Automotive DC-DC Converter

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
Automotive DC-DC Converter (Isolated)

- High Voltage Battery (~400V)
- Low Voltage Battery (12V)
- Battery Reverse Protection/Load Switch
- Insulated Driver
- Insulated Driver
- Control Circuit
- Insulated Feedback
- CAN Line
- TVS
Automotive DC-DC Converter (Non-Isolated buck type)
Automotive DC-DC Converter (Non-Isolated boost type)
Device selection points
- It is necessary to select the product with the optimum current rating for each application.
- It is necessary to select a small surface mount package suitable for miniaturization of the ECU.
- Current feedback circuit to the MCU should be low power consumption.

Proposals from Toshiba
- Low power consumption of the system is realized by low on-resistance U-MOS series 100V N-ch power MOSFET
- Photocouplers with excellent environmental resistance Transistor output photocoupler
- Both device protection and signal quality is realized TVS diode (for CAN communication)

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
DC-DC converter circuits (non-isolated boost / buck types)

**Device selection points**
- It is necessary to select the product with the optimum current rating for each application.
- It is necessary to select a gate driver according to the performance of the switching device to be driven.
- It is necessary to select a small surface mount package suitable for miniaturization of the ECU.

**Proposals from Toshiba**
- Low power consumption of the system is realized by low on-resistance
  U-MOS series 100V N-ch power MOSFET
  U-MOS series 40V N-ch power MOSFET

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
SW for power supply ON/OFF control and reverse connection protection (1)

Power supply ON/OFF control and reverse connection protecting circuit (N-ch method 12V)

Battery (12V) --- Power Supply --- Gate Driver --- MCU --- Internal control circuit

- ON/OFF control switch
- Power supply reverse protection

Gate Driver:

1. General-purpose small-signal MOSFET
2. General-purpose small-signal bipolar transistor
3. General-purpose small-signal bias resistor built-in transistor (BRT)
4. One-gate logic (L-MOS)

Device selection points
- It is necessary to select the product with the optimum current rating for each application.
- It is necessary to select a gate driver according to the performance of the switching device to be driven.
- It is necessary to select a small surface mount package suitable for miniaturization of the ECU.

Proposals from Toshiba
- Low power consumption of the system is realized by low on-resistance
  U-MOS series 40V N-ch power MOSFET
- Gate driver with protection diagnostic function
  Gate driver (for switch)
- Various product lineups and small packages
  General-purpose small-signal MOSFET
  General-purpose small-signal bipolar transistor
  General-purpose small-signal bias resistor built-in transistor (BRT)
  One-gate logic (L-MOS)
- Both device protection and signal quality is realized
  TVS diode (for CAN communication)

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
SW for power supply ON/OFF control and reverse connection protection (2)

Power supply ON/OFF control and reverse connection protecting circuit (N-ch method 48V)

Device selection points
- It is necessary to select the product with the optimum current rating for each application.
- It is necessary to select a gate driver according to the performance of the switching device to be driven.
- It is necessary to select a small surface mount package suitable for miniaturization of the ECU.

Proposals from Toshiba
- Low power consumption of the system is realized by low on-resistance
  U-MOS series 100V N-ch power MOSFET
- Various product lineups and small packages
  General-purpose small-signal MOSFET
  General-purpose small-signal bipolar transistor
  General-purpose small-signal bias resistor built-in transistor (BRT)
  One-gate logic (L-MOS)
- Both device protection and signal quality is realized
  TVS diode (for CAN communication)

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page

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Recommended Devices
Device solutions to address customer needs

As described above, in the design of Automotive DC-DC Converters, “Improvement of reliability”, “Reduction of power consumption” and “Miniaturization” are important factors. Toshiba’s proposals are based on these three solution perspectives.

- Protection and diagnosis
  - Improvement of reliability
- Reduction of power consumption
  - High efficiency
  - Low loss
- Miniaturization
  - Small size package
Device solutions to address customer needs

<table>
<thead>
<tr>
<th></th>
<th>Protection and diagnosis</th>
<th>High efficiency - Low loss</th>
<th>Small size package</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>U-MOS series 100V N-ch power MOSFET</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>2</td>
<td>Transistor output photocoupler</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>3</td>
<td>TVS diode (for CAN communication)</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>4</td>
<td>U-MOS series 40V N-ch power MOSFET</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>5</td>
<td>Gate driver (for switch)</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>6</td>
<td>General-purpose small-signal MOSFET</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>7</td>
<td>General-purpose small-signal bipolar transistor</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>8</td>
<td>Small-signal bias resistor built-in transistor (BRT)</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>9</td>
<td>One-gate logic (L-MOS)</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>
Low loss (reduced chip resistance)

Using low chip resistance technology to contribute to reduced power consumption systems

Low on-resistance contributes to reduced system power consumption.

Small, high-heat-dissipation package

Development of low-loss, high-heat-dissipation packages by adopting a Cu connector structure

Ensuring mountability by using the Wettable Flank (WF) structure

Line up

<table>
<thead>
<tr>
<th>Part number</th>
<th>Drain current</th>
<th>On-resistance (Max) @VGS=10V</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>TK60S10N1L</td>
<td>60A</td>
<td>6.11mΩ</td>
<td>DPAK+</td>
</tr>
<tr>
<td>XPH4R10ANB</td>
<td>70A</td>
<td>4.1mΩ</td>
<td>SOP Advance(WF)</td>
</tr>
<tr>
<td>XPW4R10ANB</td>
<td>70A</td>
<td>4.1mΩ</td>
<td>DSOP Advance(WF)</td>
</tr>
<tr>
<td>TK160F10N1L</td>
<td>160A</td>
<td>2.4mΩ</td>
<td>TO-220SM(W)</td>
</tr>
<tr>
<td>TK60R10N1L</td>
<td>60A</td>
<td>6.31mΩ</td>
<td>D2PAK+</td>
</tr>
</tbody>
</table>

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Contributes to safe improvement and design miniaturization.

1. High insulation
   Non-electrical communication provides excellent insulation. Moreover, the light receiving chip is Faraday shielded and provides excellent noise resistance.

2. Small package
   A lineup of the SO4 package, reduced mounting area by 30% compared with conventional SO6 package. It contributes to reduce mounting area of the board.

3. Assurance of maximum operating temperature of 125°C
   High heat resistance package allows an operating temperature range of -40 to 125°C as well as a longer life. The TLX9000/9300 has built-in base-emitter resistor to reduce dark currents at high temperatures.

<table>
<thead>
<tr>
<th>Line up</th>
<th>Part number</th>
<th>TLX9291A / TLX9185A</th>
<th>TLX9000 / TLX9300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolation Voltage [Vrms]</td>
<td>3750</td>
<td>3750</td>
<td></td>
</tr>
<tr>
<td>Collector-emitter voltage [V]</td>
<td>80</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Dark current [nA] @Ta=125°C</td>
<td>&lt; 10 @ VCE=48V</td>
<td>&lt; 10 @ VCE=24V</td>
<td></td>
</tr>
<tr>
<td>Conversion efficiency (%) @ Ij=5mA, VCE=5V, Ta=25°C</td>
<td>50 ~ 600</td>
<td>100 ~ 600 (GB rank)</td>
<td></td>
</tr>
<tr>
<td>Conversion efficiency (saturation) (%) @ Ij=1mA, VCE=0.4V, Ta=25°C</td>
<td>&gt; 30</td>
<td>&gt; 30</td>
<td></td>
</tr>
</tbody>
</table>

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TVS diode (for CAN communication)
DF3D18FU / DF3D29FU / DF3D36FU

TVS diode absorbs static electricity (ESD) from external terminals, prevents circuit malfunction and protects devices.

1. Improve ESD absorbability
Improved absorption of ESD through our proprietary Zener process. (Both low operating resistance $R_{\text{DYN}}$ and low capacitance $C_t$)

2. Ensuring high signal integrity
Supports in-vehicle LAN communication such as CAN, CAN-FD, FlexRay. Lower capacitance ensures higher signal integrity.

3. High ESD immunity
Compliant products with ISO10605 Standard > ±20 kV
IEC61000-4-2 Standard > ±20 kV (L4)

### Capacitance between terminals vs $R_{\text{DYN}}$

![Capacitance between terminals vs $R_{\text{DYN}}$](chart.png)

### 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>$V_{\text{ESD}}$ (kV) @ISO10605</td>
<td>±30</td>
<td>±30</td>
<td>±20</td>
</tr>
<tr>
<td>$V_{\text{RMS}}$ (Max) [V]</td>
<td>12</td>
<td>24</td>
<td>28</td>
</tr>
<tr>
<td>$C_t$ (Typ./Max) [pF]</td>
<td>9 / 10</td>
<td>1.1</td>
<td>6.5 / 8</td>
</tr>
<tr>
<td>$R_{\text{DYN}}$ (Typ.) [Ω]</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 (including but not limited to constant voltage diode applications).

*1: Toshiba Electronic Devices & Storage Corporation
*2: Measurements of the commercial product

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The advanced U-MOS IX-H processes enables low on-resistance and low noise, thereby reducing power consumption.

**1 Low loss (reduced chip resistance)**

Using low chip resistance technology to contribute to reduced power consumption systems.

Chip resistance of 61% reduction per unit area (compared to UMOSIV)

**2 Compact, low-loss package**

By adopting a Cu connector structure and a double-sided heat dissipation structure,
Development of low-loss, high-heat-dissipation packages

**3 Low noise (low EMI)**

Optimized chip process, reduce surge voltage and ringing time.

---

**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>Drain current</th>
<th>On-resistance (Max) @VGS=10V</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>XPN3R804NC</td>
<td>40A</td>
<td>3.8mΩ</td>
<td>TSON Advance(WF)</td>
</tr>
<tr>
<td>TK1R4S04PB</td>
<td>120A</td>
<td>1.35mΩ</td>
<td>DPAK+</td>
</tr>
<tr>
<td>TPHR7904PB</td>
<td>150A</td>
<td>0.79mΩ</td>
<td>SOP Advance(WF)</td>
</tr>
<tr>
<td>TPWR7904PB</td>
<td>150A</td>
<td>0.79mΩ</td>
<td>DSOP Advance(WF)</td>
</tr>
<tr>
<td>TKR74F04PB</td>
<td>250A</td>
<td>0.74mΩ</td>
<td>TO-220SM(W)</td>
</tr>
<tr>
<td>TK1R5R04PB</td>
<td>160A</td>
<td>1.5mΩ</td>
<td>D2PAK+</td>
</tr>
</tbody>
</table>

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A charge pump for the FET gate drive is built-in, allowing for easy semiconductor relay configuration.

1. Built-in charge pump
   No external add-ons required for driving the N-channel on the high side, making it easy to configure a semiconductor relay.

2. Logic level drive
   Direct control is possible from microcomputer and CMOS logic.

3. Small package
   The small surface mount PS8 contributes to the miniaturization of equipment.

---

**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TPD7104AF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>High-side gate driver</td>
</tr>
<tr>
<td>Number of output</td>
<td>1 output</td>
</tr>
</tbody>
</table>

**Features**

- Operating power supply voltage range: 5 to 18 V
- Built-in charge pump
- Built-in power supply reverse connection protection function
  (Supported for power supply reverse connection protection FET applications)
Choose from a wide array of small packages which contribute to the miniaturization and reduction of power consumption of equipment.

1. **Small package**
   Starting with the SOT-723 (VESM 1.2mm\(^2\) package), a lineup of various small packages is available, contributing to space savings during mounting.

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

3. **AEC-Q101 qualified**
   AEC-Q101 qualified and can be used for a wide range of automotive applications.

### Small signal package lineup

![Small signal package lineup diagram](image)

### 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_{DSQCL}) [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_{ON@VGS=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>MOS Type</td>
<td>N-channel</td>
<td>P-channel</td>
<td>P-channel</td>
</tr>
</tbody>
</table>

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## Extensive product lineup to meet all your needs.

### 1 Extensive lineup of packages

Various package lineups, such as 1in1, 2in1 are provided and suitable product for circuit board design can be selected.

### 2 Various product lineup

Various product lineups, such as general-purpose, low-noise, low $V_{CE\text{sat}}$ and high-current types, are provided. Products can be selected depending on the application.

### 3 AEC-Q101 qualified

AEC-Q101 qualified and can be used for a wide range of automotive applications.

### Extensive product lineup

<table>
<thead>
<tr>
<th>Classification</th>
<th>$V_{CEO}$ [V]</th>
<th>$I_C$ [mA]</th>
<th>NPN</th>
<th>PNP</th>
<th>NPN</th>
<th>PNP</th>
<th>NPN</th>
<th>PNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>General purpose</td>
<td>50</td>
<td>150</td>
<td>2SC4738</td>
<td>2SA1832</td>
<td>2SC4116</td>
<td>2SA1586</td>
<td>2SC2712</td>
<td>2SA1162</td>
</tr>
<tr>
<td>Low noise</td>
<td>50</td>
<td>500</td>
<td>2SC3325</td>
<td>2SA1162</td>
<td>2SC2712</td>
<td>2SA1162</td>
<td>2SC4117</td>
<td>2SA1587</td>
</tr>
<tr>
<td>High-current</td>
<td>120</td>
<td>1700</td>
<td>2SC4117</td>
<td>2SA1587</td>
<td>2SC2713</td>
<td>2SA1163</td>
<td>2SC4117*</td>
<td>2SA1587*</td>
</tr>
</tbody>
</table>

### Line up

- **SSM (SOT-416)**
- **USM (SOT-323)**
- **UFM (SOT-323F)***
- **S-Mini (SOT-346)**

*Return to Block Diagram TOP*
Extensive product lineup to meet all your needs.

1. Built-in bias resistor type (BRT)
   The BRT reduces the number of parts contributing to miniaturization and shorter production times.

2. Extensive lineup of package and pin assignment
   Various package lineups, such as 1in1, 2in1 are provided and suitable product for circuit board design can be selected.

3. AEC-Q101 qualified
   AEC-Q101 qualified and can be used for a wide range of automotive applications.

### Line up

<table>
<thead>
<tr>
<th>Part number</th>
<th>NPN (BRT)</th>
<th>PNP (BRT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSM (SOT-416)</td>
<td>RN1114</td>
<td>RN2114</td>
</tr>
<tr>
<td>S-Mini (SOT-346)</td>
<td>RN1414</td>
<td>RN2414</td>
</tr>
<tr>
<td>$V_{CEO}$ (Max) [V]</td>
<td>50</td>
<td>-50</td>
</tr>
<tr>
<td>$I_C$ [mA]</td>
<td>100</td>
<td>-100</td>
</tr>
</tbody>
</table>

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One-gate logic (L-MOS)  
TC7SH / TC7WH / TC7SZ / TC7WZ series

**Value provided**

### Extensive product lineup to meet all your needs.

#### 1. Small package

A standard multi gate CMOS is separated into individual or dual gates and embedded in a small package. This can be suited for simpler designs and contributes to miniaturization.

#### 2. Extensive lineup

The VHS/SHS series, which is widely used in Automotive, offers a wide range of functions, including a total of 230 products.

#### 3. AEC-Q100 qualified (reliability levels)

AEC-Q100 qualified and can be used for a wide range of automotive applications.

### Line up

<table>
<thead>
<tr>
<th>Package</th>
<th>VHS series</th>
<th>SHS series</th>
</tr>
</thead>
<tbody>
<tr>
<td>USV (SOT-353)</td>
<td>TC7ZH series</td>
<td>TC7SZ series</td>
</tr>
<tr>
<td>US8 (SOT-765)</td>
<td>TC7WH Series</td>
<td>TC7WZ series</td>
</tr>
<tr>
<td>$V_{CC}$ [V]</td>
<td>2.0 ~ 5.5</td>
<td>1.65/1.8 ~ 5.5</td>
</tr>
<tr>
<td>$Io$ [mA]</td>
<td>8</td>
<td>24</td>
</tr>
</tbody>
</table>

$^{*}$ Compliant products with AEC-Q100’s reliability test only

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