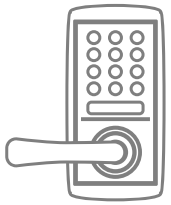
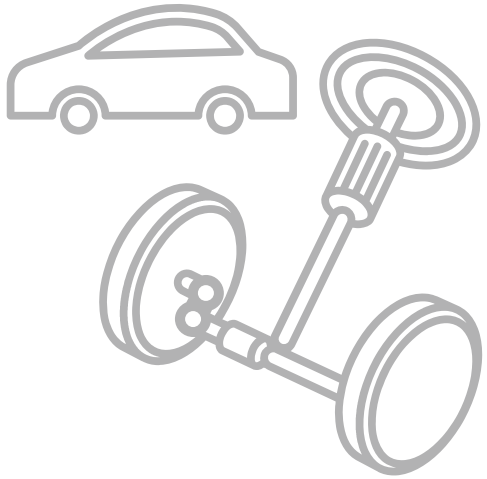
TOSHIBA

R21

Automotive Electric Power Steering

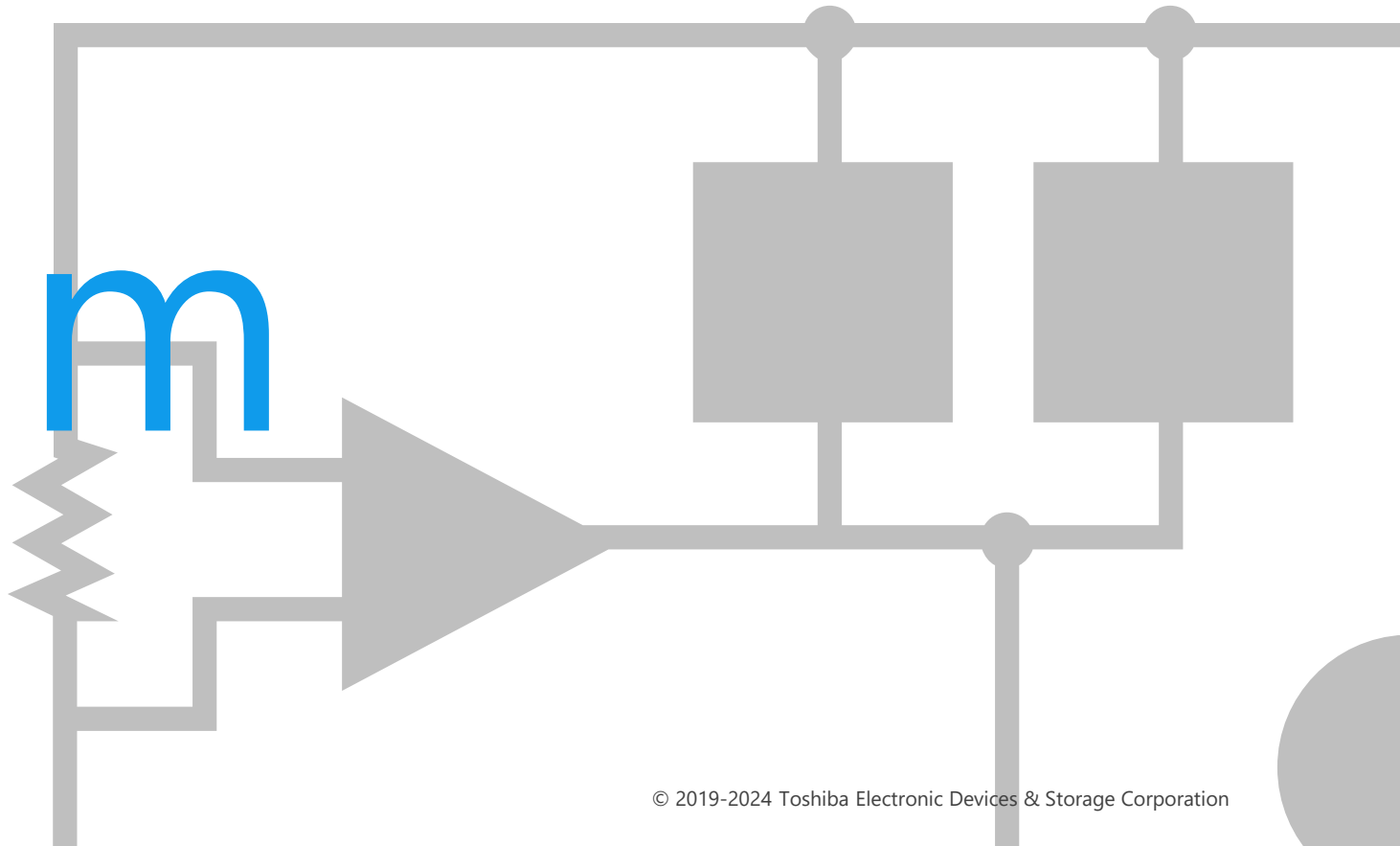
Solution Proposal by Toshiba





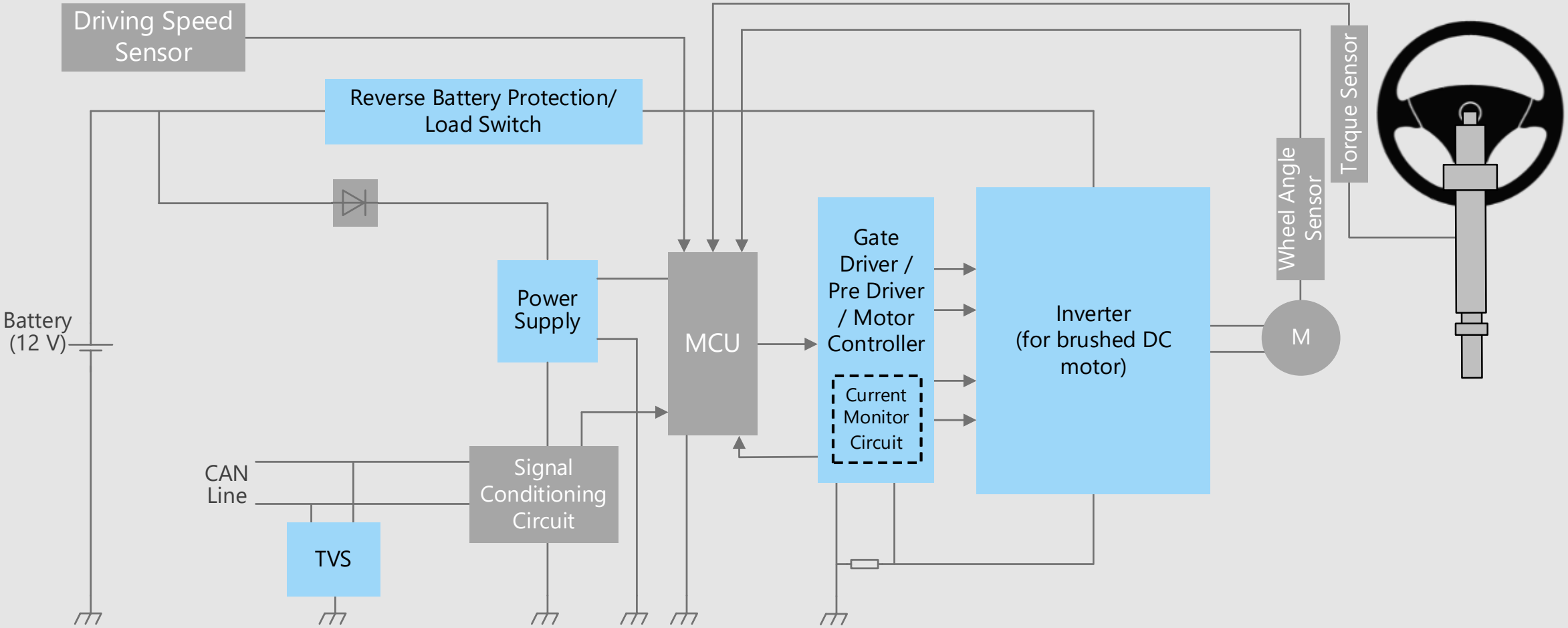
Toshiba Electronic Devices & Storage Corporation provides comprehensive device solutions to customers developing new products by applying its thorough understanding of the systems acquired through the analysis of basic product designs.

Block Diagram



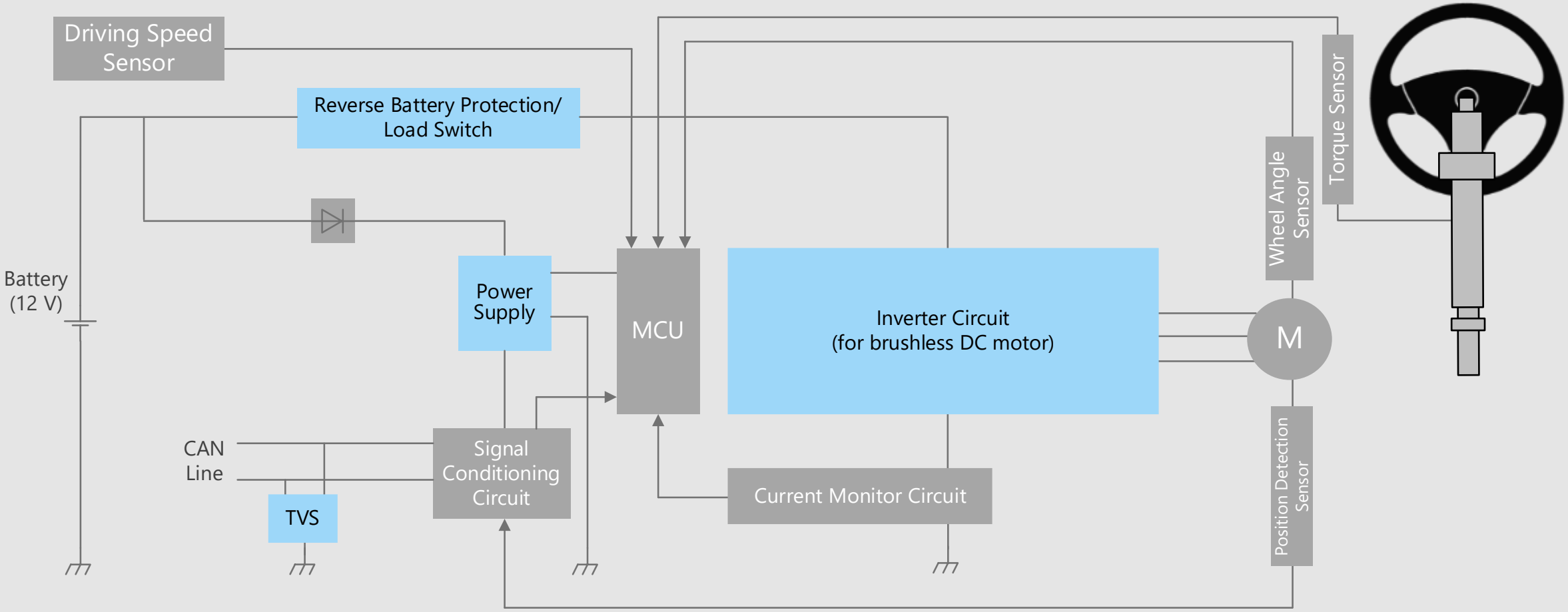
Electric Power Steering　Overall block diagram

Brushed DC motor type



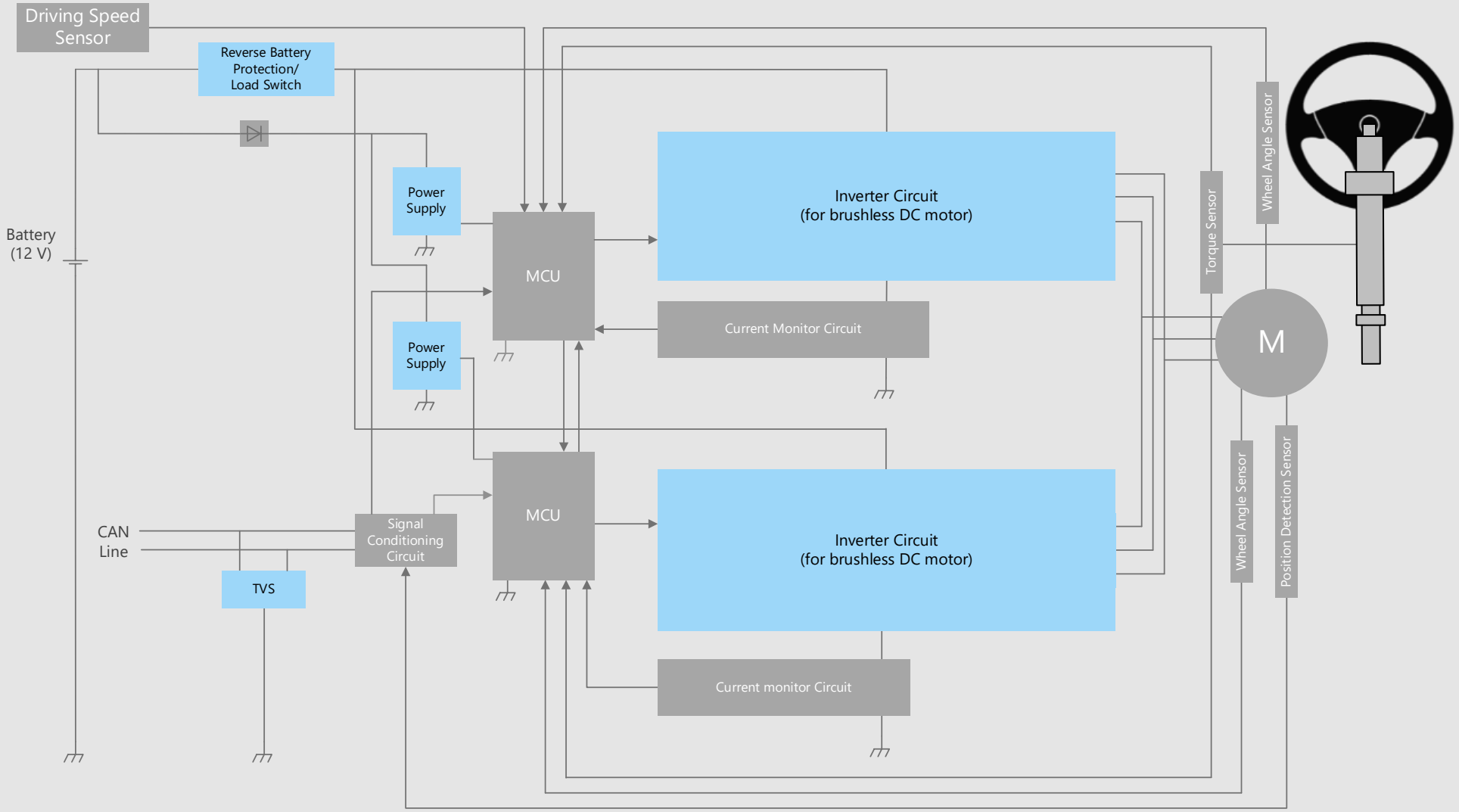
Electric Power Steering　Overall block diagram

Brushless DC motor type



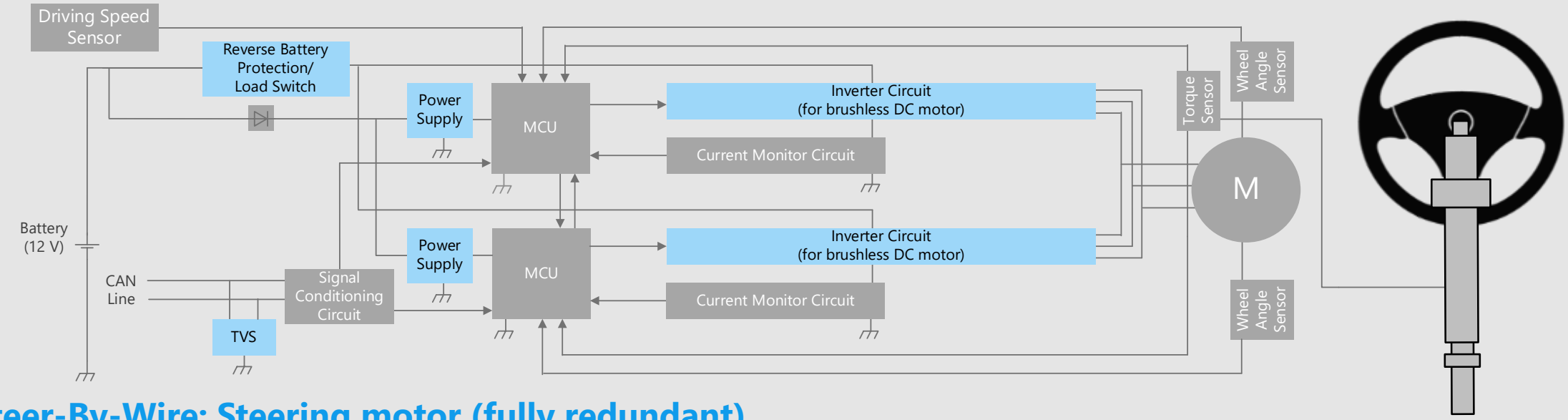
Electric Power Steering　Overall block diagram

Brushless DC motor type (fully redundant)

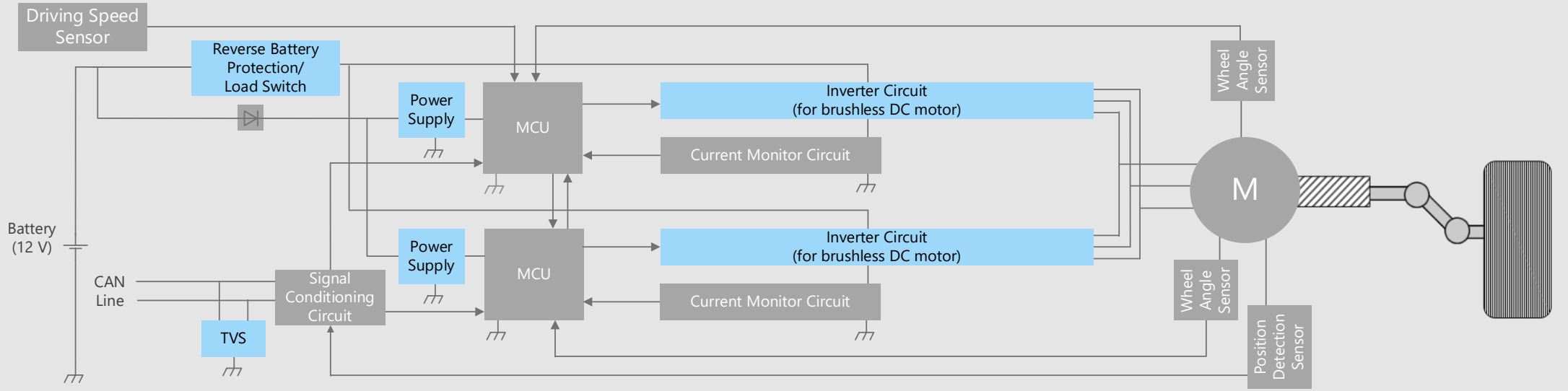


Electric Power Steering　Overall block diagram

Steer-By-Wire: Reaction force motor (fully redundant)

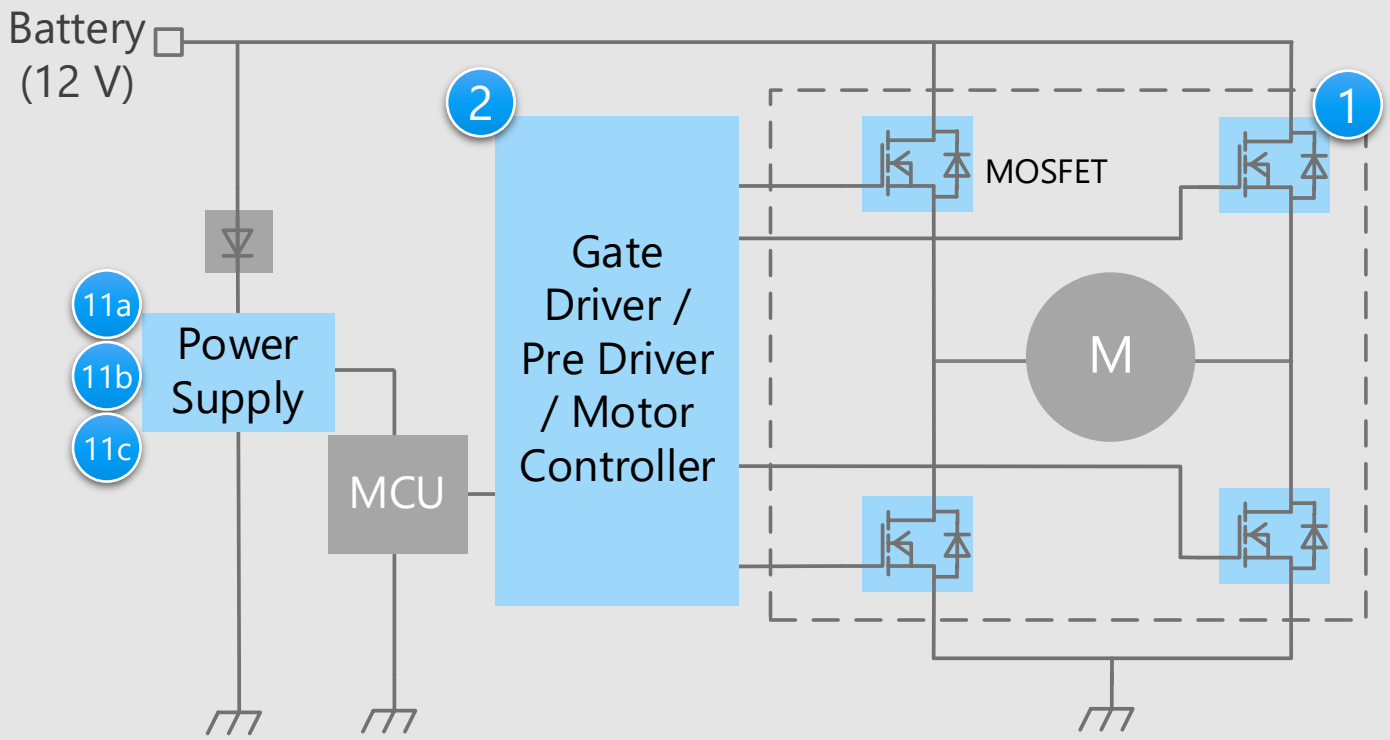


Steer-By-Wire: Steering motor (fully redundant)



Electric Power Steering　Detail of brushed DC motor drive

Brushed DC motor drive circuit (N-ch type)



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

Criteria for device selection

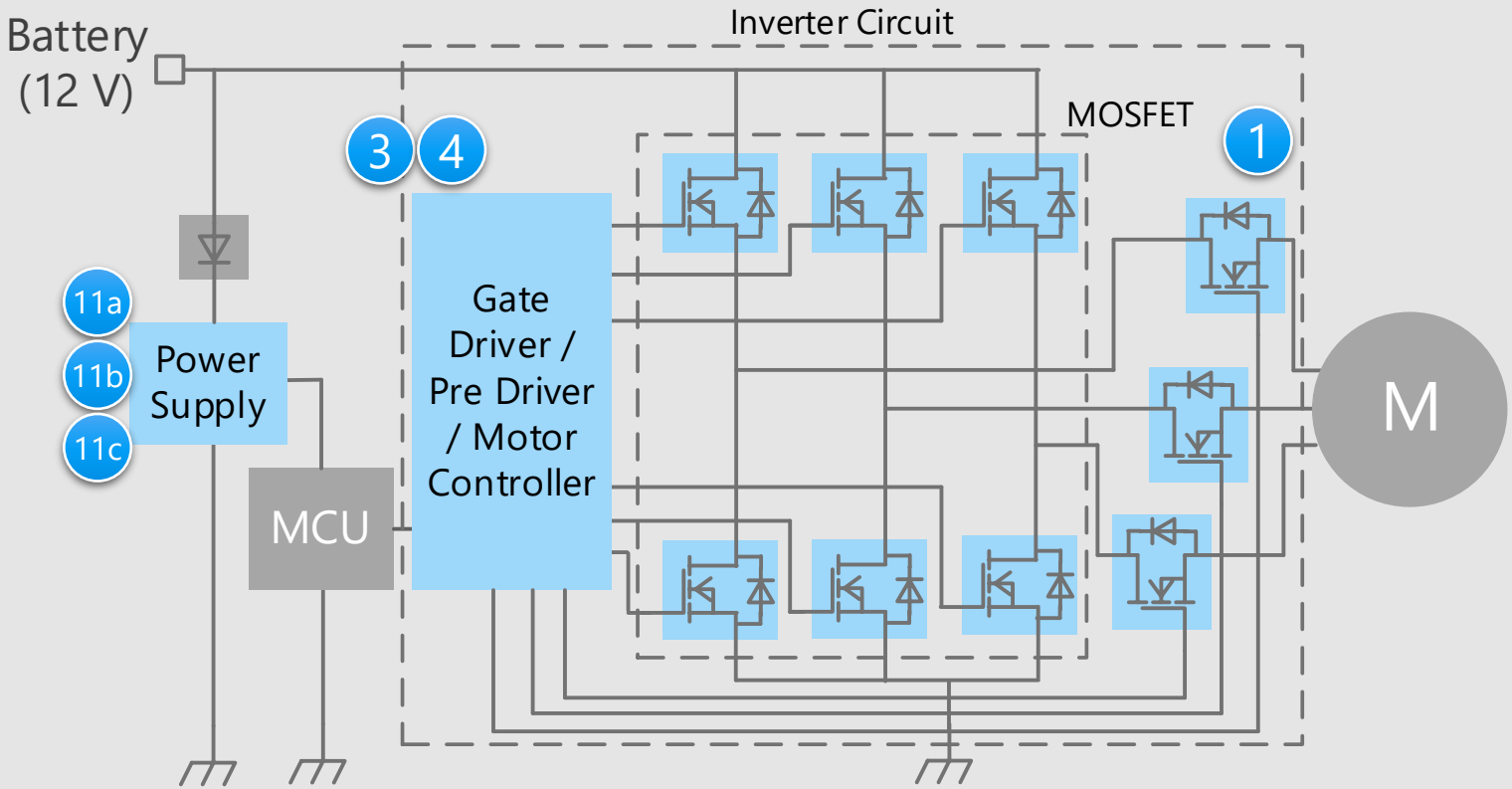
- It is necessary to select the product with the suitable voltage and current ratings for each application.
- It is necessary to select a motor controller according to the characteristics of the switching device to be driven.
- A small surface mount package is suitable for realizing miniaturization of the ECU.

Proposals from Toshiba

- **Low on-resistance contributes to low power consumption of the system**
  U-MOS Series 40 V N-ch MOSFET　1
- **H-bridge pre driver compliant with automotive functional safety standard**
  Brushed DC motor pre driver　2
- **Voltage regulator with low current consumption**
  Power supply IC (for MCU)　11a
- **High accuracy power supply**
  Power supply IC (for MCU, built-in tracker)　11b　11c

Electric Power Steering　Detail of brushless DC motor drive

Brushless DC motor drive circuit (N-ch type)



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

Criteria for device selection

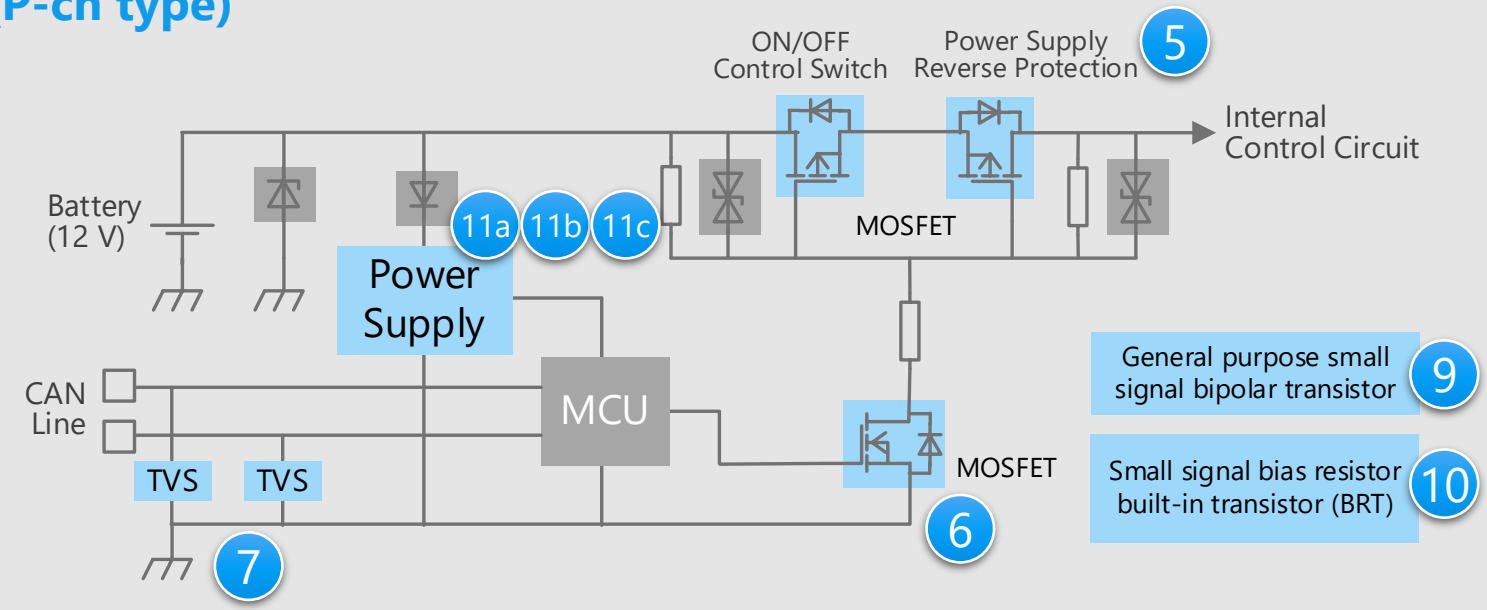
- It is necessary to select the product with the suitable voltage and current ratings for each application.
- It is necessary to select a gate driver according to the characteristics of the switching device to be driven.
- A small surface mount package is suitable for realizing miniaturization of the ECU.

Proposals from Toshiba

- **Low on-resistance contributes to low power consumption of the system**
  U-MOS Series 40 V N-ch MOSFET　1
- **Gate driver with built-in protection and diagnostic function**
  Gate driver (for motor)　3
- **Full bridge pre driver compliant with automotive functional safety standard**
  Brushless DC motor pre driver　4
- **Voltage regulator with low current consumption**
  Power supply IC (for MCU)　11a
- **High accuracy power supply**
  Power supply IC (for MCU, built-in tracker)　11b 11c

Detail of switch for power supply ON/OFF control and reverse connection protection (1)

Power supply ON/OFF control and reverse connection protecting circuit (P-ch type)



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

Criteria for device selection

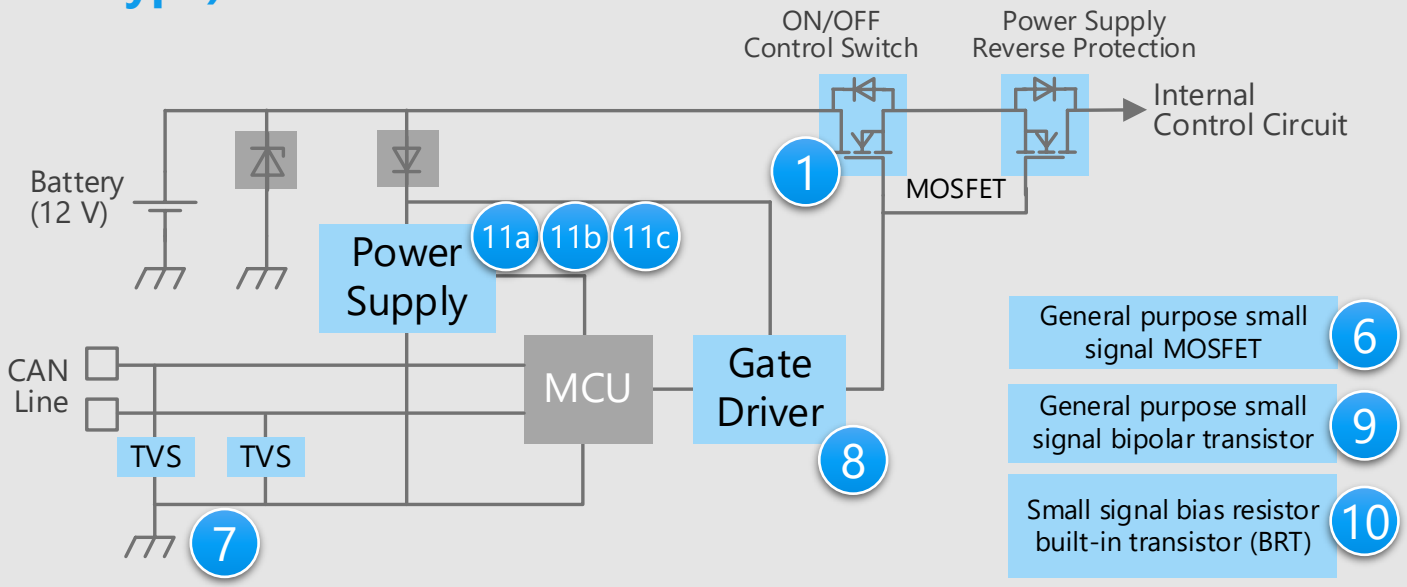
- It is necessary to select a gate driver according to the characteristics of the switching device to be driven.
- A small surface mount package is suitable for realizing miniaturization of the ECU.

Proposals from Toshiba

- **Low on-resistance contributes to low power consumption of the system**
  U-MOS Series -40 V / -60 V P-ch MOSFET 5
- **Extensive product lineup**
  General purpose small signal MOSFET 6
  General purpose small signal bipolar transistor 9
  Small signal bias resistor built-in transistor (BRT) 10
- **Suitable for ESD protection**
  TVS diode (for CAN communication) 7
- **Voltage regulator with low current consumption**
  Power supply IC (for MCU) 11a
- **High accuracy power supply**
  Power supply IC (for MCU, built-in tracker) 11b 11c

Detail of switch for power supply ON/OFF control and reverse connection protection (2)

Power supply ON/OFF control and reverse connection protecting circuit (N-ch type)



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

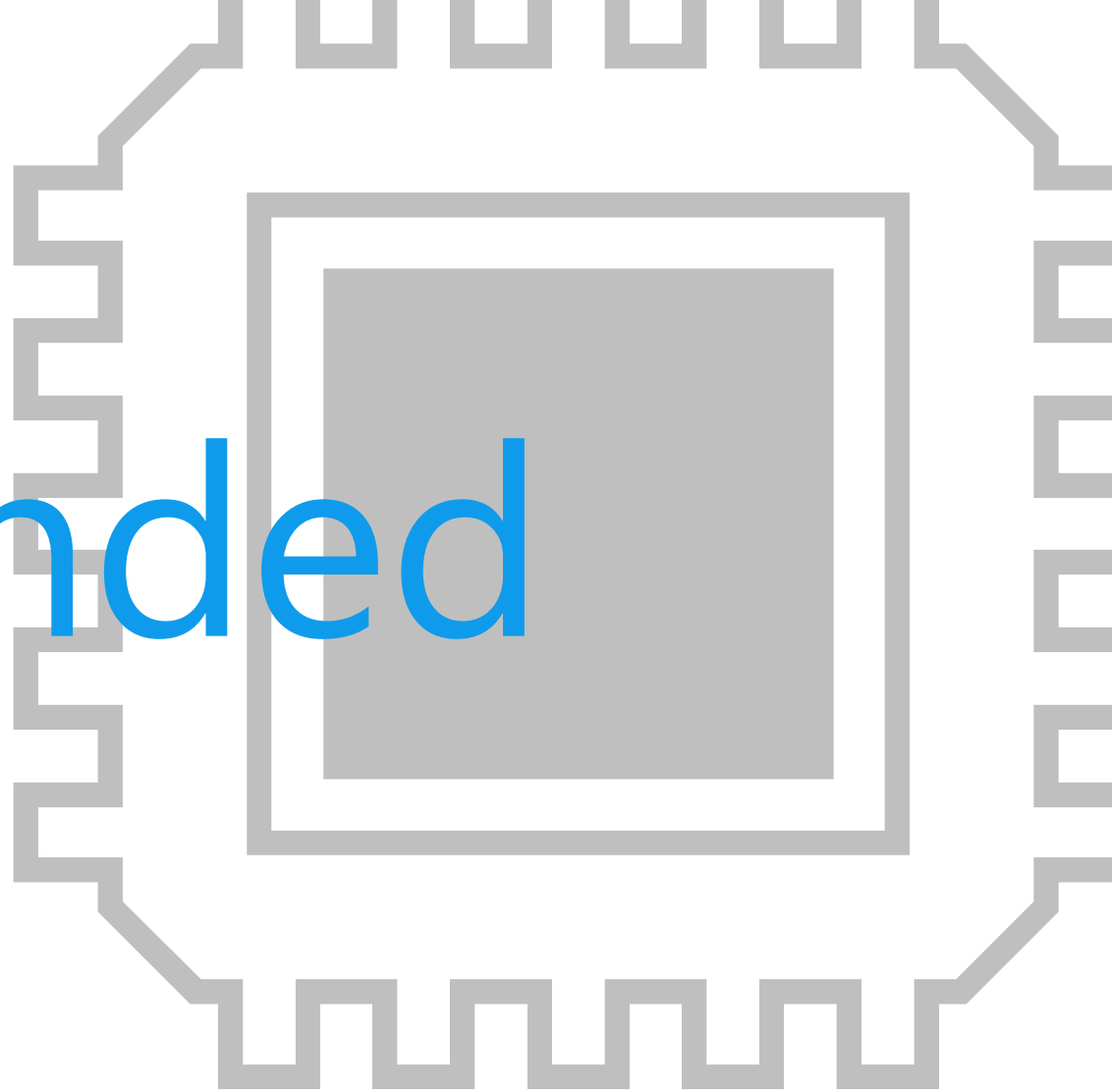
Criteria for device selection

- It is necessary to select a gate driver according to the characteristics of the switching device to be driven.
- A small surface mount package is suitable for realizing miniaturization of the ECU.

Proposals from Toshiba

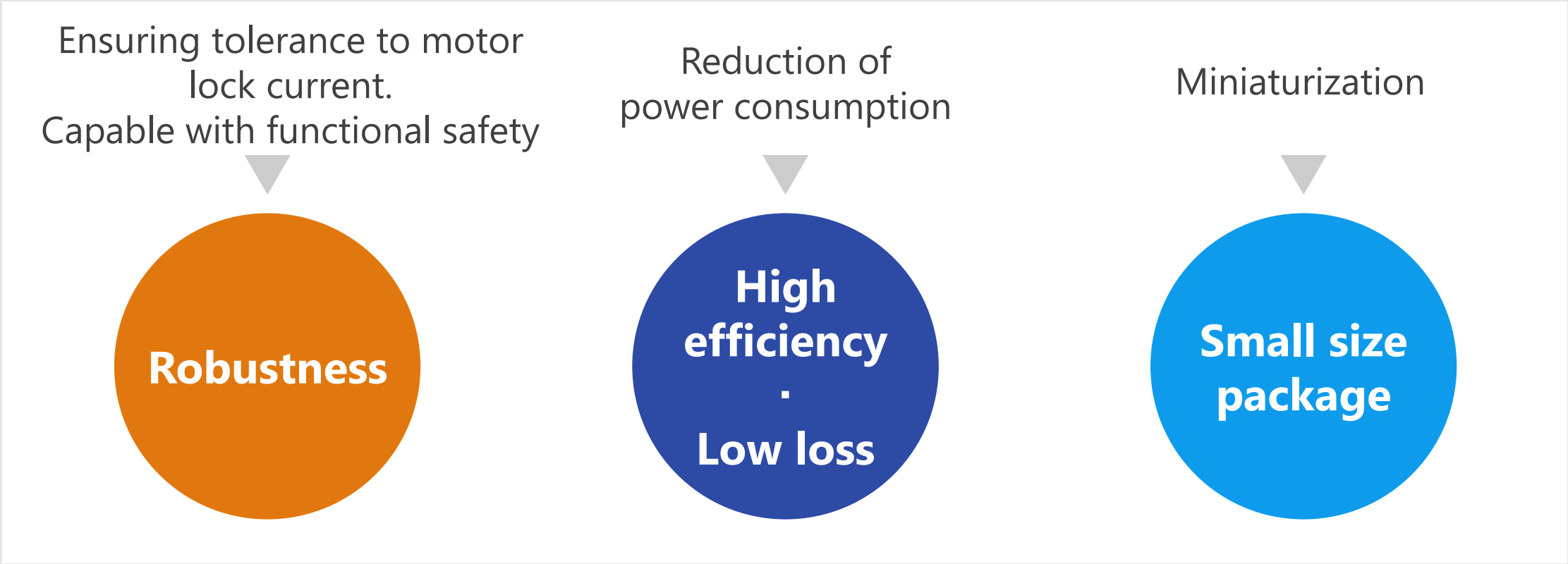
- **Low on-resistance contributes to low power consumption of the system** 1
  U-MOS Series 40 V N-ch MOSFET
- **Gate driver with built-in protection and diagnostic function** 8
  Gate driver (for switch)
- **Extensive product lineup** 6 9 10
  General purpose small signal MOSFET
  General purpose small signal bipolar transistor
  Small signal bias resistor built-in transistor (BRT)
- **Suitable for ESD protection** 7
  TVS diode (for CAN communication)
- **Voltage regulator with low current consumption** 11a
  Power supply IC (for MCU)
- **High accuracy power supply** 11b 11c
  Power supply IC (for MCU, built-in tracker)

Recommended Devices



Device solutions to address customer needs

As described above, in the design of Electric Power Steering, **“Ensuring tolerance to motor lock current. Capable with functional safety”**, **“Reduction of power consumption”** and **“Miniaturization“** are important factors. Toshiba’s proposals are based on these three solution perspectives.



Device solutions to address customer needs

		Robustness	High efficiency · Low loss	Small size package
1	U-MOS Series 40 V N-ch MOSFET	●	●	●
2	Brushed DC motor pre driver	●	●	
3	Gate driver (for motor)	●		●
4	Brushless DC motor pre driver	●	●	
5	U-MOS Series -40 V / -60 V P-ch MOSFET	●	●	●
6	General purpose small signal MOSFET		●	●
7	TVS diode (for CAN communication)	●		●
8	Gate driver (for switch)	●		●
9	General purpose small signal bipolar transistor			●
10	Small signal bias resistor built-in transistor (BRT)			●
11	Power supply IC (for MCU)		●	●

1 U-MOS Series 40 V N-ch MOSFET

XPN3R804NC / TK1R4S04PB / XPHR7904PS / TPWR7904PB / XPJR6604PB / XPQR3004PB

Robustness | High efficiency · Low loss | Small size package

Value provided

The latest process enables low on-resistance and low noise, thereby reducing power consumption.

1 Low loss (reduced on-resistance)

Using low on-resistance technology to contribute to reduced power consumption systems.
On-resistance of 44 % reduction per unit area.
(compared to Toshiba's U-MOSⅧ-H products)

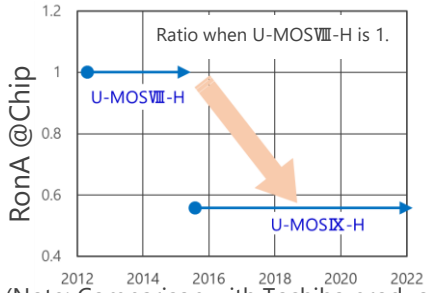
2 Small and low loss package

By adopting a Cu clip structure and a double-sided heat dissipation structure, low loss and high heat dissipation are realized.
Wettable Flank (WF) package contributes to good mountability.

3 Low noise (low EMI)

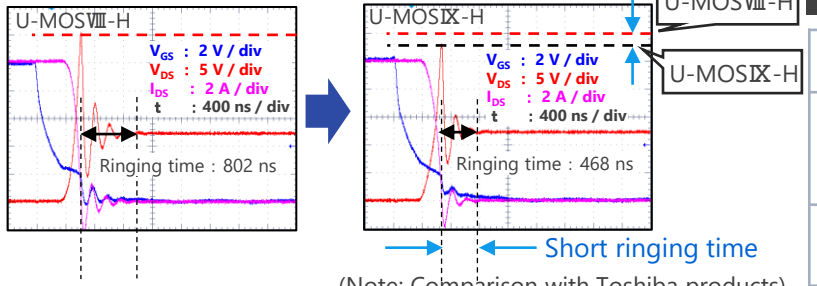
Improved chip process reduces surge voltage and ringing time.

Low loss: RonA trend



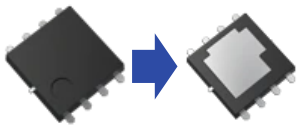
(Note: Comparison with Toshiba products)

Low noise: Switching waveform



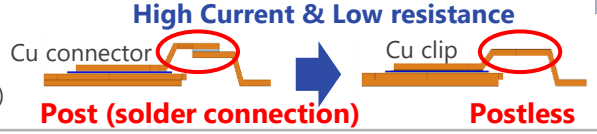
(Note: Comparison with Toshiba products)

DSOP Advance(WF)L double-sided cooling package



Thermal resistance is reduced by 76 % @t = 3 s, mounted on board
Compared to Toshiba's SOP Advance(WF)

S-TOGL™ & L-TOGL™ Cu clip structure



Lineup

Part number	XPN3R804NC	TK1R4S04PB	XPHR7904PS	TPWR7904PB	XPJR6604PB	XPQR3004PB
Package	TSON Advance(WF)	DPAK+	SOP Advance(WF)	DSOP Advance(WF)L	S-TOGL™	L-TOGL™
Rated drain current [A]	40	120	150	150	200	400
On-resistance (Max) [mΩ] @V_{GS} = 10 V	3.8	1.35	0.79	0.79	0.66	0.30

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2 Brushed DC motor pre driver

TB9057FG

Robustness | High efficiency · Low loss | Small size package

Value provided

Compliant with automotive functional safety standard (ISO 26262: ASIL-D) and motor current detecting function is built in.

1 Compliant with automotive functional safety standard

Compliant with ISO 26262 ASIL-D. [Note1] FMEDA [Note2] and safety manuals can be provided.

[Note1] Automotive Safety Integrity Level

[Note2] Failure Modes Effects and Diagnostics Analysis

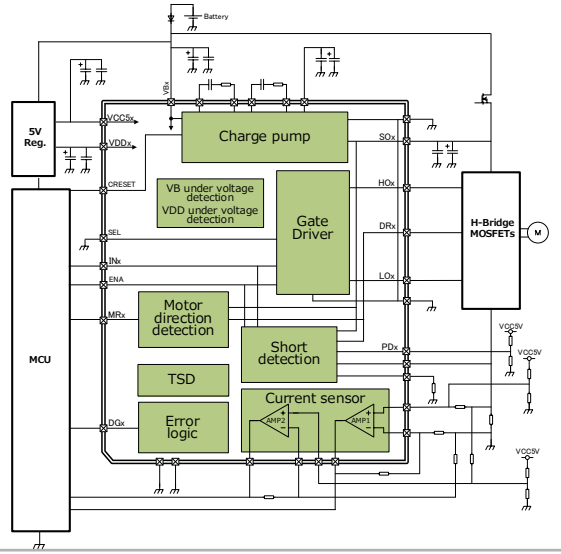
2 Built-in motor current detection amplifier

Two channels of motor current detection amplifiers are built in to make them redundant.

3 AEC-Q100 qualified

It is AEC-Q100 qualified and it can be used for various automotive applications.

TB9057FG
Reference Circuit Diagram



Lineup

Part number		TB9057FG
Package		LQFP48
Package body size		7.0 x 7.0 mm
Function	Control method	Direct
	External MOSFET (High side / Low side)	N-ch / N-ch
	Detection of overheating, low voltage and short circuit	✓
	Output of detection function diagnosis result	✓

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3 Gate driver (for motor)

TPD7211F / TPD7212F / TPD7212FN

Robustness | High efficiency · Low loss | Small size package

Value provided

The high gate drive current capability reduces MOSFET losses and improves the efficiency of system.

1 High gate drive current

High drive current capability and high speed switching contribute to reduce the loss.

TPD7211F: ±0.5 A

TPD7212F, TPD7212FN: -1 / +1.5 A

2 Built-in protection / diagnostic output function

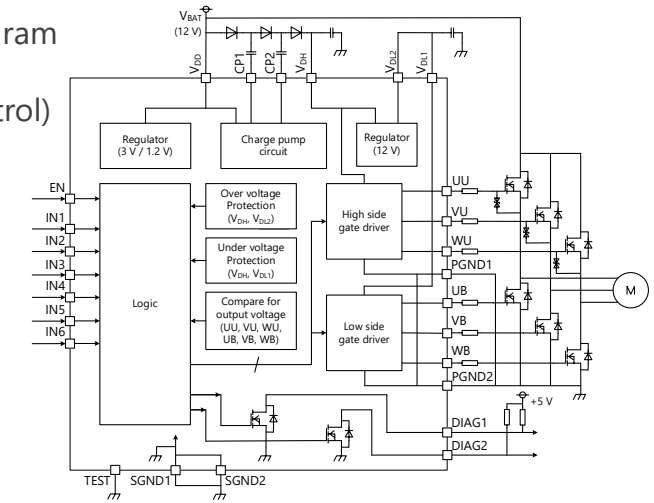
MOSFET is turn off when a signal is input that causes arm short circuit.

Functions to monitor abnormalities of the power supply voltage and output voltage are built in.

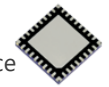
3 Small surface mount package

PS-8, WQFN32 and SSOP30 are small surface mount packages. They contribute to miniaturization of system.

Example of application and block diagram of TPD7212F, TPD7212FN
(Three phase brushless DC motor control)



Lineup

Part number	TPD7211F	TPD7212F / TPD7212FN
Function	Half bridge output gate driver	Gate driver for three-phase brushless motor
Number of output	2 outputs	6 outputs
Package	 PS-8 (2.8 x 2.9 mm)	TPD7212F Back surface  WQFN32 (5 x 5 mm) TPD7212FN  SSOP30 (7.6 x 10.2 mm)
Features	・For high side P-ch MOSFET drive	・For driving high side N-ch MOSFET (with built-in charge pumps) ・Built-in voltage monitoring function (power supply, output)

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4 Brushless DC motor pre driver

TB9081FG / TB9083FTG

Robustness | High efficiency · Low loss | Small size package

Value provided

Compliant with automotive functional safety standard (ISO 26262: ASIL-D) and safety relay drivers are built in.

1 Compliant with automotive functional safety standard

Compliant with ISO 26262 ASIL-D. [Note1] FMEDA [Note2] and safety manuals can be provided.

[Note1] Automotive Safety Integrity Level

[Note2] Failure Modes Effects and Diagnostics Analysis

2 Built-in safety relay drivers and motor current detection amplifiers

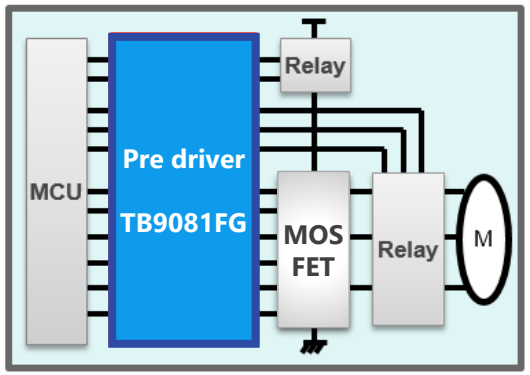
The safety relay drivers are built in for the power supply side MOSFETs and the motor phase cut MOSFETs. In addition, a 3 channels of motor current detection amplifiers are built in to support 3 shunts.

3 AEC-Q100 qualified

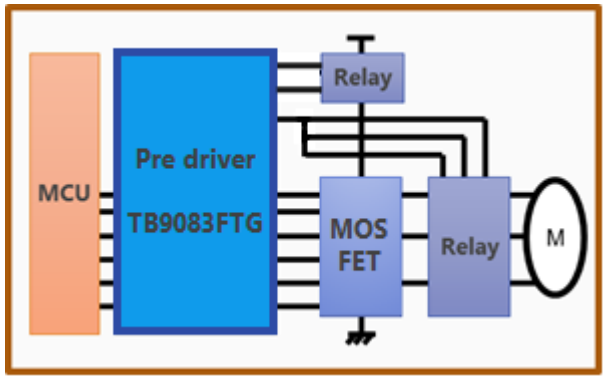
It is AEC-Q100 qualified and it can be used for various automotive applications.

Built-in safety relay drivers

TB9081FG: 5 channels



TB9083FTG: 3 channels



Lineup

Part number		TB9081FG	TB9083FTG
Package		LQFP64	WQFN48
Package body size		10.0 x 10.0 mm	7.0 x 7.0 mm
Operating ambient temperature		Ta = -40 to 125 °C	Ta = -40 to 150 °C
Function	Control method	Direct	Direct
	External MOSFET (High side / Low side)	N-ch / N-ch	N-ch / N-ch
	Detection of overheating, low voltage and short circuit	✓	✓
	Output of detection function diagnosis result	✓ (BIST [Note3])	✓ (BIST)

[Note3] Built-in Self Test

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5 U-MOS Series -40 V / -60 V P-ch MOSFET

XPN9R614MC / XPN27016MC* / TJ90S04M3L / TJ60S06M3L / XPH3R114MC / XPH8R316MC

Robustness | High efficiency · Low loss | Small size package

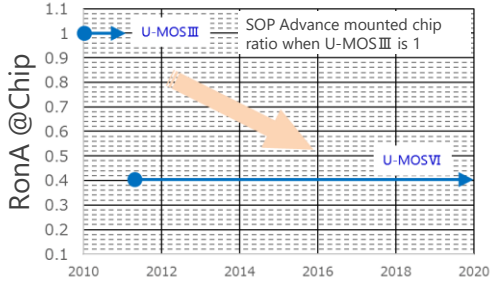
Value provided

Low on-resistance contributes to reduce system power consumption.

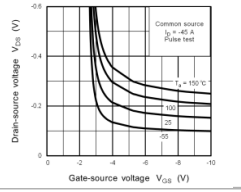
1 Low loss (reduced on-resistance) and logic level drive

Using a low on-resistance technology contributes to reduce system power consumption.
A lineup of logic level drive type is supported.
The on-resistance per area is reduced by 60 %.
(compared to Toshiba's U-MOSⅢ products)

Low loss: RonA reduction trend



(Note: Comparison with Toshiba products)



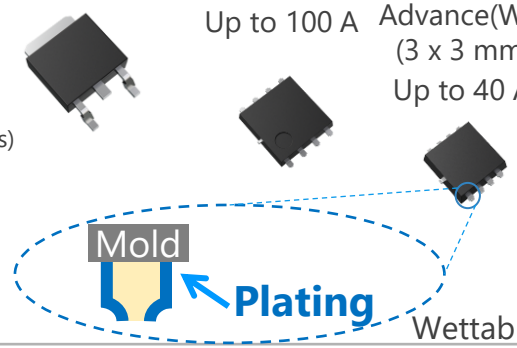
Logic level drive
TJ90S04M3L
V_{DS} - V_{GS}

Large current, small size, high power dissipation package

DPAK+
(6.5 x 9.5 mm)
Up to 90 A

SOP Advance(WF)
(5 x 6 mm)
Up to 100 A

TSON Advance(WF)
(3 x 3 mm)
Up to 40 A



Wettable Flank (WF) structure

2 Small and low loss packages

By adopting a Cu connector structure, a low loss and high power dissipation package is realized.
Wettable Flank (WF) package contributes to good mountability.

Lineup

Part number	XPN9R614MC	XPN27016MC*	TJ90S04M3L	TJ60S06M3L	XPH3R114MC	XPH8R316MC
Package	TSON Advance(WF)		DPAK+		SOP Advance(WF)	
Rated Drain-source voltage[V]	-40	-60	-40	-60	-40	-60
Rated drain current [A]	-40	-25	-90	-60	-100	-90
On-resistance (Max) [mΩ] @V_{GS} = 10 V	9.6	27.3	4.3	11.2	3.1	8.3

*: Under development (The specifications are subject to change without notice.)

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6 General purpose small signal MOSFET

SSM3K7002KF / SSM3J168F / SSM3J66MFV

Robustness | High efficiency · Low loss | Small size package

Value provided

Wide lineup of small packages contribute to reduce the size and power consumption of system.

1 Small package

A lineup of various small packages such as SOT-723 (VESM 1.2 x 1.2 mm package) is available, contributing to reduce mounting area.

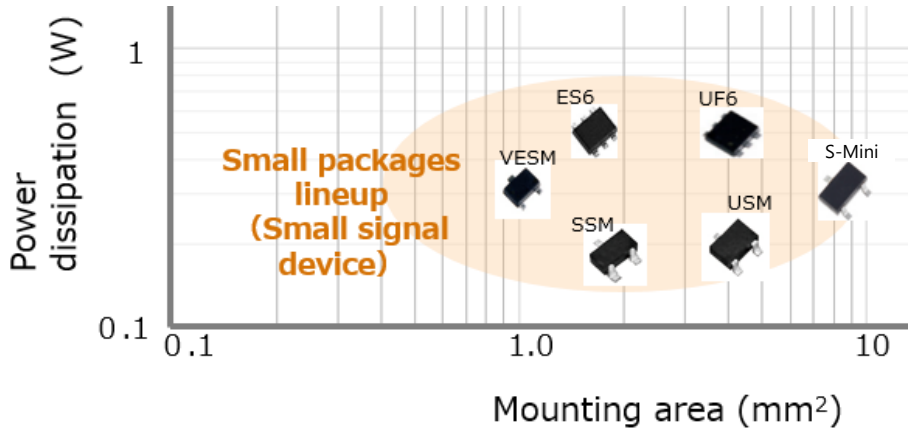
2 Low voltage drive

SSM3J66MFV can be driven at low gate-source voltage of 1.2 V.

3 AEC-Q101 qualified

AEC-Q101 qualified and can be used for various automotive applications.

Small signal package lineup



Lineup

Part number		SSM3K7002KF	SSM3J168F	SSM3J66MFV
Package		S-Mini (SOT-346)	S-Mini (SOT-346)	VESM (SOT-723)
V_{DSS} [V]		60	-60	-20
Rated drain current [A]		0.4	-0.4	-0.8
$R_{DS(ON)}$ @$\|V_{GS}\|$=4.5 V [Ω]	Typ.	1.2	1.4	0.31
	Max	1.75	1.9	0.39
Drive voltage [V]		4.5	-4.0	-1.2
Polarity		N-ch	P-ch	P-ch

◆Return to Block Diagram TOP

7 TVS diode (for CAN communication)

DF3D18FU / DF3D29FU / DF3D36FU

Robustness | High efficiency · Low loss | Small size package

Value provided

TVS diodes prevent system damage and malfunction caused by electrostatic discharge (ESD).

1 Improve ESD pulse absorbability

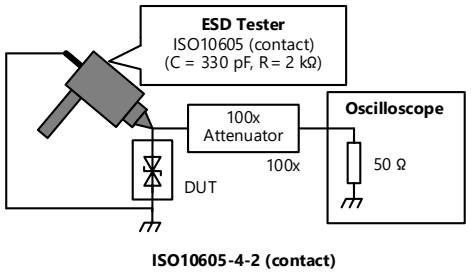
Toshiba proprietary Zener process improves the ESD pulse absorption of TVS diodes.
(Achieving both low dynamic resistance R_{DYN} and low capacitance between terminals C_t)

2 Supports CAN, CAN FD and FlexRay

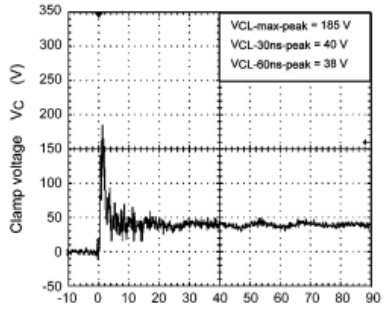
These are products applicable to in-vehicle LAN communication such as CAN, CAN FD and FlexRay.

3 High ESD immunity

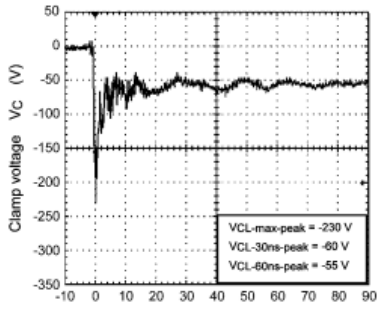
V_{ESD} > ±30 kV @ISO 10605
V_{ESD} > ±20 kV @IEC 61000-4-2 (Level 4)



ISO10605-4-2 (contact)



DF3D36FU +15kv (ISO10605)



DF3D36FU -15 kV (ISO10605)

Lineup

Part number	DF3D18FU	DF3D29FU	DF3D36FU
Package	USM (SOT-323) 		
V_{ESD} [kV] @ISO 10605	±30	±30	±20
V_{RWM} (Max) [V]	12	24	28
C_t (Typ. / Max) [pF]	9 / 10		6.5 / 8
R_{DYN} (Typ.) [Ω]	0.8	1.1	1.5

(Note) The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.
This product is an ESD protection diode and cannot be used for purposes other than ESD protection.

◆Return to Block Diagram TOP

8 Gate driver (for switch)

TPD7104AF / TPD7106F / TPD7107F

Robustness | High efficiency · Low loss | Small size package

Value provided

A charge pump circuit for the N-ch MOSFET gate drive is built in, allowing for easy semiconductor relay configuration.

1 Built-in charge pump circuit

Built-in charge pump circuit enables N-ch MOSFET as high side switch.
Easy to configure a semiconductor relay.

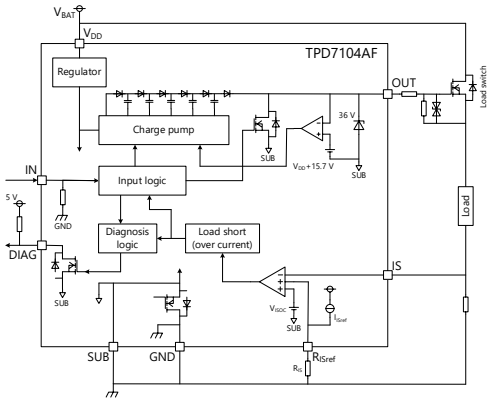
2 Can be controlled by logic level voltage

It is possible to be controlled directly by output signal of MCUs or CMOS logic ICs.

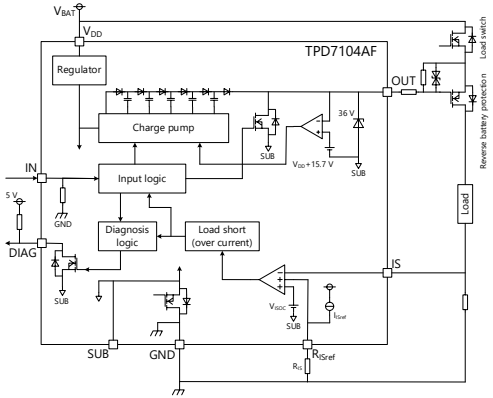
3 Small package

The small surface mount packages such as PS-8, SSOP16 and WSON10A contribute to the miniaturization of equipment.

Semiconductor relay (switch) application (TPD7104AF)



Power supply reverse connection protection MOSFET control (TPD7104AF)



Back to back configuration

Lineup

Part number	TPD7104AF	TPD7106F	TPD7107F
Package	PS-8 (2.8 x 2.9 mm)	SSOP16 (5.5 x 6.4 mm)	WSON10A (3 x 3 mm)
Function	High side gate driver	High side gate driver	High side gate driver
Output	1	1	1
Features	・Operating power supply voltage range: 5 to 18 V ・Built-in power supply reverse connection protection function (Protective MOSFET control with back-to-back circuitry)	・Operating power supply voltage range: 4.5 to 27 V ・Built-in power supply reverse connection protection function (Protective MOSFET control with back-to-back circuitry)	・Operating power supply voltage range: 5.75 to 26 V ・Current sense output ・Protective functions; overcurrent, overtemperature, GND disconnect, etc. reverse battery connection ・Diagnosis output; overcurrent, load open, overtemperature, etc.

◆Return to Block Diagram TOP

9 General purpose small signal bipolar transistor

2SC2712 / 2SA1162 / 2SC4116 / 2SA1586 / 2SC4738 / 2SA1832

Robustness | High efficiency · Low loss | Small size package

Value provided

Extensive product lineup to meet customers' needs.

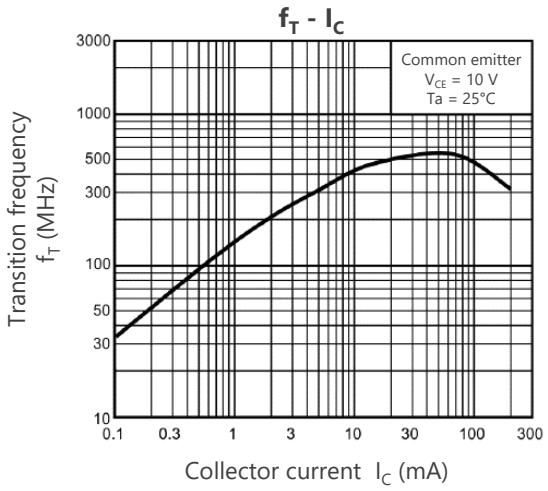
1 Extensive lineup of packages

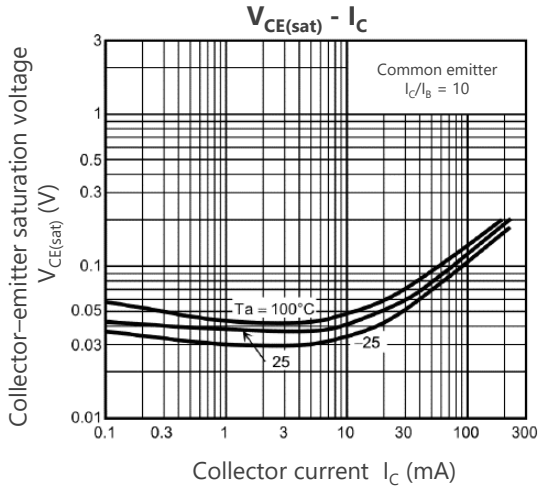
Various packages such as 1-in-1, 2-in-1 are provided and suitable products for circuit board design are selectable.

2 AEC-Q101 qualified

AEC-Q101 qualified and can be used for various automotive applications.

Characteristic examples of 2SC2712





Lineup

Part number	2SC4738	2SA1832	2SC4116	2SA1586	2SC2712	2SA1162
Package	SSM (SOT-416) 		USM (SOT-323) 		S-Mini (SOT-346) 	
Polarity	NPN	PNP	NPN	PNP	NPN	PNP
$\lvert V_{CEO} \rvert$ [V]	50	-50	50	-50	50	-50
$\lvert I_C \rvert$ [mA]	150	-150	150	-150	150	-150

◆Return to Block Diagram TOP

10 Small signal bias resistor built-in transistor (BRT)

RN1907FE / RN2907FE / RN1901 / RN2901 Series

Robustness | High efficiency · Low loss | Small size package

Value provided

Extensive product lineup to meet customers' needs.

1 Built-in bias resistor type (BRT: Bias Resistor built-in Transistor)

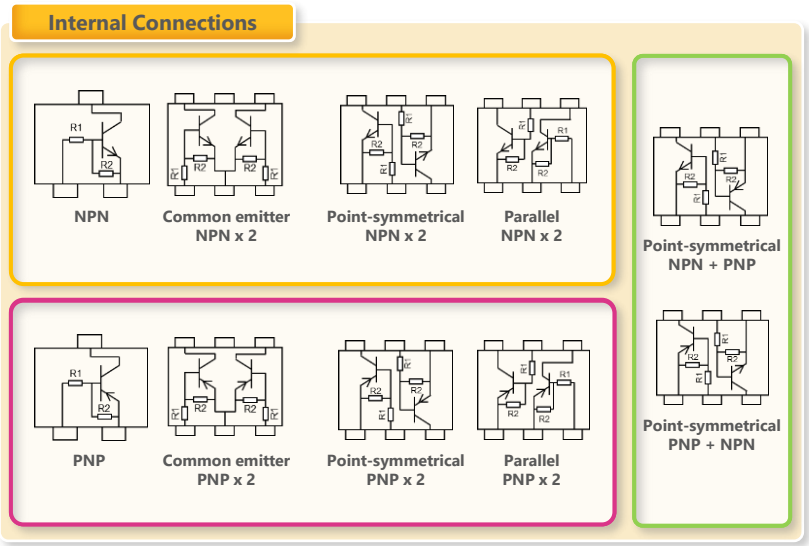
The BRTs contribute to reduction of the number of components, assembly workload and mounting area of circuit boards.

2 Extensive lineup of package and pin assignment

Various package lineups, such as 1-in-1, 2-in-1 and various pin assignment type are provided and suitable products for circuit board design are selectable.

3 AEC-Q101 qualified

AEC-Q101 qualified and can be used for various automotive applications.



Lineup

Part number	RN1907FE	RN2907FE	RN1901	RN2901
Package	ES6 (SOT-563) 		US6 (SOT-363) 	
Polarity	NPN	PNP	NPN	PNP
V_{CEO} [V]	50	-50	50	-50
I_C [mA]	100	-100	100	-100

◆Return to Block Diagram TOP

11a Power supply IC (for MCU)

TB9005FNG

Robustness | High efficiency · Low loss | Small size package

Value provided

This is voltage regulator with low current consumption, and various monitoring functions such as WDT [Note] contribute to improving system stability.

[Note] Watchdog Timer

1 Low current consumption

External transistor type voltage regulator with low current consumption.
Load stability is 1 % (Max) (@ILOAD = 1 to 300 mA) .

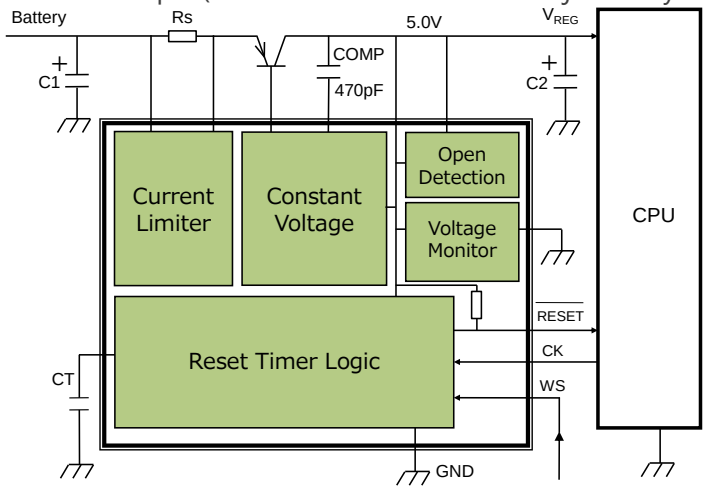
2 Built-in WDT and various monitoring functions

The WDT monitors the operation of the MCU.
In addition, current detection functions contribute to improving system stability.

3 AEC-Q100 qualified

It is AEC-Q100 qualified and can be used for various automotive applications.

Application circuit example (The current limiter can be adjusted by an external resistor.)



Lineup

Part number		TB9005FNG
Package		SSOP20 (6.4 x 7.0 mm)
Current consumption I_{CC} (Typ.) [µA]		90 (@V_{IN} = 12 V, Ta = 25 °C)
Load stability VLOAD (Max) [%]		1 (@ILOAD = 1 to 300 mA)
Function	Number of outputs	1ch (5 V)
	Circuit type	External transistor type
	WDT, overcurrent limitation	✓

◆Return to Block Diagram TOP

11b Power supply IC (for MCU, built-in tracker)

TB9044AFNG

Robustness | High efficiency · Low loss | Small size package

Value provided

This is a high accuracy power supply IC for automotive and contributes to the functional safety of the system with various monitoring functions.

1 Built-in high accuracy power supply for automotive MCUs

This is built in 5 V power supply IC for an automotive MCU and 3 tracking power supplies for sensors.

2 Compliant with automotive functional safety standard

Compliant with ISO 26262 ASIL-D. [Note1] FMEDA [Note2] and safety manuals can be provided.

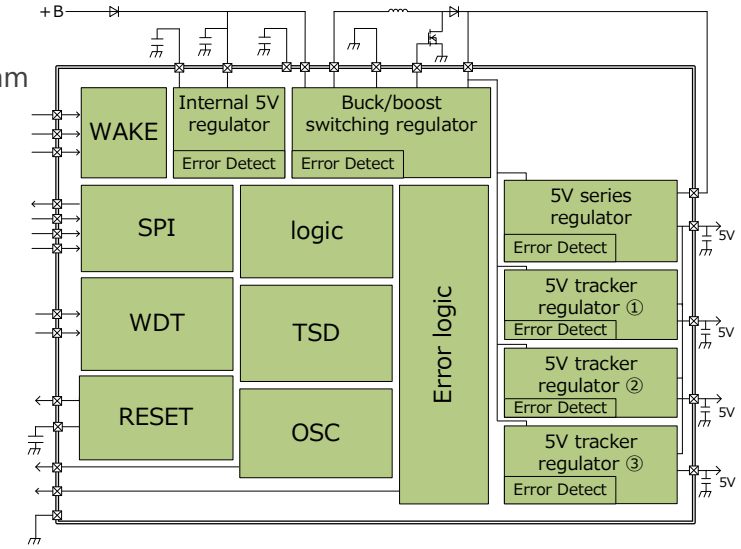
[Note1] Automotive Safety Integrity Level

[Note2] Failure Modes Effects and Diagnostics Analysis

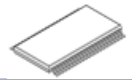
3 AEC-Q100 qualified

It is AEC-Q100 qualified and it can be used for various automotive applications.

TB9044AFNG
Functional Block Diagram



Lineup

Part number		TB9044AFNG
Package		HTSSOP48-P-300-0.50 
Package body size		8.1 x 12.5 mm
Operating voltage range		2.7 to 28 V
Function	LDO1 output voltage (1ch)	5.0 V @400 mA
	Tracking voltage difference (3ch)	LDO1 ± 20 mV @100 mA
	WDT[Note3] , over temperature detection, overcurrent detection	✓

[Note3] Watchdog Timer

◆Return to Block Diagram TOP

Power supply IC (for MCU, built-in tracker)

TB9045FNG Series

Robustness | High efficiency · Low loss | Small size package

Value provided

This is a high accuracy power supply IC for automotive and contributes to the functional safety of the system with various monitoring functions.

1 Built-in high accuracy power supply for automotive MCUs

This is built in 5 V power supply IC for an automotive MCU and 3 tracking power supplies for sensors. 4 voltage types (1.1/1.2/1.25/1.5 V) of power supplies are provided for the core of MCU.

2 Compliant with automotive functional safety standard

Compliant with ISO 26262 ASIL-D. [Note1] FMEDA [Note2] and safety manuals can be provided.

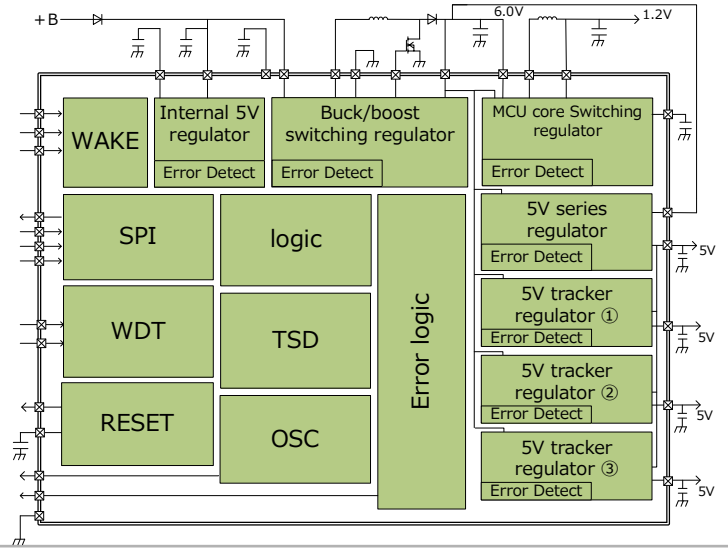
[Note1] Automotive Safety Integrity Level

[Note2] Failure Modes Effects and Diagnostics Analysis

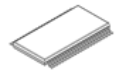
3 AEC-Q100 qualified

It is AEC-Q100 qualified and it can be used for various automotive applications.

TB9045AFNG
Functional Block Diagram



Lineup

Part number		TB9045FNG -110	TB9045FNG -120	TB9045FNG -125	TB9045FNG -150
Package		HTSSOP48-P-300-0.50 			
Package body size		8.1 x 12.5 mm			
Operating voltage range		2.7 to 28 V			
Function	Core power supply voltage (1ch) @800 mA	1.1 V	1.2 V	1.25 V	1.5 V
	LDO1 output voltage (1ch)	5.0 V @400 mA			
	Tracking voltage difference (3ch)	LDO1 ± 20 mV @100 mA			
	WDT[Note3] , over temperature detection, overcurrent detection	✓			

[Note3] Watchdog Timer

◆Return to Block Diagram TOP

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