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DEPARTMENT OF ELECTRICAL ENGINEERING

EE Undergraduate Laboratory

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Basics of Power Supplies -

Use of the HP E3631A Programmable Power Supply

Contents

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Introduction

Each workstation in the EE Undergraduate laboratory is equipped with regulated DC power supplies. The focus of this write-up is on the use the Hewlett-Packard (HP) E3631A triple output power supply. As with the other instruments at each workbench, the HP E3631A power supply incorporates state-of-the-art digital technologies and provides many useful functions. The supply can be remotely programmed and read by computer via a General Purpose Interface Board (GPIB). Each station is provided with a User's Manual which can be consulted for detailed information on the more advanced functions of the power supply.

Basics of Power Supplies

A regulated power supply provides electrical energy which is precisely controlled. Power supplies can be of the type *Constant-Voltage*, *Constant-Current*, and the *Constant-Voltage/Constant-Current* sources. A Constant-Voltage (CV) supply provides a DC voltage that can be set to any desired value over a specified range. An ideal constant -voltage supply has a zero output impedance, as illustrated in Figure 1a. On the other hand, a constant-current (CC) supply gives a regulated current independent of the voltage over the load (up to the maximum allowable voltage), as shown in Figure 1b.
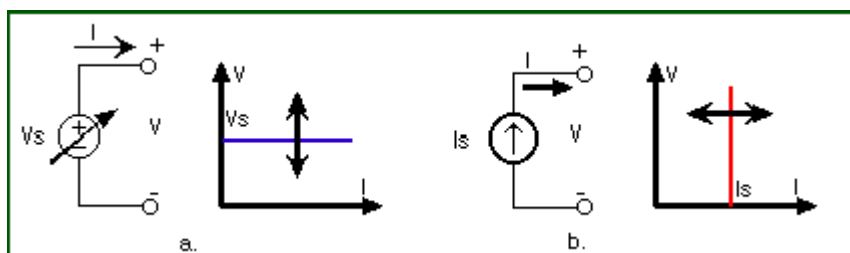
Figure 1: Output characteristic of a constant-voltage (a) and constant-current (b) supply.

A more versatile power supply is the *Constant-Voltage/Constant-Current* supply which can be used to provide either a constant voltage or a constant current. Figure 2 illustrates the I-V characteristic of such a supply. The values E_s and I_s are selected by the operator from the front panel or programmed through the GPIB interface.
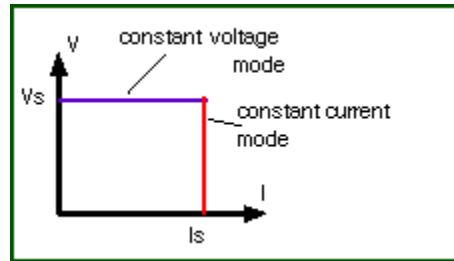

Figure 2: Output characteristic of a constant-voltage/ constant-current supply.

Lets look at the operating modes of such a CV/CC power supply. Assume that one connects a resistive load to the power supply as shown in Figure 3. The supply has been set at a voltage $V=V_s$ and current $I=I_s$ (see later on how to do this). The current through the resistor is then given by Ohm's law: $I=V/R$. As long as the current is below the maximum value I_s, the voltage over the resistor will be constant and equal to V_s. The power supply operates thus in the *CV mode* as shown in Figure 3. However, if one decreases the resistance such that the current exceeds the maximum allowable value I_s, the current will be limited to I_s and the power supply operates in the *CC mode*. The resistance $R_c=V_s/I_s$ is called the critical resistance and determines whether one operates in the CV ($R_L>R_c$) or CC ($R_L>R_c$) mode.
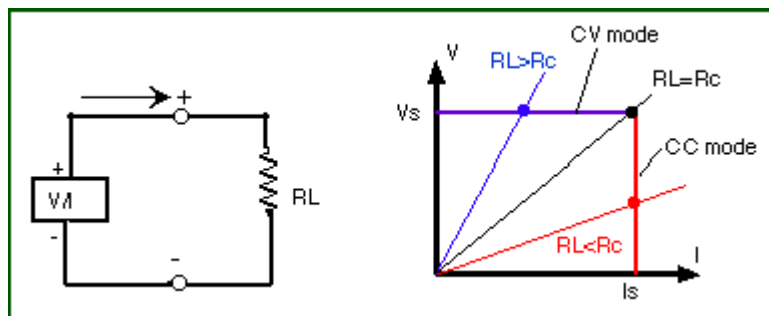

Figure 3: Operating point of a CV/CC power supply.

HP E3631A Triple Output DC Power Supply

The HP power supply in the lab is of the *constant-voltage/constant-current* type as described above. The objective of this section is to give a "hands-on feel" for adjusting the various range controls of the power supply and to give some instructions for connecting the supply to provide both positive and negative voltages.

Figure 4 shows the front panel of the HP E3631A power supply. Italicized print indicates the switch functions. The shaded switches will not be used in this write-up. These switches control the more advanced features built into the equipment. Consult the User's Manual for more information.
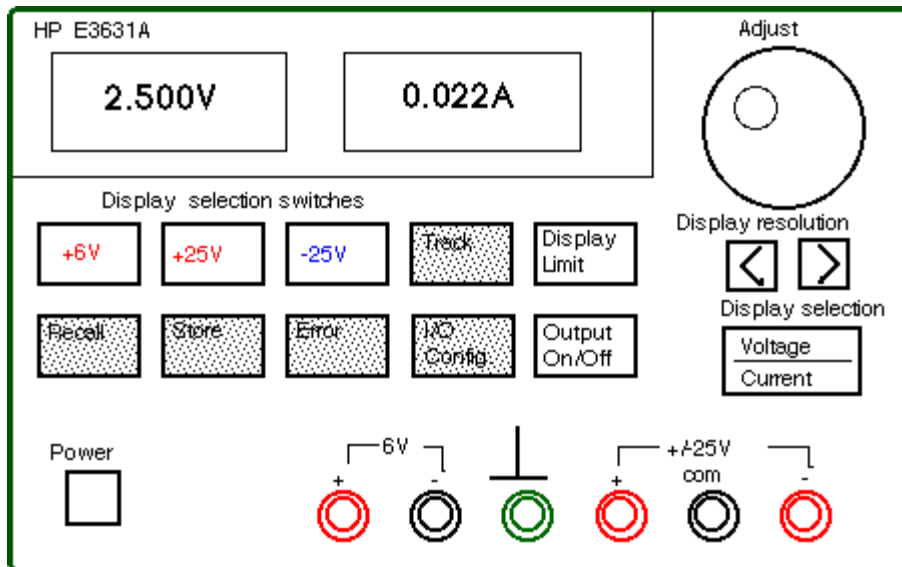
Figure 4: Front panel of the HP E3631A triple output power supply.

The power supply has a triple output: +6V/5A, +25V/1A and -25V/1A supplies. These outputs (binding posts) are located at the lower right-hand side of the front panel of the supply (see Figure 4). In addition, the power supply has a earth ground terminal (indicated by the ^ sign) which is connected to the chassis and earth ground through a 3-wire ground receptacle. This is done for safety considerations (see write-up on Safety in "Electrical Laboratory Practice").

A Simplified View of a Power Supply

Lets look at the power supply in the constant-voltage (CV) mode. A CV power supply can be considered to be a "near-ideal" battery with a very low internal resistance. As explained in the section above, its voltage will remain constant if its current rating (set to I_s by the user) is not exceeded. Figure 5 illustrates this view of the power supply. Note that the ground terminal (^) is isolated from the battery and is connected to the chassis (or case) ground, which is also connected to the earth ground through the 3-wire receptacle. The +25V and -25V supplies' outputs have a common output terminal (denoted by "com") which is isolated from the case or chassis ground. The positive or negative terminals of each output can be grounded or each output can be left floating with respect to the ground (must be kept within +/-240V from the chassis ground).
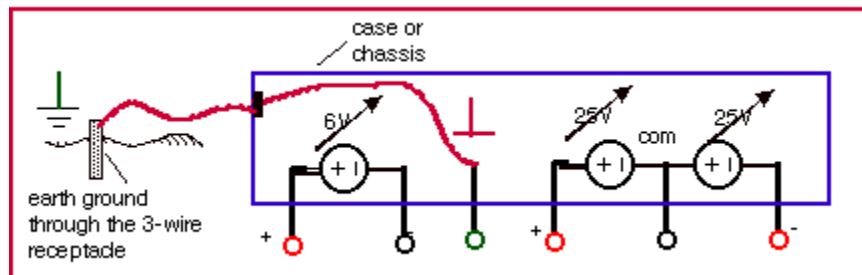

Figure 5: Simplified view of the triple output power supply

Figure 6 shows a few examples of how the power supply can be connected. In Figure 6a we are using both the +25V and -25V supplies and the common point has been connected to the ground. This means that one side of the two loads, R_{load1} and R_{load2}, are connected to the chassis (and earth) ground which has a zero voltage at that node. In Figure 6b the common point between the two loads is not connected to the ground which means that this node is floating with respect to the ground. However, the voltage over the loads will be the same as

in Figure 6b. Both methods of wiring can be used and usually give the same results. One can also connect the two power supplies in series as shown in Figure 6c in order to double the output voltage (to a maximum of 50 V). One can connect the + or - 25V terminal to the ground to pin down the voltage at one end.
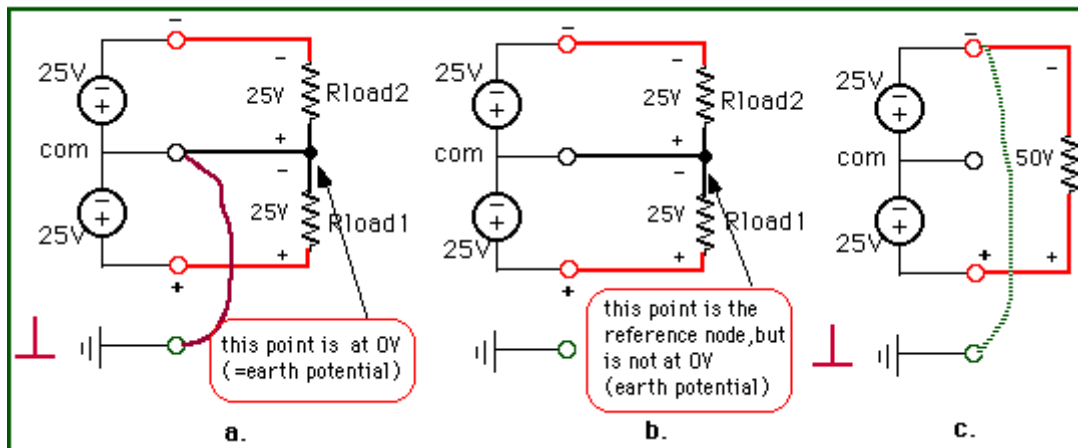

Figure 6: Power supply connections

Figure 7 shows the case where one uses the +25V, -25V and -6V power supplies in one circuit. All supplies have a common connection (the reference node) which can or cannot be connected to the ground.
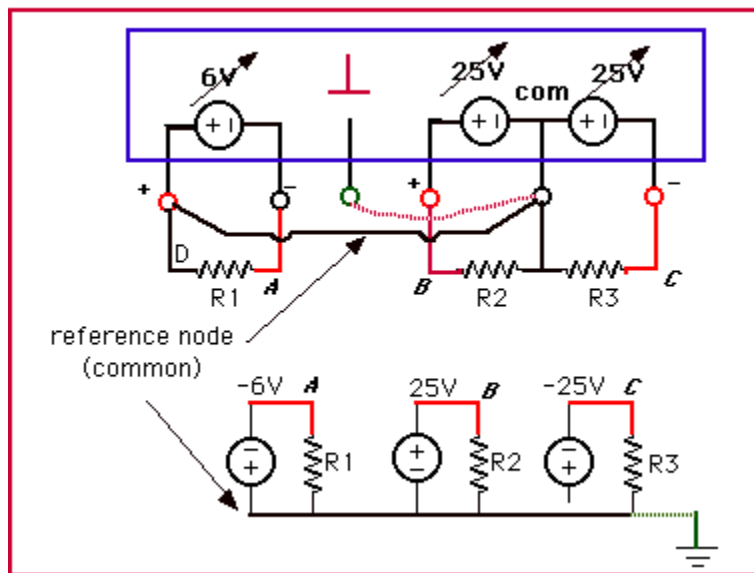

Figure 7: Power supply connection using the three power supplies; the top figure shows the actual connection, and the bottom one gives the circuit schematic.

Constant Voltage(CV) Operation

1. Connect the desired circuit to the power supply's output terminals.

2. Turn the power supply on. After going to a start-up routine, the power supply's outputs will be disabled (the OFF annunciator is on).

3. Enable the outputs by pressing the **Output On/OFF key** (see Figure 9) The CV and +6V annunciators will be on to indicate that the power supply operates in the *constant voltage* mode and that the +6V display is selected. You can adjust the *blinking* digit to select the desired output voltage by turning the large knob on

the top right of the front panel. The display is in the *meter* mode, i.e. the display shows the *actual* output voltage and current.

To set up the +25 V power supply, press the **+25V** key to select the display and adjust the +25V supply voltage. The same can be done for the -25V supply.
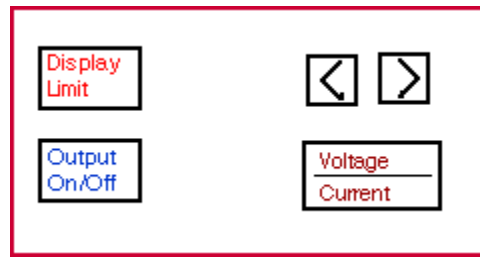

Figure 8: Front panel selections

The next step is to select the maximum current (limit I_s). Setting the current limit will ensure that the supply can provide enough current (and does not go into the constant current mode as explained in section "Basics of Power Supplies" above). In addition, it will protect your circuit from drawing too much current and from being damaged.

4. Set the display for *limit* mode by pressing the **Display Limit** key. You will notice the LMT annunciator blinking to indicate that the display is in the *limit* mode. The display shows the actual voltage and current *limit* values of the selected supply.

5. Press the **Vol/Cur** key. The second digit of the ammeter will be blinking. Adjust the knob (use the > or < buttons to switch to another digit) to set the desired current limit (make sure the LMT annunciator is still blinking).

6. When you press the **Vol/Cur** key again the voltage digit will be blinking. You can now adjust the voltage output.

7. To return to the *meter* mode press the **Display Limit** or let the display time-out to return automatically to the *meter* mode. The LMT annunciator will be off.

NOTE: to check that you are operating in the *constant voltage* mode for the +25V or -25V supplies make sure the +25V or -25V annunciator is on. For the +6V supply, the +6V and CV annunciators will be on. If the CC annunciator is on, choose a higher current limit.

Constant Current (CC) Operation

The power supply can be used as a current source. This is done in a similar way as for the CV mode.

1. Connect the desired circuit to the power supply output terminals.

2. Turn the power supply on. The power supply's outputs will be disabled (the OFF annunciator is on).

3. Enable the outputs by pressing the **Output On/OFF key** (see Figure 8) The CV and +6V annunciators will be on to indicate that the power supply operates in the *constant voltage* mode and that the +6V display is selected. The display is in the *meter* mode, i.e. the display shows the actual output voltage and current.

To set up the +25 V power supply, press the **+25V** key to select the display and adjust the +25V supply voltage. Do the same for the -25V supply.

4. Set the display for *limit* mode by pressing the **Display Limit** key. You will notice the LMT annunciator blinking to indicate that the display is in the *limit* mode. The display shows the actual voltage and current limit values of the selected supply.

5. You will notice that the second digit of the voltmeter is blinking. Turn the large knob to set the desired voltage *limit* (make sure the LMT annunciator is still blinking).

6. Press the **Vol/Cur** key. The second digit of the ammeter will be blinking. Adjust the desired output current that the current source will supply.

7. To return to the *meter* mode press the **Display Limit** or let the display time-out to return automatically to the *meter* mode. The LMT annunciator will be off.

NOTE: To verify that you are operating in the *constant current* mode check that the +6V and CC annunciator is on if you are using the +6V supply. For the +25V or -25V supplies make sure the +25V or -25V annunciator is on. If the CV annunciator is on, choose a higher voltage limit.

Disabling the Outputs

Sometimes you need to disable the voltage or current outputs. This can be done without switching off the power supply so that you do not lose the settings. To disable the outputs, press the **Output On/OFF** key. The **OFF** annunciator will go on. To enable the outputs, press **Output On/OFF** again.

Other features.

The HP E3631A has several other useful features. They include tracking operation (the +25 and -25V outputs track each other); storing and recalling operating states (up to 3 different settings can be stored); system related controls, and remote interface configuration (GPIB and RS-232). Consult the User's Manual for details on these features.

Specifications

- Output Ratings:
    - +6V Output: 0 to +6V: 0 to 5A
    - +25V Output: 0 to +25V: 0 to 1 A
    - -25V Output: 0 to -25V: 0 to 1 A
- Ripple and Noise
    - +6V Output: < 0.35 mV rms and <2 mV p-p; current: <2 mA rms
    - +25V: < 0.35 mV rms and <2 mV p-p; current: <500 microA rms
    - -25V: < 0.35 mV rms and <2 mV p-p; current: <500 microA rms
- Load Regulation:
    - Voltage: <0.01% + 2mV
    - Current: <0.01% + 250 microAmp

Acknowledgments:

Thanks to George Hanka and Sid Deliwala for contributing to this write-up and giving helpful suggestions.

References:

1. User's Guide, HP E3631A Triple Output DC Power Supply, Hewlett Packard.
2. C. F. Coombs, "Electronic Instrument Handbook", McGraw-Hill, Inc., New York, 1995.