

**Proposed Test Protocol for Calculating
the Energy Efficiency of Internal Ac-Dc Power Supplies
Revision 6.1**

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Revision History

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1.0	Feb 15, 2004	First draft released.
2.0	June 1, 2004	Section on “Product-specific loading guidelines” added.
3.0	Aug 1, 2004	Definitions of measurement parameters modified to match IEEE standard.
4.0	Dec 1, 2004	Comments from Australia on proportional allocation method received. Enhanced proportional allocation method to calculate the power supply loading was included in this revision.
5.0	Aug 1, 2005	Addition of measurement provisions to capture the effects of cyclically operating cooling fans. Changes in the power measurement accuracy.
6.0	Mar 15, 2006	Scope was modified to focus on internal power supplies that are detachable, have nameplate ratings, and use standard connectors. Specifications for power measurement equipment refined. Addition of provisions to guide measurement of power supply ac power consumption during standby mode.
6.1	May 8, 2006	Wiring diagram was modified to reduce possibility for introduction of errors at very low load measurements.

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1. Scope

This document specifies a test protocol for calculating the energy efficiency of internal ac-dc power supplies. 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 power supply that has multiple output voltages: +12 V, +5 V, +3.3 V, and -12 V (See Appendix B). External power supplies – often referred to as ac adapters – are contained in a housing separate from the devices they power and 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 internal power supplies that meet the following criteria:

- i. Power supplies that have detailed input and output ratings on their name plate or in available literature from their manufacturer, specifying the maximum loads that can safely be placed on each individual dc output voltage bus and, where necessary, groupings of those voltage busses
- ii. Power supplies that have industry standard connectors that allow the dc output voltage busses to be connected and disconnected from the powered product non-destructively
- iii. Power supplies that can be easily detached from the housing of the product they power without causing harm to other circuits and components of the product

Power supplies physically integrated within the main circuit board of the device they are powering are specifically not covered by this test procedure, as are power supplies that have a combination of ac and dc output voltage busses. 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*, this test protocol establishes consistent loading guidelines for ac-dc internal power supplies.

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 single and multiple output ac-dc internal power supplies. Existing standards occasionally give conflicting approaches and requirements for efficiency testing, all of which this test protocol seeks to clarify.

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, *Household Electrical Appliances – Measurement of Standby Power*
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.

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

Devices designed to convert ac voltage into dc voltage for the purpose of powering electrical 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 Dc Signal

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

3.6 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:

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

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, including any integrated cooling fans.

3.7 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.

3.8 Multiple-Output Power Supply

A power supply designed to provide more than one dc voltage level or bus.

3.9 Open-Frame Modular Internal Power Supply

A power supply whose components are grouped on a single printed circuit board but are not enclosed in a case, as shown in Figure B-1 (b). Such power supplies are installed inside the appliance that they power, have easily accessible inputs and outputs, and can be separated from the appliance without causing damage to other components and circuits.

3.10 Output Voltage Bus

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

3.11 True Power Factor

True power factor is the ratio of the active, or real, power (P) consumed in watts to the apparent power (S) drawn in volt-amperes, with

$$PF = \frac{P}{S} \quad \text{Eq. 3-2}$$

and

$$S = \sqrt{P^2 + Q^2} \quad \text{Eq. 3-3}$$

Where

PF is power factor,

P is active power in watts,

Q is reactive power in volt-amperes,

S is total power in Volt-amperes.

This definition of power factor includes the effect of both displacement and distortion in the input current (and/or voltage) waveform. (ref. IEEE Std 1515-2000)

3.12 Crest Factor

The crest factor is defined as the ratio of peak current to rms current (or peak voltage to rms voltage). For a pure sinusoidal waveshape the crest factor is 1.414, while for a pure constant dc load the crest factor is 1.0.

3.13 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.

3.14 Rated Ac Input Voltage Range

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

3.15 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.

3.16 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.

3.17 Rated Dc Output Power

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

3.18 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.

3.19 Rated Input Frequency

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

3.20 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.

3.21 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.

3.22 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.

3.23 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:

$$V_{RMS} = \sqrt{\frac{1}{T} \int_0^T V^2(t) dt} \quad \text{Eq. 3-4}$$

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)

3.24 Single-Output Power Supply

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

3.25 Standby Mode

Standby represents the mode during which all dc power is delivered through the standby voltage rail of the power supply (see Section 3.26).

3.26 Standby Voltage Rail (Vsb)

The standby voltage rail is the output voltage bus that is present whenever ac power is applied to the ac inputs of the supply. (ref. Intel Power Supply Design Guidelines Rev. 0.5)

3.27 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)

3.28 Test Voltage Source

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

3.29 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:

$$THD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \dots + I_n^2}}{I_1} \quad \text{Eq. 3-5}$$

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

3.30 UUT

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

3.31 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

$$V_{UNB} = (\max[V_{AN}, V_{BN}, V_{CN}] - \min[V_{AN}, V_{BN}, V_{CN}]) \quad \text{Eq. 3-6}$$

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.

$$V_{UNB\%} = \frac{V_{UNB}}{\left(\frac{V_{AN} + V_{BN} + V_{CN}}{3}\right)} \times 100$$

Eq. 3-7

(ref. IEEE Std 1515-2000)

4. Standard Conditions for Efficiency Testing

4.1 General Provisions

Input voltage, frequency, output bus loading, and in some cases, the duty cycle of the fan inside the power supply are among the variables that can impact the efficiency of an internal 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 needed.

4.2 Input Voltage and Frequency

An ac reference source shall be used to provide input voltage to the UUT. As is specified in IEC 62301, the input to the UUT shall be the specified voltage $\pm 1\%$ and the specified frequency $\pm 1\%$. The UUT shall be tested at two voltage and frequency combinations: 115 V at 60 Hz and 230 V at 50 Hz if its nameplate input voltage and frequency indicate that it can operate safely under both conditions. If testing at both conditions is not possible, the UUT shall be tested at one of the above voltage and frequency combinations that is closest to its nameplate input voltage and frequency. If voltage and/or frequency ranges are not specified by the manufacturer (or the nameplate value is unclear), the UUT shall not be tested.

4.3 Power Supply Loading

The efficiency of the UUT shall be measured at 20%, 50%, and 100% of nameplate output current. Testing at a 10% loading condition is required for internal power supplies that are designed to be operated in redundant configurations and optional for non-redundant power supplies. The ac power consumption of the power supply shall also be measured under a special standby loading condition. Other loading conditions may be identified that are relevant to the manufacturer and user of the power supply. Procedures for loading internal power supplies with multiple dc voltage busses are described in detail in Section 6.1.1 below.

In some cases, the manufacturer may specify a minimum current requirement for each bus of the power supply. In these cases, it is important to ensure that the 10% or 20% loading point is not lower than the minimum current requirement. In cases where the minimum current requirement exceeds the test method's calculated load point for a given voltage bus, the value of the minimum current requirement should be used to load the bus. The percent load of the load point shall be properly recorded in any test report based on the new load values used for the busses with minimum loading requirements.

Prior to power measurements, the UUT shall be allowed to operate at each load point for at least 15 minutes in order to allow the power supply to reach a steady state of operation.

4.4 Duty Cycle of Power Supply Fan

In some power supply designs, the duty cycle (expression of percent on time) of a cooling 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 switches on. If the heat sink cools down below the set temperature value, the fan switches 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 capture the

effect of the duty cycle of the fan on the efficiency of the power supply, the input and output power measurements shall be integrated over a period of 30 minutes¹ (after thermal equilibrium of the power supply is reached) 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*).

¹ Accumulated energy approach to get average power consumption (Please refer to section 4.3, IEC 62301 Ed 1.0): Where the instrument can accumulate energy over a user selected period, the period selected shall not be less than 5 minutes. The integrating period shall be such that the total recorded value for energy and time is more than 200 times the resolution of the meter for energy and time. Determine the average power by dividing the accumulated energy by the time for the monitoring period.

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 where practicable (as is specified in IEEE 1515-2000). The input voltage source shall be deemed inadequate and different voltage source shall be used if the input voltage varies at any point during the test by more than $\pm 1\%$ of the specified source voltage for the test (115 Vac or 230 Vac).

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 13th 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 UUT shall be able to maintain the required current loading set point for each output voltage within an accuracy of $\pm 0.5\%$. If electronic load banks are used, their settings should be adjusted such that they provide a constant current load to the UUT.

5.4 Test Leads and Wiring

Appropriate American Wire Gauge (AWG) wires have to be selected for different part of wiring connections depending on the maximum current carried by the conductor in order to avoid overheating of wires from excessive loading and to reduce excessive voltage drop across the wires which may lead to incorrect efficiency measurements. For detailed information and guidance on measurement and wiring, please refer to Annex B in IEEE 1515-2000. The Table B.2, “Commonly used values for wire gages and related voltage drops” in IEEE 1515-2000 gives the relation between the voltage drop across the conductor as a function of three variables: current carried by the conductor, conductor AWG, and conductor length. The voltage drop across the conductor carrying the current must be added or subtracted to the appropriate voltage measurements (please refer to Figure 1 below) if the input and output measurements of the UUT are not taken directly at the connector pins.

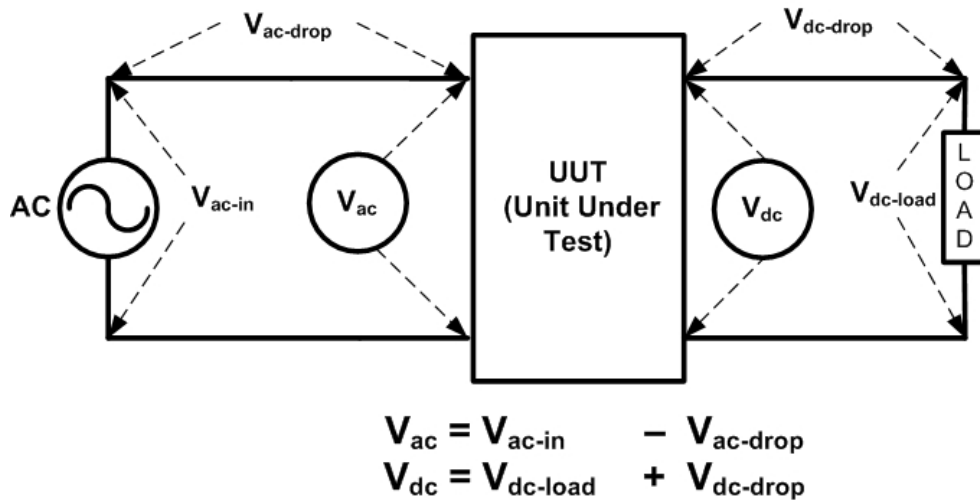


Figure 1 Input and Output Voltage Measurements

The generic test setup can be made as shown in Figure 2 below. The ac power meter used in the efficiency test should be capable of measuring the ac voltage, ac current, ac power, power factor, and total harmonic distortion of current. The dc power meter should be capable of measuring dc voltage, dc current, and dc power on all dc voltage outputs of the device. All power metering equipment should meet the accuracy requirements described in section 5.5 of this document. The dc load(s) shall be capable of drawing constant current during the course of the test and shall meet the tolerances specified in section 5.3 of this document.

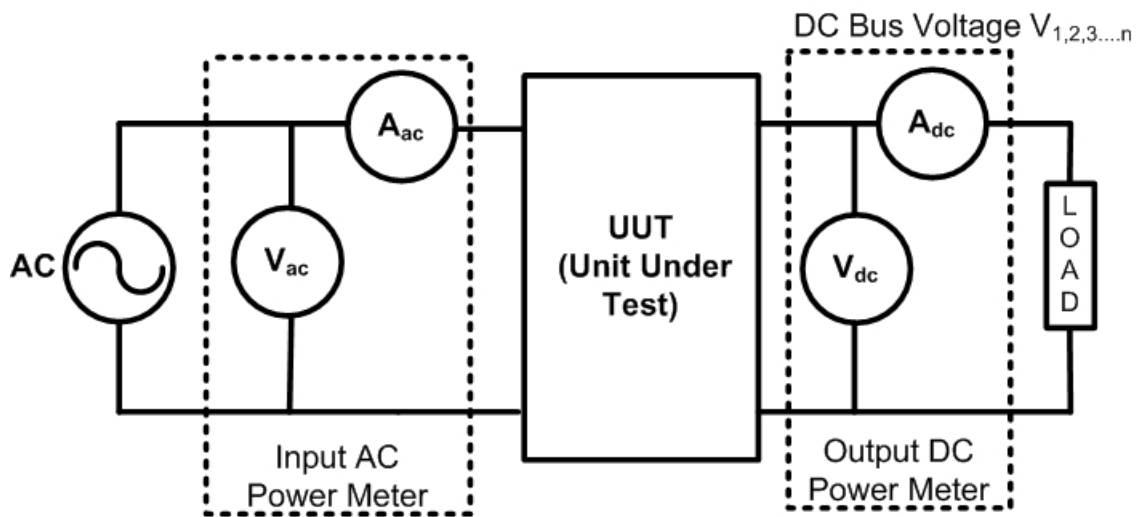


Figure 2 Generic Efficiency Test Setup

5.5 Measurement Instrumentation Accuracy

Power measurements shall be made with a suitably calibrated voltmeter and ammeter or power analyzer as specified under IEC 62301. Measurements of power of 0.5 W or greater shall be made with an uncertainty of less than or equal to 2% at the 95% confidence level. Measurements of power of less than 0.5 W shall be made with an uncertainty of less than or equal to 0.01 W at the 95% confidence level. The power measurement instrument shall have a resolution of:

- i. 0.01 W or better for power measurements of 10 W or less.
- ii. 0.1 W or better for power measurements of greater than 10 W up to 100 W
- iii. 1 W or better for power measurements of greater than 100 W.

For appliances connected to more than one phase, the power measurement instrument shall be equipped to measure total power of all phases connected.

For further details please see Annex D of IEC 62301 and ISO Guide to the Expression of Uncertainty in Measurement.

5.6 Test Room

As is specified in IEC 62301, the tests shall be carried out in a room that has an air speed close to the UUT of ≤ 0.5 m/s, and the ambient temperature shall be maintained at $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$ throughout the test. There shall be no intentional cooling of the UUT by use of separately powered fans, air conditioners, or heat sinks. The UUT shall be tested on a thermally non-conductive surface.

5.7 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 shall be loaded up to the test load for a period of at least 15 minutes or for a period sufficient that the total input power reading over two consecutive five-minute intervals does not change by more than $\pm 1\%$.

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, because voltage regulation may not remain constant under a range of loading conditions.

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. 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 described 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 20%, 50% and 100% of rated output power. A measurement at 10% is required for redundant power supplies and optional for non-redundant power supplies. The UUT's nameplate specifies the maximum rated dc output current on each output voltage bus, and care should be taken not to exceed those values. However, loading the busses to their *individual* current maximums often will exceed the *overall* rated dc output power of the power supply. In some cases, ratings are established for a subgroup of the output voltage busses. These *subgroup* ratings can also be exceeded if the busses 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.

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

Step 2: If $D \geq 1$, 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

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

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 $D \geq 1$.

Table 6-2: 50% Loading Guideline for $D \geq 1$

Output Voltage of Each Bus	50% 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:

$$I_{bus} = \frac{D * X * I_n}{100}$$

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 6-3 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	50% 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 computer power supply with an overall rated dc output power of 330 W and a rated dc output power of 150 W for the +5 V and +3.3 V busses 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 the subgroup and overall current ratings 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 $D_S \geq 1$, 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.

However, if 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 $D_T \geq 1$ 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	$D_T * D_{S6} * I_6 * \frac{X}{100}$

6.1.2 Method of Current Allocation for Measuring the Ac Power Consumption of a Computer Internal Power Supply in the Standby Condition

Measurement of the ac power consumption of computer internal power supplies operated in standby mode shall be conducted by connecting the power supply to an ac voltage source through its ac input and applying the following current loads to its standby voltage rail (+5Vsb): 100 mA, 250 mA, and 1,000 mA. (ref. Intel Power Supply Design Guidelines Rev. 0.5)

For power supplies designed to power other electronic products, measurement of the ac power consumption in standby mode shall be conducted by connecting the power supply to an ac voltage source through its ac input and applying current loads to the standby voltage rail equal to 20%, 50%, and 100% of its nameplate current rating. Testers may choose to test the ac power consumption during standby mode at other load points *in addition* to the above recommended load points if these loads better characterize the real loads placed on the standby voltage rail when installed in its intended product.

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. Record the ambient environmental conditions at the site of the test, including:
 - Ambient temperature
 - Elevation of test location
 - Barometric pressure
 3. Calculate the loading criteria for each output voltage bus for each loading level defined by the loading guidelines used for the UUT.
 4. Complete the test setup 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 setup for testing power supplies.
 5. Set the power source input voltage and frequency (if programmable) as per the test requirement.
 6. 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.
 7. If the fan turns on intermittently, then follow the procedure outlined in section 4.4.
 8. Measure and record the following at each load condition. For dc values, record separate values for each dc output voltage bus:
 - Rms ac input power
 - Rms ac input voltage
 - Rms ac input current
 - Power factor
 - Total harmonic distortion of input current
 - Dc output voltage

- Dc output current
 - Dc output power
9. Calculate the efficiency of the power supply for the loading condition using the equation:

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

Where, P_{in} is the true rms input power and $P_{o,i}$ is the output power of the i^{th} bus.

10. Repeat this procedure for other loading conditions.
11. Measure and record the ac power consumption of the UUT in standby mode at the load points specified in section 6.1.2 of this document.

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 provides 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.

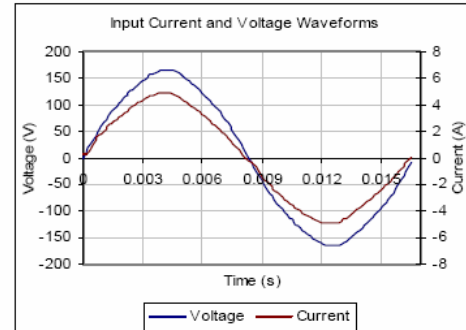
8. Appendix A: Example Efficiency Report for an Internal Desktop PC Power Supply

Computer Power Supply Efficiency Test Report

TYPICAL EFFICIENCY (50% Load): 78.6%
AVERAGE EFFICIENCY : 73.7%



Specimen No.	9
Manufacturer	xxxx
Model	xxxx
Serial	xxxx
Year	N/A
Type	ATX12V
Test Date	3/11/2005
Tested By	BV
Ambient Temp	23.5°C

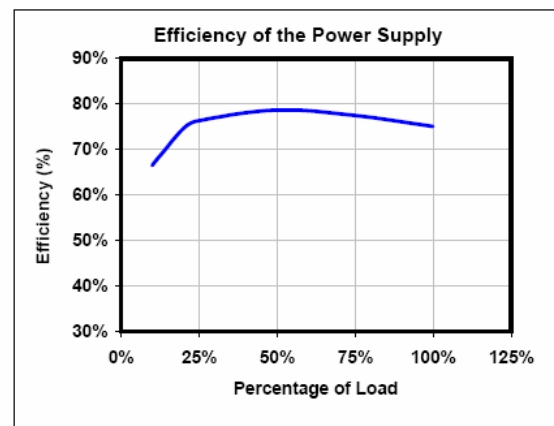
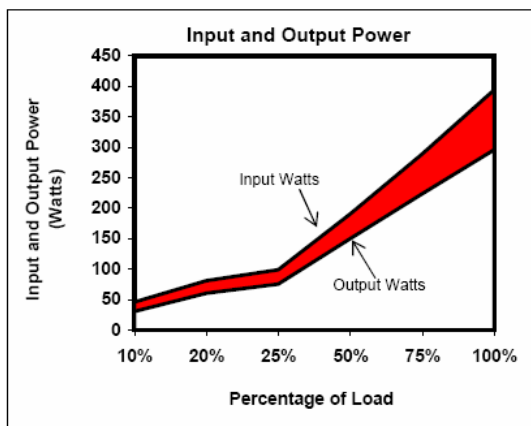


Input AC Current Waveform ($I_{THD} = 4.1\%$ at 100% Load)

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.

I_{RMS} A	PF	I_{THD} (%)	Load (%)	Input Watts	DC Terminal Voltage (V)/ DC Load Current (A)					Output Watts	Efficiency %		
					12V1/18.0	12V2/NA	-12.0/0.8	-5.0/NA	5.0/30.0			3.3/28.0	5.0VSB/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%	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%	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%	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%



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

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

Note: For more sample test reports please refer to www.EfficientPowerSupplies.org

9. Appendix B: Internal Power Supply Discussion

The common housing structures for internal power supplies considered in this test procedure are enclosed-frame and open-frame as shown in the Figure B-1. Internal power supplies within an enclosure could be fan-cooled.



(a) Enclosed Frame Internal Power Supplies



(b) Open-frame Internal Power Supplies

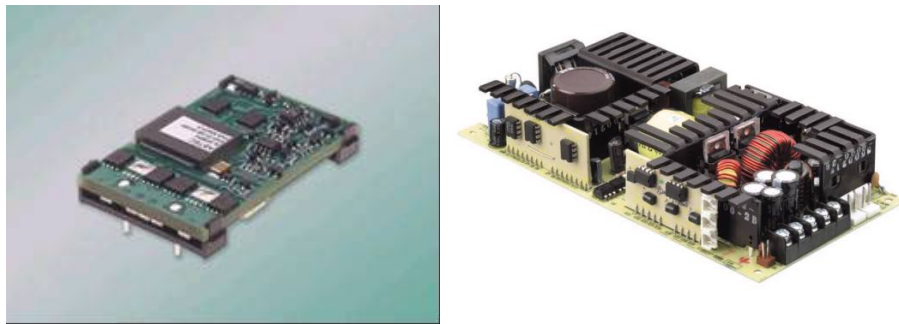


Figure B-1. Examples of a) enclosed frame and b) open frame internal power supplies (Courtesy Astec Power, Artesyn Technologies)

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