

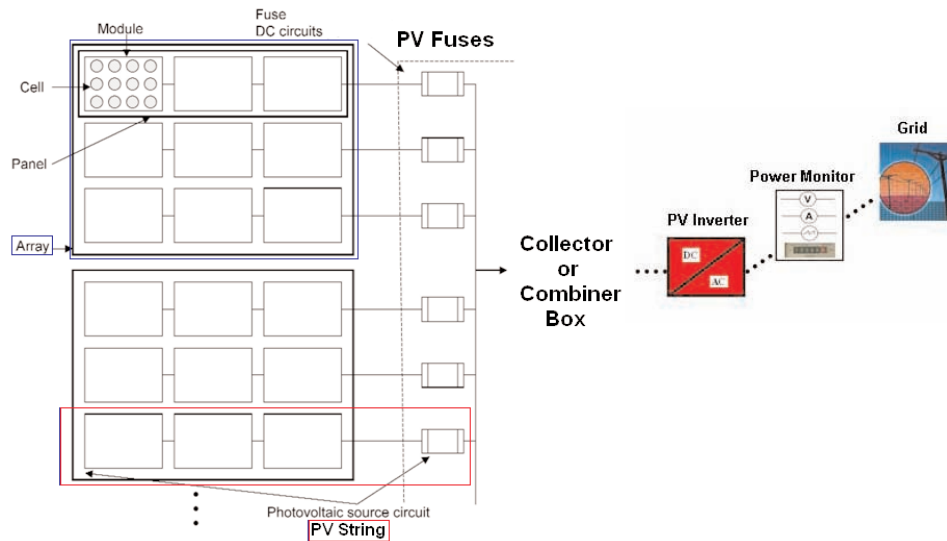
# Photovoltaic System Overcurrent Protection

## Introduction

Solar Photovoltaic (PV) systems have, over the last fifty years, evolved into a mature, sustainable and adaptive technology.

This technology is improving as solar cells increase in efficiency and modules attain better aesthetic appearance.

As a result, solar power is gaining more acceptance and is becoming an increasingly cost-effective and clean alternative to conventional energy sources.



- A number of PV panels in series is termed a string
- A number of strings in parallel is termed an array

## Photovoltaic Protection System from Cooper Bussmann

As the installations and demand for PV systems increases so does the need for effective electrical protection.

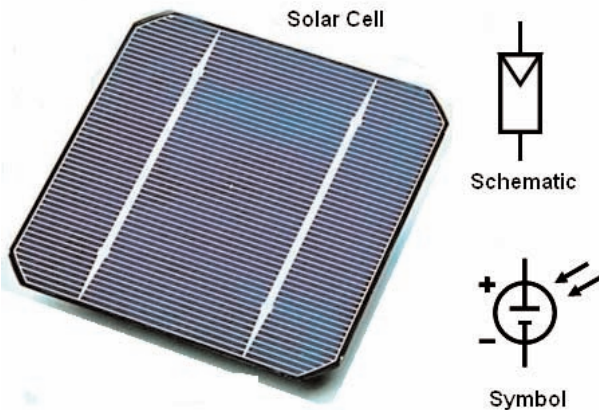
PV systems, as with all electrical power systems, must have appropriate overcurrent protection for equipment and conductors.

Cooper Bussmann (the world leader in overcurrent protection products) has developed a revolutionary new fuse link for protecting photovoltaic systems.

This development was implemented through coordinated research and testing with leading Solar Panel/Solar System manufacturers.



## How Solar Power Systems work |



Solar Power generation systems are made of Photovoltaic cells and Power inverters. The photovoltaic cells utilise the power of sunlight to convert photons to clean DC (Direct Current) electricity.

The Electricity generated by the Solar Cells is then fed into a Power Inverter (PV inverter) that converts and regulates the DC source into usable AC power.

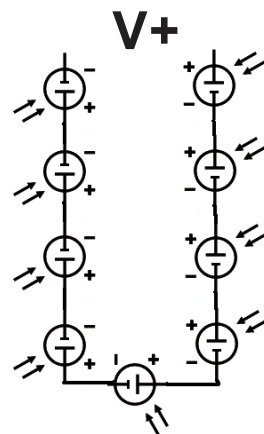
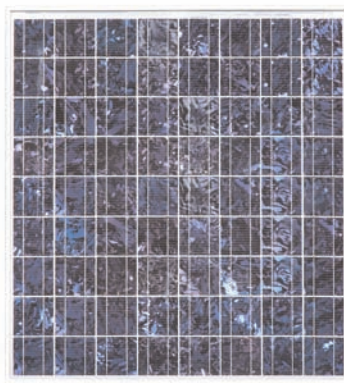
The AC power can then be used locally for specific remote equipment, residential homes or fed directly back into the power grid and used as environmentally clean energy.

Energy content of sunlight: sunlight has an energy content of 1kW (1000 watts) per square meter.

The typical Solar Panel achieves between 10% and 15% efficiency conversion.

## Solar Power Protection System from Cooper Bussmann |

Figure 1



The voltage output of a Solar Panel/Array is defined by the number of individual cells in series. An individual panel (see Fig. 1) is made up of a series string of photovoltaic cells.

Globally there is a push for utilizing higher voltages (trending to 1000Vdc and above).

- A number of PV panels in series is termed a string
- A number of strings in parallel is called an array

The vast majority of large Solar Farms in North America are 600Vdc, but following the lead from Europe to increase voltages up to 1000Vdc to achieve more efficiency.

## Variations of Solar Panel Output

The most widely used Solar Panels for systems greater than 20kW are the 4", 5" and 6" Poly-crystalline silicon type.

The Silicon type panel can achieve up to approx 7.5A maximum power current per panel. Again there is no specific preference as economics also play a role in the selection of Solar Cell type.

A word of caution is do not assume all 4", 5" and 6" Solar panel designs are equal between different manufacturers. The maximum power output current of the panels can vary as much as 35% between manufacturers of equal solar cell dimension designs... always select proper conductors/fuses based on the specific  $I_{sc}^*$  characteristics of the manufacturers specification.

\* $I_{sc}$ : Short circuit current



## Overcurrent Protection of PV Systems

The National Electrical Code® defines the maximum circuit current as 125% of the short-circuit current of the PV module ( $I_{sc}$ ). The conductors and the overcurrent protective device are then sized at 125% of the maximum circuit current or  $1.56 \times I_{sc}$ . Additionally, International standards such as BS EN7671 Sec 712 for Solar Photovoltaic (PV) Power Supply systems specify that conductors current carrying ability must be equal to or greater than  $1.25 \times I_{sc\ STC}^*$  at any location. The  $I_{sc}$  is published by the PV module manufacturers on datasheets. The  $I_{sc}$  is typically only 110-115% of the maximum power current ( $I_{pm}$ ) of the PV module.

This means that unlike typical grid connected AC systems, the available short circuit current is limited and the overcurrent protective devices will need to operate effectively on low levels of fault current. For this reason Cooper Bussmann has conducted extensive research and development of fuses that are specifically designed and tested to safely protect PV systems with high DC voltages and low fault currents.

- DCM - 600Vdc
- PV - 1000Vdc

\* $I_{sc\ STC}$ : The Electrical data applies under Standard Test Conditions (STC): Radiation 1000 W/m<sup>2</sup> with a spectrum of AM 1.5 and at cell temperature of 25°C.



DCM - 600Vdc



PV Fuse - 1000Vdc

## Selecting Fuse Links for PV String Protection

Depending on the desired capacity of the PV system, there may be several PV strings connected in parallel to achieve higher currents and subsequently more power.

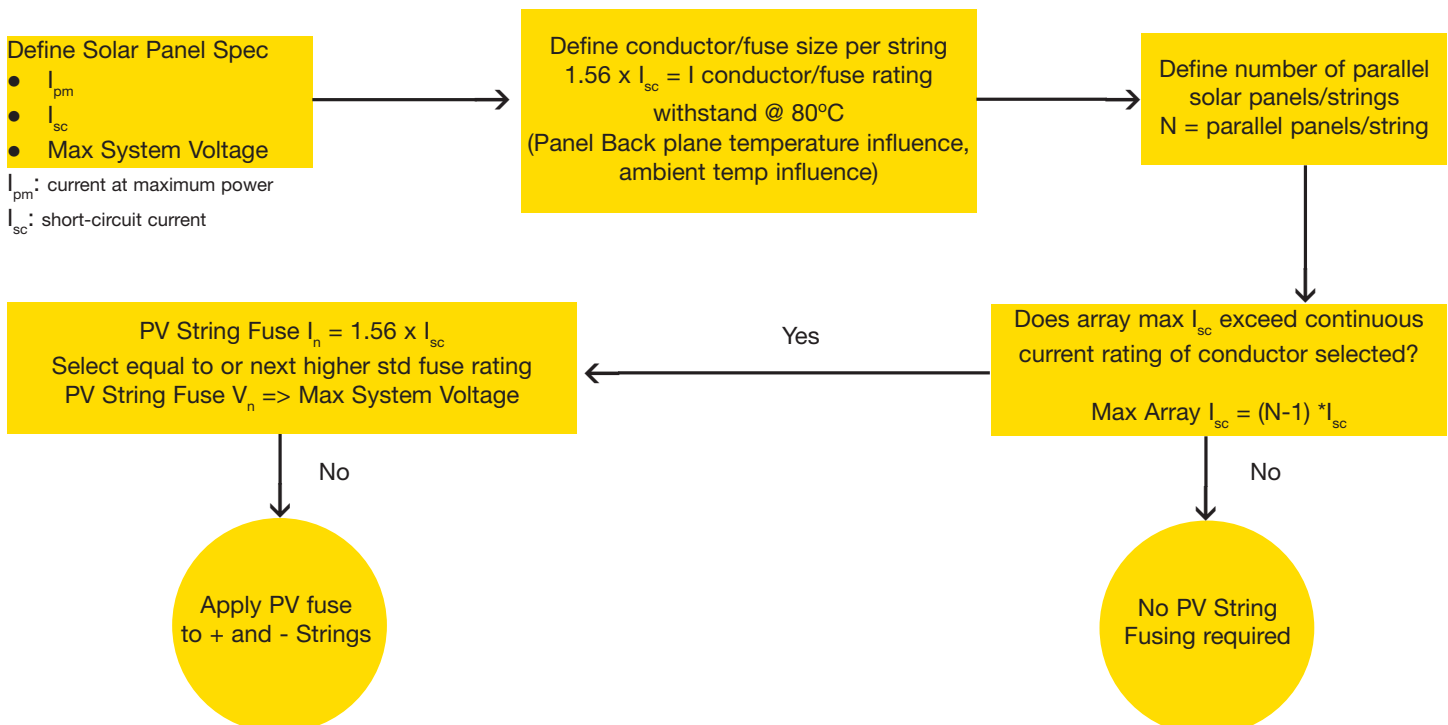
PV systems that have three or more strings connected in parallel need to have each string protected (systems that have less than three strings will not generate enough fault current to damage the conductors/equipment and therefore do not present a safety hazard as long as the conductor was sized properly based on local code requirements).

Where three or more strings are connected in parallel a fuse on each string will protect the conductors from damage and help minimise any safety hazards. It will also isolate the faulted string so that the rest of the PV system can continue to generate electricity.

- Protection of Conductors
- Isolate damaged PV modules



## PV Fuse Selection Flow-Chart



## Fuse Rating for PV Applications |

Once it has been determined that maximum short-circuit current ( $(N-1)I_{sc}$ ) exceeds continuous current rating of conductor, follow the recommendations of selecting the proper PV string fuse.

### Example 1: Solar Panel String Fusing

$$I_{sc} = 5.37A$$

$$I_{pm} = 4.83A$$

Max System Voltage = 1000Vdc (max value of series panels)

Conductor Size Formula =  $1.56 * I_{sc} = 1.56 * 5.37 = 8.38A$

Conduct Size = 14AWG or  $2.5mm^2 = 10.25A @ 80^{\circ}C$

$N = 4$  (4 parallel Solar Panel Strings)

$$\text{Array Max } I_{sc} = (N-1) * I_{sc} = (4-1) * 5.37 = 16.11A$$

Array Max  $I_{sc}$  is greater than conductor withstand, therefore string fuses are required

$$I_n = 1.56 * I_{sc} \text{ (individual panel only)} = 8.37A \text{ min fuse rating}$$

Select next higher std rating of 10A: PV-10A10F

Fuse selected will protect selected conductor

Min wire size: 14AWG or  $2.5mm^2 = 10.25A @ 80^{\circ}C$

### Typical Solar Panel Specification

Module Description	
Cell Type	Polycrystalline Silicon
Cell Size	125mm <sup>2</sup> (5")
No of Cells and Connection	72 in Series
Maximum System Voltage	1,000Vdc
Electrical Data	
Maximum Power Voltage (Vpm)	34.6V
Open Circuit Voltage (Voc)	43.1V
Maximum Power Current (Ipm)	4.83A
Short Circuit Current (Isc)	5.37A



## DCM Fuses Technical Data 1/10 - 30A/600Vdc



### Description

- Full range of DC Midget in 10x38mm
- AC Maximum Interrupting Rating of 100kA at 600Vac
- DC Maximum Interrupting Rating at 50kA at 600Vdc
- DC Minimum Interrupting Rating of 200% rated current at 600Vdc

### Catalogue Symbol

- DCM

### Type of Operation

- Fast-acting 1/10 to 30A

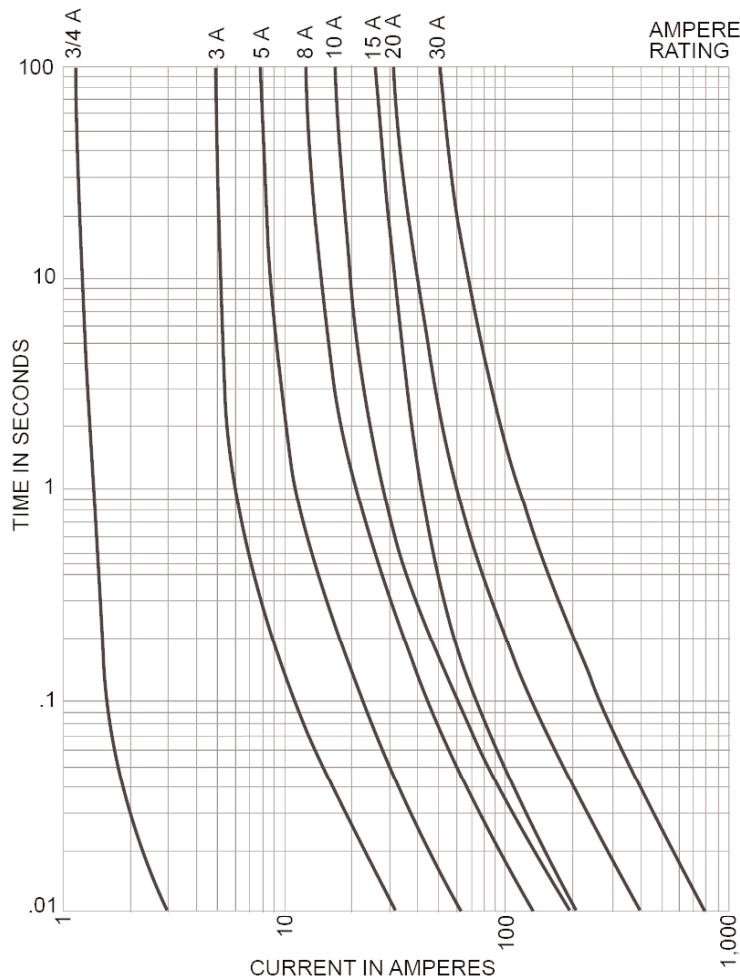
### Fuse holders

Recommended fuse blocks/fuse holders for 10x38mm fuses:

- Open fuse blocks: BM Series, 3743
- Finger-safe fuse holders: OPM-NG-SC3, OPM-NG-SM3, OPM-1038, CHMD Series
- Panel mount fuse holders: HPF Series, HPS Series, HPG & HPD, HPM Series, HPC-D, HPS2 Series

### Time-Current Curves

Time-Current Characteristic Curves—Total Clearing



### Standards/Approvals

- UL Listed STD 248-14 (File E19180, Guide JDYX)
- CSA Certified C22.2 NO 248.14 (Class 1422-01, File 53787)

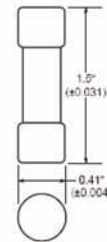
### Ratings

- Rated voltage: 600Vdc
- Amps: 1/10 to 30A
- Breaking capacity: 100k at 600Vac  
50k at 600Vdc

### Packaging

- MOQ: 10 Packaging

### Dimensions - in



## PV Fuse Link Technical Data 1 - 15A/1000Vdc



### Description

- A range of 10x38mm fuse links specifically designed for protecting photovoltaic strings. These fuse links are capable of interrupting low overcurrents associated with faulted photovoltaic string arrays (reverse current, multi-array fault).

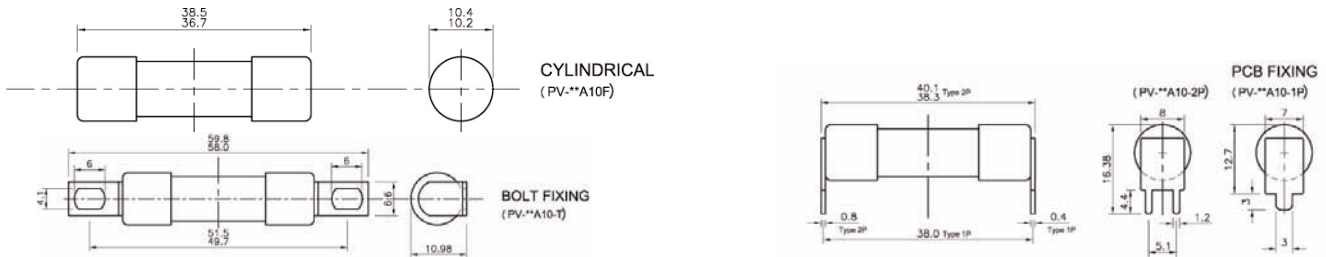
### Catalogue Symbol/Fixing

- PV-(amp rating)A10F - Cylindrical
- PV-(amp rating)A10-T - Bolt
- PV-(amp rating)A10-1P - Printed Circuit Board
- PV-(amp rating)A10F-2P - Printed Circuit Board

### Class of Operation

- gR - (PV)

### Dimensions - mm



### Standards/Approvals

- Manufactured in accordance with IEC 60269

### Ratings

- Volts: 1000Vdc
- Amps: 1 to 6A, 8A, 10A, 12A & 15A
- Breaking Capacity: 33kA dc
- Min Interrupting:  $1.3 \times I_n$
- PV Fuse Link Coordination with: 4", 5" & 6" solar cells
- Time constant (L/R): Under 1ms

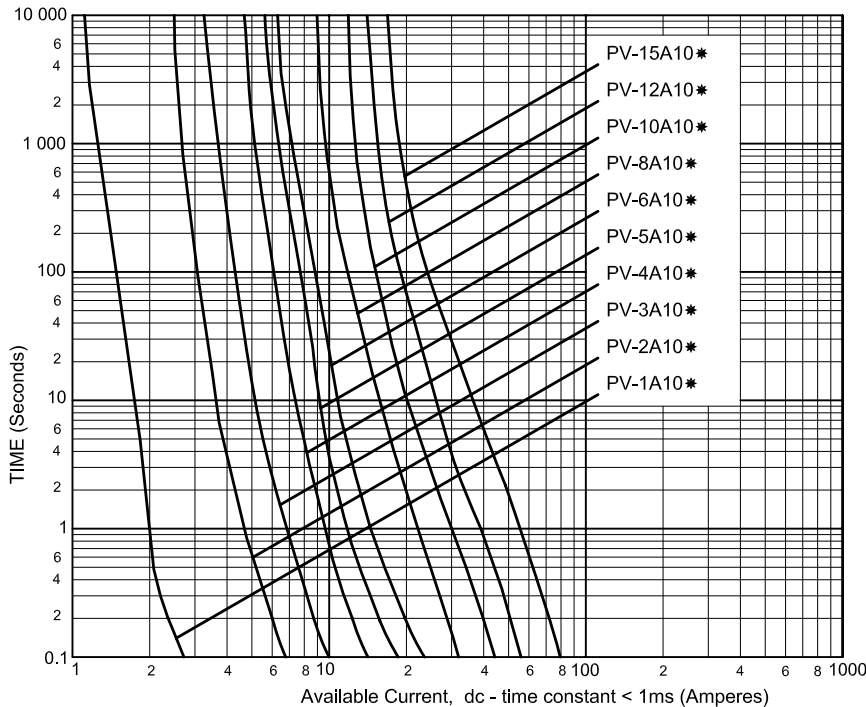
### Packaging

- MOQ: 10 Packaging 100% recyclable

### Fuse Holders

- PCB clip: 1A3400-09
- Modular fuse holder: CHM1D

### Time-Current Curves



\* Refers to fixing/mounting types, for example PV-15A10F



## Fuse Block For PV and DCM Fuse Links - BM Fuse Block

### Description

- Type M fuse block for use with any 10x38 fuses

### Catalogue Symbol

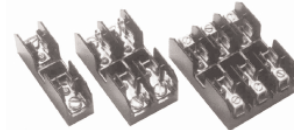
- BM Series

### DIN Rail Adapters

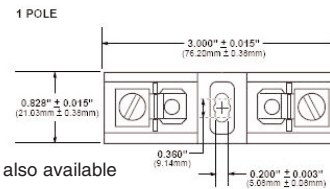
- DRA-1 and DRA-2

### Standards/Approvals

- UL Recognized, UL 512, Guide IZLT2, File E14853
- CSA Certified C22.2 No 39, Class 6225-01, File 47235
- BM603xPQ self certified for 1000Vdc



### Dimensions - in



### FUSEBLOCK LABEL (EXAMPLE SHOWN)



## Fuse Holders For PV and DCM Fuse Links - CHMD and CHM1D-PV-IEC Modular Fuse Holders

### Description

- The CHMD and CHM1D-PV-IEC modular fuse holders, accommodates 10x38mm fuse links

### Catalogue Symbol

- CHMD Series
- CHM1D-PV-IEC

### Ratings

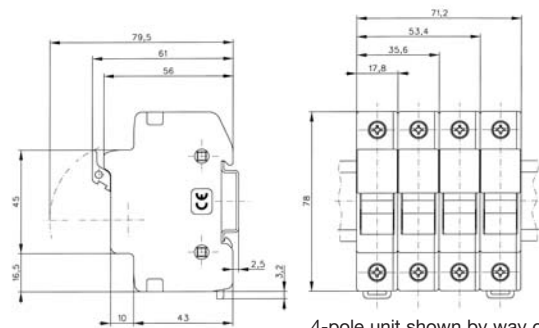
- CHMD Series is rated at 690Vdc
- CHM1D-PV-IEC is rated at 1000Vdc

### Standards/Approvals

- CHMD Series UL Recognized UL512, Guide IZLT2, File E14853, CSA Certified C22.2 No 39, Class 6225-01 File 47235. Approvals at 600Vdc.
- CHM1D-PV-IEC, type test certificate of compliance with IEC 60269-1 for a rating of 1000Vdc.



### Dimensions - mm



## Fuse Clips For PV and DCM - 1A3400 Series

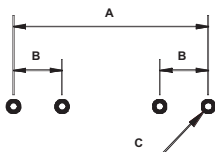
### Description

- Fuse clip for 10mm diameter fuses with end stops and straight leads 20 Amps maximum

### Catalogue Symbol:

- 1A3400

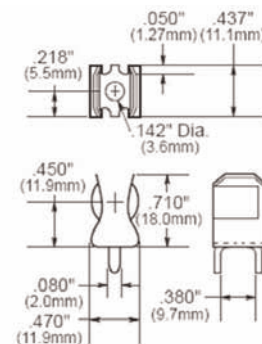
### Footprint - in (mm)



- A = 1.625" (41.28)
- B = 0.405" (10.29)
- C = (4 holes) = 0.091" - 0.095" (2.31 - 2.41)

For board thickness up to 0.125" (3.18)

### Dimensions - in (mm)



# Cooper Bussmann® Products and Technical Expertise Delivered Worldwide

## Customer Assistance

### Customer Satisfaction Team

The Cooper Bussmann® Customer Satisfaction Team is available to answer questions regarding Cooper Bussmann products.

Calls can be made between:

#### United States:

Monday – Friday, 8:00 a.m. – 4:30 p.m. for all US time zones.

The Customer Satisfaction Team can be reached via:

- Phone: 636-527-3877
- Toll-free fax: 800-544-2570
- E-mail: [busscustsat@cooperindustries.com](mailto:busscustsat@cooperindustries.com)

#### Emergency and After-Hours Orders

To accommodate time-critical needs, Cooper Bussmann offers emergency and after-hours service for next flight out or will call. Customers pay only standard price for the circuit protection device, rush freight charges and a modest emergency fee for this service. Emergency and after-hours orders should be placed through the Customer Satisfaction Team. Call:

- Monday – Friday, 8:00 a.m. – 4:30 p.m. Central Time 636-527-3877
- After hours 314-995-1342

#### Europe:

Monday-Thursday 7.30 am - 5.30 pm GMT

Friday 7.30 am - 5.00 pm GMT

The Customer Satisfaction Team can be reached via:

- Phone: 00 44 (0) 1509 882 600
- Fax: 00 44 (0) 1509 882 786
- E-mail: [bulesales@cooperindustries.com](mailto:bulesales@cooperindustries.com)

### Application Engineering

Application Engineering assistance is available to all customers. The Application Engineering team is staffed by university-qualified electrical engineers who are available by phone with technical and application support

#### United States:

Monday – Friday, 8:00 a.m. – 5:00 p.m. Central Time.

Application Engineering can be reached via phone, fax or email:

- Phone: 636-527-1270
- Fax: 636-527-1607
- E-mail: [fusetech@cooperindustries.com](mailto:fusetech@cooperindustries.com)

#### Europe:

Monday – Thursday 8.30 am – 4.30 pm GMT

Friday 8.30 am - 4.00 pm GMT

Application Engineering can be reached via phone, fax or email:

- Phone: 00 44 (0) 1509 882 699
- Fax: 00 44 (0) 1509 882 794
- E-mail: [buletechnical@cooperindustries.com](mailto:buletechnical@cooperindustries.com)

### Online Resources

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