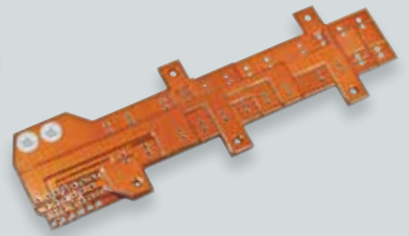
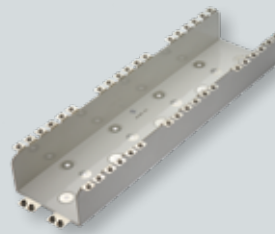




Ferraz Shawmut | Eldre | Idealec | FTCAP

SOLUTIONS FOR  
POWER MANAGEMENT

LAMINATED  
BUS BAR  
SOLUTIONS



EXPERTISE FROM DESIGN  
THROUGH MANUFACTURE

# A GLOBAL REPUTATION FOR QUALITY

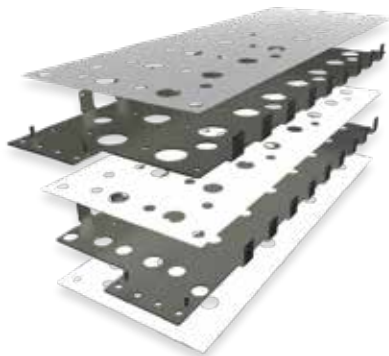
Mersen is a global expert in electrical power and advanced materials. Mersen designs innovative solutions to address its clients' specific needs to enable them to optimize their manufacturing process across numerous industrial sectors.

## LEVERAGING OVER 65 YEARS OF EXPERIENCE

In 2012, Mersen added laminated bus bar manufacturing to its extensive portfolio of products. Along with other solutions for power management such as cooling and fuses, Mersen has created a powerful bundled product offering for the protection and management of power electronics.

## WHAT IS A LAMINATED BUS BAR?

Laminated bus bars are engineered components consisting of layers of fabricated copper separated by thin dielectric materials, laminated into a unified structure. Sizes and applications range from surface-mounted bus bars the size of a fingertip to multilayer bus bars that exceed 20 feet in length. Laminated bus bar solutions are routinely used for low volumes up through tens of thousands per week.



## WHY CHOOSE LAMINATED BUS BAR?

Bus bars reduce system costs, improve reliability, increase capacitance, lower inductance, and eliminate wiring errors. Additionally, the physical structure of bus bars offers unique features in mechanical design. Multilayer bus bars offer a structural integrity that wiring methods just can't match.

## A REPUTATION FOR QUALITY

Mersen's reputation for outstanding technical expertise, product quality, and engineered safety is the result of over a century of design and manufacturing knowledge, coupled with state-of-the-art equipment in four ISO-9001 registered facilities. Each facility manufactures single and multilayer bus bars, as well as fully integrated solutions in which the laminated bus bar also serves as a platform for a multitude of discreet components:

- In Europe, our 5,000 m<sup>2</sup> plant in Angers, France offers full design and manufacturing capability of all bus bar solutions, and is IRIS certified to better serve the rail industry.  

- In North America, our 110,000 ft<sup>2</sup> plant in Rochester, New York offers full design and manufacturing capability of all bus bar solutions, and is AS9100D and IRIS certified, and ITAR registered.  

- In Asia, our 6,500 m<sup>2</sup> plant in Shanghai, China offers full design and manufacturing capability of all bus bar solutions.  

- In India, our 3,720 m<sup>2</sup> plant in Bangalore offers full manufacturing capability for all bus bar solutions.  


# OUR VALUE PROPOSITION: PEACE OF MIND

## SUPERIOR QUALITY FROM DESIGN THROUGH MANUFACTURE

From the first design consultation through dock-to-stock shipments, Mersen provides our customers with innovative bus bar solutions. You're always assured that we've omitted nothing in our quest for customer satisfaction. Let us offer you the same peace of mind that thousands of other companies have enjoyed for more than 60 years. Here are just a few reasons:

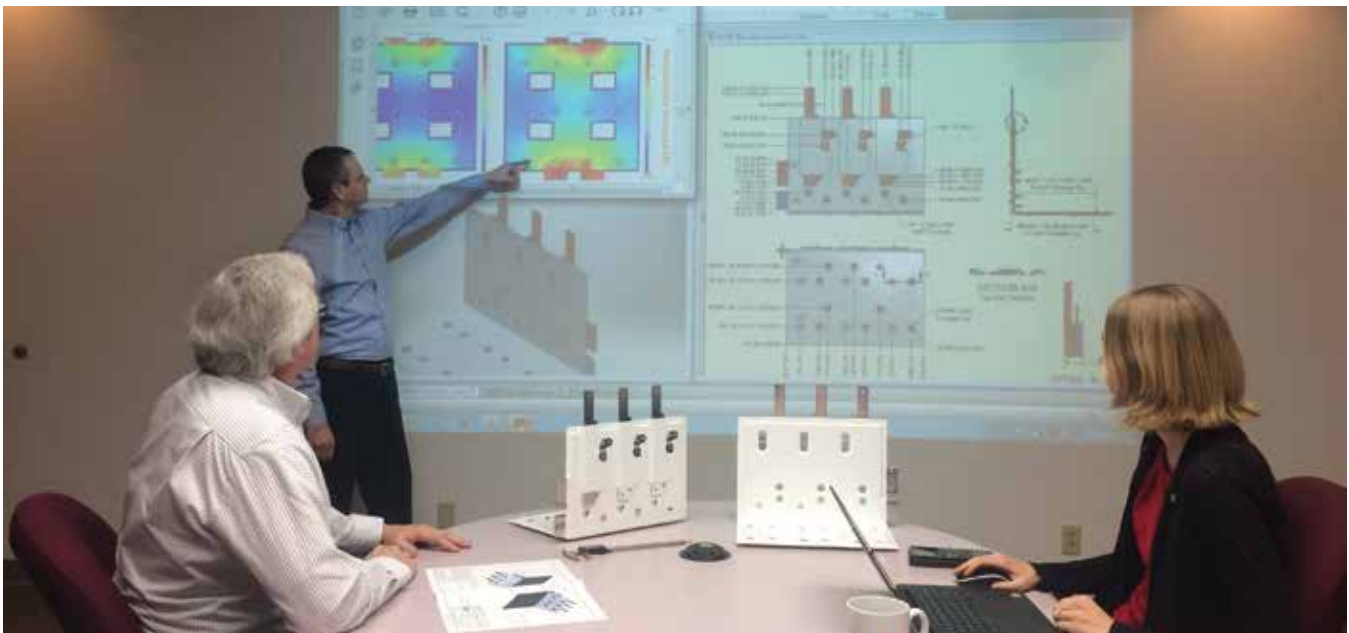
- **State-of-the-art metal fabrication** is a key component to producing quality products. Our state-of-the-art metal fabrication process is performed in-house and includes CNC fabricators, photo-chemical machining, production punch presses, CNC press brakes, and various edge conditioning processes. We offer a wide range of metal joining processes including ultrasonic welding, induction brazing, torch brazing, and soldering.
- **Plating** – Our network of plating vendors can produce almost any finish to meet your needs. Finishing options include tin, tin-lead, nickel, copper, silver, and gold. Plating is conducted under tight, laboratory-controlled conditions, and plating thickness is monitored to meet required specifications per customer requirements. Careful

data monitoring, in-process controls, and x-ray testing combine to ensure a quality finish.

**Properly selected insulation** is the key factor to a bus bar's electrical integrity. We utilize a wide variety of dielectric materials, including Nomex, Tedlar, Mylar, Kapton, Epoxy-Glass, GPO, Gatex, and Phenolics; readily available to meet virtually any specification. In addition to traditional sheet lamination systems, we maintain our own electrostatic powder coating department that produces a quality epoxy finish with high dielectric protection for bus bars with geometric forms, or those used in harsh environments.

- **Assembly and Lamination** is controlled using sophisticated laminating systems specifically designed and manufactured for each bus bar. Hardware and interconnection devices can be added before or after the laminating and plating process.

Precision manufacturing of dielectric components is crucial in laminated bus bar production. To ensure quality, we maintain calibrated humidity and temperature controlled conditions to store our insulation. Precision steel rule dies are used for cutting the insulation, ensuring uniformity of size to produce quality bus bars.





# BUS BARS BUILT FOR THE REAL WORLD

## QUALITY AND PERFORMANCE FOR VARIOUS MARKETS

Mersen has a keen understanding of the unique challenges customers face in each of the markets we serve. We deliver extensive product expertise and unbeatable applications support, enabling our customers to optimize their market performance. We are experts in designing, simulating, manufacturing, and testing bus bar solutions to serve AC and DC power electronics applications where Wide Band Gap (SiC, GaN) and Silicon (IGBT, Thyristors) technologies are used for power conversion and battery-related applications. We cater to the unique needs of many markets and applications.

## STRAIGHT TO THE OPTIMUM DESIGN

Mersen engineers can work with inverter manufacturers at very early stages of design to integrate the passive components such as cooling, bus bars and fuses within the inverter. Using a variety of Multiphysics simulation toolsets, Mersen engineers can evaluate the thermal and electrical performance of the heat sinks and bus bars within the overall inverter design. This approach is called the Integrated Architecture approach and allows for the most optimum design footprint of the overall inverter assembly by sourcing the cooling and bus bar solutions along with semiconductor protection fuses all from one source. For more information on cooling and fuses, please visit [ep.mersen.com](http://ep.mersen.com).



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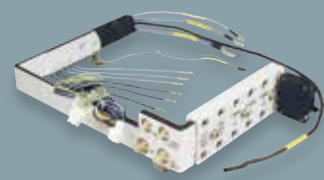
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# ENGINEERING SUPPORT AND TESTING FOR EACH DESIGN

## MULTIPHYSICS MODELLING

Building a prototype is simply time consuming, due to the number of various specialized operations involved, and can sometimes be incompatible with the client deadline. Once the prototype has been finalized, running the test itself is not so easy, especially as the worst case scenario has to be investigated. High temperature, complex or high current electrical client conditions might not be easy to recreate.

Oversized constructions do not fit in a typical environmental chamber. The test can therefore turn out expensive and add unnecessary study time. That's why simulation is a handy tool to boost development processes.

By adding pre-test steps in the conception phase, design flaws can be spotted and eliminated before going through the prototype manufacturing process. Overheating areas or overly thick plates are not always clear to determine by calculations.

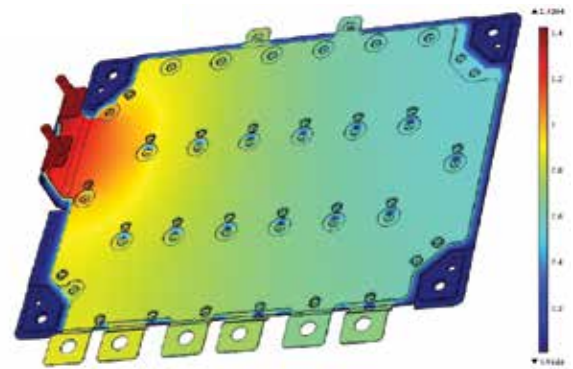
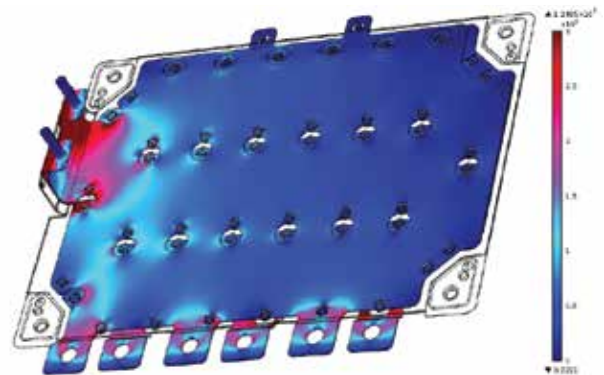
## THERMAL AND ELECTRICAL SIMULATIONS

Mersen application engineers can conduct temperature rise simulation on the bus bar prototypes. This will ensure the most thermally efficient bus bar design will go to production, providing our customers optimum product performance and lowest heat dissipation. In addition to temperature rise simulations, prototype pieces can also be subjected to electrical current flow simulations, inductance values, and skin effect calculations. Mersen has perfected pre-design rules over many years of experience and can provide a very efficient design from the get go.

## HI-POT AND PARTIAL DISCHARGE TESTING

Rigorous testing is completed on each part prior to shipment to ensure long term reliability. In

addition to dielectric withstanding, or insulation breakdown testing (aka "HiPot"), Mersen performs Partial Discharge testing using the state-of-the-art Hipotronics PD test station. Mersen's engineering and quality team uses DFM (Design For Manufacturability) techniques such as FMEA (Failure Mode Analysis) to evaluate each order to assure smooth transition without failures throughout the process.



## WE CAN HELP YOU WITH ANY DESIGNS OR SPECIFICATIONS

We at Mersen provide FREE consultation for our customers to be able to directly discuss their design requirements with our expert application and product specialists. We take pride in striving to provide fast response time, usually within one business day. We provide one-on-one design and engineering support to arrive at the best fit solution every time. Visit [ep.mersen.com](http://ep.mersen.com) for contact information.

# MARKETS SERVED: POWER ELECTRONICS AND SILICON CARBIDE (SiC) APPLICATIONS



## POWER ELECTRONICS

The higher switching speed of today's IGBT demands a low inductance power path which is uniquely delivered by the Mersen laminated bus bar. Mersen's innovative Power Electronic designs provide the ultimate in low inductance DC power which is the "life blood," securing the best suppression of parasitic transients and safe operation for long life. The Mersen laminated bus bar is the key component of the DC power circuit, enabling the IGBT / Electrolytic and Film Capacitor circuit to provide perfect power and trouble-free service.

### MOTOR DRIVE BUS BAR

Thin copper conductors, separated by insulation material of only thousandths of an inch, provide the ultimate in low inductance for IGBT-based motor drives. Incorporating electrolytic capacitors into the same structure simplifies packaging and reduces the effects of transient overshoots. Note the addition of Snubber Capacitors and Resistors built into the laminated bus bar!



Size: 7" x 9" (25 mm x 228 mm) | Thickness: .040" (1 mm) | Voltage: 475VDC | Current: 150A

### CAPACITOR BUS BAR FOR MOTOR DRIVE

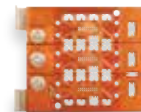
Six electrolytic capacitors are easily connected to this edge-sealed, two-layer laminated bus bar providing a low inductance power path for a low horsepower, variable speed motor drive. Note the use of a bonded insulator strip along the length of the bus bar to provide additional "creepage" protection between the plus and minus terminals.



Size: 1.8" x 6.3" (46 mm x 160 mm) | Thickness: .040" (1 mm) | Voltage: 480VDC | Current: 60A

### CAPACITOR BUS BAR FOR MOTOR DRIVE

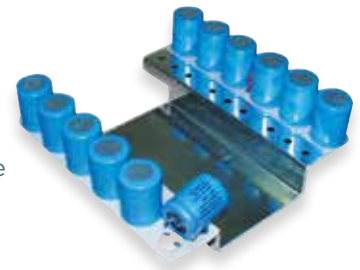
A laminated bus bar assembly consisting of three power layers and one signal layer with a total of 59 conductors providing a very low inductance power path and complete gate drive circuitry all designed for a wave-solder assembly process. This bus bar is used in a system powered by 24 MOSFETs. It includes Electrolytic Capacitors, heatsinks, and MOVs.



Size: 5" x 7" (127 mm x 178 mm) | Conductors: .060" (1.5 mm) (gate circuit: .025" [.63 mm]) | Voltage: 28VDC | Current: 1000A peak

### MOUNTING STRUCTURE FOR CAPACITOR BANK

Laminated bus bars provide a low inductance connection for capacitors. The assembly was designed for an automated production process and the assembly is the DC capacitor bank used in conjunction with high-current, high-speed switching applications. Positive and negative layers are formed and laminated without outside insulation. This design includes two rows of capacitors soldered into position.



Length: 8" (203 mm) | Width: 7.5" (190 mm) | Voltage: 28V | Current: 100A

# MARKETS SERVED: POWER ELECTRONICS AND SILICON CARBIDE (SiC) APPLICATIONS



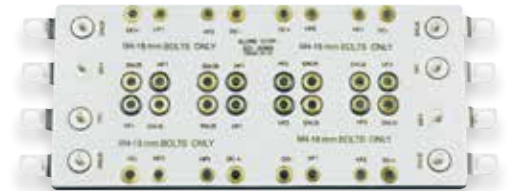
## SILICON CARBIDE (SiC) APPLICATIONS

Mersen is your solution partner for Silicon Carbide (SiC) applications. The next generation of Power Conversion Systems Enabled by SiC Power Devices is now a reality. As the global trends promote greener energy with more strict regulations and standards, newer and more efficient switching devices such as Silicon Carbide (SiC) devices are gaining acceptance in various markets from transportation to solar industries. Compared to silicon devices, SiC devices switching can exceed several 100s of kHz, offering substantial improvements in efficiency.

SiC devices also provide enhanced power density and higher operating temperature, making them a very attractive alternative to bigger and less efficient silicon family of devices. As SiC devices can operate at much higher switching frequencies, parasitic inductance and “skin effect” phenomena become crucial considerations for bus bar designs. Mersen engineering teams can work closely with customers to design bus bars to compensate for “skin effect” and to build the most efficiently cooled power bus bar solution.

### HIGH-FREQUENCY WELDING

Connecting a complex network including Power IGBTs, Diodes, Resistors, and Film Capacitors, this multilayer epoxy edge-filled bus bar provides a compact low inductance solution. Thirty-two bushings are brazed into position and maintain tightly controlled coplanar mounting surfaces on both top and bottom. Alternating the plus and minus layers throughout the assembly counters the skin effect of high frequencies.



Size: 5" x 9" (127 mm x 229 mm) | Voltage: 115VDC | Current: 125A |  
Thickness: .030" x .060" (0.76 mm x 1.5 mm)

### HIGH FREQUENCY INVERTER

High-frequency applications present a unique thermal challenge requiring the addition of water-cooling for efficient operation. When thermal considerations exceed conventional means of heat dissipation, one option is to add watercooling to the system. This design contains five cooling lines soldered directly onto the epoxy powder coated conductors to maintain a constant temperature. Due to the high frequency of the AC voltage, “skin effect” plays a big role in the heat created from the bus and without this additional cooling, the bus would surely overheat.



Size: 9" x 32" (228 mm x 813 mm) |  
Thickness: .030" and .060" (0.76 mm x 1.5 mm) |  
Voltage: 600V | Current: 700A



# MARKETS SERVED: INDUSTRIAL



## INDUSTRIAL

The rough and rugged world of the industrial environment demands a constant and consistent supply of quality products delivered right to the production floor. Mersen's industrial bus bar design solutions extend over half a century, delivering the ultimate in optimized, laminated bus bars to countless manufacturers of motor drives, fork lift trucks, welding machines, power generators, industrial testing machines, and much more. Mersen's laminated bus bar designs provide application specific characteristics, achieving a consistent level of performance that cannot be matched through wires, cables, or simple bars of copper.

### RACK MOUNT POWER DISTRIBUTION

Mounted inside a circuit breaker power tray, individual bus bars are nested in a machined FR-4 frame to provide output connections. This assembly assures proper safety separation as well as single component installation.

Size: 6" x 12" (152 mm x 305 mm) | Voltage: 48V | Current: 280A |  
Conductors: .125" (3.2 mm)



### MEDICAL IMAGING

This space-saving design incorporates five conductors in two layers with clinch hardware at each end. Its laminated, edge-sealed construction is formed to stay out of the way within a tightly packaged medical testing device.

Size: 8"L x 7"W x 6"H (203 mm x 178 mm x 152 mm) |  
Voltages: 3.3V, 5V, 12V | Current: 75A | Conductors: .040" (1 mm)



### FORK LIFT TRUCK BUS BAR

Six-conductor, laminated bus bar assembly combines DC and AC bus bars, as well as a fuse connection, all in one compact package! The system is designed to fit perfectly in a limited space and provides power to a variable speed motor in a rugged industrial environment.

Size: 7" x 7" (178 mm x 178 mm) | Current: 150A | Voltage: 42V |  
Conductors: .060" (1.5 mm)



### COMPACT IGBT BUS BAR

This unique laminated IGBT bus bar delivers low-inductance DC power within a confined area. The design also includes six separate bus bars arranged as AC output with in-line diode connections.

Size: 4" x 19" (102 mm x 483 mm) | Conductors: .050" (1.3 mm) |  
Voltage: 600VDC/150VAC | Current: 120A (DC) / 220A (AC)





## MARKETS SERVED: INDUSTRIAL

### INDUSTRIAL INVERTER BUS BAR

Designed for low-inductance IGBT phase bus bar through 90 degree formed input connections, including raised top contact surfaces to accommodate snubber capacitors. High-temperature insulation material easily handles the demanding thermal requirements.

Size: 8" x 12" (203 mm x 305 mm) | Voltage: 475VDC | Current: 200A |  
Conductors: .080" (2 mm)



### FREQUENCY INVERTER BUS BAR

An excellent layout containing two large DC bus bars, along with the three AC output bus bars laminated directly on top making a complete laminated power distribution system all under a single part number! Note the inclusion of Faston tabs for current sensing and press-fit studs for balancing resistors.

Size: 13" x 18" (330 mm x 457 mm) | Current: 820A | Voltage: 550VDC |  
Conductors: .060" and .125" (1.52 mm and 3.2 mm)



### VARIABLE FREQUENCY DRIVE

This simple yet complex design incorporates DC and AC bus bars, plus accommodations for three current sensors at the AC output points, all built into a flexible, geometric package designed to fit into a tight, confined operating area!

Size: 10" x 15" (254 mm x 381 mm) | Current: 100A | Voltage: 550VDC |  
Conductors: .040" and .060" (1 mm and 1.5 mm)



# MARKETS SERVED: MILITARY



## MILITARY

Uncompromising performance and reliability are a must for military and aerospace systems and applications. That is why laminated bus bars designed by Mersen are commonplace in a wide range of military applications, including missile guidance equipment, phase-array radar systems, sonar and radar tracking stations, airborne equipment, tanks, submarines, and numerous space programs. Mersen's laminated bus bars offer other advantages for defense use, too. Their superior electrical characteristics help defense systems achieve maximum electrical performance and efficiency. Laminated bus bars are also known to provide the most compact means of packaging, achieving the highest overall system performance where physical space is a premium.

### HIGH-CURRENT BOARD LEVEL

Dense packaging is a hallmark of laminated bus bars as shown in this 20-layer edge-filled design with Kapton insulation to withstand high temperatures from soldering. Made for a special defense application, the design distributes power through wide tabs inserted and soldered into a backplane. Power inputs are located at one end for easy connection with a cable assembly.

Size: 1.2" x 10" (30.48 mm x 254 mm) | Conductors: .020" (0.5 mm) per layer | Voltage: 12VDC | Current: 50A per conductor



### SURFACE MOUNT FOR DEFENSE POWER ELECTRONICS

Used in tandem, one as a high-temp, high-current board for switching components and the other is densely populated with chip capacitors. The use of Kapton insulation allows full solderability for surface mount components. Both bus bars are epoxy edge filled and designed to withstand extremely demanding conditions of temperature and altitude.

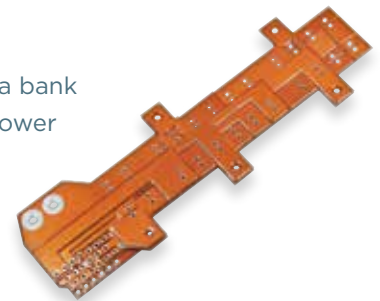
Length: approximately 4" (102 mm) each | Voltage: 200VDC | Current: 260A | Conductors: .025" and .050" (0.63 mm and 1.27 mm)



### LAMINATED POWER BACKPLANE

High-current power distribution is easily handled with this six layer, twenty-one conductor laminated bus bar. Designed to function as a "high-current backplane," a bank of special connectors are soldered directly to the bus bar, and used to distribute power within a turret control system.

Size: 3" x 11" (76 mm x 279 mm) | Conductors: .030" (0.76 mm) | Voltage: 12VDC | Current: 30A

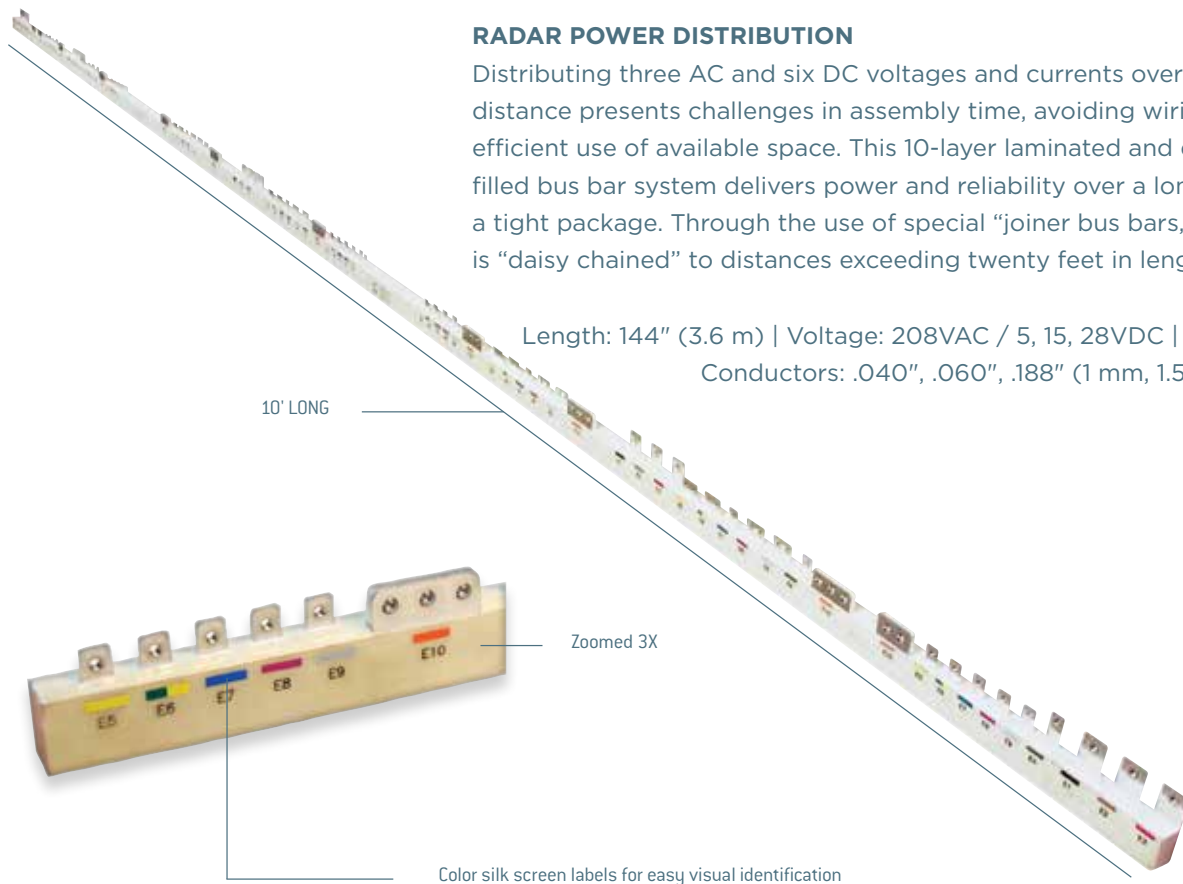


## MARKETS SERVED: MILITARY

### RADAR POWER DISTRIBUTION

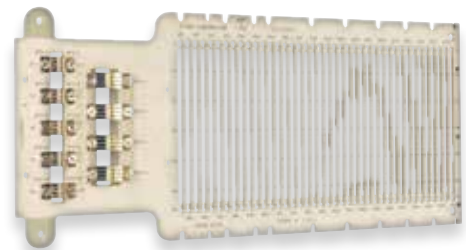
Distributing three AC and six DC voltages and currents over a long distance presents challenges in assembly time, avoiding wiring errors, and efficient use of available space. This 10-layer laminated and epoxy edge-filled bus bar system delivers power and reliability over a long distance in a tight package. Through the use of special "joiner bus bars," the system is "daisy chained" to distances exceeding twenty feet in length.

Length: 144" (3.6 m) | Voltage: 208VAC / 5, 15, 28VDC | Current: 25A |  
Conductors: .040", .060", .188" (1 mm, 1.5 mm, 4.8 mm)



### MISSILE GUIDANCE SYSTEM

A complex and unique laminated bus bar design provides high-power distribution over a backplane with solder tabs for output connectors and gold plated input connections. This application for a laminated bus bar provides power within a Missile Guidance system. The pluggable input connections on this laminated bus bar are gold plated to provide low resistance and high reliability between the bus bar and its subsystem. Forty pairs of outputs from the bus bar to the backplane are made by solder connections. The bus bar is entirely encapsulated using epoxy edge fill provide a complete hermetic seal.

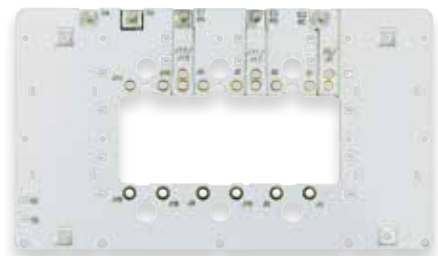


Size: 8" x 18" (203 mm x 457 mm) | Conductors: .040" (1.0 mm) | Voltage: 48V | Current: 190A

### SPACECRAFT POWER INVERTER

This laminated bus bar design demonstrates excellent packaging efficiency. By designing all electrical connection points for the IGBTs, Capacitors, I/O, and monitoring devices in one clean bus bar, overall system reliability is improved and optimal electrical performance is assured.

Size: 16" x 28" (406 mm x 711 mm) | Thickness: .093" and .25"  
(2.4 mm x 6.35 mm) | Voltage: 480V | Current: 240A





## MARKETS SERVED: TRANSPORTATION



### TRANSPORTATION

Whether it's carrying the high current necessary to power heavy equipment, rail, and subway cars—or reducing weight and enhancing packaging efficiency for the latest aircraft and hybrid vehicles—Mersen laminated bus bars bring unique advantages to the transportation industry that are not available with traditional wiring or single conductor bars. A properly engineered laminated bus bar provides the lowest overall system inductance and the most balanced and distributed capacitance, making it the perfect match for the high demands of the transportation equipment industry. Mersen laminated bus bars help transportation equipment manufacturers achieve their reliability goals.

### ALTERNATIVE FUEL SYSTEMS

Fuel cells and hybrid electric vehicles require rugged, reliable power distribution. Heavy duty construction with epoxy powder coating as a dielectric allows this laminated bus bar design to perform to specifications in harsh environments.

Size: 6" x 14" (152 mm x 356 mm) | Voltage: 600VDC | Current: 150A | Conductors: .125" (3.2 mm)



### TRACTION DRIVE

Modern traction drives combine high current and high voltage in highly confined spaces. Mersen's design experience utilizes individually laminated conductors, glass insulation spacers, and unique copper bushing "vias" to achieve an efficient, concentrated package with a minimum of special tools.

Size: 7" x 11" (178 mm x 279 mm) | Conductors: .040" (1 mm) | Voltage: 1200VDC | Current: 250A



### LOCOMOTIVE TRACTION

The laminated bus bar for train traction inverter combines high current and high voltage. Long term durability and continuous operation in hostile environments demand high quality and consistency. The laminated bus bar has 3 layers individually laminated with perfect sealed edges and fully insulated mounting holes, built and tested to meet customer partial discharge requirements.

Size: 24" x 11.8" (610 mm x 300 mm) | Voltage rating at 2100V | High Pot test at 5200VAC | Current: 900A



## MARKETS SERVED: TRANSPORTATION

### LOCOMOTIVE TRACTION DRIVE

High horsepower traction drives benefit from the low inductance power path made possible by Mersen laminated bus bars. Laminated bus bars are the essential component that connect IGBTs and capacitors together. By minimizing system inductance, transient over-shoots are reduced which greatly simplifies the need for complex snubber circuitry. Laminated bus bar designs for motor drives can contain a number of modular bus bars, linked together, to connect all of the system components into one complete system.



Length: 10.5" (267 mm) | Width: 8" (203 mm) | Voltage: 600VDC | Current: 650A

### HIGH-END AUDIO / PCB BUS BAR

Uniquely designed two-layer, 18 conductor, PCB-style bus bar saves valuable board space while delivering low-impedance power to power semiconductors in automotive sound systems. All conductors are made of .025" (.635 mm) copper, plated for solderability and the entire assembly is formed at a right angle.



Length: 10" (254 mm) | Width: 1.5" (38 mm) | Voltage: 12V | Current: 6A to 16A



# MARKETS SERVED: EV/HEV AND ELECTRICAL ENERGY STORAGE (EES)



## EV/HEV AND ELECTRICAL ENERGY STORAGE (EES)

Electric/Hybrid Electric Vehicles (EV/HEV) and Electrical Energy Storage (EES) are amongst the top fastest-growing industries in today's electrical energy markets. As these new technologies evolve, the need to keep pace with their technological advancements is critical for any manufacturer supplying into these markets. Mersen is committed to push boundaries and to introduce game-changing and disruptive technologies to make EV/HEV and EES applications safer and more reliable. Smart monitoring bus bars for

battery applications in electric vehicles and energy storage can handle both high power and small control signals in a single battery connection solution.

### MONITORING BUS BAR EXAMPLES FOR BATTERY CONNECTIONS

To cope with the growing demand of constant voltage and temperature monitoring in power electronics applications such as lithium-ion and ultra-capacitors packs, Mersen has engineered an innovative concept that combines in a single customized device a laminated bus bar, a flexible circuit, thermal sensors, and other custom electronic components. It allows, with only one part, to make both the power connections and the signal collection from each cell independently, so the status of each cell is delivered to the Battery Management System via a custom connector.



- Improved inventory management
- Faster assembly time
- Withstanding of cells micro-movements during charge/discharge process
- No wiring errors
- Best signal quality by a highly engineered and precision controlled welding technique to reduce the voltage drop
- Increased current carrying capacity



### HYBRID VEHICLES

Designed with automotive reliability in mind, this two-layer, laminated bus bar joins parallel rows of batteries together in a hybrid vehicle application.

Size: 3" x 4" (76.2 mm x 101.6 mm) | Thickness: .093" (2.36 mm) |  
Voltage: 60VDC | Current: 40A





# MARKETS SERVED: EV/HEV AND ELECTRICAL ENERGY STORAGE (EES)

## ELECTRIC VEHICLE POWER DISTRIBUTION

When power has to be routed through tight confines that twist and turn, Mersen's epoxy powder coating provides 100% dielectric protection. This two-conductor laminated assembly includes bonded ceramic chokes, nylon reinforced mounting holes, and floating clinch hardware for easy installation and optimized electrical performance in an automotive environment.

Size: 4" x 9" (102 mm x 229 mm) | Conductors: .125" (3.2 mm) | Voltage: 150VDC | Current: 100A



## ELECTRIC VEHICLE CHARGE PORT

Planar power technology is enhanced through laminating with thin dielectric materials which yields a sealed, rugged structure. This design is formed into a "U" shape and is electrically tested underwater to assure performance.

Size: 7" (178 mm) square | Thickness: .020" (0.5 mm) | Voltage: 140VDC | Current: 40A



## ELECTRIC VEHICLE POWER ELECTRONICS

Individually laminated, this two-conductor bus bar connects electrolytic capacitors and IGBTs in a small, lightweight package for an EV Inverter.

Size: 3" x 6" (76 mm x 152 mm) | Conductors: .020" (0.5 mm) | Voltage: 150VDC | Current: 60A



# MARKETS SERVED: RENEWABLE ENERGY



## RENEWABLE ENERGY

As the depletion of fossil fuels drives our attention towards renewable energy sources to power our daily lives, Mersen's laminated bus bars can be found in new, but familiar territory. Whether it's in Solar, Wind Power, or Fuel Cells, the creation of DC energy feeds directly through Mersen's low inductance laminated bus bars into an IGBT and capacitor circuit, delivering the safe and efficient power our customers demand. Mersen's quality-engineered laminated bus bars use state-of-the-art materials and manufacturing techniques that minimize weight and maximize simplicity!

### SOLAR POWER

Multilayer, laminated bus bar used in a Photovoltaic Inverter application. Diodes, IGBTs, and Electrolytic Capacitors are all easily interconnected in one compact power distribution structure.

Size: 16" x 28" (406 mm x 711 mm) | Voltage: 48VDC | Current: 240A | Conductors: .050" (1.3 mm)

### MOUNTING STRUCTURE FOR CAPACITOR BANK

This rugged two-layer, four-conductor bus bar is production built for a Hybrid Transit Inverter application. The perimeter is a laminated sealed-edge construction. It shows the system simplicity of combining capacitors and IGBTs into a single bus bar system.

Size: 12" x 18" (305 mm x 457 mm) | Thickness: .125" (3.2 mm) | Voltage: 475V | Current: 250A per layer

### WINDMILL INVERTER

This laminated bus bar design demonstrates excellent packaging efficiency. By designing all electrical connection points for the IGBTs, Capacitors, I/O, and monitoring devices in one clean bus bar, overall system reliability is improved and optimal electrical performance is assured.

Size: 16" x 28" (406 mm x 711 mm) | Thickness: .093" and .25" (2.4 mm and 6.3 mm) | Voltage: 480V | Current: 240A

### LAMINATED BUS BAR WITH HINGED CONNECTION JOINTS

Innovative laminated bus bar with hinged connection joints from Mersen allows ease of access to components such as IGBT and capacitors installed under the bus bars in tight assemblies such as inverters and drives. This robust and effective bus bar design reduces inverter stack assembly foot print as well as cutting down on maintenance time. Ease of access provides other benefits such as limiting the possibility of damaging the components being removed and eliminating cross wiring errors.



## MARKETS SERVED: DATACOM



### DATACOM

As data volume and broadband use continue to expand, performance demands increase for high-speed servers, blade servers, network backbone equipment, engineering work stations, and such data storage systems as disk arrays. Mersen laminated bus bars help these computer equipment designers meet that challenge, offering uncompromising electrical performance while minimizing EMI, RFI, and crosstalk. The low profile of a laminated bus bar provides computer equipment manufacturers with the ultimate package efficiency, ease of service, and consistent quality necessary to satisfy the most demanding customers. A properly engineered power distribution plan utilizing laminated bus bars can also include thermal management, with the bus bar acting as a heat sink. The bus bar's form-fitting designs can help increase the air flow within a system where space is at a premium.

### PCB to PCB

Two bus bar examples for DC power connections between circuit boards. These assemblies use an edge-sealed construction and employ a special insulating washer that allows compression of the two conductors onto the board while insulating the fastener from the live conductor.



Size: 0.5" x 2" (12.7 mm x 50 mm) | Thickness: .030" x .060"  
(0.76 mm x 1.5 mm) | Voltage: 48V | Current: 35A

### INFORMATION STORAGE SYSTEMS

These bus bars are stamped, brazed, machined, and colored-coded epoxy powder coating dielectric insulation for differing voltages. Power interconnects directly from the power supply with included hardware so you get everything in one rugged package.

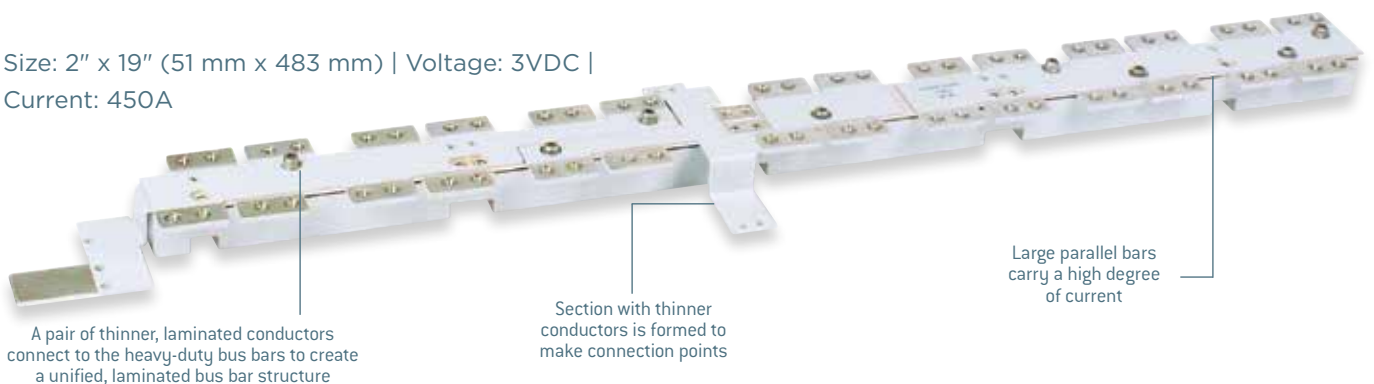


Size: 1.2" x 19" (30.5 mm x 482 mm) | Voltage: 48VDC | Current: 300A

### SUPERCOMPUTER BUS BAR

Modern supercomputer systems operate at extremely low voltages and require a high concentration of current. This two-conductor bus bar assembly is constructed from machined, stamped, and soldered components that are insulated with a high-quality epoxy powder coating, then laminated together to provide a low inductance power path distributed across a large circuit board or backplane.

Size: 2" x 19" (51 mm x 483 mm) | Voltage: 3VDC |  
Current: 450A



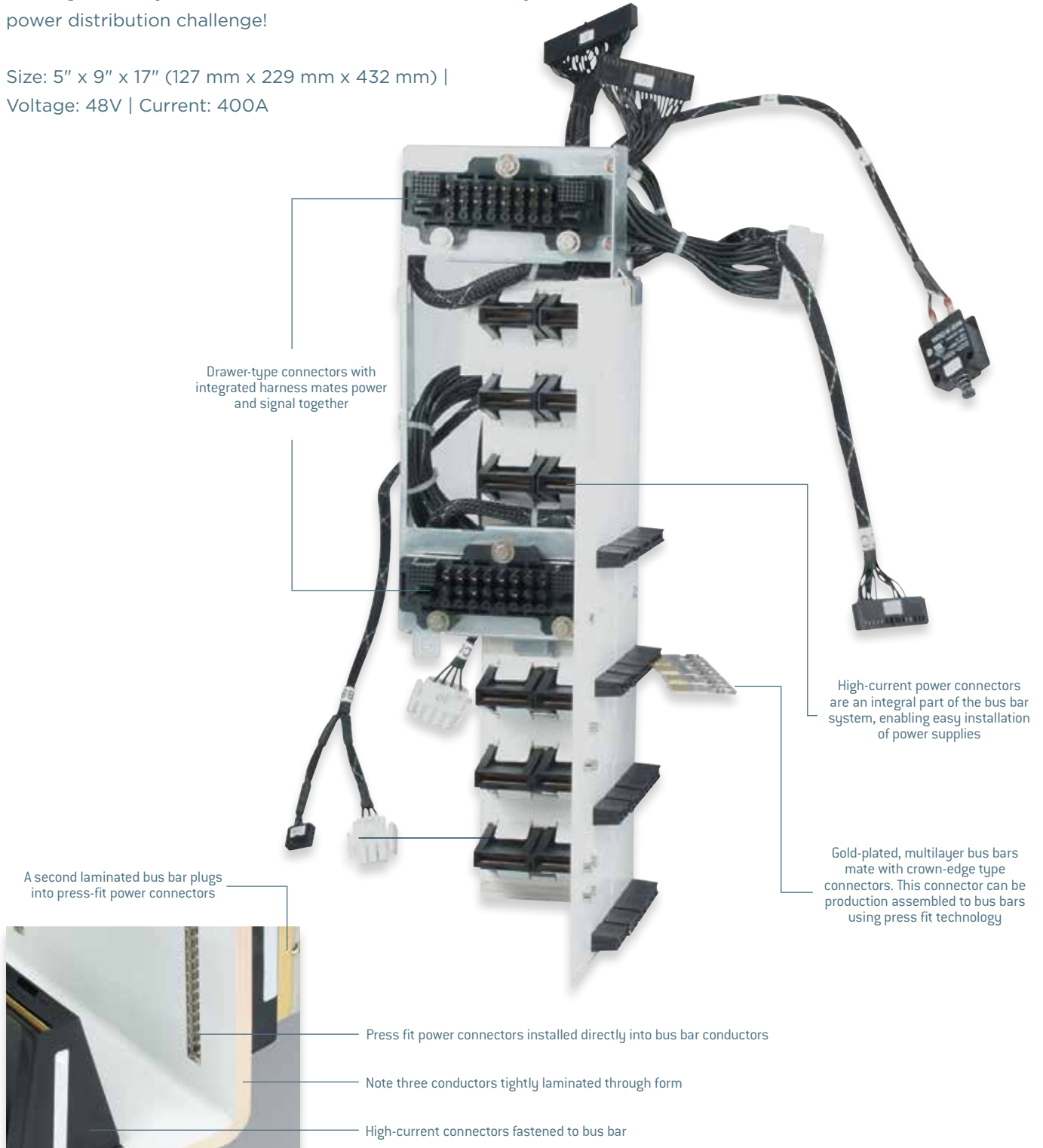


# MARKETS SERVED: DATACOM

## HIGH-END SERVERS IN DATA CENTERS

An excellent combination of value! This multilayer, laminated bus bar incorporates several different connectors for both power and signal, and through careful engineering, a wire harness is used for signal distribution. Mersen can engineer fully tested and serialized solutions to solve your power distribution challenge!

Size: 5" x 9" x 17" (127 mm x 229 mm x 432 mm) |  
Voltage: 48V | Current: 400A

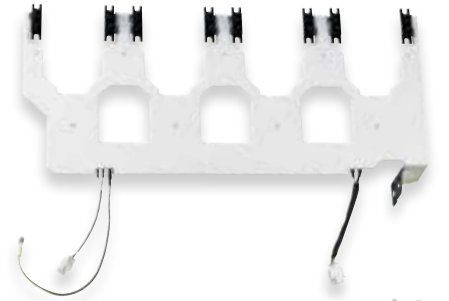


# MARKETS SERVED: DATACOM

## POWER BACK PLANE

Distributing power to eight blades in a large server is easily accomplished with this two-conductor laminated bus bar complete with blind mate power connectors. Short cable assemblies are built into the bus bar for system monitoring. Formed tabs at bottom accommodate in-line fuse connections.

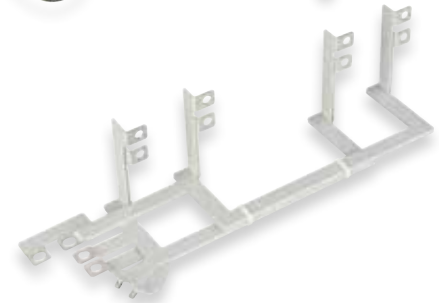
Size: 16" x 28" (406 mm x 711 mm) | Voltage: 48VDC | Current: 240A | Conductors: .060" (1.5 mm)



## COMPUTER BACK PLANE POWER DISTRIBUTION

Epoxy powder coating allows multiple conductors, formed to differing geometries, to be assembled into a single unit. Insulated and bonded together, this assembly carries power to the backplane without adding costly and complex layers to the backplane.

Length: 14" (356 mm) | Thickness: .060" (1.5 mm) | Voltage: 3VDC and 5VDC | Current: 100A



## COMPUTER BACK PLANE

Redundant power supplies plug into this laminated bus bar design and feed high-current power into the computer backplane. Note the five glass (FR-4) mounting supports, which are bonded to the structure, to create a rigid, insulated mounting system. Nine "Crown Clip" high-current connectors distribute power from the power supply onto the backplane.

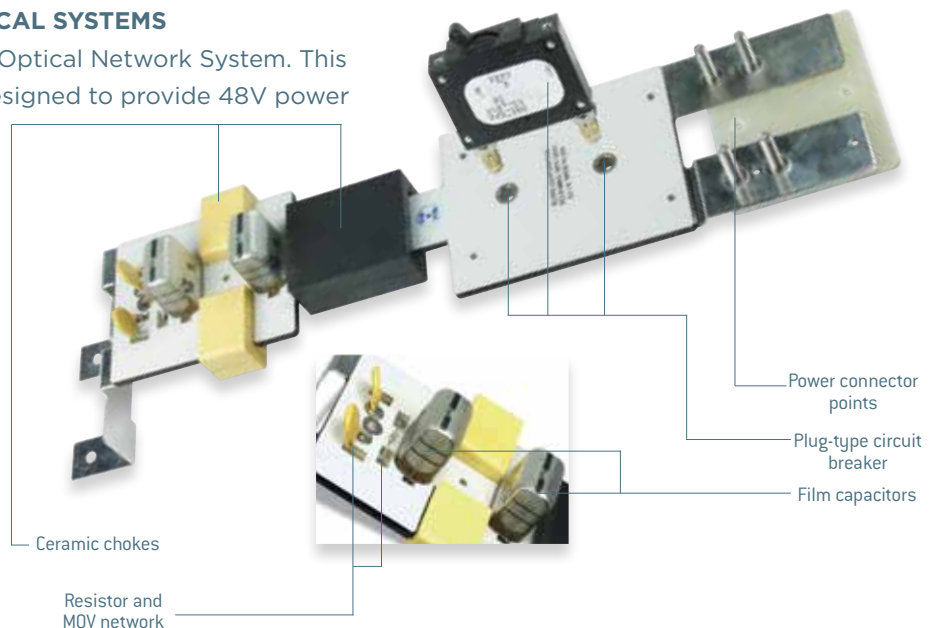
Size: 12" x 9" (305 mm x 229 mm) | Thickness: .125" (3.2 mm) per layer | Voltage: 48V | Current: 250A per layer



## POWER DISTRIBUTION FOR OPTICAL SYSTEMS

Power distribution bus bar used in Optical Network System. This efficient and compact bus bar is designed to provide 48V power onto a backplane from its power supply, through circuit protection, common and differential mode inductors, film capacitors, and resistors, all without the need for a separate PCB for the soldered connections of the resistors and capacitors!

Size: 5" X 18" (127 mm x 457 mm) | Voltage: 48VDC | Current: 75A | Conductors: .050" (1.27 mm)



## MARKETS SERVED: TELECOMMUNICATION



### TELECOMMUNICATION

In the intensely competitive telecommunication market, manufacturers of equipment for Cellular Base Stations and Internet Routers must offer their customers exceptional performance and dependability. With their consistent quality, excellent electrical characteristics, minimal EMI, RFI, and crosstalk, Mersen laminated bus bars provide the perfect solution! Mersen laminated bus bars offer telecommunications equipment manufacturers many other advantages too — including ease of assembly, superior thermal management, reduced weight, packaging efficiency, and overall cost effectiveness over alternative means of power distribution.

#### CELLULAR BASE STATION POWER DISTRIBUTION

An economical design that carries power from multiple power supplies onto the backplane within a Base Station Cabinet. Individually laminated and assembled together reducing a complex wiring scheme to a simple component, saving both space and assembly time.

Size: 7" x 7" x 19" (178 mm x 178 mm x 483 mm) | Voltage: 48VDC |  
Conductor thickness: .060" (1.5 mm) | Current: 125A



#### ROUTER BACKPLANE DISTRIBUTION

Two-conductor laminated bus bars designed to distribute DC power from dual power supplies across the backplane of an internet router. The insulation system uses a molded-edge seal around the perimeter as a cost-effective means of providing the proper creepage distance between the two conductors while protecting the individual conductors from dust and contaminants. Due to the low voltage of the system, Mersen engineers assure that the design has sufficient cross sectional area for a minimal voltage drop.

Size: 12" x 18" (305 mm x 457 mm) | Voltage: 48VDC | Current: 250A |  
Conductors: .090" (2.3 mm)



#### INTERNET ROUTER

This two-conductor bus bar distributes DC power within an internet router. The laminated structure utilizes tabs with offset forms and clinch hardware to mount directly onto the mid-plane, while allowing for proper airflow. High-current pluggable connectors are mounted directly to the bus bar for interchangeable power supplies.

Length: 18" (457 mm) | Width: 12" (305 mm) |  
Voltage: +5V, -5V | Current: 110A

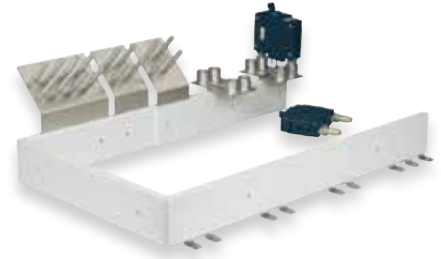


# MARKETS SERVED: TELECOMMUNICATION

## INTERNET BUS BAR SYSTEM

U-shaped, with angled power input tabs, feeding around a rack-mounted frame. The unit also has plated, soldered bushings for bullet-style circuit breakers.

Size: 5" x 9" x 17" (127 mm x 229 mm x 432 mm) | Voltage: 48V | Current: 400A | Conductors: .060" (1.5 mm)



## REDUNDANT POWER INPUT

When system requirements call for redundant power supplies, laminated bus bars are ideal! This two-layer design utilizes press-fit sockets for power supply input and mates downstream with a custom power distribution network.

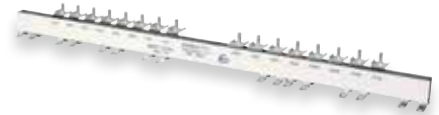
Size: 3.5" x 8" (89 mm x 203 mm) | Voltage: 48VDC | Current: 50A | Conductors: .125" (3.2 mm)



## BACK PLANE POWER DISTRIBUTION

Sixteen-layer laminated bus bar distributes +48V and return across a back plane in a rack system for a network routing application. Heavy-gauge clinch hardware and anti-rotation tabs accommodate cable connections. The entire assembly is hermetically sealed using epoxy edge fill.

Size: 1" x 18" (25 mm x 457 mm) | Conductors: .032" (0.76 mm) | Current: 75A per layer | Voltage: 48VDC



## TELECOMMUNICATIONS BOARD LEVEL POWER DISTRIBUTION

When board space is at a premium, laminated bus bars provide the perfect space-saving solution. The bus bar is designed to be soldered into a PCB and includes an integrated connector, which allows for interchangeability of either the power supply or PCB.

Size: 0.6" x 10" (15.2 mm x 254 mm) | Conductors: .050" (1.27 mm) | Current: 80A | Voltage: 60VDC



## CIRCUIT BREAKER BUS BAR

This seven conductor, nickel-plated assembly receives filtered input power, routed through pluggable breakers and directed to output terminals within a rack-mounted system. Such compact routing offers improved packaging and improved air flow—both key benefits of laminated bus bars.

Size: 3" x 6" (76.2 mm x 152.4 mm) | Voltage: 48VDC | Current: 75A | Conductors: .060" (1.5 mm)





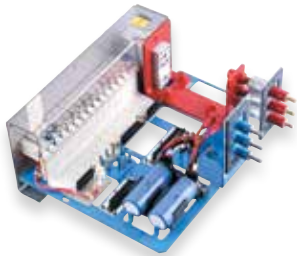
# VALUE-ADD SERVICES

## SUB AND FULL ASSEMBLY SERVICES

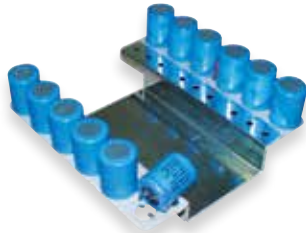
Multilayer bus bars offer a structural integrity that wiring methods just can't match. Mersen's Value Added bus bar designs incorporate a variety of components built right in, such as capacitors and cabling. Each one is safety tested and certified, all designed to help simplify your life at the system assembly level. Every day Mersen's innovation delivers complete multicomponent bus bar and power distribution assemblies around the world to our dedicated family of customers.



In addition to sub assembly services, Mersen can now provide Full Assembly services upon request, where power modules, cooling, bus bars, capacitors and other typical sub components can be assembled in house and shipped to customers as a fully assembled unit.



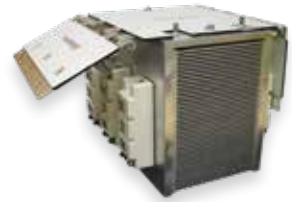
**CIRCUIT BREAKER PLATFORM**



**CAPACITORS SOLDERED ON BUS BAR ASSEMBLY**

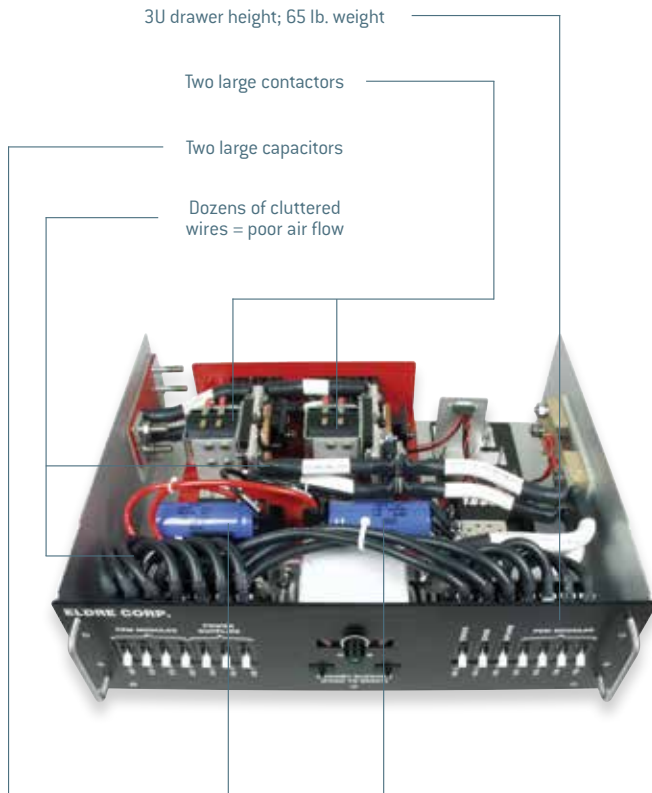


**POWER AND SIGNAL DISTRIBUTION**

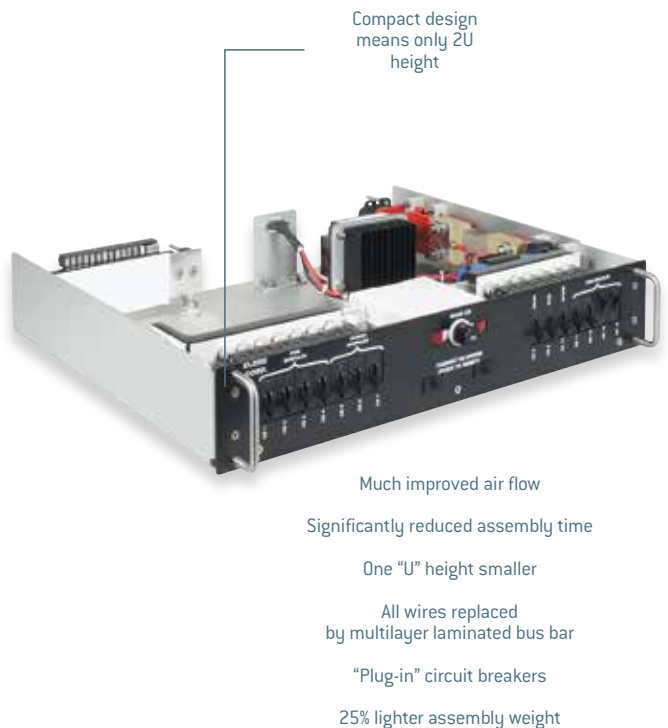


**BUS BAR AND COOLING ASSEMBLY**

## PDA UNIT BEFORE BUS BAR













## PDA UNIT WITH BUS BAR



Electrical connections utilizing bus bars and other mechanical fixtures often face challenges of thermal expansion, tight tolerances and the stress of vibration based on the environment they are deployed in. This can negatively affect the performance, reliability, and longevity of the application. Mersen’s BusFLEXX line of conforming connectors is custom designed to help eliminate these challenges. A large variety of unique flexible and conforming connection features can be strategically designed into our bus bars to meet customers’ specific requirements.

Mersen’s innovative BusFLEXX connectors allow for connectivity of cables to bus bars, electrical/electronic components to bus bars and even bus bar to bus bars wherever there is a need for mechanical gap tolerances and/or thermal compensation. The connectors can have static or +/-1mm dynamic properties up to three rotational axis (X,Y and Z) and provide a cost effective yet long lasting connection methods. Mersen design engineers can work closely with customers to solve their specific design needs for custom-made conforming connectors. In addition, connectors can be designed with certain amount of flexibility and spring tension, reducing the harsh effect of vibration/harmonics on hard connections.

The following table highlights some of the many existing designs possible. Contact Mersen for more information.

Connectors	Connection Type	Dynamic Axis	Unique Feature	Benefit for users	Typical application examples
<b>Concept A - Key Lock Bushing</b> 	Bolted Thru	X,Y	Characteristics of conventional bushings but with axial movement {x,y}.	<ul style="list-style-type: none"> <li>- Field replaceable</li> <li>- Moves freely on bus bar, until bolted connection is made</li> <li>- No soldering required</li> </ul>	Power Module/ Capacitor Connection
<b>Concept B - Ball Socket</b> 	Bolted	X,Y,Z	Pivots, Ball & Socket Feature.	<ul style="list-style-type: none"> <li>- Compensates for Angular Mismatch</li> <li>- Moves freely on bus bar, until bolted connection is made</li> </ul>	Orbital Interface Connection
<b>Concept C - Articulating Plate</b> 	Bolted	Axial Z	Louver band technology to keep electrical connection thru hinge. 0 to 90 degree connections possible.	<ul style="list-style-type: none"> <li>- Dynamic Motion Possible</li> <li>- Compensates for Height and Angularity Mismatch</li> <li>- Potential situations involving harmonics &amp; vibration</li> </ul>	Power Distribution
<b>Concept E - Sliding Plate</b> 	Bolted	X,Y,Z	Louver band technology to keep electrical connection thru Press fit bushings.	<ul style="list-style-type: none"> <li>- Dynamic Motion in Z Axis Possible</li> <li>- Floating Nut Allows for Compensation in X &amp; Y directions until bolted connection is made</li> </ul>	Power Distribution
<b>Concept I - Crush Bushing</b> 	Bolted Thru	X,Y,Z	Conformable.	<ul style="list-style-type: none"> <li>- Makes Bushing Conformal to misalignment in the Z axis</li> <li>- Helps compensate for angularity mismatch between Connections</li> <li>- No soldering required</li> </ul>	Power Module/ Capacitor Connection
<b>Concept L - Flex Bridge (Eiffel Tower)</b> 	Bolted	X,Y,Z	Spring Copper Alloy.	<ul style="list-style-type: none"> <li>- Dynamic Compensation for misalignment in X, Y, &amp; Z Axis</li> <li>- Design can be modified for different heights, amperages, and connections types</li> <li>- Can be used in High Resonance Applications</li> </ul>	Power Distribution
<b>Concept M - Conformal Tab</b> 	Bolted	X,Y,Z	Can be soldered on or fabricated directly into conductor depending on conductor thickness.	<ul style="list-style-type: none"> <li>- Will conform to mating terminals</li> <li>- Floating nut will allow movement in x,y directions</li> </ul>	Power Module/ Capacitor Connection
<b>Concept O - Captive Thread Bushing</b> 	Bolted Thru	X,Y	Characteristics of conventional bushings but with axial movement {x,y}.	<ul style="list-style-type: none"> <li>- Field replaceable</li> <li>- Moves freely on bus bar, until bolted connection is made</li> <li>- No soldering required</li> </ul>	Power Module/ Capacitor Connection
<b>Concept S - Floating Bushing</b> 	Bolted Thru	Z	Louver band technology to keep electrical connection thru soldered bushing. Slight Axial movement possible.	<ul style="list-style-type: none"> <li>- Z Axis Mobility</li> <li>- Dynamic Applications possible</li> </ul>	Power Module/ Capacitor Connection
<b>Concept T - Louver Band Washer</b> 	Contact Washer	Z	To replace washers used by customers to take up gaps in assemblies. Fills gaps in planar connections.	<ul style="list-style-type: none"> <li>- High Current interface between 2 flat conductors</li> <li>- Highly flexible</li> <li>- Dynamic Applications</li> <li>- Compensates for expansion and contraction</li> </ul>	Power Distribution

# MHI-T™ LAMINATED BUS BARS FOR HIGH TEMPERATURE APPLICATIONS

## BUILT TO TAKE THE HEAT!

Today's customers are turning to Wide Band Gap (WBG) technologies such as SiC and GaN based power modules to increase power densities in their drives and inverters designs. Due to their inherent nature, WBG modules in turn introduce an increased level of heat into their laminated bus bars connectors. Increased temperature rises on standard laminated bus bars may cause partial or complete breakdown of the bonding agent (glue) of the insulation, causing the insulation to lift and separate from the conductor surface, creating potential unsafe shock or short circuit faults. Mersen aims to address this increased temperature rise in WBG power modules by designing bus bars with higher temperature tolerances.

Using a combination of polyamid dielectric insulation and high temperature adhesive, and through a long series of testing and qualification steps, today's Mersen MHi-T High Temperature Bus Bars are designed and manufactured to respond to an increasing demand for higher power levels in power converters.



### Features and Benefits

- Insulation materials expertise and qualification procedure cycle used across all Mersen bus bar sites
- Three solutions already available @ 105, 130 & 180°C:
  - MHi-T105™
  - MHi-T130™
  - MHi-T180™
- A fully qualified and standard compliant insulation film offer:
  - REACH and RoHS
  - CTI (400V)
  - UL94 - Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances VO certified
  - EN45545-2 - Fire testing of materials and components for trains, Certified HL3 Class for R1 and R7

### Electrical performances

- Insulation film CTI: 175-250V / Class 3 (Determined by UL)
- Electrical breakdown: >8kV

### High operating temperature

- Operating temp.: -50°C to 180°C (Up to 200°C peak)
- According to UL tests: Insulation film RTI (220°C)

### Applications

- Motor Drives, Rail, Photovoltaic, Wind, Aeronautics, UPS and Oil & Gas

## BEST OF BOTH WORLDS? YES, IT IS POSSIBLE!

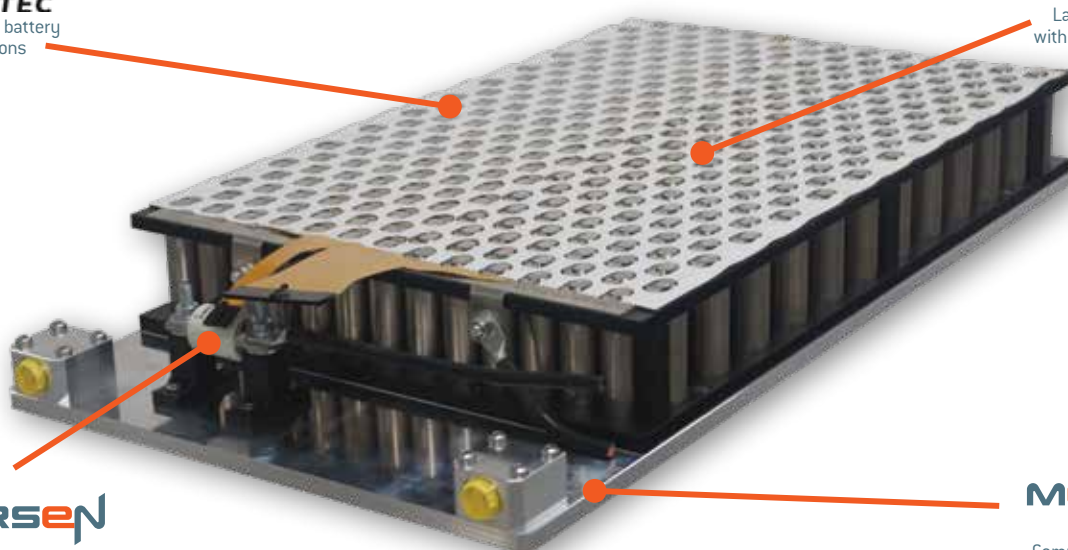
As e-mobility and battery energy storage applications grow in number and power density, designers are always looking to reduce the foot print of the battery assemblies without compromising the efficiency or modularity of their power systems. Customers are looking to components manufacturers to create standardized battery assemblies that benefit from the latest technologies available to produce a leading \$/KW and kWh/Kg on a modular and flexible platform. In short, designers want the best of both worlds being high efficiency and high flexibility, in sourcing their battery assembly solutions for their applications.

Mersen is an expert in thermal management, overcurrent protection devices and laminated monitoring bus bars. F & K DELVOTEC has pioneered the unique laser bonding equipment and processes. Mersen and F & K DELVOTEC has joined forces to create the optimum battery assembly solution to support 21700 series battery assembly systems.

## BENEFITS ARE NUMEROUS...

Unlike traditional battery interconnect solutions, the F & K DELVOTEC laser bonder interface guarantees a high speed, safe, robust & efficient connection of the battery cells to the laminated bus bar. This method is more than four times faster than conventional wire / ribbon insertion and welding. The laminated bus bar is ultra-thin single-layer with interleaved contacts. The busbar is also a “smart” bus bar meaning that it not only powers the battery cells but also monitors temperature and voltage of battery cells as needed. Bus bars also eliminate wiring error and provide an extra degree of robustness against shock and vibration in e-mobility installations. To protect the battery assembly from over currents, a special low watt loss/ high cycling DC rated fuse is installed. The battery assembly is then secured onto a super compact (only 7mm thick) liquid cooled cold plate, providing a homogenous cooling to all battery cells.

In short, the Mersen and F & K DELVOTEC technology products and process solutions provide a safe, reliable, modular and secure customizable battery assemblies to our customers.



Laminated bus bar with monitoring feature



DC Fuse



Compact and low profile vacuum brazed cold plate



## UNIQUE FEATURES IN MECHANICAL DESIGN

The physical structure of bus bars offers unique features in mechanical design. For example, complete power distribution subsystems can also act as structural members of a total system. The proper design of bus bars depends on an application's mechanical and electrical requirements. This section includes basic formulas and data to aid design engineers in specifying bus bars for power distribution systems. Once an outline of a bus bar has been established, specific design and manufacturing considerations will affect the cost.

We've provided basic design criteria to help you specify bus bars for your application. The information required to specify a bus bar includes conductor material, number of conductors (including ground), dimensions (length, width and thickness), interconnection schemes, mounting configuration (if required), type of finish, and choice of insulation material.

## CONDUCTORS

Conductor material selection is critical in meeting electrical performance and mechanical rigidity requirements. Common materials used are copper, aluminum, and a variety of copper alloys. The material chosen, the mechanical constraints, and the electrical performance for the specific application determine the conductor's minimum mechanical dimensions (see Conductor Size in the Electrical Design section).

Thermal considerations may require system ventilation to remove excess heat from the bus bar. In this case, bus bar configuration might be low in profile, thereby changing the orientation of the bus structure and the airflow. Bus bars may also serve to remove heat from components by performing as a heat sink.

The selection of tabs or terminations may determine conductor thickness if there's a need to accept studs, nuts, tabs, or threaded inserts. Minimum mechanical requirements for the connection style chosen

must be considered for overall efficiency and cost effectiveness.

## GROUNDS

The ground return conductor should be equal in size and circular mil area to its corresponding voltage conductor. A few advantages of a separate ground return are:

1. double the effective capacitance;
2. greater area for cooling, to minimize the voltage drop due to temperature rise;
3. drastically reduced intercoupling effects and
4. the opportunity for advantageous shielding between levels, obtained by the use of interleaved grounds.

## MOUNTING

To mount a bus bar to an assembly structure, hardware (studs, holes, etc.) can be manufactured into the conductors. An alternative ground plane may be added as support for the bus bar assembly and to provide a platform for mounting hardware.

## FINISH

Mersen's extended network of plating vendors offers finishes in tin, tin-lead, nickel, silver, or gold. Plating is a major consideration in designing a bus bar because it is the point of contact for all bus bar electrical connections. The plating can provide advantageous electrical properties, decreasing the voltage drop. When gold is used, it is generally only plated on termination surfaces to minimize cost.

## INSULATION

Bus bars use many different types of adhesive-coated insulation materials to permit structure layers to be laminated together. There are added benefits from an electrical perspective. Insulation provides an inside and outside barrier to its installed environment. Insulations can increase the capacitance and lower the inductance and impedance. Commonly used insulation materials are Nomex®, Tedlar®, Mylar®, Kapton®, Ultem®, Mylar/Tedlar, Tedlar/Mylar/Tedlar,

# LAMINATED BUS BAR DESIGN GUIDE

Valox®, epoxy-glass, heat shrink tubing, and epoxy powder coating. There are many different thicknesses of these insulation materials available. Contact a Mersen engineer for more information. Special insulations are available upon request.

## COST CONSIDERATIONS

Prices of bus bar assemblies vary depending upon quantity ordered. In addition, individual dimensional characteristics, materials, manufacturing techniques, the interconnection scheme, plating finish, insulation, and hardware requirements affect overall cost. Mersen engineers are available to assist in developing the most efficient and cost-effective design to provide solutions to any power distribution problem. The earlier we are involved in your design process, the more cost effective your solution is likely to be. Early involvement enables us to optimize both ease of manufacturing and turnaround time.

## ELECTRICAL DESIGN

Important characteristics of laminated bus bars are resistance, series inductance, and capacitance. As performance parameters of electronic equipment and components become more stringent, these characteristics take on even more importance.

In determining the impedance of a power distribution system, these characteristics are significant in solving two of the most important problems for designers—resistance and noise. It is important, therefore, to understand the electrical characteristics of the laminated bus bar.

Figure 1 shows a basic two-conductor laminated bus bar and Figure 2 shows its equivalent circuit. The bus bar is composed of two parallel conducting plates separated by a dielectric.

The equivalent circuit illustrates the associated inductance (L), capacitance (C), and resistance (R), which are most often uniformly distributed along the bus bar. We discuss the basic relationships between physical dimensions and electrical parameters in the following analysis.



**Figure 1.**  
*Physical Representation*



**Figure 2.**  
*Electrical Equivalent*

## CONDUCTOR SIZE

Calculating conductor size is very important to the electrical and mechanical properties of a bus bar. Electrical current-carrying requirements determine the minimum width and thickness of the conductors. Mechanical considerations include rigidity, mounting holes, connections, and other subsystem elements. The width of the conductor should be at least three times the thickness of the conductor.

Additions of tabs and mounting holes change the cross sectional area of the conductor, creating potential hot spots on the bus bar. The maximum current for each tab or termination must be considered to avoid hot spots.

Cross-sectional area and the length determine bus bar conductor size. Cross-sectional area (A) is equal to conductor thickness (t) multiplied by conductor width (w).

A value of approximately 400 circular mils per ampere is a traditional basis for design of single conductors. Since bus bars are not round, circular mils must be converted to mils squared (simply multiply the circular mils value by 0.785).

The following formula determines the minimum cross-sectional area of a conductor. This area should be increased by five percent for each additional conductor laminated into the bus structure.

This extra five percent is a safety factor compensating for the compounding heat gain within the conductors.

# LAMINATED BUS BAR DESIGN GUIDE

This equation calculates the minimum cross sectional area necessary for current flow:

$$A = 400(I)(0.785)[1+.05(N-1)](1*10^{-6}) \text{ inches}^2$$

A = cross-sectional area of the conductor in inches<sup>2</sup>

I = Max DC current in amperes

N = Number of conductors in the bus assembly

To calculate the cross-sectional area of an AC current source, you must take frequency into consideration (See the section on Skin Effect).

Note: This formula has a breakdown point at approximately 400 amps of current. For calculations involving larger currents, we suggest you contact a Mersen engineer and refer to the ampacity table listed on [www.busbar.com](http://www.busbar.com). In addition, you can find ampacity charts and comparative graphs at the Copper Development Association's website, [www.copper.org](http://www.copper.org).

## CAPACITANCE

Capacitance of the bus arrangement depends upon the dielectric material and physical dimensions of the system. Capacitance varies only slightly with frequency change, depending on the stability of the dielectric constant. This variation is negligible and therefore is omitted in this analysis:

$$C = \frac{0.225(K)(w)(l)}{(d)} \text{ picofarads}$$

Increased capacitance results in a decreasing characteristic impedance. Low impedance means greater effective signal suppression and noise elimination. It is therefore desirable to develop maximum capacitance between conductor levels. This may be achieved by:

1. keeping the dielectric as thin as possible, consistent with good manufacturing and design practices
2. using dielectrics having a high relative permittivity (k factor)

## SKIN EFFECT

Because of skin effect phenomena, inductance and resistance are dependent on frequency. At high frequency, currents tend to flow only on the surface of the conductor. Therefore the depth of penetration of the electromagnetic energy determines the effective conducting volume.

The skin depth is given by:

$$SD = \frac{1}{\sqrt{\pi(f)(M)(1/\rho)}} \text{ inches}$$

For Copper:

$$SD = \frac{2.6}{\sqrt{f}} \text{ inches}$$

As frequency increases, inductance decreases to a limiting value, whereas the resistance increases indefinitely as the frequency approaches infinity.

## INDUCTANCE

Maintaining a low inductance results in a low characteristic impedance and greater noise attenuation. When minimum inductance is a design objective, consider these tips:

1. Minimize the dielectric thickness.
2. Maximize the conductor width.
3. Increase the frequency.

There are two types of inductance to be determined: internal inductance, which is a result of flux linkages within a conductor and external inductance, which is determined by the orientation of the two current-carrying conductors.

Distribution of current throughout a conductor at high frequencies is concentrated near the surfaces (called the "skin effect"). The internal flux is reduced and it is usually sufficient to consider only the external inductance. At low frequencies, however, the internal inductance may become an appreciable part of the total inductance. The formula for calculating the internal inductance at a low frequency is extremely lengthy and thus omitted in this analysis.

# LAMINATED BUS BAR DESIGN GUIDE

The formula for external inductance is:

$$L = \frac{31.9(d)(l)}{(w)} \text{ nano henrys}$$

High-Frequency Inductance ( $t > SD$ )

$$L_t = \frac{31.9(d+SD)(l)}{(w)} \text{ nano henrys}$$

## RESISTANCE

To calculate the DC conductor resistance, the following formula applies (Resistance at 20°C):

$$R_{DC} = \frac{\rho(l)}{(w)(t)} \text{ ohms}$$

$$R_{DC} = \frac{0.68 \cdot (10^{-6})(l)}{(w)(t)} \text{ ohms}$$

To determine DC conductor resistance at temperatures above 20°C, use this formula:

$\alpha$  = Temp. coefficient of resistivity of copper at 20°C is 0.00393

$$R_2 = R(1+0.00393(T_2-T_1)) \text{ ohms}$$

$R_2$  = Resistance at elevated temperature ( $T_2$ )

$R$  = Resistance at 20°C ( $T_1$ )

For high frequencies the skin depth is taken into consideration. The formula for AC resistance is:

For ( $t > 2SD$ )

$$R_{AC} = \frac{2(l)\rho}{(SD)(w)} \text{ ohms}$$

AC resistance at 20°C

$$R_{AC} = \frac{2(l)0.68 \cdot 10^{-6}}{(SD)(w)} \text{ ohms}$$

## VOLTAGE DROP

As current travels across a conductor, it loses voltage. This is caused by the resistivity of the conductor. The losses are referred to as voltage drop. Use this formula to calculate the voltage drop across the conductors:

$$V_D = 2(R)(I)$$

$$R = \frac{\rho(l)}{(w)(t)} \text{ ohms}$$

$$VD = \frac{2(\rho)(l)(I)}{(w)(t)} \text{ Volts}$$

### TABLE OF DEFINITIONS

A	Cross sectional area of a conductor in inches squared (in <sup>2</sup> )	$l$	Length of conductor in inches	$T_1$	Temperature at point 1 in C°
C	Capacitance in picofarads	L	Inductance in nano henrys	$T_2$	Temperature at point 2 in C°
$\partial$	Thickness of dielectric in inches	$L_t$	Total inductance at high frequency	w	Width of conductor in inches
$\rho$	Resistivity of the conductor in ohms/inch	M	Permeability of nonmagnetic materials = $31.9 \cdot 10^{-9}$ henrys/inch	$V_d$	Voltage drop in volts
f	Frequency in hertz	R	Resistance in ohms	$\pi$	Pi = 3.141592
I	Current in amps	SD	Skin depth in inches	$\alpha$	Temperature coefficient of resistivity
K	Dielectric constant	t	Thickness of the conductor in inches	z	Impedence



# LAMINATED BUS BAR DESIGN GUIDE

## RESISTANCE, INDUCTANCE, AND CAPACITANCE COMPARISONS



### TWISTED PAIR

#10 AWG wire (solid) — 36" long  
 Insulation thickness (approx.) = .030"  
 Conductor area = .00815 in<sup>2</sup>  
 RDC (calculated) = .006 ohms

Freq (Hz)	RAC (ohms)	L (μhenrys)	C (pfd)
10 <sup>3</sup>	0.006	0.700	50.0
10 <sup>6</sup>	0.078	0.464	53.6
10 <sup>7</sup>	0.160	0.478	48.1

#18 AWG wire (stranded) — 36" long  
 Insulation thickness (approx.) = .015"  
 Conductor Area = .00127 in<sup>2</sup>  
 RDC (calculated) = .038 ohms

Freq (Hz)	RAC (ohms)	L (μhenrys)	C (pfd)
10 <sup>3</sup>	0.038	0.800	52.5
10 <sup>6</sup>	0.275	0.557	57.3
10 <sup>7</sup>	1.300	0.540	52.0



### MERSEN BUS BARS

Mersen bus bar — 36" long x 1.5" wide x .010" thick  
 Insulation thickness = .006" AMRON™ 2–5  
 Conductor area = .015 in<sup>2</sup>  
 RDC (calculated) = .0032 ohms

Freq (Hz)	RAC (ohms)	L (μhenrys)	C (pfd)
10 <sup>3</sup>	0.0032	0.0200	6400
10 <sup>6</sup>	0.0190	0.0060	6085
10 <sup>7</sup>	0.0610	0.0058	7480

Mersen bus bar — 36" long x .125" wide x .010" thick  
 Insulation thickness = .006" AMRON 2–5  
 Conductor Area = .00125 in<sup>2</sup>  
 RDC (calculated) = .038 ohms

Freq (Hz)	RAC (ohms)	L (μhenrys)	C (pfd)
10 <sup>3</sup>	0.038	0.3000	700
10 <sup>6</sup>	0.233	0.0738	678
10 <sup>7</sup>	0.738	0.0614	667

# LAMINATED BUS BAR DESIGN GUIDE

## TYPICAL CONVERSION CHARACTERISTICS

Wire Size Gauge	RAC (ohms)	Cir Mils	Sq Inches	Thick (in.)	Width (in.)	Current Carrying Capacity (amps)	DC Resistance of a 2-Conductor Bus (milliohm/ft)
22	.0253	640	.0005	.005	.101	1.52	32.44
16	.0508	2580	.0020	.005	.406	6.13	8.04
14	.0641	4110	.0032	.005	.646	9.75	5.05
10	.1019	10380	.0082	.010	.815	24.62	2.00
8	.1285	16510	.013	.015	.865	39.35	1.26
4	.2043	41740	.033	.030	1.092	99.20	.500
0	.3249	106000	.084	.045	1.850	252.00	.200
00	.3648	133000	.105	.045	2.320	316.00	.160

## INSULATION

Mersen utilizes many insulation systems to meet different applications. These systems combine the dielectric materials detailed in the table on the next page. By combining different materials with selective edge-conditioning techniques, our insulating systems are designed to exceed any and all of your electrical, mechanical, and environmental requirements.

Amron™ dielectric products were specifically developed for use in the manufacture of bus bars. Many of the products are coated with a B-stage resin that is reactivated during the assembly process. Most of our insulating systems are UL Recognized. Reference [www.ul.com](http://www.ul.com) for a material listing. File No. E53800.

**AMRON 1:** Series 1 are polyvinyl fluoride (PVF) films. PVF films are chemical- and solvent-resistant, demonstrate excellent molding characteristics, and have both a high dielectric constant (K-factor) as well as a high dielectric strength (Trade name: Tedlar®).

**AMRON 2:** Series 2 are aromatic polyamide polymer papers. Mechanical toughness, thermal stability, and solvent resistance are some of its characteristics (Trade name: Nomex®).

**AMRON 3:** Series 3 are polyimide films. These films are recommended for high temperature applications (Trade name: Kapton®).

**AMRON 4:** Series 4 is a composite film, made up of Amron 6 and Amron 1. Used exclusively as outside insulation, these films provide an excellent scuff-resistant coating (Mylar/Tedlar).

**AMRON 5:** Series 5 is also a composite film made up of Amron 6 and Amron 1. These films are used as internal insulation and are recommended for high dielectric strength applications (Tedlar/Mylar/Tedlar).

**AMRON 6:** Series 6 are polyethylene terephthalate (PET) films. PET are polyester films which offer an excellent balance of electrical, chemical, thermal, and physical properties (Trade name: Mylar®).

**AMRON 7:** Series 7 is a composite insulator made up of Amron 2 and Amron 6. This composite combines the mechanical toughness of Nomex with the electrical properties of Mylar (Nomex/Mylar/Nomex).

**AMRON 8:** Series 8 are laminated sheets constructed from continuous-filament type glass fabric with a flame-retardant epoxy resin binder. Good fabrication, high dielectric, and physical strength make this material suitable for many electrical applications (NEMA Grade FR-4).

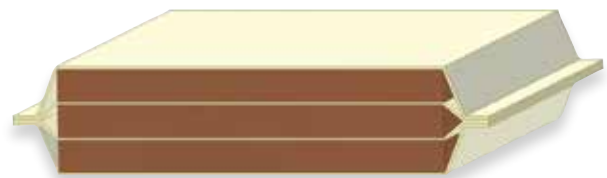
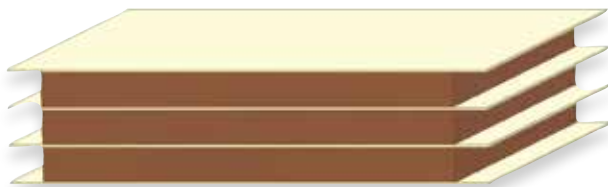
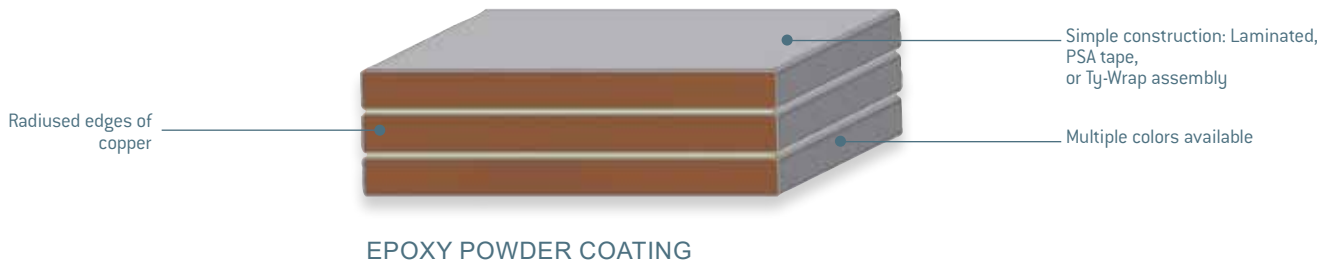
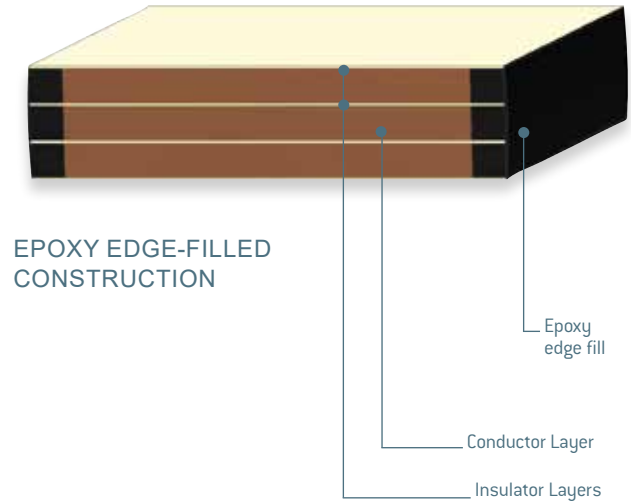
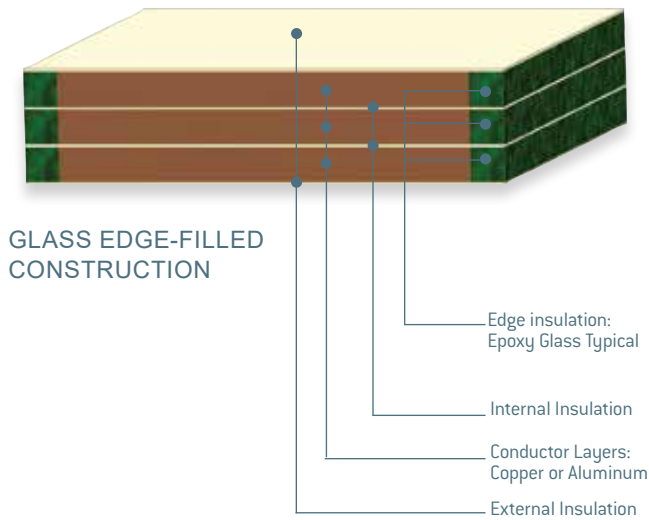
**AMRON 9:** Series 9 are epoxy powder coatings. These coatings exhibit exceptional durability. Amron 9 should be used where conventional insulation, due to part geometry, is not practical.

Note: The insulations listed above are standard materials used in the manufacture of our bus bars. Many other dielectric materials, among them Valox®, Ultem®, and PEN, can be incorporated into your design to meet specific requirements.

Be sure to consult with a Mersen application engineer in selecting insulation, as values may fluctuate after insulation has been applied.

# LAMINATED BUS BAR DESIGN GUIDE

## BUS BAR INSULATION TECHNIQUES



# LAMINATED BUS BAR DESIGN GUIDE

## STANDARDS

These lists detail the specifications that our standard conductor material, insulation, and plating processes meet. Incorporating these standards into your own specifications (notes) will help reduce manufacturing costs and reduce cycle times.

Conductor Material		
CDA 110	Copper	ASTM B152/B187
CDA 260	Brass	ASTM B36
CDA 510	Phosphate Bronze	ASTM B103
CDA 172	Beryllium Cu. 25	ASTM B194/B196
CDA 194	Copper Alloy	ASTM B465
Alloy 42	Nickel/Iron	ASTM F-30
1100-H12	Alloy Aluminum	ASTM B209

Insulation		
Amron 1	Tedlar®/PVF	L-P-1040
Amron 2	Nomex®	MIL-I-24204
Amron 3	Kapton®	MIL-P-46112
Amron 6	Mylar®/PET	MIL-I-631
Amron 8	FR-4	MIL-I-24768/27
Amron 9	Epoxy Powder Coating	ASTM D3451
Amron 10	Ultem®	
Amron 11	Valox®	
Epoxy Edge Fill	Black or White	MIL-I-16923

Plating	
Tin	ASTM B545
Nickel	QQ-N-290/AMS 2403
Electroless Nickel	MIL-C-26074
Sulfamate Nickel	MIL-P-27418
Gold	ASTM B488
Silver	QQ-S-365
Copper	AMS 2418
Tin-Lead (60/40)	AMS-P-81728; ASTM B579
Tin-Lead (90/10)	MIS-41177
Anodize	MIL-A-8625
Chromate	MIL-C-5541
Passivate	QQ-P-35

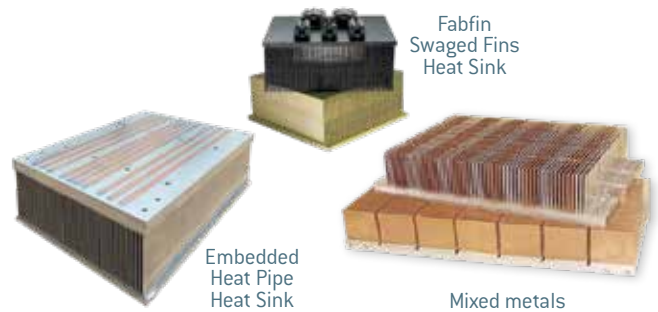


## HIGH-PERFORMANCE COOLING SOLUTIONS FOR POWER ELECTRONICS

Mersen integrates its extensive cooling expertise and patented heat sink technology into power electronics applications to make them more efficient, reliable, and profitable. Our unique knowledge of air, phase change, and liquid cooled heat sinks enables Mersen to help customers find the right customized thermal protection solution for their unique applications.

### AIR COOLING SOLUTIONS

Mersen's air cooled Fabfin® heat sink stands out from ordinary extruded heat sinks because of its higher fins, giving it excellent performances. Using a swaging process means a variety of its higher fins and increased height-to-space ratio types of fins can be used.



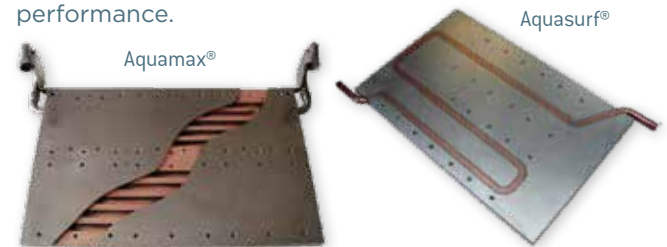
### HEAT PIPES FOR INSTANTANEOUS COOLING ACTION

The high heat losses from press-pack or IGBT power devices can easily be conveyed outward via heat pipe cooling units. A heat pipe is a device that uses “phases change” to efficiently conduct large amounts of heat between two solid surfaces.



### LIQUID COOLING SOLUTIONS

Power electronics components (SiC, IGBTs, thyristors) need a cooling solution that is both effective and reliable, especially when installed in a confined space. To ensure maximum reliability, Mersen has mastered vacuum brazing technology for liquid cooled solutions to achieve guaranteed water tightness with no seams, robustness, corrosion free, and excellent thermal performance.



### SEMICONDUCTOR AND BATTERY PROTECTION FUSES

Mersen supports OEM designers and equipment maintenance personnel with a comprehensive line of semiconductor protection and battery protection fuses for global use.

#### TYPICAL APPLICATIONS

- Power inverters, converters, and rectifiers
- AC and DC drives
- Electric Vehicles and Electric Energy Storage
- DC common bus and DC grids
- Reduced voltage motor starters
- UPS systems
- Protection of Capacitor banks
- Switchboard and control panels



## GLOSSARY OF TERMS

- **Capacitance**  
Measured in farads, it is the opposition to voltage changes in an alternating current circuit, causing voltage to lag behind current; exhibited by two conductors separated by an insulator.
- **Capacitor**  
A passive electronic component that stores energy in the form of an electrostatic field. In its simplest form, a capacitor consists of two conducting plates separated by an insulating material called the dielectric. The capacitance is directly proportional to the surface areas of the plates, and is inversely proportional to the separation between the plates. Capacitance also depends on the dielectric constant of the material separating the plates.
- **Choke**  
An inductor designed to present a high impedance to alternating current.
- **Clearance**  
The clearance is defined as shortest distance through the air between two conductive elements.
- **Common Collector Connection**  
Same as grounded collector connection. Also called the emitter-follower. A mode of operation for a transistor in which the collector is common to both the input and the output circuits and is usually connected to one of the power rails.
- **Common Emitter Connection**  
Same as grounded emitter connection. A mode of operation for a transistor in which the emitter is common to the input and output circuits. The base is the input terminal and the collector is the output terminal.
- **Conductivity**  
How easily something allows electric current to pass through it. If a substance is a good conductor or highly conductive (for example copper or brass), it will allow electrons to pass freely through it, offering only minor resistance.
- **Corona**  
A luminous discharge due to ionization of the air surrounding a conductor caused by a voltage gradient exceeding a certain critical value.
- **Corona Extinction Voltage (CEV)**  
The highest voltage at which a continuous corona of specified pulse amplitude no longer occurs, as the applied voltage is gradually decreased from above the corona inception value.
- **Corona Inception Voltage (CIV)**  
The lowest voltage at which a continuous corona of specified pulse amplitude occurs as the applied voltage is gradually increased.
- **Creepage Distance**  
The shortest distance separating two conductors as measured along a surface touching both conductors.
- **Dielectric**  
Nonconducting material used to isolate and/or insulate energized electrical components.
- **Dielectric Constant (K)**  
The property of the dielectric material that determines how much electric energy can be stored in a capacitor of a particular size by a value of applied voltage.
- **Dielectric Strength**  
The maximum voltage an insulating material can withstand without breaking down.

# GLOSSARY OF TERMS

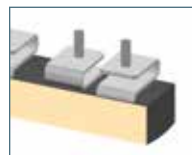
- **EMI, RFI**  
Acronyms for various types of electrical interference: electromagnetic interference and radio-frequency interference.
- **Hi-Pot Test (High Potential Test)**  
A test performed by applying a high voltage for a specified time to two isolated points in a device to determine the adequacy of insulating material.
- **Impedance**  
(Z) Measured in ohms, it is the total opposition to the flow of current offered by a circuit. Impedance consists of the vector sum of resistance and reactance.
- **Insulation Resistance**  
The resistance offered, usually measured in megaohms, by an insulating material to the flow of current resulting from an impressed DC voltage.
- **Insulators**  
Materials which prevent the flow of electricity. Nonconductive materials used to separate electric circuits.
- **Inverter**  
An electric or electronic device for producing alternating current from direct current.
- **Partial Discharge**  
A type of localized discharge resulting from transient gaseous ionization in an insulation system when the voltage stress exceeds a critical value.
- **Resistance**  
R and measured in ohms. Opposition to current flow and dissipation of energy in the form of heat.
- **Self-inductance**  
The property of a conductor that produces an induced voltage in itself with changing current. The term inductance alone means self-inductance. When a varying current in one conductor induces a voltage in a neighboring conductor, the effect is called mutual inductance.
- **Shield**  
Partition or enclosure around components in a circuit to minimize the effects of stray magnetic and radio-frequency fields.
- **Shunt**  
A low-value precision resistor used to monitor current.
- **Snubber**  
A resistor-capacitor (RC) network used to reduce the rate of rise of voltage in switching applications.
- **Voltage Drop**  
Conductors carrying current always have inherent resistance or impedance to the current flow. Voltage drop is the amount of voltage loss that occurs through all or part of the circuit due to impedance.



**THREE-LAYER BUS BAR  
WITH INDEPENDENT  
FASTON TABS AT  
LONG END**

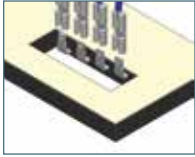


**PRESS-FIT BUSHINGS  
WITH CROWN BAND  
INSERTS**

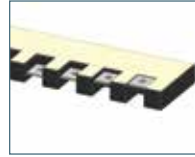


**FLEXIBLE TABS  
FOR LOW  
PROFILE AREAS**

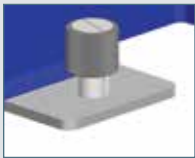
# GLOSSARY OF TERMS



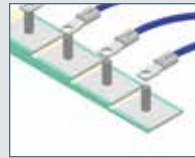
FASTON TABS FROM INSIDE THE BUS BAR, SAVES SPACE



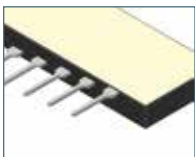
BOLT ON TABS CONFINED WITHIN THE BUS BAR, SAVES SPACE AND MATERIAL



PANEL HARDWARE



CLINCH HARDWARE FOR RING LUGS



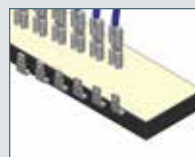
SQUARE PINS FOR SOLDER CONNECTIONS OR WIRE WRAP



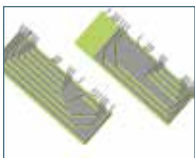
FASTON TABS EXTENDING BEYOND THE BUS BAR OR WITHIN



MOLDER HARDWARE, IDEAL FOR THIN MATERIALS AND HIGH TORQUE APPLICATIONS



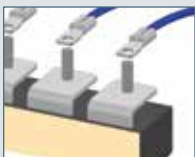
FASTON TABS ALONG THE EDGE WITH FORMS FOR EASY ACCESS



MULTILAYER AND MULTI-CONDUCTOR TABS FOR PCB POWER



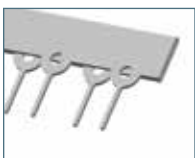
FLANGE TAB CONSTRUCTION WITH CLINCH HARDWARE



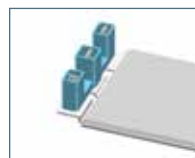
RING LUG TERMINATIONS USING CLINCH STUD HARDWARE IN FORMED TABS



SOLDER PIN CONNECTION WITH THERMAL RELIEF



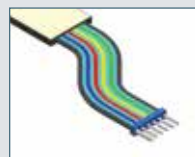
SOLDER PINS FOR PCB CONNECTION WITH THERMAL RELIEF HOLES IN BUS BAR



CONNECTORS IN PLASTIC HOUSING, SOLDERED INTO EACH CONDUCTOR



CLINCH STUD HARDWARE IN SIDE TAB INTERCONNECT (NOTE OFFSET FORM IN TAB)



FLEX CIRCUIT INTEGRATED INTO BUS BAR FOR FLEXIBLE INTERCONNECTION



HIGH CURRENT POWER RECEPTACLE WITH CROWN-BAND INSERTS

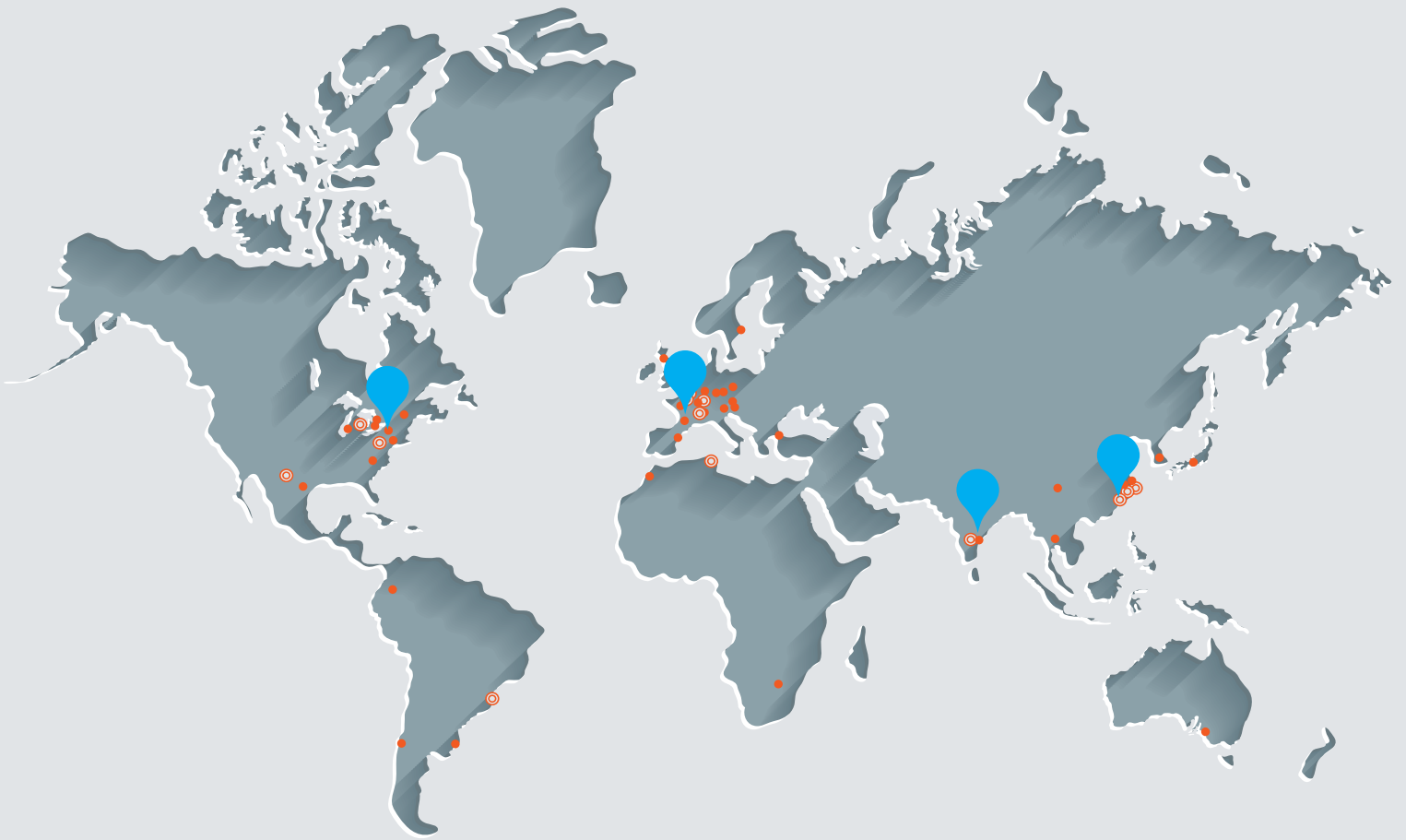


THREE-LAYER BUS BAR UTILIZING EMBOSSED "DIMPLES" FOR COPLANAR INTERCONNECTION









MERSEN IS A GLOBAL EXPERT  
IN ELECTRICAL POWER AND  
ADVANCED MATERIALS

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