



Bud Industries, Inc.

Enclosure Design Tips Handbook

*A guide to selecting cabinets, enclosures and
other packaging systems for electronic products.*

INTRODUCTION

The selection of a cabinet, enclosure, or other packaging for an electronic product presents the designer or systems integrator with a variety of choices, in addition to certain criteria that will be dictated by the nature of the application.

This booklet summarizes some of the more important issues of packaging for electronic systems and products, with the goal of helping you evaluate your options quickly, and then select the optimum solution for your application. Enclosure types are summarized in Table 1.

Many enclosure solutions can be delivered with custom features or modifications.

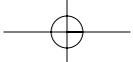
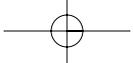
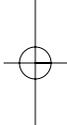
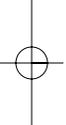


TABLE OF CONTENTS

1. ENCLOSURE TYPES	2
Cabinet racks (incl. NEMA 12)	3
Server racks	4
Co-location racks	4
Seismic racks	5
Open racks (Large open racks, table-top racks, swing-frame, relay racks)	6
Wall mount cabinets	7
Rack mount enclosures	8
Card racks	9
Portable cabinets	10
Chassis	12
Small metal enclosures	11
Cast metal enclosures	13
Plastic boxes, NEMA 4x enclosures	13
2. ACCESSORIES (Panels, shelves, brackets, casters, feet, levelers, fans)	14
3. MATERIALS & FINISHES	15
4. BASICS OF COOLING	17
5. TYPICAL RACK DIMENSIONS & TOLERANCES	18
6. COMMONLY USED STANDARDS	21
7. STANDARDS ASSOCIATIONS	24



1. ENCLOSURE TYPES

Table 1. Summary of Enclosure Types.

ENCLOSURE	MAJOR FEATURES	TYPICAL APPLICATIONS	SEE PAGE
Cabinet Racks, including NEMA 12.	Fully enclosed floor-standing cabinets. Provide a controllable environment. Front and rear doors for security. NEMA 12 cabinets have gasketed doors and sides.	Floor-mount enclosure for general-purpose mounting of instruments and equipment with 19", 23", or 24" wide panel space.	3
Server Racks	Similar to floor mount cabinet racks, except with heavily ventilated side panels and rear door.	Used where protection and security are needed for mounting of deeper instruments and communication equipment.	4
Co-Location Racks	Overall cabinet divided into individual compartments. Heights from approx. 24" to 39".	Use where independent sub cabinets are required.	4
Seismic Racks	Heavy duty. Designed and tested to Bellcore Zone 4 requirements (#GR-63-CORE, Issue 1).	Applications that may be subjected to shock and vibration.	5
Open Racks Table-top Racks Swing-Frame Racks	Open framework designed to mount 19" and 23" panel widths. Includes smaller swing-frame and wall-mount racks.	Applications requiring maximum free-air ventilation, or easy access to equipment sides and rear panels.	6
Wall Mount Cabinets	Small, relatively shallow wall-mountable enclosure with door.	Network hubs & mounting of telecom, datacom, industrial controls & equipment.	7
Portable Cabinets	For assembling desktop 19" systems in heights of approx. 18" to 26".	Small systems where portability is needed.	10
Card Racks	Modular packaging system for mounting circuit boards and custom electronics.	Data acquisition, telecom	9
Small Cabinets	Available in a wide range of sizes and styles, including sloping front, cases with handles, tilting feet, and computer-styled enclosures. Typical materials: steel, formed aluminum.	Used for housing of prototype or finished, medium to small electronic products, instruments, telecom devices.	11
Chassis	Aluminum formed and welded construction, with optional bottom plate.	Construction of products and prototypes. Provides protections and structure.	12
Accessories	Fans, fan trays, blowers, handles, feet, casters, levelers, slides, panels shelves, power strips, internal cable brackets.	Provide cooling, mobility, slide-out access to instruments, power distribution, etc.	14
Small Metal Enclosures Cast Metal Enclosures	Available in a wide range of sizes and styles. May include covers, gasketing, screws, rubber feet, or other hardware. Typical materials: aluminum.	Used to house and protect small electronic products, components, instruments, telecom devices, etc.	13
Plastic Boxes NEMA, UL & IEC Enclosures	Available in a wide range of sizes and styles. May include plastic or metal covers, gasketing, screws, rubber feet, or other hardware. Typical materials: polycarbonate, polystyrene, ABS plastic.	Used for housing of small or hand-held electronic products, component packaging, instruments, telecom devices, etc.	13

CABINET RACKS

Floor-mount enclosed cabinet racks are among the largest enclosures used in electronic applications, and are offered in many styles and with a wide range of accessories. Cabinet racks are available with a 19", 23", or 24" wide panel space.

An enclosed cabinet is a good choice where rack-mountable equipment needs to be housed safely and securely. An enclosed rack offers a controllable environment for equipment cooling. Ventilated panels and various types of fan trays and arrays are available to manage airflow, which has become increasingly critical as the power demands of some types of systems escalate. Many enclosed cabinet designs accept lockable accessory front and rear doors to provide equipment security, or transparent doors to permit equipment monitoring.

The choice of a specific model depends on load, accessibility cosmetic and configuration requirements, and any applicable standards.



Cabinet Rack

CABINET RACKS	
Applications	General electronic rack mounting applications, telecom, datacom, industrial controls, test and measurement systems.
Dimensional Considerations	Typical ext dimensions to 86" H, 36" D (approximate) 19" wide panel space is most common. 23" is used in the telecom/datacom. 24" is used for factory automation systems. Adapters enable 19" equipment to mounted with 23" or 24" equipment.
Load Considerations	Maximum equipment weight is approximately 1200 pounds. Racks utilizing a welded steel internal frame offer the highest weight-bearing capacity. Aluminum frames provide slightly less weight capacity.
Construction	Steel and/or aluminum. Fully assembled cabinets can reduce product costs by eliminating cabinet assembly time. "Knock-down" (user-assembled) cabinets provide a lower-cost alternative where less weight capacity is needed, or where it is impossible to transport a pre-assembled cabinet to the location where it will be used. Additional choices and considerations: <ul style="list-style-type: none"> • Width panel openings (23" or 24") • Adequate access holes to simplify cable routing. • Removable side panels that can provide additional access to equipment. • Adjustable rear mounting rails that can be used to support heavy equipment. • NEMA 12 cabinets have gasketed doors and sides.

SERVER RACKS & CO-LOCATION RACKS

Server and Co-location racks are ideal for applications requiring maximum ventilation and air flow.

Server racks are similar to cabinet racks, except that side panels and doors are heavily ventilated. A locking, solid metal or transparent front door may be used for protection and security. Extra cabinet depth permits mounting of deeper instruments or equipment.

Co-location racks resemble server racks that have been divided up into individual compartments. Individual sections are designed to be fully independent and secure, and are available in heights ranging from approximately 24 to 39 inches. Typically, each section has its own door. Side panels may be one-piece units that extend the full height of the cabinet rack assembly.



SERVER RACKS & CO-LOCATION RACK

SERVER RACKS & CO-LOCATION RACKS	
Applications	Telecom, datacom, communication systems, general electronic rack mounting applications. Server cabinets provide extra depth. Equipment mounting rails are designed to support a variety of commercial servers. Co-location racks are ideal where independent, securable sub cabinets are required.
Dimensional Considerations	19" wide panel space. Server racks - typical ext dimensions to 86" H, 42" D (approximate). Co-location racks - typical ext dimensions to 86" H, 34" D (approximate).
Load Considerations	Typical weight capacity: 1200 lb for Server Racks. Typical weight capacity: 1200 lb for Co-location Racks. Consult the vendor to confirm load bearing capacity.
Construction	Steel and/or Aluminum. Available pre-assembled. Available with transparent front doors Complementary designs enable Server and Co-location racks to be used together. Kits may be available to enable Server Racks to be joined for additional equipment capacity and stability. Anchoring to the floor is recommended.

SEISMIC RACKS

Seismic racks offer the maximum level of seismic protection for equipment to be operated under conditions of shock or vibration. Seismic cabinets are rated according to Telcordia (formerly Bellcore) #63-GR-CORE standards, with Zone 4 representing the most demanding requirements.

The rated weight carrying capacity of a cabinet is normally based on a uniformly distributed load. If your cabinet will be used in a shock or mobile environment (i.e. aboard trucks or ships), testing under the actual or simulated load conditions may be necessary.

Seismic cabinets should be anchored to the floor with a suitable anchor kit.



SEISMIC RACK

SEISMIC RACKS	
Applications	General equipment rack mounting in environments that may be subjected to shock or vibration.
Dimensional Considerations	19" wide panel opening External dimensions to 75" H, 30" D (approximate). Check with your vendor for other sizes.
Load Considerations	Rated weight capacity is normally based on the uniformly distributed load that the cabinet was tested and rated for. If cabinet will be used in a shock or mobile environment, testing under the actual or simulated load conditions may be necessary.
Construction	Welded steel Use floor anchor kits to secure cabinet.

OPEN RACKS

Open frame racks are a good choice in applications requiring maximum cooling, or free and immediate access to the front, rear, and sides of equipment – no doors or side covers are used. Open frame racks are available to accept 23" as well as 19" wide instrument panels. If security is a concern, open frame racks should be used within lockable rooms.

Wall-mount and Desktop racks are a shorter version of the open rack for use where floor space is not available. Wall-mount designs include fixed types, as well as "swing-frame" types that open away from the wall to provide rear panel access.

Loads are supported completely by the rails comprising the rack frame. Make sure that the load capacity is adequate for the application, and that the base is large enough to provide stability for the rack as it will be populated.



OPEN RACKS

OPEN RACKS	
Applications	Most suitable for light-weight, shallow-depth equipment mounting. Useful for telecom, datacom, phone switching systems, network components.
Dimensional Considerations	19" and 23" wide panel openings External dimensions to 100" H, 30" D (approximate). Check with your vendor for other sizes.
Load Considerations	Load capacity ranges from a few tens of pounds for desktop units, to approximately 1000 lb for full-size racks. Consult the manufacturer.
Construction	Steel and/or aluminum. Typically knock-down, bolt-together construction, for assembly by the user. Check for availability of kits to permit joining racks.

WALL MOUNT CABINETS

Wall mount cabinet enclosures are a cost-effective alternative where equipment needs are modest and not likely to increase for an application.

Double-hinged split cabinets are also available, which open like a book to offer access to rear panels, or to provide multiple layers of rack mounting space. Lockable and transparent doors are available with some models to provide security or visual access to equipment panels.



WALL-MOUNT CABINETS

WALL-MOUNT CABINETS	
Applications	Mounting and enclosing a limited amount of relatively shallow equipment directly to a wall or other vertical surface.
Dimensional Considerations	19" wide panel opening External dimensions range from 24" to 48" H, 6" to 22" D (approximate).
Load Considerations	Typical weight capacity 75 lb. to 400 lb.
Construction	Steel and/or aluminum. Preassembled

RACK MOUNT CHASSIS

Rack mount chassis provide a range of enclosures for the assembly of rack-mountable equipment and instruments. Some rack mountable equipment may also be used as desk-top or portable equipment, so detachable handles, rack mounting brackets, or other hardware may be desirable. Availability of ventilation panels is also important to maintain safe operating temperatures.



RACK MOUNT CHASSIS

RACK MOUNT CHASSIS	
Applications	Packaging for electronic instruments, circuits, and components that will typically be installed in a 19" rack.
Dimensional Considerations	Mounts in a 19" wide panel opening. Height – 1U to 8U (1.75" to 14"). Depth 8.5" to 22" (approximate)
Load Considerations	Light loads unless supported by external brackets.
Construction	Steel, aluminum Handles can provide convenience during rack mounting.

CARD RACKS

Card racks are chassis-like enclosures used to assemble circuit boards and components into modular electronic instrumentation. The card rack itself is designed to mount in a 19" rack. Modules can be changed or rearranged to permit quick, convenient equipment modifications.

Modular systems can hold a number of individual sub-modules, each of which must mesh with rails, guides, connectors, lock screws, and other hardware within the modular chassis. Dimensional precision and stability are important to eliminate the possibility of binding and misalignment.



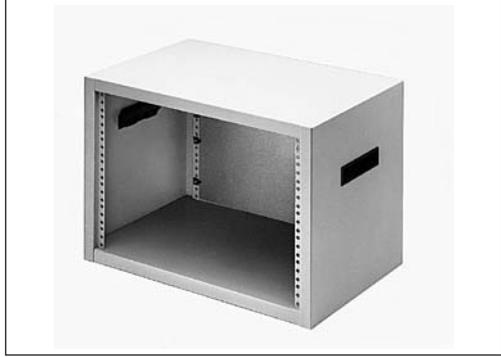
CARD RACK

CARD RACKS	
Applications	Packaging of electronic circuit cards in modular units that can be installed or removed from a 19" sub-rack. Modular cabinets are often used in mission-critical applications (data acquisition, telecom, and industrial control) that are governed by regulations and standards for construction, vibration, fire worthiness, and other factors.
Dimensional	Sub-rack unit mounts in a 19" wide panel opening. Individual plug-in modules vary in width. Height – 2U or 3U (3.5" or 5.25"). Depth 11.5" to 14" (approximate) Modules accept cards up to 4.4" x 10.78"
Load Considerations	N/A.
Construction	Aluminum Internal card rack construction includes card guides, locks, mounting rails, and other structural members. Individual modules are independent enclosures with front panels, top, bottom, sides, and back.

PORTABLE CABINETS

Portable cabinets are small cabinet racks used to house a limited amount of 19" wide instrumentation or equipment. Internally, portable cabinets offer limited space for power strips and other accessories. Generally, no internal framework is present. Externally, portable cabinets accept rubber feet, but not casters, levelers, or anchor kits.

The weight capacity may be up to 500 pounds. Heavily loaded cabinets should be supported on sturdy surfaces.



PORTABLE CABINET

PORTABLE CABINETS	
Applications	Mounting and enclosing a limited amount of equipment for desktop, portable, or semi-portable applications where enclosed equipment and instruments do not exceed approximately 20" in depth.
Dimensional Considerations	19" wide panel opening. External dimensions range from 7" to 30" H, and to 21" D (approximate).
Load Considerations	Typical weight capacity up to 500 lb. Check for weight limits when using built-in handles to lift and carry the cabinet.
Construction	Steel and/or aluminum. Fully assembled. Front or rear doors and panels, and rear mounting rails may be available – check with your vendor. Handles and other accessories may be available to aid in portability of fully loaded cabinets.

SMALL METAL CABINETS

Small cabinets are used to package instrumentation and equipment requiring a maximum volume of approximately 1 cubic foot. Small cabinets include convenience features such as strap handles, sloping fronts, tilting bails, and latches, to name a few. They are generally not intended for rack mounting, although mounting hardware may be available for some types.

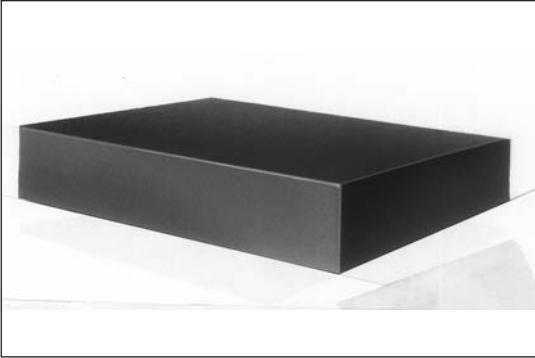


SMALL METAL CABINET

SMALL METAL CABINETS	
Applications	Practically an unlimited range of applications. Used for prototypes or finished, medium to small electronic products, instruments, telecom devices, computer peripherals, and control panels, etc.
Dimensional Considerations	Extremely wide range of dimensions and styles. Typical height and width to 12" x 12" x 15"
Load Considerations	N/A.
Construction	Typical materials: steel, formed aluminum, extruded aluminum.

CHASSIS

Metal chassis provide support and protection for electronic circuits. A bottom cover is often available. Check dimensions and accessories for specific chassis models.



CHASSIS

CHASSIS	
Applications	A platform for construction of circuits and subassemblies that generally fit within a larger case, rack, or cabinet. Used as a basic building block in a very wide range of applications.
Dimensional Considerations	Extremely wide range of dimensions and styles. Typical height and width from approximately 4" x 4" to 17" x 17"; depth from 1" up to 6".
Load Considerations	N/A.
Construction	Aluminum

Small Enclosures

TYPE	TYPICAL FEATURES	APPLICATIONS
<p>Die Cast Metal</p> 	<p>Aluminum boxes and covers. Sizes range to approximately 9" x 6" x 3".</p>	<p>Housing of electronic and electrical assemblies. Pneumatic and hydraulic devices. Applications requiring a sturdy enclosure.</p>
<p>NEMA 4 Die Cast</p> 	<p>NEMA 4 aluminum enclosures typically offer sealed construction and/or gasketing for resistance to atmospheric contaminants, spray, and corrosion. Designed to IP65 of IEC529 and NEMA 4 specifications. Available with wall mounting holes and cover. Attaching screws are outside the sealing area to prevent entry of moisture and dust. Cover incorporates a recessed gasket. Most models have internal guides for mounting PCBs. Cover mounting holes are roll threaded; screws are captive and recessed. Finishes: natural finish or gray.</p>	<p>Housing of sensitive electronic and electrical assemblies. Pneumatic and hydraulic devices. Applications requiring a sealed enclosure.</p>
<p>UL, NEMA 4X, Polycarbonate, & ABS Enclosures</p> 	<p>Similar in appearance to NEMA 4 aluminum enclosures, except they are constructed from polycarbonate or ABS plastic, and satisfy specific NEMA, UL, or IEC codes. May contain aluminum panels, PC board guides, or mounting bosses. Transparent doors or covers may be available. Sizes range to approximately 24" x 16" x 10".</p>	<p>Housing of sensitive electronic and electrical assemblies. Applications requiring a sealed enclosure.</p>
<p>Molded ABS Plastic Cases</p> 	<p>Cases are available in various shapes and sizes, with features such as sloped or flat panels, removable panels, interlocking "clamshell" case halves, and internal reinforcements. Molded plastic cases provide a finished appearance and are available in a variety of colors. They are generally usable without further painting. Guides and bosses may be present for mounting PC boards. Rubber feet may be included. Sizes range to approximately 24" x 16" x 10".</p>	<p>Instrumentation Telecom equipment Data acquisition</p>
<p>Hand Held Enclosures</p> 	<p>Enclosures are designed for portable hand-held and pocket applications, including ergonomic shapes, interlocking lids, access panels for batteries, and windows that can be used for opto displays. Many features of standard molded plastic cases also apply.</p>	<p>Consumer electronic devices Hand-held remote controls</p>
<p>Economy, Utility, and Potting Boxes</p> 	<p>This class of enclosures offer basic packaging and protection for small circuits and components. It includes economy metal and plastic boxes which are generally offered unfinished, or in a limited number of colors. Covers are usually available. Sizes range to approximately 6" x 6" x 6".</p>	<p>Small electronic devices Electronic accessories Prototypes Component packaging Potted assemblies</p>

2. ACCESSORIES

Rack accessories such as shelves, panels, handles, desk tops, and drawers provide a finished appearance, add security, and improve convenience and work efficiency for the user. Accessories for the interior, such as cable clamps, brackets, fans, and other cooling accessories can help reduce clutter and improve system operation. Pre-drilled holes for mounting of casters, levelers, and eyebolts eliminate the need for system integrators to drill or modify the cabinet, which can save considerable time on the assembly floor.

ACCESSORIES	
Cooling	<ul style="list-style-type: none"> • Fans, fan trays, & blowers • Temperature controls
Power Management	<ul style="list-style-type: none"> • Cable management brackets • Power strips and distribution
Internal Slide Hardware	<ul style="list-style-type: none"> • Mounting flanges, brackets, and adapters • Slide brackets & mechanisms
External Panels and Hardware	<ul style="list-style-type: none"> • Blank filler panels • Handles & locks • Screws, nuts, washers & clip nuts
Shelves and Drawers	<ul style="list-style-type: none"> • Fixed and sliding shelves • Sliding drawers • Keyboard and mouse shelves • Fixed and folding desk tops
Transport & Anchoring Hardware	<ul style="list-style-type: none"> • Casters, feet & levelers • Seismic anchors • Anti-tilt bars & other safety equipment

ACCESSIBILITY

Lift-off and reversible (left or right hinged) doors that can be moved out of the way can simplify and speed equipment installation. Side panels that can be removed from outside will greatly enhance accessibility to interior components and cabling at the interior sides of a cabinet.

EXPANDABILITY

Two or more cabinets may be required to house all the equipment associated with an application. Kits are available that allow cabinets to be ganged together into a "suite." This offers a number of advantages, including greater stability, and easier management of interconnecting cables.

The user must insure that the cabinets can be ganged together easily and the manufacturer supplies the proper hardware kit.

CABLE MANAGEMENT

Sufficiently large external access holes on the top and bottom of a cabinet are a must for cabling in most applications. Knock-outs in the front and rear of the cabinet frame are desirable for bringing in power cables.

Internally, the routing and anchoring of cables is extremely important in making a system neat and serviceable, and for assuring the highest signal integrity. Various types of cable clips, straps, and panels are available for this purpose.

Also, pay close attention to the routing of analog signals, digital signals, and power, as well as the type of cabling being used to carry each. Be aware of the possibility of noise coupling, hum, cross-talk, and other undesirable conditions that can occur when cables are bundled together. In audio applications, for example, power and digital signals are often routed to one side of the cabinet, and audio signals to the other side.

3. MATERIALS & FINISHES

COMMONLY USED MATERIALS – METALLIC

Material	Cost	Strength	Corrosion Resistance	Suggested Uses and Applications
Carbon Steel	Low	High	Poor	General indoor and outdoor applications – requires painting or powdercoating
Galvannealed Steel (steel with electrocoated zinc finish on both sides)	Low to Moderate	High	Good	General indoor and outdoor applications – requires painting for some indoor applications and all outdoor applications
Stainless Steel	High	High	Excellent	General indoor and outdoor applications – does not require painting Food and pharmaceutical applications Marine applications
Aluminum	Moderate	Moderate	Good to Excellent	General indoor and outdoor applications – does not require painting Food applications Marine applications

COMMONLY USED MATERIALS – NON-METALLIC

Material	Cost	Chemical Resistance	Suggested Uses and Applications
ABS	Low	Low	General indoor applications
ABS/PC Blend	Low	Low to Moderate	General indoor applications
Polycarbonate	Moderate	Moderate	General indoor and outdoor applications
PC/PBT Blend	Moderate	Moderate	General indoor and outdoor applications Marine applications
Fiberglass	High	High	General indoor and outdoor applications Indoor and outdoor applications where extreme chemical, temperature, or moisture are of concern Marine applications

Comparisons above reflect the basic resins. Enhancements can be made to all of the above resins to improve their flammability, electrical properties, chemical resistance, UV resistance, mechanical properties, and thermal properties.

COMMONLY USED FINISHES FOR METALLIC ENCLOSURES

Finish	Used On	Cost	Advantages	Disadvantages	Suggested Uses
Anodize	Aluminum	Moderate	Enhances appearance Moderately non-conductive	Easily marred Not recommended for castings	General indoor and outdoor applications
Zinc Plating	Steel	Moderate	Improves appearance Protects against corrosion Can be colored	Can enhance imperfections in material Part size limited Limited colors	Component parts for indoor and outdoor applications
Paint	Aluminum and Steel	Moderate to High	Improves appearance Increases corrosion resistance and weatherability Unlimited color choices	Moderately mar resistant	General indoor and outdoor applications
Powdercoat	Aluminum and Steel	Low to Moderate	Improves appearance Increases corrosion resistance and weatherability Unlimited color choices Improves mar resistance		General indoor and outdoor applications Extreme exposure applications

COMMONLY USED FINISHES FOR NON-METALLIC ENCLOSURES

The color of non-metallic enclosures is part of the resin and is molded into the part. Except for internal coatings for EMI/RFI protection, secondary finishes are usually not required. Certain grades within the basic resin families can be plated or painted, if necessary.

4. BASICS OF COOLING

Waste heat generated by equipment within a cabinet is the single factor most affecting equipment reliability. Therefore, an effective cooling strategy can be critical. The most commonly used cooling methods, in order of increasing cost, are:

- Natural convection
- Forced convection (Exhaust fans and blowers)
- Air conditioning

Heat may also be lost through conduction between objects in contact, or through radiation (heat transfer that occurs through electromagnetic waves). Most systems manage heat through a combination of methods, even though one may be emphasized. For example, a processor chip may be cooled using a heat sink (conduction) that includes a fan (forced convection). Enclosure manufacturers can provide guidance to users in selecting the proper cooling approaches.

Natural convection cooling is adequate for most applications that generate mild heat, provided the cabinet offers an unrestricted internal air path. The user must insure that the cabinet has sufficient venting at both the top and bottom to promote airflow and a chimney effect. Louvers are a popular form of air entry and exit for convection cooling because they provide some protection against dust entry, and hide the contents of the cabinet.

Where natural convection is inadequate, forced convection can be used. An exhaust fan can be added at the top of the cabinet. Alternately, a blower can be used at the bottom of the cabinet to create high internal pressure within the cabinet. Hot air will then be exhausted at the top of the cabinet through vents, or an exhaust fan at the top can be added to improve air flow. Static back pressure requirements need to be determined through empirical measurement – they can't be calculated. The high pressure inside the cabinet also prevents entry of dust and lint.

BASIC AIR FLOW CALCULATIONS

The amount of airflow that must be provided to achieve a desired cooling performance is expressed by the following equations:

$$\begin{array}{l} \text{For } \Delta T \text{ in } ^\circ\text{F:} \\ \text{AIR FLOW (ft}^3\text{/min)} = \frac{\text{BTU/hr}}{1.08 \times \Delta T_F} = \frac{3170 \times kW}{\Delta T_F} \end{array}$$

$$\begin{array}{l} \text{For } \Delta T \text{ in } ^\circ\text{C:} \\ \text{AIR FLOW (ft}^3\text{/min)} = \frac{\text{BTU/hr}}{1.95 \times \Delta T_C} = \frac{1760 \times kW}{\Delta T_C} \end{array}$$

Typical values for ΔT are 10°C or 18°F. Add a 25% for safety margin (12.5°C and 23°F). Note that ΔT represents the temperature rise over ambient air temperature. If ambient is too high, it may be difficult or impossible to maintain a safe operating temperature without air conditioning. Air conditioning is used in critical high-heat generating environments, and allows cooler-than-ambient air to be circulated through the cabinet.

5. TYPICAL RACK DIMENSIONS & TOLERANCES

The following dimensions and tolerance are according to standard EIA-310-D, and govern rack-mount cabinet and panel dimensions. For a complete specification, contact the Electronic Industries Association, Engineering Department, 2500 Wilson Blvd., Arlington, VA 22201.

PANEL WIDTH	INCHES	MILLIMETERS
	19 ± 0.016	482.6 ± 0.4
	23 ± 0.016	584.2 ± 0.4
	24 ± 0.016	609.6 ± 0.4
	30 ± 0.016	762.0 ± 0.4

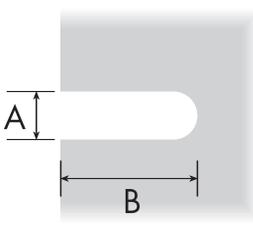
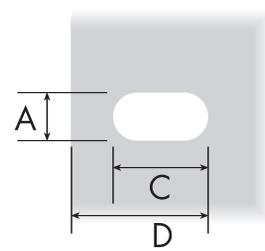
EQUIPMENT FRONT PANEL HEIGHT	INCHES	MILLIMETERS
	$(N \times U) - 0.315$ N = RACK UNITS U = 1.75	$(N \times U) - 0.8$ N = RACK UNITS U = 44.45

CABINET PANEL & CHASSIS SPACE DIMENSIONS (19" RACK)	INCHES	MILLIMETERS	
	MIN. HORIZ. CHASSIS OPENING	17.716	450
	HORIZ. HOLE CTRS.	8.307 ± 0.059	465 ± 1.5
	MIN. HORIZ. PANEL SPACE	19.031	483.4
	MIN. VERTICAL	$(N \times U) + 0.031$	$(N \times U) + 0.8$

Standard Vertical Hole Centers in Panels

Hole Centers		1U	2U	3U	4U	5U	6U	7U	8U	9U	10U	11U	12U
mm	inches	hole position, measured from top edge of panel											
6.0	0.236	•	•										
37.7	1.484	•		•	•	•	•	•	•	•	•	•	•
82.2	3.236		•										
94.9	3.736			•			•						
126.6	4.984							•					
139.3	5.484				•				•	•	•		
171.1	6.736						•					•	•
183.8	7.236					•		•					
215.5	8.484								•				
228.2	8.984						•						
272.7	10.736							•					
280.0	11.024									•			
304.4	11.984										•		
317.1	12.484								•			•	
361.6	14.236									•			•
406.0	15.984										•		
450.5	17.736											•	
494.9	19.484												•

Panel Hole Styles & Dimensions

STD. OPEN SLOT			STD. CLOSED SLOT		
					
	MILLIMETERS	INCHES		MILLIMETERS	INCHES
A	7.1mm ± 0.3mm	0.279 ± 0.012	A	7.1mm ± 0.3mm	0.279 ± 0.012
B	14.7mm ± 1.2mm	0.579 ± 0.047	C	10.3mm ± 0.4mm	0.405 ± 0.0157
			D	13.7mm ± 0.4mm	0.527 ± 0.0157

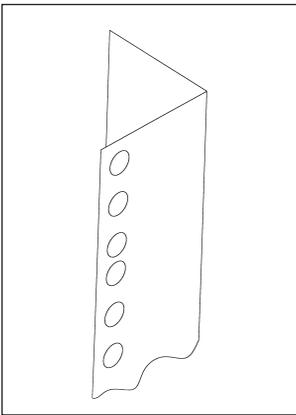
USABLE CABINET DEPTH

The usable depth in a cabinet rack is the maximum usable space between the equipment front mounting surface and the rear mounting surface, and varies from approximately 17" to 42". The addition of connectors and cabling from the rear panels of equipment or instruments can add several more inches to cabinet depth requirements. You will also need to factor in all accessories such as power strips, cooling devices and mounting brackets.

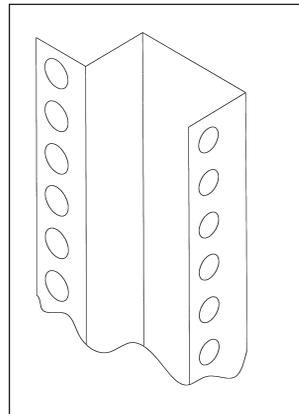
MOUNTING RAILS

One of the most important features in a rack is the design of the equipment mounting rail. Most mounting rails are pre-tapped with #10-32 or #12-24 threads, although some manufacturers use metric thread (M5 or M6) fasteners. Some manufacturers provide round or square holes in their mounting rails that require the insertion of clip nuts or cage nuts prior to the installation of equipment in the rack. Pre-tapped holes are preferred because they save significant time in assembly. However, clip or cage nuts are easy to replace individually, and may offer advantages where there is any possibility that threads may be damaged or worn through frequent equipment changes.

The shape of the mounting rail is also important because it contributes to rigidity, and to the ease of mounting other hardware and accessories inside the cabinet. L-shaped rails provide only one mounting flange at the front of the cabinet, so additional brackets may be needed for adding accessories inside the cabinet. Some manufacturers provide a question mark shaped rail that has an accessory mounting flange in addition to the equipment mounting flange. This flange makes it easy to mount accessories such as shelves and slides behind the front panel. Mounting rails that can be adjusted forward or backward in the cabinet allow additional flexibility in equipment mounting.



"L" Shaped Mounting Rail



Mounting Rail with
Accessory Flange

6. COMMONLY USED STANDARDS

NEMA, UL, CSA, and IEC RATINGS

NEMA, UL, and CSA are organizations that write standards commonly used in North America. They are similar in their descriptions, applications, and performance. IEC produces similar standards that are used in Europe, but increasingly referenced in North America. Even though the IEC performance criteria is similar to NEMA, the interpretation of the performance and the testing conditions can vary, thereby, making an exact comparison difficult.

UL and CSA require testing by qualified testing facilities, while NEMA and IEC do not require this testing and leaves adherence to the standard up to the manufacturer of the product. Shown in Table 1 below are abbreviated descriptions of the commonly used NEMA, UL, and CSA environmental standards and ratings associated with the enclosure industry, and governed by these organizations. Table 2 shows the IEC or IP ratings for the similar types of standards. Table 3 is an approximate cross-reference between the IEC and NEMA ratings. These tables are to be used for general reference only. Consult the appropriate organization and standard prior to specifying your enclosure.

Table 1

Enclosure Rating	NEMA Standard 250	UL Standard 50 and 508	CSA Standard C22.2 No.94
Type 1	For indoor use to provide a degree of protection against incidental contact with the enclosed equipment; and to provide a degree of protection against falling dirt.	For indoor use primarily to provide a degree of protection against limited amounts of falling dirt.	For indoor use to protect against accidental contact with live parts.
Type 2	For indoor use to provide a degree of protection against incidental contact with the enclosed equipment; and to provide a degree of protection against falling dirt, dripping and lightly splashing liquids.	For indoor use primarily to provide a degree of protection against limited amounts of falling water and dirt.	For indoor use to provide a degree of protection against dripping and light splashing of non-corrosive liquids and falling dirt.
Type 3	For either indoor or outdoor use to provide a degree of protection against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, snow, and windblown dust; and be undamaged by the external formation of ice on the enclosure.	For outdoor use primarily to provide a degree of protection against rain, sleet, wind blown dust and damage from external ice formation.	For indoor or outdoor use; to provide a degree of protection against rain, snow, and windblown dust; to be undamaged by external formation of ice on enclosure.
Type 3R	For either indoor or outdoor use to provide a degree of protection against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, snow; and be undamaged by the external formation of ice on the enclosure.	For outdoor use primarily to provide a degree of protection against rain, sleet, and damage from external ice formation.	For indoor or outdoor use; to provide a degree of protection against rain, snow; to be undamaged by external formation of ice on enclosure.

Table 1 cont.

Enclosure Rating	NEMA Standard 250	UL Standard 50 and 508	CSA Standard C22.2 No.94
Type 4	For either indoor or outdoor use to provide a degree of protection against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, snow, windblown dust, splashing water, and hose-directed water; and be undamaged by the external formation of ice on the enclosure.	For indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water, hose-directed water, and damage from external ice formation.	For indoor or outdoor use; to provide a degree of protection against rain, snow, windblown dust, splashing and hose-directed water; to be undamaged by external formation of ice on enclosure.
Type 4X	For either indoor or outdoor use to provide a degree of protection against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, snow, windblown dust, splashing water, hose-directed water, and corrosion; and be undamaged by the external formation of ice on the enclosure.	For indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing and hose-directed water, and damage from external ice formation.	For indoor or outdoor use; to provide a degree of protection against rain, snow, windblown dust, splashing and hose-directed water; to be undamaged by external formation of ice on enclosure; resists corrosion.
Type 6	For either indoor or outdoor use to provide a degree of protection against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, hose-directed water, and entry of water during an occasional temporary submersion at a limited depth; and be undamaged by the external formation of ice on the enclosure.	For indoor or outdoor use primarily to provide a degree of protection against hose-directed water, and the entry of water during occasional temporary submersion at a limited depth and damage from external ice formation.	For indoor or outdoor use: provides a degree of protection against entry of water during temporary submersion.
Type 12	For indoor use to provide a degree of protection against incidental contact with the enclosed equipment; and to provide a degree of protection against falling dirt, circulating dust, lint, fibers, and flyings; and against dripping and lightly splashing liquids.	For indoor use primarily to provide a degree of protection against circulating dust, falling dirt, and dripping non-corrosive liquids.	For indoor use: provides a degree of protection against circulating dust, lint, fibers, and flyings; and against dripping and lightly splashing of non-corrosive liquids; not provided with knockouts.
Type 13	For indoor use to provide a degree of protection against incidental contact with the enclosed equipment; and to provide a degree of protection against falling dirt, circulating dust, lint, fibers, and flyings; and against spraying, splashing, and seepage of water, oil, and non-corrosive coolants.	For indoor use primarily to provide a degree of protection against dust, spraying of water, oil, and non-corrosive coolant.	For indoor use: provides a degree of protection against circulating dust, lint, fibers, and flyings; seepage and spraying of non-corrosive liquids, including oils and coolants.

Table 2

Protection against hazardous parts and solid objects		IP Protection Rating		Protection against water
Hazardous Parts	Solid Object	1st Figure	2nd Figure	Water
Non-protected	Non-protected	0	0	Non-protected
Protected against access to hazardous parts with the back of a hand	Protected against solid foreign objects of 50mm diameter and greater	1	1	Protected against vertically falling water drops
Protected against access to hazardous parts with a finger	Protected against solid foreign objects of 12.5mm diameter or greater	2	2	Protected against vertically falling water drops when enclosure tilted up to 15 degrees
Protected against access to hazardous parts with a tool	Protected against solid foreign objects of 2.5mm diameter or greater	3	3	Protected against spraying water
Protected against hazardous parts with a wire	Protected against solid foreign objects of 1.0mm diameter or greater	4	4	Protected against splashing water
Protected against hazardous parts with a wire	Dust-protected	5	5	Protected against water jets
Protected against hazardous parts with a wire	Dust-tight	6	6	Protected against powerful water jets
			7	Protected against the effects of temporary submersion in water
			8	Protected against the effects of continuous submersion in water

Example of IP classification: IP23 would mean protection against touching hazardous parts with either a finger or a solid object greater than 12mm in diameter (the #2 in the example), and protection against spraying water (the #3 in the example).

Table 3

NEMA RATING	Type 1	Type 2	Type 3	Type 3R	Type 4	Type 4X	Type 6	Type 12	Type 13
IP RATING*	IP23	IP30	IP64	IP32	IP66	IP66	IP67	IP55	IP65

*Approximate cross reference

TELCORDIA (FORMERLY BELLCORE)

Telcordia Technologies (formerly Bellcore) plays an important role in the development of standards for the telecommunications industry. The primary specification that is used for standard enclosures is #GR-63-CORE. This specification lists, among other requirements, the preferred overall sizes of racks and enclosures, but more importantly is the seismic risk zone ratings established for different parts of the United States and the testing requirements for these ratings.

In general, the United States is divided up into four Earthquake Risk Zones ranging from Zone 0 through to Zone 4. The geographical areas designated as Zone 0 present no substantial earthquake risk. Areas that are designated Zone 1 through Zone 4 represent an increasingly higher risk of earthquake activity, with Zone 4 being the greatest risk.

Consult this specification prior to choosing an enclosure, if there are any concerns about earthquake activity.

7. STANDARDS ASSOCIATIONS

American National Standards Institute (ANSI)

1819 L Street, NW
Washington, DC 20036
www.ansi.org

Canadian Standards Association (CSA)

178 Rexdale Boulevard
Toronto, Ontario, Canada
M9W 1R3
www.csa.ca

Conformite Europeene (CE)

European Economic Community

Electrical/Electronic Manufacturers Association of Canada (EEMAC)

10 Carlson Court, Suite 500
Rexdale (Toronto), Ontario, Canada
M9W 6L2

Electronic Industries Association (EIA)

2500 Wilson Blvd
Arlington, Virginia 22201
www.eia.org

Federal Communications Commission (FCC)

445 12th St. S.W.
Washington DC 20554

Institute Of Electrical And Electronics Engineers (IEEE)

445 Hoes Lane
Piscataway, NJ 08855-1331
www.ieee.org

International Electrotechnical Commission (IEC)

3 Rue de Varembe
CP131
CH-1211 Geneva 20
Switzerland
www.iec.ch

International Society Of Automotive Engineers (SAE)

400 Commonwealth Drive
Warrendale, PA 15096-0001
www.sae.org

Joint Industry Council

7901 Westpark Drive
McLean, VA 22101

National Electrical Manufacturers Association (NEMA)

1300 North 17th Street
Suite 1847
Rosslyn, Virginia 22209
www.nema.org

National Fire Protection Association (NFPA)

1 Batterymarch Park
Quincy, MA 02269-9101
www.nfpa.org

Telcordia Technologies

(formerly BellCore)
445 South Street
Morristown, New Jersey 07960-6438
www.telcordia.com

TÜV Product Service

Segensworth Road
Fareham Hampshire
PO15 5RH
United Kingdom
www.tuvps.co.uk

Underwriters Laboratories Inc. (UL)

333 Pfingsten Road
Northbrook, IL 60062
www.ul.com



Bud Industries, Inc.

Bud Industries, Inc., founded in 1928, is the nation's leading manufacturer of enclosures and related products for the electronics and data industries. The Bud line includes products ranging from small hand held boxes to large cabinet racks, products made from plastic as well as metal, and standard electronic products as well as those that meet NEMA and Seismic requirements. Bud's standard line of over 2500 products is heavily stocked by distribution as well as the company, allowing same day shipment on over 90 percent of the enclosures sold. Modified standard and custom products are also available, as is complete design support.

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