Automotive LED Headlamp

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
LED Headlamp  Overall block diagram

- Battery (12 V)
- CAN Line
- TVS
- Power Supply
- Reverse Battery Protection / Load Switch
- DC-DC Converter
- MCU
- Driver
- Internal Control Circuit
- Signal Conditioning Circuit
- MCU Driver
- Current Monitor Circuit
- LED Lighting Circuit Part
  - Matrix Control Circuit
    - DRL, High Beam, Low Beam, Other Lights
    - Other Lighting Systems with ADAS (e.g. AFS)
Criteria for device selection
- It is necessary to select the product with the suitable 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.
- The dead time must be considered to prevent the occurrence of shoot through current.

Proposal from Toshiba
- **Low power consumption of the system is realized by low on-resistance**
  - U-MOS Series 100 V N-ch MOSFET
  - U-MOS Series 60 V N-ch MOSFET

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
Criteria for device selection
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Proposal from Toshiba
- Low power consumption of the system is realized by low on-resistance Semi-power MOSFET

LED matrix control circuit (1)

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
Low power consumption of the system is realized by low on-resistance Semi-power MOSFET

Various product lineups and small packages
Small signal bias resistor built-in transistor (BRT)

Criteria for device selection
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* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
LED Headlamp Switch for power supply ON/OFF control and reverse connection protection (1)

**Power supply ON/OFF control and reverse connection protection circuit (P-ch type)**

![Circuit Diagram]

**Criteria for device selection**
- It is necessary to select the product with the suitable 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 -40 V / -60 V P-ch MOSFET
- Various product lineups and small packages
  - General purpose small signal MOSFET
  - General purpose small signal bipolar transistor
  - Small signal bias resistor built-in transistor (BRT)
- Both device protection and signal quality are realized
  - TVS diode (for CAN communication)

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

**Power supply ON/OFF control and reverse connection protection circuit (N-ch type)**

```
<table>
<thead>
<tr>
<th>Battery (12 V)</th>
<th>CAN Line</th>
<th>Power Supply</th>
<th>Gate Driver</th>
<th>Internal control circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

**Criteria for device selection**
- It is necessary to select the product with the suitable 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 40 V N-ch 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  
  Small signal bias resistor built-in transistor (BRT)
- **Both device protection and signal quality are realized**  
  TVS diode (for CAN communication)

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
Recommended Devices
Device solutions to address customer needs

As described above, in the design of LED headlamp, “Improvement of reliability”, “Reduction of power consumption” 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>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 100 V N-ch MOSFET</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>2</td>
<td>U-MOS Series 60 V N-ch MOSFET</td>
<td>✔️</td>
<td>✔️</td>
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<tr>
<td>3</td>
<td>Semi-power MOSFET</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>4</td>
<td>U-MOS Series -40 V / -60 V P-ch MOSFET</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>5</td>
<td>TVS diode (for CAN communication)</td>
<td></td>
<td>☑️</td>
</tr>
<tr>
<td>6</td>
<td>General purpose small signal bipolar transistor</td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>7</td>
<td>Small signal bias resistor built-in transistor (BRT)</td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>8</td>
<td>U-MOS Series 40 V N-ch MOSFET</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>9</td>
<td>Gate driver (for switch)</td>
<td>✗</td>
<td>✔️</td>
</tr>
<tr>
<td>10</td>
<td>General purpose small signal MOSFET</td>
<td></td>
<td>✔️</td>
</tr>
</tbody>
</table>
1 Low loss (reduced on-resistance)

Using low on-resistance technology to contribute to reduced power consumption systems.
On-resistance per unit area has been reduced by 18%.
(compared to Toshiba’s U-MOS VIII-H products)

Low loss: RonA reduction trend

2 Small and high power dissipation package

The small and high power dissipation packages are developed by adopting Cu clip or Cu connector structure.
Wettable Flank (WF) package contributes to good mountability.

Lineup

<table>
<thead>
<tr>
<th>Part number</th>
<th>Rated drain current [A]</th>
<th>On-resistance (Max) [mΩ] @VGS = 10 V</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>XPN1300ANC</td>
<td>30</td>
<td>13.3</td>
<td>TSON Advance(WF)</td>
</tr>
<tr>
<td>XPN2400ANC*</td>
<td>(20)</td>
<td>(23.5)</td>
<td>DPAK+</td>
</tr>
<tr>
<td>TK60S10N1L</td>
<td>60</td>
<td>6.11</td>
<td>DPAK+</td>
</tr>
<tr>
<td>XPH4R10ANB</td>
<td>45</td>
<td>6.3</td>
<td>SOP Advance(WF)</td>
</tr>
<tr>
<td>XPH6R30ANB</td>
<td>45</td>
<td>6.3</td>
<td>SOP Advance(WF)</td>
</tr>
<tr>
<td>XPW4R10ANB</td>
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<td>6.3</td>
<td>SOP Advance(WF)</td>
</tr>
<tr>
<td>XPW6R30ANB</td>
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<td>6.3</td>
<td>SOP Advance(WF)</td>
</tr>
<tr>
<td>XPQ1R00AQB*</td>
<td>(300)</td>
<td>(1.03)</td>
<td>L-TOGTM</td>
</tr>
</tbody>
</table>

* : Under Development (Values enclosed in parentheses are tentative specifications. The specification is subject to change without notice.)

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Value provided

Low on-resistance contributes to reduce system power consumption.

1. Low loss (reduced on-resistance)

Using a low on-resistance technology contributes to reduce system power consumption.
The on-resistance per area is reduced by 40%.
(compared to Toshiba's U-MOS IV products)

Low loss: RonA reduction trend

Large current, small size, high power dissipation package

- DPAK+ (6.5 x 9.5 mm) Up to 90 A
- SOP Advance(WF) (5 x 6 mm) Up to 100 A
- TSON Advance(WF) (3 x 3 mm) Up to 40 A

(Note: Comparison with Toshiba products)

2. Small and high power dissipation package

By adopting a Cu connector structure, a high power dissipation package is realized.
Wettable Flank (WF) package contributes to good mountability.

Lineup

<table>
<thead>
<tr>
<th>Part number</th>
<th>Rated drain current [A]</th>
<th>On-resistance (Max) [mΩ] @VGS = 10 V</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>XPN12006NC</td>
<td>20</td>
<td>12.0</td>
<td>TSON Advance(WF)</td>
</tr>
<tr>
<td>XPN6R706NC</td>
<td>40</td>
<td>6.7</td>
<td>TSON Advance(WF)</td>
</tr>
<tr>
<td>XPH3R206NC</td>
<td>70</td>
<td>3.2</td>
<td>SOP Advance(WF)</td>
</tr>
<tr>
<td>XPH2R106NC</td>
<td>110</td>
<td>2.1</td>
<td>SOP Advance(WF)</td>
</tr>
<tr>
<td>TK90S06N1L</td>
<td>90</td>
<td>3.3</td>
<td>DPAK+</td>
</tr>
</tbody>
</table>

(Wettable Flank (WF) structure)

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Low on-resistance, small and high power dissipation packages contribute to miniaturization and low power consumption of the systems.

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

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

2. **Small and high power dissipation package**

Small and high power dissipation packages contribute to space saving during mounting. TSOP6F (2.9 x 2.8 mm)

3. **AEC-Q101 qualified**

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

### Power dissipation per area

- **Pw-Mini**
- **SOT-23F**
- **TSOP6F**

### Lineup

<table>
<thead>
<tr>
<th>Part number</th>
<th>SSM6K810R</th>
<th>SSM6K809R</th>
<th>SSM6K804R</th>
<th>SSM6J808R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_{DS} [V]</td>
<td>100</td>
<td>60</td>
<td>40</td>
<td>-40</td>
</tr>
<tr>
<td>I_{d} [A]</td>
<td>3.5</td>
<td>6</td>
<td>12</td>
<td>-7</td>
</tr>
<tr>
<td>R_{DS(ON)} [mΩ]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>@</td>
<td>V_{GDS}</td>
<td>= 4.5 V</td>
<td>65</td>
<td>36</td>
</tr>
<tr>
<td>Polarity</td>
<td>N-ch</td>
<td>N-ch</td>
<td>N-ch</td>
<td>P-ch</td>
</tr>
</tbody>
</table>

(Note: Comparison with Toshiba products)
Low on-resistance contributes to reduce system power consumption.

1. **Low loss (reduced on-resistance) and logic level drive**

Using a low on-resistance technology contributes to reduce system power consumption. A lineup of logic level drive type is supported. The on-resistance per area is reduced by 60% (compared to Toshiba’s U-MOSⅢ products).

![Low loss: RonA reduction trend](image)

<table>
<thead>
<tr>
<th>RonA @ Chip</th>
<th>Low on-resistance contributes to reduce system power consumption.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RonA @ Chip</td>
<td>Reduced on-resistance per area by 60% compared to Toshiba’s U-MOSⅢ products.</td>
</tr>
</tbody>
</table>

Large current, small size, high power dissipation package

- **DPAK+ (6.5 x 9.5 mm)**
  - Up to 90 A

- **SOP Advance(WF) (5 x 6 mm)**
  - Up to 100 A

- **TSON Advance(WF) (3 x 3 mm)**
  - Up to 40 A

2. **Small and low loss packages**

By adopting a Cu connector structure, a low loss and high power dissipation package is realized. Wettable Flank (WF) package contributes to good mountability.

![Small and low loss packages](image)

<table>
<thead>
<tr>
<th>Part number</th>
<th>Rated drain-source voltage [V]</th>
<th>Rated drain current [A]</th>
<th>On-resistance (Max) [mΩ] @VGS = -10 V</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>XPN9R614MC</td>
<td>-40</td>
<td>-40</td>
<td>9.6</td>
<td>TSON Advance(WF)</td>
</tr>
<tr>
<td>XPH3R114MC</td>
<td>-40</td>
<td>-100</td>
<td>3.1</td>
<td>SOP Advance(WF)</td>
</tr>
<tr>
<td>XPH8R316MC*</td>
<td>-60</td>
<td>(-90)</td>
<td>(8.3)</td>
<td></td>
</tr>
<tr>
<td>TJ90S04M3L</td>
<td>-40</td>
<td>-90</td>
<td>4.3</td>
<td>DPAK+</td>
</tr>
</tbody>
</table>

* Under development (Values enclosed in parentheses are tentative specifications. Specifications are subject to change without notice.)

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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. (Achieving 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**

   - $V_{\text{ESD}} > \pm 30 \text{ kV} @ \text{ISO 10605}$
   - $V_{\text{ESD}} > \pm 20 \text{ kV} @ \text{IEC 61000-4-2 (Level 4)}$

---

**Lineup**

<table>
<thead>
<tr>
<th>Part number</th>
<th>DF3D18FU</th>
<th>DF3D29FU</th>
<th>DF3D36FU</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Packaage</strong></td>
<td>USM (SOT-323)</td>
<td>USM (SOT-323)</td>
<td>USM (SOT-323)</td>
</tr>
<tr>
<td>$V_{\text{ESD}}$ [kV] @ISO 10605</td>
<td>±30</td>
<td>±30</td>
<td>±20</td>
</tr>
<tr>
<td>$V_{\text{RWM}}$ (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>6.5 / 8</td>
<td></td>
</tr>
<tr>
<td>$R_{\text{DYN}}$ (Typ.) [$\Omega$]</td>
<td>0.8</td>
<td>1.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

(Note) The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted. This product is an ESD protection diode and cannot be used for purposes other than ESD protection.

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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 with the application.

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

Characteristic examples of 2SC2712

<table>
<thead>
<tr>
<th>Classification</th>
<th>$V_{CEO}$ [V]</th>
<th>$I_C$ [mA]</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>General purpose</td>
<td>50</td>
<td>150</td>
<td>2SC4116</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>500</td>
<td>2SC2712</td>
</tr>
<tr>
<td>Low noise</td>
<td>120</td>
<td>100</td>
<td>2SC4117</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>1700</td>
<td>2SC2195*</td>
</tr>
<tr>
<td>High current</td>
<td>50</td>
<td>2000</td>
<td>TTA501</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>2500</td>
<td>TTC501</td>
</tr>
</tbody>
</table>

* indicates UFM package

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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.

### Lineup

<table>
<thead>
<tr>
<th>Package</th>
<th>Part number</th>
<th>NPN (BRT)</th>
<th>PNP (BRT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESG (SOT-563)</td>
<td>RN1907FE</td>
<td>RN2907FE</td>
<td></td>
</tr>
<tr>
<td>USG (SOT-363)</td>
<td>RN1901</td>
<td>RN2901</td>
<td></td>
</tr>
<tr>
<td>$V_{CEO}$ [V]</td>
<td>50</td>
<td>-50</td>
<td></td>
</tr>
<tr>
<td>$I_C$ [mA]</td>
<td>100</td>
<td>-100</td>
<td></td>
</tr>
</tbody>
</table>

*Return to Block Diagram TOP*
The latest processes enables low on-resistance and low noise, thereby reducing power consumption.

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

   Using low on-resistance technology to contribute to reduced power consumption systems.
   On-resistance of 44 % reduction per unit area.
   *(compared to Toshiba’s U-MOSⅧ-H products)*

2. **Small and low loss package**

   By adopting a Cu clip structure and a double-sided heat dissipation structure, low loss and high heat dissipation are realized.
   Wettable Flank (WF) package contributes to good mountability.

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

   Improved chip process reduces surge voltage and ringing time.

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**Value provided**

**U-MOS Series 40 V N-ch MOSFET**

XPN3R804NC / TK1R4S04PB / XPHR7904PS / TPWR7904PB / XPJ6604PB* / XPQR3004PB

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**Lineup**

- **Part number**
- **Rated drain current [A]**
- **On-resistance (Max) [mΩ] @ VGS = 10 V**
- **Package**

<table>
<thead>
<tr>
<th>Part number</th>
<th>Rated drain current [A]</th>
<th>On-resistance (Max) [mΩ] @ VGS = 10 V</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>XPN3R804NC</td>
<td>40</td>
<td>3.8</td>
<td>TSON Advance(WF)</td>
</tr>
<tr>
<td>TK1R4S04PB</td>
<td>120</td>
<td>1.35</td>
<td>DPAK+</td>
</tr>
<tr>
<td>XPHR7904PB</td>
<td>150</td>
<td>0.79</td>
<td>SOP Advance(WF)</td>
</tr>
<tr>
<td>TPWR7904PB</td>
<td>150</td>
<td>0.79</td>
<td>DSOP Advance(WF)L</td>
</tr>
<tr>
<td>XPJ6604PB*</td>
<td>(200)</td>
<td>(0.66)</td>
<td>S-TOGLTM</td>
</tr>
<tr>
<td>XPQR3004PB</td>
<td>400</td>
<td>0.30</td>
<td>L-TOGLTM</td>
</tr>
</tbody>
</table>

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*: Under development (Values enclosed in parentheses are tentative specifications. Specifications are subject to change without notice.)

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A charge pump circuit for the N-ch 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-ch MOSFET as high side switch. Easy to configure a semiconductor relay.

**2 Can be controlled by logic level voltage**
It is possible to be controlled directly 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.

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**Gate driver (for switch)**
TPD7104AF / TPD7106F / TPD7107F

**Lineup**

<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>
<tr>
<td>Function</td>
<td>High side gate driver</td>
<td>High side gate driver</td>
<td>High side gate driver</td>
</tr>
<tr>
<td>Output</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Features**
- Operating power supply voltage range: 5 to 18 V
- Built-in power supply reverse connection protection function
  (Protective MOSFET control with back-to-back circuitry)
- Operating power supply voltage range: 4.5 to 27 V
- Built-in power supply reverse connection protection function
  (Protective MOSFET control with back-to-back circuitry)
- 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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General purpose small signal MOSFET
SSM3K7002KF / SSM3J168F / SSM3J66MFV

Value provided

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>Mounting area (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Small packages lineup (Small signal device)

SSM3K7002KF / SSM3J168F / SSM3J66MFV

<table>
<thead>
<tr>
<th>Lineup</th>
<th>SSM3K7002KF</th>
<th>SSM3J168F</th>
<th>SSM3J66MFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part number</td>
<td>S-Mini (SOT-346)</td>
<td>S-Mini (SOT-346)</td>
<td>VESM (SOT-723)</td>
</tr>
<tr>
<td>V_DSS [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_DSONG @[V_GS] = 4.5 V [Ω]</td>
<td>1.2 Typ.</td>
<td>1.4</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>1.75 Max</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>
</tbody>
</table>

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