Introduction
of
Smart Power Modules

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Motion Control System Team
HV Functional Power Group

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| A/C | Air-Conditioner | NTC | Negative Temperature Coefficient |
| BLDC | Brush-less DC | OCP | Over Voltage Protection |
| BS | Boot Strap | PFC | Power Factor Correction |
| CAN | Controller Area Network | PKG | Package |
| CPM | Compact Power Module | PSC | Partial Power Factor Correction Switching Converter |
| CIB | Converter Inverter Brake | PWM | Pulse Width Modulation |
| DBC | Direct Bonding Copper | PROT | Protection |
| DIP | Dual In-line Package | PCB | Printed Circuit Board |
| EMI | Electro-Magnetic Interference | QA | Quality Assurance |
| EMC | Electro-Magnetic Compatibility | SPM | Smart Power Module |
| ESR | Equivalent Series Resistance | SPIU | Smart Power Integrated Unit |
| FCS | Fairchild Semiconductor | SEER | Seasonal Energy Efficiency Rating |
| FOC | Field Oriented Control | SC | Short Circuit |
| FRD | Fast Recovery Diode | SRM | Switched Reluctance Motor |
| FWD | Free-Wheeling Diode | SIP | Single In-Line Package |
| F/F | Flip Flop | SMD | Surface Mounted Device |
| FRFET | Fast Recovery body diode MOSFET | SOA | Safe Operating Area |
| FPS | Fairchild Power Switch | SCWT | Short Circuit Withstands Time |
| HVIC | High Voltage gate driver IC | UV | Under Voltage |
| IM | Induction Motor | UVP | Under Voltage Protection |
| IGBT | Insulated Gate Bipolar Transistor | UVLO | Under Voltage Lock-Out |
| INV | Inverter | VVVF | Variable Voltage Variable Frequency |
| LVIC | Low Voltage gate driver IC | VSD | Variable Speed Drive |
| MI | Modulation Index | 1N | One Separate Negative Rail Emitter |
| MCU | Micro Controller Unit | 3N | Three Separate Negative Rail Emitter |
| MFG | Manufacturing | | |
Contents

1. Why Motor Drives
2. SPM Introduction
3. Design Considerations of SPM
4. SPM Values
Chapter 1. Why Motor Drives
Why/How Motion Control?

**WHY:**
- Speed Control → Energy Savings
- Speed and Torque Control → High Efficiency and Performance
- Speed and Position Control → High Efficiency and Performance

**HOW:** by Variable Voltage and Variable Frequency in 3-phase ac motor configuration
Trend of Motor Technology

Trend is Inverter-driven Motion !!

DC Motor
→ AC Motor
→ Induction Motor
→ Synchronous Motor
→ Reluctance
→ Permanent Magnet (BLDC)
→ Brushless DC (BLDC)
→ Surface Mounted Permanent Magnet (SMPMM)
→ Interior Permanent Magnet (IPMM)
→ Synchronous Reluctance (SynRM)
→ Switched Reluctance (SRM)
→ Permanent Magnet Assisted SynRM (PMA-SynRM)

Trend goes to higher efficiency and better performance

Use of VVVF, FOC Inverter
High-speed operation enhances total efficiency of entire system
Faster & better torque & speed control
Wide-speed operation
Additional functions that give comfort & reliability

Why motor drives?
Inverter Technology Trend

Keeping Higher performance and Efficiency!

How to achieve Lower Cost Solution!!
The U.S. Department of Energy announced on April 2nd that it will enforce a seasonal energy efficiency rating (SEER) standard of 13 for residential central air conditioners starting in January 2006.

This represents a 30 percent increase in energy efficiency compared to the previous SEER standard.

New regulations from government agencies within the European Community

Japan government has announced the need of 20% higher efficiency than present efficiency level in order to meet Kyoto Protocol from 2010, particularly in Air-conditioners and Refrigerators.
Chapter 2. SPM Introduction
### Basic Structure

<table>
<thead>
<tr>
<th>SPU</th>
<th>&gt; 10kW (600V 450A)</th>
<th>6-IGBT/FRD with thermal sensor + Gate Driver + Protection + DC/DC Converter + CAN MCU + I/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPIM</td>
<td>&lt; 10kW (600V 100A 1200V 50A)</td>
<td>6-IGBT/FRD for inverter + Inverter Gate Driver + PFC + PFC controller + Thermistor + Protection + MCU</td>
</tr>
<tr>
<td>CPM</td>
<td>&lt; 10kW (600V 100A 1200V 50A)</td>
<td>6-IGBT/FRD for inverter + Rectifier + Dynamic brake + Thermistor</td>
</tr>
<tr>
<td>SPM1</td>
<td>&lt; 10kW (600V 100A 1200V 50A)</td>
<td>6-IGBT or MOSFET / FRD for inverter + Gate driver with Protection + Thermostat</td>
</tr>
<tr>
<td>SPM2</td>
<td>&lt; 5kW (600V 75A)</td>
<td>6-IGBT / FRD for inverter + Gate driver with Protection (SC, UV, Soft Shut down) + Thermistor</td>
</tr>
<tr>
<td>SPM3</td>
<td>&lt; 2.2kW (600V 30A)</td>
<td>6-IGBT / FRD for inverter + Gate driver with Protection (SC, UV, Soft Shut down) + Thermistor</td>
</tr>
<tr>
<td>SPM4</td>
<td>&lt; 1kW (600V 15A)</td>
<td>6-IGBT / FRD for inverter + Gate driver with Protection (SC, UV, Soft Shut down) + Thermistor</td>
</tr>
<tr>
<td>SPM5</td>
<td>&lt; 0.1kW (500V 3A)-MOSFET</td>
<td>6-MOSFET for inverter + Gate driver with Protection (UV) + Thermostat</td>
</tr>
</tbody>
</table>
External View of SPM Product Group

- **CPM/SPM1 Series**
- **SPM2 Series**
- **SPM3 Series**
- **SPM4 SIP1 Series**
- **SPM4 SIP2 Series**
- **SPM5 Series**
# Overview of SPM2 and SPM3 Products

<table>
<thead>
<tr>
<th>Developed</th>
<th>PKG</th>
<th>Developed</th>
<th>PKG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SPM2</strong></td>
<td>SPM2 PKG with Ceramic substrate</td>
<td><strong>V2 SPM3</strong></td>
<td>SPM3 PKG with DBC substrate</td>
</tr>
<tr>
<td>600V-10/15/20/30A</td>
<td>SPM2 PKG with DBC substrate</td>
<td>600V-3/5/10/15A</td>
<td>SPM3 PKG with Ceramic substrate</td>
</tr>
<tr>
<td><strong>SPM3</strong></td>
<td>V2 SPM3</td>
<td><strong>V2 SPM3</strong></td>
<td>SPM3 PKG with DBC substrate</td>
</tr>
<tr>
<td>600V-50A, 75A</td>
<td>MOSFET SPM3</td>
<td>600V-15/20/30A</td>
<td><strong>SRM-SPM</strong> : 600V-50A</td>
</tr>
<tr>
<td><strong>Developing</strong></td>
<td>V3 SPM3</td>
<td><strong>PSC-SPM</strong> : 600V-20A</td>
<td><strong>PFC-SPM</strong> : 600V-20/30/50A</td>
</tr>
<tr>
<td>600V-3/5/10/15A</td>
<td>V3 SPM3</td>
<td>600V-15/20/30A</td>
<td></td>
</tr>
</tbody>
</table>

**SPM2** PKG with Ceramic substrate: 60x31

**SPM2** PKG with DBC substrate: 60x31

**SPM3** PKG with Ceramic substrate: 44x26.8

**SPM3** PKG with DBC substrate: 44x26.8

**SPM3** PKG with Ceramic substrate: 44x26.8
Details of SPM2 Series

- **Line-up – SPM2:**
  - 600V/10A, 15A, 20A, 30A – with Ceramic Substrate
  - 600V/50A, 75A – with DBC Substrate

- **Major Applications:**
  - Consumer appliance inverters (Air conditioner, Treadmill)
  - Low power industrial inverters

- **Feature:**
  - Built-in thermistor (NTC)
  - Short-circuit protection with soft shut-down control using sense-IGBTs
  - Good thermal resistance and isolation capacity with ceramic/DBC substrate
  - 3 N-terminals for low-cost current sensing
Details of SPM3 Series

- **Line-up - V2 SPM3**:  
  - 600V/3A, 5A, 10A, 15A –with ceramic  
  - 600V/15A, 20A, 30A –with DBC

- **Line-up - V3 SPM3 (under development)**:  
  - 600V/3A, 5A, 10A, 15A – V3 SPM3 with ceramic  
  - 600V/15A, 20A, 30A – V3 SPM3 with DBC  
  - V3 SPM3 = enhanced IGBT

- **Major Applications**:  
  - Consumer appliance inverters  
    (Air conditioner, Washing machine, Refrigerator, etc)  
  - Low power industrial inverters  
    (Industrial inverter, Water pump, Treadmill, Elevator door, etc)

- **Feature**:  
  - Good thermal resistance  
  - Small size & Large pin-to-pin spacing with zigzag package structure  
  - 3 N-terminals for low-cost current sensing
Details of MOSFET-SPM3

- **Line-up:**
  - 500V/ 5A (1.35Ω(typ.)), 6A (1.15Ω(typ))
- **Major Applications:**
  - Low power consumer appliance inverters (Refrigerator, Fan)
- **Feature:**
  - 3-phase MOSFET inverter with driver IC
  - Good thermal resistance
  - Small size & Large pin-to-pin spacing with zigzag package structure
  - 3 N-terminals for low-cost current sensing
Details of SRM-SPM3

- Line-up:
  - 600V/50A - SPM3 package with DBC

- Major Applications:
  - Single-phase SRM drives
    (Vacuum cleaner)

- Feature:
  - Good thermal resistance
  - IGBT switching speed control with external capacitor
  - Built-in thermistor (NTC)
  - Small size & Large pin-to-pin spacing
    with zigzag package structure
  - Divided N-terminals for low-cost current sensing
Details of PFC-SPM3

PSC-SPM (Partial switching PFC)
- **Line-up:**
  - 600V/20A - SPM3 package with DBC
- **Major Applications:**
  - Low/Medium power consumer appliances such as Room air conditioner
- **Feature:**
  - Good thermal resistance
  - Same package as SPM3
  - Built-in thermistor for temperature sensing
  - LVIC with UVP, OCP

PFC-SPM (Full switching PFC)
- **Line-up:**
  - 600V/20A, 30A, 50A - SPM3 package with DBC
- **Major Applications:**
  - Medium/high power consumer appliance such as Package/System air conditioner
- **Feature:**
  - Good thermal resistance
  - Built-in shunt resistor
  - Same package as SPM3
  - Built-in thermistor for temperature sensing
  - LVIC with UVP, OCP

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# Overview of SPM4, SPM5 and CPM Products

<table>
<thead>
<tr>
<th>PKG</th>
<th>SPM4 SIP1 PKG</th>
<th>SPM4 SIP2 PKG</th>
<th>SPM5 PKG</th>
<th>CPM PKG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developed</td>
<td></td>
<td></td>
<td>V1 SPM5 DIP</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>500V</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2A (3.3 Ω(typ)), 3A (1.9 Ω(typ))</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>250V 3A (1.4 Ω(typ))</td>
<td></td>
</tr>
<tr>
<td>Developing</td>
<td>SPM4</td>
<td>SPM4</td>
<td>V2 SPM5 SMD</td>
<td></td>
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<tr>
<td></td>
<td>600V-3/5/8/10/12/15A</td>
<td>600V-3/5/8/10/12/15A</td>
<td>500V- 2 / 3A</td>
<td>600V / 1200V CPM CIB</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>250V - 3A</td>
<td>1200V- 15A, 25A</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>LV-SPM5 DIP, SMD</td>
<td>600V- 30A, 50A</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>60V 40mΩ(typ)</td>
<td>600V / 1200V CPM Inv.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1200V- 25A, 35A, 50A</td>
</tr>
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<td></td>
<td></td>
<td>600V- 50A, 75A, 100A</td>
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<td></td>
<td>600V/1200V SPM1</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>600V- 50A, 75A, 100A</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1200V- 10A, 15A, 25A</td>
</tr>
</tbody>
</table>

SPM Introduction
Details of SPM4-SIP1

- Line-up (under development):
  - 600V/3A, 5A, 8A, 10A, 12A, 15A
  - 1N / 3N terminal
- Major Applications:
  - Consumer appliance inverters (Air conditioner, Washing machine, Refrigerator, Water pump, etc)
  - Low power industrial inverters (Fan Motor, Industrial Inverter, etc)
- Feature:
  - Cross-Conduction Prevention Logic
  - Large pin spacing and signal/power pins separation
  - Single-In-Line package
  - 3 N-terminals for low-cost current sensing
  - Built-in thermistor
• **Line-up (under development):**
  - 600V/3A, 5A, 8A, 10A, 12A, 15A
• **Major Applications:**
  - Consumer appliance inverters (Air conditioner, Washing machine, Refrigerator, Water pump, etc)
  - Low power industrial inverters
• **Feature:**
  - Single-In-Line package
  - 3 N-terminals for low-cost current sensing
  - Built-in thermistor
Details of MOSFET-SPM4-SIP2

- **Line-up (under development)**:
  - 500V / 5A(1.35Ω(typ.)), 6A(1.15Ω(typ.)), 9A(0.8Ω(typ.))

- **Major Applications**:
  - Low power consumer appliance inverters
    (Refrigerator, Fan)

- **Feature**:
  - 3phase MOSFET inverter
  - Single-In-Line package
  - 3 N-terminals for low-cost current sensing
  - Built-in thermistor
Details of SPM5 V1 Series

- **Line-up**:  
  - V1 SPM5 DIP: 500V 2A (3.3Ω(typ)), 3A (1.9Ω(typ)) & 250V 3A (1.4Ω(typ))  
  - V1 SPM5 SMD: 500V 2, 3A & 250V 3A (under development)  
  - Transfer-molded full-pack package  

- **Major Applications**:  
  - Fan motor, water pump, etc.  
  - Small motor applications up to 150W  

- **Feature**:  
  - High power density compared to small package  
  - Ruggedness (Switching and short-circuit)  
  - Low conducted and radiated EMI (Slow dV/dt & dl/dt)  
  - HVIC with UVP  

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Chap. 2  
SPM Introduction
Details of SPM5 V2 Series

- **Line-up (under development)**
  - V2 SPM5 DIP and SMD: 500V 2A \((3.3\,\Omega\,\text{typ})\), 3A \((1.9\,\Omega\,\text{typ})\) & 250V 3A \((1.4\,\Omega\,\text{typ})\)
  - LV-SPM5 DIP and SMD: 60V 40m\(\Omega\,\text{typ}\)
- **Major Applications**:
  - Fan motor, water pump, etc.
  - Small motor applications up to 150W
- **Feature**:
  - High power density compared to small package
  - Ruggedness (Switching and short-circuit)
  - Low conducted and radiated EMI (Slow dV/dt & dI/dt)
  - HVIC with UVP
Details of CPM Series

• Line-up (Under Development):
  - CPM CIB: 600V/30A, 50A
    1200V/15A, 25A
  - CPM Inverter: 600V 50A, 75A, 100A
    1200V 25A, 35A, 50A
  - Transfer-molded DBC package

• Major Applications:
  - Industrial Inverter, System A/C

• Feature:
  - High power density in a small package
  - 3-phase Rectifier and IGBT inverter (CIB)
  - 3-phase IGBT inverter (Inverter Only)
  - Built-in Thermistor for temperature sensing
  - Good thermal resistance
  - 3 N-terminals for low-cost current sensing
  - Various other topologies may be considered on demand
• Line-up – SPM1 (under development):
  - 600V/50A, 75A, 100A
  - 1200V/10A, 15A, 25A

• Major Applications:
  - Industrial Inverter, System A/C

• Feature:
  - High power density in a small package
  - 3-phase IGBT inverter
  - Built-in Thermistor for temperature sensing
  - Good thermal resistance
  - 3 N-terminals for low-cost current sensing
Application Example - Washing Machines

* Low Voltage Drive under 40V (Currently)

* High Voltage Drive 500V 1A grade (Future)
Application Example - Air Conditioners

Chap. 2
SPM Introduction
Application Example - Refrigerators

AC Input → VSD → SPM3 or SPM4 → CONTROL BOARD

- Compressor Motor
- Evaporator Fan Motor
Chapter 3. SPM Design Considerations
• Insulated Gate Bipolar Transistor
• Voltage controlled
• Conducts current from collector to emitter when a positive voltage is applied from the gate to the emitter
• Modules include a free-wheeling diode (FWD)
• Fundamental Parameters
  • $V_{CES}$ Collector-emitter voltage rating
  • $I_{C}$ Collector current rating
Key Parameters & Definitions

- $V_{CE(SAT)}$ – IGBT saturation voltage; On-state collector to emitter voltage drop while conducting current.
- $R_{TH(j-c)}$ – Thermal resistance; Specifies the resistance to heat flow from chip to base plate (Junction to Case).
- $E_{SW(on)}$ – Turn-on switching energy; Energy dissipated during turn-on.
- $E_{SW(\text{off})}$ – Turn-off switching energy; Energy dissipated during turn-off.
- Total Loss – (Watts) = (conduction losses + switching losses)
  
  \[ = \text{(duty factor} \times V_{CE(SAT)} \times I_C) + ((E_{SW(on)} + E_{SW(\text{off})}) \times \text{frequency}). \]

The total power dissipated in the device.

Used to determine heat sink size and junction temperature rise.
### Collector-Emitter Saturation Voltage Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Symbol</th>
<th>Test Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector–Emitter Saturation Voltage</td>
<td>$V_{CE(sat)}$</td>
<td>$V_{CC} = V_{BS} = 15\text{V}$, $V_{IN} = 5\text{V}$, $I_C = 20\text{A}$, $T_{J} = 25^\circ\text{C}$</td>
<td>–</td>
<td>–</td>
<td>2.3</td>
<td>V</td>
</tr>
</tbody>
</table>

**Graph:**

- **Collector-Emitter Saturation Voltage Characteristics (Typical)**
- **Collected Voltage $V_{CE(sat)}$ (V)** vs **Collector Current $I_C$ (A)**
- Curves for $T_{J} = 125^\circ\text{C}$ and $T_{J} = 25^\circ\text{C}$
Switching Time

(a) turn-on

(b) turn-off
Switching Energy ($E_{SW}$)

Turn-on and Turn-off Switching Losses

energy-ON

Energy -ON

energy-OFF

Energy -OFF

Turn-on and Turn-off Switching Losses
**Nameplate Current Rating**

Is the rating that is used in the device part number. For example, the nameplate rating of FSBS10CH60 is 10A.

Many manufactures use a so called “i\(\text{dc}\)” rating for their nameplate. An \(i\text{dc}\) rating is the DC current that will cause the IGBT chip junction temperature to reach \(T_j(\text{max})\) with the module’s base plate held at a constant arbitrary temperature \(T_c\).

The \(i\text{dc}\) “rated” current can be computed from:

\[
i\text{dc} = \frac{[T_j(\text{max}) - T_c]}{[V_{ce}(\text{at} i_T) \times R_{TH(j-c)}]}
\]

Where:
- \(i\text{dc}\) = DC current rating
- \(V_{ce}(\text{at} i_T)\) = Collector to emitter Voltage at \(i_T\)
- \(T_j(\text{max})\) = Maximum junction temperature
- \(R_{TH(j-c)}\) = Junction to case thermal impedance
- \(T_c\) = Arbitrarily selected case temperature

The current rating (\(i\text{dc}\)) depends on the following:

- Selection of \(T_c\) - Lower \(T_c\) gives higher \(i\text{dc}\) rating
- Selection of \(T_j(\text{max})\) - Some manufacturers use a conservative 125C while others use 150C. Higher \(T_j(\text{max})\) gives higher \(i\text{dc}\) rating
- Measurement method for \(R_{TH(j-c)}\) - Using the under chip method gives lower thermal impedance and higher \(i\text{dc}\) rating
Nameplate Current Rating

Fairchild does not use $i_{DC}$ ratings as a basis for nameplate current ratings. However many manufacturers use this method for rating their modules. Please see the following table for examples of how these ratings can be misleading.

Comments on $i_{DC}$ ratings:
- $i_{DC}$ ratings are generally useless for device selection
  (These ratings consider DC loss only and ignore switching losses and SOA)
- $i_{DC}$ ratings are generally useless for comparing devices from different manufacturers
  (Rating is influenced by selection of $T_c$, $T_j(\text{max})$ and thermal impedance measurement point)

To properly select a device you should consider:
- On State Conduction (DC) Losses
- Switching Losses
- Thermal Impedance $R_{TH(j-c)}$
- Available heat sink/cooling method
- Maximum ambient temperature
- Turn-off switching SOA
- Free Wheel Diode Utilization
<table>
<thead>
<tr>
<th>Module with Nameplate rating 75A, 1200V</th>
<th>Maximum Vce(sat) (V)</th>
<th>Maximum Rth(j-c)(C/W) Tc under Chip</th>
<th>iT(A) Tj(max)=150C Tc=25C</th>
<th>iT(A) Tj(max)=150C Tc=80C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brand A</td>
<td>2.5</td>
<td>0.22</td>
<td>168</td>
<td>112</td>
</tr>
<tr>
<td>Brand B</td>
<td>4.0</td>
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<tr>
<td>Brand C</td>
<td>3.1</td>
<td>0.21</td>
<td>147</td>
<td>98</td>
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<tr>
<td>Brand D</td>
<td>3.6</td>
<td>0.27</td>
<td>107</td>
<td>73</td>
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<tr>
<td>Brand F</td>
<td>3.0</td>
<td>0.25</td>
<td>130</td>
<td>88</td>
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<tr>
<td>Brand A (50A)</td>
<td>2.9</td>
<td>0.31</td>
<td>115</td>
<td>75</td>
</tr>
</tbody>
</table>

**Chap. 3**
Design Considerations of SPM
Key Points 1

- When comparing devices, the specific electrical characteristics (Vce(sat), Esw(on&off), $R_{th}$) must be evaluated. At Actual Operating Conditions !!

- These parameters must be compared under the same test conditions, as most manufacturers spec these under varying conditions.

- These can usually be obtained from the data sheet values or performance curves.

- When comparing thermal impedance the case temperature ($T_c$) measurement point is very important.

- An under chip measurement point yields a considerably lower value for thermal impedance than the edge of base plate value for $R_{th}$. 
Key Points 2

- There are different methods to calculate power losses.
- One method uses a basic/general formula to estimate total loss.
- The sinusoidal loss calculation provides a more realistic value for total inverter loss.
- Both are intended for comparison purposes only.
- Actual loss values are dependant on the specific application.
- $\Delta T_j$ is found by multiplying losses and $R_{th}$.
- The change in junction temperature helps in determining which device runs cooler.
- Of course the lower the $\Delta T_j$ the more reliable the system or the less heat sinking is required.

Power Loss Calculation !!
$\Delta T_j$ Calculation !!
Loss and Allowable Tc - Example

Device: FSBS10CH60

\(V_{dc} = 300\text{V}, V_{cc} = V_{bs} = 15\text{V}, F_{sw} = 15\text{kHz},\)

Output Current Frequency \(\geq 60\text{Hz}, R_{th(j-c)} = \text{max},\)

3-phase Sine-PWM, Power Factor = 0.95, Modulation Index = 0.8

\(V_{CE(sat)} = \text{Typical}, \text{Switching loss} = \text{Typical}, T_{j} = 125^\circ\text{C}\)
Structure

SPM = Power device + Driver IC + Package → Performance & Protection & Reliability

Power device = IGBT with FRD (or MOSFET)
Driver IC = HVIC & LVIC
Package = Transfer Molding with Ceramic or DBC
Target:
Low conduction/switching loss
Long short-circuit withstand time
Low switching noise

IGBT Trade-offs:
Low conduction loss ↔ low OFF-switching loss
Low conduction loss ↔ long short-circuit withstand time

System Design Trade-offs
Low switching noise ↔ low ON-switching loss
A: For low switching frequency applications
e.g., Air conditioner ($f_{sw} = 5\text{KHz}$)

B: For high switching frequency applications
  e.g., Washing machine ($f_{sw} = 15\text{KHz}$)

C: For all applications
IGBT $V_{ce(sat)}$ (on-drop voltage) : Trade-off with $T_f$

From right to left, $V_{cc}=13V, 15V, 20V$

**ON**

$V_{cesat} = 2.2V@15A$

$V_{cesat} = 2.0V@15A$

$V_{cesat} = 1.8V@15A$

**OFF**

$T=25[\deg]$

From right to left, $V_{cc}=13V, 15V, 20V$

$T=125[\deg]$

From right to left, $V_{cc}=13V, 15V, 20V$
IGBT Short-circuit Endurance

- Worst case: High Vcc (High Ic), High Vdc

* Test conditions: Worst, Vcc=20V, Tc=125°C
- Fast Recovery Diode
- Small $I_{rr}$ and $T_{rr}$ and soft recovery (tb/ta) $\rightarrow$ Low loss and good $dv/dt$
- Trade-off between $V_f$ and $T_{rr}$
Switching Parameters

1. Current Measuring using shunt resistor
   → Key time : ON command to current build-up

2. Voltage Generation for sensorless control
   → Key time : ON command to 50% voltage transient
   → Key time : OFF command to 50% voltage transient
PWM Considerations

Overmodulation  Loss & Heat

Current distortion  Audible Noise

EMI

Confidential
Low cost & simple to detect over-current
Idc = 0 in zero-vector period
Phase-current detection in effective-vector period
→ complex
→ impossible when voltage gets small esp. at high Fsw

Chap. 3
Design Considerations of SPM
Current Measurement

Phase-current = voltage drop on resistor when low-side IGBT is turn-on

Complex to detect over-current
Loss Calculation

- SPM Loses = Conduction + Switching + Leakage (negligible)
- Conduction Loss = almost same for all kinds of PWM methods
- Switching Loss = 66% in case of discontinuous PWM
- Leakage Loss = negligible

- by Linear Approximation,

\[
\nu_T = V_T + R_T \times i [V]
\]
\[
\nu_D = V_D + R_D \times i [V]
\]

*IGBT On loss energy* = \( E_{T,ON} \times i [J] \)

*IGBT Off loss energy* = \( E_{T,OFF} \times i [J] \)

*diode On loss energy* = \( E_{D,ON} \times i [J] \)

*diode Off loss energy* = \( E_{D,OFF} \times i [J] \)
Loss Calculation

\[ V_{dc} \]

\[ i_{as} \quad i_{bs} \quad i_{cs} \]

\[ I_{\text{max}} \]

\[ M I = \frac{V_{\text{as, peak}}}{V_{dc} / 2} \]

\[ E_{T,\text{OFF}} \quad E_{T,\text{ON}} \]

\[ E_{D,\text{OFF}} \quad E_{D,\text{ON}} \]

\[ \int v \cdot i \]

\[ E_{\text{ON}} \quad E_{\text{OFF}} \]
losses[W] in one IGBT and one diode are as below in case of continuous PWMs. Total SPM losses are six fold.

\[ P_{\text{con.T}} = \frac{I_{\text{max}}}{2\pi} V_T + \frac{I_{\text{max}}}{8} V_T M I \cos \phi + \frac{I_{\text{max}}}{8} R_T + \frac{I_{\text{max}}}{3\pi} R_T M I \cos \phi \]

\[ P_{\text{con.D}} = \frac{I_{\text{max}}}{2\pi} V_D - \frac{I_{\text{max}}}{8} V_D M I \cos \phi + \frac{I_{\text{max}}}{8} R_D - \frac{I_{\text{max}}}{3\pi} R_D M I \cos \phi \]

\[ P_{\text{sw.T}} = \frac{(E_{\text{T.ON}} + E_{\text{T.OFF}}) f_{\text{sw}} I_{\text{max}}}{\pi} \]

\[ P_{\text{sw.D}} = \frac{(E_{\text{D.ON}} + E_{\text{D.OFF}}) f_{\text{sw}} I_{\text{max}}}{\pi} \]
Tj Calculation

- Thermal Equivalent Circuit
  - Tj : Junction temperature. Can’t be over guaranteed value.
  - $R_{\thetajc}$ : Thermal resistance (junction to case) [deg/W]
  - $Z_{\thetajc}$ : Thermal impedance (junction to case) [deg/W]

\[
R_{\thetajc} = \frac{T_j - T_c}{P_D}
\]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{\theta hj-c}$</td>
<td>Junction to Case Thermal Resistance</td>
<td>Inverter IGBT part (per 1/6 module)</td>
<td>-</td>
<td>-</td>
<td>1.63</td>
<td>°C/W</td>
</tr>
<tr>
<td>$R_{\theta hj-c}$</td>
<td></td>
<td>Inverter FWD part (per 1/6 module)</td>
<td>-</td>
<td>-</td>
<td>2.55</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

Note:
2. For the measurement point of case temperature ($T_c$), please refer to Figure 2.
Tj Calculation

- **Tj Calculation with Rθjc**
  - \( T_c = \text{measured value} \), \( R_{θjc} = \text{max value from datasheet} \), \( P_d = \text{calculated value} \)
  - \( T_j = T_c + R_{θjc} \cdot P_D \)

Ex) \( T_c = 100^°\text{C} \) when \( P_d = 10\text{W} \) is consumed with \( R_{θjc} = 1\text{deg/W} \),

\[
T_j = T_c + R_{θjc} \cdot P_D = 110^°\text{C}
\]

←Average junction temperature using average \( P_d \) and steady-state thermal impedance
**Tj Calculation**

R₀jc is steady-state value of Z₀jc

\[
T_j - T_c @ t = P_1 \times Z_{jc}(t) - P_2 \times Z_{jc}(t-t_1)
\]

\[Z_{jc} \text{ is steady-state value of } Z_{jc}\]
Tj Calculation

- Tj Calculation with Zθjc
- Using actual Pd and Zθjc

Output frequency = 60Hz

Output frequency = 1 Hz
Life-time Calculation

Power Cycle Test
power device is heated and cooled repeatedly by external current injection under specific temperature and time. The change in $\Delta T_{ca}$ should be less than 10deg (water cooling is used). Test variable is $\Delta T_{jc}$ and the number of cycles.

Fig.1. Basic circuit for power cycle test. Fig.2. Pulse duty of current for power cycle test

Fig.3. Example plot of power cycle test

Chap. 3 Design Considerations of SPM
Main Failure Mechanism

= Difference in thermal expansion coeff. between two adjacent materials

Bonding Worn out

Solder Crack
Step-1: Divide period so that $I_{\text{max}}$ is same from typical load pattern

Washing machine

Step-2: Calculate $\Delta T_{jc}$

$T_{c}$ is measured value and assumed to be constant

$\Delta T_{jc} = P_1 \times Z_{0jc}(t_1 + t_2 + \ldots t_7) - P_1 \times Z_{0jc}(t_2 + t_3 + \ldots t_7) + P_2 \times Z_{0jc}(t_2 + t_3 + \ldots t_7) - P_2 \times Z_{0jc}(t_3 + t_4 + \ldots t_7) \ldots + P_7 \times Z_{0jc}(t_7)$

$P_n$ from loss calculation

$Z_{0jc}$ from thermal impedance

<table>
<thead>
<tr>
<th>n</th>
<th>$I_{\text{max}}$</th>
<th>$P_n$</th>
<th>$t_n$</th>
<th>$t_{n+\ldots+t7}$</th>
<th>$Z_{0jc}(t_{n+\ldots+t7})$</th>
<th>$\Delta T_{jc}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.9</td>
<td>2.2</td>
<td>1.71</td>
<td>5.87</td>
<td>2.66</td>
<td>0.2</td>
</tr>
<tr>
<td>2</td>
<td>7.8</td>
<td>9.6</td>
<td>1.46</td>
<td>4.16</td>
<td>2.57</td>
<td>1.4</td>
</tr>
<tr>
<td>3</td>
<td>9.1</td>
<td>11.3</td>
<td>1.04</td>
<td>2.7</td>
<td>2.42</td>
<td>1.6</td>
</tr>
<tr>
<td>4</td>
<td>11.2</td>
<td>14.0</td>
<td>0.68</td>
<td>1.66</td>
<td>2.28</td>
<td>2.0</td>
</tr>
<tr>
<td>5</td>
<td>14.1</td>
<td>18.9</td>
<td>0.53</td>
<td>0.98</td>
<td>2.14</td>
<td>2.7</td>
</tr>
<tr>
<td>6</td>
<td>9.8</td>
<td>13.1</td>
<td>0.3</td>
<td>0.45</td>
<td>2.00</td>
<td>4.5</td>
</tr>
<tr>
<td>7</td>
<td>5.9</td>
<td>6.8</td>
<td>0.15</td>
<td>0.15</td>
<td>1.65</td>
<td>11.2</td>
</tr>
</tbody>
</table>

$\Delta T_{jc} = 23.5$
Step-3 : Calculate Life-time
From power-cycle graph provided by maker

\[
10 \cdot M_{cyc} \cdot \frac{1 \text{ opr}}{500 \text{ cyc}} \cdot \frac{1 \text{ day}}{1.5 \text{ opr}} \cdot \frac{1 \text{ year}}{365 \text{ day}} = 36.5 \text{ year}
\]
## Input Interface

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Active HIGH</th>
<th>Active LOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply</td>
<td>Fail safe sequence</td>
<td>Power on/off sequence must be:</td>
</tr>
<tr>
<td>Turn-on/off Sequence</td>
<td></td>
<td>ON : CPU 5V → SPM 15V → Power 300V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OFF : Reverse Order</td>
</tr>
<tr>
<td>5V/ 3.3V Compatibility &amp;</td>
<td>Internal R pull-down = 3.3 ~ 5 KΩ</td>
<td>Internal V pull-up = 15V or 6.2V</td>
</tr>
<tr>
<td>Simple Interface Circuit</td>
<td></td>
<td>Internal R pull-up = 150KΩ or 50KΩ</td>
</tr>
<tr>
<td>&amp; Low noise acceptability</td>
<td></td>
<td>Needs another pull-up resistor to limit the MCU output.</td>
</tr>
<tr>
<td>Photo-coupler Interface</td>
<td>Needs Inverter</td>
<td></td>
</tr>
<tr>
<td>Interface Circuitry</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><img src="https://via.placeholder.com/150" alt="Diagram" /></td>
<td></td>
</tr>
<tr>
<td></td>
<td><img src="https://via.placeholder.com/150" alt="Diagram" /></td>
<td></td>
</tr>
</tbody>
</table>

- **Active HIGH**: No need for external pull-down resistor due to built-in one.
- **Active LOW**: Low Noise Acceptability with 3.3KOhm internal pull-down resistor.

---

### 5V/3.3V Compatibility & Simple Interface Circuit
- **Active HIGH**: Internal R pull-down = 3.3 ~ 5 KΩ
- **Active LOW**: Internal V pull-up = 15V or 6.2V

### Power Supply Turn-on/off Sequence
- **FAIL SAFE**: ON: CPU 5V → SPM 15V → Power 300V
- **FAIL SAFE**: OFF: Reverse Order

### Interface Circuitry
- **CPU**: ![Input Interface Circuit](https://via.placeholder.com/150)
- **SPM**: ![Input Interface Circuit](https://via.placeholder.com/150)

---

### Chap. 3
**Design Considerations of SPM**
## Maximum Ratings

### Tj=25°C

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>( V_{PN} )</td>
<td>450V</td>
<td>The maximum steady-state (non-switching mode) voltage between P-N. A brake circuit is necessary if P-N voltage exceeds this value.</td>
</tr>
<tr>
<td>Supply Voltage (surge)</td>
<td>( V_{PN(surge)} )</td>
<td>500V</td>
<td>The maximum surge voltage (non-switching mode) between P-N. A snubber circuit is necessary if P-N surge voltage exceeds this value.</td>
</tr>
<tr>
<td>Collector-emitter voltage</td>
<td>( V_{CES} )</td>
<td>600V</td>
<td>The sustained collector-emitter voltage of built-in IGBTs.</td>
</tr>
<tr>
<td>Each IGBT Collector current</td>
<td>( \pm I_{C} )</td>
<td>10A</td>
<td>The maximum allowable DC continuous IGBT collector current at Tc=25°C.</td>
</tr>
<tr>
<td>Junction Temperature</td>
<td>( T_{J} )</td>
<td>-20 ~ 125°C</td>
<td>The maximum junction temperature rating of the power chips integrated within SPM is 150°C. However, to insure safe operation, the average junction temperature should be limited to 125°C. Although IGBT and FRD chips will not fail immediately at TJ = 150°C, they may be degraded by repetitive operation at this temperature.</td>
</tr>
<tr>
<td>Self Protection Supply Voltage Limit (Short Circuit Protection Capability)</td>
<td>( V_{PN PROT} )</td>
<td>400V</td>
<td>Under the conditions of Vcc=13.5V ~ 16.5V, non-repetitive, less than 2( \mu )s. The maximum supply voltage for safe IGBT turn off under SC “Short Circuit” or OC “Over Current” condition. The power chip may be damaged if supply voltage exceeds this specification.</td>
</tr>
</tbody>
</table>
### Bias Voltage

<table>
<thead>
<tr>
<th>Control Voltage Range [V]</th>
<th>SPM Function Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ~ 4</td>
<td>Control IC does not operate. Under voltage lockout and fault output do not operate. dV/dt noise on the main P-N supply might trigger the IGBTs.</td>
</tr>
<tr>
<td>4 ~ 12.5</td>
<td>Control IC starts to operate. As the under voltage lockout is set, control input signals are blocked and a fault signal Fo is generated.</td>
</tr>
<tr>
<td>12.5 ~ 13.5</td>
<td>Under voltage lockout is reset. IGBTs will be operated in accordance with the control gate input. Driving voltage is below the recommended range so $V_{CE(sat)}$ and the switching loss will be larger than those under normal condition.</td>
</tr>
<tr>
<td>13.5 ~ 16.5</td>
<td>Normal operation. This is the recommended operating condition.</td>
</tr>
<tr>
<td>16.5 ~ 20</td>
<td>IGBTs are still operated. Because driving voltage is above the recommended range, IGBTs’ switching is faster. It causes increasing system noise. And peak short circuit current might be too large for proper operation of the short circuit protection.</td>
</tr>
<tr>
<td>Over 20</td>
<td>Control circuit in the SPM may be damaged.</td>
</tr>
</tbody>
</table>
Protection : UVLO

Input Signal

Protection Circuit State

Control Supply Voltage

Output Current

Fault Output Signal

UV_{CCR}

UV_{CCD}

Restart

Filtering?

10us filtering

Industrial : \(1/f_{sw} \sim 2/f_{sw}\)
Home appliances : \(\sim 2\text{ms}\)

Needs low-to-high input transition to turn on IGBT again

How Long?
Protection : SC

- Lower arms control input
- Protection circuit state
  - SET
  - RESET
  - Soft turn-off for small voltage spike
- External filter needed with 1~2us time constant
- Output Current
- Sensing Voltage (of the shunt resistance)
- Fault Output Signal
  - How Long?
  - External filter delay + IC delay + IGBT off delay = over 2 μsec
  - IC filtering < 500nsec

Chap. 3
Design Considerations of SPM
HVIC : General Structure

-Function :
IN signal can be transferred to HO

-Merit :
Short propagation delay (short deadtime)
Long lifetime & Low cost

-Demerit :
No signal transfer when VS is negative
Poor noise immunity due to edge-trigger and F/F structure
C_BS : Close to the pins as possible. At least one low ESR capacitor should be used to provide good local de-coupling.

D_BS : Withstand voltage more than 600V. Fast recovery (recovery time < 100ns) device to minimize the reverse charge.

R_BS : Slow down the dV_BS/dt. Determines the time to charge the bootstrap capacitor.
HVIC : Latch-off

- Turned off shortly after turning on

![Diagram showing a Short Pulse Generator with various voltage levels and waveforms, including V_B, V_HO, V_GR, V_BR, V_DS, V_GS, V_BS, and V_HO waveforms with a high dV/dt signal.](image)
Turned on when freewheeling current occurs in the off state
HVIC : Latch-on

- Turned on shortly after turning off

Design Considerations of SPM

Chap. 3
No response to input (note: -Vs level in datasheet)
HVIC : Latch-off

- input off-signal is very narrow
  (Minimum off-pulse width > 1us recommended)
HVIC : dv/dt immunity test

Test Result: dv/dt test (FCS’s HVIC)

Zoomed Image

Yellow curve (V8 pin voltage) shows steep slope of \(-68.8V/ns\).

For the dv/dt noise from -1V/ns to above -50V/ns, FSC’s HVIC shows no malfunction.

Test Result: dv/dt test (Competitor’s HVIC)

For \(-dv/dt=58.14V/ns\)

Malfunction: Output state is changed.
Chap. 3
Design Considerations of SPM
HVIC : Extended -Vs operation

(1) Allowable VS < -V: HIN command is processed.
(2) Allowable VS > -V: HIN command is missed.

VCC=VBS COM=0V Ta=28°C

Design Considerations of SPM

www.fairchildsemi.com
HVIC: Temperature Independency

**Turn-on delay**

- $t_{on}$: Turn-on Delay Time
- $t_{off}$: Turn-off Delay Time
- $t_{rise}$: Turn-on Rise Time
- $t_{fall}$: Turn-off Fall Time

**UVLO Level**

- FCS High-Side Driver
- Competitor’s HVIC
- VCCUV+
- VCCUV-
- VCCUV

---

Chap. 3
Design Considerations of SPM
Chapter 4. SPM Values
Factors driving the need for SPM

1. Energy saving initiatives
   - forcing the adoption of newer and complex power drive stages.
   - forcing household appliance manufacturers to adopt energy saving motor solutions, requiring more complex electronic drive solutions.

2. Different types of appliances use different power drive solutions
   - different devices can be successfully integrated into one SPM to satisfy these diverse needs.

3. The increased rate of technological advances in the consumer appliance industry
   - forcing a strong reduction of time to market on companies.
   - designers of these controls face enormous pressure to provide cost-effective solutions in the shortest possible time.
Integration of analog, discrete and package technology

Integration of discrete components

- IGBTs/FRFETs
- HVICs
- LVIC

A protection circuit using analog components causes time delays and noise

Design Considerations

- Needs optimization for switching and short-circuit dynamics using external components
- SPM optimizes driving characteristics for built-in power devices

Assembling these parts may increase manufacturing time and cause low yields.

Manufacturing Impact

SPM, which integrates all diverse components, enhances productivity while simplifying manufacturing

SPM Values

- reduced total system cost
- reduced development time
- easy management
- optimized control flexibility
- higher reliability

Chap. 4

SPM Values
### SPM Effect

Using SPM is in line with modern application trends (smaller, more efficient, better performance) and offers added benefits such as increased reliability and improved time to market.

<table>
<thead>
<tr>
<th>Impact of using SPM on…</th>
<th>BOM cost</th>
<th>System cost</th>
<th>Time to market</th>
<th>0h failures</th>
<th>Failures in time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced number of components</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>High performance</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Increased reliability</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Less board space or application volume</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Easier and faster design</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Reproducible performance</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

**Chap. 4 SPM Values**

www.fairchildsemi.com
Reduced number of components

- Biggest impact is in saving mounting cost
  - Production time saved for hand-assembly / heatsink to 1 component instead of 6 heatsinks
- Reduced logistics and purchasing efforts
- Fairchild Semiconductor is a proven, high-volume power semi supplier with excellent quality
High performance

- Performance criteria are:
  - Power density – how large is the system for a given output power?
  - EMI behaviour – shielding / filtering efforts?
  - Thermals – how complicated / expensive is cooling the system?
- With Fairchild SPM, power density can be the highest
- Power switches and drivers are precisely matched, improving EMI
- Switching speed can be changed externally, improving EMI – no flexibility lost over discrete solution
- The Thermal resistance from devices to case and case to heatsink is very low
- DIP package allows easy mounting in standard production lines

Direct bond to copper („DBC“)
Increased reliability

- All devices in a module are tested together at the end of production
  - Fairchild performs reliability and quality engineering on the modules
  - For discrete solutions, the customer needs to perform QA eng.
- Protection functions are close to the power devices
  - Built-in and tested, no external components
- Lower thermal resistance results in lower temperature change over a load cycle, increasing reliability
- Standardized high-power wiring is optimized
  - Less parasitic components
  - Better control of peak voltages
Less board space or application volume

- Smaller system size has many advantages
  - System is less expensive (PCB space, system volume, mounting efforts)
  - New options for system design (e.g. adding the inverter to the panel controller)
- Motion-SPM in mini-DIP package: 44mm x 27mm
- Height 7mm vs 19mm for TO220
  - However, heatsink to be considered
- Discrete solution is considerably larger
  - Must respect minimum distances between components

Ultra-compact, low height complete control board with Motion-SPM in SMP3, auxiliary supply with FPS, and microcontroller
Easier and faster design

- Time to market is a significant success factor
  - Bringing innovation to end market yields higher margins – the earlier, the better
  - Shortening the design time improves time to market significantly
  - Consider manufacturing / ramp-up impact – reduced number of issues using modules
- High-power wiring can be standardized
  - Added flexibility – for different output power: (One SPM package size covers 3A to 30A designs)
  - Standardized PCB layout will comply with layout rules
  - Remove interaction between devices in a discrete solution

Excerpt from Motion-SPM product portfolio in SMP3 package – Adapt application easily across wide power range

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Rating</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic</td>
<td>3A/600V</td>
<td>FSBS3CH60</td>
</tr>
<tr>
<td>Ceramic</td>
<td>5A/600V</td>
<td>FSBS5CH60</td>
</tr>
<tr>
<td>Ceramic</td>
<td>10A/600V</td>
<td>FSBS10CH60</td>
</tr>
<tr>
<td>Ceramic</td>
<td>15A/600V</td>
<td>FSBS15CH60</td>
</tr>
<tr>
<td>DBC</td>
<td>15A/600V</td>
<td>FSBB15CH60</td>
</tr>
<tr>
<td>DBC</td>
<td>20A/600V</td>
<td>FSBB20CH60</td>
</tr>
<tr>
<td>DBC</td>
<td>30A/600V</td>
<td>FSBB30CH60</td>
</tr>
</tbody>
</table>
Reproducible performance

• Performance variations are much more under control, accomplished within the module, 100% tested
  • Gate drivers are fine tuned to switches
  • Large impact on efficiency, EMI and safe operation
• Reduce the amount of effort elsewhere in the system to compensate (potentially cumulative) device variations
  • Larger bus capacitors, stronger input rectifiers, snubber circuits – less effort required
• Overall, system cost can be reduced through less variation of system performance
More than the sum of their parts

- SPMs are rich in features and customer benefits
- The value is uniquely defined by the customer’s design, manufacturing and business needs

Simplified Design:
- Fewer components to choose and lay out
- Highest power efficiency
- Lowest radiated and conducted EMI
- Rapid time-to-market

Streamlined Mfg:
- Reduced board space
- Lower number of inserts and solder joints
- Reduced test and visual inspection time

Higher Value Solution:
- Leading edge technology
- Optimized system performance
- Quick design cycles
- Highest quality and reliability

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Why Customers Choose SPM Inverters  
- by Application

- Many new designs now in production or qualification
- Broad spectrum of customers and applications
- Each design takes advantage of a unique combination of SPM configuration and associated features/benefits

<table>
<thead>
<tr>
<th>Advantage</th>
<th>End Product</th>
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<tbody>
<tr>
<td></td>
<td>Air Conditioner</td>
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<tr>
<td>Small Size</td>
<td></td>
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<tr>
<td>Higher Efficiency</td>
<td>P</td>
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<tr>
<td>Reduced Noise</td>
<td>s</td>
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<tr>
<td>Lower Mfg Cost</td>
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<tr>
<td>Higher Mfg Yield</td>
<td>P</td>
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<tr>
<td>Fewer Field Failures</td>
<td>P</td>
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</tbody>
</table>

P = Primary Choice Criteria  
s = Secondary
Summary of SPM Benefits

- **Design and Development**
  - Save space
  - Compact design
  - Easier to meet efficiency & EMI regulations
  - Save development time
  - Reduce time to the market

- **Manufacturing: single component instead of several**
  - Easier procurement
  - Lower assembly cost (single placement, no special steps)
  - Higher yield (pre-tested, fewer connections)

- **The right technology for the future**
  - Cutting edge technology
  - Higher efficiency
  - High quality and reliability
To satisfy More Needs of Customers

Finding

a New Smart Power Module Solution

Welcome Customized Module

with Open Arms