

# Bodo's Power Systems®

## 1700V X-Series HVIGBT Power Modules with Excellent Performance and Reliability

*High performance 1700V HVIGBT power modules providing reliable solutions for railway applications.*

*The railway applications require components with high quality and high efficiency, especially the converter drives should have reliable and robust switching devices. It is an established practice to utilize 1700V IGBT modules to operate directly on the catenary with the DC voltages below 1000V or in 3-level configuration with catenary DC voltages above 1000V.*

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Mitsubishi Electric continuously improves the quality of the IGBT power modules concerning three key concepts:

- Robust power module design considering high margin of safe operating area,
- Low power losses using latest chip generation,
- Quality control with dedicated production lines and traceability.

Mitsubishi Electric has several years of experience and a long development history of 1700V modules for railway application from the start of this century. This year MITSUBISHI ELECTRIC has released the latest generation of 1700V IGBT power modules called X-Series that satisfies requirements of railway applications. Fig. 1 shows the historical evolution of the 1700V HVIGBT modules indicating the continuous reduction of the IGBT forward voltage. The IGBT forward voltage contributes to the converter power loss reduction. IGBT forward voltage reduction has continuously been achieved during the development of each series. The remarkable step in the reduction of the forward voltage was the implementation of the trench gate structure

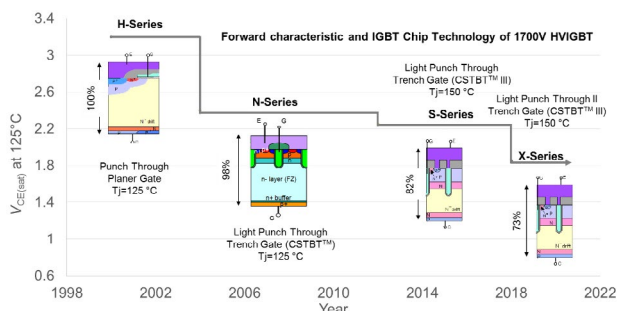


Figure 1: Chronology of 1700V IGBT chip forward voltage reduction.

in the beginning of 2000s [1]. For further reducing the forward voltage the IGBT chip structure was optimized and thinner chips were used. In the latest 1700V X-Series the state of the art 7th Generation chip technology is applied in conjunction with a further reduction of IGBT thickness. Additionally, several optimizations on the chip back side (collector side) were carried out.





Circuit	Foot print	Current rating	Type name
Single 1 in 1		2400A	CM2400HCB-34X
		3600A	CM3600HC-34X
Single 1 in 1		1600A	CM1600HC-34X
		2400A	CM2400HC-34X
Chopper		1200A	CM1200E4C-34X
Dual 2 in 1		1000A	CM1000DC-34X (Si)
		1200A	CM1200DC-34X (Si)
		1200A	CMH1200DC-34X (SiC hybrid)

Table 1: 1700V X-Series Line-up

The 1700V X-Series contains three module packages. The first is the conventional package with the footprint dimensions of 190mm x 140mm. The second type is also conventional having the footprint size of 130mm x 140mm. The third package is the new standard dual

package called LV100 with the footprint of 140mm x 100mm. The complete line-up of the X-Series 1700V IGBT modules is shown in table 1.

**High current 1700V HVIGBT X-Series single modules.**

The conventional 1in1 packages were completely reworked compared to the previous N-Series. The chip layout inside the module was optimized for better thermal conductivity and better power cycling life time. Inside the module a newly developed high performance silicone gel is used. The operation temperature now is covering the range from -50°C to 150°C. The new X-series modules will receive the UL certification. Furthermore, these modules were proven during the qualification against the humidity influence. That is an important factor for the operation in the harsh railway environment.

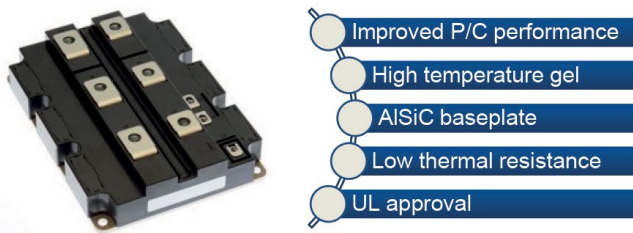


Figure 2: 1700V X-Series single modules features

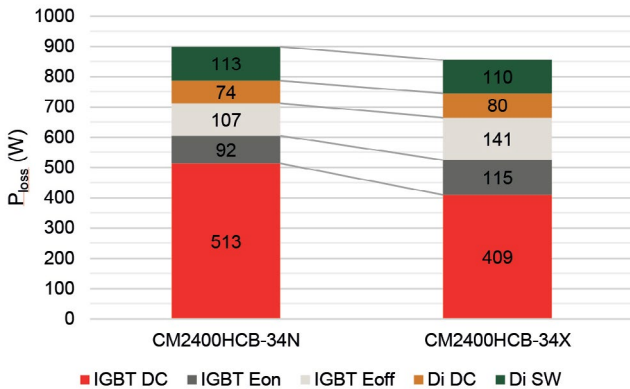


Figure 3: X-Series power loss simulation under the conditions:  $V_{CC}=850V$ ,  $I_{peak}=1200A$ ,  $PF=0.85$ ,  $M=1$ ,  $f_{sw}=1kHz$ ,  $f_o=60Hz$ ,  $T_j=125°C$ .

The standard package type is available since many years on the market. Then converter manufacturers have proven reliability records of the converters having this package type in the field. Now it is possible to boost the converter performance using the cutting edge technology of X-Series modules. The small size package (130mm x140mm) is favorite choice for compact water cooled application. The large package (190mm x 140mm) with its low case to heatsink thermal resistance  $R_{th(c-f)}$  is especially attractive for air cooled applications. In the Figure 3 is shown the potential of the power loss reduction for single X-Series device CM2400HCB-34X compared to the previous N-Series.



**Dual LV100 X-Series 1700V modules**

The standard LV100 package was developed with the target to cope with high switching speed devices like 1700V X-series modules and modules having Silicon Carbide technology. The low inductive package structure is one of the key advantages of this device.

Thanks to low package inductance and comfortable construction of the DC-Link connection, it is possible to switch off the device at high current without increasing the turn off gate resistance. The IGBT turn off measurement result at maximum turn off conditions  $V_{CC}=1200V$ ,  $I_C=2400A$ ,  $R_{g(off)}=R_{g(nominal)}$ ,  $L_s=40nH$  and  $T_j=150°C$  is shown in Figure 4. Even at such conditions the overvoltage spike is below the maximum blocking voltage of 1700V.

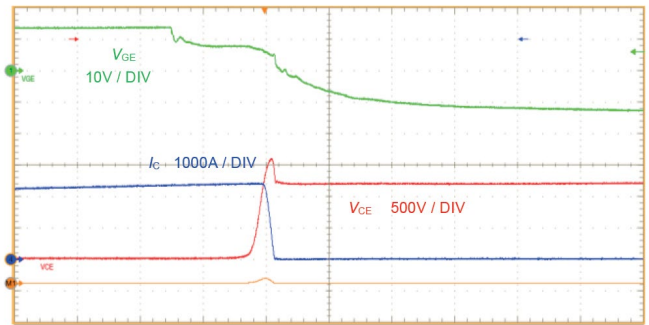


Figure 4: CM1200DC-34X turn off event at high current and maximum DC-Link voltage.

Furthermore the diode performance was enhanced in the LV100 module. Compared to the previous S-Series the diode forward voltage was reduced by more than 15%. At the same time the reverse recovery energy was reduced by more than 25%.

The current density in the LV100 package was increased by about 30% from 13.2A/cm<sup>2</sup> to 17.1A/cm<sup>2</sup> for CM1200DC-34X compared to CM2400HC-34N device. To carry the high output current the device has three screws at AC output terminal.

The forward characteristics of IGBT and FWDi has positive temperature coefficients that is essential for good module parallel operation.

Additionally this package provide the flexibility of converter power scaling by module paralleling. This point is also an additional challenge for converter designer. To overcome this challenge the proposed reference test setup [2] can be used in combination with these modules.

**Conclusion**

The introduced 1700V X-Series utilize the cutting edge chip and package technologies. The modules offers the highest reliability combined with low power losses and flexibility.

**References**

- [1] S. Iura, E. Suekawa, K. Morishita, M. Koga, E. Thal. "New 1700V IGBT Modules with CSTBT." PCIM Europe 2004.
- [2] Dr. J. Weigel. "Paralleling of High Power Dual Modules: Standard Building Block Design for Evaluation of Module Related Current Mismatch." EPE'18 ECCE Europe.