Automotive Integrated Starter Generator

Solution Proposal by Toshiba
Toshiba Electronic Devices & Storage Corporation provides comprehensive device solutions to customers developing new products by applying its thorough understanding of the systems acquired through the analysis of basic product designs.
Block Diagram
ISG (Integrated Starter Generator)  Overall Block Diagram (1)

12 V Integrated Starter Generator

12 V

Power Supply

CAN Transceiver

TVS

Reverse Battery Protection / Load Switch

MCU

Gate Driver / Motor Driver

Inverter (Brushless)

M

Angle Sensor
48 V Integrated Starter Generator

- 48 V
- 12 V
- CAN
- TVS
- Power Supply
- MCU
- Gate Driver / Motor Driver
- Inverter (Brushless)
- Angle Sensor
Criteria for device selection
- It is necessary to select the product with the suitable voltage and current ratings for each application.
- It is necessary to select a gate driver according to the characteristics of the switching device to be driven.
- A small surface mount package is suitable for realizing miniaturization of the ECU.

Proposal from Toshiba
- Low on-resistance contributes low power consumption of the system
U-MOS Series 40 V 80 V / 100 V N-ch MOSFET
- Gate driver with built-in protection and diagnosis functions
Gate driver (for motor)
- Pre driver with built-in safety relay drivers
Brushless DC motor pre driver
ISG (Integrated Starter Generator)  Detail of CAN transceiver protection

**Criteria for device selection**
- A small surface mount package is suitable for realizing miniaturization of the ECU.

**Proposal from Toshiba**
- **Suitable for ESD protection**
  - TVS diode (for CAN communication)
- **Extensive product lineup**
  - General purpose small signal MOSFET
  - General purpose small signal bipolar transistor
  - Small signal bias resistor built-in transistor (BRT)
Criteria for device selection
- It is necessary to select the product with the suitable voltage and current ratings for each application.
- It is necessary to select a gate driver according to the characteristics of the switching device to be driven.
- A small surface mount package is suitable for realizing miniaturization of the ECU.

Proposal from Toshiba
- Low on-resistance contributes low power consumption of the system
  U-MOS Series 40 V / 80 V / 100 V N-ch MOSFET
- Gate driver with built-in protection and diagnosis functions
  Gate driver (for switch)
Recommended Devices
Device solutions to address customer needs

As described above, in the design of ISG, “Ensuring tolerance to motor lock current and immunity. Capable with functional safety”, “Reduction of power consumption” and “Miniaturization” are important factors. Toshiba’s proposals are based on these three solution perspectives.

Ensuring tolerance to motor lock current and immunity. Capable with functional safety

Reduction of power consumption

Miniaturization

Robustness

High efficiency
Low loss

Small size package
# Device solutions to address customer needs

<table>
<thead>
<tr>
<th></th>
<th>Device Description</th>
<th>Robustness</th>
<th>High efficiency - Low loss</th>
<th>Small size package</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>U-MOS Series 40V / 80 V / 100 V N-ch MOSFET</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Gate driver (for motor)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Brushless DC motor pre driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>TVS diode (for CAN communication)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>General purpose small signal MOSFET</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>General purpose small signal bipolar transistor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Small signal bias resistor built-in transistor (BRT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Gate driver (for switch)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The combination of low on-resistance and low noise by the latest U-MOS series process and a small package contributes to system performance improvement.

1. **Low loss (reduced on-resistance)**

Using low on-resistance technology to contribute to reduced power consumption systems.

2. **Low noise (low EMI)**

Improved chip process reduces surge voltage and ringing time.

3. **Compact gull wing package**

Package size reduced by 23% compared to D2PAK (10 x 5 mm). Gull wing shaped leads to reduce mounting solder stress in high environments with ambient temperature and mechanical stress.

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**Value provided**

- **High efficiency**
- **Low loss**
- **Small size package**
- **Robustness**

**U-MOS Series 40 V / 80 V / 100V N-ch MOSFET**

XPQ1R004PB / XPQR3004PB / XPQR8308QB / XPQ1R00AQB

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**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>Drain-source voltage</th>
<th>Drain current</th>
<th>On-resistance (Max) @VGS=10 V</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>XPQ1R004PB*</td>
<td>40 V</td>
<td>200 A</td>
<td>1.0 mΩ</td>
<td>L-TOGL™</td>
</tr>
<tr>
<td>XPQR3004PB*</td>
<td>40 V</td>
<td>400 A</td>
<td>0.3 mΩ</td>
<td></td>
</tr>
<tr>
<td>XPQR8308QB*</td>
<td>80 V</td>
<td>400 A</td>
<td>0.83 mΩ</td>
<td></td>
</tr>
<tr>
<td>XPQ1R00AQB*</td>
<td>100 V</td>
<td>400 A</td>
<td>1.0 mΩ</td>
<td></td>
</tr>
</tbody>
</table>

* : Under development (The specification is subject to change without notice.)

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The high gate drive current capability reduces MOSFET losses and improves the efficiency of system.

1. **High gate drive current**

   High drive current capability and high speed switching contribute to reduce the loss.
   - TPD7213FN: ±2 A
   - TPD7212F, TPD7212FN: -1 A / +1.5 A

2. **Built-in protection / diagnostic output function**

   MOSFET is turned off when a signal is input that causes arm short circuit. Functions to monitor abnormalities of the power supply voltage and output voltage are built-in.

3. **Small surface mount package**

   WQFN32, SSOP16, SSOP30

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Example of application and block diagram of TPD7212F, TPD7212FN (Three-phase brushless DC motor control)

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**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TPD7213FN*</th>
<th>TPD7212F / TPD7212FN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>Half bridge gate driver</td>
<td>Gate driver for Three-phase brushless motor</td>
</tr>
<tr>
<td>Number of output</td>
<td>2 outputs</td>
<td>6 outputs</td>
</tr>
<tr>
<td>Package</td>
<td>SSOP16 (5.5 x 6.4 mm)</td>
<td>WQFN32 (5 x 5 mm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SSOP30 (10.2 x 7.6 mm)</td>
</tr>
<tr>
<td>Features</td>
<td>Suitable for 48V battery system</td>
<td>For driving high-side N-ch MOSFET (with built-in charge pumps)</td>
</tr>
<tr>
<td></td>
<td>Can be used to drive a high side N-ch MOSFET</td>
<td>Built-in voltage monitoring function (power supply, output)</td>
</tr>
</tbody>
</table>

*: Under development (The specification is subject to change without notice.)

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**Compliant with automotive functional safety standard (ISO 26262: ASIL-D) and safety relay drivers are built in.**

1. **Compliant with automotive functional safety standard**

   Compliant with ISO 26262 ASIL-D, [Note 1] FMEDA [Note 2] and safety manuals can be provided.

   [Note 1] Automotive Safety Integrity Level
   [Note 2] Failure Modes Effects and Diagnostics Analysis

2. **Built-in safety relay drivers and motor current detection amplifiers**

   The safety relay drivers are built in for the power supply side MOSFETs and the motor phase cut MOSFETs. In addition, a 3 channels of motor current detection amplifiers are built in to support 3 shunts.

3. **AEC-Q100 qualified**

   It is AEC-Q100 qualified and it can be used for various automotive applications.

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**Built-in safety relay drivers**

- **TB9081FG**: 5 channels
- **TB9083FTG**: 3 channels

---

**Part number**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TB9081FG</th>
<th>TB9083FTG*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>LQFP64</td>
<td>WQFN48</td>
</tr>
<tr>
<td>Package size</td>
<td>10.0 x 10.0 mm</td>
<td>7.0 x 7.0 mm</td>
</tr>
<tr>
<td>Operating ambient temperature</td>
<td>$T_a = -40$ to 125 °C</td>
<td>$T_a = -40$ to 150 °C</td>
</tr>
<tr>
<td>Function Control method</td>
<td>Direct</td>
<td>Direct</td>
</tr>
<tr>
<td>External MOSFET (High side / Low side)</td>
<td>N-ch / N-ch</td>
<td>N-ch / N-ch</td>
</tr>
<tr>
<td>Detection of overheating, low voltage and short circuit</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Output of detection function diagnosis result</td>
<td>✔ (BIST [Note 3])</td>
<td>✔ (BIST)</td>
</tr>
</tbody>
</table>

[Note 3] Built-in Self Test

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* TB9083FTG: Under development (The specification is subject to change without notice.)
TVS diodes prevent system damage and malfunction caused by electrostatic discharge (ESD).

1. **Improve ESD pulse absorbability**

   Toshiba proprietary Zener process improves the ESD pulse absorption of TVS diodes. (Both low dynamic resistance $R_{\text{DYN}}$ and low capacitance between terminals $C_t$)

2. **Supports CAN, CAN FD and FlexRay**

   These are products applicable to in-vehicle LAN communication such as CAN, CAN FD and FlexRay.

3. **High ESD immunity**

   - $V_{\text{ESD}} > \pm 30 \text{ kV} @ \text{ISO 10605}$
   - $V_{\text{ESD}} > \pm 20 \text{ kV (L4)} @ \text{IEC61000-4-2}$

**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>DF3D18FU</th>
<th>DF3D29FU</th>
<th>DF3D36FU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>USM (SOT-323)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{\text{ESD}} [\text{kV}] @ \text{ISO 10605}$</td>
<td>$\pm 30$</td>
<td>$\pm 30$</td>
<td>$\pm 20$</td>
</tr>
<tr>
<td>$V_{\text{RW}} (\text{Max}) [\text{V}]$</td>
<td>12</td>
<td>24</td>
<td>28</td>
</tr>
<tr>
<td>$C_t (\text{Typ.} / \text{Max}) [\text{pF}]$</td>
<td>9 / 10</td>
<td>6.5 / 8</td>
<td></td>
</tr>
<tr>
<td>$R_{\text{DYN}} (\text{Typ.}) [\Omega]$</td>
<td>0.8</td>
<td>1.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**NOTE:** This product is an ESD protection diode and cannot be used for purposes other than ESD protection.

(*) Measurements of the commercial product

(Based on Toshiba’s measurement data)
Wide lineup of small packages contribute to reduce the size and power consumption of system.

1. **Small package**
   A lineup of various small packages such as SOT-723 (VESM 1.2 x 1.2 mm package) is available, contributing to reduce mounting area.

2. **Low voltage drive**
   SSM3J66MFV can be driven at low gate-source voltage of 1.2 V.

3. **AEC-Q101 qualified**
   AEC-Q101 qualified and can be used for various automotive applications.

---

**Small signal package lineup**

<table>
<thead>
<tr>
<th>Power dissipation (W)</th>
<th>1.0</th>
<th>0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mounting area (mm²)</td>
<td>10</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>SSM3K7002KF</th>
<th>SSM3J168F</th>
<th>SSM3J66MFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>S-Mini (SOT-346)</td>
<td>S-Mini (SOT-346)</td>
<td>VESM (SOT-723)</td>
</tr>
<tr>
<td>(V_{DS} [V])</td>
<td>60</td>
<td>-60</td>
<td>-20</td>
</tr>
<tr>
<td>(I_D [A])</td>
<td>0.4</td>
<td>-0.4</td>
<td>-0.8</td>
</tr>
<tr>
<td>(R_{DS(ON)} \at \mid V_{GS} \mid =4.5 , V [\Omega])</td>
<td>Typ. 1.2</td>
<td>1.4</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Max 1.75</td>
<td>1.9</td>
<td>0.39</td>
</tr>
<tr>
<td>Drive voltage [V]</td>
<td>4.5</td>
<td>-4.0</td>
<td>-1.2</td>
</tr>
<tr>
<td>Polarity</td>
<td>N-ch</td>
<td>P-ch</td>
<td>P-ch</td>
</tr>
<tr>
<td>Polarity</td>
<td>N-ch</td>
<td>P-ch</td>
<td>P-ch</td>
</tr>
</tbody>
</table>

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General purpose small signal bipolar transistor
2SC2712 / 2SA1162 / 2SC4116 / 2SA1586 / TTA501 / TTC501 and others

Value provided

Extensive product lineup to meet customers’ needs.

1 Extensive lineup of packages
Various packages such as 1-in-1, 2-in-1 are provided and suitable products for circuit board design are selectable.

2 Extensive product lineup
Various product lineups, such as general purpose, low noise, low $V_{CE(sat)}$ and high current types are provided. Products can be selected in accordance to the application.

3 AEC-Q101 qualified
AEC-Q101 qualified and can be used for various automotive applications.

Characteristic examples of 2SC2712
Extensive product lineup to meet customers’ needs.

1. **Built-in bias resistor type**
   (BRT : Bias Resistor built-in Transistor)

   The BRTs contribute to reduction of the number of components, assembly workload and mounting area of circuit boards.

2. **Extensive lineup of package and pin assignment**

   Various package lineups, such as 1-in-1, 2-in-1 and various pin assignment type are provided and suitable products for circuit board design are selectable.

3. **AEC-Q101 qualified**

   AEC-Q101 qualified and can be used for various automotive applications.

---

### Line up

<table>
<thead>
<tr>
<th>Package</th>
<th>Part number</th>
<th>NPN (BRT)</th>
<th>PNP (BRT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES6 (SOT-563)</td>
<td>RN1907FE</td>
<td>RN2907FE</td>
<td></td>
</tr>
<tr>
<td>US6 (SOT-363)</td>
<td>RN1901</td>
<td>RN2901</td>
<td></td>
</tr>
</tbody>
</table>

- **V_{CEO} (Max) [V]**
  - 50
  - -50

- **I_{C} [mA]**
  - 100
  - -100

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A charge pump circuit for the N-channel MOSFET gate drive is built in, allowing for easy semiconductor relay configuration.

1. **Built-in charge pump circuit**
   - Built-in charge pump circuit enables N-channel MOSFET as high side switch.
   - Easy to configure a semiconductor relay.

2. **Can be controlled by logic level voltage**
   - It is possible that Direct control by output signal of MCUs or CMOS logic ICs.

3. **Small package**
   - The small surface mount packages such as PS-8, SSOP16 and WSON10A contribute to the miniaturization of equipment.

---

**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TPD7104AF</th>
<th>TPD7106F</th>
<th>TPD7107F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>PS-8 (2.8 x 2.9 mm)</td>
<td>SSOP16 (5.5 x 6.4 mm)</td>
<td>WSON10A (3 x 3 mm)</td>
</tr>
</tbody>
</table>
| Features    | • Operating power supply voltage range: 5 to 18 V  
• Built-in power supply reverse connection protection function  
(Supported for power supply reverse connection protection MOSFET applications) | • Operating power supply voltage range: 4.5 to 27 V  
• Built-in power supply reverse connection protection function  
(Supported for power supply reverse connection protection MOSFET applications) | • Operating power supply voltage range: 5.75 to 26 V  
• Current sense output  
• Protective functions; overcurrent, overtemperature, GND disconnect etc.  
• Reverse battery connection  
• Diagnosis output; overcurrent, load open, overtemperature etc. |

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