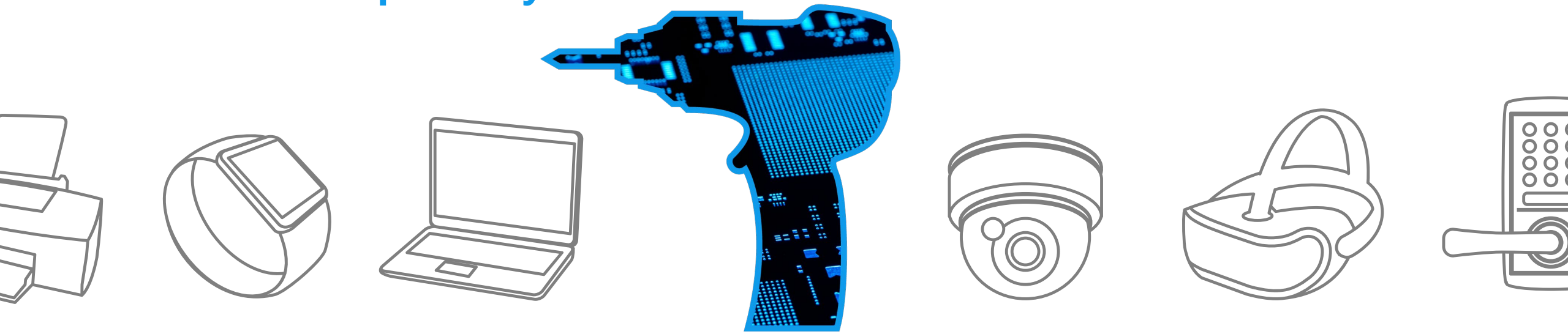
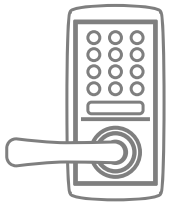
TOSHIBA

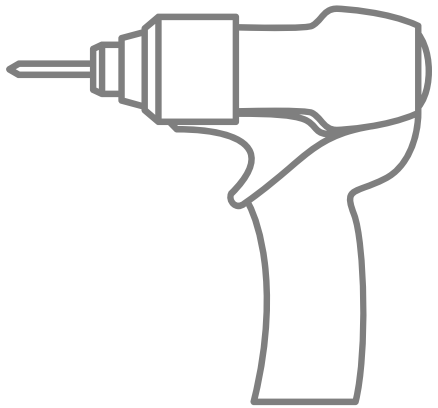
R21

Cordless Power Tool

Solution Proposal by Toshiba

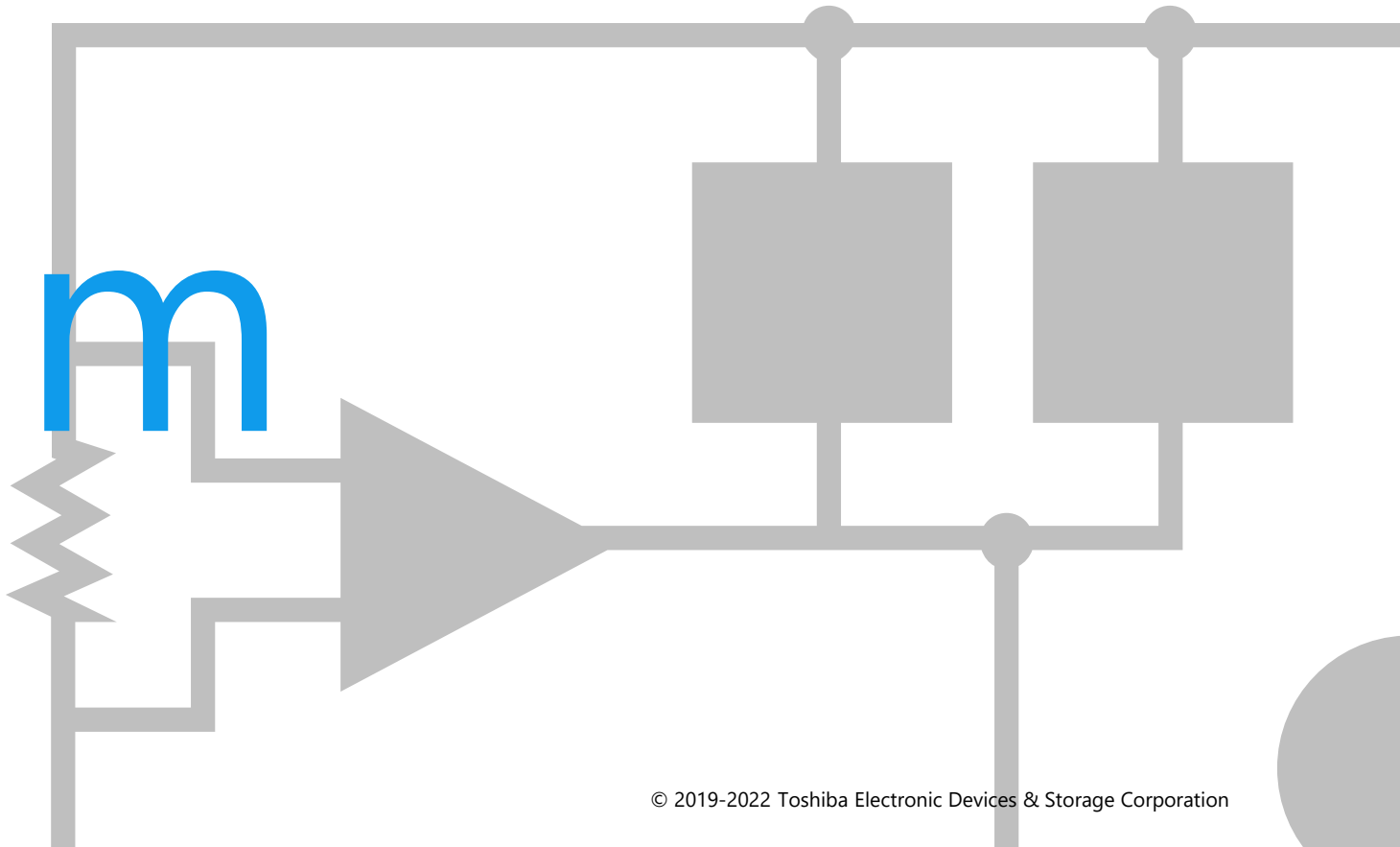




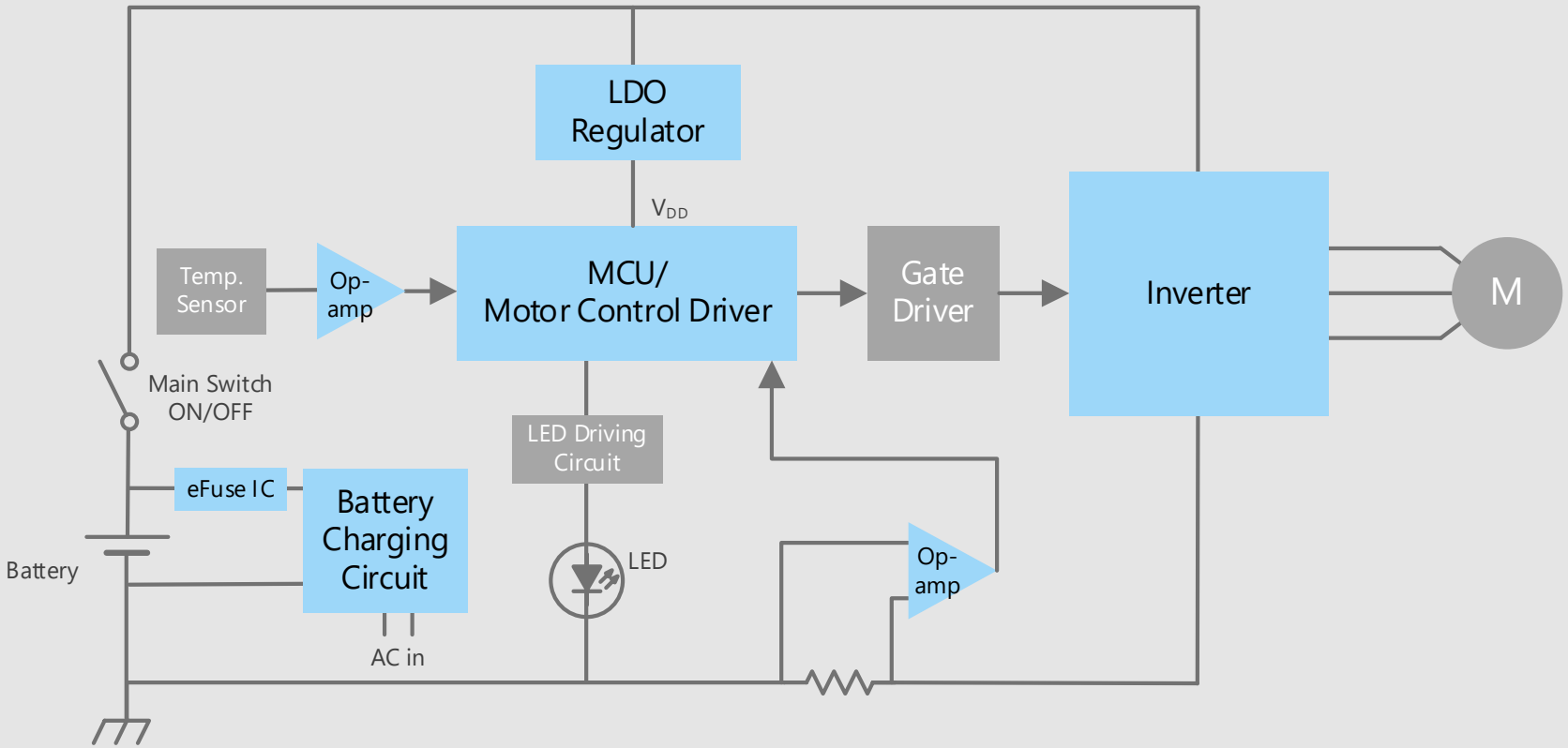


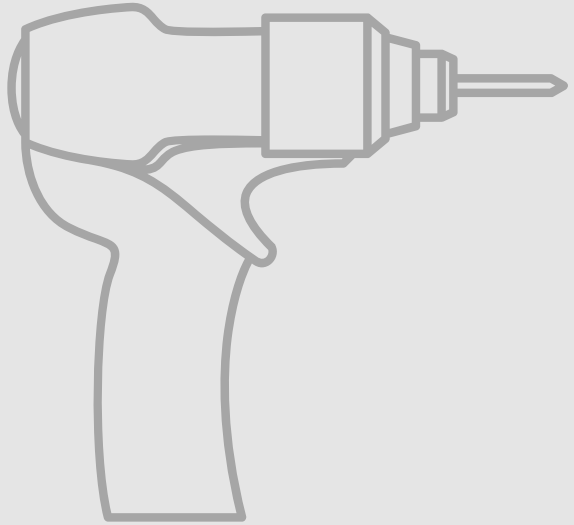
Toshiba Electronic Devices & Storage Corporation provides comprehensive device solutions to customers developing new products by applying its thorough understanding of the systems acquired through the analysis of basic product designs.

Block Diagram



Cordless Power Tools　Overall block diagram



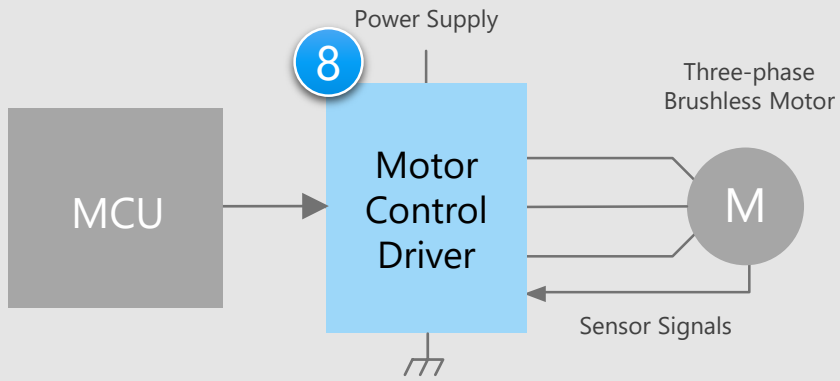


Cordless Power Tools　Details of motor drive unit (1)

Motor drive circuit

Brushless DC motor

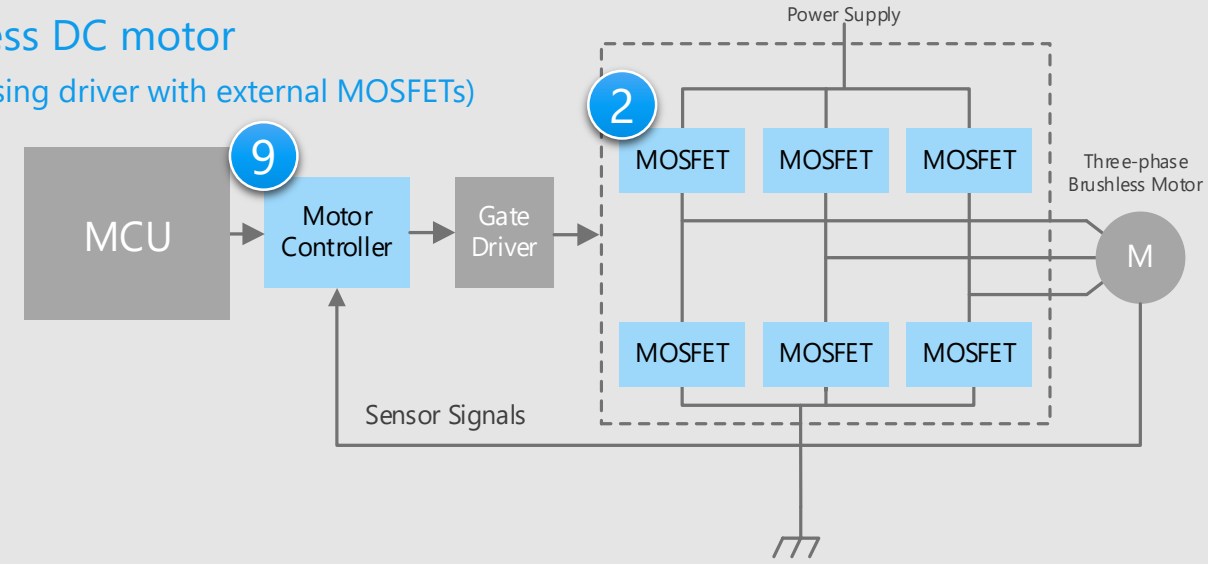
(Circuit using driver with built-in MOSFETs)



Motor drive circuit

Brushless DC motor

(Circuit using driver with external MOSFETs)



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

Criteria for device selection

- By using motor driver, one can easily drive a three-phase brushless DC motor using inverter control which is increasingly popular in recent years.
- System can drive high capacity brushless DC motor by using motor controller with external MOSFET.
- A set with low heat generation and low power consumption can be realized by using MOSFET with low on-resistance and high heat dissipation characteristics as driver.

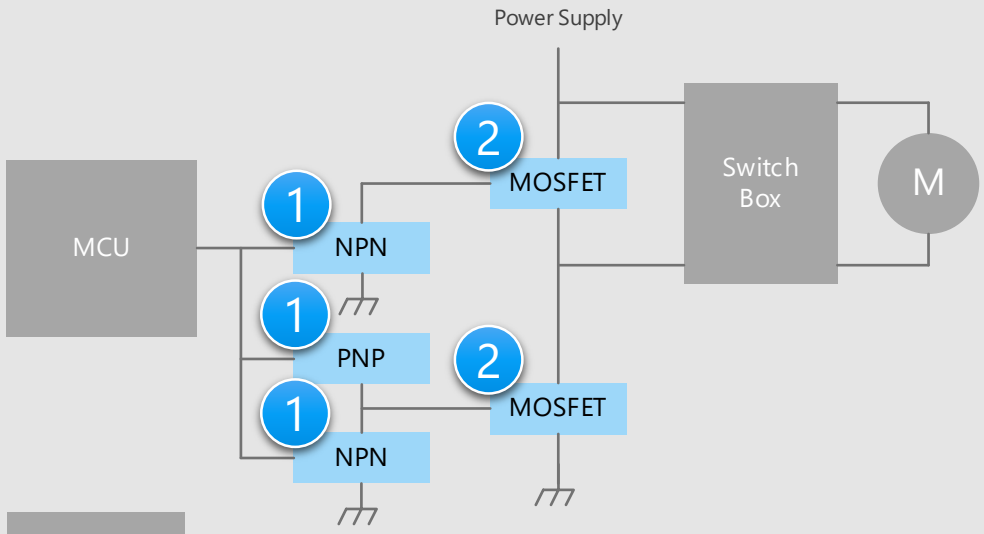
Proposal from Toshiba

- **U-MOS Series MOSFET with low on-resistance and good heat performance**
  U-MOS Series MOSFET 2
- **Motor control driver with built-in MOSFETs that can easily drive three-phase brushless DC motor**
  Three-phase brushless DC motor driver (Built-in MOSFETs) 8
- **Motor controller with external MOSFETs that can drive high capacity three-phase brushless motor.**
  Three-phase brushless DC motor controller (External MOSFETs) 9

Cordless Power Tools　Details of motor drive unit (2)

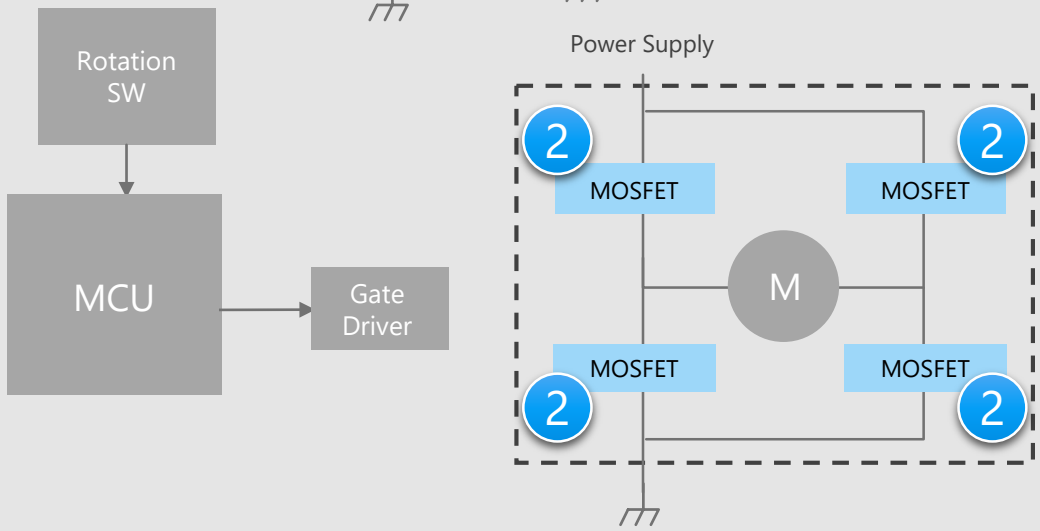
Motor drive circuit

Brushed DC motor/
Mechanical switching



Motor drive circuit

Brushed DC motor/
MOSFET switching



<u>* Click on the numbers in the circuit diagram to jump to the detailed descriptions page</u>

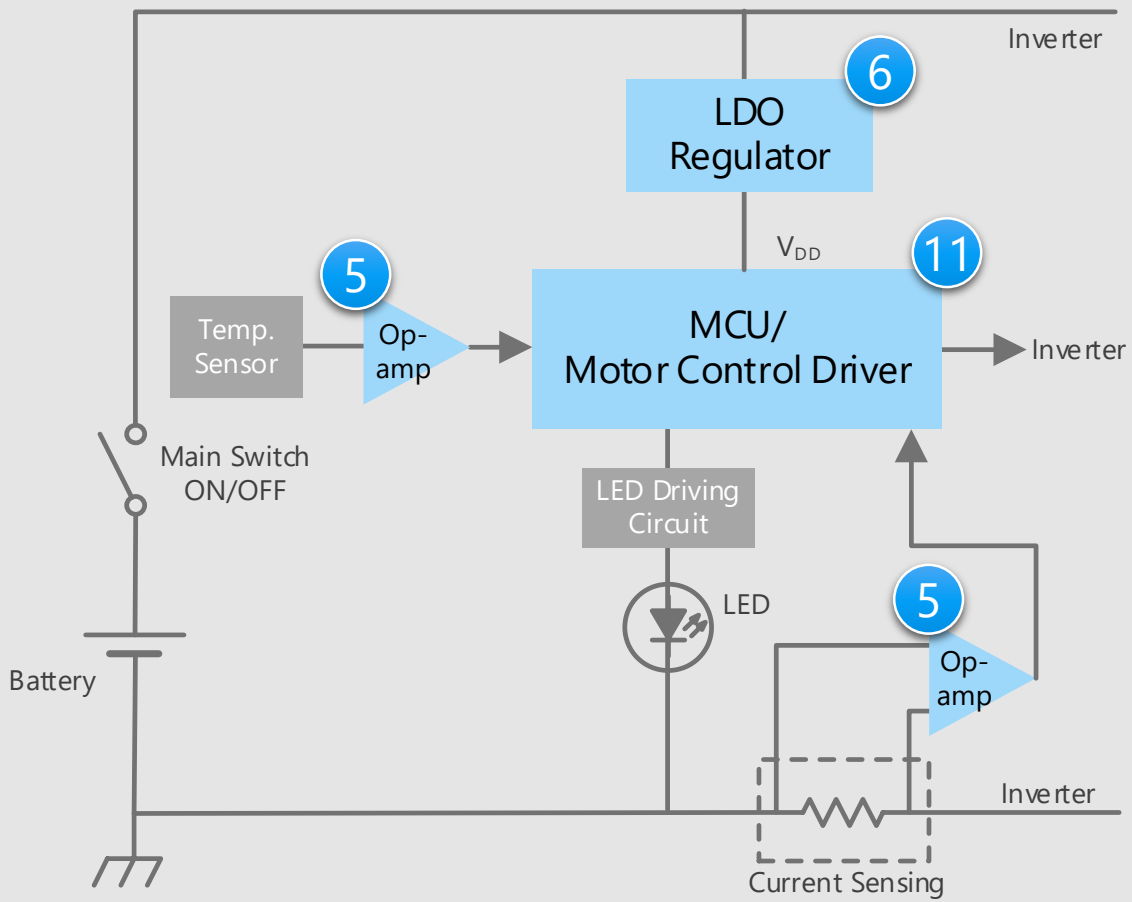
Criteria for device selection

- A gate driver circuit composed of bipolar transistors is suitable for high speed switching of MOSFETs.
- Low loss, high efficiency MOSFET is suitable for the brushless motor drive.
- A high breakdown MOSFET is required taking into account the motor's counter electromotive force.
- Small package products contribute to the reduction of circuit board area.

Proposal from Toshiba

- **Transistor for gate driving**
  Bipolar transistor 1
- **U-MOS Series MOSFET with low on-resistance and good heat performance**
  U-MOS Series MOSFET 2

MCU peripheral circuit



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

Criteria for device selection

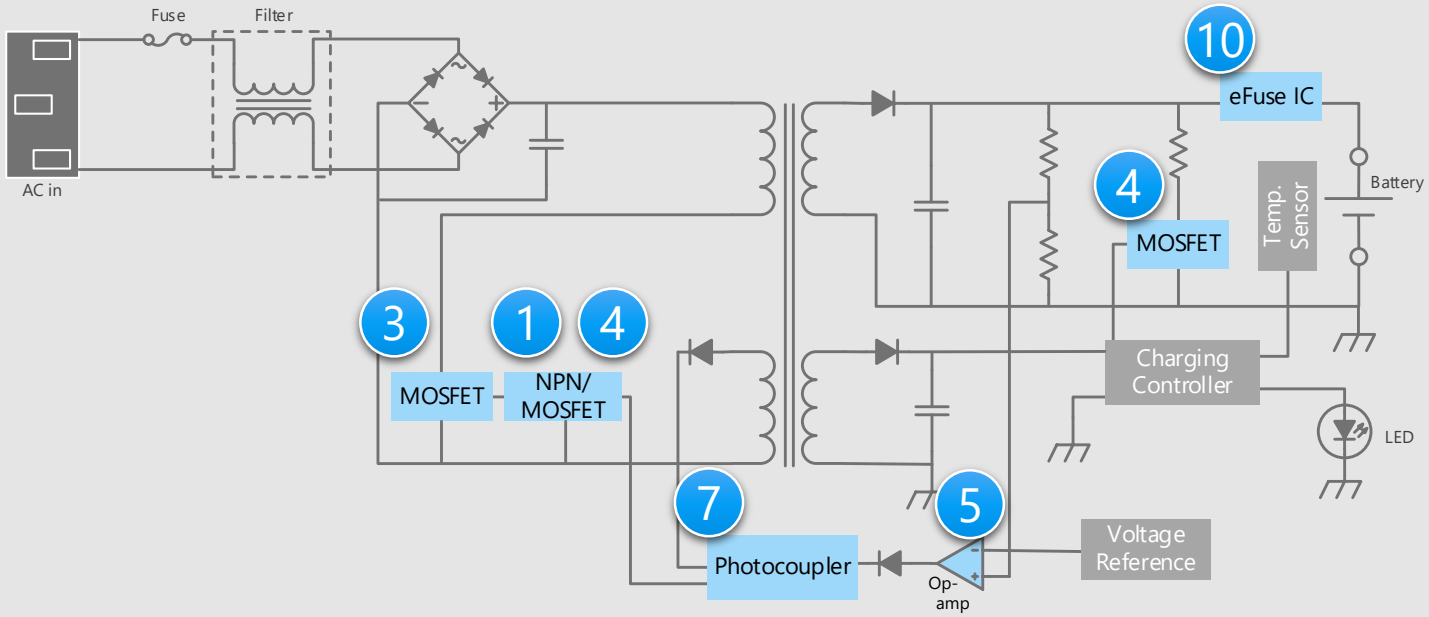
- Low noise operational amplifiers are suitable for amplifying small signals detected by various sensors.
- LDO regulators are suitable for power supply circuits with low ripple noise and stable voltage.
- General purpose MCU suitable for system control and monitoring.

Proposal from Toshiba

- **Amplifies signals detected by various sensors with low noise**
  Low noise operational amplifier 5
- **Small surface mount LDO regulator suitable for power tools having high noise**
  Small surface mount LDO regulator 6
- **MCU suitable for motor control**
  MCU M370 / M470 / M4K Group 11

Cordless Power Tools　Detail of battery charger unit

Battery charging circuit



<u>* Click on the numbers in the circuit diagram to jump to the detailed descriptions page</u>

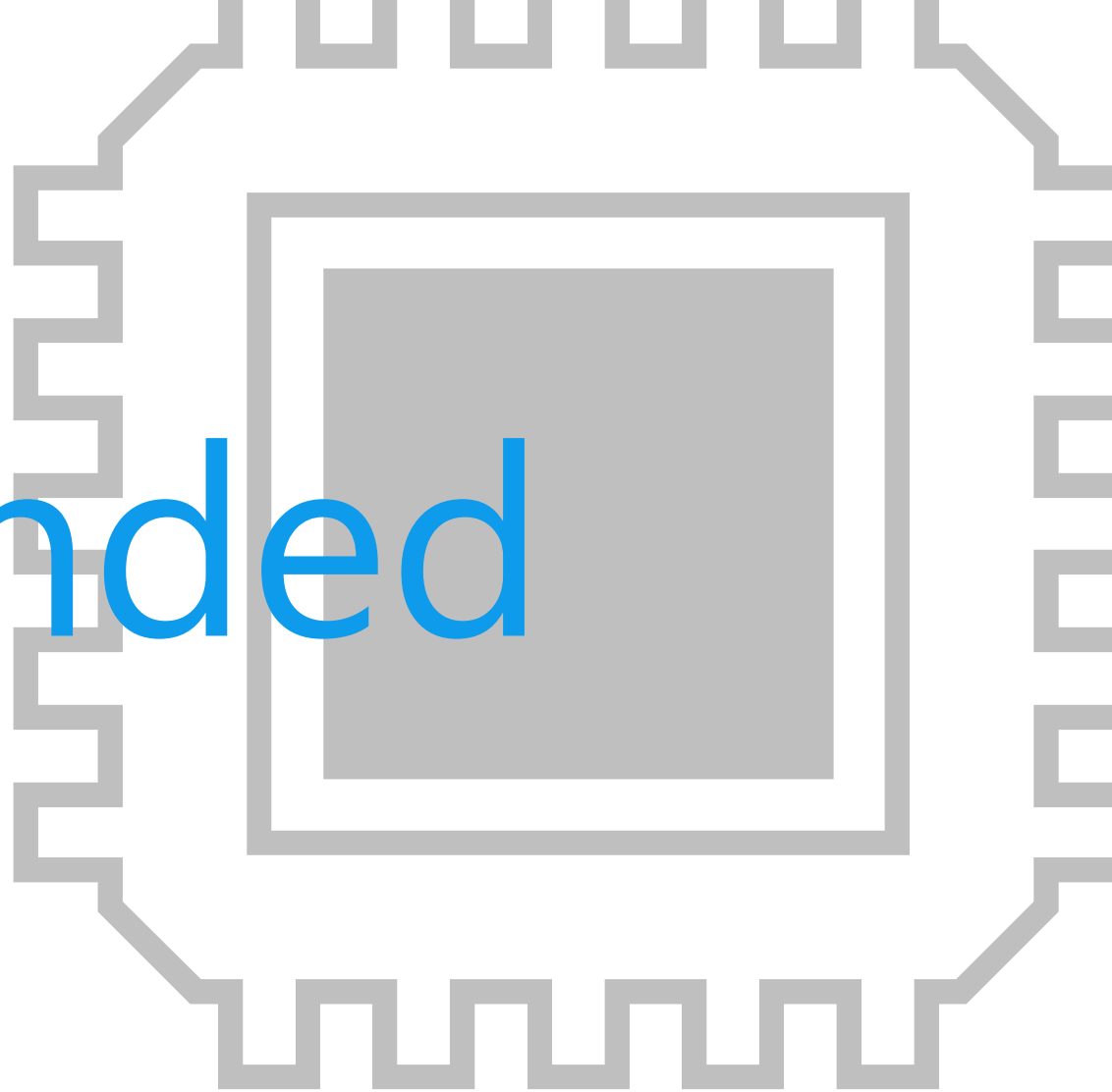
Criteria for device selection

- High voltage and low on-resistance MOSFET is suitable for primary circuit in AC-DC power supply.
- In general, a photocoupler is used for voltage feedback to the primary side to the AC-DC power supply.

Proposal from Toshiba

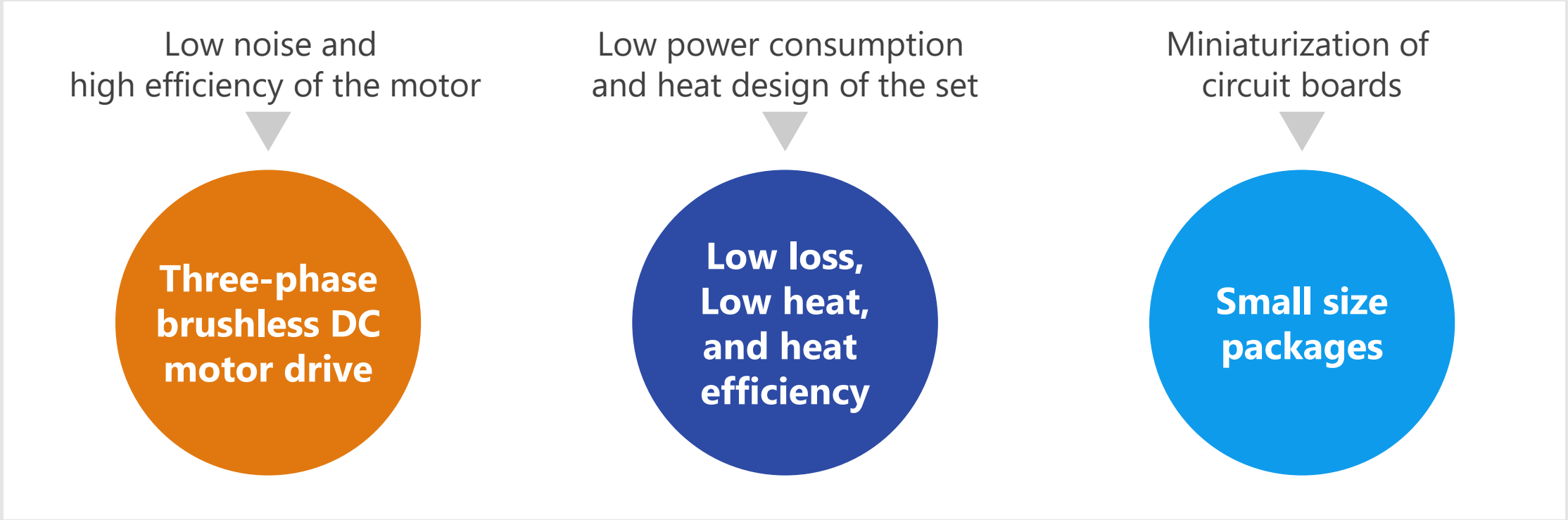
- **Transistor for gate driving** (1)
  Bipolar transistor
- **DTMOS IV MOSFET , good for high efficiency power switching** (3)
  DTMOSⅣ Series MOSFET
- **Small signal MOSFET for low voltage switching** (4)
  Small signal MOSFET
- **Low noise op-amp to capture fluctuations in current consumption accurately** (5)
  Low noise operational amplifier
- **High current transfer ratio and high temperature operation makes easy to design.** (7)
  Transistor output photocoupler
- **eFuse IC for robust protection** (10)
  Electronic Fuse (eFuse IC)

Recommended Devices

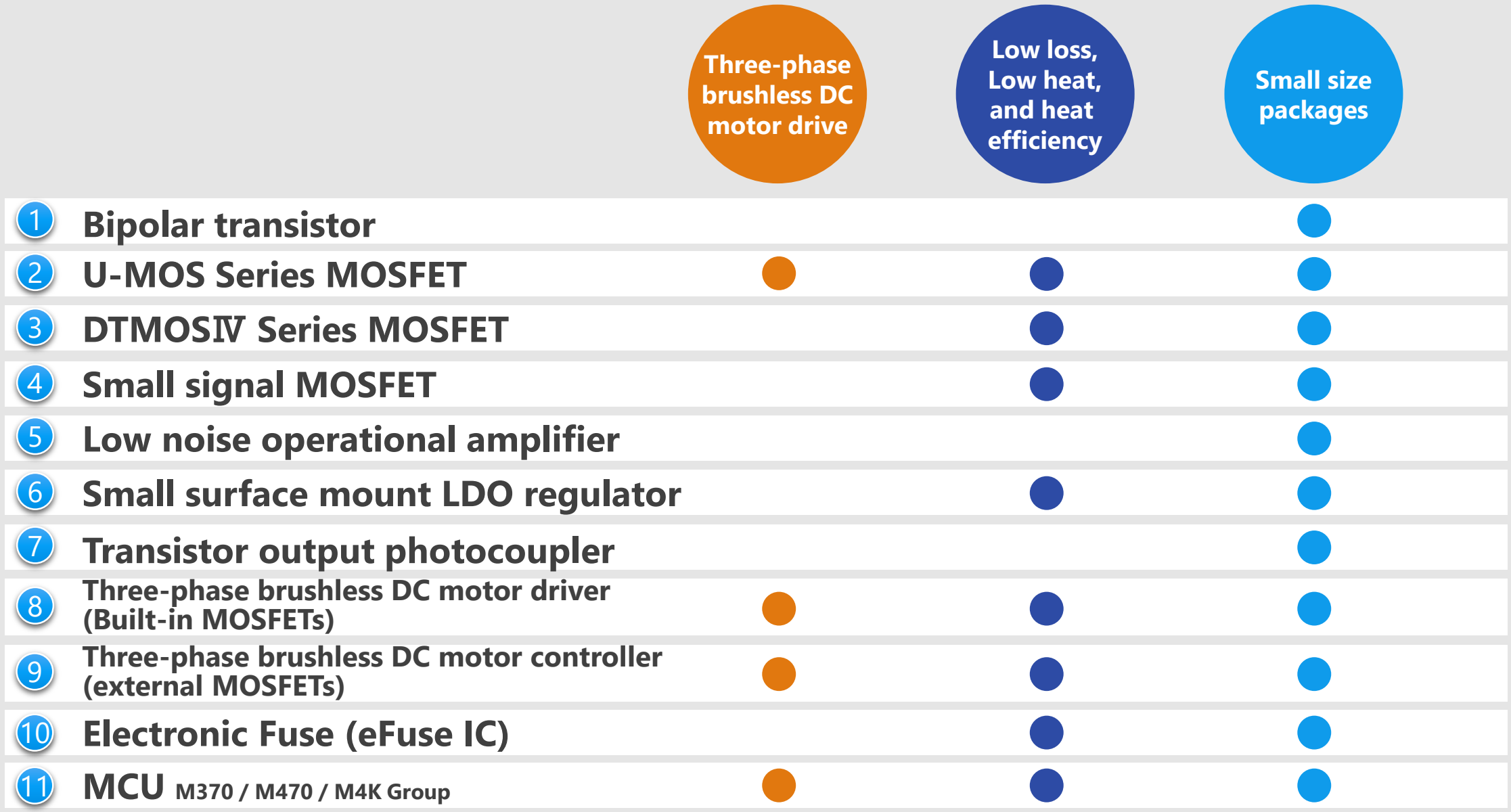


Device solutions to address customer needs

As described above, in the design of cordless power tool, **"Low noise and high efficiency of the motor"**, **"Low power consumption and heat design of the 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



1 Bipolar transistor

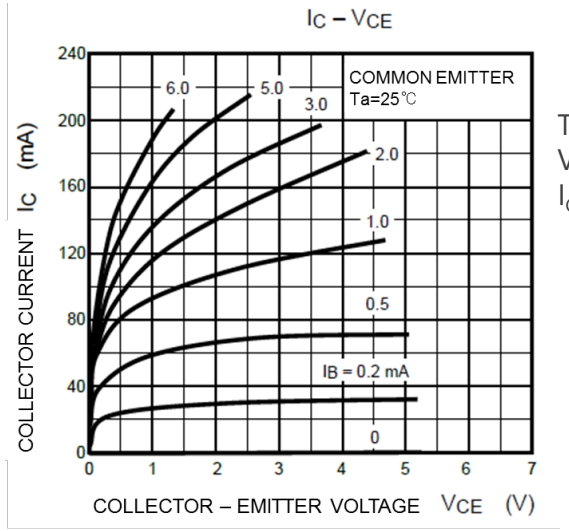
TMBT3906 / TMBT3904 / 2SC4116

Value provided

Various products are provided for radio frequency applications, power supply applications and others.

1 High voltage

High voltage allows for large loads and instantaneous voltage changes.



TMBT3904
V_{CEO} = 50 V
I_C = 200 mA

2 High current (rated collector current)

It covers a wide range of applications from high frequency applications to power supply applications.

Lineup

Part number	TMBT3906	TMBT3904	2SC4116
Package	SOT23 	SOT23 	USM 
V_{CEO} [V]	-50	50	50
I_C [mA]	-200	200	150
$V_{CE(sat)}$ (Max) [V]	-0.25	0.2	0.25
h_{FE}	100 to 300	100 to 300	70 to 700
Polarity	PNP	NPN	NPN

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2 U-MOS Series MOSFET

TPWR6003PL / TPWR8004PL / TPHR8504PL / TPHR7404PU / TPH2R408QM / TPH4R008QM / TK5R1P08QM / TK6R9P08QM

Three-phase brushless DC motor drive | Low loss, Low heat, and heat efficiency | Small size packages

Value provided

Contributes to lower heat generation of system by providing low on-resistance lineup and a highly heat dissipation package (DSOP Advance).

1 Low $R_{DS(ON)}$ (on-resistance)

By keeping the $R_{DS(ON)}$ (drain-source on-resistance) low, heat build-up and power consumption can be reduced. Products are prepared from on-resistance of 0.36 mΩ (Typ.).

2 Small Q_{OSS}

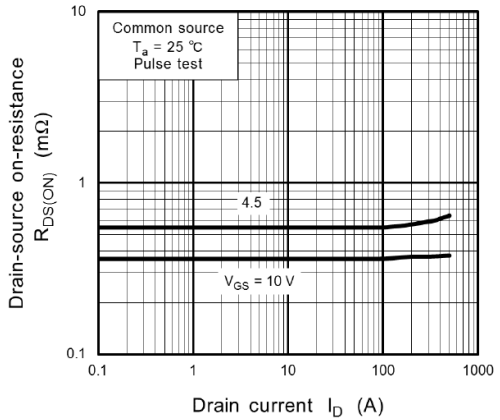
Contributes low loss due to small Q_{OSS}. TPWR8004PL's performance index $R_{DS(ON)}$ x Q_{OSS} is deducted to 63 % [Note] than competitor's products.

3 Variety of packages

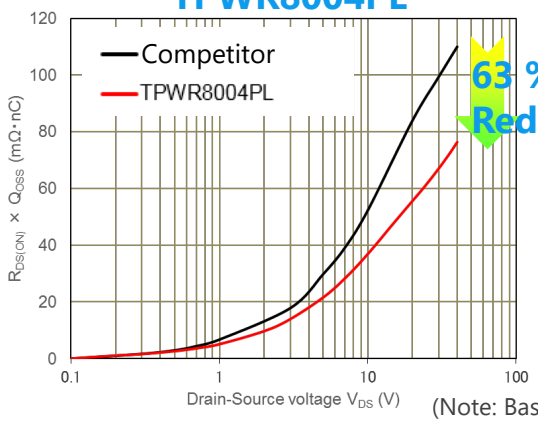
Adding SOP Advance of industry standard package, DSOP Advance of double-side heat dissipation package on same footprint had been prepared.

[Note] As of November 2017 for MOSEFTs with equivalent ratings (as surveyed by Toshiba)

Low on-resistance
TPWR6003PL



$(R_{DS(ON)}$ x $Q_{OSS})$ - V_{DS}
TPWR8004PL



(Note: Based on Toshiba's measurement data)

Lineup

Part number		TPWR6003PL	TPWR8004PL	TPHR8504PL	TPHR7404PU	TPH2R408QM	TPH4R008QM	TK5R1P08QM	TK6R9P08QM
Package		DSOP Advance		SOP Advance SOP Advance(N)				DPAK	
V_{DSS} [V]		30	40	40	40	80	80	80	80
I_D [A]		150 (412*)	150 (340*)	150 (340*)	150 (400*)	120 (200*)	86 (140*)	84 (105*)	62 (83*)
$R_{DS(ON)}$ [mΩ] @V_{GS} = 10 V	Typ.	0.36	0.65	0.7	0.51	1.9	3.1	4.2	5.5
	Max	0.6	0.8	0.85	0.74	2.43	4	5.1	6.9
Polarity		N-ch	N-ch	N-ch	N-ch	N-ch	N-ch	N-ch	N-ch
Generation		U-MOSⅨ-H	U-MOSⅨ-H	U-MOSⅨ-H	U-MOSⅨ-H	U-MOSⅧ-H	U-MOSⅧ-H	U-MOSⅧ-H	U-MOSⅧ-H

* : Silicon limit

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3 DTMOSⅣ Series MOSFET

TK12A60W / TK10A60W / TK17A80W

Three-phase brushless DC motor drive | Low loss, Low heat, and heat efficiency | Small size packages

Value provided

30 % reduction in RonA performance index (compared with Toshiba conventional products), improving power supply efficiency and contributing to miniaturization.

1 RonA 30 % reduction

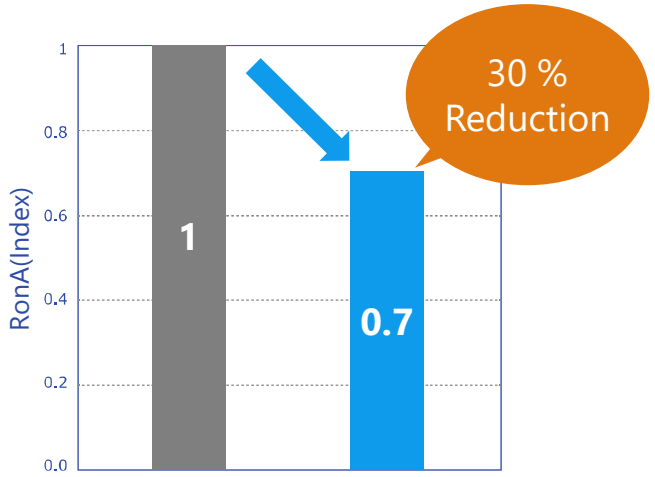
Adoption of newly developed single-epitaxial process to reduce the performance index RonA by 30 %. (Compared with DTMOSⅢ products from Toshiba)

2 Reduction of on-resistance increase at high temperatures

The single epitaxial process reduces the on-resistance increase at high temperatures.

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 others.



Note: Toshiba internal comparison

Lineup

Part number		TK12A60W	TK10A60W	TK17A80W
Package		TO-220SIS 	TO-220SIS 	TO-220SIS 
V_{DSS} [V]		600	600	800
I_D [A]		11.5	9.7	17
$R_{DS(ON)}$ [Ω] @V_{GS} = 10 V	Typ.	0.265	0.327	0.25
	Max	0.3	0.38	0.29

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4 Small signal MOSFET

SSM6K513NU / SSM6N55NU / SSM6J507NU

Three-phase brushless DC motor drive | Low loss, Low heat, and heat efficiency | Small size packages

Value provided

Suitable for power switching and contribute to miniaturization.

1 Low voltage operation

Operates down to $|V_{GS}|$ = 4.5 V.

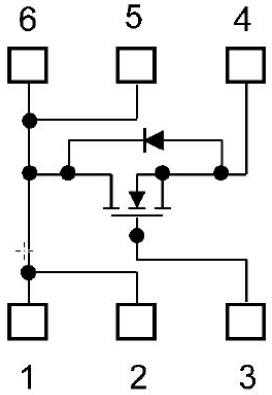
2 Low on-resistance

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

3 Small package

Sealed in SOT-1220 (2.0 x 2.0 mm) package.

Internal circuit
SSM6K513NU



Lineup

Part number		SSM6K513NU	SSM6N55NU	SSM6J507NU
Package		UDFN6B (SOT-1220)	UDFN6 (SOT-1118)	UDFN6B (SOT-1220)
Polarity		N-ch	N-ch x 2	P-ch
V_{DSS} [V]		30	30	-30
I_D [A]		15	4	-10
$R_{DS(ON)}$ [mΩ] @$\|V_{GS}\|$ = 4.5 V	Typ.	8.0	48	19
	Max	12	64	28

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5 Low noise operational amplifier

TC75S67TU

Three-phase brushless DC motor drive | Low loss, Low heat, and heat efficiency | Small size packages

Value provided

Small signals detected by various sensors can be amplified with very low noise.

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

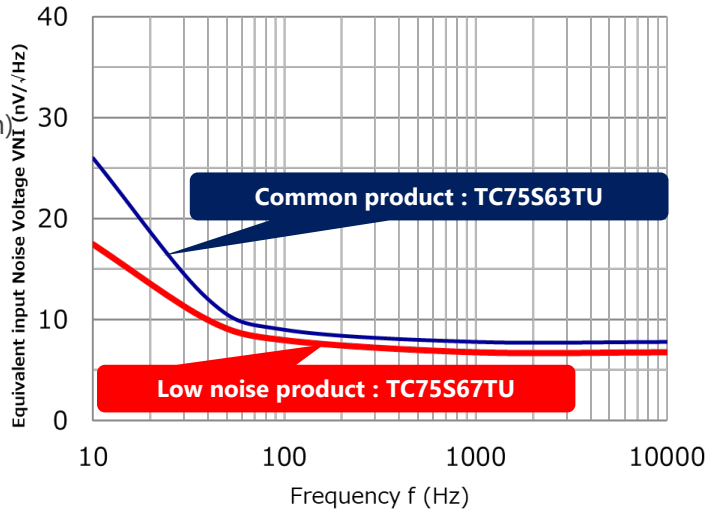
Small signals detected by various sensors [Note] can be amplify with low noise using CMOS operational amplifier by optimizing the processing. We achieved low input equivalent noise voltage.

[Note] Sensor types: vibration detection sensor, shock sensor, accelerometer, pressure sensor, infrared sensor, temperature sensor, etc.

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

Low current consumption characteristics are realized by using the CMOS process.

Noise characteristics
(Toshiba internal comparison)



Lineup

Part number	TC75S67TU
Package	UFV 
$V_{DD,SS}$ (Max) [V]	±2.75
$V_{DD,SS}$ (Min) [V]	±1.1
I_{DD} (Typ.) [μA]	430
V_{NI} [nV/√Hz] (Typ.) @f = 1 kHz	6

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6 Small surface mount LDO regulator

TAR5SB Series

Three-phase brushless DC motor drive | Low loss, Low heat, and heat efficiency | Small size packages

Value provided

Wide lineup from general purpose type to small package type are provided. These products are suitable for high performance requirements.

1 Low dropout voltage

V_{IN}-V_{OUT} = 0.2 V (Max)
(TAR5SB23 to TAR5SB50)

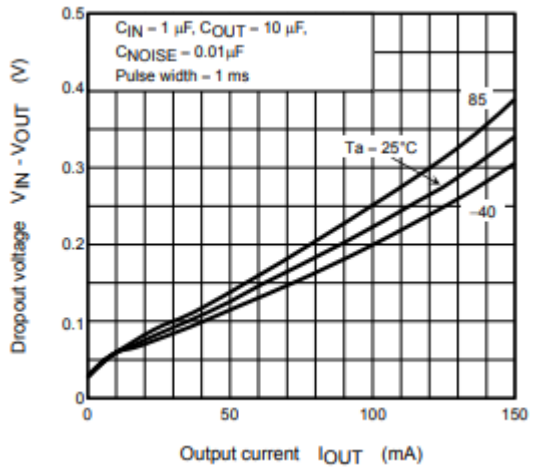
2 Low output noise voltage V_{NO}

The low output noise voltage V_{NO} is also reduced to 30 µVrms (Typ.), making it even more applicable for analog circuits.

3 Can be used with ceramic capacitors

With improved various characteristics, it is now possible to use ceramic capacitors for external capacitor functions.

V_{IN}-V_{OUT} - I_{OUT}
(TAR5SB23 to TAR5SB50)



Lineup

Part number	TAR5SB Series
Package	SMV (SOT-25) 
V_{IN} [V]	15
I_{OUT} [mA]	200
V_{IN} –V_{OUT} (Max) [V]	0.2 (TAR5SB23 to TAR5SB50)
Output range [V]	1.5 to 5.0

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7 Transistor output photocoupler

TLP385

Three-phase brushless DC motor drive | Low loss, Low heat, and heat efficiency | Small size packages

Value provided

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

1 High current transfer ratio

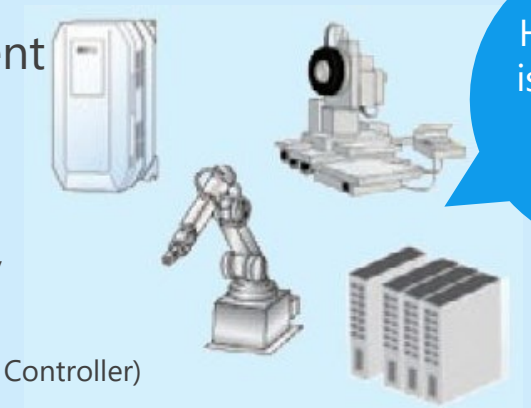
This is a high-isolation photocoupler that optically couples a phototransistor and a GaAs infrared light emitting diode. High current transfer ratio is realized at I_F = 5 mA.

2 Operating temperature is expanded to 110 °C

It is designed to operate even under severe temperature.

Industrial equipment

- General purpose inverter
- Servo amplifier
- Robot
- Machine Tool
- High output power supply
- Security equipment
- Semiconductor tester
- PLC (Programmable Logic Controller)



High level of isolation and noise blocking

Lineup

Part number	TLP385
Package	4pin SO6L 
BV_S [Vrms]	5000
T_{opr} [°C]	-55 to 110

◆Return to Block Diagram TOP

8 Three-phase brushless DC motor driver (Built-in MOSFETs)

TC78B016FTG

Three-phase brushless DC motor drive | Low loss, Low heat, and heat efficiency | Small size packages

Value provided

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

1 High efficiency is achieved for a wide range of rotation speeds

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

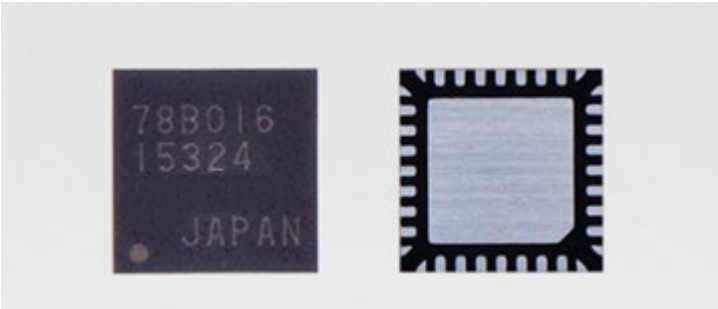
2 Motor control with low noise, and low vibration

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

3 Low loss, Low heat

Since the output on-resistance is a small 0.24 Ω (Typ.), the power loss of the IC itself during operation can be kept low.

[Note] Comparison with Toshiba products



WQFN36 package (5 x 5 x 0.8 mm)

Lineup

Part number	TC78B016FTG
Power supply voltage	6 to 30 V (operating range)
Output current	3 A (operating range)
Drive system	Sine wave drive system
Features	Phase control : Optimum phase control of voltage and current Hall device / Hall IC compatible Speed control input: PWM signal / analog voltage input Error detection: Thermal shutdown, overcurrent detection, motor lockout detection Output on-resistance (sum of top and bottom): 0.24 Ω (Typ.)

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9 Three-phase brushless DC motor controller (external MOSFETs)

TB6584FNG / TB6584AFNG / TB6634FNG

Three-phase brushless DC motor drive | Low-loss, low-heat, and heat efficiency | Small size packages

Value provided

High voltage and high current brushless DC motor driving can be implemented by external MOSFETs.

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 3rd party evaluation board and PSpice® data for development and design are prepared.

[Note] Comparison with Toshiba products

TB6584FNG, TB6584AFNG

SSOP30 Package (10.2 x 7.6 x 1.6 mm)

Lineup

Part number	TB6584FNG	TB6584AFNG	TB6634FNG
Power supply voltage	6 to 16.5 V (operating range)		
Output current	0.002 A (for driving MOSFET) (operating range)		
Drive system	Sine wave drive system / Square wave drive system		
Features	Phase control: Automatic (current feedback) Hall device / Hall IC compatible Internal regulator: 5 V / 30 mA (Max) Error detection: overcurrent protection, abnormal position signal protection, undervoltage lockout, motor restrained detection (TB6634FNG)		

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Electronic Fuse (eFuse IC)

TCKE8 Series / TCKE7 Series

Three-phase brushless DC motor drive | Low loss, Low heat, and heat efficiency | Small size packages

Value provided

Electronic fuse (eFuse IC) can be used repeatedly to protect circuits from abnormal conditions such as overcurrent and overvoltage.

1 Can be used repeatedly

When overcurrent flows through the electronic fuse (eFuse IC), the internal detection circuit operates and switches off the internal MOSFET. It is not destroyed by a single overcurrent and can be used repeatedly.

2 IEC 62368-1 certified

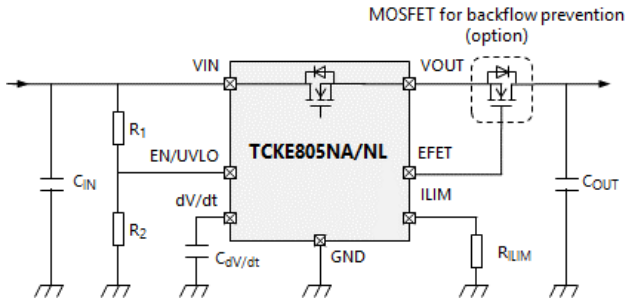
Toshiba's eFuse ICs are certified to the international safety standard IEC 62368-1 (G9: Integrated circuit (IC) current limiters) and contribute to robust protection and simplification of circuit design.

3 Rich protection functions

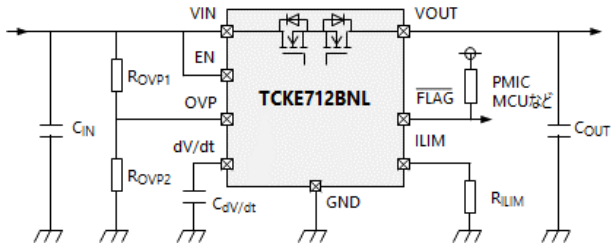
TCKE8 Series: short-circuit protection, overcurrent protection, overcurrent clamp function, overvoltage clamp function, thermal shut down, inrush current suppression, backflow prevention (optional), etc.

TCKE7 Series: short-circuit protection, overcurrent protection, overvoltage protection, thermal shut down, FLAG signal output, backflow prevention (built-in), etc.

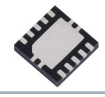
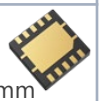
Reference circuit example of TCKE8 Series



Reference circuit example of TCKE7 Series



Lineup

Part number	TCKE800NA/NL	TCKE805NA/NL	TCKE812NA/NL	TCKE712BNL
Package	WSON10B 3.0 x 3.0 x 0.75 mm  			WSON10 3.0 x 3.0 x 0.75 mm 
V_{IN} [V]	4.4 to 18			4.4 to 13.2
R_{ON} (Typ.) [mΩ]	28			53
Return function	NA: Automatic return NL: Latch type (external signal control)			Latch type (external signal control)
V_{OVC} (Typ.) [V]	-	6.04	15.1	Adjustable

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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 motors and peripherals.

2 Equipped with motor control logic circuit

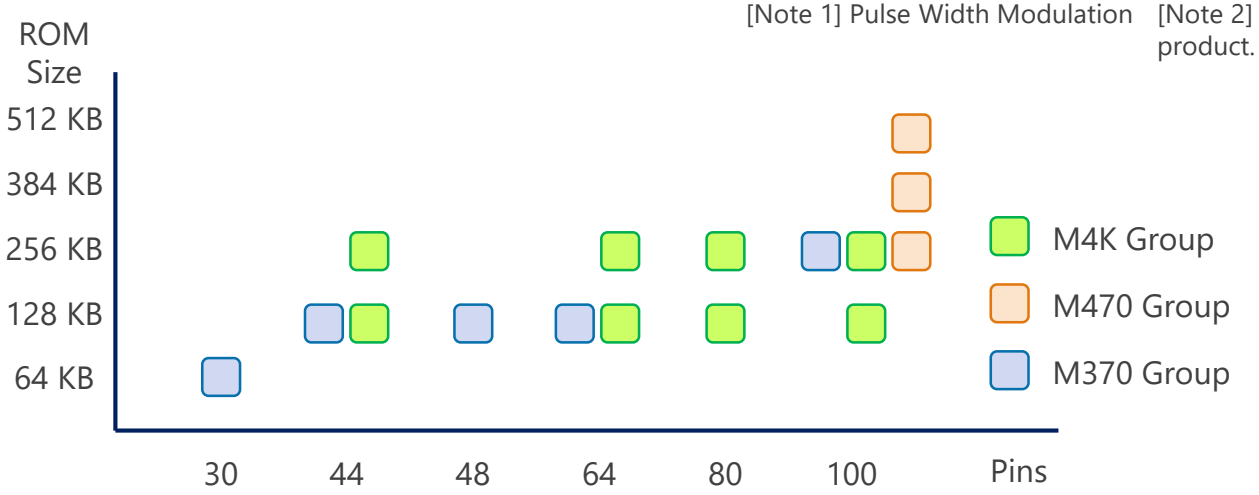
Versatile three phase PWM [Note 1] output and sensing timing make both high efficiency and low noise possible. The advanced encoder reduces CPU load of each PWM processing.

3 Equipped with analog circuit for motor control

High speed and high accuracy AD converters are integrated, allowing conversion timing and PWM output to be linked. Such as high performance operational amplifier is integrated on-chip. [Note 2]

[Note 1] Pulse Width Modulation

[Note 2] The number of AD converter units and the built-in operational amplifier differ depending on the product.



Lineup

Series	Group	Function
TXZ+™4A Series	M4K Group	Arm® Cortex®-M4, 160 MHz operation 4.5-5.5 V, includes 4th gen VE, Data Flash
TX04 Series	M470 Group	Arm® Cortex®-M4, 120 MHz operation 4.5-5.5 V, includes 3rd gen VE
TX03 Series	M370 Group	Arm® Cortex®-M3, 80 MHz operation 4.5-5.5 V, includes 1st gen VE

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If you are interested in these products and have questions or comments about any of them, please do not hesitate to contact us below:

Contact address: https://toshiba.semicon-storage.com/ap-en/contact.html

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