ATX Version 3.1 Multi Rail Desktop Platform Power Supply

Design Guide

Revision 2.1

September 2023

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Revision History

Document Number	Revision Number	Description	Revision Date
336521	0.5	• Initial release of combined power supply design guide • Combined CFX12V, LFX12V, ATX12V, SFX12V, and TFX12V content into one desktop power supply design guide • CFX12V content derived from revision 1.2 — Updated 12V1 current for 300 W configuration — Updated efficiency loading for 300 W configuration • LFX12V content derived from revision 1.1 • ATX12V content derived from revision 2.2 • SFX12V content derived from revision 3.1 • TFX12V content derived from revision 2.1 — Updated 12V1 current for 300 W configuration — Updated efficiency loading for 300 W configuration • Updated Capacitive Load section to use standard capacitor values • Updated 5 VSB efficiency recommendations for Digital Office platforms • Removed power-down warning from power supply timing diagram • Marked sections with labels to indicate REQUIRED, RECOMMENDED, or OPTIONAL items	January 2006
	1.0	• Added 12V2 Current for Processor Configurations table • Added revision numbers to form factor specific chapters	June 2006
	1.1	• Removed outdated ENERGY STAR* requirements and added some new ENERGY STAR information. • Updated Typical Power Distribution tables for all power supply form factors and updated minimum loads. • Updated cross regulation figures. • Added Flex ATX power supply form factor. • Updated capacitive loading table. • Clarified over voltage and over current verbiage. • Added Power-up Cross Loading Condition section. • Other changes shown in red with change bars.	March 2007
	1.2	• Section 4.3.1 and Added max of 400 mV Ripple/Noise to PS_ON and PWR_OK signals • Section 14.2 Figure 49 replaced to implement change in dimension C	February 2008

Document Number	Revision Number	Description	Revision Date
		• Section 4.3 Added Power-down timing to Figure 4-3 and Table 4-10: Power Supply Timing Table 4-10 (T6 > 1 ms) • Section 8.3 Clarified Class D requirements. Added additional references for EMC requirements by country • Section 4.5.9 Added Climate Savers Computing text • Updated all Cross-regulation graphs • Section 2 updated configuration charts • Removed dates from reference documentation. Refer to the latest version available • Updated Figure 58	
	1.3	• Updated Section 4.2.3 Remote sensing to recommended level • Added Section 4.2.10 12 V2DC Minimum Loading Recommendation • Added Section 4.4.2 +5 VSB Fall time Recommendation • Updated Section 4.2.9 Voltage Hold-up Time • Updated Section 4.5.9 Overall Power Supply Efficiency and ENERGY STAR • Changed Floppy Drive Connector to OPTIONAL level • Changed Section 5.2.2.6 Serial ATA Connectors to Required level • Update Table 2-1: 12V2 Current for Processor Configurations • Updated Table 4-2: DC Output Voltage Regulation -12V to recommended level • Updated Table 4-5: Recommended System DC and AC power consumption • Updated Table 4-10 Power Supply Timing recommended value • Updated Table 4-16: Efficiency versus Load	July 2012
	1.31	• Updated Table 4-5 Recommended System DC and AC power consumption • Changed Section 4.2.10 12 V2DC Minimum Loading to REQUIRED • Updated Section 4.3.6 Rise Time • Updated — CFX12V Specific Guidelines to version 1.5 — LFX12V Specific Guidelines to version 1.3 — ATX12V Specific Guidelines to version 2.4 — SFX12V Specific Guidelines to version 3.3 — TFX12V Specific Guidelines to version 2.4 — Flex ATX Specific Guidelines to version 1.1	April 2013

Document Number	Revision Number	Description	Revision Date
	1.4	• Updated Section 1.2, Table 1-1 with new terminology • Updated Section 2.1 peak and sustained current requirements • Updated Section 3.1 Table 4-1 – removed current values in table • Updated Section 4.2.2, Table 4-3 – 12V1 and 12V2 new step size, added 12V3/4 step size • Updated Section 4.2.4 - low power 5VSB efficiency • Updated Section 4.2.6, Table 4-7 – Decoupling cap values were changed • Added Figure 4-2 in Section 4.2.8 • Updated Section 4.2.10, Table 4-9 – 12V2 recommendation is now required • Updated Section 4.3, Table 4-10 now shows T0, Timing requirements T1 and T3 added for ALPM and note about timing requirements in the year 2020 • Updated Section 4.3.4 to provide recommendation to increase current on 5VSB for computers with ALPM • Added Figure 4-6 in section 4.3.6 for more clarity • Updated Section 4.4.2 5VSB fall time as recommendation and loading conditions used in the test plan • Re-wrote Section 4.5.8 for overall efficiency targets – Added Section about Low Load Condition • Re-wrote Section 4.5.9 to include Efficiency recommendations for current Energy Regulations • Updated Section 5.1 to include labeling instructions for which DG timings are supported by the PSU • Updated Section 5.2.2.3 Floppy Drive Connector to be reference only • Added Section 5.2.2.4 for PCIe* AIC connectors • Updated Section 5.2.2.4.2, added Table 5-5 +12V power 8 pin connector pin out • Updated Section 6.1 – Acoustic note about acoustic targets can be customer specific • Sections 11, 12, 13, 14, 15 and 16 Added form factor revision summary to beginning of each form factor specific section • Added new Intel Test Plan Section	June 2017
	1.41	• Update Section 2.1 – Table 2-1 for 12V2 Processor sustained and peak power updates • Added Section 2.2 for HEDT processors support • Updated Section 4.5.8 and added Table 4-15 • Update Section 4.3 – add note for T3	October 2017

Document Number	Revision Number	Description	Revision Date
		• Update Section 4.5.9 – for ENERGY STAR* Computers Version 7.0 • Updated Chapters 11, 12, 13, 14, 15, and 16 CFX12V Specific Guidelines to version 1.61 LFX12V Specific Guidelines to version 1.41 ATX12V Specific Guidelines to version 2.51 SFX12V Specific Guidelines to version 3.41 TFX12V Specific Guidelines to version 2.51 Flex ATX Specific Guidelines to version 1.21 • Updated Test Plan Sections 16.2.1 and Table 16-2 - 12V2 load table - to match Table 2-1 • Updated Test Plan Sections 16.2.2 and Table 16-3 for new 95W load of 21A Continuous • Updated Test Plan Sections 16.3.3 and Table 16-10 – added 12W load level • Updated Test Plan Section 16.6 to include mention of PSU for new CPU TDP levels mentioned in Section 2.1	
	1.42	• Update Table 2-1: 12V2 Current for Processor Configurations. • Update Figure 4-3: Power Supply Timing. • Add Figure 4-5: +5VSB Power on timing versus VAC. • Add note Table 5-10: Serial ATA* Power Connector Pin-out: +3.3V is removed from SATA V3.2 spec. • Updated Chapters 11, 12, 13, 14, 15, and 16 CFX12V Specific Guidelines to version 1.62 LFX12V Specific Guidelines to version 1.42 ATX12V Specific Guidelines to version 2.52 SFX12V Specific Guidelines to version 3.42 TFX12V Specific Guidelines to version 2.52 Flex ATX Specific Guidelines to version 1.22 • Remove Test Plan Section. Refer to Document #338448 for test plan. • Add Section 10.2 Reliability – PS_ON# toggle for S0ix mode.	May 2018
	1.43	• Update Table 2-1: 12V2 Current for Processor Configurations. • Change -12VDC capacitive load from 3300uF to 330uF. • Updated Chapters 11, 12, 13, 14, 15 and 16 CFX12V Specific Guidelines to version 1.63 LFX12V Specific Guidelines to version 1.43 ATX12V Specific Guidelines to version 2.53 SFX12V Specific Guidelines to version 3.43 TFX12V Specific Guidelines to version 2.53 Flex ATX Specific Guidelines to version 1.23 • Update Table 4-5 5VSB efficiency	March 2019
	1.43.01	• Updated Table 2-1 to correct the 12V2 peak current requirement of 165W.	May 2020

Document Number	Revision Number	Description	Revision Date
		• Changed the Section 1.1 topic to "Alternative Low Power Mode" for Power Supplies. • Added PSU Addendum for all future processor support in Section 2.1. • Updated Section 4.5.9 to support Energy Star v8.	
	2.0	• Updated text for clarity in Section 1: Introduction • Section 1.1 added second reference for ALPM in Section 4.3.3 • Section 1.2 – Added new Reference Documentations to list • Updated Table 2-1 and reference text for Processors • Section 2.2- Updated to provide clarity • Added ALL of Section 3 – PCIe* Add-in Card Consideration • Updated Section 4.2.1 and Table 4-2: DC Output Voltage Regulation– +12V Voltage range changed • Updated Table 4-3 - DC Voltage step size modified for 12V2 & 12V3/4. • Added Table 4-4: DC Output Transient Slew Rate and text describing Slew Rate • Updated Table 4-10: Power Supply Timing – Previous Required value is now Legacy Timings and Previous Recommended is now Required. • Updated Section 4.3.3 – to include mention response to PS_ON# changes beyond 100 ms • Simplified Table 4-15: Low Load Efficiency Requirements • Section 5.1 – Added mention for label of all PSUs should state revision of the specification that it meets and 12VHPWR label for power level supported • Section 5.2.2.4 – PCIe* Graphics Card Connector section increased detail for all 3 connector options including new 12VHPWR connector. • Chapter 11, 12, 13, 14, 15, and 16 – Changed table at beginning of each section to represent new mechanical size Specification Revision.	February 2022
	2.01	• Table 2-1 - Changed top row from 165W to 150W and associated power values to correspond to latest updates in the PSU Design Guide Addendum document. • Table 3-3 - Duty Cycle for Peak Events change to match the PSU Test Plan document. • Table 3-4 - Whole table updated related to Duty Cycle for Peak Events change to match the PSU Test Plan document. • Table 4-3 - Added Note #4 that references Dynamic Mode testing for each 12VHPWR Connector in the system.	February 2023

Document Number	Revision Number	Description	Revision Date
		• Section 4.2.2 - Fixed reference for Table 4-4 on page 32. • Table 4-4 – Changed word "Rated" to "Recommended" in the top row of the table. • Table 4-12 - Note 2 – Updated reference from an external document to Section 10.2, which already covered the items listed in this document. • Table 4-16 – Added column for 10% Load as defined in ENERGY STAR* for Computers v8 • Section 5.1 – Changed how 12VHPWR connector power limit labeling can be done. Change from "Required" to "Recommended" for having the 12VHPWR connector power limit on the 12VHPWR connector. Reason is if a PSU uses a modular design with detachable cables, then the 12VHPWR power limit can be listed on PSU Label. 12VHPWR connector limit must be listed in one of these locations. • Section 5.2.2.4.3 PCI Express* (PCIe*) 12VHPWR Auxiliary Power Connector (Optional for PSU ≤ 450 watts, Recommended for PSU > 450 watts) – Added mention of two options for 12VHPWR Connector, header changed to "Recommended" for PSUs> 450 watts • Figure 5-3 and Figure 5-4 – updated figures with new pictures of both 12VHPWR connector options • Section 5.2.2.4.3 and Figure 5-10 – Added paragraph & figure about 12VHPWR Cable Plug Connection Recommendations	
	2.1	• The 12VHPWR connector's PCB Header's internal pin lengths have been modified. Therefore, the connector has been given a new name. 12VHPWR connector name has been changed throughout the document to "12V-2x6". The "Cable Plug" side of the connector has not changed and is compatible with new PCB Header connector definition. • Section 1.2 – Reference documents to PCI-SIG document about PCIe CEM 5.0 changed to Rev 5.1. Previous ECNs have been removed as these changes have been included in Rev 5.1. Changed language in section 3.1 to list how PCIe CEM Rev 5.1 now incorporates all previous ECNs • Updated Table 3-1 with 2 new additional columns • Updated Figure 3-1 to show two new Power Excursion limit lines. PCIe CEM Slot (Blue) and "Before Software Configuration" message (Green) lines are new. • Updated Table 3-5 to show the different current values for the different power values that can be used with the 12V-2x6 connector. • Updated Table 3-6 with new sense line definition for 150 Watt and 0 Watt Sustained power levels.	September 2023

Document Number	Revision Number	Description	Revision Date
		• Updated Table 4-3. Note 6 has been added to show that Dynamic Load testing for "-12V" rail has moved from Required to Recommended. • Added Table 4-8 to show the new Voltage Hold Up time levels. Before only a Required level was 17 ms @ 100% load. Now there is both a Required level and Recommended level. • Updated Table 4-10 with the T5 value has both Required and Recommend level that corresponds to changes in Table 4-8. • Additions to Section 5.2.2.4.3, for new 12V-2x6 connector drawings. Figure 5-4 to Figure 5-9 all updated or new. • Updated to Section 5.2.2.4.3 – Cable Plug Connection Recommendation has been replaced to technical details to look at for internal connections.	

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1 Introduction

This document aligns to ATX Specification Version 3.1

This document provides design suggestions for various power supply form factors. The power supplies are primarily intended for use with desktop system designs. It should not be inferred that all power supplies must conform exactly to the content of this document, though there are key parameters that define mechanical fit across a common set of platforms. Since power supply needs vary depending on system configuration, the design specifics described are not intended to support all possible systems. The REQUIRED sections are intended to be followed for all systems. The RECOMMENDED sections may be modified based on system design. Lastly, the sections labeled as OPTIONAL, which would not be required for all designs, may prove helpful to some designs.

1.1 Alternative Low Power Mode for Power Supplies

Computers continue to change and introduce new power states. One of these new power states is generically called an Alternative Low Power Mode (ALPM). Some examples of Alternative Low Power Modes are Microsoft* Windows* 10 Modern Standby* or Google* Chrome* Lucid Sleep. These new power states have created requirements for power supplies. Below is a summary of these requirements as they are mentioned throughout the document.

- Section 4.2.4 – Other Lower Power System Requirements:
  - Table 4-5 shows that ALPM requirements are at the 0.55 A and 1.5 A load levels.
- Section 4.3 - Timing, Housekeeping and Control:
  - Table 4-10 has a note about values of T1 and T3 that are required to support ALPM.
- Section 4.2.2–Reliability – PS_ON# Toggle for S0ix Mode and Section 10.2:
  - The number of times a PSU toggles on and off is expected to increase.

  Section 4.3.3: PS_ON# – REQUIRED
  - PSU response quickly to toggling of PS_ON# signal.

1.2 Reference Documentation

The following documents are referenced in various sections of this design guide. The document may not be up to date; refer to the latest version. For guidelines not specifically mentioned here, refer to the appropriate document.

Document	Document Number /Source
European Association of Consumer Electronics Manufacturers (EACEM*) Hazardous Substance List / Certification	AB13-94-146
IEEE* Recommended Practice on Surge Voltages in Low-Voltage AC Circuits	ANSI* C62.41-1991
IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits	ANSI C62.45-1992
Nordic national requirement in addition to EN 60950	EMKO-TSE (74-SEC) 207/94
American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz for EMI testing	ANSI C63.4
UL 60950-1 First Edition –CAN/CSA-C22.2 No. 60950-1-03 First Edition, IEC 60950-1: 2001 + Amendments and National Deviations, EN 60950-1: 2001 + Amendment A11: EU Low Voltage Directive (73/23/EEC) (CE Compliance) GB-4943 (China) CNS 14336: (Taiwan BSMI) FCC*, Class B, Part 15 (Radiated and Conducted Emissions) CISPR* 22 / EN55022, 5th Edition (Radiated and Conducted Emissions) EN55024 (ITE Specific Immunity) EN 61000-4-2 – Electrostatic Discharge EN 61000-4-3– Radiated RFI Immunity EN 61000-4-4– Electrical Fast Transients EN 61000-4-5 – Electrical Surge EN 61000-4-6 – RF Conducted EN 61000-4-8 – Power Frequency Magnetic Fields EN 61000-4-11 – Voltage Dips, Short Interrupts and Fluctuations EN61000-3-2 (Harmonics) EN61000-3-3 (Voltage Flicker) EU EMC Directive ((8/9/336/EEC) (CE Compliance)) IEC 62368	
PCI Express* Card Electromechanical Specification Revision 5.1	PCISIG.com
ENERGY STAR for Computers Version 8.0	https://www.energystar.gov/products/spec/computers_version_8_0_pd

Document	Document Number /Source
European Union Energy Related Products(ErP) Lot 6	https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficient-products/standby
Power Supply Efficiency Labeling Program – 80 plus Organization	80plus.org
Generalized Test Protocol for Calculating the Energy Efficiency of Internal Ac-Dc and Dc-Dc Power Supplies Revision 6.7.1	EPRI – Listed at 80plus.org website
Efficiency (ETA) and Noise (LAMBDA) programs: Cybenetics LTD	Cybenetics.com

1.3 Terminology

Table 1-1 defines the acronyms, conventions, and terminology that is used throughout the design guide.

Table 1-1: Conventions and Terminology

Acronym, Convention/ Terminology	Description
ALPM	Alternative Low Power Mode, ALPM replaces the traditional Sleep Mode (ACPI S3) with a new sleep mode. An example of ALPM is with Microsoft* Windows Modern Standby* or Lucid Sleep with Google* Chrome*.
AWG	American Wire Gauge
BA	Declared sound power, LwAd. The declared sound power level shall be measured according to ISO* 7779 for the power supply and reported according to ISO 9296.
CFM	Cubic Feet per Minute (airflow).
Monotonically	A waveform changes from one level to another in a steady fashion, without oscillation.
MTBF	Mean time between failure.
Noise	The periodic or random signals over frequency band of 0 Hz to 20 MHz.
Non-ALPM	Computers that do not use Alternative Low Power Mode use traditional Sleep Mode (ACPI S3).
Overcurrent	A condition in which the current demand on a supply output exceeds its rated output current. This commonly occurs if there is a "short circuit" condition in the load attached to the supply.
PFC	Power Factor Correction.
p-p	Peak-to-Peak Voltage Measurement.

Acronym, Convention/ Terminology	Description
PWR_OK	PWR_OK is a "power good" signal used by the system power supply to indicate that the +5VDC, +3.3 VDC and +12VDC outputs are above the under-voltage thresholds of the power supply.
Ripple noise	The periodic or random signals over a frequency band of 0 Hz to 20 MHz.
Rise Time	Rise time is defined as the time it takes any output voltage to rise from 10% to 90% of its nominal voltage.
Surge	The condition where the AC line voltage rises above nominal voltage.
VSB or Standby Voltage	An output voltage that is present whenever AC power is applied to the AC inputs of the supply.

Table 1-2: Support Terminology

Category	Description
Optional	The status given to items within this design guide, which are not required to meet design guide, however, some system applications may optionally use these features. May be a required or recommended item in a future design guide.
Recommended	The status given to items within this design guide, which are not required to meet design guide, however, are required by many system applications. May be a required item in a future design guide.
Required	The status given to items within this design guide, which are required to meet design guide and a large majority of system applications.

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2 Processor Configurations

2.1 Processor Configurations - RECOMMENDED

The processor power in a desktop computer is provided by the 12V2 power rail of power supplies with multiple power rails. To meet the desktop processor power needs, a desktop power supply must provide the current value listed in Table 2-1 for the 12V2 voltage rail. Table 2-1 shows the various processor current requirements represented by the desktop processor's TDP. If a power supply only has one 12V rail, then Table 2-1 shows the amount of current that needs to be dedicated to the desktop processor in a system level power budget.

Table 2-1: 12V2 Current for Processor Configurations

PSU 12V2 Capability Recommendations		
Processor TDP	Continuous Current	Peak Current
150 W	33 A	60 A
125 W	26 A	39 A
65 W	23 A	34 A
35 W	11 A	19 A

NOTES:

1. If the power supply supports the 240 VA Energy Hazard protection requirement, then current levels for the 12 Volt rail above 18 Amps must be divided into multiple 12 V rails.
2. Continuous current is defined for the processors PL2 (Turbo) power limit since desktop processors are expected to stay at PL2 for many seconds, sometimes close to 1 minute. For a PSU, any time over 1 second is considered Continuous current.
3. Peak Current is defined for the processor's PL4 which defines Peak current for a max time of 10 ms.

All future processor power/PSU current requirements will be defined in a document titled *ATX12VO and ATX12V PSU Design Guide Addendum* (#621484) that is applicable to both Single Rail and Multi Rail ATX Power Supplies. Refer to that document for details of where these values come from.

2.2 High End Desktop Market Processor Considerations

The High-End Desktop market requires power supplies with higher power levels than typical mainstream market. The EPS12V specification is often referenced for these designs. The EPS12V specification is a power supply form factor for the server market. This Desktop ATX Power Supply Design Guide includes higher power levels to support these higher performance desktop computers.

2.2.1 Modular Power Supply Connectors

A modular power supply, with multiple detachable cable options, is recommended to provide the greatest flexibility to the end user. This approach reduces the chassis volume consumed by unused power cables which improves both cable routing and cooling.

The dedicated 12V CPU connectors on the motherboard are either a single 8 pin (2x4) connector, or one or two 4 pin (2x2) connectors, detailed in Section 5.2.2.5 +12 V Power Connector. These are often referenced as *EPS12V* connectors.

Section 5.2.2.4 *PCI-Express (PCIe*) Add-in Card Connector* details three cable/connector options that deliver +12 V power rails to a PCIe* Add-in Card. While each of the three connectors provides a 12V rail to power the chassis component, they use different pin locations and mechanical keying, and are not directly interchangeable. Therefore, a modular design is an option to support multiple end use configurations.

For example, the end user might require a power supply to support a system with a lower-power or non-overclocked CPU and multiple higher-power graphics cards and thus populate the PSU outputs with multiple power cables configured for the PCIe* graphics cards. Alternatively, a higher power overclocked CPU system mounting a single, lower power graphics card may require more 12V CPU power and a single plug for PCIe* power. A modular power supply allows connectors on the power supply to provide 12V power and then the end user can select the appropriately configured cable/plug to provide 12V power in their system with no change to the pinout of the PSU itself.

Three examples of modular designs are shown below. The orange box in each picture identifies the connectors on the power supply that provide 12V power rails.

18 AWG wire is typically used to meet the 6-8 Amp/pin requirements of most chassis components. (An important exception is the 12V-2x6 connector, which requires thicker, 16 AWG wires.) Based on this example of 6-8 Amp/pin, the following recommendation applies to how much power/current may be supported by each connector determined by the number of +12V pins included in that connector. Using Table 2-1, the number of pins and connectors for motherboard 12V CPU (EPS12V) connectors can be calculated.

- 12-16 A support for 2x2 (4pin) connector
- 18-24 A support for 2x3 (6pin) connector
- 24-32 A support for 2x4 (8pin) connector

A distinction must be made between the current per pin *available* from the PSU through a connector pin and 18 AWG wire vs. the maximum *demand* for current from the connected chassis component such as a PCIe* Card or motherboard 12V CPU connector(s).

For example, a standard 2x3 PCIe* power connector supporting a graphics card will draw no more than 6.75 Amps total through its three power pins and two ground pins. Similarly, the 2x4 PCIe* power connector will draw no more than 13.5 Amps total through three power pins and three ground pins.

It is possible to reduce the number of conductors consumed at the PSU by providing the 12V to a 2x4 PCIe* card power connector through a 2x2 modular connector at the power supply, for example. Before reducing the conductor count, the PSU designer should also consider the copper losses and the resulting voltage drop incurred by the two cable connectors and a length of the 18 AWG conductor.

This recommendation is based on common design practice. The PSU and system designer may deviate from this guidance but remains responsible for designing the PSU to meet all electrical, thermal, safety and reliability requirements based on the application of the PSU.

It is important to recognize that the 600W 12V-2x6 cable/plug described in PCIe* CEM Revision 5.1 (detailed in Section 5.2.2.4.3), requires 16 AWG wire and a per-pin current capacity of 9.2 A. Modular PSU designs supporting the 12V-2x6 cable/connector may benefit from implementing a corresponding 12V-2x6 header on the PSU chassis that would accept a symmetric "double-ended" 12V-2x6 cable/connector harness, instead of a proprietary connector. This simplifies management of the four required sideband conductors.

2.2.2 Overclocking Recommendations

The power levels listed in Section 2.1 - Processor Configurations - RECOMMENDED are for processors that follow the Plan of Record (POR) power levels that include Turbo Mode. If the processor is overclocked, then power requirements will be increased. If the power supply is expected to support end users who intend to overclock then the 12V power rail to the processor should be higher than what is listed in Table 2-1: 12V2 Current for Processor Configurations.

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3 PCI Express* Add-in Card Considerations

The PCI Express* (PCIe*) Card Electromechanical Specification (CEM Spec) provides thermal, power, mechanical, and signal integrity design guidance for the PCI Express* Add-in Card (AIC) form factor. This includes the card's electrical and mechanical interface with a host system board, chassis, and power supply.

The 5.0 Revision of the PCIe* CEM specification introduced multiple updates that directly affect this power supply specification. The newer, 5.1 Revision of the PCIe CEM spec provides important corrections, revisions, and clarifications of the features first introduced in CEM 5.0. *This ATX power supply specification has been updated to reflect the content in the PCIe 5.1 CEM specification.*

1. Two new Auxiliary Power Connectors were introduced to deliver up to 600 W through a single cable connector. The *12V-2x6** connector supports 600 W on the 12V rail while the *48VHPWR* connector provides 600 W on a 48V rail. Four sideband signal conductors on each connector permit simple, direct signaling between the Add-in Card and power supply to aid in power supply and card configuration.

2. A Power Excursion allowance was established to allow Add-in Cards to make brief, high-current demands on power while keeping average power within specified limits.

3. The maximum power consumption for a single PCIe Add-in Card was increased from 300 W to 675 W.

4. A 48V (nominal) power rail was added. The 48V rail is expected to be deployed chiefly in large data centers. No support for this 48V rail is proposed in this ATX power supply specification. PSU vendors are free to include 48V support, at their discretion.

*The 12V-2x6 connector described in PCIe CEM 5.1 replaces the 12VHPWR connector introduced in PCIe CEM 5.0, to address reliability concerns that were observed in the 12VHPWR connector. **New power supply designs should mount only the 12V-2x6 connector and the 12VHPWR connector should be deprecated.**

While many of the relevant PCIe specification updates are duplicated here for convenience, designers should confirm that they have the most up-to-date information by consulting the reference documentation on https://www.pcisig.com. The information below is drawn from the PCIe* documentation at the time of publication.

Historically, prior to the PCIe* CEM 5.0 specification, Add-in Card power consumption beyond 300 W was not allowed. Earlier generations of PCIe* Add-in Cards were limited to 300 watts or below, drawing up to 75 W from the card slot, and additional increments of 75 W and 150 W delivered through one or more 2x3 and 2x4 12V Auxiliary Power Cables, to reach the aggregated card maximum power of 300 W.

The 5.1 CEM specification allows cards to consume 675 W of continuous power. This power is the maximum that may be drawn from all power rails, combined. For example, an Add-in Card might draw 75 W through its card edge connector and 600 W through a 12V-2x6 cable plug, for a total of 675 W.

3.1 PCIe* Add-in Card Power Excursions

Prior to Revision 5.0, the PCI Express* CEM specification did not provide any allowance that would permit an Add-in Card to exceed the TDP power for its designated power range. This effectively confined the absolute power consumption of each Add-in Card to a hard limit such as 10 W, 75 W, 150 W, 225 W, or 300 W, even when it would be advantageous for the Add-in Card to make short-duration high-current demands on a power rail.

It is recognized that while many existing PCIe* CEM products frequently exceeded the card power limits, in violation of prior PCIe* CEM specs, their power supplies were never explicitly designed to withstand these excursions. Consequently, power excursions beyond these limits, however brief, could cause unexpected (and untraceable) card or system malfunctions, potentially triggering PSU overcurrent protection (OCP) or voltage droop. This risk increased when multiple PCIe* Add-in Cards were installed in a system.

The newest PCIe* CEM spec addresses the need for occasional power excursions by permitting the Add-in Card to briefly exceed the nominal limits on supply power while still abiding by the limits on a time-averaged basis. This allows the power supply and Add-in Card to jointly endure increased card power demands having a limited duration and magnitude.

The PCIe* CEM specification introduces the concept of *Sustained Power,* the average power delivered though a single power cable in a 1-second moving interval. This allows the card and power supply to operate within existing power and thermal envelopes, since the excursions' durations are very short and infrequent, and will not measurably increase the average temperature of any component.

These updates are described in the PCI Express* Card Electromechanical (CEM) Specification, Revision 5.1. This section of the ATX Power Supply Design Guide will draw on this PCIe* CEM Rev 5.1 content to provide design guidance for power supplies that meet the permitted power excursions of PCIe* Add-in Cards.

Power excursions are allowed in a PCIe* Add-in Card when it draws power through either a connected 12V-2x6 Auxiliary Power cable connector or a 48VHPWR Auxiliary Power cable connector. Similar power excursions are not permitted for the legacy 2x3 and 2x4 PCIe* Auxiliary Power connectors since that would introduce backward compatibility risks with legacy power supplies.

Power excursions are also permitted on the 12 V rail drawn from the baseboard through PCIe Add-in Card connector's card edge. *No excursions are permitted on the 3.3V and 3.3*V_{aux} *domains; these two power rails must continue to abide by the legacy Add-in Card power limits.*

The power supply must be able to provide voltages that remain within the requirements defined in Table 4-2 (Section 4.2) during the defined power excursions. Add-in Card power consumption excursion limits are defined by the ***maximum ratio***

(R) of average power consumption in any ***continuous time interval*** (T) relative to the maximum sustained (average) power of that Add-in Card.

The Add-in Card must concurrently adhere to the power excursion limits for all time interval lengths as defined in Table 3-1 and Figure 3-1 as well as the rolling time average of the sustained power of the card. Table 3-1 shows the power excursion limits for all time intervals in which "R" is calculated by dividing the average power consumption in a continuous time interval of length "T" but the maximum sustained power of that Add-in Card. The Add-in Card must also stay within all voltage tolerances and current as defined in Section 3.2 and Table 3-5.

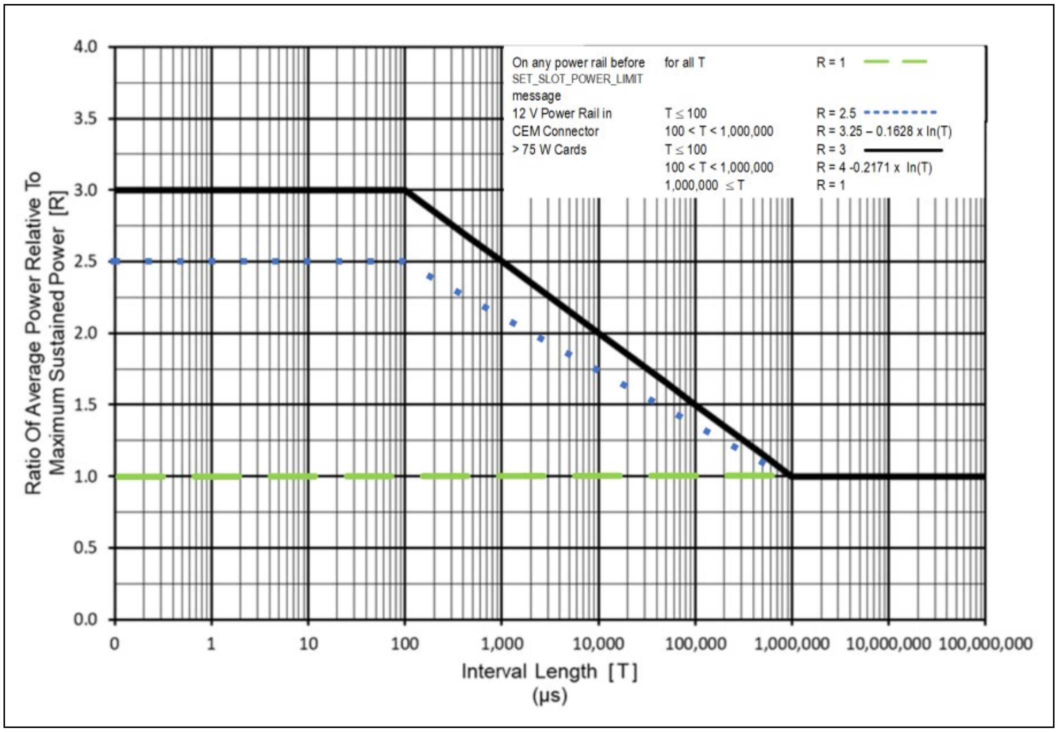
Table 3-1: PCI Express* CEM Add-in Card Power Excursion Limits Table

Average Power Calculation Interval Length in micro-seconds(μs) "T"	Ratio of Average Power in Interval "T" Divided by Maximum Sustained Power "R" Max			Notes
	On Any Power Rail Before "Set_Slot_Power_Limit" Message	+12V Power Rail in CEM Connector for all Add-in Cards	Total Card Power for > 75 W Cards	
≤ 100 μs	1	2.5	3	1,2,4
>100 and <1,000,000 μs (1 sec)	1	3.25–0.1628 x ln(T)	4 – 0.2171 x ln(T)	1,3,4
≥1,000,000 μs (1 sec)	1			1,4

NOTES:

1. $R = \frac{\text{average power during internal T}}{\text{Max Sustained Power (ie.TDP)}}$.
2. This is also the max ratio of instantaneous power relative to maximum sustained power.
3. ln() is the natural logarithm function.
4. The Add-in Card must always and concurrently adhere to power excursion limits for all time interval lengths as well as the limits defined for Power Supply Rail Requirements in Table 3-5.

Figure 3-1: PCI Express* CEM Add-in Card Power Excursion Limits Chart



3.1.1 PCIe* Add-in Card and PSU Power Budgets

Three dominant power demands dictate the total system power provisioning:

1. CPU power consumption
2. PCIe Add-in Card power level
3. Rest-of-Platform power demand

Rest-of-Platform (ROP) collectively includes anything in a system (memory, storage, motherboard, peripherals, etc.) not including the PCIe Add-in Cards or CPU. Table 3-2 provides examples that generally balance these three power demands to obtain an overall PSU power rating. The PCIe power entries in the table are standard power levels for PCIe Add-in Cards defined in the PCIe CEM 5.1 Specification. As a consequence of the introduction of 450 W and 600 W Card power levels, the wide range of possible PCIe card power demands plays a dominant role in setting total platform power supply ratings.

These configurations will also serve as test cases for evaluating power supply excursions. The peak power demands of the PCIe Add-in Cards at each power level can guide the peak power demands of the PSU.

In cases where a PCIe Add-in Card has a sustained power not listed, use these values as a minimum value for all cards up to these power levels. The table below should be considered as a minimum power level based on Rest of Platform (ROP) power. The

ROP assumptions are shown in Table 3-2 below. If a system designer plans more ROP power, the overall platform power budget for a system must be increased. If a system designer plans less ROP power, then the PSU size can also decrease. In the case of ROP values lower than what is shown in Table 3-2, the calculations should be done for Peak Power Requirement for this specific system. If the Peak Power requirements for this specific system exceed the values shown in Table 3-3 then a PSU with support for higher peak power levels would be needed.

The CPU continuous power comes from Table 2-1, taking the current value and multiplying by 11.2 Volts to create a power value and round up slightly. The CPUs used in these examples are the 65W TDP for the first row and 125W TDP for all other rows.

Note: This is a recommendation for a Power Budget and guidance that is needed to define PSU Peak Power Excursion levels. These power budgets also assume only one PCIe Add-in Card will use these power excursions. If more than one PCIe Add-in Card is installed in the system, then the system designer needs to verify the power supply can provide enough power for all components in the system including the Peak Power Excursions of all components. This industry standard PSU Design Guide does not provide a standard definition for that type of system design.

Table 3-2: PCIe* AIC and PSU Power Budget used for Peak Power Excursion Test Cases

PCIe* AIC Power (W)	CPU Continuous Power (W)	Rest of Platform (W)	PSU Rated PSU Size (W)
75	275	100	450
150	300	100	550
225	300	125	650
300	300	150	750
450	300	250	1000
600	300	300	1200

- Rest of Platform power here will not apply to all systems.
  - If Rest of Platform power is higher than what is in the table, increase the PSU size respectively.
  - If Rest of Platform power is lower than what is listed in the table the PSU size can also be reduced, but Peak Power requirements might then go beyond what is listed in Table 3-3. The table above represents a balance between ROP and Peak Power Excursions.
- CPU Power and Rest of Platform Power can vary from this table which would result in custom Peak Power requirements.

3.1.2 PSU Power Excursion

Based on the power budgets in Table 3-2 and peak power of both the Processor detailed in Table 2-1 and the PCIe* Add-in Cards in Section 3.1, the following Peak Power Requirements are defined for the Power Supply. The peak time for each power level is defined in Table 3-3. The largest power excursion coming from PCIe Add-in cards comes from the 12V-2x6 connector, therefore the table is split into two different power levels where it is expected that power supplies greater than 450 watts will have at least one 12V-2x6 connector. If a power supply doesn't have the 12V-2x6 connector the peak power requirements will be less and can meet the first column.

Table 3-3: PCIe* AIC and PSU Power Budget used for Peak Power Excursion

Power Excursion % of PSU Rated Size **PSU ≤ 450 watts & PSUs without 12V-2x6 Connector**	**Power Excursion % of PSU Rated Size** **PSU > 450 watts & 12V-2x6 Connector present**	**Time for Power Excursion (TE)**	**Testing Duty Cycle**
150%	200%	100 µs	5%
145%	180%	1 ms	8%
135%	160%	10 ms	12.5%
110%	120%	100 ms	25%
100%	100%	Infinite	--

NOTE: Peak Power defined in this table correspond to Platform Level Power Budgets described in Table 3-2 if CPU or Rest of Platform power is reduced from Table 3-2 to reduce PSU size, then custom Power Excursion % of PSU rated size must also be calculated.

The Testing Duty Cycle is not defined in the PCIe* CEM Gen 5.1, but it must be defined to create a test criterion specific to a power supply. The Testing Duty Cycle defines the percentage of time the Power Excursion value peaks with the remainder of the time defined as a Time Constant (T_C). The Power Level defined is to have the RMS value during this Dynamic Load test to be the Rated Wattage of the Power Supply. Table 3-4 shows an example of how the testing criteria for power excursions of 1000 Watt Power Supply using an RMS value to average the rated power of a power supply. This calculation is the same as what is described in the PCIe* CEM Gen 5.1. For all power supplies with a rated wattage different than 1000 watts a similar RMS calculation needs to be performed.

Figure 3-2: Duty Cycle Definition

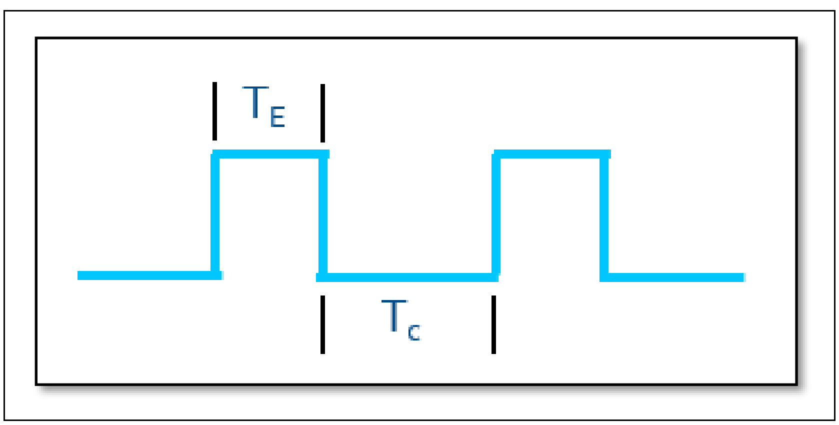


Table 3-4: Duty Cycle Example Test Criteria for a 1000W PSU – RMS

Duty Cycle	Time Constant (T_C)	Time for Power Excursion (T_E)	Power @ T_C	Power @ T_E
5%	1900 µs	100 µs	917.7 W	2000 W
8%	11.5 ms	1 ms	897.3 W	1800 W
12.5%	70 ms	10 ms	881.6 W	1600 W
25%	300 ms	100 ms	923.8 W	1200 W

NOTES:

1. The Capacitive Load mentioned in Table 4-7 is expected to be applied to this test scenario.
2. Total Test time for each Power Excursion testing time is expected to last until thermal saturation occurs in the PSU.
3. More details about test time for each row above and formulas to calculate T_C and T_E power values for different PSU sizes will be detailed in the "Desktop Platform Form Factor Power Supply Test Plan – Doc #338448

3.2 PCIe* AIC Auxiliary Power Connectors

The PCIe CEM 5.1 specification defines three 12V Auxiliary Power Connectors to be used with PCIe Add-in Cards that apply to desktop power supplies:

- 75 W 2x3 connector
- 150 W 2x4 connector
- 600 W 12V-2x6 connector

Section 5.2 specifies the Mechanical information for all DC Power Connectors. Note that the Voltage Tolerance listed below is different from this Power Supply Design Guide for the Low voltage tolerance Table 4-2, the reason for the difference is allowing for voltage drop on a motherboard from the Main Power Connector to the motherboard to the PCIe* Edge Card Connector. Table 3-5 shows the voltage tolerance required to the PCIe* Add-in Card at both the motherboard edge card connector and Auxiliary Power connectors. Each Auxiliary Power Connector must have voltage pins that belong to the same +12V power converter, if multiple voltage rails exist from the PSU.

Table 3-5: Auxiliary Power Connectors Power Supply Rail Requirements - +12V Only

+12V Power Rail Characteristic	2x3 Connector	2x4 Connector	12V-2x6 Connector			
Sustained Power[2, 4]	75 Watts	150 Watts	150 W[5]	300 W[5]	450 W[5]	600 W[5]
+ 12 V Voltage Range	+5% / -8%	+5% / -8%	+5% / -8%			
Current[3, 4, 5] (Max RMS)	6.75 Amps	13.5 Amps	13.75 A[1,5]	27.5 A[1,5]	41.25 A[1,5]	55 A[1,5]

NOTES:

1. The maximum current slew rate for the 12V-2x6 connector interface shall be no more than 5.0 A/µs.
2. Maximum sustained power (Maximum of average power in any continuous 1 second interval).
3. Maximum of root-mean-square (RMS) of current in any continuous 1 second interval.
4. The main reference limit is the maximum allowed sustained power per connector and Add-in Card type. Add-in Card and System must concurrently comply with all power and voltage and current requirements in this table for the applicable connector and other requirements in this specification for the Add-in Card type.
5. Maximum instantaneous and other excursions exceeding these limits are defined in Section 3.1 of this document.

3.3 PCIe* Add-in Card 12V-2x6 Auxiliary Power Connector Sideband Signals

The new 12V-2x6 connector carries four sideband signals that communicate between the Power Supply and the PCIe* Card. The sideband signals are:

- SENSE0 (Required)
- SENSE1 (Required)
- CARD_PWR_STABLE (Optional)
- CARD_CBL_PRES# (Required/Optional)

For the most current and detailed description of the electrical requirements of the sideband signals, refer to section 5.3 – Optional Sideband Signal in the **PCI Express* Card Electromechanical Specification, Revision 5.1** (often shortened to "PCIe CEM 5.1 Spec"). That document is available from www.pcisig.com. Physical specifications for the 12V-2x6 Cable Plug and mating PCB Header are provided in section 5.2.2.4.2 of this document, and are also detailed the **PCIe CEM 5.1 Spec.**

When multiple 12V-2x6 Auxiliary Power Connectors are present in system, their sideband conductors and the signals they carry are independent among separate connected and unconnected PCIe cards and cables.

3.3.1 SENSE0 & SENSE1 (Required)

Support for the SENSE0 & SENSE1 sideband signals is required for both power supplies and Add-in Cards mounting the 12V-2x6 connector. SENSE0 & SENSE1 communicate important 12V power level information from the PSU to the Add-in Card, and must be configured by the power supply. These sideband signals set the maximum power available to the Add-in Card the though the cable during both initial power up and during normal system operation.

Four power levels, 600, 450, 300, and 150 watts, are configured by the SENSE0 and SENSE1 signals to allow power supplies having different power capacities (and Add-in Cards with a range of power demands) to deliver 12V power using a common connector interface. The SENSE0/SENSE1 encodings that define the power levels are detailed in Table 3-6.

The PCIe CEM 5.1 specification designates these levels as "Connector Initial Permitted Power" and "Connector Maximum Permitted Power" to indicate the power limits supported by the power supply through the 12V-2x6 Auxiliary Power Connector. The maximum power levels indicated are the maximum sustained power supported by this Auxiliary Power Connector alone, and do not include power drawn separately through the motherboard card edge connector, separate power cable plugs, or any other source.

A power supply supporting the 12V-2x6 auxiliary power connector must short the appropriate SENSE signals to ground or leave them floating at a high impedance (Open) to indicate the *600 watt*, *450 watt*, and *300 watt* sustained power limits of the power supply. For a *non-modular* power supply with a hard-wired 12V-2x6 cable plug assembly, the SENSE0 and SENSE1 pins may be configured with a jumper wire to ground, at the cable plug end, within the body of the plug itself, or internal to the power supply.

Support for the *150 watt* sustained power level is configured by providing a short between the SENSE0 & SENSE1 signals, presenting a 0 ohm resistance *between* the SENSE0 and SENSE1 pins at the cable plug. For a *non-modular* power supply with a hard-wired 12V-2x6 cable plug assembly, the SENSE0 and SENSE1 pins may be united with a jumper wire at the cable plug end, within the body of the plug itself, or internal to the power supply.

For the 150 watt configuration, the SENSE0 & SENSE1 pins must be shorted to each other but must remain floating (high impedance) with respect to ground. If these pins were also (mistakenly) shorted to ground, the card would misread the available power as 600 watts instead of 150 watts.

A *modular* power supply supporting detachable 12V-2x6 cables, must configure the SENSE0 and SENSE1 pins only within the power supply, for all power levels, to ensure correct operation when interchangeable "double-ended" 12V-2x6 cable assemblies are used.

These SENSE signals must not change state while PCI Express CEM Add-in Card edge has the main +3.3V applied. Support for the SENSE0/SENSE1 sideband signals is independent of the two optional sideband signals defined for the 12V-2x6 connector (CARD_PWR_STABLE & CARD_CBL_PRES#).

Table 3-6: PCI Express* 12V-2x6 Connector Power Limits

SENSE0	SENSE1	Initial Permitted Power at System Power Up	Maximum Sustained Power after Software Configuration[3]
Ground	Ground	375 W	600 W
Open	Ground	225 W	450 W
Ground	Open	150 W	300 W
Short[2]		100 W	150 W

SENSE0	SENSE1	Initial Permitted Power at System Power Up	Maximum Sustained Power after Software Configuration[3]
Open	Open	0 W[1]	0 W[1]

NOTES:

1. For an Add-in Card to draw any power through the 12V-2x6 Connector, it must monitor SENSE0 and SENSE1.
2. 150 W is indicated by SENSE0 and SENSE1 being connected by a resistance of 0 Ω.
3. An Add-in Card may draw up to the maximum permitted power defined in this table in addition to other power sources.

3.3.2 CARD_PWR_STABLE (Optional)

This optional sideband signal functions as a “Power Good” indicator from the Add-in Card to the PSU. When this signal is asserted, the Add-in Card confirms that local power rails on the Add-in Card lie within their operating voltage limits. This signal can provide a fault detection alert from the Add-in Cards to the PSU, which can provide the PSU an opportunity for protective measures.

If CARD_PWR_STABLE signal is supported by an Add-in Card, the signal it will be implemented in an open collector / open-drain configuration.

When implemented in the power supply, the signal must be tied to a 4.7 kΩ pull-up resistor to +3.3V. The PSU must monitor the state of the CARD_PWR_STABLE with a high impedance 3.3V logic compatible device input.

The Add-in Card will set this signal to Open (high impedance) whenever its local power rails that are critical to correct operation are within their operating limits. When the Add-in Card directly drives this signal low (0 / Ground), any of its local power rails are outside of their operating limits results in a fault for the Add-in Card. The Add-in Card must drive this signal low for at least 100 ms or as long as the input power stays outside of the voltage specification detailed in Table 3-5: Auxiliary Power Connectors Power Supply Rail Requirements - +12V Only in Section 3.2 of this document. When the voltage returns to within correct operating ranges and the fault is done, the signal will change to open (high impedance). If or when a fault is corrected the Add-in Card again sets this signal to open (high impedance).

Support for this optional sideband signal does not rely on any of the other sideband signals defined for the 12V-2x6 connector and can be implemented independently of other of these sideband signals.

3.3.3 CARD_CBL_PRES# (Optional in Power Supply)

This sideband signal has two functions:

- Primary Function:
  - In its primary role, this sideband conductor provides a constant DC logic signal from the Add-in Card to the power supply to indicate that the 12V-2x6 Auxiliary Power Connector is correctly attached to an Add-in Card.

  - While the power supply is not required to support this signal, every PCIe* CEM Add-in Card mounting the 12V-2x6 PCB Header connector must support this primary function of CARD_CBL_PRES# by properly terminating it at the card level. This guarantees that any power supply that monitors CARD_CBL_PRES# can detect the presence or absence of every connected PCIe card.
    - For modular power supplies, with "double-ended" 12V-2x6 cable assemblies, for example, this also confirms whether the 12V-2x6 cable plug connector is attached and fully seated in its mating 12V-2x6 PCB header connector in the power supply.
    - Consequently, any unused or incompletely seated 12V-2x6 connector in series between the PSU and the Add-in Card will de-assert CARD_CBL_PRES# and appear as unused or incompletely inserted.
- Secondary Function:
  - This sideband signal can optionally provide additional communication between the Add-in Card, and PSU, and the host system to identify connectivity between any combination of 12V-2x6 and installed Add-in Card by means of the PCIe "Power Budgeting Sense Detect Register". This allows the system to correlate which system and power cables are used with a specific PCIe* card slot. This function requires system-level integration with the motherboard that may lie beyond the scope of a standard ATX power supply. Card-level support for this secondary function is optional.

Note that CARD_CBL_PRES# is implemented only for system power supply management support. This signal cannot be used by the Add-in Card to determine the available power level, for example. Power limits are communicated separately from the power supply to the Add-in Card by the SENSE0 & SENSE1 signals. The CARD_CBL_PRES# conductor must traverse the length of the cable between the Add-in Card and the PSU. Support for this optional sideband signal does not directly rely on the other sideband signals defined for the 12V-2x6 connector and its can be implemented independently of other of these sideband signals.

CARD_CBL_PRES# Primary function
(Optional on PSU, Required on Add-in Card)

Every Add-in Card mounting the 12V-2x6 PCB Header connector must terminate the CARD_CBL_PRES# conductor by tying its connector pin to ground through a 4.7 kΩ pull-down resistor. Since all Add-in Cards are required to implement this card presence logic, the CARD_CBL_PRES# signal will always be available to any PSU that implements the optional circuitry to monitor the state of the CARD_CBL_PRES# conductor.

Any power supply that (optionally) monitors CARD_CBL_PRES# must implement a high-impedance 3.3V logic compatible device input. The 4.7 kΩ on the Add-in Card serves as a strong pull-down, tying the CARD_CBL_PRES# to ground at the Add-in Card end of the cable. The pull-down should be implemented to present the active-low to the cable CARD_CBL_PRES# conductor even when no power is applied. For a power supply to detect the active low presence condition of the CARD_CBL_PRES# signal, a 100 kΩ (weak) pull-up resistor to 3.3 V is required within the PSU.

This allows the power supply to poll individual CARD_CBL_PRES# signals from separate 12V-2x6 cables to determine the presence (low impedance to ground) or absence (floating) of connected PCIe cards even before main power is applied to the 12V bus, and at any time thereafter. Any floating CARD_CBL_PRES# conductors will be pulled high to 3.3V by the detection circuitry in the PSU and recorded as unconnected cables, while conductors pulled low by the PCIe card termination will be detected as connected PCIe Add-in Cards. Knowledge of the quantity of connected devices can be used for PSU-level or system-wide power management, to selectively allocate power among multiple 12V-2x6 connectors using for example, by means of the SENSE0 and SENSE1 pins, before applying 12V power.

If this feature is used and the SENSE0 & SENSE1 signals are dynamically changed they must be changed only when the power supply is in Standby Mode (PS_ON# is de-asserted and Main Power rails are not on). Once PS_ON# becomes active and the main power rails achieve their full voltages, the SENSE0 & SENSE1 sideband signals must not change state.

Example: A power supply that has sufficient rated power, after satisfying other system power requirements, to deliver 600 watts to a single PCIe* Add-in Card could be configured, by means of SENSE0 and SENSE1, to support multiple topologies, following CARD_CBL_PRES# detection.

A. One PCIe* Add-in Card is detected, and that single card may draw 600 watts.

B. Two PCIe* Add-in Cards are detected, and each card may draw 300 watts.

C. Three or Four PCIe* Add-in Cards are detected, and each card may draw 150 watts.

D. Five PCIe* cards are detected.

   - Four cards may draw 150 watts.
   - One card may draw 0 watt, since insufficient power is available after allocating to the other four cards at the lowest (150 watt) power level

     Note that 0W is a valid configuration for a connected card. 0W is encoded with the "Open-Open" SENSE0-SENSE1 setting.

These combinations are provided as an example. It is important to recognize that power budgeting is often inexact, and many Add-in Cards will not consume 100% of the power allocated by SENSE0 and SENSE1 (150, 300, 450, or 600 watts).

In the example Case D, above, if the PSU designer or system integrator has specific knowledge that the power consumption of some (or all) of the Add-in Cards falls well below the full 150 watts, the SENSE0 and SENSE1 encoding may be configured to enable all five cards at 150 watts, instead of disabling one card at the 0W level to explicitly confine the total allocated power to 600 watts.

CARD_CBL_PRES# Secondary function (Optional)

The enumeration of connected PCIe Add-in Cards using CARD_CBL_PRES, as described above, identifies whether 12V2x6 cables are connected or unused. While this provides the *quantity* of connected cards, it does not convey any additional insight into the Add-in Card's actual power consumption, function, or location (e.g., PCIe Slot 2).

The secondary function of the CARD_CBL_PRES# enables the system to map the connectivity of individual 12V-2x6 cables to specific PCIe Add-in Cards. Support for this secondary function requires deliberate chassis-level integration and communication with Add-in Cards through the system board. While support for this secondary function is currently beyond the scope of mainstream ATX power supply designs, it is not discouraged, and is included for completeness.

To support this secondary function, the power supply must selectively apply 3.3 V directly to the CARD_CBL_PRES# conductor for those cables whose connectivity is confirmed. The PSU is allowed to drive this signal high with a push-pull driver to 3.3V. This voltage defeats the 4.7 kΩ pull-down in the Add-in Card, driving CARD_CBL_PRES# to a logic high, which Add-in Cards may detect with optional circuitry.

When supporting the secondary function, the Add-in Card reads this signal on a high impedance 3.3V logic compatible input and records the logic high/low state in the "Power Budgeting Sense Detect" registers.

The intended use of this signal is to successively assert the CARD_CBL_PRES# conductor in individual 12V-2x6 cable connectors and then to read the Power Budgeting Sense Detect registers of the Add-in Cards (using custom hardware and software) to map the connectivity of the specific power cables to specific Add-in Card components. The function and location of the Add-in Cards must be identified separately, at the system level, to complete this mapping. The additional 12V-2x6 cable connectivity knowledge obtained can enable more nuanced chassis-level power management. Adoption of this capability will likely be confined to high-end server systems designed by system integrators or cloud service providers, for example.

3.3.4 Sideband Signals DC Specifications (Required)

The four sideband signals defined for the 12V-2x6 connector DC Specifications are shown in Table 3-7. This is the requirement defined by the PCIe* CEM 5.1 Specification for the Add-in Cards.

Table 3-7: PCI Express* 12V-2x6 Connector – Sideband Signal DC Specifications

Symbol	Parameter	Conditions	Min	Max
V_{HMAX}	Max High Voltage any Pin			3.3 V +0.5 V
V_{IL}	Input Low Voltage		-0.2 V	+0.8 V
V_{IH}	Input High Voltage		+2.0 V	3.3 V +0.2 V
V_{OL}	Output Low Voltage	7.0 mA	-0.2 V	+0.5 V
V_{OH}	Output High Voltage (refer note)	4.0 mA	+2.4 V	3.3 V + 0.2 V
$R_{PULL-UP}$	Pull-up / Pull-down Resistance tolerance		-10%	+10%

NOTE: For Open-Collector/Open Drain Signal CARD_PWR_STABLE output a pull-up is required. There is no VOH specification for this signal.

§§

4 Electrical

The following electrical requirements are required and must be met over the environmental ranges as defined in Chapter 7 (unless otherwise noted).

4.1 AC Input - REQUIRED

Table 4-1 lists AC input voltage and frequency requirements for continuous operation. The power supply shall be capable of supplying full-rated output power over two input voltage ranges rated 90-135 VAC and 180-265 VAC rms nominal. The correct input range for use in each environment may be either switch-selectable or auto-ranging. The power supply shall automatically recover from AC power loss. The power supply must be able to start up under full loading at 90 VAC.

Note: OPTIONAL - 115 VAC or 230 VAC only power supplies are an option for specific geographical or other requirements.

Table 4-1: AC Input Line Requirements

Parameter	Minimum	Nominal[1]	Maximum	Unit
Vin (115 VAC)	90	115	135	VAC_{rms}
Vin (230VAC)	180	230	265	VAC_{rms}
Vin Frequency	47	-	63	Hz

NOTE: Nominal voltages for test purposes are considered to be within ±1.0 V of nominal.

4.1.1 Input Over Current Protection – REQUIRED

The power supply is required to incorporate primary fusing for input over current protection to prevent damage to the power supply and meet product safety requirements. Fuses should be slow-blow-type or equivalent to prevent nuisance trips.

4.1.2 Inrush Current – REQUIRED

Maximum inrush current from power-on (with power-on at any point on the AC sine) and including, but not limited to, three-line cycles, shall be limited to a level below the surge rating of the AC switch if present, bridge rectifier, and fuse components. Repetitive ON/OFF cycling of the AC input voltage should not damage the power supply or cause the input fuse to blow.

4.1.3 Input Under Voltage – REQUIRED

The power supply is required to contain protection circuitry such that the application of an input voltage below the minimum specified in Table 4-1, shall not cause damage to the power supply.

4.2 DC Output – REQUIRED

Desktop Power Supplies provide multiple DC Voltage outputs. This section describes the characteristics of each of these DC voltage power rails.

4.2.1 DC Voltage Regulation – REQUIRED

The DC output voltages are required to remain within the regulation ranges shown in Table 4-2, when measured at the load end of the output connectors under all line, load, and environmental conditions specified in Chapter 7.

The lower voltage range for 12V is allowed to be -7% to allow for the power excursion requirements now described in Section 3.1. To compensate for these power excursions the nominal voltage could be changed to 12.1 or 12.2 Volts, depending on Power Supply design.

Table 4-2: DC Output Voltage Regulation

Output	Range	Min	Nom	Max	Unit
+12V1DC[2]	+5% / -7%	+11.20	+12.00	+12.60	V
+12V2DC[2]	+5% / -7%	+11.20	+12.00	+12.60	V
+5VDC	±5%	+4.75	+5.00	+5.25	V
+3.3VDC	±5%	+3.14	+3.30	+3.47	V
-12VDC[3]	±10%	-10.80	-12.00	-13.20	V
+5VSB	±5%	+4.75	+5.00	+5.25	V

NOTES:

1. Voltage tolerance is required at all connectors
2. +12V1DC and +12V2DC requirement applies to all +12V power rails
3. -12VDC output is optional

4.2.2 DC Output Current – REQUIRED

The below table summarizes the expected output transient step sizes for each output. All items in the below table are REQUIRED, unless specifically called out as RECOMMENDED.

Table 4-3: DC Output Transient Step Sizes

Output	Maximum Step Size (% of rated output amps)	Maximum Step Size (A)
+12V1DC [5]	40% (Required) 70% (Recommended)	-
+12V2DC [5]	85% of CPU supported in Table 2-1[2]	-
+12V3/4 [5]	Steps from 100% → 300%[4] 30% → 100% [3]	

Output	Maximum Step Size (% of rated output amps)	Maximum Step Size (A)
+5VDC	30%	-
+3.3VDC	30%	-
-12VDC	-	0.1[6]
+5VSB	-	0.5

NOTES:

1. Example of how to use this table, for a rated +5 VDC output of 14A, the transient step would be 30% x 14 A = 4.2 A. Testing for a 4.2 A step size would result in testing starting at 9.8A going up to 14A.
2. 12V2 rails are typically used for CPU power. CPU step size will have more updated values in the Power Supply Design Guide Addendum (# 621485) which will be used to determine the 85% value
3. 12V3/V4 rails are typically used for PCIe* Add-in Card connectors. This recommendation is based on Chapter 3 where PCIe* Add-in Card needs are discussed. The step size will come from the amount of PCIe* Add-in Card power supported based on the size of the PSU in Table 3-2.For more detail reference the *Desktop Platform Form Factor Power Supply Test Plan* (Doc #338448)
4. If a power supply has multiple 12V-2x6 connectors, Dynamic testing shall be done on each 12V-2x6 connector. For more detail reference the *Desktop Platform Form Factor Power Supply Test Plan* (Doc #338448)
5. Power supplies that have one combined 12V rail shall perform Dynamic testing on the one 12V rail with multiple tests which simulate different system level workloads: 12V1 (total system), 12V2 (CPU Load), and 12V3/V4 (PCIe AIC).
6. "-12VDC" Voltage rail Dynamic Step Size levels are RECOMMENDED.

Output voltages should remain within the regulation limits of Table 4-2, for instantaneous changes in load as specified in Table 4-3 and for the following conditions:

- Simultaneous load steps on the +12 VDC, +5 VDC, and +3.3 VDC outputs (all steps occurring in the same direction)
- Load-changing repetition rate of 50 Hz to 10 kHz
- AC input range per Section 2.1 and Capacitive loading per Table 4-7

The transient load slew rate is defined in Table 4-4 based on whether the PSU supports the PCIe* 12V-2x6 Connectors. This usually can be correlated to the PSU's Rated Wattage, which is listed as a guidance.

Table 4-4: DC Output Transient Slew Rate

Output	PSU without PCIe* 12V-2x6 Connectors (Recommended Size ≤450 watts)	PSU with PCIe* 12V-2x6 Connector (Recommended Size >450 watts)
All +12V	2.5 A/µs	5.0 A/µs
+5V	1.0 A/µs	1.0 A/µs

Output	PSU without PCIe* 12V-2x6 Connectors (Recommended Size ≤450 watts)	PSU with PCIe* 12V-2x6 Connector (Recommended Size >450 watts)
+3.3V	1.0 A/µs	1.0 A/µs
+5VSB	0.1 A/µs	0.1 A/µs
-12V	0.1 A/µs	0.1 A/µs

4.2.3 Remote Sensing - RECOMMENDED

Remote sensing is recommended. Remote sensing can accurately control motherboard loads by adding it to the PSU connector. The +3.3 VDC output should have provisions for remote sensing to compensate for excessive cable drops. In low power PSU, remote sensing is recommended. The default sense should be connected to pin 13 of the main power connector. Refer Figure 5-2. The power supply should draw no more than 10 mA through the remote sense line to keep DC offset voltages to a minimum.

4.2.4 Other Low Power System Requirements

To help meet multiple world-wide Energy Regulations the +5VSB standby rail must meet the following efficiency as shown in Table 4-5 which is measured with the main outputs off (PS_ON# high state). These World-Wide Energy Regulations and standards include: Blue Angel* system requirements, RAL-UZ 78, US Presidential executive order 13221, ENERGY STAR*, ErP Lot 6 requirements (2010 and 2013 levels), and 2014 ErP Lot 3 requirements. Additionally, if any Computers use an Alternative Low Power Mode (ALPM) then the +5VSB standby efficiency has similar requirements as shown below.

Table 4-5: Recommended Standby Rail DC and AC Power Efficiency

5VSB Load Target	5VSB Actual Load	Efficiency Target (both 115V and 230V input)	Remark
Max / Label	3.0A / Label	75%	Recommend
1.5 A		75%	REQUIRED ALPM and ErP Lot 3 2014
1.00 A		75%	Recommend
0.55 A		75%	REQUIRED ALPM and ErP* Lot 3 2014
90 mA		55%	Recommend
45 mA		45%	REQUIRED ErP* Lot 6 2013

4.2.5 Output Ripple Noise - REQUIRED

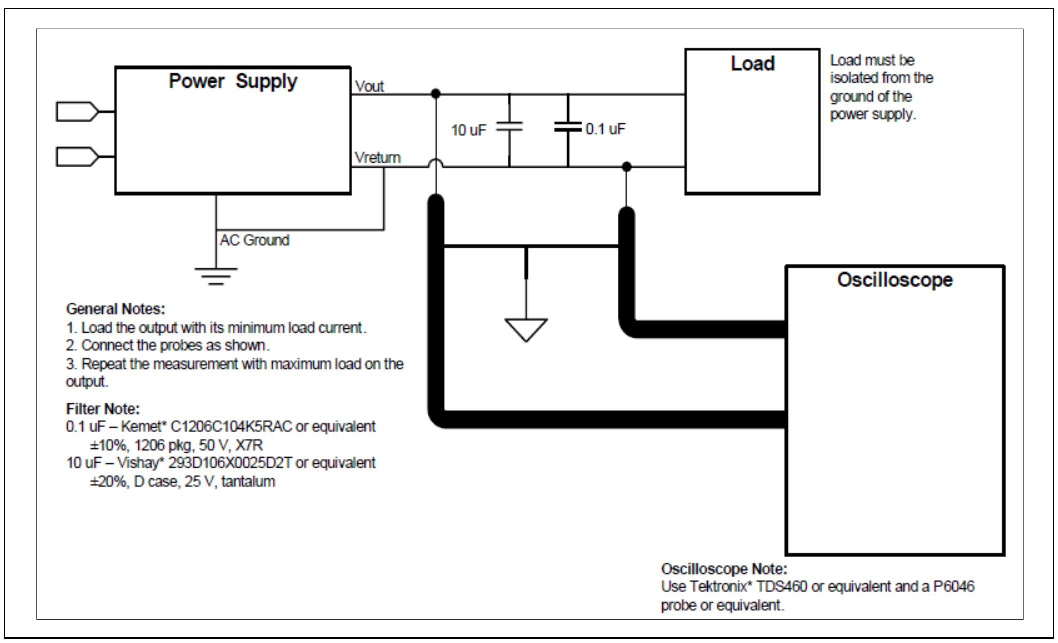
The output ripple and noise requirements listed in Table 4-6 shall be met throughout the load ranges specified for the appropriate form factor and under all input voltage conditions as specified in Table 4-1.

Ripple and noise are defined as periodic or random signals over a frequency band of 10 Hz to 20 MHz. Measurements shall be made with an oscilloscope with 20 MHz of bandwidth. Outputs should be bypassed at the connector with a 0.1µF ceramic disk capacitor and a 10 µF electrolytic capacitor to simulate system loading. Refer to Figure 4-1 for the differential noise measurement setup.

Table 4-6: DC Output Noise/Ripple

Output	Maximum Ripple and Noise (mV p-p)
+12V1DC	120
+12V2DC	120
+5VDC	50
+3.3VDC	50
-12VDC	120
+5VSB	50

Figure 4-1: Differential Noise Test Setup



4.2.6 Capacitive Load – RECOMMENDED

The power supply should be able to power up and operate within the regulation limits defined in Table 4-2, with the following capacitances simultaneously present on the

DC outputs. These Capacitive Loads are to simulate what a motherboard / system provides when connected to a power supply.

Table 4-7: Output Capacitive Loads

Output	Capacitive Load (μF)
+12V1DC	3,300
+12V2DC	3,300
+5VDC	3,300
+3.3VDC	3,300
-12VDC	330
+5VSB	3,300

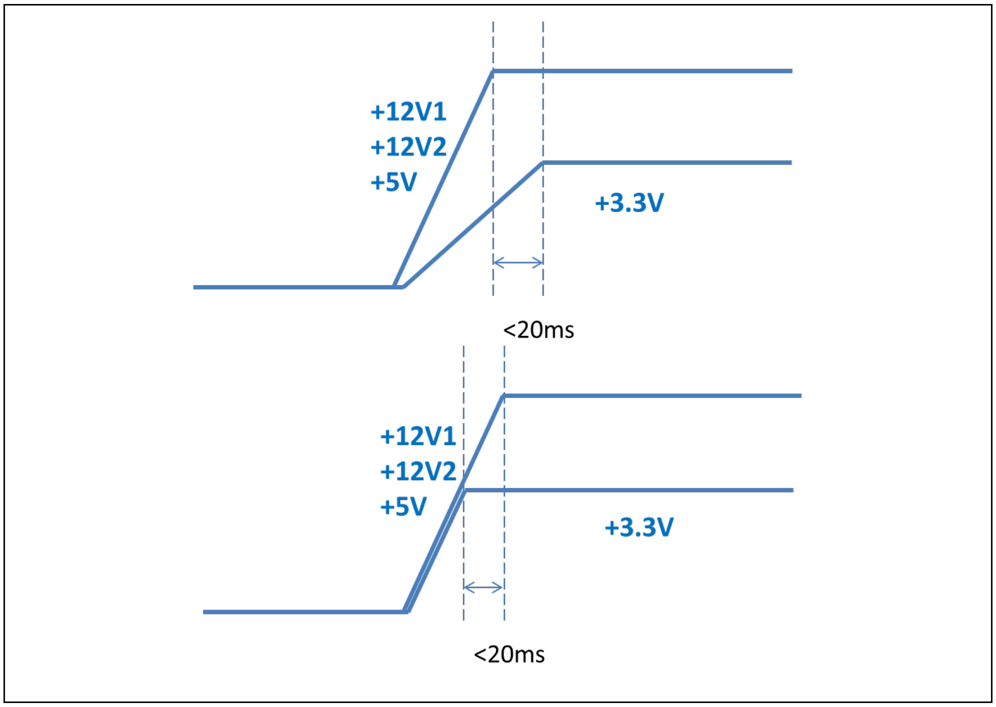
4.2.7 Closed Loop Stability - REQUIRED

The power supply shall be unconditionally stable under all line/load/transient load conditions including capacitive loads specified in Section 4.2.6. A minimum of 45 degrees phase margin and 10 dB gain margin is recommended at both the maximum and minimum loads.

4.2.8 +5V DC / +3.3V DC Power Sequencing - REQUIRED

The +12V1 DC / +12V2 DC and +5 VDC output levels must be equal to or greater than the +3.3 VDC output at all times during power-up and normal operation. The time between any output of +12V1 DC / +12V2 DC and +5 VDC reaching its minimum in-regulation level and +3.3 VDC reaching its minimum in-regulation level must be ≤ 20 ms as shown in Figure 4-2.

Figure 4-2: Power Supply Timing



4.2.9 Voltage Hold-Up Time – REQUIRED/RECOMMENDED

The power supply shall maintain output regulations per Table 4-2 despite a loss of input power at the low-end nominal range-115 VAC / 47 Hz or 230 VAC / 47 Hz according to Table 4-8.

Table 4-8: Voltage Hold-Up Time

Criteria	REQUIRED	RECOMMENDED
Output Loading	100% of Full Load	80% of Full Load
Time (T5 + T6)	12 ms	17 ms

4.2.10 12V2 DC Minimum Loading - REQUIRED

The power supply +12 V2DC shall maintain output regulations per Table 4-2 and meet minimum current values below.

Table 4-9: 12V2 DC Minimum Current

Output	Minimum current (A)
+12V2 DC	0A (Required)

Output	Minimum current (A)
+12V1 DC	0A (recommended)

4.3 Timing, Housekeeping and Control – REQUIRED

Figure 4-3: Power on Timing

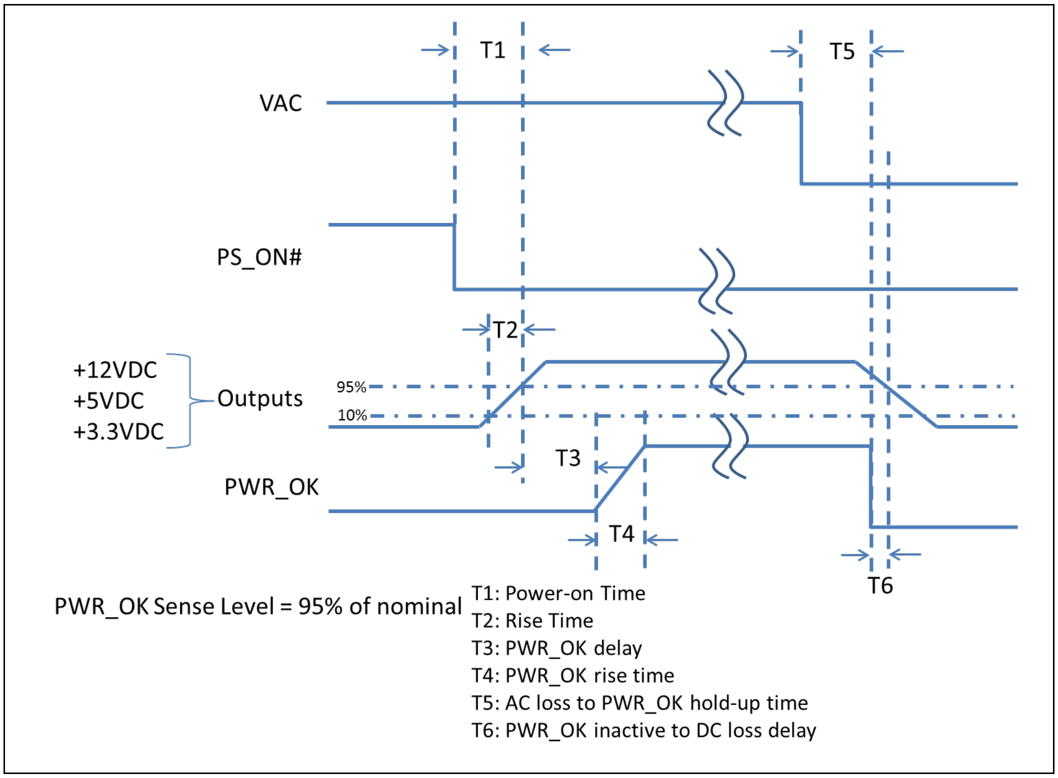


Table 4-10: Power Supply Timing

Parameter	Description	Value		
		Legacy Timings[1]	Required	Recommended
T0	AC power on time	-	<2s	-
T1	Power-on time[7]	< 500 ms	< 200 ms	<150 ms[8]
T2	Rise time	-	0.2 – 20 ms	-
T3	PWR_OK delay[7]	100 ms[2] – 500 ms	100 ms[2] – 250 ms	100 ms[2] – 150 ms[8]
T4	PWR_OK rise time	-	< 10 ms	-
T5	AC loss to PWR_OK hold-up time	-	> 11 ms[3]	> 16 ms[4]
T6	PWR_OK inactive to DC loss delay	-	> 1 ms[5]	> 1 ms[6]

1. Value in the Legacy column list timings for power supplies designed before the year 2020. In 2020, the T1 and T3 timings have moved from the Legacy timing to the new Required column for all new power supply designs.
2. T3 minimum time faster than 100 ms is not recommended for previous generation motherboards and systems. All design tolerances must be considered before allowing T3 faster than 100 ms.
   a. A T3 time less than 100 ms may be designed based on system requirements and a need to provide faster PSU and system turn on capability. However, PSU and system designers are highly recommended to verify and ensure no PSU and system compatibility problems exist, especially for previous generation motherboards and systems.
3. T5 Required value to be defined for both Full/Light load conditions.
4. T5 Recommended value is defined for 80% of full load condition.
5. T6 Required value to be defined for coming from both Full/Light load conditions.
6. T6 Recommended value is defined for coming from 80% of full load condition.
7. PSUs are recommended to label or indicate the timing value for system designer and integrator reference for T1 and T3. This allows system designers to optimize “turn on” time within the system.
8. Timing values recommended for systems that use ALPM.

4.3.1 PWR_OK – REQUIRED

PWR_OK is a “power good” signal. This signal shall be asserted high by the power supply to indicate that the +12 VDC, +5 VDC, and +3.3 VDC outputs are within the regulation thresholds listed in Table 4-2 and that sufficient mains energy is stored by the converter to guarantee continuous power operation within the specification for at least the duration specified in Section 4.2.9. Conversely, PWR_OK should be de-asserted to a low state when any of the +12 VDC, +5 VDC, or +3.3 VDC output voltages fall below its voltage threshold, or when mains power has been removed for a time sufficiently long enough, such that power supply operation cannot be guaranteed. The electrical and timing characteristics of the PWR_OK signal are given in Table 4-11.

PSU manufacturers are required to label or tag PSU DG revision or ATX spec revision to show compliance and reflect the timing supported.

Table 4-11: PWR_OK Signal Characteristics

Signal Type	+5 V TTL compatible
Logic level low	< 0.4 V while sinking 4 mA
Logic level high	Between 2.4 V and 5 V output while sourcing 200 µA
High state output impedance	1 kΩ from output to common
Max Ripple/Noise	400 mV p-p

4.3.2 Power-Up Cross Loading Condition – REQUIRED

In the time frame between PS_ON# assertion and PWR_OK assertion (T1+T3), the power supply may be subjected to a cross load condition on the 12 V, 3.3 V and 5 V rails. The power supply must be able to successfully power up and assert PWR_OK when 12 V (or combination of 12V1 and 12V2) is loaded to ≤ 0.1 A and 3.3 V and/or 5 V are loaded to 0-5 A.

4.3.3 PS_ON# – REQUIRED

PS_ON# is an active-low, TTL-compatible signal that allows a motherboard to remotely control the power supply in conjunction with features such as soft on/off, Wake on LAN*, or wake-on-modem. When PS_ON# is pulled to TTL low, the power supply should turn on the four main DC output rails: +12 VDC, +5 VDC, +3.3 VDC, and -12 VDC. When PS_ON# is pulled to TTL high or open-circuited, the DC output rails shall not deliver current and must be held at zero potential with respect to ground. PS_ON# has no effect on the +5VSB output, which is always enabled whenever the AC power is present. To support systems with ALPM this is required for all power supplies. The power supply may be asked to turn back on before all voltage rails have turned off. The power supply must be able to turn back on via a change in the PS_ON# signal after 100 ms of the PS_ON# signal being de-asserted. Table 4-12 lists PS_ON# signal characteristics.

The power supply shall provide an internal pull-up to TTL high. The power supply shall also provide de-bounce circuitry on PS_ON# to prevent it from oscillating on/off at startup when activated by a mechanical switch. The DC output enable circuitry must be SELV-compliant.

The power supply shall not latch into a shutdown state when PS_ON# is driven active by pulses between 10 ms to 100 ms during the decay of the power rails. When PS_ON# de-asserts (turn on the PSU) with a time that is greater than 100 ms, from when it is first asserted (turns off), the PSU must respond to this request and turn back on all voltages rails no matter where the voltage rails are in ramping down the voltage to an Off state.

Table 4-12: PS_ON# Signal Characteristics

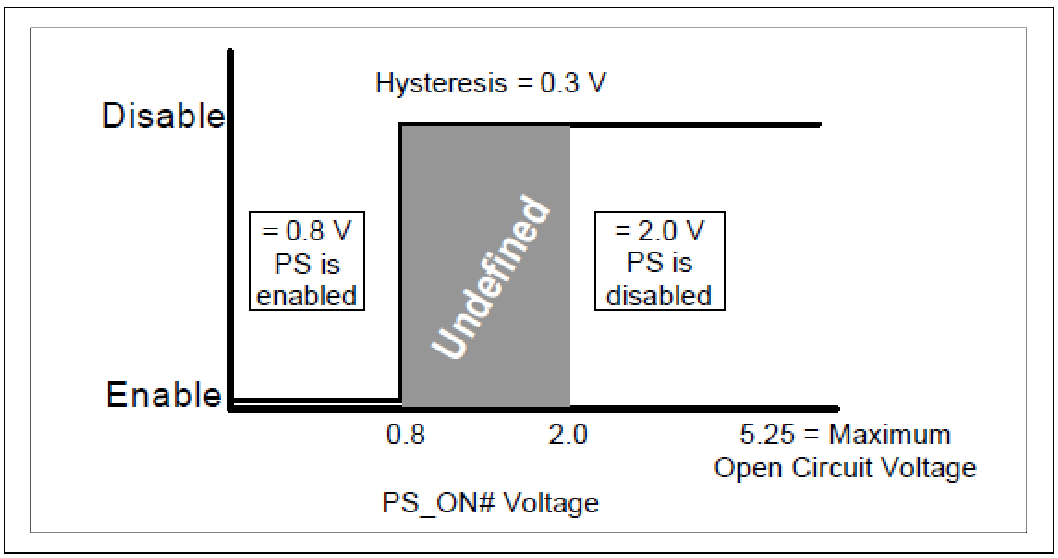
Parameter	Minimum	Maximum
V_{IL}	0	0.8 V

Parameter	Minimum	Maximum
I_{IL} (V_{IN} = 0.4 V)	-	-1.6 mA[1]
V_{IH} (I_{IN} = 200 uA)	2.0 V	-
V_{IH} open circuit	-	-5.25 V
Ripple / Noise		400 mV p-p

NOTES:

1. Negative current indicates that the current is flowing from the power supply to the motherboard.
2. Due to PS_ON# toggle on/off frequently, system and PSU component's reliability should be considered based on the days, months, or years of claimed warranty listed on product specification. Refer to Section 10.2 for more details about PSU design considerations for S0ix mode.

Figure 4-4: PS_ON# Signal Characteristics



4.3.4 +5VSB – REQUIRED

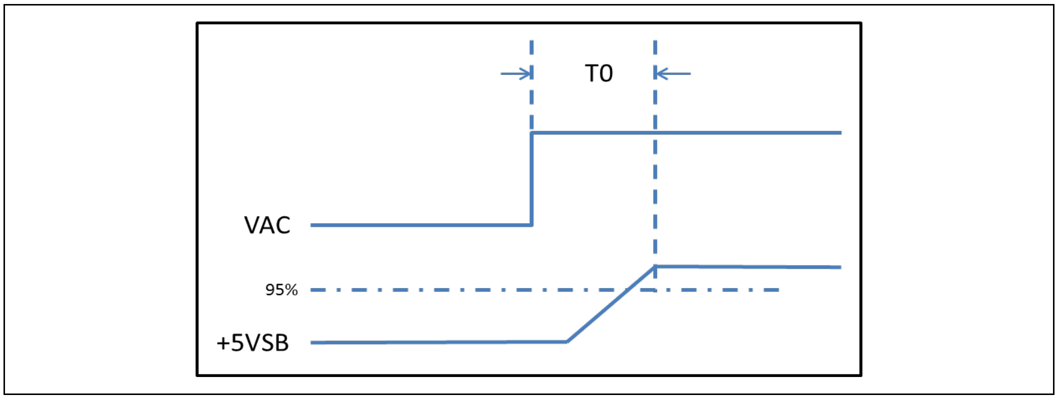
+5VSB is a standby supply output that is active whenever the AC power is present. This output provides a power source for circuits that must remain operational when the five main DC output rails are in a disabled state. Example uses include soft power control, Wake on LAN, wake-on-modem, intrusion detection, Alternative Low Power Modes (ALPM) or suspend state activities.

The power supply must be able to provide the required power during a "wake up" event. If an external USB device generates the event, there may be peak currents as high as 3.5 A, lasting no more than 500ms.

Over current protection is required on the +5VSB output regardless of the output current rating. This ensures the power supply will not be damaged if external circuits draw more current than the supply can provide.

With new modes of operation for computers like Alternative Low Power Modes (ALPM) the continuous current rating of the 5VSB rail is recommended to be at least 3 A. Some scenarios like USB Power Charging in ALPM could require more current on the 5VSB rail.

Figure 4-5: +5VSB Power on timing versus VAC



4.3.5 Power-On Time – REQUIRED

The power-on time is defined as the time from when PS_ON# is pulled low to when the +12 VDC, +5 VDC, and +3.3 VDC outputs are within the regulation ranges specified in Table 4-2. The power-on time shall be less than 500 ms (T1 < 500 ms).

+5VSB shall have a power-on time of two second maximum after application of valid AC voltages as shown in Figure 4-5. The 5VSB power on time is T0 as listed in Section 4.3.4.

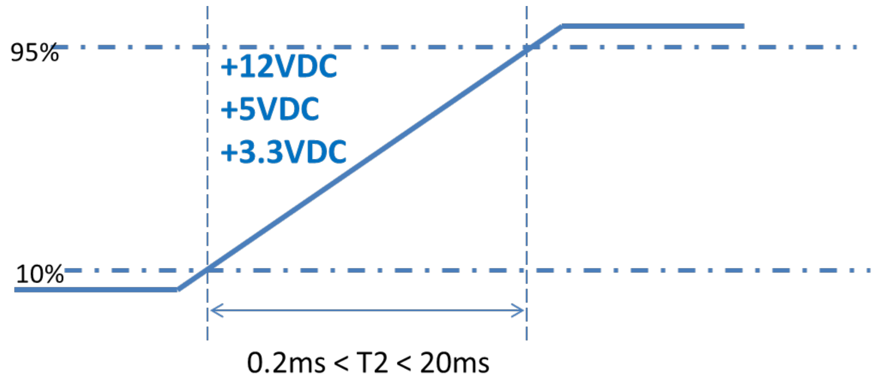
4.3.6 Rise Time – REQUIRED

The output voltages shall rise from 10% of nominal to within the regulation ranges specified in Table 4-2 within 0.2 ms to 20 ms (0.2 ms ≤ T2 ≤ 20 ms). The total time for Rise time of each voltage is listed in Table 4-10 as T2.

There must be a smooth and continuous ramp of each DC output voltage from 10% to 95% of its final set point within the regulation band, while loaded as specified.

The smooth turn-on requires that, during the 10% to 95% portion of the rise time, the slope of the turn-on waveform must be positive and have a value of between 0 V/ms and [Vout, nominal / 0.2] V/ms. Also, for any 5 ms segment of the 10% to 95% rise time waveform, a straight line drawn between the end points of the waveform segment must have a slope ≥ [Vout, nominal / 20] V/ms.

Figure 4-6: Rise Time Characteristics



	Min slew rate (10-95%)	Max Slew Rate (10-95%)	Min Slew Rate for any 5ms segment (10-95%)
+12VDC	0V/ms	60V/ms	0.6V/ms
+5VDC	0V/ms	25V/ms	0.25V/ms
+3.3VDC	0V/ms	16.5V/ms	0.165V/ms

4.3.7 Overshoot at Turn-On / Turn-Off – REQUIRED

The output voltage overshoot upon the application or removal of the input voltage, or the assertion/de-assertion of PS_ON#, under the conditions specified in Table 4-2, shall be less than 10% above the nominal voltage. No voltage of opposite polarity shall be present on any output during turn-on or turn-off.

4.4 Reset After Shutdown

If the power supply latches into a shutdown state because of a fault condition on its outputs, the power supply shall return to normal operation only after the fault has been removed and the PS_ON# has been cycled OFF/ON with a minimum OFF time of one second.

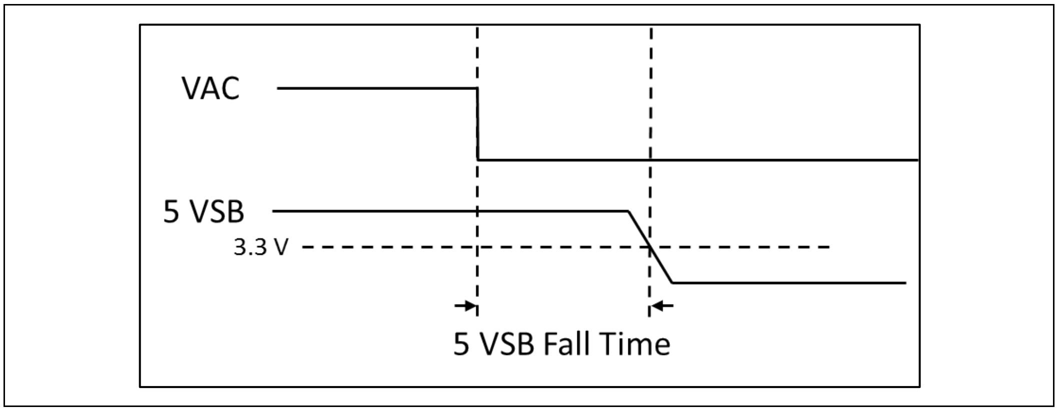
4.4.1 +5VSB at Power-Down – REQUIRED

After AC power is removed, the +5VSB standby voltage output must remain at its steady state value for the minimum hold-up time specified in Section 4.2.9 until the output begins to decrease in voltage. The decrease shall be monotonic in nature, dropping to 0.0 V. There shall be no other disturbances of this voltage at or following removal of AC power.

4.4.2 +5VSB Fall Time - RECOMMENDATION

Power supply 5VSB is recommended to go down to low level within 2 seconds under any load condition after AC power is removed as shown in Figure 4-7. Intel® test plan will test at Light 20% Load. If system requires specific +5VSB fall time, the PSU design is recommended to support it.

Figure 4-7: 5VSB Fall Time



4.5 Output Protection

4.5.1 Over Voltage Protection (OVP) – REQUIRED

The over voltage sense circuitry and reference shall reside in packages that are separate and distinct from the regulator control circuitry and reference. No single point fault shall be able to cause a sustained over voltage condition on any or all outputs. The supply shall provide latch-mode over voltage protection as defined in Table 4-13.

Table 4-13: Over Voltage Protection

Output	Minimum (V)	Nominal (V)	Maximum (V)
+12 VDC (or 12V1DC and 12V2DC)	13.4	15.0	15.6
+5VDC	5.74	6.3	7.0
+3.3VDC	3.76	4.2	4.3
+5VSB[1]	5.74	6.3	7.0

NOTE: Over voltage protection is RECOMMENDED but not REQUIRED for this output. While over voltage protection is not required for this output, system damage may occur in the case of an over voltage event.

4.5.2 Short Circuit Protection (SCP) – REQUIRED

An output short circuit is defined as any output impedance of less than 0.1 ohms. The power supply shall shut down and latch off for shorting the +3.3V DC, +5V DC, or +12V DC rails to return or any other rail. The +12V1 DC and 12V2 DC should have separate short circuit and over current protection. Shorts between main output rails and +5VSB shall not cause any damage to the power supply. The power supply shall either shut down and latch off or fold back for shorting the negative rails. +5VSB must be capable of being shorted indefinitely. When the short is removed, it is recommended that the power supply shall recover automatically or by cycling PS_ON#. Optionally, the power supply may latch off when a +5VSB short circuit event occurs. The power supply shall be capable of withstanding a continuous short circuit to the output without damage or overstress to the unit (for example, to components, PCB traces, and connectors) under the input conditions specified in Table 4-1.

4.5.3 No-Load Situation – REQUIRED

Damage or hazardous conditions shall not occur with all the DC output connectors disconnected from the load. The power supply may latch into the shutdown state.

4.5.4 Over Current Protection (OCP) – REQUIRED

Current protection must be designed to limit the current to operate within safe operating conditions.

Over current protection schemes, where only the voltage output that experiences the over current event is shut off, may be adequate to maintain safe operation of the power supply and the system; however, damage to the motherboard or other system components may occur. The recommended over current protection scheme is for the power supply to latch into the shutdown state. PSU connectors, cables and all other components should not be melted or damaged prior reaching to the OCP trigger.

4.5.5 Over Temperature Protection (OTP) – REQUIRED

The power supply shall include an over-temperature protection sensor, which can trip and shut down the power supply at a preset temperature point. Such an overheated condition is typically the result of internal current overloading or a cooling fan failure. If the protection circuit is non-latching, then it should have hysteresis built in to avoid intermittent tripping. PSU connectors, cables and all other components should not be melted or damaged prior reaching to the OCP trigger.

4.5.6 Output Bypass – REQUIRED

The output return may be connected to the power supply chassis and will be connected to the system chassis by the system components.

4.5.7 Separate Current Limit for 12V2 - OPTIONAL

The 12 V rail on the 2x2 power connector should be a separate current limited output to meet the requirements of UL and EN 62368-1. This only applies if the PSU is complying a 240VA Energy Hazard Safety Requirement; most power supplies are not currently designed to meet this requirement.

4.5.8 Overall Power Supply Efficiency Levels

The efficiency of the power supply should be tested at nominal input voltage of 115 VAC input and 230 VAC input, under the load conditions defined in the *Generalized Test Protocol for Calculating the Energy Efficiency of Internal Ac-Dc and Dc-Dc Power Supplies* document. This document defines how to determine full load criteria based on the label of each rail of the power supply. The loading condition for testing efficiency represents fully loaded systems, typical (50%) loaded systems, and light (20%) loaded systems.

The Efficiency requirements listed below are applicable to AC Input voltage of 115V.

Table 4-14: Efficiency versus Load Minimum Requirements

Loading	Full Load (100%)	Typical Load (50%)	Light Load (20%)
REQUIRED Minimum Efficiency	70%	72%	65%

Low Load Efficiency

Computers have decreased Idle power greatly since 2005, to where PSU loss is a big concern for overall AC power of a computer in Idle Mode. The lowest DC load for computers at this Idle Mode is determined to be 10 Watts for mainstream computers and could go lower. Computers with PSU larger than 500 watts are also expected to have more components and therefore the Idle Mode will be at a higher DC Load. A PSU above 500 watts will use the Low Load Efficiency set at the 2% level. The Low Load Efficiency requirements are shown in Table 4-15: Low Load Efficiency Requirements.

Table 4-15: Low Load Efficiency Requirements

Low Load Efficiency	10W / 2%
Required	60%
Recommended	70%

The 10-Watt load conditions are defined in the Test Plan (#338448).

4.5.9 Power Supply Efficiency for Energy Regulations - ENERGY STAR* and CEC (California Energy Commission) PC Computers with High Expandability Score - RECOMMENDED

The efficiency of the power supply should be tested at nominal input voltage of 115 VAC input and 230 VAC input, under the load conditions defined in the form factor specific sections, and under the temperature and operating conditions defined in Chapter 7. The loading condition for testing efficiency represents fully loaded systems, typical (50%) loaded systems, and light (20%) loaded systems. For systems being sold into the state of California that meet the High Expandability Computer definition (details at the referenced CEC website below) are required to meet the efficiency target list in Table 4-17: Efficiency versus Load for CEC PC Computers with High Expandability Computers*.

Visit ENERGY STAR* Computers Ver.8 (ES v8) website for more details:

- https://www.energystar.gov/products/spec/computers_version_8_0_pd

Visit CEC* website for more details:

- https://www.energy.ca.gov/rules-and-regulations/appliance-efficiency-regulations-title-20 or
- https://energycodeace.com/content/reference-ace-t20-tool then select section "(v) Computers…"

Note: Check ENERGY STAR* and CEC website for the latest specification update.

Table 4-16: Efficiency versus Load for ENERGY STAR*

Loading	Full Load (100%)	Typical Load (50%)	Light Load (20%)	10% Load	PFC @ 50% load	Remarks
RECOMMENDED Minimum Efficiency	82%	85%	82%	80%	≥0.9	ENERGY STAR* v8 for 500W and below
RECOMMENDED Minimum Efficiency	87%	90%	87%	80%	≥0.9	ENERGY STAR* v8 for above 500W

Table 4-17: Efficiency versus Load for CEC PC Computers with High Expandability Computers*

Loading	Full Load (100%)	Typical Load (50%)	Light Load (20%)	PFC @ 50% load
REQUIRED Minimum Efficiency for 115V PSU	87%	90%	87%	≥0.9
REQUIRED Minimum Efficiency for 230V PSU	88%	92%	88%	≥0.9

*Details about High Expandability Computers definition check CEC computer regulation.

The RECOMMENDED minimum efficiency levels shown in Table 4-16 are required for internal power supplies within the ENERGY STAR* for Computers Version 8.0 specification.

§§

5 Mechanical

This chapter contains mechanical guidelines that apply to desktop power supplies regardless of form factor. For form factor specific design guides refer to Chapter 11 through Chapter 16.

5.1 Labeling and Marking - RECOMMENDED

The following is a non-inclusive list of suggested markings for each power supply unit. Product regulation stipulations for sale into various geographies may impose additional labeling requirements.

Manufacturer information: Manufacturer's name, Part number and Lot date code, etc., in human-readable text and/or bar code formats.

Nominal AC input operating voltages (100-127 VAC and 200-240 VAC) and current rating certified by all applicable safety agencies.

DC output voltages and current ratings.

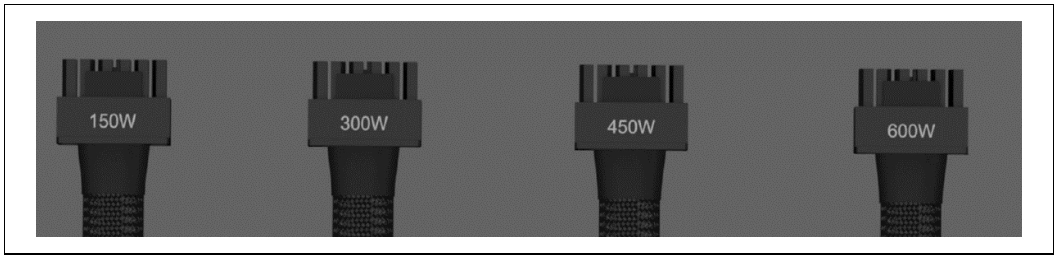
Revision number of the ATX, SFX, etc. specification that the power supply meets.

Access warning text ("Do not remove this cover. Trained service personnel only. No user serviceable components inside.") must be in English, German, Spanish, French, Chinese, and Japanese with universal warning markings.

Power Supplies are recommended to list if it meets the Recommended Timing values (T1 & T3) in product documentation. There are two levels of timing for T1 and T3 a power supply can support as detailed in Table 4-10. This will help power supplies that meet the lower T1 & T3 timing values highlight that it meets the lower timing values to OEMs and end users.

12V-2x6 connector/cable harnesses that are hard-wired to the power supply shall be labeled indicating the **maximum power supported** according to the SENSE0/1 encoding implemented for each connector. If PSU is a modular design or if the Sense lines are dynamic (can change in standby mode only), another location on the PSU (highly recommended to be on the PSU Voltage Rail label) and the product documentation must describe the power levels supported. If the criteria for different power levels based on the number of PCIe* Add-in Cards connected that must be described for the OEM or end user as well. SENSE0/1 are described in Section 3.3.1 of this document. An example of these labels is illustrated in Figure 5-1 below.

Figure 5-1: 12V-2x6 Connector Labeling Example



5.2 Connectors - REQUIRED

5.2.1 AC Connector

The AC input receptacle must be an IEC 320 type or equivalent. In lieu of a dedicated switch, the IEC 320 receptacle may be considered the mains disconnect.

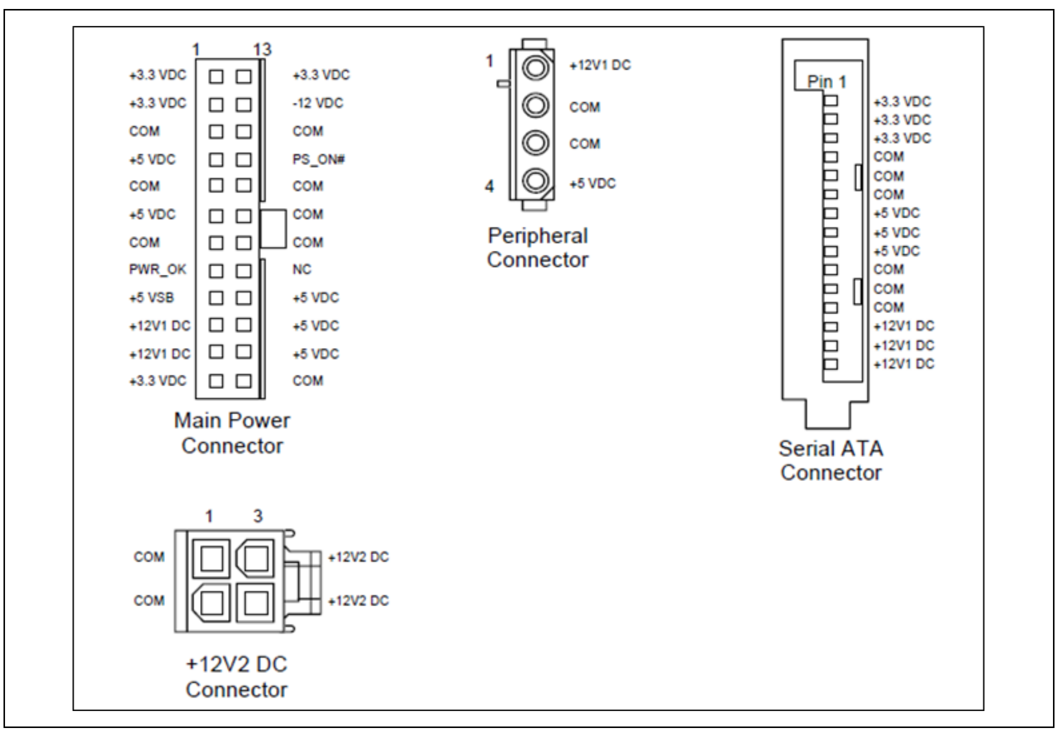
5.2.2 DC Connectors

Table 5-1: Main Power Connector Pin-Out shows pin outs and profiles for typical power supply DC harness connectors. The power supply requires an additional two-pin, power connector.

UL Listed or recognized component appliance wiring material rated min 85 °C, 300 VDC shall be used for all output wiring.

There are no specific requirements for output wire harness lengths, as these are largely a function of the intended end-use chassis, motherboard, and peripherals. Ideally, wires should be short to minimize electrical/airflow impedance and simplify manufacturing, yet they should be long enough to make all necessary connections without any wire tension (which can cause disconnections during shipping and handling). The recommended minimum harness length for general-use power supplies is 150 mm for all wire harnesses. Measurements are made from the exit port of the power supply case to the wire side of the first connector on the harness.

Figure 5-2: Connectors (Pin-side view, not to Scale)



NOTE: Peripheral Connector is optional, does not show any PCIe* Add-in Card Connectors or 8 pin 12V2 connector.

5.2.2.1 Main Power Connector – REQUIRED

Connector: Molex* Housing: 24 Pin Molex Mini-Fit Jr. PN# 39-01-2240 or equivalent.

Contact: Molex 44476-1112 (HCS) or equivalent (Mating motherboard connector is Molex 44206-0007 or equivalent).

18 AWG is suggested for all wires except for the +3.3 V supply and sense return wires combined into pin 13 (22 AWG).

Table 5-1: Main Power Connector Pin-Out

Pin	Signal	Color		Pin	Signal	Color
1	+3.3V DC	Orange		**13**	+3.3V DC [+3.3 V default sense]	Orange [Brown]
2	+3.3V DC	Orange		**14**	-12V DC	Blue
3	COM	Black		**15**	COM	Black
4	+5V DC	Red		**16**	PS_ON#	Green
5	COM	Black		**17**	COM	Black
6	+5V DC	Red		**18**	COM	Black
7	COM	Black		**19**	COM	Black
8	PWR_OK	Gray		**20**	Reserved	NC
9	+5VSB	Purple		**21**	+5V DC	Red
10	+12V1 DC	Yellow		**22**	+5V DC	Red
11	+12V1 DC	Yellow		**23**	+5V DC	Red
12	+3.3V DC	Orange		**24**	COM	Black

5.2.2.2 Peripheral Connectors

Connector: AMP* 1-480424-0 or Molex* 15-24-4048 or equivalent.

Contacts: AMP 61314-1 or equivalent.

Table 5-2: Peripheral Connector Pin-out

Pin	Signal	Color[1]
1	+12V1 DC	Yellow
2	COM	Black
3	COM	Black
4	+5 VDC	Red

Note: 18 AWG wire.

5.2.2.3 Floppy Drive Connector – Do Not Include (For Historical Reference Only)

Connector: AMP* 171822-4 or equivalent.

Table 5-3: Floppy Connector Pin-out

Pin	Signal	Color[1]
1	+5V DC	Red
2	COM	Black
3	COM	Black
4	+12V1 DC	Yellow

Note: 20 AWG wire.

5.2.2.4 PCI-Express (PCIe*) Add-in Card Connectors (Recommended)

These are optional connectors for the power supply to support additional power needed by any PCI Express* Add-in Card (AIC). The most common PCIe* Add-in Card that uses these connectors are discrete graphics cards. The PCIe* CEM Specification defines different connectors based on the power used by the Add-in Card which can range from 75 watts up to 600 watts.

5.2.2.4.1 PCI Express* (PCIe*) 2x3 Auxiliary Power Connector (Recommended)

The 2x3 Power Connector is designed to provide 75 watts to the PCIe* Add-in Cards and has the following requirements:

- Current Rating: 8.0 A/pin/position maximum to a 30 °C T-Rise above ambient temperature conditions at +12 VDC, with all six contacts energized.
- Mated Connector Retention: 30.00 N minimum when plug pulled axially.

<u>Cable Assembly Contact and Housing Details:</u>

- Housing Material: Thermoplastic
- Pin Contact Base Material: Brass alloy or equivalent
- Pin Contact Plating: Sn alloy
- Flammability: UL94V-1 Minimum - Material certification or certificate of compliance is required with each lot to satisfy the Underwriters Laboratories follow-up service requirements.
- Lead Free Soldering: Connector must be compatible with lead free soldering process.

Table 5-4: PCIe* 2x3 Auxiliary Power Connector Pin Assignment (75 watts)

Pin	Signal	Color[1]	Pin	Signal	Color[1]
1	+12V3/V4	Yellow	4	COM	Black
2	+12V3/V4	Yellow	5	Sense	Black
3	+12V3/V4	Yellow	6	COM	Black

NOTES:

1. Wire Size: 18 AWG
2. The Sense pin on the 2x3 auxiliary power connector must be connected to ground either directly in the power supply or via a jumper to an adjacent ground pin in the connector. This pin is used by a PCI Express* 2x3 150 W/225 W/300 W Add-in Card to detect whether the 2x3 auxiliary power connector is attached.

5.2.2.4.2 PCI Express* (PCIe*) 2x4 Auxiliary Power Connector (Recommended)

The 2x4 Auxiliary Power Connector consists of a *PCB Header*, mounted on a PCIe* Add-in Card, and a mating 2x4 *Cable Plug* harness*.* The 2x4 PCB header is designed to accept both the mating 2x4 Cable Plug as well as the 2x3 cable plug, for backward-compatibility. The Add-in Card PCB Header is keyed to ensure that a 2x3 cable plug from a PSU will be properly aligned when it is mated with a 2x4 PCB Header. Two Sense pins in the 2x4 PCB header allow the PCIe* Add-in Cards to detect the power available from the cable. The 2x4 Cable Plug asserts (grounds) two sense pins to indicate that 150 watts are available to the PCIe* Add-in Card through this cable, while the 2x3 plug asserts only one sense pin, to signal that only 75 watts may be drawn from the cable. The 2x4 Cable Plug has the following requirements:

- Current Rating: 7.0 A per pin/position maximum to a 30 °C T-Rise above ambient temperature conditions at +12 VDC with all eight contacts energized.
- Mated Connector Retention: 30.00 N minimum when plug is pulled axially.

<u>Cable Assembly Contact and Housing Details:</u>

- Housing Material: Thermoplastic; Note that this connector has unique mechanical keying to avoid incorrect insertion of a cable plug intended for a different type of connector.
- Pin Contact Base Material: Brass alloy or equivalent
- Pin Contact Plating: Sn alloy

- Flammability: UL94V-1 Minimum - Material certification or certificate of compliance is required with each lot to satisfy the Underwriters Laboratories follow-up service requirements.
- Lead Free Soldering: Connector must be compatible with lead free soldering process.

Table 5-5: PCIe* 2x4 Auxiliary Power Connector Pin Assignment (150 watts)

Pin	Signal	Color[1]	Pin	Signal	Color[1]
1	+12V3/V4	Yellow	5	COM	Black
2	+12V3/V4	Yellow	6	SENSE0	Black
3	+12V3/V4	Yellow	7	COM	Black
4	SENSE1	Black	8	COM	Black

NOTE: 18 AWG wire.

Table 5-6: PCIe* 2x4 Auxiliary Power Connector Sense Pin Decoding by AIC

Sense 1	Sense 0	Description
Ground	Ground	A 2x4 connector is plugged into the card. The card can draw up to 150 W from the auxiliary power connector
Ground	Open	Reserved
Open	Ground	A 2x3 connector is plugged into the card. The card can only draw up to 75 W from the auxiliary power connection
Open	Open	No auxiliary power connector is plugged in

For a sense pin that needs to be grounded, it must be connected to ground either directly in the power supply or via a jumper to an adjacent ground pin in the connector.

5.2.2.4.3 PCI Express* (PCIe*) 12V-2x6 Auxiliary Power Connector (Optional for PSU ≤ 450 watts, Recommended for PSU > 450 watts)

The 12V-2x6 Auxiliary Power connector is designed to deliver up to 600 watts of 12V power directly to a PCIe* Add-in Card. This power connector is not compatible with the 2x3 or 2x4 auxiliary power connectors. The 12V-2x6 connector power pins have a 3.0 mm spacing, while the contacts in a 2x3 and 2x4 connector lie on a larger 4.2 mm pitch. The 12V-2x6 auxiliary power connector includes twelve large contacts to carry power and four smaller contacts beneath, to carry the sideband signals.

The two mating components of the 12V-2x6 are the *Cable Plug,* which terminates the cable harness, and the *PCB Header*, which is mounted on the Add-in Card and, optionally, within a modular power supply.

The connector performance requirements are as follows:

- Power Pin Current Rating: (Excluding sideband contacts) 9.2 A per pin/position with a limit of a 30 °C T-Rise above ambient temperature conditions at +12 VDC with all twelve contacts energized. The connector body must display a label or embossed H++ characters to indicate support of 9.2 A/pin or greater. Refer to Figure 5-5 for the approximate positioning of the H++ marker on the 12V-2x6 Right Angle (R/A) PCB Header.

- Mated Connector Latch Retention: 45.00 N minimum when plug pulled axially.

The 12V-2x6 cable plug housing has been defined with two options that provide different physical shroud designs for the sideband signals, as shown in Figure 5-3. The thumb-ridge feature is present on one design (Option 1) and absent on the other (Option 2).

Figure 5-3: 12V-2x6 Cable Plug Connector

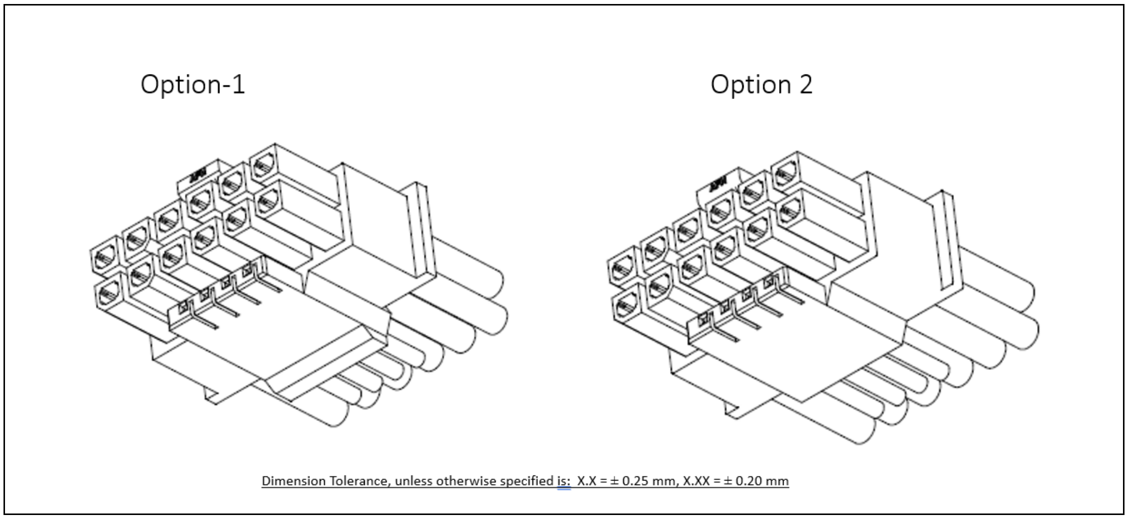
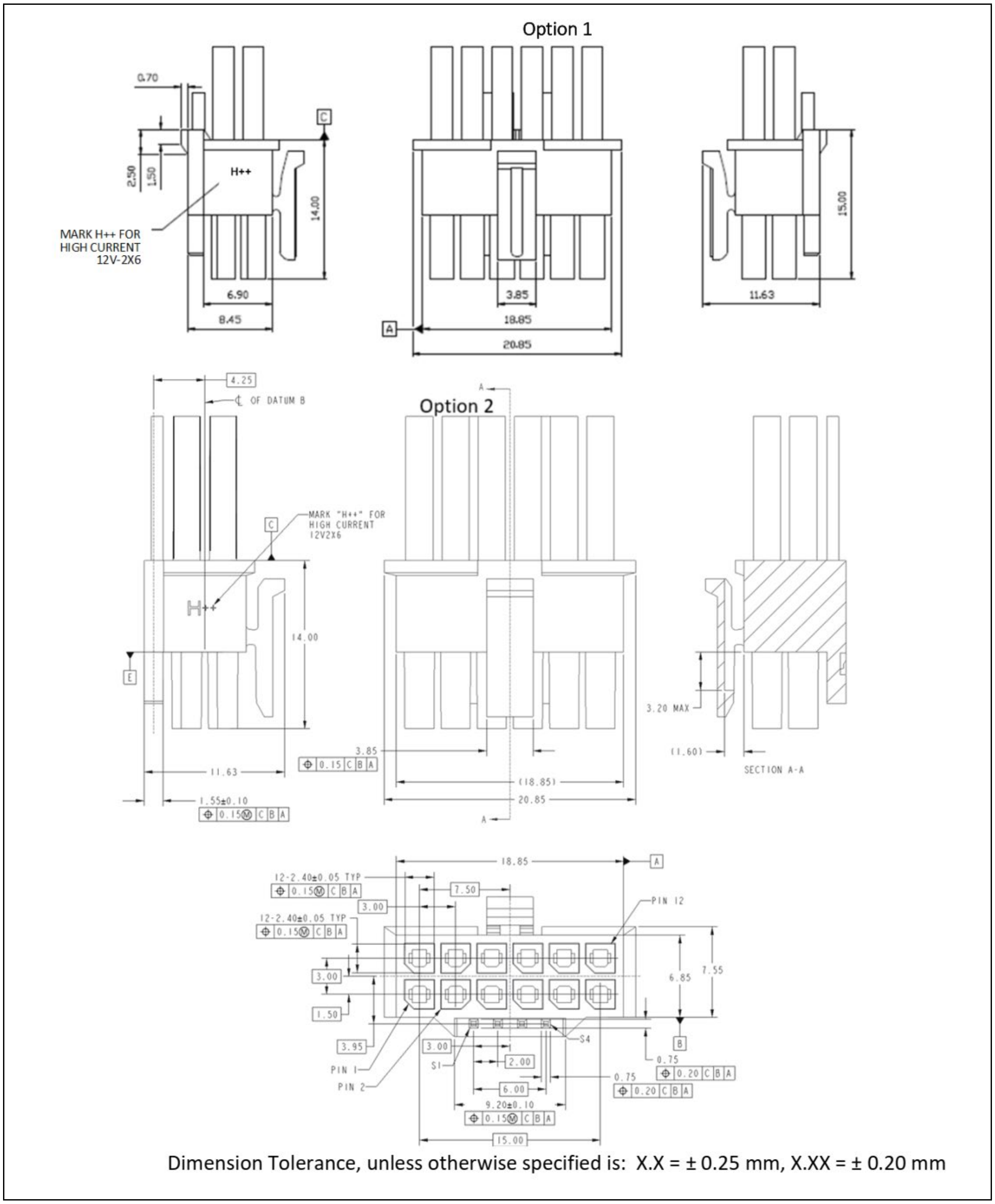


Figure 5-4: 12V-2x6 Cable Assembly



The cable plug connector housing for the 12V-2x6 connector has all dimensions shown in mm. Slight changes to this connector that do not affect connector mating are permitted. Reference latest PCI-SIG documentation for latest information about this connector.

<u>12V-2x6 Cable Plug Assembly Contact and Housing Details:</u>

- Housing Material: Thermoplastic Glass Fiber Filled, UL94V-0
- Color: Black
- Pin Contact Material: Copper Alloy
- Power Pin Contact Plating: Tin plated on contact area
- Signal Pin Contact Plating: Tin plated on contact area
- All dimensions are in mm
- Connector must be compatible with a lead-free soldering process.

Wire Details:

- Power/Ground Pin Wire Size: 16 AWG
  - All 12 pins must be connected to the power supply using 16 AWG cable, with no depopulation
- Sideband Signals Pin Wire Size: 28 AWG

If a power supply uses a modular cable connection, an additional 12V-2x6 PCB Header connector will be required in the housing of the power supply to accept "double-ended" 12V-2x6 cables. Details below are provided via the PCIe CEM Revision 5.1 Specification.

Special Note on 12V-2x6 vs. 12VHPWR connectors

The 12V-2x6 PCB connector is labeled with a "H++" to differentiate it from the previously defined 12VHPWR connector, which was labelled with the "H+" symbol.

The 12VHPWR connector, introduced in the earlier 2.0 revision of this document and the PCIe CEM 5.0 Specification, has been deprecated and replaced with the 12V-2x6 connector, as shown in th PCIe CEM 5.1 specification. While the 12V-2x6 connector specification is mechanically identical to the 12VHPWR connector in most respects, multiple updates have been incorporated into the newer, 12V-2x6 connector, to improve its reliability.

The chief improvements introduced in the 12V-2x6 connector include:

- The power pins have been lengthened and the sideband pins have been shortened in the PCB Header to ensure first-mate/last break engagement of the power pins. This mechanical revision is present in the 12V-2x6 PCB header component to ensure that the sideband pins engage only after the power pins are sufficiently mated.

- The sideband signals SENSE0/SENSE1 definitions, which signal maximum available power available from the PSU, have been updated, as shown in Table 3-6.
  - The 150 watts power level now requires the SENSE0/SENSE1 pins to be shorted together in the power supply or the cable.
  - When both SENSE0/SENSE1 are unasserted, as defined by their high-impedance Open-Open state, no power may be drawn by the load. This is new SENSE0/SENSE1 combination now defines the new 0 watt state, which was not present in the 12VHPWR connector.

These updated SENSE0/SENSE1 combinations ensure that an Add-in Card may only draw power only when the power pins and the sideband pins are engaged and correctly asserted. The Open-Open condition signals that the PCB plug is either poorly seated or absent. These two conditions are now functionally equivalent. A PCIe CEM 5.1 Add-in Card will explicitly interpret the Open-Open SENSE0/SENSE1 stat as the 0 watt configuration, and it will not attempt to draw power from the cable.

- It is important that the power supply provide these updated SENSE0/SENSE1 encodings to the cable, to ensure compatibility with PCIe CEM 5.1 compliant Add-in Cards. See 3.3.1 for more details on SENSE0/SENSE1 encoding.

Figure 5-5: 12V-2x6 PCB Header

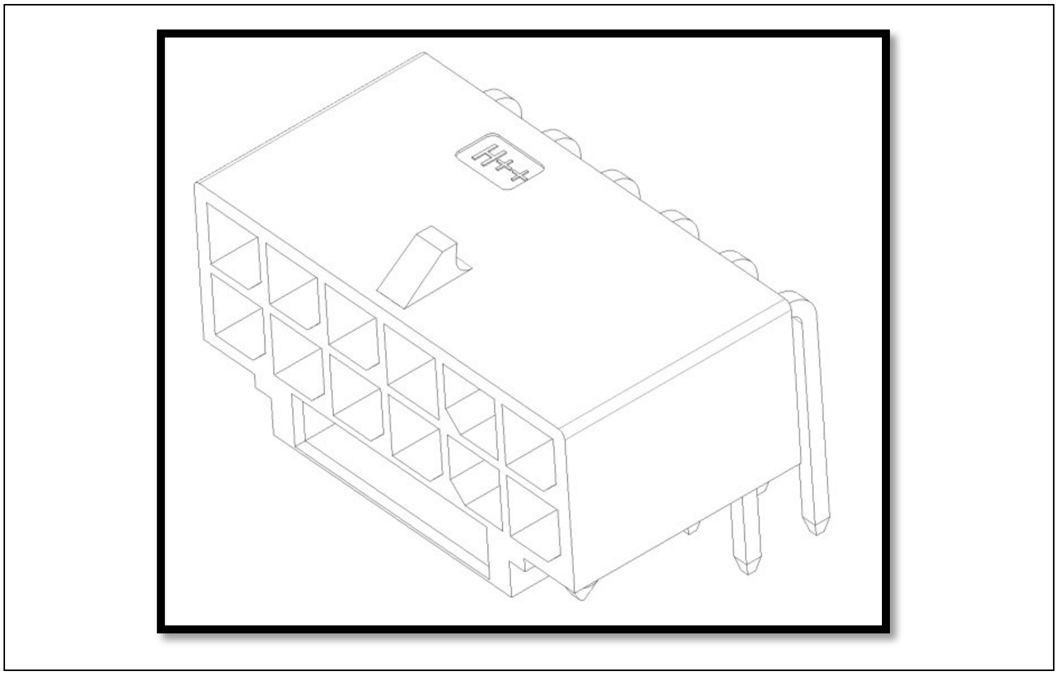


Figure 5-6: 12V-2x6 PCB Header Dimensions – Front View

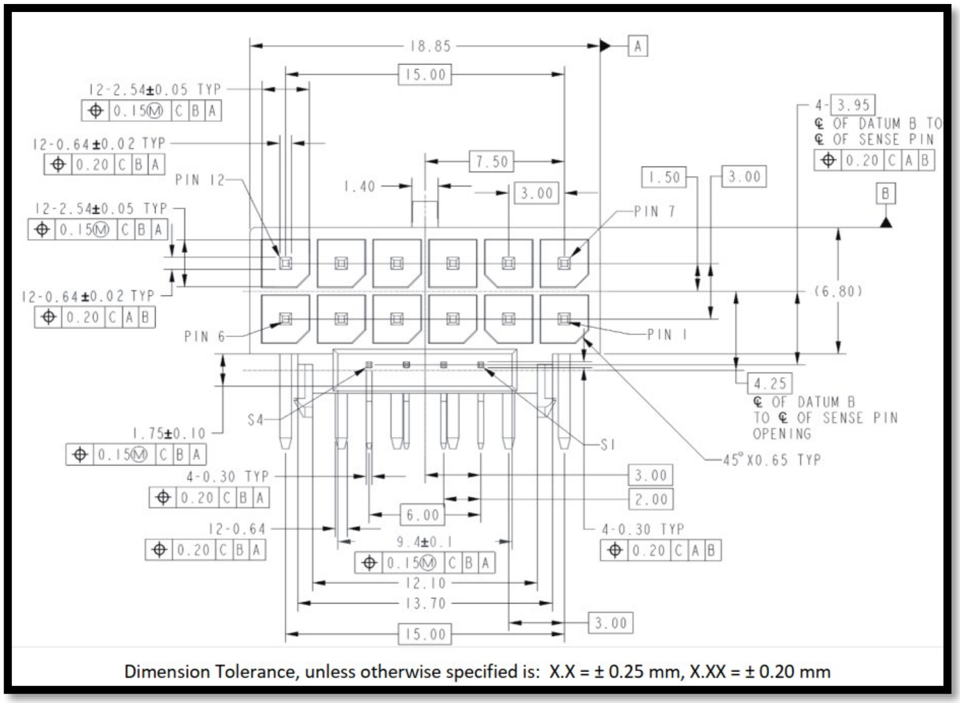


Figure 5-7: 12V-2x6 PCB Header – Side View

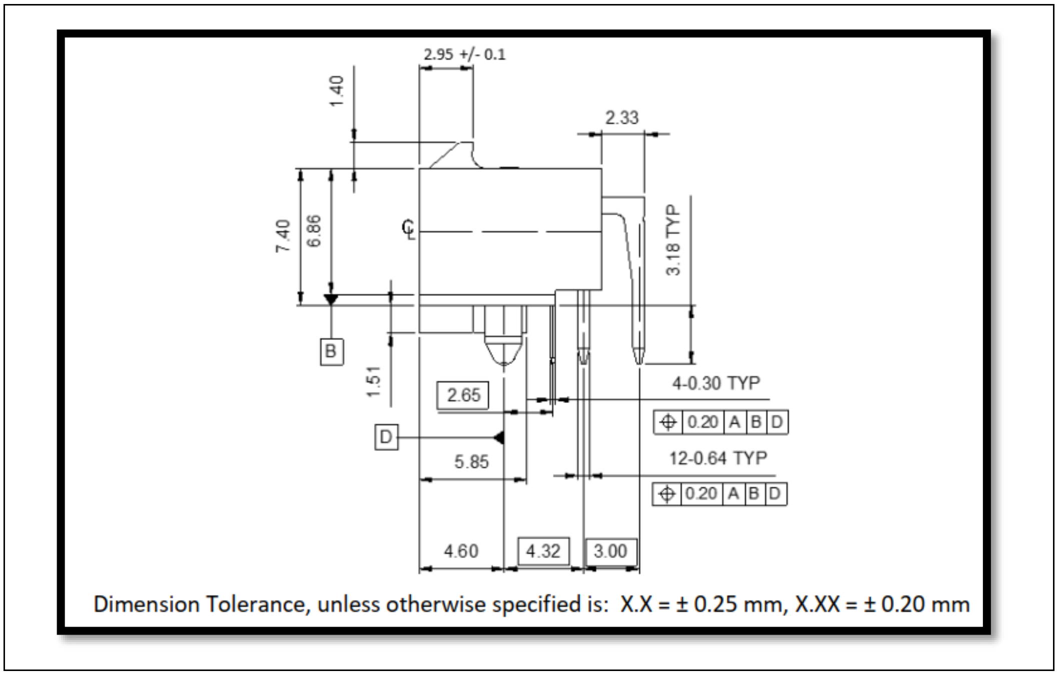


Figure 5-8: 12V-2x6 PCB Header – Side View, Highlighting Contact Dimensions

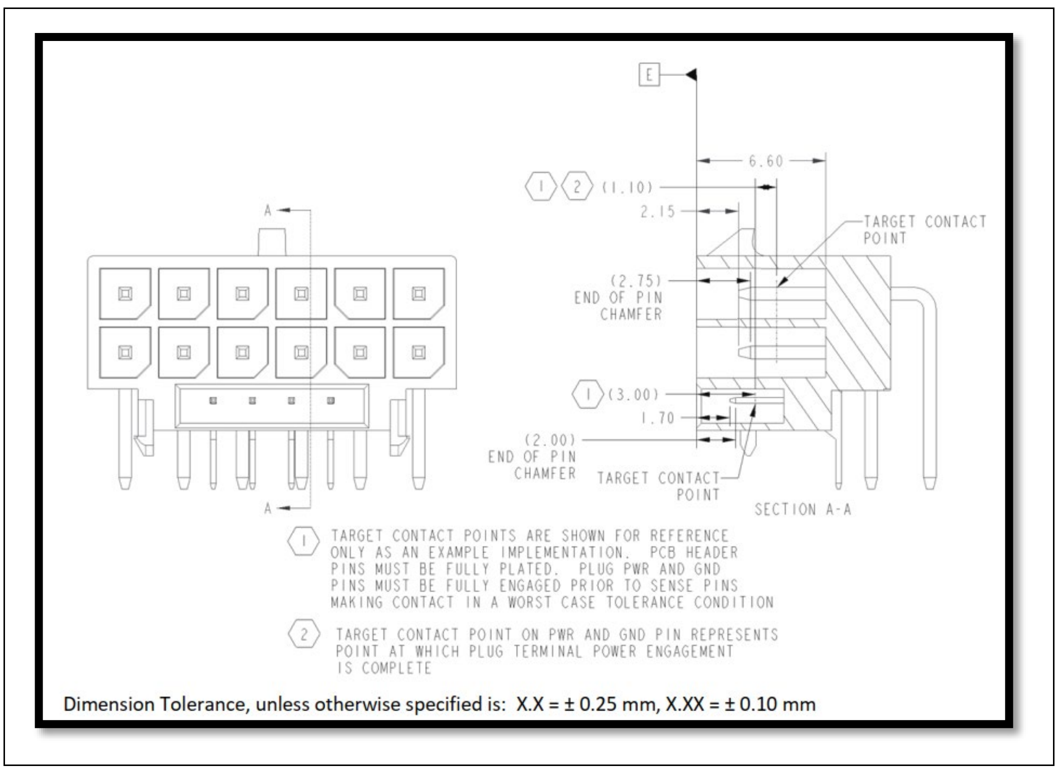
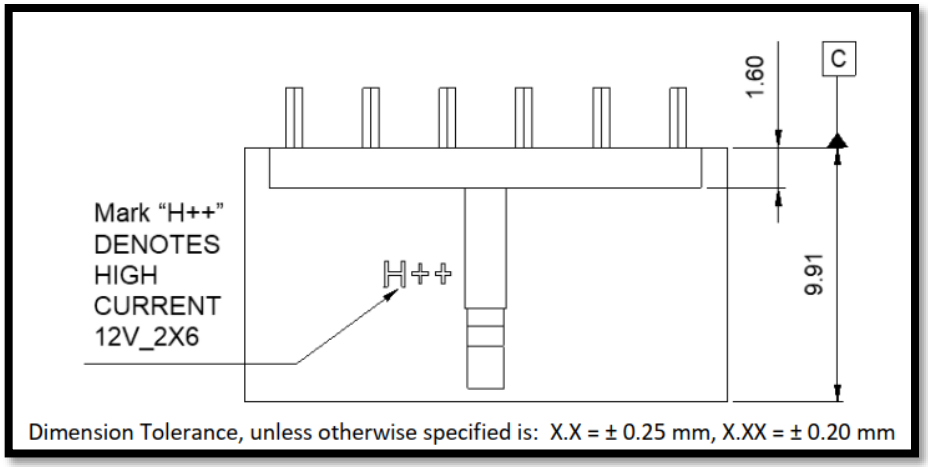


Figure 5-9: 12V-2x6 PCB Header – Top View



12V-2x6 Cable Plug Connection Recommendations

Crimp Contacts inside of the cable plug are may use either the 4-Spring design or the 3-dimple design (as shown in Figure 5-10). Both designs can meet the design and reliability requirements that are needed to provide the high current per pin of the 12V-2x6 connector. Whether using the 4-Spring or 3-Dimple Design, the design criteria recommended for these mechanical connections are listed below:

- Temperature Rise
  - Tested according to method EIA 364-70
  - 30 °C
- Temperature Life
  - Test Connector environmental tests shall follow EIA-364-1000.01
  - Test after 50 insertion-removal cycles
  - Field Temperature: 65°C
  - Field Life = Seven Years
- Low Level Contact Resistance (LLCR)
  - Tested according to method EIA 364-23C
  - All pins LLCR < 6 mOhms initial insertion
  - All pins LLCR < 6 mOhms after 30 insertion-removal cycles
  - LLCR shall not vary on any pin more than 50% from the average for each of these groups
    - Pins 1 – 6
    - Pins 7 – 12

Figure 5-10: 12V-2x6 Cable Plug Connection Recommendation

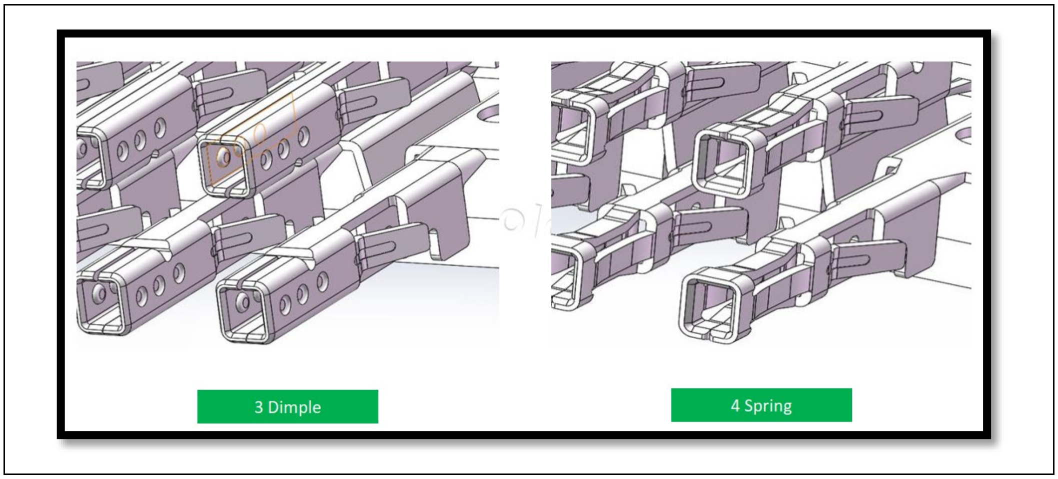


Image courtesy of Wieson Technologies Co., Ltd.

Table 5-7: PCIe* 12V-2x6 Auxiliary Power Connector Pin Assignment (600 watts)

Pin	Signal	Color[1]
1	+12V3/V4	Yellow
2	+12V3/V4	Yellow
3	+12V3/V4	Yellow
4	+12V3/V4	Yellow
5	+12V3/V4	Yellow
6	+12V3/V4	Yellow
S1	CARD_PWR_STABLE	Blue
S2	CARD_CBL_PRES#	Blue

Pin	Signal	Color[1]
7	COM	Black
8	COM	Black
9	COM	Black
10	COM	Black
11	COM	Black
12	COM	Black
S3	SENSE0	Blue
S4	SENSE1	Blue

The electrical function for the sideband pins S1- S4 is detailed in Section 3.3 of this document.

5.2.2.5 +12 V Power Connector

Connector: Molex* 0039012040 or equivalent.

Contact: Molex 44476-1112 (HCS) or equivalent (Mating motherboard connector is Molex 39-29-9042 or equivalent).

Table 5-8: +12 V Power 4 pin Connector Pin-out

Pin	Signal	Color[1]		Pin	Signal	Color[1]
1	COM	Black		3	+12V2 DC	Yellow
2	COM	Black		4	+12V2 DC	Yellow

Note: 18 AWG wire.

Table 5-9: +12 V Power 8 pin Connector Pin-Out

Pin	Signal	Color[1]		Pin	Signal	Color[1]
1	COM	Black		5	+12V2 DC	Yellow
2	COM	Black		6	+12V2 DC	Yellow
3	COM	Black		7	+12V2 DC	Yellow
4	COM	Black		8	+12V2 DC	Yellow

Note: 18 AWG wire.

5.2.2.6 Serial ATA* Connectors – REQUIRED

This is a required connector for systems with Serial ATA devices.

The detailed requirements for the Serial ATA Power Connector can be found in the "Serial ATA: High Speed Serialized AT Attachment" specification, Section 6.3 "Cables and connector specification".

http://www.serialata.org/

Note: Connector pin numbers and wire numbers are not 1:1. Carefully check to confirm the correct arrangement.

Assembly: Molex* 88751 or equivalent.

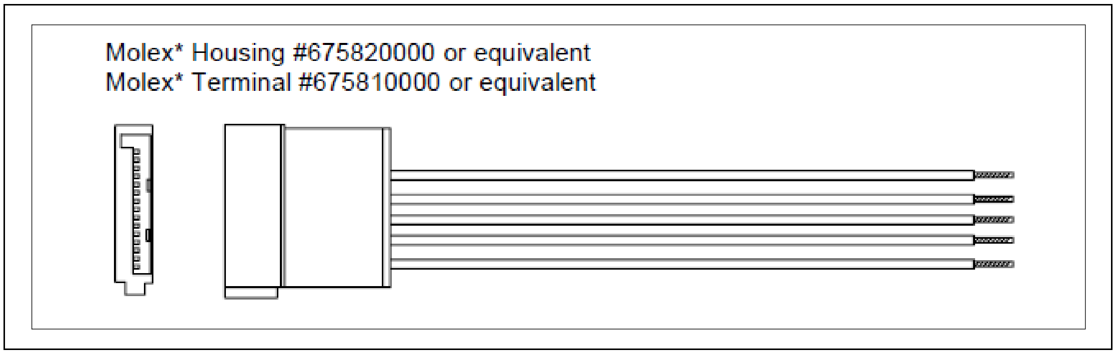
Table 5-10: Serial ATA* Power Connector Pin-out

Wire	Signal	Color[1]
5	+3.3V DC	Orange[2]
4	COM	Black
3	+5V DC	Red
2	COM	Black
1	+12V1 DC	Yellow

NOTES:

1. 18 AWG wire.
2. +3.3V DC is removed from SATA V3.2 spec. but it is recommended if there is backward compatibility concern.

Figure 5-11: Serial ATA* Power Connector



5.3 Airflow and Fans - RECOMMENDED

The designer's choice of a power supply cooling solution depends in part on the targeted end-use system application(s). At a minimum, the power supply design should ensure its own reliable and safe operation.

5.3.1 Fan Location and Direction

In general, exhausting air from the system chassis enclosure via a power supply fan at the rear panel is the preferred, most common, and most widely applicable system-level airflow solution. However, some system/chassis designers may choose to use other configurations to meet specific system cooling requirements.

5.3.2 Fan Size and Speed

A thermally sensitive fan speed control circuit is recommended to balance system-level thermal and acoustic performance. The circuit typically senses the temperature of the secondary heatsink and/or incoming ambient air and adjusts the fan speed as necessary to keep power supply and system component temperatures within specification. Both the power supply and system designers should be aware of the dependencies of the power supply and system temperatures on the control circuit response curve and fan size and should specify them carefully.

Fan should not turn on at the same time as PS_ON# is Asserted. This is because of power optimization at low levels and Alternative Low Power Modes. Two options to consider:

1. Wait for at least 2 seconds before the fan turns on.
2. Fan needs to be only turned on when the PSU needs the thermal cooling.

The power supply fan should be turned off when PS_ON# is de-asserted (high). In this state, any remaining active power supply circuitry must rely only on passive convection for cooling.

5.3.3 Venting

In general, more venting in a power supply case yields reduced airflow impedance and improved cooling performance. Intake and exhaust vents should be large, open, and unobstructed as possible so as not to impede airflow or generate excessive acoustic noise. In particular, avoid placing objects within 0.5 inches of the intake or exhaust of the fan itself. A flush-mount wire fan grill can be used instead of a stamped metal vent for improved airflow and reduced acoustic noise.

The limitations to the venting guidelines above are:

- Openings must be sufficiently designed to meet the safety requirements described in Chapter 9.
- Larger openings yield decreased EMI-shielding performance. Refer to Chapter 8.
- Venting in inappropriate locations can detrimentally allow airflow to bypass those areas where it is needed.

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6 Acoustics

6.1 Acoustics – RECOMMENDED

It is recommended that the power supply be designed with an appropriate fan, internal impedance, and fan speed control circuitry capable of meeting the acoustic targets listed in Table 6-1: Recommended Power Supply Acoustic Targets.

The power supply assembly should not produce, and prominent discrete tone determined according to ISO 7779, Annex D.

Sound power determination is to be performed at 43 C, at 50% of the maximum rated load, at sea level. This test point is chosen to represent the environment seen inside a typical system at the idle acoustic test condition, with the 43 C being derived from the standard ambient assumption of 23 C, with 20 C added for the temperature rise within the system (what is typically seen by the inlet fan). The declared sound power shall be measured according to ISO 7779 and reported according to ISO 9296.

Different customers might have different acoustic specifications. Any power supply design is recommended to follow any specific customer requirements.

Table 6-1: Recommended Power Supply Acoustic Targets

	Idle (BA)	Typical (50% load) (BA)	Maximum (BA)
Minimum	3.5	4.0	5.0
Target	3.0	3.8	4.5

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7 Environmental

The following subsections define environmental specifications and test parameters, based on the typical conditions to which a power supply may be subjected during operation or shipment.

7.1 Temperature – RECOMMENDED

- Operating ambient +10 °C to +50 °C (At full load, with a maximum temperature rate of change of 5 °C/10 minutes, but no more than 10 °C/hr.)
- Non-operating ambient -40 °C to +70 °C (Maximum temperature rate of change of 20 °C/hr.)

7.2 Thermal Shock (Shipping) - RECOMMENDED

- Non-operating -40 °C to +70 °C
- 15 °C/min ≤ dT/dt ≤ 30 °C/min
- Tested for 50 cycles; Duration of exposure to temperature extremes for each half cycle shall be 30 minutes.

7.3 Humidity – RECOMMENDED

- Operating To 85% relative humidity (non-condensing)
- Non-operating to 95% relative humidity (non-condensing)
- Note: 95% relative humidity is achieved with a dry bulb temperature of 55 °C and a wet bulb temperature of 54 °C.

7.4 Altitude – RECOMMENDED

- Operating to 10,000 ft.
- Non-operating to 50,000 ft.

7.5 Mechanical Shock – RECOMMENDED

- Non-operating 50 g, trapezoidal input; velocity change ≥ 170 in/s
- Three drops on each of six faces are applied to each sample.

7.6 Random Vibration – RECOMMENDED

- Non-operating 0.01 g^2/Hz at 5 Hz, sloping to 0.02 g^2/Hz at 20 Hz, and maintaining 0.02 g^2/Hz from 20 Hz to 500 Hz. The area under the PSD curve is 3.13 grams. The duration shall be 10 minutes per axis for all three axes on all samples.

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8 Electromagnetic Compatibility

The following subsections outline applicable product regulatory requirements for the power supplies. Additional requirements may apply dependent upon the design, product end use, target geography, and other variables.

8.1 Emissions – REQUIRED

The power supply shall comply with FCC Part 15, EN55023 and CISPR 22, 5th ed., meeting Class B for both conducted and radiated emissions with a 4 dB margin. Tests shall be conducted using a shielded DC output cable to a shielded load. The load shall be adjusted as follows for three tests: No load on each output; 50% load on each output; 100% load on each output. Tests will be performed at 100 VAC 50Hz, 120 VAC 60 Hz, and 230 VAC 50 Hz power. Additionally, for FCC certification purposes, the power supply shall be tested using the methods in 47 CFR 15.32(b) and authorized under the Declaration of Conformity process as defined in 47 CFR 2.906 using the process in 47 CFR 2.1071 through 47 CFR 2.1077.

8.2 Immunity - REQUIRED

The power supply shall comply with EN 55024 and CISPR 24 prior to sale in the EU (European Union), Korea, and possibly other geographies.

8.3 Input Line Current Harmonic Content - OPTIONAL

Class D harmonic limits will be determined at the time of measurement based on the actual power draw from the mains.

Table 8-1 is a partial list of countries and their current EMC requirements. Additional requirements may apply dependent upon the design, product end use, target geography, and other variables.

Table 8-1: EMC Requirement by Country

Country	Requirements Document
EU (European Union)	EN61000-3-2
Japan	JEIDA MITI
China	CCC and GB 17625.1
Russia	GOST R 51317.3.2

8.4 Magnetic Leakage Field - REQUIRED

A PFC choke magnetic leakage field must not cause any interference with a high-resolution computer monitor placed next to or on top of the end-use chassis.

8.5 Voltage Fluctuations and Flicker – REQUIRED

The power supply shall meet the specified limits of EN61000-3-3 (IEC 61000-3-3) and amendment A1 to EN 61000-3-3 (IEC 61000-3-3/A1) for voltage fluctuations and flicker for equipment drawing not more than 16VAC, connected to low voltage distribution systems.

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9 Safety

The following subsections outline sample product regulations requirements for a typical power supply. Actual requirements will depend on the design, product end use, target geography, and other variables. Consult your company's Product Safety and Regulations department or an accredited third-party certification agency for more details.

9.1 North America – REQUIRED

The power supply must be certified by an NRTL (Nationally Recognized Testing Laboratory) for use in the USA and Canada under the following conditions:

- The power supply UL report "Conditions of Acceptability" shall meet in the intended application of the power supply in the end product.
- The supply must be recognized for use in Information Technology Equipment including Electrical Business Equipment per UL 60950-1 First Edition. The certification must include external enclosure testing for the AC receptacle side of the power supply.
- The supply must have a full complement of tests conducted as part of the certification, such as input current, leakage current, hi-pot, temperature, energy discharge test, transformer output characterization test (open-circuit voltage, short-circuit performance), and abnormal testing (to include stalled-fan tests and voltage-select–switch mismatch).
- The enclosure must meet fire enclosure mechanical test requirements per clauses 2.9.1 and 4.2 of the above-mentioned standard.
- Production hi-pot testing must be included as a part of the certification and indicated as such in the certification report.
- There must not be unusual or difficult conditions of acceptability such as mandatory additional cooling or power de-rating. The insulation system shall not have temperatures exceeding their rating when tested in the end product.
- The certification mark shall be marked on each power supply.
- The power supply must be evaluated for operator-accessible secondary outputs (reinforced insulation) that meet the requirements for SELV.
- The proper polarity between the AC input receptacle and any printed wiring boards connections must be maintained (that is, brown=line, blue=neutral, and green=earth/chassis).
- The fan shall be protected by a guard to prevent contact by a finger in compliance with UL accessibility requirements.

9.2 International – REQUIRED

The vendor must provide a complete CB certificate and test report to IEC 60950-1. The CB report must include ALL CB member country national deviations as appropriate for the target market. All evaluations and certifications must be for reinforced insulation between primary and secondary circuits.

The power supply must meet the RoHS requirements for the European Union, Peoples Republic of China and other countries which have adopted the RoHS requirements for banned materials.

9.3 Proscribed Materials - REQUIRED

The following materials must not be used during design and/or manufacturing of this product:

- Cadmium shall not be used in painting or plating - REQUIRED.
- Quaternary salt and PCB electrolytic capacitors shall not be used - REQUIRED.
- CFC's or HFC's shall not be used in the design or manufacturing process - REQUIRED.
- Mercury shall not be used - REQUIRED.
- Some geographies require lead free or RoHS compliant power supplies - REQUIRED.

9.4 Catastrophic Failure Protection - RECOMMENDED

Should a component failure occur, the power supply should not exhibit any of the following:

- Flame
- Excessive smoke
- Charred PCB
- Fused PCB conductor
- Startling noise
- Emission of molten material
- Earth ground fault (short circuit to ground or chassis enclosure)

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10 Reliability

10.1 Reliability - RECOMMENDED

The de-rating process promotes quality and high reliability. All electronic components should be designed with conservative device de-ratings for use in commercial and industrial environments.

Electrolytic capacitor and fan lifetime and reliability should be considered in the design as well.

10.2 Reliability – PS_ON# toggle for S0ix mode - REQUIRED

Computer can periodically wake from S0ix depending on operation system, installed software, user interaction and other design implementation. Such wakes can have impact not only to the PSU reliability, but also be a source of end user annoyance with PSU fan spinning on then off again.

In order to optimize desktop platform power consumption, Intel provides design recommendation to enable power supply PS_ON# toggle on/off during S0 idle power mode (S0ix) to save both system and PSU power. The power supply PS_ON# signal may toggle on/off every 180s (PSU to be on for up to 1s and off for 180s) when customer desktop designs implement S0 idle which is different from the legacy desktop platform design that PS_ON# only toggles once when turned on. The S0ix mode is used in systems that use Alternative Low Power Modes. This on / off toggling comes from scheduled OS maintenance tasks that occur in the background that necessitate bringing the PC on in order to execute CPU instructions.

Although the periodicity for on/off toggling is non-deterministic, it can happen regularly after the system has entered the S0ix idle mode with PS_ON# de-asserted. If the computer turns on/off every 180 seconds, the worst-case scenario would be 480 times in one day and 175,200 times in one year. The power supply needs to be able to handle this many cycles for the life of the power supply.

To have a better user experience, and avoid PSU fan acoustic noise annoyance, system and PSU designers should have at least two seconds delay time for the PSU fan to spin up after PS_ON# assertion. A PSU is expected to support running at full load without any electrical, thermal components (i.e., IC, MOSFET, diode, transformer, inductor, capacitor, relay, fan, etc.) damaged or degraded during the period of time before the warranty expired. Due to the frequent PS_ON# toggle on/off, system and PSU component's reliability should be considered based on the days, months, or years of claimed warranty listed on product specification. This is also mentioned in Section 5.3.2.

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11 CFX12V Specific Guidelines 2.1

For Compact Form Factor with 12-volt connector power supplies.

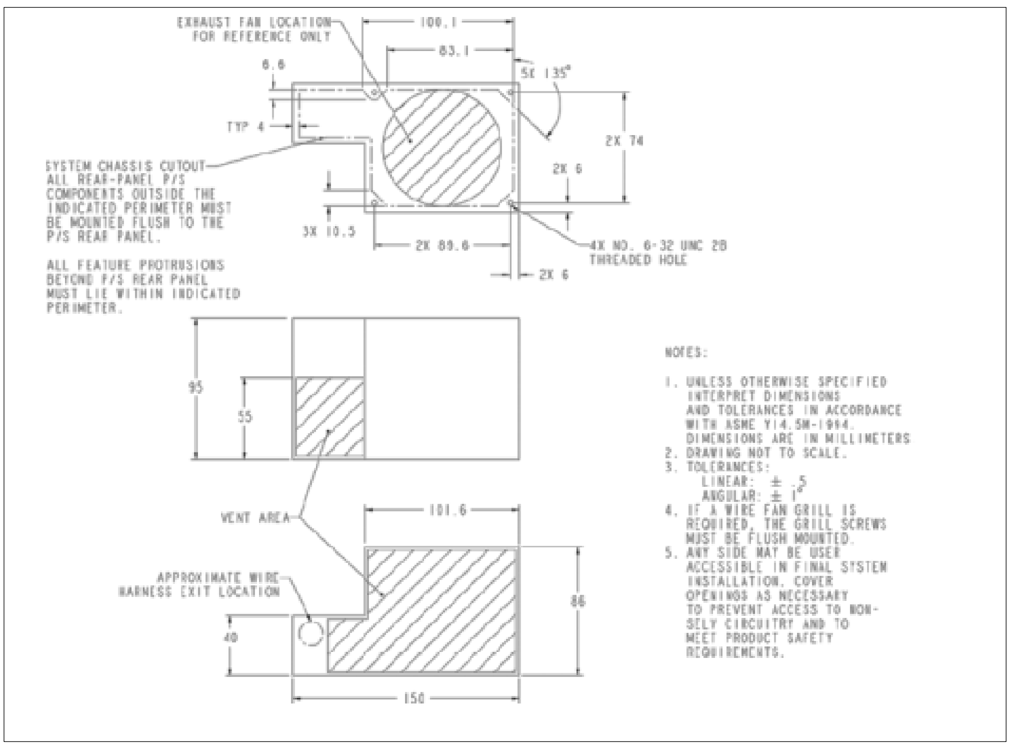
All Form Factors Revision Summary:

PSU DG	CFX12V	LFX12V	ATX12V	SFX12V	TFX12V	Flex ATX
2.1	2.1	2.1	3.1	4.1	3.1	2.1

11.1 Physical Dimensions – REQUIRED

The power supply shall be enclosed and meet the physical outline shown.

Figure 11-1: CFX12V Mechanical Outline



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12 LFX12V Specific Guidelines 2.1

For Low Profile Form Factor with 12-volt connector power supplies.

All Form Factors Revision Summary:

PSU DG	CFX12V	LFX12V	ATX12V	SFX12V	TFX12V	Flex ATX
2.1	2.1	2.1	3.1	4.1	3.1	2.1

12.1 Physical Dimensions - REQUIRED

The power supply shall be enclosed and meet the physical outline shown in Figure 12-1, applicable. Mechanical details are shown in Figure 12-2. Details on the power supply slot feature are shown in Figure 12-3. The recommended chassis slot feature details are shown in Figure 12-4.

Figure 12-1: LFX 12V Mechanical Outline

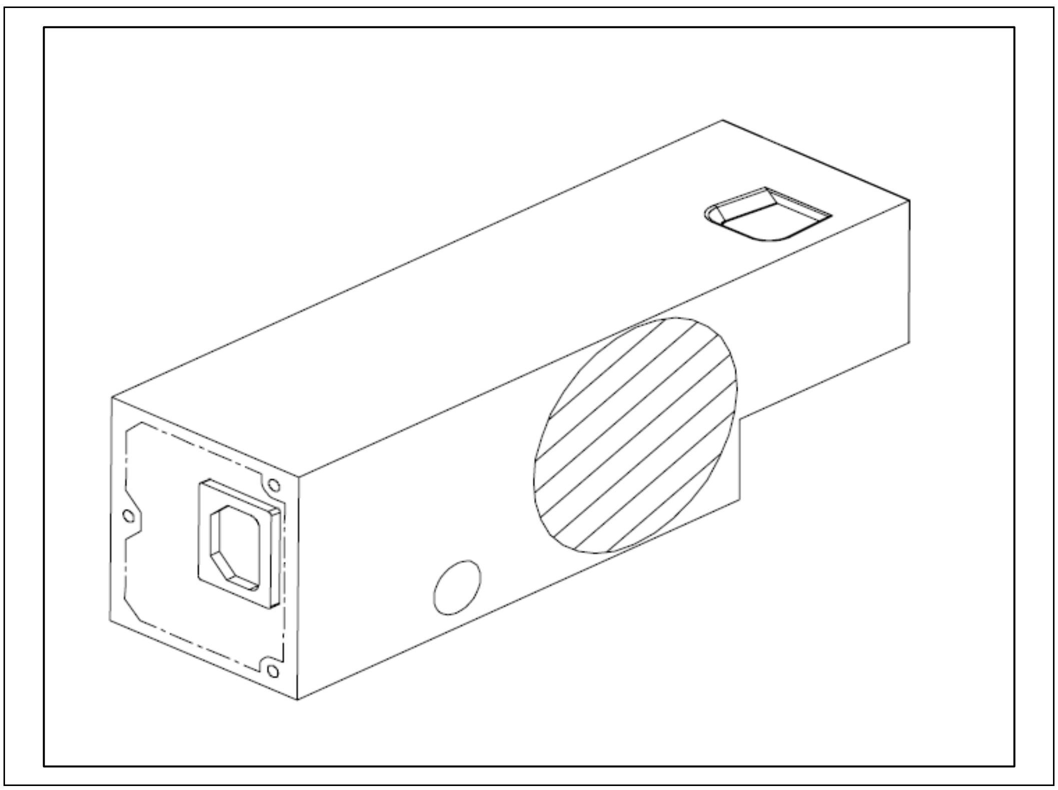


Figure 12-2: Mechanical Details

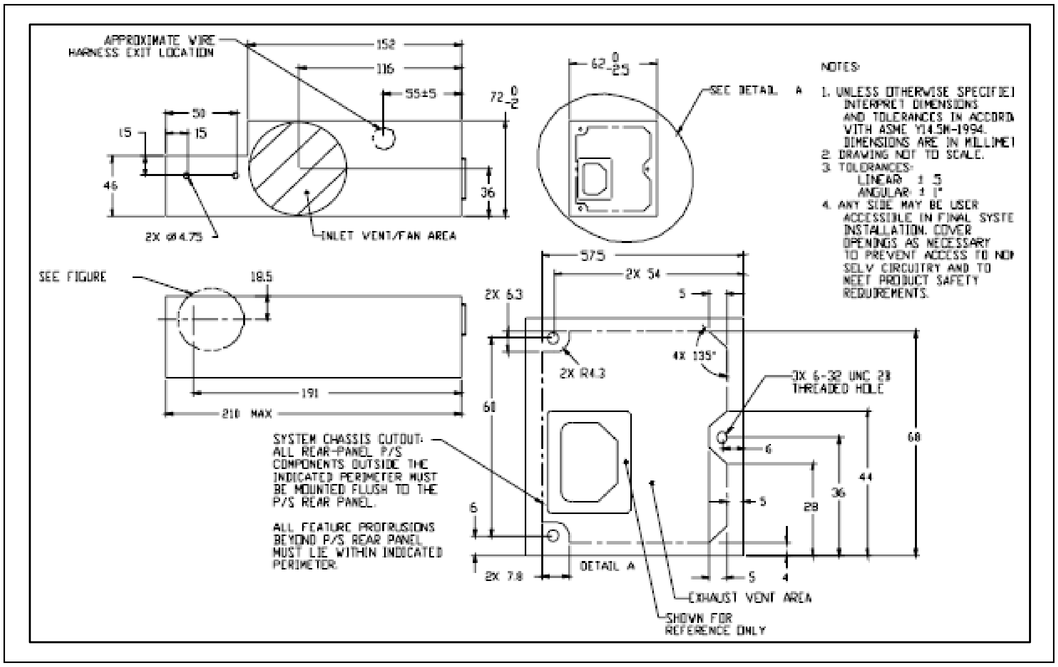


Figure 12-3: PSU Slot Feature Detail

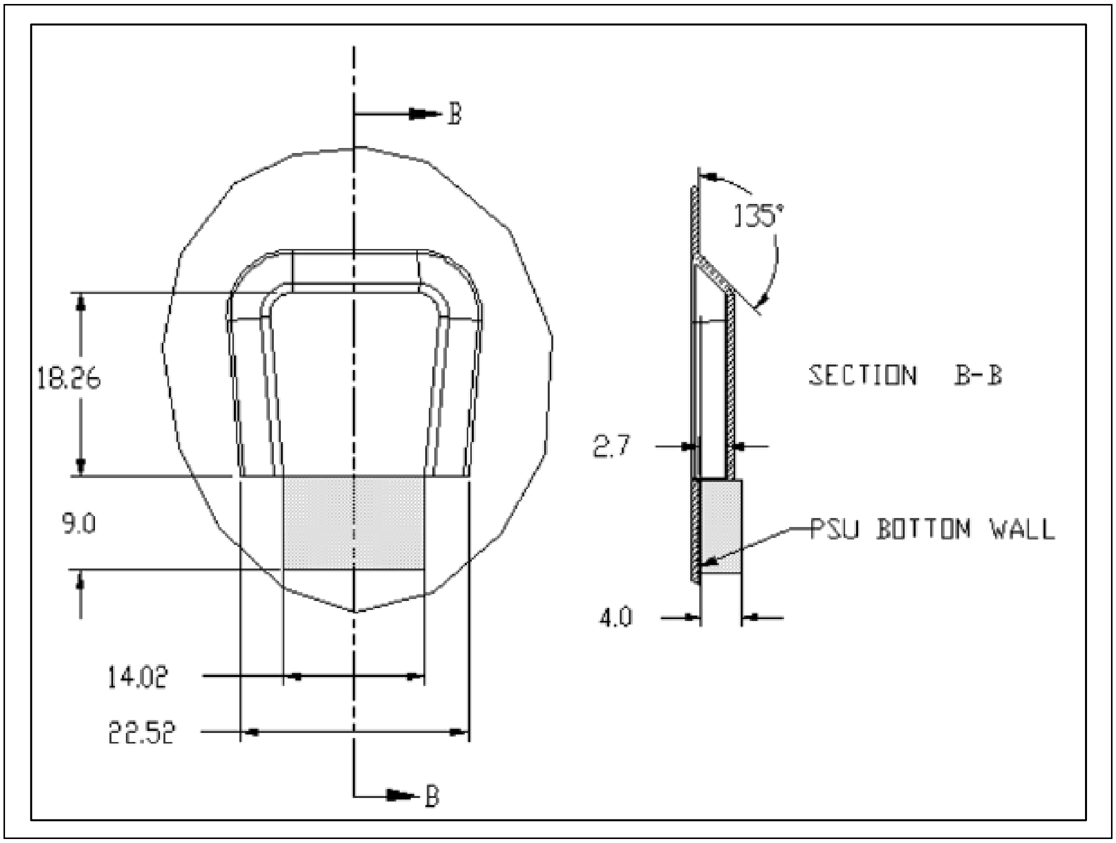
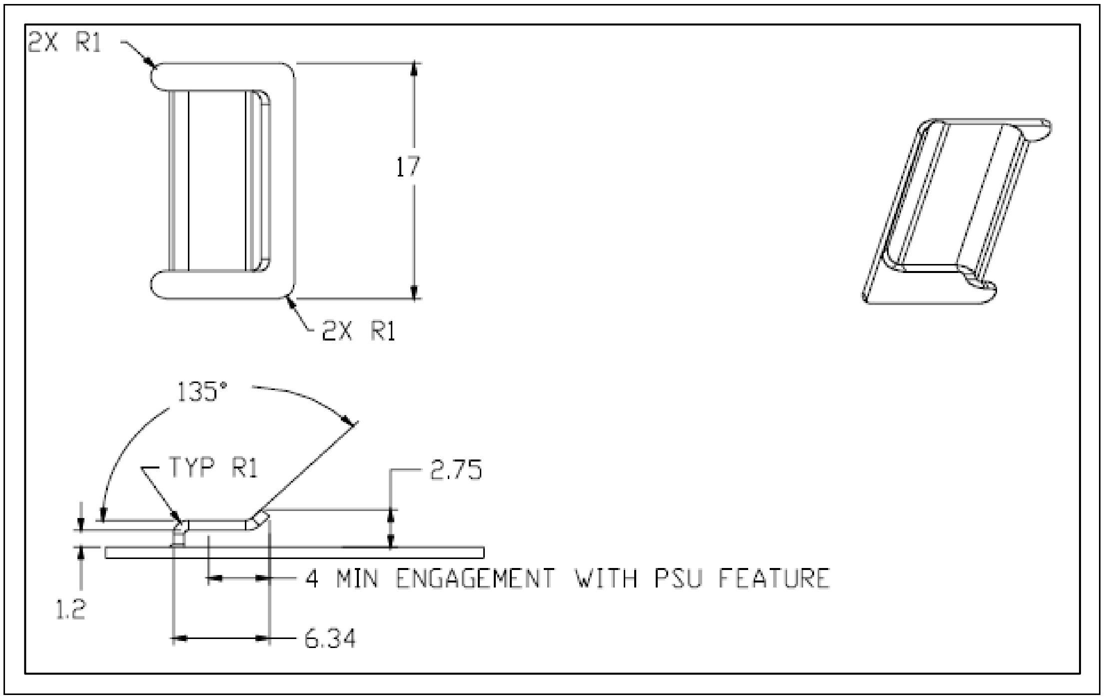


Figure 12-4: Recommended Chassis Tab Feature



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13 ATX12V Specific Guidelines 3.1

For ATX Form Factor with 12-volt connector power supplies.

All Form Factors Revision Summary:

PSU DG	CFX12V	LFX12V	ATX12V	SFX12V	TFX12V	Flex ATX
2.1	2.1	2.1	3.1	4.1	3.1	2.1

Figure 13-1: Power Supply Dimensions for Chassis that does not Require Top Venting

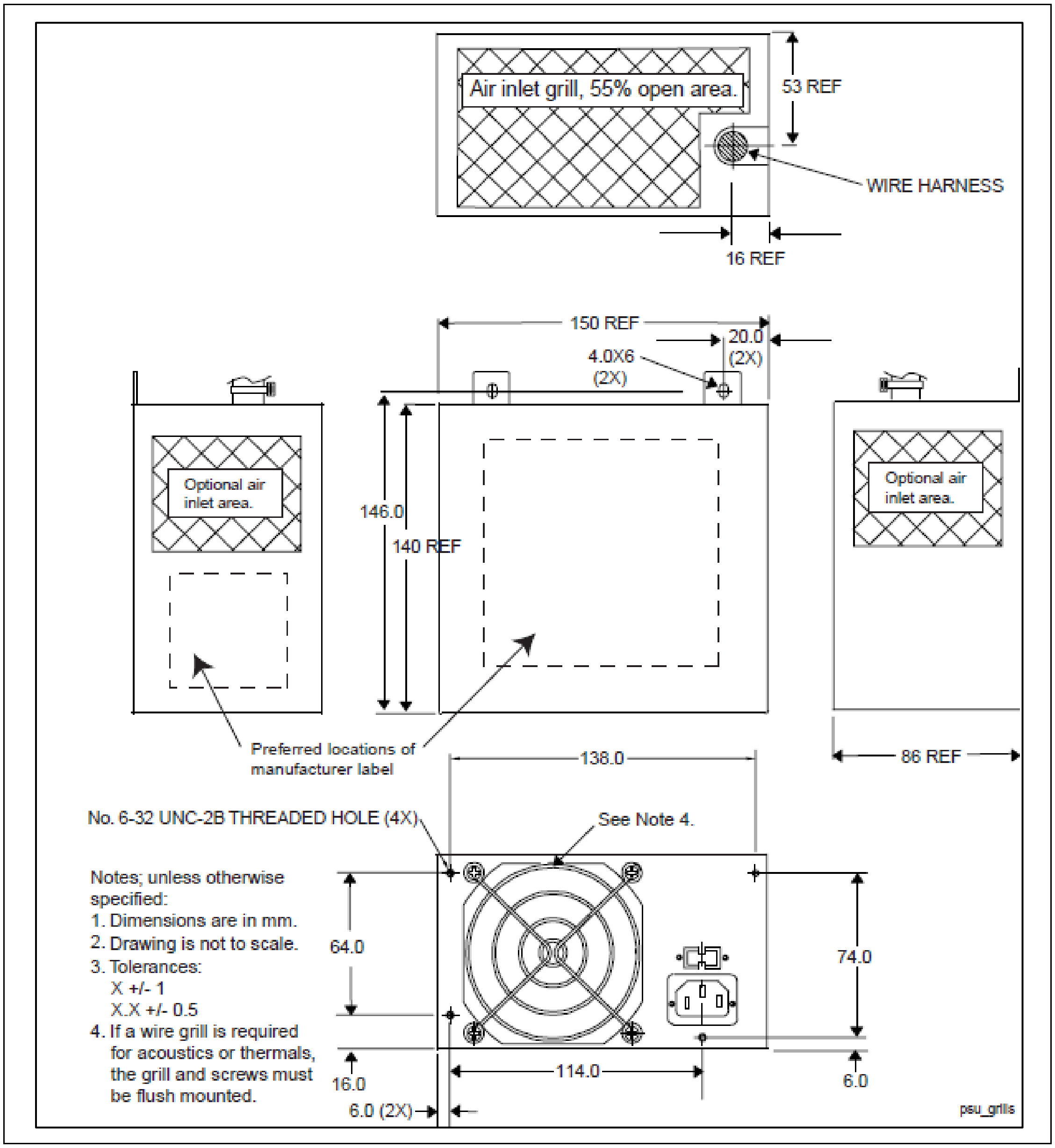
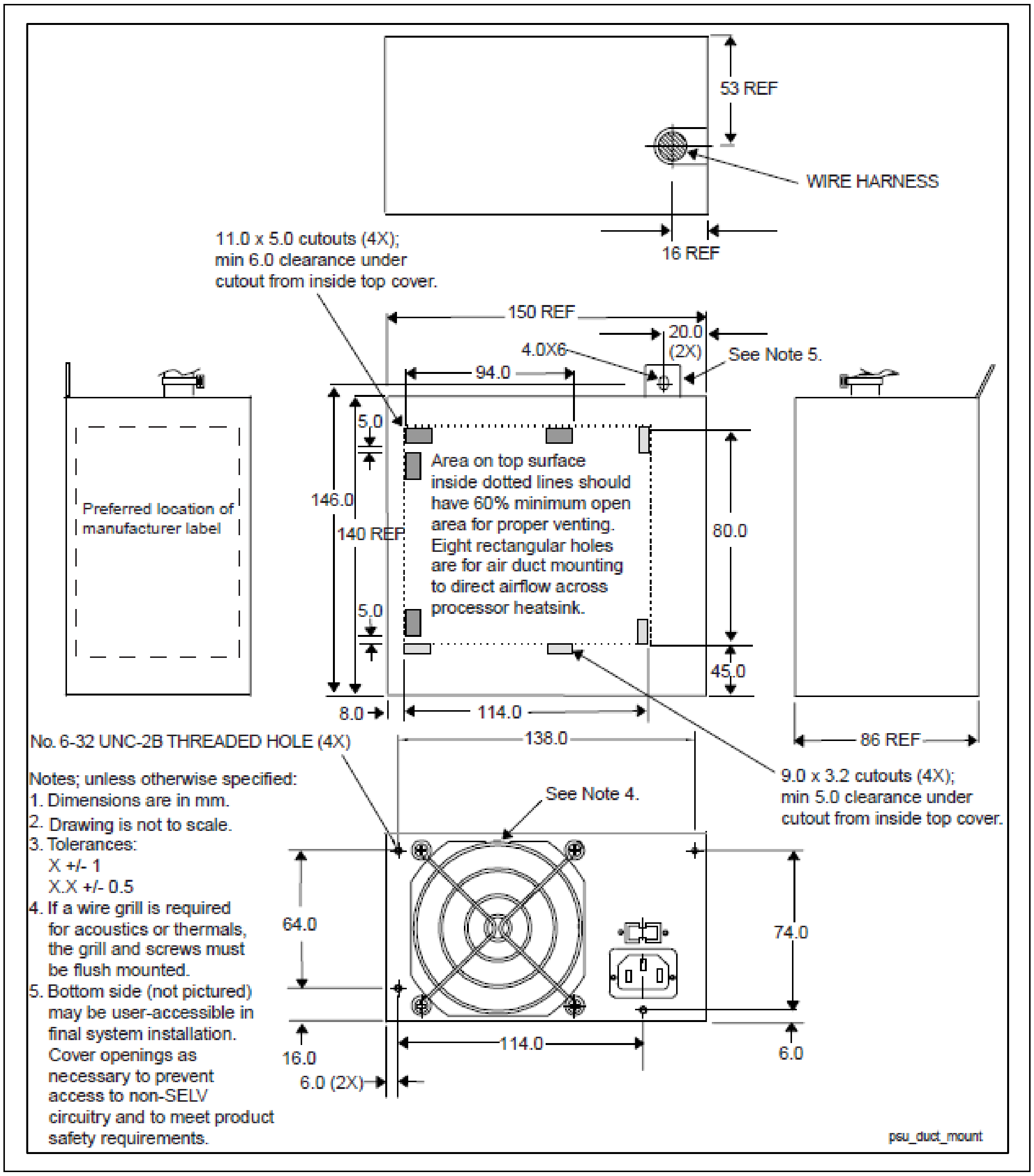


Figure 13-2: Power Supply Dimensions for Chassis that Require Top Venting



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14 SFX12V Specific Guidelines 4.1

For Small Form Factor with 12-volt connector power supplies.

All Form Factors Revision Summary:

PSU DG	CFX12V	LFX12V	ATX12V	SFX12V	TFX12V	Flex ATX
2.1	2.1	2.1	3.1	4.1	3.1	2.1

14.1 Lower Profile Package - Physical Dimensions - REQUIRED

The power supply shall be enclosed and meet the physical outline shown in Figure 14-1.

14.2 Fan Requirements - REQUIRED

The fan will draw air from the computer system cavity pressurizing the power supply enclosure. The power supply enclosure shall exhaust the air through a grill located on the rear panel. Refer to Figure 14-2. The movement of the fan to the computer system cavity is to help limit the acoustic noise of the unit.

The fan will be 40 mm.

Figure 14-1: 40 mm Profile Mechanical Outline

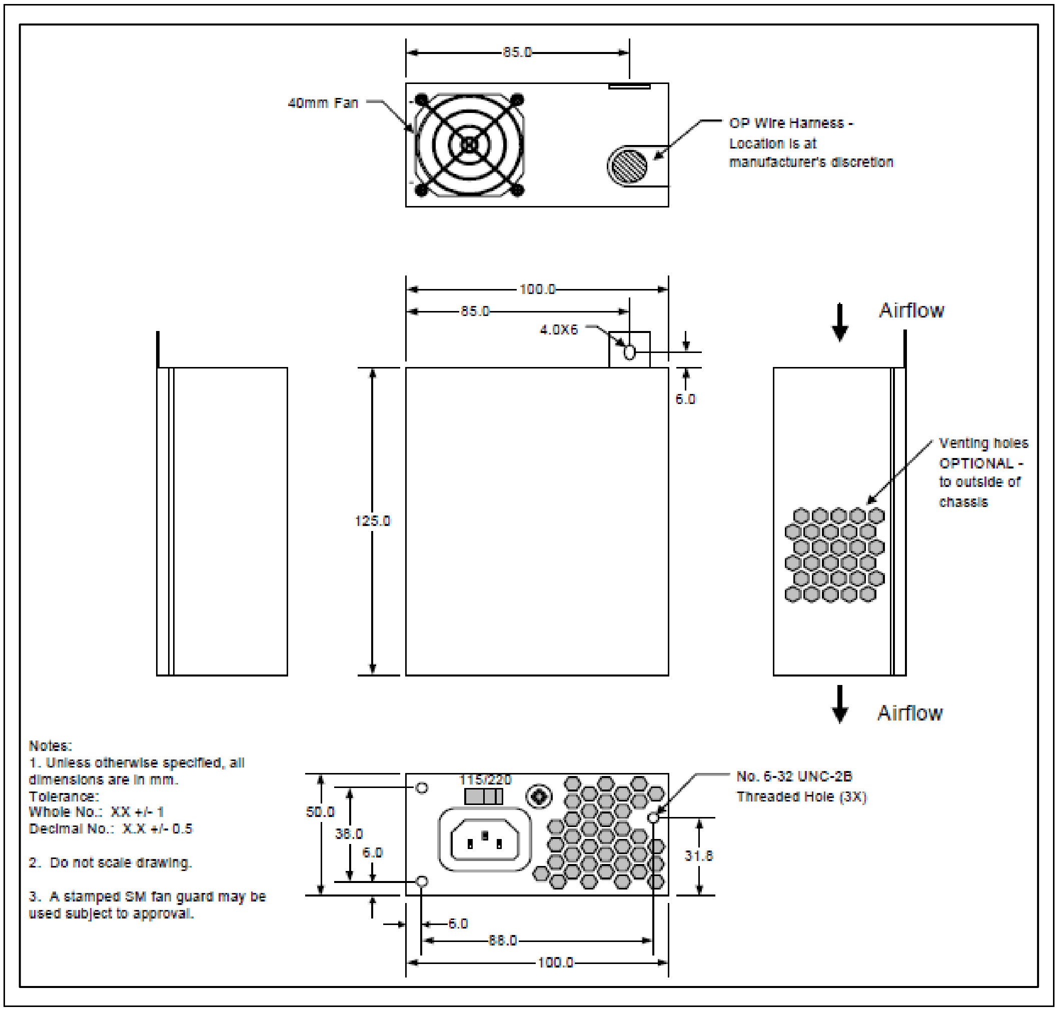
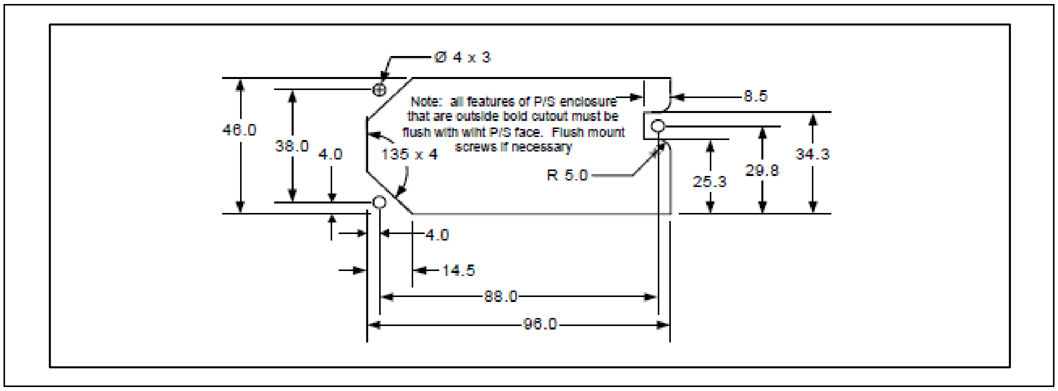


Figure 14-2: Chassis Cutout



14.3 Top Fan Mount Package - Physical Dimensions - REQUIRED

The power supply shall be enclosed and meet the physical outline shown in Figure 14-3.

14.4 Fan Requirements - REQUIRED

The fan will draw air from the computer system cavity pressurizing the power supply enclosure. The power supply enclosure shall exhaust the air through a grill located on the rear panel. Refer to Figure 14-4. Moving the fan to the computer system cavity helps to limit the acoustic noise of the unit.

The fan will be 80mm.

To prevent damage to the fan during shipment and handling, the power supply designer should consider recessing the fan mounting, as shown in Figure 14-5.

Figure 14-3: Top Mount Fan Profile Mechanical Outline

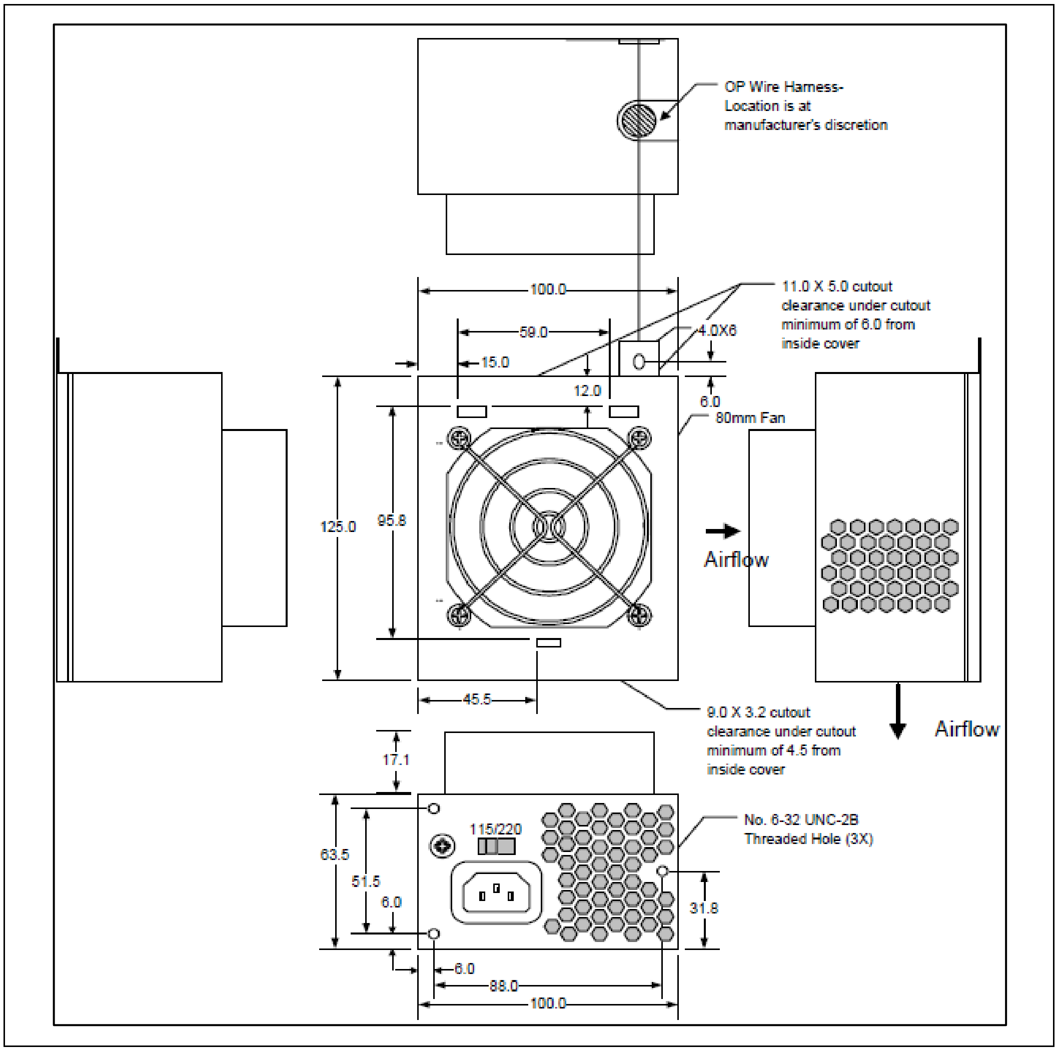


Figure 14-4: Chassis Cutout

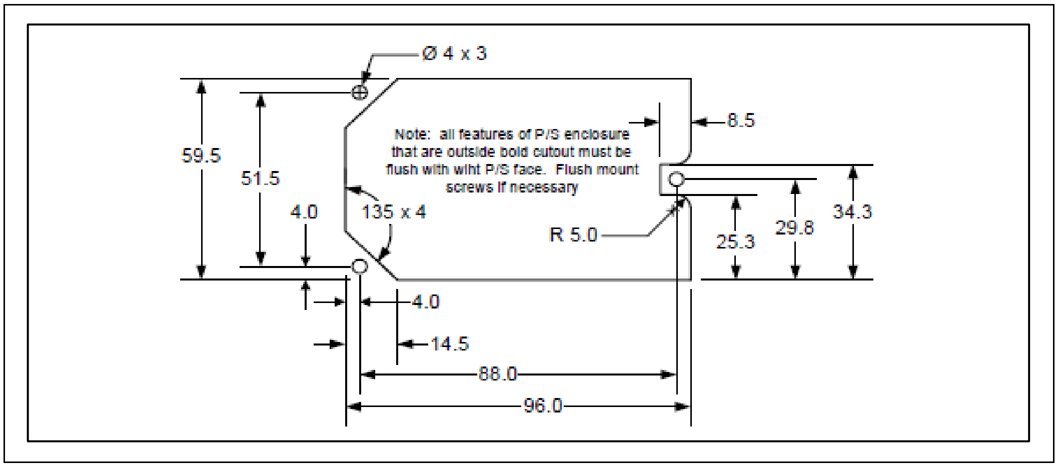
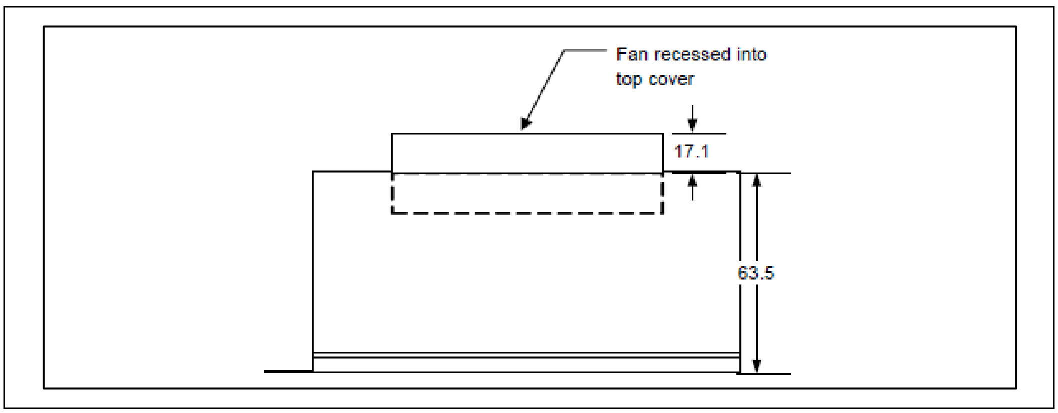


Figure 14-5: Recessed Fan Mounting



14.5 Reduced Depth Top Mount Fan - Physical Dimensions - REQUIRED

The power supply shall be enclosed and meet the physical outline shown in Figure 14-6.

14.6 Fan Requirements - REQUIRED

The fan will draw air from the computer system cavity pressurizing the power supply enclosure. The power supply enclosure shall exhaust the air through a grill located on the rear panel. Refer to Figure 14-7. Moving the fan to the computer system cavity helps to limit the acoustic noise of the unit.

The fan will be 80 mm.

Figure 14-6: Reduced Depth Top Mount Fan Profile Mechanical Outline

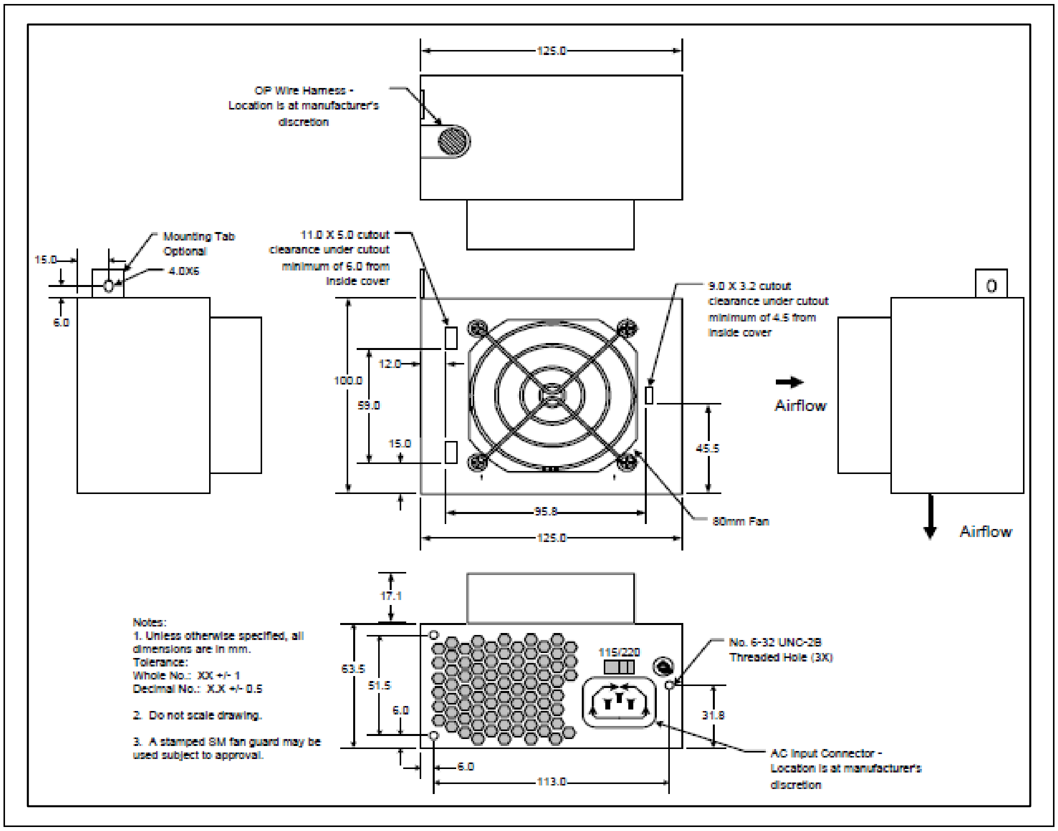
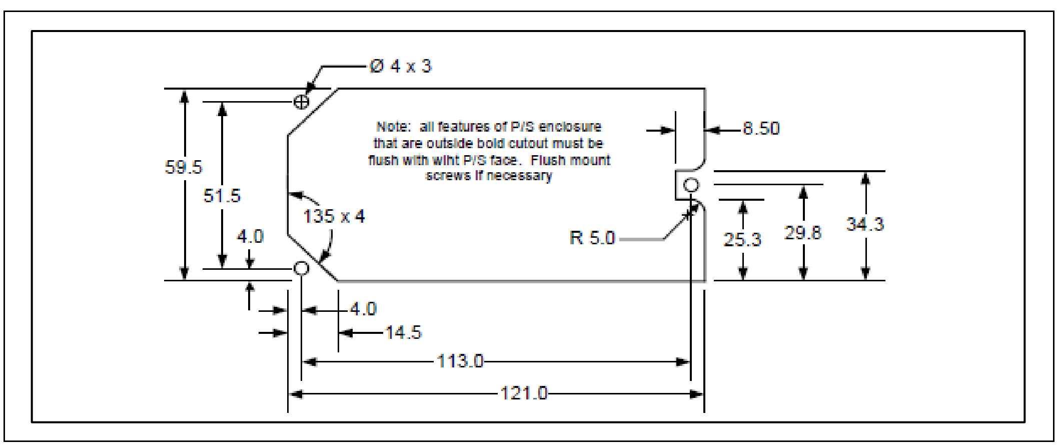


Figure 14-7: Chassis Cutout



14.7 Standard SFX Profile Package – Physical Dimensions - REQUIRED

The power supply shall be enclosed and meet the physical outline shown in Figure 14-8.

14.8 Fan Requirements - REQUIRED

The fan will draw air from the computer system cavity pressurizing the power supply enclosure. The power supply enclosure shall exhaust the air through a grill located on the rear panel. Refer to Figure 14-9. The movement of the fan to the computer system cavity is to help limit the acoustic noise of the unit.

The fan will be 60 mm.

Figure 14-8: 60 mm Mechanical Outline

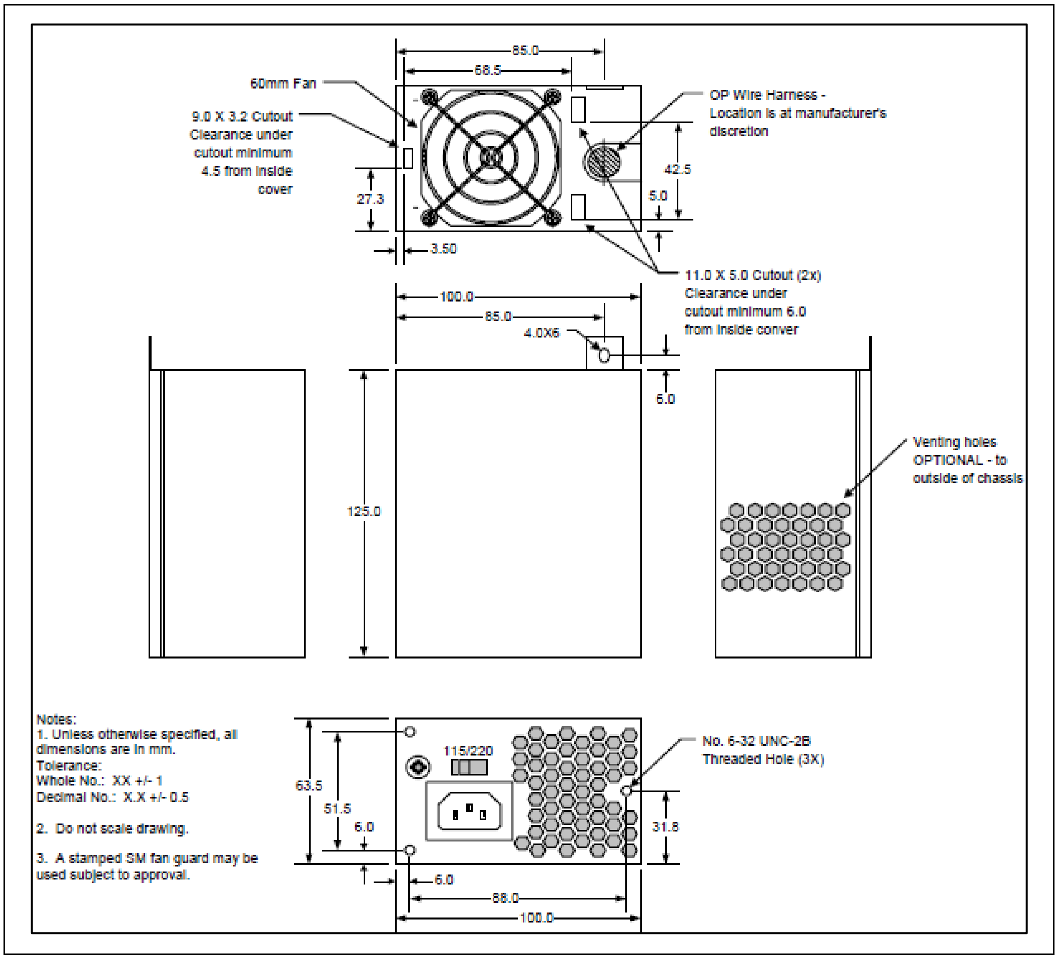
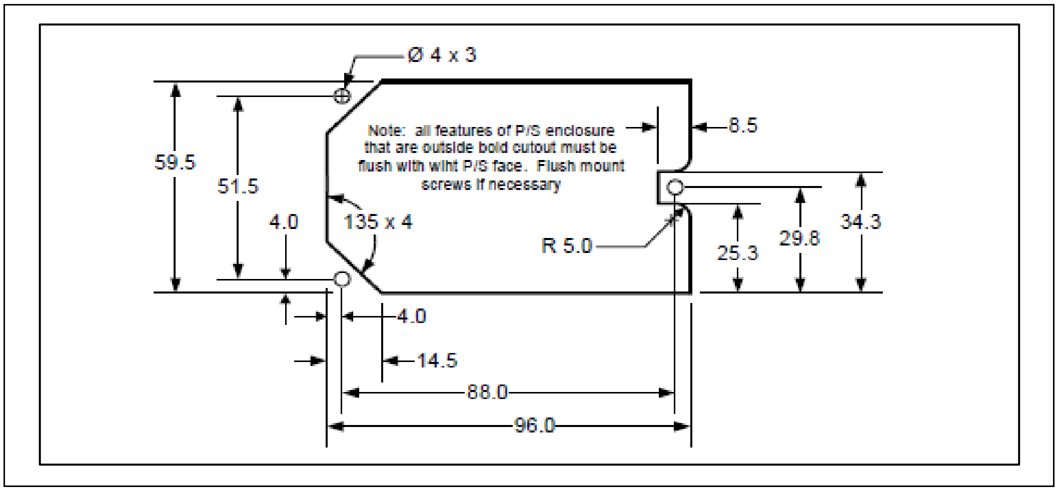


Figure 14-9: Chassis Cutout



14.9 PS3 Form Factor-Physical Dimensions - REQUIRED

The power supply shall be enclosed and meet the physical outline shown in Figure 14-10.

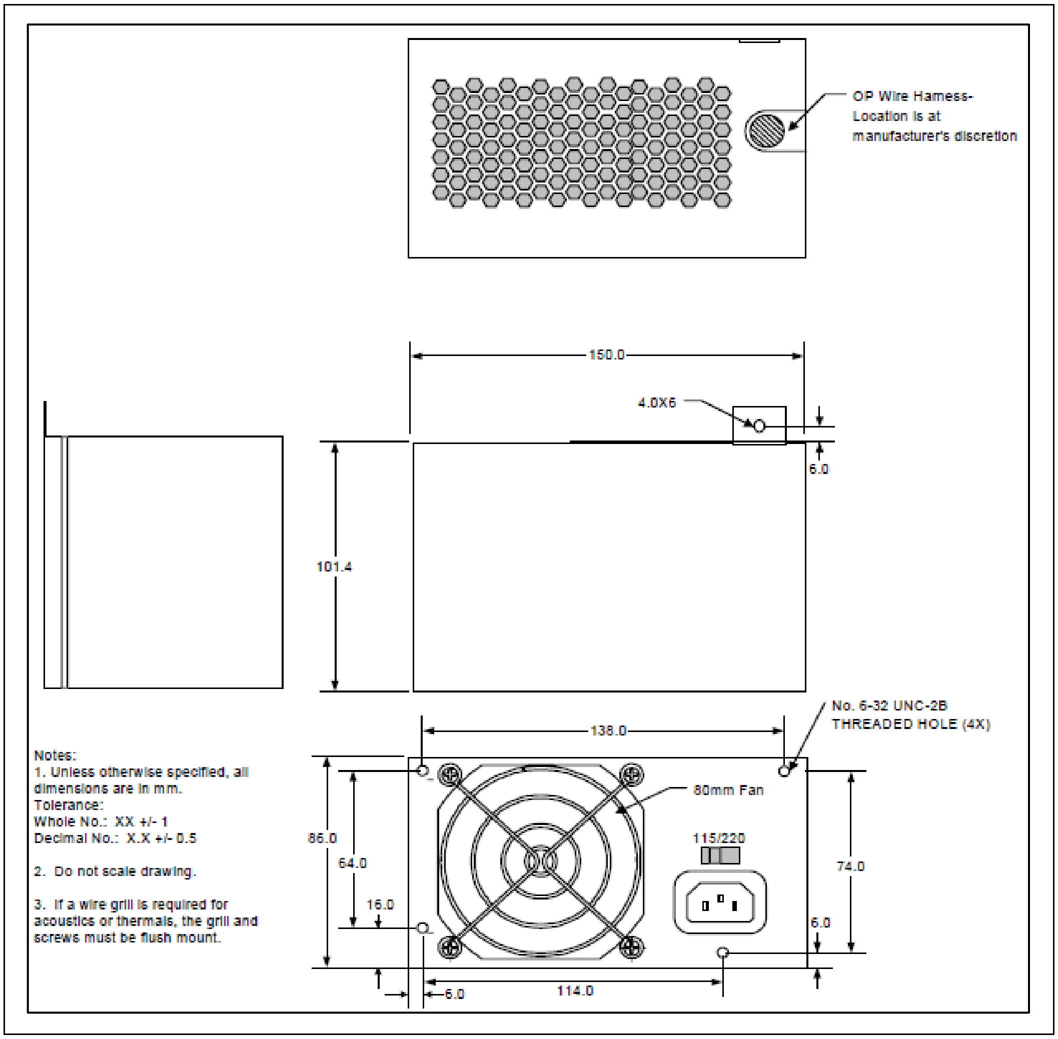
14.10 Fan Requirements - REQUIRED

An 80 mm axial fan is typically needed to provide enough cooling airflow through a high performance Micro ATX system. Exact CFM requirements vary by application and endues environment, but 25-35 CFM is typical for the fan itself.

For consumer or other noise-sensitive applications, it is recommended that a thermally sensitive fan speed control circuit be used to balance system-level thermal and acoustic performance. The circuit typically senses the temperature of an internal heatsink and/or incoming ambient air and adjusts the fan speed as necessary to keep power supply and system component temperatures within specification. Both the power supply and system designers should be aware of the dependencies of the power supply and system temperatures on the control circuit response curve and fan size and should specify them very carefully.

The power supply fan shall be turned off when PS_ON# is de-asserted (high). In this state, any remaining active power supply circuitry must rely only on passive convection for cooling.

Figure 14-10: PS3 Mechanical Outline



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15 TFX12V Specific Guidelines 3.1

For Thin Form Factor with 12-volt connector power supplies.

All Form Factors Revision Summary:

PSU DG	CFX12V	LFX12V	ATX12V	SFX12V	TFX12V	Flex ATX
2.1	2.1	2.1	3.1	4.1	3.1	2.1

15.1 Physical Dimensions - REQUIRED

Figure 15-1: Mechanical Outline

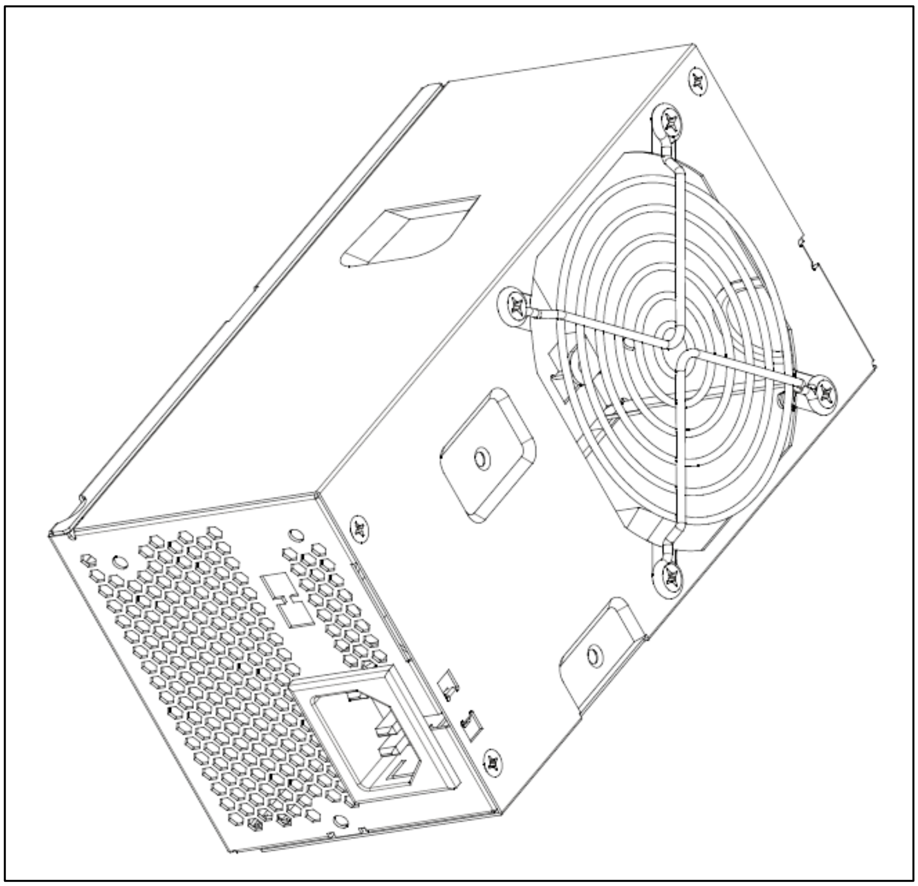
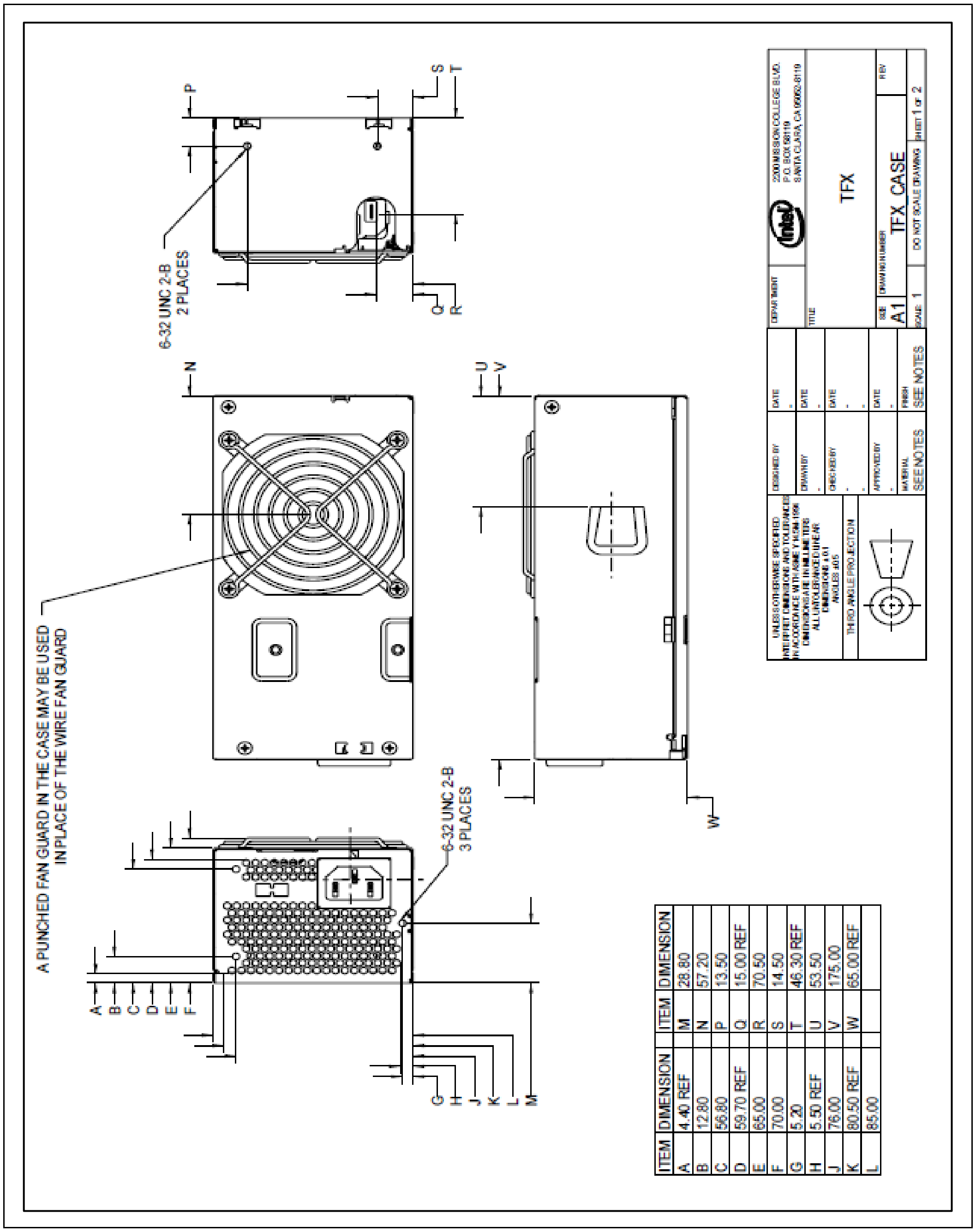
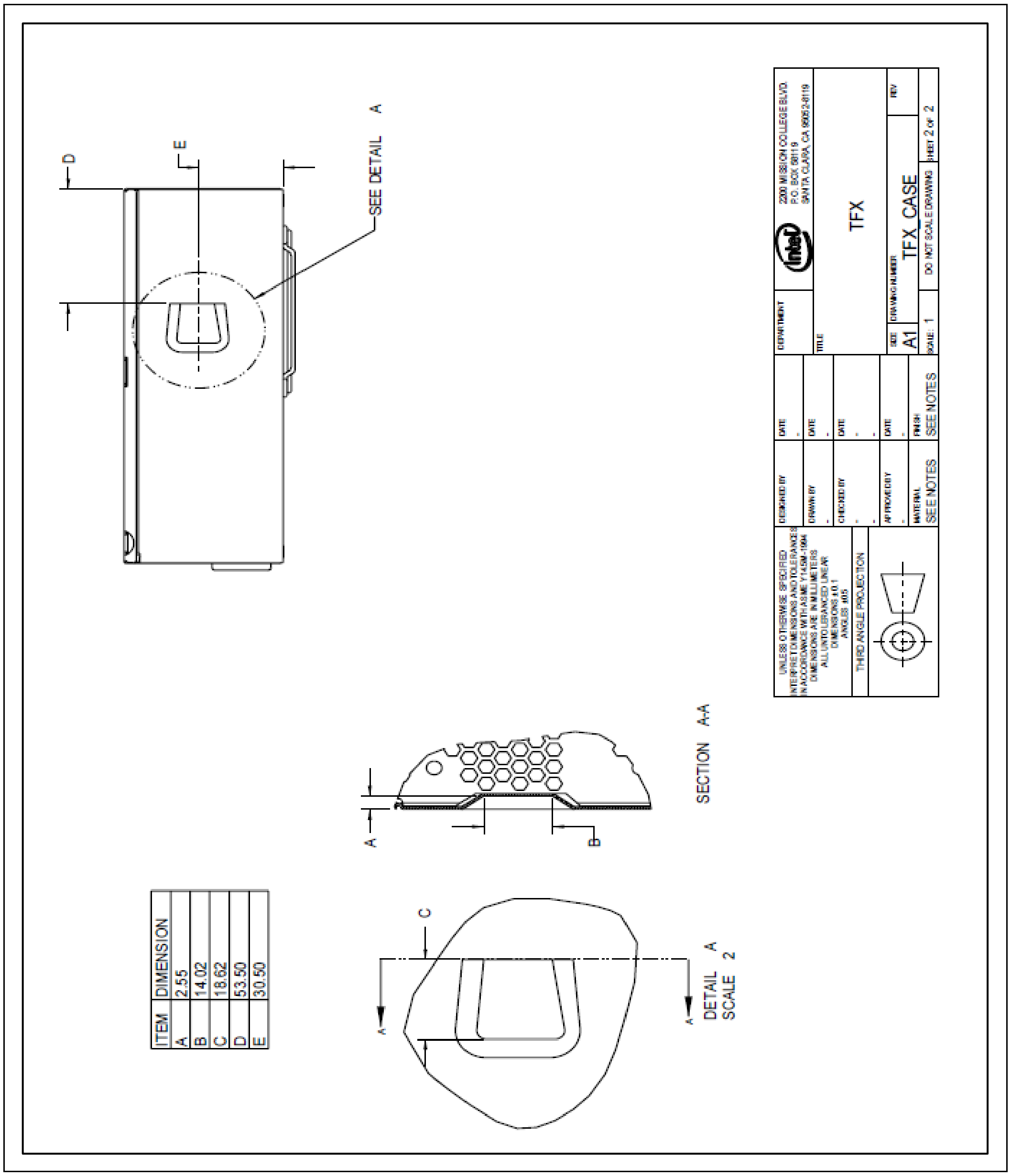


Figure 15-2: Dimensions and Recommended Feature Placements (not to scale)



ITEM	DIMENSION	ITEM	DIMENSION
A	4.40 REF	M	28.80
B	12.80	N	57.20
C	56.80	P	13.50
D	59.70 REF	Q	15.00 REF
E	65.00	R	70.50
F	70.00	S	14.50
G	5.20	T	46.30 REF
H	5.50 REF	U	53.50
J	76.00	V	175.00
K	80.50 REF	W	65.00 REF
L	85.00		

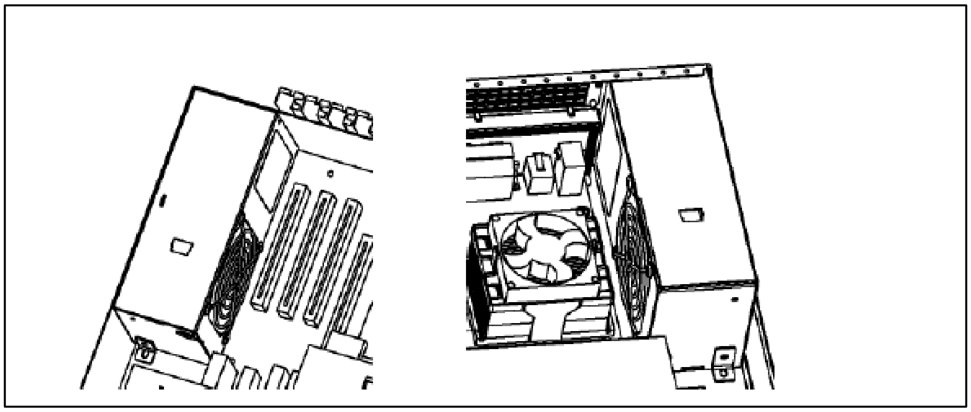
Figure 15-3: Power Supply Mounting Slot Detail



15.2 Mounting Options - RECOMMENDED

The TFX12V mechanical design provides two options for mounting in a system chassis. The unit can be mounted using one of the mounting holes on the front end (non-vented end) or a chassis feature can be designed to engage the slot provided in the bottom of the supply. To accommodate different system chassis layouts, the TFX12V power supply is also designed to mount in two orientations (fan left and fan right) as shown in Figure 15-4. A mounting hole and slot should be provided for each orientation as shown in Figure 15-2. Details of a suggested geometry for the mounting slot are shown in Figure 15-3.

Figure 15-4: Fan Right and Fan Left Orientations of Power Supply in a Chassis



15.3 Chassis Requirements - RECOMMENDED

To ensure the power supply can be easily integrated, the following features should be designed into a chassis intended to use a TFX12V power supply:

- Chassis cutout (normally in the rear panel of the chassis) as shown in Figure 15-5.
- EITHER a mounting bracket to interface with the forward mounting hole on the power supply OR a mounting tab as shown in Figure 15-6 to interface with the mounting slot on the bottom of the power supply.

Figure 15-5: Suggested TFX12V Chassis Cutout

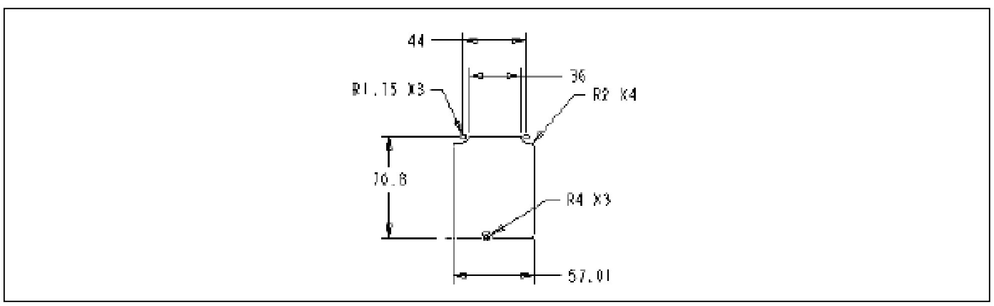
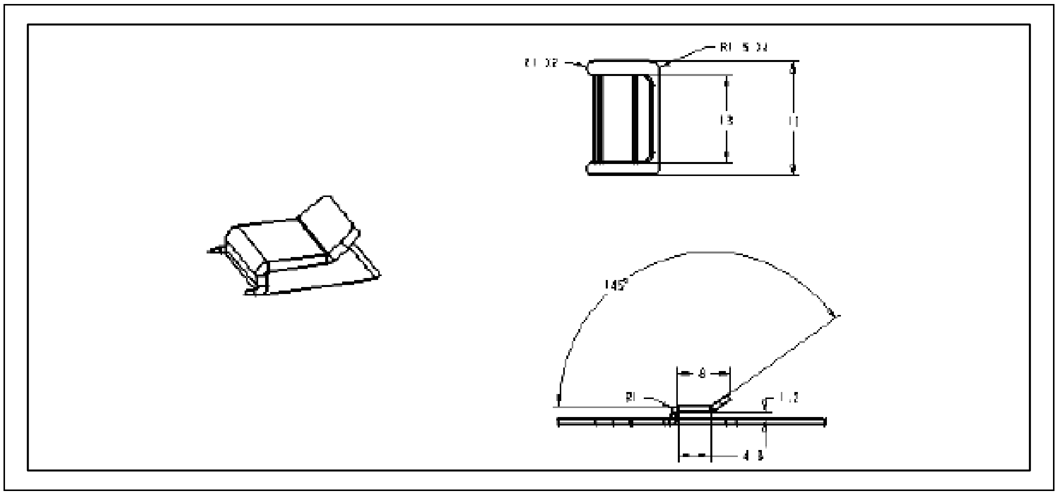


Figure 15-6: Suggested Mounting Tab (chassis feature)



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16 Flex ATX Specific Guidelines 2.1

For Flex ATX Form Factor with 12-volt connector power supplies.

All Form Factors Revision Summary:

PSU DG	CFX12V	LFX12V	ATX12V	SFX12V	TFX12V	Flex ATX
2.1	2.1	2.1	3.1	4.1	3.1	2.1

16.1 Physical Dimensions – REQUIRED

Figure 16-1: Mechanical Outline

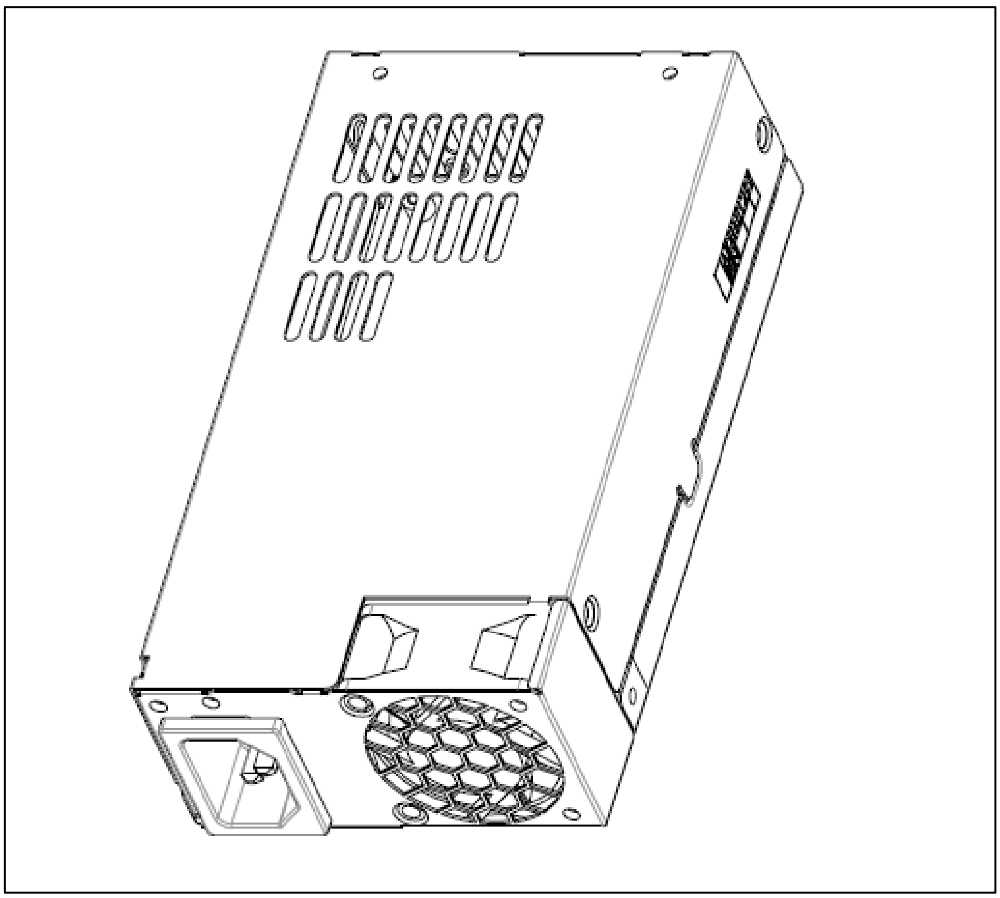
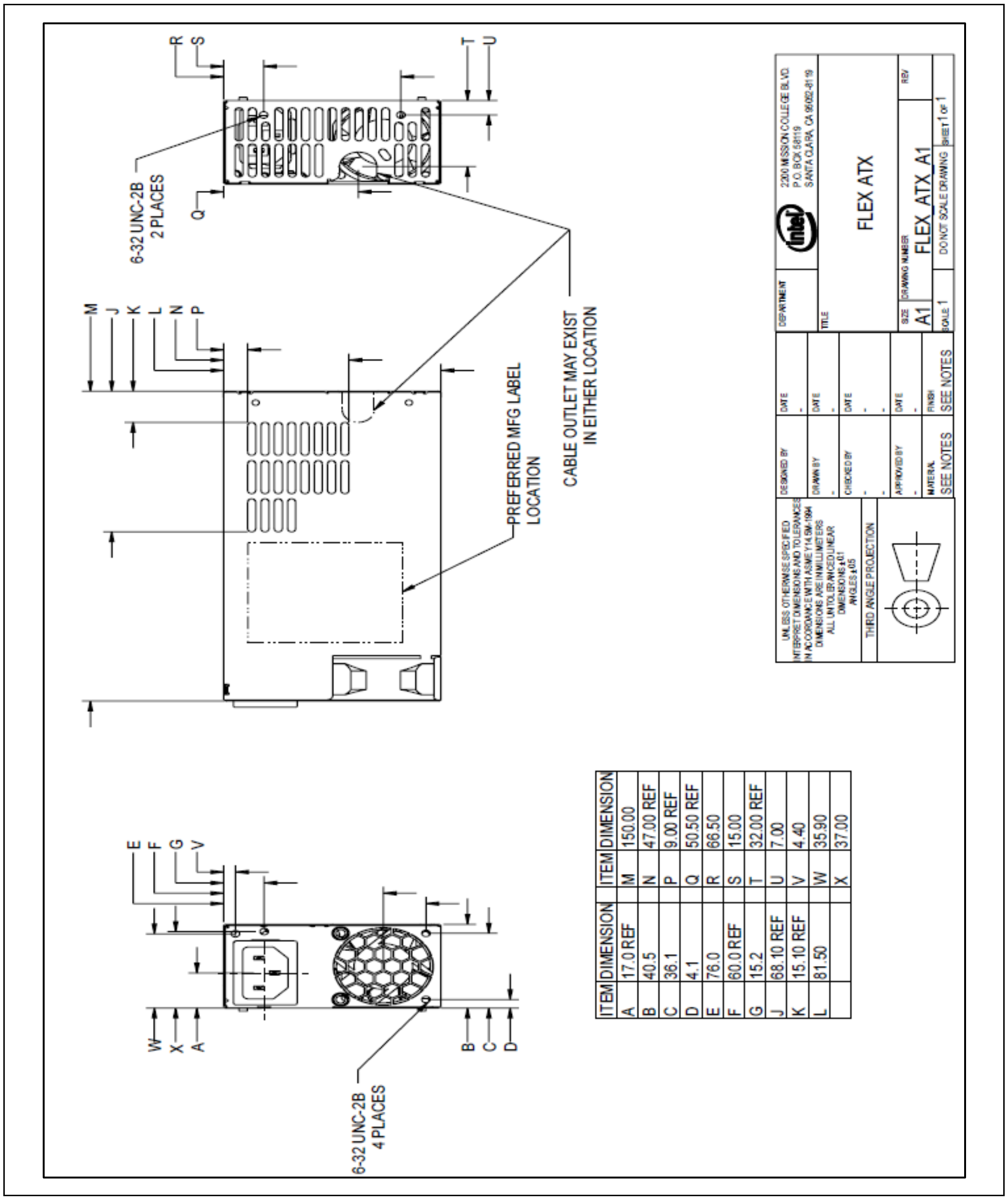


Figure 16-2: Dimensions and Recommended Feature Placements (not to scale)



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