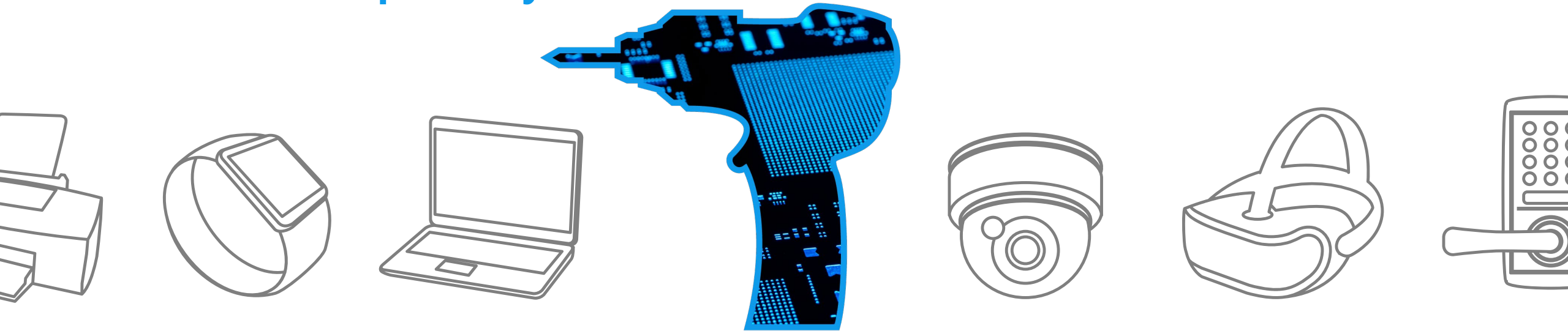


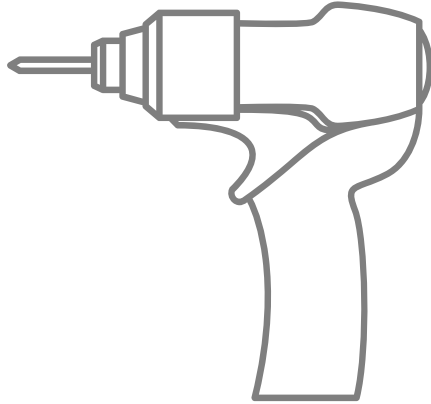
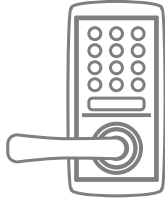
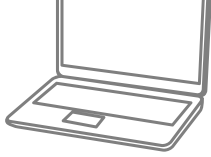
TOSHIBA

Cordless Power Tool

Solution Proposal by Toshiba

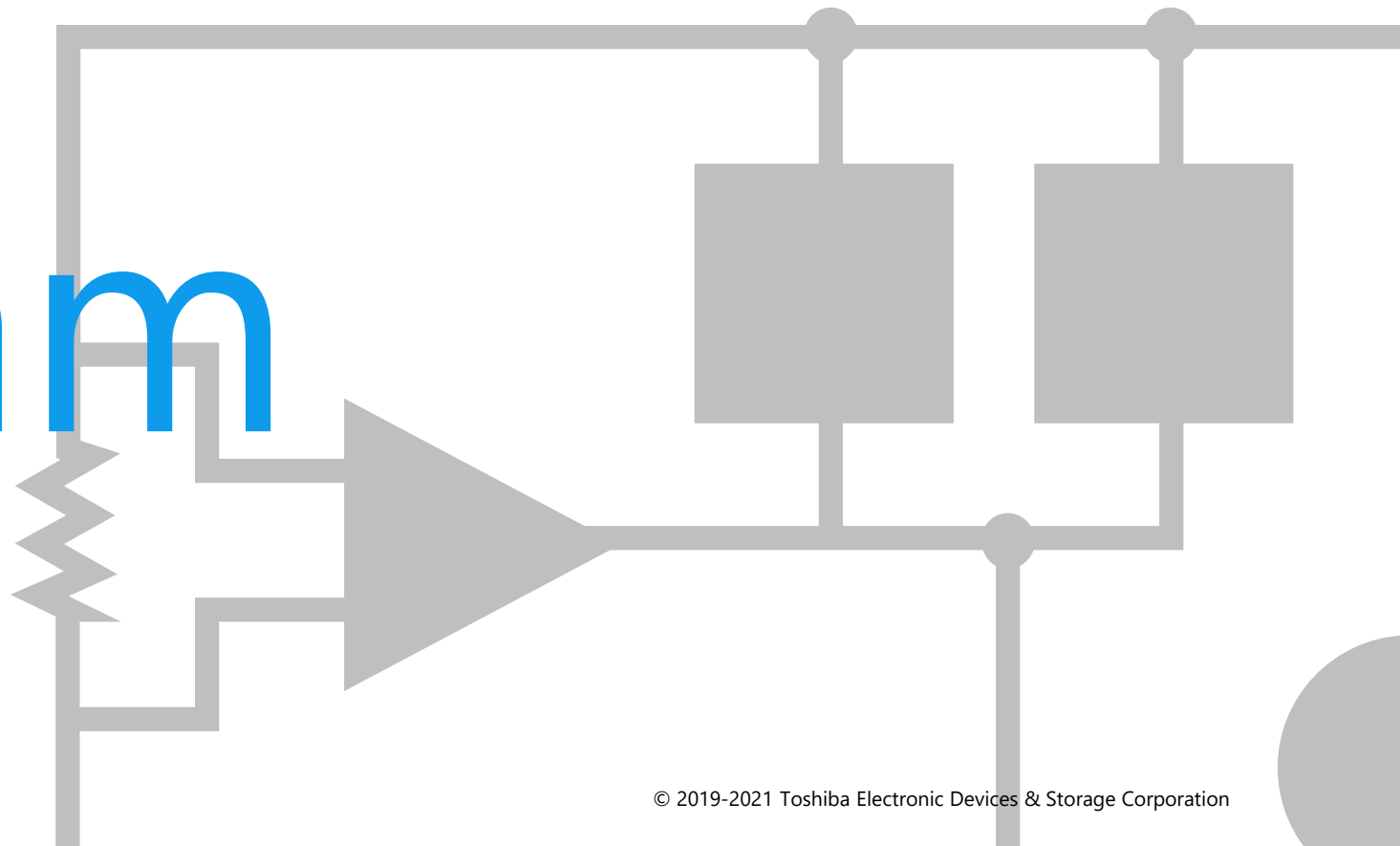
R20



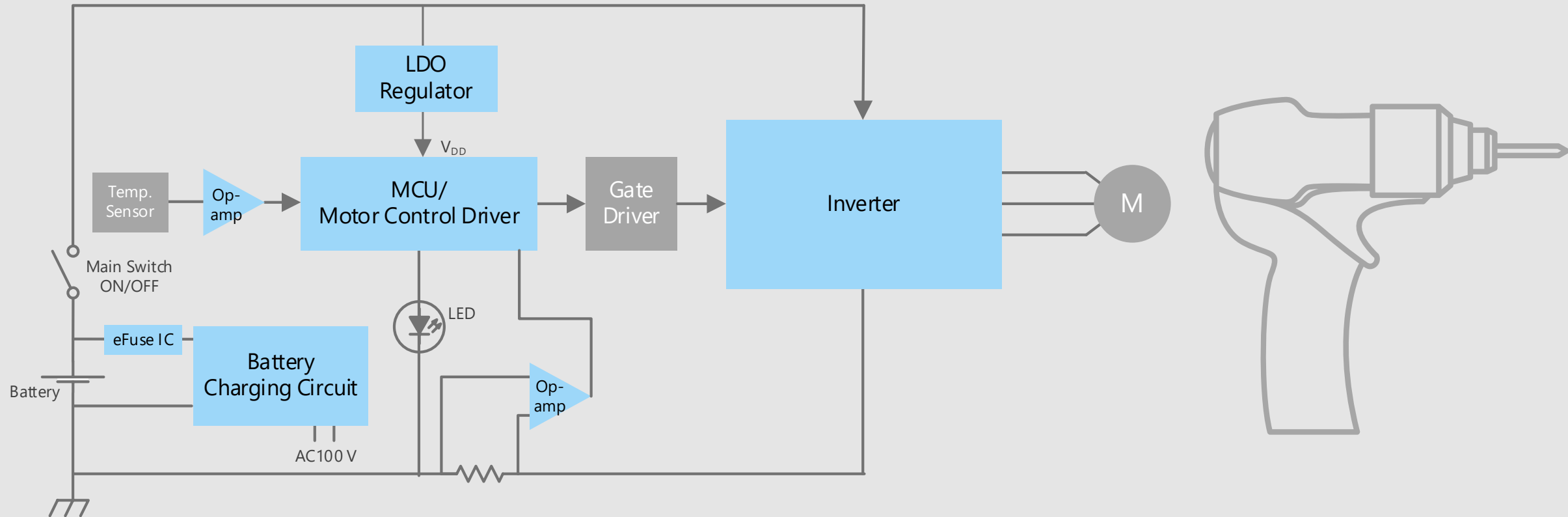


Toshiba Electronic Devices & Storage Corporation provides comprehensive device solutions to customers developing new products by applying its thorough understanding of the systems acquired through the analysis of basic product designs.

Block Diagram



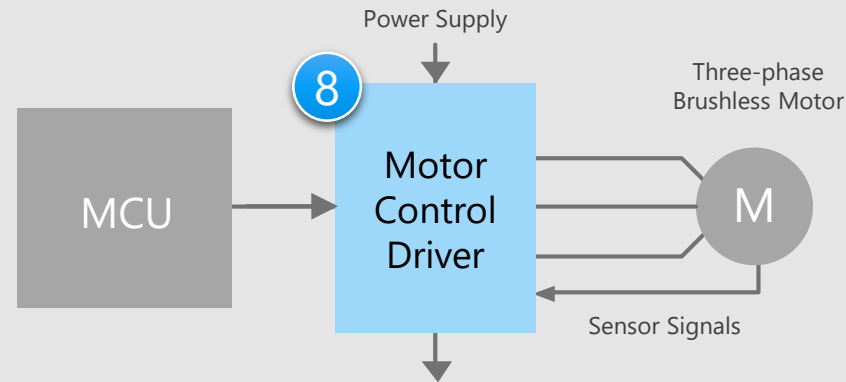
Cordless Power Tools Overall block diagram



Cordless Power Tools Details of motor drive unit (1)

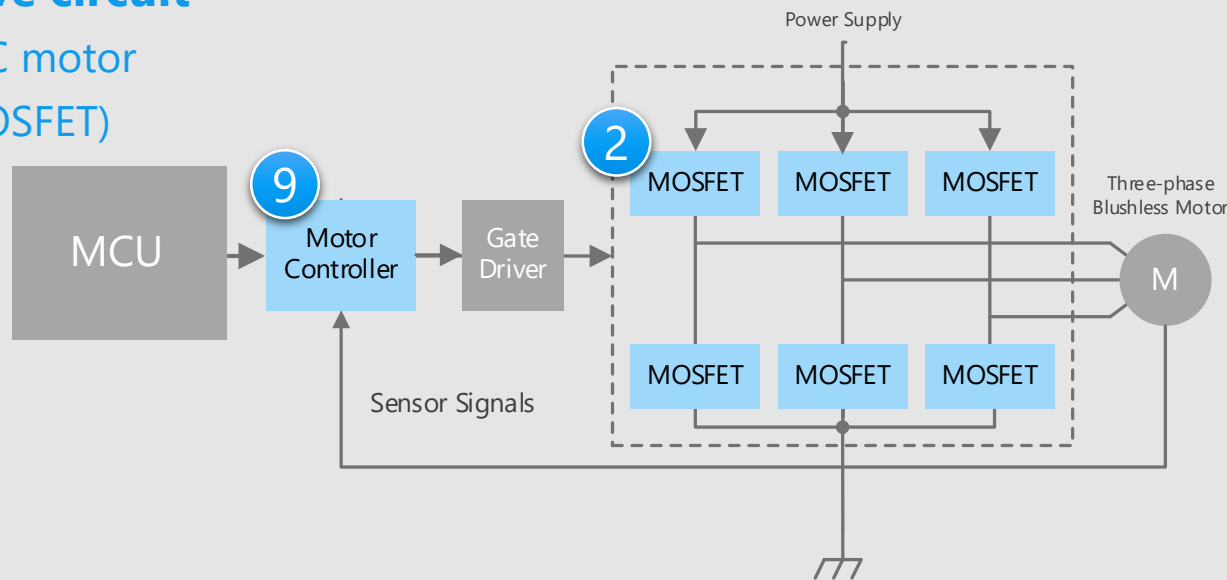
Motor drive circuit

Brushless DC motor
(integrated MOSFET)



Motor drive circuit

Brushless DC motor
(external MOSFET)



Criteria for device selection

- By using motor driver, one can easily drive a three-phase brushless motor using inverter control which is increasingly popular in recent years.
- System can drive high capacity brushless 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

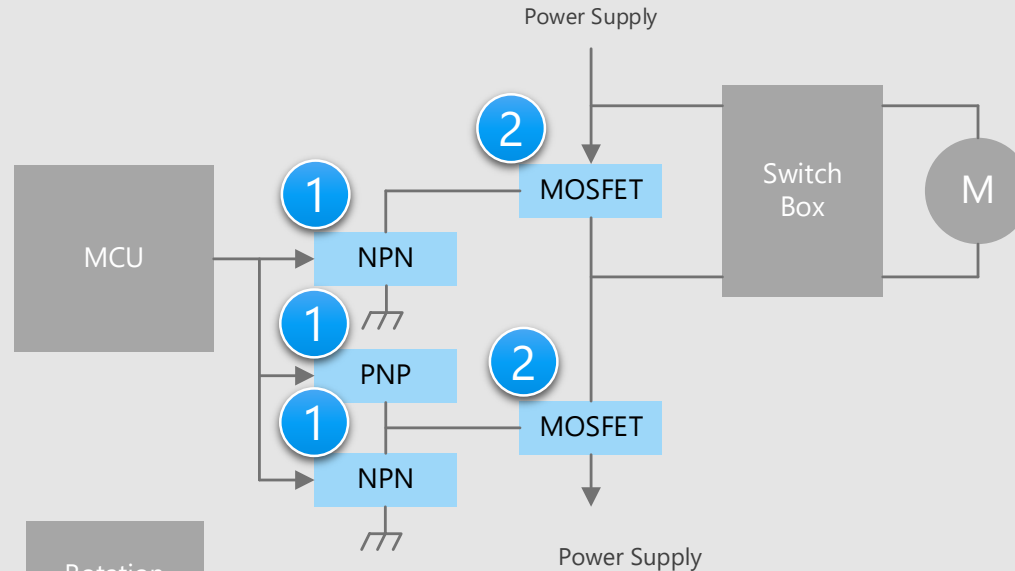
- **U-MOS Series MOSFET with low on-resistance and good heat performance** 2
U-MOS Series power MOSFET
- **Motor control driver with built-in MOSFET that can easily drive three-phase brushless motor** 8
Three-phase brushless DC motor driver (w/MOSFET)
- **Motor controller with external MOSFET that can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

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

Cordless Power Tools Details of motor drive unit (2)

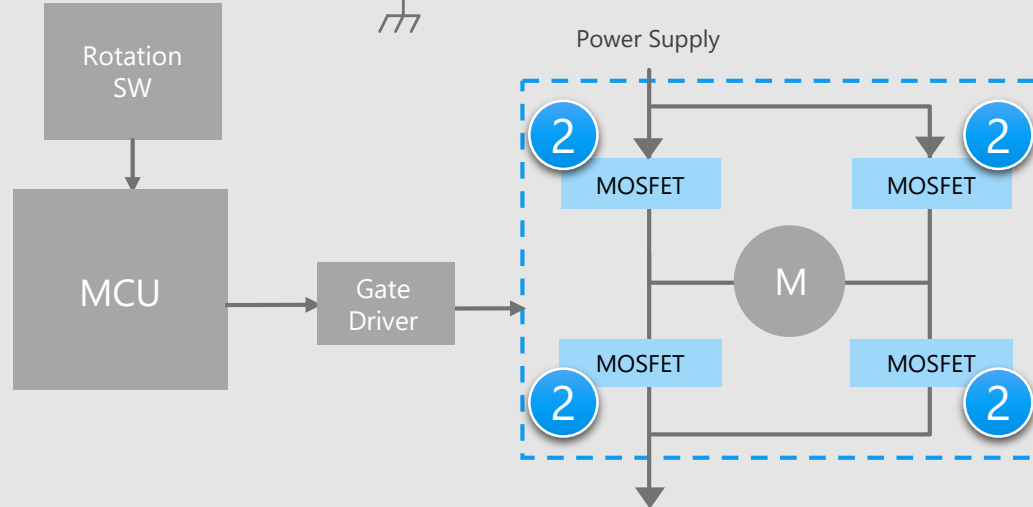
Motor drive circuit

Brushed DC motor/
Mechanical switching



Motor drive circuit

Brushed DC motor/
MOSFET switching



Criteria for device selection

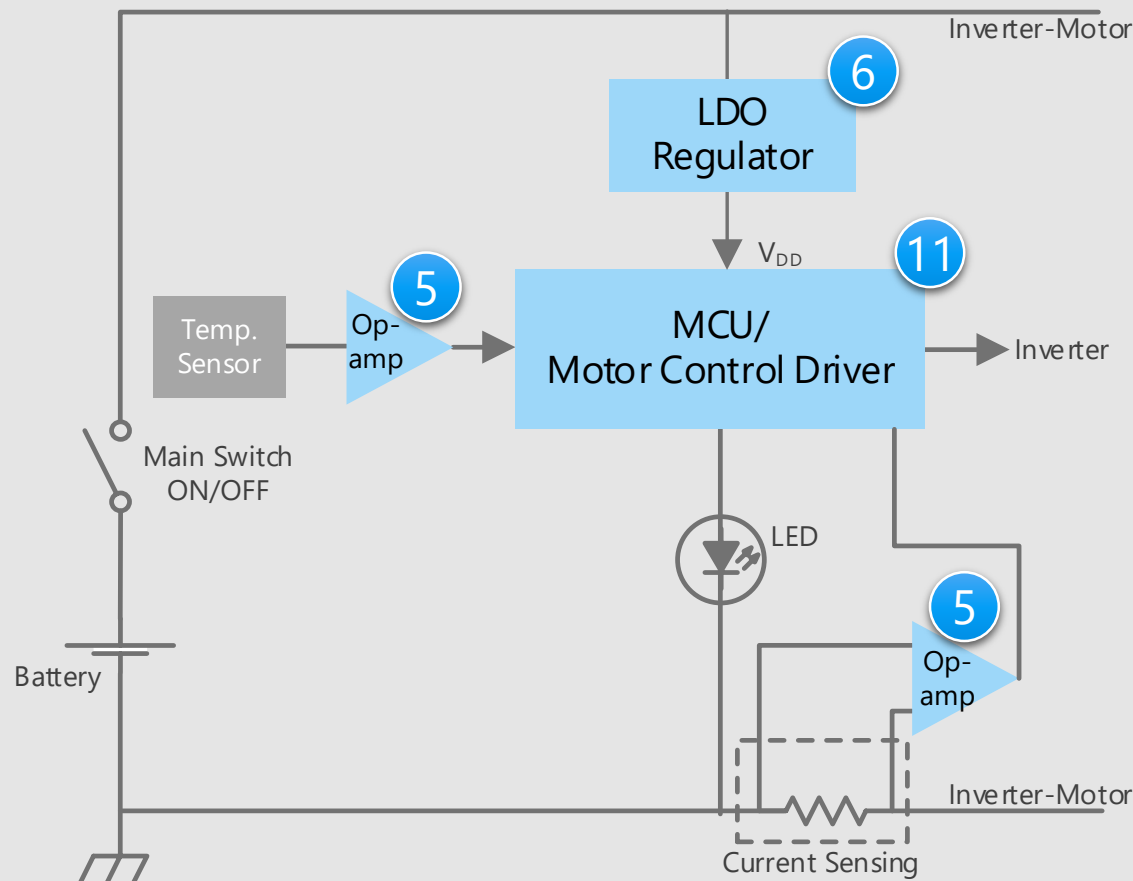
- MOSFET driver can be configured using bipolar transistors (NPN/PNP).
- Low loss, high efficiency MOSFET is suitable for the brushless motor drive.
- A high breakdown MOSFET is required taking into account the motor's counter electromotive force.
- Board area can be reduced by adopting small package devices.

Proposal from Toshiba

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

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

MCU peripheral circuit



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

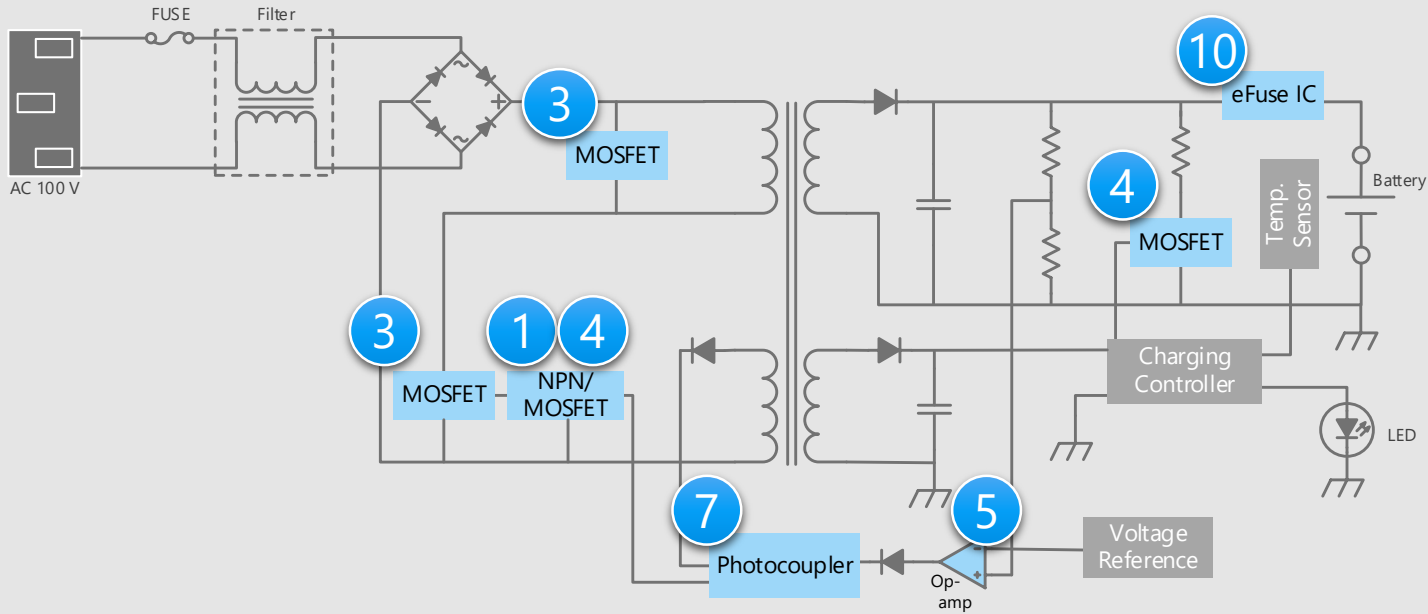
Criteria for device selection

- By monitoring the system power supply current, detection of abnormal equipment state and battery overcurrent protection become possible.
- Stable system is realized by adopting op-amps and LDO power supplies resistant to noise from the motor drive section.
- General purpose microcontroller suitable for system control and monitoring.

Proposal from Toshiba

- **Low noise operational amplifier to capture fluctuations in current consumption accurately** (5)
Low noise operational amplifier
- **Small surface mount LDO regulator suitable for power tools having high noise** (6)
Small surface mount LDO regulator
- **General purpose microcontroller for easy software development** (11)
Microcontroller

Battery charging circuit



Criteria for device selection

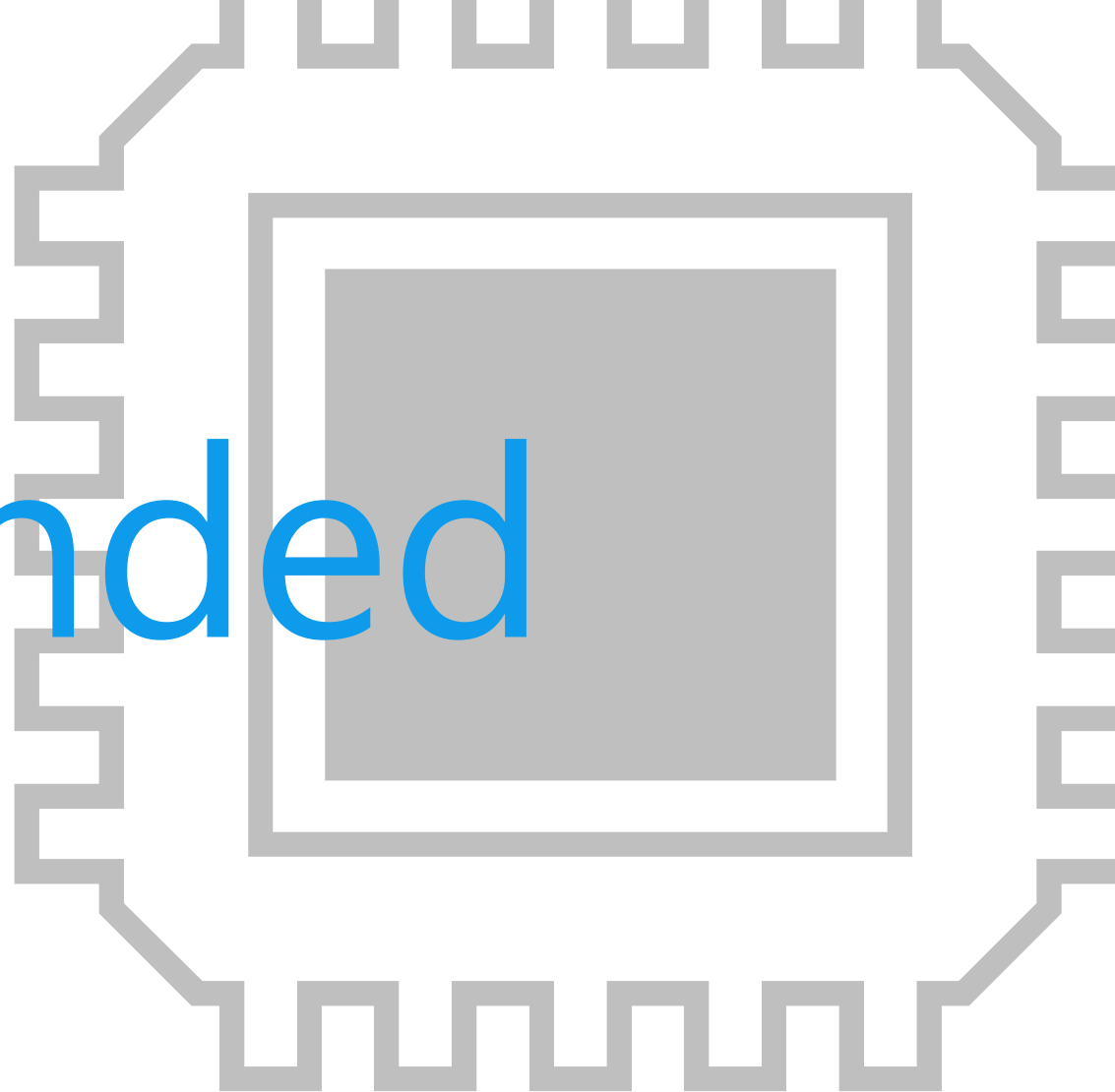
- High voltage and low on-resistance MOSFET is suitable for AC-DC power PFC circuit.
- In general, a photocoupler is used for voltage feedback to the primary side to the AC-DC power supply.

Proposal from Toshiba

- **Transistor for gate driving**
Bipolar transistor
- **DTMOS IV MOSFET , good for high efficiency power switching**
DTMOS IV Series power MOSFET
- **Small signal MOSFET for low voltage switching**
Small signal MOSFET
- **Low noise op-amp to capture fluctuations in current consumption accurately**
Low noise operational amplifier
- **Transistor output photocoupler with superior environmental resistance**
Transistor output photocoupler
- **eFuse IC for robust protection**
Electronic Fuse (eFuse IC)

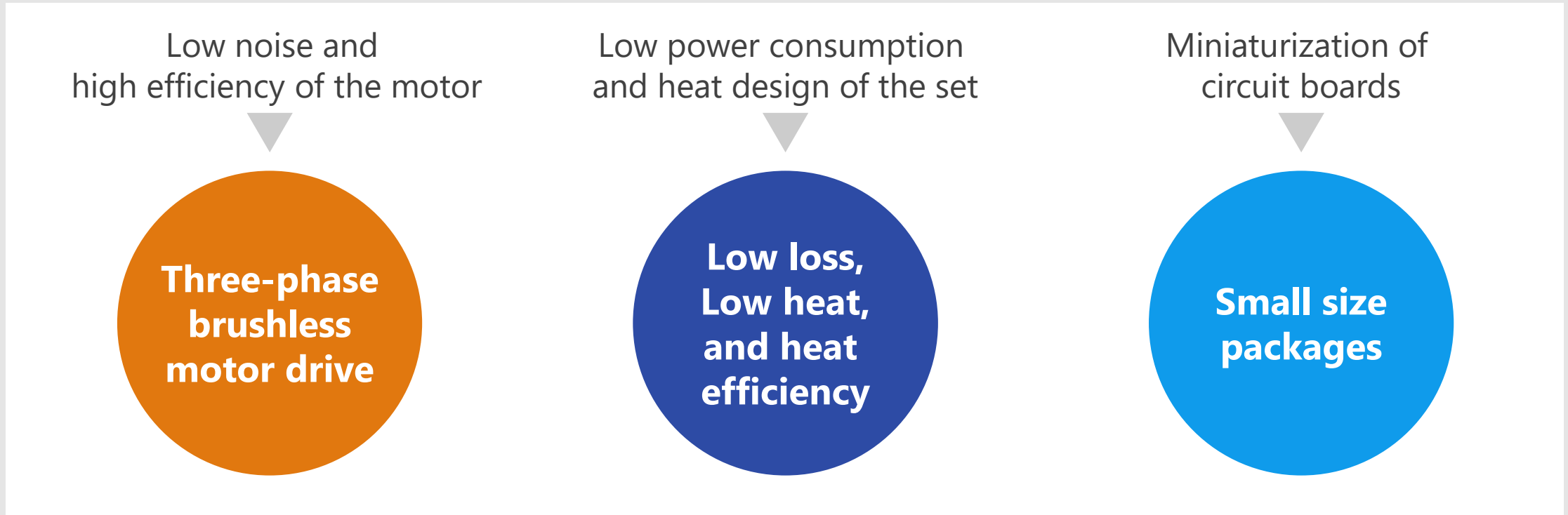
* Click on the numbers in the circuit diagram to jump to the detailed descriptions page

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

Three-phase
brushless
motor drive

Low loss,
Low heat,
and heat
efficiency

Small size
packages

①	Bipolar transistor			
②	U-MOS Series power MOSFET	●	●	●
③	DTMOS IV Series power MOSFET		●	●
④	Small signal MOSFET		●	●
⑤	Low noise operational amplifier			●
⑥	Small surface mount LDO regulator		●	●
⑦	Transistor output photocoupler			●
⑧	Three-phase brushless DC motor driver IC (w/MOSFET)	●	●	●
⑨	Three-phase brushless DC motor driver IC (external MOSFET)	●	●	●
⑩	Electronic Fuse (eFuse IC)		●	●
⑪	Microcontroller	●	●	●

Value provided

We provide a variety of packages covering a wide range of applications from high frequency to power supply usages.

1 High voltage (rated collector loss)

Because of the high voltage, it can tolerate large loads and instantaneous voltage changes. It also contributes to countermeasures against product life.

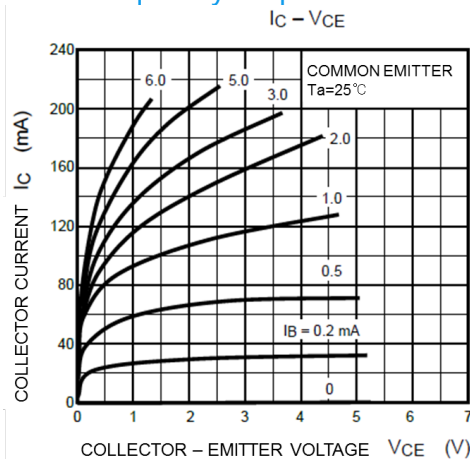
2 Large current (rated collector current)

We provide a variety of packages covering a wide range of applications from high frequency to power supply usages, particularly for products requiring high current capability.

3 Enhancement type

Because it is an enhancement type where no collector current flows when there is no base voltage, the device is easy to operate.

High voltage and high current are realized, making it suitable for low frequency amplification



TMBT3904

High voltage : $V_{CEO} = -50\text{ V}$ High current : $I_C = -150\text{ mA}$

Line up

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

[◆Return to Block Diagram TOP](#)

Value provided

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

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

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

2 Small Q_{OSS}

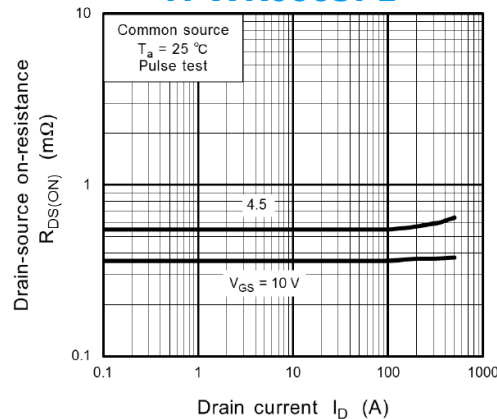
Contributes low output loss due to small Q_{OSS} . TPWR8004PL's performance index $R_{DS(ON)} \times Q_{OSS}$ is deducted to 63 %*¹ than competitor's products.

*1 As of November 2017 for MOSEFTs with equivalent ratings (as surveyed by Toshiba)

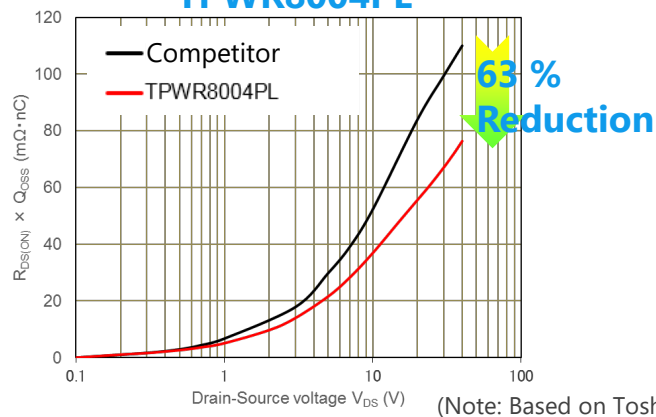
3 Variety of packages

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

Low on-resistance TPWR6003PL







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



(Note: Based on Toshiba's measurement data)

Line up

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

* : Silicon limit

[Return to Block Diagram TOP](#)

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

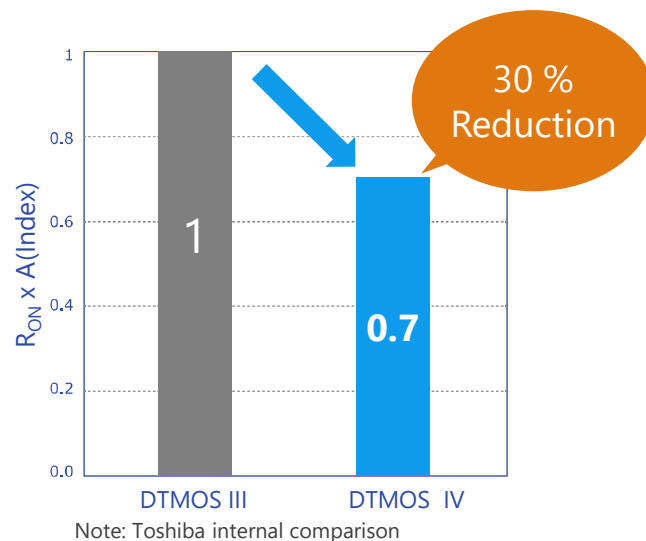
Adoption of newly developed single-epitaxial process to reduce the performance index RonA by 30 %. (Compared with DTMOS III products from Toshiba)

2 Reduction of on-resistance increase at high temperatures

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

3 Optimization of gate switching speed

Optimization of gate switching speed has been achieved by reduction of C_{OSS} (by 12 %, compared with Toshiba conventional products) and low on-resistance (using super-junction DTMOS structure).



Line up

Part number		TK12A60W	TK10A60W	TK17A80W
Package		TO-202SIS 	TO-202SIS 	TO-202SIS 
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

[Return to Block Diagram TOP](#)

Value provided

Suitable for power switching and contribute to miniaturization.

1 Driving by low voltage

Can be driven by $V_{GS} = 4.5$ V.

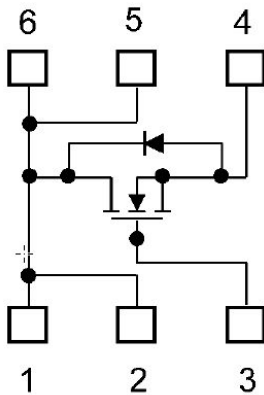
2 Low on-resistance

Heat dissipation and power consumption can be reduced by low on-resistance between source and drain.




3 Small package

Packaged in SOT-1220 (2.0 x 2.0 mm) form factor.

Internal circuit
SSM6K513NU



Line up

Part number	SSM6K513NU	SSM6N55NU	SSM6J507NU
Package	UDFN6B 	UDFN6B 	UDFN6B 
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
	Max	12	64

[◆Return to Block Diagram TOP](#)

5 Low noise operational amplifier

TC75S67TU

Three-phase
brushless
motor drive

Low loss,
Low heat,
and heat
efficiency

Small size
packages

Value provided

Very small signals detected by various sensors can be amplified with very 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.)

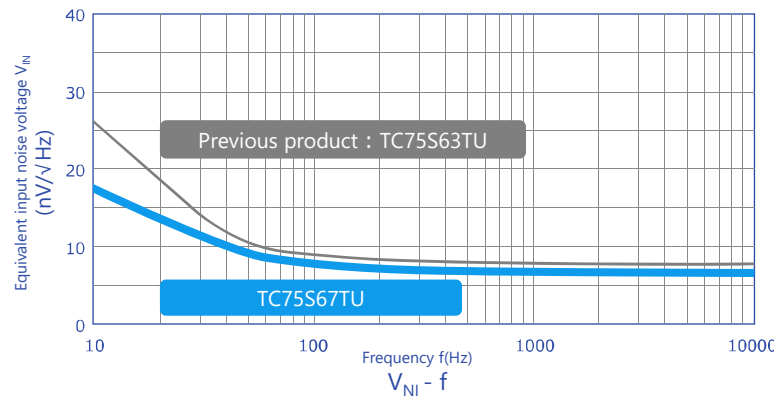
The low current consumption characteristics of the CMOS processing contributes to the extension of battery life of the compact IoT devices.

3 Low voltage operation


Can be operated in case of $V_{DD} = 2.2$ to 5.5 V.

Low noise characteristics

(Toshiba internal comparison)



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} [nV/ $\sqrt{\text{Hz}}$] (Typ.) @ $f = 1$ kHz	6

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

[Return to Block Diagram TOP](#)

6 Small surface mount LDO regulator

TAR5SB Series

Three-phase
brushless
motor drive

Low loss,
Low heat,
and heat
efficiency

Small size
packages

Value provided

To meet high performance demands with optimum products, we offer from general purpose to small package devices.

1 Low dropout voltage

Dropout characteristics have been greatly improved by the newly developed process. (50 % improvement : Toshiba comparison)

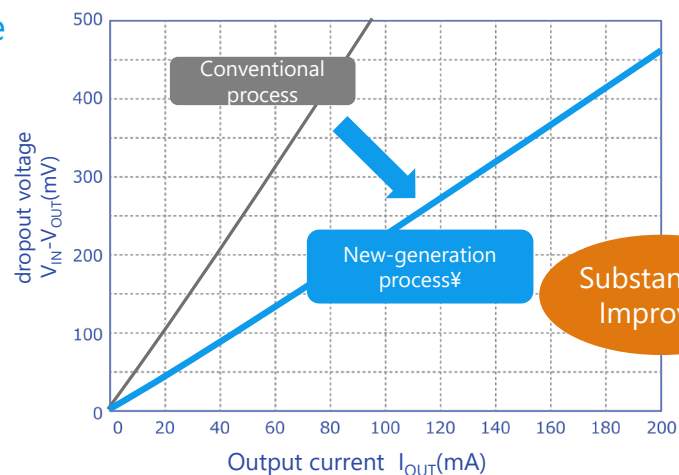
2 Low output noise voltage V_{NO}

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

3 Can be used with ceramic capacitors


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

Low dropout voltage



Note: Toshiba internal comparison

Line up

Part number	TAR5SB Series
Package	SOT25 
V_{IN} (Max) [V]	15
I_{OUT} (Max) [mA]	200
$V_{IN} - V_{OUT}$ (Max) [V]	0.2
Output range [V]	1.5 to 5.0

[Return to Block Diagram TOP](#)

Value provided

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

1 High current transfer ratio

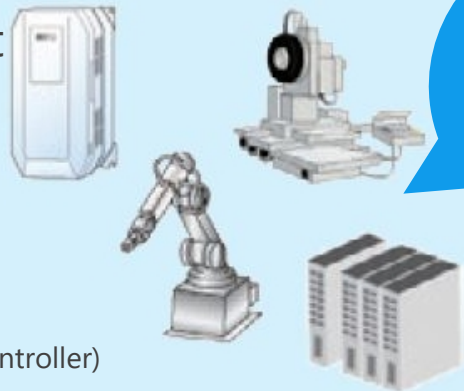
This is a high-isolation photocoupler that optically couples a phototransistor and a GaAs infrared light emitting diode. High current transfer ratio is realized at $I_F = 5 \text{ mA}$.

2 Operating temperature is expanded to 110 °C

It is designed to operate even under severe temperature environments such as those for inverter devices, robots, machine tools, and high output power supplies.


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
insulation
and noise
blocking

Line up

Part number	TLP385
Package	4 pin SO6L 
BV_S (Min) [Vrms]	5000
T_{opr} [deg.C]	-55 to 110

[◆Return to Block Diagram TOP](#)

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

With the ability to adjust the phase of the voltage and current individually for different types of motors with a simple setting, a high-efficiency drive is realized.

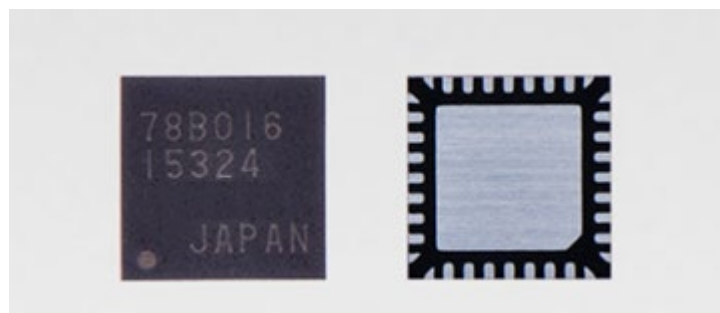
2 Motor control with low noise, and low vibration

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

Since the output on-resistance is a small $0.23\ \Omega$ (Typ.), the power loss of the IC itself during operation can be kept low.



WQFN36 package (5 x 5 x 0.8 mm)

Line up

Part number	TC78B016FTG
Power supply voltage	6 to 30 V (operating range)
Output current	3 A (operating range)
Drive system	Sine wave drive system
Other/Features	Phase control : Optimum phase control of voltage and current Hall device / Hall IC compatible Speed control input: PWM signal/ analog voltage input Exception detection function: Overheating detection, overcurrent detection, motor lock detection Output on-resistance (sum of top and bottom): $0.23\ \Omega$ (Typ.)

[◆Return to Block Diagram TOP](#)

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

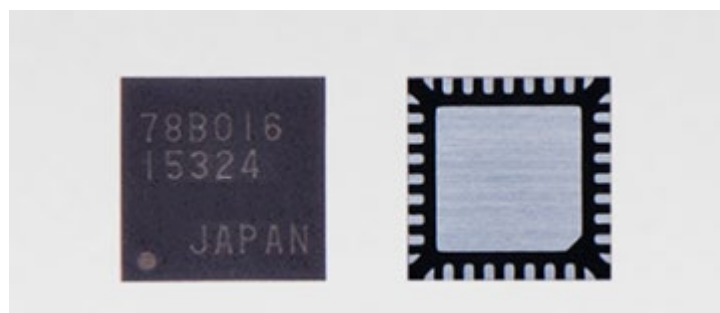
With the ability to adjust the phase of the voltage and current individually for different types of motors with a simple setting, a high efficiency drive is realized.

2 Motor control with low noise, and low vibration

The use of a sinusoidal drive system featuring a smooth current waveform contributes to the low noise and low vibration of the motor, as compared to a square wave drive system.

3 Low loss, Low heat

Since the output on-resistance is a small $0.23\ \Omega$ (Typ.), the power loss of the IC itself during operation can be kept low.



WQFN36 package (5 x 5 x 0.8 mm)

Line up

Part number	TC78B016FTG
Power supply voltage	6 to 30 V (operating range)
Output current	3 A (operating range)
Drive system	Sine wave drive system
Other/Features	Phase control : Optimum phase control of voltage and current Hall device / Hall IC compatible Speed control input: PWM signal/ analog voltage input Exception detection function: Overheating detection, overcurrent detection, motor lock detection Output on-resistance (sum of top and bottom): $0.23\ \Omega$ (Typ.)

[◆Return to Block Diagram TOP](#)

Value provided

High voltage and high current motor driving can be implemented by external MOSFET.

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).

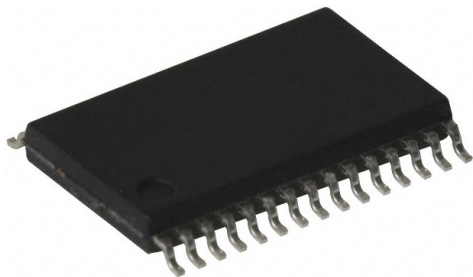
2 Motor control with low noise, and low vibration

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

[Note] Comparison with our products

3 Sufficient development support

Various supports such as 3rd party evaluation board and PSpice® data for development and design are prepared.



TSOP30 Package (10.2 x 7.6 x 1.6 mm)

Line up

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		
Other/Features	Phase control : Automatic (current feedback) Hall device / Hall IC compatible Internal regulator: 5 V / 30 mA (Max) Exception detection function: Current limit protection, position detect error, low voltage, motor lock detection (TB6634FNG)		

[◆Return to Block Diagram TOP](#)

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 IEC62368-1 certified

Toshiba's eFuse ICs are certified to the international safety standard IEC62368-1 (G9: Integrated circuit (IC) current limiters) and contribute to robust protection and simplification of circuit design.

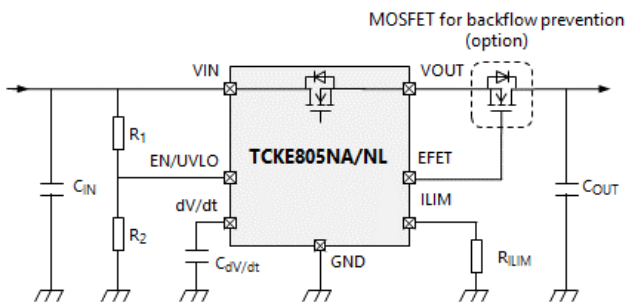
Note: TCKE712BNL is scheduled to be certified in Sep. 2021.

3 Rich protection functions

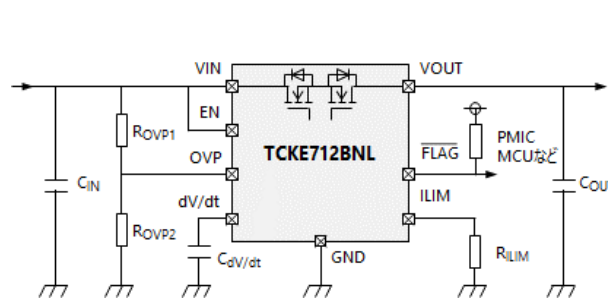
TCKE8 Series: short-circuit protection, overcurrent protection, overcurrent clamp function, overvoltage clamp function, thermal shut down, inrush current suppression, backflow prevention (optional), etc.

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



Line up

Part number	TCKE800NA/NL	TCKE805NA/NL	TCKE812NA/NL	TCKE712BNL
Package	WSO10B 3.0 x 3.0 x 0.75 mm			WSO10 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	15.0	Adjustable

[◆Return to Block Diagram TOP](#)

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.

Arm® Core	Arm® Cortex®-M0	Arm® Cortex®-M3	Arm® Cortex®-M4
TXZ+™ Family Advanced Class ~ 200 MHz		TXZ+™3A Series Coming Soon M3H	TXZ+™4A Series <Group> M4K M4M M4G M4N
TXZ™ Family ~ 160 MHz		TXZ™3 Series <Group> M3H(1) M3H(2)	TXZ™4 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		TXZ+™3E Series Coming Soon	
Toshiba Core	8bit	32bit	
TLCS Family TX Family	TLCS 870/C1 Series TLCS 870/C1E Series	TLCS 900 Series TX19 Series	

[Note] (*) : Pulse Width Modulation

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
TXZ+™4A Series	M4K Group	Arm® Cortex®-M4, includes 4 th gen VE

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