voltage range is ________ to ________ VAC. Use the product within this range only.

☐ Input fuse

The rating of this product's input fuse is ________A, ________VAC, and ________.

WARNING

- To avoid electrical shock, always disconnect the AC power cable or turn off the switch on the switchboard before attempting to check or replace the fuse.
- Use a fuse element having a shape, rating, and characteristics suitable for this product. The use of a fuse with a different rating or one that short circuits the fuse holder may result in fire, electric shock, or irreparable damage.

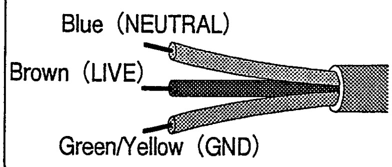
☐ AC power cable

The product is porvided with AC power cables described below. If the cable has no power plug, attach a power plug or crimp-style terminals to the cable in accordance with the wire colors specified in the drawing.

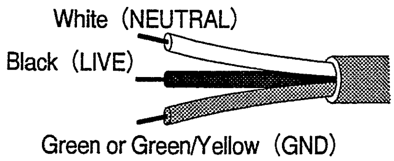
WARNING

- The attachment of a power plug or crimp-style terminals must be carried out by qualified personnel.

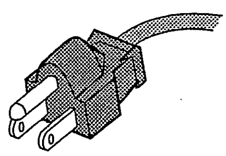
☐ Without a power plug



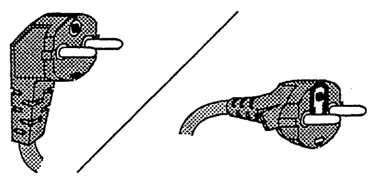
☐ Without a power plug



☐ Plugs for USA



☐ Plugs for Europe



☐ Provided by Kikusui agents

Kikusui agents can provide you with suitable AC power cable.
For further information, contact your Kikusui agent.

☐ Another Cable ________________________________

 Kikusui Part No. Z9-000-027 IB001681

KIKUSUI

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SECTION 1. GENERAL

1-1. Description

The PAD-L Power supply is designed for high operation reliability and excellent electrical performance. It is a universal-purpose industrial power supply which can be used as a variable power source for research and development, or as a fixed power source for long time aging test. Features of the PAD-L Power Supply can be summarized as follows:

1. Improved power factor at low output voltage:

   A choke input system is used for the rectifier filter circuit, thereby reducing the apparent input current and improving the power factor. This led to a smaller power transformer and consequently to a compact and light power supply.

2. Less waveform distortion caused to the AC input line:

   As the choke input system is used, the input current waveform is less distorted with harmonics, thereby reducing waveform distortion to the AC input line.

3. Excellent temperature coefficient:

   Very low temperature drift characteristics of 50 ppm/°C is attained by using premium-quality parts, improved circuits, and forced air cooling. Time-elapse drift (aging drift) also is very low.

4. Fast transient response:

   A wide-band error amplifier is used to ensure stable frequency - gain, phase characteristics.

5. Low ripple and noise voltages:

Ripple and noise voltages are low, both in rms and peak values.

The output voltage is finely adjustable from 0 V to the rated voltage with a 10-turn potentiometer.

The power supply has a current/voltage limit switch to preset a current/voltage value. The set value of constant-voltage/constant-current operation can be checked when in operation.

The power supply has internal protectors such as voltage detector, current detector and temperature detector. An overvoltage protector (OVP), of which set voltage is adjustable from the front panel, also is incorporated as a standard feature. A high speed overvoltage protector (a thyristor crowbar protector) is avairable as setting thyristor switch OFF.

The power supply is housed in a casing for bench top use. It can be installed on a standard 19-inch (500-mm) rack.

The user is requested to read thoroughly this instruction manual before operating the power supply.

Caution:

> It is highly recommended to set the thyristor crowbar switch to "ON" for a load the allowable voltage range of which is very narrow and which could be damaged when a slight overvoltage is applied. But if batteries or large capacitors are loaded, set the thyristor crowbar switch to "OFF."

1-2. Specifications

Model	PAD 8-100 L	
Name	Regulated DC Power Supply	
Input supply	100V/200V ±10%, 50Hz/60Hz AC, 1 φ	
Power consumption		
Output		
Output voltage	10 turns	0 - 8V
	Voltage resolution (theoretical value)	Approx. 1.5mV
Output current	1 turn	0 - 100A
	Current resolution (theoretical value)	Approx. 47mA
Constant voltage characteristics		
Regulation *1	Against ±10% variation of line voltage	0.005% + 1mV
	Against 0 - 100% variation of output current	0.005% + 2mV
Ripple and noise *2	(5Hz - 1MHz)	500μV rms
Transient response *3	(5 - 100%)	100μsec
Temperature coefficient	(typical value)	50ppm/°C
Remotecontrol resistance and voltage		Approx. 0 - 10kΩ, 0 - 10V
Constant current characteristics		
Regulation	Against ±10% variation of line voltage	3mA
	Against 0 - 100% variation of output voltage	5mA
Ripple and noise *2	(5Hz - 1MHz)	100mA rms
Remote control resistance and voltage		Approx. 0 - 550Ω, 0 -0.3V
Ambient temperature		0 - 40°C
Ambient humidity		10 - 90% RH
Cooling	Forced air cooling	
Output polarity and withstanding voltage from chassis	It is possible to ground positive or negative terminal.	Max. ±250V
Protections		
OVP Adjustable voltage range		Approx. 3 - 10V
OVP Response time (Input switch is cut off.)		Approx. 200μsec
Operation temperature of its detection in cooling package	(Input switch is cut off.)	100°C
Input fuse	15mm dia. 15A (for 200V Line), 30A (for 100V Line)	
Output fuse	100A	

Constant voltage mode operation indication

Light emitting diode (green) C.V

Constant current mode operation indication

Light emitting diode (red) C.C

Meter

Voltmeter	Full scale DC 8V	Class 2.5
Ammeter	Full scale DC 100A	Class 2.5

Insulation between chassis and line (DC 500V) More than 30MΩ

Between chassis and line (DC 500V)		More than 30MΩ
Between chassis and output (DC 500V)		More than 20MΩ

Dimensions *4	430W × 160H × 490D mm (16.93W × 6.30H × 19.29D in.)
(max.)	431W × 175H × 595D mm (16.97W × 6.89H × 23.43D in.)
Weight	Approx. 46 kg (101 lbs.)

Accessories (in carton)

Instruction manual .... 1 copy

Input line fuse (spare)

15A for 200V .... 1 ea.

30A for 100V .... 1 ea.

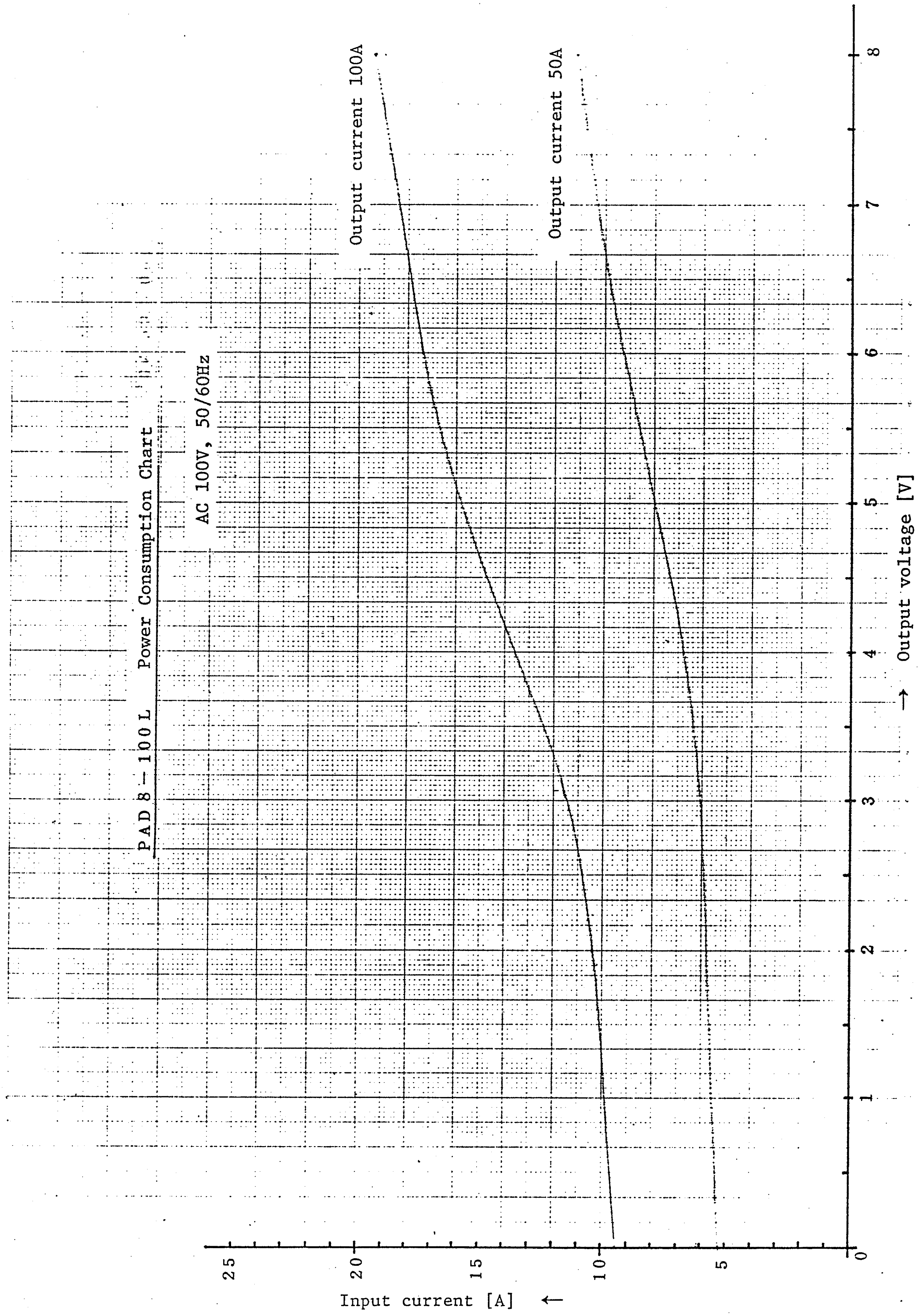
Notes:

*1 Measurement by using sensing terminals

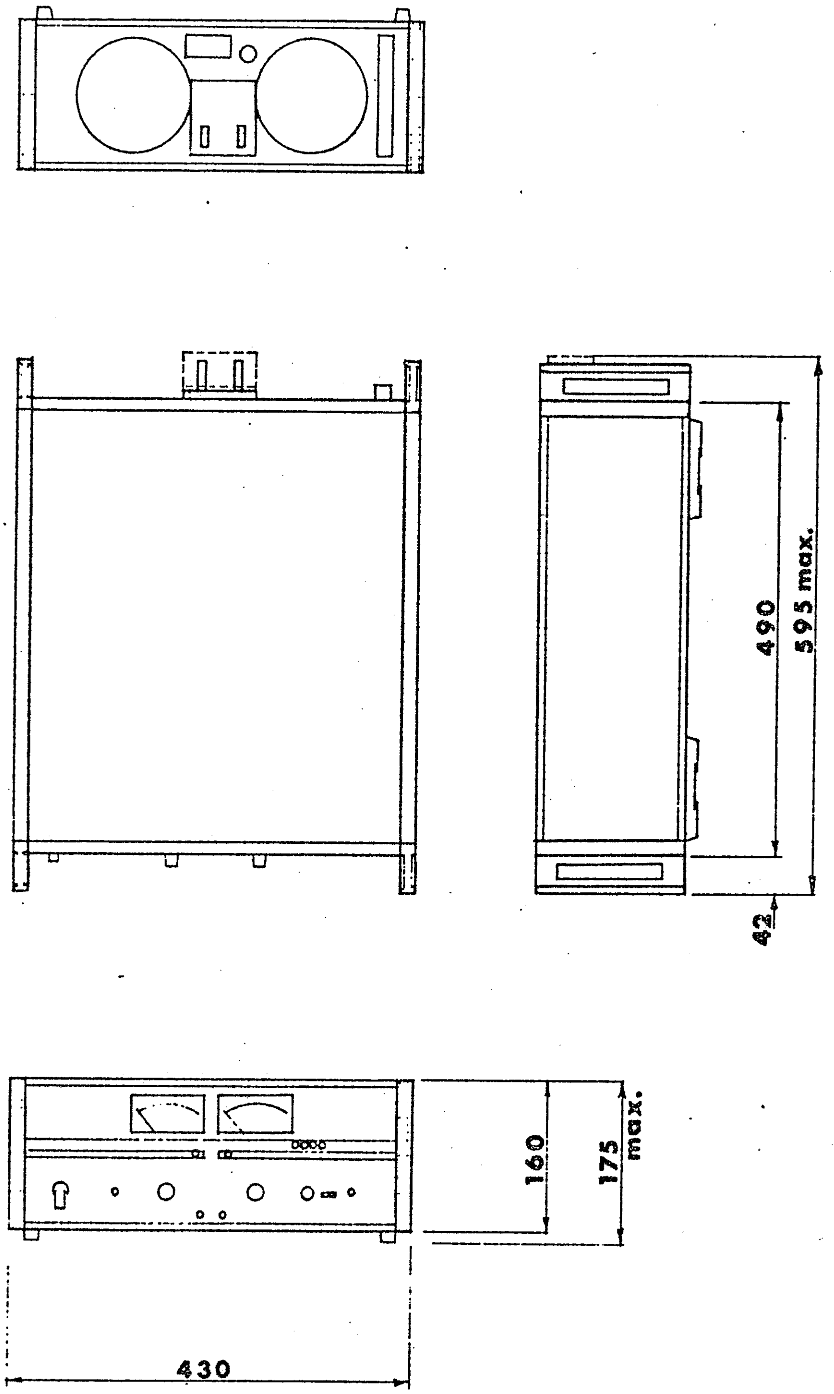
*2 Measurement by grounding positive or negative output

*3 Recavery time of output voltage to within 0.05% + 10mV

*4 It is possible to be mounted on 19-inch or 500-mm standard rack with the rack mount frame (option).



PAD 8 - 100 L Power Consumption Chart
AC 100V, 50/60Hz
Output current 100A
Output current 50A
→ Output voltage [V]
0
1
2
3
4
5
6
7
8
Input current [A] ←
25
20
15
10
5



Unit: mm

Figure 1-1. Mechanical outline drawing

SECTION 2. OPERATION

2-1. Precaution for Operation (Installation)

1. Input power

   - The input voltage range is 90 - 110 V (180 - 220 V*), 48 - 62 Hz single-phase AC.

   - The input power fuse rating is

     30A for 100 V
     *15A for 200 V.

   - For current consumption, see the power consumption charts.

2. Power cord

   - A power cord (cabtire cable) of core wires of 3.5 mm^2 accompanies the power supply.

   - Securely connect the core wires with crimping terminals or other appropriate method.

   - The green wire is for ground. Be sure to connect this wire to a good earth ground for safety.

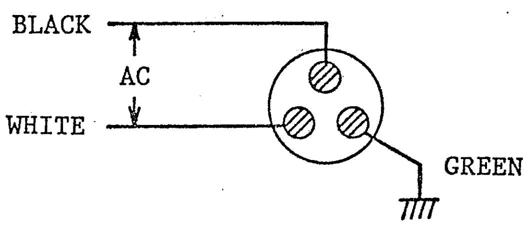


Figure 2-1. Cross section of cabtire cable

3. Output

   - Make sure that the jumpers of the terminal blocks on the rear panel are securely connected as shown in Figure 2-2.

- The output power is available either at the front panel (binding post terminals) or at the rear panel (terminal blocks).

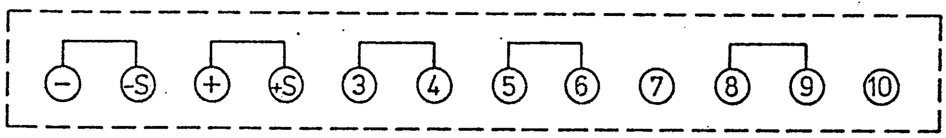


Figure 2-2

- Normally, connect either one of the output terminals to the GND terminal with the shorting bar.

- For connecting the output to a load, use wires of a sufficient current rating referring to Table 2-1. If wires of an insufficient current rating is used, the voltage at the load may become unstable due to voltage drop in the wires, or the wires may be overheated in an extreme case.

4. Ambient temperature

- The ambient temperature range for the power supply to satisfy the specification performances is 0°C to 40°C (32°F to 104°F). The power supply should be used within this range. If it is operated at a high ambient temperature, the internal temperature detector circuit trips and the input power switch is turned off. If this has happened, cool it and then turn on the power again. There is an exponential relationship between ambient temperature and semiconductor life, electrolytic capacitor life and transformer insulation life. Note that components are rapidly deteriorated at high temperatures. It is important not to operate the power supply at an abnormally high ambient temperature also from the viewpoint of its life.

- o If the power supply is used at a temperature lower than -10°C, its operation may become unstable. If the power supply is to be used at low temperatures, specify so when ordering.

5. Place for use

- o Pay attention so that the ventilation ports (top and bottom) and the fan air outlet are not blocked.
- o Hot air comes out of the fan air outlet. Do not place near the outlet an object which is not heat resistant.
- o Do not use the power supply in a highly humid or dusty place as such can cause failures.
- o Select a place where is reasonably free from vibration.
- o Do not place a high sensitivity instrument on or near the power supply which produces a strong electric and magnetic fields.

6. Note for carrying

- o The center of gravity of the power supply is at a leftward position. Be careful when raising the power supply without using the handles.

Notes for loads:

Note that the output may become unstable depending on characteristics of loads as follows:

(a) When the meter reading (average value) is less than the preset value, if the current has peaks which exceed the preset value, the operation is driven into the constant current domain for the short periods of time and the output voltage falls. Observing carefully, it can be seen that the constant-current indicator lamp becomes dim.

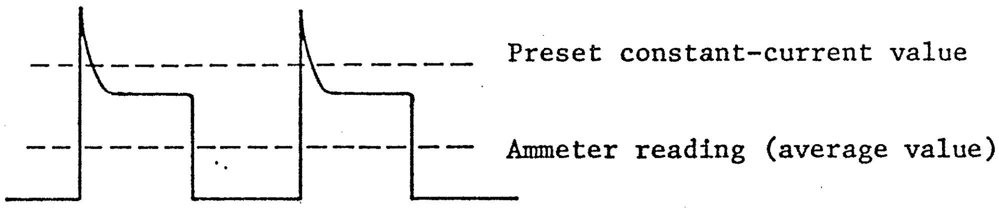


Figure 2-3. Load current with peaks

In this case, raise the preset value or increase the current rating.

(b) When a regenerative load (such as inverter, converter, or transformer) is connected to the power supply, as it cannot absorb the reverse current fed from the load, the output voltage increases and becomes unstable. In such a case, connect a bypass resistor (R) in parallel with the load and feed in this resistor a current larger than the maximum reverse current.

$$R\ [\Omega] \leqq \frac{E_0\ [V]}{I_{RP}\ [A]}$$

where, E_0: Output voltage
I_{RP}: Maximum reverse current

Table 2-1. Wire gauges and current ratings

Ta = 30°C (86°F)

Nominal cross section	Maximum current recommended by Kikusui	Maximum current designated by Electrical Installation Technical Ordinance (Article 29) JAPAN
38 mm^2	100 A	162 A
50 mm^2		190 A
60 mm^2		217 A
80 mm^2	200 A	257 A
100 mm^2		298 A
150 mm^2	300 A	395 A
200 mm^2		469 A

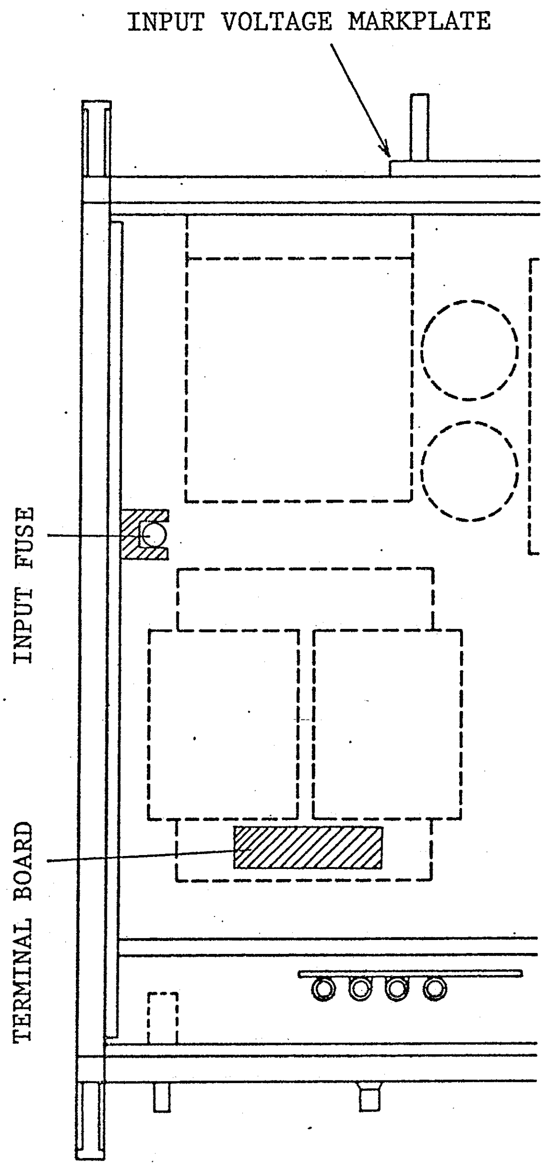
2-2. AC Input Requirements (100 V, 200 V)

The power supply can be converted for operation on a 100 V (±10%) line or a 200 V line by changing internal terminal board connections.

1. Change connections on terminal board of main power transformer. (See Figure 2-4.)

2. Change input power fuse.
   For 100 V AC .... 30 A
   For 200 V AC .... 15 A

3. Change input voltage markplate. (See Figure 2-5.)



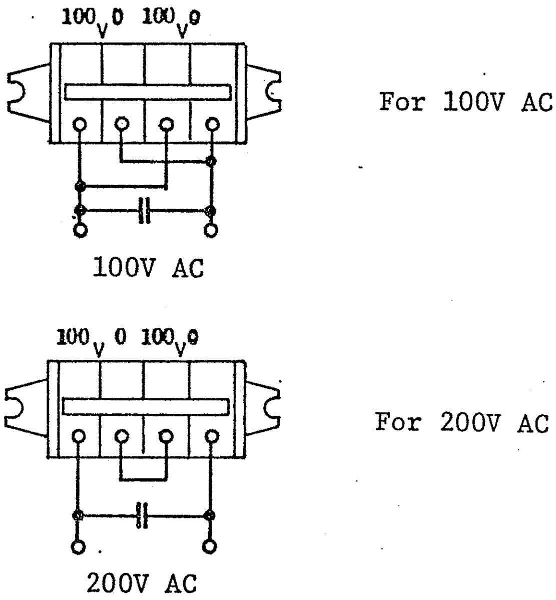


Figure 2-4

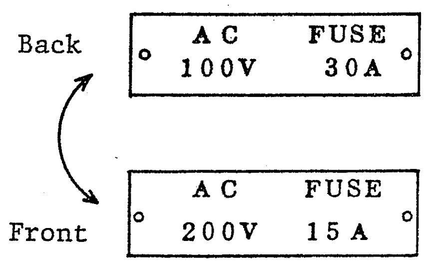


Figure 2-5

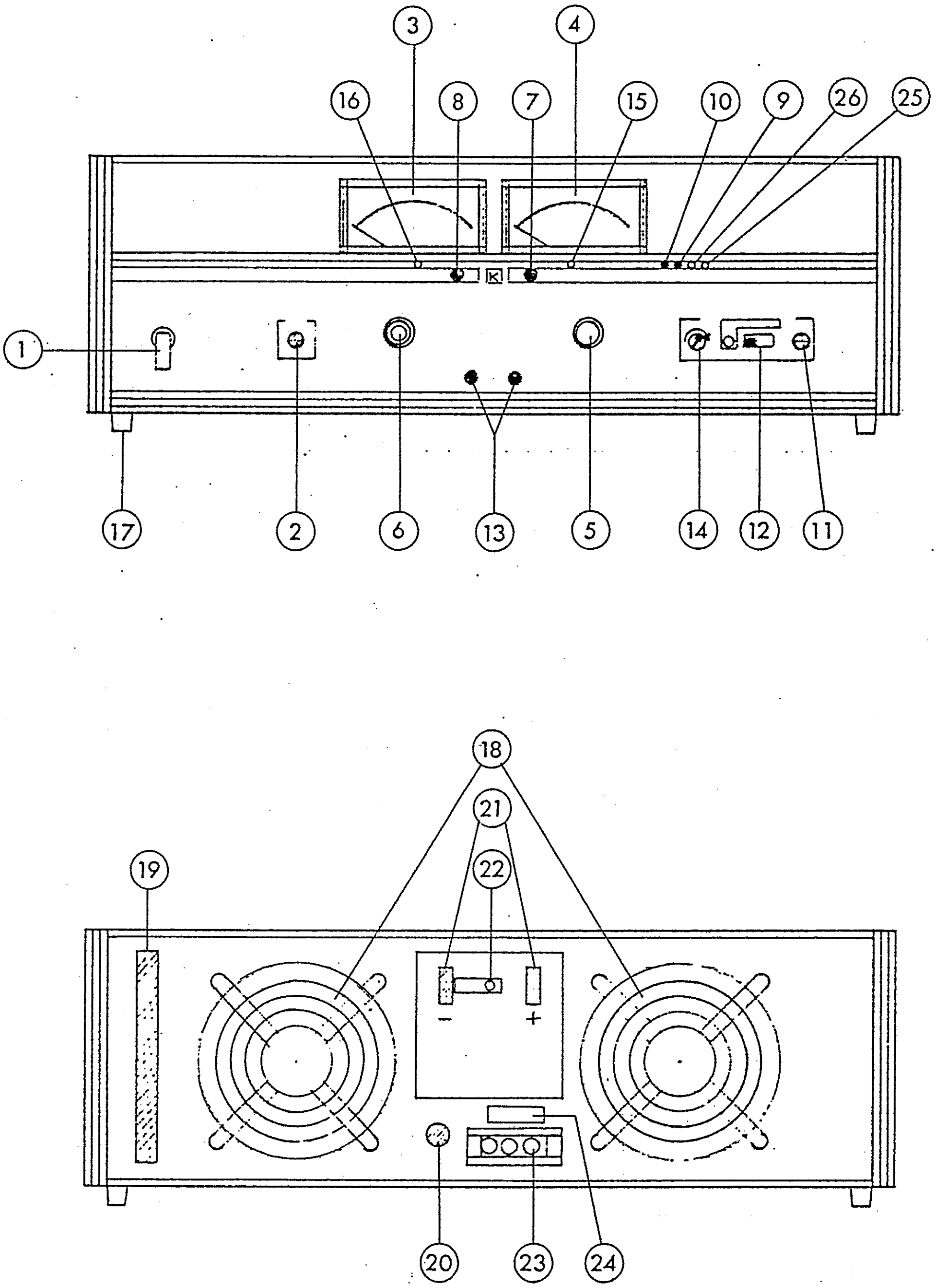


Figure 2-6. Front panel and rear panel

2-3. Explanation of Front and Rear

Panel items and descriptions

1. POWER switch:

   Circuit breaker serves as AC power switch. When thrown to the upper position, the input power is turned on and C.V. or C.C. lamp lights.

   Note: The input power is automatically turned off when any one of the internal protectors (over voltage protector, voltage detector, current detector and temperature detector) has tripped. The input power cannot be turned on immediately after it is turned off by the above cause. Eliminate the cause, wait about 60 seconds and then turn on the input power.

2. CURRENT/VOLTAGE LIMIT switch:

   Push to set crossover point of CV/CC. The ammeter indicates the preset constant-current value and the voltmeter indicates the preset constant-voltage value.

3. Ammeter:

   Monitors output current. Class 2,5

4. Voltmeter:

   Monitors output voltage. Class 2.5

5. Voltage setting knob:

   Adjusts output voltage for constant-voltage operation.
   10-turn potentiometer

6. Current setting knob:

Adjusts current for constant-current operation.
1 turn potentiometer

7. C.V. (constant-voltage operation indicator lamp):

Energizes in constant-voltage mode. Green LED

8. C.C. (constant-current operation indicator lamp):

Energizes in constant-current mode. Red LED

9. Voltmeter calibration resistor (R101):

For voltmeter calibration. (Periodically calibrate the voltmeter referring to SECTION 6 "MAINTENANCE.")

10. Ammeter calibration resistor (R102):

For ammeter calibration. (Periodically calibrate the ammeter referring to SECTION 6 "MAINTENANCE.")

11. OVP preset switch:

Push to the OVP reset switch; the voltmeter indicates the trip voltage of overvoltage protector (OVP).

12. Thyristor crowbar switch:

Select ON-OFF for thyristor which connected DC output parallel when OVP trips.
Be sure to set SW-OFF, if batteries or big capacitors are loaded.

13. VOLTAGE CHECK*

For checking the output voltage from the front panel.
Can be set at the output voltage using the chips supplied.
Fuse (0.1A) is incorporated.

14. Overvoltage protector (OVP) setting (See 3-3 "Operation Method of Overvoltage Protector."):

    When the output voltage has exceeded the set value due to inadvertent operation or instrument failure, the input power switch is instantaneously cut off to protect the load.

15. Zero adjustment of voltmeter:

    To adjust the voltmeter at 0 V.

16. Zero adjustment of ammeter:

    To adjust the ammeter at 0 A.

17. Rubber stud

18. Fan exhaust area:

    Air exit of the cooling package. As hot air comes out of this outlet, do not obstruct. The outlet must be positioned 30 cm or over from wall.

19. Terminal block:

    Terminals for remote control and series/parallel operation of two or more units. (See SECTION 4 "APPLICATIONS TO VARIOUS USES.")

20. DIN terminal

    Output signal for constant voltage and constant current. Input signal for power switch off. (See 4-8, 4-9)

21. Output terminals:

    Provide the output power.

22. GND terminal:

Be sure to connect this terminal to a good earth ground.

23. Input terminals:

The input power for the instrument is connected to these terminals.

24. Input voltage markplate

25. Output voltage offset control (V.os):

For adjustment of output voltage when the voltage setting knob is turned to the counterclockwise extreme position or for adjustment of input offset voltage when in remote control with voltage signal.

26. Output current offset control (I.os):

For adjustment of output current when the current setting knob is turned to the counterclockwise extreme position or for adjustment of input offset voltage when in remote control with voltage signal.

2-4. Constant-voltage Operation

Check at first that the AC line voltage is 100V (200V) ±10% AC. Then, proceed as follows:

(1) Turn the current setting knob to the extremely counterclockwise position.

(2) Turn on the input power switch. The C.C. lamp (red LED) will light indicating that the instrument power is on.

(3) Keeping depressed the current/voltage limit switch, set the output voltage at the required value with the voltage setting knob. By this procedure, setting of the output voltage is complete. (At this stage, the output power is not delivered to the output terminals yet.)

(4) Gradually turn clockwise the current setting knob to the point where the C.V. lamp (green) lights and the output power is delivered to the output terminals.

Setting of current limit

(5) Keeping depressed the current/voltage limit switch, set the required constant current value with the current setting knob. Once this setting is done, no output current larger than the set value flows even when the load is rapidly changed. (The load is protected by automatically changing the instrument operation from the constant-voltage mode to the constant-current mode. This function is called "crossover".)

Notes:

1. Pay attention when setting the O.V.P. voltage. At the instant the O.V.P. circuit operates, the input power switch is cut off. Set the O.V.P. voltage with an allowance of approximately 10%.

2. When the load resistance is unpredictable or it is predicted to vary largely or when it has a large inductance and rapid voltage application is undesirable, gradually increase the output current by increasing the output voltage or by gradually turning the current setting knob from the counterclockwise position in the clockwise direction.

2-5. Constant-current Operation

(1) Make it sure that the AC line voltage is 100V (200V) ±10%. Then, connect the input power.

(2) Turn on the input power switch. The C.V. or C.C. lamp will turn on indicating that the power supply is in the operating state.

(3) Keeping depressed the current/voltage limit switch, set the current at the required value with the constant-current knob and, at the same time, set the voltage limit value with the constant-voltage knob. Once this setting is done, the load is protected against overvoltage.

(4) Turn off the input power switch. Connect the load to the output terminals of the power supply and, then, turn on the input power switch.

Notes:

1. If the load has a large inductance and it is undesirable to apply rapidly a large current, set the current setting knob in the extremely counterclockwise position and, then, turn on the power switch and gradually increase the current.

2. If the current/voltage limit switch is depressed when in the constant-current mode, the output current is reduced by approximately 2 mA from the preset value. Pay attention if the load is of such nature that this 2 mA change is critical.

SECTION 3. PROTECTORS

3-1. Description

Regulated DC power supplies are used, as their name indicates, to supply regulated powers to loads of various types of electronic equipment. Demands for regulated DC power supplies have rapidly increased in recent years. As is the case for other types of electronic equipment, these instruments are required to include features of fast response, high reliability, high efficiency, high power factor, compactness, light weight, and economical price. Various types of power supplies are available on the market today. When selecting regulated DC power supplies, in addition to satisfying the required performances, special attention must be paid to some particular requirements which are slightly different from those required by other types of electronic equipment which handle electronic signals.

The above difference comes from the fact that regulated DC power supplies handle "powers." Malfunctioning or erroneous operation of the power supply leads to shut down of the overall system, damage to the power supply equipment and expensive load equipment, or to a fire in an extreme case. As the power supply provides the base for the entire electric and electronic circuits of the system to which it supplies the power, its reliability is very important. Protective features, which prevent serious damage when the power supply should fail, are important factors to be taken into consideration when selecting a power supply.

The PAD-L Regulated Power Supplies have been designed fully taking the above matters into consideration, as instruments of very high reliability. They employ premium quality components, with sufficient derating. They are incorporated with protectors which lead them to "the safer side" should they fail. Individual protectors are explained in this section.

3-2. Explanation of Protectors

(1) Presettable overvoltage protector

OVP trip voltage can be set from the instrument front panel by the voltmeter.

If the output voltage exceeds the preset voltage,

- In case of thyristor crowbar switch - ON (for semi-conductor etc):

  The power switch is cut off and thyristor that connected DC output parallel turn on.

- In case of thyristor crowbar switch - OFF (for batteries or large capacitors load):

  The power switch is cut off.

Caution

If batteries or large capacitors are loaded, be sure to set sw-off.

(2) Voltage detector

When the rated voltage of the electrolytic filter capacitor is exceeded due to such erroneous operation as disconnected jumper of the terminal block on the rear panel or due to a failure of the rectifier circuit, the input power switch is instantaneously cut off.

(3) Current detector

When in such erroneous operation as that the jumper of the terminal block of the rear panel is inadvertently left disconnected or when the current limiting circuit has failed, the control transistors are cut off and at the same time the input power switch is cut off or the current is limited at approximately 120% of the rated current.

(4) Temperature detector

Detects temperature of the cooling package (semiconductor cooling unit). When temperature of the cooling fins have become higher than approximately 100°C due to ambient temperature rise or cooling fan failure, the input power switch is cut off.

(5) Power fuse

Limits the input current.

(6) Output fuse

Limits the output current.

Both fuses are current limiting type of fuses meeting the requirements of JIS and model-approved by the Electrical Appliance Control Ordinance. The fuses employ a ceramic insulation tube and silica sand arc killer, and are free of flame when blown out.

3-3. Operation Method of Overvoltage Protector (OVP)

Setting procedure

(1) Push to the OVP preset switch, the voltmeter indicates the trip voltage of OVP.

(2) Set OVP trip voltage with a screwdriver.

SECTION 4. APPLICATIONS

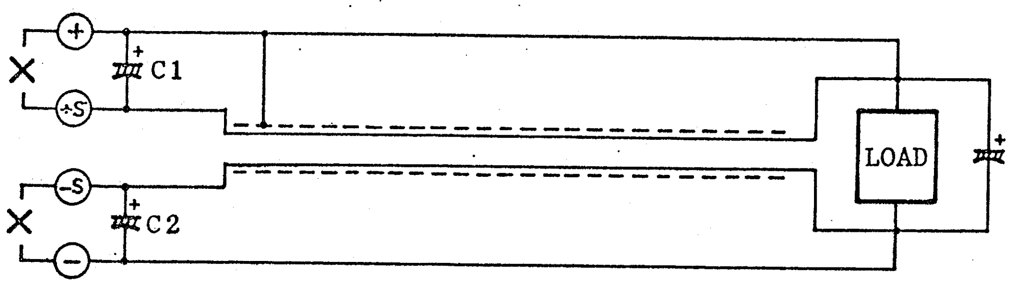
4-1. Remote Sensing

Voltage drop caused by the load connection wire resistance and contact resistance can be compensated for.

1. Turn off the input power switch.

2. Disconnect the jumper wires from between +S and ⊕ terminals and between −S and ⊖ terminals on the instrument rear panel.

3. Connect the +S and −S wires to the point where the output voltage drop is required to be compensated for. (Use a shielded cable in order to prevent induction of ripple voltage. Connect the external shielding wire to the ⊕ line of the output.)



C1, C2: 100μF, 16WV

Figure 4-1

Notes: 1. By this remote sensing feature, up to approximately 1.2 V of voltage drop per one-way of connection wire can be compensated for. Note that, if the voltage drop is larger than 0.3 V, the maximum rated voltage is reduced by the corresponding amount.

2. If the load connection cable is longer than 3 - 5 meters, phase shift caused by inductance and capacitance of the cable wires becomes noticeable and the circuit may oscillate. In such a case, connect capacitors C1 and C2 and connect an electrolytic capacitor of several hundred microfarads in parallel with the load as shown in Figure 4-1.

4-2. Output Voltage Control with an External Voltage or Resistance

o Control with an external resistance - I

1. Turn off the input power switch. (Be sure to turn off the input power switch whenever connecting or disconnecting wires of the rear terminals.)
2. Disconnect the jumper from between terminal (3) and (4).
3. Connect a 100-ohm potentiometer and another potentiometer (R1) between terminals (4) and (5).
4. Set R1 at zero and so adjust the 100-ohm potentiometer that the output voltage becomes zero.

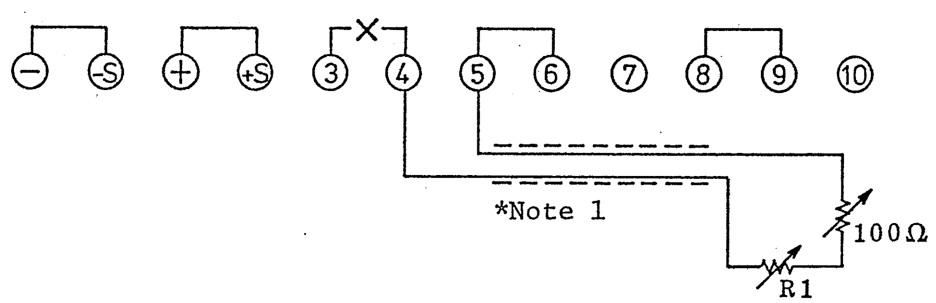


Figure 4-2

$$\text{Output voltage } E_o \fallingdotseq \frac{E_{max} \cdot R1}{10} \text{ [V]}$$

Where, $10 \geq R1$ [kΩ]

Emax: Rated output voltage [V]

*Note 1: Use a 2-core shielded cable or a pair of stranded wires. Connect the shield wire to the "+" output terminal.

- Application

  - By using a fixed resistor and a potentiometer, the voltage can be varied by plus or minus several percent of the set voltage.

  - Resolution of the output voltage depends on resistor R1. Therefore, required resolution can be obtained by using an appropriate value of potentiometer for R1.

  - A programmed voltage can be obtained by varying the resistance with switch setting. (For this purpose, use switches of a closed circuit type or continuous type which do not cause momentary open circuit.)

- Control with an external resistance - II

(This method is a fail-safe method free from overshoots even when resistors are switched.)

1. Turn off the input power switch.
2. Disconnect the jumper from between terminals ⑤ and ⑥.
3. Connect the resistor (potentiometer R2) between terminals ⑤ and ⑥.

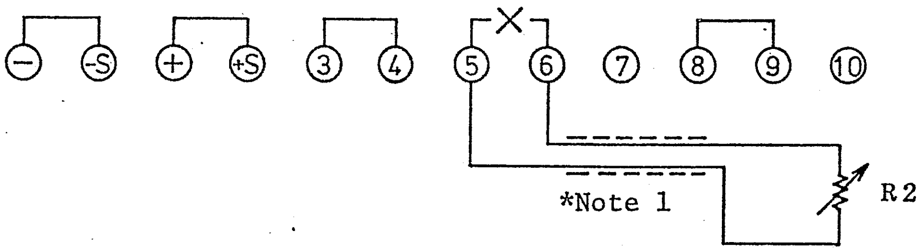


Figure 4-3

$$Eo = \frac{b}{a + R2} \times Eref \ [V]$$

Eo: Output voltage

Eref: Reference voltage, 0 to 10 V

R2: $0 \leqq R2 \leqq \infty$ (infinitive)

$a = 3.4\ k\Omega$, $b = 2.7\ k\Omega$

The output voltage (Eo) is inversely proportional to the resistance (R2) as shown below. Therefore, when the circuit has become open due to switching of resistors or a failure, the resistance becomes infinity and the output is reduced to zero.

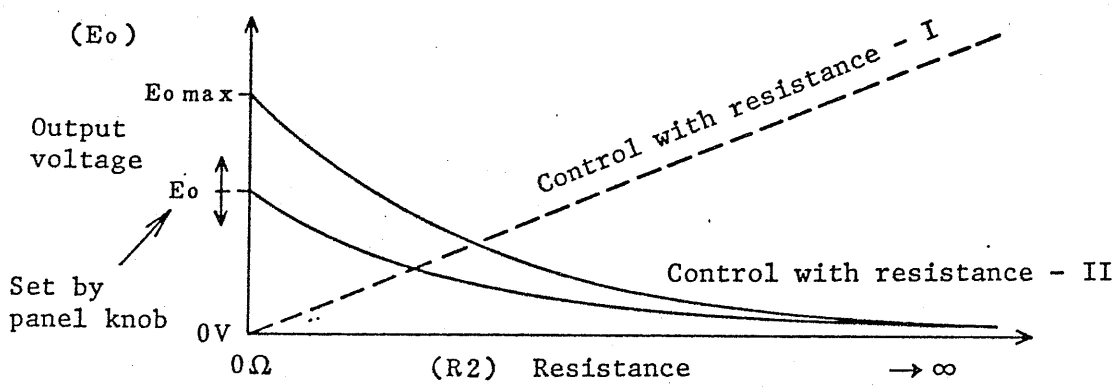


Figure 4-4

- Output voltage Eo can be calculated from R2 and Eref, using the above equation. Eref can be set by means of the voltage setting knob on the front panel. (When the knob on the front panel is to be made ineffective, disconnect the shorting bar from between terminals ③ and ④ and connect a 10-kΩ resistor of good temperature coefficient between terminals ④ and ⑤ as when in "control with resistance - I.")

- The primary objective of this mode of operation is to attain such a fail-safe feature that the output voltage drops when the output circuit is inadvertently made open. A disadvantage of this mode of operation is that a high resistor is required when programming for operation at low voltages. In general, a potentiometer of 0 - 200 kΩ or thereabout is used. (When using a high resistor, pay attention to its temperature coefficient and noise property.)

- Control with an external voltage

  1. Turn off the input power switch.
  2. Disconnect the jumper from between terminals ⑤ and ⑥.
  3. Apply an external control voltage between terminals ⑥ and (+S). (Pay attention to the polarity.)
     The terminal for the common line of the control voltage signal is (+S). The external control voltage signal must be of an isolated type. Note that the power supply may be damaged if the control voltage signal is not of an isolated type. When the output is controlled for both constant-current and constant-voltage simultaneously, the respective control voltage signals must be of an isolated type because the common lines of the two control circuits are not connected in common.

  * The instrument may be damaged if there is a wrong connection or an abnormally large voltage is applied. Check for them once more before turning on the instrument power.

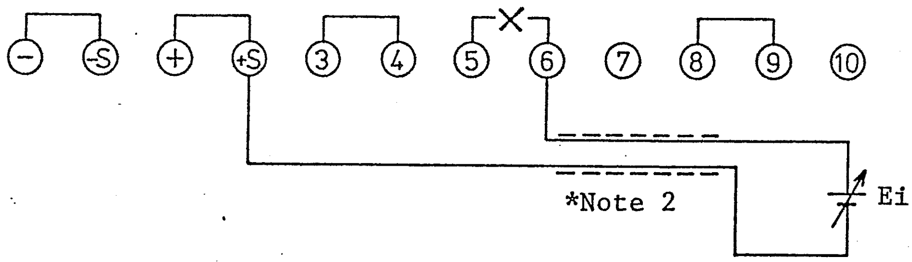


Figure 4-5

Output voltage $E_o \fallingdotseq \frac{E_{max} \cdot E_i}{10}$ [V]

Where, $0 \leqq E_i \leqq 11$ V

Eo: Output voltage [V]

Ei: Input control voltage [V]

Emax: Maximum rated voltage [V]

Notes:

1. Make sure that the output voltage does not exceed the maximum rated voltage.
2. Before this operation, set the OVP circuit in order to guard against overvoltage.
3. Keep the input control voltage within a range of 0 V to 11 V.
4. The input resistance between terminals ⑥ and +S is approximately 12.5 kΩ.
5. Noise included in the input control voltage is amplified and reflected on the output voltage. Sufficiently reduce the noise component of the input control voltage.

*Note 2: Use a 2-core shielded cable or a pair of stranded wires. Connect the shield wire to the "+" output terminal.

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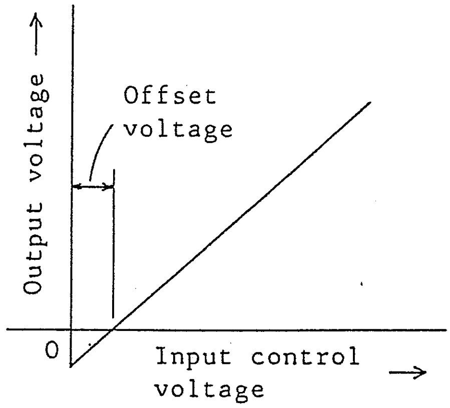
o There is an offset voltage between the input control voltage and the output voltage as shown below.



The input offset voltage can be adjusted with the output voltage offset control.

4-3. On-off Control of Output

A. For voltage preset with voltage limit switch when output is off

1. Turn off the input power switch.
2. Connect an external switch between terminals (9) and (10).
3. Turn on the input power switch. If the external switch is turned on, the output becomes almost zero. If it is turned off, the output power is delivered.

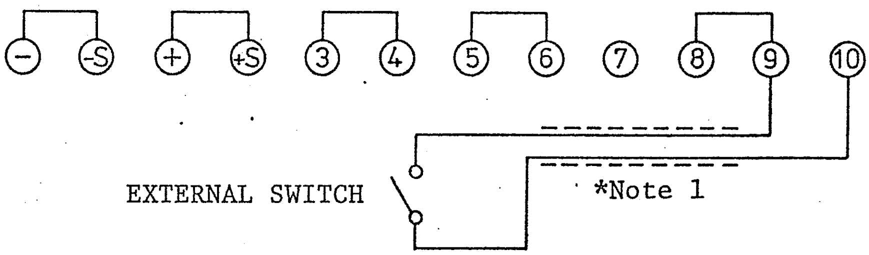


Figure 4-6

Note: When the output is in the off state, the output voltage of less than 0.6 V in the reverse polarity may be produced and a current of approximately 10 mA may flow depending on the type of the power supply. If such remaining voltage is not allowable, use method B explained in the subsequent paragraph. When the output is off, the current limit switch cannot be used.

B. To make the output voltage accurately zero volts

1. Turn off the power switch.
2. Connect an external switch and a 100-ohm potentiometer between terminals (4) and (5).
3. Turn on the input power switch. Next, turn on the external switch.

4. Adjust the output voltage to zero volts with the potentiometer.

5. If the external switch is turned on, the output voltage becomes zero; if it is turned off, the output power is delivered.

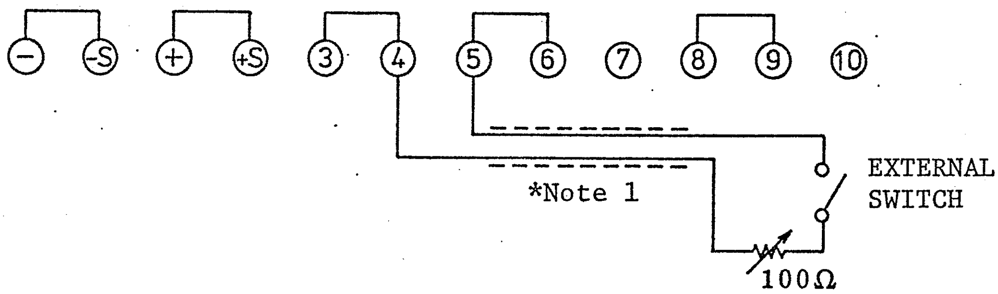


Figure 4-7

Note: When the output is off, the voltage limit switch cannot be used.

4-4. Output-current Control with an External Voltage or Resistance

o Control with an external resistance

1. Turn off the input power switch. (Be sure to turn off the power switch whenever connecting or disconnecting wires of the rear terminals.)

2. Disconnect the jumper from between terminals ⑧ and ⑨.

3. Connect R2 and R3 potentiometers between terminals ⑨ and ⑩.

4. Adjust the 10-ohm potentiometer so that the output current becomes zero when R2 is zero.

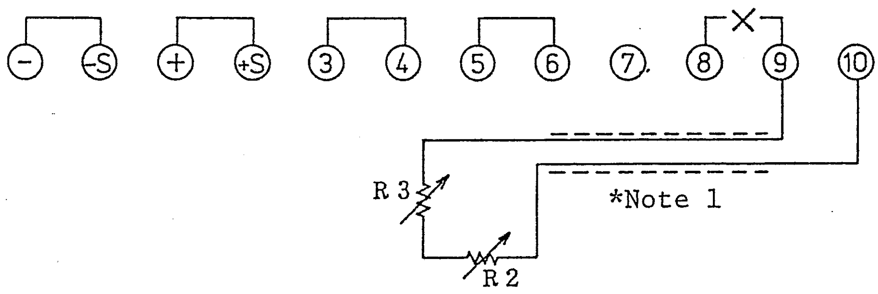


Figure 4-8

Output current Io $\fallingdotseq \frac{R2 \cdot Iomax}{550}$ [A]

*Note 2

Where, R2 $\leqq$ 550 [Ω]   R3: Approx. 10 - 30 [Ω]

Iomax: Rated output current [A]

*Note 1: Use a 2-core shielded cable. Connect the shield wire to the "+" output terminal.

*Note 2: Linearity between R2 and Io is approximately 5%.

o Control with an external voltage

1. Turn off the power switch.
2. Disconnect the jumper from between terminals ⑧ and ⑨.
3. Throw switch SW1 on PCB A-200 board to the upper position as shown in Figure 4-10. For location of the PCB, see Figure 6-1.
4. Connect electrolytic capacitor between terminals ⑨ and ⑩.
5. Apply the external control voltage between terminals ⑨ and ⑩. The potential of control common terminal ⑩ is alomost idedtical with that of output terminal ⊕. The external control voltage signal must be of an isolated type.

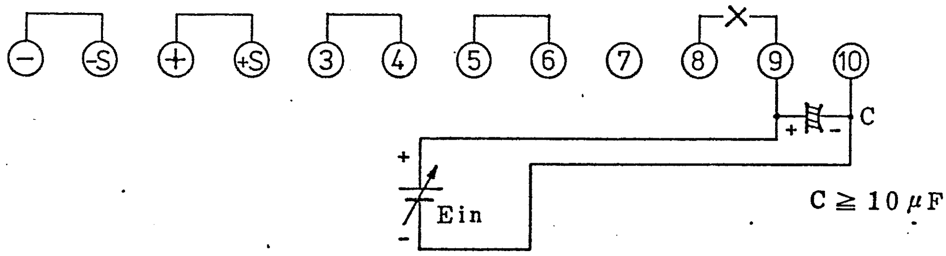


Figure 4-9

$$I_{out} \fallingdotseq \frac{E_{in}}{R} \text{ [A]}$$

Where, Ein [V] ≦ Einmax

Iout: Output current

Ein: Input current

R: Detecting resistor = 3.3 mΩ

Einmax: Maximum input voltage = 330 mV

Notes:

1. Make sure that the output current does not exceed the maximum rated current.
2. The input voltage (external control voltage) must be within a range of 0 V to the maximum input voltage.
3. Noise included in the input voltage is amplified and reflected on the output voltage. Sufficiently reduce the noise component of the input signal.

4. Be sure to throw switch SW1 to the original state (lower position) after the operation in the remote control mode is over.

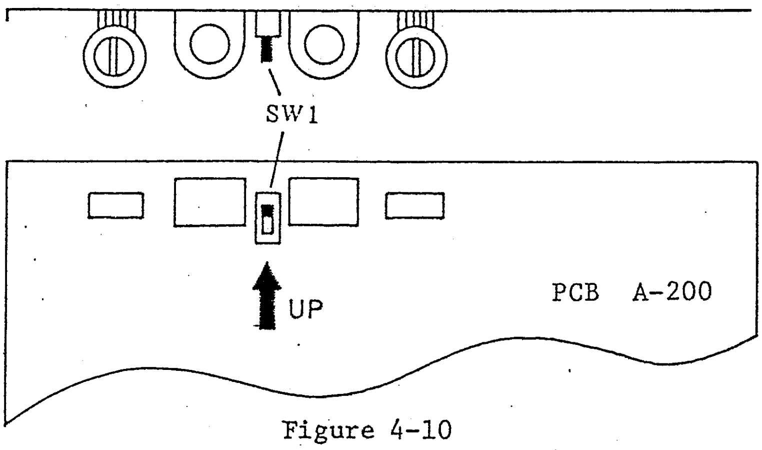
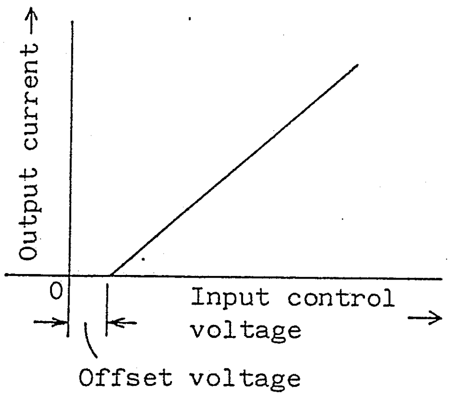


Figure 4-10

o There is an offset voltage between the input control voltage and the output current as shown below.

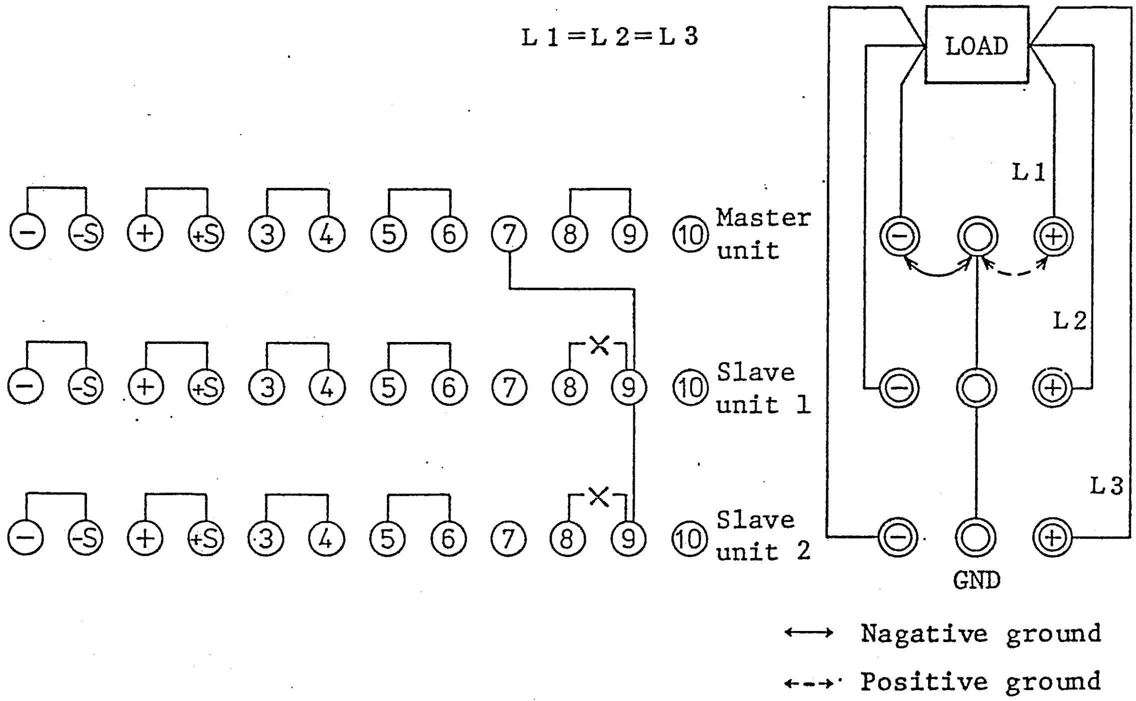


For particular applications which do not tolerate this offset voltage, adjust it with the output current offset control.

4-5. One-control Parallel Operation

One master unit and any number of slave units can be operated in parallel to increase the current capacity, controlled by one unit (master unit) for operation.

1. Turn off the input power switch.
2. Disconnect the jumper from between terminals (8) and (9) of each slave unit.
3. Connect terminal (7) of the master unit to terminals (9) of all slave units.
4. Connect parallel the output terminals of all units, for each polarity.



Set the constant-voltage setting knobs of all slave units to maximum position. Of the master unit, the green LED lamp lights to indicate the constant-voltage mode; of the slave units, the red LED lamps light to indicate the constant-current mode.

Figure 4-11

5. For one-control parallel operation, connect the GND terminals as shown in Figure 4-11.

6. For one control parallel operation with remote sensing, disconnect the jumper wires from between +S and + terminals and -S and - terminals of the master unit, and make required connections for the master unit as explained in 4-1 "remote sensing".

Note: Set the constant-voltage setting knobs of the slave units to the maximum position. For the wire gauges for the required currents, see Table 2-1.

4-6. One-control Series Operation

One master unit and a required number of slave units can be operated in series to obtain a higher output voltage (up to 250 V), controlling only one unit (master unit) for operation.

1. Turn off the input power switch.

2. Disconnect the jumper from between terminals ⑤ and ⑥ of each slave unit.

3. Connect ⑥ to +S as shown in Figure 4-12.

4. Connect the rear output terminal as shown in Figure 4-13.

5. Set the current setting knobs of all slave unit in the maximum position.

6. Adjust R220 on PCB A-200 (See Figure 6-1.) in slave so that slave output voltage is as same as master output voltage.

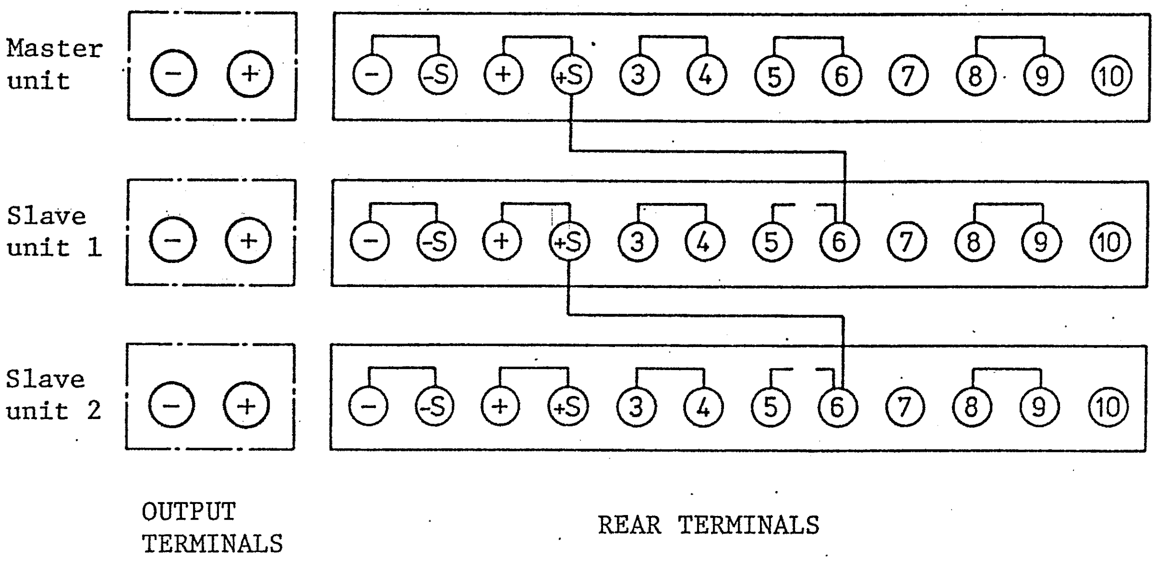


Figure 4-12. Terminal connections

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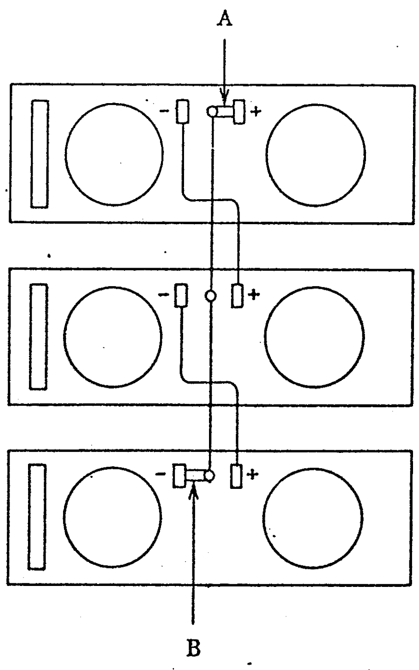


A: Positive ground

B: Negative ground

Figure 4-13. Rear output terminal connections

Notes:

1. Make the total series output voltage not higher than 250 V.
2. Set the constant-current setting knobs of the slave units at the maximum position.
3. Pay attention to the wattage of the external resistors (R1 and R2).
4. Values of R1 and R2 may slightly differ from the calculated value. Adjust the values of R1 and R2 as required.

Applications:

1. For one-control series operation with remote sensing, disconnect the jumper from between terminals +S and "+" terminals of the master unit and that from between -S and "-" terminals of slave unit 2 (the last slave unit). (See 4-1 "Remote Sensing.")

4-7. Constant-current Charge/Discharge of Battery or Capacitor

o Charge (constant current)

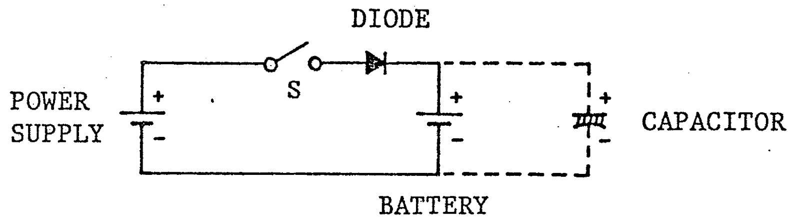


Figure 4-14

1. Keeping depressed the current/voltage limit switch, set the charge end voltage with the constant voltage setting knob and the charge current with the constant-current setting knob.

2. Close switch S so that the charging operation starts. When the charge end voltage is reached, the charging operation stops automatically. (The power supply employs a potentiometer burn protection circuit.)

Notes: 1. Connect the battery in the same polarity with the power supply. (If it is connected in the reverse polarity, the power supply may be damaged.)

2. If the output voltage of power supply is lower than the battery voltage or if the power switch is off, a current of several hundreds milliamperes flows from the battery into the power supply. If this current is not allowable, connect a diode in series with the battery as shown in Figure 4-14.

o Discharge (constant current)

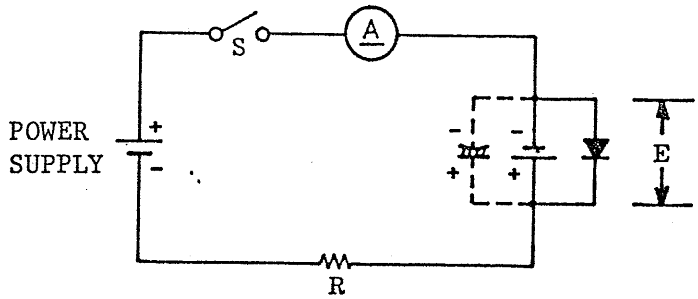


Figure 4-15

Resistance of R: $R = \dfrac{E[V]}{I[A]}$

Power consumption by R: $P = I^2R$ [W]

where, E: Terminal voltage of battery or capacitor when starting discharge

R: Discharge resistor

I: Discharge current (constant current)

D: Reverse current blocking diode

1. Set the output voltage of the power supply with the constant-voltage setting knob to a voltage higher by several volts than the terminal voltage of the battery or capacitor which is to be discharged. (Once this setting is done, constant-current discharge is done until the voltage of the battery or capacitor becomes zero.)

2. Calculate the resistance of the discharge load resistor (R). Pay attention to the wattage of the resistor.

3. Keeping depressed the current/voltage limit switch, set the discharge current with the constant-current setting knob.

4. Close switch S. Constant-current discharge operation will start.

Notes: 1. To stop discharge, open switch S. (Even when the input power switch of the power supply is cut off, the discharge current flows through the diode which is connected in parallel with the output circuit of the power supply.)

2. Be sure to connect the discharge load resistor (R). (If the battery or capacitor is directly connected, the power supply may be damaged.)

3. Be sure to connect the reverse current blocking diode.

4-8. Remote Turning Off of The Power Switch

To turn off the power switch, short-circuit between terminal ① and ⑤ on the rear DIN terminal.

Note: As terminals ① and ⑤ are at the potential of the "+" terminal of the filter capacitor, a floated (isolated) external contact signal is required for the remote control signal.

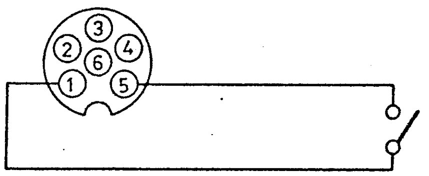


Figure 4-16

4-9. Output contact signal of Constant-Voltage mode and Constant-Current mode Operation

Constant Voltage mode

Constant Current mode
or Power Switch OFF

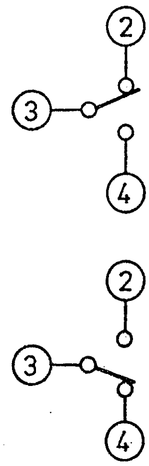


Figure 4-17

Note: o Constant rating: DC 24 V, 1 A or AC 100 V, 0.5 A

o Isolation from ground: DC 250 V

SECTION 5. THEORY OF OPERATION

5-1. Description of Pre-regulation Circuit

Before describing the operating principles of individual circuits of the power supply, history of variable regulated DC power supplies are very briefly introduced in the following.

Figure 5-1 shows a series control circuit. This circuit, as compared with other types of control circuits, has a higher control accuracy and provides an output of higher quality. The output voltage is variable for a wide range. Therefore, this circuit is widely used for variable DC power supplies. This circuit, however, has a disadvantage that, when the output power is supplied to a load at a low voltage, V_{CE} increases and consequently collector loss P_C ($P_C = V_{CE} \times I_C$) increases and, therefore, rectifier voltage V_C is required to be varied with respect to the output voltage.

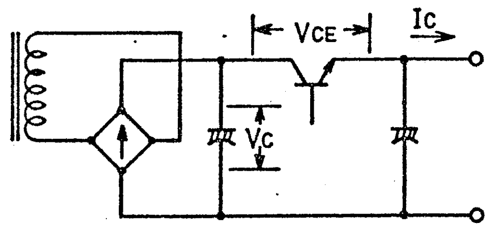


Figure 5-1
Series-controled power supply

Figure 5-2 shows a power supply circuit which employs a relay system. Variation of the output voltage is detected and transformer taps are switched with a relay circuit to compensate for

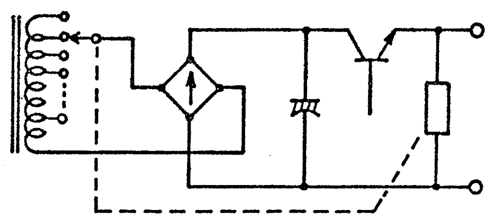


Figure 5-2
Variable regulated DC power supply circuit with relay switching.

output variation. The PAC Series Power Supplies employs this system. This system provides excellent power supplies up to approximately 200 watts. For larger power supplies, however, this relay system has such disadvantages that mechanical contacts have limited life and require maintenance, a number of relays are required to reduce the collector loss, and consequently the reliability falls and the cost rises. To solve the problem, solid-state switching circuit has become most common.

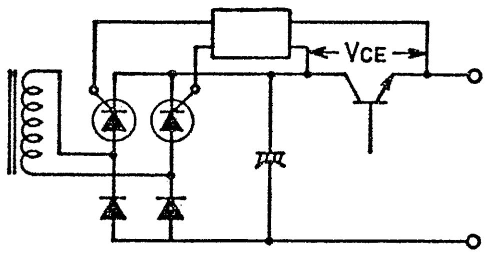


Figure 5-3
Variable regulated DC power supply with SCRs

Figure 5-3 shows the SCR system employed by the PAD Series Power Supplies. This system provides a fast response and V_{CE} can be maintained almost constant by phase control and, therefore, it enables high-accuracy large-rating variable power supplies. Thus, a large number of this type of power supplies have been manufactured by Kikusui. However, problems have risen regarding increase of ripple current of the electrolytic capacitor as the filter circuit is a capacitor input type, the surge current of SCRs, and overheating due to copper loss of the transformer when the power factor has become poor.

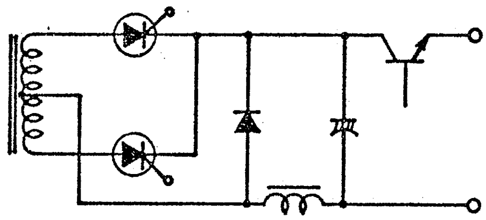
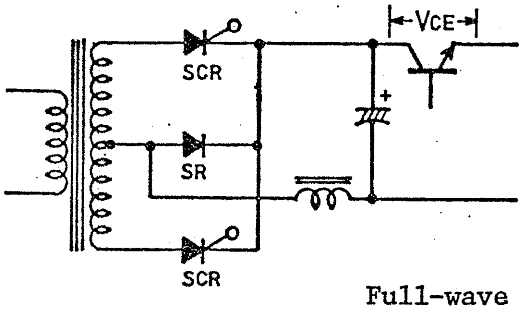


Figure 5-4
Principle of PAD-L Series Power Supplies

The PAD-L Series Power Supplies have solved the above problems by using a choke-input type filter circuit, and are the most reliable variable regulated DC power supplies available.

5-2. Controlled Rectifier Circuit and Filter Circuit



Full-wave rectifier circuit

Figure 5-5

- o This circuit rectifies the current with phase-controlled SCRs and the collector-emitter voltage of the series control transistor is maintained constant to reduce the collector loss.

- o The filter circuit is a single-stage inversed-L choke input type.

- o SR is a freewheeling diode, which is used as the load (filter circuit) of the rectifier circuit, is inductive in order to commutate the energy stored in the reactor and turn off the SCRs.

- o This circuit, when the conducting angle of SCRs has become narrower, can prevent degradation of power factor (which is inherent to the phase-controlled circuit) more effectively as compared with the capacitor-input filter circuit. It also solves the problems of ripple current of electrolytic filter capacitor and overheating of the transformer, and reduces the rectified output ripples. The PAD-L Series Power Supplies also employ a bridge rectifier circuit.

5-3. Phase Control Circuit

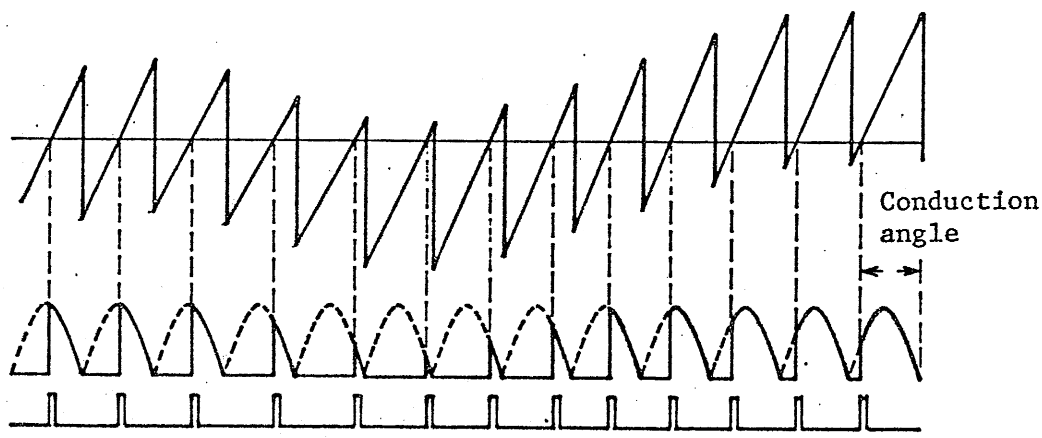


Figure 5-6

This circuit is a pulse phase modulator which operates in synchronization with the AC line frequency. When the collector-emitter voltage (V_{CE}) is large, the generated pulse signal is for a wider conduction angle and, when the voltage is lower, the signal is for a narrower conduction angle and, thus, the circuit so controls SCRs that V_{CE} becomes constant.

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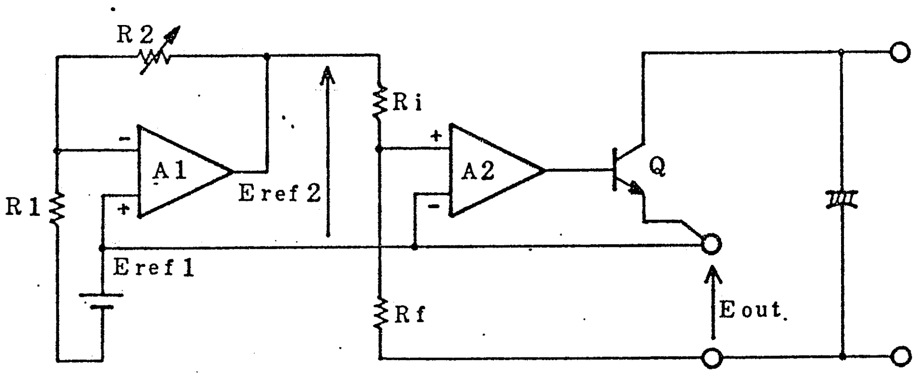
5-4. Constant-voltage Circuit



Eref 1:	Reference voltage 1
Eref 2:	Reference voltage 2
Ri:	Input resistance
Rf:	Feedback resistance

Figure 5-7

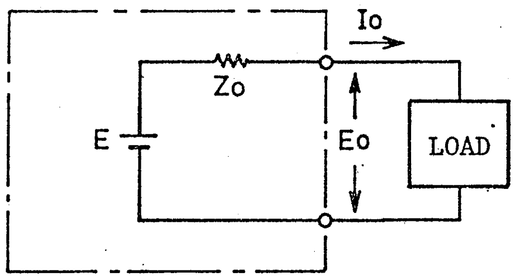
Output voltage Eout can be expressed as follows (A1 is an ideal amplifier):

$$\text{Eout} = -\frac{\text{Rf}}{\text{Ri}}\,\text{Eref 2}$$

Thus, the output voltage depends only on Eref 2, Ri and Rf. The output voltage is linearly proportional to Rf and Eref 2. For this power supply, Eref 2 is varied to control the output voltage. Eref 2 is produced by amplifying Eref 1, and this voltage is linearly varied by R2.

To obtain a stable output voltage, such components as Eref 1 diode, R1, R2, Ri, Rf, A1 and A2 must be sufficiently stable against change in external conditions. This power supply employs for the Eref 1 diode a zener diode of excellent temperature characteristics. The resistors are metal-film resistors and wound-wire resistors of excellent temperature coefficient and aging characteristics. Amplifiers A1 and A2 employ monolythic ICs which ensure high gain, wide band and low drift.

The major factors caused by line voltage variation are variation of the operating point of the error amplifier and variation of the reference voltage due to dynamic resistance of the reference diode. To guard against these variations, a stabilized internal auxiliary voltage source is used. Load variation ($\partial Vo/\partial Io$: output variation caused by output current variation) is affected by output impedance (internal resistance) Zo. (See Figure 5-8.)



$$Eo = E - IoZo$$

$IoZo$ = Load variation component

Figure 5-8

Denoting by A the open loop gain attained by error amplifier A2 and power transtor Q, output impedance Zo can be expressed as follows:

$$Zo = \frac{Ro}{1 + AB}$$

where, $$B = \frac{Ri}{Rf + Ri}$$

Ro: Output impedance of the circuit when no error amplifier is connected

The above equation indicates that the output impedance is improved to 1/(1+AB) by connecting amplifier A2 and effecting a feedback circuit.

5-5. Constant-current Circuit

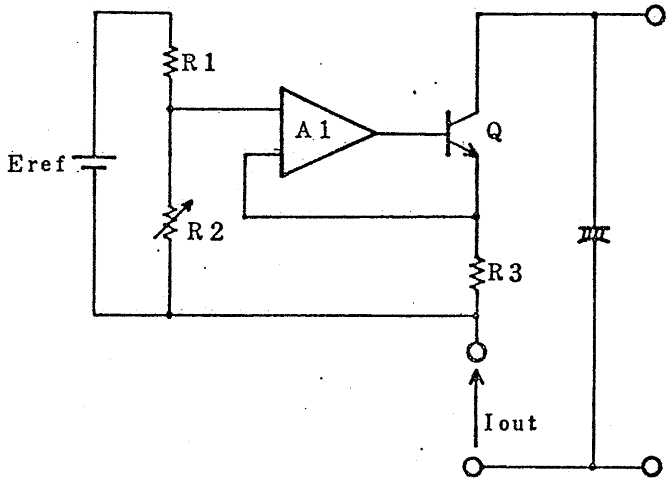


Figure 5-9

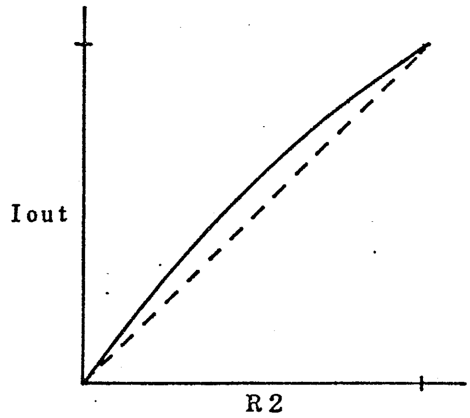


Figure 5-10

Eref:	Reference voltage for constant current
R2:	Output current control potentiometer
R3:	Output current detection resistor

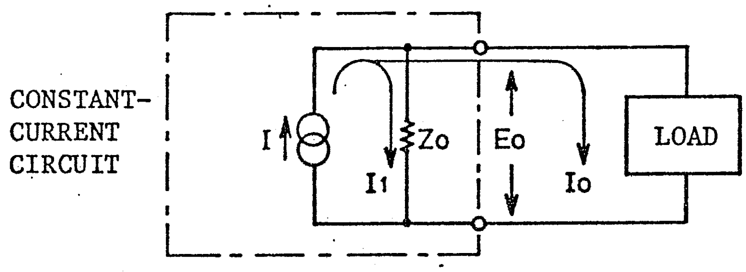
Output current Iout can be expressed as follows (A1 assumes an ideal amplifier):

$$Iout = \frac{R2}{R3(R1 + R2)} \times Eref$$

This equation indicates that the output current depends on Eref, R1, R2 and R3. Of this power supply, the output current is controlled by varying R2. Note that the relationship between R2 and Iout is not linear as indicated with a solid line in Figure 5-10.

To ensure a stable output current, Eref, R1, R2 and R3 must be sufficiently stable against change in external conditions (line voltage change, ambient temperature change, aging, and load change). Error amplifier A1 must be a high-gain wide-band DC amplifier with less drift.

Of the constant-current circuit, the larger the output impedance (Zout), the smaller is the load variation (∂Io/∂Vo: output current variation caused by output voltage variation). (See Figure 5-11).



Io = I - I1

where, I1 = Eo/Zo = Load current variation component

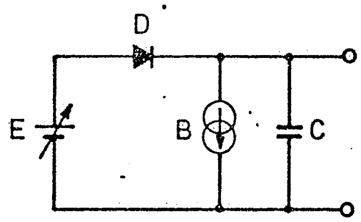
Figure 5-11

Denoting by gm the mutual conductance attained by erro amplifier A1 and power transistor Q, output impedance Zo can be written as follows:

Zo = (1 + gm R3) Ro

In this equation, Ro is the output impedance of the circuit before connecting the error amplifier. This equation indicates that the output impedance is improved by (1 + gm R3) times by connecting amplifier A1 and providing negative feedback.

5-6A. Differences from Ideal Constant-voltage Supply



E: Ideal constant-voltage supply

D: Ideal diode

B: Internal bleeder circuit

C: Capacitor

Figure 5-12. Equivalent circuit of series-controlled constant-voltage DC power supply

- o Cannot sink current:

  Figure 5-12 shows an equivalent circuit of a series-controlled constant-voltage power supply of the type used for this and other power supplies. An ideal diode is connected in series. This type of power supply is for a load of such type that it simply drains the current and does not send back the current. For such load as a battery which sends back a current, however this power supply cannot sink such current.

  This problem can be solved by using a parallel-controlled power supply or one which has a bi-polarity output. Such power supplies, however, will provide less efficiency and high cost for the same power.

  The problem can be solved by connecting a resistor in parallel with the load and feeding in the resistor a current larger than the maximum reverse current. When the reverse current is small, the problem may be solved by connecting an electrolytic capacitor in parallel with the load. When the load is an inverter, a filter circuit may be provided in the input circuit to reduce the reverse current.

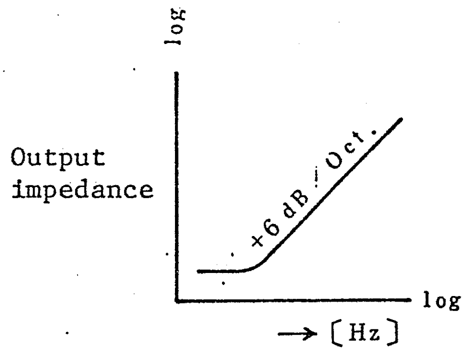


Figure 5-13

Frequency vs output impedance characteristics

o Output impedance is not infinity, with certain frequency characteristics:

Figure 5-13 shows that the output impedance (internal resistance) of this power supply increases as the frequency increases. This is because the gain of the loop including the error amplifier decreases. Better frequency characteristics, as well as DC output impedance characteristics such as for load variation, are a desirable feature for the power supply.

This feature must be such that not only the high gain region of the error amplifier is extended to a higher frequency range but also the phase characteristics are correct.

A shorter transient response time means better frequency characteristics of output impedance. Transient response time is an index for evaluation at the time range and output impedance is that at the frequency range.

5-6B. Difference from Ideal Constant-current Power Supply

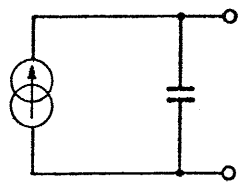


Figure 5-14

Figure 5-14 shows an equivalent circuit of this power supply operating as a constant-current source. A capacitor is connected in parallel with an ideal power supply.

There is no problem when the load is resistive. However, if the load is of such nature that it varies rapidly, pay attention to the fact that the output voltage also varies rapidly and the charge/discharge current of the capacitor is superimposed on the output current.

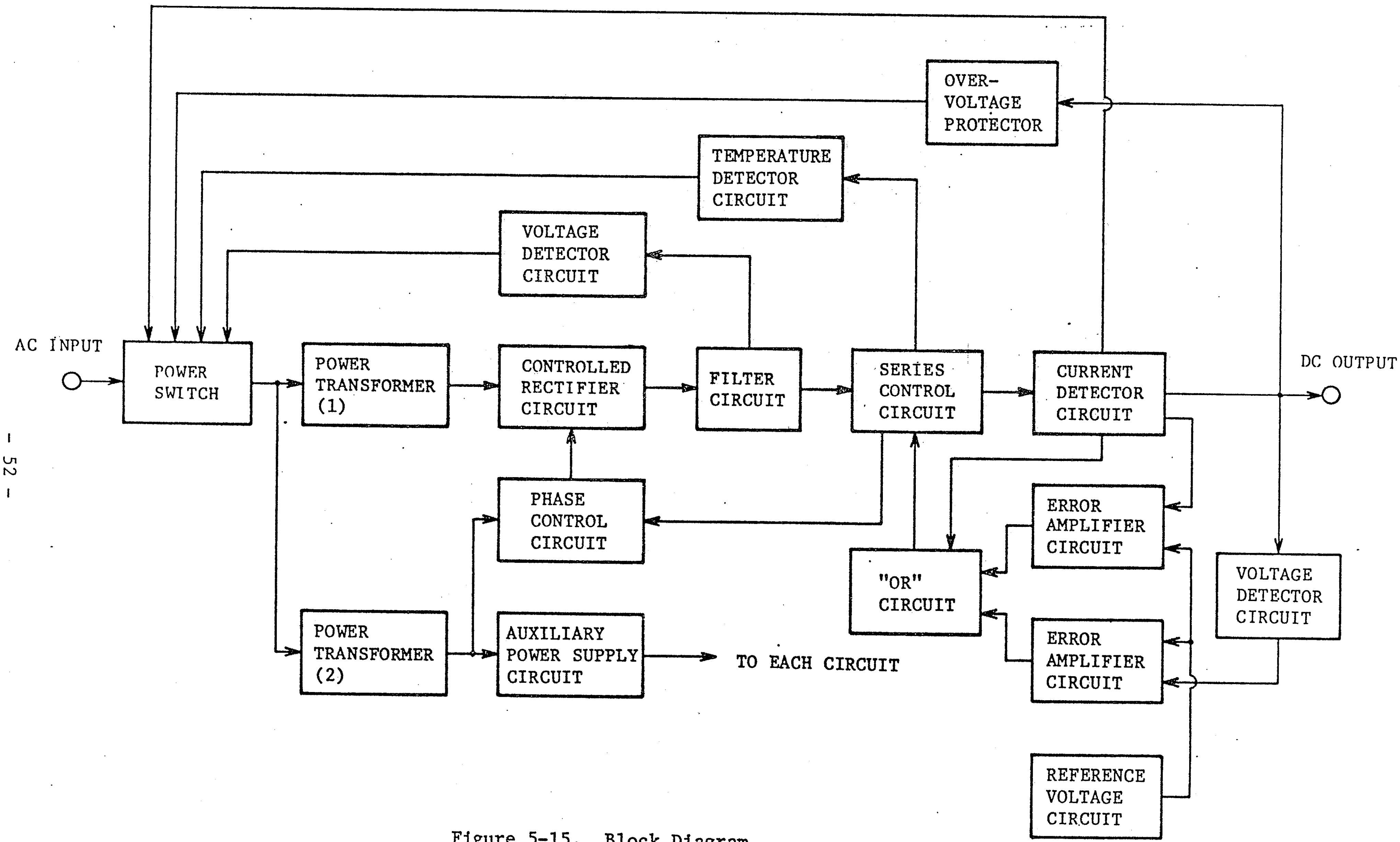


Figure 5-15. Block Diagram

SECTION 6. MAINTENANCE

6-1. Inspection and Adjustment

Periodically inspect and adjust the power supply so that it maintains its initial performance for a long time.

6-1-1. Removing Dust and Dirt

6-1-2. Inspecting the Power Cord and Plug

6-1-3. Calibrating the Voltmeter

6-1-4. Calibrating the Ammeter

6-1-5. Calibrating the Current/Voltage Limit Switch

6-1-6. Adjusting the Maximum Variable Constant-voltage Range

6-1-7. Adjusting the Maximum Variable Constant-current Range

6-1-1. Removing Dust and Dirt

When the instrument panel has become dirty, lightly wipe it with a cloth moistened with diluted neutral soapsuds or alcohol and, then, wipe it with a dry cloth. Do not use benzine or thinner. Blow away dust collected inside the instrument and in the ventilation holes of the casing, using a compressed air or a vacuum cleaner.

6-1-2. Inspecting the Power Cord and Plug

Check for that the vinyl cover of the cord is not damaged. Check the plug for play , loose screws and damage.

6-1-3. Calibrating the Voltmeter

Connect an external voltmeter of an accuracy of 0.5% or better to the output terminals, set the output voltage at the value indicated on Table 6-1, and calibrate the instrument voltmeter with R101 at the right-hand section on the front panel. (See the panel illustration on page 14.)

6-1-4. Calibrating the Ammeter

Connect an external ammeter of an accuracy of 0.5% or better in the output circuit, set the output current at the value indicated on Table 6-1, and calibrate the instrument ammeter with R102 at the right-hand section on the front panel. (See the panel illustration on page 14.)

6-1-5. Calibrating the Current/Voltage Limit Switch

- o Calibration of limit current

  Set the output current at the value indicated on Table 6-1. Press the current/voltage limit switch and so adjust R253 that the ammeter indicates the set current value.

- o Calibration of limit voltage

  Set the output voltage at the value indicating on Table 6-1. Press the current/voltage limit switch and so adjust R209 that the voltmeter reads the set voltage value. (See Table 6-1.)

6-1-6. Adjustment of Maximum Variable Constant-voltage Range

Connect to the output terminals an external voltmeter of an accuracy of 0.5% or better, set the constant-voltage setting knob in the maximum position (extremely clockwise position), and so adjust R220 on PCB A-200 that the instrument voltmeter reads the value indicated on Table 6-1.

6-1-7. Adjustment of Maximum Variable Constant-current Range

Connect in the output circuit an external ammeter of an accuracy of 0.5% or better, set the constant-current setting knob in the maximum position (extremely clockwise position), and so adjust R249 on PCB A-200 that the instrument ammeter reads the value indicated on Table 6-1. (See Figure 6-1.)

6-1-8. Adjustment of V_{CE} of Series Transistor

Maintain constant the AC input voltage at 100 V (200 V) Connect a load and apply the rated voltage and feed the rated current. In this state, connect a mean-value-indicating voltmeter between positive terminal of filter capacitor and "+" output terminal, and so adjust R326 that the voltmeter reads the value indicated on Table 6-1. (See Figure 6-1.)

		PAD 8-100L
Voltmeter adj	R101	8 V
Ammeter adj	R102	100 A
Current limit adj	R253	100 A
Voltage limit adj	R209	8 V
Maximum voltage adj	R220	8.5A
Maximum current adj	R249	105 A
V_{CE} adj	R311	3 V

Table 6-1

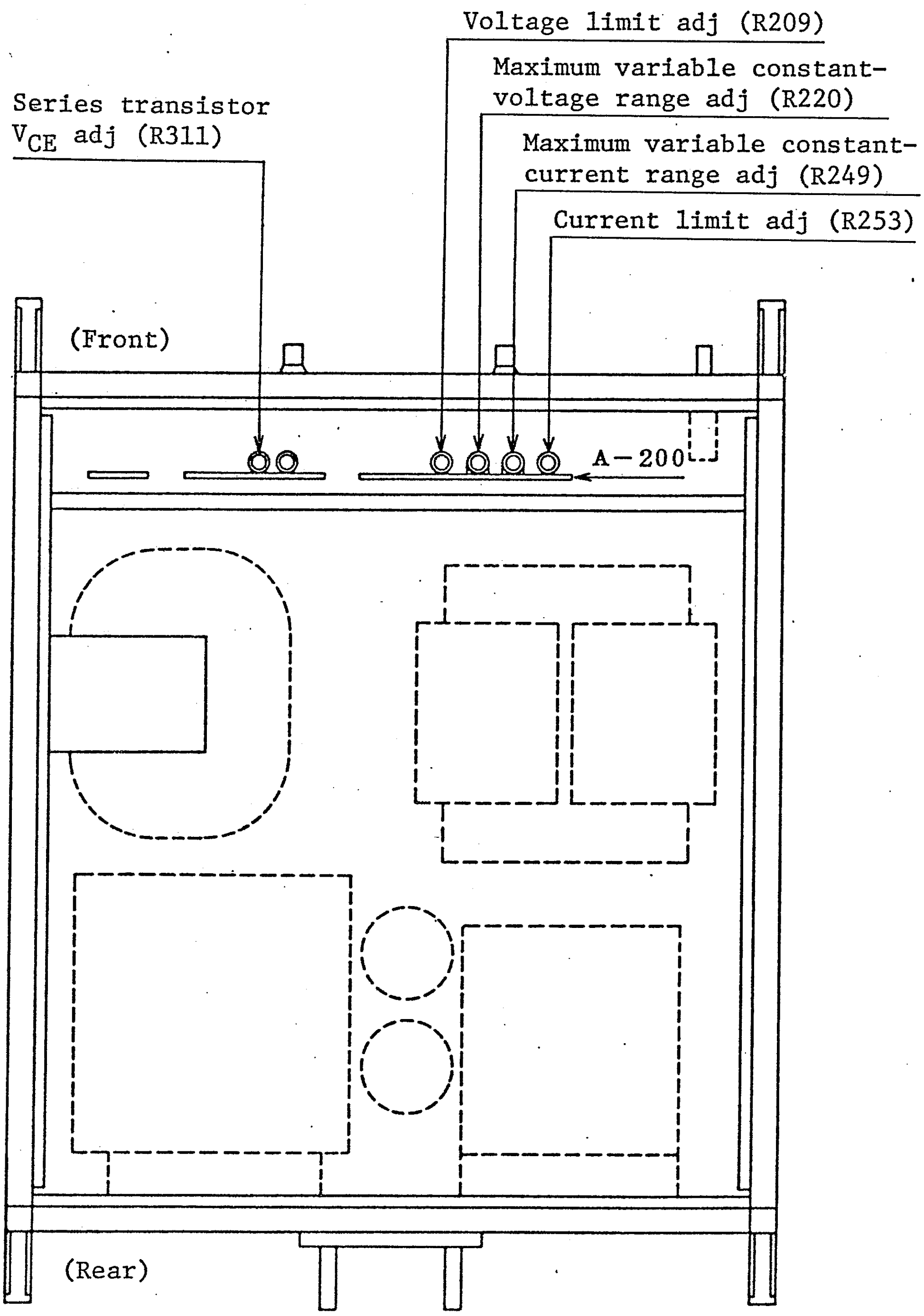


Figure 6-1 (Top view)

6-2. Troubleshooting

The most probable causes of troubles are shown in the following table. When a failure of the power supply is found, contact Kikusui agent in your area.

Symptom	Check item	Probable cause
Power switch cannot be turned off (or turns off soon).	1. Has the overvoltage protector tripped?	o Set voltage too low
	2. Shorting bar disconnected?	o Disconnected or loose shorting-bar
	3. Is fan stalled?	o Trip of overheat protector (Replace fan.)
	4. Other than the above	o Trip of protector due to a failure of rectifier circuit
No output (No output is produced at all or only a slight output is produced.)	1. Is the input power fuse blown?	o Input line voltage too high (Replace fuse.) o Failure of rectifire circuit
	2. Is lamp lighted?	If not lighted, o Open-circuiting of power cord
	3. Are the lamps alternately lighting, indicating rapid transitions of operating domains	o Too narrow constant-voltage and constant-current setting ranges

Symptom	Check item	Probable cause
	4. Are the shorting-bars correctly connected?	o Wrong connection of shorting-bar(s)
	5. Is the output power fuse blown out?	o Output current flowed exceeding the rated value o Power transistor failure
	6. Is the circuit oscillating?	o Phase inversion caused by remote sensing circuit (Connect an electrolytic capacitor at the load end.) Refer to 4.1. o (Re-adjust)
	7. Is a current flowing despite no load?	If flowing, o Failure of the protective diode connected in parallel with the output (This diode may be damaged if such load as battery is connected in the reverse polarity.)
	8. Other than the above	o Circuit failure
Abnormally high output	1. Is the shorting-bar disconnected? (Between 3 and 4 .)	o Disconnected or loose shorting-bar o Malfunctioning OVP circuit

Symptom	Check item	Probable cause
	2. Output voltage (current) cannot be reduced	o Power transistor failure o Bleeder circuit failure
Unstable output	1. Is the shorting-bar(s) loose?	o Incorrect connection of the shorting-bar(s)
	2. Is the AC line voltage correct?	o AC line voltage not within the specified range
	3. Special type of load	o See 2-4.
	4. When matter of drift is critical	o Allow approximately 30 minutes of stabilization time.
	5. Other than the above	o Circuit failure
Large ripple voltage	1. Is the AC line voltage correct?	o Input voltage too low
	2. Are the sensing terminals securely connected to the output terminals?	o Securely connect the sensing terminals
	3. Is a strong source of magnetic or electric field present near the power supply? (Is there no nearby auto-transformer, power transformer, or an oscillating source?) (Especially when in the constant-current mode)	o Electromagnetic induction (Move the source of ttouble. Strand the wires.)
	4. Other than the above	o Circuit failure o (Re-adjust)