Air Conditioner

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
Air Conditioner

Details of AC-DC converter unit

Criteria for device selection
- High voltage MOSFETs are suitable for primary switching of AC-DC converters.
- The transistor output photocoupler is for signal isolation.

Proposals from Toshiba
- Suitable for high efficiency voltage switching
  π-MOSⅧ Series MOSFET
- High current transfer ratio and high temperature operation have been achieved
  Transistor output photocoupler
- Supply the power with low noise
  Small surface mount LDO regulator

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

**Active type**

```
\[ \text{PFC Circuit} \]
```

- MOSFETs with high speed switching and low on-resistance are suitable for active type PFC circuit.
- IGBTs with low collector-emitter saturation voltage are suitable for partial switching type PFC circuit.

**Proposals from Toshiba**

- Suitable for high efficiency power supply switching
  - DTMOSVI Series MOSFET
- IGBT which is suitable for high voltage and high current system
  - Discrete IGBT
- Suitable for PFC and motor control
  - MCU M4K Group / M470 Group / M370 Group

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
Air Conditioner Details of fan (indoor/outdoor) and compressor unit

Fan section (indoor/outdoor units)

High voltage IPD

MCD (controller) + high voltage IPD

MCU (Three-phase motor controller) + high voltage IPD

Compressor section

Criteria for device selection

- IPDs are suitable for fan motor drive in indoor and outdoor units.
- MOSFET with short reverse recovery time is suitable for motor drive in compressors.
- By using brushless motor drivers, three-phase brushless DC motors can be controlled easily.

Proposals from Toshiba

- Suitable for inverter
  DTMOS IV (HSD) [Note] Series MOSFET
- High voltage motor driver circuit
  High voltage IPD
- Easy motor drive
  Motor driver
- Suitable for PFC and motor control
  MCU M4K Group / M470 Group / M370 Group
- Easy software development using general purpose CPU cores
  MCU M3H Group

[Note] 4th generation DTMOS with high speed diode

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

MCU

Three-phase motor control

MOSFET

Gate Driver

Brushless

Brushless

[1c 5b 5a 6b 6c 6d 7a 7b]
Air Conditioner  Details of cleaning, louver and valve control unit

Cleaning section

Motor Control Driver or Transistor Array

Louver section

Transistor Array

Valve control section

Photocoupler

Criteria for device selection
- By using brushless DC motor drivers, three-phase brushless DC motors can be controlled easily.
- Stepping motor driver enables efficient motor control by optimizing real-time current to the motor.
- Brushed DC motor driver allows motor driving with low power consumption.

Proposals from Toshiba
- Easy motor drive
  Motor driver
- Triac driver for high dv/dt
  Triac output photocoupler
- Suitable for PFC and motor control
  MCU M4K Group / M470 Group / M370 Group
- Easy software development using general purpose CPU cores
  MCU M3H Group
- High efficiency and high current driver with built-in low loss DMOS FET
  Transistor array

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
Criteria for device selection

- Isolation devices such as transistor output photocouplers are effective when voltage difference exists between outdoor and indoor GNDs.
- MCUs are suitable for system monitoring and control.

Proposals from Toshiba

- High current transfer ratio and high temperature operation have been achieved
  Transistor output photocoupler
- Supply the power with low noise
  Small surface mount LDO regulator
- Suitable for PFC and motor control
  MCU M4K Group / M470 Group / M370 Group
- Easy software development using general purpose CPU cores
  MCU M3H Group

Air Conditioner Details of microcontroller and isolation unit

Microcontroller section
Power control block for outdoor unit

Criteria for device selection

- Isolation devices such as transistor output photocouplers are effective when voltage difference exists between outdoor and indoor GNDs.
- MCUs are suitable for system monitoring and control.

Proposals from Toshiba

- High current transfer ratio and high temperature operation have been achieved
  Transistor output photocoupler
- Supply the power with low noise
  Small surface mount LDO regulator
- Suitable for PFC and motor control
  MCU M4K Group / M470 Group / M370 Group
- Easy software development using general purpose CPU cores
  MCU M3H Group

Isolation circuit
Between outdoor and indoor units

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
Air Conditioner  Details of sensor input unit (1)

**Dust sensor circuit**

- Power Supply
- LDO
- Drive Circuit
- Dust Sensor
- Op-amp
- Output (MCU)

**Human sensor circuit**

- Power Supply
- LDO
- Pyroelectric Infrared Sensor
- Op-amp
- Output (MCU)

**Criteria for device selection**
- PSRR (Power Supply Rejection Ratio) of LDO regulator is an important parameter for sensor modules.
- The operational amplifier should be low current consumption or low noise device.
- Small package products contribute to the reduction of circuit board area.

**Proposals from Toshiba**
- **Supply the power with low noise**
  Small surface mount LDO regulator
- **Amplification of detected very small signal with low noise**
  Low current consumption op-amp / Low noise op-amp

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
Air Conditioner  Details of sensor input unit (2)

Temperature sensor circuit

Criteria for device selection
- PSRR (Power Supply Rejection Ratio) of LDO regulator is an important parameter for sensor modules.
- The operational amplifier should be low current consumption or low noise device.
- Small package products contribute to the reduction of circuit board area.

Proposals from Toshiba
- Supply the power with low noise
  Small surface mount LDO regulator
- Amplification of detected very small signal with low noise
  Low current consumption op-amp / Low noise op-amp

Humidity sensor circuit

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

Power Supply

LDO

Photodiode

Op-amp

Output (MCU)

Criteria for device selection
- PSRR (Power Supply Rejection Ratio) of LDO regulator is an important parameter for sensor modules.
- The operational amplifier should be low current consumption or low noise device.
- Small package products contribute to the reduction of circuit board area.

Proposals from Toshiba
- **Supply the power with low noise**
  Small surface mount LDO regulator
- **Amplification of detected very small signal with low noise**
  Low current consumption op-amp / Low noise op-amp

* Click on the numbers in the circuit diagram to jump to the detailed descriptions page
Air Conditioner  Detail of key input unit

**Key input circuit**

- **Key Input**
  - **Keys** → **TVS** → **MCU**

**Criteria for device selection**
- TVS diodes are suitable for protection from ESD pulses coming in key input unit.
- Small package products contribute to the reduction of circuit board area.

**Proposals from Toshiba**
- Easy software development using general purpose CPU cores
  - **MCU M3H Group**
- Absorb static electricity to prevent malfunction of the circuit
  - **TVS diode**

*Click on the numbers in the circuit diagram to jump to the detailed descriptions page*
Recommended Devices
As described above, in the design of air conditioner, “Quietness/efficiency of motors”, “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>Brushless DC motor drive</th>
<th>High efficiency / low loss</th>
<th>Small size packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>π-MOS VIII / DTMOS VI / DTMOS IV (HSD) Series MOSFET</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Transistor output photocoupler / Triac output photocoupler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Discrete IGBT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Small surface mount LDO regulator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>High voltage IPD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Motor driver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>MCU M4K Group / M470 Group / M370 Group / M3H Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>TVS diode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Low current consumption op-amp / Low noise op-amp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Transistor array</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Realizes improvement of power supply efficiency by reduction of RonA by 24 % (comparison of Toshiba’s conventional products) and contributes miniaturization of set.

1. RonA reduced by 24 %
   By using π-MOSⅧ chip design, figure of merit RonA is reduced by 24 % (comparison of Toshiba’s π-MOSⅣ products).

2. Qg reduced by 23 %
   By using π-MOSⅧ chip design, Qg is reduced by 23 % (comparison of Toshiba’s π-MOSⅣ products). Reduction of switching loss is expected.

3. Coss reduced by 18 %
   By using π-MOSⅧ chip design, Coss is reduced by 18 % (comparison of Toshiba’s π-MOSⅣ products). Improvement for light load conditions is expected.

Turn-off waveform

Toshiba’s conventional product

TK9J90E

By using π-MOSⅧ chip design, Qg is reduced by 23 % (comparison of Toshiba’s π-MOSⅣ products).

Reduction of switching loss is expected.

By using π-MOSⅧ chip design, Coss is reduced by 18 % (comparison of Toshiba’s π-MOSⅣ products).

Improvement for light load conditions is expected.
Realizes improvement of power supply efficiency by 40 % reduction of $R_{DS(ON)} \times Q_{gd}$ (comparison of Toshiba’s conventional products).

1. $R_{DS(ON)} \times Q_{gd}$ reduced by 40%

Using a single epitaxial process, the figure of merit $R_{DS(ON)} \times Q_{gd}$ was reduced by 40 % by optimizing the structure (comparison of Toshiba’s DTMOS IV-H 600 V products). By realizing low $R_{DS(ON)} \times Q_{gd}$, device switching loss was reduced contributing to improvement in power supply efficiency of equipment.

2. RonA reduced by 18 %

The figure of merit RonA of the latest generation [Note1] DTMOS VI has been reduced by 18 % compared with the previous generation (Toshiba’s DTMOS IV 650 V products). Achieving low on-resistance while maintaining high voltage contributes to high efficiency of equipment.

**Lineup**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TK065U65Z</th>
<th>TK040N65Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>TOLL</td>
<td>TO-247</td>
</tr>
<tr>
<td>$V_{DS}$ [V]</td>
<td>650</td>
<td>650</td>
</tr>
<tr>
<td>$I_D$ [A]</td>
<td>38</td>
<td>57</td>
</tr>
<tr>
<td>$R_{DS(ON)}$ [Ω] @$V_{GS}$ = 10 V</td>
<td>Typ. 0.051</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td>Max 0.065</td>
<td>0.040</td>
</tr>
<tr>
<td>Polarity</td>
<td>N-ch</td>
<td>N-ch</td>
</tr>
</tbody>
</table>

[Note 1] As of March 2023

[Notes:

R_{DS(ON)}: I_D = 28.5 A, V_{GS} = 10 V
Q_{gd}: V_DD = 400 V, I_D = 57 A, V_{GS} = 10 V
Polarity: N-ch

Plots the mean of the measured values.

Comparison of $R_{DS(ON)} \times Q_{gd}$ [Note 2]

DTMOS IV
TK62N60W

DTMOS IV-H
TK62N60X

40% decrease from DTMOS IV-H (Toshiba internal comparison)

DTMOS VI
TK040N65Z

TK62N60W (600 V, 40 mΩ)
TK62N60X (600 V, 40 mΩ)
TK040N65Z (650 V, 40 mΩ)

Test Condition
$R_{DS(ON)}$: $I_D = 28.5$ A, $V_{GS} = 10$ V
$Q_{gd}$: $V_{DD} = 400$ V, $I_D = 57$ A, $V_{GS} = 10$ V
Plots the mean of the measured values.

The figure of merit RonA has been reduced by 30 % (compared with Toshiba conventional products), then contribute to improve efficiency of power supply.

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

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 other factors.

**Lineup**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TK20A60W5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>TO-220SIS</td>
</tr>
<tr>
<td>$V_{DSS}$ [V]</td>
<td>600</td>
</tr>
<tr>
<td>$I_D$ [A]</td>
<td>20</td>
</tr>
<tr>
<td>$R_{ON, 1\Omega}$ @ $V_{GS} = 10$ V</td>
<td>Typ. 0.15 Max 0.175</td>
</tr>
<tr>
<td>Polarity</td>
<td>N-ch</td>
</tr>
</tbody>
</table>

(Note) Compared with Toshiba conventional products
Transistor output photocoupler
TLP383 / TLP293 / TLP385

High CTR (Current Transfer Ratio) is realized even in low input current range (I_F = 0.5 mA).

1. High current transfer ratio

The TLP383 and TLP293 is a high isolation photocoupler that optically couples a phototransistor and high output infrared LED. Compared to Toshiba’s conventional products (TLP385), higher CTR (Current Transfer Ratio) in low input current range (@I_F = 0.5 mA) is realized.

2. High temperature operation

The TLP383 and TLP293 are designed to operate even under severe ambient temperature conditions.

Lineup

<table>
<thead>
<tr>
<th>Part number</th>
<th>TLP383</th>
<th>TLP293</th>
<th>TLP385</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>4pin SO6L</td>
<td>SO4</td>
<td>4pin SO6L</td>
</tr>
<tr>
<td>BV_{f} [Vrms]</td>
<td>5000</td>
<td>3750</td>
<td>5000</td>
</tr>
<tr>
<td>T_{op} [°C]</td>
<td>-55 to 125</td>
<td>-55 to 125</td>
<td>-55 to 110</td>
</tr>
</tbody>
</table>

(Note) Toshiba internal comparison
Using a triac with high dv/dt pre-driver for solenoid valve control suppresses false turn-on.

1. **Low input and zero crossing input control**

This device optically couples a photo triac and a high power infrared LED, providing high isolation equivalent to an electromagnetic relay. Capable of low input operation, the photo coupler can be directly controlled by a microcontroller.

2. **High dv/dt**

The TLP3083 is a triac having a high dv/dt of 2000 V/μs (Typ.). With a high OFF-state voltage of 800 V, it can work with various AC power supplies.

**Example of AC switch using triac output photocoupler**

![Diagram of AC switch using triac output photocoupler]

**Lineup**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TLP3083</th>
<th>TLP3073</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>Spin DIP6</td>
<td></td>
</tr>
<tr>
<td>Output type</td>
<td>Zero crossing functionary (ZC)</td>
<td>Non zero crossing functionary (NZC)</td>
</tr>
<tr>
<td>BVs [Vrms]</td>
<td>5000</td>
<td></td>
</tr>
<tr>
<td>T_{opr} [°C]</td>
<td>-40 to 100</td>
<td></td>
</tr>
</tbody>
</table>

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Switching devices for high voltage (600 V or more) and high current (30 A or more) application. Lineup of low $V_{CE(sat)}$ products are effective in reducing conduction loss.

1 High speed, low saturation voltage

By adopting a thin wafer punch-through structure, high speed turn-off characteristics and low $V_{CE(sat)}$ characteristics are realized.

2 High breakdown tolerance

Toshiba has a lineup of products with high breakdown tolerance (short circuit withstand time $t_{sc}$ and reverse bias safe operating area RBSOA).

3 Enhancement type

Since collector current does not flow when gate voltage is not applied for enhancement devices, handling is easy.

Active type PFC circuit example using discrete IGBT (GT50JR22)

```
IGBT

V_{out} = f_{sw} = 20 to 35 kHz
```

Lineup

<table>
<thead>
<tr>
<th>Part number</th>
<th>GT50JR22</th>
<th>GT30J122A</th>
<th>GT50J123</th>
<th>GT30J65MRB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>TO-3P(N)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Built-in FWD</td>
<td>✓ (RC structure)</td>
<td>-</td>
<td>-</td>
<td>✓ (RC structure)</td>
</tr>
<tr>
<td>$V_{CE(sat)}$ [V]</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>650</td>
</tr>
<tr>
<td>$I_{c}$ [A]</td>
<td>50</td>
<td>30</td>
<td>59</td>
<td>60</td>
</tr>
<tr>
<td>Max $V_{CE(sat)}$ [V]</td>
<td>2.20</td>
<td>2.8</td>
<td>2.50</td>
<td>1.80 @ $I_{c} = 30$ A</td>
</tr>
<tr>
<td>Max $t_{sc}$ [μs]</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Max RBSOA</td>
<td>-</td>
<td>-</td>
<td>120 A, 600 V (full square)</td>
<td>-</td>
</tr>
</tbody>
</table>

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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 $I_{B(ON)}$ is realized by utilizing CMOS process and unique circuit technology. (TCR3U Series)

![Lineup](image-url)

<table>
<thead>
<tr>
<th>Features</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>$I_{OUT}$ (Max) [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>15 V Input voltage</td>
<td>Bipolar type</td>
<td></td>
</tr>
<tr>
<td>PSRR (Typ.) [dB]</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>$I_{B}$ (Typ.) [μA]</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 with TCR3U series.
It is a brushless DC motor driver with built-in MOSFETs or IGBTs and can be driven at a variable speed by control signals from the MCU.

### 1. Built-in circuit required to drive the motor

It contains a level shifting high side driver, low side driver and MOSFETs or IGBTs.

- **TPD4204F**: MOSFET output
- **TPD4163F/TPD4163K/TPD4164F/TPD4164K**: IGBT output

### 2. Motor drive terminals and control terminals are separated

High voltage and large current terminals and the control terminals are separated on both sides of the package, thereby eliminating the complexity of wiring.

### 3. Various protection functions

- Over current and under voltage protection, shutdown and thermal shutdown functions are available.

---

**Lineup**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TPD4204F</th>
<th>TPD4163F</th>
<th>TPD4164F</th>
<th>TPD4163K</th>
<th>TPD4164K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>P-SSOP30-1120-1000-001</td>
<td>P-HSOP31-0918-080-002</td>
<td>P-HDIP30-1233-178-001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_{BB} [V]</td>
<td>600</td>
<td>13.5 to 16.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_{out} [A]</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>V_{CC} [V]</td>
<td>13.5 to 16.5</td>
<td>13.5 to 16.5</td>
<td>13.5 to 16.5</td>
<td>13.5 to 16.5</td>
<td>13.5 to 16.5</td>
</tr>
</tbody>
</table>

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This product optimizes for brushless DC motor driving and has the functions required for motor driving into one package.

1. Contributing to low power consumption
The power consumption can be reduced by replacing from the AC motor to a brushless DC motor.

2. Contributing to reducing the number of parts
Built-in functions and protection functions required for inverter operation can reduce the number of parts.

3. Contributing to reduction of circuit board area
The use of small surface mount packages contributes to the reduction of circuit board area.

Lineup

<table>
<thead>
<tr>
<th>Part number</th>
<th>TPD4162F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>P-HSSOP31-0918-0.80-002</td>
</tr>
<tr>
<td>$V_{BB}$ [V]</td>
<td>600</td>
</tr>
<tr>
<td>$I_{OUT}$ [A]</td>
<td>0.7</td>
</tr>
<tr>
<td>$V_{CC}$ (Max) [V]</td>
<td>17.5</td>
</tr>
<tr>
<td>Protective function</td>
<td>Current limitation, overcurrent protection, thermal shutdown, under voltage protection</td>
</tr>
</tbody>
</table>
Support low voltage motor drive (2.5 V (Min)) and contributes to the power saving of set.

1. **Low voltage operation**
   Motor power supply voltage is 2.5 V (Min) for low voltage applications such as battery operation devices.

2. **Low current consumption**
   Standby current is 2 μA or less (IC total) for power saving of devices.

3. **Error detection functions**
   Over current detection (ISD), thermal shutdown (TSD) and under voltage lockout (UVLO) are available.

### Part Numbers and Specifications

<table>
<thead>
<tr>
<th>Part number</th>
<th>TC78H621FNG</th>
<th>TC78H660FNG</th>
<th>TC78H660FTG</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_out [V]</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>I_out [A]</td>
<td>1.1</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Ron (upper and lower sum) (Typ.) [Ω]</td>
<td>0.8</td>
<td>0.48</td>
<td>0.48</td>
</tr>
<tr>
<td>Control interface</td>
<td>PHASE input</td>
<td>IN/PHASE inputs</td>
<td>IN/PHASE inputs</td>
</tr>
<tr>
<td>Step</td>
<td>2phase/1-2phase excitation</td>
<td>2phase/1-2phase excitation</td>
<td>2phase/1-2phase excitation</td>
</tr>
<tr>
<td>Motor power supply voltage</td>
<td>2.5 V (Min)</td>
<td>2.5 V (Min)</td>
<td>2.5 V (Min)</td>
</tr>
<tr>
<td>Error detection function</td>
<td>ISD, TSD, UVLO</td>
<td>ISD, TSD, UVLO</td>
<td>ISD, TSD, UVLO</td>
</tr>
<tr>
<td>Package</td>
<td>P-TSSOP16-0505-0.65-001</td>
<td>P-VQFN16-0303-0.50-001</td>
<td>P-VQFN16-0303-0.50-001</td>
</tr>
</tbody>
</table>

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Toshiba’s proprietary technology eliminates the need for phase adjustment and achieves high efficiency for a wide range of rotation speeds.

1. **High efficiency in a wide range of rotation speeds**
   Toshiba’s automatic lead angle control technology realizes a high efficiency drive regardless of motor speed, load torque or power supply voltage.

2. **Motor control with low noise and low vibration**
   Sine wave drive system with smooth current waveforms contributes to lower motor noise and vibration compared to conventional square wave drive system [Note].

3. **Small package**
   VQFN32 package is adopted for TC78B042FTG, which requires small space. SSOP30 package is adopted for TC78B041FNG as conventional type.

### Lineup

<table>
<thead>
<tr>
<th>Feature</th>
<th>TC78B041FNG</th>
<th>TC78B042FTG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part number</td>
<td>TC78B041FNG</td>
<td>TC78B042FTG</td>
</tr>
<tr>
<td>Power supply voltage</td>
<td>6 to 16.5 V</td>
<td>6 to 16.5 V</td>
</tr>
<tr>
<td>Drive type</td>
<td>Sine wave</td>
<td>Sine wave</td>
</tr>
<tr>
<td>Features</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto lead angle control for optimizing voltage and current phases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall element or hall IC input</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward/reverse rotation switch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor lock detection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selectable pulse number of rotation pulse signal output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Built-in 5 V regulator (VREF pin)</td>
<td>Built-in 5 V</td>
<td>Built-in 5 V</td>
</tr>
<tr>
<td>Built-in 5 V regulators (VREF/VREF2 pin)</td>
<td></td>
<td>regulators</td>
</tr>
<tr>
<td>Error detection positive input</td>
<td>Error detection positive/negative input</td>
<td></td>
</tr>
<tr>
<td>Package</td>
<td>SSOP30-P-300-0.65</td>
<td>P-VQFN32-0505-0.50-005</td>
</tr>
</tbody>
</table>

[Note] Comparison with Toshiba products

SSOP30-P-300-0.65 Package (10.2 x 7.6 x 1.6 mm)
P-VQFN32-0505-0.50-005 Package (5 x 5 x 1 mm)
High voltage and high current brushless DC motor driving can be implemented by external IPD.

1. **High efficient motor control by automatic phase control**
   Automatic phase controller by current feedback is integrated adding conventional fixed phase voltage input (32 steps).

2. **Motor control with low noise and low vibration**
   Sine wave drive system with smooth current waveforms contributes to lower motor noise and vibration compared to conventional square wave drive system [Note].

3. **Sufficient development support**
   Various supports such as third party evaluation board and PSpice® data for development and design are prepared.

**Lineup**

<table>
<thead>
<tr>
<th>Feature</th>
<th>TB6584FNG</th>
<th>TB6584AFNG</th>
<th>TB6634FNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part number</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply voltage</td>
<td>6 to 16.5 V (operating range)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output current</td>
<td>0.002 A (for MOSFET driver)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drive mode</td>
<td>Sine wave drive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Features</td>
<td>Lead angle control: Auto phase control (current feedback)</td>
<td>Sensor input: Hall device/Hall IC compatible</td>
<td>Internal regulator: 5 V, 30 mA (Max)</td>
</tr>
<tr>
<td></td>
<td>Error detection: overcurrent protection, abnormal position signal protection</td>
<td>undervoltage lockout, motor restrained detection (TB6634FNG)</td>
<td></td>
</tr>
</tbody>
</table>

**SSOP30-P-300-0.65 Package (10.2 x 7.6 x 1.6 mm)**

[Note] Comparison with Toshiba products
Value provided

A motor control IC and IGBTs are integrated into one package, contributing to the miniaturization of circuit boards.

1 A motor control IC and IGBTs

A motor control IC with sine wave PWM drive function and IGBTs with 600 V and 2 A characteristics are integrated into one package.

2 Motor control with low noise and low vibration

Sine wave drive system with smooth current waveforms contributes to lower motor noise and vibration compared to conventional square wave drive system [Note].

3 High heat dissipation

HDIP30 package is adopted for TB67B000AHG, which has high heat dissipation. HSSOP34 package is adopted for TB67B000AFG, which is smaller than HDIP30.

[Note] Comparison with Toshiba products

---

**Lineup**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TB67B000AHG</th>
<th>TB67B000AFG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating voltage range</td>
<td>Power supply for control: 13.5 to 16.5 V</td>
<td>Power supply for motor drive: 50 to 450 V</td>
</tr>
<tr>
<td>Output current</td>
<td>2 A</td>
<td></td>
</tr>
<tr>
<td>Drive type</td>
<td>Sine wave PWM drive / Wide angle commutation</td>
<td></td>
</tr>
<tr>
<td>Lead angle control</td>
<td>0 to 58 degrees 32 steps / 0 to 28 degrees 16 steps</td>
<td></td>
</tr>
<tr>
<td>Speed command input voltage</td>
<td>Motor operation: 2.1 to 5.4 V</td>
<td></td>
</tr>
<tr>
<td>Features</td>
<td>IGBT three-phase bridge, oscillator circuit, built-in bootstrap diode, overcurrent protection, thermal shutdown, undervoltage lockout, motor lock detection</td>
<td></td>
</tr>
<tr>
<td>Package</td>
<td>P-HDIP30-1233-1.78-001</td>
<td>P-HSSOP34-0918-0.80-001</td>
</tr>
</tbody>
</table>

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System cost reduction, higher efficiency and less development work.

1. **Equipped with motor control co-processor**
   Toshiba’s original co-processor vector engine (VE) for motor control reduces CPU load and allows control of multiple motors and peripherals.

2. **Equipped with motor control circuit**
   A variety of three-phase PWM\(^1\) waveforms and AD converters enable highly efficient, low noise control. The Advanced Encoder (A-ENC) reduces the load of CPU process in detecting the position performed for each PWM.

3. **Provide development support tools**
   Third party evaluation boards and sample programs that can be used to shorten the development time are provided. Toshiba has begun offering a new, simple, versatile motor control software development kit (MCU Motor Studio).\(^2\)

---

**Lineup**

<table>
<thead>
<tr>
<th>Series</th>
<th>Group</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXZ+™4A Series</td>
<td>M4K Group</td>
<td>Arm® Cortex®-M4, 160 MHz operation 4.5 to 5.5 V, three motor control (Max), Data Flash</td>
</tr>
<tr>
<td>TX04 Series</td>
<td>M470 Group</td>
<td>Arm® Cortex®-M4, 120 MHz operation 4.5 to 5.5 V, two motor control (Max)</td>
</tr>
<tr>
<td>TX03 Series</td>
<td>M370 Group</td>
<td>Arm® Cortex®-M3, 80 MHz operation 4.5 to 5.5 V, two motor control (Max)</td>
</tr>
</tbody>
</table>

\(^1\) Pulse Width Modulation

\(^2\) For M4K Group and will gradually expand for TXZ+™ Series products

---

[Return to Block Diagram TOP]
MCU is equipped with many peripheral functions. MCU contributes to higher functionality as a system control MCU.

1 **Built-in Arm® Cortex®-M3 CPU core**

MCU is equipped with Arm Cortex-M3 core. Maximum operation frequency is 120 MHz.

2 **Various lineup of built-in memories and packages**

M3H group integrates both 512 KB (Max) code and 32 KB data flash memories which support 100,000 write cycle endurance, and has a wide lineup of package from 64 to 144 pins.

3 **Equipped with many peripheral functions**

M3H Group have many peripheral functions such as UART, SPI, I2C, 12bit AD converter, 8bit DA converter, three-phase PWM [Note1] output, ENC and digital LCD driver [Note2], etc.

[Note 1] Pulse Width Modulation
[Note 2] 64 pin products aren’t equipped with digital LCD driver.

### Lineup

<table>
<thead>
<tr>
<th>Series</th>
<th>Group</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXZ+™3A Series</td>
<td>M3H Group</td>
<td>Arm® Cortex®-M3, 120 MHz, 2.7 to 5.5 V operation</td>
</tr>
</tbody>
</table>

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Absorbs static electricity from external terminals, prevents circuit malfunction and protects devices.

1. High ESD pulse absorption performance
   Improved ESD absorption compared to Toshiba’s 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 and devices using Toshiba own technology.

3. Suitable for high density mounting
   A variety of small packages are available.

TVS diode
DF2B7BSL / DF2B5M4SL / DF2B6M4SL

<table>
<thead>
<tr>
<th>Lineup</th>
<th>DF2B7BSL</th>
<th>DF2B5M4SL</th>
<th>DF2B6M4SL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part number</td>
<td>SL2</td>
<td>SL2</td>
<td>SL2</td>
</tr>
<tr>
<td>Package</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{ESD}$ [kV]</td>
<td>±30</td>
<td>±20</td>
<td>±20</td>
</tr>
<tr>
<td>$V_{BWM}$ (Max) [V]</td>
<td>5.5</td>
<td>3.6</td>
<td>5.5</td>
</tr>
<tr>
<td>$C_t$ (Typ.) [pF]</td>
<td>12</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>$R_{DYN}$ (Typ.) [Ω]</td>
<td>0.2</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

(Note) This product is an ESD protection diode and cannot be used for purposes other than ESD protection.

- Return to Block Diagram TOP
Lineup includes low current consumption type that contributes to low power consumption and a low noise type that maximizes the performance of high performance sensors.

1. Low voltage operation

We have a lineup of low power supply voltage-driven operational amplifiers using CMOS process for low power supply voltage-driven wearable equipment.

2. Low current consumption

(TC75S102F) $I_{DD} = 0.27 \, \mu A$ (Typ.)

CMOS processes have been used to achieve lower current consumption. This contributes to lower power consumption and longer life of wearable equipment.

3. Low noise

(TC75S67TU) $V_{NI} = 6.0 \, [nV/\sqrt{Hz}]$ (Typ.) @$f = 1 \, kHz$

This CMOS operational amplifier can amplify minute signals detected by various sensors [Note] with low noises. By optimizing the process, the equivalent input noise voltage has been reduced.

**TC75S102F**

**Current Consumption Characteristic**
(Toshiba internal comparison)

**TC75S67TU**

**Noise Characteristic**
(Toshiba internal comparison)

- **Part number**
  - TC75S102F
  - TC75S67TU

- **Package**
  - SMV
  - UFV

- **$V_{DD} - V_{SS}$ [V]**
  - 1.5 to 5.5
  - 2.2 to 5.5

- **$V_{IO}$ (Max) [mV]**
  - 1.3
  - 3

- **CMV$_{IN}$ (Max) [V]**
  - $V_{DD}$
  - 1.4 (@$V_{DD} = 2.5 \, V$)

- **$I_{DD}$ (Typ. / Max) [$\mu A$]**
  - 0.27 / 0.46 (@$V_{DD} = 1.5 \, V$)
  - 430 / 700 (@$V_{DD} = 2.5 \, V$)

- **$V_{NI}$ (Typ.) [nV/$\sqrt{Hz}$] @$f = 1 \, kHz$**
  - -
  - 6

---

[Note] Sensor types: vibration, shock, acceleration, pressure, infrared, temperature, etc.
DMOS FET is used for the output of drive circuit and realizes low loss. And CMOS input can control directly from controller’s I/O, etc.

1 Rich product lineup

In addition to the listed products, we have lineup of various packaged products (such as DIP, SOL, SOP, SSOP, etc.) and source output type products.

2 Built-in output clamp diode

Built-in output clamp diode regenerates the back electromotive force generated by switching of an inductive.

3 Higher current drive is possible

The load can be driven with higher current by connecting multiple outputs in parallel.

(Note) Equivalent circuit may be simplified for explanatory purpose.

<table>
<thead>
<tr>
<th>Lineup</th>
<th>TBD62003AFWG</th>
<th>TBD62083AFG</th>
<th>TBD62064AFAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part number</td>
<td>Package</td>
<td>Package</td>
<td>Package</td>
</tr>
<tr>
<td></td>
<td>P-SOP16-0410-1.27-002</td>
<td>SOP18-P-375-1.27</td>
<td>P-SSOP24-0613-1.00-001</td>
</tr>
<tr>
<td>Package</td>
<td>Sink</td>
<td>Sink</td>
<td>Sink</td>
</tr>
<tr>
<td>Output type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of channels</td>
<td>7ch</td>
<td>8ch</td>
<td>4ch</td>
</tr>
<tr>
<td>Input level</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>I_{OUT} [mA/ch]</td>
<td>500</td>
<td>500</td>
<td>1500</td>
</tr>
<tr>
<td>V_{OUT} [V]</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

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