Smart Plug

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
Smart Plug  Overall block diagram
Smart Plug  Detail of wireless and key switch section

Wireless and key switch input circuit

Criteria for device selection
- Since components such as key switches and antennas which may be exposed to the outside environment, ESD protection circuitry may be required.

Proposal from Toshiba
- Prevent circuit malfunctions by absorbing electrostatic discharge (ESD) from external terminals
  TVS diode

* Click on the blue circled numbers above to view detailed descriptions.
Smart Plug  Details of AC switch section (1)

**Criteria for device selection**
- Schottky barrier diodes are suitable for freewheeling diodes used in inductive loads such as relays.
- Low power AC switches can be realized using photorelays.

**Proposal from Toshiba**
- **Diodes suitable for freewheeling diodes**
  Schottky barrier diode
- **Small package and low on-resistance MOSFET**
  Small signal MOSFET
- **Designed for high AC isolation voltage**
  Photorelay

* Click on the blue circled numbers above to view detailed descriptions.
Details of AC switch section (2)

AC switch circuit using photovoltaic output photocouplers and MOSFETs (around 0.3 A to 1 A)

AC switch circuit using triac and triac output photocouplers (1 A or more)

Criteria for device selection
- Isolated AC switch can be realized using a MOSFET driven by a photovoltaic output photocoupler.
- AC switch can be realized using a triac driven by a triac output photocoupler.

Proposal from Toshiba
- Photocoupler for direct MOSFET driving
  Photovoltaic output photocoupler
- Suitable for high efficiency power switching
  DTMOS IV Series MOSFET
- Photocoupler suitable for AC control
  Triac output photocoupler

* Click on the blue circled numbers above to view detailed descriptions.
 Criteria for device selection
- For the power supply of an IC including an analog circuit such as wireless control, a low noise power supply is required for stable operation of the set.

Proposal from Toshiba
- Supply the power with low noise
Small surface mount LDO regulator

* Click on the blue circled numbers above to view detailed descriptions.
Recommended Devices
As described above, in the design of Smart Plug, “AC isolation”, “Low power consumption of set” and “Miniaturization of circuit boards” are important factors. Toshiba’s proposals are based on these three solution perspectives.
Device solutions to address customer needs

<table>
<thead>
<tr>
<th></th>
<th>High voltage • Isolation</th>
<th>High efficiency • Low loss</th>
<th>Small size packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TVS diode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Schottky barrier diode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Small signal MOSFET</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Photorelay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Photovoltaic output photocoupler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>DTMOSIV Series MOSFET</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Triac output photocoupler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Small surface mount LDO regulator</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Absorbs static electricity (ESD) from external terminals, prevents circuit malfunction and protects devices.

1 High ESD pulse absorption performance

Improved ESD absorption compared to our conventional products. (50 % reduction in operating resistance) For some products, both low operating resistance and low capacitance are realized and ensures high signal protection performance and signal quality.

2 Suppress ESD energy by low clamp voltage

Protect the connected circuits/devices using Toshiba own technology.

3 Suitable for high density mounting

A variety of compact packages are available.

**Lineup**

<table>
<thead>
<tr>
<th>Part number</th>
<th>DF2B7ASL</th>
<th>DF2B5M4SL</th>
<th>DF2B6M4SL</th>
<th>DF2B6M4BSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SL</td>
<td>SL2</td>
<td>SL</td>
<td>SL2</td>
</tr>
<tr>
<td>$V_{ESD}$ (kV)</td>
<td>±30</td>
<td>±20</td>
<td>±20</td>
<td>±8</td>
</tr>
<tr>
<td>$V_{RWM}$ (Max) [V]</td>
<td>5.5</td>
<td>3.6</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>$C_t$ (Typ.) [pF]</td>
<td>8.5</td>
<td>0.2</td>
<td>0.2</td>
<td>0.12</td>
</tr>
<tr>
<td>$R_{DYN}$ (Typ.) [Ω]</td>
<td>0.2</td>
<td>0.5</td>
<td>0.5</td>
<td>1.05</td>
</tr>
</tbody>
</table>

(Note) This device is for ESD protection only and cannot be used for purposes other than ESD protection.
Schottky barrier diode
CRS03 / CRS13

Value provided

The schottky barrier diode suitable for small equipment applications.

1 High speed switching

It is suitable for high speed switching applications.

2 Small package

This small package is suitable for high density mounting.

CRS13 Characteristics Curves

<table>
<thead>
<tr>
<th>Forward current $I_F$ (A)</th>
<th>Forward voltage $V_F$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>0</td>
</tr>
<tr>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Lineup

<table>
<thead>
<tr>
<th>Part number</th>
<th>CRS03</th>
<th>CRS13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>S-FLAT™</td>
<td></td>
</tr>
<tr>
<td>$V_{BRM}$ (V)</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>$I_{F(AV)}$ (A)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>$V_{FM}$ (Max) (V)</td>
<td>0.45</td>
<td>0.55</td>
</tr>
<tr>
<td>$I_{RBM}$ (Max) (μA)</td>
<td>100</td>
<td>50</td>
</tr>
</tbody>
</table>

Return to Block Diagram TOP
**Value provided**

**Suitable for power switching and contribute to miniaturization.**

**1 Low voltage operation**

Operates down to $V_{GS} = 1.5$ V

**2 Low on-resistance**

By reducing on-resistance between the drain and source, heat generation and power consumption can be kept low.

**Lineup**

<table>
<thead>
<tr>
<th>Part number</th>
<th>SSM3K36FS</th>
<th>SSM3K56FS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SSM</td>
<td>SSM</td>
</tr>
<tr>
<td>$V_{DS}$ [V]</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>$I_D$ [A]</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>$P_D$ [W]</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>$R_{DGON}$ (Max) [Ω] @ $V_{GS} = 4.5$ V</td>
<td>0.66</td>
<td>0.235</td>
</tr>
<tr>
<td>Polarity</td>
<td>N-ch</td>
<td>N-ch</td>
</tr>
</tbody>
</table>

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Photorelay consists of an infrared light emitting diode optically coupled to a photo-MOSFET and is suitable for replacing mechanical relays.

1. **Low on-resistance**
   - Maximum on-resistance $R_{ON}$ at turn-on is 2 Ω (at $I_{ON} = 0.6$ A).

2. **Wide range of ON current**
   - Wide range of allowed ON current $I_{ON}$ suitable for power line control (maximum 0.6 A : A connected) [Note1]

3. **Various lead forming option**
   - Lead forming options (through-hole type and lead forming options. Five total selections) allow design freedom and miniaturization of the set.

[Note1] Please refer to the technical data sheet for connection.

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### Internal equivalent circuit

- UL certified UL1577, File No. E67349
- cUL certified CSA Component Acceptance Service No.5A File No. E67349
- UL-recognized: UL 508, File No.E499232 [Note2]
- VDE-approved: EN 60747-5-5 [Note3]

[Note2] Please refer Absolute Maximum Ratings (UL-recognized UL 508) for UL 508 products.
[Note3] When a VDE approved type is needed, please designate the Option (D4).
Photovoltaic output photocoupler
TLP3906 / TLP3910

Photocoupler consists of an infrared light emitting diode optically coupled to a photo-diode array and is suitable for driving gate of MOSFET.

1 For MOSFET gate driver
Photodiode is connected in series, suitable for driving the gate of MOSFET.

2 No need to use external discharging resistor
Since the control circuit is on the detector side, there is no need to connect an external discharging resistor.

3 Improved switching speed
Maximum value of $t_{on}$ and $t_{off}$ are 1 ms and 0.5 ms, respectively. (TLP3910)

Internal equivalent circuit

UL certified UL1577, File No.E67349
cUL certified CSA Component Acceptance Service No.SA File No.E67349
VDE certified EN60747-5-5 (TLP3906/TLP3910), EN62368-1 (TLP3906) [Note]
[Note] To specify a VDE certified model, request a (V4) model

<table>
<thead>
<tr>
<th>Part number</th>
<th>TLP3906</th>
<th>TLP3910</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>4pin SO6</td>
<td>SO6L</td>
</tr>
<tr>
<td>$I_I$ [mA]</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>$V_{OC}$ (Min) [V]</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>$I_{SC}$ (Min) [$\mu$A]</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>$BV$ [Vrms]</td>
<td>3750</td>
<td>5000</td>
</tr>
<tr>
<td>Creepage distance (Min) [mm]</td>
<td>5.0</td>
<td>8.0</td>
</tr>
</tbody>
</table>

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30 % reduction in the figure of merit RonA (compared with Toshiba conventional products), improving power supply efficiency and contributing to miniaturization.

1. **RonA 30 % reduction**
   
   Adoption of newly developed single-epitaxial process to reduce the figure of merit RonA by 30 %.
   (Compared with DTMOS III products from Toshiba)

2. **Reduction of on-resistance increase at high temperature**
   
   The single epitaxial process reduces the on-resistance increase at high temperature.

3. **Optimization of switching speed**
   
   Optimization of switching speed has been achieved by reduction of $C_{oss}$ (by 12 %, compared with Toshiba conventional products) and others.

### Lineup

<table>
<thead>
<tr>
<th>Part number</th>
<th>TK8P60W</th>
<th>TK16G60W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>DPAK</td>
<td>D2PAK</td>
</tr>
<tr>
<td>$V_{oss}$ [V]</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>$I_{D}$ [A]</td>
<td>8.0</td>
<td>15.8</td>
</tr>
<tr>
<td>$P_{D}$ [W]</td>
<td>80</td>
<td>130</td>
</tr>
<tr>
<td>$C_{iss}$ (Typ.) [pF]</td>
<td>570</td>
<td>1350</td>
</tr>
<tr>
<td>$R_{ON}$ (Max) [Ω]</td>
<td>0.5</td>
<td>0.19</td>
</tr>
<tr>
<td>Polarity</td>
<td>N-ch</td>
<td>N-ch</td>
</tr>
</tbody>
</table>

(Note) Compared with Toshiba conventional products
Photocoupler suitable for AC switching.

1. **Small package (4pin SO6)**
   Thin 4pin SO6 (3.7 x 7.0 x 2.1 mm) package allows high density mounting.

2. **High isolation voltage (3750 Vrms)**
   Isolation voltage is 3750 Vrms. Insulator thickness is 0.4 mm, creepage and clearance distances are 5.0 mm. Compliant with reinforced insulation safety standards.

3. **Compatible with zero-cross output**
   Maximum output current is 70 mA. Higher output is possible using main triac connection. Zero-cross (ZC) compatible output is also available.

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### Pin layout

- **TLP265J / TLP267J**
  - 1. Anode
  - 3. Cathode
  - 4. Triac pin
  - 6. Triac pin

- **TLP266J / TLP268J**
  - 1. Anode
  - 3. Cathode
  - 4. Triac pin
  - 6. Triac pin

### Lineup

<table>
<thead>
<tr>
<th>Part number</th>
<th>TLP265J</th>
<th>TLP266J</th>
<th>TLP267J</th>
<th>TLP268J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>4pin SO6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Type</td>
<td>Non-ZC</td>
<td>ZC</td>
<td>Non-ZC</td>
<td>ZC</td>
</tr>
<tr>
<td>V_{DRM} [V]</td>
<td>600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_{T (Max)} [mA]</td>
<td>10</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_{TRMS} [mA]</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B_{VZ} [Vrms]</td>
<td>3750</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Return to Block Diagram TOP*
Wide lineup from general purpose type to small package type are provided. Contribute to realize a stable power supply not affected by fluctuation of battery.

1. **Low dropout voltage**
   - The originally developed latest process significantly improved the dropout voltage characteristics.

2. **High PSRR Low output noise voltage**
   - Many product series that realize both high PSRR (Power Supply Rejection Ratio) and low output noise voltage characteristics are provided. They are suitable for stable power supply for analog circuit.

3. **Low current consumption**
   - 0.34 μA of \( I_{B\text{(ON)}} \) is realized by utilizing CMOS process and unique circuit technology. (TCR3U Series)

### Lineup

<table>
<thead>
<tr>
<th>Part number</th>
<th>TCR15AG Series</th>
<th>TCR13AG Series</th>
<th>TCR8BM Series</th>
<th>TCR5BM Series</th>
<th>TCR5RG Series</th>
<th>TCR3RM Series</th>
<th>TCR3U Series</th>
<th>TCR2L Series</th>
<th>TAR5 Series</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Features</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low dropout voltage</td>
<td>Low voltage</td>
<td>High PSRR</td>
<td>High PSRR Low noise</td>
<td>Low current consumption</td>
<td>15 V input voltage</td>
<td>Bipolar type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{\text{OUT}} (\text{Max}) ) [( \text{A} )]</td>
<td>1.5</td>
<td>1.3</td>
<td>0.8</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSRR (Typ.) [dB] ( \text{at} \ f = 1 \text{kHz} )</td>
<td>95</td>
<td>90</td>
<td>98</td>
<td>98</td>
<td>100</td>
<td>100</td>
<td>70</td>
<td>-</td>
<td>70</td>
</tr>
<tr>
<td>( I_{B} (\text{Typ.}) ) [( \mu\text{A} )]</td>
<td>25</td>
<td>56</td>
<td>20</td>
<td>19</td>
<td>7</td>
<td>7</td>
<td>0.34</td>
<td>1</td>
<td>170</td>
</tr>
</tbody>
</table>

Note: Toshiba internal comparison

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