Electronic Housings: Considerations, Standards and Practices for Industrial Applications

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Abstract
Circuit housings used in industrial and utility applications have requirements often not needed in the commercial or consumer electronics industries. The device may be used in locations as diverse as in a chemical factory, wind turbine, transit station, offshore platform, wastewater control panel, or a Smart Grid communications box. These applications often require a high degree of resistance to shock and vibration. They may also be required to operate over wide temperature ranges, especially if mounted in outdoor locations where a lot of electronic equipment is now deployed. They might need to adhere to specific shielding requirements or conform to certain physical sizes and shapes. Others may require DIN mounting options or have touch-safe connector requirements. This presentation will introduce the audience to these issues and provide information about how organizations such as the IEC address them with standards and approvals.

Introduction
For the purposes of this paper and presentation, it is important to define the "industrial" market. It is different from the commercial, residential, and consumer electronics markets in several ways. These differences include exposure to more extreme temperatures, the potential for more severe vibration and a noisy electrical environment.

In brief, it can refer to a location or place like an automotive factory, petrochemical refinery, pulp and paper plant, railway switching yard, telecommunications tower, water treatment facility and many others.

Or it can refer to different types of equipment such as:
- Material handling (conveyors, forklifts, baggage handling, cranes and hoists)
- People movers (elevators, escalators, moving walk-ways)
- Machinery (packaging, metal and wood, pulp and paper, industrial ovens)
- Building automation (security, HVAC, energy monitoring and lighting controls)
- Work vehicles (tractors, trucks, construction equipment, tugboats)

Figure 1 shows a sampling of "industrial" applications and locations.

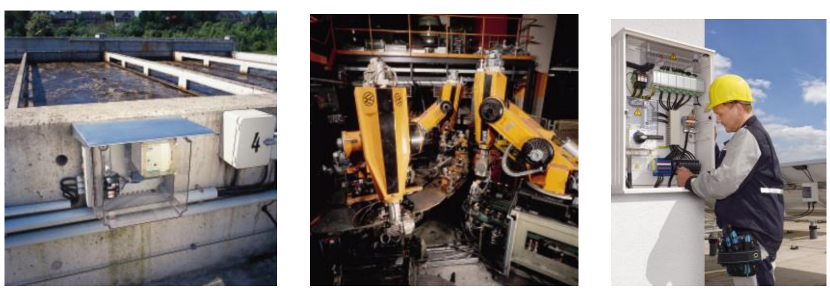


Figure 1: Examples of Industrial Applications

This paper discusses how the selection of electronic housings plays an important role in functionality of devices intended for industrial locations or equipment. We'll first consider how the device is installed. We'll then work backwards toward the design and selection of suitable electronic housings.

Physical Location of Electronic Circuits in Industrial Applications
To use electronic devices in the areas discussed above, it is necessary to understand the general way they are deployed in these applications. The devices are usually mounted within a box, often called an electrical cabinet, junction box, control cabinet, or in Germany, a "switching cabinet." Although there are exceptions, many are made of steel (mild or stainless) and can range from very small (100 mm x 100 mm) to quite large (more than two meters high).

The primary purpose of the cabinet is to physically protect devices inside from environmental affects and to protect personnel from hazardous electrical (and sometimes mechanical) energy. Metal cabinets provide a considerable amount of EMI/RFI protection from outside sources. Industrial devices inside the cabinet are required to have a lesser amount of environmental protection, typically IP20, meaning it is not protected from water incursion.

IP20 also refers to the electrical safety, which we will discuss in the "Connection Technology Considerations" section of this paper. Devices mounted outside a cabinet need a higher level of protection, typically IP65 or IP67, which is roughly equivalent to NEMA 4X. [1]

Inside the cabinet, near the back wall but separated by an air gap, is a sheet of metal called the mounting plate, where devices attach as shown in Figure 2. Using the mounting plate, the user can conveniently mount and wire the devices outside the cabinet on an ergonomically correct worktable and then place them into the cabinet when finished.

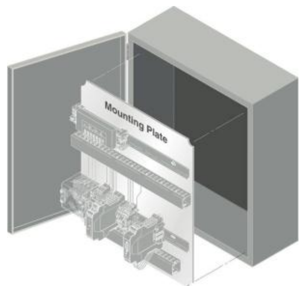


Figure 2: Control Cabinet with Mounting Plate

One method of mounting electronic devices used inside the cabinet is called "panel mounting." This usually means that the device has four mounting holes in its corners to attach it to the mounting plate. While this provides secure attachment, it requires that holes be placed in precise locations to match up with the mounting holes. Since devices come in many different dimensions and sizes, it means the holes can only be used by one particular product in that one location. Still, panel mounting is a good option for very heavy devices or in applications where there are very few devices to be installed.

Another method, developed in Europe, is now simply called "DIN rail." [2] This method eliminates the drawbacks of panel mounting by providing a system for mounting devices that does not require individual holes. Standard DIN rail is 35 mm wide, 7.5 mm high, and is available in two-meter lengths. The rail shape is sometimes referred to as a "top-hat." Both un-perforated and perforated versions are available, as shown in Figure 3.

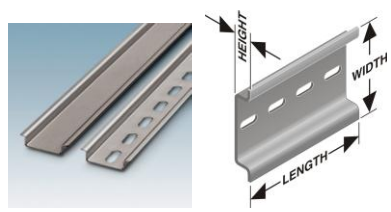


Figure 3: Standard DIN Rail

DIN rail is cut to length and secured to the mounting plate. Individual devices are aligned perpendicularly and snapped onto the DIN rail with the use of a special mounting foot, rather than directly onto the mounting plate. DIN rail is available in different metals including passivated steel, stainless steel, copper and aluminum. There are also dimensionally different variations of the standard DIN rail. A smaller version exists for smaller components. A "high profile" version, measuring 15 mm high, gives more clearance from the mounting plate and provides a stiffer rail for heavier components. [3]

Horizontal orientation of the PCBs inside the housing refers to boards placed in a parallel plane with the rail. Vertical refers to those placed in a plane "normal" to the rail (either in the same direction as the rail or crossing over it). In the housing shown in Figure 4, the PCBs are mounted vertically.

Figure 4: Vertical PCBs in Housings

Electronic housing attach to DIN rail using a mounting foot that physically secures the housing to the rail as illustrated in Figure 5. To place a housing onto a DIN rail, it is angled up and the bottom is clicked into place. This is much quicker than mounting on a panel, since the operation requires no tools.

Figure 5: Mounting Foot

To remove from the DIN rail, use a screwdriver to pull the mounting foot open while lifting the housing off. The mounting foot usually attaches to the lower side of a horizontally mounted DIN rail. The end-user and installer advantages of the DIN rail system have made it the de-facto standard for much of the industrial marketplace. Designers of multipart systems gain flexibility because they can modularize the functionality of the individual devices. We will explore this more in the section titled "Design Optimization with Busing."

Types of Electronic Housings

The simplest form of electronic housing is a tray that holds a PCB board with a DIN rail mounting foot on the bottom. PCB boards are square or rectangular. Many designs have the components exposed, although a variety of covers are available to provide basic protection from electrical shock and to protect the circuitry from mechanical damage. The tray systems generally offer the designer the lowest cost method of placing an electronic circuit onto DIN rail as shown in Figure 6.

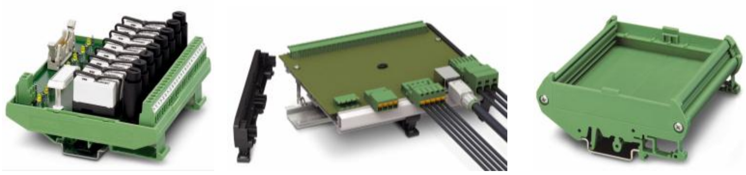


Figure 6: Trays - With and Without PCB and Components

Figure 7 shows an enclosed housing with a horizontal PCB board. This type of housing offers more functionality than the tray. They better protect the PCB inside and provide a higher level of safety from shock.

Figure 7: Electronic Housing with Horizontal PCB

Figure 8 shows a more functional housing with a vertically mounted PCB board. The housing consists of a lower housing with guides that precisely position the PCB, while the upper housing attaches to the PCB board. It can be opened to perform calibration or configuration using the DIP switches. This is especially useful for the designer of multipurpose devices. The top portion of the housing can be opened with the simple operation of a screwdriver. A special catch at the bottom of the PCB prevents the board from coming all the way out of the housing.

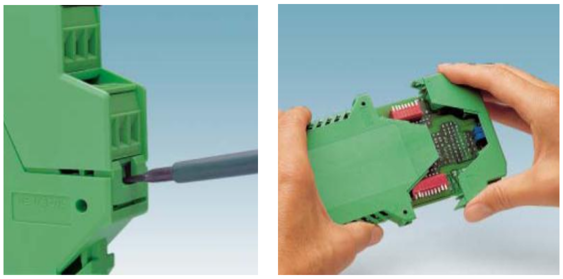


Figure 8: Housing Designed for Opening

“Building automation” refers to lighting controls, HVAC controls, fire and alarm, security, power monitoring, circuit protection devices, and much more. DIN 43880 defines the physical dimensions of building automation devices so they can fit into a control cabinet with standard openings, much like a circuit panel cutouts work in the United States and Canada. [4] More and more equipment must adhere to this system, especially in applications installed as a part of facilities management. Figure 9 shows a complete panel with the overlaying plate and door.

Figure 9: Building Automation Housings per DIN 43880

Grounding Considerations
Electrically, the cabinet and door, the mounting plate, and DIN rail are almost always bonded together and electrically grounded.[5] This prevents energized metal parts from creating a dangerous situation for workers. It also provides a convenient location for electronic devices to connect to ground without having to run a separate wire. Some housings provide the option for a ground contact to be included that connects the PCB circuitry to the DIN rail, as shown in Figure 10.

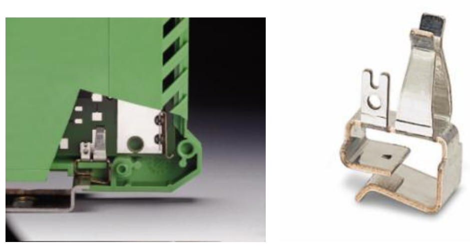


Figure 10: Ground Connection in Housing and a Close-Up View of the Ground Contact

When using a grounding contact on the PCB, it is important to make a distinction between protective earth (PE) used to protect personnel and functional earth (FE), which ensures proper operation of the device. The PE eliminates dangerous voltages and conducts potentially high currents through a low resistance path. The FE to drains the EMI layers of unwanted noise through a low impedance path.

Engineering the FE through the ground contact requires the realization that many devices will use the DIN rail as a ground connection. The rail therefore could become a pathway for noise, defeating its original purpose. For this reason, the PCB designer may want to incorporate galvanic separation between the circuitry and the ground contact.

Engineering the PE through the ground contact requires some consideration, and the user should verify with the housing manufacturer before implementing. According to IEC 60947-7-2:2002,[6] the entire PE electrical path including the ground contact, the PCB and the traces must be capable of handling the maximum current rating of the power connectors for up to one second. Many connectors capable of accepting up to 2.5 mm^2 conductors (roughly equivalent to 14 AWG) have a maximum current rating up to 300 A, so it is not a trivial issue. In the worst case scenario, a properly designed device will provide PE protection, but it is possible that the housing material in the vicinity of the ground contact will melt from the I^2R heating and need to be replaced.

Design Optimization with Busing
When designing a series of devices intended to be used together, housings with integrated wire busing provide benefits to both manufacturers and end-users. Consider a system consisting of a controller that accesses signals from different types of input/output (I/O) circuits. If it is designed as a single component and if customers require different combinations of I/O or controllers, the manufacturer needs to assign unique part numbers for each of the variations. Just a few possible combinations will create many part numbers.

Even if it is designed as a configurable system, for example, a rectangular chassis with card slots, the manufacturer needs substantial time and effort to configure the system before delivery. Such systems routinely had large, unique part numbers that were "built-up" at the factory to specify the functionality desired in the final device.

If such a system is designed as a backplane or perhaps on a single large PCB, customization for individual customers becomes prohibitively expensive. Modification to one part could affect other parts of the circuit, so great care is needed when making changes. Such designs also the limit the potential space savings, since generally the external dimensions of the final device cannot be smaller even if it requires less functionality.

Using a wiring bus with modular DIN rail-mounted housings simplifies both design and use of the final products. Controller and I/O functionality can be designed independently as modular components. The user of the devices selects the required functionality and orders the necessary components using standard part numbers. This requires less effort and costs on the manufacturer's part, since they are off-the-shelf items. System configuration is done at the installation location rather than at the manufacturer. The user only needs to purchase and install the devices that will provide the necessary functionality.

This is possible because busing allows fast and easy connection of power and/or signals between different devices. Both parallel and series connection are possible. Depending on the housing design, somewhere between five and 16 poles are usually available. One method is to place connector on the DIN rail that mates with a connector on the underside of the housing, as shown in Figure 11.

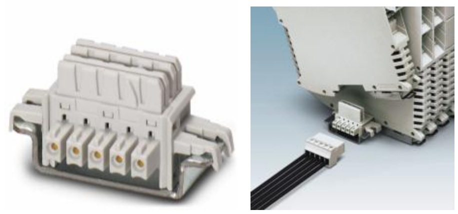


Figure 11: Bus Connectors under Housing

Another method is to attach connectors to the side of the housing. This allows adjacent housings to mate as shown in Figure 12. Regardless of the type being considered, the designer must consider the limitations of any particular bus in regards to current capacity, maximum voltage, and the ability to pass high frequency signals.

Figure 12: Bus Connectors on Side of Housing

Connection Technology Considerations

The connection of power and signal to internal PCB from outside housing can be done in simple manner by terminating conductors directly to fixed PCB terminal block that is already assembled into the electronic housing or terminating into stand alone connector and plug onto mating PCB header as shown in Figure 13.

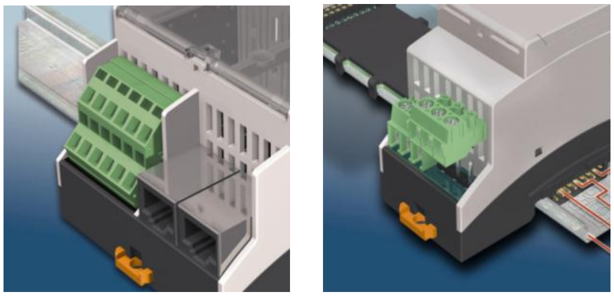


Figure 13: Fixed PCB Connection vs. Pluggable

Table 1 summarizes the criteria to consider when deciding whether to use fixed or pluggable connectors.

Table 1: Fixed vs. Pluggable Connectors

	Features	Benefits	Application
Housings with Fixed PCB Connection	Terminal block is permanently attached to PCB	No additional connector costs	If restriction applies to prevent separations of connectors from PCB.
Housings with Pluggable Connection	Header is permanently attached to PCB and mating pluggable terminal block	Easier maintenance. Reduce field installation time using pre-assembled cable	If devices need to be changed or disconnected frequently

Depending on customer's installation preferences and application needs, there are various wire termination techniques for either fixed PCB connector or pluggable terminal blocks. These connection technologies are illustrated in Figure 14.

Screw connection with tension sleeve is most widely used in industrial housings. Maximum contact force can be achieved per contact surface per conductor cross section. Often transverse grooves are manufactured onto the current bar to ensure that the oxide films on the conductor are broken for gas-tight connection with low contact resistance. The flat clamping part base ensures tight connection of cable to be clamped securely.

Spring-cage technology allows easy wire termination without any special tool or pre-treatment of conductors. The spring is opened with a screwdriver through the actuation shaft as the conductor is inserted into the spring-cage through the separate conductor shaft.

***Industrial-grade* insulation displacement connection (*IDC*) technology** is used in many industrial applications that need fast field installations without stripping off the wire insulation.

Push-in leg spring connection allows fast and tool-free connection of conductors for both solid and stranded conductors with ferrule. The user can simply insert the wire into the terminal point and press against the current by the leg spring. By integrating different color lever, the user can easily identify the connection point and simplify the wiring layout.

Micro insulation pierce connection (IPC) technology is similar to IDC. Micro IPC allows fast connection without using any tool. The user can insert wire through wire guide and simply close the lever to terminate conductors. Due to simplicity and micro contact design, this type of connection technology is ideal for small electronic housings for high density signal and I/O.

Figure 14: Screw Cage Clamp, Spring-Cage, Push-in Leg-Spring, IDC, Micro IPC Technology

Regardless of different terminating methods, the users need to evaluate the type of conductors, size, rated voltage, and current rating for applicable housing prior to connector selection.

Housing Customization

The color for housings used for standard applications is often determined by the manufacturer’s color scheme and can be an important part of brand identity. Combining different housing colors (for example on the upper half, lower half, connectors) can signify certain functionality or create visual appeal, as shown in Figure 15.

Figure 15: Housing Colors

However, devices intended for use in either intrinsically safe devices or for safety system applications will generally use a color designated for these applications. Although they sound similar, these are different applications.

Intrinsically safe circuits (I.S. circuits) are designed for areas where explosive gases are present, and energy in the form of sparks or heat could ignite them. I.S. circuits operate at very low energy levels, so any sparks and heat generated by the electronic devices are lower than the ignition energy required for combustion. The color for I.S. devices (and the terminals, wires, and raceways) is usually bright or light blue, similar to RAL 5015 or Pantone 3015.

Safety relays and systems are designed primarily for applications involving machine safety. These devices take a signal from an emergency stop button, light curtain, or other safety apparatus and then shut down the machine in a manner that prevents injury. These systems are designed to be “fail-safe.” That means if they aren’t operating correctly for any reason (such as “stuck” relay contacts), the device defaults to a condition that ensures safety is not compromised. The usual color is bright yellow, similar to RAL 1018 or Pantone 123.

Selection of Custom Housings

It often becomes necessary to make openings in the electronic housing for displays or operating elements. These openings can be made using mechanical processes such as milling, or by using individual tool mold inserts in the injection molding process. Deciding which to use depends on the design and financial parameters.

Milling requires no investment, but the unit cost is higher than the injection molding process. Milling is best suited for small production quantity, generally up to several thousand. The advantage of milling is that any change can be quickly realized at minimum cost. In contrast, injection molding requires higher investment than milling. Due to shorter production times, however, the piece cost will be lower. Figure 16 shows both techniques.

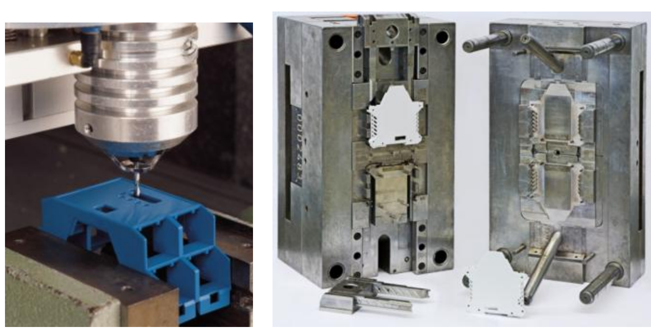


Figure 16: Milling Operation and Injection Molding Cavity

Printing text or graphics on housings has many benefits. Printing allows the users to easily identify the display function in an electronic device. Printing can be on entire housing surface or only on certain components.

Pad printing is widely recognized for labeling of electronics housing. A legible and high-contrast print can be made based on your electronic print copy. A wide range of printing colors is available. Laser printing can generally be used on all thermoplastics. Readability and contrast ratios largely depend on the particular plastic/color combination, the wavelength of the laser and the process parameters, and therefore need to be determined accordingly. Silk screening is a cost-effective solution for printing logos or control legends on a large surface of electronic housing. Figure 17 shows two popular printing options.

Figure 17: Pad and Laser Printing

Power Dissipation

The ability of electronic housing to dissipate power in the form of heat is an important criterion when selecting housing. The designer must understand the source and condition of power consumption to properly dissipate the heat generated by the devices. Improper thermal analysis could lead to undesirable breakdowns of end product system or even potential risk of fire. Therefore, it is critical to understand the internal heat dissipation and how heated air is removed from the device.

The following factors can affect the power dissipation of electronic systems:

- PCB arrangement and number of layers of assembled PCB
- Component selection: PCB circuitry components
- Installation: orientation of housing, spacing between housing
- Physical design of electronic housing: size, vent
- Insulation characteristics
- Operating voltage, leakage current
- Ambient temperature
- General environmental conditions
- Power dissipation and thermal resistance data from semiconductor and housing manufacture

Intuitively, the bigger housings with more free airspace can dissipate more heat than those with less volume. On the other hand, the user may be able to reduce the physical size of the housings after carefully considering the above factors.

Housing manufacturers usually provide power dissipation data similar to that shown in Table 2. However, the users must evaluate the data provided and compare it to the electrical characteristics of the system design in conjunction with actual application environment.

Table 2: Maximum Heat Dissipation:
How Vents and Spacing Change the Maximum Allowed Heating [7]

20°C Ambient Temperature	Vents Present?	
	Yes	No
No spacing between housings	4.4 W	4.3 W
20 mm between housings	8.4 W	7.1 W

If the application requires ambient temperatures higher than 20° C, a reduction factor curve is applied. This is a multiplier used to determine the maximum amount of energy allowed in the housing at those temperatures. The reduction factor of a particular housing, illustrated in Figure 18, indicates a sharp reduction of allowable heat generation at 80° vs. 20° C. Since each product family varies due to specific product requirements, the user will need to refer to the manufacturer's power dissipation and reduction factor data. The user must pay special attention to any applications that involve elevated temperatures by conducting actual validation test or simulating the finished product's electrical behaviors.

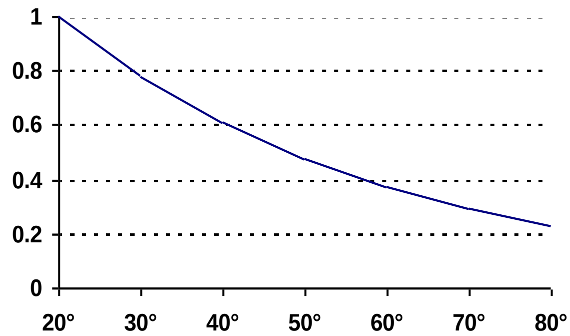


Figure 18: Representative Reduction Factor Curve per increasing temperature (in °C) [8]

The internal heat dissipation can be evaluated in various techniques by measuring actual junction temperature of active components, thermography, and CFD (Computation Fluid Dynamics). The electrical and thermal response can be quantitatively evaluated with a thermography picture.

Thermography is very valuable technique to detect the hot spots in respect to heat source in PCB assemblies. It helps the designer identify and correct the hot spot by optimizing the electrical and mechanical design of the electronic housing before the design is committed to production. Figure 19 shows a re-design that reduced the heat generated in a housing.

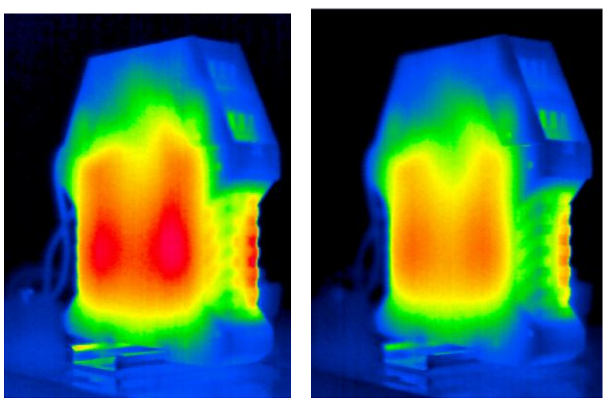


Figure 19: Thermography Image of Hot Spots Before and After Design Correction

Insulation Coordination vs. Housing Spacing
Insulation coordination is an additional consideration to ensure the proper insulation levels of electronic components and electronics housings. It uses empirical data analysis by correlating the insulation characteristics and required spacing of housings based on overvoltage, rated impulse withstand voltage, equipment installation category, and pollution degree. However, this analysis is not intended to replace the system qualification. Since there may be process variation, it is important to follow up with actual test validation and periodic rechecking of clearance to withstand the specified voltages.

There are several guidelines for insulation coordination and housing spacing, including *UL 840 Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment*. UL 840 specifies the air distance (clearance) and over surface distance (creepage) spacing between electrical potentials for safe operation of electrical equipment. These distances are important to prevent potential arcing or leakage currents and takes into consideration the pollution degree and overvoltage protection category since both will influence the performance. Overvoltage category is the grouping of products based on typical installation with respect to overvoltage protection and available energy.[9] The pollution degree is the level of pollution present at the product's location, where the clearance and creepage measurements are taken. For example, Pollution Degree 1 means no pollution or only dry or non-conductive pollution, which has very little impact on the electrical behavior. Pollution Degree 2 represents a temporary conductive as result of condensation.

UL 508 standard covers the test criteria for industrial control devices and automation process systems for use in ordinary locations in accordance with the National Electric Code, NFPA 70. Temperature, overvoltage and undervoltage, dielectric withstand, and short circuit testing validate proper design of electronics housing spacing.

Materials of Construction
Electronic housings can be made from many types of insulation materials. An important selection criterion is to source products from manufacturers who can document that the materials used meet environmental safety regulations like RoHS, VDE, UL and CE marking.

Polyamide is one of the most versatile thermoplastic materials for many engineering applications. Due to good electrical, mechanical, and chemical resistance properties, polyamide is commonly used in industrial electronic housing. It is heat stabilized and can endure temperatures up to 105° C degree. Polyamide reinforced with fiber is characterized by great rigidity, hardness, and resistance to higher temperatures than non-reinforced polyamide.

Polycarbonate contributes many advantages due to rigidity, dielectric strength, and dimensional stability. The material is widely used in electrical applications, because of its high volume resistivity advantage that decreases, and low or almost zero moisture absorption. Polycarbonate can handle temperature up to 125^{o} C. When humidity is introduced to an environment, the amorphous material only absorbs moisture to a very limited degree. It is used for items such as large, rigid electronics component housings. Polycarbonate is particularly suited for use in cover profiles, marking materials or connector plug lever in industrial electronic housings.

Polyvinyl chloride (PVC) is commonly used in the electronics industry due to competitive price. Housing and transparent covers are made of extruded PVC (UL 94-V0). The maximum permitted operating temperature is 50^{o} C. If the application environment requires higher than 50^{o} C, the user can consider high temperature resistant polycarbonate thermoplastic material. While most thermoplastic materials are processed with injection molding using ready-to-use molding and extrusion material, PVC is processed as a powder in the extruder.

Acrylnitrile butadiene styrene (ABS) has good mechanical impact properties and rigidity while maintaining dimensional stability. The material provides precision surface quality, well suited for metallic coating such as nickel.

Tests and Approvals

Degree of Protection per DIN EN 60529
Electrical safety is one of the most important concerns of the connection technologies used on electronic housings. The IEC 60529/DIN VDE 0470-1 defines the two degrees of protection against the external influences or accidental contact of body parts (hand and finger), dust and water to electrical housings for safety and ensures the reliable product performance. In general, electronic housings protected by industrial-grade cabinets are considered as IP20 unless more stringent environmental protection is required.

Touch Proof, IEC 60529
Electrical devices and systems must be designed to protect the service and maintenance people from potential electrical shocks during installation or maintenance. To check shock-hazard protection, a test finger or a test ball is applied at a defined force to every opening of the connecting devices.

“Back of hand” safety requires that an area 100 mm around the live components must not be able to shock a hand. To test, a 50-mm diameter metal ball is rolled around the connector or housing with a pressure of 50 N. The area within 30 mm of a live part must also be finger-safe. This is tested by using a metal rod roughly the diameter of a small finger (12.5 mm). For a product to successfully pass the test, the probe can not come in contact with any live voltage. Electrical devices rated IP20 have passed these tests. Figure 20 shows test apparatus being used with standard PCB terminal blocks.

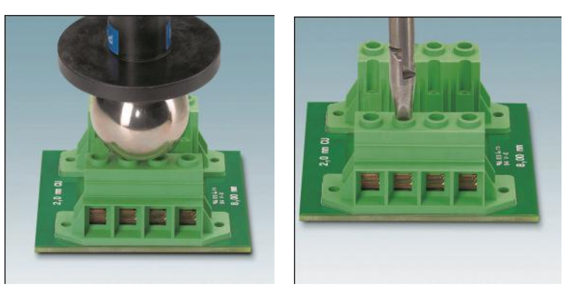


Figure 20: “Back of Hand” and “Finger” Safety Tests per IEC 60529

UL 94 Flammability Test

Underwriters Laboratory Standard 94[10] is the most widely accepted test for flammability performance of thermoplastics. There are two steps of test programs on insulating material that measure the material's ability to extinguish the flame.

The first step evaluates the material's tendency either to extinguish or to spread the flame when subjected to flame ignition. The second test program measures the ignition resistance of the plastic to electrical ignition. The material's resistance to ignition and surface tracking characteristics is described in UL 746A, which is similar to the test procedures described in IEC 60112, 60695 and 60950.

Among the 12 flame classifications defined in UL 94, V0 is commonly molded in fabricating industrial electronic housing. The V0 classification requires testing of the material in a vertical position based on material's ability to self-extinguish within a specified time after the flame ignition is removed. Materials classified as UL 94 V0 have the greatest degree of protection against fire.

UL 746A Short Term Evaluation

According to UL 508, Industrial Electrical Equipments, a polymeric electrical housing shall comply with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746A. In addition to determining whether the material is able to self-extinguish or spread the flame, it is also important to evaluate the material's resistance when exposed to possible flame ignition source. UL 746 is short-term evaluation of material's resistance to three basic tests: Relative Thermal Index (RTI), Hot-wire Ignition (HWI), High-current Arc Resistance to Ignition (HAI), and High-voltage Arc Tracking Rate (HVTR).

IEC Glow-Wire Test (IEC 60695-2)

IEC 60695 [11] is tested to measure, describe, and rank the properties of materials in response to heat caused by contact with an electrically heated wire under controlled laboratory conditions. The Glow Wire Test is used to simulate the ability of product to extinguish fire or not producing particles to spread fire when the product is exposed to excess thermal stress such as a fault current flowing through a wire, overloading of components, and/or simply due to bad connections. While UL 746C requires the insulated live parts to be tested for HWI, HAI, and HVATR, the Glow-Wire Test to IEC 60695-2-11 is used to test individual electrical components and assemblies. The test is exposed to specified glow wire temperature for 30 seconds. The test is considered passing if meeting test criteria DIN IEC 60695-2-11 (VDE 0471-2-11):2009-12 which is basically:

a. No ignition occurs at all.
b. If ignition does occur, flames or glowing material is extinguished within 30 seconds after removal of the glow element.
c. Flammable materials placed underneath the test specimen or the specified layer do not ignite.

Figure 21 illustrates glowing element pressed into electronic housing in a progression of steps.

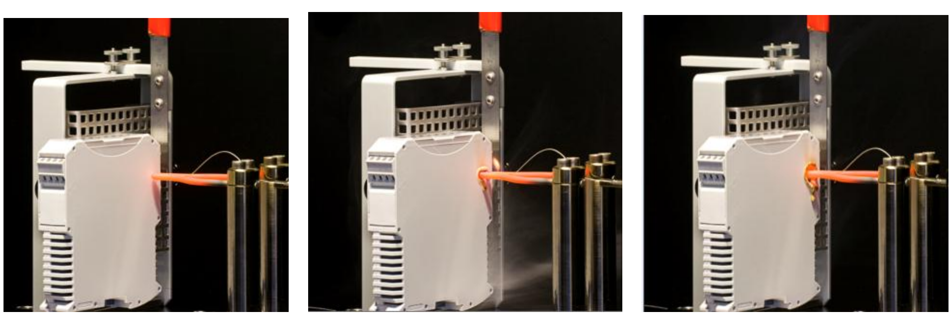


Figure 21: Glow Wire Test on Electronic Housing

The glow wire test can be also defined as Glow Wire Ignition Test (GWIT) and Glow Wire Flammability Index (GWFI) to test the behavior of the material. The difference is that GWIT and GWFI are usually done in solid electrical insulating material (disc or plate).

GWFI (Glow Wire Flammability Index) is the highest temperature at which the flame extinguishes within 30 seconds after 3 successive applications. Typically, the penetration depth of the heated resistor is limited to 7 mm. Detail test criteria and procedures for GWFI (Glow Wire Flammability Ignition) are specified under IEC 60695-2-12.

GWIT (Glow Wire Ignition Temperature) is 25° C above the highest temperature measured at which no flame occurs. A glow wire with specified temperature is applied to the thermoplastic at 1 Newton for 30 seconds in three consecutive times.

Vibration Test

The typical industrial environment exposes electronic systems to a high degree of shock and vibration. The tests in accordance to DIN EN 60068 2-6:2008 (vibration safety) and 600668-2-7:2008 (shock test) determine the ability of components to withstand the specified severities of sinusoidal vibration by simulating rotation, pulsating, and oscillating forces.

Table 3 shows the vibration test conditions applied to an electronic housing**.**

Table 3: Vibration Testing per DIN EN 60068

Frequency	10 to 150 Hz
Sweep speed	1 octave/min
Amplitude	0.35 mm (10 to 58.1 Hz)
Acceleration	5 g (58.1 to 150 Hz)
Test duration	2.5 h per axis
Test direction	x, y, z, in all 3 dimensions
Test weight on the PCB	200 g
Condition of test candidate	Annealed conditioned 2 %

The general criteria for vibration test is to ensure no damage occurs that would affect further use of the device, that everything remains secured on the PCB and housing, and that contact resistance doesn't rise more than 1.5 mΩ.

Climate Testing

The climate and environments are accelerated life tests to ensure product reliability in various environmental conditions such as temperature, humidity, atmospheric pressure, and salt water. The industrial electronic housings are subjected to series of accelerated temperature shock tests between -40 to 105°C. Based on the evaluation of climate test, the users can determine the quality and long-term effects of the product use.

The climate test evaluates the following parameters:

- Contact resistance (before and after) and Withstand voltage
- Cold storage test (DIN EN 60068-2-1: 1995-03), shown in Figure 22
- Temperature change (DIN EN 60068-2-14:2000-08)
- Heat storage (DIN EN 60068-2-2:1994-08)
- Damp heat storage (DIN EN 60068-2-30:2000-02)

Figure 22: Electronic Housings Tested to DIN EN 60068-2-1

Design-In-Process for Electronic Housings

Today's industrial device manufactures face many challenges, including the need for shorter product development cycles while also reducing the overall system cost. Many equipment vendors often break away from their traditional vertical integration and create strategic partnerships with expert suppliers, such as housing manufacturers, to deliver the new product innovation.

A stage-gate or milestone process is an operational roadmap. It is used in product development cycle from idea inception to product launch, as shown in Figure 23. Stage-gate process accelerates the time-to-market, while delivering quality and managing the potential risk. Each stage is separated by decision gates, which are critical to execute prior to moving on to the next stage of product development.

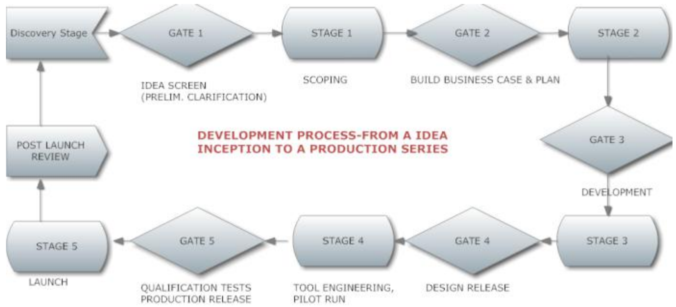


Figure 23: Stage-Gate Process

Stage 1, applied to a development of an electronic device, begins the “scoping” process. This requires close cooperation between the technical teams of both the customer and housing supplier. The team’s goal is to define the technical requirements so the project can be completed on schedule. For a complete technical specification and quotation, the team must discover the following criteria during the scoping process:

- Dimensions of desired finished housing
- Mounting style (DIN rail or panel)
- Type of housing
- Housing and connector colors
- Printing and labeling requirements
- Operating temperature
- Housing material type
- Number of poles (# of termination points)
- Number of PCB and orientation of PCB
- Types of connection technology
- Bus connections desired
- Electrical (voltage, current, power dissipation)
- Pollution degree and overvoltage category
- Agency approvals required
- Unit quantities
- Target dates

After the customer approves the budgetary quote and project plan, the housing supplier’s design team will construct the concept design in CAD and hold a design review meeting prior to building actual mold tooling. Upon request, the manufacturer can supply a rapid prototype to the customer to validate the form-fit-function compared to the customer’s future application uses. Pilot samples from the production tool will be fully evaluated to comply with all necessary pre-defined test plans. Finally, it is important to have a post-launch review with both teams to deliver continuous technology innovation for the next product generations.

Conclusion

The industrial marketplace offers increasing opportunities for designers of PCBs as the manufacturing, process, utility, and transportation segments rely on more and more electronics. This paper has discussed some of the nuances of matching the electronic housing options with the application requirements. We hope this paper will provide the foundation for further study.

Authors

Mike Nager graduated from the University of Scranton with a BS in Electronics Engineering (1988) and is a senior member of IEEE. He has worked for manufacturers of industrial controls including Moore Products, Leeds & Northrop, ifm efector, and Phoenix Contact. He has published papers in periodicals including Control Engineering, Industrial Computing, Machine Design and Plant Engineering. He heads the Industry Management department of Phoenix Contact, one of the world’s leading manufacturers of industrial devices, connectors, and housings. He works out of the Phoenix Contact Inc. Americas headquarters in Harrisburg PA.

Kristy Yi holds a BS in Mechanical Engineering Technology (1996) and an MBA (2003) from Penn State University. She held various leadership positions from Senior Industrial Engineer, Product Engineer and Product Manager for leading manufactures including Berg, FCI, Tyco, and Phoenix Contact. She has developed high speed/high volume connector manufacturing systems and connectors for both consumer and industrial markets. She is the Product Manager for Americas Device Connection Technology. Kristy is a member of ODVA and Fieldbus Foundation and works out of the Phoenix Contact Inc. Americas headquarters in Harrisburg, PA.

Jan Maksel holds a Graduate Engineer degree (2006) in Industrial Engineering (Wirtschaftingenieur) from the University of Applied Science and Arts in Göttingen, Germany. His study included a combination of both engineering and business topics. He has worked for world leading companies including ABB (Automation Unit), KSB (a manufacturer of pumps and automation), Sartorius AG (a manufacturer of weighing technology), and Phoenix Contact. He is Phoenix Contact’s Product Manager for Electronic Housings and works out of its global headquarters in Blomberg Germany.

References

[1] The direct comparison between IP rating and NEMA ratings can’t be made and the differences are beyond the scope of this paper. A simple internet search will direct the reader to many informative discussions on the topic. At the time of writing, a “harmonization” effort has begun.

[2] The name is DIN is based on the Deutsches Institut für Normung (translation: German Institute for Standardization). DIN rail dimensions according to EN 60715 are 15 x 7.5 mm

[3] EN 60715 also defines the 15 x 5.5 mm and 35 x 15 mm DIN rail variations

[4] DIN 43880 Built-in equipment for electrical installations; overall dimensions and related mounting dimensions

[5] In some situations, the DIN rail will be electrically isolated from the backplane with the use of non-metallic standoffs. This can be used to establish an isolated ground to ensure signal integrity as well as for other purposes. If the DIN rail is not grounded than other precautions such a shielding and labeling must be utilized to protect personnel from accidental shock.

[6] IEC 60947-7-2:2002 Low-voltage switchgear and control gear - Part 7-2: Ancillary equipment - Protective conductor terminal blocks for copper conductors. Applies to protective conductor terminal blocks with PE function up to 120 mm2 (250 MCM) and to protective conductor terminal blocks with PEN function equal to and above 10 mm2 (AWG 8).

[7] Data from Phoenix Contact ME 12,5 series of electronic housings

[8] Data from Phoenix Contact UEG series of electronic housings

[9] Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment-UL 840: ISBN 0-7629-1049-6; March 2, 2007

[10] UL 94, the Standard for Safety of Flammability of Plastic Materials for the Parts in Devices and Appliances testing. http://www.ul.com

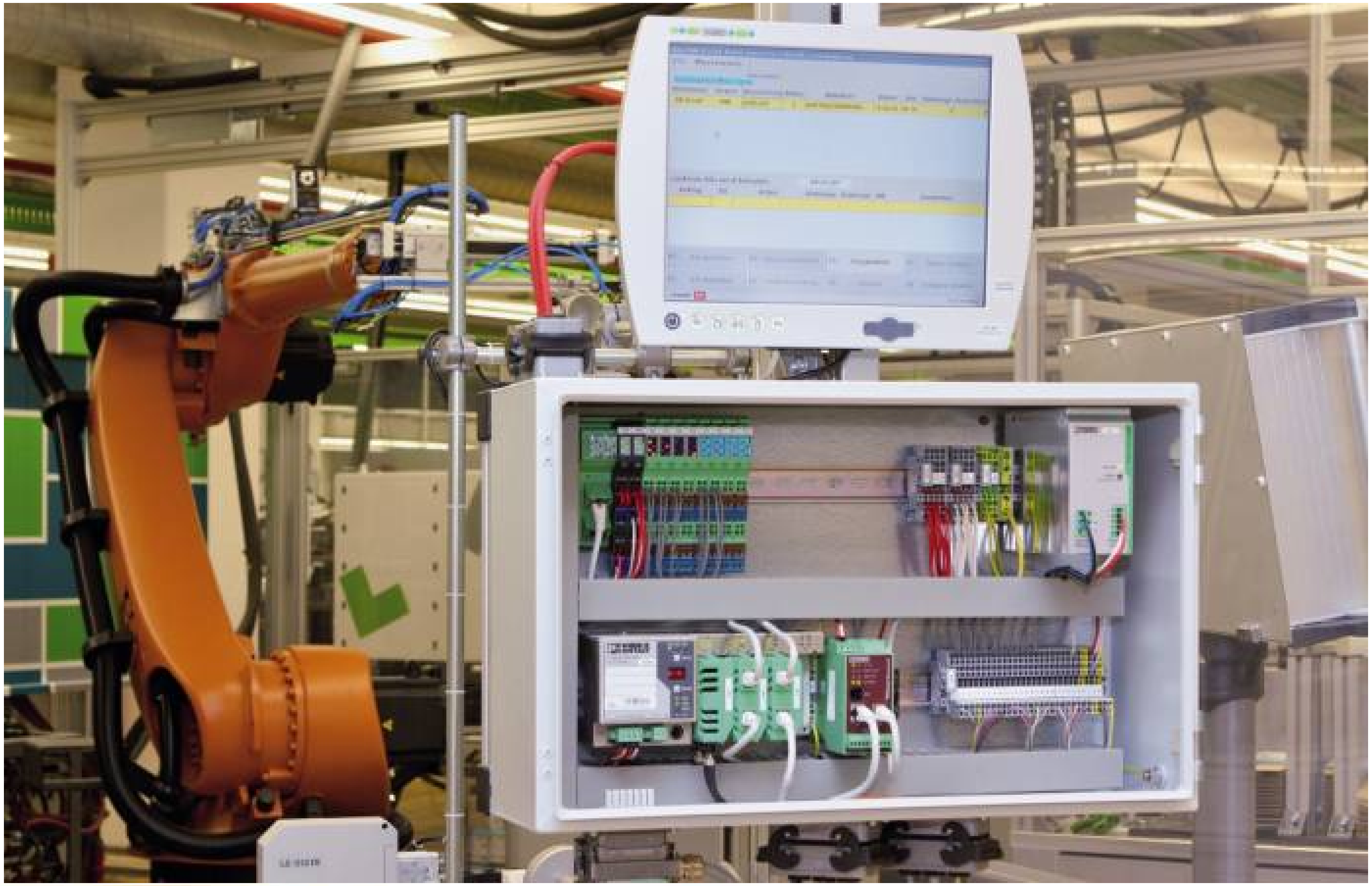
[11] IEC 60695-2-12 Fire hazard testing - Part 2-12: Glowing/hot-wire based test methods - Glow-wire flammability index (GWFI) test method for materials and IEC 60695-2-11, Fire hazard testing - Part 2-11: Glowing/hot-wire based test methods - Glow-wire flammability test method for end-products

Electronic Housings

Considerations, Standards and Practices
for Industrial Applications

Mike Nager
Phoenix Contact, Inc.

What is Industrial?



This…

Not That!

Flickr/ rack in pro tools suite / Chris Campbell

This…

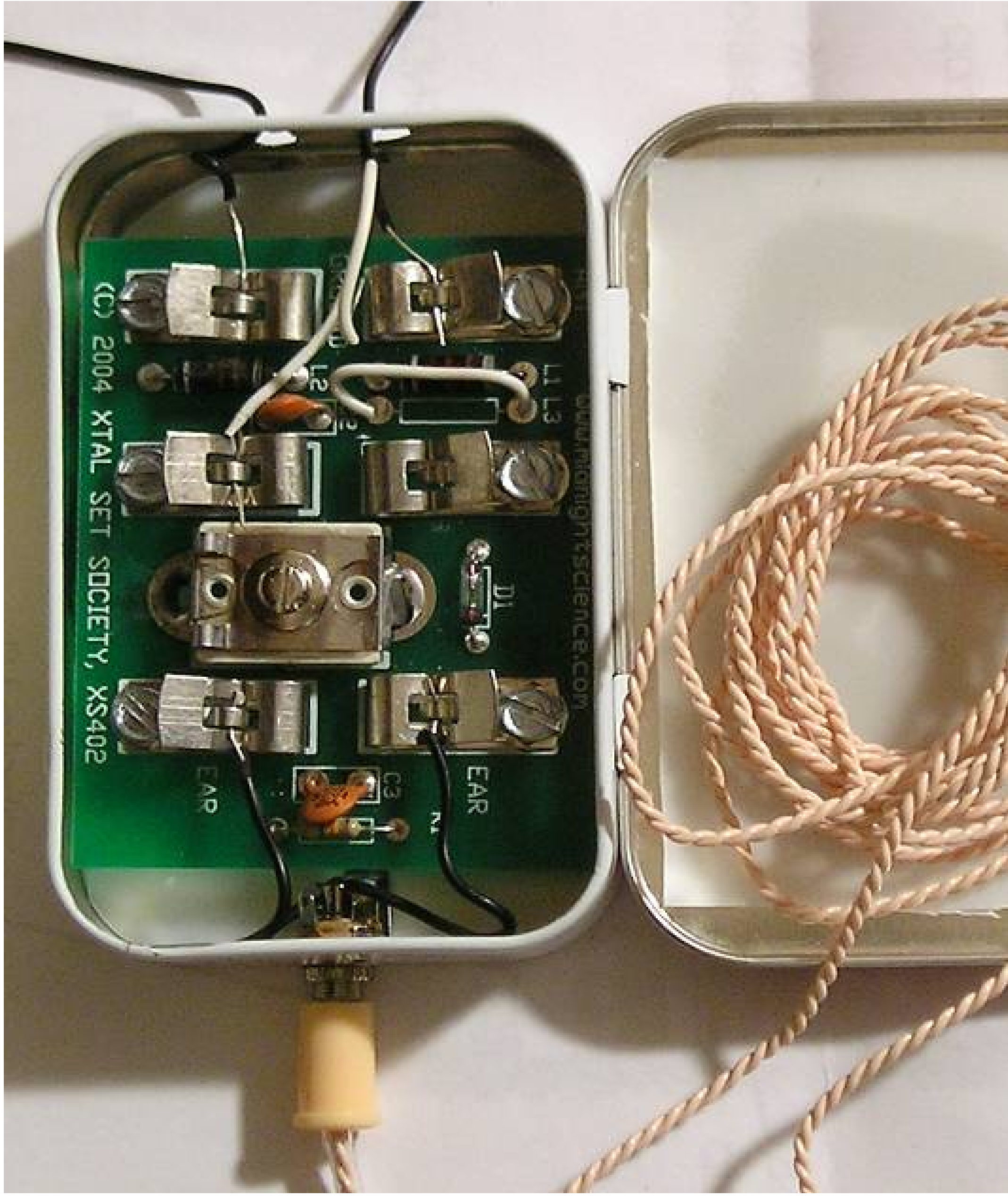
Flickr/Pelco Surveillance Cameras/takomabibelot

Not That!

Flickr/ the pinky rack / pallotron

This…

Not That!



Flickr/ altoids crystal radio /BitHead

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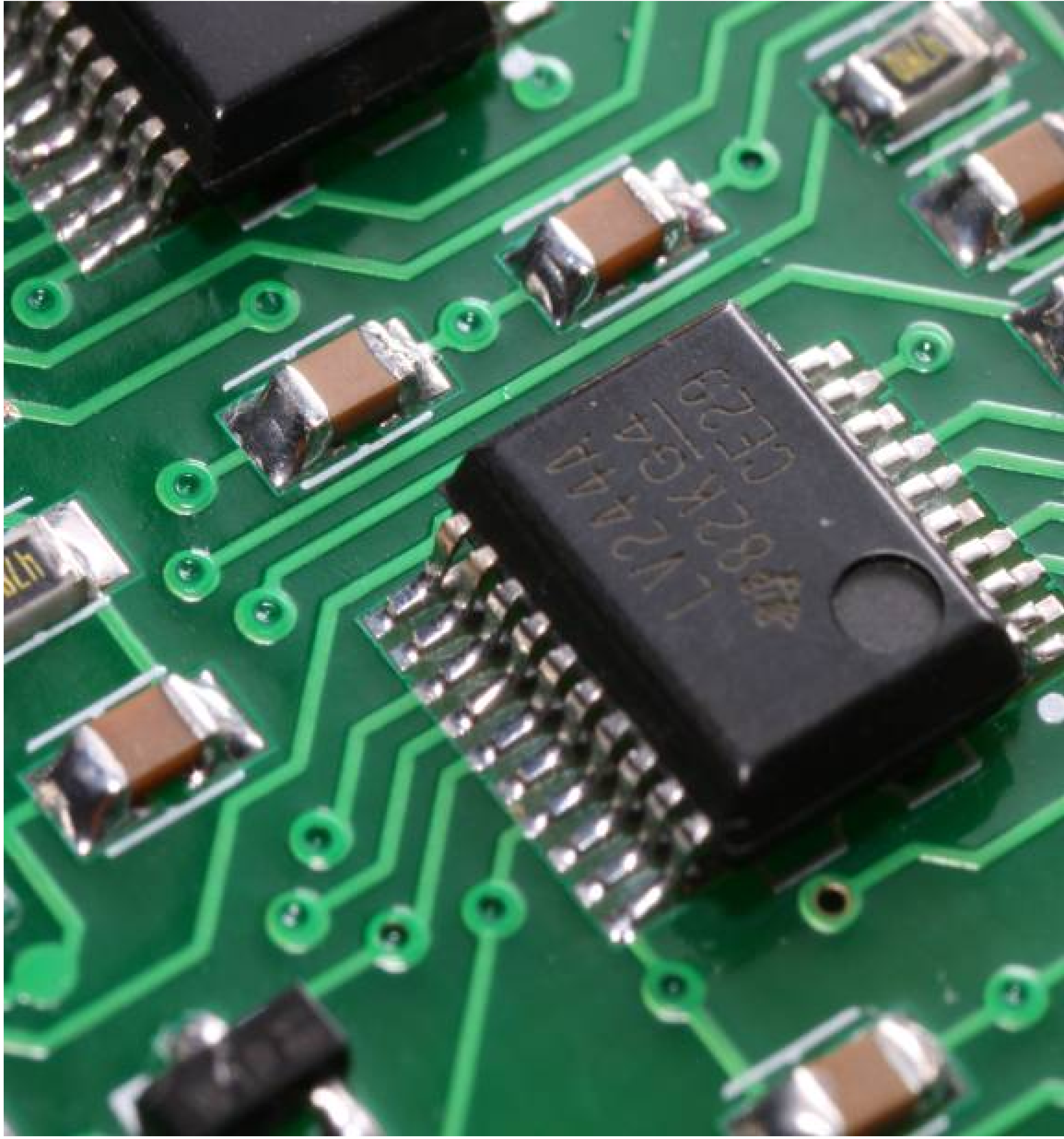
Flickr / Not a sign of sunshine / cablefreak

Not That!

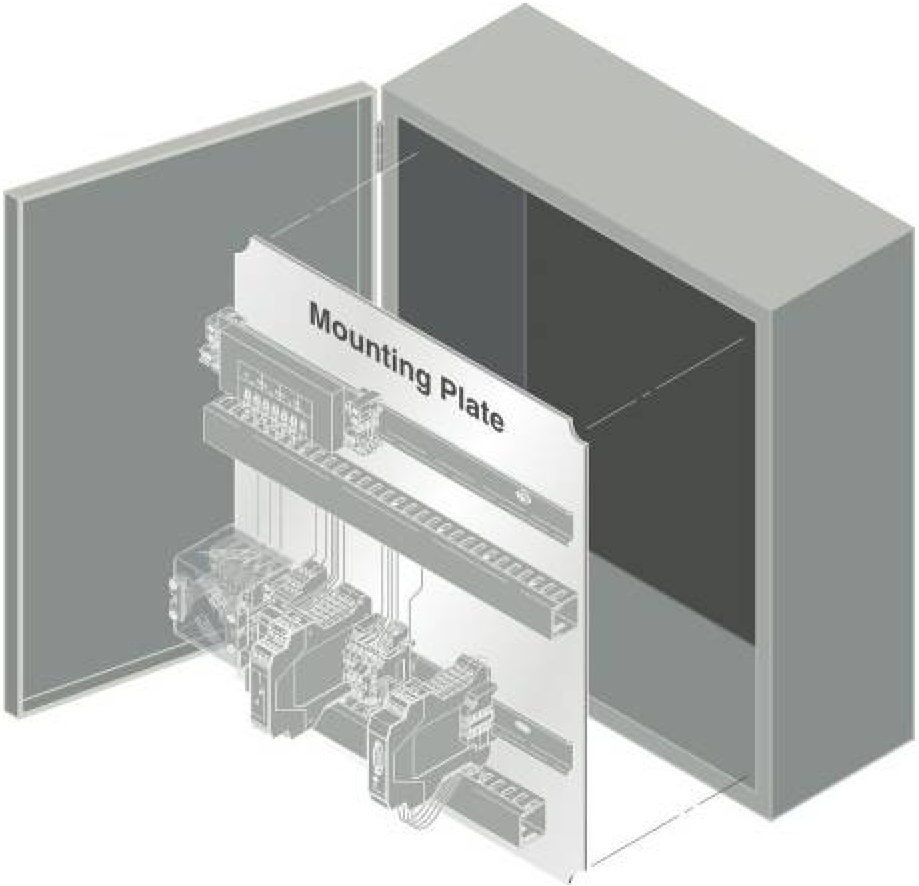
Flickr/Jardin Electrique/meddygarnet

How to Protect a Sensitive Product?



Flickr / JTAG board 1 / AMagill

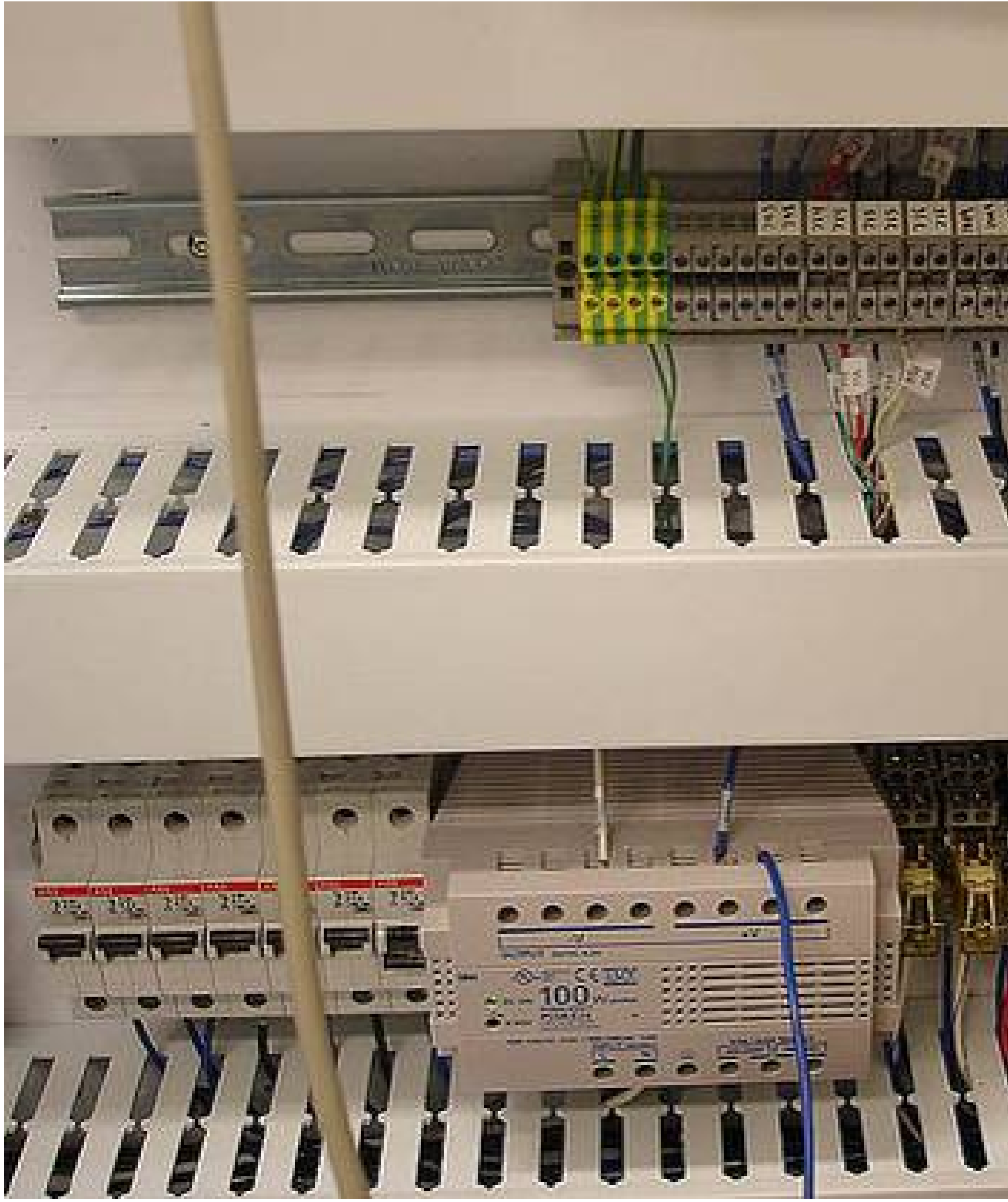
Control Cabinets



Panel Mount

Flickr / backs of small drives / Фигушки

DIN rail Mount



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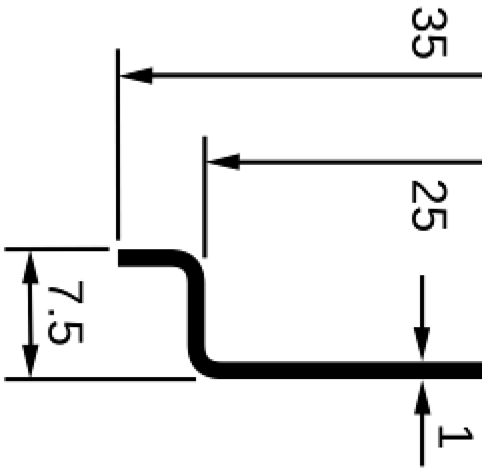
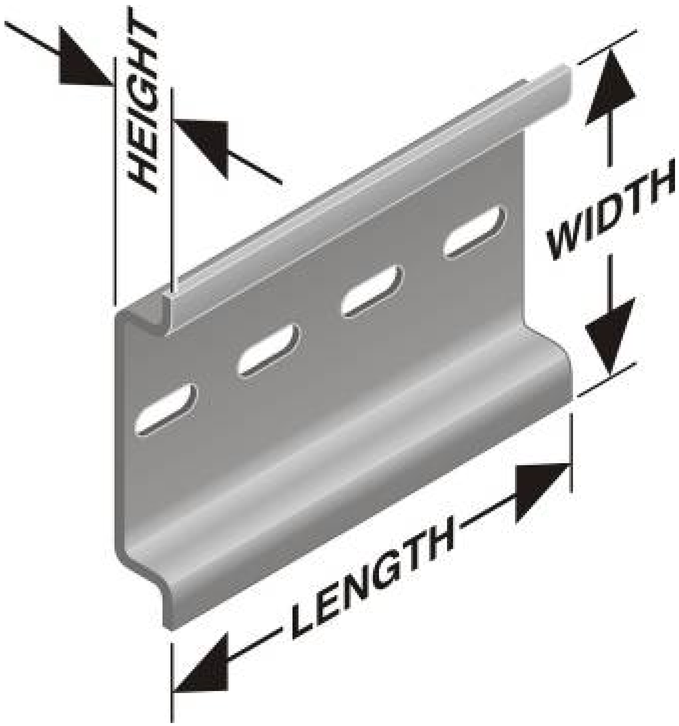
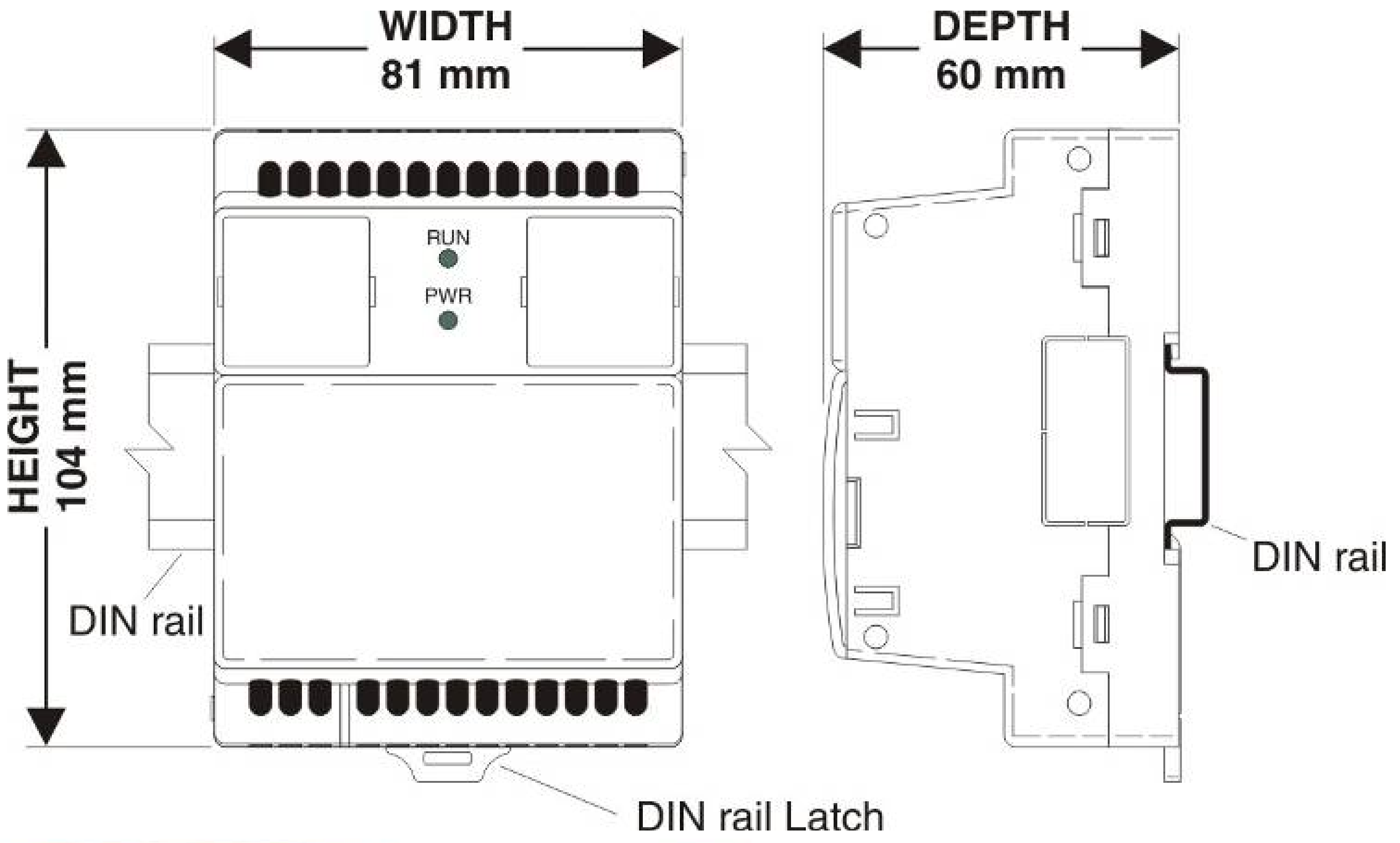
DIN Rail Dimensions



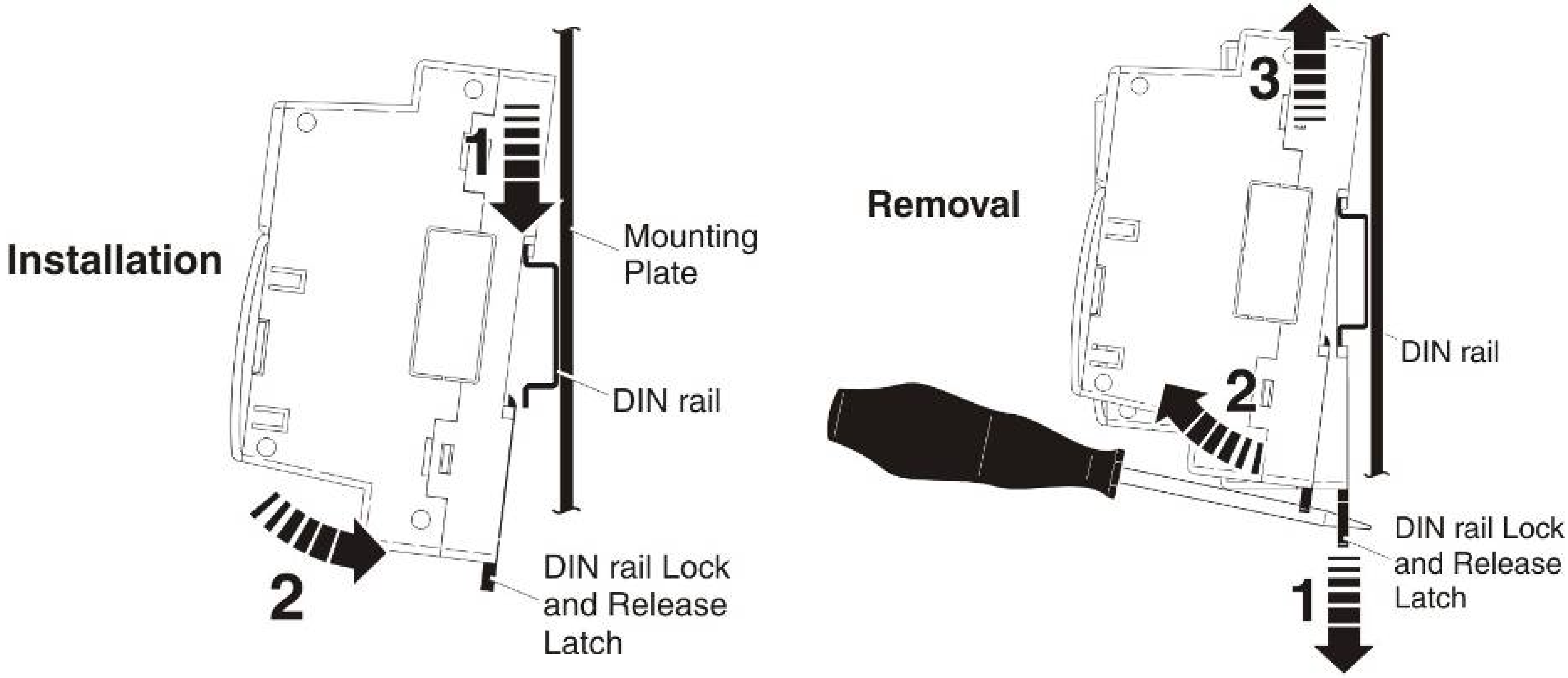


DIN Rail Variations

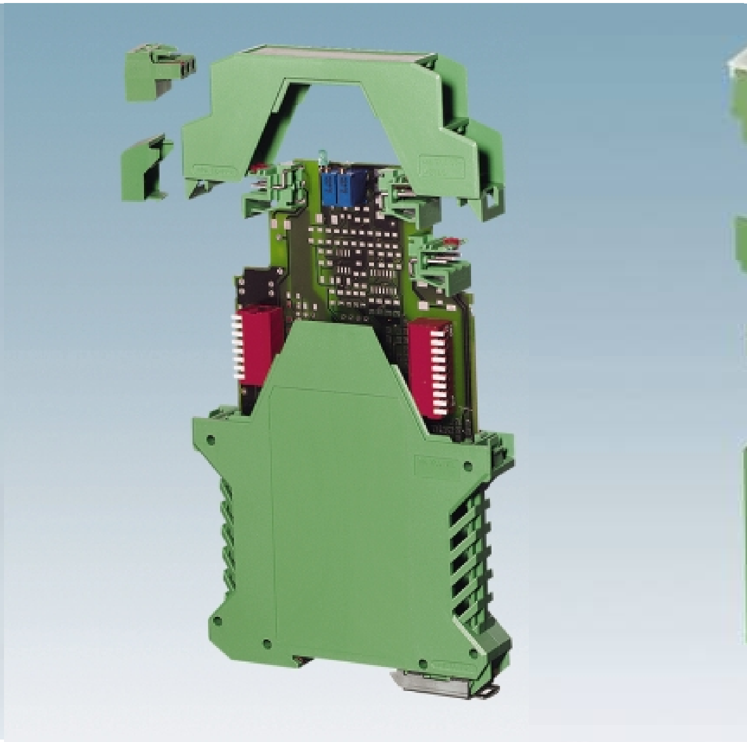
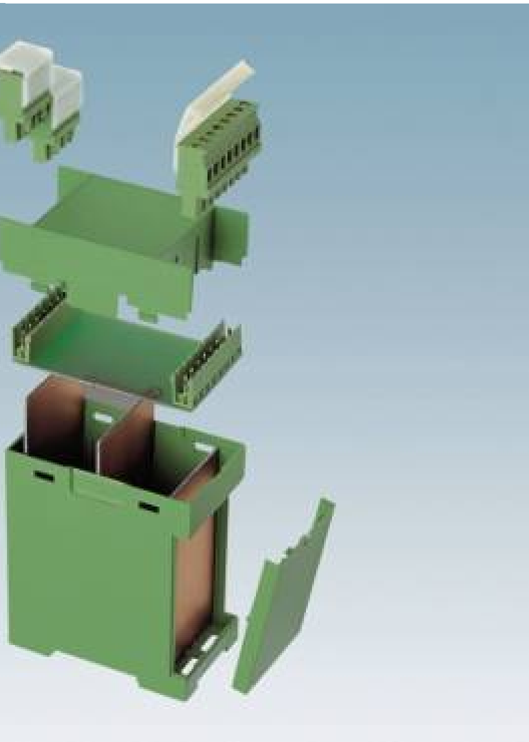
Dimension Convention



Easy On / Easy Off



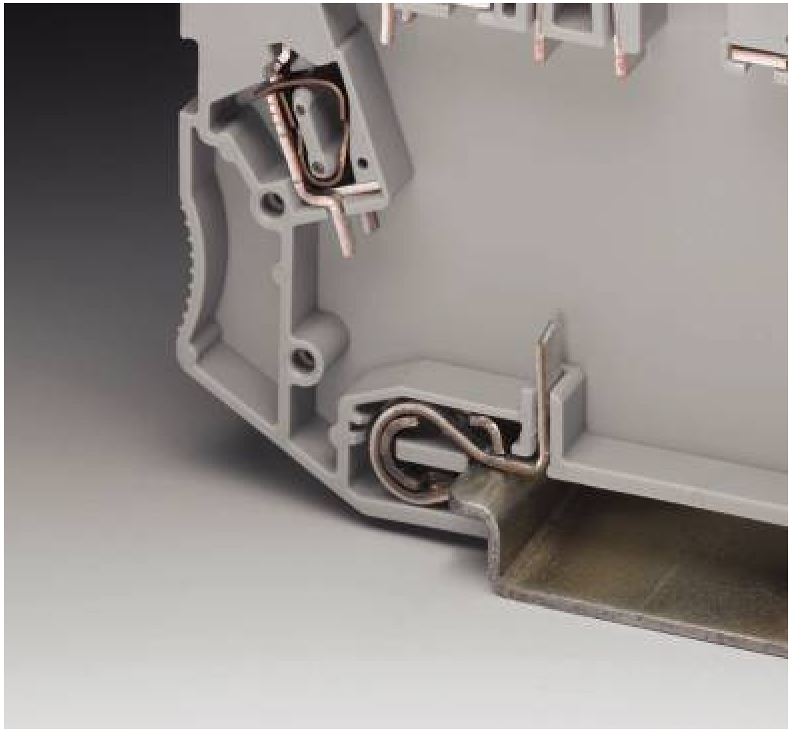
Vertical and Horizontal PCBs

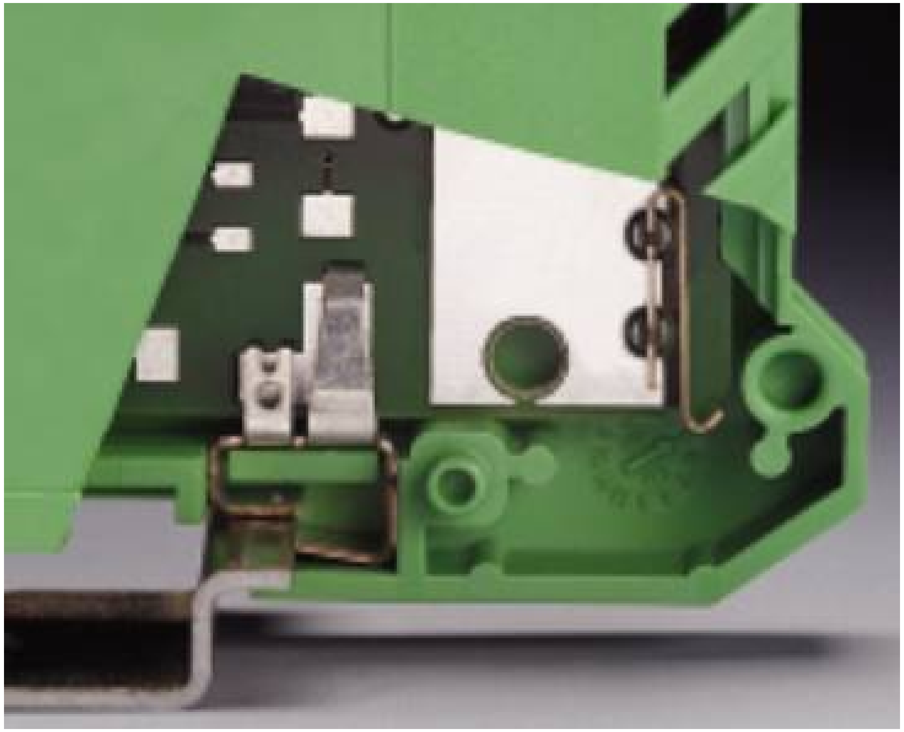




Grounding

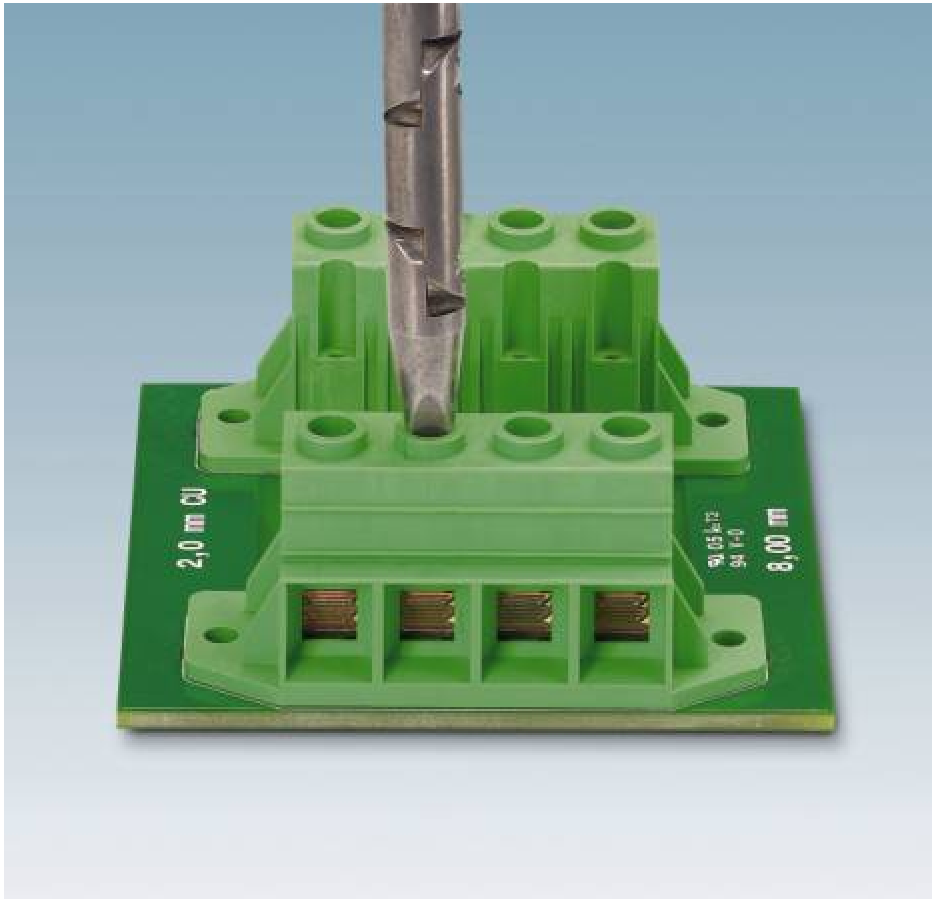
Flickr / Keeping my feet on the ground / purplemattfish

Grounding





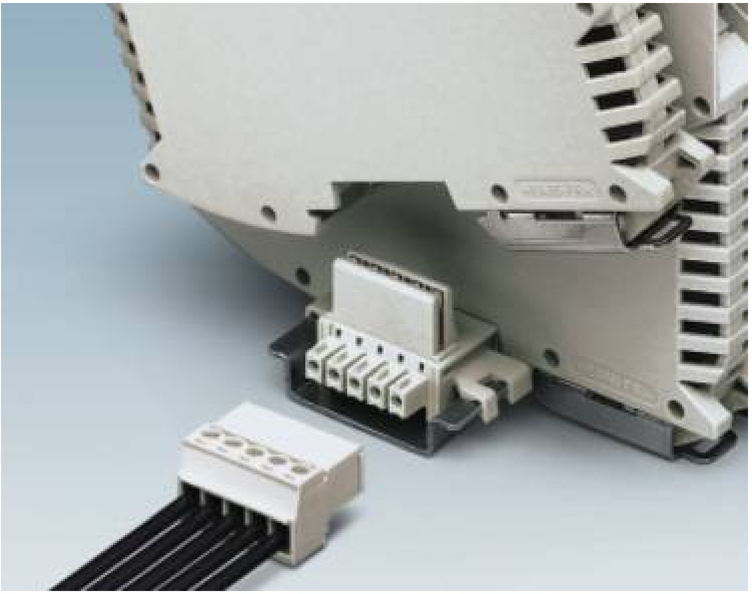
IP Ratings

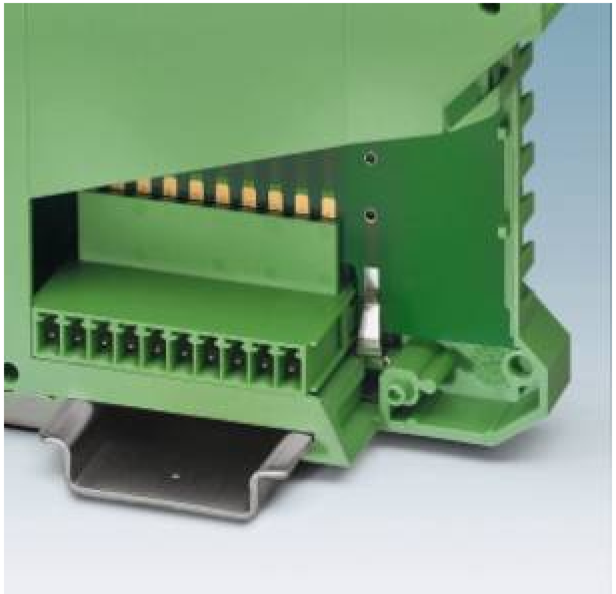


Busing Options

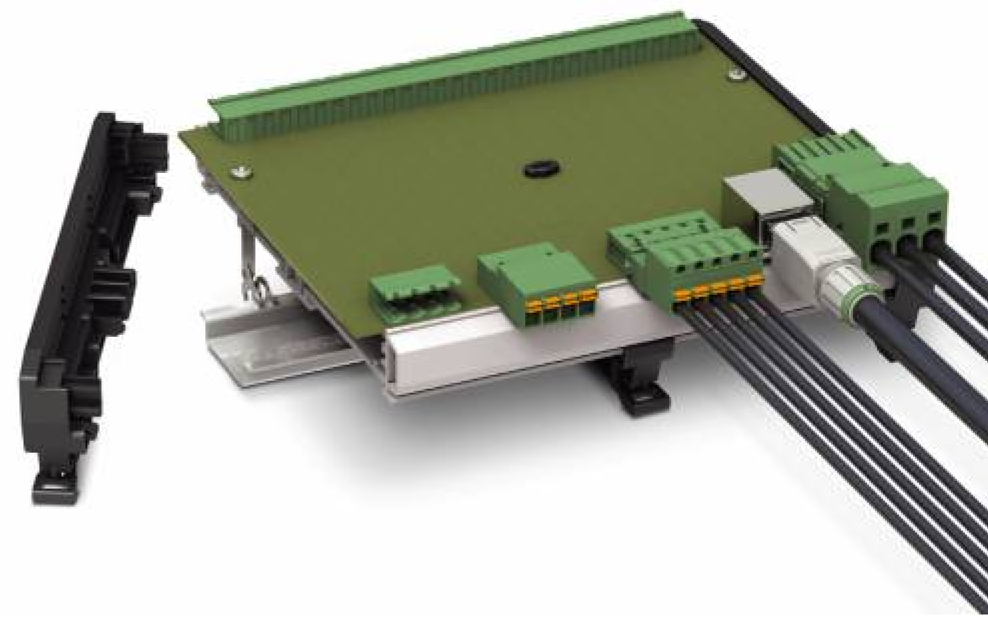
Flickr / East London Bus Group / AndrewHA

Busing Options

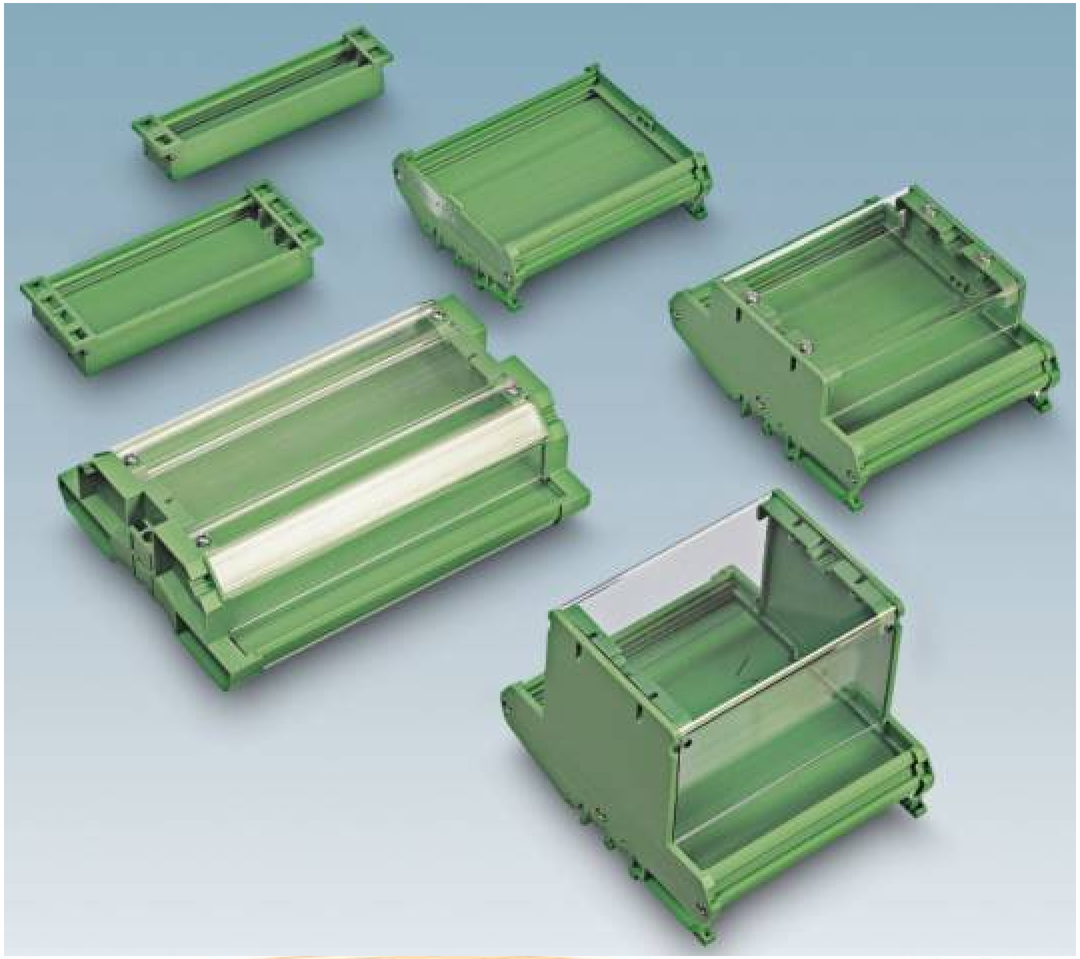




PCB “Trays”

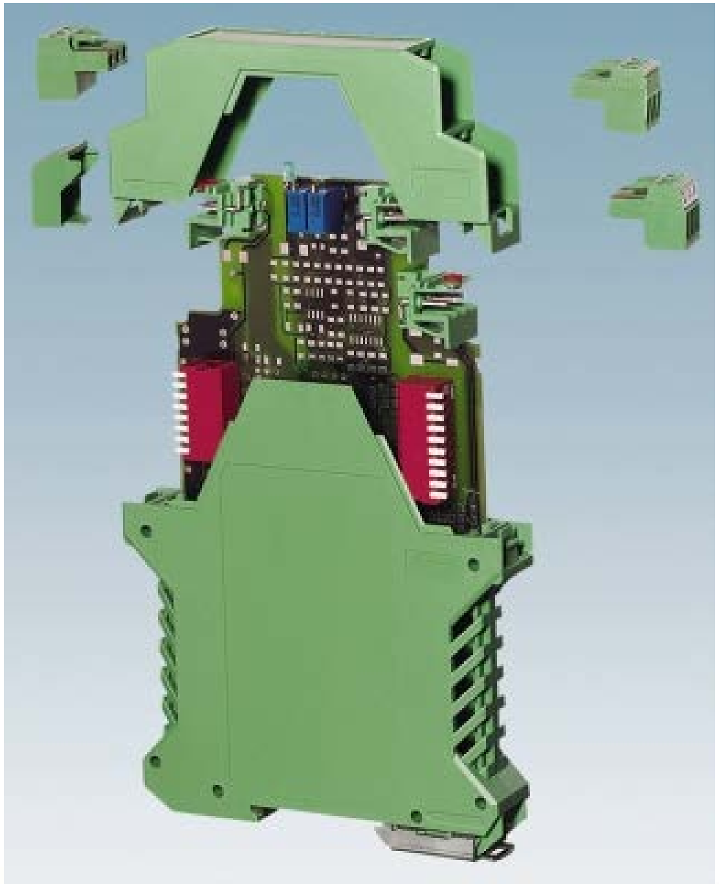


Tray Accessories



- Protective Covers
- Labels

More Functional Housing

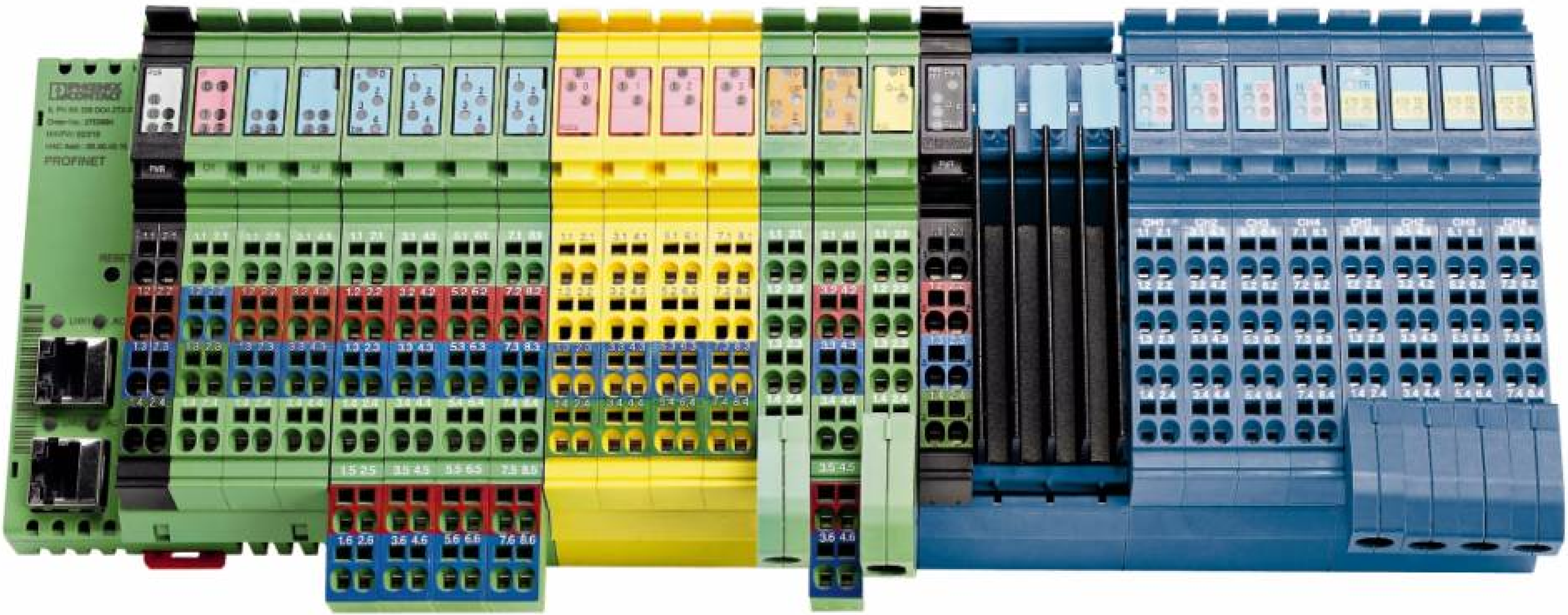


- Fully Enclosed
- IP20
- Vented
- User Configurable PCB
- Removable or Fixed Connectors
- Grounding via DIN rail
- Narrow design

Building Automation

- DIN 43880
- For ‘built-in’ electronics
- Standardized dimensions

Special Application Colors



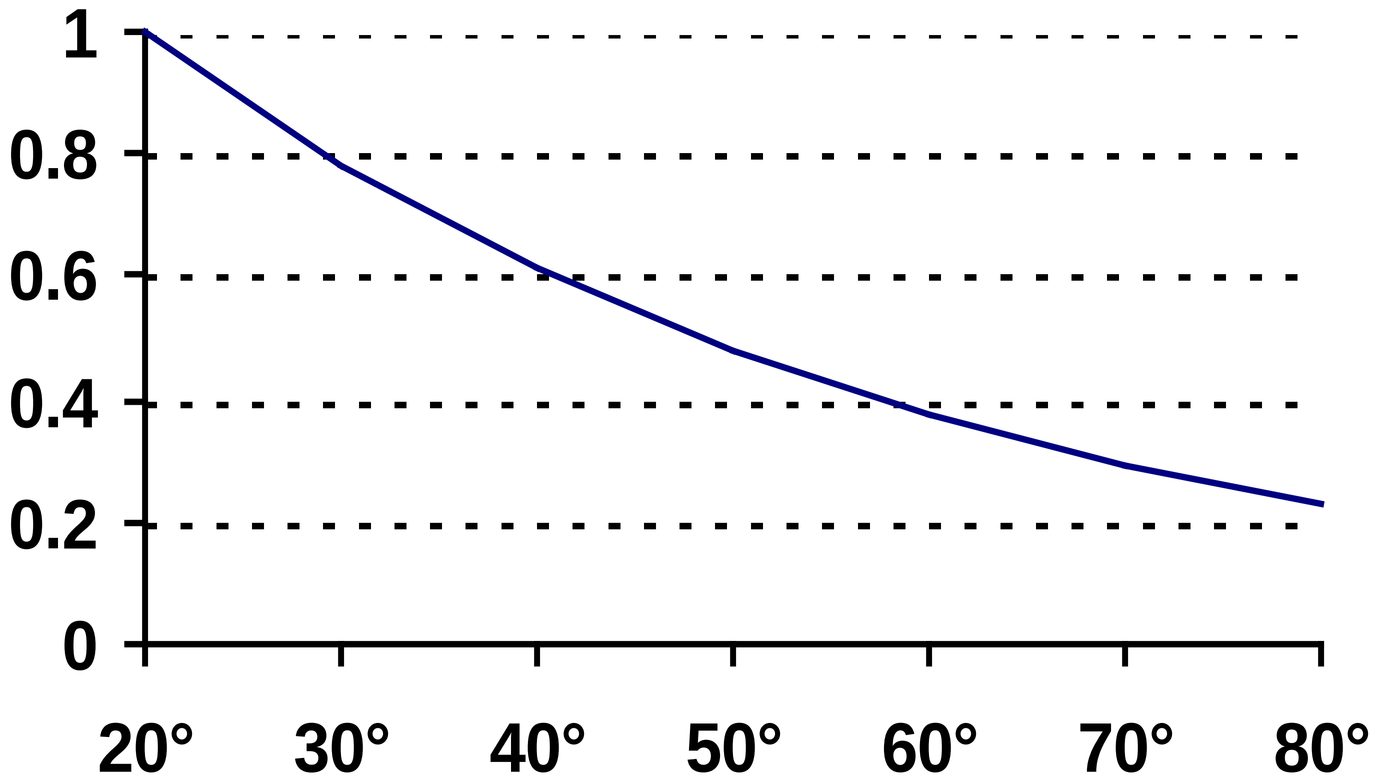
Power Dissipation

Table 2: Maximum Heat Dissipation:
How Vents and Spacing Change the Maximum Allowed Heating [i]

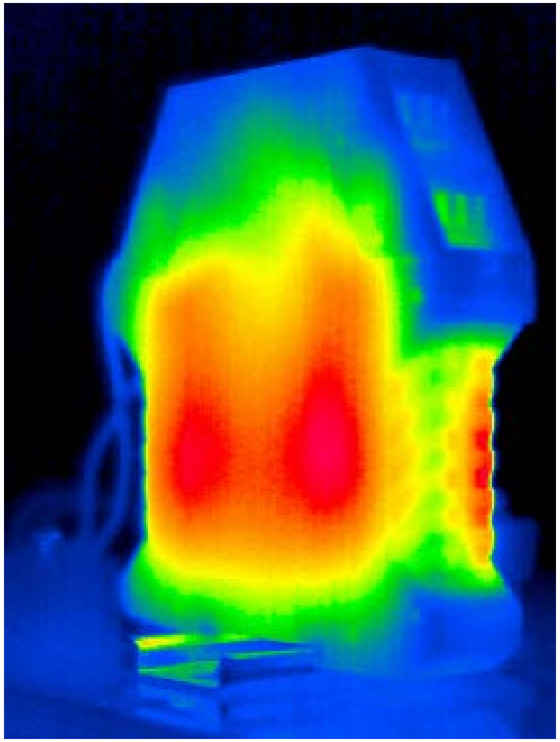
@ 20° C Ambient Temperature	Vents Present?	
	Yes	No
No spacing between housings	4.4 W	4.3 W
20 mm between housings	8.4 W	7.1 W

[i] Data from Phoenix Contact ME 12,5 series of electronic housings

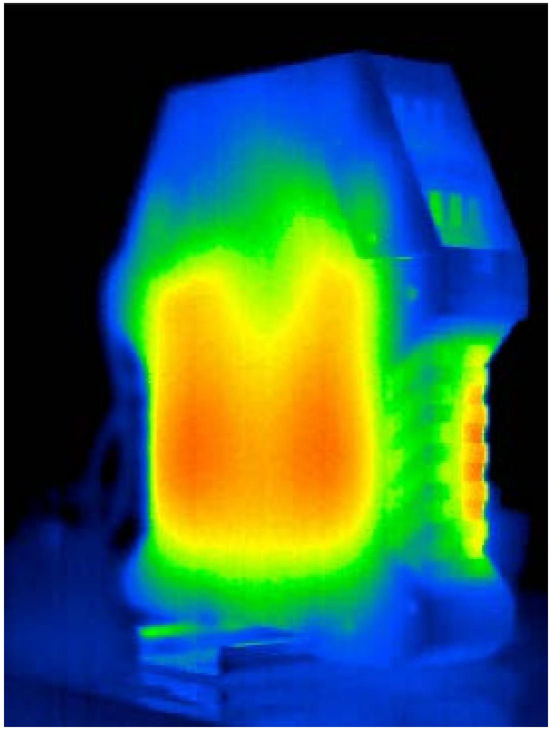
Temperature Derating



Thermography

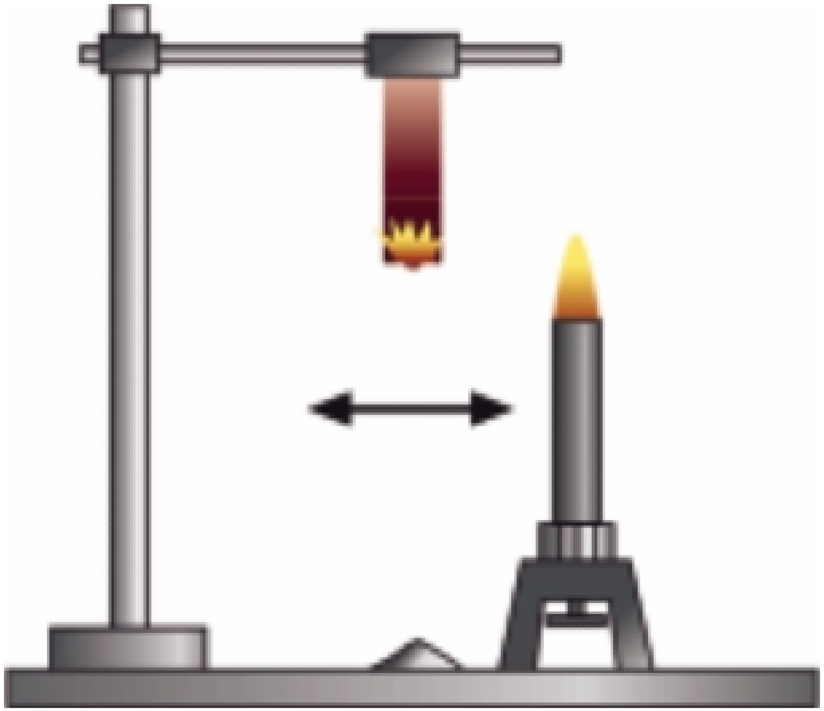


Before

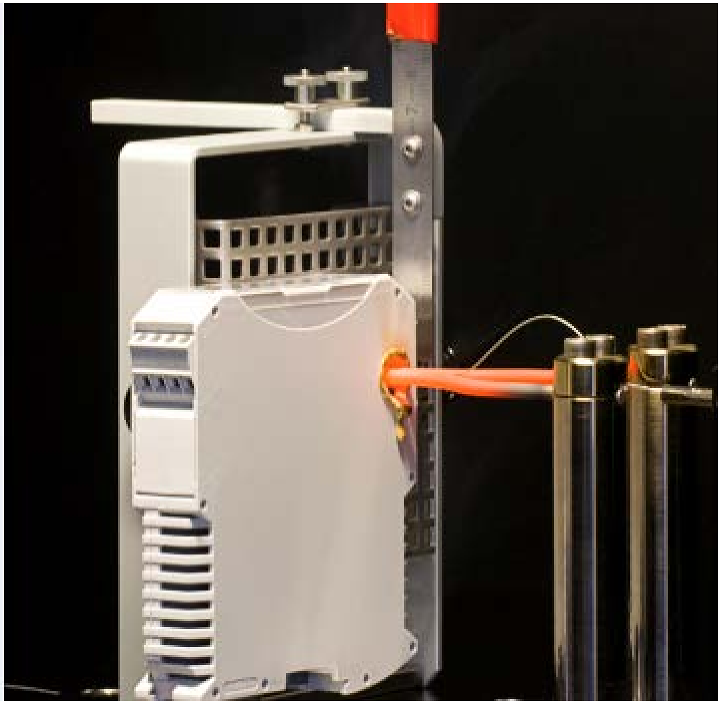


After

Test and Standards to prevent…



UL94

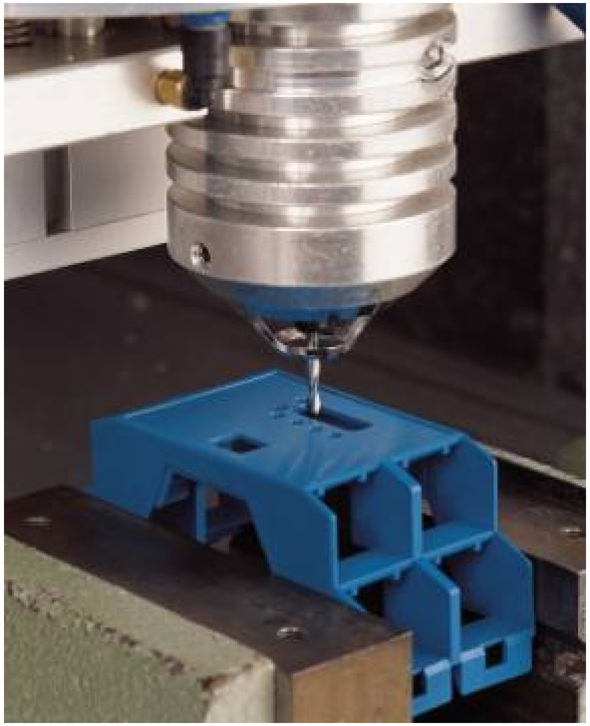


IEC Glow Wire Test

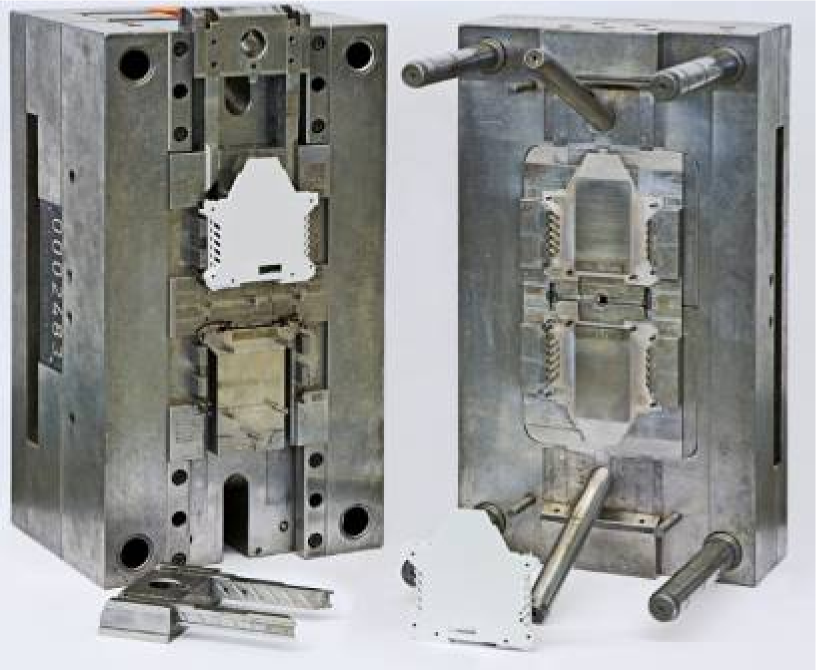
This.

Flickr/ inside the control box / Tom Gill (lapstrake)

Customization

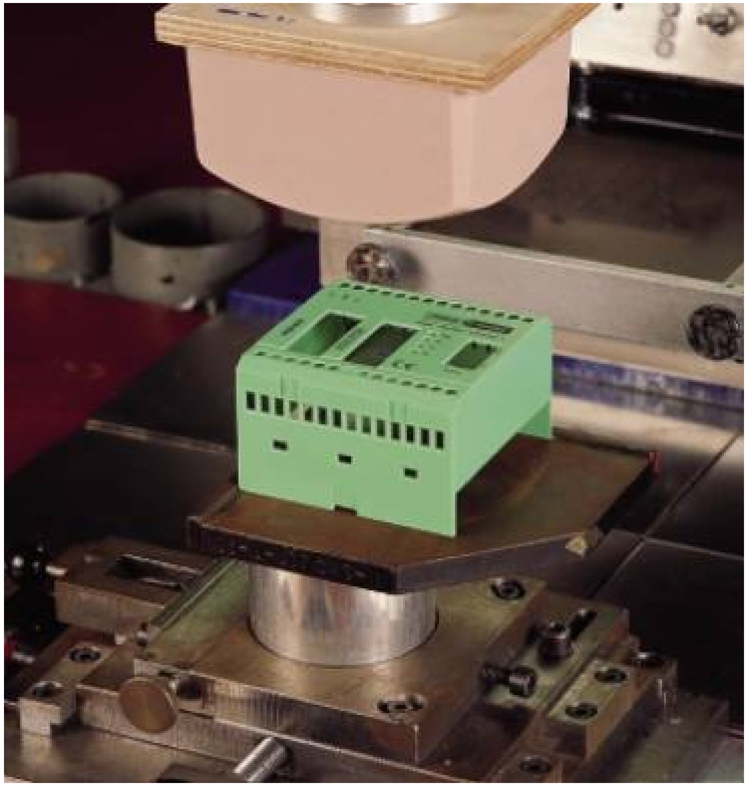


Milling



Injection Molding

Printing

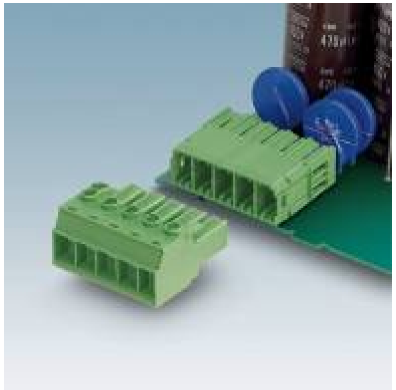


Pad Printing

Laser Etching

Connectors

Pluggable
or Fixed



Technologies

Questions?

Flickr/Kookaburra-in-the-junction box/Trois Têtes (TT)

Thank you

Can be contacted at Mike Nager on LinkedIn, Twitter

Mike Nager
mnager@hotmail.com