Constant-Current Power Supply for Hydrogen or Deuterium Lamp

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The purpose of this note is to describe a compact constant-current dc power supply capable of supplying currents of 2 A or less at potentials of 110 V or less. The high effective output resistance (100 kΩ) leads to very stable operation of discharge lamps; output fluctuations arising from ac ripple and line or load changes are less than 100 μA. A useful result is that the lamps can be operated at a considerably lower power, and thus have a longer life, than is possible with less closely regulated supplies. A 50 W hydrogen lamp (Sylvania HAK-50) can be operated at a power level of 31 W and a 35 W deuterium lamp (DE-350) at 15 W. Transient recovery time following a line voltage or load disturbance—which may be important in some rapid-sweep spectroscopic applications—is less than 1 msec and thus considerably smaller than that of most moderately priced commercial units (200 msec). An additional advantage is the ease with which the lamp may be started. Following the usual momentary operation of the self-contained starting circuit, the regulator automatically reaches the preset current and no further adjustment is necessary.

The regulator circuit, which is shown in Fig. 1, is similar in principle to that described by Ryley and Gambling.[1] The partially filtered dc output of a controlled rectifier (C20B) is applied to the discharge lamp L in series with a regulated power transistor (2N3714). The latter, which is controlled by a high-gain operational amplifier, regulates out the remaining ripple and keeps the current constant at a value determined by the setting of potentiometer C. A subsidiary feedback loop via the 2N3904 transistor regulates the controlled rectifier so that the potential across the power transistor (2N3714) is between 20 and 25 V at all times—the lower limit is set by ripple at the output of the controlled rectifier and by anticipated line voltage fluctuations.

Circuit requirements in the present case are less stringent than those of Ref. 1. Thus, because the load is noninductive, a simple firing circuit[2] for the controlled rectifier can be used. Also because the voltage and power capabilities of the power transistor are quite high (80 V and 40 W if mounted as in Fig. 1) no special protection is necessary to compensate for transient effects. The use of the high-gain operational amplifier A simplifies the regulator circuitry in addition to providing the high output resistance and close regulation mentioned above.

Two potential sources of radio interference are present in this circuit. The first consists of sharp pulses produced when the controlled rectifier fires. Their effect in the control circuit is removed by inductance L_2 and capacitor C_5 and transmission to the ac supply is prevented by capacitor C_1. The second source of high frequency is the negative resistance of the discharge lamp which leads to an oscillation of several megahertz and 30 V across it. Capacitor C_2

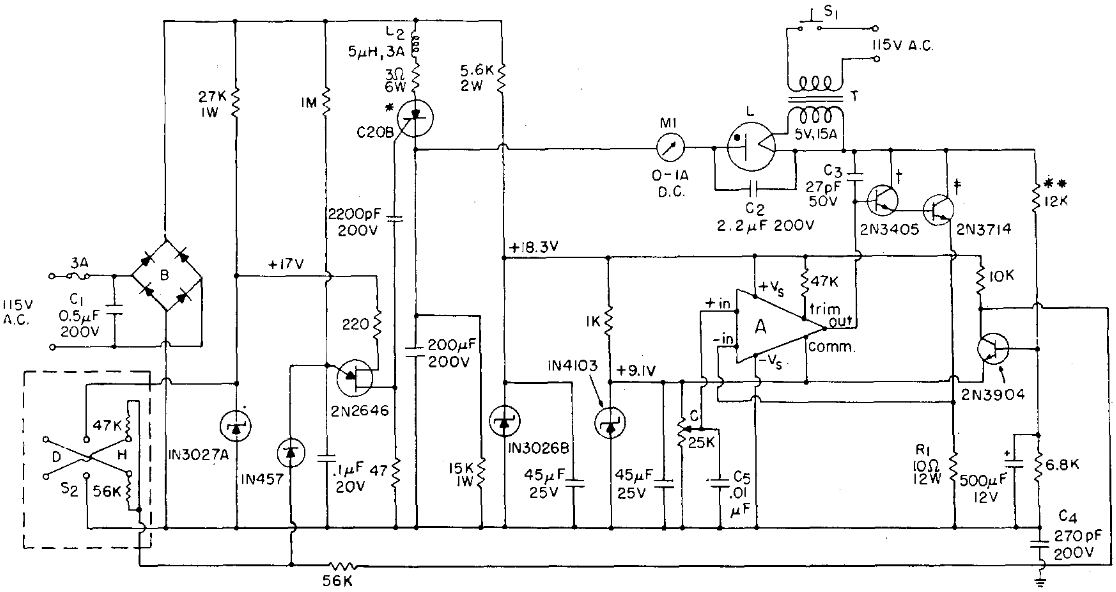

Fig. 1. Circuit of constant-current dc power supply. L—Hydrogen lamp HAK-50 or deuterium lamp DE-350; T—lamp starting transformer; B—bridge rectifier, 200 V, 1 A; A—economy operational amplifier (Analog model 111 or equivalent); S_1—lamp starting switch; S_2—lamp selector switch (H—hydrogen, D—deuterium); *—chassis mounted—(insulated); †—chassis mounted—(self-insulated); ‡—mounted on insulated heat sink (Delco 7270725 or equivalent); **—adjust to give 20–25 V across 2N3714 for normal ac line voltage. All resistors ½ W unless otherwise marked.

reduces this effect to a fraction of a volt. Further reduction to a few millivolts can be obtained by means of capacitors C_3 and C_4.

Performance of the circuit, over a period of 6 months in a typical vacuum spectrometer application, has been excellent. After a 5 min warmup period, the output current has a temperature coefficient, arising mainly from the 1N4103 Zener diode, of about 0.6 mA/C°. Under most operating conditions this is negligible, but it can be reduced to about 5 μA/C°, if desired, by the use of a temperature-compensated Zener diode.

The writer wishes to acknowledge the contribution of R. M. Boulet, who built most of the experimental versions of this circuit and measured their performance.

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[1] J. E. Ryley and W. A. Gambling, J. Sci. Instr. **39**, 600 (1962).

[2] *Silicon Controlled Rectifier Manual*, F. W. Gutzwiller, Ed. (General Electric Components Department, Auburn, N. Y.), 3rd ed.

Sapphire Rod Thermosensor

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We have been concerned with the crystal growth of refractory semiconductors with melting points in the temperature range near 1500°C. To obtain these temperatures, rf heating (~500 kc) is used. When thermocouples fabricated from the metals of the platinum family are used for thermosensing the following limitations were observed:

(1) The thermocouples are expensive and must be carefully fabricated.

(2) The relatively rapid rate of recrystallization and fracture at the above temperatures severely limits the useful life of these thermocouples.

(3) The thermocouples must be shielded, in some manner, from rf pickup.

The use of a sapphire rod-thermopile assembly for thermosensing is well known and commercial assemblies are readily available. These are operated by sighting the heated object with the sapphire rod which in turn pipes the radiant energy to the thermopile, where it is converted into a dc voltage. The sapphire rod in many applications is external to the heated object and must sight through a glass envelope. This is a disadvantage, because at high temperatures appreciable clouding of the envelope occurs. This clouding results in a decrease of the radiant energy to the thermopile and therefore interferes with the control process. For example, when a susceptor was independently controlled at a fixed temperature of 1500°C, the dc output of the thermopile dropped an amount equivalent to 200C° in a 16 h period.

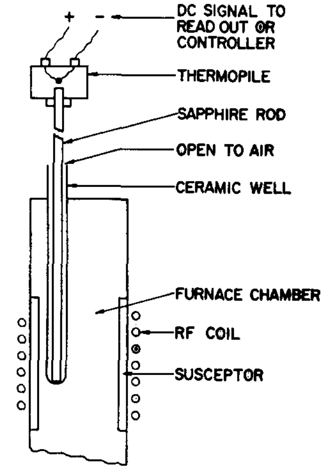

Fig. 1. Schematic representation of the sapphire thermosensor during operation.

To circumvent this problem, we have used the sapphire rod as a substitute for a thermocouple, i.e., the sapphire rod itself is directly inserted deeply into a ceramic thermocouple well (see Fig. 1), and therefore it is at the high temperature of the furnace. The output of the thermopile is sensitive to the position of the sapphire rod within the well, and a reproducible calibration can best be achieved by positioning the sapphire rod directly against the bottom of the well, as shown in Fig. 1. The thermopile itself is, of course, outside of the furnace. Each ensemble is calibrated prior to use. A plot of temperature vs dc millivolt output for such a thermosensor is shown in Fig. 2. In this case a Minneapolis Honeywell Radiamatic thermopile and 3 mm ×41 cm sapphire rod were used; the calibration was performed against a thermocouple within a tubular resistance furnace.

Such thermosensors have been very stable in our application. A single saphire rod has been used in dozens of runs (temperatures to about 1600°C for approximately 16–24 h per run). No noticeable change in the output voltage vs temperature has been observed. In the operating range of 1500°C the thermal sensitivity is excellent—about 1 mV per 3°C with an accuracy of better than

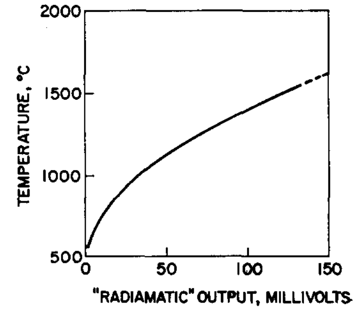

Fig. 2. Temperature vs dc output voltage of thermosensor.