Proposed Test Protocol For Calculating The Energy Efficiency of Internal Ac-Dc Power Supplies

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1. Scope

This document specifies a test protocol for calculating the energy efficiency of internal ac-dc power supplies typically used in computers, televisions, monitors, and other electronic appliances. Internal power supplies are located in the same housing as the product that they power. An example of this type of power supply is a desktop computer ATX 12 V power supply, which has multiple output voltages: +12 V, +5 V, +3.3 V, -12 V, and -5 V. (*See Appendix A*). External power supplies, often referred to as ac adapters, are contained in a housing separate from the devices they power, are not included in the scope of this document. In addition, ac-ac voltage conversion equipment such as ac transformers and dc-dc voltage conversion equipment are not included in the scope of this document. The test protocol in this document applies specifically to single-phase or three-phase power supplies with ac input and a single or multiple dc outputs.

Building upon the efficiency test protocol outlined in Section 4.3 of IEEE Std. 1515-2000, *IEEE Recommended Practice for Electronic Power Subsystems: Parameter Definitions, Test Conditions, and Test Methods,* the test protocol specified here establishes a consistent loading guideline for ac-dc internal power supplies that often have multiple output voltages.

1.1 Intent

The intent of this document is to use existing industry standards that have been created for electronic test and measurement to develop a consistent and repeatable method for measuring the energy efficiency of ac-dc internal power supplies. Existing standards occasionally give conflicting approaches and requirements for efficiency testing that this test protocol seeks to clarify. In addition, other documents give multiple protocols, whereas this document focuses solely on the efficiency of the power supply.

2. References

The following list includes documents used in the development of this proposed test protocol; if the following publications are superseded by an approved revision, the revision shall apply:

1. IEEE Std 1515-2000, *IEEE Recommended Practice for Electronic Power Subsystems: Parameter Definitions, Test Conditions, and Test Methods*.
2. IEEE Std 519-1992, *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*.
3. IEC 62301 Ed 1.0, *Measurement of Standby Power* (Committee Draft)
4. Draft IEC 62018 Ed. 1, *Energy Management Requirements*.
5. UL 60950, 3rd Edition, *Information Technology Equipment – Safety – Part 1: General Requirements*, April 1, 2003.
6. IEC 61000-4-7 Ed.2, *Electromagnetic Compatibility (EMC) - Part 4-7: Testing and Measurement Techniques - General Guide on Harmonics and Interharmonics. Measurements and Instrumentation, for Power Supply Systems and Equipment Connected Thereto*.
7. IEC 61000-3-2, *Electromagnetic Compatibility (EMC) – Part 3-2: Limits – Limits for Harmonic Current Emissions (Equipment Input Current 16 A per Phase)*.
8. IEC 60050, *International Electrotechnical Vocabulary - Electrical and Electronic Measurements and Measuring Instruments*.
9. IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*.
10. *Power Supply Design Guidelines* (*website: www.formfactors.org*) , Intel Corporation
11. *Energy Star Guidel*ines (website: www.energystar.gov), United States Environmental Protection Agency

3. Definitions

For the purpose of this document, the following definitions apply. For terms not defined here, definitions from IEC 60050, IEC 62301, and IEEE 100 are applicable.

3.1 Ac-Dc Power Supply

This term refers to devices designed to convert AC voltage to DC voltage for the purpose of powering electronic equipment.

3.2 Ac Signal

A time-varying signal whose polarity varies with a period of time T and whose average value is zero. (ref. IEEE Std 1515-2000).

3.3 Ambient Temperature

Temperature of the ambient air immediately surrounding the unit under test (UUT). (ref. IEEE Std 1515-2000).

3.4 Apparent Power (S)

The product of RMS voltage and current (VA). Also called the *total power*.

3.5 Board-Only Modular Internal Power Supply

A power supply whose components are grouped on a single printed circuit board, but not enclosed, as shown in Figure B-1 (c). Such power supplies are installed inside the appliance and have easily accessible inputs and outputs..

3.6 Dc Signal

A signal of which the polarity and amplitude do not vary with time. (ref. IEEE Std 1515-2000)

3.7 Efficiency

The ratio, expressed as a percentage, of the total real output power (produced by a conversion process) to the real power input required to produce it, using the following equation:

$$\eta = \frac{\sum_i P_{o,i}}{P_{in}} \times 100 \qquad \textbf{\textit{Eq. 3-1}}$$

where $P_{o,\,i}$ is the output power of the i^{th} output. The input power (P_{in}), unless otherwise specified, includes all housekeeping and auxiliary circuits required for the converter to operate.

3.8 Enclosed-Frame Modular Internal Power Supply

A power supply encased in a modular enclosure, as shown in Figure B-1 (a). The enclosure is installed inside the appliance and has easily accessible inputs and outputs.

3.9 Multiple-Output Power Supply

A power supply designed to provide more than one dc voltage level, including one with two, three, four, or more voltage levels (or buses).

3.10 Open-Frame Modular Internal Power Supply

A power supply whose components are grouped inside a case but not enclosed, as shown in Figure B-1 (b). Such power supplies are installed inside the appliance and have easily accessible inputs and outputs.

3.11 Output Voltage Bus

Any of the dc outputs of the power supply, to which loads can be connected and current and power supplied. These buses may supply power at different voltage levels depending on the design of power supply and the product being powered.

3.12 Rated Ac Input Voltage

The supply voltage declared by the manufacturer in the specification of the power supply. For a single-phase power supply, this refers to line-to-neutral voltage, and for a three-phase power supply, this refers to the line-to-line voltage.

3.13 Rated Ac Input Voltage Range

The supply voltage range (minimum/maximum) as declared by the manufacturer in the specification of the power supply.

3.14 Rated Dc Output Current

The dc output current for each output dc bus of the power supply as declared by the manufacturer in the specification or nameplate of the power supply. If there is a discrepancy between the specification and the nameplate, the nameplate rating shall be used.

3.15 Rated Dc Output Current Range

The dc output current range (minimum/maximum) for each output voltage bus of the power supply as declared by the manufacturer in the specification of the power supply.

3.16 Rated Dc Output Power

The maximum dc output power as specified by the manufacturer. This may apply to the total power for all voltage buses, some subset thereof, or a single voltage bus.

3.17 Rated Dc Output Voltage

The dc output voltage for each output voltage bus of the power supply as declared by the manufacturer in the specification of the power supply.

3.18 Rated Input Frequency

The supply ac input frequency of the power supply as declared by the manufacturer in the specification of the power supply.

3.19 Rated Input Frequency Range

The supply ac input frequency range (minimum/maximum) of the power supply as declared by the manufacturer in the specification of the power supply.

3.20 Rated Input Current

The input current of the power supply as declared by the manufacturer in the specification of the power supply. For a three-phase supply, rated input current refers to the input current in each phase.

3.21 Rated Input Current Range

The input current range (minimum/maximum) for a power supply as declared by the manufacturer in the specification of the power supply. For a three-phase supply, rated input current refers to the input current in each phase.

3.22 Rms (Root Mean Square)

The square root of the average of the square of the value of the function taken throughout the period. For instance, the RMS voltage value for a sine wave may be computed as:

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T v^2(t)dt} \qquad \textbf{\textit{Eq. 3-2}}$$

where

T is the period of the waveform,

$V(t)$ is the instantaneous voltage at time t,

V_{RMS} is the RMS voltage value.

(ref. IEEE Std 1515-2000)

3.23 Single-Output Power Supply

Power supplies designed to provide one dc voltage level, on one output voltage bus.

3.24 Steady State

The operating condition of a system wherein the observed variable has reached an equilibrium condition in response to an input or other stimulus in accordance with the definition of the system transfer function. In the case of a power supply, this may involve the system output being at some constant voltage or current value. (ref. IEEE Std 1515-2000)

3.25 Test Voltage Source

The test voltage source refers to the device supplying power (voltage and current) to the unit under test (UUT).

3.26 Total Harmonic Distortion (THD)

The ratio, expressed as a percent, of the RMS value of an ac signal after the fundamental component is removed to the rms value of the fundamental. For example, THD of current can be defined as:

$$THD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + ...{I_n}^2}}{I_1} \qquad \textbf{\textit{Eq. 3-3}}$$

where I_n = rms value of *n*th harmonic of the current signal.

3.27 UUT

Unit under test. (ref. IEEE Std 1515-2000)

3.28 Voltage Unbalance

The maximum difference between rms phase to neutral or phase-to-phase voltage amplitudes at the UUT input terminals. For example, for a wye-connected, three-phase system

$$V_{UNB} = (\max[V_{AN}, V_{BN}, V_{CN}] - \min[V_{AN}, V_{BN}, V_{CN}]) \qquad \textbf{\textit{Eq. 3-4}}$$

where

V_{AN}, V_{BN}, V_{CN} are the phase voltage magnitudes, and

V_{UNB} is the maximum phase voltage unbalance.

Percent voltage unbalance is calculated by multiplying the maximum voltage unbalance by 100 and dividing the result by the average of the three phase voltages.

$$V_{UNB\%} = \frac{V_{UNB}}{\left(\frac{V_{AN} + V_{BN} + V_{CN}}{3}\right)} \times 100 \qquad \textbf{\textit{Eq. 3-5}}$$

(ref. IEEE Std 1515-2000)

4. Standard Conditions for Efficiency Testing

4.1 General Provision

Input voltage, frequency, output bus loading and the duty cycle of the fan inside the power supply (in some cases) are among the variables that can impact the efficiency of an ac-dc power supply. Sections 4.2 , 4.3 and 4.4 below recommend a minimum set of requirements in order to control these variables while measuring internal power supply efficiency. Beyond these minimum conditions, the manufacturer and user of the power supply may determine additional requirements, such as harmonic distortion or unbalance specification as need be.

4.2 Input Voltage and Frequency

The input voltage and frequency to be used for measurement shall be +/- 1% of the rated ac voltage and frequency. If the rated ac voltage and/or frequency are unclear from the power supply specification, or if the power supply is rated for more that one voltage or frequency (such as a 50/60 hertz dual-rated power supply), the input voltage and frequency shall be selected based on what is appropriate for the country in which the power supply would be used.

4.3 Power Supply Loading

The loading guidelines provided in this protocol is applicable to any single input multiple output ac-dc internal power supplies. The efficiency of the power supply shall be measured at 10%, 20% (light load), 50% (typical load) and 100% (full load) of rated current. In addition to these four load conditions, other loading conditions may be identified that are relevant to the manufacturer and user of the power supply. Procedures for loading power supplies are described in detail in Section 6.1.1 below. If the manufacturer has specified loading guidelines, then those shall prevail, even if they are less comprehensive than those above. The 10% loading point is included in this revision to enable testing of redundant power supplies used in server applications. Testing at a load conditions below 10% load, should be guided by IEC 62301 Ed 1.0, *Measurement of Standby Power*, which establishes the measurement methods for low power mode operation of an appliance.

4.4 Duty Cycle of Power Supply Fan

In some recent power supplies the duty cycle (ON time) of the fan is controlled by the temperature of the heat sink. If the heat sink inside the power supply reaches a certain set temperature value the fan turns ON and if the heat sink cools down below the set temperature value the fan turns OFF. The duty cycle of the fan can then influence the efficiency of the power supply especially during the time of measurement. In order to overcome the effect of the duty cycle of the fan over the efficiency of the power supply, the input and output power shall be integrated over a period of 30 minutes or five fan cycles, whichever is reached first (one fan cycle consists of one ON pulse followed by one OFF pulse). For power measurement procedure refer to section 4 of IEC 62301 (*Measurement of Standby Power)*.

5. Instrumentation and Equipment

5.1 General Provisions

These procedures are meant to ensure the accurate and consistent measurement of power supplies across testing laboratories. Please refer to Annex B of IEEE 1515-2000, *IEEE Recommended Practice for Electronic Power Subsystems: Parameter Definitions, Test Conditions, and Test Methods*, for guidelines for general test practices and to section 4, Annex B and D of IEC 62301, Ed. 1.0, *Measurement of Standby Power*, for a discussion on evaluating measurement uncertainty.

5.2 Test Voltage Source

The input voltage source shall be capable of delivering at least 10 times the nameplate input power of the UUT (as is specified in IEEE 1515-2000). Regardless of the ac source type, the THD of the supply voltage when supplying the UUT in the specified mode shall not exceed 2%, up to and including the 13^{th} harmonic (as specified in IEC 62301). The peak value of the test voltage shall be within 1.34 and 1.49 times its rms value (as specified in IEC 62301).

The voltage unbalance for a three-phase test source shall be less than 0.1%.

5.3 Test Dc Loads

Active dc loads such as electronic loads or passive dc loads such as rheostats used for efficiency testing of the ac-dc power supply shall be able to maintain the required current loading set point for each output voltage within an accuracy of +/- 0.5%.

5.4 Measurement Instrumentation Accuracy

Power measurements shall be made with a suitably calibrated voltmeter and ammeter or power analyzer. As is specified in IEC 62301, measurements of active power of 0.5 W or greater shall be made with an uncertainty of ≤ 2%. Measurements of active power of less than 0.5 W shall be made with an uncertainty of ≤ 0.01 W. The power measurement instrument shall have a resolution of 0.01W or better for active power. Measurements of voltage and current shall be made with an uncertainty of ≤ 2%.

5.5 Test Room

The following are recommendations for the test room environment, based on IEC 62301, Ed. 1.0, *Measurement of Standby Power*:

- The tests shall be carried out in a room in which the air speed close to the UUT is 0.5 m/s
- The ambient temperature shall be maintained at 23°C (+/- 5°) throughout the test.

  Note: The measured power for some products and modes may be affected by other ambient conditions (for example, illumination and temperature).

5.6 Warm-up Time

Internal temperature of the components in a power supply could impact the efficiency of the unit. As a general recommendation before testing, each UUT should be loaded up to the test load for a period of at least five minutes or, preferably, for a period sufficient that the total input power reading over two consecutive five-minute intervals does not change more than 5%.

6. Loading Criteria For Efficiency Testing

6.1 General Provisions

Loading criteria for ac-dc power supplies shall be based on rated dc output current and not on rated dc output power. For example consider the 50% loading condition for a 50 W, +5 V single-output power supply with a rated dc output current of 10 A. The load condition is achieved by adjusting the dc load (using a rheostat or electronic load bank) connected to the 5 V bus output so that 5 A of current is flowing on the bus. This is *not* equivalent to adjusting the load bank until the load on that bus dissipates 25 W of power. For power supplies with multiple output voltage busses, defining a consistent loading criteria is much more difficult because each bus has a rated dc output current, but the sum of the power dissipated from each bus loaded to these rated currents may exceed the overall rated dc output power of the power supply. A proportional allocation method is recommended for providing consistent loading guidelines for multiple output internal ac-dc power supplies. This method is elaborated in detail in the next section.

6.1.1 Proportional allocation method for loading multiple output ac-dc power supplies

This section shows a procedure for developing loading guidelines based on a proportional allocation method. Measurements shall be taken at loading points of 10%, 20%, 50% and 100% of rated output power. In some power supplies, the nameplate specifies the rated dc output current on each output voltage bus, and care should be taken to stay within those values. However, loading the buses to their individual current maximums often will exceed the overall rated dc output power of the power supply. In some cases, limits are established for a subset of the output voltage busses. These limits can also be exceeded if the buses are loaded to their individual current maximums. The following sections provide procedures for loading multiple-output ac-dc power supplies by using a calculated derating factor (D).

6.1.1.1 Method of Proportional Allocation Based on Overall Power Supply Rated Dc Output Current With No Sub-group Ratings

The manufacturer has provided rated dc output current limits for each bus and an overall rated dc output power for the power supply. The approach for loading criteria is as follows:

Assume a power supply with four output voltage busses. A sample output specification of this power supply is shown in Table 6-1.

Table 6-1: Labels for Output Variables

Rated Dc Output Voltage of Each Bus	Rated Dc Output Current of Each Bus	Rated Overall Dc Output Power
V_1	I_1	P
V_2	I_2	
V_3	I_3	
V_4	I_4	

Step 1: Calculate the derating factor *D* using the procedure outlined in Eq. 6-1.

$$D = \frac{P}{(V_1 * I_1) + (V_2 * I_2) + (V_3 * I_3) + (V_4 * I_4)} \qquad \textbf{Eq. 6-1}$$

Step 2: If D 1, then it is clear that loading the power supply to the rated dc output current for every bus does not exceed the overall rated dc output power for the power supply. For this case, the required output dc current on each bus for *X*% loading can be determined by

$$I_{bus} = I_n * \frac{X}{100} \qquad \textbf{Eq. 6-2}$$

where I_{bus} is the required output dc current for that bus at X percent load and I_n is the rated dc output current for that bus. For example, Table 6-2 shows the guideline for 50% loading of the power supply based on D 1.

Table 6-2: 50% Loading Guideline for* D *1

Output Voltage of Each Bus	75% Loading Guideline
V_1	$0.5*I_1$
V_2	$0.5*I_2$
V_3	$0.5*I_3$
V_4	$0.5*I_4$

Step 3: If, however, $D<1$, it is an indication that loading each bus to its rated dc output current will exceed the overall rated dc output power for the power supply. In this case, the following loading criteria using the derating factor can be adopted:

$$I_{bus} = \frac{D * X * I_n}{100} \qquad \textbf{Eq. 6-3}$$

This effectively derates the output dc current of each output voltage bus such that at 100% load, the overall load will equal the rated dc output power of the power supply. It also derates other load levels. For example, Table 6-6 shows the guideline for 50% loading of the power supply based on $D<1$.

***Table 6-3: 50% Loading Guideline for* D<1**

Output Voltage of Each Bus	75% Loading Guideline
V_1	$D*0.5*I_1$
V_2	$D*0.5*I_2$
V_3	$D*0.5*I_3$
V_4	$D*0.5*I_4$

6.1.1.2 Method of Proportional Allocation Based on Overall Power Supply Rated Dc Output Current with Sub-group Ratings

In some cases, the power supply manufacturer specifies the rated dc output power for a subgroup of busses in addition to the overall rated dc output power of the power supply. An example of this type of power supply is a PC power supply with an overall rated dc output power (for example, 330 W) and a rated dc output power of 150 W for the +5 V and +3.3 V buses combined. Loading each bus to its individual rated dc output current may now exceed both the overall power supply's rated dc output power and the subgroup's rated dc output power. This section outlines a procedure for ensuring that both maximum limits are not exceeded.

Assume a power supply with six output voltage busses with an overall rated dc output power P_T. Let the rated dc output power for subgroup busses 1 and 2 be P_{S1-2} and a rated power for subgroup busses 3 and 4 be P_{S3-4} and the ratings for bus 5 and 6 be simply equal to the product of their individual voltages and currents. A sample output specification of this power supply is shown in Table 6-4

Table 6-4 Output Variable Labels for Maximum Rating of Subgroup Output Voltage Bus

Output Voltage of Each Output Bus	Maximum Rated Output Current of Each Bus	Maximum Rated Output Wattage for Subgroups V_1, V_2 and V_3, V_4	Maximum Power Supply Total Rating
V_1	I_1	P_{S1-2}	P_T
V_2	I_2		
V_3	I_3	P_{S3-4}	
V_4	I_4		
V_5	I_5	P_{S5}	
V_6	I_6	P_{S6}	

Step 1: Calculate derating factors D_{S1} to D_{S6} for each of the subgroups as shown in Eq. 6-4.

$$D_{S1-2} = \frac{P_{S1-2}}{(V_1 * I_1 + V_2 * I_2)}$$

$$D_{S3-4} = \frac{P_{S3-4}}{(V_3 * I_3 + V_4 * I_4)}$$

$$D_{S5} = \frac{P_{S5}}{(V_5 * I_5)}$$

$$D_{S6} = \frac{P_{S6}}{(V_6 * I_6)}$$

Eq. 6-4

If the derating factor D_S >=1, then it is clear that when the subgroup is loaded to the rated dc output currents, the subgroup rated output powers will not be exceeded and there is no need for derating.

If however one or more D_S factors are less than 1 then the subgroup power will be exceeded if the outputs are loaded to their full output currents and there is a need for derating.

Step 2:

There is also a need to check whether the sum of the subgroup maximum rated powers is greater than the total maximum power rating of the power supply (P_T). If the sum of the subgroup maximum rated powers is greater than the overall power rating of the power supply then a second derating factor D_T must be applied. This factor is calculated as shown below:

$$D_T = \frac{P_T}{P_{S1-2} + P_{S3-4} + P_5 + P_{S6}}$$ ***Eq. 6-5***

If $D_T >= 1$ then no derating is needed.

If $D_T < 1$ then the derating for each of the outputs has to be applied and is shown below.

For example, Table 6-5 shows the guideline for X% loading of the power supply based on $D_S<1$ and $D_T<1$.

Table 6-5 Output Loading Current Calculation for Each Individual and Sub-group Bus Voltages

Output Voltage	Output Current Rating	Subgroup	Output Loading Current
V_1	I_1	1-2	$D_T * D_{S1-2} * I_1 * \frac{X}{100}$
V_2	I_2		$D_T * D_{S1-2} * I_2 * \frac{X}{100}$
V_3	I_3	3-4	$D_T * D_{S3-4} * I_3 * \frac{X}{100}$
V_4	I_4		$D_T * D_{S3-4} * I_4 * \frac{X}{100}$
V_5	I_5	5	$D_T * D_{S5} * I_5 * \frac{X}{100}$
V_6	I_6	6	$D_T * D_{S6} * I_6 * \frac{X}{100}$

7. Measurement Procedures

1. Record all the input and output specifications of the ac-dc power supply provided by the manufacturer in the power supply specification sheet. These may include one or more of the following specifications:
   - Rated input ac voltage
   - Rated input ac voltage range
   - Rated input ac current
   - Rated input ac current range
   - Rated input frequency
   - Rated input frequency range
   - Rated output dc power
   - Rated output dc current
   - Rated output dc current range
   - Rated output dc voltage
   - Rated output dc voltage range
2. Calculate the loading criteria for each output voltage bus for each loading level defined by the loading guidelines used for the UUT.
3. Complete the test set-up with the source, UUT, load, and measurement instrumentation. Refer to IEEE 1515 Annex B, *General Test Practices*, for general guidelines and recommended practices for measurement and instrumentation set-up for testing power supplies.
4. Set the power source input voltage and frequency (if programmable) as per the test requirement.
5. Load the output voltage busses (using either a rheostat or an electronic dc load bank) based on the loading criteria established for the UUT within the tolerance levels specified in this protocol.
6. If the fan turns ON intermittently then follow the procedure outlined in section 4.4.
7. Measure and record true rms input power, rms input voltage, rms input current, rms input current, total harmonic distortion, and output dc voltage and output current for each voltage bus.
8. Calculate the efficiency of the power supply for the loading condition using the equation:

$$\eta = \frac{\sum_i P_{o,i}}{P_{in}} \times 100 \qquad \textbf{\textit{Eq. 7-1}}$$

   Where, P_{in} is the true rms input power and $P_{o,i}$ is the output power of the i^{th} bus.
9. Repeat this procedure for other loading conditions.

7.1. Test Report

In the test report, graphically display the key data (measured and calculated) from the test along with a description of the power supply that includes the manufacturer's model name and model number, specifications, and loading criteria. Appendix A gives an example test report for an ac-dc power supply and a graphical representation of power supply efficiency under different loading conditions. For additional information on power supply test reports and other relevant information refer to the website *www.efficientpowersupplies.org*.

8. Appendix A: Example Efficiency Report for an Internal Desktop PC Power Supply

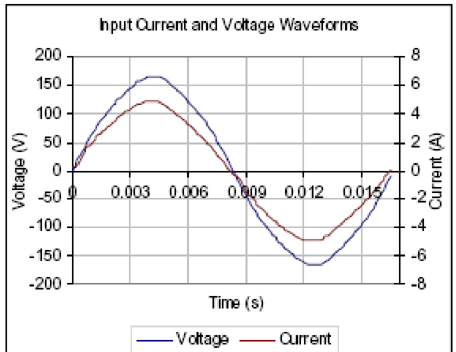
Computer Power Supply Efficiency Test Report

TYPICAL EFFICIENCY (50% Load): 78.6%
AVERAGE EFFICIENCY : 74.7%

Specimen No.	9
Manufacturer	xxxx
Model	xxxx
Serial	xxxx
Year	N/A
Type	ATX12V
Test Date	3/11/2005

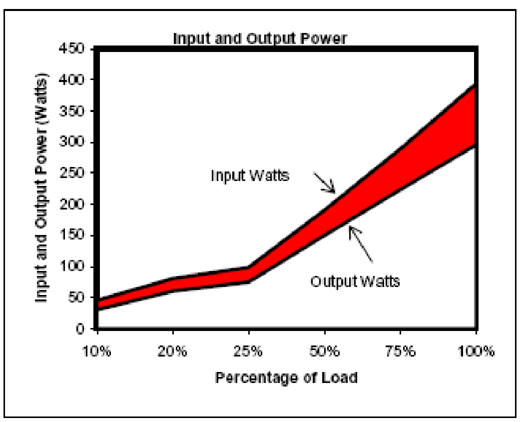
Rated Specifications	Value	Units
Input Voltage	100-240	Volts
Input Current	5	Amps
Input Frequency	50/60	Hz
Combined Max. Output Power on 5V&3.3V	200	Watts
Combined Max. Output Power on 12V	N/A	Watts
Combined Max. Output Power on 5V,3.3V&12V	N/A	Watts
Rated Output Power	**300**	**Watts**

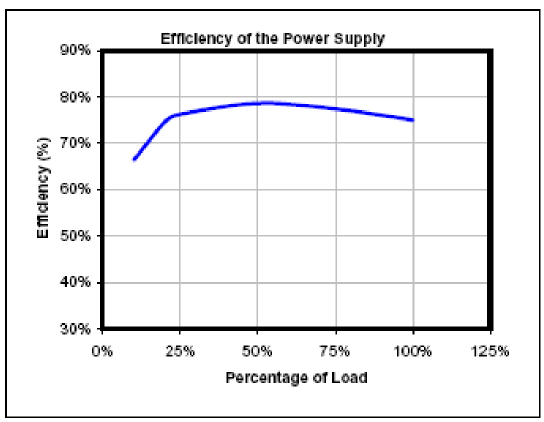
Note: All measurements were taken with Input voltage at 115 V nominal and 60 Hz.



Input AC Current Waveform (I_{THD} = 4.1% at 100% Load)

I_{RMS} A	PF	I_{THD} (%)	Load (%)	Fraction of Load	Input Watts	DC Terminal Voltage (V)/ DC Load Current (A)							Output Watts	Efficiency %
						12V1/18.0	12V2/N/A	-12.0/0.8	-5.0/NA	5.0/30.0	3.3/28.0	5.0 SB/2.0		
0.41	0.97	21.4%	10%		46	12.1/1.24	N/A	-12.2/0.06	N/A	5.09/1.70	3.27/1.59	5.03/0.14	30	66.4%
0.71	0.99	13.1%	20%	Light	81	12.1/2.48	N/A	-12.1/0.11	N/A	5.07/3.40	3.26/3/18	5.02/0.28	60	74.6%
1.66	0.99	7.1%	50%	Typical	191	12.1/6.2	N/A	-12.3/0.28	N/A	5.01/8.50	3.21/7.96	4.98/0.69	150	78.6%
3.43	1.00	4.1%	100%	Full	394	12.1/12.4	N/A	-12.3/0.55	N/A	4.88/17.0	3.08/15.89	4.90/1.38	296	75.0%





EPRI SOLUTIONS

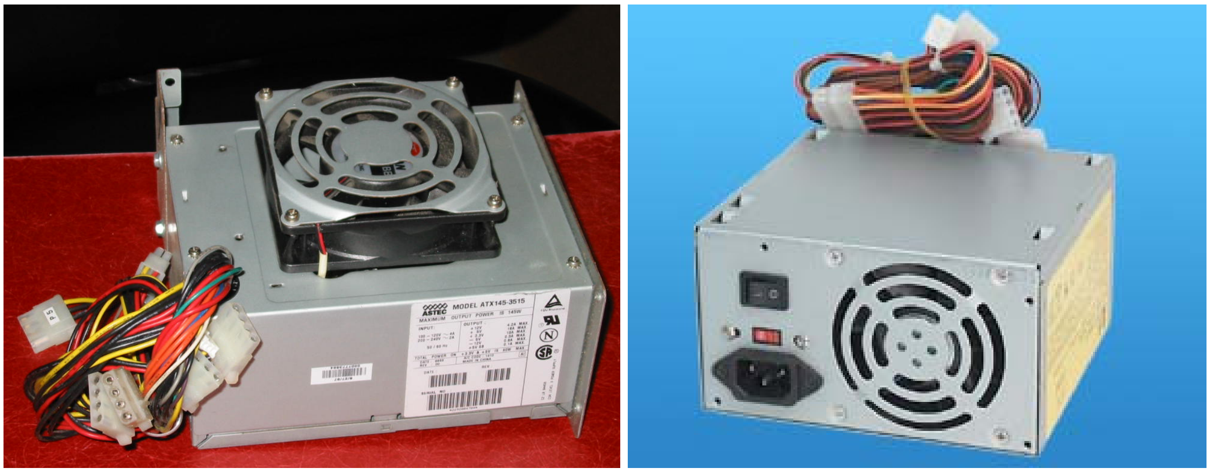
These tests were conducted as a part of California Energy Commission's intiative to improve PC power supply efficiency during active mode operation.

Test Laboratory: EPRI Solutions Inc., Knoxville, TN.

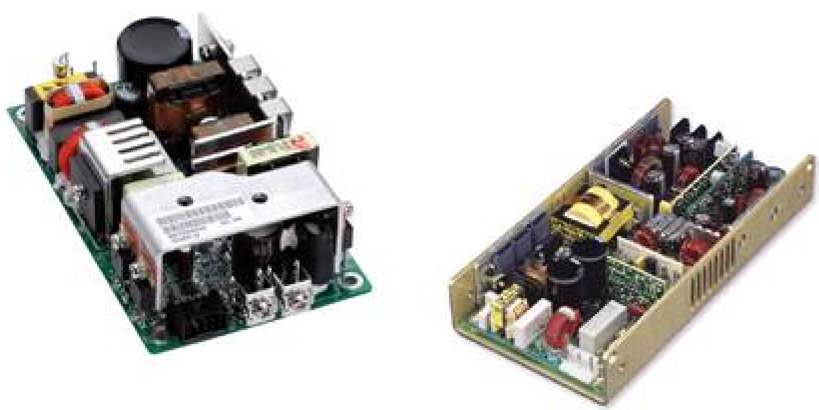
NOTE: For more sample test reports please refer to **www.efficientpowersupplies.org**

9. Appendix B: Internal Power Supply Discussion

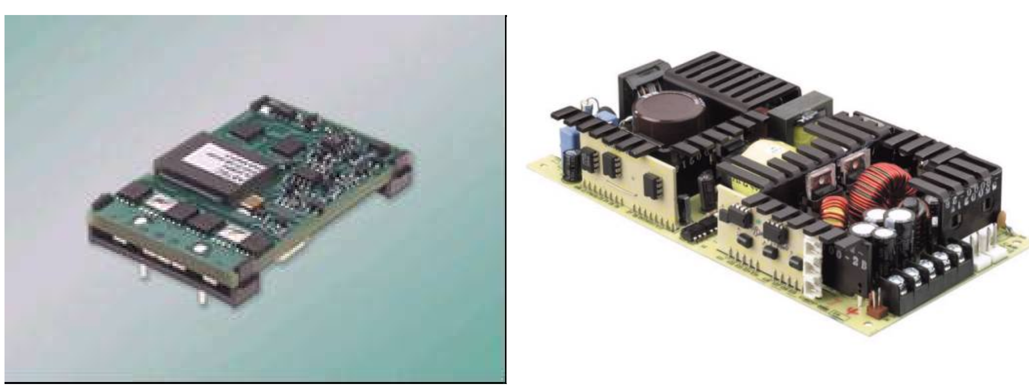
Three common housing structures for internal power supplies are enclosed-frame, open-frame and board-only, as shown in the Figure B-1. Internal power supplies within an enclosure could be fan-cooled.



(a) Enclosed Frame Power Supplies



(b) Open-frame Power Supplies



(c) Board-Only Power Supplies

Figure B-1. Examples of a) Enclosed Frame b) Open Frame and c) Board-Only Power Supplies (Courtesy Astec Power, Artesyn Technologies)

Output ratings of a cross-section of internal power supplies used in various product classes and their loading criteria are shown in the tables below.

Table B-1: output specification of a 300 W internal power supply for an ATX 12 V form factor desktop personal computer

Voltage Rail Number	Output Voltage	Min. Current (A)	Max. Current (A)	Peak Current (A)
V_1	+12	1.0	18.0	19.5
V_2	+5	0.5	26.0	--
V_3	+3.3	0.5	27.0	--
V_4	-12	0.0	0.8	--
V_5	+5 (Standby)	0.0	2.0	2.5

Table B-2: output specification of a 220 W internal power supply for an TFX 12 V form factor desktop personal computer

Voltage Rail Number	Output Voltage	Min. Current (A)	Max. Current (A)	Peak Current (A)
V_1	+12	1.0	15	17
V_2	+5	0.3	13	--
V_3	+3.3	0.5	17	--
V_4	-12	0.0	0.3	--
V_5	+5 (Standby)	0.0	2.0	2.5

Table B-3: Output specification of a 200W internal power supply for a cathode Ray Tube (CRT) Display

Voltage Rail Number	Dc Bus Voltage (V)	Continuous Current Rating (A)	Required Voltage Regulation
V_1	135	0.75	+/- 1V
V_2	30	1.2	5%
V_3	15	0.5	5%
V_4	7	1.2	5%

Table B-4: Output specification of a 55W internal power supply for a Liquid Crystal Display (LCD)

Voltage Rail Number	Dc Bus Voltage (V)	Continuous Current Rating (A)	Required Voltage Regulation
V_1	12	1.2	5%
V_2	5	8	3%

Table B-5: Output specification of a 360W internal power supply for a Plasma Display Panel (PDP)

Voltage Rail Number	Dc Bus Voltage (V)	Continuous Current Rating (A)	Required Voltage Regulation
V_1	170	1.3	+/- 2V
V_2	65	0.9	5%
V_3	15	0.9	5%
V_4	13.5	0.6	7%
V_5	12	0.6	5%
V_6	5	0.7	5%
V_7	5 (standby)	0.15	5%

Table B-6: Output specification of a 30W internal power supply for a digital set top box

Voltage Rail Number	Dc Bus Voltage (V)	Continuous Current Rating (A)
V_1	30	0.03
V_2	18	0.5
V_3	12	0.6
V_4	5	3.2
V_5	3.3	3.0