TOSHIBA

Motor Solutions Guide

SEMICONDUCTOR & STORAGE PRODUCTS
https://toshiba.semicon-storage.com/

Reasons why Toshiba's motor drivers are chosen

The Interplay of Heritage and Practice

System proposals based on 40 years of experience

Experience in collaborative development with system manufacturers in Japan and abroad

Deployment of power electronics technology cultivated with R&D and SBUs of Toshiba

Development and Growth

Contributions to efficiency improvement and energy saving

Increase in the flexibility of system design

Reduction in the amount of heat generated by semiconductor devices

Increase in motor drive performance

Reduction in package size

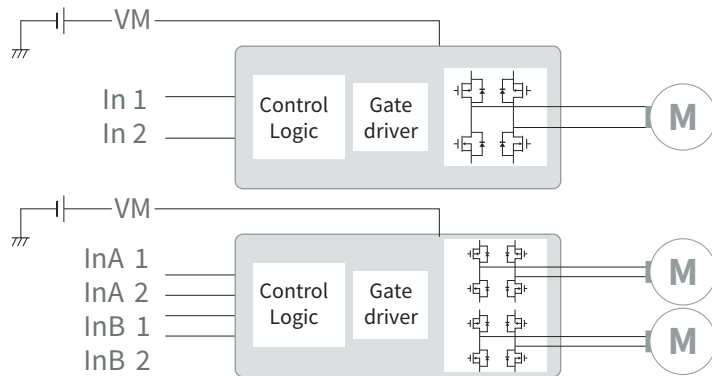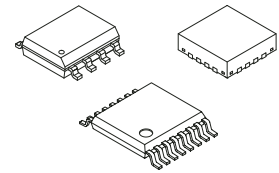# Serving as the "Heart and Soul" of Motors

Types of Toshiba's Motor Drivers and Their Applications

Brushed DC Motor Driver (H-Bridge Driver) ICs p.6

VM

In 1
In 2

Control Logic | Gate driver

M

VM

InA 1
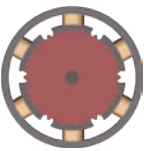InA 2
InB 1
InB 2

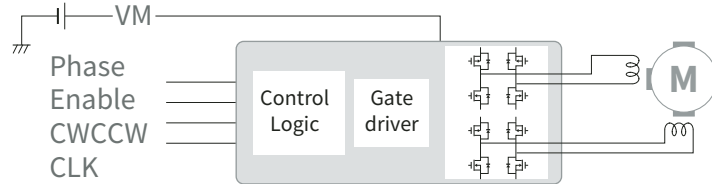Control Logic | Gate driver

M
M

Applications
- Consumer electronics
- Industrial equipment
  – Factory automation systems, multi-function printers, office equipment
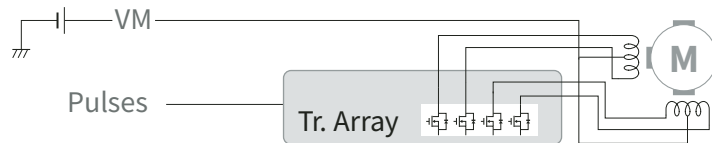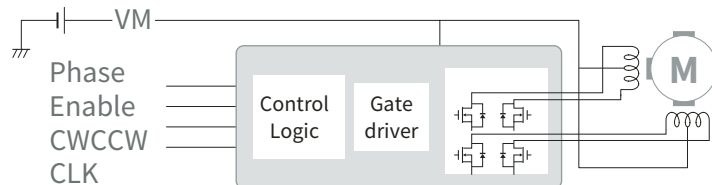 – Vending machines, home appliances, housing equipment
  – Others

Stepping Motor Driver ICs p.8

• Bipolar solution

VM

Phase
Enable
CWCCW
CLK

Control Logic | Gate driver

M

• Unipolar solution

VM

Phase
Enable
CWCCW
CLK

Control Logic | Gate driver

M

VM

Pulses

Tr. Array

M

Applications
- Factory automation systems
- Office equipment
  – Multi-function printers
  – Camera lenses, security cameras
  – Vending machines, sewing machines
  – Amusement equipment
  – Automatic teller machines (ATMs)
  – Others
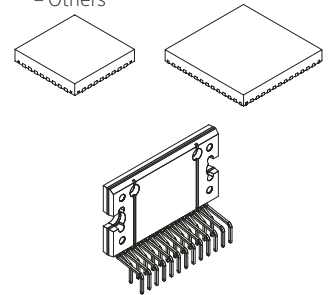
Small Low-Voltage BLDC Motor Driver ICs p.12
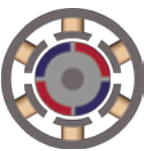
• Low-power single-chip solution

VM

VSP
FG

Control Logic | Gate driver

M

Single-phase, three-phase
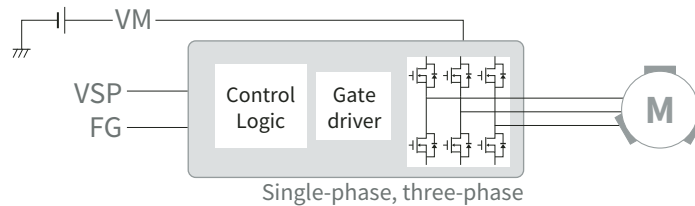
• High-current solution using external MOSFETs

VM

VSP
FG

Control Logic | Gate driver

M

Single-phase, three-phase   MOSFET
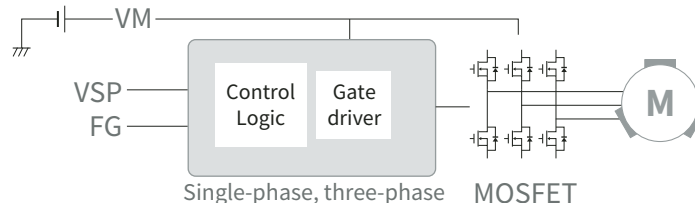
Applications
- PC fans
- Server fans
- Pumps
- Home appliances, housing equipment

4
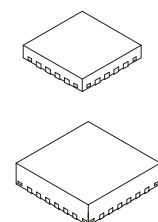
High-Voltage Brushless DC Motor Driver ICs p.14

• Three-phase brushless DC motor drivers (with integrated power devices)

Applications
• Home appliance motors
  – Air conditioner fans
  – Refrigerator compressors
  – Washing machine fans and refrigerator fans
  – Air purifiers
  – Ceiling fans
  – Others

AC — PFC — <VM> <Vcc>
MCU
VS — Control Logic — Gate driver — M
FG
Square wave

AC — PFC — <VM> <Vcc>
MCU
VS — Control Logic — Gate driver — M
FG
Sine wave
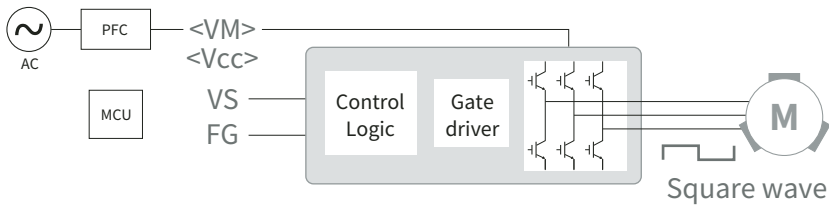
• Microcontrollers with Vector Engines (VE)
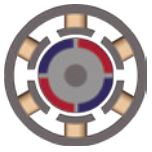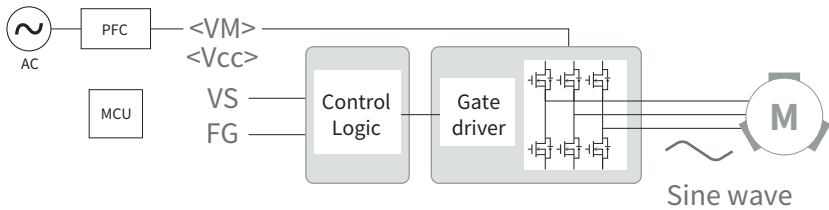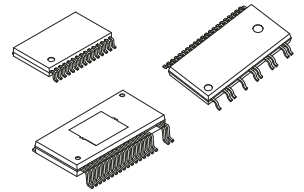
Applications
• Air conditioner compressors and fans
• Refrigerator fans and washing machine fans
• Ceiling fans
• Other home appliance motors

AC — PFC — <VM> <Vcc>
Motor Control MCU / Vector Engine — Gate driver — M / IPM
Sine wave
Gate driver / IPD — M
Sine wave
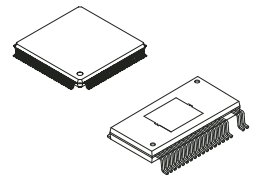
Discrete Semiconductor Devices

• Photocouplers (IGBT/MOSFET drivers, isolation amplifiers) p.18

Custom ASIC MCU — Isolation-Amplifier Gate driver — IGBT-M — M
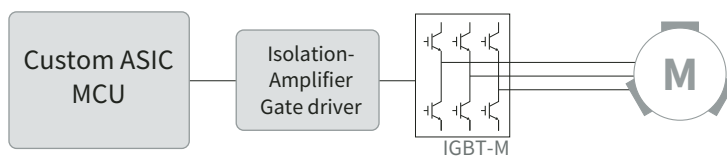
Applications
• Inverters, AC servos
• Uninterruptible power supplies (UPS), high-power standby power supplies (SPS)
• Power conditioners for photovoltaic power generation

• Mid- to high-V_{DSS} MOSFETs p.20

• Mid- to high-voltage SiC SBDs and discrete IGBTs p.21

• Low-V_{DSS} MOSFETs p.22
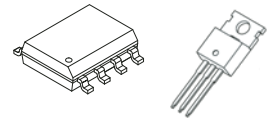
MCUs: Microcontrollers for Camera and Other Small Applications p.24

• MCUs in small packages suitable for high-precision analog-controlled equipment

* See the Automotive Solutions catalog for automotive motor drivers.

Brushed DC Motor Drivers (H-Bridge Drivers)

Fabricated using a leading-edge BiCD process with low power consumption and low output on-resistance, sealing in thermally enhanced small packages, Toshiba's brushed DC motor drivers help improve the efficiency and reduce the size of motor applications. Toshiba provides brushed DC motor drivers with different supply voltage and output current levels and with different numbers of channels. Therefore, you can select motor driver ICs that best suit your target motors.

Applications
Consumer electronics and industrial equipment
– Factory automation systems, multi-function printers, office equipment, robotic vacuum cleaners, fan motors, vending machines, home appliances, housing equipment, etc.

Technical discussion

- Latest BiCD and CD silicon technologies:
  The sophisticated high-voltage 0.13 µm silicon technology helps increase the current and reduce the on-resistance of driving transistors, making it possible to drive a motor with high efficiency and reduce the power consumption of the IC.
  Toshiba's product portfolio includes brushed DC motor drivers fabricated using a 0.13-µm high-voltage silicon technology.

- Incorporating a standby power consumption reduction circuit: TB67H450FNG
 The TB67H450FNG, a high-voltage motor driver, provides a maximum standby current of only 1 µA, making it possible to reduce system standby power consumption. The TB67H450FNG is particularly suitable for reducing the standby discharge current of battery-powered devices.

50 V 3.5 A Brushed DC Motor Driver (TB67H450FNG)

- Typical pinout
- Wide supply voltage range: 4.5 to 44 V
- Low output on-resistance: 0.6 Ω typical (high side + low side)
- Low standby supply current: 1 µA maximum at VM = 24 V and Ta = 25°C
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)
- Small package: HSOP8 with E-pad

HSOP8
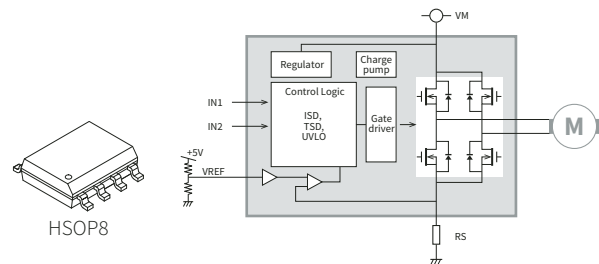
8 V 2.0/4.0 A Dual Brushed DC Motor Driver (TC78H653FTG)

- Ideal for battery (e.g., dry cell) operations because of low supply voltage (1.8 V or higher)
- Supply voltage range: 1.8 to 7.5 V (suitable for low supply voltage drive)
- Low output on-resistance: 0.22 Ω typical per channel (high side + low side)
  * In Large mode: 0.11 Ω typical
- Low standby supply current: 0.22 µA maximum at VM = 3 V and Ta = 25°C
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)
- Small package: QFN16 with E-pad

QFN16-0303
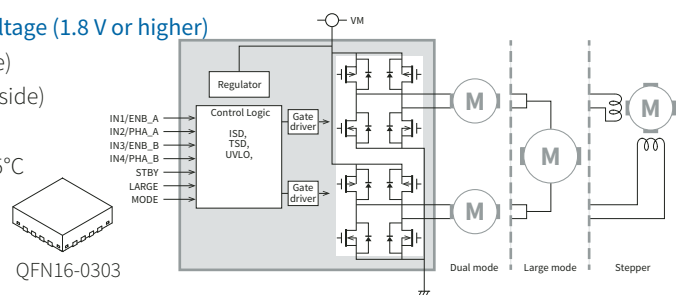
40 V 3.5/5.0 A Four-Channel Brushed DC Motor Driver (TB67H452FTG)

- Capable of driving up to four brushed DC motors
- Wide supply voltage range: 6.3 to 38 V
- Low output on-resistance: 0.6 Ω typical per channel (high side + low side)
  * In Dual mode: 0.3 Ω typical
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)
- Small package: QFN48 with E-pad

QFN48-0707
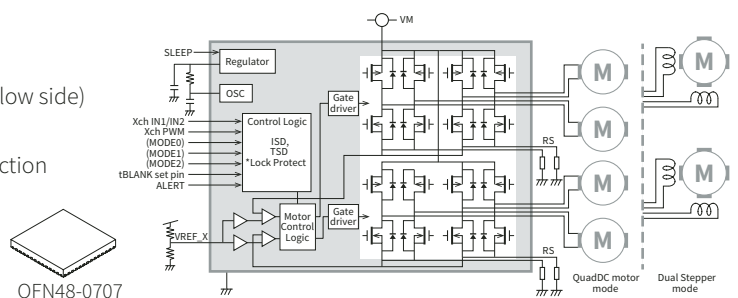
50 V 4.5/9.0 A Dual Brushed DC Motor Driver (TB67H420FTG)

- High-current drive (9 A)
- Advanced Current Detection System (ACDS)
- Wide supply voltage range: 10 to 47 V
- Low output on-resistance: 0.33 Ω typical per channel (high side + low side)
  * In Large mode: 0.165 Ω typical
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)
- Small package: QFN48 with E-pad

QFN48-0707

50 V 3.0/6.0 A Dual Brushed DC Motor Driver (TB67H401FTG)

- Current limiter and flag (for motor lock detection)
- Wide supply voltage range: 10 to 47 V
- Low output on-resistance: 0.25 Ω typical (high side + low side)
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)
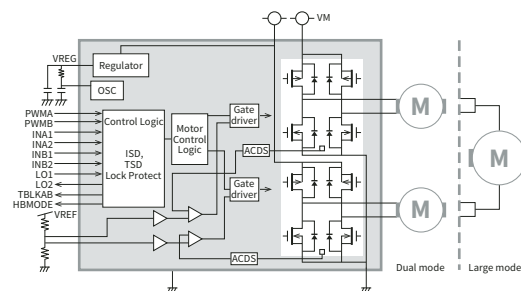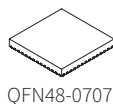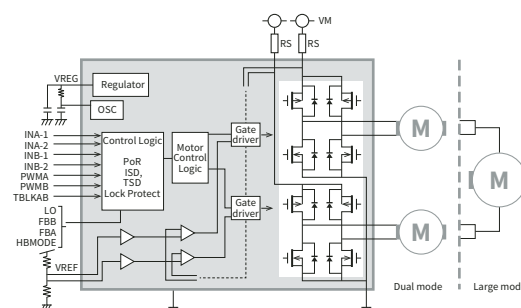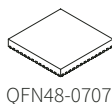- Small package: QFN48 with E-pad

QFN48-0707

● Major Brushed DC Motor Driver products

| Part Number | Large Mode | Absolute Maximum Ratings | | Output Ron [Ω] | Circuits (Ch) | C.C. PWM | Single Power Supply | Protection | | | Temp. Range T_A | Package |
		Voltage [V]	Current [A]					UVLO (1)	ISD (2)	TSD (3)		
TB67H301FTG		40	3.0	1.00	1	●		●	○/◇	○/◇	-40 to +85°C	QFN24
TB67H302HG		50	5.0	0.40	2	●	●	●	○	○	-30 to +85°C	HZIP25
TB67H303HG		50	10	0.20	1	●	●	●	○	○	-30 to +85°C	HZIP25
TB67H400AFTG/AFNG/AHG/ANG	●	50	4.0 / 8.0(4)	0.49 / 0.25(4)	2 / 1(4)	●	●	●	○	○	-20 to +85°C	QFN48/HTSSOP48/HZIP25/SDIP24
TB67H401FTG *	●	50	3.0 / 6.0(4)	0.49 / 0.25(4)	2 / 1(4)	●	●	●	○	○	-20 to +85°C	QFN48
TB67H410FTG/NG	●	50	2.5 / 5.0(4)	0.80 / 0.40(4)	2 / 1(4)	●	●	●	○	○	-20 to +85°C	QFN48/SDIP24
TB67H420FTG	●	50	4.5 / 9.0(4)	0.33 / 0.17(4)	2 / 1(4)	●	●	●	○	○	-20 to +85°C	QFN48
TB67H450FNG *		50	3.5	0.6	1	●	●	●	○	◇	-40 to +85°C	SOP8
TB67H452FTG	●	40	3.5 / 5.0(4)	0.60 / 0.30 (4)	4 / 2(4)	●	●	●	○	○	-20 to +85°C	QFN48
TC78H600FTG/FNG		18	1.0	1.20	2	●		●	○	◇	-20 to +85°C	QFN24/SSOP20
TC78H611FNG		18	1.1	0.80	2			●	○	◇	-30 to +85°C	TSSOP16
TC78H621FNG		18	1.1	0.80	2			●	○	◇	-30 to +85°C	TSSOP16
TC78H630FNG		18	2.1	0.40	1			●	○	◇	-30 to +85°C	TSSOP16
TC78H651AFNG *		8	2.0	0.22	2		●	●	○	◇	-40 to +105°C	TSSOP16
TC78H653FTG *	●	8	2.0 / 4.0(4)	0.22 / 0.11(4)	2 / 1(4)		●	●	○	◇	-40 to +105°C	QFN16
TC78S121FTG/FNG	●	40	3.5 / 5.0(4)	0.60 / 0.30 (4)	4 / 2(4)	●	●	●	○	○	-20 to +85°C	QFN48/HTSSOP48
TC78S122FTG/FNG	●	40	3.5 / 5.0(4)	0.60 / 0.30 (4)	4 / 2(4)	●	●	●	○	○	-20 to +85°C	QFN48/HTSSOP48

* : New product
Note (1): Under voltage Lockout
(2): Overcurrent detection
(3): Thermal shutdown
(4): Large Mode

○ Latch type
◇ Non latch type

Stepping Motor Drivers

Fabricated using a leading-edge BiCD process with low power consumption and low output on-resistance, Toshiba's stepping motor drivers in thermally enhanced small packages help improve the efficiency and reduce the size of motor applications. These stepping motor drivers incorporate a high-speed, high-precision control technology required for factory automation systems and office equipment, and help reduce the number of external parts required, simplifying system design. Toshiba provides stepping motor drivers with different supply voltage and output current levels and with different numbers of channels. Therefore, you can select motor driver ICs that best suit your target motors.

<Bipolar Stepping Motor Drivers>   <Unipolar Stepping Motor Drivers>
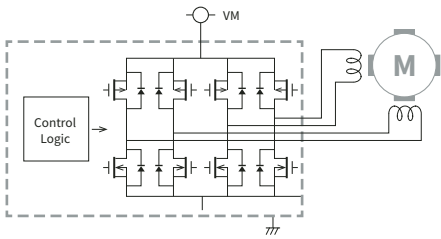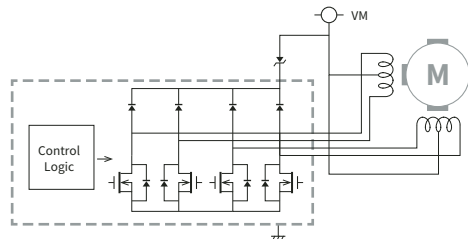
Motor control driver : MCD   Motor control driver : MCD   Tr. array
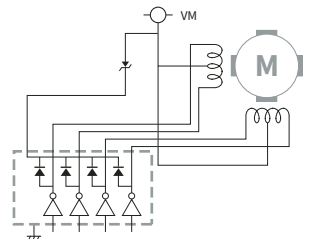
Applications

Factory automation systems, office equipment, vending machines, sewing machines, security cameras, amusement equipment, automatic teller machines (ATMs), etc.

Technical discussion

- Advanced Dynamic Mixed Decay (ADMD):
  Toshiba's original ADMD technology controles decay current more adequately than the conventional mixed-decay mode, making highly efficient motor control possible at high rpm.

- Active Gain Control (AGC):
  AGC is Toshiba's unique stepping motor technology to automatically optimize the drive current in real time according to load torque. It helps reduce unnecessary current, drastically cut power consumption and heat generation.

- Advanced Current Detection System (ACDS):
  Toshiba's original ACDS technology enables motor drive with highly accurate constant current without requiring external current-sensing resistors, which contribute to reduce part count, to save board area as well..

- Microstepping:
  The 128-microstep decoder enables high-precision microstepping control only with a clock pulse input. Stair-stepped approximation of a sine wave helps reduce excessive current, heating, and motor vibration, leading to smooth and quiet motor rotation.

- Error detection
  - Thermal Shutdown
  - Overcurrent detection
  - Power-On Reset
  - Motor load open detection

AGC : Activie Gain Control

Motor Current

Necessary current (necessary torque)

AGC drive current

The drive current is automatically optimized.
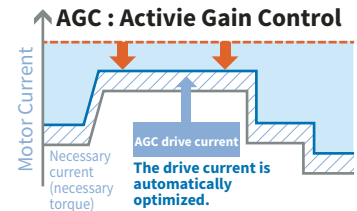
Microstepping

Close approximation of a sine wave reduces the power loss of motor applications.

Bipolar Stepping Motor Drivers

50 V 5.0 A PWM Chopper-Type Bipolar Stepping Motor Driver (TB67S128FTG)

- Allows microstepping (1/128th step)
- Low output on-resistance: 0.25 Ω typical (high side + low side)
- Advanced Dynamic Mixed Decay (ADMD)
- Active Gain Control (AGC)
- Advanced Current Detection System (ACDS)
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), VM power-on reset (POR), motor load open detection (OPD)
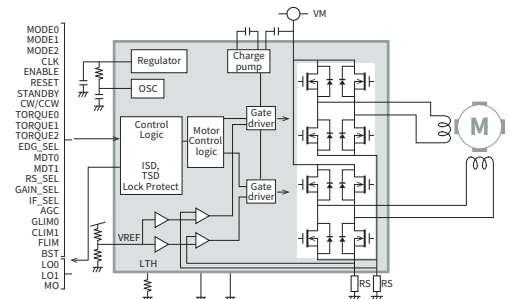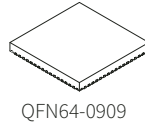- Small package: VQFN64 with E-pad

QFN64-0909

* RS: These current-sensing resistors can be added externally or incorporated on-chip.

50 V 4.0 A Two-Phase Bipolar Stepping Motor Drivers (TB67S101AFTG/AFNG/ANG, TB67S102AFTG/AFNG, TB67S103AFTG, TB67S109AFTG/AFNG, TB67S105FTG)

- Advanced Dynamic Mixed Decay (ADMD)
- Allows 1/32nd-step operation (TB67S103A, TB67S109A)
- Low output on-resistance: 0.49 Ω typical (high side + low side)
  * TB67S105: 0.6 Ω typical (high side + low side)
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), VM power-on reset (POR)
- Interfaces: Clock input, serial input, phase input
- packages: QFN48、HTSSOP48、HZIP25、SDIP24

QFN48-0707

HTSSOP48
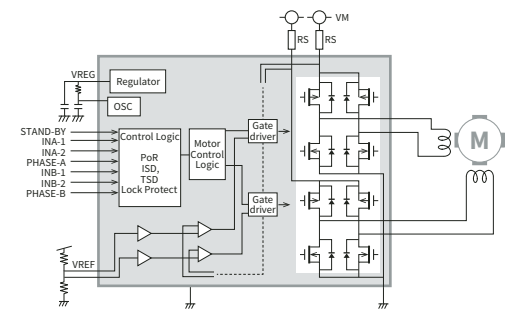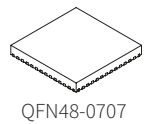
40 V 2.0 A PWM Chopper-Type Dual Stepping Motor Drivers (TC78S121FNG/FTG, TC78S122FNG/FTG)

- Capable of controlling two bipolar stepping motors
- Low output on-resistance: 0.6 Ω typical per channel (high side + low side)
  * In Large mode: 0.3 Ω typical
- Single power supply
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), VM power-on reset (POR)
- Interfaces: Clock input, phase input
- Small packages: HTSSOP48, QFN48

QFN48-0707

HTSSOP48
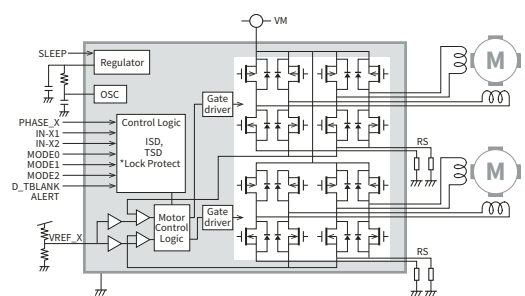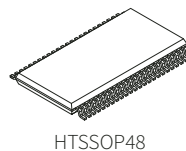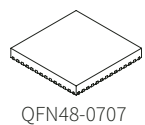
50 V 2.0 A Bipolar Stepping Motor Driver (TB67S261FTG, TB67S265FTG, TB67S269FTG)

- Stepping modes:TB67S265FTG: Full-step, half-step
  TB67S261FTG: Up to 1/4th step
  TB67S269FTG: Up to 1/8th step, 1/16th step, 1/32nd step
- Low output on-resistance: 0.8 Ω typical (high side + low side)
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD),VM power-on reset (POR)
- Interfaces: Clock input, serial input, phase input
- packages: QFN48（7 mm x 7 mm）

QFN48-0707

50 V 4.5/3.0/2.0 A Single-Channel Bipolar Stepping Motor Drivers (TB67S249FTG/289FTG/279FTG)

- Active Gain Control(**AGC**)
- Advanced Current Detection System (**ACDS**)
- Low output on-resistance:
  S249: 0.33 Ω typ., S279: 0.6 Ω typ., S289: 0.4 Ω typ.
  (high-side + low-side)
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO), motor load open detection (OPD)
- Small package: QFN48
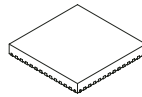
QFN48-0707
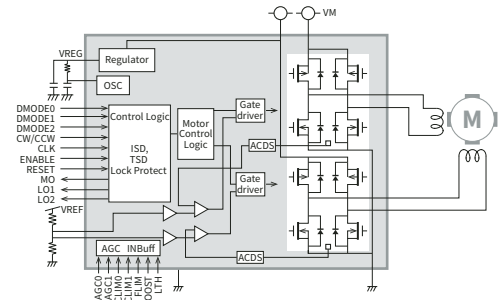
● Major Stepping Motor Driver products for Bipolar Motor Applications

Part Number	Interface			Absolute Maximum Ratings		Stepping Mode									Active Gain Control	Protection			Package
	Clock	Phase	Serial	Voltage [V]	Current [A]	Constant Current Cont.	Full	Half	1/4	1/8	1/16	1/32	1/64	1/128		UVLO	ISD	TSD	
TB62261FTG/FTAG		●		40	1.8 (FTG)/1.5 (FTAG)	●	●	●	●							●	●	●	QFN48/QFN36
TB62262FTG/FTAG	●			40	1.8 (FTG)/1.5 (FTAG)	●	●	●	●							●	●	●	QFN48/QFN36
TB62269FTG/FTAG *	●			40	1.8	●	●	●	●	●	●	●				●	●	●	QFN48/QFN32
TB6600FG/HG	●			50	4.5 (FG)/5.0 (HG)	●	●	●	●	●	●					●	●	●	HQFP64/HZIP25
TB67S101AFTG/AFNG/ANG		●		50	4.0	●	●	●	●							●	●	●	QFN48/HTSSOP48/SDIP24
TB67S102AFTG/AFNG	●			50	4.0	●	●	●	●							●	●	●	QFN48/HTSSOP48
TB67S103AFTG	●		●	50	4.0	●	●	●	●	●	●					●	●	●	QFN48
TB67S105FTG			●	50	3.0	●	●	●	●							●	●	●	QFN48
TB67S109AFTG/AFNG	●			50	4.0	●	●	●	●	●	●					●	●	●	QFN48/HTSSOP48
TB67S213FTAG		●		40	2.5	●	●	●	●							●	●	●	QFN36
TB67S215FTAG	●			40	2.5	●	●	●	●							●	●	●	QFN36
TC78S600FTG/FNG	●			18	1.0	●		●	●	●	●					●	●	●	QFN24/SSOP20
TB6613FTG	●		●	6	0.8	●		●					●			●		●	QON44
TB67S261FTG		●		50	2.0	●	●	●	●							●	●	●	QFN48
TB67S265FTG			●	50	2.0	●	●	●								●	●	●	QFN48
TB67S269FTG	●			50	2.0	●	●	●	●	●	●	●				●	●	●	QFN48
TC78S121FTG/FNG *		●		40	2.0 x 2 ch	●	●	●								●	●	●	QFN48/HTSSOP48
TC78S122FTG/FNG *	●			40	2.0 x 2 ch	●	●	●								●	●	●	QFN48/HTSSOP48
TB67S209FTG *	●			50	4.0	●	●	●	●	●	●					●	●	●	QFN48
TB67S289FTG *	●			50	3.0	●	●	●	●	●	●				●	●	●	●	QFN48
TB67S508FTG *	●	●		40	3.0	●	●	●								●	●	●	QFN36
TB67S511FTAG *		●		40	2.0	●	●	●								●	●	●	QFN36
TB67S512FTAG *	●			40	2.0	●	●	●								●	●	●	QFN36
TB67S521FTAG *		●		40	2.8	●	●	●								●	●	●	QFN36
TB67S522FTAG *	●			40	2.8	●	●	●								●	●	●	QFN36
TB67S249FTG *	●			50	4.5	●	●	●	●	●	●	●			●	●	●	●	QFN48
TB67S279FTG *	●			50	2.0	●	●	●	●	●	●	●			●	●	●	●	QFN48
TB67S128FTG *	●			50	5.0	●	●	●	●	●	●	●	●	●	●	●	●	●	QFN64
TC78H670FTG **	●			20	2.0	●	●	●	●	●	●	●	●	●		●	●	●	QFN16

* : New Product
** : Under development
* Only major motor drivers are listed above. For the complete list, visit our website.

Unipolar Stepping Motor Driver

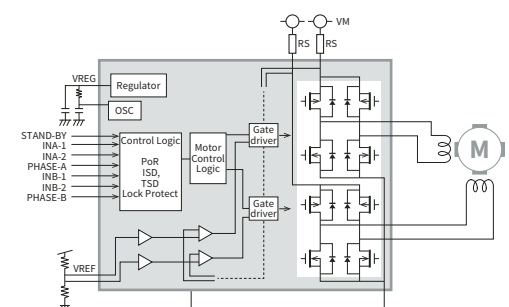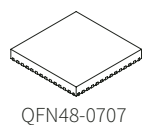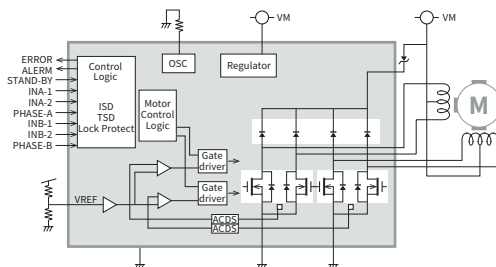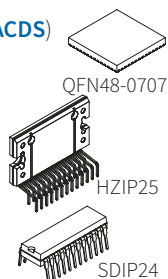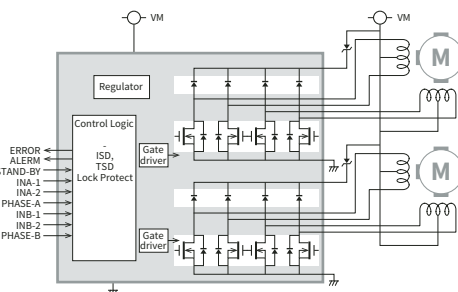### 84 V 3.0 A Unipolar Stepping Motor Drivers (TB67S141FTG/HG/NG, TB67S142FTG/HG/NG, TB67S145FTG, TB67S149FTG/FG/HG)

- Constant-current drive and Advanced Current Detection System (**ACDS**)
- Full-, half-, 1/4th-, 1/8th-, 1/16th-, and 1/32nd-step commutation
- Low output on-resistance: 0.25 Ω typical
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)
- Interfaces: Phase input, clock input, serial input
- Package: QFN48, HZIP25, SDIP24

QFN48-0707
HZIP25
SDIP24

80 V 1.5 A Unipolar Stepping Motor Driver (TB67S158FTG/NG)

- Constant-voltage drive
- Capable of controlling two unipolar stepping motors
- Stepping modes: Full-step, half-step
- Low output on-resistance: 0.5 Ω typical
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)
- Interfaces: Phase input, clock input, serial input, full parallel input
- Package: QFN48, SDIP24

QFN48-0707
SDIP24

80 V 1.5 A Unipolar Stepping Motor Driver (TB67S111PG)

- Constant-voltage drive
- Stepping modes: Full-step, half-step
- Low output on-resistance: 0.35 Ω typical
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)
- Interfaces: full parallel input
- Package: DIP16

DIP16
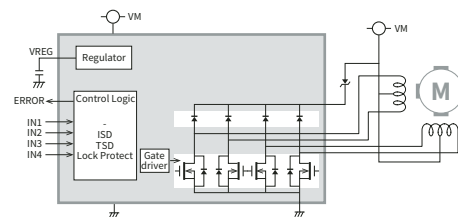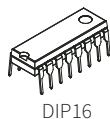
● Major Stepping Motor Driver products for Unipolar Motor Applications

Part Number	Interface				Absolute Maximum Ratings			Output On-Resistance [Ω]	Stepping Mode									Protection			Package
	Full Parallel Input	Clock	Phase	Serial	Voltage [V]	Output Voltage [V]	Current [A]		Constant Current Cont.	Full	Half	1/4	1/8	1/16	1/32	1/64	1/128	UVLO	ISD	TSD	
TB67S111PG	●				45	80	1.5	0.35		●	●							●	●	●	DIP16
TB67S141FTG/NG/HG			●		45	84	3.0	0.25		●	●							●	●	●	QFN48/SDIP24/HZIP25
TB67S142FTG/NG/HG		●			45	84	3.0	0.25	●	●	●	●						●	●	●	QFN48/SDIP24/HZIP25
TB67S145FTG				●	45	84	3.0	0.25	●	●	●	●	●	●	●			●	●	●	QFN48
TB67S149FTG/FG/HG		●			45	84	3.0	0.25	●	●	●	●	●	●	●			●	●	●	QFN48/HSOP28/HZIP25
TB67S158FTG/NG	●	●	●	●	80	80	1.5×2ch	0.7		●	●							●	●	●	QFN48/SDIP24
TB67S179FTG		●			80	80	1.5	0.25	●	●	●	●	●	●	●			●	●	●	QFN48

50 V 1.5 A DMOS Transistor Arrays (TBD62064A/TBD62308A)

- Clamp diodes
- Package: DIP16, HSOP16, SSOP24
- Pin-compatible with the previous equivalents (TD62064A/308A)

DIP16
HSOP16
SSOP24
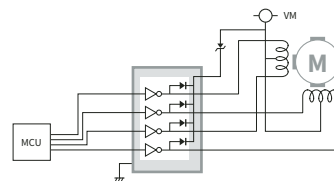
● Major Transistor Array products

Part Number	出力形式	# Outputs	Output Current [A]	Output Voltage [V]	Output On-Resistance [Ω]	Clamp Diode	Active Input Level	Package
TBD62064APG/AFG/AFAG	Sink	4	1.5	50	0.45	●	H	DIP16/HSOP16/SSOP24
TBD62308APG/AFG/AFAG			1.5	50	0.38	●	L	DIP16/HSOP16/SSOP24

Small Low-Voltage BLDC Motor Driver ICs

Toshiba provides motor driver ICs suitable for small BLDC motor applications. Housed in a small package, Toshiba's high-efficiency BLDC motor driver ICs incorporate a unique control technology that automatically minimizes the current-voltage phase difference of a motor, reducing its acoustic noise and power consumption.

Applications
- PC and server fans, small fans

Technical discussion – Reducing power consumption and acoustic noise

- Intelligent Phase Control
  Intelligent Phase Control (InPAC) is the state-of-the-art motor control technology developed by Toshiba. InPAC minimizes the current-voltage phase difference of a motor over the entire rpm range to improve its power efficiency. Because phase control is automated, InPAC provides an efficiency improvement regardless of the rpm, load torque, and supply voltage of the motor and therefore helps reduce the development workload required for setup and phase adjustment. (See the boxed explanation on Page 16.)

- Closed-loop speed control
  Toshiba provides BLDC motor driver ICs that incorporate a closed-loop speed control circuit, which maintains a constant motor speed by reducing variations in rpm due to supply voltage and load variations.

- Sensorless and sine-wave drive technologies
  Toshiba provides an extensive lineup of BLDC motor driver ICs that incorporate sensorless and sine-wave drive technologies, which make it possible to reduce the number of parts required for and therefore the size of motor applications, improve their power efficiency, and reduce a motor's acoustic noise. You can select BLDC motor drivers that best suit your application needs.

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18 V 3.5 A Three-Phase BLDC Motor Driver (TC78B025FTG)

- Intelligent Phase Control
- Closed-loop speed control
- Operating supply voltage range: 4.5 to 16 V
- Single-sensor-based sine-wave and 150-degree commutation
- Low output on-resistance: 0.2 Ω typical (high side + low side)
- RPM control input: PWM or analog voltage input
- Support for Hall effect sensor elements and Hall ICs
- Motor lock protection and automatic recovery functions
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), overcurrent limit protection (OCP), undervoltage lockout (UVLO)
- Small package: VQNF24

QFN24-0404
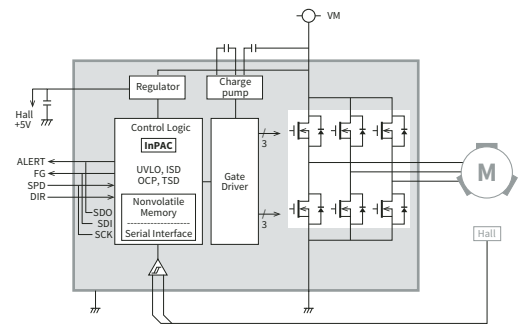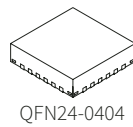
18 V Three-Phase BLDC Motor Predriver (TC78B027FTG)

- Intelligent Phase Control
- Closed-loop speed control
- Operating supply voltage range: 5.0 to 16 V
- Single-sensor-based sine-wave and 150-degree commutation
- Drives external N-channel + N-channel half-bridges
- RPM control input: PWM or analog voltage input
- Support for Hall effect sensor elements and Hall ICs
- Motor lock protection and automatic recovery functions
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), overcurrent limit protection (OCP), undervoltage lockout (UVLO)
- Small package: QNF24

QFN24-0404
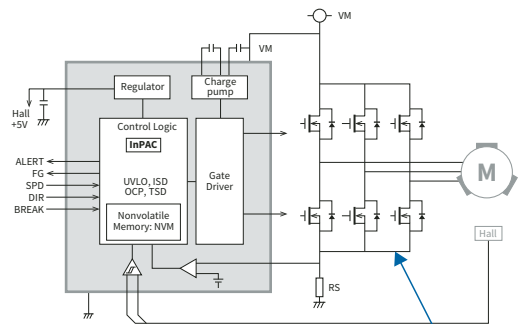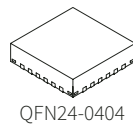
See Page 22 for external MOSFETs.

18 V 1.5 A Single-Phase Full-Wave Driver (TC78B002FTG/FNG)

- Operating supply voltage range: 3.5 to 16 V
- Soft switching (capable of sine-wave commutation)
- Integrated boot sequence
- Motor lock protection and automatic recovery functions
- Quick start function
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)
- On-chip voltage regulator: 5 V typical, 10 mA maximum
- Small packages: QNF16, SSOP16

SSOP16

QFN16-0303

40 V Single-Phase Full-Wave Predriver (TC78B006シリーズ)

- Operating supply voltage range: 3.5 to 30 V
- Soft switching (capable of sine-wave commutation)
- Drives a pair of external P-channel and N-channel half-bridges
- Motor lock protection and automatic recovery functions
- Quick start function
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)
- On-chip voltage regulator: 5 V typical, 10 mA maximum
- Small packages: QFN16, SSOP16

SSOP16

QFN16-0303

See Page 22 for external MOSFETs.
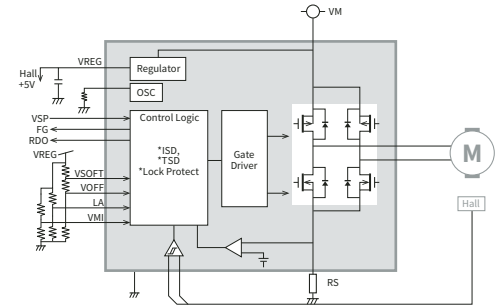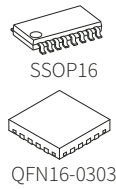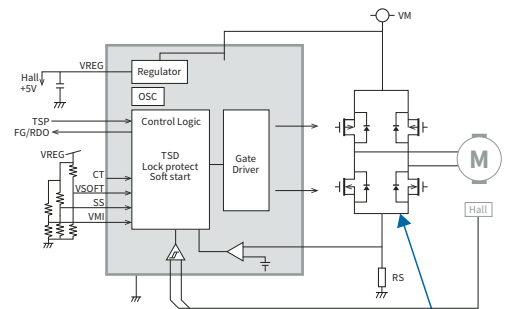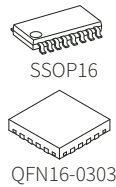
40 V 3.0 A Three-Phase BLDC Motor Driver (TC78B016FTG)

- Intelligent Phase Control
- Operating supply voltage range: 6 to 30 V
- Three-sensor-based sine-wave commutation
- Low output on-resistance: 0.24 Ω typical (high side + low side)
- RPM control input: PWM or analog voltage input
- Support for Hall effect sensor elements and Hall ICs
- Motor lock detection
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), overcurrent limit protection (OCP), undervoltage lockout (UVLO)
- Small packages: QFN36

QFN36-0505
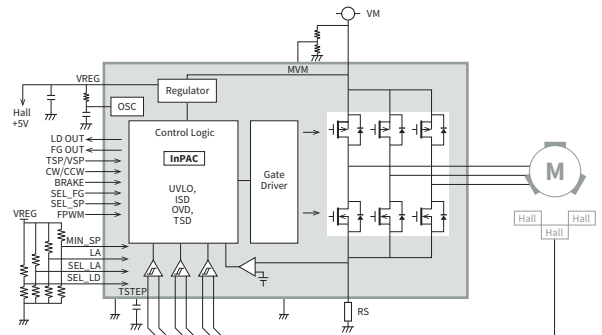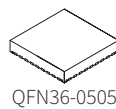
● Major Low-Voltage small BLDC Motor Driver products

Part Number	1-Phase	3-Phase	Pre Driver	Driver	Voltage [V]	Current [A]	Sensor-less	Hall Sensor Inputs (# Sensors)	Square	Sine	External Input	Auto (current FB)	Auto (rpm FB)	Auto (InPAC)	Closed Loop	Package
					Absolute Maximum Ratings		Position Sensing		Commutation Waveform		Lead Angle Control					
TB6605FTG		●	●		30	0.02		3	●	●			●			QFN36
TB67B001FTG/AFTG		●		●	25	3.0	●		●	●			●			QFN36
TB67B008FNG/AFNG/BFNG/CFNG		●		●	25	3.0	●		●	●			●			SSOP24
TB67B008FTG/AFTG/BFTG/CFTG		●		●	25	3.0	●		●	●			●			QFN24
TB67Z800FTG		●		●	25	3.0										QFN36
TC78B002FTG/FNG	●			●	18	1.5		1	●	●	●					QFN16, SSOP16
TC78B004FTG		●	●		31	0.1		3		●		●				QFN40
TC78B006 Series	●		●		40	0.02		1	●	●						QFN16, SSOP16
TC78B009FTG **		●	●		30	0.2	●		●	●			●			QFN36
TC78B015FTG		●		●	25	3.0		1	●	●			●			QFN36
TC78B015AFTG		●		●	36	3.0		1	●	●			●			QFN36
TC78B016FTG		●		●	40	3.0		3	●	●			●	●		QFN36
TC78B015BFTG/CFTG **		●		●	36	3.0		3	●	●			●			QFN36
TC78B025FTG *		●		●	18	4.0		1	●	●	●		●	●	●	QFN24
TC78B027FTG *		●	●		18	0.2		1	●	●	●		●	●	●	QFN24

    * : New product
    ** : Under development

High-Voltage BLDC Motor Driver ICs

To reduce a motor's power consumption and acoustic noise, BLDC motors are increasingly used for home appliances. Toshiba provides monolithic ICs incorporating IGBTs fabricated with the latest silicon-on-insulator (SOI) process and multi-chip modules combining well-proven MOSFETs and a driver IC. These BLDC motor driver ICs are available with a rated supply voltage ranging from 250 to 600 V and a rated output current ranging from 0.7 to 5 A, making them suitable for high-efficiency motor applications with an input voltage of 100 to 220 V-AC. Housed in a small package, they also help reduce the board area.

<Output current of up to 1 A: Square-wave commutation>

<Output current of up to 5 A: Sine-wave commutation>
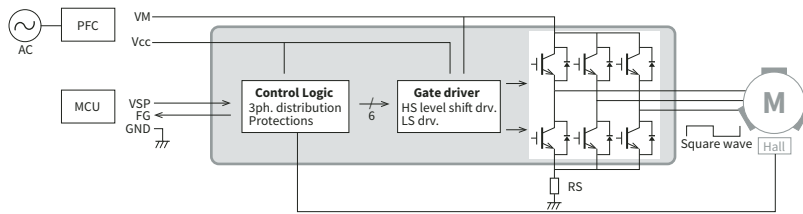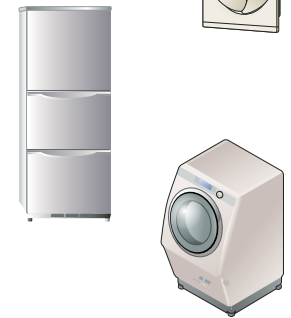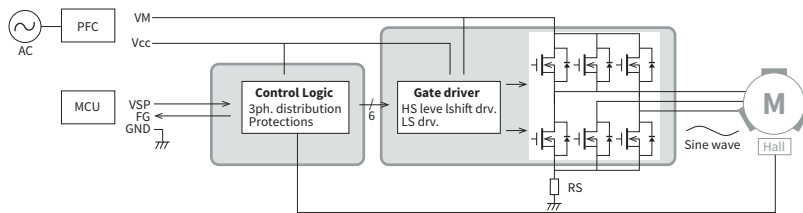
Applications
Home appliances
– Air conditioner fans, refrigerator fans, refrigerator compressors, washing machine fans, air purifiers, ceiling fans, etc.

600 V 2.0 A High-Voltage Three-Phase BLDC Motor Driver (TB67B000AHG/AFG)

- SiP (PWM controller and 600-V IPD combination)
- Three-sensor-based sine-wave PWM and trapezoidal commutation
- Support for Hall effect sensor elements and Hall ICs
- External lead angle control
- On-chip oscillator (external resistor required)
- Motor lock detection
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)
- Package: HDIP30/HSSOP34

HDIP30
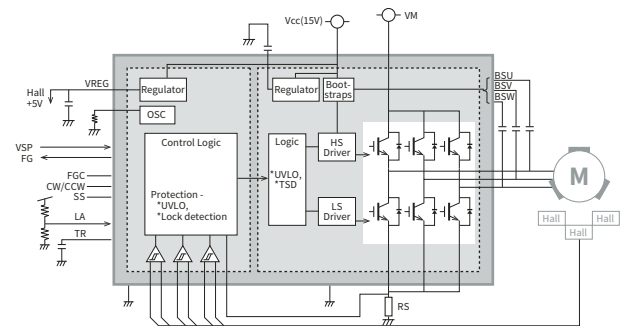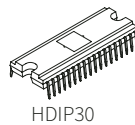
● Major High-Voltage BLDC Motor Driver products Incorporating a Controller (for Sine-Wave Commutation)

Part Number	Absolute Maximum Ratings		Commutation Waveform		Position Sensing		Lead Angle Control				Package
	Voltage [V]	Current [A]	Square	Sine	Sensor-less	Hall Sensor Inputs (# Sensors)	External Input	Auto (current FB)	Auto (rpm FB)	Auto (InPAC)	
TB67B000HG/FG	500	2	●	●		3	●				HDIP30/HSSOP34
TB67B000AHG/AFG	600	2	●	●		3	●				HDIP30/HSSOP34

Three-Phase BLDC Motor Driver Incorporating Power Devices (for Square-Wave Commutation)

Capable of phase switching via Hall effect sensor or Hall IC inputs and variable motor speed control via a speed control input

- High-voltage IC fabricated with an SOI process
- Available with a rated voltage ranging from 250 to 600 V and a rated current ranging from 0.7 to 1.0 A
- Incorporates a bootstrap circuit, for high-side gate-drivers
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)

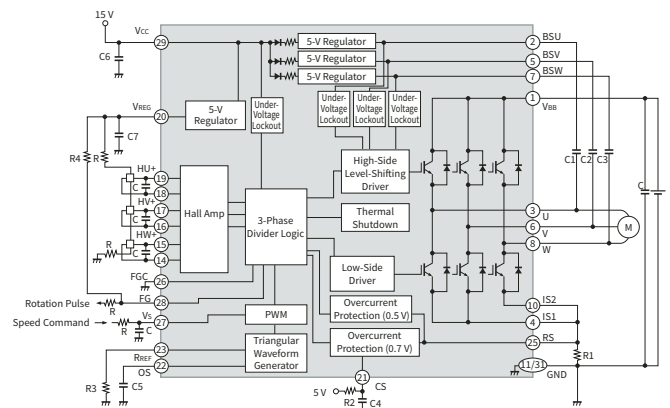Package
- HSSOP31

HSSOP31

Three-Phase BLDC Motor Driver Incorporating Power Devices (for Sine-Wave Commutation)

Capable of sine-wave commutation when combined with a controller (listed on the next page)

- High-voltage IC fabricated with an SOI process
- Available with a rated voltage ranging from 500 to 600 V and a rated current ranging from 2.0 to 5.0 A
- Incorporates a bootstrap circuit, for a high-side gete-drivers
- Protection features: Thermal shutdown (TSD), overcurrent protection (ISD), undervoltage lockout (UVLO)

Package
- HSSOP31, SSOP30, HDIP30

HSSOP31   SSOP30   HDIP30
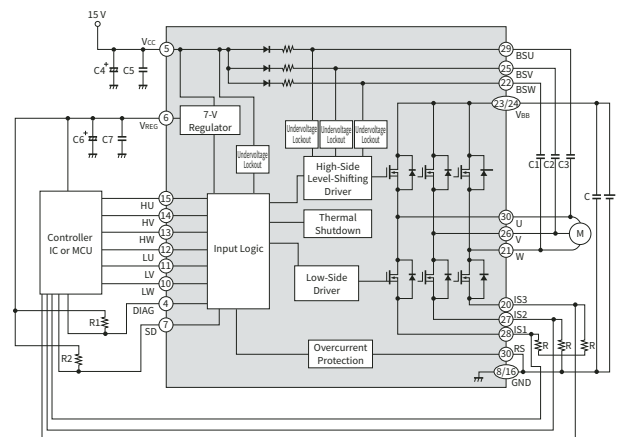
● Major High-Voltage BLDC Motor Driver products (for Square-Wave and Sine-Wave Commutation)

| Part Number | Absolute Maximum Ratings | Package | Three-Phase Distribution PWM Circuit | Commutation Waveform | | Position Sensing | | Output Stage | Structure |
				Square	Sine	Sensor-less	Hall Sensor Inputs (# Sensors)		
TPD4151F	250V / 1A	HSSOP31	●	●	–	–	3	IGBT	Monolithic IC
TPD4162F	600V / 0.7A	HSSOP31	●	●	–	–	3	IGBT	Monolithic IC
TPD4166F	600V / 1A	HSSOP31	●	●	–	–	3	IGBT	Monolithic IC
TPD4204F	600V / 2.5A	SSOP30	–					MOSFET	Multi-chip module
TPD4206F	500V / 2.5A	SSOP30	–					MOSFET	Multi-chip module
TPD4207F	600V / 5A	SSOP30	–	(*1)		(*1)		MOSFET	Multi-chip module
TPD4164F **	600V / 2A	HSSOP31	–					IGBT	Monolithic IC
TPD4164K **	600V / 2A	HDIP30	–					IGBT	Monolithic IC

** : Under development   (*1) Depends on the preceding controller

Controller Logic

Sine-Wave PWM Three-Phase BLDC Motor Controllers (TC78B041FNG/TC78B042FTG)

- Intelligent Phase Control
- Operating supply voltage range: 6 to 16.5 V
- Three-sensor-based sine-wave commutation
- Support for Hall effect sensor elements and Hall ICs
- Forward and reverse rotation
- Motor lock detection
- Selectable output pulse count per rotation
- On-chip voltage regulator: 5 V typical, 35 mA maximum
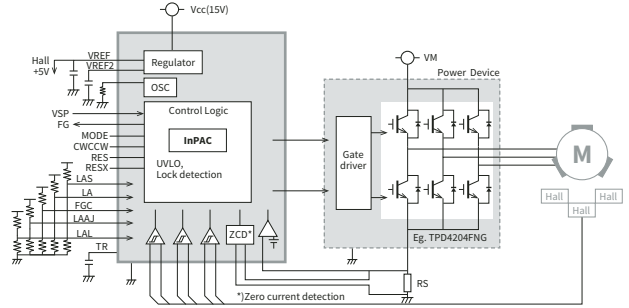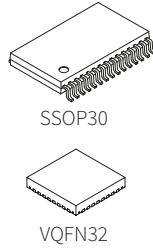- Output current limiting
- Small packages: SSOP30, VQFN32

SSOP30

VQFN32

● Major High-Voltage BLDC Motor Driver and Controller products

| Part Number | Absolute Maximum Ratings | | Commutation Waveform | | Position Sensing | | Lead Angle Control | | | | Closed Loop | Package |
	Voltage [V]	Current [A]	Square	Sine	Sensor-less	Number of Hall Sensor Inputs	External Input	Auto (current FB)	Auto (rpm FB)	Auto (InPAC)		
TB6551FAG	12	0.002		●		3	●					SSOP24
TB6556FG	12	0.002		●		3	●	●				SSOP30
TB6584FNG/AFNG	18	0.002		●		3	●	●				SSOP30
TB6586FG/AFG/BFG	18	0.002	●			3	●					SSOP24
TB6631FNG	18	0.002		●		3	●		●			SSOP30
TB6634FNG	18	0.002		●		3	●	●				SSOP30
TB67B054FTG	18	0.002		●		3	●	●				QFN32
TC78B041FNG *	18	0.002		●		3	●			●		SSOP30
TC78B042FTG *	18	0.002		●		3	●			●		QFN32

* : New Product

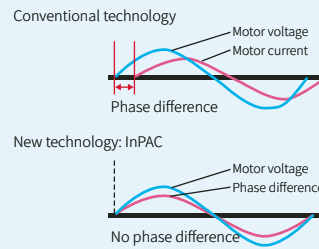## Intelligent Phase Control for automatic lead angle control

- Toshiba's unique motor drive technology provides high-efficiency and quiet motor operation.
- Automatic lead angle control eliminates the need for complicated adjustment.

   To drive a BLDC motor efficiently, it is necessary to control the phase of the motor drive voltage so that the phase of the motor's induced voltage matches that of the motor current. This is called lead angle adjustment. Since the lead angle varies with a motor's rpm and load torque, lead angle adjustment is a complicated task. Unless the lead angle is properly adjusted, the polarities of the motor voltage and current reverse at zero-crossing points, producing braking torque. This causes acoustic noise and vibration and reduces motor efficiency. Although vector control is employed for high-capacity motors, it has not been widely applied to small motors because of the need for intensive computing and parameter tuning.

   Intelligent Phase Control (InPAC) is a technique for automatic lead angle control to achieve high-efficiency motor drive with a simple circuit. InPAC monitors only the polarities of a motor's current and induced voltage, and accordingly adjusts the phase of the motor drive voltage so that they change simultaneously. Because this process is automated, InPAC eliminates the need for complicated lead angle adjustment and requires no external parts. InPAC is effective regardless of a motor's rpm, load torque, and supply voltage and enables a high-efficiency motor operation. Toshiba provides an extensive portfolio of BLDC motor drivers incorporating InPAC. InPAC is Toshiba's unique motor drive technology.

Intelligent Phase Control for automatic lead angle control

InPAC detects motor current and automatically minimizes a motor's voltage-current phase difference.

Conventional technology
- Motor voltage
- Motor current
- Phase difference

New technology: InPAC
- Motor voltage
- Phase difference
- No phase difference

Features:
- Adjustment-free: Eliminates the need for complicated lead angle adjustment
- Low power consumption: Reduces power consumption over a wide rpm range (Approx. 20% reduction at 3000 rpm in comparison with Toshiba's previous technology)
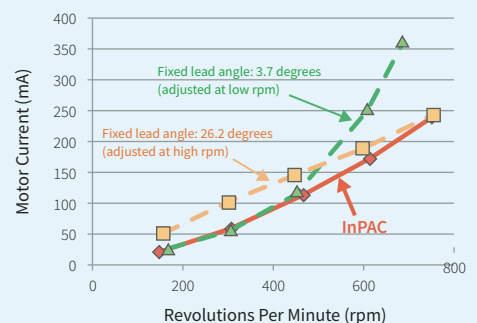
Microcontrollers with Vector Engine (VE)

Toshiba's original coprocessor offloads the CPU considerably.

- Various motor control functions: On-chip peripherals suitable for controlling high-performance BLDC motors, including Vector Engines (VEs), programmable motor drivers (PMDs), encoders (ENCs), AD converters (ADCs), and allows 5 V single-supply operation
- Reliable basic performance: Arm® Cortex®-M3 and Cortex®-M4 cores with a maximum clock rate of 120 MHz
- Extensive lineup: MCUs with 32 to 100 pins, 64 to 512 KB memory options, extensive package lineup
- Extended maximum operating temperature range: -40 to +105°C
- Efficient evaluation environment: Extensive debugging functions and evaluation boards
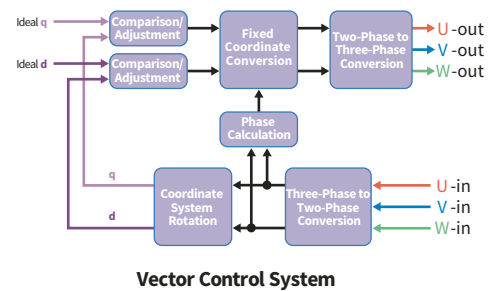
Applications
- Air conditioner compressors and fans, refrigerator fans, washing machine fans, ceiling fans, and other home appliance motors

Technical discussion — Microcontrollers for motor applications –

- **Vector engine (VE)**

Vector control is a technique for efficiently turning a BLDC motor over low- to high-rpm regions. To simplify mathematical computations, vector control converts the three-phase AC components (i.e., coil currents) into two-phase orthogonal components, which define the magnetic flux and torque of a motor respectively. This conversion involves three-phase to orthogonal transformation, coordinate system rotation, reverse transformation, and other computations. The Vector Engine performs these mathematical computations in dedicated hardware, considerably offloading the CPU and simplifying software design. Additionally, Toshiba's vector control MCUs contain programmable motor drivers (PMDs), high-speed AD converter interfaces and other peripheral hardware units necessary for motor control in order to perform a sequence of motor control tasks efficiently.

The Vector Engine provides high-speed PWM drive and high-resolution vector control, making it possible to drive motors with high efficiency and low acoustic noise.

Vector Control System

MCUs with Vector Engine (VE) for Inverter Home Appliance Applications (TMPM475xxxx)

- Arm Cortex-M4 with FPU
- Operating frequency: 120 MHz, operating voltage: 4.5 to 5.5 V
- 256 to 512 KB code flash memory
- 100-pin
- Capable of controlling up to two motors simultaneously
- CAN (1 ch)
- Hardware peripherals for motor control (A-VE, PMD, A-ENC, ADC)
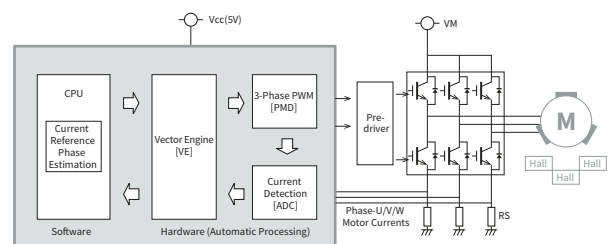
● Major MCU products with Vector Engine (VE)

| Part Number	Maximum Operating Frequency (MHz)	ROM (Flash) (Kbyte)	Motor Controllers (ch)	12-Bit AD Converter (ch) (Conversion time)	Encoder Input Circuits (ch)	CAN (ch)	I/O Port (ch)	Package
TMPM370FYDFG/FYFG	80	256	2	22 (2μS)	2		76	QFP100/LQFP100
TMPM372FWUG	80	128	1	11 (2μS)	1		53	LQFP64
TMPM373FWDUG	80	128	1	7 (2μS)	1		37	LQFP48
TMPM374FWUG	80	128	1	6 (2μS)	2		33	LQFP44
TMPM376FDDFG/FDFG	80	512	2	22 (2μS)	2		82	QFP100/LQFP100
TMPM375FSDMG	40	64	1	4 (2μS)	1		21	SSOP30
TMPM37AFSQG	40	64	1	5 (2μS)			13	VQFN32
TMPM470FYFG/FZFG/FDFG	120	256/384/512	2	23 (1μS)	2		79	LQFP100
TMPM475FYFG/FZFG/FDFG	120	256/384/512	2	23 (1μS)	2	1	79	LQFP100

Photocouplers

Toshiba's extensive portfolio of high-performance IC-output and other types of photocouplers provides total solutions for inverter systems. Toshiba provides smart IGBT gate drivers with protection features fabricated using the latest 0.13-µm BiCD process and high-luminance optically isolated isolation amplifiers.

IGBT/MOSFET-Drive Photocoupler with Overcurrent Protection (TLP5214A)

The TLP5214A is an isolated IGBT/MOSFET gate driver. It provides a protection feature called DESAT, which monitors the saturation voltage, $V_{CE(sat)}$, of an IGBT and performs a soft shutdown of its output when $V_{CE(sat)}$ exceeds 6.5 V typical in the event of an overcurrent condition. Additionally, the TLP5214A is housed in the thin SO16L package and provides active Miller clamping, rail-to-rail output, and other features, reducing the number of external components. This helps reduce bill-of-material (BOM) costs and board size. The TLP5214A provides a clearance distance of 8 mm and guarantees an isolation voltage of up to 5 kVrms, making it suitable for applications requiring high insulation performance.

- $V_{CE(sat)}$ detection and shutdown protect an IGBT/MOSFET in the event of overcurrent.
- The FAULT signal is fed back to the controller at high speed.
- Active Miller clamping prevents IGBT/MOSFET failures due to Miller current.
- A rail-to-rail output reduces power loss.
- Maximum output peak current: 4.0 A
- Propagation delay (t_{pHL} / t_{pLH}): 150 ns max


SO16L

TLP5214A
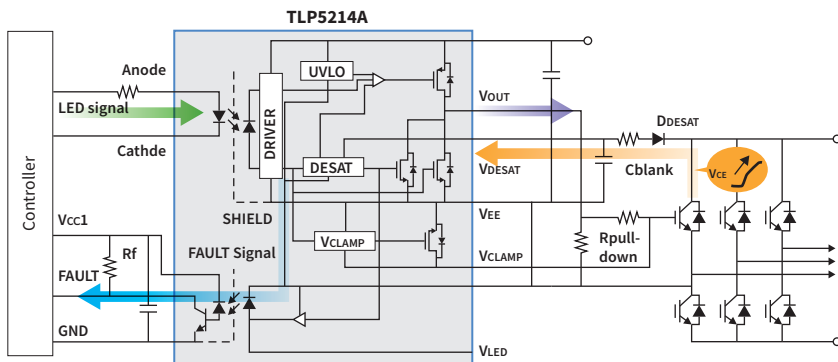
Soft Shutdown Waveform Example
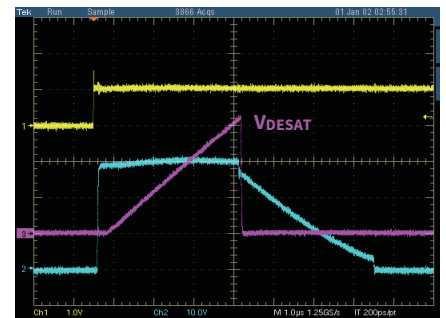
Conditions:
I_F = 10mA, V_{CC} = 30V, R_g = 10Ω, C_g = 25nF, Ta = 25°C
I_F: 10mA/div, V_O: 10V/div, V_{DESAT}: 2V/div, 1µs/div

High-Precision Isolation Amplifier with a High-Performance $\Delta\Sigma$AD Converter (TLP7820)

Typical AC servo inverters for industrial applications require feedback of the motor current. Therefore, the signal lines of a CPU or an MPU that control inverter circuitry at low voltage must be isolated from the current lines of a three-phase motor that operated at high voltage.
Toshiba's optically isolated isolation amplifier, the TLP7820, provides a solution for this requirement. The TLP7820 has an analog-output delta-sigma AD converter.

- Exhibits primary-side current consumption of only 9 mA typical and thus helps to reduce the size of power supplies
- Unique test mode that makes it possible to monitor internal characteristics
- Housed in the thin SO8L package and thus can be soldered on the backside of a PCB

SO8L(LF4)

Inverter Circuit Application Example
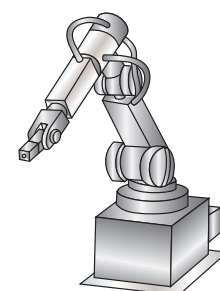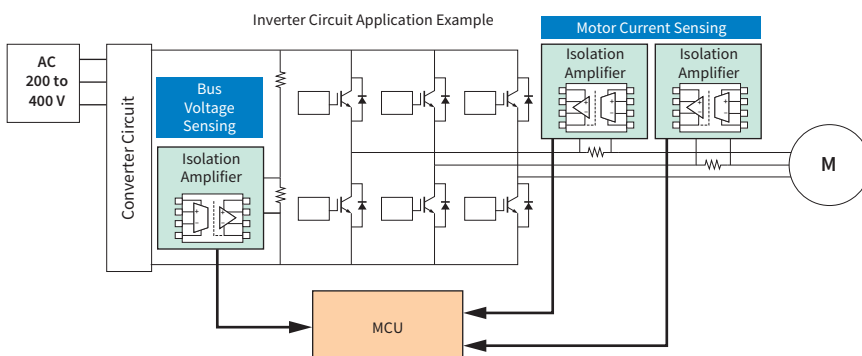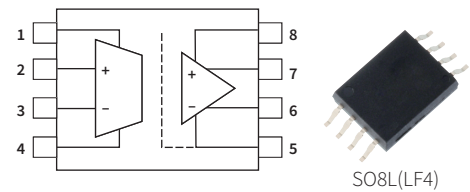
Recommended Photocouplers for Motor Applications

● IC Output IPM Drive

Part Number	Pin Configuration	Toshiba's Package Name	Features	Propagation delay time	Output	Isolation voltage t=60s (Vrms)	Safety Standards[1]				
							UL 1577[2]	c-UL[3]	VDE[4]	VDE[5]	CQC[6]
TLP2719		SO6L SO6L(LF4)	Reinforced insulation VCC = 4.5 to 20 V Topr (max) 100℃ I_O/I_F 15 to 55% (@IF=16 mA)	2 µs (max)	Open-collector (Analog signal output)	5000	○	○	○	○	○
TLP2704		SO6L SO6L(LF4)	Reinforced insulation VCC = 4.5 to 20 V Topr (max) 125℃ Threshold Input Current (max) 5 mA	550 ns (max)	Open-collector (Inverter logic output)	5000	○	○	○	○	○
TLP2745		SO6L SO6L(LF4)	Reinforced insulation Topr (max) 110℃ Threshold Input Current (max) 1.6 mA	120 ns (max)	Totempole (Buffer logic output)	5000	○	○	○	○	○

● IC Output IGBT/MOSFET Gate Drive

Part Number	Pin Configuration	Toshiba's Package Name	Features	Propagation delay time	Peak output current	Threshold Input Current (mA)	Isolation voltage t=60s (Vrms)	Safety Standards[1]				
								UL 1577[2]	c-UL[3]	VDE[4]	VDE[5]	CQC[6]
TLP5214A		SO16L	Smart gate drive photocoupler Direct drive of a mediumpower IGBT/MOSFET Overcurrent protection, Soft shutdown Active miller clamp Rail to Rail output Topr (max) 110℃	0.15 µs (max)	±4.0 A	I_{FLH}=6 (max)	5000	○	○	○	○	–
TLP5754 TLP5754 (LF4)		SO6L SO6L (LF4)	Direct drive of a mediumpower IGBT/MOSFET Rail to Rail output Topr (max) 110℃	0.15 µs (max)	±4.0 A	I_{FLH}=4 (max)	5000	○	○	○	○	○
TLP5774 TLP5774 (LF4)		SO6L SO6L (LF4)	Direct drive of a mediumpower IGBT/MOSFET Vcc = 10V (min) Topr (max) 110℃	0.15 µs (max)	±4.0 A	I_{FLH}=2 (max)	5000	○	○	○	○	○

● Isolation Amplifier Analog output

Part Number	Pin Configuration	Toshiba's Package Name	Features	Specifications			Input side supply current (I_{DD}1)/ Output side supply current (I_{DD}2) (mA/mA)	Isolation voltage t=60s (Vrms)	Safety Standards[1]				
									UL 1577[2]	c-UL[3]	VDE[4]	VDE[5]	CQC[6]
TLP7820		SO8L (LF4)	Analog output Isolation amplifier Gain = 8.2 (typ.) Topr (max) 105℃	Gain accuracy (Ta=25℃ Rank max)	Output nonlinearity	Input offset voltage	12/10	5000	○	○	○	○	○
				±0.5% ±1% ±3%	0.02%	0.9 mV							
TLP7830		SO8L (LF4)	1 bit Digital & CLK output Isolation amplifier Topr (max) 105℃	SNDR Ta=25℃ (typ)	SNR Ta=25℃ (typ)	INL (LSB) (typ)	12/8.0	5000	○	○	○	○	○
				75 dB	80 dB	4							

● High Speed Communications

Part Number	Pin Configuration	Toshiba's Package Name	Features	Data Rate (typ.@NRZ)	Output	@$I_{F (IN)}$ (mA)	Isolation voltage t=60sec (Vrms)	Safety Standards[1]				
								UL 1577[2]	c-UL[3]	VDE[4]	VDE[5]	CQC[6]
TLP2768A		SO6L SO6L(LF4)	Reinforced insulation Topr (max) 125℃	20M bit/s	Open-collector (Inverter logic output)	I_{FHL}=5 (max)	5000	○	○	○	○	○

● Transistor Output DC Input

Part Number	Pin Configuration	Toshiba's Package Name	Features	CTR				V_{CEO} (V)	Isolation voltage t=60s (Vrms)	Safety Standards[1]				
				Rank	Min (%)	Max (%)	@I_F, V_{CE} (mA, V)			UL 1577[2]	c-UL[3]	VDE[4]	VDE[5]	CQC[6]
TLP183		4pin SO6	Reinforced insulation Low input drive current Topr (max) 125℃	–	50	600	0.5, 5	80	3750	○	○	○	○	○
				Y	50	150								
				YH	75	150								
TLP185 (SE		4pin SO6	Reinforced insulation General-purpose	GR	100	300	5, 5	80	3750	○	○	○	○	○
				GRL	100	200								
TLP291 (SE		SO4	Reinforced insulation Lead pitch : 1.27 mm	GRH	150	300	5, 5	80	3750	○	○	○	○	○
				GB	100	600								
TLP293		SO4	Reinforced insulation Low input drive current Topr (max) 125℃	BL	200	600	0.5, 5	80	3750	○	○	○	○	○
				BLL	200	400								

Note (1): Certified to safety standards. For details on certification status, contact your Toshiba sales representative.
　UL/c-UL/CQC: ○: Approved △: Approval pending as of April 2019
　VDE: ○: Approved △: Approval pending as of April 2019
　Specify VDE-certified devices with option V4 or D4
　UL: Underwriters Laboratories (UL) is a safety consulting and certification company.
　c-UL: c-UL Mark is the UL Mark for Canada.
　VDE: VERBAND DEUTSCHER ELECTROTECHNISCHER e.V.
　CQC: China Quality Certification center

(2): UL 1577 Standard for Optical Isolators
(3): UL 1577 Optical Isolators Certified for Canada
(4): EN 60747-5-5
(5): EN 60065, EN 60950-1 or EN 62368-1
(6): GB4943.1, GB8898

High-Voltage MOSFETs (Super-Junction MOSFET)

Fabricated with a single-epitaxial process, Toshiba's super-junction MOSFET DTMOS-IV series provides RonA 30% lower than that of the previous DTMOS-III series and therefore helps reduce system size and power consumption.

Technical discussion – High efficiency and low heat generation because of low Ron and short recovery time –

- The three DTMOSIV series satisfy various requirements for MOSFETs.

• DTMOSIV	Standard series	Part number suffix: W	e.g. TK31N60W
• DTMOSIV HSD	High-speed diode series	Part number suffix: W5	e.g. TK31N60W5
• DTMOSIV-H	High-speed-switching series	Part number suffix: X	e.g. TK31N60X

- DTMOS IV (HSD) Series

  The DTMOSIV HSD series provides a recovery time approximately 70% shorter than the standard DTMOSIV series and thus helps reduce recovery loss due to the parasitic diode. It is the ideal choice for half- and full-bridges for AC-DC power supplies as well as for motor drive applications.

- 30% lower RonA than the previous series

  Due to reduced RonA, the DTMOS IV series helps improve power efficiency.
  This makes it possible to house more chips in a single package, contributing to reducing the size of motor applications.
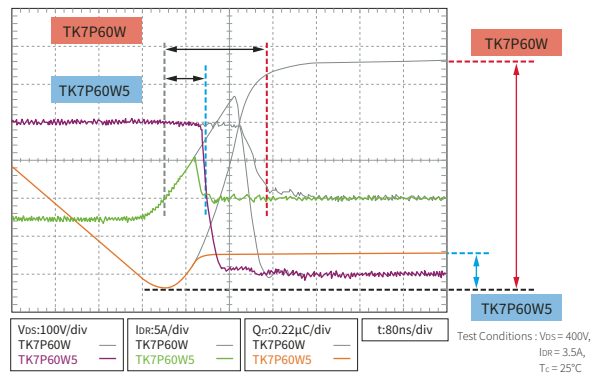
- Coss loss: Eoss reduction

  The reduced Eoss helps improve efficiency at light load.

- The use of a single-epitaxial process helps reduce on-resistance and therefore temperature increase.

  The reduction in temperature increase in the high-temperature region contributes to improving efficiency.

- Reverse Recovery Waveform of the Parasitic Diode (Standard series vs. HSD series)

V_{DS}:100V/div		I_{DR}:5A/div		Q_{rr}:0.22μC/div		t:80ns/div	Test Conditions : V_{DS} = 400V,
TK7P60W	—	TK7P60W	—	TK7P60W	—		I_{DR} = 3.5A,
TK7P60W5		TK7P60W5		TK7P60W5			T_C = 25°C

Comparisons of Representative Parts

DTMOSIV	Standard Series	HSD Series
Part Number	**TK7P60W**	TK7P60W5
Package	DPAK	DPAK
Ratings	600V/7A	600V/7A
On-resistance (max)	0.60Ω	0.67Ω
Recovery time (trr)	230ns	75ns

DTMOSIV HSD Series (with 600-V V$_{DSS}$ and High-Speed Recovery Diode)

I_D (A)	$R_{DS(ON)}$ MAX (Ω)	DPAK (TO-252)	D2PAK (TO-263)	DFN8×8	TO-220	TO-220SIS	TO-3P (N)	TO-247	Q_g (nC) Typ.	C_{iss} (V_{DS}=300V) (pF) Typ.	t_{rr} (ns) Typ.
7	0.65 / 0.67	TK7P60W5 (0.67Ω)				TK7A60W5			16	490	75
8	0.54 / 0.56	TK8P60W5 (0.56Ω)				TK8A60W5			22	590	80
9.7	0.45					TK10A60W5			23	720	85
15.8	0.23 / 0.24		TK16G60W5	TK16V60W5 (0.24Ω)	TK16E60W5	TK16A60W5	TK16J60W5	TK16N60W5	43	1350	100
20	0.175 / 0.19			TK20V60W5 (0.19Ω)	TK20E60W5	TK20A60W5	TK20J60W5	TK20N60W5	55	1800	110
25	0.14 / 0.15			TK25V60X5 (0.15Ω)*1	TK25E60X5*1	TK25A60X5*1		TK25N60X5*1	60	2400	120
30.8	0.099 / 0.109			TK31V60W5 (0.109Ω)			TK31J60W5	TK31N60W5	105	3000	135
38.8	0.074						TK39J60W5	TK39N60W5	135	4100	150
61.8	0.045						TK62J60W5	TK62N60W5	205	7100	170

*1: High speed switching/recovery type, suffixed by "X5"

DTMOSIV HSD Series (with 650-V V$_{DSS}$ and High-Speed Recovery Diode)

| I_D (A)	$R_{DS(ON)}$ MAX (Ω)	DPAK (TO-252)	D2PAK (TO-263)	DFN8×8	TO-220	TO-220SIS	TO-3P (N)	TO-247	Q_g (nC) Typ.	C_{iss} (V_{DS}=300V) (pF) Typ.	t_{rr} (ns) Typ.
13.7	0.3		TK14G65W5		TK14E65W5	TK14A65W5		TK14N65W5	40	1300	100
17.3	0.23					TK17A65W5			50	1800	110
22	0.16 / 0.17			TK22V65X5 (0.17Ω)		TK22A65X5			50	2400	110
27.6	0.13 / 0.14			TK28V65W5 (0.14Ω)				TK28N65W5	90	3000	115
35	0.095					TK35A65W5		TK35N65W5	115	4100	130
49.2	0.057							TK49N65W5	185	6500	145

Discrete IGBTs

The current sixth-generation discrete IGBTs are fabricated with small field-stop and gate geometries to reduce power loss. Toshiba will employ a field-stop structure and a new gate structure for the seventh-generation IGBTs to further optimize the trade-off between high-speed switching speed and low power loss.

Gen. 3 — Typical punch-through
Gen. 4 — NPT — High ruggedness — (NPT : Non-Punch-Through)
Gen. 6 — Field-stop — Current main product
Gen. 7 — The device structure is being researched. — Optimization of the field-stop structure ⇒Improvement in trade-off — Reduction in capacitance using a new gate structure ⇒Increase in switching speed

Eoff–V$_{CE(sat)}$ Performance of Each Generation

IGBTs with V$_{CES}$ = 600 V, Ta = 25°C

Gen. 7: The device structure is being researched.

(Current density: As per design target of each generation)

Major 600-V D-IGBTs

| V$_{CE}$ Rating | I$_C$ Rating | Part Number | V$_{CE (sat)}$ @Rated I$_C$ | | Power Dissipation P$_C$ | Package |
			Typ.	Max		
600V	15A	GT15J341	1.5V	2.0V	30W	TO-220SIS
	20A	GT20J341			45W	TO-220SIS
	30A	GT30J341			230W	TO-3P (N)

TO-220SIS   TO-3P (N)
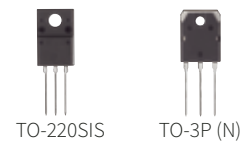
SiC Schottky Barrier Diodes

Toshiba offers an extensive portfolio of small, high-efficiency diodes, including SiC Schottky barrier diodes (SBDs) featuring high-speed operation and low forward loss.

The use of the Junction Barrier Schottky (JBS) structure reduces leakage current compared to the typical SBD structure, making it possible to realize stable operation even at high voltage and high current.

Features of the Second-Generation Products (Compared to the First-Generation Products)

70% higher allowable peak forward surge current (I$_{FSM}$)

Second generation

First generation

Generates less heat at the same current level

30% lower switching loss (examples of 650-V and 10-A diodes)

Switching Loss (P$_{Qc}$ - V$_R$), f = 100 kHz

First generation

Second generation
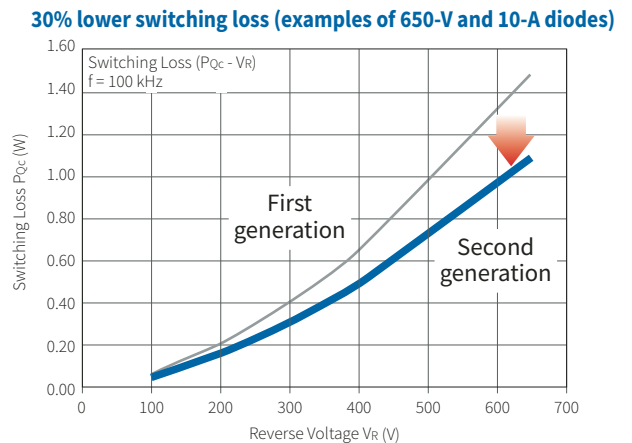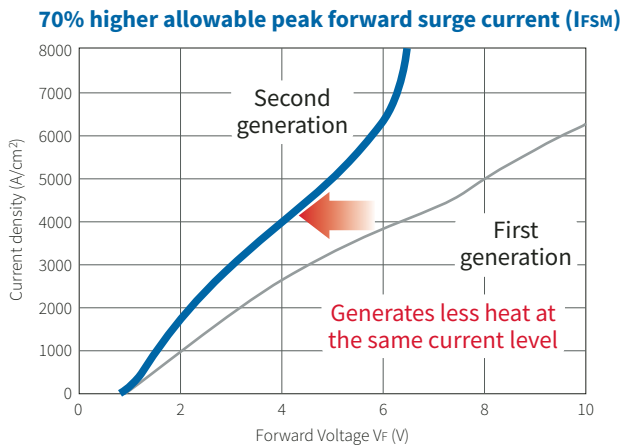
Major SiC Schottky Barrier Diode products

| Absolute Maximum Ratings | | Part Number / Packaging | | | Electrical Characteristics (Ta=25°C) | | | |
| V$_{RRM}$ (V) | I$_{F (DC)}$ (A) | TO-220-2L | TO-220-2L (Isolation) | TO-247 (Center tap) | V$_F$ (V) @IF (DC) | | Cj (pF) @650V, 1MHz | I$_{RRM}$ (uA) @V$_{RRM}$ |
					Typ.	Max		
650	2	TRS2E65F			1.45	1.6	8.7	20
	3	TRS3E65F			1.45	1.6	12	20
	4	TRS4E65F	TRS4A65F		1.45	1.6	16	20
	6	TRS6E65F	TRS6A65F		1.45	1.6	22	30
	8	TRS8E65F	TRS8A65F		1.45	1.6	28	40
	10	TRS10E65F	TRS10A65F		1.45	1.6	36	50
	12	TRS12E65F	TRS12A65F		1.45	1.6	44	60
	12			TRS12N65FB **	1.45	1.6	22 [1]	30 [1]
	16			TRS16N65FB **	1.45	1.6	28 [1]	40 [1]
	20			TRS20N65FB **	1.45	1.6	36 [1]	50 [1]
	24			TRS24N65FB **	1.45	1.6	44 [1]	60 [1]

** : Under development   (1) Per leg per device

TO-220-2L   TO-220F-2L (isolated)

TO-247 (center-tapped)
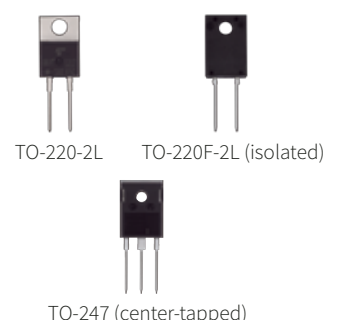
Low-Voltage MOSFETs

Toshiba has endeavored to reduce the power losses of MOSFET by optimizing cell structure with fine integration technologies.

Features
- Low on-resistance due to the use of a small-geometry process
- Low power losses due to an improved trade-off between on-resistance and charge characteristics
- MOSFETs with a wide range of V_{DSS} and extensive packaging options suitable for various applications
- High avalanche ruggedness and ESD tolerance
- Optimized device structure for ease of application design with switching noise reduced

Conduction and Output Charge Losses

* Comparison with a MOSFET from another manufacturer (as surveyed by Toshiba in August 2019)

$R_{DS (ON)} \times Qoss$
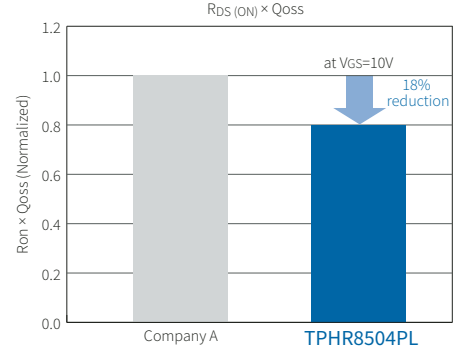
$R_{DS(ON)}$: Drain-source on-resistance (figure of merit for conduction loss)
Qoss: Output charge (figure of merit for output charge loss)

Technical discussion – Reducing system size and increasing power density –

- DSOP Advance (double-sided-cooling package)
1. The DSOP Advance package efficiently dissipates heat from the metal plates on the top and bottom surfaces.
   The DSOP Advance package provides a higher current capacity than the conventional package of the same size and therefore helps save PCB space and reduce the system size.
2. The DSOP Advance package is footprint-compatible with the SOP Advance package.
   The DSOP Advance package can be replaced by the SOP Advance package without modifying the PCB layout.
3. The DSOP Advance package has lower resistance.

Top   Bottom

Double sided cooling
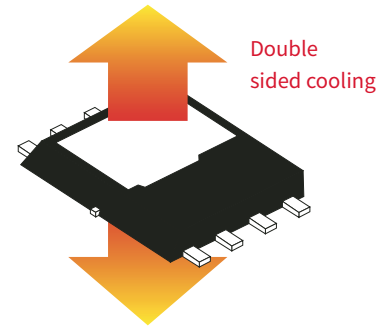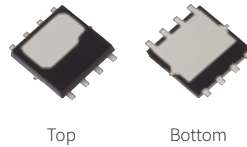
U-MOSIX-H／U-MOSVIII-H series
Major 30-V, 40-V, and 60-V MOSFET products in the SOP Advance and SOP Advance (N) Packages

Part Number	Series	Absolute Maximum Ratings			$R_{DS (ON)}$ (mΩ)				C_{iss} (Typ.) (pF)	Q_g (Typ.) (nC)	r_g (Typ) (Ω)
		V_{DSS} (V)	V_{GSS} (V)	I_D (A)	$V_{GS}=10V$		$V_{GS}=4.5V$				
					Typ.	Max.	Typ.	Max.			
TPH1R403NL	U-MOSVIII-H	30	+/-20	150SL	1.2	1.4	1.7	2.1	3400	46	1.1
TPHR9203PL	U-MOSIX-H	30	+/-20	280SL	0.61	0.92	0.91	1.29	5800	81	0.5
TPHR9003NL	U-MOSVIII-H	30	+/-20	220SL	0.77	0.9	1.1	1.4	5300	74	1.2
TPHR6503PL	U-MOSIX-H	30	+/-20	393SL	0.41	0.65	0.6	0.89	7700	110	0.6
TPH1R204PL	U-MOSIX-H	40	+/-20	246SL	1.0	1.24	1.5	2.1	5500	74	0.6
TPHR8504PL	U-MOSIX-H	40	+/-20	340SL	0.7	0.85	1.0	1.4	7370	103	0.6
TPH2R306NH	U-MOSVIII-H	60	+/-20	130SL	1.9	2.3	–	–	4700	72	1.1
TPH2R506PL	U-MOSIX-H	60	+/-20	160SL	1.9	2.5	2.8	4.4	4180	60	0.6
TPH1R306PL	U-MOSIX-H	60	+/-20	260SL	1.0	1.34	1.5	2.3	6250	91	0.5

SOP Advance

SOP Advance (N)

Major 30-V, 40-V, and 60-V MOSFET products in the DSOP Advance Package

Part Number	Series	Absolute Maximum Ratings			$R_{DS (ON)}$ (mΩ)				C_{iss} (Typ.) (pF)	Q_g (Typ.) (nC)	r_g (Typ) (Ω)
		V_{DSS} (V)	V_{GSS} (V)	I_D (A)	$V_{GS}=10V$		$V_{GS}=4.5V$				
					Typ.	Max.	Typ.	Max.			
TPWR8503NL	U-MOSVIII-H	30	+/-20	300SL	0.72	0.85	1.0	1.3	5300	74	1.2
TPWR6003PL	U-MOSIX-H	30	+/-20	412SL	0.36	0.6	0.6	0.84	7700	110	0.6
TPWR8004PL	U-MOSIX-H	40	+/-20	340SL	0.65	0.8	0.95	1.4	7370	103	0.6
TPW1R005PL	U-MOSIX-H	45	+/-20	300SL	0.75	0.99	1.15	1.65	7700	122	0.6
TPW1R306PL	U-MOSIX-H	60	+/-20	260SL	0.95	1.29	1.5	2.3	6250	91	0.5

DSOP Advance

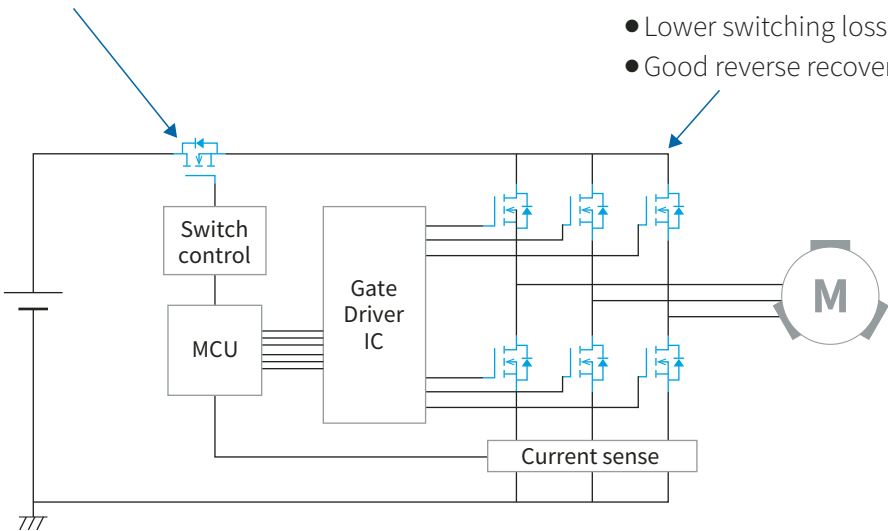## Low-Voltage MOSFET Applications (Power Tools)

Low-voltage MOSFET is applied to wider voltage range because of the variety of battery voltage such as 12 and 48V. Toshiba provides wide variety of voltage and package lineup.

<Requirement for MOSFETs for main switch applications>
- Low on-resistance

<Requirements for MOSFETs for motor drive applications>
- Low on-resistance
- Lower switching loss
- Good reverse recovery performance

Electric Speed Controller (ESC) Module for Industrial Drone Applications (TPMD0001A)

The TPMD0001A is an ESC module containing the TMPM475FYFG vector control MCU and the TPH1R204PL MOSFETs with low heat dissipation in a small package. It handles two-way communication via Control Area Network (CAN). Two-way CAN communication allows the ESC to transmit information about voltage, current, temperature, etc. to the main controller, greatly improving a drone's safety performance, i.e., the ability not to crash or become uncontrollable.

The use of vector control helps reduce the power consumption, vibration, and acoustic noise of a motor as well as its rpm variations due to load variations. The TPMD0001A helps reduce the size and weight of 24-V/50-A-class ESCs.

TPMD0001A

MCU:TMPM475FYFG   MOSFET : TPH1R204PL
TPMD0001A
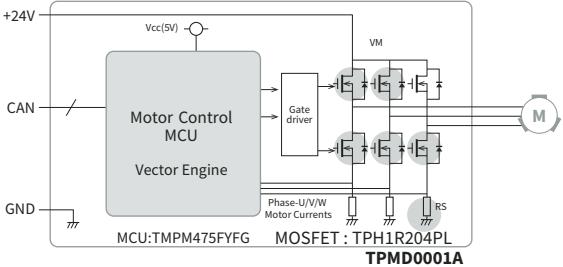
Microcontrollers for Camera and Other Small Applications

Toshiba provides MCUs in small packages incorporating a high-resolution programmable pulse generator (PPG) suitable for high-precision analog-controlled equipment. These MCUs allow parallel processing, making it possible to reduce the operating frequency.

Features

- Up to four programmable servo/sequence controller (PSC) units (suitable for servo computation, motor control, and communication sequencing for camera shake compensation)
- High-resolution PPG for ultrasound control
- Various timer serial interfaces

Applications
- Security cameras, camera lenses, digital video cameras

MCUs with a Programmable Servo/Sequence Controller (PSC) suitable for high-precision motor control applications (TMPM343FDXBG/10XBG)

The TMPM343FDXBG and TMPM310XBG incorporate a programmable serve/sequence controller (PSC) required for camera shake compensation, auto-focus tracking for video, lens control and overall system control, as well as motor controller/drivers and analog circuitry. The high-performance ARM Cortex-M3 core provides high-speed computation.
Additionally, a micro-step driver and a high-resolution programmable phase generator (PPG) enable smooth and quiet motor operation.

- ARM Cortex-M3 core
  - Supply voltage: 2.7 to 3.6 V (regulated on-chip)
  - Maximum operating frequency: 50 MHz
  - On-chip memory: Flash ROM 512 KB/1 MB
    SRAM FD: 48 KB + 32 KB (PSC)
    F10: 64 KB + 32 KB (PSC)
- Motor driver
  - Operating voltage: 2.5 V to 5.5 V (with the driver on)
    2.7 V to 3.6 V (peripheral analog blocks)
- On-chip peripherals
  - PSC: 4 units
  - 12-bit AD converters (for MR sensors):
    3 unit (8 channels + 4 channels x 2)
  - 16 bit HS PWM (high-resolution PPG output):
    8 channels (4 channels + 4 channels)
  - 16-bit timer:
    16 channels (free-running, compare output, PPG output)
  - Two-phase input pulse counter:
    3 channels (for MR sensors)
  - Serial interfaces:
    32-bit TSPI: 4 channels, UART: 1 channel, I²C: 1 channel
- Package: VFBGA162 (7 x 7 mm, 0.5 mm pich)

  - DMAC: 3 units
  - Hall Bias Control: 2 channels
  - 10-bit DAC: 6 channels
  - Op-amp: 10 channels (incl. VCA 4 channels)
  - Photo interrupter/ encoder interface:
    4 channels (two-phase 2 units)
  - 7-bit micro-step controllers: 3 units (with the MO function)
  - H-SW driver: 8 channels
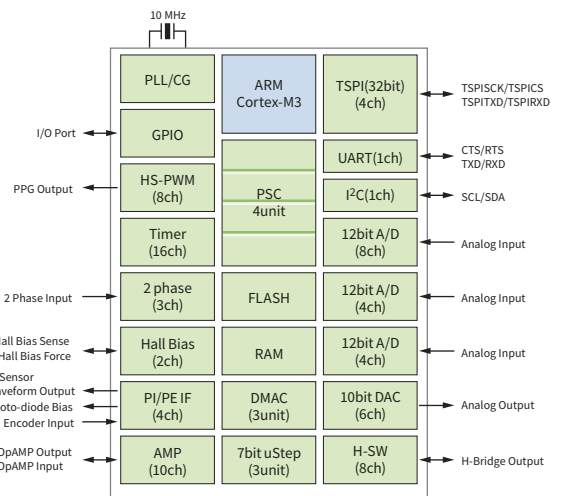
System Block Diagram (Camera Lens)
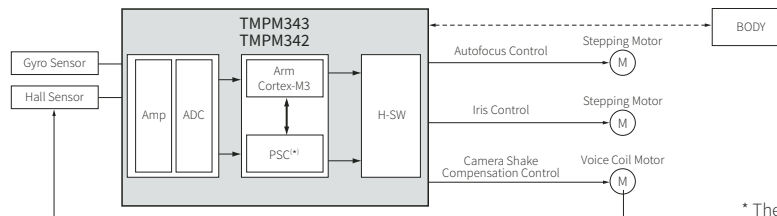
* The TMPM343 contains four PSC units.
  The TMPM342 contains one PSC unit.

● Microcontrollers for Camera and Other Small Applications

Part Number	Maximum Operating Frequency (MHz)	ROM(Flash) (K Bytes)	SRAM (K Bytes)	PSC (ch)	PPG (ch)	PHC (ch)	I/O Port (ch)	Package
TMPM342FYXBG	40	256	36	1	8	2	63	VFBGA142
TMPM343FDXBG	50	512	80	4	16	3	59	VFBGA162
TMPM343F10XBG		1024	96					
TMPM440FEXBG	100	768	80	1	4	PHC: 2 EPH: 1	228	VFBGA289
TMPM440F10XBG		1024						

MCU Development Support Tools

Various development tools are available for Arm-core-based MCUs. Visit Toshiba's website to choose the best development tools and partners that suit your needs.

Development Environment

■Genuine MDK-Arm development environment

arm KEIL

■IAR Systems' EWARM development environment

IAR Embedded Workbench

Sample Programs

Our website provides sample programs that customers can use as references to evaluate the functionality of our microcontrollers and develop applications.
Sample programs for motor control are available among those for the M370 Group of the TX03 Series.

Sample Program/Function		Description	Product Name						
			TMPM 370	TMPM 372	TMPM 373	TMPM 374	TMPM 375	TMPM 376	TMPM 37A
Motor Control Circuit	PMD	This example demonstrates the phase outputs.	V	V	V	V	V	V	V

https://toshiba.semicon-storage.com/ap-en/design-support/referencedesign.html

Evaluation Kits

In order to evaluate whether to use Toshiba's microcontroller, it is advisable to use entry-level or other evaluation kits to start software development. Evaluation kits are available from development environment and evaluation kit vendors.

For details of evaluation kits, visit our website at:

https://toshiba.semicon-storage.com/jp/product/microcomputer/designsupport/reference-model.html

TMPM375

TMPM37A

TMPM475

ESP-kikaku Co., Ltd

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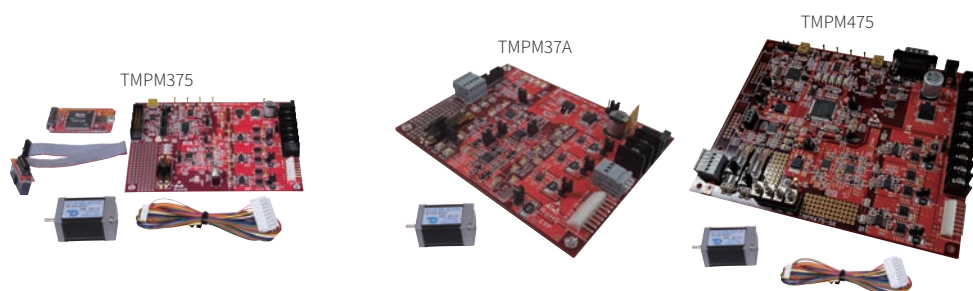
Reference Design Center

- The Reference Design Center is an open environment that provides reference designs for motor control and other applications to help you save the time and effort required for circuit design and consideration.

https://toshiba.semicon-storage.com/ap-en/design-support/referencedesign.html
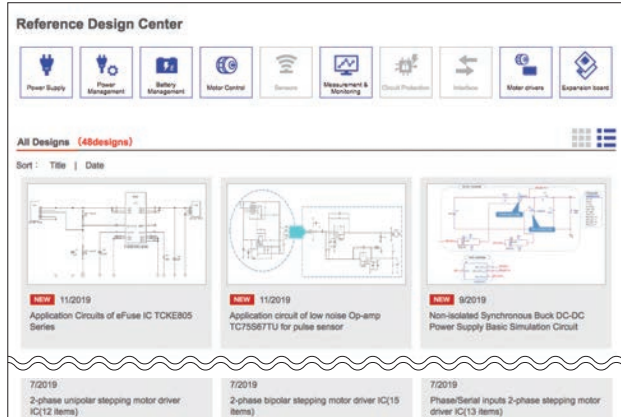
- In addition to technical documents, the Reference Design Center provides data for electronic design automation (EDA) tools, which can be modified, processed, and partially used to suit your design according to its specifications.

Design Documents

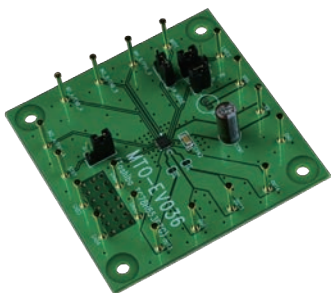Circuit Schematics

BOM

Reference Guides

Design Files
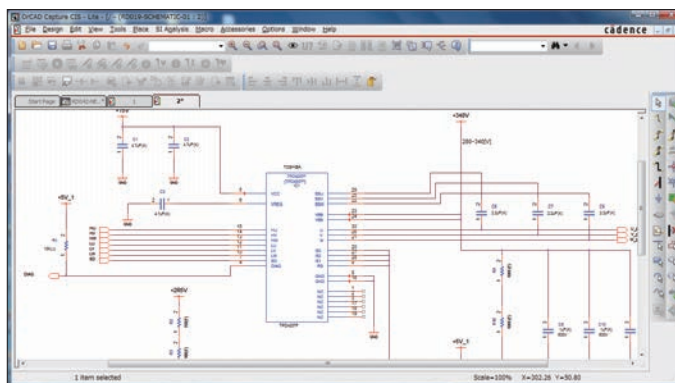
Circuit Data (OrCAD®)

- Circuit schematics
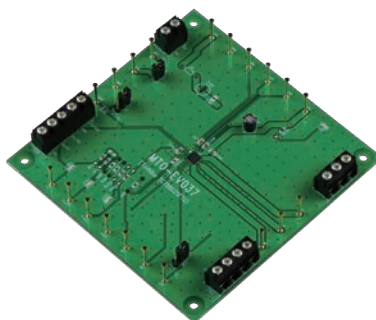- PCB files
- PCB fabrication data
- etc.

Development Support Tools

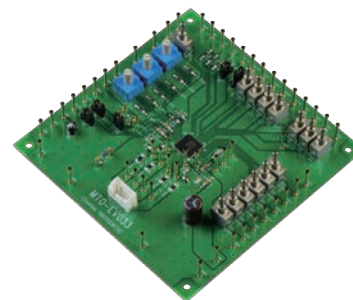- More than 100 types of MCD evaluation boards are available for different types of motors.

| Brushed DC Motor Driver | BLDC Motor Driver | Stepping Motor Driver |

- You can purchase evaluation boards from one of the following online sites.
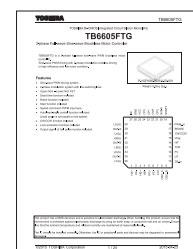
https://www.digikey.jp/
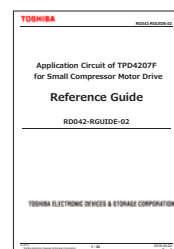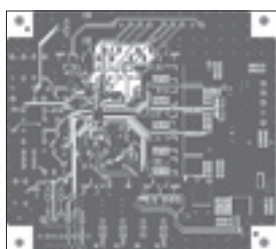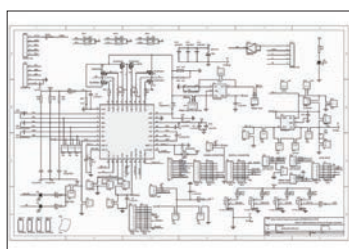
Digi-Key Elctronics

http://sv.marutsu.co.jp/toshiba/

Marutsuelec Co., Ltd.

- Development documents and simulation models (datasheets, reference guides, BOM lists, PCB files, and PSpice models) are available for download from Toshiba's website.

Motor Solutions Guide

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