Improve Voltage Regulation Using Remote Sense
Ideally, lead connections from your power supply to your load have no resistance. In reality, lead resistance increases with lead length and wire gauge. When a power supply delivers current through the connecting cables, the voltage may decrease at the load. To compensate, you can use remote sensing to correct for the voltage drop.

Remote or 4-wire sensing uses two pairs of cables: the first pair as the load leads, the second pair as the sense leads. The sense leads measure the voltage at the load. The power supply increases or decreases its output voltage based on voltage measurements at the load, compensating for any losses in the load leads.

In Figure 1, the power supply increased its output voltage 160 mV to compensate for the 80 mV (0.02 Ω * 4.0 A) voltage drop resulting from the resistance (voltage loss) in each load lead. The default setting on the power supply is local or 2-wire sensing, which measures the voltage at the power supplies output terminals (± Out). In the 2-wire scenario the voltage at the load would be about 160 mV below the set output.

Using remote sense will improve the accuracy and consistency of your measurements. Without remote sense, the voltage applied to your device will change over time affecting other measurements. Providing a constant voltage is key to creating consistent measurements.
Remote sensing, also known as 4-wire sensing, improves the voltage regulation at the load. Remote sensing monitors the voltage at the load rather than at the output terminals and, therefore, is more accurate. Remote sensing is especially useful for significant lead resistance, for high current, or for load impedance that varies such as a reactive load.

In Figure 2, the chart indicates the output voltage and current changing over time to maintain a constant 5 V across a reactive load. Since remote sensing is independent of other power supply functions, it functions regardless of how the instrument is programmed. Remote sensing does not affect constant current operation.

**Figure 2.** Output voltage and current adjusted over time to maintain 5 V on a reactive load
Setting up Remote Sense

Some power supplies use a physical connection between the sense and output terminals. Performing a 4-wire connection requires the removal of the physical connection. Forgetting to replace the physical connection and, then, attempting a 2-wire operation may cause some personal frustration. Other power supplies like the E36300 series use built-in relays that connect or disconnect the ± sense terminals from their corresponding ± output terminals.

![Figure 3](image-url) Some power supplies use a physical connection to make a local sense measurement

![Figure 4](image-url) With a press of a button, the E36300 series uses internal relays to switch between local 2-wire and remote 4-wire sensing

Example setup

As an example, the E36312A is configured as shown in Figure 1. Each of the load leads is just over 4 feet of stranded 16 AWG wire rated for 13A. The load leads, twisted together, have a total resistance of 35 mOhm in 8 feet or 4.37 mOhm/ft. The sense leads use twisted 20-gauge wire.
Open sense leads

The sense leads are part of the power supply’s output feedback path. It is important to make reliable sense lead connections to avoid an open circuit. The power supply includes protection resistors that reduce the effect of an open circuit during 4-wire-sensing. Without the protection resistors, the power supply would measure zero volts on the open circuit and increase the output voltage. Even with the protection resistors, it is always a good idea to set an over-voltage limit.

<table>
<thead>
<tr>
<th>Sense leads connected</th>
<th>Output voltage</th>
<th>Load voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.140 V</td>
<td>5.000 V</td>
</tr>
<tr>
<td>Positive sense lead open</td>
<td>5.057 V</td>
<td>4.919 V</td>
</tr>
<tr>
<td>Both sense leads open</td>
<td>5.242 V</td>
<td>5.098 V</td>
</tr>
<tr>
<td>Negative sense lead open</td>
<td>5.328 V</td>
<td>5.186 V</td>
</tr>
</tbody>
</table>

Figure 5. The power supply output swung less than 5% when a sense lead became disconnected.

Over-voltage protection considerations

Most power supplies have an over-voltage (OVP) feature that protects sensitive DUTs and circuitry from exposure to potentially damaging voltage. Configuring an over-voltage limit is a best practice when using remote sense. If the remote sense leads become shorted, reversed, or driven by an active load, the output can swing from a safe level to its max output. OVP is measured at the output terminals, regardless of the 2-wire or 4-wire sense settings. Set the OVP trip point higher than the load voltage added to any voltage drop at the load leads. For example, in Figure 2, the output voltage never exceeded 5.2 V which accounted for both the lead resistance and the reactive load. At steady state, the power supply output is 5.140 V to compensate for the lead resistance.
Output noise considerations

Any noise picked up on the sense leads will appear at the output terminals and may adversely affect load regulation. Twist the sense leads or use a ribbon cable to minimize any electromagnetic interference (EMI) from external noise. In extremely noisy environments, you may need to shield the sense leads. Ground the shield at the power supply end only, and do not use the shield as one of the sensing conductors.

Conclusion

Remote or 4-wire sensing provides a direct feedback loop between the load and the power supply. The feedback loop will regulate voltage at the load, compensating for any drop in voltage due to lead resistance as well as reactance in the load. Even with relatively short connecting wires, a 4-wire connection can significantly improve load regulation. Always set and enable over-voltage protection to defend against an overvoltage condition, such as shorted or reversed remote sensing lines.

For information on Keysight DC power supplies, visit: http://www.keysight.com/find/powersupply