ROLINX®
MADE FOR POWER

ROLINX® Laminated Busbar

Design Rules Version 01 (12/2015)

ROGERS CORPORATION

Content

1. Introduction

This document shall be used as a guideline for those who are involved in the design and specification of laminated busbars. The guideline provides general information that should be considered for a typical busbar design.

2. Configuration

The busbars are available in the following configurations:

// Single layer – consisting of a single conductor that is either insulated or un-insulated
// Multi-layer – consisting of two or more conductors that are separated by insulation layers

The multi-layers configuration can be also insulated or un-insulated on the outside layer of the conductor. There are many configurations for different insulation configurations and sealing methods.

For the outside insulations the following options are available:

// Flexible polyester film (PET)
// Polyimide film (PI)

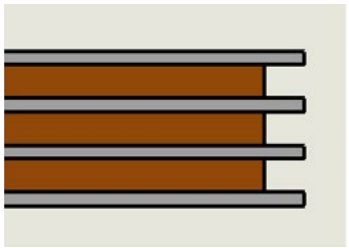
For the inner insulation the following options are available:

// Flexible polyester film (PET)
// Rigid glass matt reinforced polyester (DM1)
// Rigid glass cloth epoxy material (FR4)

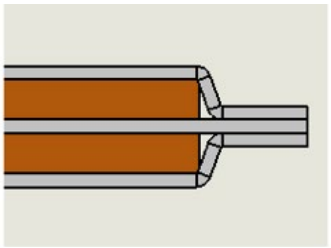
The following technics for the edge insulation are available:

// Open mould – no sealing
// Closed mould – sealed mould/edge
// Potting

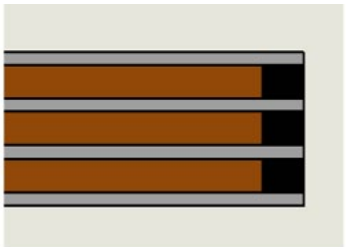
Open mould



Closed mould



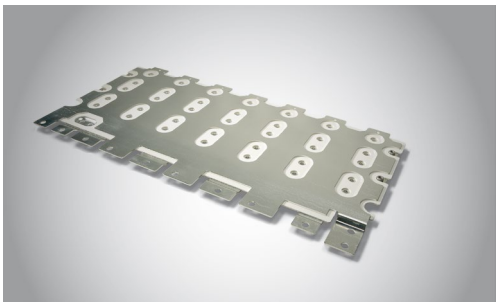
Potting



3. Products

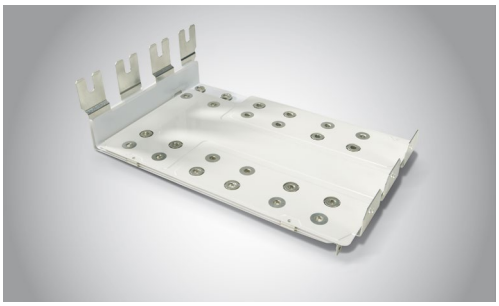
Rogers is offering the following products for laminated busbars:

// **ROLINX® Easy** is designed for low and medium voltage applications with lower electrical performance requirements. ROLINX Easy is a laminated busbar solution without outer insulation and a closed mould technology, offering high short circuit resistance, optimized inductivity and high currents above 1000A.



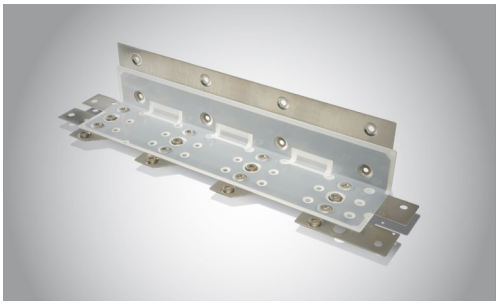
- // High short circuit resistance and low inductivity
- // A cost effective alternative for stacked busbars
- // Manufactured in a controlled production process
- // The ease of use helps to reduce installation times

// **ROLINX® Performance** is designed for medium and high voltage application and in combination with high currents over 1000A. ROLINX Performance is a laminated busbar that offers all material, lamination and plating configurations with optimized inductance and design for controlling of partial discharge.



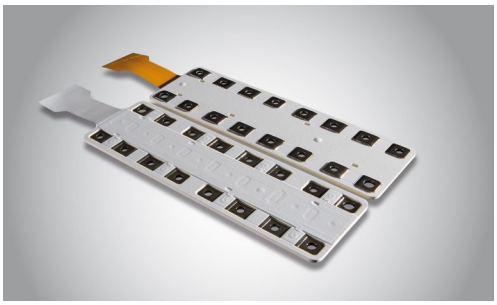
- // Provides optimized inductance
- // Designed for controlling partial discharge
- // Shaped to fit high voltage applications
- // Proven technology

// **ROLINX® Thermal** is an evolution of ROLINX Performance offering increased working temperature up to 125°C.



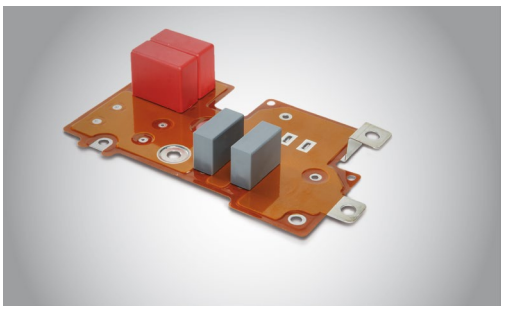
- // Developed to get more power from the existing system and design
- // Extended thermal characteristics: up to 125°C
- // Extended humidity rating
- // Designed to last

// **ROLINX® Hybrid** is designed as one piece solution that combines power and signal lines. ROLINX Hybrid is a laminated busbar for low voltage applications like battery cell connection in Electrical Vehicles.



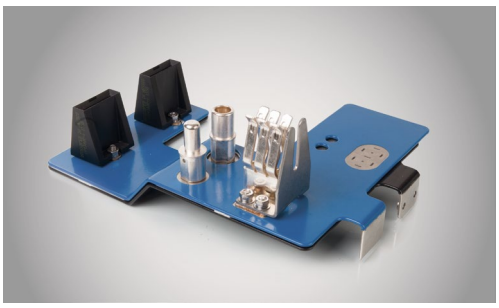
// One-piece solution for signal lines and power connection in battery modules
// Reduces installation time
// Eliminates wiring errors
// Streamlines the supply chain

// ROLINX PowerCircuit® is designed as alternative solution to traditional PCBs. It offers high voltage and current capacity with low inductance and compact 3D design.



// Compact 3D design
// Fit for high volume assembly processes
// Good thermal management
// Low inductance

// **ROLINX® Compact** is a busbar that uses epoxy powder coating as outer insulation instead of insulation films. The design rules for this product are not covered in this document.



// Optimized design fit for narrow space connection
// High power density capabilities
// High temperature resistance
// Easy to insulate very complex shapes

4. Material

4.1. Conductor

The following standard materials are available:

// Sheet Copper (Cu) – type ETP (99.9% Cu) R290 (0.5 – 0.8mm)
– type ETP (99.9% Cu) R240 (full thickness range)

// Sheet Aluminum (Al) – type 1050-H14

Standard available thickness:

Copper [mm]	0.5	0.6	0.8	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0
Aluminum [mm]	1.0	1.5	2.0	2.5	3.0	4.0	5.0				

Other thicknesses on request.

Materials properties:

	Copper	**Aluminum**
Symbol	Cu	Al
Atom number	29	13
Density (kg/m³)	8960	2702
Melting point (K)	1357	933
Specific electrical resistance (µΩmm)	16.74	26.5
Heat conductivity (W/mK)	401	237
Specific heat (J/kgK)	380	900
Thermal expansion (ppm/K)	16.5	23.1
Mohs hardness	3.0	2.75
Vickers hardness	369 MPa	100 MPa
	240HV	30HV

4.2. Insulation

Various materials can be used as outer or inner insulation for the busbars.
Selecting the right insulation depends on inductance requirements, voltage, number of conductor layers and operational environment.

4.2.1. Outer film insulations

Available outside insulations materials:

// Flexible polyester film (PET Standard) – heat resistant up to 105°C
// Flexible polyester film (PET Thermal) – heat resistant up to 125°C
// Rigid polyimide film (PI) – heat resistant for soldering temperature

Typical material specification:

Flexible insulations	RTI (°C)	CTI (V)	Dielectric constant (ε)	Heat transfer coefficient (W/mK)	Moisture absorption (%)
PET Standard	105	600	3.5	0.15	0.6
PET Thermal	125	400	3.5	0.15	0.5
PI	>200	180	3.2	0.15	2.7

Available film thicknesses (base-film + adhesive):

	75µm	145µm	155µm	270µm
PET Standard		**X**		
PET Standard shiny			X	X
PET Thermal		X		
PI	X			

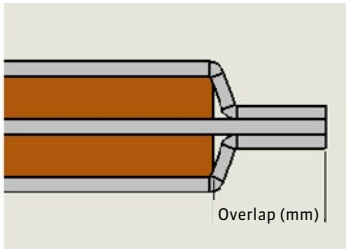
X - standard material

Overlap dimension

In order to determine the overlap the following rule can be used:

Overlap = 2 x total conductor thickness + 1 mm with a minimum of 5 mm

Closed mould



4.2.2. Inner film insulations

Typical material specification:

Flexible insulations	RTI (°C)	CTI (V)	Dielectric constant (ε)	Heat transfer coefficient (W/mK)	Moisture absorption (%)
PET Standard	105	600	3.5	0.15	0.6
PET Thermal	125	400	3.5	0.15	0.5
PI	125	180	3.2	0.15	2.7

Available film thicknesses (base-film + adhesive):

	100µm	165µm	380µm	440µm
PET Standard		**X**	X	**X**
PET Thermal		X		
PI	X			

X - standard material

4.2.3. Inner rigid insulations

Typical material specification:

Rigid insulations	RTI (°C)	CTI (V)	Dielectric constant (ε)	Heat transfer coefficient (W/mK)	Moisture absorption (%)	Thickness (mm)
DM1 - Glass matt reinforced Polyester	155	600	4.1	0.3	0.25	1 - 6
FR4 - Glass cloth epoxy material	130	200	4.7	0.3	0.1	0.5 - 6

4.3. Plating

The use of the plating materials depends on electrical and environment requirements.
The following typical plating materials are available.

	Copper	Aluminum	Thickness	Comments
Tin (Sn)	X	X	min 5µm	very soft and easy to break oxide layer
Nickel (Ni)	X	X	min 5/10µm	harder finish and scratch resistance; recommended for high temperature applications
Silver (Ag)	X		min 3µm	no oxidation (only tarnishing with sulphur) and high conductivity

Typical material properties:

	Tin	Nickel	Silver	Gold
Symbol	Sn	Ni	Ag	Au
Atom number	50	28	47	79
Density (kg/m³)	7300	8902	10500	19320
Melting point (K)	505	1726	1235	1337
Specific electrical resistance (µΩmm)	110	68.4	15.9	23.5
Heat conductivity (W/mK)	66.6	90.7	429	317
Specific heat (J/kgK)	227	440	235	128
Thermal expansion (ppm/K)	22	13.4	18.9	14.2
Mohs hardness	1.5	4.0	2.5	2.5
Vickers hardness	100 MPa	638 MPa	251 MPa	167 MPa
	30HV	300HV	70 - 130 HV	

5. Electrical parameters

5.1. Current

Typical range: 100 – 2000A

5.2. Voltage

The busbars can operate at different DC voltage levels. Typical values for nominal, rated insulation, impulse withstand, high potential and partial discharge voltages are listed below and are determinate according to IEC 60077-1, chapter 8.2.6.2.5 table 4 are the following:

Typical nominal DC voltage (V)	Rated insulation voltage Ui (V) - (nominal +40%)	Rated impulse withstand voltages Uimp (kV)
750	1050	6
1500	2100	10
3000	4200	18

The high voltage test can be determinate as per the formula :2*Ui+2kV acc. IEC 60077 during 1 minute.

The partial discharge voltage can be determinate according to (point 5.5)

5.3. Clearance distance

Clearance is the shortest distance in air between two conductive parts.

Typical clearance values according to IEC 60077 chapter 8.2.6.2 table 5 and overvoltage category 2 (OV2) are the following:

Typical nominal DC voltage (V)	Rated impulse withstand voltages Uimp (kV) 1.2/50µs	Minimum clearance distance in air (mm)
750	6	5.5
1500	10	11
3000	18	22

Overvoltage category OV2 definition:

Circuits which are not directly connected to the contact line and which are protected against overvoltages.

5.4. Creepage distance

Creepage distance means the shortest distance along the surface of a solid insulating material between two conductive parts.

Typical creepage values according to IEC 60077 chapter 8.2.6.3 table 6b and insulation materials group 1 (CTI <600V 5mm/kV) and pollution degree 2 (PD2) are the following:

Typical nominal DC voltage (V)	Rated insulation voltage Ui (V) - (nominal +40%)	Creepance distance (mm)
750	1050	5.2
1500	2100	10.6
3000	4200	21.6

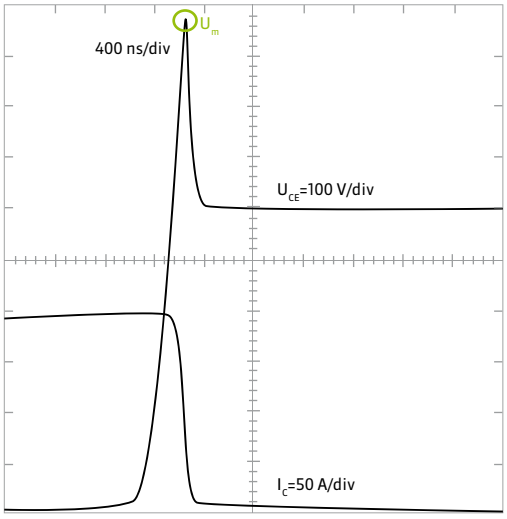
Pollution degree PD2 definition:

Normally only non-conductive pollution occurs. Occasionally, however, a temporary conductive caused by condensation is to be expected when the equipment is out of operation.

5.5. Partial discharge

The partial discharge test helps to predict future performance and reliability of busbar. Typically partial discharge should be below <10pC according to IEC 61287 at defined voltage Vtest.

- **Vtest= 1.1 Um/√2**
  - Um: maximum repetive commutation voltage at max DC voltage
  - Convert to rms (/√2) root mean square
  - 10% extra margin

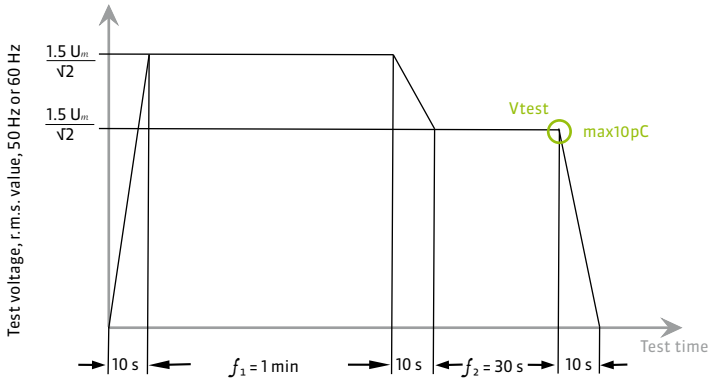


// **Test Cycle:**

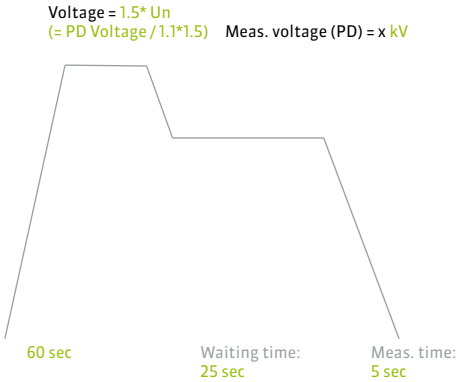
// 1 min 1.5 Um/√2

// 30s Vtest 1.1 Um/√2

// Max 10pC @ last 5 s Vtest



Um Highest recurring peak voltage across the relevant insulation voltage



6. Mechanical parameters

6.1. Physical dimensions and tolerances

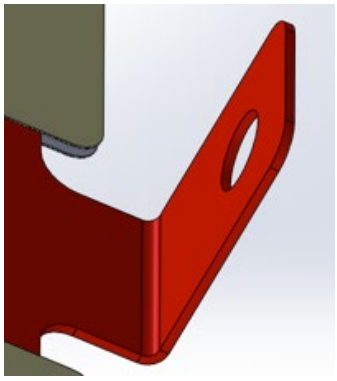
Table below lists standard tolerances for the busbars.

Dimension	Standard tolerance
Tolerance on holes	+/- 0.05mm
Distance distances	+/- 0.2mm
Sub assembly	+/- 0.6mm
Angle	+/- 1°

6.2. Bending

The bending information below gives general recommendation to minimalize the stress in the material.

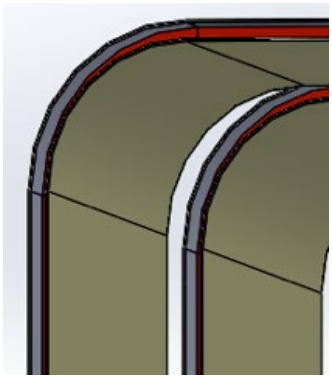
Single bending 90°



Recommendation R>T

R – Radius
T – conductor thickness

Single bending with insulation



Recommendation R=2T

R – Radius
T – conductor thickness

7. Features

There are various features to terminate the busbar for system connection. The table below describes the most common methods with some factors to be considered when designing a busbar.

Connection	**Typical current values**
Bushing	> 100A
Dishing (up to 2mm conductor)	> 50A
Star dishing (up to 3mm conductor)	> 50A
Solder pin	< 10A
Faston tab	< 20A
Fastened threaded stud	> 100A
Fastened screw	> 100A
Connectors	As per request

8. Thermal parameters

// Storage temperature range:	Min: -50°C / Max: +85°C
// Ambient temperature range:	Min: -50°C / Max: Standard +105°C, Extended +125°C
// Relative humidity:	Max: 55°C / 95% RH
// Cooling system:	Natural convection

9. General parameters

// Product life span:	Standard 25 years
// Pollution degree:	2 – typical (1 and 3 optional)
// Insulating material group I:	CTI > 600
// RoHS compliance:	Yes

10. Test specification

The parts will pass the following tests:

// Visual inspection
// Dimension check (optional)
// Partial discharge test if applicable
// High potential test

11. Labelling

Each part is equipped with an identification label showing the items indicated below:

// Customer part number + barcode
// Serial number + barcode
// Rogers part number
// Production date
// Confirmation of passed routine test (green QA-label)
// Other items on request

12. Glossary

CTI – Comparative Tracking Index
RTI – Relative Temperature Index

13. Standards

The following standards are applicable:

// EN 50124-1 2006 Railway applications – Insulation coordination –
Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment

// EN 50125-1 2000 Railway applications – Environmental conditions for equipment –
Part 1: Equipment on board rolling stock

// EN 61287-1 2007 Railway applications – Power converters installed on board rolling stock –
Part 1: Characteristics and test methods

// EN 61373 1999 Railway applications – Rolling stock equipment – Shock and vibration tests

// EN 45545-1 2013 Railway application – Fire protection on railway vehicles – Part 1: General

// IEC 60077-1 2003 Railway applications - Electric equipment for rolling stock –
Part 1: General service conditions and general rules

// UL 746C (incl. UL 94) US & CA

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Issued by Dominik Pawlik
Approved by Sebastiaan De Boodt

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