BLDC: Brushless Motor

Proposal for Electric Motor Applications

Toshiba Electronic Devices & Storage Corporation
2021.September
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02 Motor Applications
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04 Power Devices
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01

Overview of Toshiba Electronic Devices & Storage Corporation
Toshiba Group Organization

(April, 2021)

Toshiba Corp.
FY19 Sales
3,390 billion yen

President & CEO
Satoshi Tsunakawa

Finance
Common R&D
Strategy

R&D Center

Electronic Devices & Storage
Toshiba Electronic Devices & Storage Corp.
FY19 Sales
746 billion yen
* incl. NuFlare Technology, Toshiba Materials and Toshiba Hokuto Electronics

Infrastructure
Toshiba Infrastructure Systems Corp.
FY19 Sales
1,796 billion yen
* incl. Toshiba TEC, Battery and Building Solutions businesses

ICT Solutions
Toshiba Digital Solutions Corp.
FY19 Sales
252 billion yen

Energy
Toshiba Energy Systems Corp.
FY19 Sales
569 billion yen
Toshiba Electronic Devices & Storage Corp. Organization

# of employee: 24,100 (consolidated), 4,000 (non-consolidated), as of September 30, 2020

(April, 2021)
Toshiba Elec. Devices & Storage’s Consolidated Sales Revenues & OPs

(Forecasts/results announced on February 12, 2021)

(billion yen)

<table>
<thead>
<tr>
<th>FY18 (Core sales)</th>
<th>FY19 (Core sales)</th>
<th>FY20 (Core sales)</th>
</tr>
</thead>
<tbody>
<tr>
<td>933.0</td>
<td>769.4</td>
<td>828.0</td>
</tr>
<tr>
<td>354.9</td>
<td>309.7</td>
<td>346.0</td>
</tr>
<tr>
<td>578.1</td>
<td>459.7</td>
<td>3,160</td>
</tr>
</tbody>
</table>

** HDD & Others**
** Semiconductor**

* Discrete, System LSI and NuFlare Technology  ** HDD, Materials & Devices, and resale * 9.8 billion yen impairment for NFT, triggered by a decline in its stock price is included in FY18, and 4.9 billion yen and 8.0 billion yen restructuring costs in FY19 and FY20 respectively.

Net Sales

Operating Incomes

(billion yen)

<table>
<thead>
<tr>
<th>FY18 (Core OP)</th>
<th>FY19 (Core OP)</th>
<th>FY20 (Core OP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3%</td>
<td>11.5</td>
<td>1.8%</td>
</tr>
<tr>
<td>12.5</td>
<td>10.8</td>
<td>30.0</td>
</tr>
<tr>
<td>0.2</td>
<td>12.3</td>
<td>1.7%</td>
</tr>
<tr>
<td>15.0</td>
<td>12.1</td>
<td>12.0</td>
</tr>
</tbody>
</table>

** HDD & Others**
** Semiconductor**
** ROS **

Note: Core Sales (OP) means sales revenue and operating income excluding restructuring cost, etc. and impact of COVID-19.

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Our Solution for Customers

Broad product offering that solves customers’ problems

Discrete Semiconductors
- Small signal device
- Power device
- Opto device

System Devices (System LSIs)
- Analog IC
- MCU

Storage Products
- Enterprise HDD
- Consumer HDD
Focus Areas

● Industrial
  - Power Device (MOSFET, SiC, etc.)
  - Opto device (Photocoupler, etc.)
  - Motor driver
  - Linear Image Sensor
  - Semiconductor Manufacturing Equipment
  - Thermal Print Head

● Automotive
  - Motor driver
  - Power Device (MOSFET, IGBT, etc.)
  - Photocoupler
  - Bridge IC
  - Fine Ceramics

● Data Center
  - Large Capacity Nearline HDD
  - Power Device for Power Supply
  - etc.
02

Motor Applications
Toshiba Motor control technologies

Over 40 years’ experience in the semiconductor market and high-power electronics is Toshiba’s strength. We can offer new system solutions across many applications.

Home appliance
- A/C, Ref., W/M
- BLDC Motor
- Fan
- Cleaner
- Stepping Motors
- Brushed DC Motors

Automotive
- Large Motors
  - Main Motors for EV/HEV
- Medium-sized Motors
  - Blower Motors, cooling fans, and Motors for electric doors, electric power steering (EPS)
- Small Motors
  - Oil pumps, fuel pumps, water pumps, mirrors, and electronic throttles

Industry
- BLDC Motor
- AGV, Garden tool, Robotics, Fan, Power tool, printer
- In-vehicle equipment
  - Analog devices
  - ASICs/ASSPs
- MOSFET/IGBT/IPD
- Motor control driver

- Stepping Motors
Motor Control IC Line-up & Toshiba Proposals

Toshiba Provides All Necessary ICs for Motor Control Based on General Motor Control Structure

Motor Control Structure

- **Control Devices**
  - **Microcontroller Unit**
    1. System Development TAT Improvement
    2. High Efficiency Motor Control
    3. Cost Down & Downsizing
  - **Motor Control Driver**
    1. Low Power Consumption
    2. Wide Line-up
    3. Reduction of Complex Adjustment Work
  - **Power Devices**
    - **Discrete IGBT**
      1. Low Power Consumption
      2. Reduction of Short-circuit Current
      3. Low Emission Noise
    - **Low Voltage MOSFET**
      1. High Efficiency (Energy Saving)
      2. Wide Line-up
      3. Ease of Use
    - **High Voltage MOSFET**
      1. For Power Factor Correction (PFC) : DTMOS Series
      2. For Motor Drive & Inverter Circuits : MOSFET Series with Fast Reverse Recovery Diode
      3. For Switching Devices in Primary Side of Auxiliary Power Supplies : High-voltage MOSFET Series

- **HVIPD**
  1. Reduces Power Consumption (Loss)
  2. Eliminates Need for Power Supply for High-side Drive
  3. Reduces Acoustic Noise

- **System Control**
- **Motor Control**
- **Gate Driver**
- **Output Stage**
### AC-Power-Input Applications

Toshiba provides best products from wide variety of lineup according to each application.

#### Air conditioner

<table>
<thead>
<tr>
<th>Request to application</th>
<th>Request to semiconductor</th>
<th>Slot</th>
<th>Recommended products</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency (energy savings) →</td>
<td>Low power consumption device</td>
<td>①</td>
<td>M4K, M3H, M470, M370 groups</td>
<td>Efficient development, high-efficiency Motor control, cost reduction, compact size</td>
</tr>
<tr>
<td>Silent &amp; low vibration →</td>
<td>Sine-wave drive</td>
<td>②</td>
<td>TB6584, TC78B041, TC78B042, TB67B000A</td>
<td>Silent operation by 3-Phase &amp; sine-wave drive</td>
</tr>
<tr>
<td>Durability →</td>
<td>Low noise</td>
<td>②'</td>
<td>TC78B002</td>
<td>Single-Phase drive &amp; small package</td>
</tr>
<tr>
<td>Compact →</td>
<td>Small package</td>
<td>③</td>
<td>HVIPD (square-wave &amp; sine-wave)</td>
<td>Low power consumption, simplified design, Silent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>④</td>
<td>HVMOS (DTMOS IV・VI-H 600 to 650V)</td>
<td>Low conduction &amp; switching loss, durability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>⑤</td>
<td>D-IGBT for Motor (600 to 650V)</td>
<td>Low power loss, durability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>⑥</td>
<td>Small signal device (eFUSE IC, LDO, MOSFET etc)</td>
<td>Small package, accuracy, wide variety of lineup</td>
</tr>
<tr>
<td></td>
<td></td>
<td>⑦</td>
<td>Photo coupler (Tr/Triac output)</td>
<td>High conversion ratio, high temperature operation guaranteed</td>
</tr>
</tbody>
</table>

#### Refrigerator

#### Washing machine

DC24/48V or Li-ion Battery Application

Improve Application performance by best product offering for DC/battery voltage

Cordless power tool

AGV

Sever fan (24/48V bus)

<table>
<thead>
<tr>
<th>Request to application</th>
<th>Request to semiconductor</th>
<th>Slot</th>
<th>Recommended products</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-time operation →</td>
<td>Low power loss, high-efficiency drive</td>
<td>①</td>
<td>M4K, M3H, M470, M370 groups</td>
<td>Efficient development, high-efficiency Motor control, cost reduction, compact size</td>
</tr>
<tr>
<td>Silent &amp; low vibration →</td>
<td>Sine-wave drive</td>
<td>②</td>
<td>Gate Driver (under development)</td>
<td>High voltage, Lineup by internal Reg/current sense/IF</td>
</tr>
<tr>
<td>Durability →</td>
<td>Vector engine</td>
<td>②'</td>
<td>TC78B025/027/009</td>
<td>Stable operation with closed loop control</td>
</tr>
<tr>
<td>Large torque →</td>
<td>Low noise</td>
<td>③</td>
<td>LVIPD for BLDC Motor</td>
<td>Protection &amp; diagnosis function in small package</td>
</tr>
<tr>
<td>High-speed rotation control →</td>
<td>Large-current power device</td>
<td>④</td>
<td>LVMOS U-MOS IX,X-H (30 to 100V)</td>
<td>Low conduction &amp; switching loss, durability</td>
</tr>
<tr>
<td>Compact &amp; light →</td>
<td>High-efficiency control(vector control)</td>
<td>⑥</td>
<td>Small signal device (eFUSE IC, LDO, MOSFET etc)</td>
<td>Small package, accuracy, wide variety of lineup</td>
</tr>
<tr>
<td>Large capacity →</td>
<td>High speed switching</td>
<td>⑦</td>
<td>Photo coupler (Tr/Triac output)</td>
<td>High conversion ratio, high temperature operation guaranteed</td>
</tr>
</tbody>
</table>

# Proposal from Toshiba Electronic Devices & Storage Corporation

## Best product offering for wide variety of AC/DC input voltage.

<table>
<thead>
<tr>
<th>Input</th>
<th>Input voltage</th>
<th>Application</th>
<th>Solution</th>
<th>Recommended product series</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Single-Phase 100 to 120V</td>
<td>Air conditioner, Refrigerator, Washing machine</td>
<td><strong>MCU</strong>+<strong>HVIPD</strong>&lt;br&gt;<strong>MCD</strong>+<strong>HVIPD</strong>&lt;br&gt;<strong>MCU</strong>+<strong>Pre driver</strong>+<strong>HVMOS/IGBT</strong></td>
<td><strong>MCU</strong>: M4K, M3H, M470, M370&lt;br&gt;<strong>MCD</strong>: TB6584・TC78B041/042 (Controller)&lt;br&gt; TB67B000A (600V/2A)&lt;br&gt; TC78B002 (for REF Fan, 12V)&lt;br&gt; <strong>HVIPD</strong>: Square-wave &amp; sine-wave&lt;br&gt; <strong>HVMOS</strong>: DTMOSIV・VI-H (600 to 650V)&lt;br&gt; <strong>IGBT</strong>: IGBT for Motor (600 to 650V)</td>
</tr>
<tr>
<td></td>
<td>Single-Phase 200 to 240V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3-Phase 200 to 240V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC</td>
<td>DC24/48V or Li-ion battery</td>
<td>AGV, Power tool for Garden, E-bicycle, Sever fan, Cordless power tool, Cordless cleaner, Robot cleaner, Amusement device, Printer, Security camera</td>
<td><strong>MCD</strong>&lt;br&gt;<strong>MCU</strong> + <strong>LVIPD</strong>&lt;br&gt;<strong>MCU</strong> + <strong>Pre driver</strong>+<strong>LVMOS</strong></td>
<td><strong>MCU</strong>: M4K, M3H, M470, M370&lt;br&gt;<strong>MCD</strong>: High-Voltage gate driver&lt;br&gt; TC78B025/027/009 (for sever)&lt;br&gt; TB67B001・TB67H450 (for robot cleaner)&lt;br&gt; <strong>LVIPD</strong>: Low-voltage gate driver&lt;br&gt; <strong>LVMOS</strong>: U-MOSⅧ・Ⅸ・X-H (30 to 100V)</td>
</tr>
</tbody>
</table>

03

3-Phase BLDC Motor Control Devices
MCD: Motor Control Driver
Focused Application

Self-detection & No need adjustment are Keywords for next field.

HA
A/C, Washing Machines, Refrigerator, Cleaner etc..

OA
IJP/LBP/MFP, Scanner etc..

Industrial
ATM, Vending Machine, Amusement, Surveillance Camera, Robotics etc..

Fan
Server fan, Blower, Ventilation fan, Ceiling fan etc..

Battery Solution
DSC, Toy, Electric lock, 5V USB or Battery powered instruments etc..
Motor control drivers

Toshiba’s unique technologies and broad product portfolio provide outstanding capabilities for your Motor applications.

1. 40 years’ experience
   - More than 40 years’ experience in the semiconductor market for home appliances, axial fans, and industrial equipment

2. Broad product portfolio (190 products)
   - Solutions for many applications through a broad portfolio of Motor controllers and drivers

3. Unique technologies
   - Real-time adjustment
     Automatic optimization of Motor drive
     → Intelligent Phase Control
     → Active Gain Control

Value provided

Customer value / Social subject contribution
- Efficient and stable Motor control
- Environmental protection
- Improvement of device performance and reduction in power consumption

Product lineup
- Products with Active Gain Control
  TB67S249 (4.5 A), TB67S279 (2 A), TB67S289 (3 A):
    Available (stepping Motor drivers)
  TB67S128: Available (128-step stepping Motor driver)
- Products with Intelligent Phase Control
  TC78B016: Available
    (40 V, 3 A driver)
  TC78B041: Available
    (18 V, 20 mA controller)
**BLDC Motor drive technology : Intelligent Phase Control**

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**Value provided**

**One-time adjustment provides highest efficiency over wide rotational speed range.**

1. **Highest efficiency over wide rotational speed range**
   
   Automatically aligns Phases of voltage and current to achieve the highest efficiency.

2. **Adjustment is unnecessary to achieve optimum drive.**
   
   One-time adjustment optimizes Motor control over wide rotational speed range.

3. **Low noise**
   
   Three-Phase sine-wave drive provides quiet and smooth Motor rotation.

---

**Highest efficiency with one-time adjustment**

- Fixed lead angle: 3.7 degrees (Lead angle is adjusted at lower rpm.)
- Fixed lead angle: 26.2 degrees (Lead angle is adjusted at higher rpm.)

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**Customer value / Social subject contribution**

- Efficient and stable Motor control
- Environmental protection
- Improvement of device performance and reduction in power consumption

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**Product lineup**

- Products with Intelligent Phase Control
  - TC78B016FTG: Available (40 V, 3 A BLDC driver)
  - TC78B041FNG: Available (18 V, 20 mA BLDC controller)
## Intelligent Phase Control & Closed loop for 3 Phase BLDC

### 3Phase High Rating Voltage
- **12 pole Controller**
  - TB67B054
- **500V SIP**
  - TB67B000 (Driver)
- **New**
  - **Intelligent Phase Control**
    - TC78B041/042
- **600V SIP**
  - TB67B000A

### 3Phase Low Rating Voltage
- **1-Hall / 3-Hall Square Wave**
  - TB78B015/A/B/C
- **3-Hall Sine Wave**
  - TC78B016
- **Sensorless Square Wave**
  - (Driver) TC78B008 (Driver) TC78B001
- **New**
  - **3-Hall Sine Wave**
    - TC78B016
- **New**
  - **1-Hall Square Wave/Sine Wave**
    - TC78B025 (Driver), TC78B027 (Pre-driver)

### Single Phase Low Rating Voltage
- **TC78B002 (Driver)**
- **TC78B006 (Pre-driver)**

### Timeline
- ~2019
- **2020**
- **2021~**
03-2

MCU: Microcontroller Unit
**MCU**

### Value provided

**Helps system development, efficiency up, cost down and downsizing**

1. **System Development TAT Improvement**
   - Integrated Motor control hardware (VE, PMD, ADC & Encoder) helps improve system development TAT for vector control.

2. **High Efficiency Motor Control**
   - VE & Encoder reduce CPU load by doing vector calculation & position estimation on behalf of CPU. Vector control improves system efficiency.

3. **Cost Down & Downsizing**
   - Integrating external part (Op-Amp), supporting sensor-less 1-shunt (VE +PMD) and driving multiple Motors (CPU+PMD) optimize total system.

**VE : Vector Engine (next page shows details)**

**PMD : Programmable Motor Driver (next page shows details)**

---

**Customer value / Social subject contribution**

- High efficiency & stable Motor control and low noise
- Environment friendly
- Contribution to performance up and power saving on equipment

**Product lineup**

- M370 series : Arm® Cortex®-M3 core with VE
- M470 series : Arm® Cortex®-M4 core with VE
- M4K series : Arm® Cortex®-M4 core with VE

---

1 MCU can control multiple Motors and other processes (e.g. PFC)
# System Development TAT Improvement

## Shorten Development TAT by Motor Control Hardware

<table>
<thead>
<tr>
<th>3-Phase PWM (PMD)</th>
<th>AD Converter (ADC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ 3-Phase complementary PWM output and AD converter co-working</td>
<td>✓ 12-bit SAR type</td>
</tr>
<tr>
<td>✓ Ease of controlling BLDC Motor</td>
<td>✓ Conversion synchronizing with Motor control timing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vector Engine (VE)</th>
<th>Encoder (ENC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Vector calculation hardware</td>
<td>✓ Ease of obtaining Motor position</td>
</tr>
<tr>
<td>✓ Co-work with ADC &amp; PMD</td>
<td>✓ Supports direct-input of incremental encoder and hall sensor</td>
</tr>
<tr>
<td>✓ User-settable current command &amp; Phase</td>
<td></td>
</tr>
</tbody>
</table>

* Supported functionality varies depending on MCU

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High Efficiency Motor Control

Improve Motor Control Efficiency by Vector Control Hardware

**Point 1 Vector Calculation**
- Auto-calculation on coordinate transformation, PI control, etc.
- User-programmable on position & speed control.

**Point 2 Associated Functions**
- Vector calculation with 3-Phase PWM output and AD converter reduces CPU processing time significantly.

**Point 3 Encoder & Hall Sensor**
- Support 2- & 3-Phase incremental encoder with high accuracy count using both edges, rotation direction detection.
- Support hall sensor with direction, speed and RPM detection.

### Structure of Motor Control (Vector Control)

- **Software Process**
- **Hardware Process**

### Processing Time of Software (CPU clock 120MHz)

- **Only software**
- **VE+software**

Note that processing time is measured using Toshiba sample software.

Significantly reduce CPU load, High speed PWM & high accuracy vector control.
Cost Down & Downsizing

Optimize Motor Control by Integration, 1-Shunt and Multi-Motor

1. **Built-in Op-Amp**
   - Built-in functions such as Op-Amp to amplify shunt current for vector control
   - High accuracy oscillator and data flash reduce BOM

2. **1-Shunt Support**
   - PMD, a function to generate ADC trigger based on PWM waveform, supports 3-shunt as well as 1-shunt.

3. **Multi-Motor Control**
   - High speed CPU, vector engine and multiple PMDs support max. 3 Motor control.

**Example: 3 Motor Control by M4K**

- **Point 1** Built-in Op-Amp
  - Vector Engine [Hardware]
  - PMD
  - ADC
  - AMP

- **Point 2** 1-Shunt Support
  - Position, Speed & Torque Control
  - Vector Engine [Software]
  - PMD
  - ADC
  - AMP

- **Point 3** Multi-Motor Control
  - Vector Engine [Software]
  - PMD
  - ADC
  - AMP

- **Multi-Motor Support**
- **1-Shunt Support**
- **Built-in Op-Amp**
BLDC Motor Drive Devices : <IPD>
BLDC Motor Control Devices: HV-IPDs

Reduction in power consumption and efficiency improvement due to improved characteristics

1. Reduces power consumption (loss)
MOSFET modules provide roughly 36% reduction in power loss compared with conventional devices that use IGBTs at output stage.

2. Eliminates need for power supply for high-side drive
Power supply for high-side drive is unnecessary owing to Toshiba’s proprietary high-voltage SOI process and trench isolation structure as well as internal bootstrap diode.

3. Reduces acoustic noise
- Combination of MCU and MCD enables sine-wave drive.
- Smooth and quiet Motor operation

HV-IPDs provide high efficiency because of improved characteristics.

Customer value / Social subject contribution
- High-efficiency and high-performance Motor drive technology
- Environmental protection
- Improvement of system performance and reduction in power consumption

Product lineup
- MOS module-type HV-IPDs
  - TPD4204F (600 V/2.5 A, sine-wave type): Available
  - TPD4206F (500 V/2.5 A, sine-wave type): Available
  - TPD4207F (600 V/5.0 A, sine-wave type): Available
Low-Voltage IPD for Brushless Motor Drives (LVIPD)

Protection and a diagnostic function are built in a compact package, and it contributes to the miniaturization of a set, and quality improvement.

1 Various functions
   High performance
   - Built-in charge pump circuit for driving the N-channel MOSFET on the high side.
   - High current output +1A/-1.5A.
   - Driver power supply voltage, output voltage diagnosis.

2 Small package
   - It is lineup about a SOP type and the non lead QFN type. TPD7212F:WQFN32 5x5 mm (76% down)*
   - Various protection and a diagnostic function are corresponded to built-in and in-vehicle reliability, and it contributes to quality improvement of a set.

3 High added value
   - AEC-Q100 conformity (TPD7212FN)

- A detailed process is adopted and produced commercially with a compact package from conventional parts, and it contributes to the miniaturization of a set.
- Various protection and a diagnostic function are corresponded to built-in and in-vehicle reliability, and it contributes to quality improvement of a set.

Internal block diagram / The example of an application circuit

Since the charge pump circuit for a high side N-channel MOSFET drive is built in, a three Phase full bridged circuit can be constituted easily.

Customer value / Social subject contribution
- A detailed process is adopted and produced commercially with a compact package from conventional parts, and it contributes to the miniaturization of a set.
- Various protection and a diagnostic function are corresponded to built-in and in-vehicle reliability, and it contributes to quality improvement of a set.

Product lineup

<table>
<thead>
<tr>
<th>Part number</th>
<th>TPD7210F (conventional parts)</th>
<th>TPD7212F</th>
<th>TPD7212FN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SSOP24 (8x13mm)</td>
<td>WQFN32 (5x5mm)</td>
<td>SSOP30 (7.6x9.7mm)</td>
</tr>
<tr>
<td>Power supply voltage range of operation (Power supply voltage maximum rating)</td>
<td>4.5 to 18V (40V@pulse)</td>
<td>4.5 to 18V (40V@pulse)</td>
<td>4.5 to 18V (40V@pulse)</td>
</tr>
<tr>
<td>Output current</td>
<td>±1A</td>
<td>+1A/-1.5A</td>
<td>+1A/-1.5A</td>
</tr>
<tr>
<td>Operational temperature range (Junction temperature maximum rating)</td>
<td>-40 to 125°C (150°C)</td>
<td>-40 to 150°C (175°C)</td>
<td>-40 to 150°C (175°C)</td>
</tr>
</tbody>
</table>
04

Power Devices
Low withstanding voltage MOSFET (LVMOS)

Value provided

Wide lineup and easy-to-use design, contributing to energy saving and high efficiency

**1 High Efficiency (Energy saving)**

- Low On-Resistance Characteristics by Advanced Refinement Process
- Improves $R_{DS(ON)}$ and $Q_g$ trade-off by optimization of cell structure

**2 Wide Line up**

- Wide range of withstanding voltage lineups (20 to 250V)
- Support various packages from SMD to TO-220 type

**3 Ease of Use**

- Low Spike and Low Ringing Characteristics with Parasitic Snubbers
- $T_{ch}=175^\circ C$ guaranteed (U-MOSIX-H, X-H)
- High avalanche tolerance

**Customer value / Social subject contribution**

- High-efficiency performance in line with increasing energy-saving requirements (low on-resistance, low charge)
- Optimized for secondary-side synchronous rectification of power supply circuits and inverter drive of Motors in conjunction with higher efficiency
- Achieved industry-leading FOM (performance indicator)*

*As of 10th May 2021 (as surveyed by Toshiba)

**Product lineup**

- U-MOSX-H : 80V
- U-MOSIX-H : 30V, 40V, 45V, 60V, 100V
  - 40V (low spike type), 60V (low spike type)
- U-MOSVIII-H : 30V, 40V, 60V, 75V, 80V, 100V, 120V, 150V, 200V, 250V
High-voltage MOSFETs

Extensive product lineup allows you to select MOSFETs that best meet application requirements.

1. For power factor correction (PFC): DTMOS series
   - Reduces power loss and improves efficiency because of low gate capacitance, fast switching, and low on-resistance.

2. For Motor drive and inverter circuits: MOSFET series with fast reverse recovery diode
   - Reduces power loss and improves efficiency because of optimum reverse recovery characteristics of parasitic diode.

3. For switching devices on primary side of auxiliary power supplies
   - High-voltage MOSFET series (V_{DSS} = 800 to 900 V)
   - MOSFETs with V_{DSS} of 800 to 900 V are ideal as switching devices on primary side of small-capacity auxiliary power supplies for which flyback configuration is commonly used.

Customer value / Social subject contribution
- Efficiency improvement and reduction in power consumption
- Environmental protection

Product lineup

- **PFC circuits:** DTMOSVI series (650 V): Available
  - DTMOSIV-H series (600 V, 650 V): Available
- **Motor drivers:** DTMOSIV (HSD) series (600 V, 650 V): Available
- **Auxiliary power supplies:** DTMOSIV series (800 V): Available
  - High-voltage π-MOSVIII series (800 V, 900 V): Available
Discrete IGBT

Low-loss device by fine integration & field-stop structure

1 Low power consumption

- Low VCE(sat) & high speed by field-stop structure
- Low capacitance with new gate structure
  → Low Switching & drive loss

2 Reduction of short-circuit current

- Reduction of short-circuit current by reducing collector-emitter saturation current

3 Low emission noise

- Optimized chip design
- High-speed performance by reducing emission noise

Field-stop structure

VCES=600V
Ta=25℃

Customer value / Social subject contribution

- Low-loss device by field-stop structure
- Improved durability by reducing short-circuit current

Product lineup

- GT15J341 (TO-220SIS)
- GT20J341 (TO-220SIS)
- GT30J341 (TO-3PN)
SiC MOSFET

Designer-friendly product “Toshiba SiC MOSFET”

1. Wide $V_{GSS}$ specification
   - $V_{GSS}$ specification is wider than that of competitors.
   - SiC MOSFET $V_{GSS}$: -10V to 25V → designer-friendly product

2. High Vth
   - High $V_{th}$ with low On resistance
   - SiC MOSFET $V_{th}$: 5.0V(typ.)
     Spec: 4.2 to 5.8V → prevention from malfunction

3. SBD embedded in die
   - Small diode VF
     $V_{DSF} = -1.35V$ (typ.)

**Comparison in $V_{GSS}$ & Vth specifications**

**Customer value / Social subject contribution**
- Ease of design
- Prevention from malfunction
- Energy saving by high-efficiency performance
- 2nd generation 1200V SiC MOSFET (TW070J12B)
- 3rd generation 650/1200V SiC MOSFET (Under development)
## Wide lineup of current & package, contributing to energy saving and high efficiency

### 1. Low IR
- Low IR by improved JBS structure
  - IR : 50μA max @650V, 25℃

### 2. Low VF
- Low VF by thinner-wafer technology
  - VF spec, : 1.45V (typ.)
  - *3rd generation (under development)* = 1.2V

### 3. High IFSM
- High IFSM by improved JBS structure
  - 83A @ TRS10E65F

---

### Customer value / Social subject contribution
- Energy saving by low-power-loss performance
- High durability

### Product lineup
- 2nd generation 650V SiC SBD
- 3rd generation 650V/1200V SiC SBD (under development)
05

Small Signal & Opto Devices
eFuse IC (Electronic Fuse) can protect circuits from abnormal conditions such as overcurrent and overvoltage repeatedly.

1. **High-speed short-circuit protection**
   Fast Trip function instantaneously cuts off the output current when a short circuit occurs. (150ns typ:TCK8xx)

2. **Excellent protection characteristics**
   In the event of an overvoltage or overcurrent, the output voltage and output current are held stably by the overclamp.

3. **IEC62368-1 certified**
   Complied with the International Safety Standard IEC62368-1 (G9: IC Current Limiter), it provides robust protection and simplifies designs.

### Product lineup

<table>
<thead>
<tr>
<th>PN</th>
<th>Vin</th>
<th>OCP</th>
<th>OVP</th>
<th>Recovery</th>
<th>Flag</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCKE805NA</td>
<td>4.4V~18V</td>
<td>0.5A~5.0A</td>
<td>6.04V</td>
<td>Auto retry</td>
<td>None</td>
<td>WSON10/10B 3x3mm</td>
</tr>
<tr>
<td>TCKE805NL</td>
<td>4.4V~18V</td>
<td>0.5A~5.0A</td>
<td>6.04V</td>
<td>Latched</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TCKE812NA</td>
<td>4.4V~18V</td>
<td>0.5A~5.0A</td>
<td>15.1V</td>
<td>Auto retry</td>
<td>None</td>
<td></td>
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<tr>
<td>TCKE812NL</td>
<td>4.4V~18V</td>
<td>0.5A~5.0A</td>
<td>15.1V</td>
<td>Latched</td>
<td>None</td>
<td></td>
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<tr>
<td>TCKE800NA</td>
<td>4.4V~18V</td>
<td>0.5A~5.0A</td>
<td>None</td>
<td>Auto retry</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TCKE800NL</td>
<td>4.4V~18V</td>
<td>0.5A~5.0A</td>
<td>None</td>
<td>Latched</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TCKE712BNL*</td>
<td>4.4V~15V</td>
<td>0.5A~3.65A</td>
<td>Adjustable</td>
<td>Latched</td>
<td>Available</td>
<td></td>
</tr>
</tbody>
</table>

* Planned to obtain IEC62368-1 certification

---

**Value provided**

### eFuse IC (Electronic Fuse)

- **Power input**
- **eFuse IC**
- **PMIC**
- **MCU**

- Short circuit protection
- Over Current protection
- Overvoltage protection
- Reverse current blocking
- Inrush current protection
- Thermal Shutdown
- International Safety Standards (IEC62368-1)
Small package LDO regulator

Value provided

Low Dropout Voltage in various packages

1. Low Drop-out

Improve drop-out performance by new process technologies
(50 % lower drop-out vs previous gen.)

2. High PSRR
Low noise output

Suitable for RF, sensors, Camera and audio power supply

3. Low quiescent current

Achieved ultra low Iq (ON):0.34 μA: TCR3U series by using original circuit technologies

Product lineup

<table>
<thead>
<tr>
<th>I_{OUT}(A)</th>
<th>Series</th>
<th>Future</th>
<th>PSRR(dB) typ@1kHz</th>
<th>Iq (μA) typ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>TCR15AG</td>
<td>Low drop-out · High PSRR</td>
<td><a href="mailto:95@0.9V">95@0.9V</a></td>
<td>25</td>
</tr>
<tr>
<td>1.3</td>
<td>TCR13AG</td>
<td>Low drop-out · High PSRR</td>
<td><a href="mailto:90@0.9V">90@0.9V</a></td>
<td>52</td>
</tr>
<tr>
<td>0.8</td>
<td>TCR88BM</td>
<td>Low drop-out · High PSRR</td>
<td><a href="mailto:98@0.8V">98@0.8V</a></td>
<td>20</td>
</tr>
<tr>
<td>0.5</td>
<td>TCR5RG</td>
<td>High PSRR · Low noise</td>
<td><a href="mailto:100@2.8V">100@2.8V</a></td>
<td>7</td>
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<tr>
<td>0.5</td>
<td>TCR5BM</td>
<td>Low drop-out · High PSRR</td>
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<tr>
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<td>TCR3RM</td>
<td>High PSRR · Low noise</td>
<td><a href="mailto:100@2.8V">100@2.8V</a></td>
<td>7</td>
</tr>
<tr>
<td>0.3</td>
<td>TCR3U</td>
<td>Low Iq</td>
<td><a href="mailto:70@0.8V">70@0.8V</a></td>
<td>0.34</td>
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<tr>
<td>0.3</td>
<td>TCR3D</td>
<td>Standard</td>
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<td>65</td>
</tr>
<tr>
<td>0.2</td>
<td>TCR2L</td>
<td>Low Iq</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>0.2</td>
<td>TCR2E</td>
<td>Standard</td>
<td><a href="mailto:73@2.5V">73@2.5V</a></td>
<td>35</td>
</tr>
<tr>
<td>0.2</td>
<td>TAR5</td>
<td>Vin 15V, Bipolar process</td>
<td>70</td>
<td>170</td>
</tr>
</tbody>
</table>

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CMOS OPAMP for sensors

Value provided

Suitable small signal use case for various sensors required high accuracy

1 Low noise output

Achieved very low noise output, WW top class[1] by original process and circuit

![Graph showing noise performance comparison](image)

2 Low Off set

Achieved Low off set, $V_{\text{IO}}$ max: 1.3 mV (TC75S102/103)

![Graph showing noise performance comparison](image)

3 Low quiescent current

Achieved Low $I_{\text{DD}}$: 0.3 $\mu$A, TC75S102

Product lineup

<table>
<thead>
<tr>
<th>Spec</th>
<th>TC75S67TU</th>
<th>TC75S102xx</th>
<th>TC75S103xx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Low noise</td>
<td>Low $I_{\text{DD}}$-$V_{DD}$</td>
<td>Standard</td>
</tr>
<tr>
<td>$V_{\text{DD}}, V_{SS}$</td>
<td>2.2 to 5.5V</td>
<td>1.5 to 5.5V</td>
<td>1.8 to 5.5V</td>
</tr>
<tr>
<td>$I_{\text{DD}}$</td>
<td>430$\mu$A</td>
<td>0.3$\mu$A</td>
<td>100$\mu$A</td>
</tr>
<tr>
<td>$V_{\text{IO}}, V_{\text{DD}}$ drift</td>
<td>3mV:Max</td>
<td>1.3mV:Max</td>
<td>1.3mV:Max</td>
</tr>
<tr>
<td>$f_T$</td>
<td>3.5MHz</td>
<td>0.6kHz</td>
<td>350kHz</td>
</tr>
<tr>
<td>$SR$</td>
<td>1.0V/ms</td>
<td>0.35V/ms</td>
<td>0.6V/$\mu$s</td>
</tr>
</tbody>
</table>

[1] Toshiba original research in Dec 2020
Small package Schottky Barrier Diode

Value provided

Down sizing by new package US2H which is low Rth

1. Low Rth
   New US2H package is lower thermal resistance Rth compared with competitors

2. Low VF and Low IR
   Improved key trade off performances (VF vs IR) for $V_R$=30 to 60V and $I_O$=1 to 2A products

3. Common footprint
   US2H (SOD-323HE)
   2.5x1.4x0.6 mm
   is same footprint of competitors

<table>
<thead>
<tr>
<th>Product lineup</th>
<th>$V_R$ (V)</th>
<th>$I_O$ (A)</th>
<th>$VF(V)@2A$</th>
<th>$I_r$ (μA) max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUHS20S30</td>
<td>30</td>
<td>2.0</td>
<td>0.34</td>
<td>500 @$V_R$=30V</td>
</tr>
<tr>
<td>CUHS15S30</td>
<td>30</td>
<td>1.5</td>
<td><a href="mailto:0.37@1.5A">0.37@1.5A</a></td>
<td>500 @$V_R$=30V</td>
</tr>
<tr>
<td>CUHS20S40</td>
<td>40</td>
<td>2.0</td>
<td>0.40</td>
<td>300 @$V_R$=40V</td>
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<tr>
<td>CUHS15S40</td>
<td>40</td>
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<td><a href="mailto:0.45@1.5A">0.45@1.5A</a></td>
<td>200 @$V_R$=40V</td>
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<tr>
<td>CUHS20F30</td>
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<td>2.0</td>
<td>0.40</td>
<td>60 @$V_R$=30V</td>
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<tr>
<td>CUHS15F30</td>
<td>30</td>
<td>1.5</td>
<td><a href="mailto:0.46@1.5A">0.46@1.5A</a></td>
<td>50 @$V_R$=30V</td>
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<tr>
<td>CUHS20F40</td>
<td>40</td>
<td>2.0</td>
<td>0.47</td>
<td>60 @$V_R$=40V</td>
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<tr>
<td>CUHS15F40</td>
<td>40</td>
<td>1.5</td>
<td>0.57</td>
<td>50 @$V_R$=40V</td>
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<tr>
<td>CUHS10F60</td>
<td>60</td>
<td>1.0</td>
<td>–</td>
<td>40</td>
</tr>
<tr>
<td>CUHS15F60</td>
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<td><a href="mailto:0.66@1.5A">0.66@1.5A</a></td>
<td>50</td>
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<tr>
<td>CUHS20F60</td>
<td>60</td>
<td>2.0</td>
<td>0.52</td>
<td>70</td>
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<td>CUHS15S60</td>
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<td>1.5</td>
<td><a href="mailto:0.57@1.5A">0.57@1.5A</a></td>
<td>200</td>
</tr>
<tr>
<td>CUHS20S60</td>
<td>60</td>
<td>2.0</td>
<td>0.46</td>
<td>650</td>
</tr>
</tbody>
</table>
Transistor output photocoupler

Reduction of board space and maintenance-free reliability are major merits

1. **High conversion efficiency** (I_f=5mA)

Optically coupled high-isolation photo coupler with a phototransistor and a high-power infrared LED, enabling low input current control and high conversion efficiency compared to conventional electromagnetic relays and isolation transformers.

2. **Designed for high temperature operation up to 110°C**

Designed to operate under extreme conditions of ambient temperature such as inverter devices, robots, machine tools and high output power supplies.

---

### Value provided

**Industrial equipment**
- Inverters
- Servo amplifiers
- Robots
- Tooling machines
- High output power supplies
- Security equipment
- Semiconductor testers
- Programmable logic controllers

**High isolation and noise suppression**

---

### Product lineup

<table>
<thead>
<tr>
<th>Part Number</th>
<th>TLP385</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>4pin SO6L</td>
</tr>
<tr>
<td>BV_s (Min) [Vrms]</td>
<td>5000</td>
</tr>
<tr>
<td>T_{opr} [°C]</td>
<td>-55 ~ 110</td>
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</tbody>
</table>
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