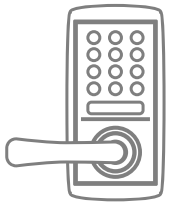
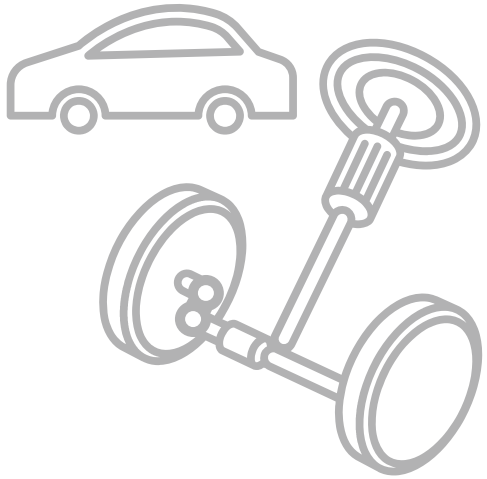
TOSHIBA

R17

Automotive Electric Power Steering

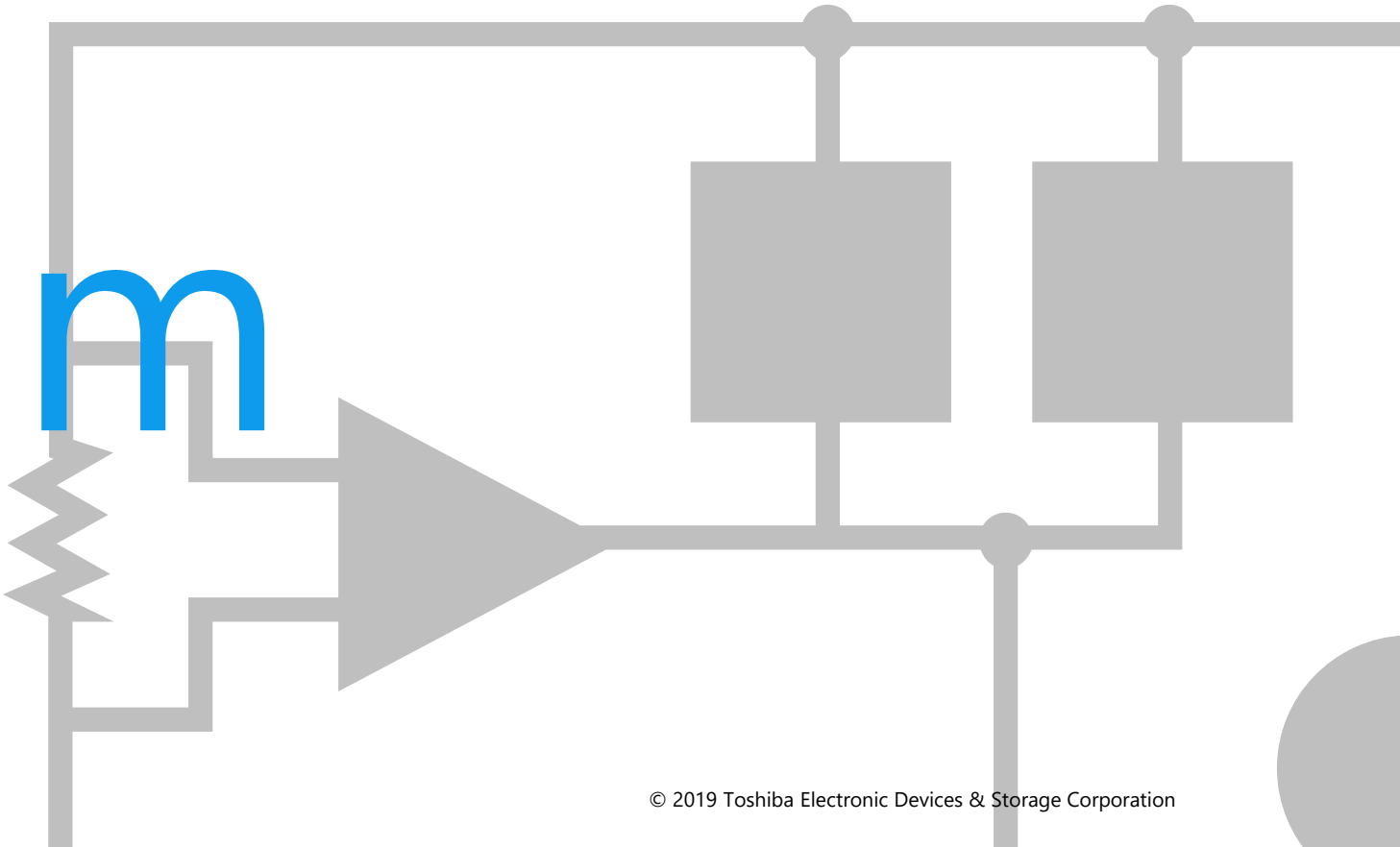
Solution Proposal by Toshiba



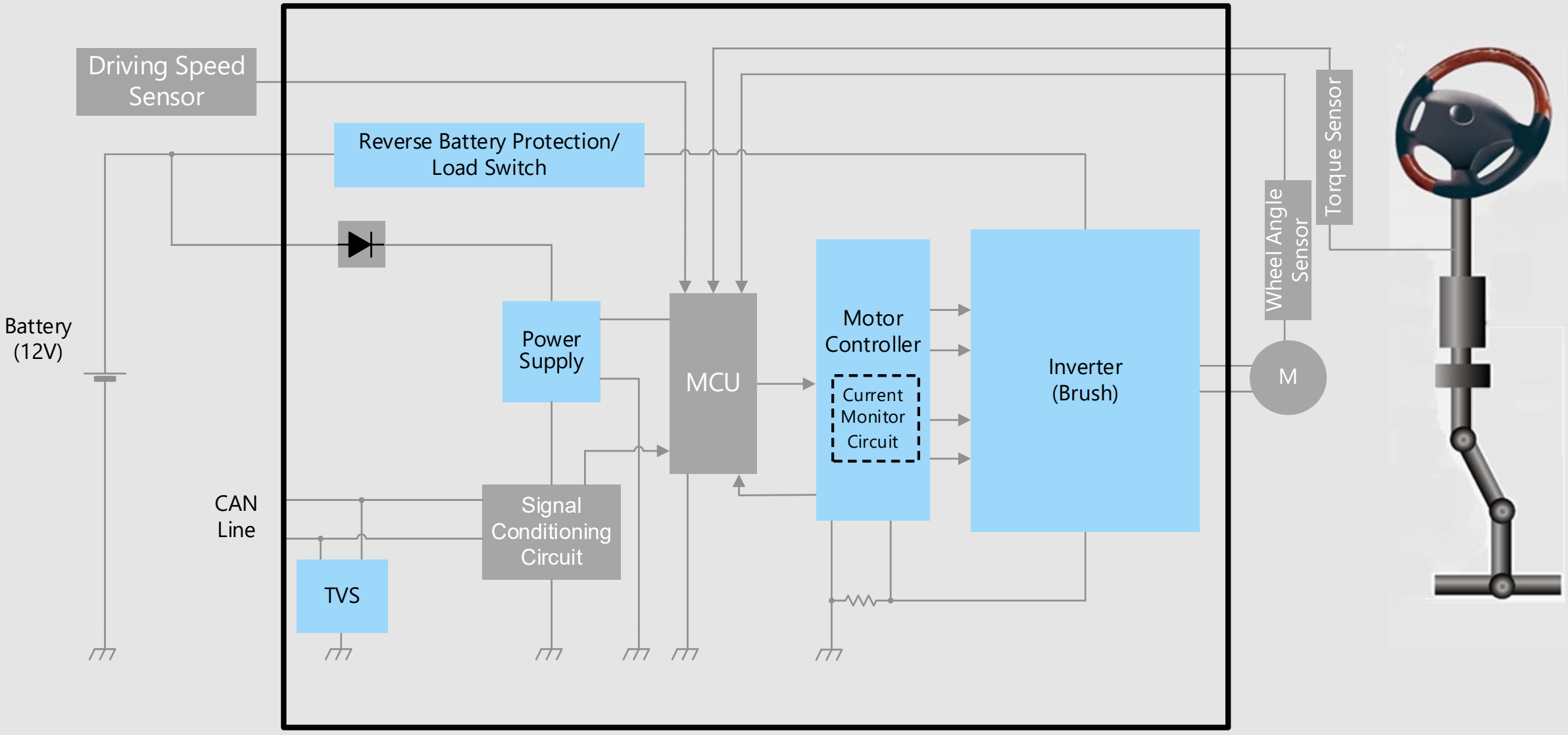


Toshiba Electronic Devices & Storage Corporation provides comprehensive device solutions to customers developing new products by applying its thorough understanding of the systems acquired through the analysis of basic product designs.

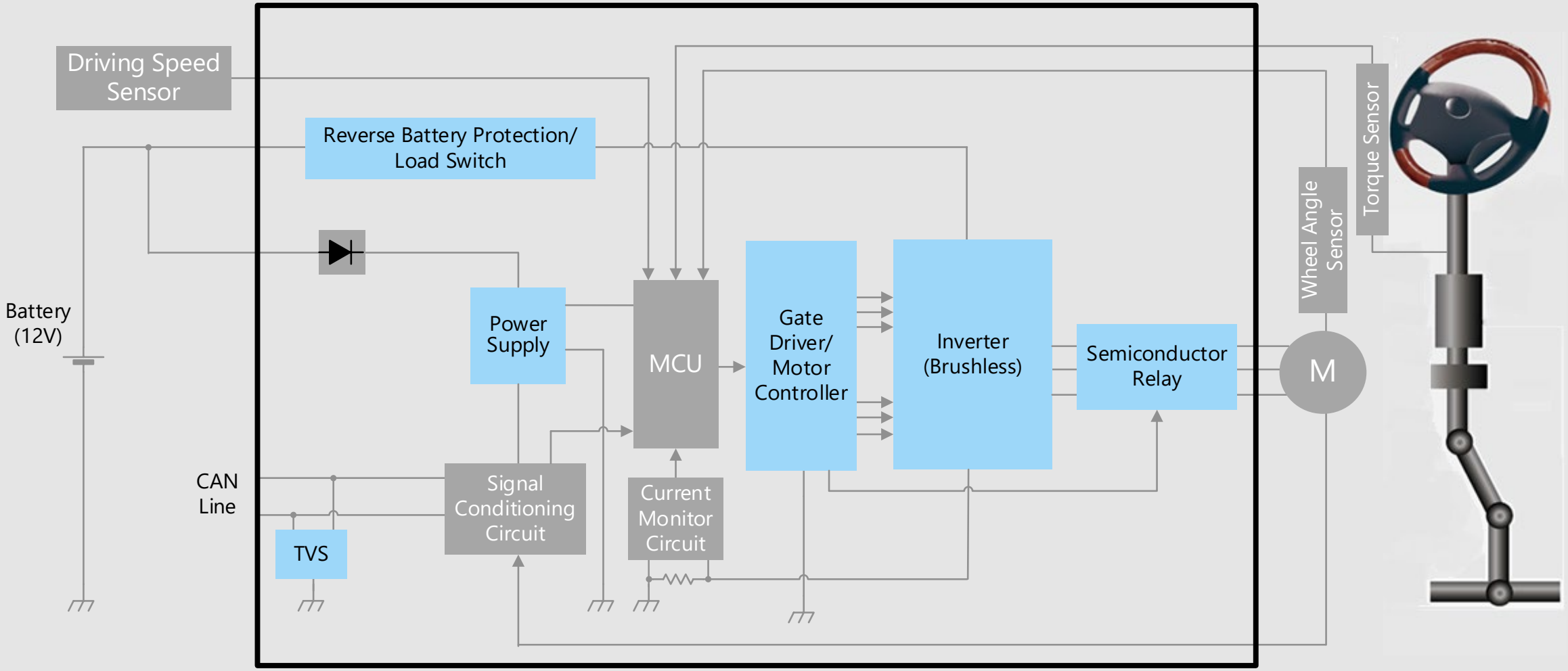
Block Diagram



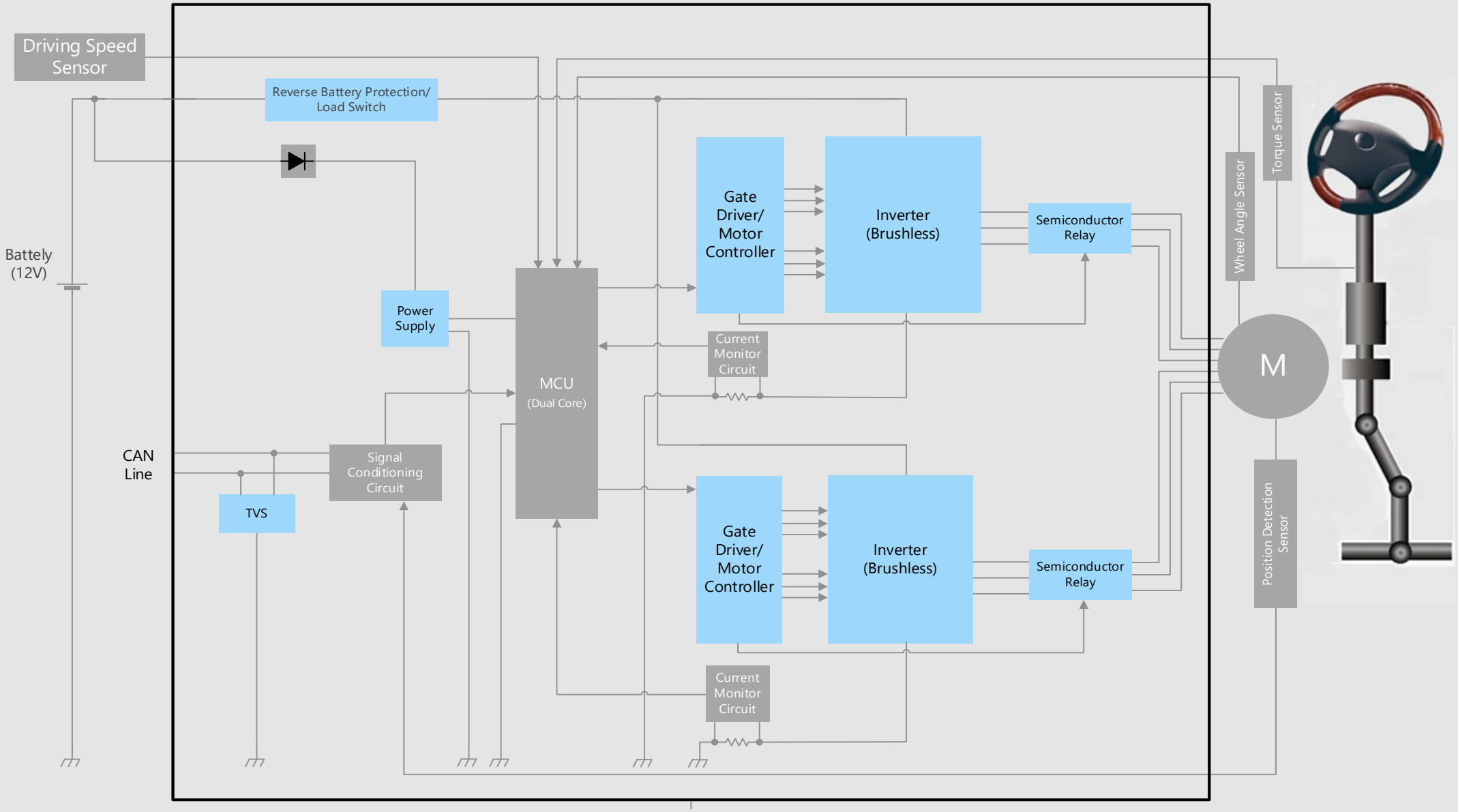
Electric Power Steering (Brush motor)



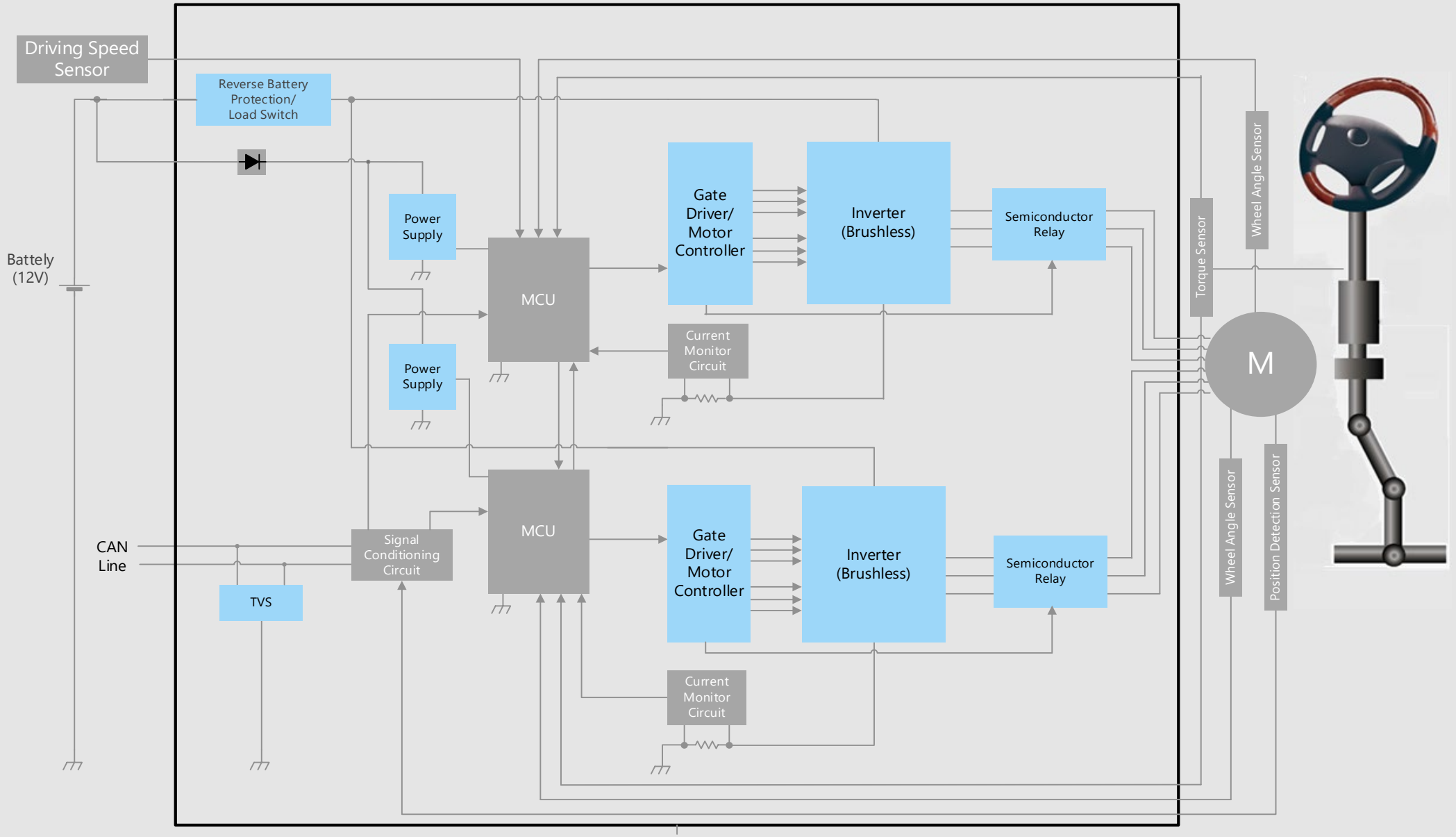
Electric Power Steering (Brushless motor)



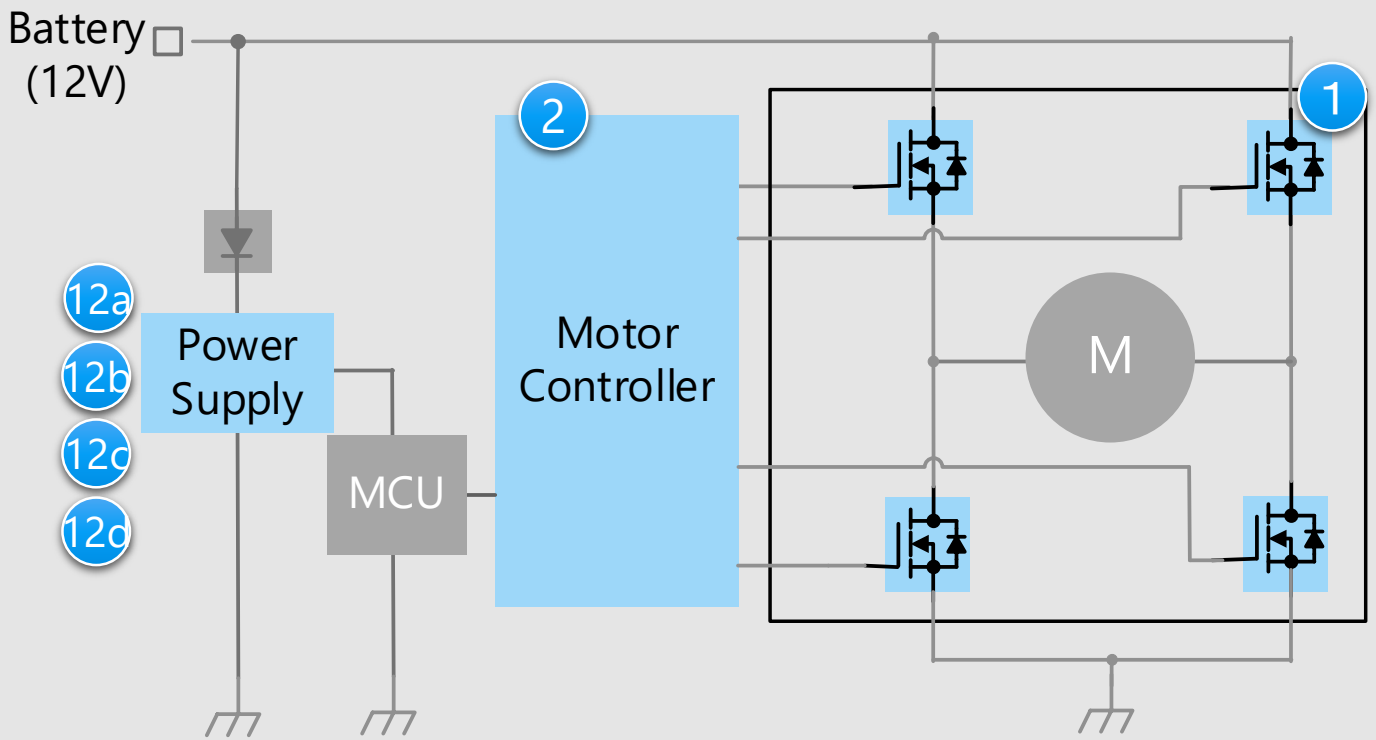
Electric Power Steering (Brushless motor, Partially redundant)



Electric Power Steering (Brushless motor, Fully redundant)



Brush motor drive circuit



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

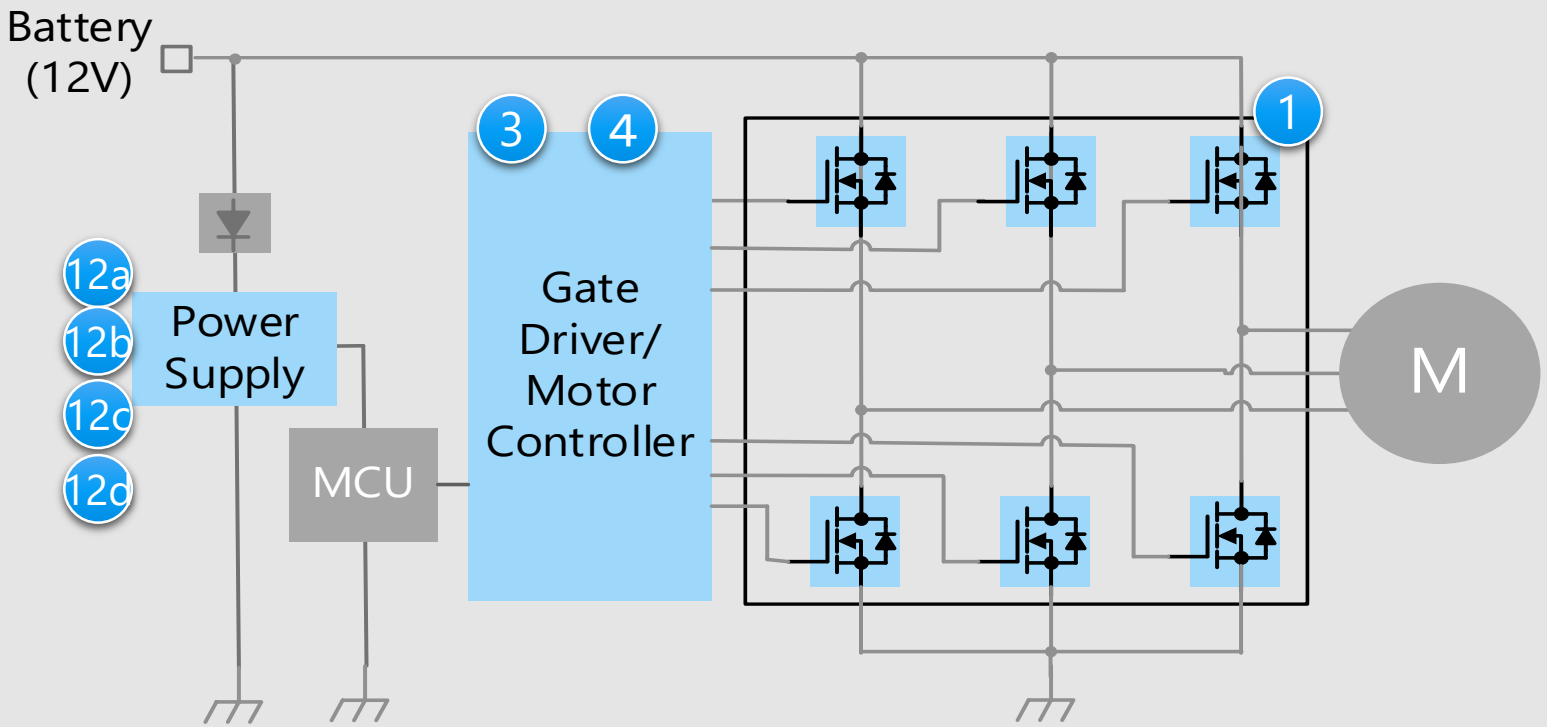
Device selection points

- It is necessary to select the product with the optimum current rating for each application.
- It is necessary to select a motor controller according to the performance of the switching device to be driven.
- It is necessary to select a small surface mount package suitable for miniaturization of the ECU

Proposals from Toshiba

- **Low power consumption of the system is realized by low on-resistance**
  U-MOS series 40V N-ch power MOSFET (1)
- **H-bridge drive circuit is realized**
  Motor controller (for brush motor) (2)
- **5V regulator with low current consumption**
  Power supply IC (for MCU)
  (TB9021 is Diode Built-in) (12a, 12b)
- **Power supply with a Built-in tracker**
  Power supply IC (for MCU+tracker) (12c, 12d)

Brushless motor drive circuit



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

Device selection points

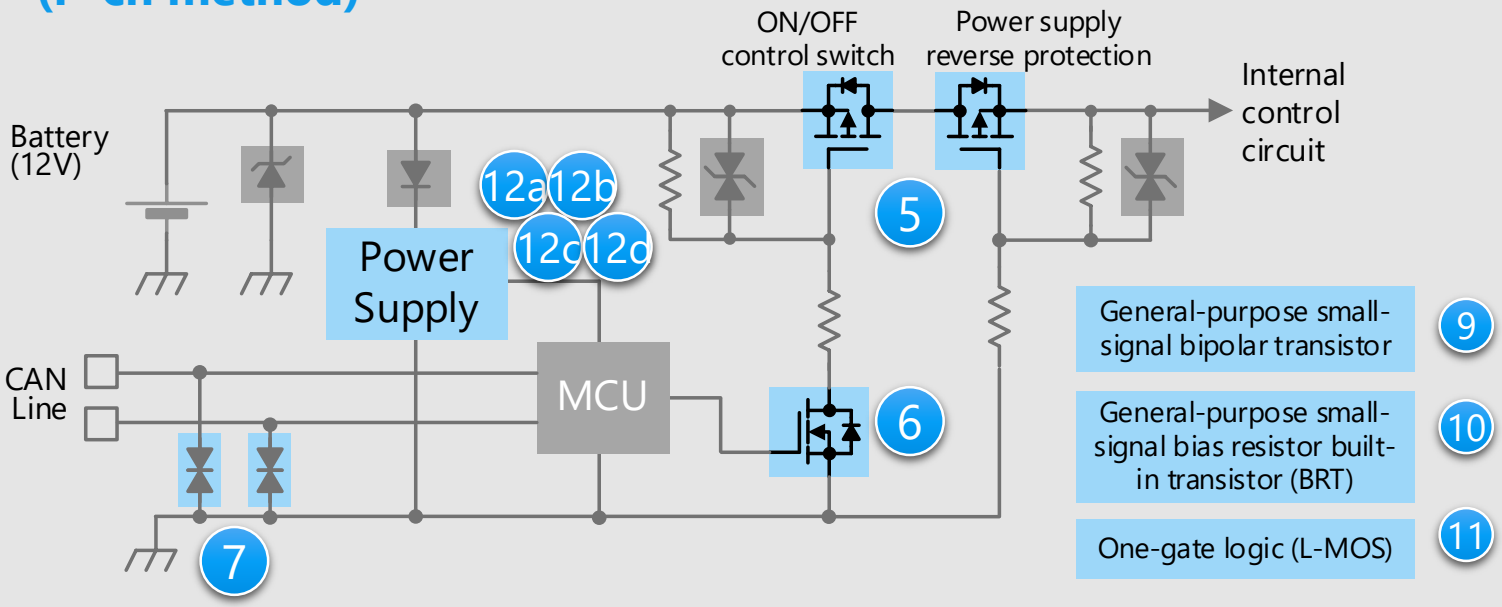
- It is necessary to select the product with the optimum current rating for each application.
- It is necessary to select a gate driver controller according to the performance of the switching device to be driven.
- It is necessary to select a small surface mount package suitable for miniaturization of the ECU

Proposals from Toshiba

- **Low power consumption of the system is realized by low on-resistance**
  U-MOS series 40V N-ch power MOSFET (1)
- **Gate driver with protection diagnostic function**
  Gate driver (for motor) (3)
- **Full-bridge drive circuit is realized**
  Motor controller (for brushless motor) (4)
- **5V regulator with low current consumption**
  Power supply IC (for MCU)
  (TB9021 is Diode Built-in) (12a, 12b)
- **Power supply with a Built-in tracker**
  Power supply IC (for MCU+tracker) (12c, 12d)

SW for power supply ON/OFF control and reverse connection protection (1)

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



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

Device selection points

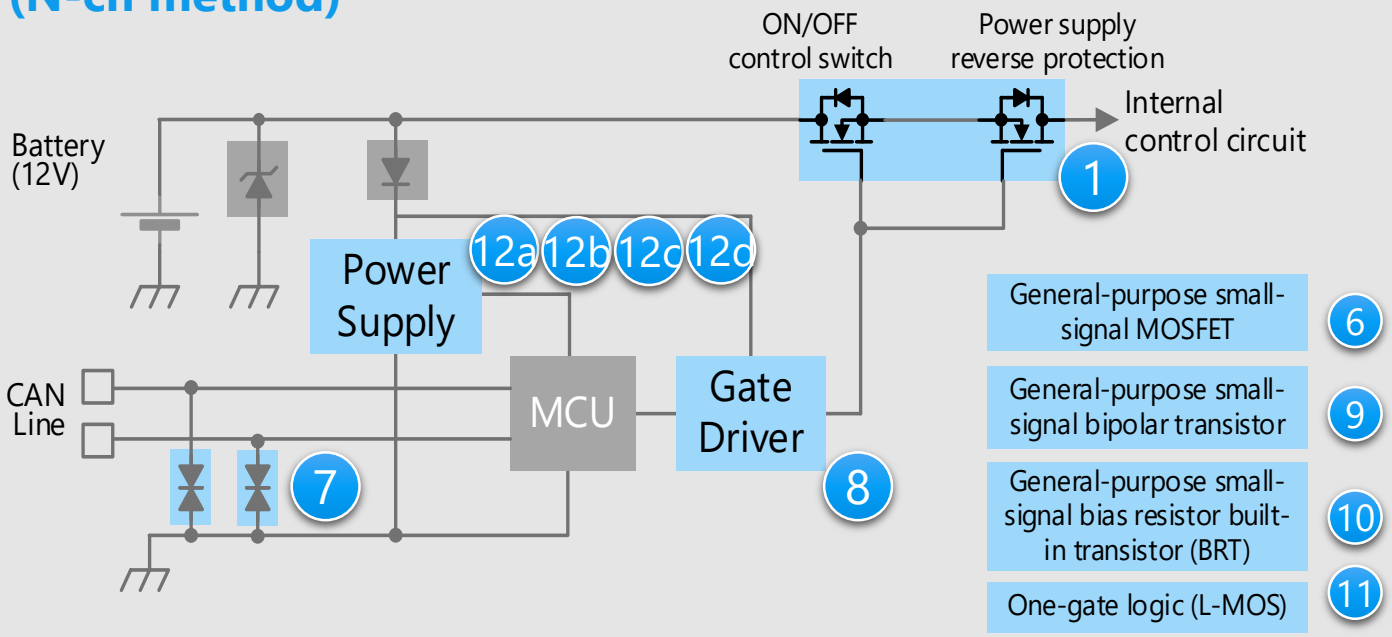
- It is necessary to select the product with the optimum current rating for each application.
- It is necessary to select a gate driver according to the performance of the switching device to be driven.
- It is necessary to select a small surface mount package suitable for miniaturization of the ECU.

Proposals from Toshiba

- **Low power consumption of the system is realized by low on-resistance** 5
  U-MOS series -40V / -60V P-ch power MOSFET
- **Various product lineups and small packages** 6
  General-purpose small-signal MOSFET
  General-purpose small-signal bipolar transistor 9
  Small-signal bias resistor built-in transistor(BRT) 10
  One-gate logic (L-MOS) 11
- **Both device protection and signal quality is realized**
  TVS diode (for CAN communication) 7
- **5V regulator with low current consumption**
  Power supply IC (for MCU) 12a 12b
  (TB9021 is Diode Built-in)
- **Power supply with a Built-in tracker**
  Power supply IC (for MCU+tracker) 12c 12d

SW for power supply ON/OFF control and reverse connection protection (2)

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



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

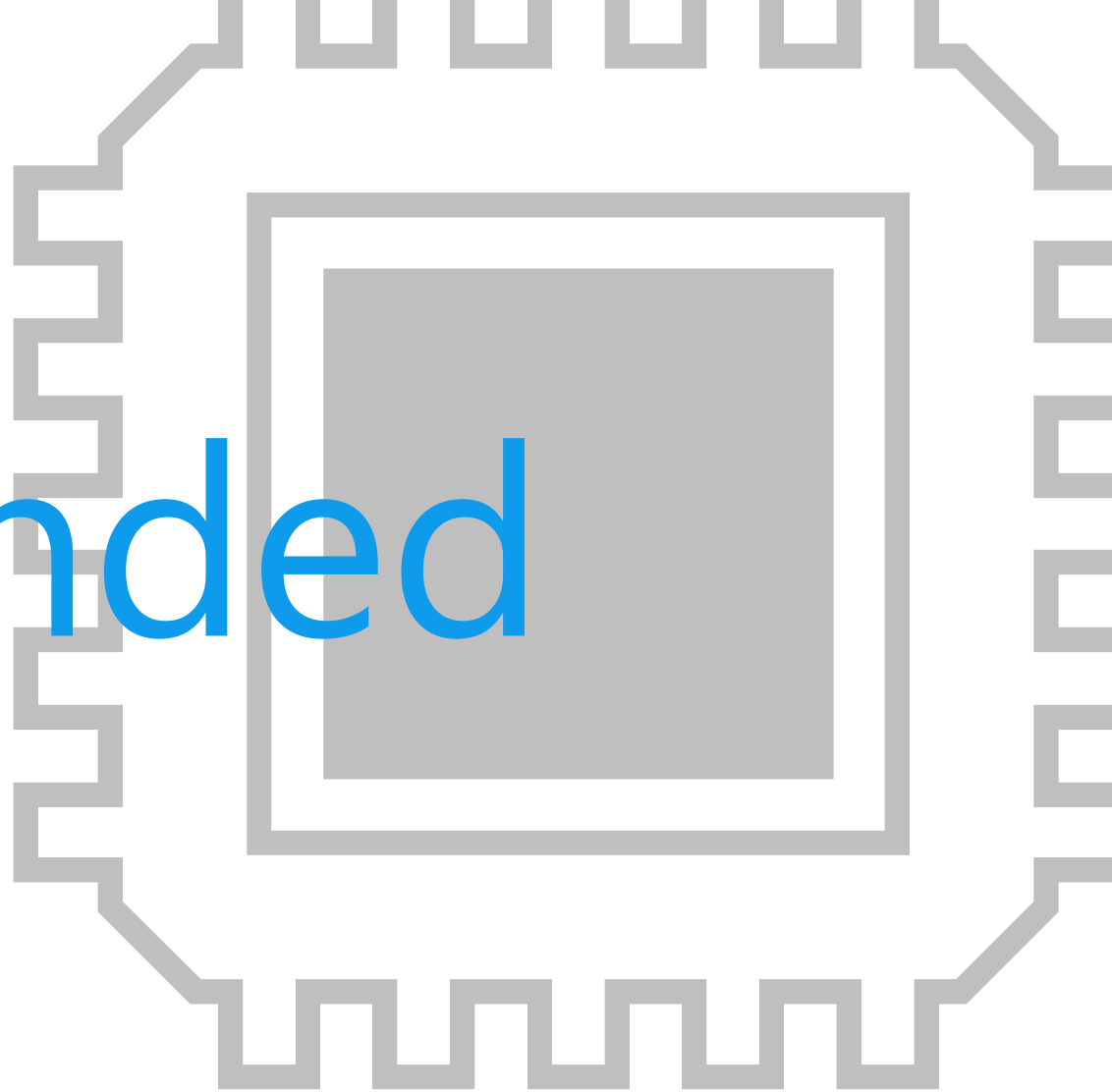
Device selection points

- It is necessary to select the product with the optimum current rating for each application.
- It is necessary to select a gate driver according to the performance of the switching device to be driven.
- It is necessary to select a small surface mount package suitable for miniaturization of the ECU.

Proposals from Toshiba

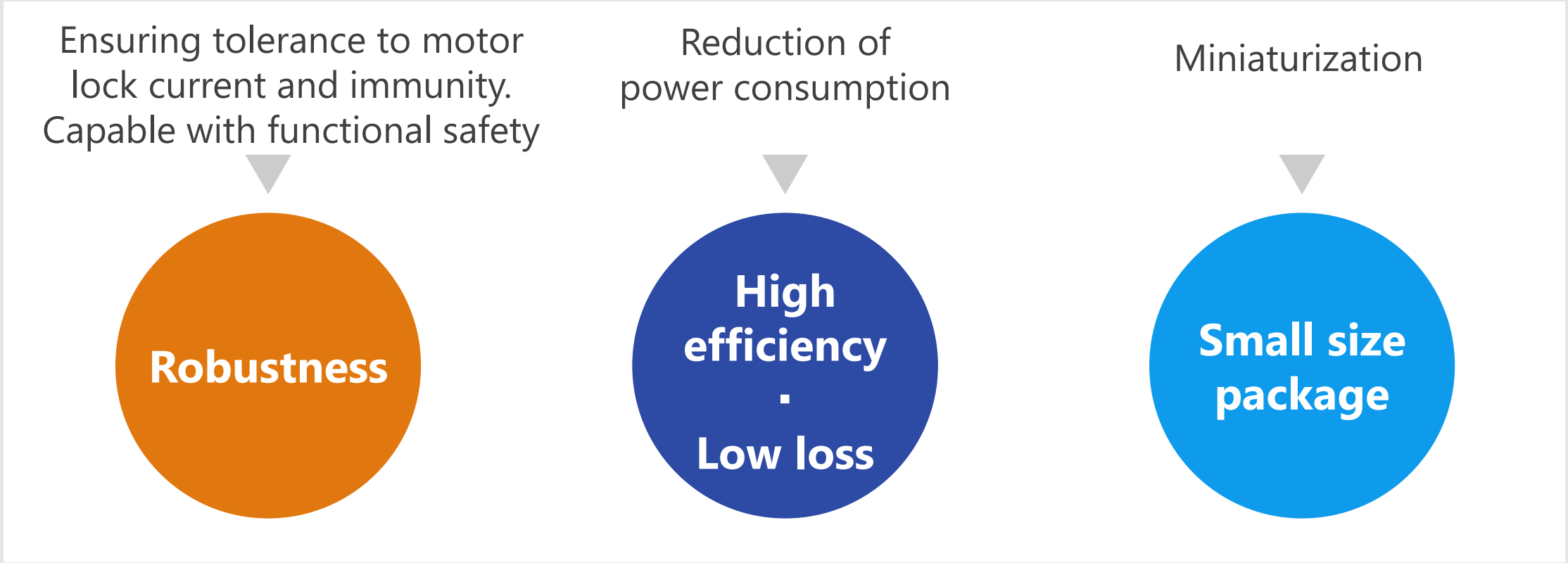
- **Low power consumption of the system is realized by low on-resistance** (1)
  U-MOS series 40V N-ch power MOSFET
- **Gate driver with protection diagnostic function** (8)
  Gate driver (for switch)
- **Various product lineups and small packages** (6, 9, 10)
  General-purpose small-signal MOSFET
  General-purpose small-signal bipolar transistor
  Small-signal bias resistor built-in transistor(BRT)
  One-gate logic (L-MOS)
- **Both device protection and signal quality is realized** (11)
  TVS diode (for CAN communication)
- **5V regulator with low current consumption** (7)
  Power supply IC (for MCU)
  (TB9021 is Diode Built-in)
- **Power supply with a Built-in tracker** (12a, 12b, 12c, 12d)
  Power supply IC (for MCU+tracker)

Recommended Devices



Device solutions to address customer needs

As described above, in the design of Power Sliding Door, “Ensuring tolerance to motor lock current and immunity. 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 40V N-ch power MOSFET	●	●	●
2	Motor controller (for brush motor)	●	●	
3	Gate driver (for motor)	●		●
4	Motor controller (for brushless motor)	●	●	●
5	U-MOS series -40V / -60V P-ch power 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	One-gate logic (L-MOS)			●
12	Power supply IC		●	●

1 U-MOS series 40V N-ch power MOSFET

XPN3R804NC / TK1R4S04PB / TPHR7904PB / TPWR7904PB / TKR74F04PB / TK1R5R04PB

Robustness | High efficiency · Low loss | Small size package

Value provided

The advanced U-MOS IX-H processes enables low on-resistance and low noise, thereby reducing power consumption.

1 Low loss (reduced chip resistance)

Using low chip resistance technology to contribute to reduced power consumption systems.
Chip resistance of 61% reduction per unit area (compared to UMOSIV)

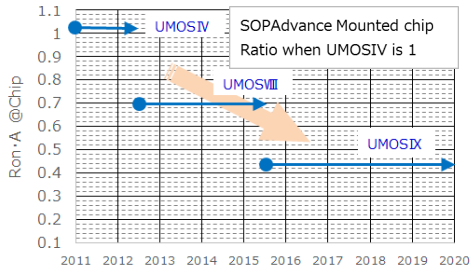
2 Compact, low-loss package

By adopting a Cu connector structure and a double-sided heat dissipation structure, Development of low-loss, high-heat-dissipation packages

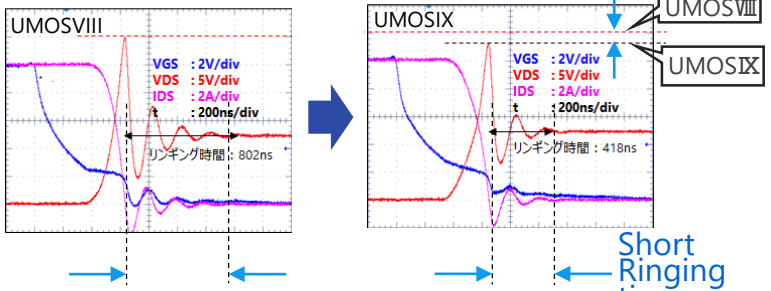
3 Low noise (low EMI)

Optimized chip process, reduce surge voltage and ringing time.

Low Loss: RonA Trend



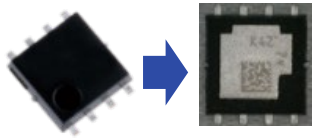
Low-noise: Switching Waveform



TO-220SM(W) Cu connector design

Package resistance reduction 64%, Compared to D2PAK

DSOP Advance(WF) double-sided cooling packages



Decrease of thermal resistance 76% reduction @t=3s, mounted on board Compared to SOP-8

Line up

Part number	Drain current	On-resistance (Max) @V_{GS}=10V	Package
XPN3R804NC	40A	3.8mΩ	TSON Advance(WF)
TK1R4S04PB	120A	1.35mΩ	DPAK+
TPHR7904PB	150A	0.79mΩ	SOP Advance(WF)
TPWR7904PB	150A	0.79mΩ	DSOP Advance(WF)
TKR74F04PB	250A	0.74mΩ	TO-220SM(W)
TK1R5R04PB	160A	1.5mΩ	D2PAK+

◆Return to Block Diagram TOP

2 Motor controller (for brush motor)

TB9057FG

Robustness | High efficiency · Low loss | Small size package

Value provided

Functional safety (ASIL-D capable) and built-in motor-current detecting function

1 Functional safety

ISO26262 compliant.
FMEDA and safety manuals can be provided.

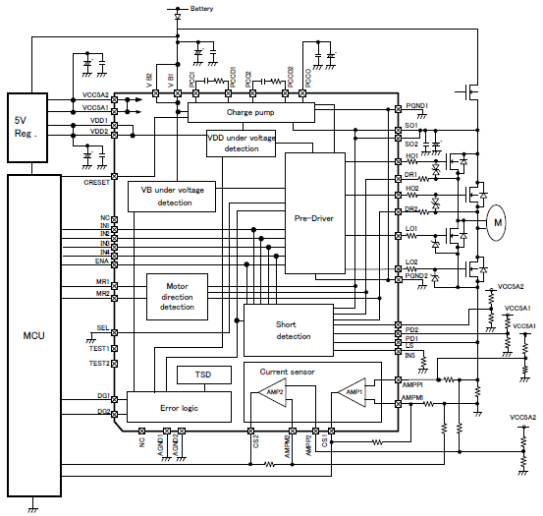
2 Built-in current detection amplifier

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

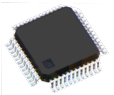
3 AEC-Q100 qualified

It is compatible with the AEC-Q100 and can be used for a wide range of Automotive applications.

TB9057FG Typical Connection Diagram



Line up

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

◆Return to Block Diagram TOP

3 Gate driver (for motor)

TPD7211F / TPD7212F

Robustness | High efficiency・Low loss | Small size package

Value provided

The large gate drive-current capability reduces power MOSFET losses and improves the efficiency of equipment.

1 Large gate drive current

Improves efficiency of high-speed FET switching.

- TPD7211F: ±0.5 A
- TPD7212F: -1 / +1.5 A

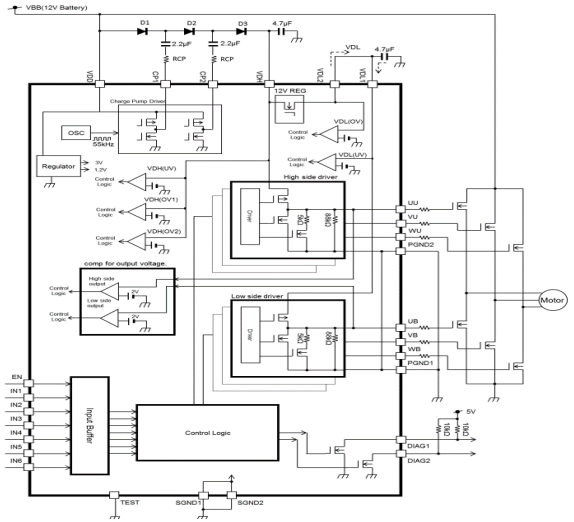
2 Built-in protection / diagnostic output function

- Hi-Lo side short is prevented and FET is switched off.
- Functions to monitor abnormalities of the power supply voltage and output voltage are built-in.

3 Small package

Small surface mount package PS8 and WQFN32

Example of application and block diagram of TPD7212F (Three-phase brushless motor control)



Line up

Part number	TPD7211F	TPD7212F
Function	Half bridge output gate driver	Gate driver for three-phase brushless motor
Number of output	2 outputs	6 outputs
Package	 PS8 (2.8 x 2.9 mm)	Back surface  WQFN32 (5 x 5 mm)
Features	・For high-side P-channel MOSFET drive	・For driving high-side N-channel MOSFET (with built-in charge pumps) ・Built-in voltage monitoring function (power supply, output)

◆Return to Block Diagram TOP

4 Motor controller (for brushless motor)

TB9081FG / TB9083FTG*

Robustness | High efficiency · Low loss | Small size package

Value provided

Functional safety (ASIL-D capable), built-in safety relay driver

1 Functional safety

ISO26262 compliant.
FMEDA and safety manuals can be provided.

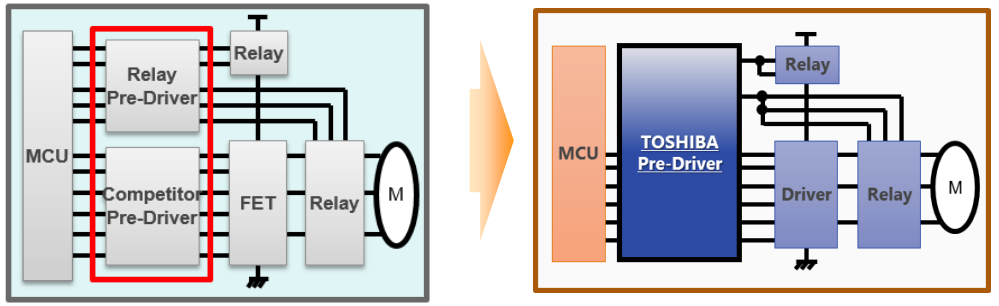
2 Built-in safety relay driver and current detection amplifier

The safety relay driver is built in for the power supply side FET and the motor phase cut FET.
In addition, a 3-channel current detection amplifier is built in to support 3 shunts.

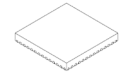
3 AEC-Q100 qualified

It is compatible with the AEC-Q100 and can be used for a wide range of Automotive applications.

Built-in safety relay driver (TB9081FG:5ch, TB9083FTG:3ch)



Line up

Part number		TB9081FG	TB9083FTG*
Package		LQFP64 	WQFN48 
Package body size		10.0 x 10.0 mm	7.0 x 7.0 mm
Operating temperature range		Tj=-40~150°C	Tj=-40~175°C
Function	Control method	Direct	Direct
	External MOSFET	N-ch / N-ch	N-ch / N-ch
	Detection of overheating, low voltage and short circuit	✓	✓
	Output of detection function diagnosis result	✓ (Built-in BIST)	✓ (Built-in BIST)

◆Return to Block Diagram TOP

* TB9083FTG: Under development

5 U-MOS series -40V, -60V P-ch power MOSFET

TJ90S04M3L / TJ60S06M3L / XPH3R114MC / TJ200F04M3L / TJ150F06M3L

Robustness | High efficiency · Low loss | Small size package

Value provided

Low on-resistance contributes to reduced system power consumption.

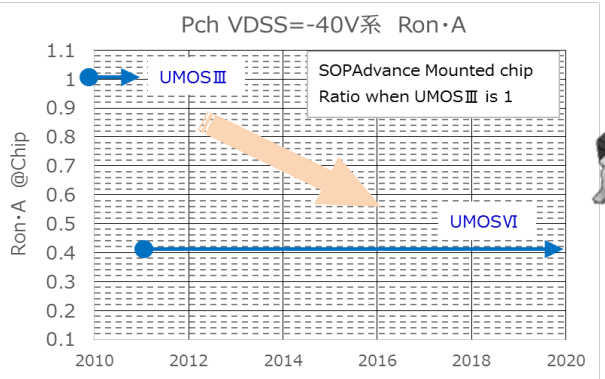
1 Low-loss (reduced chip resistance), logic-level response

Using low chip resistance technology to contribute to reduced power consumption systems
Lineup of Logic-level-drive types

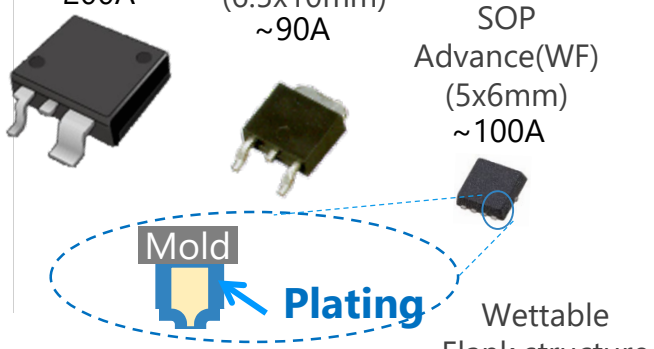
2 Small surface mount package developed

Development of low-loss, high-heat-dissipation packages by adopting a Cu connector structure
Ensuring mountability by using the Wettable Flank (WF) structure

Low Loss: RonA Reduction Trend



Large current, small size, high heat dissipation package



Line up

Part number	Drain-source Voltage	Drain current	On-resistance (Max) @V_{GS}=10V	Package
TJ90S04M3L	-40V	-90A	4.3mΩ	DPAK+
TJ60S06M3L	-60V	-60A	11.2mΩ	
XPH3R114MC	-40V	-100A	3.1mΩ	SOP Advance(WF)
TJ200F04M3L	-40V	-200A	1.8mΩ	TO-220SM(W)
TJ150F06M3L	-60V	-150A	5.6mΩ	

◆Return to Block Diagram TOP

6 General-purpose small-signal MOSFET

SSM3K7002KF / SSM3J168F / SSM3J66MFV

Robustness | High efficiency · Low loss | Small size package

Value provided

Choose from a wide array of small packages which contribute to the miniaturization and reduction of power consumption of equipment.

1 Small package

Starting with the SOT-723 (VESM 1.2mm^2 package), a lineup of various small packages is available, contributing to space savings during mounting.

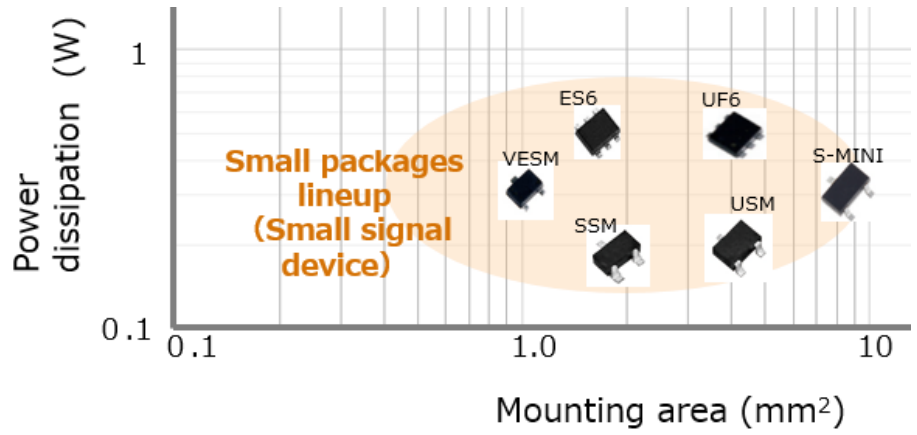
2 Low voltage drive

The gate-source voltage can be driven at a low voltage of 1.2 V(SSM3J66MFV).

3 AEC-Q101 qualified

AEC-Q101 qualified and can be used for a wide range of automotive applications.

Small signal package lineup



Line up

Part number		SSM3K7002KF	SSM3J168F	SSM3J66MFV
Package		S-Mini (SOT-346)	S-Mini (SOT-346)	VESM (SOT-723)
$V_{DS(DC)}$ [V]		60	-60	-20
I_D [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
MOS Type		N-channel	P-channel	P-channel

◆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 diode absorbs static electricity (ESD) from external terminals, prevents circuit malfunction and protects devices.

1 Improve ESD absorbability

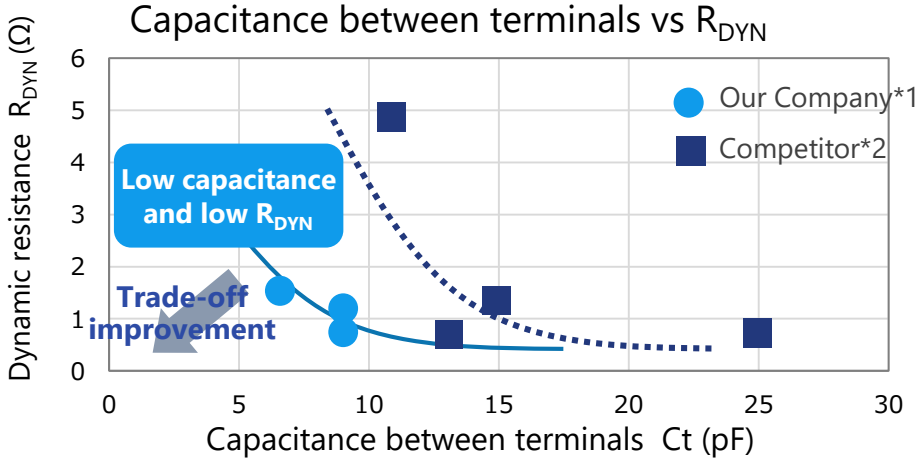
Improved absorption of ESD through our proprietary Zener process.
(Both low operating resistance R_{DYN} and low capacitance C_t)

2 Ensuring high signal integrity

Supports in-vehicle LAN communication such as CAN, CAN-FD, FlexRay. Lower capacitance ensures higher signal integrity.

3 High ESD immunity

Compliant products with
ISO10605 Standard > ±20 kV
IEC61000-4-2 Standard > ±20 kV (L4)



Line up

Part number	DF3D18FU	DF3D29FU	DF3D36FU
Package	USM (SOT-323) 		
V_{ESD} [kV] @ISO10605	±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) : This product is an ESD protection diode and cannot be used for purposes other than ESD protection (including but not limited to constant voltage diode applications).

*1:TOSHIBA Electronic Device & Strage Corporation
*2:Measurements of the commercial product

◆Return to Block Diagram TOP

8 Gate driver (for switch)

TPD7104AF

Robustness | High efficiency · Low loss | Small size package

Value provided

A charge pump for the FET gate drive is built-in, allowing for easy semiconductor relay configuration.

1 Built-in charge pump

No external add-ons required for driving the N-channel on the high side, making it easy to configure a semiconductor relay.

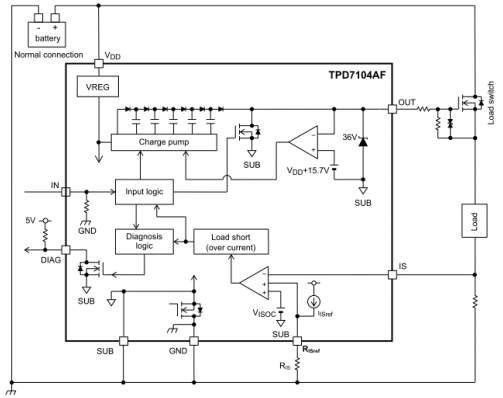
2 Logic level drive

Direct control is possible from microcomputer and CMOS logic.

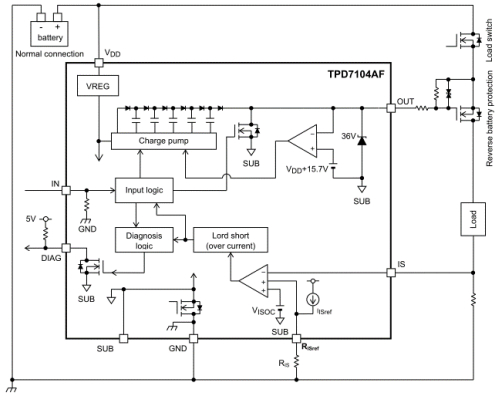
3 Small package

The small surface mount PS8 contributes to the miniaturization of equipment.

Semiconductor relay (switch) application



Power supply reverse connection protection FET control



Back to back configuration

Line up

Part number	TPD7104AF
Function	High-side gate driver
Number of output	1 output
Features	・Operating power supply voltage range: 5 to 18 V ・Built-in charge pump ・Built-in power supply reverse connection protection function (Supported for power supply reverse connection protection FET applications)

Package

PS8 (2.8 x 2.9 mm)

◆Return to Block Diagram TOP

9 General-purpose small-signal bipolar transistor

2SC2712 / 2SA1162 / 2SC4116 / 2SA1586 and others

Robustness | High efficiency · Low loss | Small size package

Value provided

Extensive product lineup to meet all your needs.

1 Extensive lineup of packages

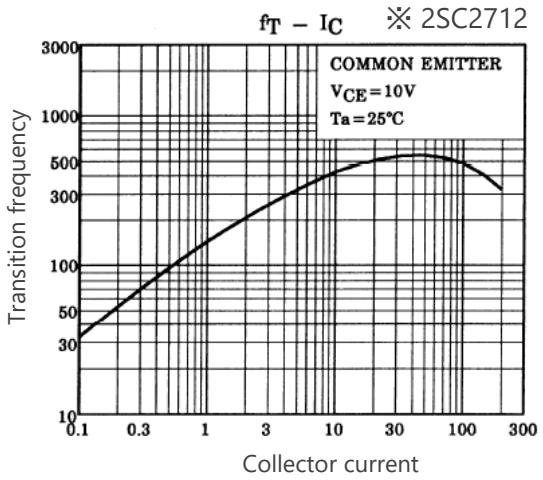
Various package lineups, such as 1in1, 2in1 are provided and suitable product for circuit board design can be selected.

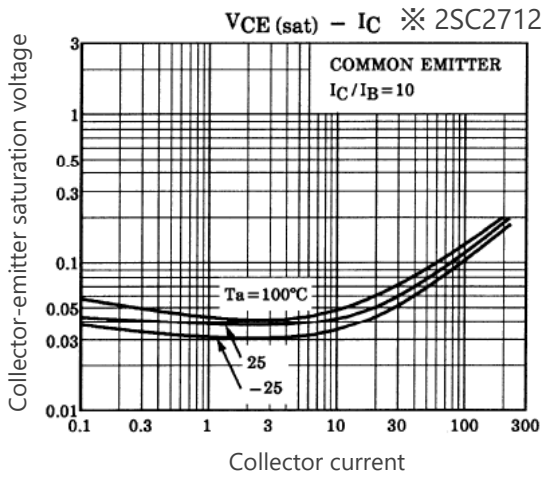
2 Various product lineup

Various product lineups, such as general-purpose, low-noise, low $V_{CE(sat)}$ and high-current types, are provided. Products can be selected depending on the application.

3 AEC-Q101 qualified

AEC-Q101 qualified and can be used for a wide range of automotive applications.





Line up

Package			SSM (SOT-416)		USM (SOT-323) UFM (SOT-323F)*		S-Mini (SOT-346)	
Classification	$\|V_{CEO}\|$ [V]	$\|I_C\|$ [mA]	NPN	PNP	NPN	PNP	NPN	PNP
General purpose	50	150	2SC4738	2SA1832	2SC4116	2SA1586	2SC2712	2SA1162
	50	500					2SC3325	2SA1313
Low noise	120	100			2SC4117	2SA1587	2SC2713	2SA1163
High-current	50	1700				2SA2195*		

◆Return to Block Diagram TOP

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

RN1114 / RN2114 / RN1414 / RN2414 series

Robustness | High efficiency · Low loss | Small size package

Value provided

Extensive product lineup to meet all your needs.

1 Built-in bias resistor type (BRT)

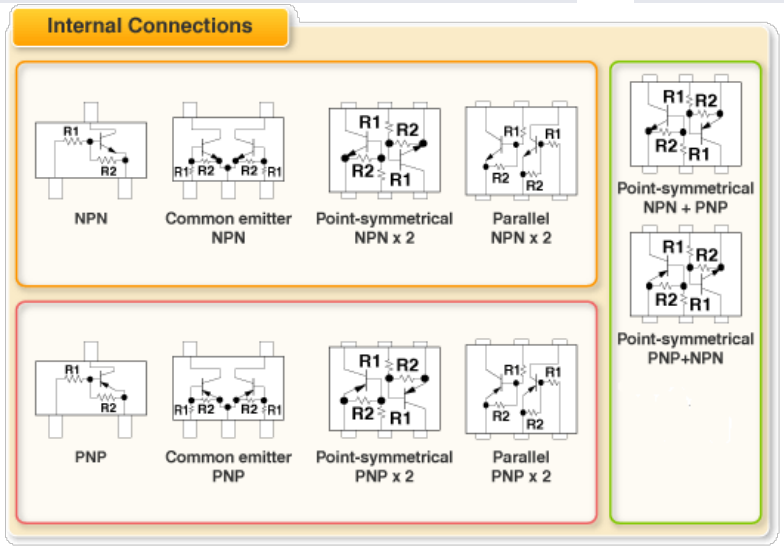
The BRT reduces the number of parts contributing to miniaturization and shorter production times.

2 Extensive lineup of package and pin assignment

Various package lineups, such as 1in1, 2in1 are provided and suitable product for circuit board design can be selected.

3 AEC-Q101 qualified

AEC-Q101 qualified and can be used for a wide range of automotive applications.



Line up

Part number		NPN (BRT)	PNP (BRT)
Package	SSM (SOT-416) 	RN1114	RN2114
	S-Mini (SOT-346) 	RN1414	RN2414
V_{CEO} (Max) [V]		50	-50
I_C [mA]		100	-100

◆Return to Block Diagram TOP

11 One-gate logic (L-MOS)

TC7SH / TC7WH / TC7SZ / TC7WZ series

Robustness | High efficiency · Low loss | Small size package

Value provided

Extensive product lineup to meet all your needs.

1 Small package

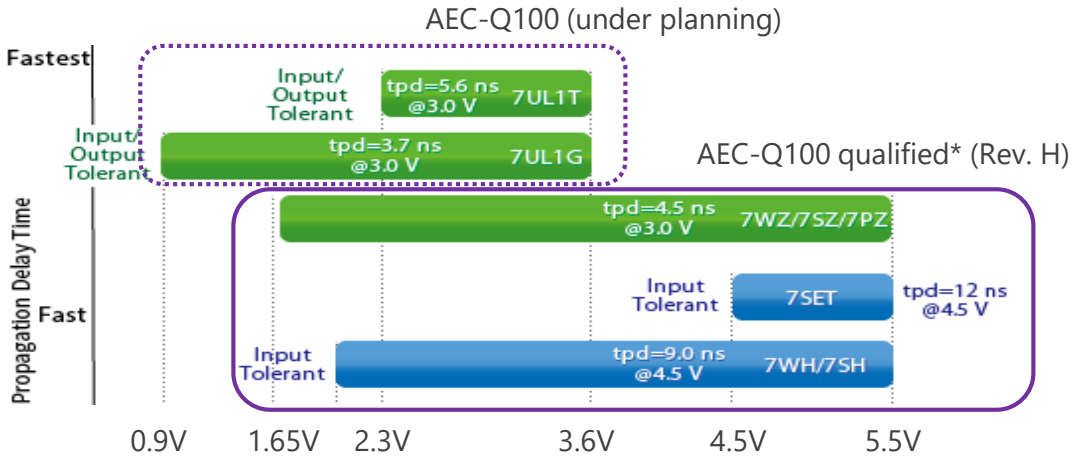
A standard multi gate CMOS is separated into individual or dual gates and embedded in a small package. This can be suited for simpler designs and contributes to miniaturization.

2 Extensive lineup

The VHS/SHS series, which is widely used in Automotive, offers a wide range of functions, including a total of 230 products.

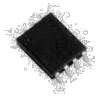
3 AEC-Q100 qualified (reliability levels)

AEC-Q100 qualified and can be used for a wide range of automotive applications.



* Compliant products with AEC-Q100's reliability test only

Line up

		VHS series	SHS series
Package	USV (SOT-353) 	TC7SH series	TC7SZ series
	US8 (SOT-765) 	TC7WH Series	TC7WZ series
V_{CC} [V]		2.0 ~ 5.5	1.65/1.8 ~ 5.5
Io[mA]		8	24

◆Return to Block Diagram TOP

12a Power supply IC (for MCU)

TB9005FNG

Robustness | High efficiency · Low loss | Small size package

Value provided

5V Regulator with low current consumption for automotive MCU. Built-in WDT and various abnormality detection circuits.

1 5V Regulator with low current consumption

5V Regulator with low current consumption used external Tr. for automotive MCU. Output voltage accuracy is +/- 2%.

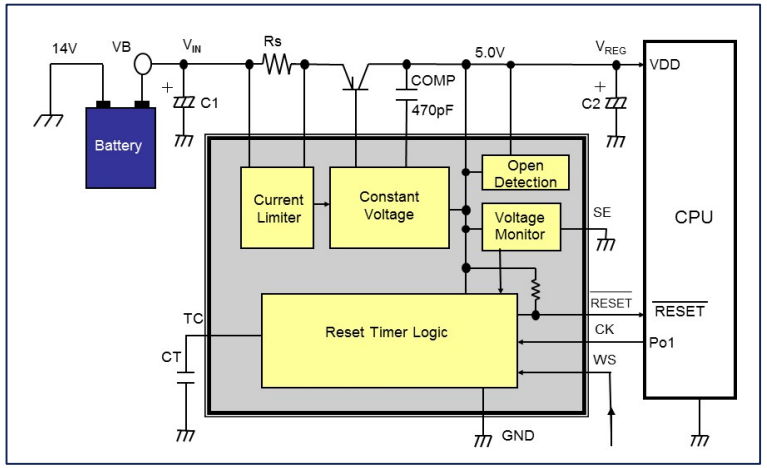
2 Current limitation value is adjustable

Load current is monitored by the external resistor, so current limitation value is adjustable by changing the resistor value.

3 Built-in WDT and various error detections.

MCU condition is monitored by using WDT. Implemented various abnormality detection circuits (UV detection, Current limitation etc.) contribute a system safety.

TB9005FNG Series Block Diagram



Line up

Part number		TB9005FNG
Package		SSOP20 
Package body size		6.4 x 7.0mm
Function	Number of outputs	1
	Output Current I_{OUT}(MAX)	Depends on External Tr.
	WDT, Overheat detection ,Overcurrent limitation	○

◆Return to Block Diagram TOP

12b Power supply IC (for MCU)

TB9021FNG

Robustness | High efficiency · Low loss | Small size package

Value provided

5V Regulator with low current consumption for automotive MCU. Built-in WDT and various abnormality detection circuits

1 5V Regulator with low current consumption

5V Regulator with low current consumption used Built-in Tr. for automotive MCU. Output voltage accuracy is +/- 2%.

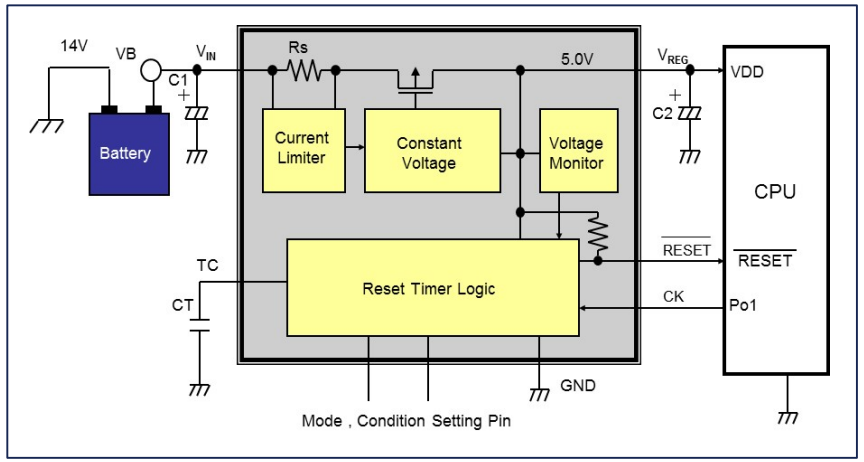
2 Built-in WDT and various error detections.

MCU condition is monitored by using WDT. Implemented various abnormality detection circuits (UV detection, Current limitation etc.) contribute a system safety.

3 AEC-Q100 qualified

It is compatible with the AEC-Q100 and can be used for a wide range of automotive applications.

TB9021FNG Series Block Diagram



Line up

Part number		TB9021FNG
Package		TSSOP16 
Package body size		5.0 x 6.4mm
Function	Number of outputs	1
	Output Current I_{OUT}(MAX)	200mA
	WDT, Overheat detection ,Overcurrent limitation	○

◆Return to Block Diagram TOP

12c Power Management IC(for MCU＋Tracker)

TB9044AFNG

Robustness | High efficiency・Low loss | Small size package

Value provided

Built-in high precision power supply for MCU, and various monitoring functions applies to functional safety.

1 Built-in high precision power supply for MCU

Built-in 5V LDO for MCU and 3ch Trackers for Sensors

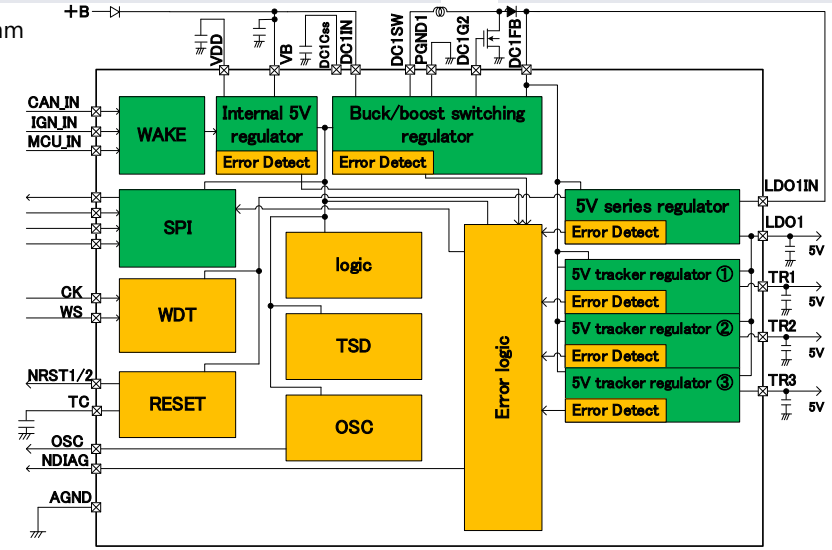
2 Functional safety(ASIL-D capable)

Built-in safety mechanism applies to functional safety, and abnormality detection functions and diagnostic functions for detection functions.

3 AEC-Q100 qualified

AEC-Q100 qualified and can be used for a wide range of automotive applications. We provide high-quality, highly reliable products.

TB9044AFNG Block Diagram



Line up

Part number		TB9044AFNG
Package		HTSSOP48 
Package body size		8.1 x 12.5mm
Function	Number of outputs	4
	Output Current I_{OUT}(MAX)	400mA/100mAx3
	WDT, Overheat detection ,Overcurrent detection	○
	Output Internal status	○

◆Return to Block Diagram TOP

Power Management IC(for MCU＋Tracker)

TB9045FNG Series

Robustness | High efficiency・Low loss | Small size package

Value provided

Built-in high precision power supply for MCU, and various monitoring functions applies to functional safety.

1 Built-in high precision power supply for MCU

Built-in 5V LDO for MCU and 3ch Trackers for Sensors. In addition, four types (1.1 / 1.2 / 1.25 / 1.5V) are available as MCU core power supplies.

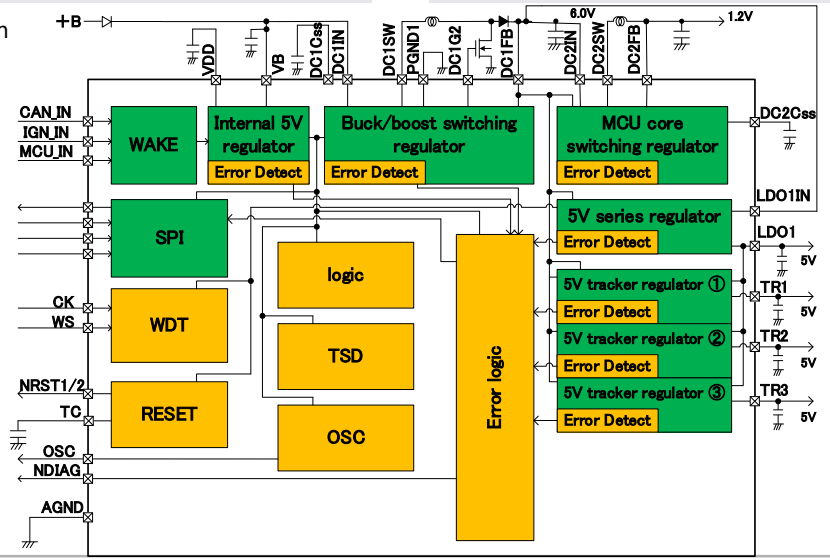
2 Functional safety(ASIL-D capable)

Built-in safety mechanism applies to functional safety, and abnormality detection functions and diagnostic functions for detection functions.

3 AEC-Q100 qualified

AEC-Q100 qualified and can be used for a wide range of automotive applications. We provide high-quality, highly reliable products.

TB9045FNG Series Block Diagram



Line up

Part number		TB9045FNG Series
Package		HTSSOP48 
Package body size		8.1 x 12.5mm
Function	Number of outputs	5
	Output Current I_{OUT}(MAX)	400mA/800mA/100mAx3
	WDT, Overheat detection ,Overcurrent detection	○

◆Return to Block Diagram TOP

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