Operating a DC power supply as constant-current and constant-voltage source

Experiment objectives

- Record current and voltage while operating a power supply as a source of constant voltage.
- Record current and voltage while operating a power supply as a source of constant current.
- Use a power supply to limit voltage and current.

Principles

In any real voltage source loaded by an external resistance of R_L, part of the overall voltage U_0 drops across the source's internal resistance R_i. This leads to the terminal voltage U being lower than U_0

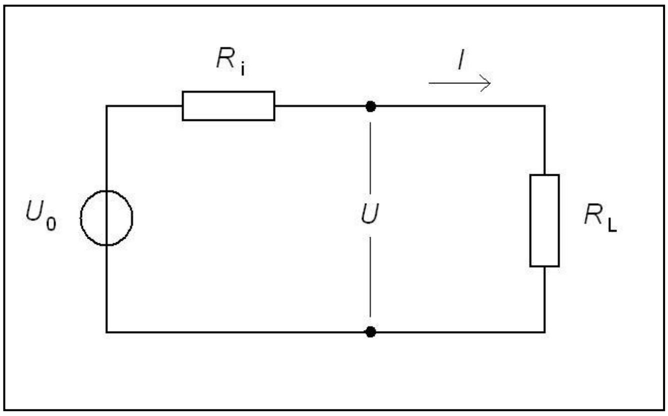


Fig. 1: Real voltage source: $U = U_0 - R_i \cdot I$

If the internal resistance $R_i = 0\ \Omega$, then the source in question is an ideal one, where the voltage U is independent of the load resistance R_L and therefore remains constant regardless of the current consumption I.

In a real current source loaded with an external resistance R_L, the current too is less than the ideal current I_0 due to a proportion of it flowing via the internal resistance R_i. The current supplied is therefore reduced to I.

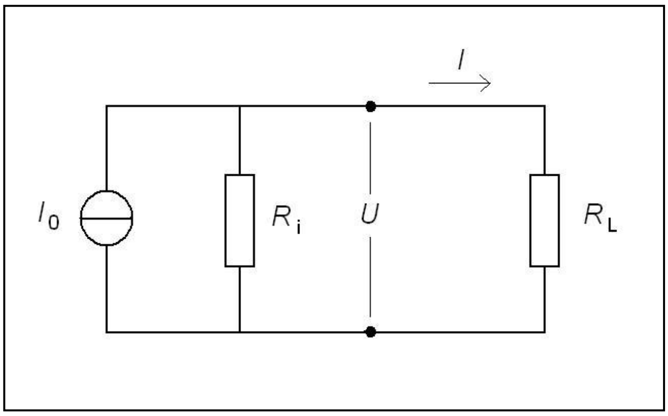


Fig. 2: Real current source: $I = I_0 - \frac{U}{R_i}$

If the internal resistance $R_i = \infty$, the source is ideal and the current I remains constant regardless of the load resistance R_L and therefore regardless of the terminal voltage U.

Both constant voltage and constant current sources can be implemented by means of electronic circuits. This means that it is possible to work with a source that is "ideal" over a certain range. The range is determined by the maximum current I_0 and voltage U_0. The maximum values are determined by the specification of the power supply or, in some cases, are adjustable to selected values.

From the maximum voltage U_0 and maximum current I_0 it is possible to determine a limiting resistance R_G

$$R_G = \frac{U_0}{I_0}$$

Constant voltage source: U = constant

If the load resistance R_L is greater than R_G, the terminal voltage U will remain constant.

$$R_L > R_G \rightarrow U = \text{constant}$$

In this range, the supply operates as an ideal voltage source.

The current I changes with the resistance R_L in accordance with Ohm's law.

$$I = \frac{U}{R_L}$$

Constant current: I = constant

If the load resistance R_L is less than R_G, then the current I remains constant.

$$R_L < R_G \rightarrow I = \text{constant}$$

In this range, the supply operates as an ideal current source.

The terminal voltage U will be reduced in accordance with Ohm's law.

$$U = R_L \cdot I$$

Kem 28-10-13

Equipment

1 AC/DC power supply, 0…15 V/0…5A......... 521 501
1 Rheostat, 10 Ω 537 32
1 Experiment lead, 32 A, 100 cm, red 501 30
1 Experiment lead, 32 A, 100 cm, blue.......... 501 31

Additionally recommended
1 LDanalog 30 multimeter............................. 531 130
1 Experiment lead, 32 A, 50 cm, red 501 25
1 Experiment lead, 32 A, 50 cm, blue............ 501 26

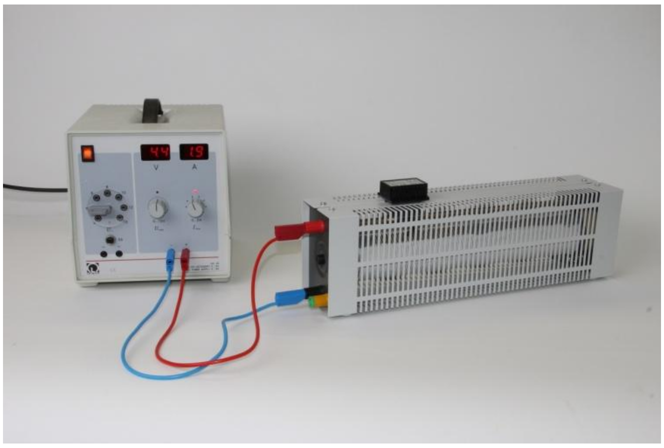


Fig. 3: Experiment set-up

Experiment set-up

- Set up the equipment as shown in Fig. 3. Do not connect up the leads yet.
- Turn on the power supply.

Note: the display indicates the voltage U and current I actually supplied to the terminals. The knobs can be used to adjust the maximum values for voltage U_0 and current I_0.

Experiment procedure

a) Constant voltage source

- Set the DC current knob to maximum (*i.e.* $I_0 \approx 5$ A).
- Use the DC voltage knob to set the voltage to a value of $U_0 = 10$ V, for example.
- Initially set the rheostat to its highest possible resistance.
- Connect the load resistor to the supply as shown in Fig. 3.
- Make a note of the voltage U and current I.
- Use the slider to reduce the load resistance and record various other pairs of voltage and current readings.
- In particular, make a note of the limiting resistance, after which the voltage is no longer the same.

Note: Initially the LED above the DC voltage knob (constant voltage mode indicator) will be lit. As of the limiting resistance, the LED above the DC current knob will come on instead (constant current mode indicator).

b) Constant current source

- Use a lead to connect the two output sockets of the power supply together (short circuit).
- Set the DC voltage knob to maximum ($U_0 \approx 15$ V).
- Use the DC current knob to set the current value to $I_0 = 3.00$ A, for example.
- Initially set the rheostat to its smallest possible resistance.
- Connect the load resistor to the supply as shown in Fig. 3.
- Make a note of the voltage U and current I.
- Use the slider to increase the load resistance and record various other pairs of voltage and current readings.
- In particular, make a note of the limiting resistance, after which the current is no longer the same.

Note: Initially the LED above the DC current knob (constant current mode indicator) will be lit. As of the limiting resistance, the LED above the DC voltage knob will come on instead (constant voltage mode indicator).

c) Voltage limiting

- Do not connect the rheostat to start with.
- Set the DC current knob to minimum (all the way to the left).
- Use the DC voltage knob to set the voltage to a value of $U_0 = 6$ V, for example.
- Use the slider to set the load resistance to about $R_L = 2$ Ω.
- Connect the load resistor to the supply as shown in Fig. 3.
- Make a note of the voltage U and current I.
- Use the DC current knob to increase the current and record various other pairs of readings for voltage U and current I.
- In particular, make a note of the limiting resistance after which the voltage and current stop changing.
- Use the slider to set the load resistance to various other values (e.g. $R_L = 5$ Ω, $R_L = 10$ Ω) and repeat the experiment.

d) Current limiting

- Do not connect the rheostat to start with.
- Set the DC voltage knob to maximum (all the way to the right).
- Use a lead to connect the two output sockets of the power supply together (short circuit).
- Use the DC current knob to set the current value to $I_0 = 1.50$ A, for example.
- Use the slider to set the load resistance to about $R_L = 10$ Ω.
- Initially set the DC voltage knob back to minimum ($U = 0$ V).
- Connect the load resistor to the supply as shown in Fig. 3.
- Make a note of the voltage U and current I.
- Use the DC voltage knob to increase the voltage and record various other pairs of readings for voltage U and current I.
- In particular, make a note of the limiting resistance after which the voltage and current stop changing.
- Use the slider to set the load resistance to various other values (e.g. $R_L = 5$ Ω, $R_L = 10$ Ω) and repeat the experiment.

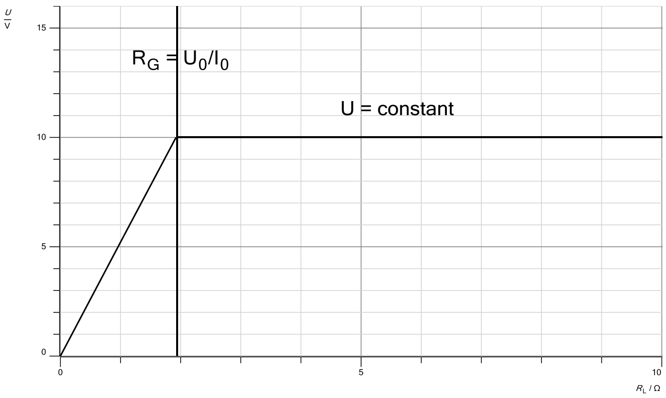
Example measurements

a) Constant voltage source

Calculate the set load resistance R_L from each pair of readings for voltage U and current I.

Table 1: Measurements when using the power supply as a constant voltage source, U_0 = 10 V

Voltage $\frac{U}{V}$	Current $\frac{I}{A}$	Load resistance $\frac{R_L}{\Omega}$
10.0	1.01	9.9
10.0	2.50	4.0
10.0	5.20	1.9
5.5	5.21	1.1
0.3	5.21	0.06



At the limit R_G the following is true:

$$R_G = \frac{U_0}{I_0} = \frac{10.0\ \text{V}}{5.20\ \text{A}} = 1.9\ \Omega$$

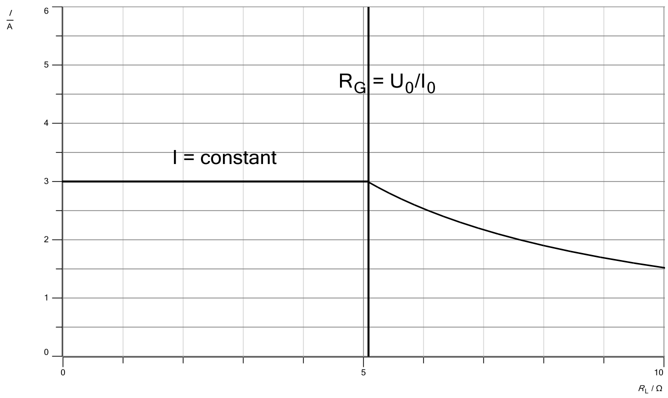
For higher resistance values where $R_L > R_G$, the voltage is constant at $U = U_0$.

b) Constant current source

Calculate the set load resistance R_L from each pair of readings for voltage U and current I.

Table 2: Measurements when using the power supply as a constant current source, I_0 = 3 A

Current $\frac{I}{A}$	Voltage $\frac{U}{V}$	Load resistance $\frac{R_L}{\Omega}$
3.00	0.0	0
3.00	0.2	0.1
3.00	10.0	3.3
3.00	15.2	5.1
2.00	15.2	7.6
1.51	15.2	10.1



At the limit R_G the following is true:

$$R_G = \frac{U_0}{I_0} = \frac{15.2\ \text{V}}{3.00\ \text{A}} = 5.1\ \Omega$$

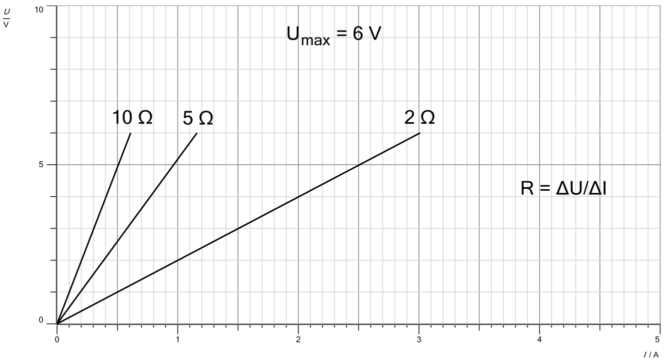
For lower resistance values where $R_L < R_G$, the current is constant at $I = I_0$.

c) Voltage limiting

Calculate the set load resistance R_L from each pair of readings for voltage U and current I.

Table 3: Measurements when using the power supply with a voltage limit U_0 = 6 V

Current $\frac{I}{A}$	Voltage $\frac{U}{V}$	Load resistance $\frac{R_L}{\Omega}$
0.20	0.4	2
0.50	1.0	
1.01	2.0	
1.51	3.0	
2.00	4.0	
2.50	5.0	
3.01	6.0	
0.20	1.1	5
0.51	2.7	
1.01	5.0	
1.20	6.0	
0.20	2.1	10
0.49	4.9	
0.60	6.0	



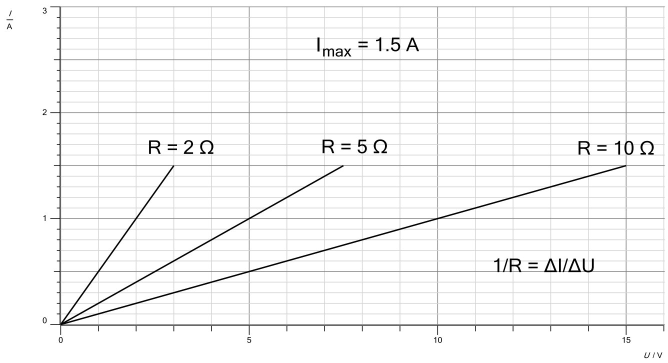
Regardless of the current I which has been set, the supply never outputs a voltage $U > U_0$.

d) Current limiting

Calculate the set load resistance R_L from each pair of readings for voltage U and current I.

Table 4: Measurements when using the power supply with a current limit I_0 = 1.5 A

Voltage $\frac{U}{V}$	Current $\frac{I}{A}$	Load resistance $\frac{R_L}{\Omega}$
0.0	0.00	10
5.0	0.51	
10.0	1.01	
15.0	1.51	
0.0	0.00	5
5.0	1.02	
7.5	1.49	
0.0	0.00	2
1.0	0.51	
3.0	1.50	



Regardless of the current V which has been set, the supply never outputs a current $I > I_0$.

Note: it is sensible to use voltage or current limiting when components being investigated may be damaged once a maximum value has been exceeded.

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