As a complex electronic subassembly, a power supply has a high number of parameters that are routinely specified by manufacturers. It is important to accurately evaluate the product initially in engineering to ensure it is fit for use in the application. It is equally important that production testing ensures an appropriate performance and quality level is maintained by the vendor.

**Equipment/Test Set-Up**

A general test set-up for power supplies is illustrated in Figure 1. This setup can be used for most critical parameters. Some general conditions apply:

**Equipment:**

1. The accuracy of voltmeters and current meters should be approximately ten times the resolution required to measure a parameter. All meters should be 4½ digit.

2. Any oscilloscopes used should have a resolution approximately ten times the parameter being measured. Bandwidth of the oscilloscope should be 20 MHz to 100 MHz.

3. The input power source used should be sufficient to supply the maximum input power required by the Unit Under Test (UUT), plus an adequate guard band.

**Example Product**

For our examples, we have used the specifications of the A512RW, a 5W DC/DC converter available from MPD.

### Specifications

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<tr>
<th>Input</th>
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<th>Measured</th>
<th>Units</th>
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<tbody>
<tr>
<td>Nominal Voltage</td>
<td></td>
<td>24.0 VDC</td>
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<tr>
<td>Voltage Range</td>
<td></td>
<td>18 to 36 VDC</td>
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<td></td>
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<tr>
<td>No Load Current</td>
<td></td>
<td>5 mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Load Current</td>
<td></td>
<td>251 250 mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflected Ripple</td>
<td></td>
<td>15 mA</td>
<td></td>
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<table>
<thead>
<tr>
<th>Output</th>
<th>Conditions</th>
<th>Specified</th>
<th>Measured</th>
<th>Units</th>
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<tbody>
<tr>
<td>Voltage</td>
<td>Nom. Input, Full Load</td>
<td>5.00 5.02 VDC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td>1.0 1.0 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>Nom. Input, Full Load</td>
<td>±1.0 ±0.4 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Line Regulation</td>
<td>Low Line to High Line</td>
<td>±0.3 ±0.2 %</td>
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<td>Load Regulation</td>
<td>Nom. Input, Full Load</td>
<td>±1.0 ±0.6 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ripple &amp; Noise</td>
<td></td>
<td>75 mV P-P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transient Recovery Time</td>
<td>to 1% for I_{load}, change of 75% to 100%</td>
<td>300 μSec</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>General</th>
<th>Conditions</th>
<th>Specified</th>
<th>Measured</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>Nom. Input, Full Load</td>
<td>83 84 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isolation Voltage</td>
<td>Input to Output</td>
<td>1,500 VDC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Power supplies with a remote sensing option should be connected in local sensing mode (with the sense leads connected to the appropriate output pin). All test equipment should be allowed sufficient time to warm-up and stabilize before any testing begins.

To help illustrate some of the examples used in this application note, we will use the A512RW, a 5W DIP compatible DC/DC converter available from MicroPower Direct. Summary specifications are given in Table 1 at left. A full data sheet is available on the MPD website.
Output Voltage Accuracy

Output accuracy is the maximum deviation between the measured output of a power supply and its specified nominal output. Typically given as a percentage, output voltage accuracy is sometimes referred to as "output voltage tolerance" or "output voltage setpoint". The measurement is made as follows:

1. Set the input voltage to the specified "nominal" level. Set the output load to 100% of rated value.
2. Measure the output voltage using a 4½ digit voltmeter. This is \( V_{\text{OUT}} \).
3. Output accuracy (as a %) equals:

\[
\frac{V_{\text{OUT}} - V_{\text{NOM}}}{V_{\text{NOM}}} \times 100
\]

Where \( V_{\text{NOM}} \) is the nominal output voltage specified for the power supply. For our unit, a measurement of 5.02 VDC yields:

\[
\frac{5.02 \text{ VDC} - 5.00 \text{ VDC}}{5.00 \text{ VDC}} \times 100 = 0.4\%
\]

Well within the specified ±1%.

Line Regulation

Line regulation specifies the change in output voltage caused by varying the input line over a specified range. Expressed as a percentage, the range is typically low line to high line. The measurement is made as follows:

1. Set the input voltage to the specified "nominal" level. Set the output load to 100% of rated value.
2. Measure the output voltage using a 4½ digit voltmeter. This is \( V_{\text{OUT}} \).
3. Change the input voltage level to low line (or the specified low value for the line regulation spec.). Measure the output voltage. This is \( V_{\text{OUTL}} \).
4. Change the input voltage level to high line (or the specified high value for the line regulation spec.). Measure the output voltage. This is \( V_{\text{OUTH}} \).
5. Line regulation (as a %) equals:

\[
\frac{V_{\text{OUTH}} - V_{\text{OUSD}}}{V_{\text{OUT}} \times 100}
\]

Where \( V_{\text{OUSD}} \) is the output voltage measured (\( V_{\text{OUTL}} \) or \( V_{\text{OUTH}} \)) that causes the greatest deviation from \( V_{\text{OUT}} \).

For our example unit, \( V_{\text{OUTL}} \) equals 5.015 VDC, while \( V_{\text{OUTH}} \) equals 5.03 VDC. Using 5.03 VDC, we derive:

\[
\frac{5.02 \text{ VDC} - 5.03 \text{ VDC}}{5.02 \text{ VDC}} \times 100 = 0.2\%
\]

Well within the specified ±0.3%.

Some unregulated power supplies specify line regulation as a "%/% change in \( V_{\text{IN}} \)". Essentially, this means the percentage change in input line voltage is factored into the calculation to derive output regulation. For a unit specified in this manner, line regulation is derived as follows:

\[
\frac{V_{\text{OUT}} - V_{\text{IN}}}{V_{\text{OUT}} \times \Delta V_{\text{IN}} \%} \times 100
\]

Where \( \Delta V_{\text{IN}} \% \) is the change in input line as a percentage and \( V_{\text{OUSD}} \) is the output voltage measured that causes the greatest deviation from \( V_{\text{OUT}} \). If our example unit was specified this way, and an output of 3.75 VDC was measured at an input of 18 VDC. We could derive the line regulation as follows:

\[
\left( \frac{5.02 \text{ VDC} - 3.75 \text{ VDC}}{24 \text{ VDC}} \right) \times 100 = 0.25 \text{ VDC}
\]

\[
\left( \frac{24 \text{ VDC} - 18 \text{ VDC}}{24 \text{ VDC}} \times 100 = 5.02 \text{ VDC} \right)
\]

This in turn equals:

\[
\frac{0.25 \text{ VDC}}{25}\% \times 100 = 1.0\%
\]

The output is changing 1% for each 1% change in input voltage. Obviously, care must be taken when using units specified this way, that the input line is very stable or that the application can operate with potential wide output swings.

Load Regulation

Load regulation specifies the change in output voltage caused by varying the output load over a specified range. Expressed as a percentage, the range will vary somewhat, dependent upon the product design; but is typically given as a condition in the manufacturers data sheet. The measurement is made as follows:

1. Set the input voltage to the specified "nominal" level. Set the output load to 100% of rated value.
2. Measure the output voltage using a 4½ digit voltmeter. This is \( V_{\text{OUTL}} \).
3. Change the output load to the specified low value. Measure the output voltage. This is \( V_{\text{OUTL}} \).
4. Load regulation (as a %) equals:

\[
\frac{V_{\text{OUTL}} - V_{\text{OUTL}}}{V_{\text{OUT}} \times 100}
\]

For our unit, an output load change of 75% to 100% is specified. At 75% load, an output voltage measurement of 5.05 VDC yields:

\[
\frac{5.02 \text{ VDC} - 5.05 \text{ VDC}}{5.02 \text{ VDC}} \times 100 = 0.6\%
\]

Well within the specified ±1%.

Output Ripple & Noise

Also called Periodic And Random Deviation, (PARD), this is the noise and ripple voltage super imposed on the output of a power supply. Output ripple is the periodic AC component and noise refers to the high frequency spikes that are unrelated to the switching frequency of the power supply.

Due to the high frequencies involved, care must be taken not to induce errors into the measurement. An oscilloscope with a minimum bandwidth of 20 MHz so that all significant harmonics of the ripple spikes are included.

Figure 2 illustrates how to make this measurement. A standard oscilloscope probe is shown in Figure 2A with a ground clip. When making measurements...
in a field of radiated, high frequency energy, the ground clip acts as an antenna. Since this could inject unwanted noise into the measurement, the clip should be disconnected and not used.

The injection of unwanted noise is eliminated by using the technique shown in Figure 2B. Here the scope probe is placed directly across the output common terminal, while the probe tip is put in contact with the voltage output pin. This creates the shortest possible connection across the power supply output terminals.

Another method for measuring true output noise and ripple is shown in Figure 2C. A 20 AWG “twisted pair” wire, approximately one foot in length, is attached between the power supply outputs and the load. An electrolytic capacitor (typically 10 μF to 50 μF) is connected across the load. The scope probe, with the ground clip disconnected, measures the the ripple at the connection of the twisted pair wires and the load. This technique will eliminate interference caused by common mode noise.

**Transient Recovery Time**

The time required for a power supply output to return to within specified limits following a step change in output load current. The specified load change and error band will vary with the product and/or manufacturer, but should be stated clearly in the product data sheet.

Using the test set-up shown in Figure 1, measure transient response as follows:

1. Set the input voltage to the specified “nominal” level.

2. Program the the adjustable load for the step load change specified by the manufacturer. In our case, this is 75% to 100% of rated load.

![Output Voltage](image)

3. With the oscilloscope triggered externally, switch the load over the specified range.

4. Measure the transient response time as illustrated in Figure 3.

If the power supply has multiple outputs, auxiliary outputs should be set to 100% load while transient recovery time is measured.

**Efficiency**

The ratio of total output power to input power, expressed as a percentage. Efficiency has become an increasingly important specification as the power density of power supplies has increased and the relative size of electronic systems has decreased. Efficiency is measured as follows:

1. Set the input voltage to the specified “nominal” level. Set the output load to 100% of rated value.

2. Using the test set-up shown in Figure 1, measure the output voltage (V<sub>out</sub>), output current (I<sub>out</sub>), input voltage (V<sub>in</sub>) and input current (I<sub>in</sub>).

3. Efficiency (as a %) equals:

   \[
   \text{Efficiency} = \frac{I_{\text{out}} \times V_{\text{out}}}{I_{\text{in}} \times V_{\text{in}}} \times 100
   \]

Returning to our example unit, if we measure the following:

- \(V_{\text{out}} = 5.02\ \text{VDC}\)
- \(I_{\text{out}} = 1.00\ \text{A}\)
- \(V_{\text{in}} = 24\ \text{VDC}\)
- \(I_{\text{in}} = 0.25\ \text{A}\)

We can then derive the units efficiency as:

- \(1.00\ \text{A} \times 5.05\ \text{VDC} = 0.25\ \text{A} \times 24.0\ \text{VDC} \times 100 = 84\%\)

At 84%, this is over the typical specification of 83%.

**I/O Isolation**

The maximum voltage (ac or dc) that can be continuously applied from the input to output or input to case of an isolated power supply.

Minimum isolation voltage levels must be maintained to meet most safety regulations. Typical isolation values specified by manufacturers are:

**AC/DC:**
- I/O 3000 VAC
- I/C 1500 VAC

**DC/DC:**
- I/O 1500 VDC (New Designs)
- 1000 VDC (Low power designs)
- 500 VDC (Old Designs)

**In Summary**

Whether power supplies are being bench tested for an engineering evaluation; sample tested at incoming as part of standard QA screening; or tested in the application as part of volume production; great care must be taken to use the correct methods and end-point specifications.

Use the expertise of the power supply manufacturer if you have any...