HEV/EV Inverter Solution
Contents

- RENESAS Introduction
- EV/HEV Motor Control Solution
- Devices Solution
Renesas Electronics Introduction
## World’s Top Automotive Semiconductor Supplier

### Auto. Semiconductor W/W

<table>
<thead>
<tr>
<th>Company</th>
<th>CY14</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Renesas Electronics</td>
<td>12.0%</td>
</tr>
<tr>
<td>2 Infineon</td>
<td>10.5%</td>
</tr>
<tr>
<td>3 ST</td>
<td>7.8%</td>
</tr>
<tr>
<td>4 Freescale</td>
<td>7.5%</td>
</tr>
<tr>
<td>5 NXP</td>
<td>6.8%</td>
</tr>
</tbody>
</table>

### Auto. Processor (MCU, SOC) W/W

<table>
<thead>
<tr>
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<th>CY14</th>
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<tbody>
<tr>
<td>1 Renesas Electronics</td>
<td>37.7%</td>
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<tr>
<td>2 Freescale</td>
<td>20.8%</td>
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<tr>
<td>3 Infineon</td>
<td>8.7%</td>
</tr>
<tr>
<td>4 TI</td>
<td>7.6%</td>
</tr>
<tr>
<td>5 Microchip</td>
<td>4.8%</td>
</tr>
</tbody>
</table>

### Auto. Analog & Power* WW

<table>
<thead>
<tr>
<th>Company</th>
<th>CY14</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Infineon</td>
<td>15.5%</td>
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<tr>
<td>2 ST</td>
<td>13.8%</td>
</tr>
<tr>
<td>3 NXP</td>
<td>9.2%</td>
</tr>
<tr>
<td>4 TI</td>
<td>8.6%</td>
</tr>
<tr>
<td>5 Renesas Electronics</td>
<td>6.2%</td>
</tr>
</tbody>
</table>

*Auto. Analog & Power = “Non-power Analog” + “Power”

Note: Ranking data includes the influence of exchange rate fluctuations.

Source: Strategy Analytics
Solutions for Automotive

Renesas semiconductors lead to higher functionality for automobiles

- High performance and low power through 40 nm process
- Multi-core, functional safety, and security
- Lineup covering eight application fields

- High-precision, low-loss drivers
- High-precision, high-voltage sensor interfaces
- Battery management ICs for HEV/EV

- Low voltage power MOSFET
- IPDs (intelligent power devices) for car body
- IGBTs for HEV/EV

- Good track record with car information systems
- R-Car covers high-end, mid-range, and entry-level
- High-performance graphics engine and image recognition technology

*Share estimated by Renesas. BiCD: Bipolar CMOS DMOS, IPD: Intelligent Power Device, IGBT: Insulated Gate Bipolar Transistor
Automotive MCU Product Series

- Individual product lineup that is consistent with the platform method on the flash memory tip, contribute to improving our customers' competitiveness

32bit High-performance MCU
- High-performance/Large Flash Memory
- Wide Product Line to cover Various ECUs
- Scalable ECU Architecture with Multi-Core

16bit Ultra Low-Power MCU
- Product variation as low-end MCU
- Ultra low power consumption (70uA/MHz)
- Reduce system cost with built-in Analog
All Line Up of Leading 40nm Automotive MCUs

First and only chip firm ready to begin mass production of Automotive MCUs at 40nm process
Expanding design-in worldwide – High Speed, Large Memory, Ultra Low Power

40nm MONOS flash

Powertrain  EV/HEV  Display  Safety  Body  Airbag

Lower power solution for more fuel-efficient cars
Functional safety solution for safe driving
High reliability and global support capability
Renesas Advantages

**Power saving technology contributing to energy savings**

- World’s first 40nm flash MCU developed through scalable MONOS* process technology
- Low power system technology cultivated by MCUs and A&P
Renesas Electronics Advantages

High Reliability, Safe and Secure technology

- High reliability and quality lead the automotive and industrial fields
- Functional safety technology cultivated by the automotive field
- Security technology to prevent attack by hackers and viruses

Continue to improve Quality toward ZERO DEFECT for Automotive Industry

1ppm

Toward ZERO DEFECT
EV/HEV Motor Control Solution
Energy Efficiency for Next Generation Green Car

CO2 emission control in major countries

Japan
U.S.
E.U.

Next-generation fuel efficient engine
Next-generation HEV/EV

Green Vehicle / Fuel Efficiency Engine
# Chinese Central Government Emission Policy

## Average fuel rate schedule:

<table>
<thead>
<tr>
<th>Year</th>
<th>MT Vehicle</th>
<th>AMT Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>6.9L/100km</td>
<td>5.5L/100km</td>
</tr>
<tr>
<td>2016</td>
<td>6.7L/100km</td>
<td>5.9L/100km</td>
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<tr>
<td>2017</td>
<td>6.4L/100km</td>
<td>6L/100km</td>
</tr>
<tr>
<td>2018</td>
<td>6L/100km</td>
<td>6.5L/100km</td>
</tr>
<tr>
<td>2019</td>
<td>5.5L/100km</td>
<td>6L/100km</td>
</tr>
<tr>
<td>2020</td>
<td>5L/100km</td>
<td>5.5L/100km</td>
</tr>
</tbody>
</table>

## Individual vehicle emission:

<table>
<thead>
<tr>
<th>Weight (Kg)</th>
<th>MT Vehicle Emission (L/100Km)</th>
<th>AMT Vehicle Emission (L/100Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>850-900</td>
<td>5.2</td>
<td>5.6</td>
</tr>
<tr>
<td>905-950</td>
<td>5.5</td>
<td>5.9</td>
</tr>
<tr>
<td>905-950</td>
<td>5.8</td>
<td>6.2</td>
</tr>
<tr>
<td>950-1000</td>
<td>6.1</td>
<td>6.5</td>
</tr>
<tr>
<td>1000-1050</td>
<td>6.6</td>
<td>7.0</td>
</tr>
<tr>
<td>1050-1100</td>
<td>6.9</td>
<td>7.2</td>
</tr>
<tr>
<td>1100-1150</td>
<td>7.3</td>
<td>7.4</td>
</tr>
<tr>
<td>1150-1200</td>
<td>7.7</td>
<td>7.7</td>
</tr>
<tr>
<td>1200-1250</td>
<td>8.1</td>
<td>8.0</td>
</tr>
<tr>
<td>1250-1300</td>
<td>8.5</td>
<td>8.3</td>
</tr>
<tr>
<td>1300-1350</td>
<td>8.9</td>
<td>8.7</td>
</tr>
<tr>
<td>1350-1400</td>
<td>9.3</td>
<td>9.0</td>
</tr>
<tr>
<td>1400-1450</td>
<td>9.7</td>
<td>9.4</td>
</tr>
<tr>
<td>1450-1500</td>
<td>10.1</td>
<td>9.6</td>
</tr>
<tr>
<td>1500-1550</td>
<td>10.5</td>
<td>10.1</td>
</tr>
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<td>1550-1600</td>
<td>10.9</td>
<td>10.6</td>
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<td>1600-1650</td>
<td>11.3</td>
<td>10.8</td>
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<td>1650-1700</td>
<td>11.8</td>
<td>11.2</td>
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<tr>
<td>1700+</td>
<td>12.3</td>
<td>12.0</td>
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Executive Summary

- Renesas developed world’s smallest class size of reference inverter kit solutions for hybrid electric vehicle and electric vehicle.

- Renesas products such as MCUs, Pre-Driver ICs and IGBTs proven by extensive automotive market experiences can realize highly efficient Inverter ECUs.

- Renesas provides not only motor application Software but also embedded testing software and wide range of EDA libraries for designing ECU system specification/validations.
Reference Design of Inverter System

Reference design as Kit Solution for Smaller, lighter, more efficient inverter in next HEV/EV

World's Smallest size EV Motor Inverter

Electromechanical air-cooled motor inverter

Various IPM/SR Motor reference design

Drive real size IPM/SR motor
Motor Generator MCU for EV/HEV Systems

Leading Motor Generator MCU for Global EV/HEV Inverter Systems by 40nm Flash MCU

Global Market Share of MCUs for EV/HEV Systems

World Wide 72% Share

MG (Motor Generator) MCU Roadmap

RH850/C1H
240MHz, DCLS, 2 RDC Motor IP (EMU2)

RH850/C1M
240MHz, SCLS, 1 RDC Motor IP (EMU2)

SH72AY
768KB, 1 RDC Motor IP (EMU)

V850E2/PG4-S
512KB, 1 RDC

40nm Flash MCU Process

RH850/C1H for Dual Motor System

RH850/C1M for Single Motor System

*Renewas reference design capacity ratio
Renesas IGBT Advantage for Inverter Systems

Renesas IGBT technology is best in the class of 650V/300A for Motor Inverter Systems. We will enhance to 900V/1200V products.
HEV/EV Motor ECU’s Reduction in Size and Weight

Kit solution of Motor MCU + μ isolator + IGBT reduces inverter size & weight and adds tremendous value for next generation HEV/EV

Process Innovation of Flash MCU

Motor control | MCU | IGBT
---|---|---
CPU core | Motor Control IP | High-speed breaker
| Vector Engine | Pre Driver | Temperature Accuracy Improvement Calibration
R/D converter | μ isolator
Motor Control (+Functional Safety)

ECU’s Reduction in Size and Weight

*Renesas reference design capacity ratio

Capacity: 4.9L
Capacity: 2.9L
Capacity: 0.9L
(-80%+α)
Technology for Smaller Inverter System

High performance IGBT and Micro Isolator controlled by Motor MCU for next generation inverter

<table>
<thead>
<tr>
<th>CY</th>
<th>2011</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>11.25L</td>
<td>4.9L 400A</td>
<td>2.9L 600A</td>
<td>0.9L 400A</td>
</tr>
<tr>
<td>Output</td>
<td>200A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- High Current High Density Technology
- Thermal Management Technology
- Micro-Isolator Technology
- 7th Generation IGBT
Offering Various Kit Solutions for EV Systems
Miniaturized Motor Distribution

Small size of integrated motor can arrange motor allocation and increase design flexibility to change size of car

1MOTOR SYSTEM  

MULTI MOTOR SYSTEM
**Inverter Kit Solution Menu**

Depending on customer’s requirement, 3 type of menu is prepared for each.

<table>
<thead>
<tr>
<th>Focus on</th>
<th>Menu</th>
<th>Configuration</th>
<th>Tool</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power rail design</td>
<td>Power Kit</td>
<td>Driver IC</td>
<td>IGB</td>
<td>Down-sizing (High performance power devices)</td>
</tr>
<tr>
<td>Heat-sink design</td>
<td>Inverter Kit</td>
<td>High accuracy temp calibration by utilizing driver software</td>
<td></td>
<td>Down-sizing</td>
</tr>
<tr>
<td>Production test time</td>
<td></td>
<td></td>
<td></td>
<td>Test procedure reduction</td>
</tr>
<tr>
<td>Entire ECU development</td>
<td>MG Kit</td>
<td>High Temp control accuracy</td>
<td></td>
<td>Down-sizing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Test procedure reduction</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Inverter Kit**
- High accuracy temperature measurement
- Fast shut-down

**Power Kit**
- High accuracy temperature measurement
- Fast shut-down

**MG Kit**
- High accuracy temperature measurement
- Motor control (+FuSa)
- Demo inverter system unit

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Kit Devices

Our kit devices cover all of major inverter system components.

- RH850/C1H (RH850/C1M)
- RAJ293001 R2A25110KSP
- IGBT+FRD
- EMU: Enhanced Motor Control Unit
- RDC: Resolver to Digital Converter
- PMIC
- Power Management IC
- RDC
- MCU
- Driver IC
- Driver IC
- RAA270000KFT
- Temp. sensor
- EMU
- Motor
- Resolver

IGBT: Insulated Gate Bipolar Transistor
FRD: Fast Recovery Diode
Temperature Management Tech. (Use Temp. Sensor in IGBT)

Accurate temperature measurement make the optimization of heat-sink design and light weight

IGBT WITHOUT Temp. Sensor
Predict delay and temp. for IGBT

IGBT WITH Temp. Sensor
Measure direct hot source in IGBT

Big size heat-sink is needed due to over margin design by prediction

Downsize heat-sink is feasible by temperature measurement control software using IGBT’s temp. sensor

[Legacy] External temp. sensor (Thermistor)

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Model Base Design Environment

Wide range of HEV/EV MCUs MBD (model base design) tools support to V shape design flow cooperation with EDA vendors.

MILS: Model In the Loop Simulation
SILS: Software In the Loop Simulation
PILS: Processor In the Loop Simulation
HILS: Hardware In the Loop Simulation
Device Solution
MCU Road Map for HEV/EV

**MG (Motor Generator)**

- **SH72AV**
  - 768KB, 1 RDC
  - Motor IP (EMU)

- **V850E2/PG4-S**
  - 512KB, 1 RDC

- **SH72AY**
  - 768KB, 1 RDC
  - Motor IP (EMU)

- **V850E2/FF4-Motor**

- **SH72A0**

- **RL78/F1x**
- **RL78/F1y**

**New**

- **RH850/C1H**
  - 240MHz, DCLS, 2 RDC
  - Motor IP (EMU2)

- **RH850/C1M**
  - 240MHz, SCLS, 1 RDC
  - Motor IP (EMU2)

- **RH850/C1x-A**
  - 320MHz, DCLS
  - 1&2 Next RDC
  - Next Motor IP

**DC/DC, Charger**

- **RH850/P1x**
- **RH850/F1x**

- **RH850/P1x-Nex**
- **RH850/F1x**

DCLS: Dual core with lock step
SCLS: Single core with lock step

* Same Solution
RH850/C1H Outline for 2 Motor MG MCU

**System**
- DMA (16ch/128ch)
- Interrupt Controller
- Error Control Module
- Main OSC
- Clock Monitor
- CRC

**32-bit CPU**
- RH850 Core with Lock-Step G3M@240 MHz
  - 1.25/3.3/5.0 V
  - -40 to +125°C
- RH850 Core G3M@240 MHz
  - 1.25/3.3/5.0 V
  - -40 to +125°C
- 2 x MPU
- 2 x I-Cache
- 2 x FPU

**Memory**
- 4MB Flash
- 32KB Data Flash
- 240KB RAM (TOTAL)

**Motor Control Subsystem**
- EMU2
- 2 x RDC2
- 2 x TSG3
- 2 x TAPA

**Interfaces**
- 4 x RS-CAN
- 2 x CSIH
- 3 x LIN
- 3 x SCI
- GPIO

**Debug**
- Nexus Class 3+
- AUD, LPD

**Analog**
- SAR A/D
- 2 x modules
RH850/C1M Outline for 1 Motor MG MCU

**System**
- DMA (16ch/128ch)
- Interrupt Controller
- Error Control Module
- Main OSC
- Clock Monitor
- CRC

**32-bit CPU**
- RH850 Core
  - with Lock-Step
  - G3M@240 MHz
  - 1.25/3.3/5.0 V
  - -40 to +125°C
- 1 x MPU
- 1 x I-Cache
- 1 x FPU

**Memory**
- 2MB Flash
- 32KB Data Flash
- 128KB RAM (TOTAL)

**Timer**
- 2 x OS Timer
- 1 x WDT
- 2 x TAUD
- 1 x TAUJ
- 2 x ENCA

**Motor Control Subsystem**
- EMU2
- 1 x RDC2
- 2 x TSG3
- 2 x TAPA

**Interfaces**
- 4 x RS-CAN
- 2 x CSIH
- 3 x SCI
- GPIO

**Debug**
- Nexus Class 3+
  - AUD, LPD

**Analog**
- SAR A/D
- 2 x modules
Motor Control Technology for EV/HEV

Motors for EVs/HEVs need to be light-weight as well as small and have high-speed rotation

Advantage:
- Built-In Resolver to Digital Converter (RDC)
- Reduce Noise influence
- Strong Collaboration with TAMAGAWA SEIKI Co.
- Built-in Enhanced Motor Control Unit (EMU)
- Low CPU Load with built-in Motor Control hardware

 lý ng To ng g c h Ky th c ng t th nh C th HEV

M t s f EVs/HEVs nd t b lght-wght s wll s smll nd hve hgh-sp d rtt n

d vantage:
- Bld-In Rsolv r t Dgtl nver (RDC)
- Redc Nise nfluene
- Strng Collbrt with TAMAGAWA SEIKI Co.
- Bld-in Enhncd Mtr Cntl Unit (EMU)
- Lw CPU Ld th bld-in Mtr Cntl hwrd

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Small Micro Isolator Technology (Pre-Driver IC)

**Contribution to downsizing and fast switch operation**
**Small & High gate drivability**

<table>
<thead>
<tr>
<th>Advantage to Photo coupler</th>
<th>Isolator</th>
<th>Coupler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay time</td>
<td>~60ns</td>
<td>~500ns</td>
</tr>
<tr>
<td>Current Consumption</td>
<td>Trans 0.1mA</td>
<td>Trans 10mA</td>
</tr>
<tr>
<td></td>
<td>Receiver 1.2mA</td>
<td>Receiver 1mA</td>
</tr>
<tr>
<td>Operation temp</td>
<td>125degC</td>
<td>105degC</td>
</tr>
<tr>
<td>IGBT drive config</td>
<td>1 package 1pcs</td>
<td>Driver IC 1pcs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coupler 1~2pcs</td>
</tr>
</tbody>
</table>

Renesas unique design:
Smaller transformer size than competitor (1/4~1/8)

Drastically Part numbers reduced (12p → 6p)

MCU

Power Module (IGBT)

Drastically Part numbers reduced (12p → 6p)

Micro Isolator + Pre-Driver

Power Module (IGBT)
IGBT Process Trend

Realized low On-voltage with HiGT design. Realized Fast switching with low capacitance structure which is optimized for HEV inverter.

HiGT : High conductivity IGBT

AE2 FS type*

AE3 Adv. FS type

AE4 Fine cell FS Type

AE5 (concept)

On Voltage x Switching Loss (Eoff) Index (Normalized)

* FS : Field Stop

Development Start

1st WS (for test sample Only)

2008 2010 2012 2014 2016 2018
High Efficiency IGBT Device Technology (600V to 1200V)

- Development of low Gate-capacity structure (AE4) realizes a low Switching loss and low VCE(sat). Efficient predominance is shown against competitors, contributes lower power consumption with smaller die.

(*1) AE4 loss is estimate value.

(*2) Renesas own structure HiGT: High conductivity Gate Bipolar Transistor
IGBT Coverage in HEV/EV System

RENESAS provides high performance & high quality IGBT bare die to various applications

Current Coverage
- 650V ~600A
- 900V ~400A
- 1200V ~300A

High Current Package
Recommend packaged IGBT for less than 30kW power
Under planning
High Current Package

Standard Voltages
- 650V
- 900V
- 1200V

Bare die

Small EV
Mild HEV

Large EV
Full - HEV

Voltage Rating (V)

HVAC: Heating, Ventilation, and Air Conditioning
Reference Integrated Motor
2.9L(45KW) HEV/EV Traction Motor Inverter

Real 45kW IPM\(^*1\) motor drive
Max 650V/600A output IGBT
- Power density 2.5 times up
  - Downsizing Inverter 4.9L \(\rightarrow\) 2.9L
  - More power output 400A \(\rightarrow\) 600A

Renesas device solution
- MCU: RH850/C1M
- PMIC: RAA270000
- Driver IC: R2A25110
- Power: IGBT(AE3)/FRD with sensor

Collaboration
- Sumitomo Shoji Machnex.

*1 Interior Permanent Magnet
HEV/EV Inverter (SR Motor)

Electromechanical integrated air-cooled motor inverter

Real 20kW SR\(^*1\) motor drive
Max 650V/400A output IGBT
- Downsizing Inverter 2.9L → 0.9L
- Temperature Calibration for Kit solution

Renesas device solution
- MCU: RH850/C1M
- PMIC: RAA270000
- Driver IC: R2A25110
- Power: IGBT/FRD with sensor

Collaboration
- with Sumitomo Shoji Machnex.

\*1 SR : Switched Reluctance
Mechanical Configuration Diagram

- Air-cooled Motor
- Heat-sink
- Inverter
- IGBT / DI board
- Pre-driver board
- MCU / PMIC board
- Connector
- Cover
- Inverter cover
## 产品应用事例
### 机电一体电机逆变器

### Specification

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>出力</td>
<td>15kW/10s 3kW/連続</td>
</tr>
<tr>
<td>出力電流</td>
<td>300Apk/10s</td>
</tr>
<tr>
<td>入力</td>
<td>300VDC (400VDC max)</td>
</tr>
<tr>
<td>I/F</td>
<td>1xResolver 2xCAN 2xAnalog 1xUART 1xShut down</td>
</tr>
</tbody>
</table>

### Power

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>IGBT</td>
<td>Renesas 650V/400A VCE(sat)=1.45V(typ) tf=100ns Temperature Di Sense IGBT</td>
</tr>
<tr>
<td>SiC-SBD</td>
<td>Renesas 650V/400A VF=1.65V</td>
</tr>
</tbody>
</table>

### Gate Driver & Current sensor

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Driver</td>
<td>Renesas マイクロアイソレータ内蔵 Active mirror clamp Current &amp;Temperature sense Soft turn-off, UVLO, LDO</td>
</tr>
<tr>
<td>Current sensor</td>
<td>LEM 400A</td>
</tr>
</tbody>
</table>

### Control

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
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<tbody>
<tr>
<td>MCU</td>
<td>Renesas RH850C1M 160MHz with FPU 2xMotor Timer Safety(Dual core Lock step) RDC</td>
</tr>
<tr>
<td>PMIC</td>
<td>Renesas RAA270000 2x5V, 1x3.3V, 1x1.25V</td>
</tr>
</tbody>
</table>