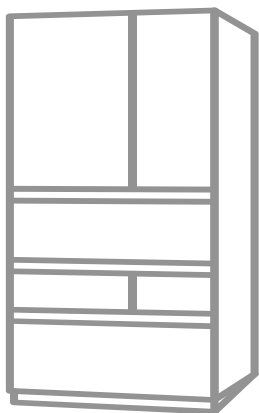


# Refrigerator

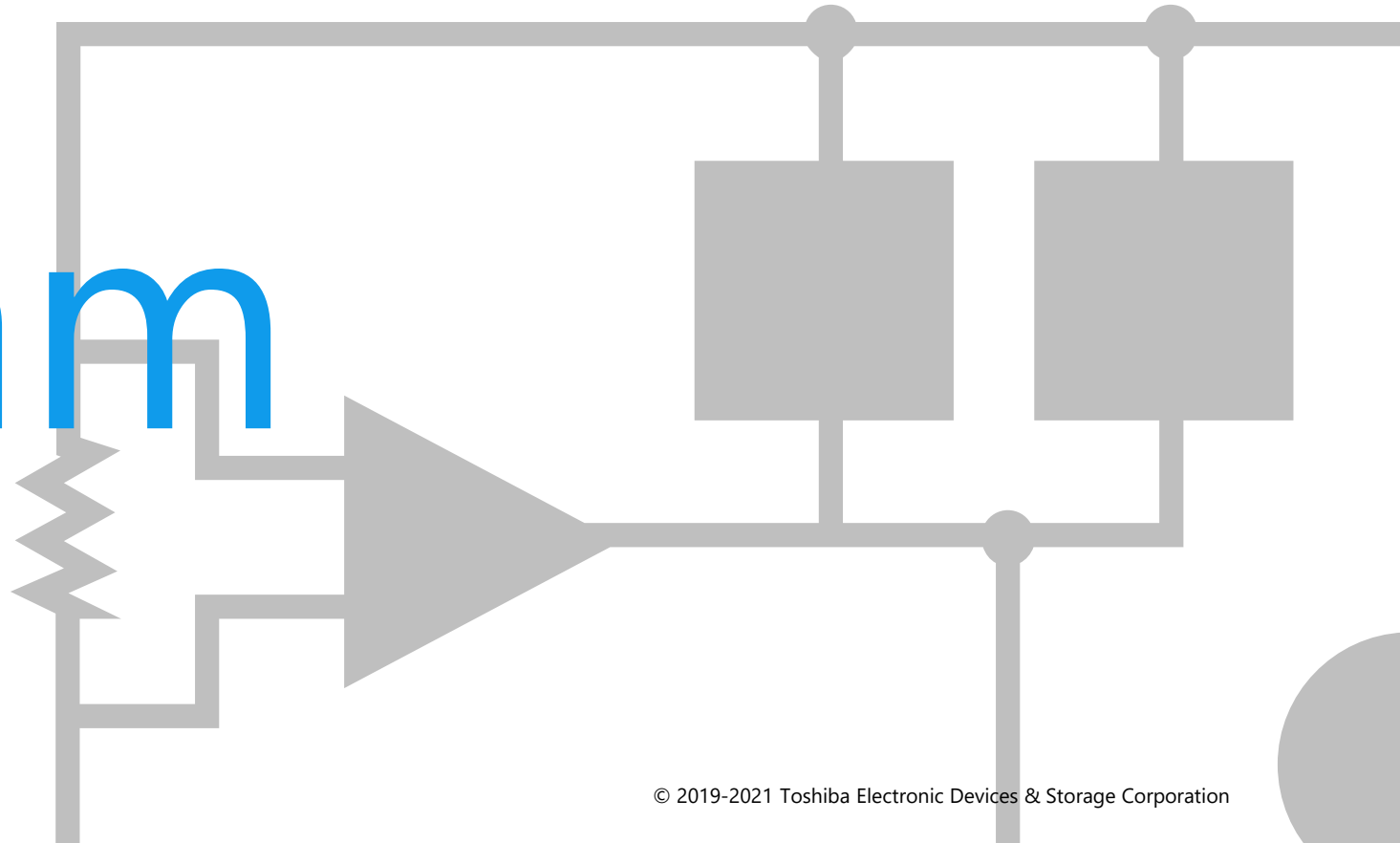
Solution Proposal by Toshiba



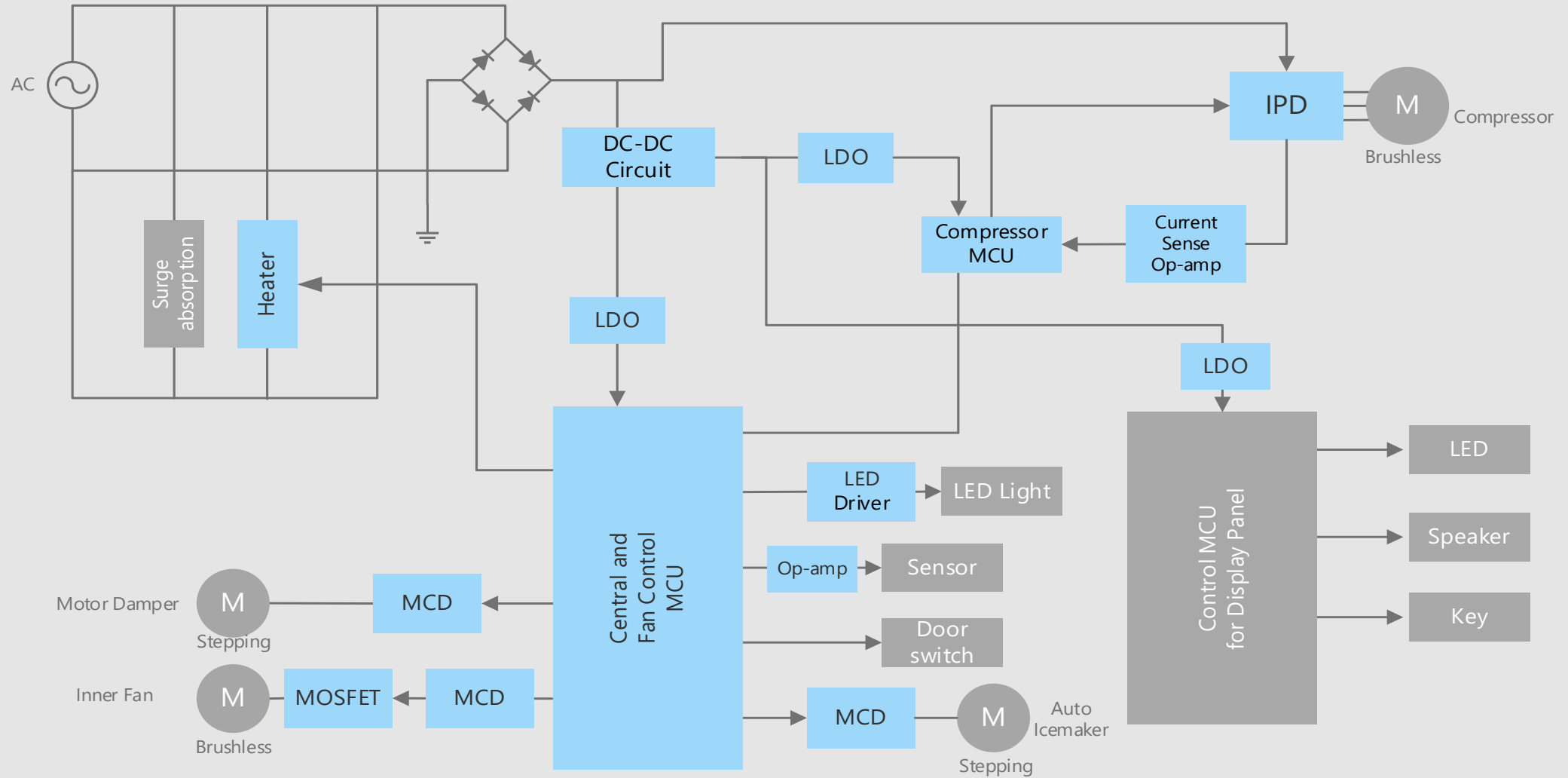


Toshiba Electronic Devices & Storage Corporation provides comprehensive device solutions to customers developing new products by applying its thorough understanding of the systems acquired through the analysis of basic product designs.

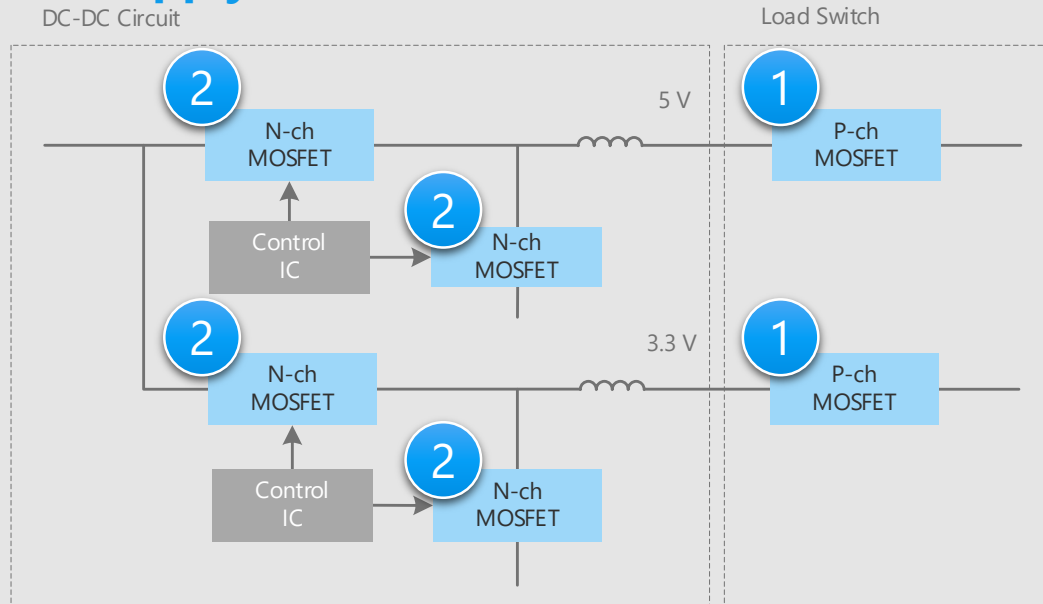
# Block Diagram



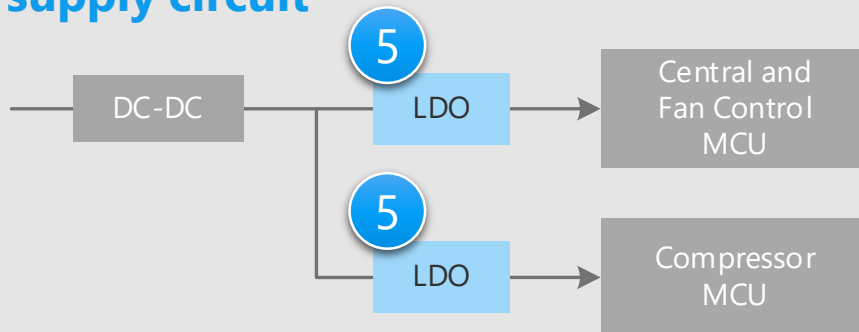
# Refrigerator Overall block diagram



## DC-DC power supply circuits



## MCU power supply circuit



## Device selection points

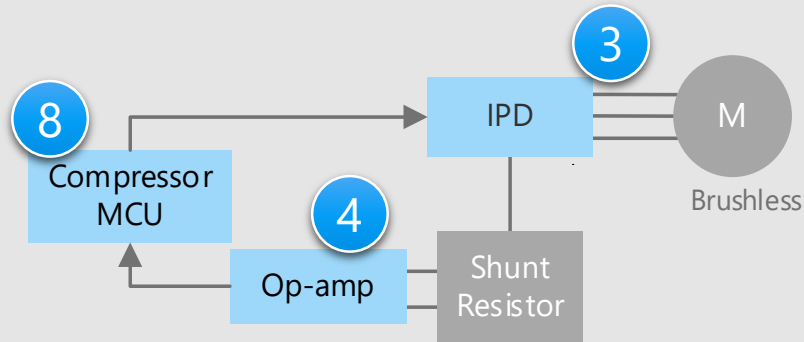
- Small-signal MOSFET is optimal for DC-DC translation.
- LDO is suitable for stable power supply to MCU

## Proposals from Toshiba

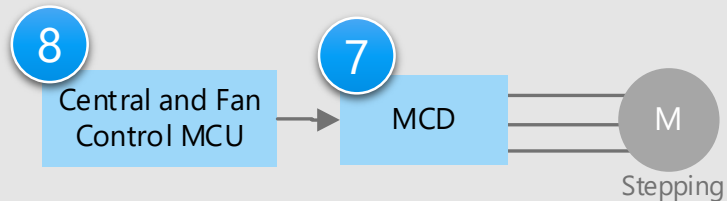
- **Setting of low power consumption with low on-resistance** 1  
U-MOS Series MOSFET (Trench Type)
- **Setting of low power consumption with low on-resistance** 2  
Small-signal MOSFET
- **Optimum power supply for environments with high power supply noise** 5  
Small surface mount LDO regulator

# Refrigerator Details of Motor Driving unit

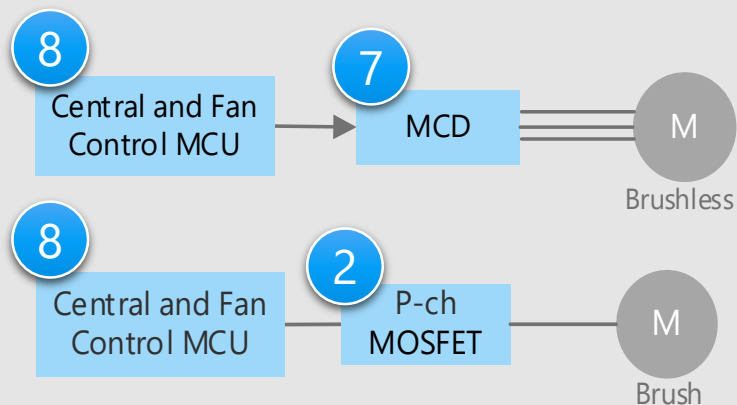
## Compressor drive circuit



## Damper drive circuit



## Fan drive circuit



## Device selection points

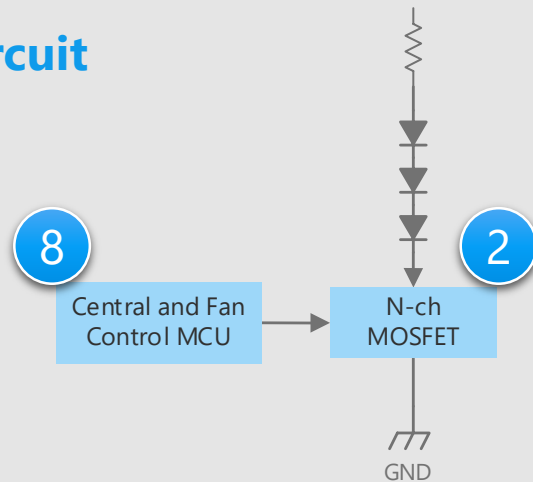
- Intelligent power devices (IPDs) are suitable for driving high-voltage motors such as compressors.
- MCDs are used for driving stepping and brushless DC motors.
- An operational amplifier is used to amplify signals such as current sensing.

## Proposals from Toshiba

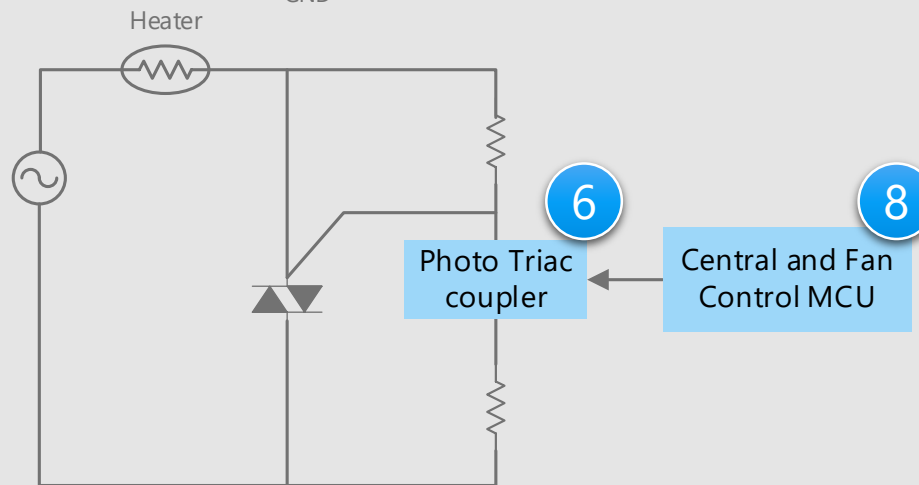
- **Setting of low power consumption with low on-resistance** (2)  
Small-signal MOSFET
- **Built-in high-voltage power MOSFET** (3)  
High-voltage three-phase motor driver
- **Operational amplifier with integrated phase compensation circuit** (4)  
General-purpose operational amplifier
- **Easy control of motors** (7)  
Motor driver
- **Easy software development using general-purpose CPU cores** (8)  
Microcontroller

# Refrigerator Details of Lamp / Heater / Sensor unit

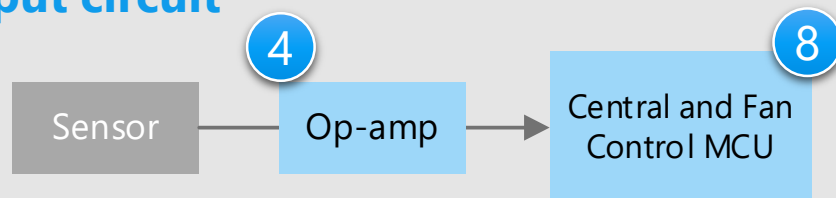
## LED driving circuit



## Heater control circuit



## Sensor input circuit



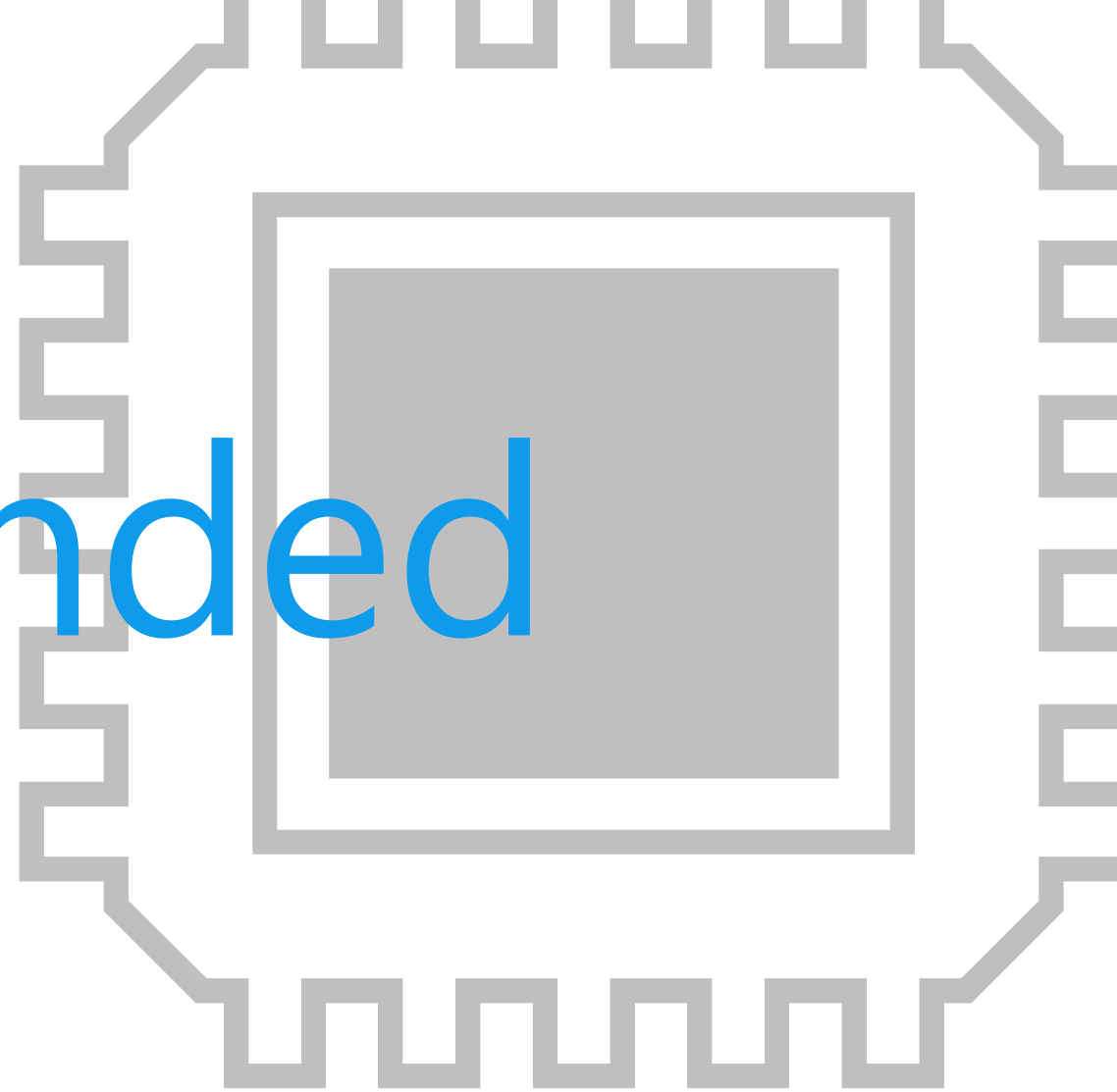
## Device selection points

- A phototriac coupler is the good way to control the AC load.
- Small-signal MOSFET is optimal for driving LEDs.

## Proposals from Toshiba

- **Switching with low on-resistance** 2  
Small-signal MOSFET
- **Operational amplifier with integrated phase compensation circuit** 4  
General-purpose operational amplifier
- **Efficient control of AC load** 6  
Triac output photo couplers
- **Easy software development using general-purpose CPU cores** 8  
Microcontroller

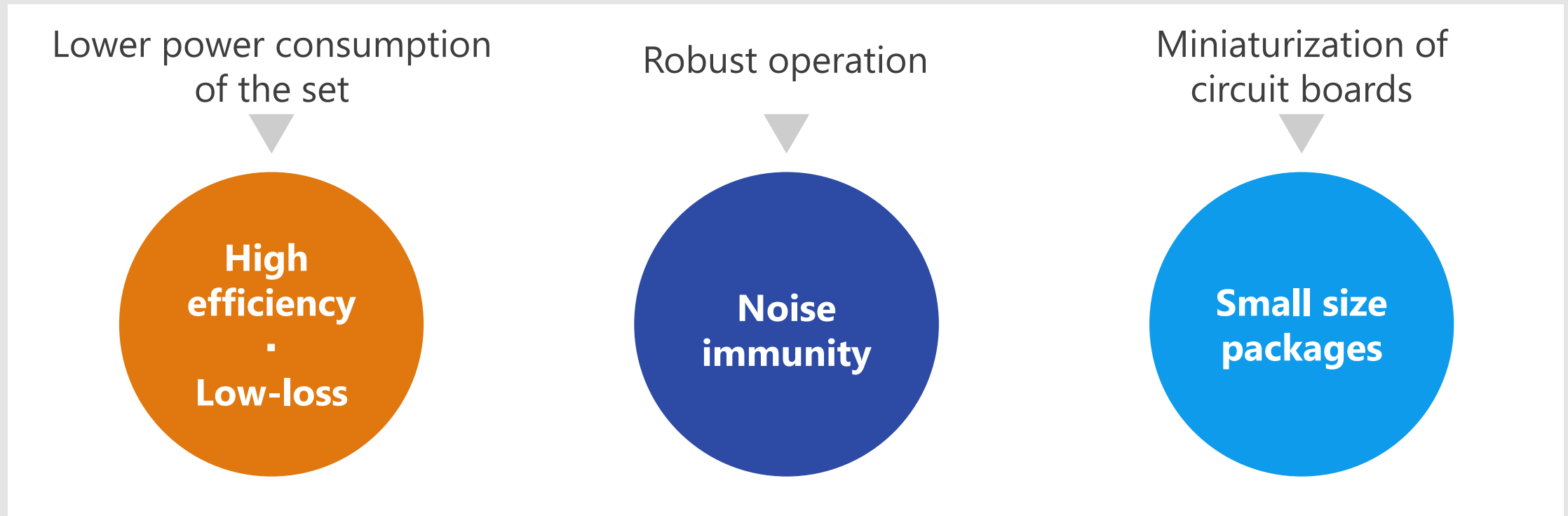
# Recommended Devices





# Device solutions to address customer needs

As described above, in the design of refrigerators, "**Low power consumption of the set**", "**Robust operation**" and "**Miniaturization of circuit boards**" are important factors. Toshiba's proposals are based on these three solution perspectives.



# Device solutions to address customer needs

High efficiency  
-  
Low-loss

Noise immunity

Small size packages

|  | High efficiency<br>-<br>Low-loss | Noise immunity | Small size packages |
|--|----------------------------------|----------------|---------------------|
| 1 U-MOSVI Series MOSFET                    | ●                                |                | ●                   |
| 2 Small-signal MOSFET                      | ●                                |                | ●                   |
| 3 High-voltage three-phase motor driver IC | ●                                |                |                     |
| 4 General-purpose operational amplifier    | ●                                | ●              | ●                   |
| 5 Small surface mount LDO regulator        | ●                                | ●              | ●                   |
| 6 Triac output photo couplers              | ●                                | ●              | ●                   |
| 7 Motor driver                             | ●                                |                | ●                   |
| 8 Microcontroller                          | ●                                |                | ●                   |

Value provided

Suitable for power management switches and easy to handle and greatly contributes to miniaturization.

## 1 Low on-resistance

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

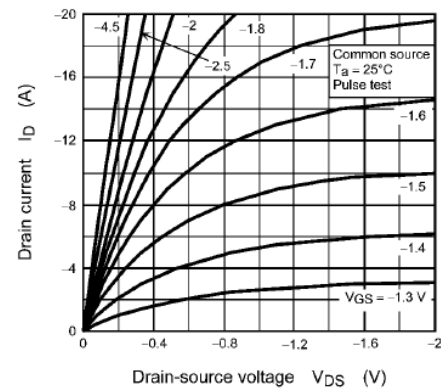
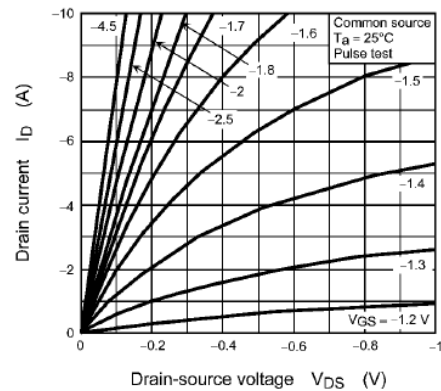
## 2 Low leakage current

Drain cut-off current  $I_{DSS} = 10 \mu\text{A}$  (max.)  
( $V_{DS} = -20 \text{ V}$ )



## 3 Enhancement type

It is easy to handle because it is an enhancement type in which no collector current when no gate voltage is applied.

TPCC8136 Characteristics Curves



Line up

| Part number   | TPCC8136   | SSM6J501NU   |
|---|--|--|
| Package   | TSON Advance  | SOT-1220  |
| $V_{DSS}$ [V]                                       | -20  | -20  |
| $I_D$ [A]   | -9.4   | -8   |
| $P_D$ [W]   | 1.9  | 1  |
| $C_{iss}$ (Typ.) [pF]                               | 2350   | 2500   |
| $R_{DS(ON)}$ (Max) [mΩ] @ $V_{GS} = -4.5 \text{ V}$ | 16   | 15.4   |
| Polarity  | P-ch   | P-ch   |

[Return to Block Diagram TOP](#)

Value provided

Suitable for power management switches and greatly contributes to miniaturization.

## 1 Low voltage drive

$V_{GS} = 4.5 \text{ V}$  drive (SSM3K333R)

$V_{GS} = 1.8 \text{ V}$  drive (SSM6P39TU)

$V_{GS} = 1.2 \text{ V}$  drive (SSM3K35AFS)

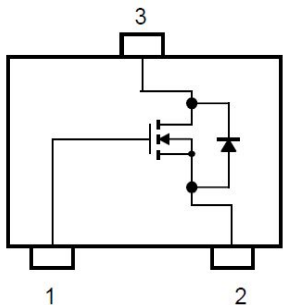
## 2 Low on-resistance

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

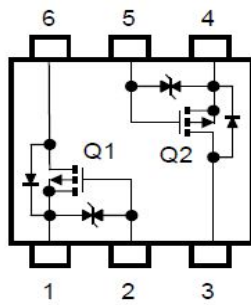
## 3 Small package

Small package is suitable for high-density mounting.

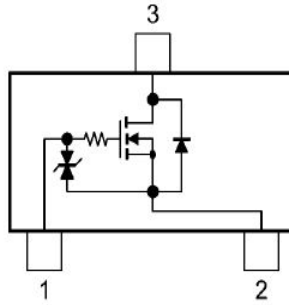
SSM3K333R  
Equivalent Circuit






SSM6P39TU  
Equivalent Circuit



SSM3K35AFS  
Equivalent Circuit



### Line up

| Part number   | SSM3K333R   | SSM3K335R | SSM3J332R | SSM3J334R | SSM6P39TU   | SSM3K35AFU  |
|---|---|-----------|-----------|-----------|---|---|
| Package   | SOT-23F  |           |           |           | UF6  | SSM  |
| $V_{DSS}$ (Min) [V]   | 30  | 30        | -30       | -30       | -20   | 20  |
| $I_D$ (Max) [A]   | 6   | 6         | -6        | -4        | -1.5  | 0.25  |
| $R_{DS(ON)}$ (Max) [ $\Omega$ ]<br>@ $V_{GS} = 4.5 \text{ V}$ | 0.042   | 0.056     | 0.05      | 0.105     | 0.213   | 1.1   |
| Polarity  | N-ch  |           | P-ch      |           | P-ch × 2  | N-ch  |

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# 3 High-voltage three-phase motor driver IC

TPD4207F

High efficiency  
Low-loss

Noise immunity

Small size packages

Value provided

A DC-brushless motor driver with a built-in MOSFET can be driven at a variable speed by control signals from the MCU.

## 1 Built-in circuitry required to drive the motor

It contains a level-shifting high-side driver, low-side driver, and power MOSFET.

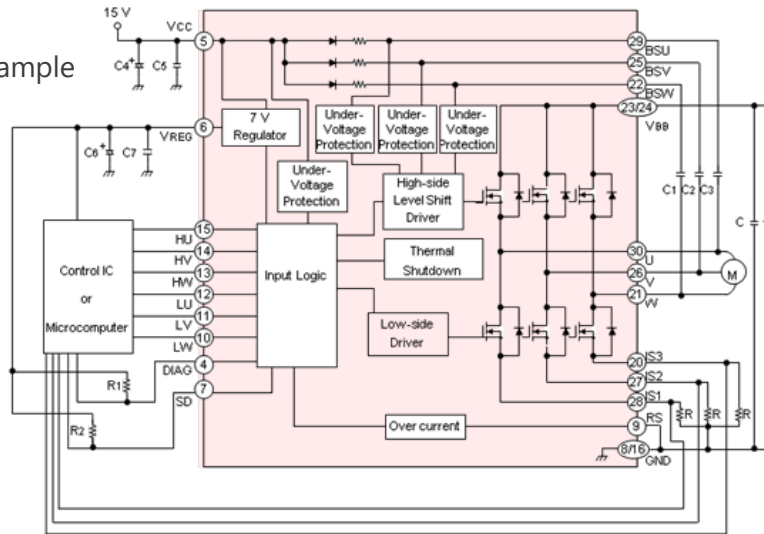
## 2 High voltage power terminals and control terminals are separated

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


## 3 Included protection functions

It has built-in over-current protection, thermal shutdown, shutdown (SD) and under-voltage protection functions.

TPD4207F  
Application Circuit Example



### Line up

| Part number             | TPD4207F  |
|-------------------------|---|
| Package                 | SSOP30  |
| $V_{BB}$ (Max) [V]      | 600   |
| $I_{OUT(DC)}$ (Max) [A] | 5.0   |
| $V_{CC}$ [V]            | 13.5 to 16.5  |

[Return to Block Diagram TOP](#)

# 4 General-purpose operational amplifier

## TC75S51FU

High efficiency  
Low-loss

Noise immunity

Small size packages

Value provided

**CMOS single-operation amplifier with a built-in phase compensator, low-voltage drive, and low-current power supply.**

### 1 Low voltage operation is possible.

Compared with bipolar general-purpose operational amplifiers, low-voltage operation is possible:  $V_{DD} = \pm 0.75$  to  $\pm 3.5$  V or 1.5 to 7 V

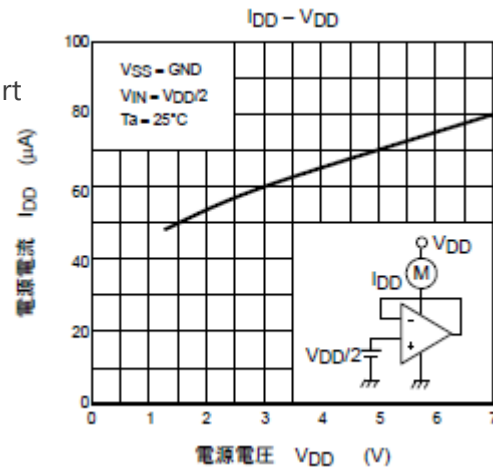
### 2 Low-current power supply $I_{DD}=60[\mu A]$ (Typ.)

The low-current power supply characteristics of CMOS processes contribute to extend the battery life of small IoT devices. [Note 1]

### 3 Built-in phase compensator circuit


Because the phase compensation circuit is built-in, there is no need for any external device.

TC75S51FU  
Characteristics chart



[Note 1] Comparison with our bipolar process operational amplifier

### Line up

| Part number                | TC75S51FU  |
|----------------------------|--|
| Package                    | USV  |
| $V_{DD(opr)}$ [V]          | $\pm 0.75$ to $\pm 3.5$ or 1.5 to 7.0  |
| $I_{DD}$ (Max) [ $\mu A$ ] | 200  |
| $f_T$ (Typ.) [MHz]         | 0.6  |

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# 5 Small surface mount LDO regulator

TCR3DF / TCR2EF Series

High efficiency  
Low-loss

Noise immunity

Small size packages

Value provided

Variety of products that meet high performance requirements, from general-purpose products to ultra-small package type.

## 1 Low dropout voltage

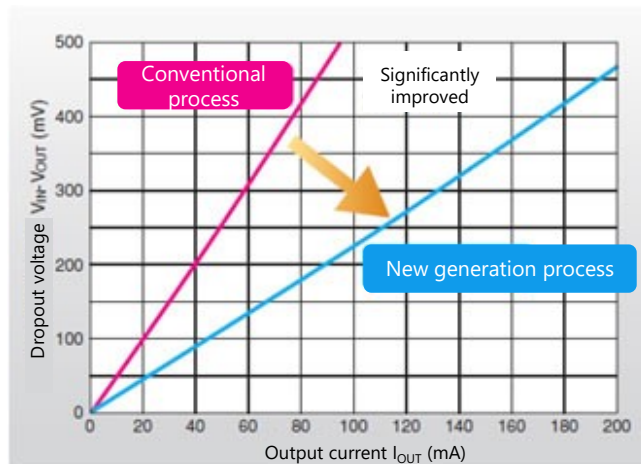
The newly developed new-generation process significantly improved the drop-out characteristics.

## 2 High ripple rejection

Our LDO regulator has a high ripple rejection characteristic, and eliminates switching noise efficiently.



## 3 Ceramic capacitors can be used.

Improved drop-out characteristics have enabled the use of ceramic capacitors as external capacitors.



(Note: Toshiba internal comparison)

### Line up

| Part number         | TCR3DF Series  | TCR2EF series  |
|---------------------|--|--|
| Package             | SMV  | SMV  |
| $V_{IN}$ (Max) [V]  | 5.5  | 5.5  |
| $I_{OUT}$ (Max) [A] | 0.3  | 0.2  |
| $V_{OUT}$ [V]       | 1.0 to 4.5   | 1.0 to 5.0   |

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# 6 Triac output photocouplers

## TLP267J / TLP3052A

High efficiency  
Low-loss

Noise immunity

Small size packages

Value provided

The photocoupler consists of a non zero cross type phototriac, optically coupled to an infrared light emitting diode.

### 1 Non zero cross type

This is suitable for the case where the operation time is short and phase control is necessary.

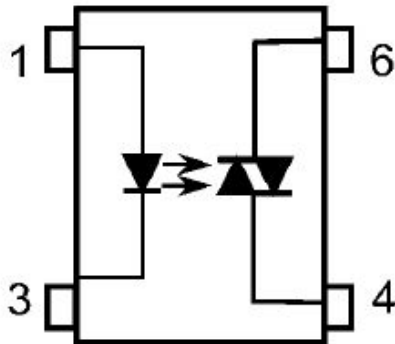
### 2 Switching characteristic

It has excellent points such as high speed, low noise and silence.

### 3 Miniaturization of mounting area



The minimum size is 3.7×7.0×2.1 mm. (SO6)

TLP267J  
Internal connection diagram



UL-approved: UL1577, File No.E67349  
 cUL-approved: CSA Component Acceptance Service No.5A File No.E67349  
 VDE-approved: EN60747-5-5, EN60065 or EN60950-1 (Note)  
 CQC-approved: GB4943.1, GB8898 Thailand Factory  
 (NOTE) When a VDE approved type is needed, please designate the Option (V4).

#### Line up

| Part number         | TLP267J  | TLP3052A   |
|---------------------|--|--|
| Package             | SO6  | 5pin DIP6  |
| $V_{DRM}$ (Max) [V] | 600  | 600  |
| $BV_S$ (Min) [Vrms] | 3750   | 5000   |
| $T_{opr}$ [°C]      | -40 to 100   | -40 to 100   |
| Feature             | Non-zero-voltage turn-on   |  |

[Return to Block Diagram TOP](#)



Value provided

## Support for low voltage motor driving (2.5 V min.) with low power consumption.

### 1 Low voltage operation

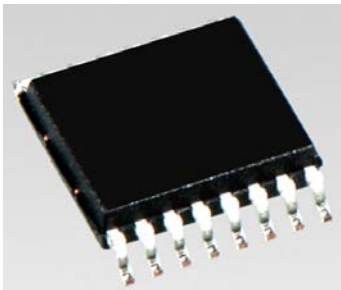
Motor driving voltage is 2.5 V min. for low voltage applications such as battery operation devices.

### 2 Low current consumption

Stand-by current is below 2  $\mu$ A (IC total) for power saving of devices.

### 3 Abnormality detection functions

Over current detection (ISD), Over heat detection (TSD) & Low voltage detection (UVLO) are available for safe motor driving.



TSSOP16 Package (5.0 mm×6.4 mm×1.2mm)

#### Line up

| Part Number  | TC78H621FNG                          | TC78H660FNG                          |
|--|--------------------------------------|--------------------------------------|
| $V_M$ (Max) [V]                                      | 18                                   | 20                                   |
| $I_{OUT}$ (Max) [A]                                  | 1.1                                  | 2.0                                  |
| $R_{on(upper\ and\ lower\ sum)}$ (Typ.) [ $\Omega$ ] | 0.8                                  | 0.48                                 |
| Control Interface                                    | ENABE / PHASE inputs                 | ENABE / PHASE inputs                 |
| Step   | Two-phase excitation                 |                                      |
| Feature  | Motor driving voltage: 2.5 V (Min)   | Motor driving voltage: 2.5 V (Min)   |
| Abnormality detection function                       | Over heat, Over current, Low voltage | Over heat, Over current, Low voltage |
| Package  | TSSOP16                              | TSSOP16                              |

[◆Return to Block Diagram TOP](#)

Value provided

## Simple fan motor drive with low noise & low vibration.

### 1 Suitable for small Fan motor

It is a single phase full-wave driver and suitable for small BLDC Fan motor.

### 2 Low noise & low vibration

Smooth waveform by soft switching drive realizes low noise and low vibration.

### 3 Small package

Small QFN16 package with high heat dissipation.



WQFN16 Package (3 mm×3 mm×0.75 mm)

#### Line up

|                            |   |
|----------------------------|---|
| VM (Max) [V]               | 18  |
| I <sub>OUT</sub> (Max) [A] | 1.5   |
| Drive type                 | Single phase full wave drive  |
| Features & Others          | PWM control<br>Soft switching drive<br>Quick start<br>Hall bias circuit<br>Error detection: Current limit, Thermal shutdown |

[◆Return to Block Diagram TOP](#)

Value provided

## System cost reduction, noise 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 with high efficiency and low noise control made possible by sense timing. The advanced encoder lightens CPU load of each PWM processing.

### 3 Equipped with analog circuit for motor control

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

#### TX Family

##### TX04 Series

To120 MHz

for High-Efficiency Signal Processing Applications

M440 Group

M460 Group

M470 Group

##### TX03 Series

To144 MHz

for a Broad Range of Applications

M310 Group

M330 Group

M340 Group

M360 Group

M370 Group

M380 Group

M390 Group

#### Line up

| Series      | Group      | Function   |
|-------------|------------|--|
| TX03 Series | M370 Group | Arm® Cortex®-M3, includes 1 <sup>st</sup> gen VE |
| TX04 Series | M470 Group | Arm® Cortex®-M4, includes 2 <sup>nd</sup> gen VE |

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