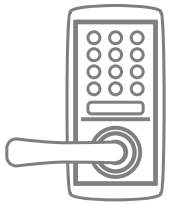
TOSHIBA

R22

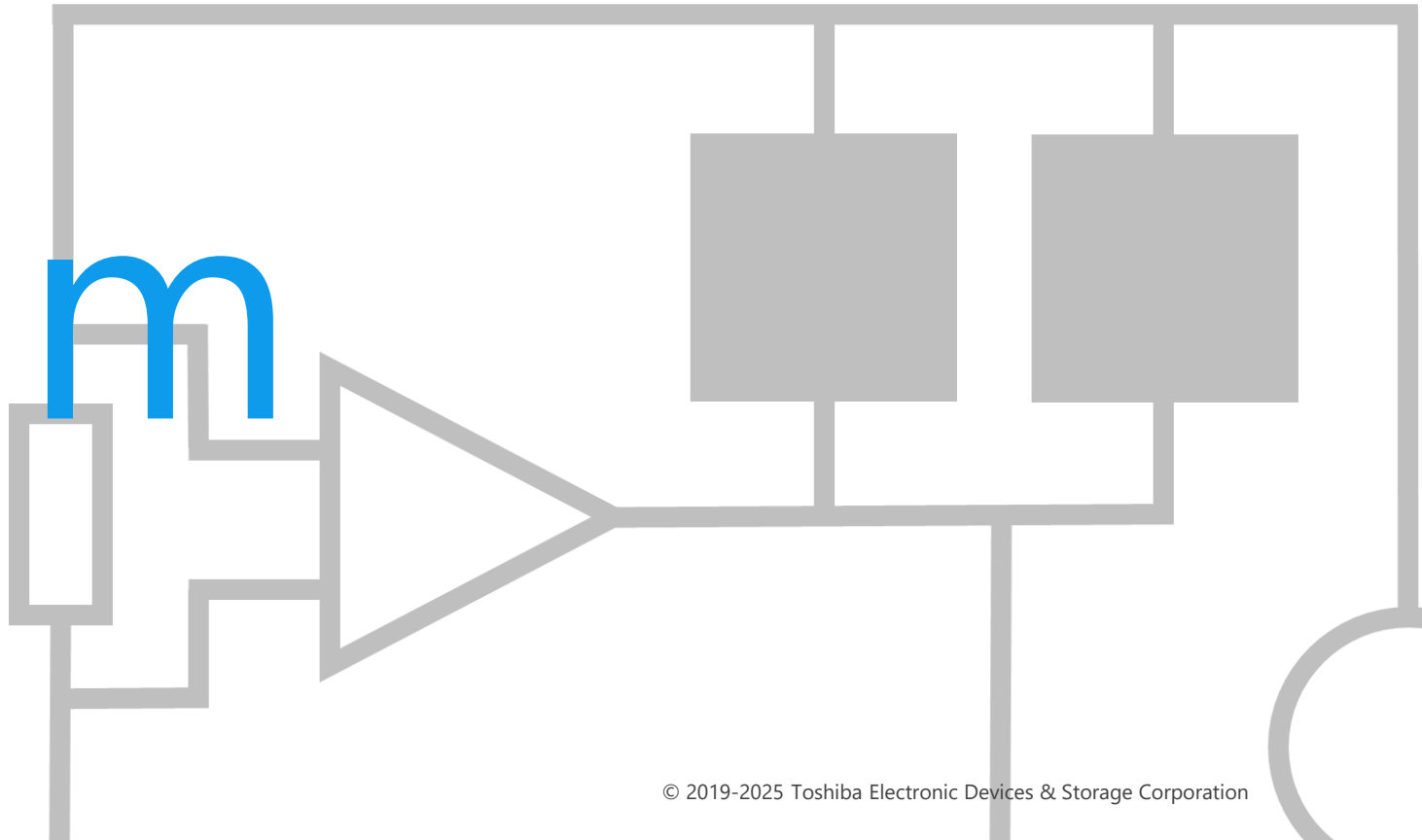
Thermostat

Solution Proposal by Toshiba

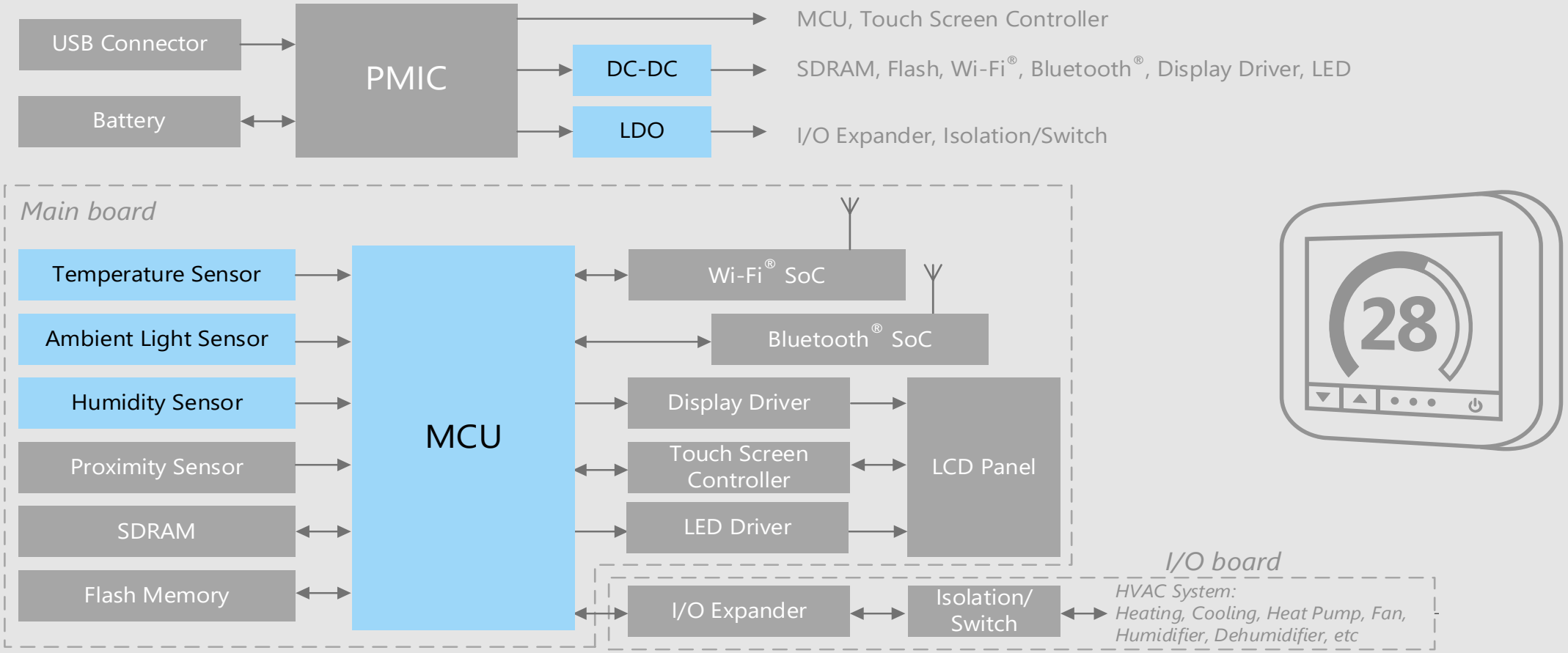


Toshiba Electronic Devices & Storage Corporation provides comprehensive device solutions to customers developing new products by applying its thorough understanding of the systems acquired through the analysis of basic product designs.

Block Diagram

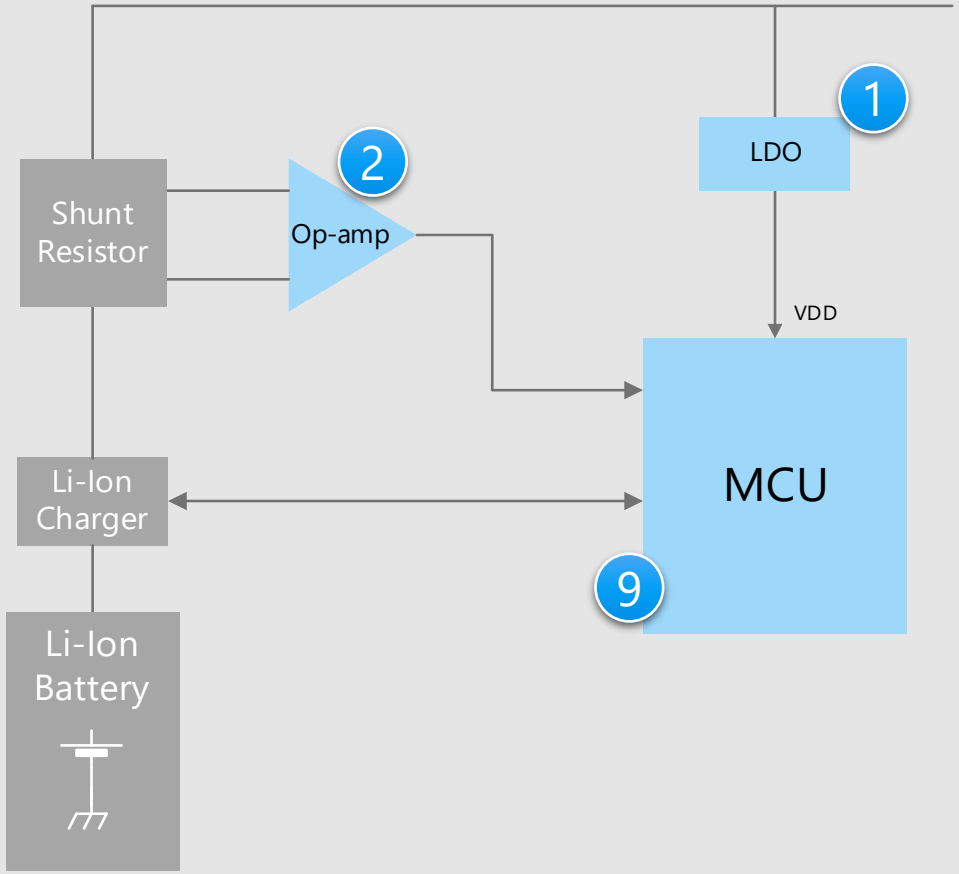


Thermostat　Overall block diagram



Thermostat　Detail of power supply unit (1)

Power supply circuit (1)



* Click the number in the circuit diagram to jump to the detailed description page

Criteria for device selection

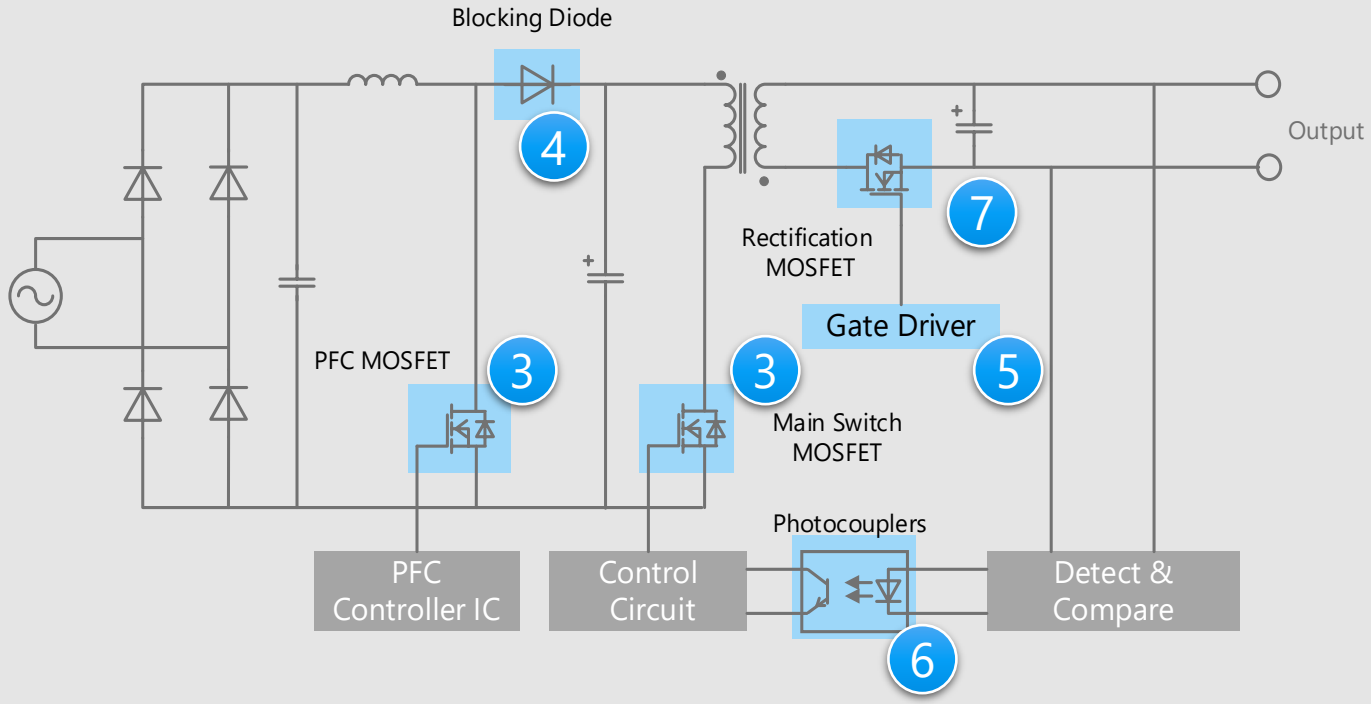
- PSRR (Power Supply Rejection Ratio) of LDO regulator is an important parameter for sensor modules.
- Small package products contribute to the reduction of circuit board area.
- The operational amplifier should be low current consumption or low noise device.

Proposals from Toshiba

- **Supply the power with low noise**
  Small surface mount LDO regulator 1
- **Amplification of detected very small signal with low noise**
  Low current consumption op-amp / Low noise op-amp 2
- **Built-in analog input interface at low power consumption and efficient software development**
  MCU 9

Thermostat　Detail of power supply unit (2)

Power supply circuit (2)



* Click the number in the circuit diagram to jump to the detailed description page

Criteria for device selection

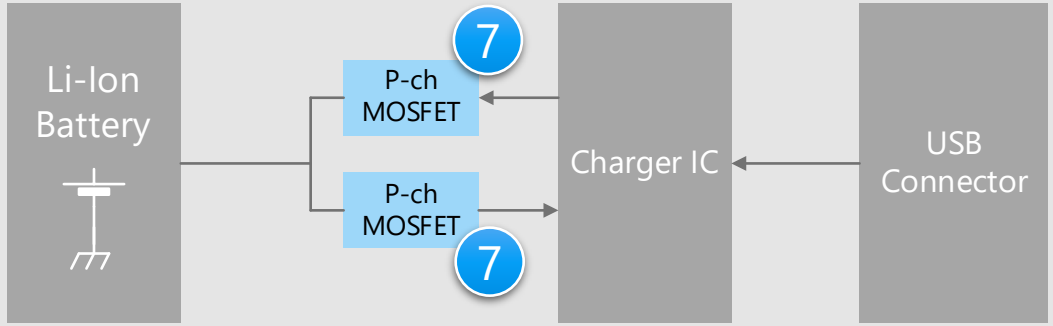
- The transistor output photocoupler is for signal isolation.
- Low power consumption can be realized by using a MOSFET with low on-resistance and high heat dissipation efficiency.
- Small package products contribute to the reduction of circuit board area.

Proposals from Toshiba

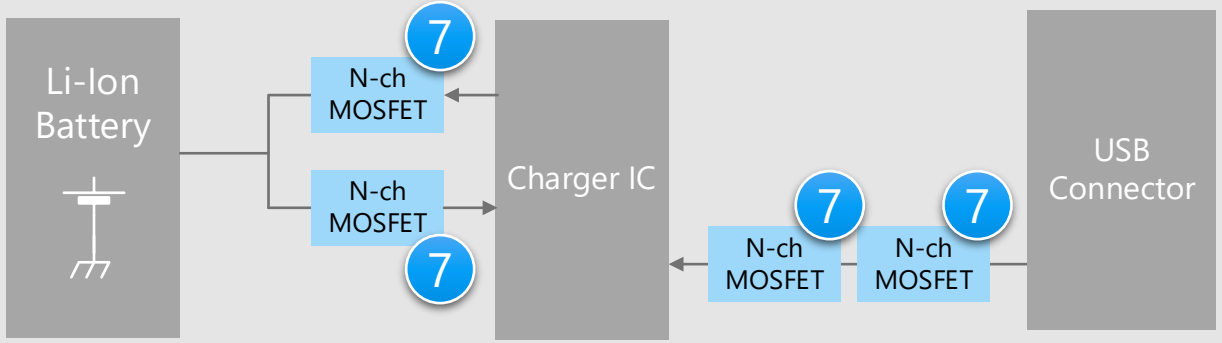
- **MOSFET with low on-resistance and high heat dissipation**
  High voltage MOSFET 3
- **Contributing to higher efficiency and miniaturization of power supply**
  SiC Schottky barrier diode 4
- **Suitable for MOSFET gate control**
  Bipolar transistor 5
- **High current transfer ratio and high temperature operation makes easy to design**
  Transistor output photocoupler 6
- **Realize a set with low power consumption by low on-resistance**
  Small signal MOSFET 7

Thermostat　Details of power supply unit (3)

Power supply circuit
P-ch MOSFET type



Power supply circuit
N-ch MOSFET type



* Click the number in the circuit diagram to jump to the detailed description page

Criteria for device selection

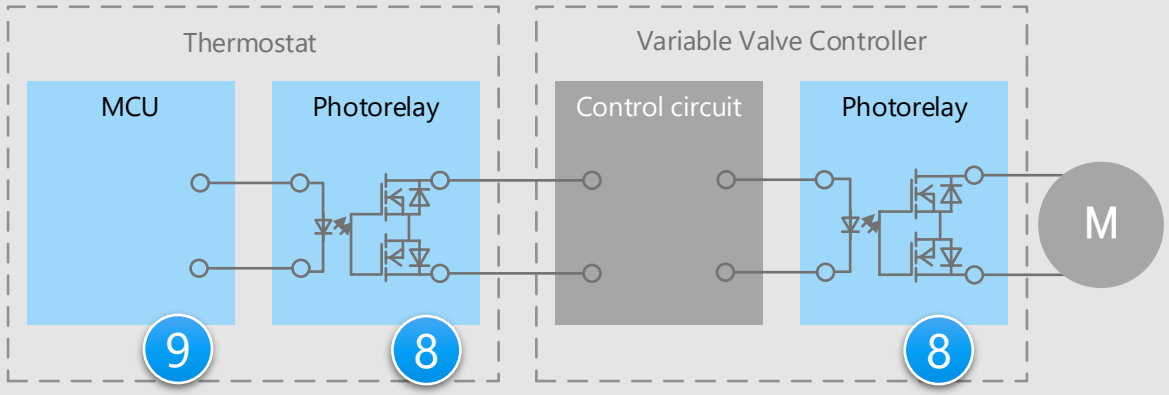
- Low power consumption can be realized by using MOSFETs with low on-resistance and high heat dissipation efficiency.
- Small package products contribute to the reduction of circuit board area.

Proposal from Toshiba

- **Realize a set with low power consumption by low on-resistance**
  Small signal MOSFET 7

Thermostat　Detail of isolation unit

Isolation circuit



* Click the number in the circuit diagram to jump to the detailed description page

Criteria for device selection

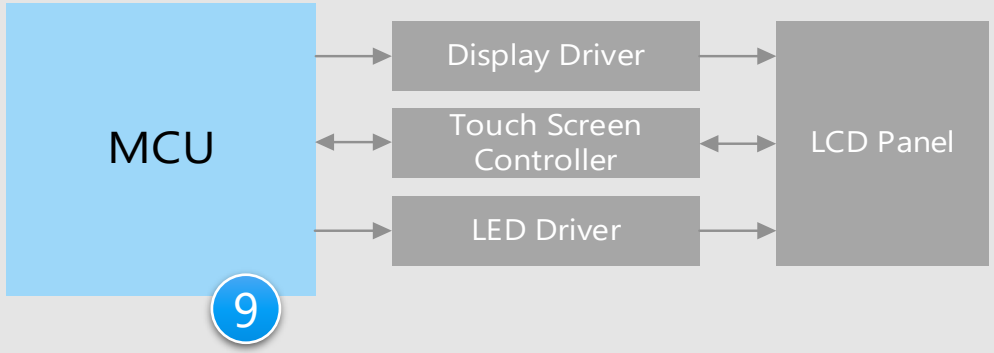
- The use of photorelays instead of mechanical relays eliminates the life limitation caused by contact wear and welding at the contact points, enabling long life and quieter operation.
- Small package products contribute to the reduction of circuit board area.

Proposals from Toshiba

- **Suitable for replacing mechanical relays**
  Photorelay 8
- **Built-in analog input interface at low power consumption and efficient software development**
  MCU 9

Thermostat　Detail of display unit

Panel display circuit



* Click the number in the circuit diagram to jump to the detailed description page

Criteria for device selection

- Data processing of various sensing data and feedback control of a system within very short time period.

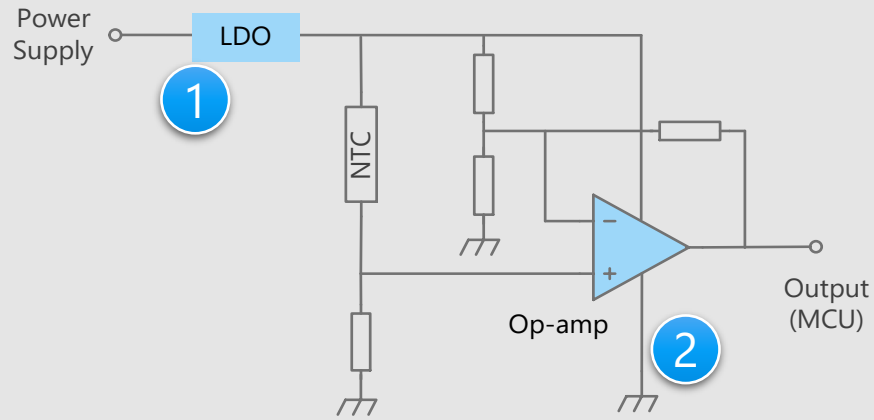
Proposal from Toshiba

- **Built-in analog input interface at low power consumption and efficient software development**
  MCU

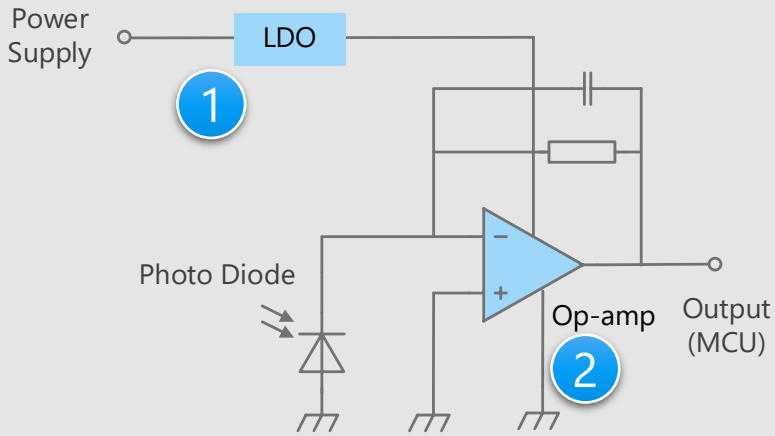
9

Thermostat　Details of sensor signal input unit (1)

Temperature sensor circuit



Ambient light sensor circuit



* Click the number in the circuit diagram to jump to the detailed description page

Criteria for device selection

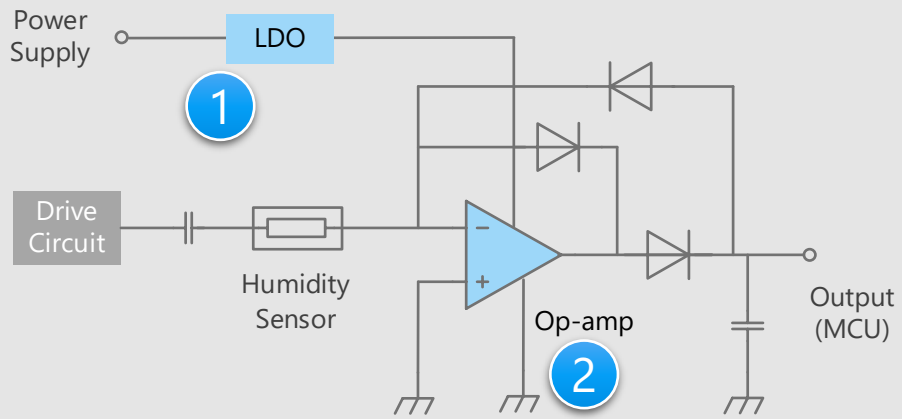
- PSRR (Power Supply Rejection Ratio) of LDO regulator is an important parameter for sensor modules.
- The operational amplifier should be low current consumption or low noise device.
- Small package products contribute to the reduction of circuit board area.

Proposals from Toshiba

- **Supply the power with low noise**
  Small surface mount LDO regulator　1
- **Amplification of detected very small signal with low noise**
  Low current consumption op-amp / Low noise op-amp　2

Thermostat　Detail of sensor signal input unit (2)

Humidity sensor circuit



Criteria for device selection

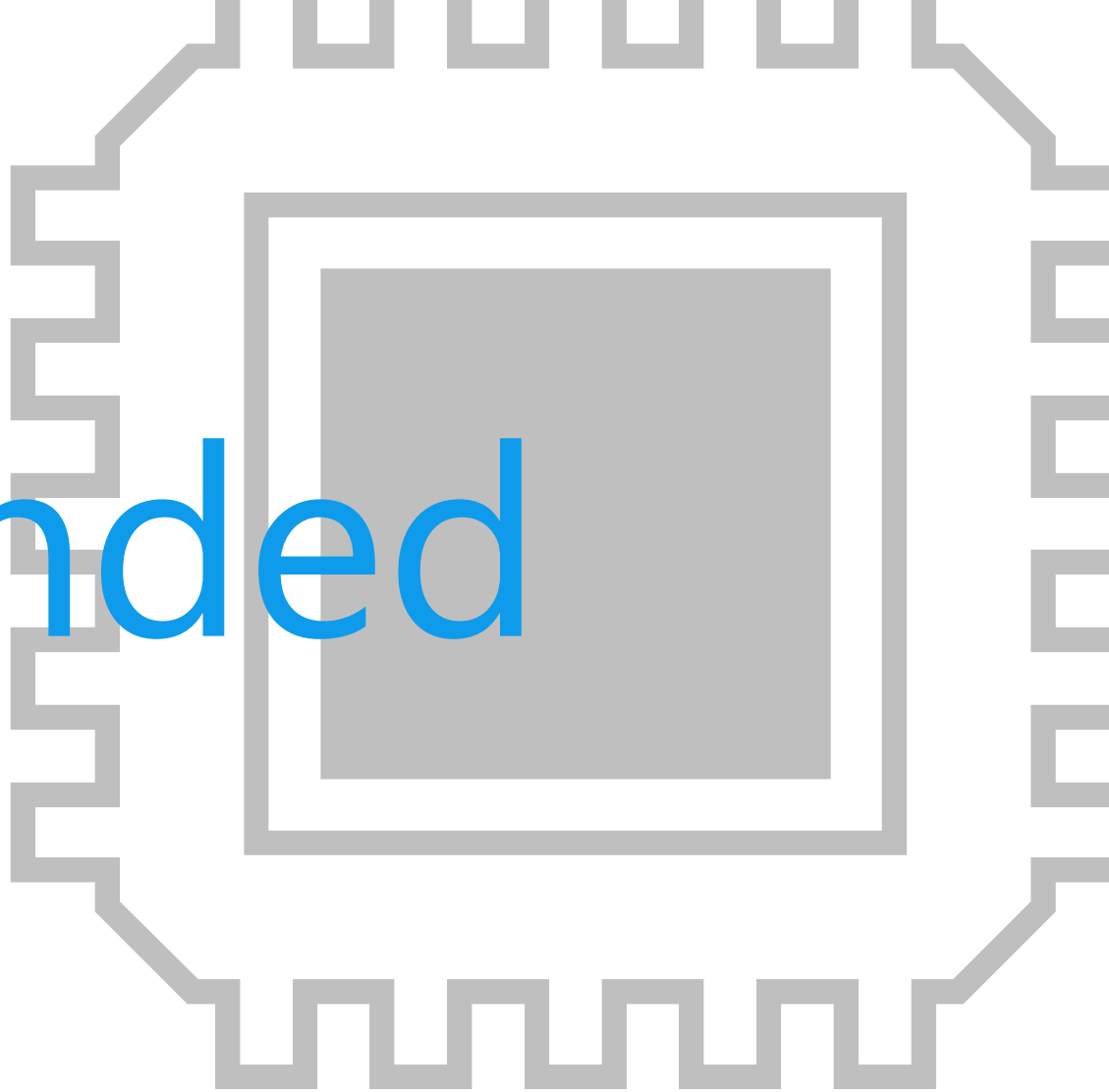
- PSRR (Power Supply Rejection Ratio) of LDO regulator is an important parameter for sensor modules.
- The operational amplifier should be low current consumption or low noise device.
- Small package products contribute to the reduction of circuit board area.

Proposals from Toshiba

- **Supply the power with low noise**
  Small surface mount LDO regulator　1
- **Amplification of detected very small signal with low noise**
  Low current consumption op-amp / Low noise op-amp　2

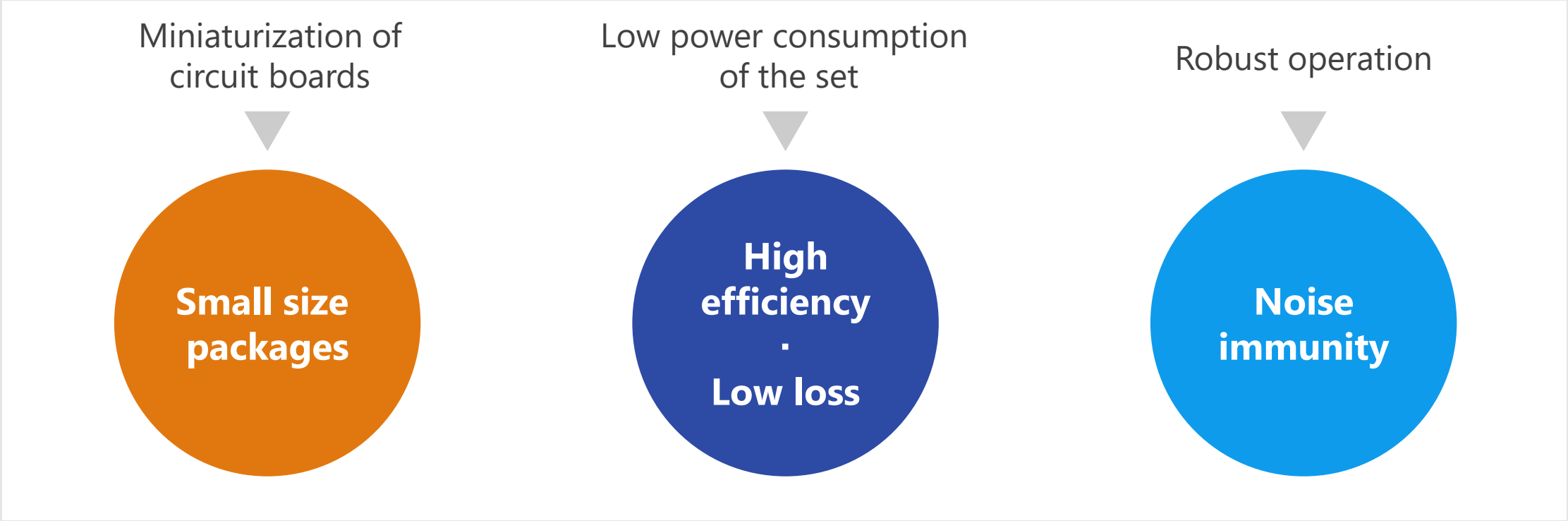
* Click the number in the circuit diagram to jump to the detailed description page

Recommended Devices



Device solutions to address customer needs

As described above, in the design of thermostat, **“Miniaturization of circuit boards“**, **“Low power consumption of the set”** and **“Robust operation”** are important factors. Toshiba’s proposals are based on these three solution perspectives.



Device solutions to address customer needs

		Small size packages	High efficiency · Low loss	Noise immunity
1	Small surface mount LDO regulator	●	●	●
2	Low current consumption op-amp / Low noise op-amp	●	●	
3	High voltage MOSFET	●	●	●
4	SiC Schottky barrier diode	●	●	●
5	Bipolar transistor	●	●	
6	Transistor output photocoupler	●	●	●
7	Small signal MOSFET	●	●	
8	Photorelay	●	●	●
9	MCU	●	●	

1 Small surface mount LDO regulator

TCR15AG / TCR8BM / TCR5FM / TCR5RG / TCR3RM / TCR3U / TCR3LM / TCR3D / TCR3EM / TCR1HF Series

Small size packages | High efficiency · Low loss | Noise immunity

Value provided

Wide lineup from general purpose type to WCSP (Wafer Level Chip Size Package) type are provided. Contribute to realize a stable power supply.

1 Low dropout voltage

Low dropout voltage characteristic has been realized by the originally developed process.

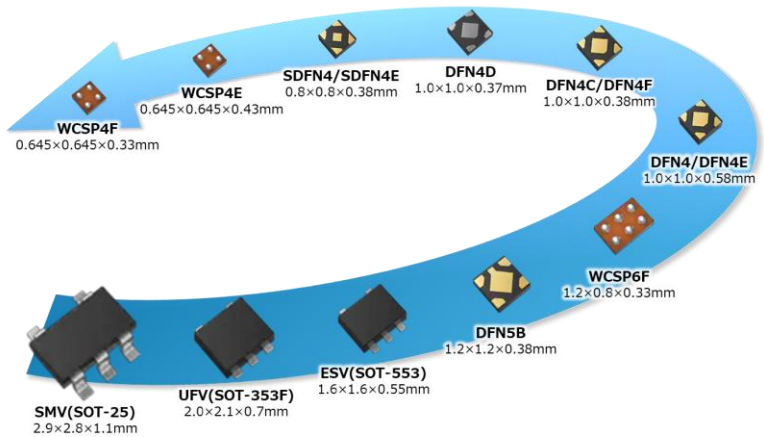
2 High PSRR Low output noise voltage

Many product series that realize both high PSRR (Power Supply Rejection Ratio) and low output noise voltage characteristics are provided. They are suitable for stable power supply for analog circuit.

3 Low current consumption

0.34 μA of $I_{B(ON)}$ is realized by utilizing CMOS process and unique circuit technology.
(TCR3U Series)

Rich package lineup



Lineup

Part number	TCR15AG Series	TCR8BM Series	TCR5FM Series	TCR5RG Series	TCR3RM Series	TCR3U Series	TCR3LM Series	TCR3D Series	TCR3EM Series	TCR1HF Series
Features	Low dropout voltage High PSRR		High PSRR Low noise Low current consumption			Low current consumption		Standard type		36 V Input voltage
I_{OUT} (Max) [A]	1.5	0.8	0.5		0.3					0.15
PSRR (Typ.) [dB] @f = 1 kHz	95	98	91	100	100	70	-	72	68	70
I_B (Typ.) [μA]	25	20	10	7	7	0.34	1	86	35	170

◆Return to Block Diagram TOP

2 Low current consumption op-amp / Low noise op-amp

TC75S102F / TC75S67TU

Small size packages | High efficiency · Low loss | Noise immunity

Value provided

The lineup includes a low current consumption type that contributes to reducing power consumption and a low noise type that brings out performance of the sensor.

1 Low voltage operation

We have a lineup of low power supply voltage-driven operational amplifiers using CMOS process for low power supply voltage-driven circuit.

2 Low current consumption (TC75S102F) I_{DD} = 0.27 [µA] (Typ.)

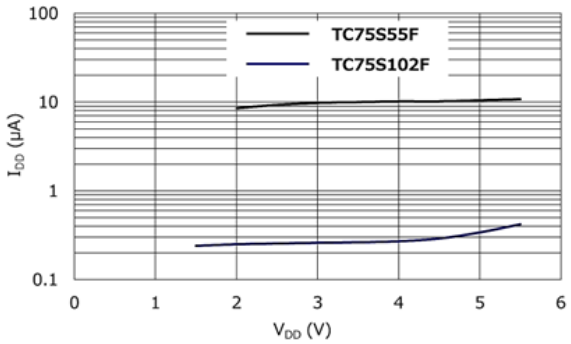
CMOS processes have been used to achieve lower current consumption. This contributes to lower power consumption of equipment.

3 Low noise (TC75S67TU) V_{NI} = 6.0 [nV/√Hz] (Typ.) @f = 1 kHz

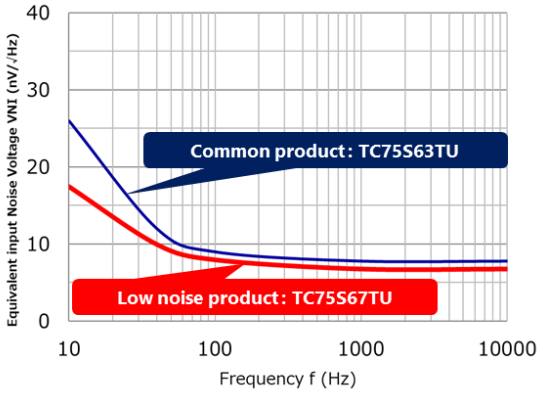
This CMOS operational amplifier can amplify minute signals detected by various sensors [Note] with very low noises. By optimizing the process, the equivalent input noise voltage has been reduced.

[Note] Sensor types: vibration, shock, acceleration, pressure, infrared, temperature, etc.

TC75S102F
Current Consumption Characteristic
(Toshiba internal comparison)



TC75S67TU
Noise Characteristic
(Toshiba internal comparison)



Lineup

Part number	TC75S102F	TC75S67TU
Package	SMV 	UFV 
V_{DD} - V_{SS} [V]	1.5 to 5.5	2.2 to 5.5
V_{IO} (Max) [mV]	1.3	3
CMV_{IN} (Max) [V]	V_{DD}	1.4 (@V_{DD} = 2.5 V)
I_{DD} (Typ. / Max) [µA]	0.27 / 0.46 (@V_{DD} = 1.5 V)	430 / 700 (@V_{DD} = 2.5 V)
V_{NI} (Typ.) [nV/√Hz] @f = 1 kHz	-	6

◆Return to Block Diagram TOP

3 High voltage MOSFET

TK18A50D / TK12P50W

Small size packages | High efficiency · Low loss | Noise immunity

Value provided

These MOSFETs are suitable for switching regulators and is easy to handle and contribute to miniaturization.

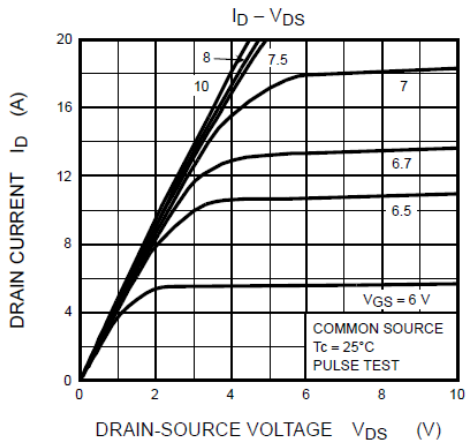
1 Low on-resistance

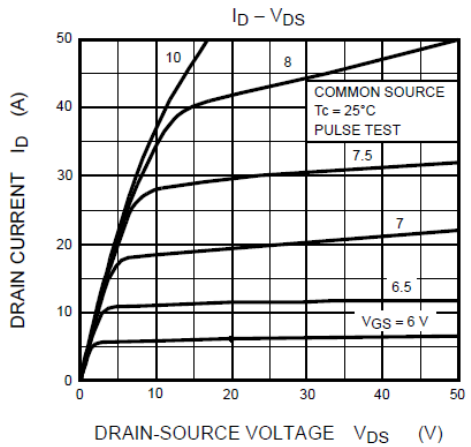
By keeping the on-resistance between the drain and source low, heat generation and power consumption can be kept low.

2 Low leakage current

Drain cut-off current: I_{DSS} = 10 μA (Max) @V_{DS} = 500 V

TK18A50D Characteristics





Lineup

Part number	TK18A50D	TK12P50W
Package	TO-220SIS 	DPAK 
V_{DSS} [V]	500	500
I_D [A]	18	11.5
P_D [W]	50	100
$R_{DS(ON)}$ (Max) [Ω]	0.27	0.34
Polarity	N-ch	N-ch

◆Return to Block Diagram TOP

4 SiC Schottky barrier diode

TRS24N65FB / TRS2E65H / TRS8E65H / TRS12E65H / TRS4V65H / TRS12V65H

Small size packages | High efficiency · Low loss | Noise immunity

Value provided

SiC SBDs [Note1] with low loss and high efficiency are realized by adopting new metal and optimizing device design.

[Note1] SBD: Schottky barrier diode

1 Low forward voltage (V_F)

For Toshiba's third generation products, new metal and thin wafer technology are introduced. V_F = 1.2 V (Typ.) is realized as compared with V_F = 1.45 V (Typ.) of Toshiba's existing products. V_F is reduced by about 17%.

2 Improvement of power supply efficiency

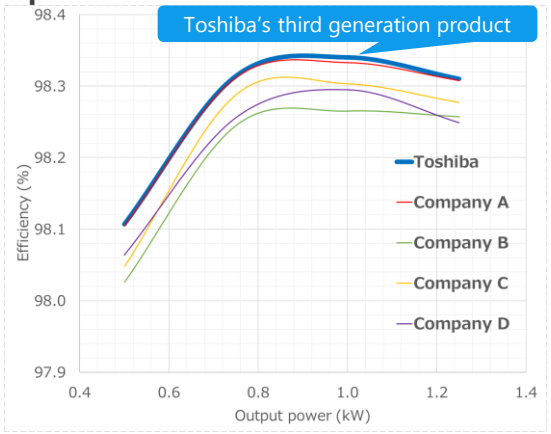
Compared with Toshiba's existing products, the trade off of V_F x Q_C [Note2] of Toshiba's third generation products have improved. About 0.1% of conversion efficiency improvement have also achieved under 800 W output condition in our test.

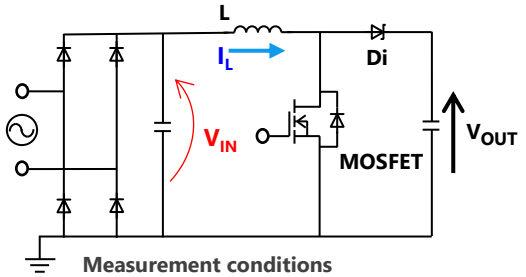
3 Expansion of package series

In addition to the existing package series, DFN8x8 surface mount package type has prepared. It contributes to miniaturization and high power density of equipment.

[Note2] The V_F x Q_c (product of forward voltage and total charge) is an index representing the loss performance of the SiC SBD. When comparing the products with the same current rating, the smaller the index, the lower the loss.

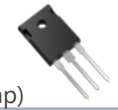
Comparison between Toshiba's third generation product and competitor products





Measurement conditions
V_{IN} = 200 V AC
V_{OUT} = 400 V DC
f = 65 kHz
MOSFET: TK040Z65Z
MOSFET external gate resistance = 4.7 Ω
T_a = 25 °C (Toshiba internal comparison, as of July 2023)

Lineup

Part number	TRS24N65FB	TRS2E65H	TRS8E65H	TRS12E65H	TRS4V65H	TRS12V65H
Package	TO-247 (Center tap) 	TO-220-2L 			DFN8x8 	
V_{RRM} [V]	650	650	650	650	650	650
$I_{F(DC)}$ [A]	12 / 24 *	2	8	12	4	12
I_{FSM} [A]	92 / 184 *	19	56	74	28	60
V_F (Typ.) [V]	1.45 @I_F = 12 A	1.2 @I_F = 2 A	1.2 @I_F = 8 A	1.2 @I_F = 12 A	1.2 @I_F = 4 A	1.2 @I_F = 12 A

*: Per Leg / Both Legs

◆Return to Block Diagram TOP

5 Bipolar transistor

HN4B101J / HN4B102J

Small size packages | High efficiency · Low loss | Noise immunity

Value provided

Bipolar transistor suitable for MOSFET gate driving.

1 High speed switching

HN4B101J

t_f = 45 / 50 ns (Typ.) (PNP / NPN)

HN4B102J

t_f = 40 / 45 ns (Typ.) (PNP / NPN)

2 High DC current gain

HN4B101J, HN4B102J

PNP: h_{FE} = 200 to 500

NPN: h_{FE} = 200 to 500

3 Low collector-emitter saturation voltage

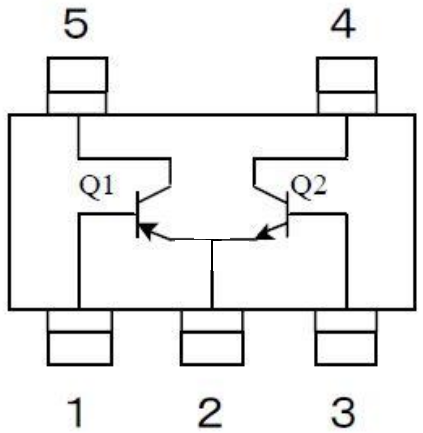
HN4B101J

$V_{CE(sat)}$ = -0.20 / 0.17 V (Max) (PNP / NPN)

HN4B102J

$V_{CE(sat)}$ = -0.20 / 0.14 V (Max) (PNP / NPN)

HN4B101J / HN4B102J
Circuit configuration



Lineup

Part number	HN4B101J	HN4B102J
Package	SMV 	SMV 
V_{CEO} [V] @Q1 / Q2	-30 / 30	-30 / 30
I_C [A] @Q1 / Q2	-1.0 / 1.2	-1.8 / 2
h_{FE} (Min / Max)	200 / 500	200 / 500
Polarity	Q1: PNP + Q2: NPN	Q1: PNP + Q2: NPN

◆Return to Block Diagram TOP

6 Transistor output photocoupler

TLP383 / TLP293 / TLP385

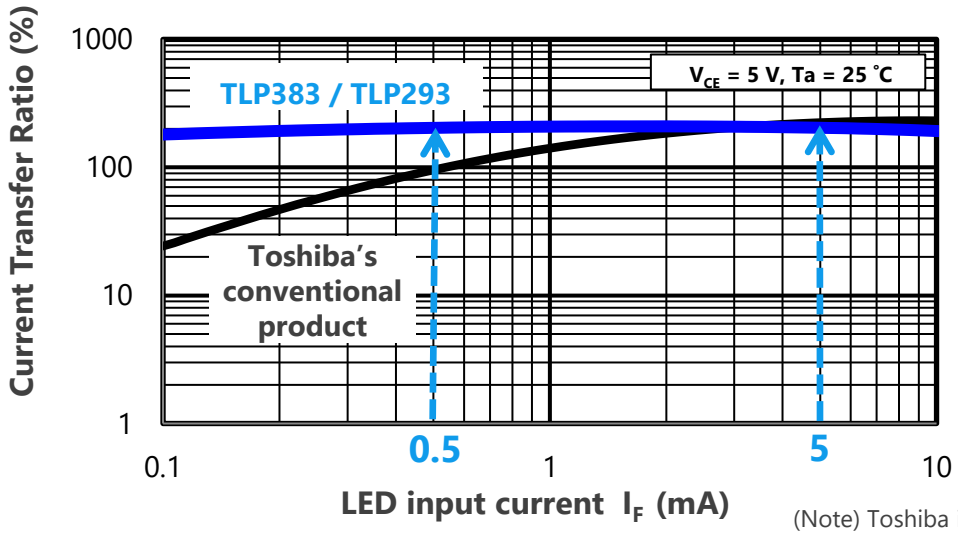
Small size packages | High efficiency · Low loss | Noise immunity

Value provided

High CTR (Current Transfer Ratio) is realized even in low input current range (I_F = 0.5 mA).

1 High current transfer ratio

The TLP383 and TLP293 are high isolation photocouplers that optically couples a phototransistor and high output infrared LED. Compared to Toshiba's conventional products (TLP385), higher CTR in low input current range (@I_F = 0.5 mA) is realized.



(Note) Toshiba internal comparison

2 High temperature operation

The TLP383 and TLP293 are designed to operate even under severe ambient temperature conditions.

Lineup

Part number	TLP383	TLP293	TLP385
Package	4pin SO6L 	SO4 	4pin SO6L 
BV_S [Vrms]	5000	3750	5000
T_{opr} [°C]	-55 to 125	-55 to 125	-55 to 110

◆Return to Block Diagram TOP

7 Small signal MOSFET

SSM6J501NU / SSM6J507NU / SSM6K518NU / SSM6K513NU / SSM6K514NU

Small size packages | High efficiency · Low loss | Noise immunity

Value provided

Suitable for power management switches and contributes to miniaturization.

1 Low voltage operation

Operates down to $|V_{GS}|$ = 1.5 V (SSM6J501NU, SSM6K518NU)

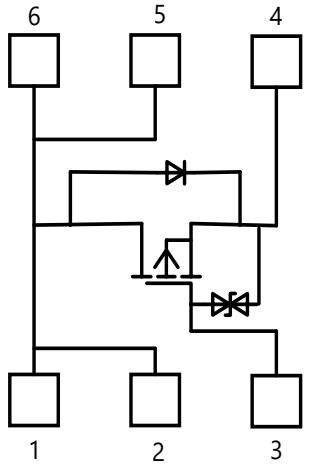
2 Low on-resistance

Heat generation and power dissipation can be kept low by keeping the on-resistance between the drain and source low.

3 Small package

UDFN6B type packages.

SSM6J501NU
Equivalent circuit diagram



Lineup

Part number	SSM6J501NU	SSM6J507NU	SSM6K518NU	SSM6K513NU	SSM6K514NU
Package	UDFN6B				
Polarity	P-ch	P-ch	N-ch	N-ch	N-ch
V_{DSS} [V]	-20	-30	20	30	40
I_D [A]	-10	-10	6	15	12
$R_{DS(ON)}$ (Max) [mΩ] @$\|V_{GS}\|$ = 4.5 V	15.3	28	33	12	17.3

◆Return to Block Diagram TOP

8 Photorelay

TLP3107A / TLP3109A / TLP3555A / TLP241B / TLP3823 / TLP3825

Small size packages | High efficiency · Low loss | Noise immunity

Value provided

Photorelay consists of an infrared light emitting diode optically coupled to a photo-MOSFET and is suitable for replacing mechanical relay.

1 Low on-resistance R_{ON}

On-resistance R_{ON} = 40 mΩ (Max)
(TLP3107A: A connection) [Note]

2 Wide current range I_{ON}

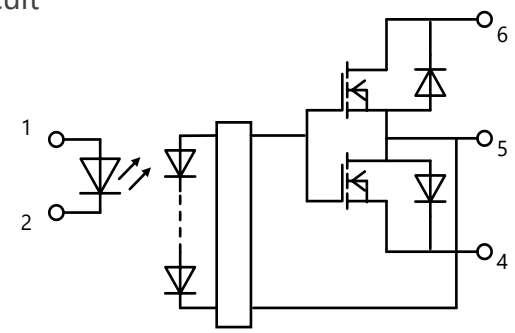
The range of on-state current I_{ON} is wide and suitable for power line control.
I_{ON} = 4.0 A (Max)
(TLP3107A: A connection) [Note]

3 Package

Packages to reduce the size of the set and improve the flexibility for design are provided.

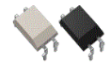
[Note] Please refer to the technical data sheet for connection.

TLP3107A
Internal equivalent circuit



Safety Standards
UL-recognized: UL 1577, File No.E67349

Lineup

Part number	TLP3107A	TLP3109A	TLP3555A	TLP241B	TLP3823	TLP3825
Package	2.54SOP6 		DIP4 		DIP8 	
I_{ON} [A]	4.0	3.0	3.0	2.0	3.0	1.5
V_{OFF} [V]	60	100	60	100	100	200
R_{ON} (Max) [mΩ]	40	65	100	200	150	500
BV_S [Vrms]	1500	1500	2500	5000	2500	2500

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Value provided

It contributes to system cost down, high efficiency system and development efficiency improvement.

1 Built-in Arm® Cortex®-M0 CPU core

Built-in Cortex-M0 core with Thumb® instruction set improves energy efficiency. Various development tool and their partners allow users many options.

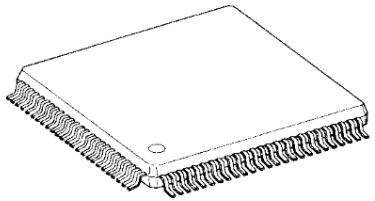
2 Suitable for sensing analog signal

Built-in multi-channel AD converter executes sensing data processing efficiently at low cost.

3 Small package and low power consumption

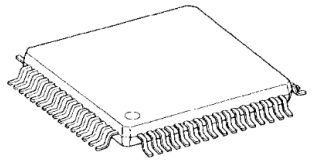
Cortex-M0 and Toshiba original NANOFLASH™ technology bring to the small package and low power consumption. They contribute to reduce circuit board area and power consumption reduction.

TMPM036FWFG



LQFP100-P-1414-0.50H

TMPM037FWUG



LQFP64-P-1010-0.50E

Lineup

Part number	TMPM036FWFG	TMPM037FWUG
Maximum operation frequency	20 MHz	20 MHz
Instruction ROM	128 KB	128 KB
RAM	16 KB	16 KB
Timer	14ch	10ch
UART / SIO	6	5
I^2C	2	1
AD converter	8ch (10bit)	8ch (10bit)

◆Return to Block Diagram TOP

Value provided

Built-in 50 % duty control function in UART, compatible with Home Bus System (HBS).

1 Built-in Arm® Cortex®-M3 CPU core

The product lineup is equipped with Arm Cortex-M3 core (maximum operation frequency of 120 MHz).
Various development tool and their partners allow users many options.

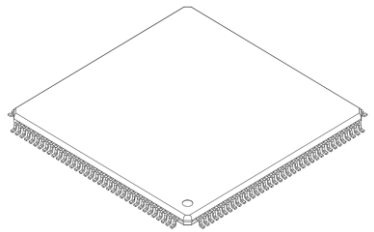
2 Compatible with HBS

UART function is equipped with 50 % duty control function and is compatible with HBS. A control system composed of HBS can be easily constructed using centralized management systems or thermostats.

3 Small package, low power consumption

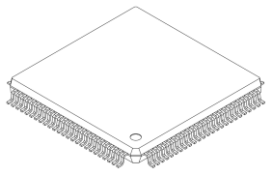
Several low power modes are available to support low power consumption.
Package lineup of LQFP144 from small LQFP64 is provided.

TMPM3HQF∗AFG



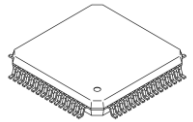
P-LQFP144-2020-0.50-002

TMPM3HNF∗AFG



P-LQFP100-1414-0.50-002

TMPM3HLF∗AUG



P-LQFP64-1010-0.50-003

Lineup

Part number	TMPM3HQFD/Z/Y/AFG	TMPM3HNFD/Z/Y/AFG TMPM3HNFD/Z/Y/ADFG	TMPM3HLFD/Z/Y/AUG
Operation frequency	120 MHz (Max)		
Code flash	512/384/256 KB		
RAM	66 KB (with parity)		
Timer	32bit x 8ch (16bit x 16ch)		
AD converter	21ch (12bit)	17ch (12bit)	12ch (12bit)
Serial communication	UART: 8ch, I^2C: 4ch, TSPI: 5ch	UART: 8ch, I^2C: 3ch, TSPI: 4ch	UART: 7ch, I^2C: 2ch, TSPI: 1ch
Package	P-LQFP144-2020-0.50-002	P-LQFP100-1414-0.50-002 P-QFP100-1420-0.65-001	P-LQFP64-1010-0.50-003

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