The Efficiency Of Internal Power Supplies: Test Procedure And Policy Developments

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Agenda

- Internal Power Supply (IPS) – General Classification
- General IPS Efficiency Test Procedure Development
- Enhanced Proportional Allocation Method
- Efficiency Test Setup and Calibration
- Test Procedure in Use: Data from Computer IPS
- Policy Developments

Need for General IPS Efficiency Test Procedure

- Previous work defined a test procedure for external power supplies (wall warts)

- These were single output devices, so efficiency was simply Pout/Pin

- IPS are multiple output devices, whose individual busses have maximum current ratings

- Often, loading the individual busses to their maximums would exceed the overall maximum for the power supply

Need for IPS Efficiency Test Procedure: Accountability for Manufacturer Claims

Product	Manufacturer Web Site Claim
	82%
	high efficiency, over 70%
	74% typical

Internal Power Supply: Types and Scope

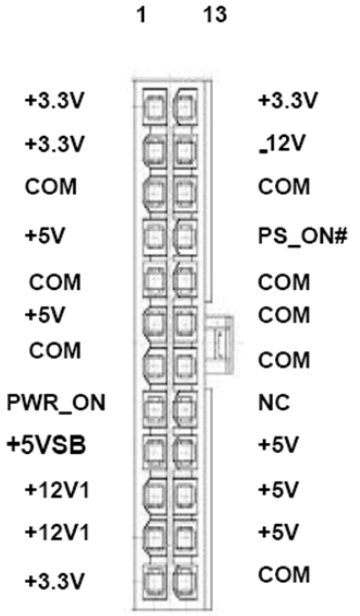
Definition: Power supplies that are located in the same housing as the product that they power (desktop computers, televisions, etc.)

Two IPS categories:

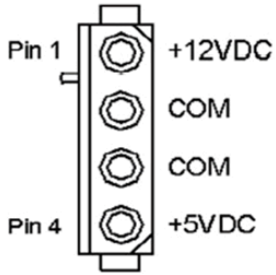
- **Separable IPS**
  - May have predefined form factors (e.g. ATX12V, SFX12V,etc)
  - May have industry design guides (e.g. www.formfactors.org)
  - Have name plate details and standard connectors
  - Can be easily removed from the powered product without causing damage
- **Non-Separable IPS**
  - Typically open frame, non-standard power supplies
  - Don't have name plate details
  - No industry specific guidelines available

Example of a Separable IPS

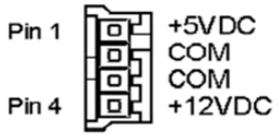
AC INPUT 交流輸入	100-240V~9A 50/60Hz					
DC OUTPUT 直流輸出	+3.3V	+5V	+12V1	+12V2	-12V	+5Vsb
	30A	30A	17A	16A	0.8A	2A
	180W Max.		396W		9.6W	10W
	500Watts					



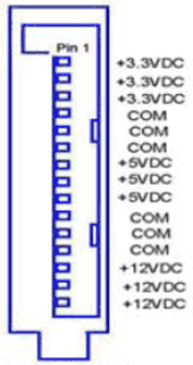
Main Power Connector



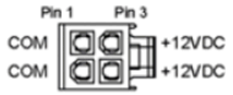
Peripheral Power Connector



Floppy Drive Power Connector

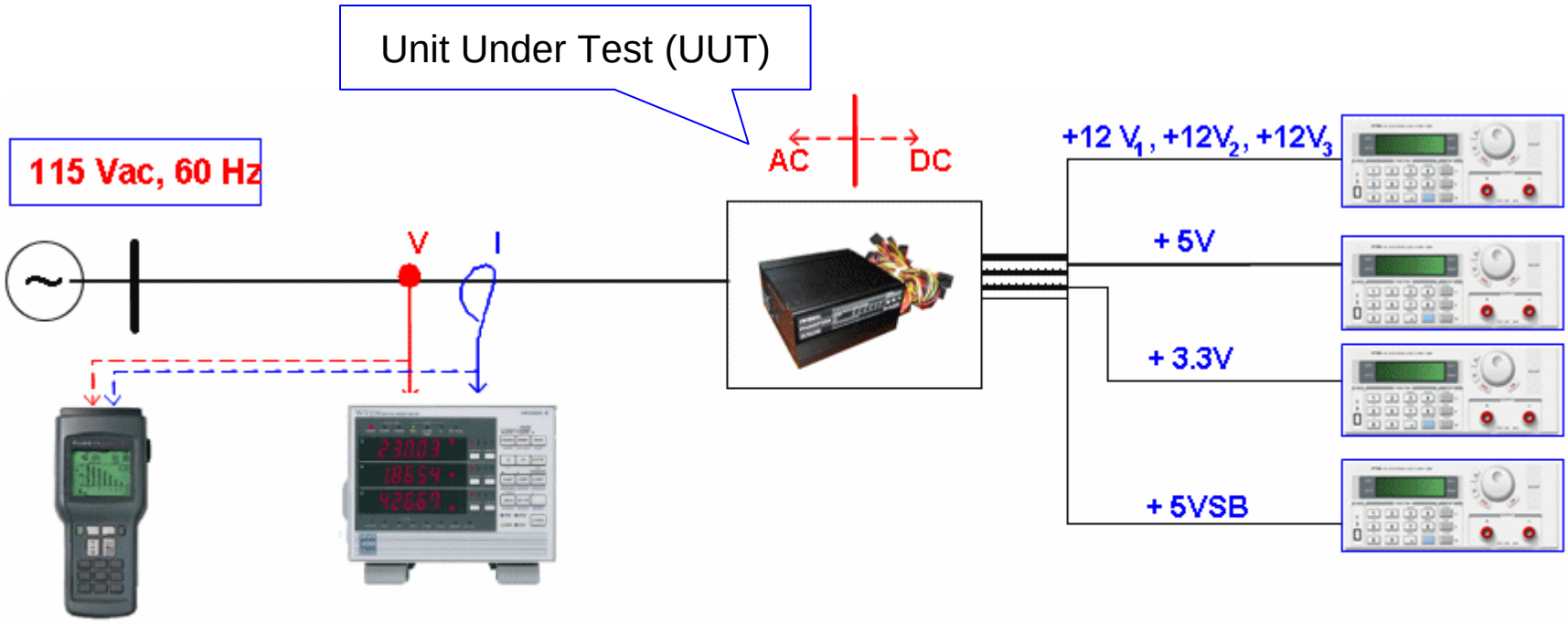


Serial ATA Connector



+12V Power Connector

Example Test Apparatus at EPRI Solutions



Enhanced Proportional Allocation Method for Loading Power Supply

AC INPUT 交流輸入	100-240V~9A 50/60Hz					
DC OUTPUT 直流輸出	+3.3V	+5V	+12V1	+12V2	-12V	+5Vsb
	30A	30A	17A	16A	0.8A	2A
	180W Max.		396W		9.6W	10W
	500Watts					

- Consider a computer power supply with six output voltage busses, two subgroups
- Loading guidelines can be calculated for any percent of the total current load
- Loading formulas ensure that subgroup and overall power ratings are not violated

Enhanced Proportional Allocation Method for Loading Power Supply

Example of power supply specification

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}	

AC INPUT 交流輸入	100-240V~9A 50/60Hz					
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	180W Max.		396W		9.6W	10W
	500Watts					

Enhanced Proportional Allocation Method for Loading Power Supply

Step 1

Calculate derating factors for each of the subgroups:

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

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

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

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

If each of the derating factors D_S are =1, then it is clear that if 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.

Enhanced Proportional Allocation Method for Loading Power Supply

If however one or more D_S factors are < 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 a need to check whether the sum of the derated subgroup maximum rated powers is greater than the total maximum power rating of the power supply. If it is then a second derating factor must be applied. This factor is as shown:

$$D_T = \frac{P_T}{P_{S1-2} + P_{S3-4} + P_5 + P_{S6}}$$

If D_T = 1 then no derating need be applied for this stage.

Enhanced Proportional Allocation Method for Loading Power Supply

If D_T < 1 then the derating for X% Loading is as shown below

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	$D_T * D_{S6} * I_6 * \frac{X}{100}$

Sample Efficiency Calculation for ATX12V PSU

$$\eta = \frac{\sum p_{out}}{p_{in}}$$

Calculated current load points

Efficiency @ 10% Load			Effic	71.89%				
AC Input				**DC Output**				
				Voltage Bus	**Load Curren**	**Calibrated V (V)**	**Calibrated I (**	**Power (Watts)**
Voltage	115.05	Volts		**12V1**	0.75	12.07	0.75	9.06
Current	0.406	Amps		**12V2**	0.71	12.06	0.71	8.57
Pf	0.82			**12V3**	0.00	0.00	0.00	0.00
Input Power	**38.32**	Watts		**-5V**	0.00	0.00	0.00	0.00
ATHD	6	16 %		**-12V**	0.02	12.20	0.02	0.24
				3.3V	1.02	3.31	1.02	3.38
				5V*	1.08	5.00	1.08	5.39
				5VSB	0.18	5.04	0.18	0.91
							Output Power	**27.55**

Total ac input power

Total dc output power

Rev. 6 Test Method: What's New?

Element	Modifications
Scope	Refined to separable internal power supplies only
Normative References	Harmonization with Intel power supply design guidelines
Equipment and Test Condition Guidelines	Clarified accuracy of voltage source. Created tighter guidelines for power meter accuracy at high loads.
Loading Guidelines	Added loading guidelines to characterize power consumption of computer power supplies in standby
Reporting Requirements	Included ambient conditions in reporting requirements.

Rev. 6 available at www.EfficientPowerSupplies.org

Summary of Testing to Date

- Over 70 desktop IPS, 30 server IPS, and handful of other consumer electronics IPS measured using this method
- Industry-standard form factors (Intel ATX, SFX, TFX, EPS1U, etc.) and several product-specific models (TV, set top box IPS) measured
- Experience testing non-separable IPS led us to refine scope of test procedure to focus on separable models (PC, server, IT, etc.)

PS Efficiency Test Setup at EPRI Solutions Laboratory

- Calibrated and dedicated test setup to measure computer power supply efficiency at various loads
- Devices with high accuracy and precision are used
- Testing facility for 80 PLUS Program (www.80plus.org)

Our Experience: the Benefits of a Generalized Approach

Old Method: Use Loading Recommended by Industry Guidelines

250W (loading shown in Amps)						
Loading	+12V1	+12V2	+5V	+3.3V	-12V	+5Vsb
Full	5.3	9.1	12	14	0.3	1.0
Typical	2.6	4.5	7.8	1.8	0.1	1.0
Light	1	1.8	1.6	1.8	0.0	1.0

Courtesy of www.FormFactors.org

- Limited to standard form factors

New Method: Calculate Loading Using Generalized Approach

+ Any separable IPS can be tested

How is the IPS Test Procedure Being Used in Policy and Utility Programs?

- Main focus on computer and server power supplies because they qualify as “separable”
- Currently no push to promote IPS efficiency in other consumer electronics products like TVs, VCRs, DVD players, etc.
- May be efficiency opportunities in other separable IPS designs such as those used in other IT equipment, slot machines, etc.

Industry Acceptance of Test Method

- Intel Corporation now features references to the loading guidelines and test method in its power supply design guide available on www.FormFactors.org

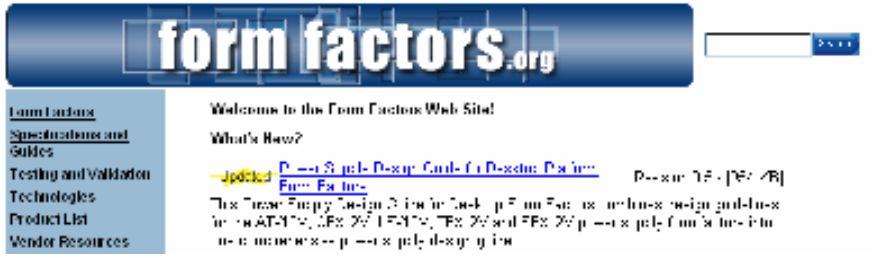


Table 9. Loading Table for Efficiency Measurements

Note: Loading calculated by method available at www.efficientpowersupplies.org

250W (loading shown in Amps)						
Loading	**+12V1**	**+12V2**	**+5V**	**+3.3V**	**-12V**	**+5Vsb**
Full	5.3	9.1	12	14	0.3	1.0
Typical	2.6	4.5	7.8	1.8	0.1	1.0
Light	1	1.8	1.6	1.8	0.0	1.0
300W (loading shown in Amps)						
Loading	**+12V1**	**+12V2**	**+5V**	**+3.3V**	**-12V**	**+5Vsb**
Full	6	10.5	9	13.5	0.3	1.0
Typical	3	5.3	4.5	6.8	0.1	1.0
Light	1.2	2.1	1.8	2.7	0.0	1.0

Who currently references the IPS test procedure?

- Referenced in Intel power supply design guide (www.FormFactors.org)

- Referenced in Ecos Consulting's 80 PLUS utility buy-down program for computers (www.80PLUS.org)

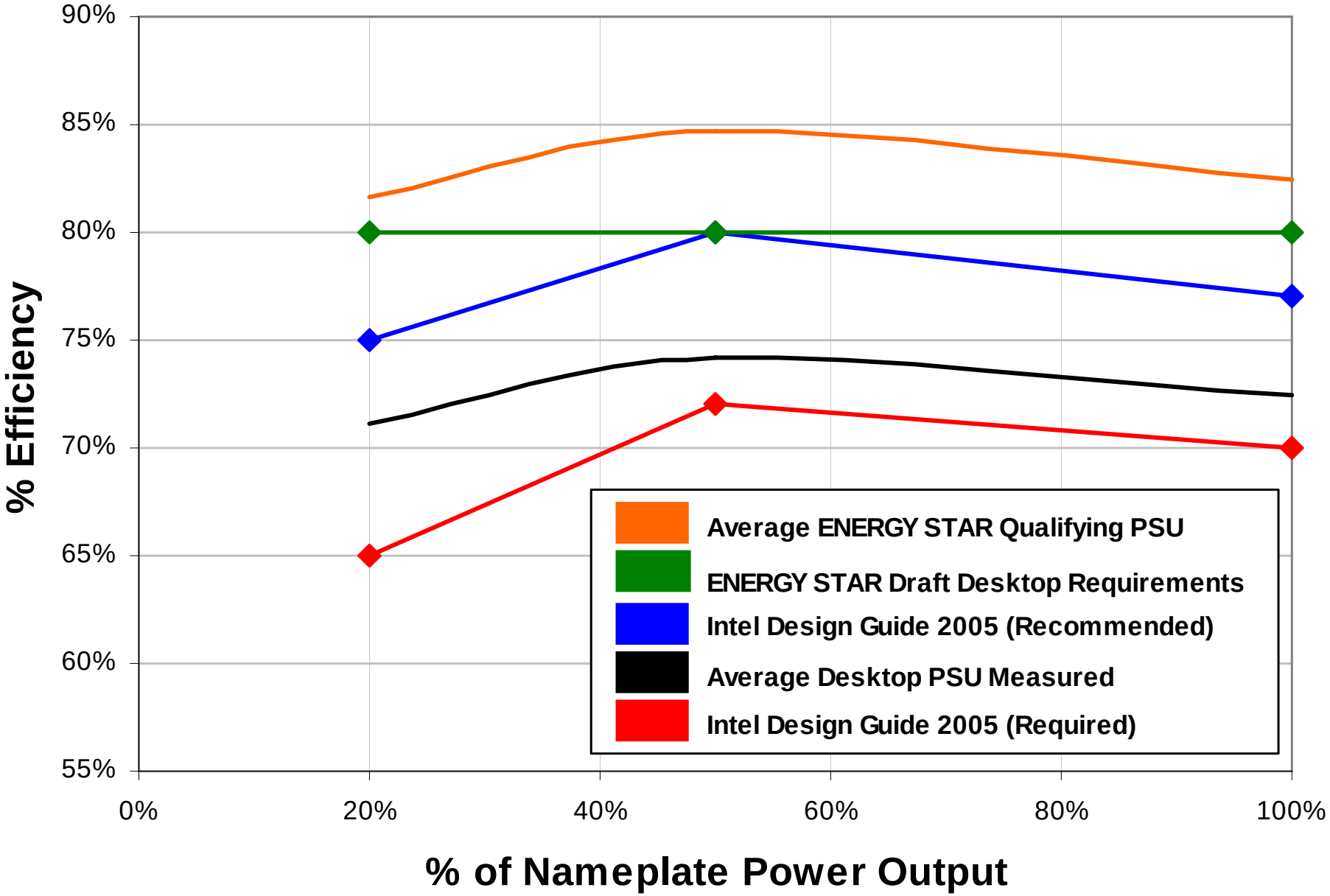
- Referenced in ENERGY STAR draft 1 revised computer specification (www.ENERGYSTAR.gov)

Higher standards for computer PSU efficiency

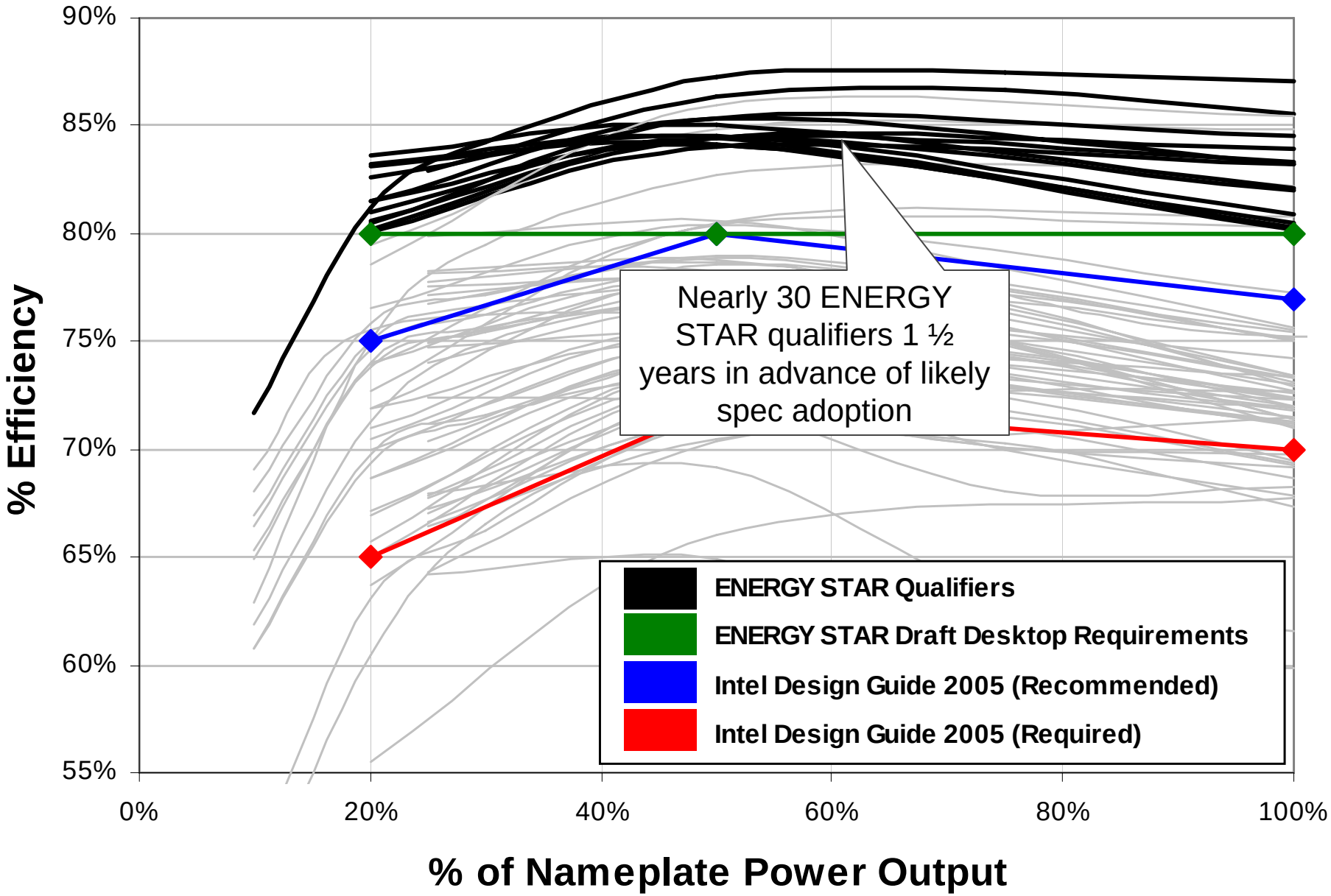
	20% Load (Light)	50% Load (Typical)	100% Load (Full)
80 PLUS* ENERGY STAR* Intel Design Guide **Optional**	80%	80%	80%
Intel Design Guide **Recommended**	72%	77%	74%
Intel Design Guide **Required**	65%	72%	70%

* Also require PF > 0.9 at 100% load

Desktop PS Efficiency: What is Typical?



Desktop PS ENERGY STAR Qualifiers



Staying Plugged in…

- Rev. 6 of internal power supply test procedure
- Written comment summary for test procedure
- Forum for California Energy Commission external power supply standards

Questions

Equipment Used (Optional Slide)

Measurement of AC input:

- Digital Power Meter

  Manufacturer: **Yokogawa**

  Model Number: **WT230**

- Power Harmonic Analyzer (for waveform capture)

  Manufacturer: **Fluke**

  Model: **Fluke 41 or Fluke 41B**

  Software: Flukeview™

Measurement of DC output:

- DC Electronic Load banks

  Manufacturer: **Circuit Specialist Inc.**

  Model Number: **CSI 3710A**

Equipment Accuracy (Optional)

Yokogawa WT230:

Accuracy (for 45Hz<f<66Hz):

V,I and P = **±(0.1% reading +0.1% range)**

Voltech PM100:

Accuracy (for 5Hz to 1kHz):

V = **±0.1% reading ±0.1% range ±10mV**

I = **±0.1% reading ±0.1% range ±1mA**

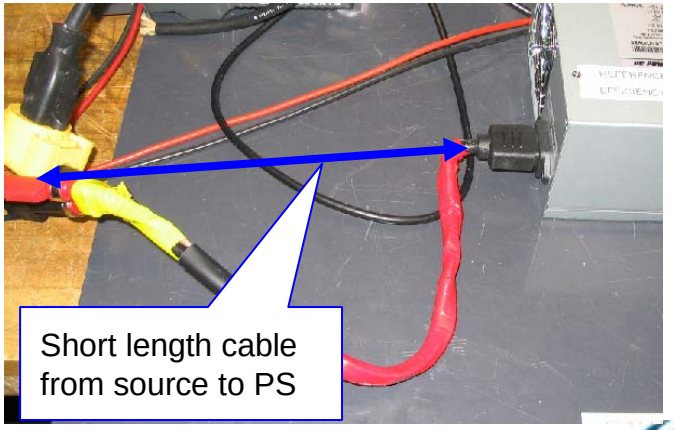
P = **±0.2% reading ±0.2% range ±5mW**

CSI 3710A DC Load:

Voltage accuracy	0.000~3.999V : 0.2%+3mV
	4.00~35.99V : 0.2%+30mV
	36.0~360.0V : 0.2%+300mV
Current accuracy	0.000~2.999A : 0.2%+3mA
	3.00~30.00A : 0.2%+30mA

Steps taken to eliminate measurement errors

- Short cable from ac power source to the input of the power supply
- Input voltage is measured right at the point of entrance eliminating voltage drop in input cable
- Short cable from PS output connectors to test fixture
- Drops in output connectors and dc test leads offset with calibration factors
- Larger diameter cables 4/0 cables used to reduce voltage drop and measurement errors



Finding the right voltage from cal factors (optional slide)

Calibrated Voltage, Current and DC Output Power of each voltage rail can be calculated using the formula:

$$V_{cal} = EL_V + V_{Cal\_Factor}$$

$$I_{cal} = EL_I + I_{Cal\_Factor}$$

$$P_{DC} = V_{cal} * I_{cal}$$

NOTE: *'EL' stands for Electronic Load*
'P_{DC}' stands for DC Power Output
'V_{Cal}' stands for Calibrated DC Output Voltage
'I_{Cal}' stands for Calibrated DC Output Current

Baseline Efficiency Measurements

The reference power supply is tested at regular intervals and its efficiency is monitored over time.