MOTHERBOARD POWER EFFICIENCY MEASUREMENT PROCESS

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Revision

Version	Release Date	Notes
0.1	Feb. 11, 2008	First draft for internal review
0.5	April 20, 2008	Deleted PS, AC-DC member list and future scope sections
0.9	May 05, 2008	Incorporated feedback from team members

1. Executive Summary

The Climate Savers Computing Initiative (CSCI) goal is to improve the energy efficiency of computers in order to save money and fight climate change. Our broad effort is to organize the global computing industry to significantly improve energy-efficient computing and thereby reduce greenhouse gas emissions.

To that end we need to establish industry-wide efficiency standards that computer manufacturers can follow, and over time we plan to raise those standards to make computers more and more efficient. But before we can establish these standards we need to publish a common process that manufacturers can follow to begin measuring power efficiency in their computers. Once manufacturers begin collecting and reporting their findings using this process, CSCI can establish baseline levels of efficiency that will help us decide on our initial standards.

This paper describes how to measure the power efficiency of server computer motherboards. Previously much attention has been given to measuring the efficiency of power supplies, but because the motherboard is a major consumer of power--and because motherboards typically contain DC-to-DC power conversion devices that contribute to inefficiency--it is central to the overall efficiency of the computer. To make significant headway in improving computer efficiency we must address the motherboard as well as the power supply. The measurement process described in this paper is the first step in addressing that need and delivering significant gains in efficiency. Clearly, other parts of the system, such as hard drives, peripheral devices and fans, also contribute to the overall efficiency of the system and warrant attention as well.

The process was determined by the CSCI Motherboard Efficiency Working Group, which includes representation from throughout the computer industry.

2. Current Scope

The Climate Savers Computing Initiative goal is to improve the power efficiency of high volume servers and desktops. The current goal of this document is to define standard motherboard efficiency measurements covering all major power conversion components of a motherboard. This document intends to define standard measurement methodologies and to determine the power efficiency for motherboards used in high-volume computers.

Server Power Efficiency

Server Power Efficiency can be described by the following formula:

Server Power Efficiency = {1 – ((power loss on the Motherboard (MB) due to power conversion*) + (power loss by Power Supply (PS)) + (power loss by HDD) + (power loss by system fans[1])/PSinput)}

or

$$SPE = 1 - \frac{Loss_{MB} + Loss_{PS} + Loss_{HDD} + Loss_{Fans}}{PS\_Input}$$

where SPE = Server Power Efficiency

SPE variables	Description	Influence factor
$Loss_{MB}$	power loss on the motherboard	High
$Loss_{PS}$	power loss by power supply	High depending on loads
$Loss_{HDD}$	power loss by hard disk drives (HDD)	Depending on drive count
$Loss_{Fans}$	power loss by system fans	Depending on fan count and operating speed

**Note: Excluding power loss due to copper.*

2.1 Intent

The intent of this document is to use existing industry standards that have been created and well accepted for electronic test and measurement to develop a consistent and repeatable method for measuring the energy efficiency of high volume server motherboards. Occasionally, existing standards give conflicting methodologies and requirements for efficiency testing. This document seeks to clarify and align with stakeholders and organizations who publish the existing methods.

[1] Integrated power supply fans are included as part of power supply power loss.

3. 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:

- IEEE Std 1515-2000, IEEE Recommended Practice for Electronic Power Subsystems: Parameter Definitions, Test Conditions, and Test Methods.

- Proposed Test Protocol for Calculating the Energy Efficiency of Internal AC-DC Power Supplies, Revision 6.1, May 2006 by EPRI Solutions, Inc. and ECOS Consulting.

4. Acknowledgements

Many thanks to the participating members of the Motherboard Efficiency Working Group (MBE WG) and organizations for their continued support, passion and dedication in improving computing equipment efficiency and protecting the climate. Special thank to Angela Kernan for making the document more pleasant to read.

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5. Glossary

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.

AC-DC Power Supply - Devices designed to convert AC voltage into DC voltage for the purpose of powering electrical equipment.

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)

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

Apparent Power (S) - The product of RMS voltage and current (VA). Also called the total power.

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

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:

$$\eta = \Sigma i\ Poi / P\ in \times 100$$

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.

Current - Electrical current is a measure of the amount of electrical charge transferred per unit time. It represents the flow of electrons through a conductive material. Current is a scalar quantity (though in circuit analysis, the direction of current is relevant). The SI unit of electrical current is the ampere, defined as 1 coulomb/second.

Electrical Load (or dummy load) - A device used to simulate an electrical load, usually for testing purposes.

Motherboard – A fully populated motherboard, including all converters (if there are plug-in modules). This may mean that the same base motherboard will have several different “parent assemblies” if different VRM’s are populated and each need to be considered separately.

POL - Point of Load

Voltage - a representation of the electric potential energy per unit charge. If a unit of electrical charge were placed in a location, the voltage indicates the potential energy of it at that point. In other words, it is a measurement of the energy contained within an electric field, or an electric circuit, at a given point. Voltage is a scalar quantity. The SI unit of voltage is the volt, such that 1 volt = 1 joule/coulomb.

6. Equipment

Equipment images are included for illustration purposes only (no product endorsement by CSCI).

6.1 Load equipment

- Electronic load

- Calibrated load resistors
- Processor socket load cards
- Memory socket load cards

6.2 Voltage measurement

- Digital Oscilloscope with averaging function

- Digital multi-meter for linear regulators

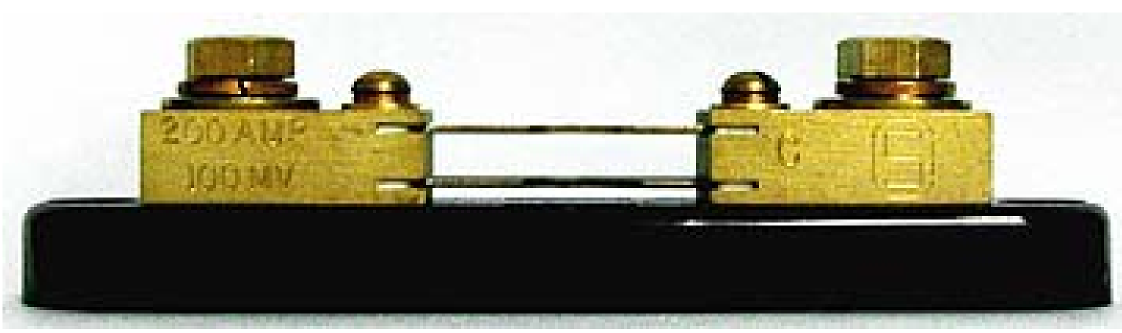
- Digital multi-meter with averaging function for switching regulators

- Data acquisition card such as a National Instruments card or Agilent

6.3 Current measurement

- Current Probe

- Shunt



7. Motherboard Power Efficiency Measurement

7.1 Temp Conditions

Ambient temp must be $25^0C \pm 5^0C$

7.2 Airflow

Provide reasonable airflow to simulate use-conditions and/or manufacturer design conditions.

7.3 Ranges, Resolution

Measure efficiency in 5% load incremental steps from 0% to 100% of regulator design spec (increasing from 0%, 5%, 10%... to 100%).

7.4 Load Profile

Dwell time at above loads should be at least three minutes, or until thermally stable. Collect and average data for a minimum of 30 seconds after reaching the thermal stability.

Collect these measurements: V_{in}, I_{in}, V_{out}, and I_{out}. It is recommended to take at least 30 samples for averaging.

7.5 Power-up Sequence

In a typical computer with multiple voltage rails, the power-up sequence may have to be specified and followed. Otherwise, component damage may result if the sequence is not in proper order. Please refer to your motherboard specification for details.

7.6 Measurement Order

Linear regulators should be measured before any components are depopulated from the board.

7.7 Voltages

CPU Core Voltage Regulator must be measured at 1.1V VID code. If the regulator does not have a 1.1V VID, then measure at the nearest VID (higher or lower). For motherboards with an Adaptive Voltage Positioning (AVP) feature (such as load-line), the feature must be disabled for testing purposes.

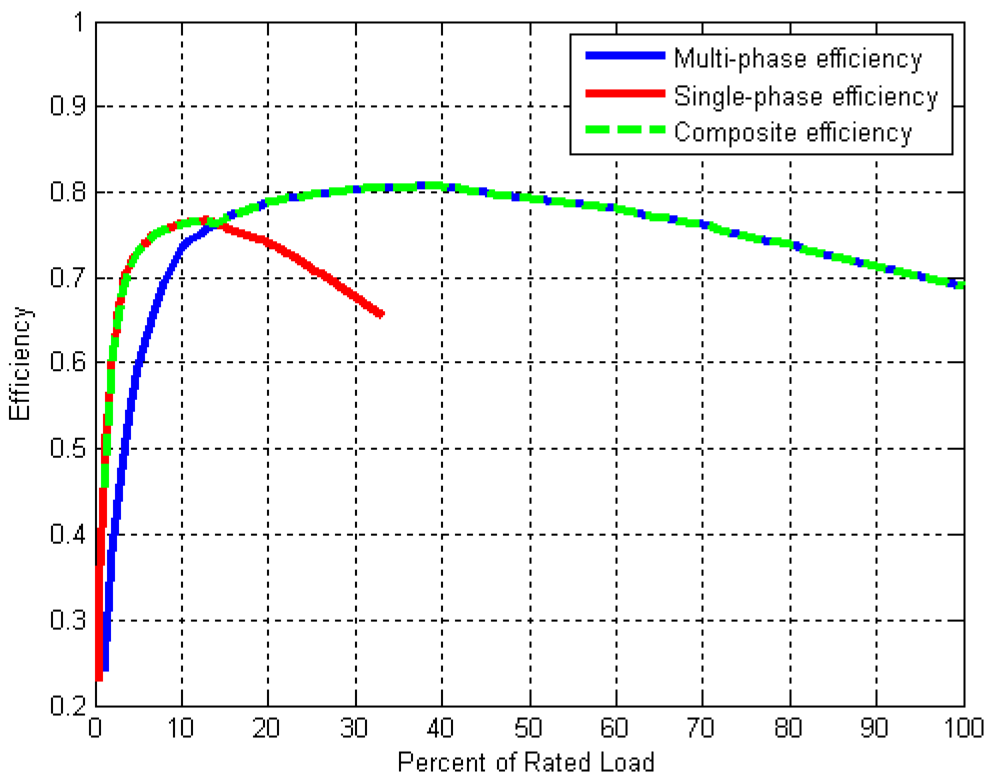
All other adjustable regulators must be measured at the highest possible programmable output voltage.

7.8 Measurement Points

As recommended guidelines, the measurement point for the input side should be before the input inductor (if one exists). For the output side, the measurement point should be right after the output inductor.

7.8.1 Switching regulators

- **CPU Core regulator**: DC load current must be drawn through the CPU socket. Measure Voltage (V_{out}) at the top-side (CPU-side) of the socket.
- **All other switching regulators**: Measure Voltage (Vout) at the output inductor(s) or as close as practical to the output inductor(s). The DC load may be attached anywhere downstream of the output voltage measurement point, including any sockets that exist. All motherboard loads (end devices such as chipset or peripheral devices, as well as any downstream regulators) MUST be physically removed prior to starting testing, such that I_{out} = 0 with no DC load attached.
- **VRs with light load efficiency enhancement features:** Measure efficiency with and without the enhancement feature enabled, and use the composite efficiency curve.



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- **Input Voltage and current** shall be measured as close to the input of the Voltage Regulator as possible.

7.8.2 Linear Regulators

- **Integrated linear regulators:** Measure the input and output voltage at the input and output pins. Current on the third pin may be neglected as you can assume that $I_{in} = I_{out}$. Current does not need to be measured.

- **Discrete linear regulators:** Measure V_{in} at the drain (collector) and V_{out} at the source (emitter) of the pass FET

7.9 Calculations

Option 1 – Loss Efficiency:

$$\textbf{MB Eff} = 1 - \frac{\sum_{i=1} \left(P_{in(i)} - P_{out(i)} \right)}{\sum_{j=1} PR_{in(j)}}$$

where:

N = number of switcher and linear regulators on MB
M = number of primary regulators on MB
Pin(i) = input power of regulator i
Pout(i) = output power of regulator i
PRin(j) = input power of primary regulator j
MB Efficiency is calculated from 0% to 100% rated load