Introduction of Smart Power Module

for Low-Power Motor Drives Applications

Sep 2004

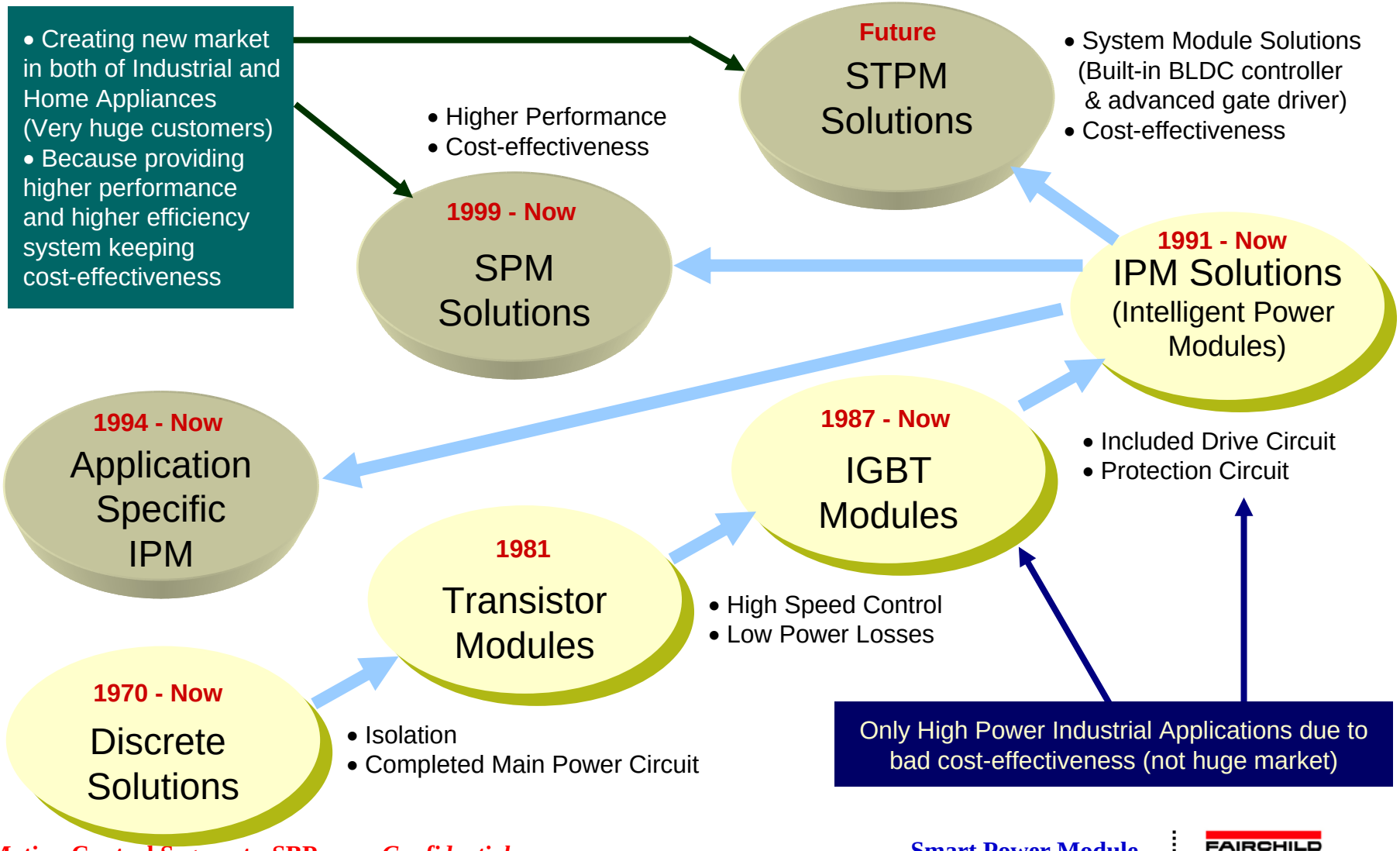
HP SPM & System Engineering Group
Fairchild Semiconductor

2. Motion Control Technology Trends

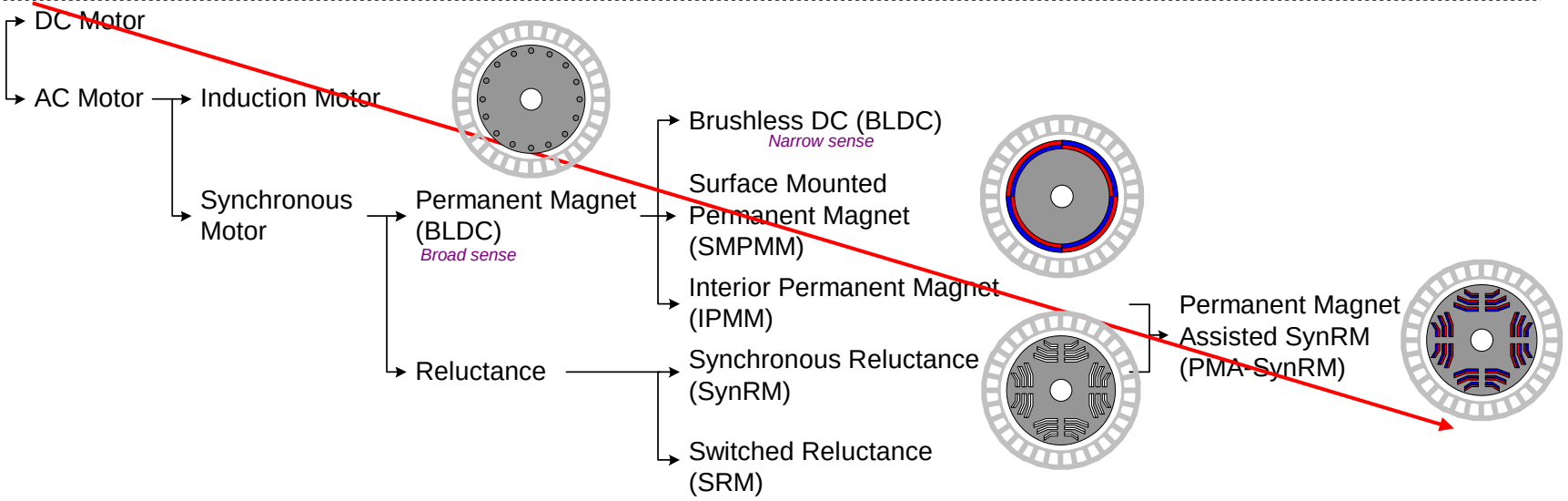
- Power Module technology Trend
- Motor technology Trend
- Technology Trend by Applications
- Motion Control Market Needs
  & Technology Challenges

History of Power Modules.. and NOW

In Half-bridge, Full-bridge and 3-phase Inverter Applications



Category & Trend of Motor Technology



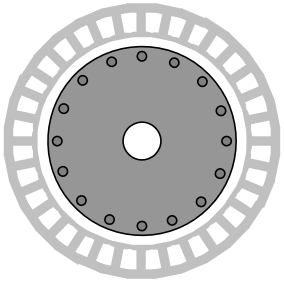
		Induction Motor	SynRM	SMPMM	PMA-SynRM
Motor	Efficiency*1	Low(89%)	Medium(91%)	High(94%)	Excellent(95%)
	Material Cost*1	Low(113%)	Low(100%)	High(150%)	High(142%)
	Mechanical	Excellent	Good	Poor	Medium
	Torque	Good	Good	Good	Excellent
	High-speed	Good	Good	Poor	Excellent
Drive	Complexity	Simple	Complex	Medium	Complex
	High-speed	Medium	Medium	Poor	Excellent
	Position-Sensorless	Easy	Complex	Medium	Complex

*1 : Data based on research result of Matsushita Electric Industrial Co.

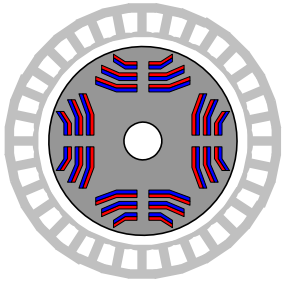
H. Murakami, “The Performance Comparison of SPMSM, IPMSM and SynRM in Use as Air-conditioning Compressor,” Conf. Rec. IEEE IAS, 1999.

Technology Trend of Air conditioner and Refrigerator
(Compressor Driving Unit)

- **Efficiency**
  - High speed operation
  - High efficiency of motor and inverter
  - Adoption of permanent magnet motor (BLDC)
  - Saving Energy by more 60% compared with conventional ON/OFF controller
- **Performance**
  - Adjustable speed drive using Sensorless Field Orientation Control
  - Vibration control due to compressor's salient structure
  - Calm and precise operation



1ϕ Induction Motor
(Conventional)

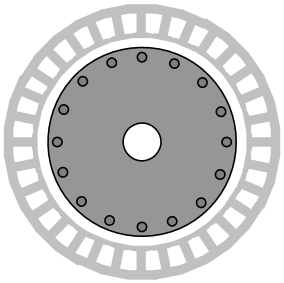


BLDC Motor (PMA-SynRM)
(Current inverter Trend)

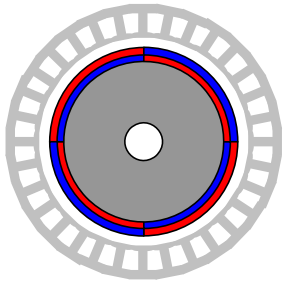
- **Engineering Challenge**
  - ***How to reduce the EMI***
  - ***How to reduce the leakage current***
  - ***How to reduce the acoustic noise***
  - ***How to increase the efficiency***

Technology Trend of Cloth Washer

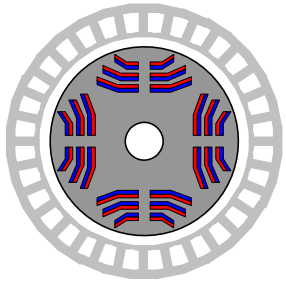
- **Efficiency**
  - Adoption of permanent magnet motor
- **Performance**
  - Wide speed operation
    - High torque @ Washing
    - High speed @ Drying
  - Sensorless Field Orientation Control
  - Silent operation



1ϕ Induction Motor with Clutch (Conventional)



BLDC-DD Motor (SMPMM) (Current inverter Trend)



BLDC-DD Motor (PMA-SynRM) (Future Trend)

- **Engineering Challenge**
  - ***Control considering large variation of the load (Control Performance)***
  - ***How to reduce the acoustic noise***
  - ***How to increase the efficiency***

Technology Trend of Fan Motor

1ϕ Induction Motor (Conventional)

BLDC Motor (SMPMM) (Current inverter Trend)

- **Efficiency**
  - Adoption of permanent magnet motor (BLDC)
  - Saving Energy by more 60% compared with conventional 1ϕ Induction motor
- **Performance**
  - Ease of control (Square-wave Control) due to simple & cost-effectiveness
  - Variable speed drive
  - Silent operation
- **Engineering Challenge**
  - *How to reduce the EMI*
  - *How to reduce the acoustic noise*
  - *How to increase the efficiency*

Motion Control Market Needs & Technology Challenges

Market Needs	Technology Challenges
Downsizing, Cost reduction	Device loss/size reduction • New device technology
Higher Efficiency (Energy Saving)	Higher switching frequency and lower dV/dt • Filter downsizing • Soft switching
Environmently-frienldy improvement • Low harmonics • Low acoustic noise • Low EMI	Elimination of electrolytic capacitors • Matrix converter
Higher Reliability	Advanced Package & Chip Technology • Flip-chip, Ribbon bonding • New packaging material

3. Competitor’s Status & Information

Competitors Status and Fairchild

MITSUBISHI

STATUS

- World champion (Now) and leading company
- Creating new building concept of end-system
- Long Development and Business experience of over 15 years
- DIP-IPM experience of over 7 years
- Acquisition of Toshiba Module / IPM Biz.
- Spin-off all discrete Biz. to form Renesas

➔ Focus & concentration on IPM/Module Biz.

TECHNOLOGY

Considered as the top-level in every fields

- IGBT, FRD and HVIC Technology for motor drives (5thGen. 1.2KV_Trench)
- PKG Technology
  - TMT PKG expands to high module (2-pack 300A/600V)
- System Technology
  - Inverter-driven motor driving
  - Product Concept and Design
- Mass Production
  - Testing technology
  - Much and Huge experience
- Fast change to new version of IPM concept
- Very big size and high technology market in Japan

MARKET

- Sales volume of DIP-IPM
  Now, 12M pcs/y
  '04 Sep, increase capa to 18M pcs/y
  (Upto 30M pcs/y 3years later)
- In Japan (Appliances)
  70% share in inverter use
- In Japan (Other applications)
  70% share
- In Korea
  70% share in inverter use
- In China
  Almost 100% share
- In Europe/US, Not much

Competing Devices

- Large DIP-IPM **(SPM2)**
- Mini DIP-IPM **(SPM3)**
- SIP-IPM **(SPM4)**
- Large-DIP PFCM **(SPM3-V)**

Competitors Status and Fairchild - Continued

IR

STATUS

- Newly started the Development and Biz.
- IR changes the IR's strategy to focus wafer business.
- Doing cooperative development and Biz. with Sanyo (but, not going well)
- Already released the System Module last year… but it seems to be just for technical point, not for Biz. One
- Establish IR-Sanyo joint Venture..but almost giving-up the module Biz.

TECHNOLOGY

- Looks excellent technology in Semiconductors: NPT-IGBTs, FRD and particularly, HVIC technology for motor drives
- She has no new idea of PKG
  → The big weak point
- So, Design concept strongly depends on the existing PKG
  → Sanyo is doing M/P (IMS)
- Releasing 6 types of PKG and 2 kinds of IPM

MARKET

- Now.. No result.. But doing very strong Promotions
- But, considered that it is very difficult to meet the market price due to the PKG problem and no value proposition

Competing Devices

- About IMDS Series
  SPM2,
  SPM3,
  SPM4

Competitors Status and Fairchild - Continued

SANYO

STATUS

- Started the business from 1999
- Now releasing new series of IPM
- She has her own PKG technology of IMST
- Recently, she is doing very close cooperating work with IR
- She does do much focusing on PDP module also

TECHNOLOGY

- Has the excellent IMS PKG technology
- But, there is no semiconductor technology (out-sourcing)
- So, The characteristics of the IPM are not so good due to old chips

MARKET

- Sanyo makes various customized modules for Audio, Video, PDP and Power AMP
- Almost only selling to Sanyo company such as Sanyo washing machines and Air-conditioners
- But, recently Sanyo Air-conditioners are using SPM2,and also she plan to use ver.2 of SPM3 for the next project

Competing Devices

(SPM2)
(SPM3)

Information of Mitsubishi-IPM

- Mitsubishi Electric To Boost Power Chip Output By 50% This Fall

TOKYO (Nikkei)--Mitsubishi Electric Corp. (6503) this fall intends to raise its monthly output of power semiconductors used in home appliances and hybrid cars by 50% to 1.5 million units, The Nihon Keizai Shimbun learned Monday.

The increase comes amid the growing popularity of energy-saving home appliances equipped with power chips.

If Chinese demand for inverter-equipped home appliances grows, the company will boost its monthly output capacity to 2-3 million units next year or later, according to the head of the Fukuoka plant. It will consider launching production in China as well.

Mitsubishi Electric has earmarked roughly 5 billion yen to beef up the final assembly lines at a plant in Fukuoka as well as install new facilities capable of producing wafers with larger diameters at a factory in Kumamoto Prefecture.

The firm expects its power chip segment, which includes devices used for hybrid cars and industrial machines, to generate sales of 70 billion yen this fiscal year, up 13% on the year.

Mitsubishi Electric, which commands more than 60% of the market for power chips used in inverter-equipped home appliances, plans to buy part of Toshiba Corp.'s (6502) power chip operations as of Oct. 1.

The firm now supplies power semiconductors to Toyota Motor Corp. (7203), Honda Motor Co. (7267) and Ford Motor Co. for use in their hybrid cars.

Source: The Nihon Keizai Shimbun Tuesday morning edition

Information of Mitsubishi-Toshiba IPM

- TOSHIBA TO TRANSFER PART OF POWER SEMICONDUCTOR BUSINESS TO MITSUBISHI ELECTRIC

TOKYO, June 17th, 2004 – Mitsubishi Electric Corporation (President and CEO: Tamotsu Nomakuchi; hereafter “Mitsubishi Electric”) and Toshiba Corporation (President and CEO: Tadashi Okamura; hereafter “Toshiba”) announced today that they have agreed in principle to transfer a majority of Toshiba’s high capacity power module business, which accounts for a small portion of its power transistor business, over to Mitsubishi Electric. The business transfer will include product development, design, manufacturing and the marketing of high capacity power module products, but will not include products for automotive use, high voltage modules1or other related products. Discussions about the exact details of the business transfer are ongoing. A final agreement is expected to be concluded by October 1st, 2004.

1 High voltage modules to be used by Toshiba’s Industrial and Power Systems & Services Company will continue to be supplied by Toshiba.

As a result of its “Focus and Concentration” strategy, Mitsubishi Electric has previously spun-off its system LSI and system memory businesses to form a new joint venture with Hitachi Corporation, called Renesas Technology Corporation. Mitsubishi Electric now concentrates its own resources on power semiconductors and high frequency optical devices, capable of achieving synergies within the company’s business. Mitsubishi Electric has been concentrating on its IGBT2 module business in inverter controller equipment for consumer products and industrial equipment, and in new areas such as hybrid cars. Mitsubishi Electric believes that this business transfer will enable it to accelerate the strength of its module business by combining both companies’ technology.

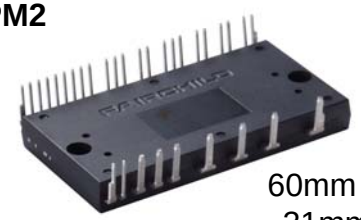
2 IGBT: Insulated Gate Bipolar Transistor

Toshiba’s semiconductor business is focused on three key industry sectors— discrete semiconductors, system LSIs and memories—and the ability to offer solutions as an integrated device manufacturer (IDM) with market-leading capabilities in the integration of design, development and production. In the discrete business, where Toshiba is the world’s number one in market share with total sales of approximately 220 billion yen in the fiscal year 2003, the company is fine-tuning its strategic direction and has decided to focus resources on power transistors, which account for approximately 40% of Toshiba’s total discrete business, for use in hybrid car and electric vehicle applications and for use in PCs and digital consumer electronics, all areas that are expected to see consistent growth. In pursuit of this strategy, Toshiba reached agreement with Mitsubishi Electric on the transfer to Mitsubishi Electric of the majority of the high capacity power module segment of Toshiba’s power transistor business, of which consists only a few percent of Toshiba’s total discrete business.

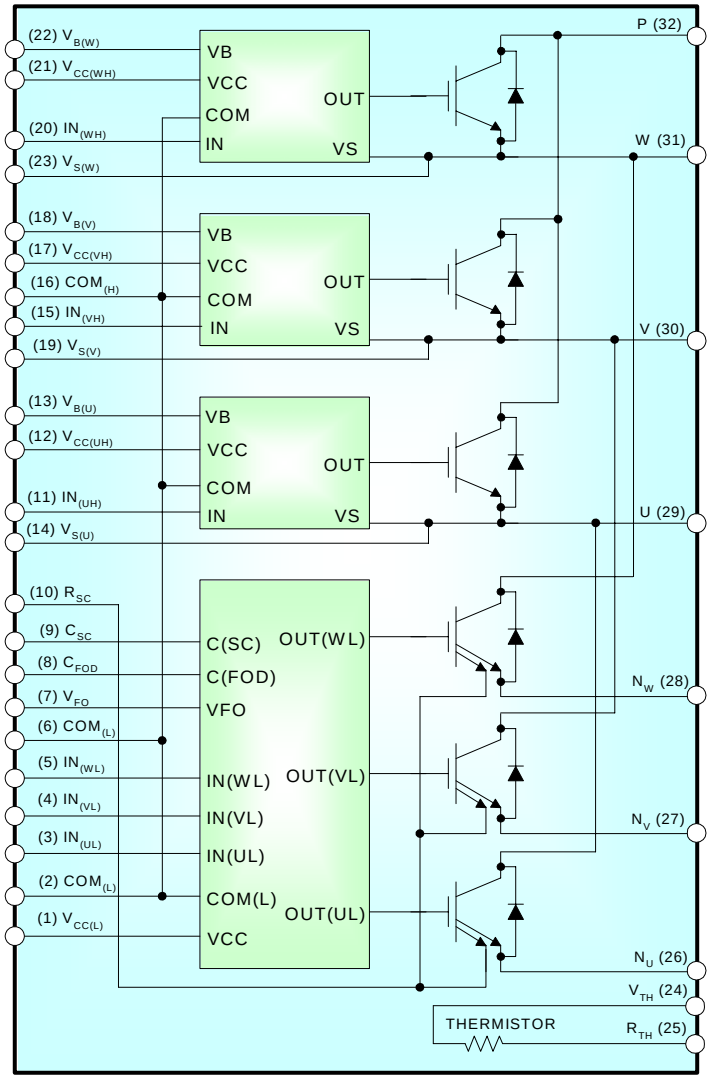
The worldwide demand for power semiconductors looks set to increase, on the back of greater demand for products reflecting a greater concern for energy saving, such as hybrid cars, solar-power generators, wind-power generators, and inverter control devices for consumer electronics and industrial equipment. However, worldwide market conditions are becoming increasingly severe as specialist manufacturers from Europe and North America become more competitive. In order to survive in these conditions, the strengthening and acceleration of the “Focus and Concentration” strategy is vital.

Both companies had been developing their power semiconductor businesses independently up until now. However, both concurred that concentrating on their specialist areas would further both companies’ competitiveness, and therefore came to an agreement at this time.

SPM2 Family
Key Features

SPM Series	Rating (Motor rating)	Features	Main Applications
SPM2  60mm X 31mm	**600V 10~30A (0.8k~2.4kW)**	**3-phase IGBT inverter with** **- 3 divided N-terminal for current sensing** **- Built-in HVIC with UVP** **- Built-in LVIC with UVP, OCP** **- Sense IGBT for low-side** **- Built-in Thermistor**	**Air conditioner** **Washing machine** **Treadmill** **Industrial inverter**

SPM2 Series



- **Line-up :**
  - **600V/10A, 15A, 20A, 30A**
- **Target Applications :**
  - **Low cost consumer appliance inverters (Air conditioner, Washing machine, Water pump, Treadmill)**
  - **Low cost industrial inverters**
- **Feature :**
  - **Optional built-in thermistor(NTC)**
  - **Short-circuit protection with soft shut- down control using sense-IGBTs**
  - **Good thermal resistance and isolation capacity with ceramic substrate**
  - **3 N-terminals for low-cost current sensing**

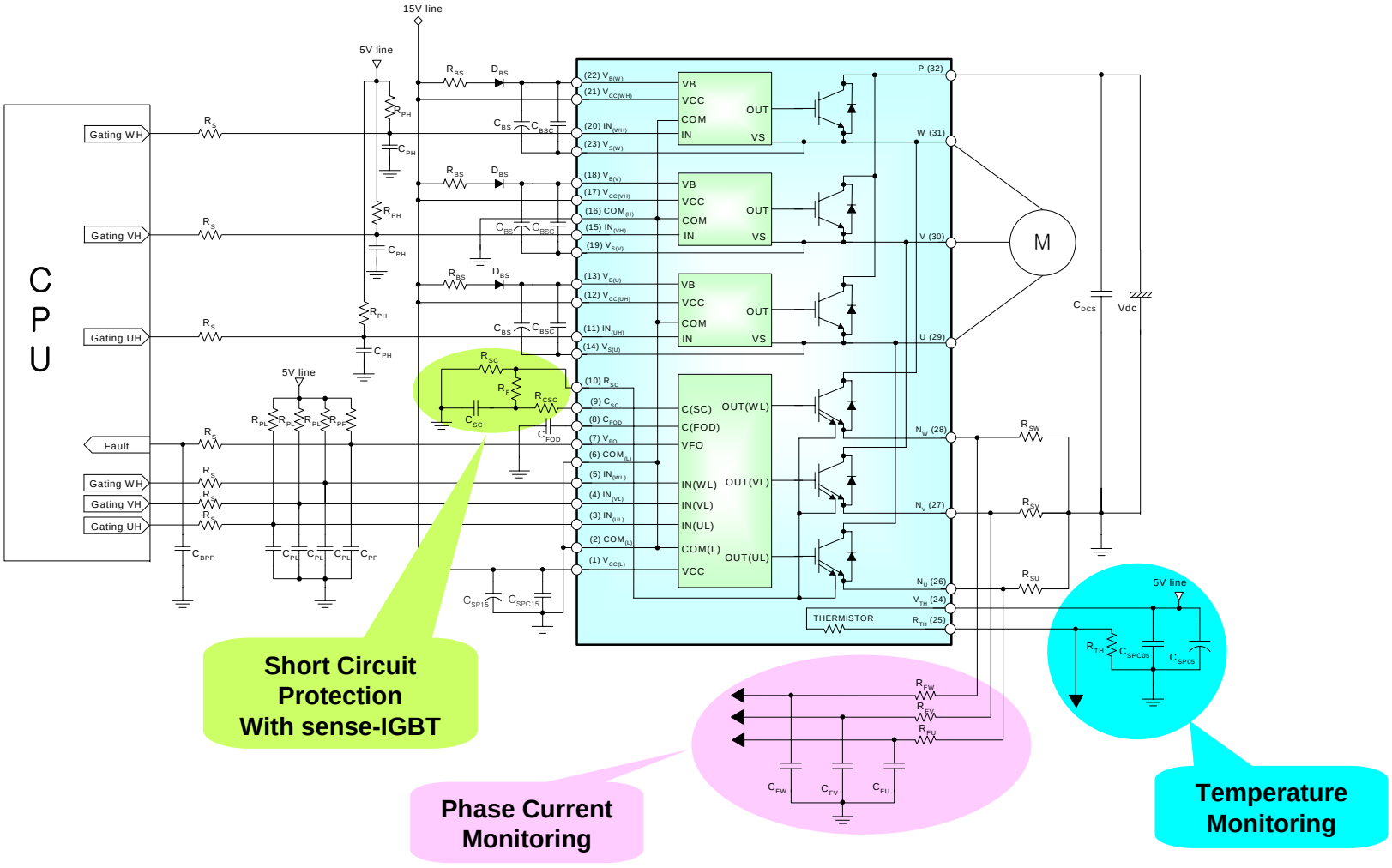
Line up of DIP-SPM (SPM2)

- Status : Mass production

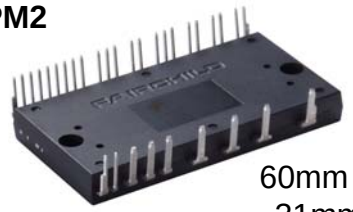
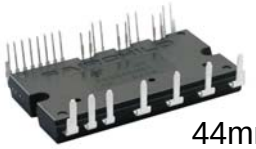
Products	BVCES (Min) (V)	IC(A)	Frequency Typ(kHz)	Motor Rating		Built in Thermistor	Major App.
				Watts (kW)	VAC (V)		
DIP-SPM (SPM2)							
FSAM10SH60A	600	10	15	1.0	220	Yes	Washing machine
FSBM10SH60A	600	10	15	1.0	220	No	Washing machine
FSAM10SM60A	600	10	5	1.0	220	Yes	Airconditioner
FSBM10SM60A	600	10	5	1.0	220	No	Airconditioner
FSAM15SH60A	600	15	15	1.5	220	Yes	Washing machine
FSBM15SH60A	600	15	15	1.5	220	No	Washing machine
FSAM15SM60A	600	15	5	1.5	220	Yes	Airconditioner
FSBM15SM60A	600	15	5	1.5	220	No	Airconditioner
FSAM20SH60A	600	20	15	2.2	220	Yes	Industrial
FSBM20SH60A	600	20	15	2.2	220	No	Industrial
FSAM20SM60A	600	20	5	2.2	220	Yes	Airconditioner
FSBM20SM60A	600	20	5	2.2	220	No	Airconditioner
FSAM30SH60A	600	30	15	3.0	220	Yes	Industrial
FSBM30SH60A	600	30	15	3.0	220	No	Industrial
FSAM30SM60A	600	30	5	3.0	220	Yes	Airconditioner
FSBM30SM60A	600	30	5	3.0	220	No	Airconditioner

SPM2 Series

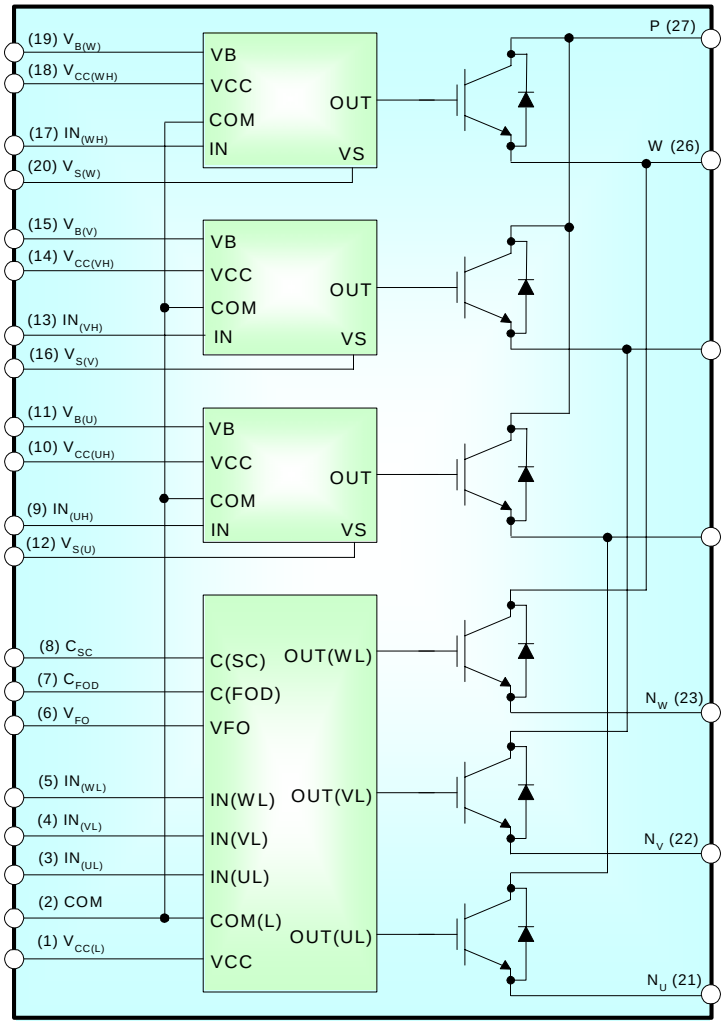
System Connection Diagram



SPM2 and SPM3 Family
Key Features

SPM Series	Rating (Motor rating)	Features	Main Applications
SPM2  60mm X 31mm	600V 10~30A (0.8k~2.4kW)	3-phase IGBT inverter with - 3 divided N-terminal for current sensing - Built-in HVIC with UVP - Built-in LVIC with UVP, OCP - Sense IGBT for low-side - Built-in Thermistor	Air conditioner Washing machine Treadmill Industrial inverter
SPM3  44mm X 26.8mm	600V 3~30A (0.25k~2.4kW)	3-phase IGBT inverter with - 3 divided N-terminal for current sensing - Built-in HVIC with UVP - Built-in LVIC with UVP, OCP - Small Footprint	Air conditioner Washing machine Refrigerator Industrial inverter

SPM3 Series



- **Line-up :**
  - **600V/3A,5A,7A,10A,15A (for Ceramic-SPM3)**
  - **600V/15A, 20A, 30A (for DBC-SPM3)**
- **Target Applications :**
  - **Low cost consumer/industrial appliance inverters (Air conditioner, Washing machine, Refrigerator, Water pump, Treadmill, servo)**
- **Feature :**
  - **Good thermal resistance**
  - **Small size & Large pin-to-pin spacing with zigzag package structure**
  - **Controllable switching speed with external gate resistor**
  - **3 N-terminals for low-cost current sensing**

Line up of Mini-SPM (SPM3)

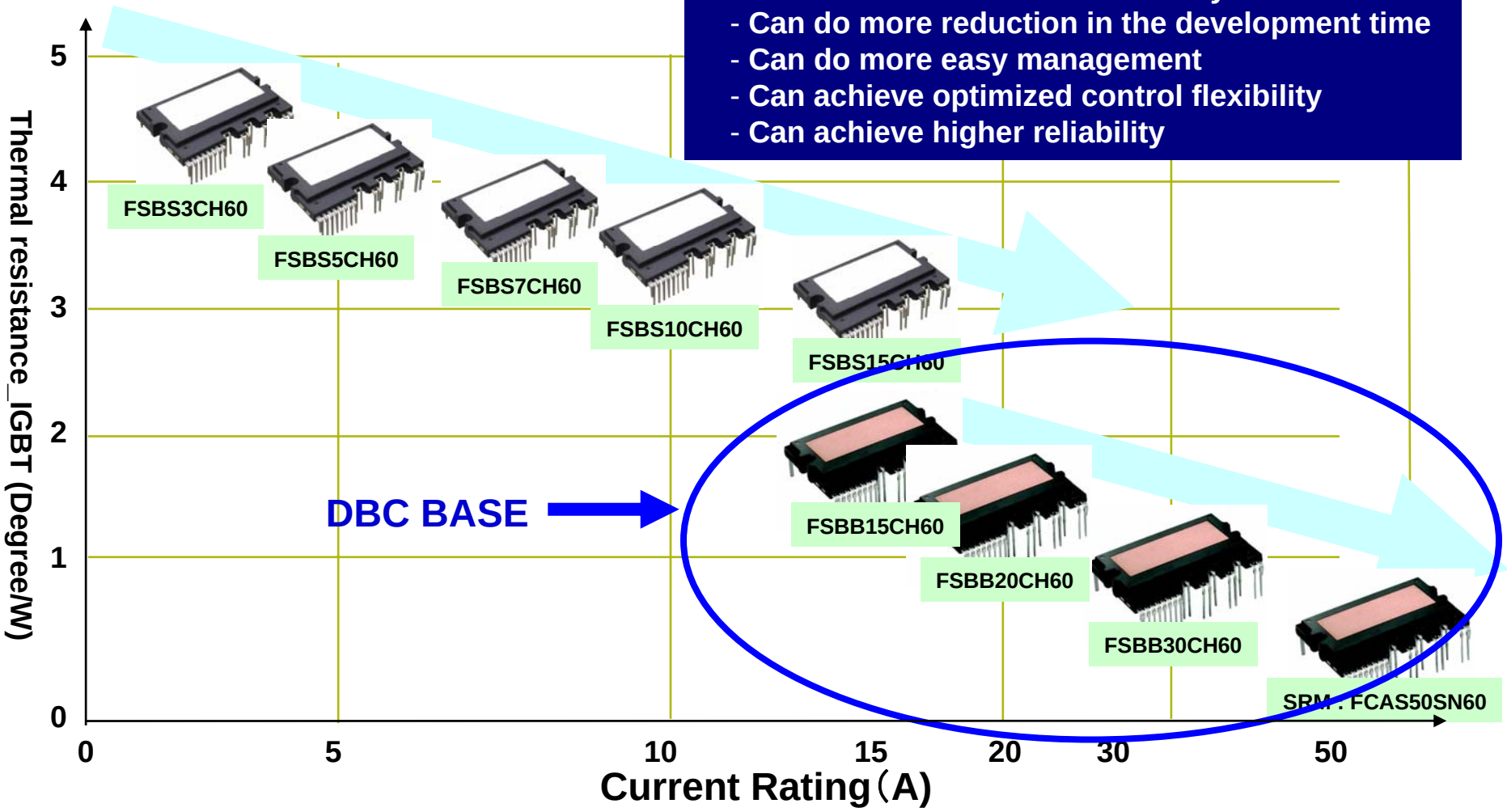
- Status : under development , Mass production : Aug,2004

Products	BVCES (Min) (V)	IC (A)	Motor Rating		Major App.
			Watts (kW)	VAC (V)	
Mini-SPM (SPM3)					
FSBS3CH60	600	3	0.3	220	Refrigerator, Fan motor
FSBS5CH60	600	5	0.45	220	Refrigerator,W/M
FSBS7CH60	600	7	0.75	220	W/M
FSBS10CH60	600	10	1	220	A/C , W/M
FSBS15CH60	600	15	1.5	220	A/C , W/M
FSBB15CH60	600	15	1.5	220	A/C , W/M
FSBB20CH60	600	20	2.2	220	A/C , W/M
FSBB30CH60	600	30	2.2	220	A/C , W/M

Controller Platform Strategy

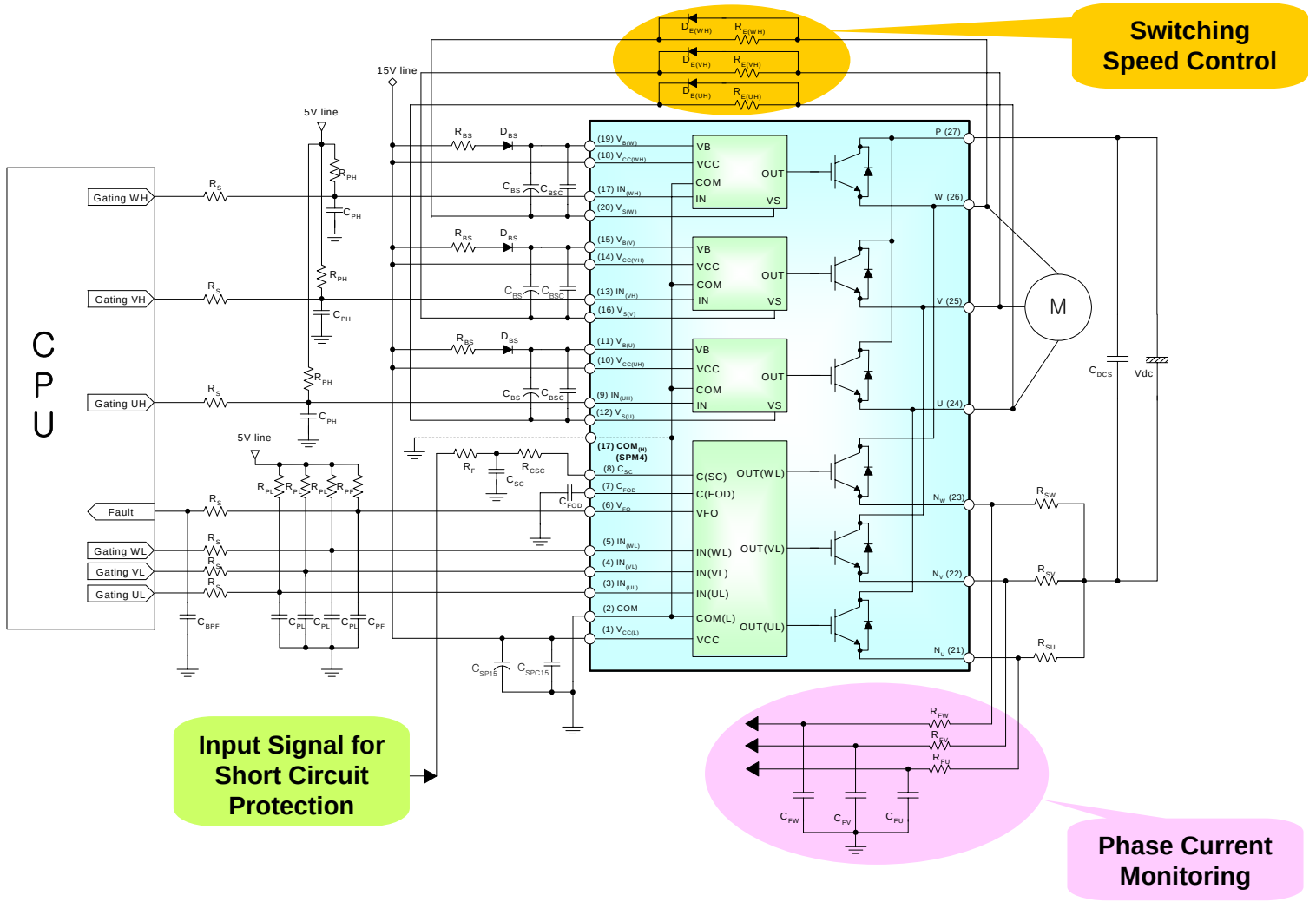
SPM3-based Control Engine Platform

- Can do more reduction in total system cost
- Can do more reduction in the development time
- Can do more easy management
- Can achieve optimized control flexibility
- Can achieve higher reliability



SPM3 Series

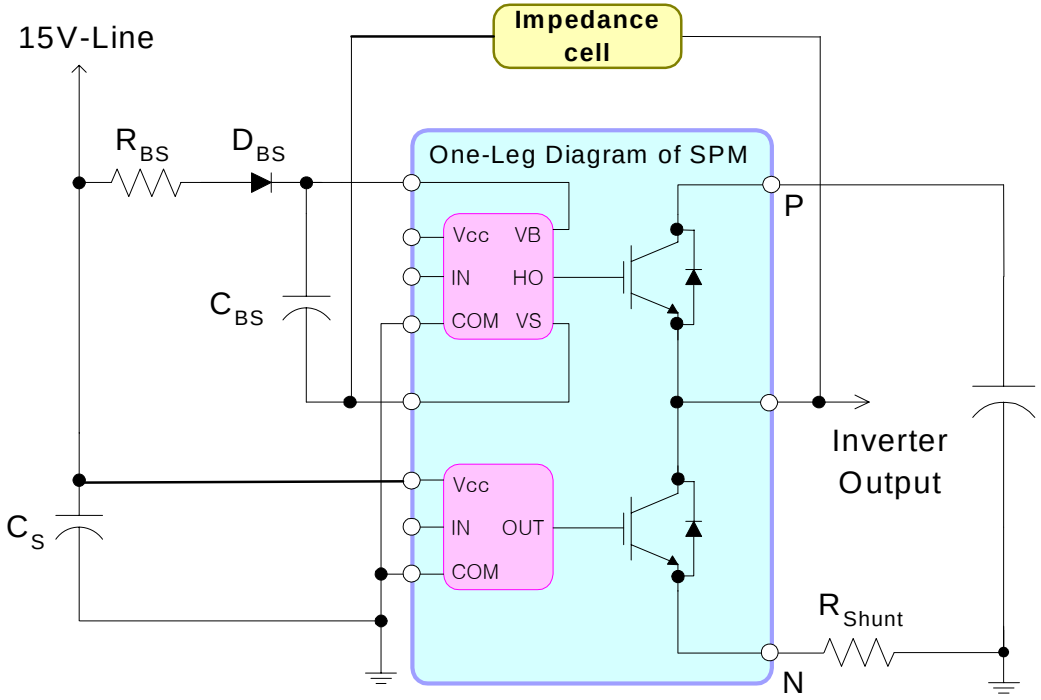
System Connection Diagram

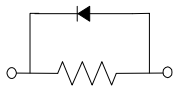
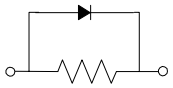
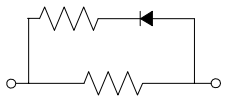


SPM3 Series

- Switching speed control

- **High side switching speed control**
  - **External impedance cell can be used**
- **Low side switching speed control**
  - **2 kinds of LVIC for high/low on-dv/dt are provided optionally**



Type	Impedance cell	Description
A		On/off dv/dt control
B		Off dv/dt control
C		On dv/dt control
D		Separate on/off dv/dt control

SPM3 with DBC(Direct Bonding Copper)

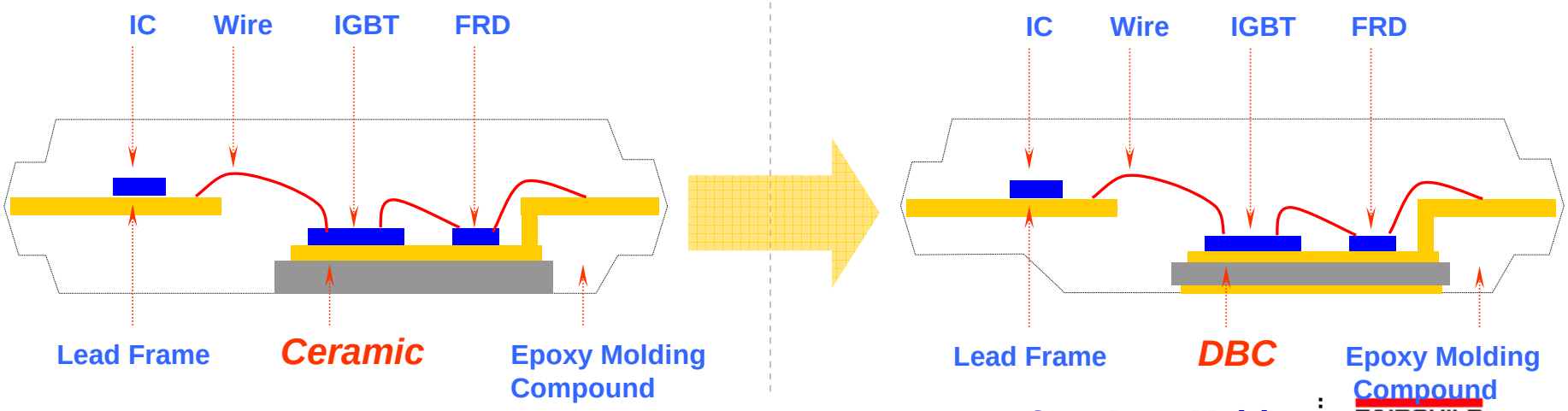
Development of DBC PKG is on-going for 15/20A SPM3

Merits : 20A Chips can be used by utilization of fine patterning

Very Low Thermal Resistance Possible by using DBC

Exactly Same in External Structure (Pin-to-Pin Compatibility to existing one)

Max. R θ*jc*	Rθ*jc* [°C/W] _ IGBT		Rθ*jc* [°C/W] _ FRD	
	Ceramic	DBC	Ceramic	DBC
10A SPM3	3.7	-	4.7	-
15A SPM3	3.1	1.64	3.6	2.46
20A SPM3	-	1.51	-	2.17



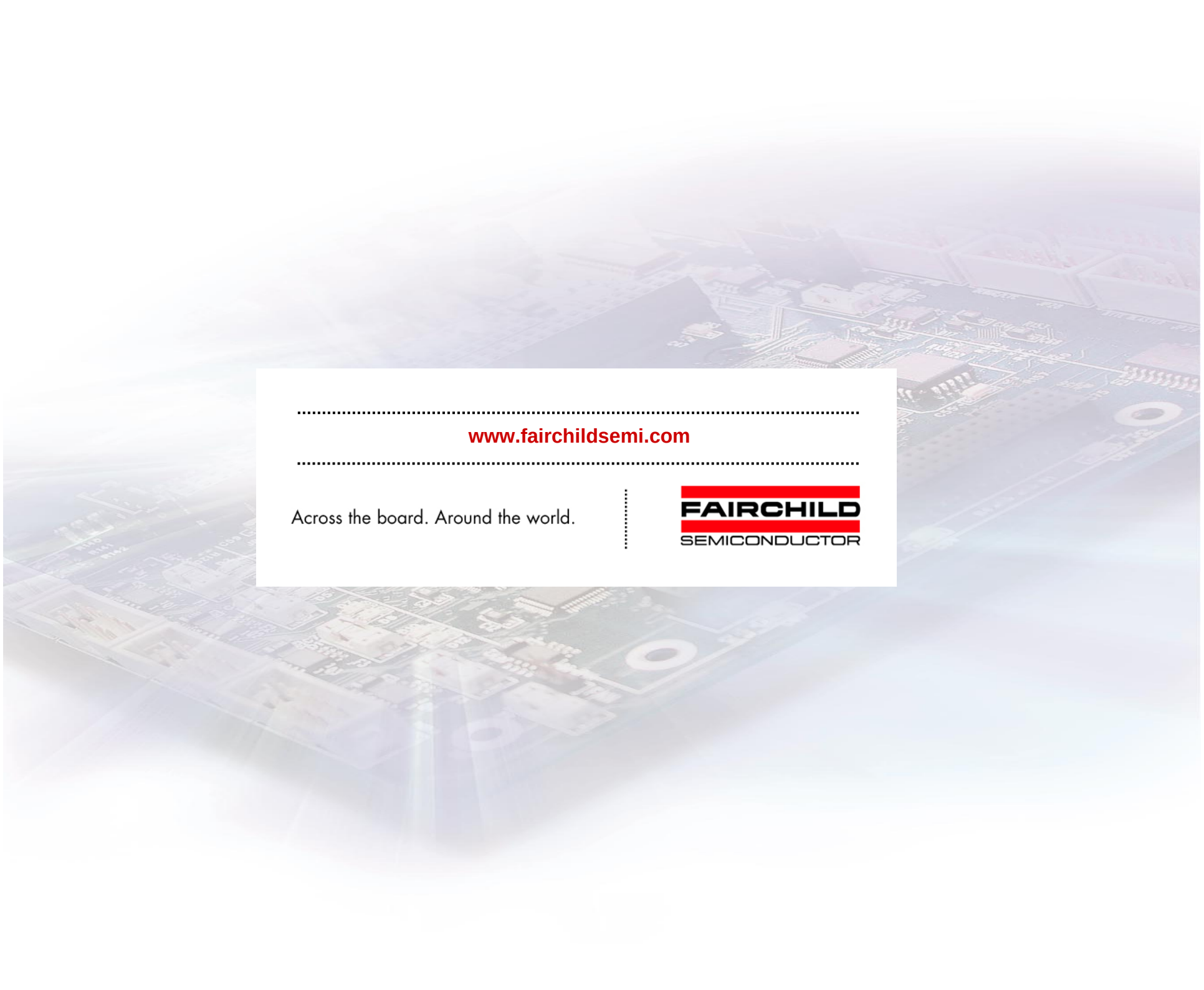
SPM Key Customers

Carrier
SAMSUNG
DAIKIN
Panasonic ideas for life
TOSHIBA
LG Electronics
FUJITSU
SANYO
SHARP
MITSUBISHI ELECTRIC HVAC Advanced Products Division
HITACHI Inspire the Next
Whirlpool

Air Conditioner

Refrigerator

Cloth Washer



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