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 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.

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Table 1: 1700V X-Series Line-up

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Foot print</th>
<th>Current rating</th>
<th>Type name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single 1 in 1</td>
<td>190mm x 140mm</td>
<td>2400A</td>
<td>CM2400HCB-34X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3600A</td>
<td>CM3600HC-34X</td>
</tr>
<tr>
<td>Single 1 in 1</td>
<td>130mm x 140mm</td>
<td>1600A</td>
<td>CM1600HC-34X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2400A</td>
<td>CM2400HC-34X</td>
</tr>
<tr>
<td>Chopper</td>
<td>130mm x 140mm</td>
<td>1200A</td>
<td>CM1200E4C-34X</td>
</tr>
<tr>
<td>Dual 2 in 1</td>
<td>100mm x 140mm</td>
<td>1000A</td>
<td>CM1000DC-34X (Si)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1200A</td>
<td>CM1200DC-34X (Si)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CMH1200DC-34X (SiC hybrid)</td>
</tr>
</tbody>
</table>

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.

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 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.

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/cm² to 17.1A/cm² for 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