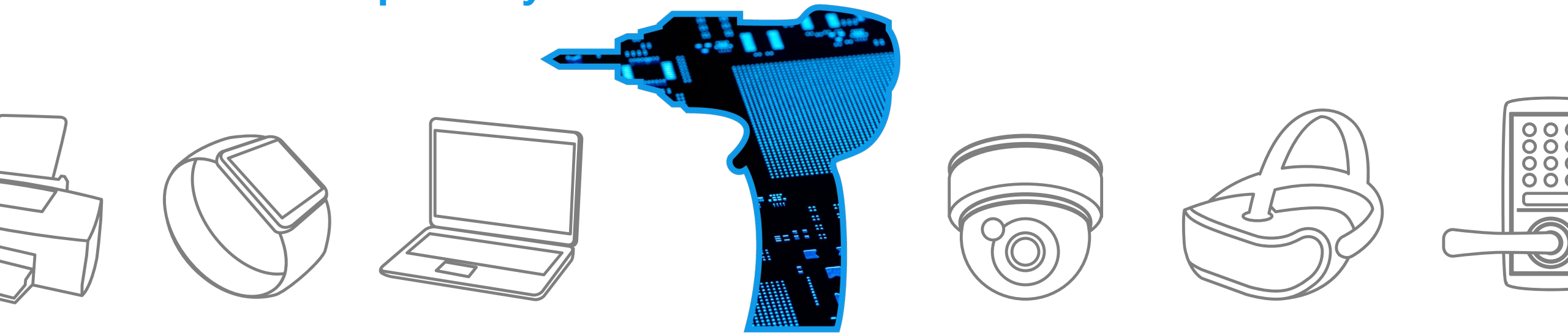
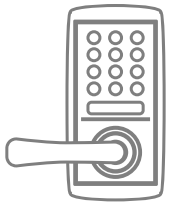
TOSHIBA

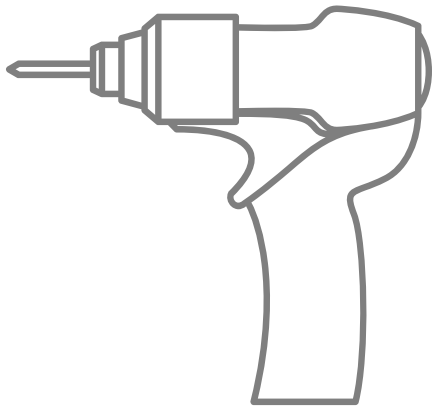
R22

Cordless Power Tool

Solution Proposal by Toshiba

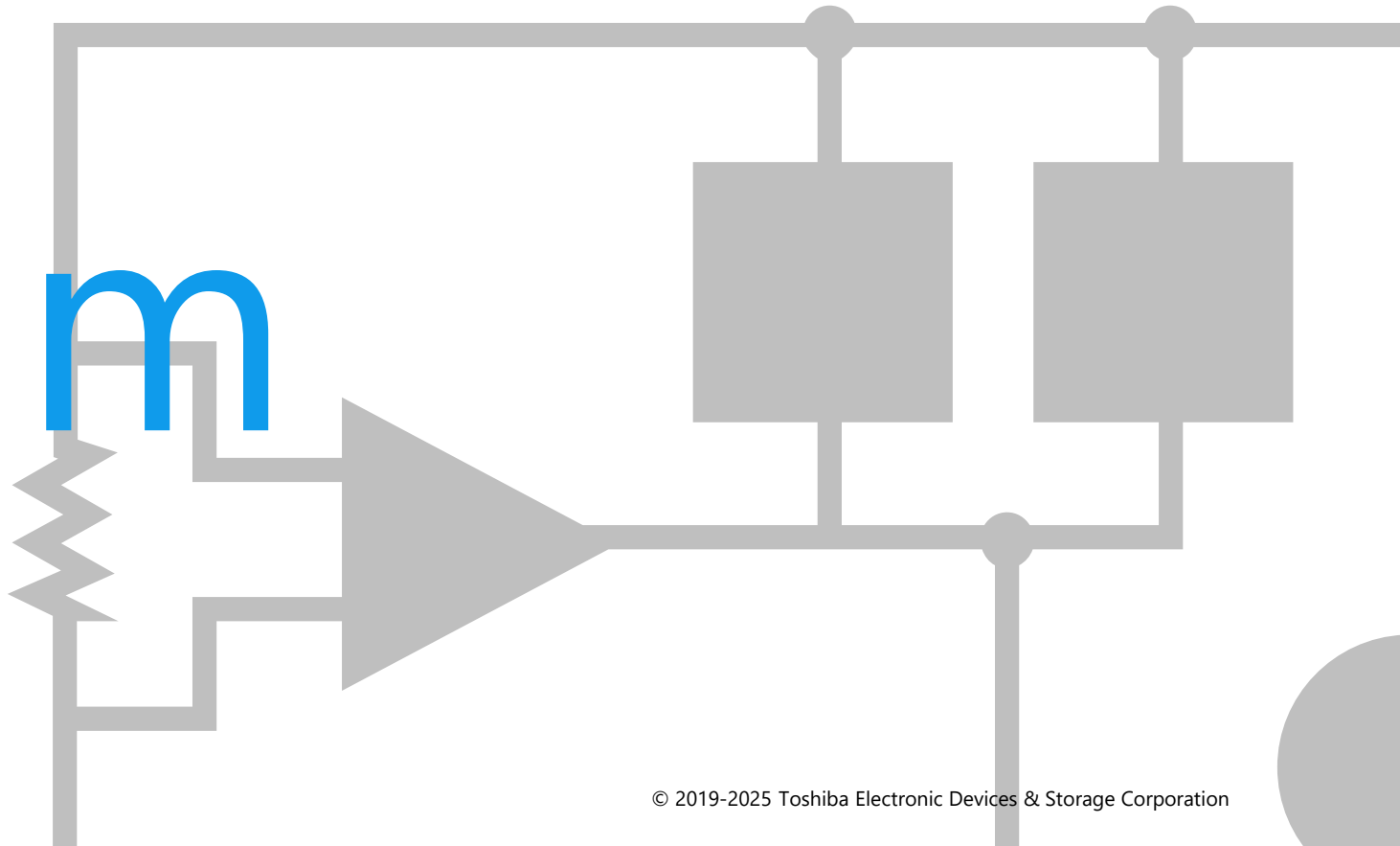




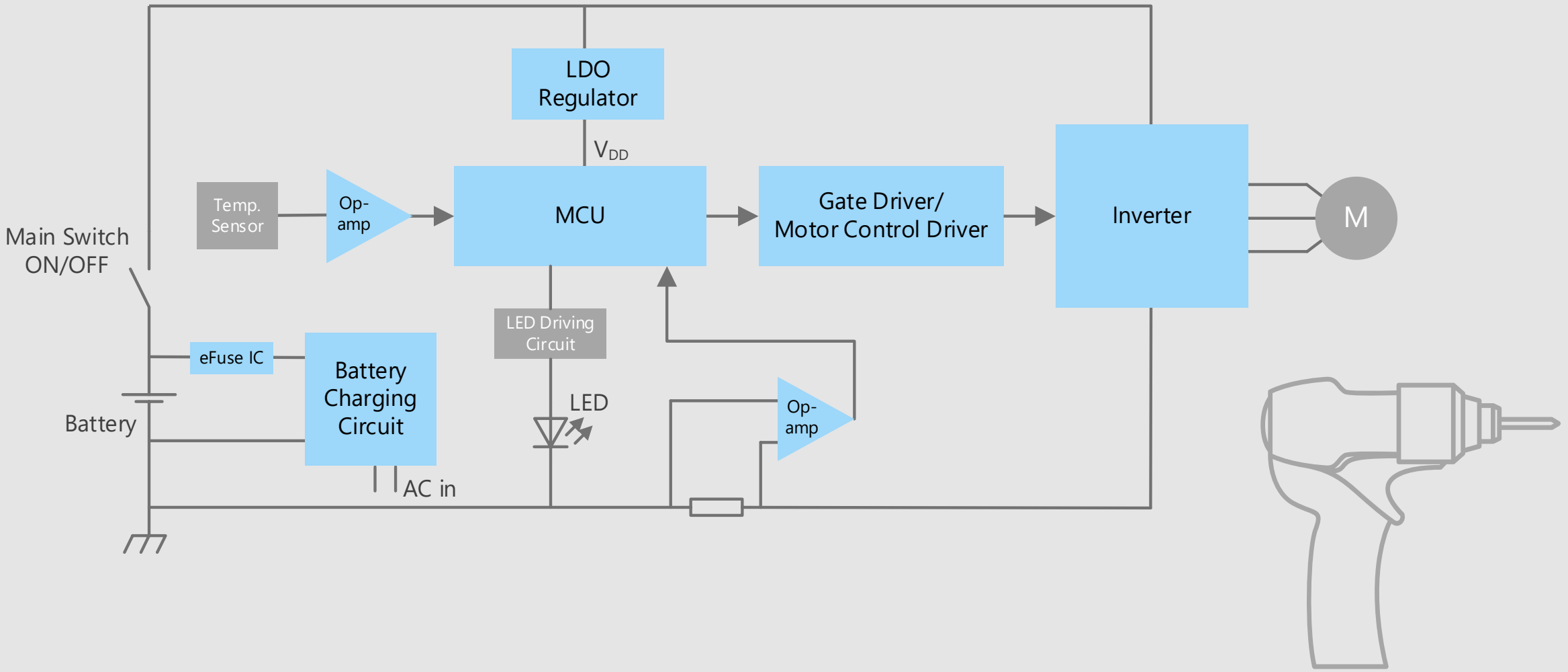


Toshiba Electronic Devices & Storage Corporation provides comprehensive device solutions to customers developing new products by applying its thorough understanding of the systems acquired through the analysis of basic product designs.

Block Diagram



Cordless Power Tools　Overall block diagram

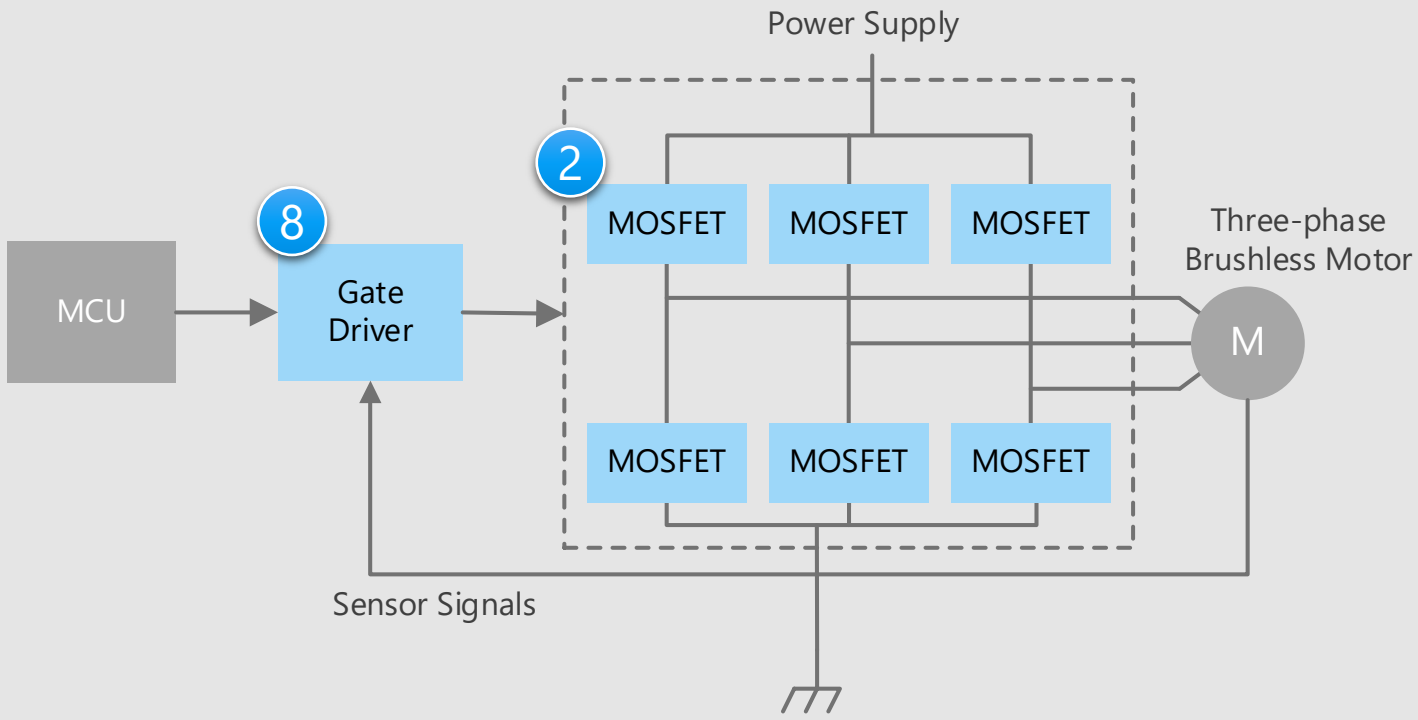


Cordless Power Tools　Details of motor drive unit (1)

Motor drive circuit

Brushless DC motor

(Circuit using gate driver and MOSFETs)



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

Criteria for device selection

- System can drive high-capacity brushless DC motor by using gate driver and external MOSFETs.
- A set with low heat generation and low power consumption can be realized by using MOSFET with low on-resistance and high heat dissipation efficiency.

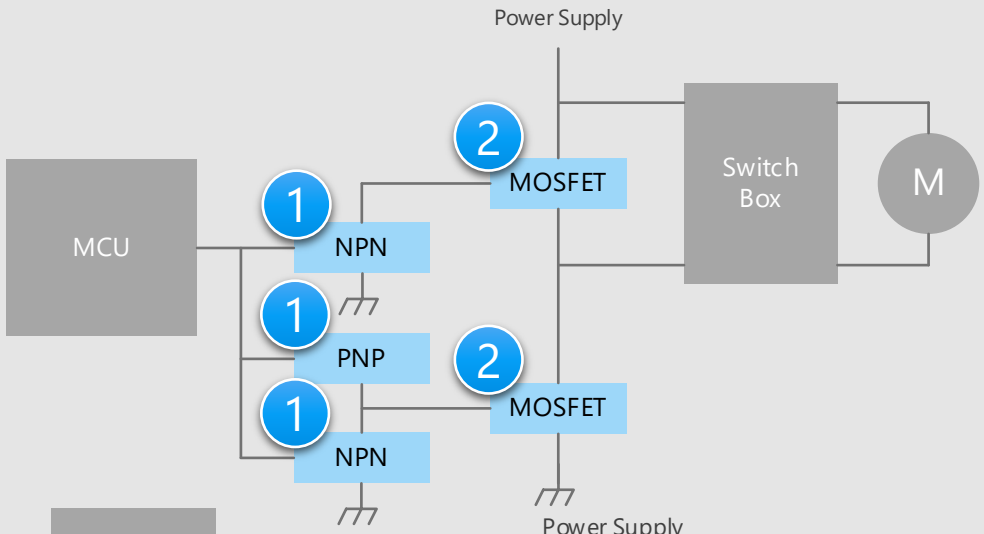
Proposal from Toshiba

- **MOSFET with low on-resistance and high heat dissipation efficiency**
  U-MOS Series MOSFET
- **Integrate functions required as a gate driver into single IC**
  Gate driver

Cordless Power Tools　Details of motor drive unit (2)

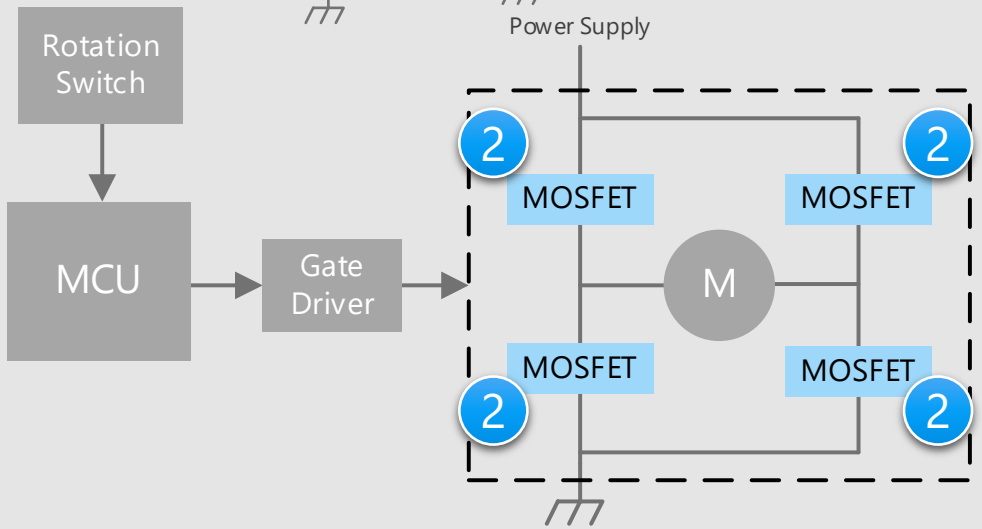
Motor drive circuit

Brushed DC motor/
Mechanical switching



Motor drive circuit

Brushed DC motor/
MOSFET switching



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

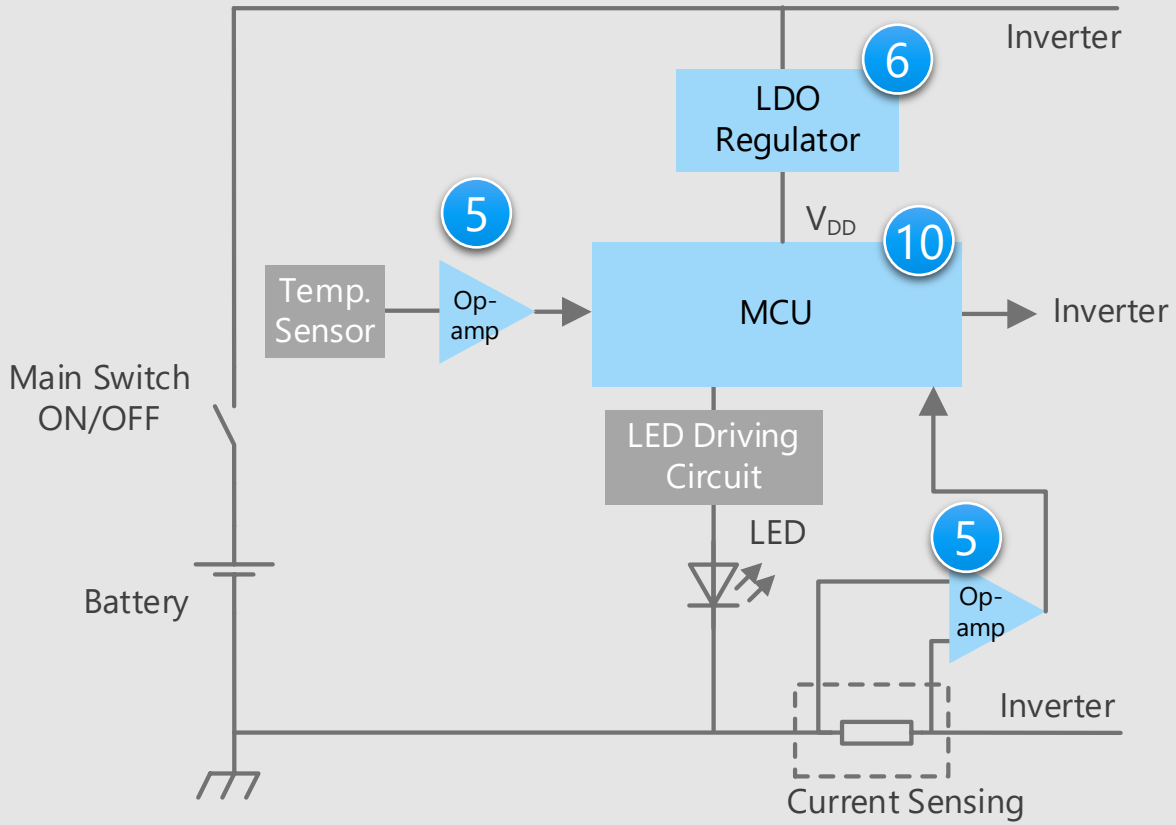
Criteria for device selection

- A gate driver circuit composed of bipolar transistors is suitable for high speed switching of MOSFETs.
- A set with low heat generation and low power consumption can be realized by using MOSFET with low on-resistance and high heat dissipation efficiency.
- A high breakdown MOSFET is required taking into accounting the motor's counter electromotive force.
- Small package products contribute to the reduction of circuit board area.

Proposal from Toshiba

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

MCU peripheral circuit



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

Criteria for device selection

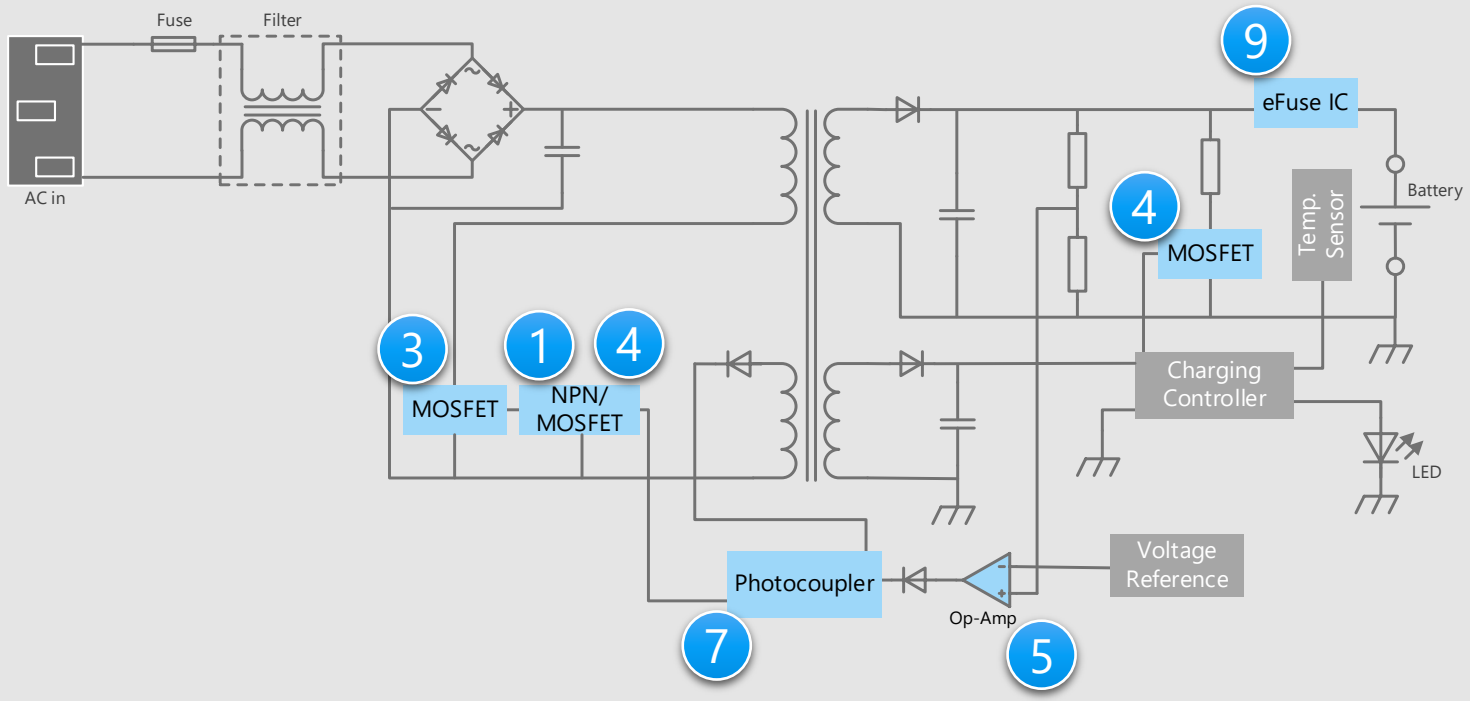
- Low noise operational amplifiers are suitable for amplifying small signals detected by various sensors.
- LDO regulators are suitable for power supply circuits with low ripple noise and stable voltage.
- General purpose MCU suitable for system control and monitoring.

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 M4K / M470 / M370 Group 10

Cordless Power Tools　Detail of battery charger unit

Battery charging circuit



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

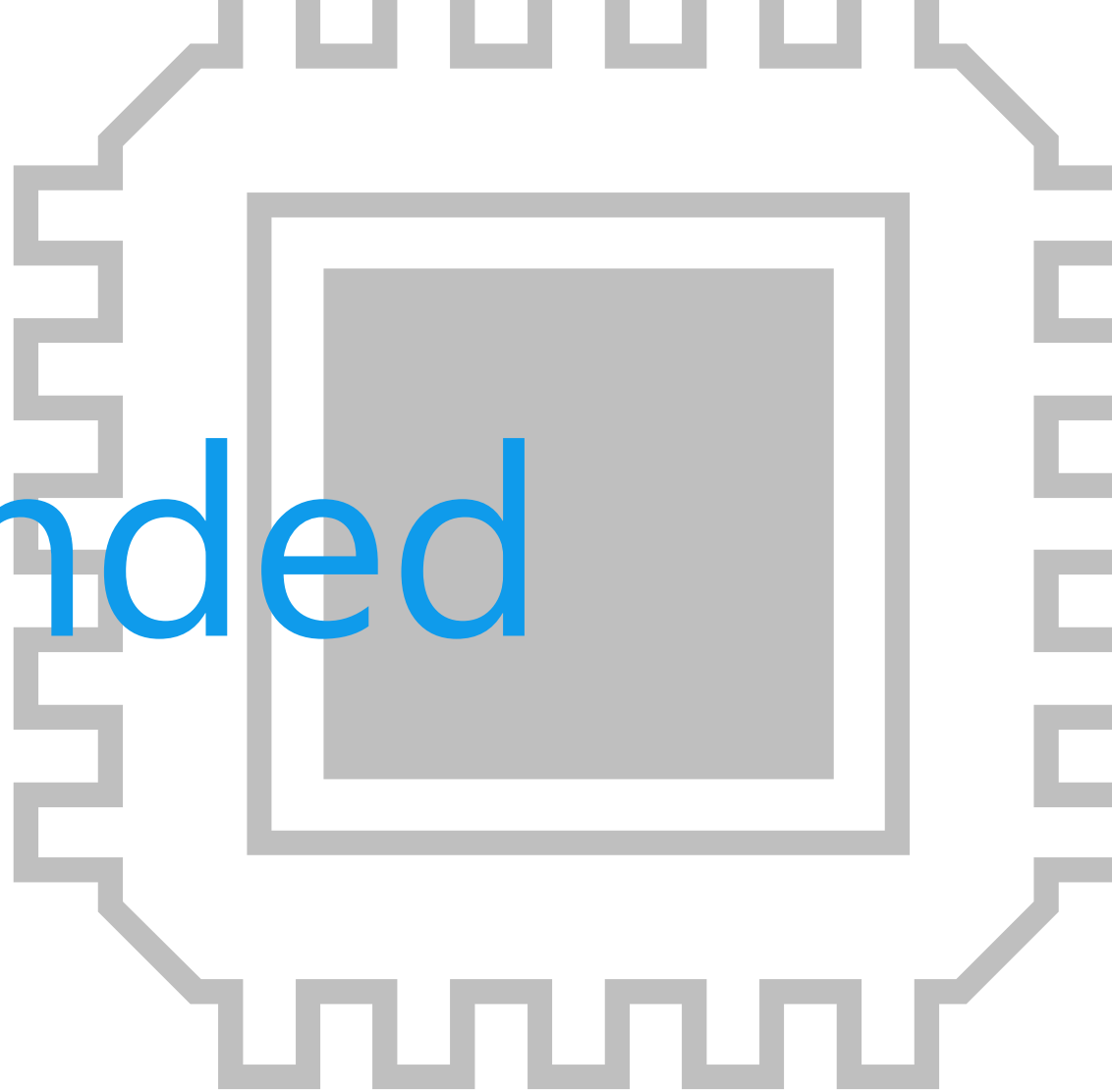
Criteria for device selection

- 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

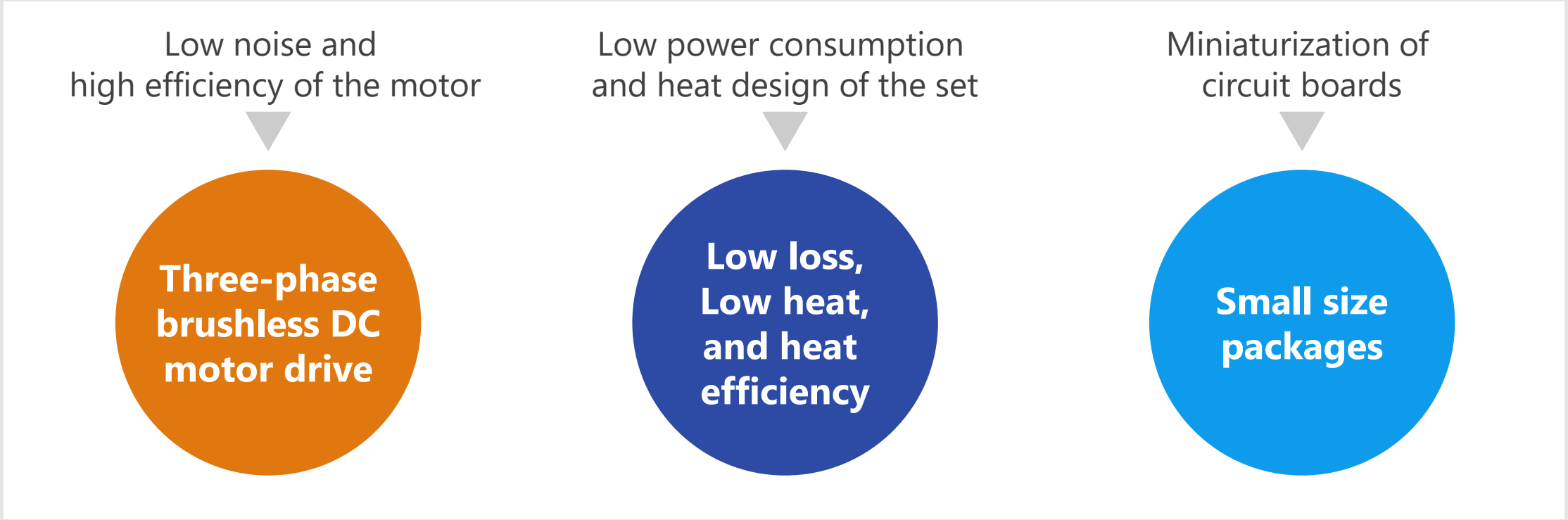
- **Transistor for gate driving** 1
  Bipolar transistor
- **DTMOS IV MOSFET , good for high efficiency power switching** 3
  DTMOSⅣ Series MOSFET
- **Small signal MOSFET for low voltage switching** 4
  Small signal MOSFET
- **Low noise op-amp to capture fluctuations in current consumption accurately** 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** 9
  Electronic Fuse (eFuse IC)

Recommended Devices

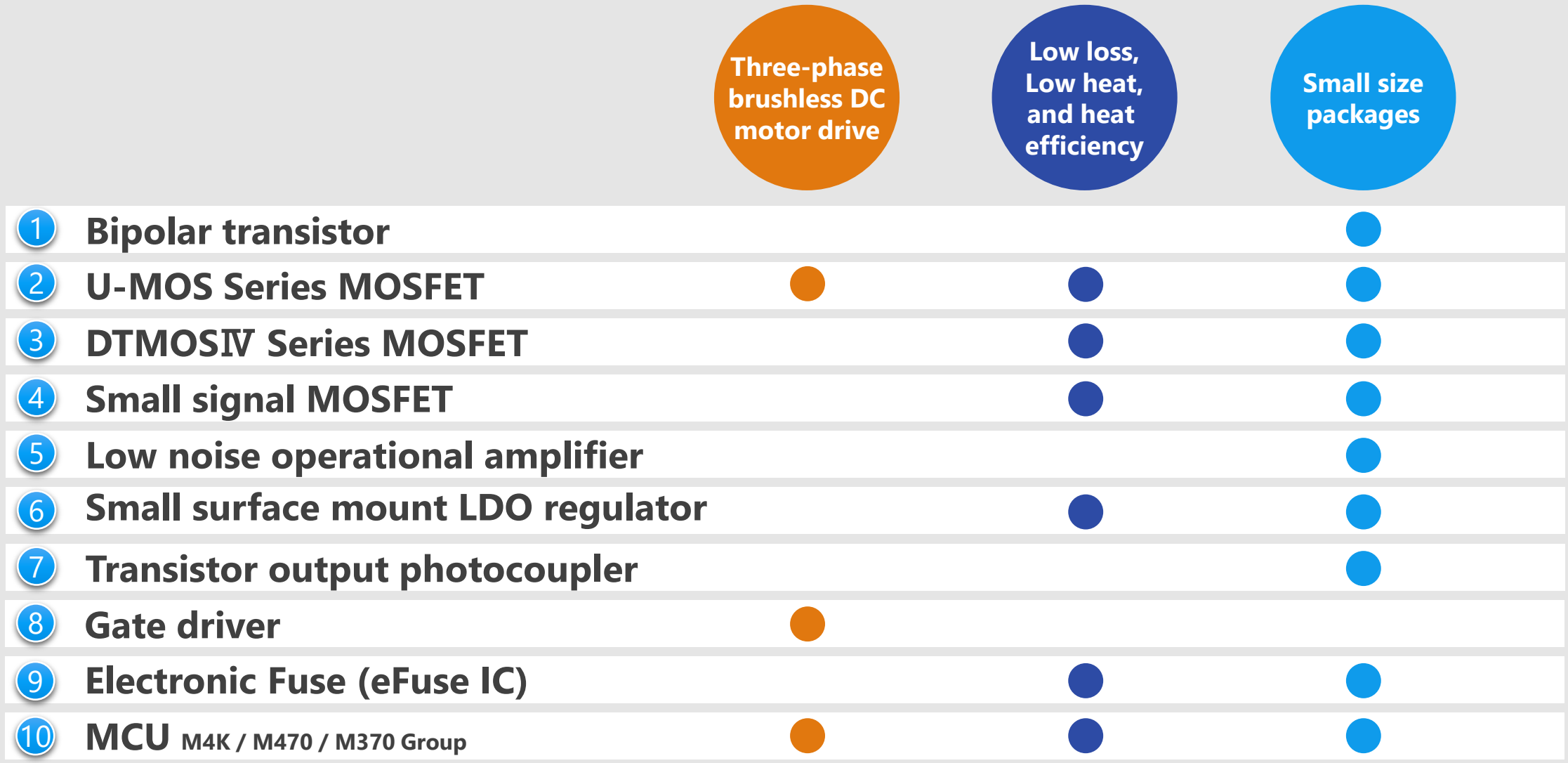


Device s to address customer needs

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 perspectives.



Device s to address customer needs



1 Bipolar transistor

TMBT3906 / TMBT3904 / 2SC4116

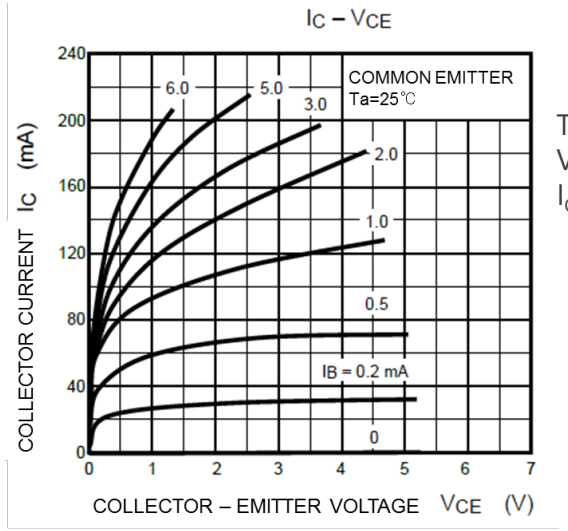
Three-phase brushless DC motor drive | Low loss, Low heat, and heat efficiency | Small size packages

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

Reduced MOSFET's main losses help to improve the efficiency of equipment and to reduce the temperature-rise of MOSFET devices.

1 Low drive loss

$R_{DS(ON)}$ x Q_g is reduced by optimizing the cell architecture.
Effective when driving at high frequencies, especially in light loads.
(U-MOSX-H 80 V Series)

2 Low recovery loss

Q_{rr} is reduced by optimizing the cell architecture. It contributes to the reduction of recovery loss when driving the motor.
(U-MOSX-H 80 V Series)

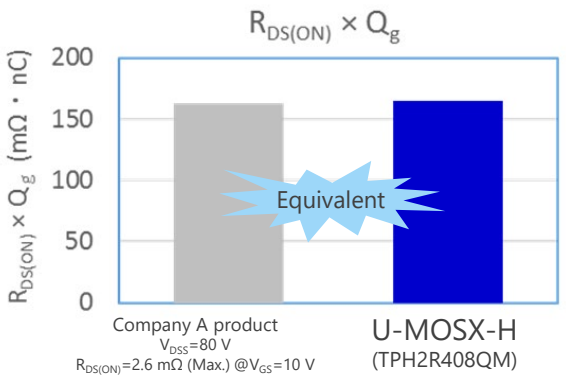
3 Variety of packages

A lineup of industry-standard-size SOP Advance packages and DSOP Advance package which is double-sided heat dissipation package is offered. These allows users to select suitable packages for their applications.

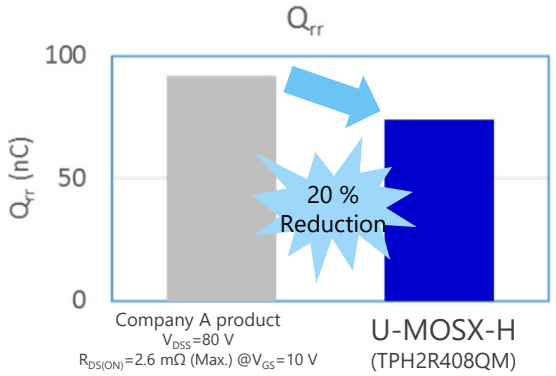
Comparison of performance indexes with other manufacturers' products

(Note: As of March 2024. Toshiba's survey.)

Conduction and drive loss



Body diode recovery loss



$R_{DS(ON)}$: Drain-source on-resistance [mΩ] (index for conduction loss) Q_g: Total gate charge [nC] (index for drive loss) Q_{rr}: Reverse recovery charge [nC] (index for recovery loss)

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-MOSX-H	U-MOSX-H	U-MOSX-H	U-MOSX-H

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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 of the set.

1 RonA 30 % reduction

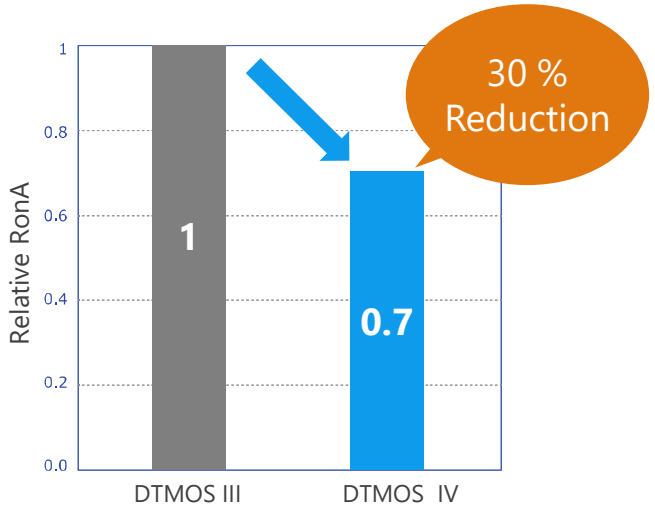
Adoption of newly developed single-epitaxial process to reduce the performance index RonA by 30 %. (Compared with DTMOSⅢ products from Toshiba)

2 Reduction of on-resistance increase at high temperatures

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

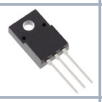
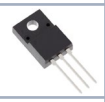
3 Optimization of switching speed

Optimization of switching speed has been achieved by reduction of C_{OSS} (by 12 %, compared with Toshiba conventional products) and others.



Note: Compared with Toshiba DTMOSⅢ products

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.

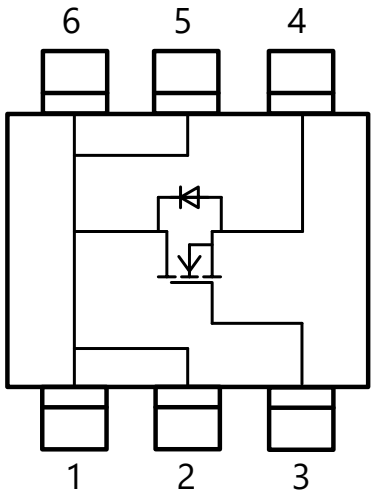
2 Low on-resistance

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

3 Small package

Sealed in SOT-1220/1118 (2.0 x 2.0 mm) package.

Internal circuit of 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

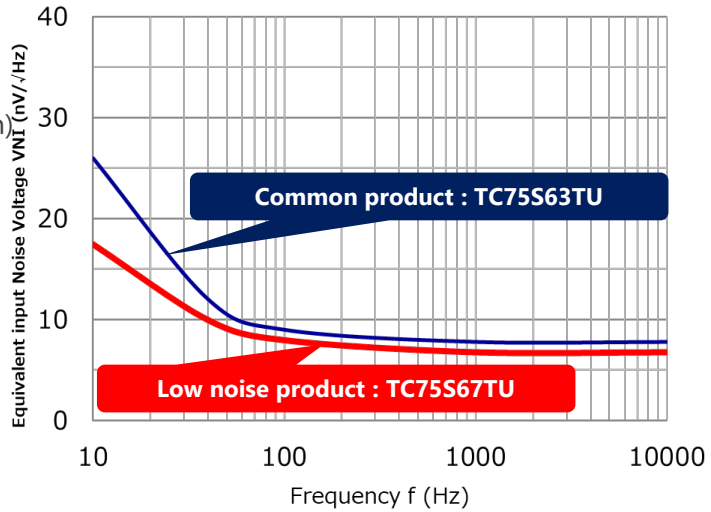
Small signals detected by various sensors [Note] can be amplify with low noise using CMOS operational amplifier. Low input equivalent noise voltage has been achieved by optimizing the processing.

[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

TCR1HF Series

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

Value provided

A wide lineup of products suitable for high-performance requirements, from general-purpose types to small package types, is offered.

1 Wide input voltage range

Operatable input voltage is up to 36 V and output voltage range is from 1.8 to 5.0 V.

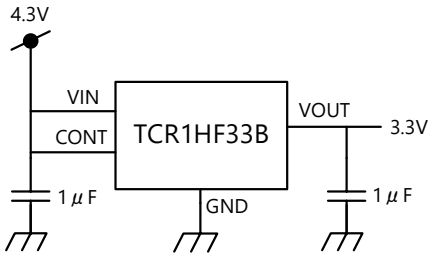
2 Low quiescent current $I_{B(ON)}$

Quiescent current $I_{B(ON)}$ is suppressed to 1 µA (Typ.), which is suitable for reducing the power consumption of equipment.

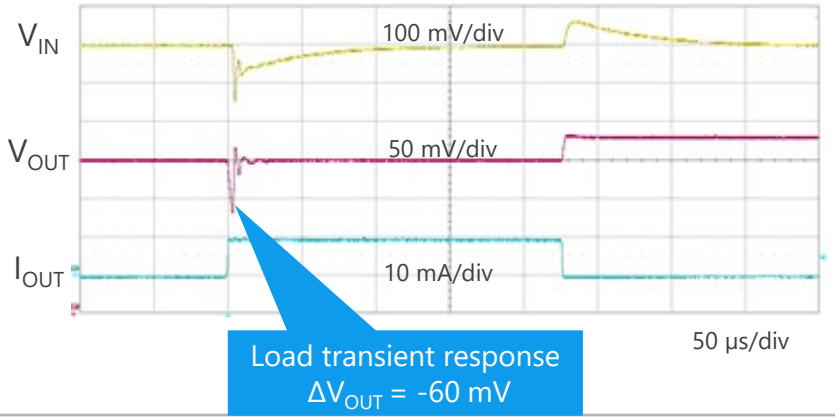
3 High speed stable operation

It has high speed load response characteristics. Stable voltage can be supplied even when high speed startup is performed from a no-load state.

Load transient measurement circuit



Load transient characteristic (0m A ↔ 10 mA)



Lineup

Part number	TCR1HF Series
Package	SMV (SOT-25) 
V_{IN} [V]	36
I_{OUT} [mA]	150
$I_{B(ON)}$ (Typ.) [µA]	1.0
Output voltage range [V]	1.8 to 5.0

◆Return to Block Diagram TOP

7 Transistor output photocoupler

TLP383

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.

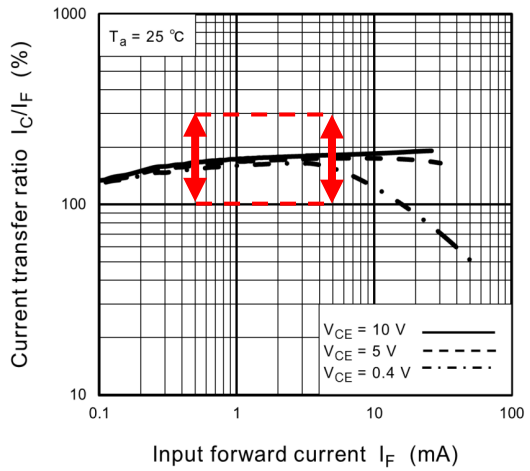
1 High and flat current transfer ratio

Current transfer ratio is flat in 0.5 to 5 mA of input current range.
This flatness is suitable for feedback use.

2 Operating temperature is expanded to 125 °C

It is designed to operate even under severe temperature.

Current transfer ratio



Example of GR rank
100 to 300 % @I_F = 0.5 mA
100 to 300 % @I_F = 5.0 mA

Lineup

Part number	TLP383
Package	4pin SO6L 
BV_S [Vrms]	5000
T_{opr} [°C]	-55 to 125

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8 Gate driver

TB67Z83x Series / TB6785x Series

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

Value provided

Integrates features required in gate drivers for power tool applications.

1 Broad operation range

Operational power supply voltage (VM) for the IC ranges from 8 to 75 V, and operational motor power supply voltage (VDRAIN) ranges from 6 to 75 V.

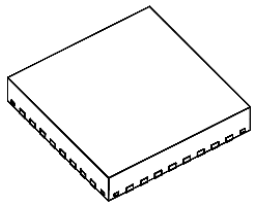
2 Multiple error detections

Error detections for not only the gate driver but also integrates features such as over current detection and gate drive monitoring to protect external MOSFETs.

3 Integrated current sense amplifier

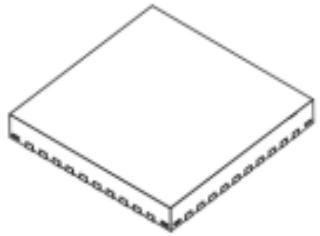
Gate driver series covers products with integrated current sense amplifiers, reducing external components.

Without current sense amplifier



QFN32 (5 x 5 mm)

Integrated current sense amplifier



QFN40 (6 x 6 mm)

Lineup

Part number	Integrate LDO	Current sense amp	Control I/F	Package
TB67Z833SFTG	3.3 V	3 channels	SPI	QFN40
TB67Z833HFTG			Hardware	
TB67Z830SFTG		None	SPI	QFN32
TB67Z830HFTG			Hardware	
TB67Z853SFTG	5 V	3 channels	SPI	QFN40
TB67Z853HFTG			Hardware	
TB67Z850SFTG		None	SPI	QFN32
TB67Z850HFTG			Hardware	

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9 Electronic Fuse (eFuse IC)

TCKE8 Series / TCKE7 Series / TCKE9 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.

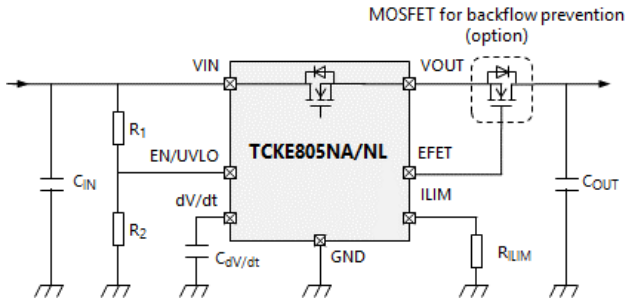
2 IEC 62368-1 certified

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.
(TCKE8 Series, TCKE7 Series)

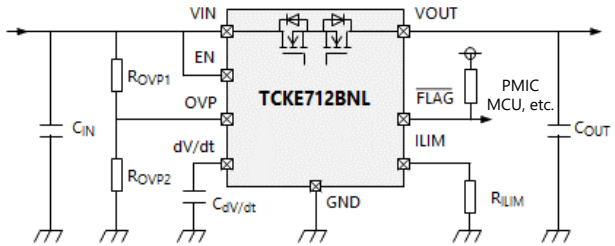
3 Rich protection functions

With many functions equipped such as short circuit protection, overcurrent protection, overheat protection, overcurrent clamping and inrush current suppression.
TCKE7 and TCKE9 series: FLAG signal output function
TCKE7 series: built-in reverse current prevention

Reference circuit example of TCKE8 Series



Reference circuit example of TCKE7 Series



Lineup

Part number	TCKE8 Series	TCKE712BNL	TCKE9 Series
Package	WSON10B 3.0 x 3.0 mm	WSON10 3.0 x 3.0 mm	WSON8 2.0 x 2.0 mm
V_{IN} [V]	4.4 to 18	4.4 to 13.2	2.7 to 23
R_{ON} (Typ.) [mΩ]	28	53	34
OCP (max) [A]	5.0	3.65	4.0
Return function	NA: Automatic return NL: Latch type	Latch type (external signal control)	NA: Automatic return NL: Latch type
V_{OVC} (Typ.) [V]	Non / 6.04 / 15.1	Adjustable	3.87 / 5.7 / 13.7 / 22.2

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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. [Note 1]

2 Equipped with motor control circuit

A variety of three-phase PWM [Note 2] 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.

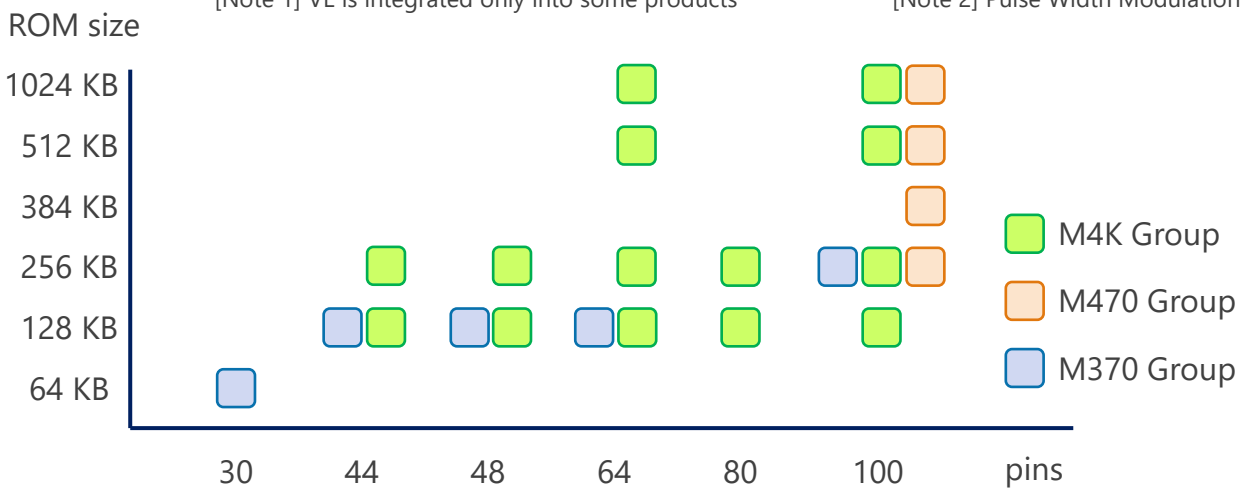
3 Provide development support tools

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). [Note 3]

[Note 1] VE is integrated only into some products

[Note 2] Pulse Width Modulation

[Note 3] MCU Motor Studio supports only some products and will expand in TXZ+™ family.



Lineup

Series	Group	Function
TXZ+™ 4A Series	M4K Group	Arm® Cortex®-M4, Max. 160 MHz operation 4.5 to 5.5 V, 3motor control (Max), Data Flash
TX04 Series	M470 Group	Arm® Cortex®-M4, Max. 160 MHz operation 4.5 to 5.5 V, 2motor control (Max)
TX03 Series	M370 Group	Arm® Cortex®-M3, 80 MHz operation 4.5 to 5.5 V, 2motor control (Max)

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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:

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