SMART POWER MODULES
for Low-Power Variable Speed Motor Drive Applications

June, 2002

Application Engineering Group
Fairchild Semiconductor

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SPM Markets

**SPM Products**

**SPM Series**

**SPIM Series**

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**Consumer**

- Air-conditioner
- Washing Machine
- Refrigerator
- Kitchen Fan

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**Industrial**

- Commercial inverter.
- Fan motor control
- Auto door control
- AC servo, DC servo
- Sewing machine
- Wire bonding machine
Why do we need Smart Power Modules?

⟹ The use of inverters in low-power motor drive, in particular, home appliances applications has been increasing due to high efficiency, high performance and so on.

⟹ SPMs are becoming more and more obvious choice for inverter makers because of their many attractive advantages:
  - Compact system design
  - Protective functions
  - Less parts counts
  - High reliability
  - Good noise Immunity

⟹ Fairchild-SPMs have achieved optimum cost-performance ratios using the following distinctive technology:
  - Multi-chip assembly on common lead-frame
  - Ceramic-based isolation packaging
SPMs give the following benefits

- **Reduced system design time:**
  SPM frees customers from the job of power circuit design.
  This allows them to launch new products faster.

- **Reduced manufacturing time:**
  All the necessary “Power” parts are inside the SPM. Customers need not worry about “Power” part assemblies. Enhanced productivity in comparison to a discrete IGBT solution.

- **High-yields in manufacturing:**
  Simplified manufacturing as all the diverse components are combined in the SPM.

- **Less components to order & stock:**
  You can order and stock the SPM as just one device. Minimized inventory levels and costs.

- **More compact system:**
  The compact and thin outline of the SPM enables the design of smaller appliances.
  In addition to a smaller size it also results in cost reduction.

- **Reduced field failure ratio:**
  The internal protection circuit of the SPM prevents failures in the IGBT-chips.
  This is effective in minimizing the failure of the “Power” part in the field.
Integrated Function of SPM

- **For inverter high-side IGBTs:**
  - Gate driving circuit
  - High voltage isolated high-speed level shifting
  - Control supply under-voltage (UV) protection

- **For inverter low-side IGBTs:**
  - Gate driving circuit
  - Short-circuit protection with soft shut-down control
  - Control supply under-voltage (UV) protection

- **Temperature monitoring:**
  - Over-temperature monitoring using built-in thermistor

- **Fault signaling:**
  - Corresponding to a SC fault (low-side IGBTs) or a UV fault (low-side supply)

- **Input interface:**
  - 5V/3.3V CMOS/LSTTL compatible, Schmitt trigger input
Trend of SPM Technology

Discrete or Conventional Module Solution

AC Source 100–264V
Diode Rectifier or PFC Unit
DC – Link Capacitors
IGBT Modules
Sen sin g Unit
Gate Drivers
Isolation Unit
Isolation Unit
CPU

Variable Voltage & Variable Frequency
Isolated Multi Power Supply for Gate Driving
Power Supply for Control

High Performance ac Drive System

Constant Voltage & Constant Frequency

AC Motors

Trend of SPM Technology

Fairchild Semiconductor – Smart Power Module
Trend of SPM Technology

Conventional IPM Solution

- **Diode Rectifier or PFC Unit**
- **DC - Link Capacitors**
- **IGBTs**
- **Gate Drivers**
- **Sensing Unit**
- **Isolation Unit**
- **Power Supply for Control**
- **CPU**

**AC Source 100~264V**

**Variable Voltage & Variable Frequency**

**Constant Voltage & Constant Frequency**

**Higher Performance and Compact Design but Higher Cost**

**Isolated Multi Power Supply for Gate Driving**

**AC Motors**
Trend of SPM Technology

Transfer-Molded Type IPM Solution (From 1999/2000)

Constant Voltage & Constant Frequency

AC Source 100~264V

Diode Rectifier or PFC Unit

DC – Link Capacitors

Improved IGBTs

HVIC Gate Controller

LVIC Gate Controller

Sensing Unit

CPU

Common Single Power Supply

Variable Voltage & Variable Frequency

AC Motors

Higher Performance
Compact Design
Lower Cost
Fairchild-SPM Series

SPM : Smart Power Module
SPIM : Smart Power Integrated Module

- Fairchild-SPM Series
  - TIP-SPM : Triple in-line package type of SPM.
  - DIP-SPM : Dual in-line package type of SPM.
  - Mini-DIP-SPM : Mini-DIP type of SPM.
  - Tiny-DIP-SPM : Tiny-DIP type of SPM.

Diagram:
- AC Source (100-264V)
- Diode Rectifier
- PFC or DB Unit
- High Performance IGBTs
- LVIC Gate Controller
- Sense - IGBTs
- Sensing Unit
- HVIC Gate Controller
- CPU
- Common Power Supply
- Variable Voltage & Variable Frequency
- AC Motors
- Constant Voltage & Constant Frequency

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SPMs and SPIM Development Status and Plan

- 3-phase IGBT Inverter
- Built-in rectifying diodes and dynamic braking or PFC circuit
- Gate driving and protection with built-in HVIC

Smart Power Modules

SPIM

600V-50A / 1200V-25A

- Development will be finished by August, 02 up to 600V-30A
- Another PKG will be used for 600V-50A and 1200V rated products

600V-50A

- Doing Mass-Production up to 600V-30A
- 50A rated product will be developed at the same PKG by July of 02

600V-30A

- Doing Mass-Production up to 600V-20A
- The 30A-product will be finished by July of 02

600V-10A

- 10A ER sample : July of 02

600V-3A

- 3A ER sample : August of 02

Tiny-Dip

SPM

Mini-Dip

Dip

Tip

Fairchild Semiconductor – Smart Power Module
## Fairchild Smart Solutions

<table>
<thead>
<tr>
<th>Smart solutions</th>
<th>Applicable motor ratings (KW)</th>
<th>Major Application</th>
<th>Common features</th>
<th>Additional features</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIP-SPM</td>
<td>0.4 - 3.7</td>
<td>Air-conditioner Washing machine.</td>
<td>- Low-loss efficient IGBTs FRDs. - Over temperature monitoring. - Short circuit protection.</td>
<td></td>
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<tr>
<td>DIP-SPM</td>
<td>0.4 - 2.2</td>
<td>Air-conditioner Washing machine.</td>
<td>- 3 Phase IGBT inverter bridge including control IC for gate driving and protection. - Low leakage current and high isolation voltage due to ceramic-based substrate.</td>
<td>- Compact solution. (Reduce board space) - Sensorless available (Remove hall sensor)</td>
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<tr>
<td>Mini-DIP-SPM</td>
<td>0.15 - 0.4</td>
<td>Kitchen Fan motor, Refrigerator Washing Machine (BLDC)</td>
<td>- Single-ground power supply due to built-in HVIC.</td>
<td></td>
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<tr>
<td>Tiny-DIP-SPM</td>
<td>- 0.15</td>
<td>Brushless BLDC Fan motor</td>
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<tr>
<td>SPIM</td>
<td>0.4 - 2.2</td>
<td>Industrial - DC serve motor - Sewing machine - Elevator.</td>
<td></td>
<td>- DBC substrate structure - Including bridge diode - Current sensing - Sensorless available - Over temperature monitoring. - Short circuit protection</td>
</tr>
</tbody>
</table>

**Additional features**

- Current protection.
- Sensorless available.
- Over temperature monitoring.
- Short circuit protection.
- Compact solution. (Reduce board space)
- Sensorless available (Remove hall sensor)
## SPM Line-up Status & Plan by Application

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Current rating</th>
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<tbody>
<tr>
<td>H</td>
<td>1A 2A 3A 5A 10A 15A 20A 30A 50A</td>
</tr>
<tr>
<td>M</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td></td>
</tr>
</tbody>
</table>

### Major Application
- **Fan motor**: X
- **Refrigerator**: X X
- **W/M**: X
- **A/C**: X X
- **Industrial**: X

- **X** indicates In development
- **Mass Production** indicates Mass Production

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Introduction to SPIM

- Development will be finished by August 02 up to 600V-30A
- Another PKG will be used for 600V-50A and 1200V rated products

• DBC (Direct Bonding Copper) Substrate Structure
• Gate Driving Circuit using HVIC for the Use of Single-power Supply
• Built-in Thermistor for internal Temperature Detection
• Short-circuit Protection using Low-side Sense-IGBTs
• Optional Single-phase Application
• Small Size of Packaging using Multi-layer Technology
• Three N-terminals for Current Control Application
Introduction to Tip-SPM & Dip-SPM

- Ceramic-based Transfer-Molded-Type Packaging
- Gate Driving Circuit using HVIC for the Use of Single-power Supply
- Optional Built-in Thermistor
- Short-circuit Protection using Low-side Sense-IGBTs
- Very Low Thermal Resistance (TIP-SPM: <1.7 at 30A Rating)
- Three N-terminals for Current Control Application (DIP-SPM)

- Doing Mass-Production up to 600V-30A
- The 30A-rated product will be finished by July of 02

- Doing Mass-Production up to 600V-20A
- The 20A-rated product will be finished by July of 02

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Fairchild Semiconductor – Smart Power Module
Introduction to Mini & Tiny-Dip-SPM

- Ceramic-based Transfer-Molded-Type Packaging
- Gate Driving Circuit using HVIC for the Use of Single-power Supply
- Short-circuit Protection using Link Shunt-resistor
- Available for TPIM (Transfer-molded-type power integrated module) according to User requirement (Just Including Power Devices)
- Tiny-Dip-SPM is very suitable for Small Fan Drive Applications using Induction/BLDC Motors
- Three N-terminals for Current Control Application (Mini-Dip-SPM)

Mini-Dip - 600V-10A

- 10A ER sample: July of 02

Tiny-Dip - 600V-3A

- 3A ER sample: August of 02

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Structure and Internal Block-Diagram of Tip-SPM

Internal Block-diagram

Ceramic Base
System Connection Diagram for Tip-SPM

Typical Application Circuit Example
Structure and Internal Block-Diagram of Dip-SPM

![Internal Block-diagram](image)

- **IGBTFRD IC**: 3.0
- **N U**: 26
- **N V**: 27
- **N W**: 28
- **U**: 29
- **V**: 30
- **W**: 31
- **P**: 32
- **V S (W)**: 22
- **V B (W)**: 21
- **V S (V)**: 19
- **V B (V)**: 18
- **C SC**: 8
- **C FOD**: 7
- **V FO**: 6
- **IN (W L)**: 4
- **IN (VL)**: 3
- **IN (UL)**: 2
- **COM (L)**: 1
- **V CC (L)**: 1
- **V SC**: 10
- **R SC**: 6
- **R TH**: 25
- **V TH**: 24
- **IN (W H)**: 20
- **IN (WH)**: 15
- **COM (H)**: 16
- **V CC (WH)**: 17
- **V CC (UH)**: 12
- **IN (UH)**: 11
- **V S (U)**: 13
- **V B (U)**: 14

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System Connection Diagram for Dip-SPM

Inverter output current sensing application

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Comparisons – Dip-SPM

- 27% Smaller Size
- 20% Lower Thermal Resistance
- Optional built-in Thermistor
- Three N-terminals for current control applications
- Short-circuit protection using Sense-IGBTs

- Lower Thermal Resistance
- Reduced System Design Time
- Reduced Manufacturing Time
- High-yield in Manufacturing
- More Compact System
- Reduced Field Failure Ratio
- Fewer components to Order and Stock

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Comparisons – Mini-Dip-SPM

- 25% Smaller Size
- Much Lower Thermal Resistance
- Available for TPIM Structure
- Three N-terminals for current control applications

- Lower Thermal Resistance
- Reduced System Design Time
- Reduced Manufacturing Time
- High-yield in Manufacturing
- More Compact System
- Reduced Field Failure Ratio
- Fewer components to Order and Stock

up to 600V-10A

49x31

44x26
Short-circuit Protection Technology
Using the Sense-IGBT

- Low cost & small space solution
- Highly precise: ≤ 8% of sensing resolution
- Auto-reset function after the fault-out duration time

Linear Operation Region
Sensing Waveform
Protected Short-circuit Current

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Comparison of Operation power Rating
Dip-SPM vs. Discrete IGBT

Comparing to a discrete approach using TO220fullpack device, at the same Tc condition of 80 °C
- Can increase the motor current (power) by around 33%
- and at the same motor current (power) condition (7A of rms value)
- Can get the temperature margin by around 11 °C

Note: General datasheet for TO220F device is considered for the comparison.
SPM Frequency

- **Air-conditioner**
  - Low Frequency: L series
  - Low, Medium Frequency
  - Medium Frequency: M series
  - Frequency range: ≤ 4 Khz
  - 3,4 Khz
  - 3 – 9 Khz

- **Washing Machine**
  - High Frequency: H series
  - Frequency range: ≥ 8 Khz
## Tip-SPM Line-up

<table>
<thead>
<tr>
<th>Product</th>
<th>Motor Rating</th>
<th>Frequency [Khz]</th>
<th>Isolation Voltage</th>
<th>application</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPAL10SH60</td>
<td>0.4KW AC100 - 264V</td>
<td>≥8</td>
<td>W/M</td>
<td></td>
</tr>
<tr>
<td>FPBL10SH60</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>FPAL15SH60</td>
<td>0.75KW AC100 - 264V</td>
<td>≥8</td>
<td></td>
<td></td>
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<tr>
<td>FPBL15SH60</td>
<td></td>
<td>≥8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FPAL15SL60</td>
<td></td>
<td>≤4</td>
<td>W/M</td>
<td></td>
</tr>
<tr>
<td>FPAL15SM60</td>
<td></td>
<td>3 ~ 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FPBL15SL60</td>
<td></td>
<td>≤4</td>
<td></td>
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<tr>
<td>FPBL15SM60</td>
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<td>3 ~ 9</td>
<td></td>
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<td>FPAL20SL60</td>
<td>1.5KW AC100 - 264V</td>
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<td>FPAL20SM60</td>
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<tr>
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<td>≤4</td>
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<tr>
<td>FPBL30SL60</td>
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<td>≤4</td>
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## Dip-SPM Line-up

<table>
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<th>Product</th>
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<th>Frequency [Khz]</th>
<th>Isolation Voltage</th>
<th>application</th>
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<tr>
<td>FSAM10SH60</td>
<td>0.4KW</td>
<td>≥ 8</td>
<td>2500Vrms</td>
<td>W/M</td>
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<td>FSBM10SH60</td>
<td>AC100 - 264V</td>
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<tr>
<td>FSAM15SH60</td>
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<td>≥ 8</td>
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<td>FSBM15SH60</td>
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<td>FSAM15SL60</td>
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<tr>
<td>*FPBL30SL60</td>
<td>AC100 - 264V</td>
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* Under development
## Cross Reference

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<th>Motor Rating</th>
<th>Fairchild</th>
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<td>0.4 KW</td>
<td>FPAL10SH60</td>
<td>PM10CSJ060</td>
<td>PS21353-G</td>
<td>STK621-220</td>
<td>W/M</td>
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<td>FPBL10SH60</td>
<td>PM10CSJ060</td>
<td>PS21353-G</td>
<td>STK621-051</td>
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<tr>
<td>0.75 KW</td>
<td>FPAL15SH60</td>
<td>PS21254-E</td>
<td>PS21454-E</td>
<td>STK621-320</td>
<td>Aircon</td>
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<td>1.5 KW</td>
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IGBT Module for Motor drive

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