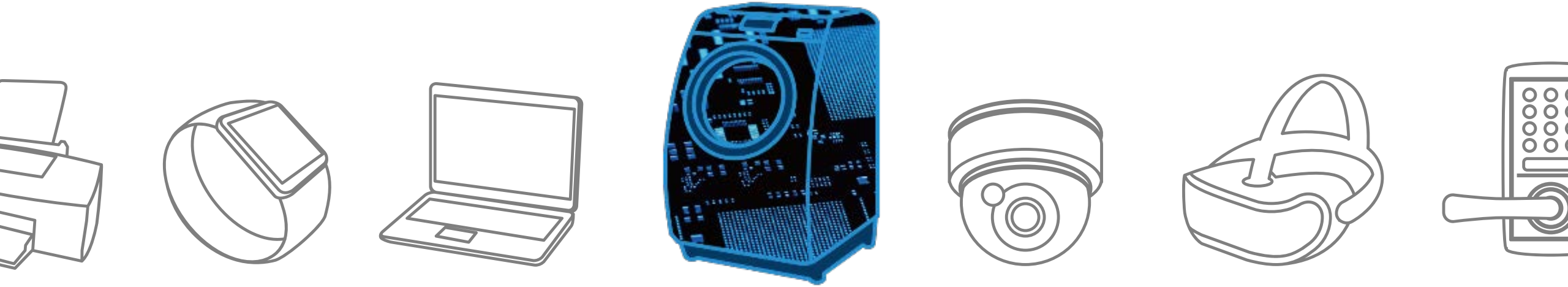
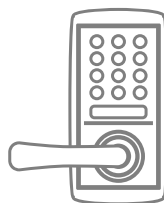


Washing Machine

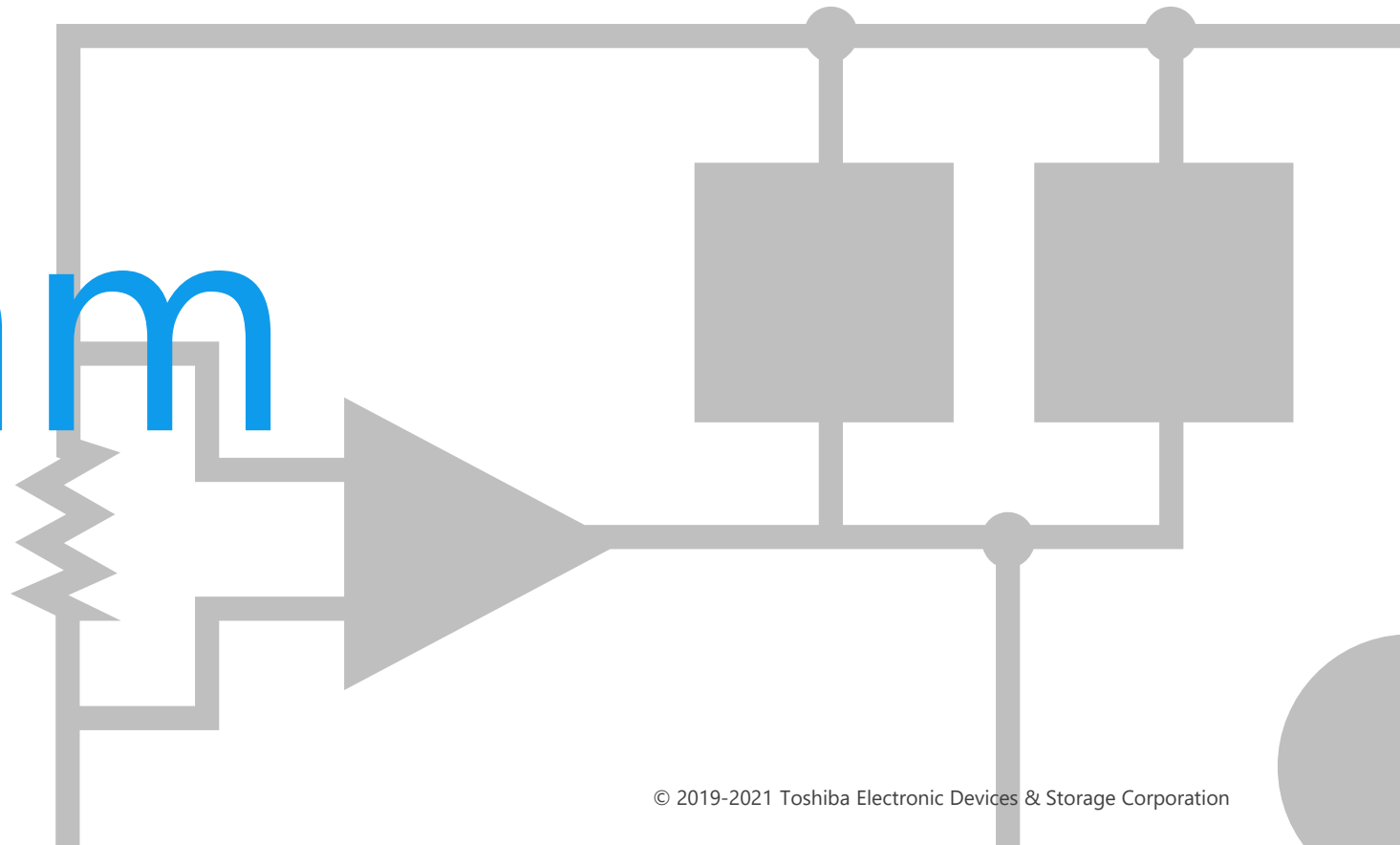
Solution Proposal by Toshiba



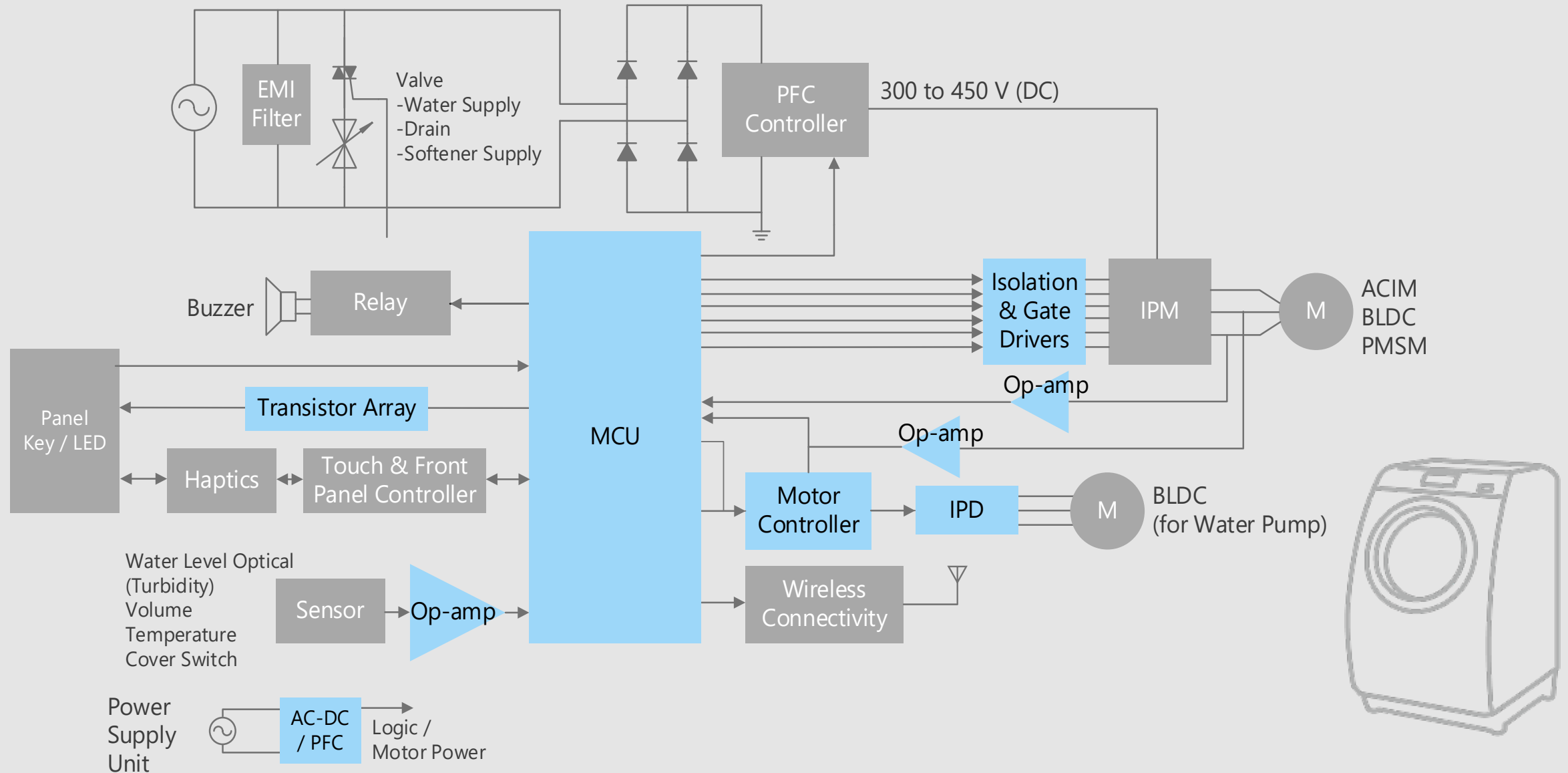


Toshiba Electronic Devices & Storage Corporation provides comprehensive device solutions to customers developing new products by applying its thorough understanding of the systems acquired through the analysis of basic product designs.

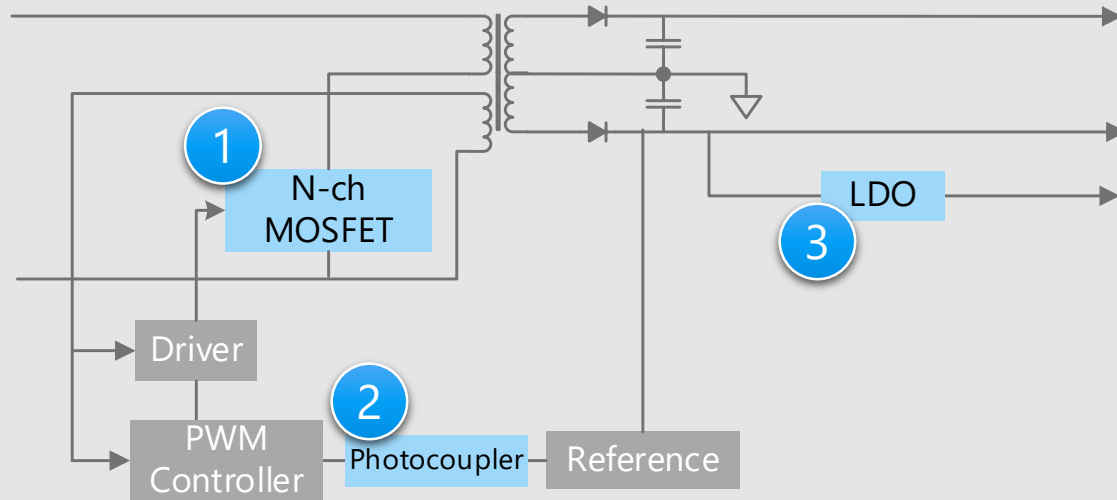
Block Diagram



Washing Machine Overall block diagram



AC-DC circuit



※ Click the number in the circuit diagram to jump to the detailed description page.

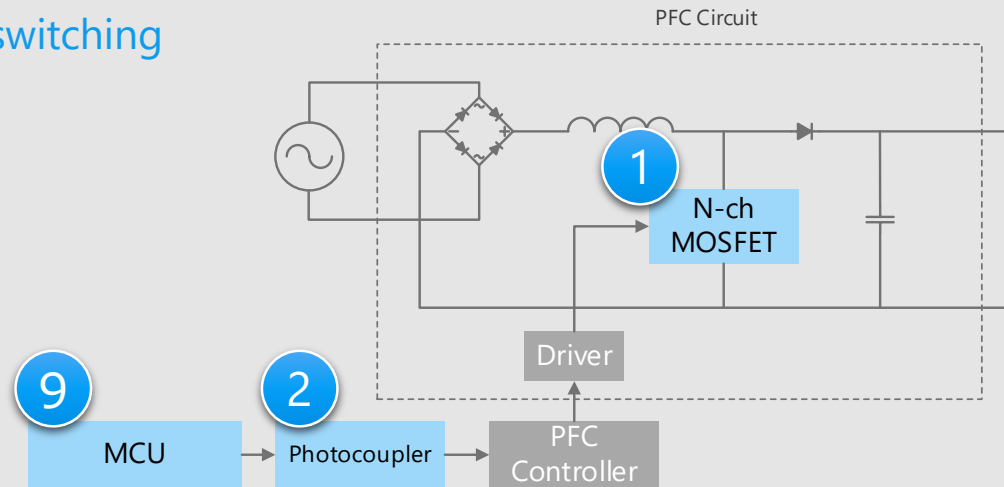
Criteria for device selection

- High voltage MOSFETs are suitable for switching on primary side of AC-DC converter.
- Transistor output photocoupler is for output voltage feedback.
- Stable system can be realized by using LDO that is resistant to noise generated by the motor drive unit.

Proposals from Toshiba

- **Suitable for high efficiency power supply switching** 1
DTMOS IV Series power MOSFET
- **Photocoupler with excellent environmental resistance** 2
Transistor output photocoupler
- **Resistant to power supply noise** 3
Small surface mount LDO regulator

PFC circuit Full switching



Criteria for device selection

- MOSFET is suitable for full switching solutions.
- Transistor output photocoupler is for signal isolation.
- Microcomputer can be used for PFC control.

Proposals from Toshiba

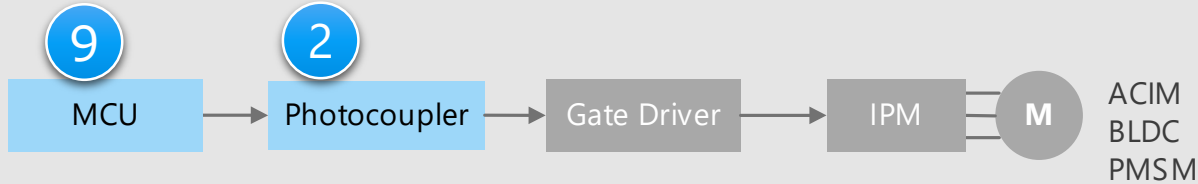
- **Suitable for high efficiency power supply switching**
DTMOS IV Series power MOSFET 1
- **Photocoupler with excellent environmental resistance**
Transistor output photocoupler 2
- **Control the system with low power consumption and high performance**
MCU 9

※ Click the number in the circuit diagram to jump to the detailed description page.

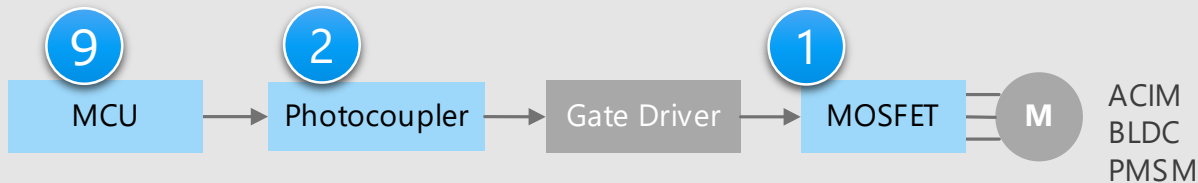
Washing Machine Detail of motor drive unit

Main motor drive unit

MCD (controller) + gate driver + IPM



MCD (controller) + gate driver + MOSFET



Water pump drive unit

MCD (controller) + high voltage IPD



※ Click the number in the circuit diagram to jump to the detailed description page.

Criteria for device selection

- IPD is suitable for water pump motor drive.
- MOSFET with reverse recovery time similar to FRD (Fast Recovery Diode) is suitable for driving the motor.
- Transistor output photocoupler is for signal isolation.
- Brushless motor driver can easily drive a three-phase brushless motor under inverter control.

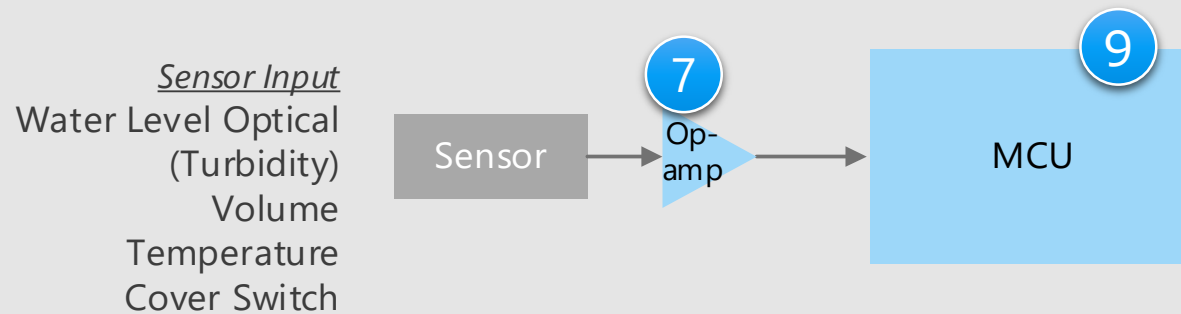
Proposals from Toshiba

- **Suitable for high efficiency power supply switching** 1
DTMOS IV Series power MOSFET
- **Photocoupler with excellent environmental resistance** 2
Transistor output photocoupler
- **Motor drive circuit with high voltage can be realized** 4
High voltage IPD
- **Easy to drive the motor** 5
Three-phase brushless DC motor driver
- **Control the system with low power consumption and high performance** 9
MCU

Communication unit



Sensor input unit



※ Click the number in the circuit diagram to jump to the detailed description page.

Criteria for device selection

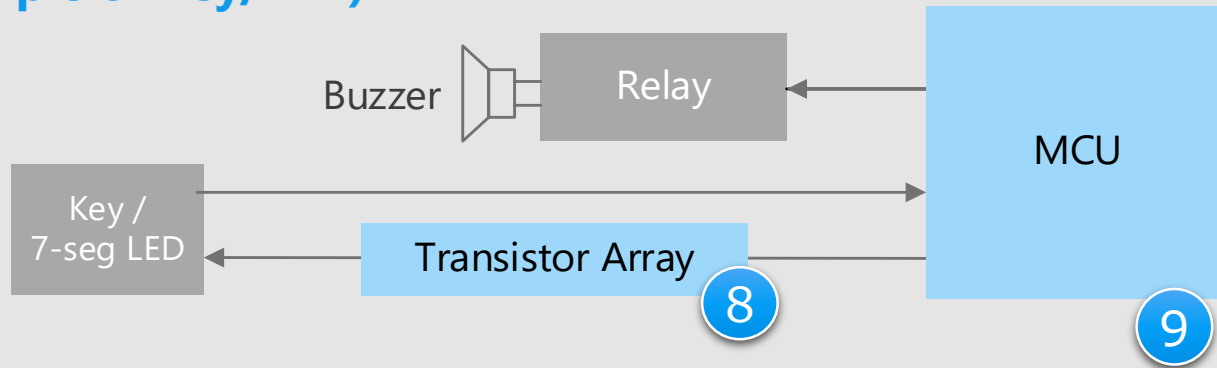
- Low R_{DYN} characteristic of ESD protection diode (TVS) is significant indicator of ESD protection performance.
- Stable system can be realized by using an operational amplifier that is resistant to noise generated by the motor drive unit.

Proposals from Toshiba

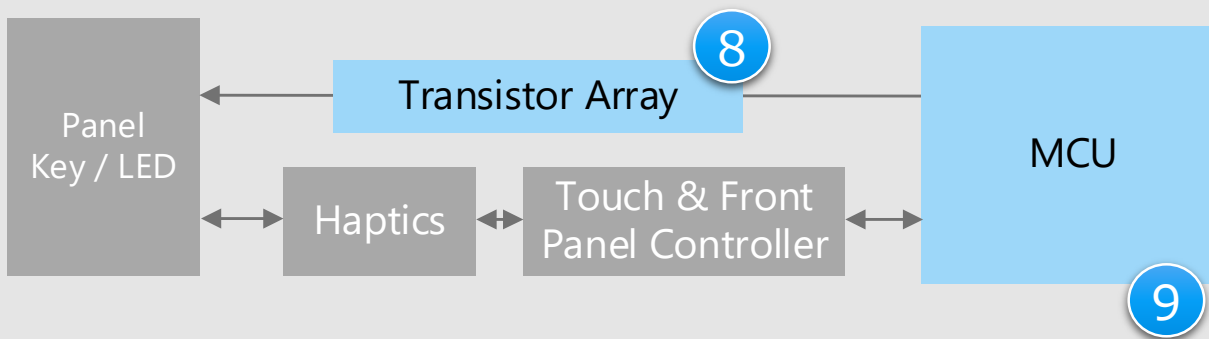
- **Absorb static electricity (ESD) from external terminals and prevent circuit malfunction** TVS diode 6
- **Accurately capturing changes of consumption current, etc.** Low noise operational amplifier 7
- **Control the system with low power consumption and high performance** MCU 9

Washing Machine Detail of operation unit

Operation unit (example of Key/LED)



Operation unit (example of Touch panel)



※ Click the number in the circuit diagram to jump to the detailed description page.

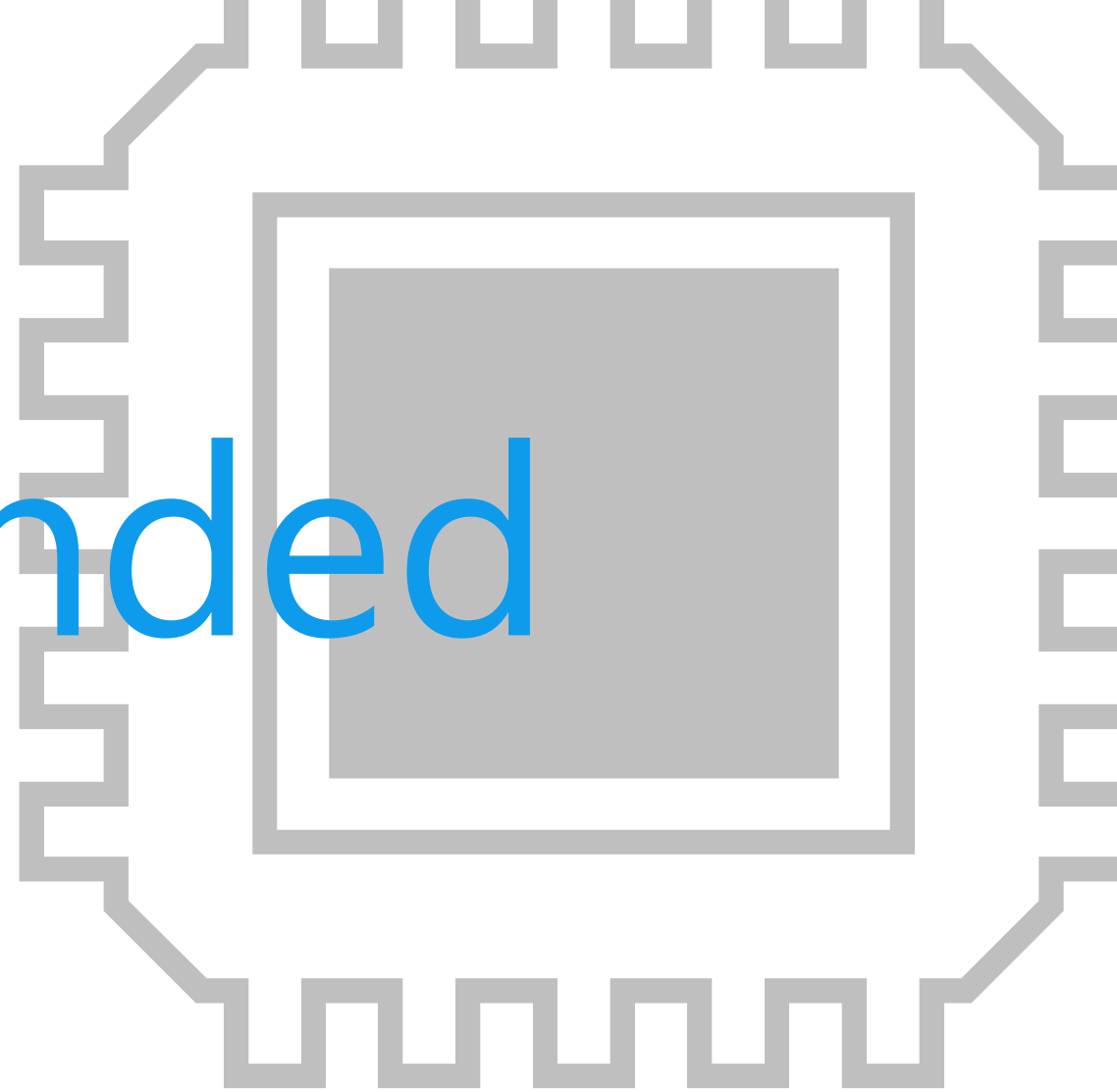
Criteria for device selection

- Transistor array with low loss is suitable for driving LED or touch panel in operation unit.

Proposals from Toshiba

- **High current and high efficiency driver with DMOS FET** 8
Transistor array
- **Control the system with low power consumption and high performance** 9
MCU

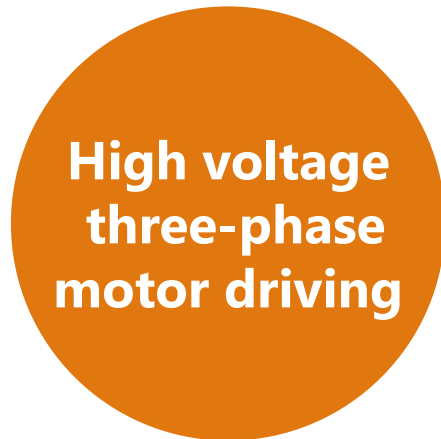
Recommended Devices



Device solutions to address customer needs

As described above, in order to design Washing Machine, “**Quieter and more efficient motors**”, “**Lower power consumption of the set**” and “**Miniaturization of circuit boards**” are important factors. Toshiba’s proposals are based on these three solution perspectives.

Quieter and more efficient
motors



Lower power consumption
of the set



Miniaturization
of circuit boards



Device solutions to address customer needs

High voltage
three-phase
motor driving

High
efficiency
·
Low loss

Small size
packages

| | | | | |
|---|--|---|---|---|
| ① | DTMOS IV Series power MOSFET | ● | ● | ● |
| ② | Transistor output photocoupler | | ● | ● |
| ③ | Small surface mount LDO regulator | | ● | ● |
| ④ | High voltage IPD | ● | ● | ● |
| ⑤ | Three-phase brushless DC motor driver | ● | ● | ● |
| ⑥ | TVS diode | | | ● |
| ⑦ | Low noise operational amplifier | | ● | ● |
| ⑧ | Transistor array | | ● | ● |
| ⑨ | MCU | ● | ● | ● |

1 DTMOS IV Series power MOSFET

TK31N60W / TK28A65W / TK20A60W5

High voltage
three-phase
motor driving

High
efficiency
·
Low loss

Small size
packages

Value provided

The performance index RonA is reduced by 30 % (compared with Toshiba conventional products) to improve power efficiency, which greatly contributes to miniaturization.

1 30 % reduction of RonA

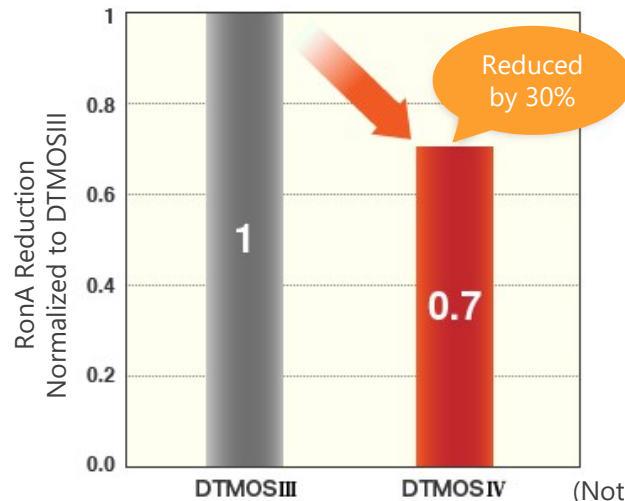
The newly developed single epitaxial process has reduced the RonA by 30 %. (Comparison of DTMOSIII products : Toshiba internal comparison)

2 Reduction of on-resistance rise at high temperature




Single epitaxial process reduces the on-resistance rise at high temperatures.

3 Optimal of gate switching speed

The gate switching speed has been optimized by reducing C_{OSS} (12 % : compared with our conventional products) and by reducing on-resistance (super junction structural DTMOS).



Line up

| Part number | TK31N60W | TK28A65W | TK20A60W5 |
|--|--|---|---|
| Package | TO-247  | TO-220SIS  | TO-220SIS  |
| V_{DSS} [V] | 600 | 650 | 600 |
| I_D [A] | 30.8 | 27.6 | 20 |
| $R_{DS(ON)}$ [Ω] @ $V_{GS} = 10$ V | Typ. | 0.073 | 0.094 |
| | Max | 0.088 | 0.11 |
| Polarity | N-ch | N-ch | N-ch |

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2 Transistor output photocoupler

TLP383 / TLP293 / TLP785 / TLP385

High voltage
three-phase
motor driving

High
efficiency
·
Low loss

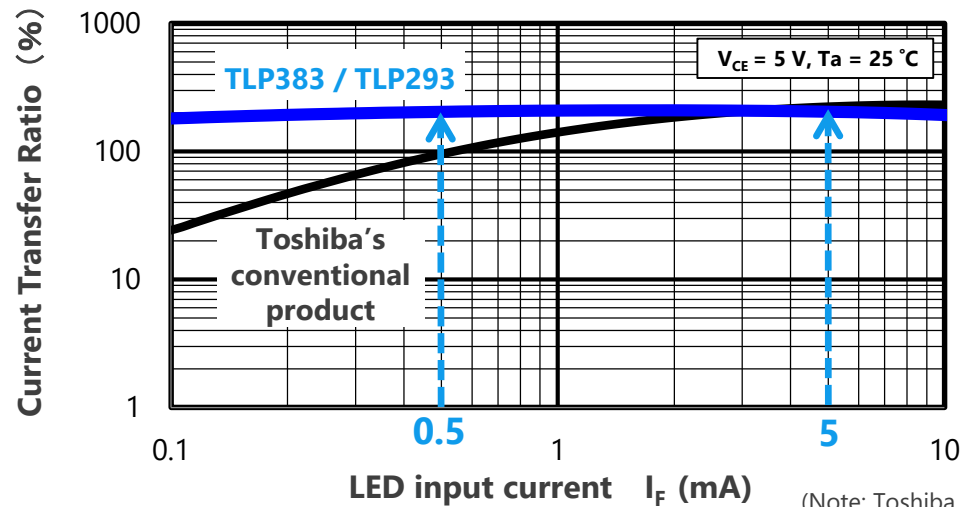
Small size
packages

Value provided

Reduction in required circuit board area and improving reliability enabling maintenance-free operation.

1 High current transfer ratio

The TLP383 / TLP293 is a high-isolation photocoupler that optically couples a phototransistor and high output infrared LED. Compared to Toshiba's conventional products (TLP785 / TLP385), higher CTR (Current Transfer Ratio) in low input current range (@ $I_F = 0.5$ mA) is realized.



2 High temperature operation

The TLP383 / TLP293 is designed to operate under severe conditions of ambient temperature environment, such as inverters, robots, machinery, and high output power supplies.

Line up

| Part number | TLP383 | TLP293 | TLP785 | TLP385 |
|--------------------------|--|--|---|--|
| Package | SO6L (4pin)  | SO4  | DIP4  | SO6L (4pin)  |
| BV_S (Min) [Vrms] | 5000 | 3750 | 5000 | 5000 |
| T_{opr} [$^\circ C$] | -55 to 125 | -55 to 125 | -55 to 110 | -55 to 110 |

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Value provided

Wide line up 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 newly developed new generation process significantly improved the dropout voltage characteristics.

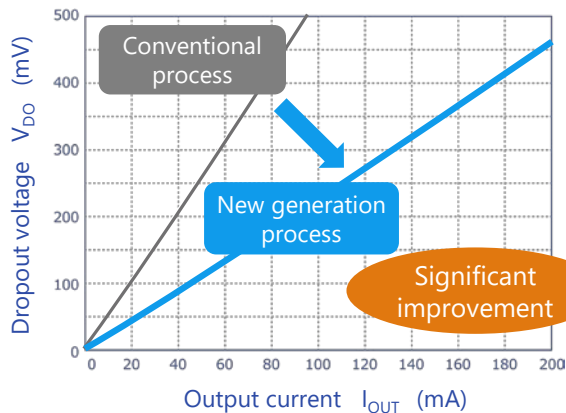
2 High PSRR Low output noise voltage

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

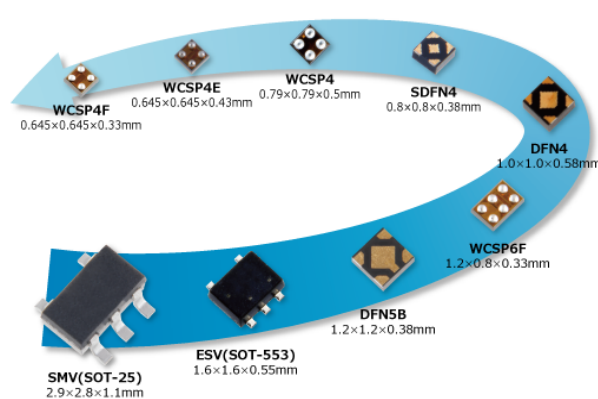
0.34 μA of $I_{B(ON)}$ is realized by utilizing CMOS process and unique circuit technology.

Low dropout voltage



Note: Toshiba internal comparison

Rich package line up



Line up

| Part number | TCR15AG Series | TCR13AG Series | TCR8BM Series | TCR5BM Series | TCR5RG Series | TCR3RM Series | TCR3U Series | TCR2L Series | TAR5 Series |
|--------------------------------|----------------------------------|----------------|---------------|---------------|---|---------------|-------------------------|--------------|-----------------------------------|
| Features | Low dropout voltage High PSRR | | | | High PSRR Low noise Low current consumption | | Low current consumption | | 15V Input voltage Bipolar type |
| I_{OUT} (Max) [A] | 1.5 | 1.3 | 0.8 | 0.5 | 0.3 | | 0.2 | | |
| PSRR (Typ.) [dB] @f=1 kHz | 95 | 90 | 98 | 98 | 100 | 100 | 70 | - | 70 |
| I_B (Typ.) [μA] | 25 | 52 | 20 | 19 | 7 | 7 | 0.34 | 1 | 170 |

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4 High voltage IPD (180° conduction type)

TPD4204F

High voltage
three-phase
motor driving

High
efficiency
·
Low loss

Small size
packages

Value provided

This product has a built-in output power MOSFET and can directly drive a brushless DC motor with an output power of 60 W or less.

1 Various built-in circuits required to drive the motor

A level shifting high side driver, low side driver and power MOSFET for output are built-in. The brushless DC motor can be driven directly by a control signal from the PWM controller IC.

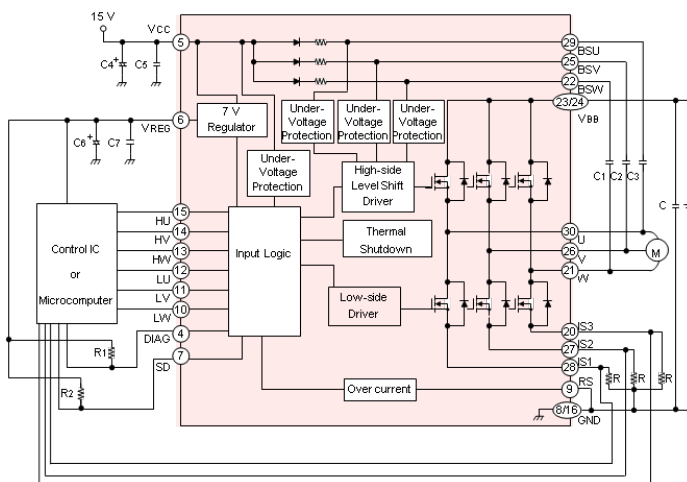
2 Various built-in circuits required to drive the motor

This IPD can be applied to AC 200 V input system even in areas where commercial power supply quality is unstable and voltages are increased to 450 V.

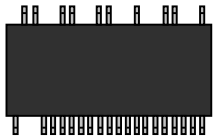
3 Small package

The compact package SSOP30 enables to realize smaller and thinner control board. This contributes to improvement of degree of freedom in design and the reduction of motor case size.

TPD4204F



Line up

| Part number | TPD4204F |
|---------------|--|
| Package | SOP30  |
| V_{BB} [V] | 600 |
| I_{OUT} [A] | 2.5 |
| V_{CC} [V] | 13.5 to 16.5 |

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Value provided

Toshiba's proprietary technology makes it unnecessary to adjust the lead angle and realizes high efficiency over a wide motor speed range.

1 High efficiency motor control over a wide motor speed range is realized

Toshiba's proprietary lead angle control technology provides high efficiency motor control regardless of motor speed, load torque and power supply voltage.

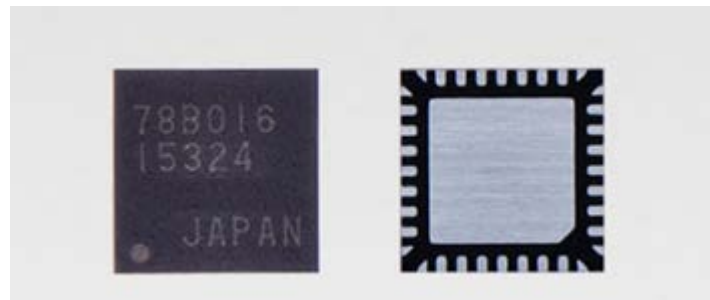
2 Low noise, low vibration motor control

Sine wave drive with smooth current waveforms contributes to lower motor noise and vibration compared to conventional rectangular wave drive^[Note]. (TC78B016FTG)

[Note] Comparison with our products

3 Low loss, low heat generation

The built-in MOSFET has a low output on-resistance of 0.23 Ω (Typ.) . Loss and heat generated by the IC during motor operation can be reduced. (TC78B016FTG)



TC78B016FTG
WQFN36 package (5 x 5 x 0.8 mm)

Line up

| Part number | TC78B016FTG (built-in MOSFET Type) | TB6575FNG |
|--|--|--|
| Power supply voltage (operating range) [V] | 6 to 30 | 4.5 to 5.5 V |
| Output current (operating range) [A] | 3 | 20 mA |
| Drive system | Sine wave drive system | Square wave drive system |
| Other / Features | Lead angle control: Optimum voltage / current phase control, Sensor input: Hall element / Hall IC compatible, Speed control input: PWM signal input / analog voltage input, Abnormality detection function: Overheat detection, Overcurrent detection, Motor lock detection, Output on-resistance (vertical sum): 0.23 Ω (Typ.) | 3-phase full-wave sensorless drive, PWM chopper drive, Overcurrent protection, Forward / reverse rotation, Lead angle control, Overlap commutation, Rotation speed sensing signal, DC excitation mode to improve startup characteristic, Forced commutation frequency can be selected. |

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Value provided

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

1 Improved ESD pulse absorption

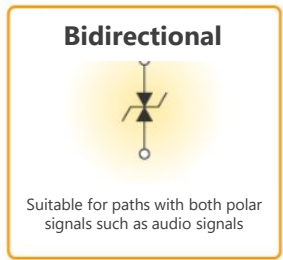
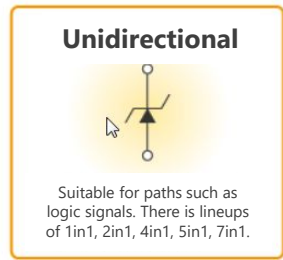
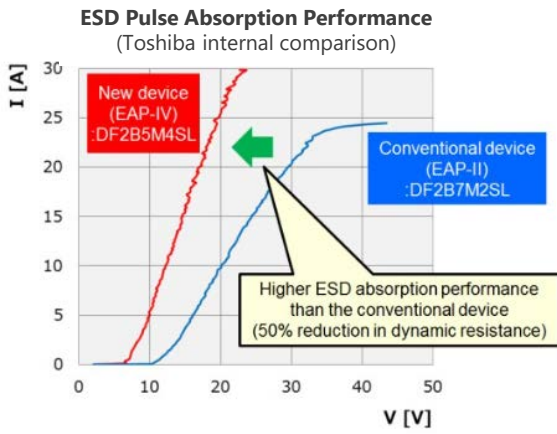
Improved ESD absorption compared to our conventional products. (50 % reduction in operating resistance)
Both low operating resistance and low capacitance are realized and ensures high signal protection performance and signal quality.

2 Reduce ESD energy by low clamp voltage

Steadily protect the connected circuits / devices using proprietary technology.

3 Suitable for high density mounting

A variety of small size packages are available.



Line up

| Part number | DF2B7ASL | DF2S6P1CT | DF2B5M4SL | DF2B6M4SL |
|-------------------------------|----------|-----------|-----------|-----------|
| Package | SL2 | CST2 | SL2 | SL2 |
| V_{ESD} [kV] | ±30 | ±30 | ±20 | ±20 |
| V_{RWM} (Max) [V] | 5.5 | 5.5 | 3.6 | 5.5 |
| C_t (Typ.) [pF] | 8.5 | 90 | 0.2 | 0.2 |
| R_{DYN} (Typ.) [Ω] | 0.2 | 0.23 | 0.5 | 0.5 |

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

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Value provided

Very small signals detected by various sensors can be amplified with low noise.

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

Very small signals detected by various sensors^[Note 1] can be amplified with low noise using CMOS operational amplifier by optimizing the processing. We achieved one of the industry's lowest^[Note 2] input equivalent noise voltage.

2 Low current consumption
 $I_{DD} = 430$ [μA] (Typ.)

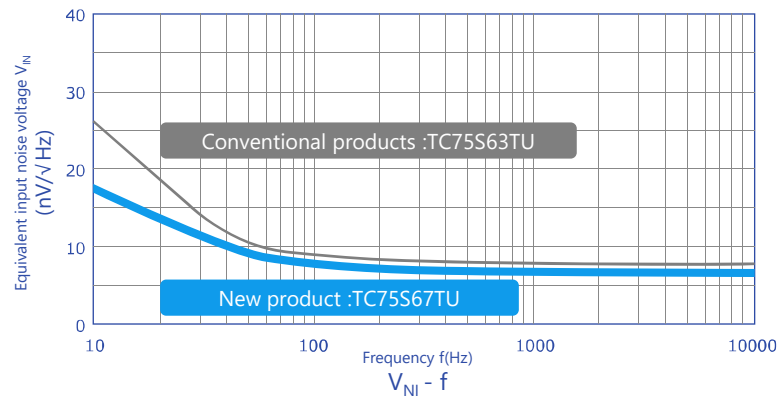
The low current consumption characteristics of CMOS processing contributes to the extension of battery life of the compact IoT devices.

3 Low supply voltage operation

$V_{DD} = 2.2$ to 5.5 V


Low noise characteristic

(Toshiba internal comparison)



[Note 1] Sensor types: vibration detection sensor, shock sensor, accelerometer, pressure sensor, infrared sensor, and temperature sensor
[Note 2] Based on Toshiba data (as of May 2017)

Line up

| | |
|---|--|
| Part number | TC75S67TU |
| Package | UFV  |
| $V_{DD,SS}$ (Max) [V] | ± 2.75 |
| $V_{DD,SS}$ (Min) [V] | ± 1.1 |
| I_{DD} (Max) [μA] | 700 |
| V_{NI} (Typ.) [nV/ $\sqrt{\text{Hz}}$] @ $f = 1$ kHz | 6 |

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Value provided

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 line up

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

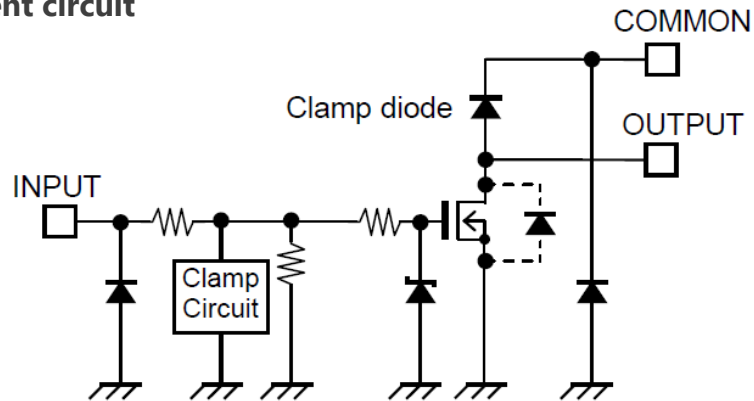
2 Output clamp diode is incorporated.

Incorporated output clamp diode regenerates the back electromotive force generated by switching of an inductive load into the load power supply.

3 Large current drive is possible.

Larger currents can also be driven by connecting multiple outputs in parallel.

Equivalent circuit



Note: Equivalent circuit may be simplified for explanatory purpose.

Line up

| Part number | TBD62003AFWG | TBD62083AFG | TBD62064AFG |
|----------------------|--------------|------------------|-------------|
| Package | SOL16 | SOP18-P-375-1.27 | HSOP16 |
| Output type | Sink | Sink | Sink |
| Number of channels | 7ch | 8ch | 4ch |
| Input level | H | H | H |
| I_{OUT} (Max) [mA] | 500 | 500 | 1500 |
| V_{OUT} (Max) [V] | 50 | 50 | 50 |

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Value provided

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 logic circuit

Versatile three-phase PWM(*) output and sensing timing make both high efficiency and low noise possible. The advanced encoder reduces CPU load of each PWM processing.

3 Equipped with analog circuit for motor control

Multiple high speed and high accuracy AD converters are integrated, allowing conversion timing and PWM output to be linked. External functions such as high performance operational amplifier are integrated on-chip.

(*) Pulse Width Modulation

| Arm® Core | Arm® Cortex®-M0 | Arm® Cortex®-M3 | Arm® Cortex®-M4 |
|--|--|---|--|
| TXZ+™ Family Advanced Class ~ 200 MHz | | TXZ3A+ Series Coming Soon M3H | TXZ4A+ Series <Group> M4K M4M M4G M4N |
| TXZ™ Family ~ 160 MHz | | TXZ3 Series <Group> M3H(1) M3H(2) | TXZ4 Series <Group> M4K(1) M4K(2) M4G(1) M4L(1) |
| TX Family ~ 120 MHz | TX00 Series <Group> M030 M060 | TX03 Series <Group> M310 M330 M340 M360 M370 M380 | TX04 Series <Group> M440 M460 M470 |
| TXZ+™ Family Entry Class ~ 40 MHz | | TXZ3E+ Series Coming Soon | |
| Toshiba Core | 8bit | 32bit | |
| TLCS Family TX Family | TLCS 870/C1 Series TLCS 870/C1E Series | TLCS 900 Series TX19 Series | |

Line up

| Series | Group | Function |
|---------------|------------|--|
| TX03 Series | M370 Group | Arm® Cortex®-M3, includes 1 st gen VE |
| TX04 Series | M470 Group | Arm® Cortex®-M4, includes 2 nd gen VE |
| TXZ4A+ Series | M4K Group | Arm® Cortex®-M4, includes 4 th gen VE |

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