How Efficient is your Power Supply Really?

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Quiz

- Question #1:
  - Does this PSU meet ClimateSavers Platinum level?
    - A. Yes
    - B. No
    - C. I don’t have enough information to answer this.
Abstract

- Accurately measuring PSU efficiency is not a trivial pursuit.
- As efficiency demands increase, Power Supply engineers are being tasked to find incremental improvements, often searching for 0.1% efficiency gains, while still maintaining a tight cost budget.
- Measuring these improvements can be obscured by the accuracy of the test equipment as well as the test methodology.
Abstract

- A 0.1% efficiency increase in a 675W power supply operating at half load, represents a little less than 1/2 of a watt.

- The accuracy of the test equipment may be 10 times worse than that 0.1% difference.

- A 94% efficient power supply might well measure between 93% and 95%, thereby possibly causing the engineer to make decisions based upon poor data.

- Note: All following examples assume 230VAC input and a 12V Output.
Test Measurement Set-up

AC Power Source

Unit Under Test

Electronic Loads

Power Analyzer

Voltage Meters
Lab Equipment Used for this Presentation

- **AC Source**
  - Chroma 61505

- **Power Analyzers**
  - Voltech PM100
  - Yokagawa WT210
  - Yokagawa WT3000

- **Voltage Meters**
  - Fluke 45
  - Agilent 34970A

- **Electronic Loads**
  - Agilent 60502B
  - Agilent N3304
  - Chroma 63630-80-60
Power Analyzer Specification Comparison

- **UUT**
  - 675W PSU, 12VFE, 230VAC Input, Platinum Efficiency

- Compare Yokagawa WT210 vs. WT3000

<table>
<thead>
<tr>
<th>Specification</th>
<th>Yokagawa WT210</th>
<th>Yokagawa WT3000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading Error %</td>
<td>0.100%</td>
<td>0.020%</td>
</tr>
<tr>
<td>Range Error % (A*V)</td>
<td>0.100%</td>
<td>0.040%</td>
</tr>
<tr>
<td>Price (Approx)</td>
<td>$1,200</td>
<td>$12,000</td>
</tr>
</tbody>
</table>

- 0.200% Accuracy has to be good enough, correct?
Power Analyzer Range Selector

- Specified Measurement Ranges
- V and I Ranges need to be independently analyzed.

<table>
<thead>
<tr>
<th></th>
<th>Yokagawa WT210</th>
<th>Yokagawa WT3000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volts Range rms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current Range rms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>0.5</td>
<td>15</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>60</td>
<td>2</td>
<td>60</td>
</tr>
<tr>
<td>100</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>150</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>300</td>
<td>20</td>
<td>300</td>
</tr>
<tr>
<td>600</td>
<td>30</td>
<td>600</td>
</tr>
<tr>
<td>1000</td>
<td>OC</td>
<td>1000</td>
</tr>
</tbody>
</table>

Input Current Ranges

230VAC Input Ranges
Power Analyzer Analysis

- Analyze Power Meter accuracy for each range vs. PSU efficiency to determine accuracy error as well as Power Dissipated (W) error.

![Graph showing power supply efficiency vs. output power for a 675W PSU]
**Power Analyzer Comparison**

Must Analyze Reading and Range Accuracy from 0-100% Load, in 10% increments, 50% FL example.

<table>
<thead>
<tr>
<th>Efficiency</th>
<th>% Load</th>
<th>WT210</th>
<th>WT3000</th>
</tr>
</thead>
<tbody>
<tr>
<td>94.1%</td>
<td>50%</td>
<td>Yokagawa</td>
<td>Yokagawa</td>
</tr>
<tr>
<td>Vin AC</td>
<td></td>
<td>230</td>
<td>230</td>
</tr>
<tr>
<td>Vin pk</td>
<td></td>
<td>325</td>
<td>325</td>
</tr>
<tr>
<td>I rms (approx)</td>
<td></td>
<td>1.56</td>
<td>1.56</td>
</tr>
<tr>
<td>Ipk (approx)</td>
<td></td>
<td>2.20</td>
<td>2.20</td>
</tr>
<tr>
<td>Input power reading (W)</td>
<td></td>
<td>358.5</td>
<td>358.5</td>
</tr>
<tr>
<td>Voltage Range</td>
<td></td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Current Range</td>
<td></td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Reading Error % (spec)</td>
<td></td>
<td>0.100%</td>
<td>0.020%</td>
</tr>
<tr>
<td>Range Error % (A^*V) (spec)</td>
<td></td>
<td>0.100%</td>
<td>0.040%</td>
</tr>
<tr>
<td>Watts Error +/-</td>
<td></td>
<td>0.9585</td>
<td>0.3117</td>
</tr>
<tr>
<td>Error % +/-</td>
<td></td>
<td>0.27%</td>
<td>0.09%</td>
</tr>
</tbody>
</table>

A 0.65W difference in measurement accuracy results in a 0.18% Error!

A 94.1% Efficient PSU could measure between 93.83% or 94.37%.
**You get what you $Pay$ For**

- Expected worst case combined Reading and Range Accuracy:
  - WT210 : +/- 0.40%
  - WT3000 : +/- 0.13%
**Meter to Meter Correlation**

- Compare 8 Voltech PM100’s Power Analyzers on the same test set-up with the same 1475W PSU

- Note: All Meters have current Calibration stickers
At ½ Load, These “Identical” Calibrated Meters measure between 91.0% and 91.8% Efficient.
AC Source

AC Power Source

Unit Under Test

Electronic Loads

Power Analyzer

Voltage Meters
**AC Source Measurement Accuracy**

- Most AC Sources have an internal Power Meter which may eliminate the need for purchasing expensive Power Analyzers.
- Understand the accuracy of the AC Source meter before concluding that External Power Analyzers are not required.
Comparison of AC Source Internal PM to External PM’s

Efficiency 230VAC compare meters with AC Source Meter

Chroma 61505
AC Source

Voltech PM100’s

Use the AC Source for Voltage Repeatability in the Test Set-up instead of a Variac
Voltage Meters
Output Voltage Meter Accuracy

- Just as the AC Source has an internal power meter, most electronic loads also have internal Voltage meters which may be used to calculate output power, although the accuracy of the voltmeter may not be good enough for precision measurements.

<table>
<thead>
<tr>
<th></th>
<th>Resolution Error</th>
<th>Offset Error</th>
<th>Accuracy Error</th>
<th>Total Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agilent 34970A VM</td>
<td>0.000%</td>
<td>0.005%</td>
<td>0.015%</td>
<td>0.020%</td>
</tr>
<tr>
<td>Fluke 45 VM</td>
<td>0.008%</td>
<td>0.015%</td>
<td>0.019%</td>
<td>0.042%</td>
</tr>
<tr>
<td>Agilent N3304A Load</td>
<td>0.008%</td>
<td>0.062%</td>
<td>0.047%</td>
<td>0.116%</td>
</tr>
<tr>
<td>Agilent 60502B Load</td>
<td>0.131%</td>
<td>0.347%</td>
<td>0.103%</td>
<td>0.581%</td>
</tr>
</tbody>
</table>
Voltmeter Accuracy Comparison

VM Combined Error Comparison
(Resolution + Accuracy + Offset Errors)

Agilent 60502B Load
Agilent N3304A Load
Fluke 45 VM
Agilent 34970A VM
Potential Wattage Error Caused by VM Accuracy

Worst Case Wattage Error Due to Output VM Accuracy
(0 to 900W)

- Agilent 60502B Load
- Agilent N3304A Load
- Fluke 45 VM
- Agilent 34970A VM
Electronic Loads

AC Power Source

Unit Under Test

Electronic Loads

Power Analyzer

Voltage Meters
### 300W Electronic Load Accuracy Comparison

- **Current Measurement Error Parameters**
  - Resolution Error
  - Accuracy Error
  - Offset Error

<table>
<thead>
<tr>
<th>Range</th>
<th>Resolution Bit Error</th>
<th>Accuracy Error %</th>
<th>Offset Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chroma N3304 60502B</td>
<td>Chroma N3304 60502B</td>
<td>Chroma N3304 60502B</td>
</tr>
<tr>
<td>6W</td>
<td>0.0092mA 0.1mA 17mA</td>
<td>0.05% 0.05% 0.05%</td>
<td>0.3mA 5mA 65mA</td>
</tr>
<tr>
<td>30W</td>
<td>0.092mA 0.1mA 17mA</td>
<td>0.05% 0.05% 0.05%</td>
<td>3mA 5mA 65mA</td>
</tr>
<tr>
<td>300W</td>
<td>0.92mA 1mA 17mA</td>
<td>0.05% 0.05% 0.05%</td>
<td>30mA 10mA 65mA</td>
</tr>
</tbody>
</table>
Agilent 60502B (300W) Current Accuracy Spec (12Vout)

Combined Error
Offset Error
Resolution Eff Error
Accuracy Error

Load watts
Error %
Agilent N3304 (300W) Current Accuracy spec (12Vout)

- Combined Error
- Offset Error
- Resolution Eff Error
- Accuracy Error

Error % vs Load Watts

Load Watts: 0, 25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 300, 325
Error %: 0.00%, 0.05%, 0.10%, 0.15%, 0.20%, 0.25%, 0.30%, 0.35%, 0.40%, 0.45%, 0.50%
Chroma 63630-80-60 current accuracy spec (12Vout)
Current Measurement Accuracy Comparison

300W Load Spec Comparisons
Current Accuracy Spec (12Vout)

- Agilent N3304A
- Agilent 60502B
- Chroma 63630-80-60
900W Load using 3 N3304A Error Accumulation

- Resolution Eff Error
- Offset Error
- Accuracy Error
- 3X N3304A
**Electronic Load – Resolution Bit Accuracy**

- Measured Lab Data
- Dwell at half-load of 675W PSU, take 50 measurements 5 seconds apart.
- Note Bit changing as load is between two bits.
- Measurement Reporting is jumping between 338.15W and 338.52W, a 1/3rd of a watt error.
- Effect on Efficiency:
  - 92.76% or 92.86%
Six Agilent 60502 Loads
Measured Efficiency Difference

These “Identical” Calibrated Loads measure up to a worst-case 0.90% difference!
At ½ Load, there may be a 0.30% reporting error!
Summary

- Accuracy Correlation is difficult with “Identical” equipment.
  - Correlation with different test equipment?
  - Customer/Factory/Certifying agency/Others...

- Calibration Errors
  - A calibration lab often only checks if a parameter is within Spec
  - The lab may not dial-in the accuracy to the center of the range.

- Understand the Capabilities of your Test Equipment!
**Summary**

- How does Emerson solve this?
  - Golden Bench – Most Accurate equipment
  - Choose equipment appropriate for the UUT
    - Do *Not* use a 4KW load to measure a 500W PSU
  - Select proper ranges for measurement
    - Understand equipment errors under the conditions where you are using it.
  - Characterize test equipment for each PSU Model
    - 500W, 750W, 2KW, etc.
    - Changing/Adding a piece of equipment requires re-characterization.
**Quiz Answer**

- **Question #1:**
  - Does this PSU meet ClimateSavers Platinum level?
    - A. Yes
    - B. No
    - C. I don’t have enough information to answer this.
    - D. Maybe

*Potential Measurement Error*

- 20%/50%/100% FL
- 675W PSU

*Error Bands*

- ½ Load Efficiency
  - Min 93.23%
  - Max 95.07%
Consider it Solved!

Embedded Power

EMERSON
Network Power