

Thermostat

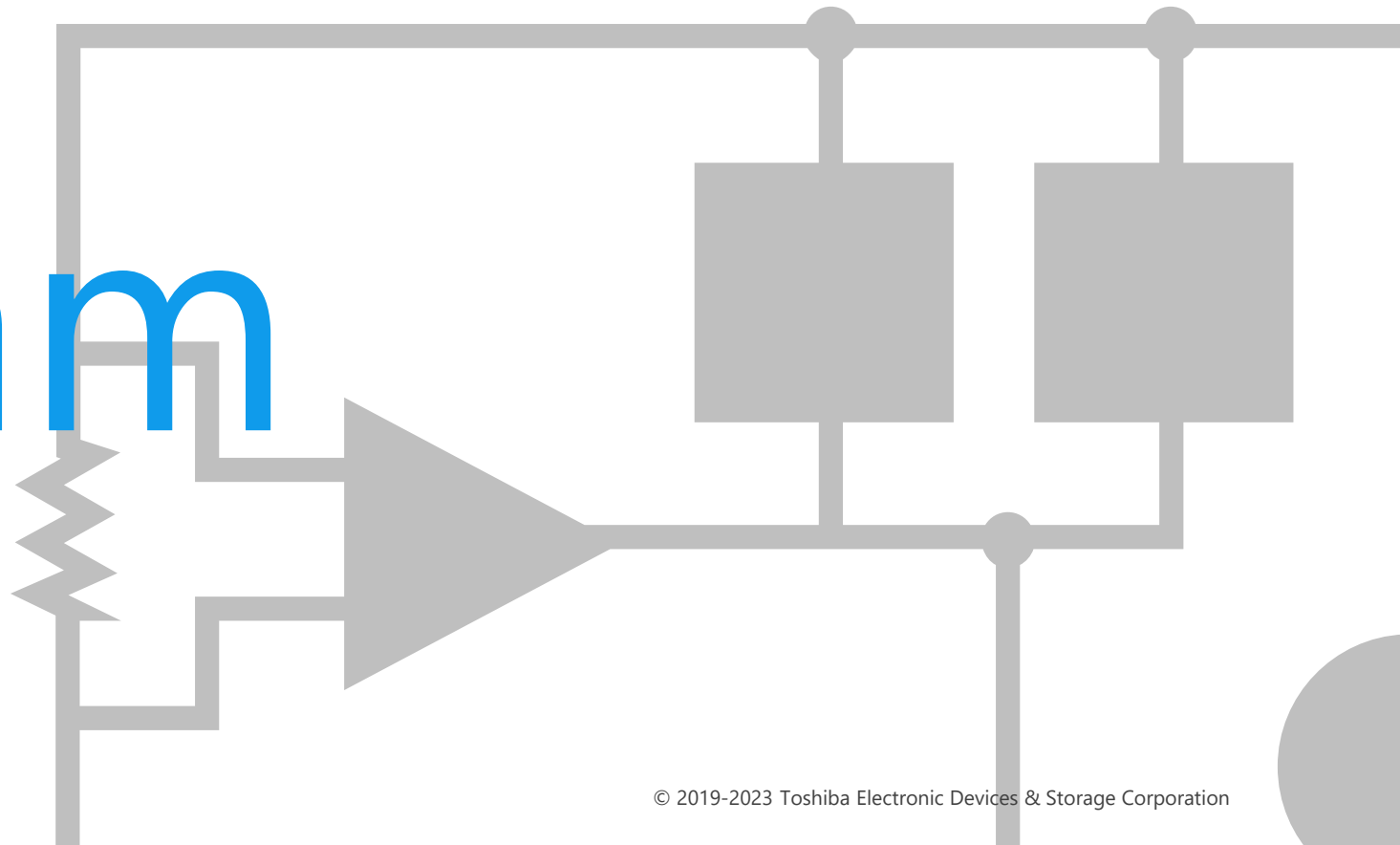
Solution Proposal by Toshiba



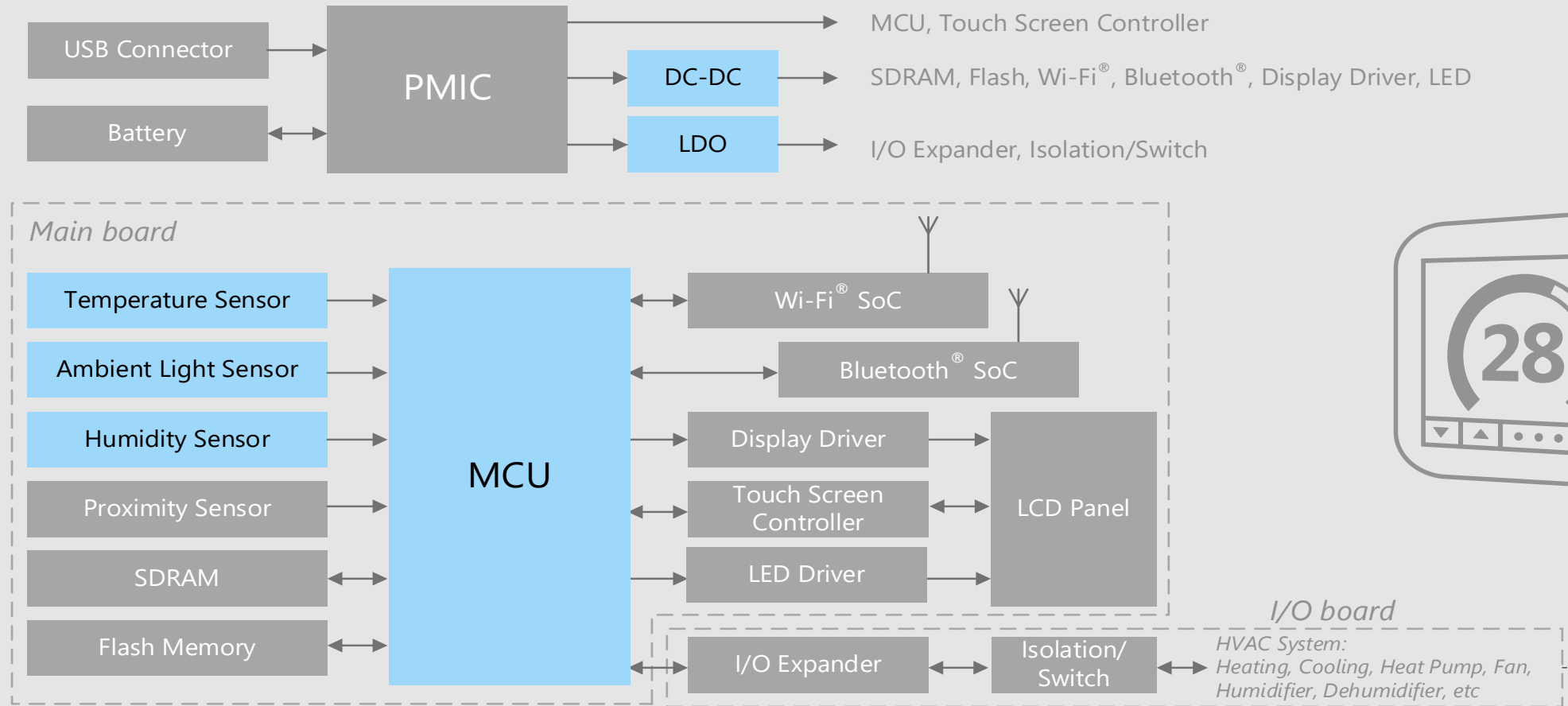


Toshiba Electronic Devices & Storage Corporation provides comprehensive device solutions to customers developing new products by applying its thorough understanding of the systems acquired through the analysis of basic product designs.

Block Diagram

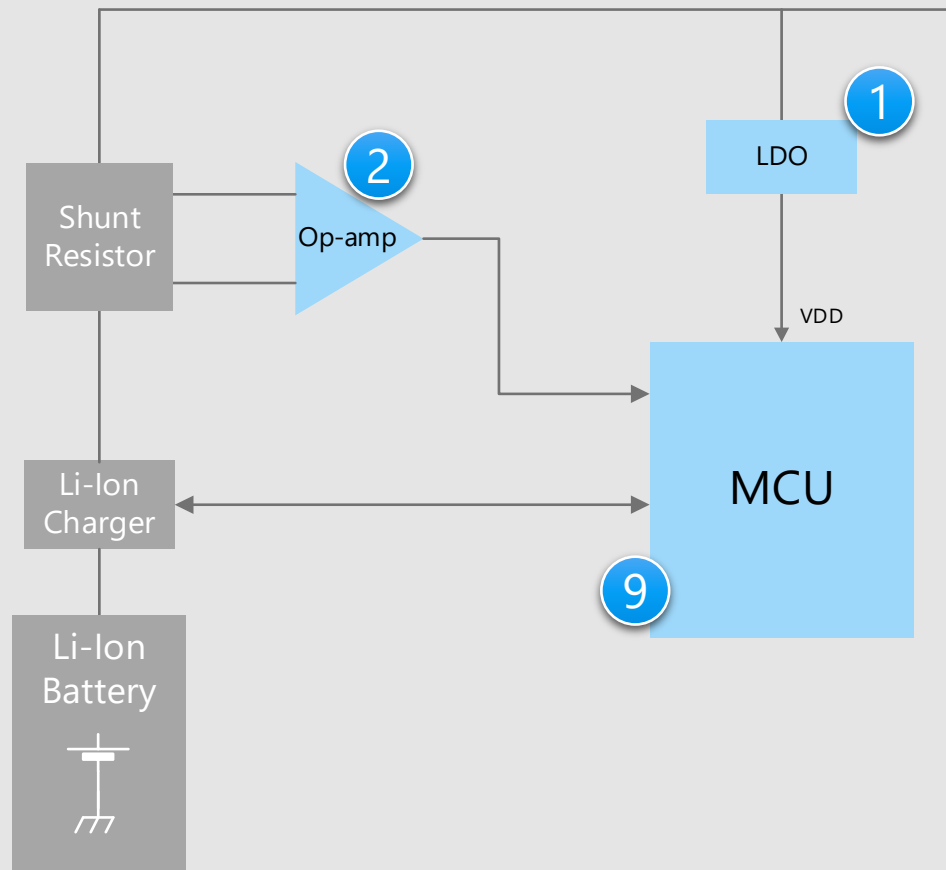


Thermostat Overall block diagram



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

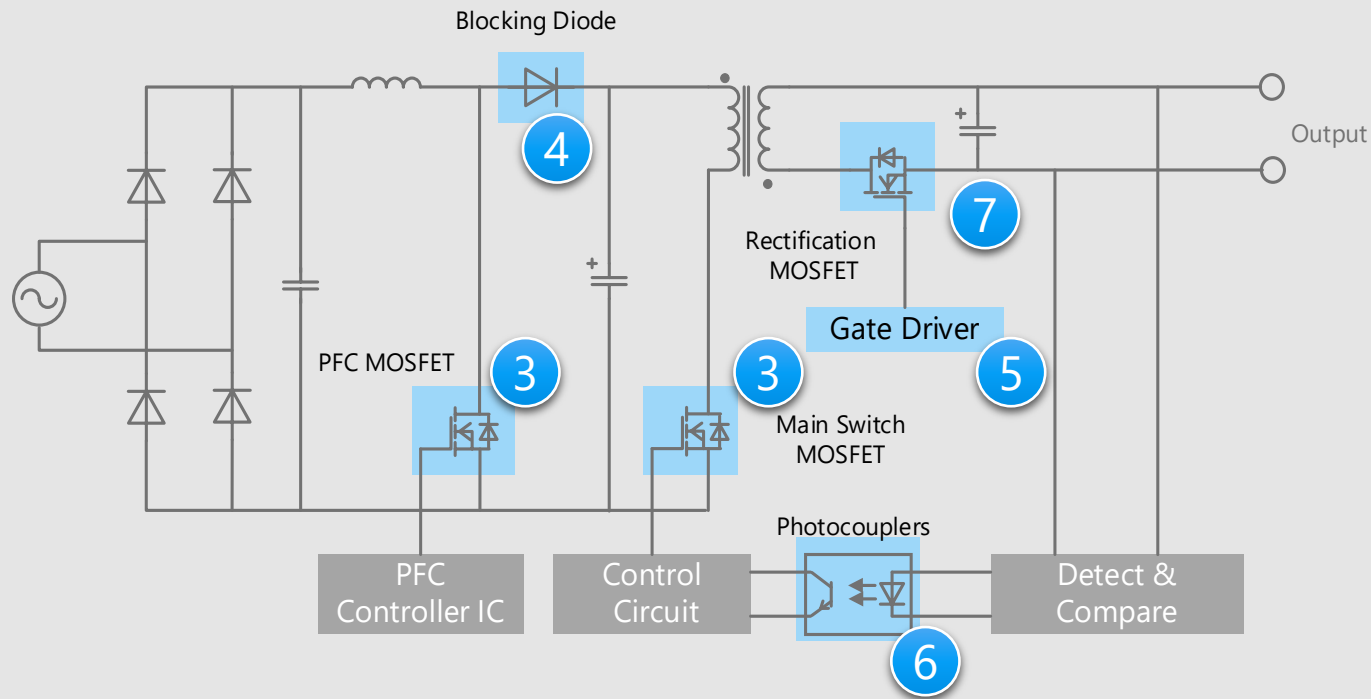
Criteria for device selection

- 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

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.

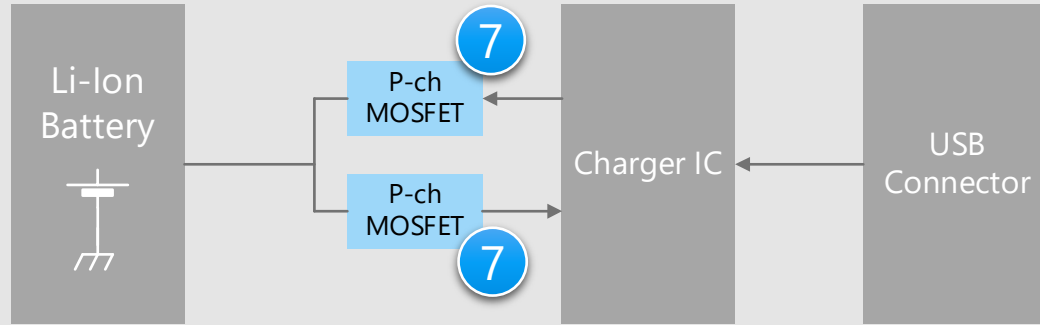
Proposals from Toshiba

- **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)

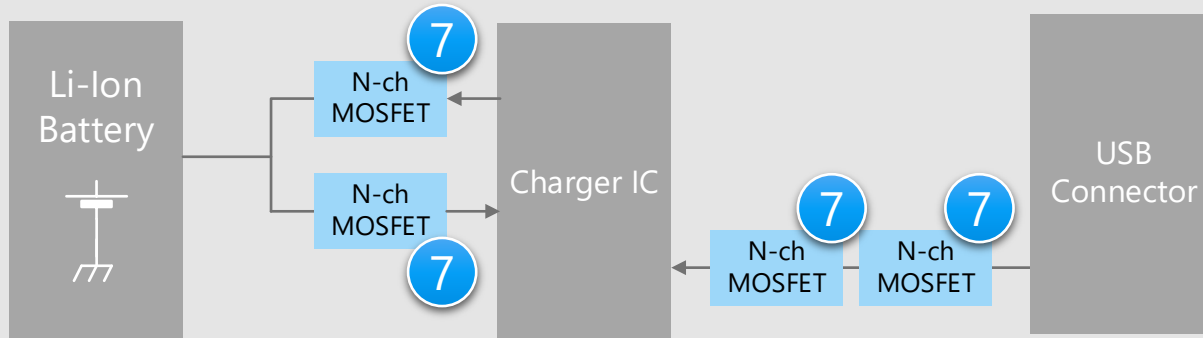
Power supply circuit

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.

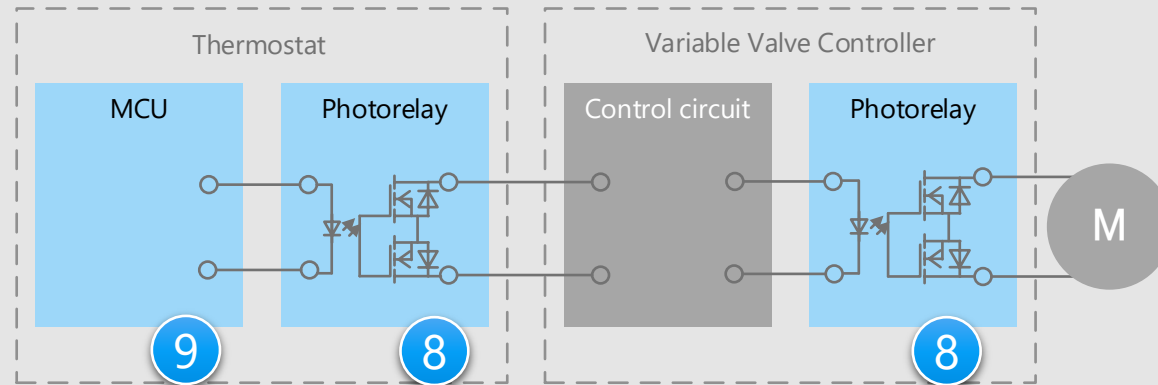
Proposal from Toshiba

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

7

Thermostat Detail of isolation unit

Isolation circuit



Criteria for device selection

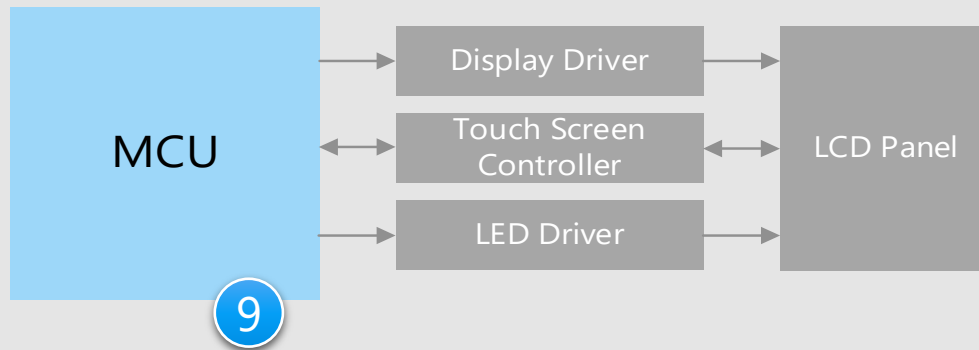
- The use of photorelays instead of mechanical relays eliminates the life limitation caused by contact wear and welding at the contact points, enabling long life and quieter operation.
- Small package products contribute to the reduction of circuit board area.

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)

* [Click the number in the circuit diagram to jump to the detailed description page](#)

Panel display circuit



Criteria for device selection

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

Proposal from Toshiba

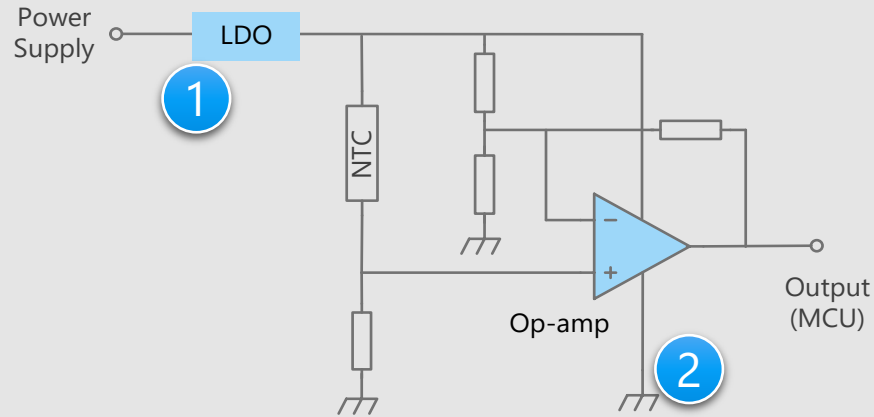
- **Built-in analog input interface at low power consumption and efficient software development**

MCU

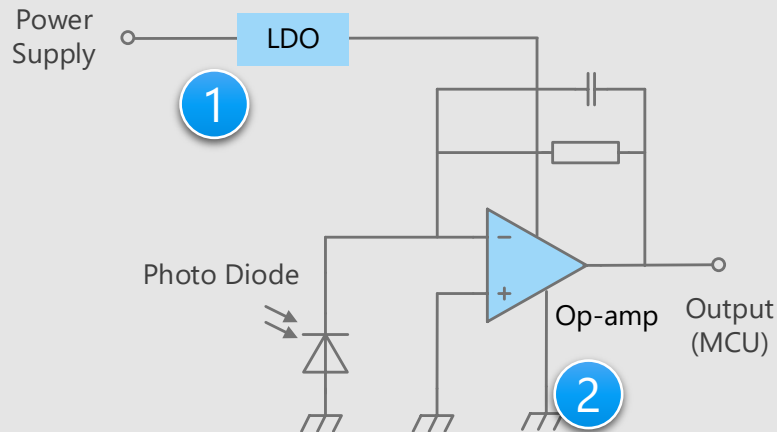
* Click the number in the circuit diagram to jump to the detailed description page

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](#)

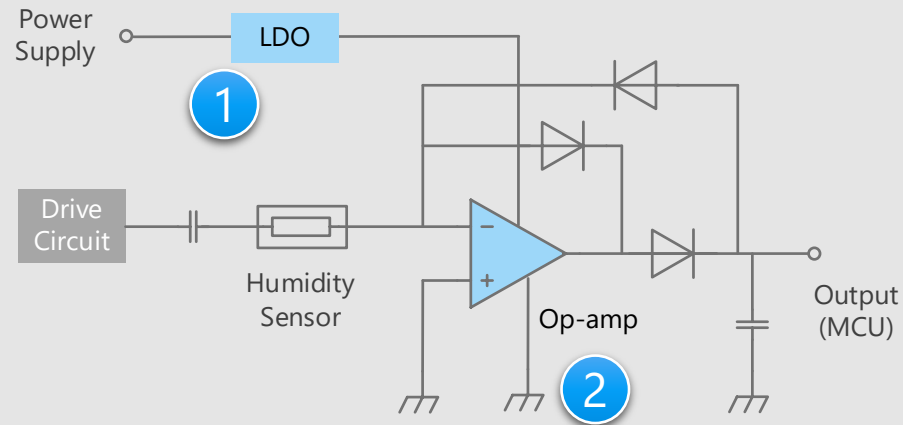
Criteria for device selection

- 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)

Humidity sensor circuit



Criteria for device selection

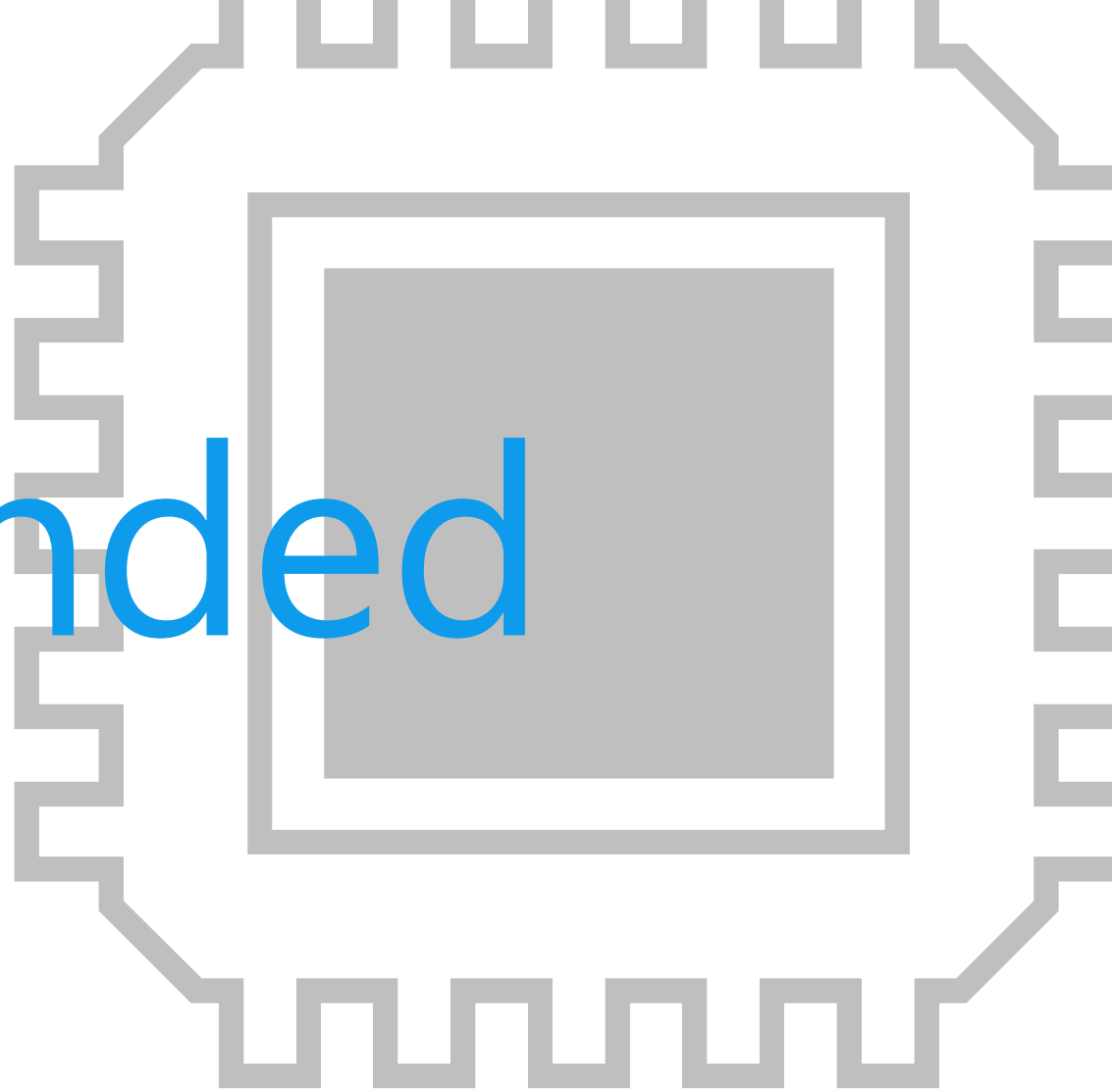
- PSRR (Power Supply Rejection Ratio) of LDO regulator is an important parameter for sensor modules.
- The operational amplifier should be low current consumption or low noise device.
- Small package products contribute to the reduction of circuit board area.

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

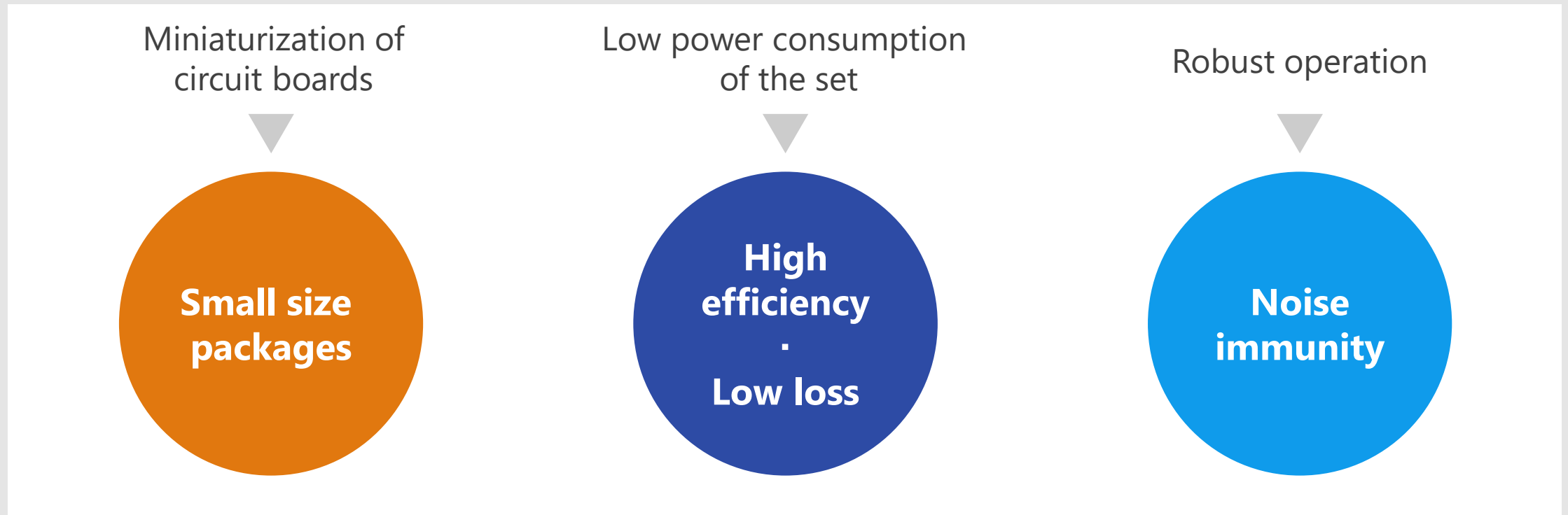
* [Click the number in the circuit diagram to jump to the detailed description page](#)

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

	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	●	●	

Value provided

Wide lineup from general purpose type to small package type are provided.
Contribute to realize a stable power supply not affected by fluctuation of battery.

1 Low dropout voltage

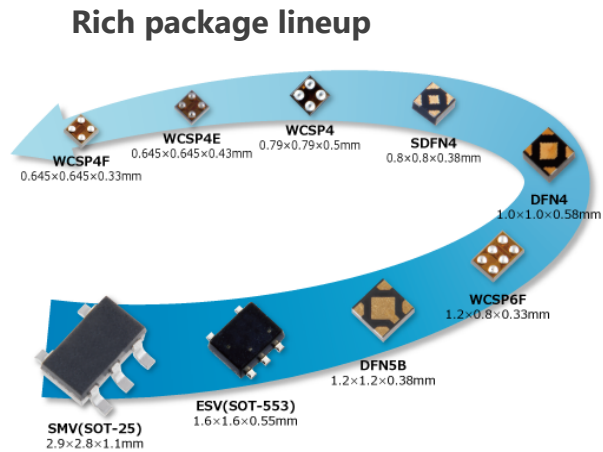
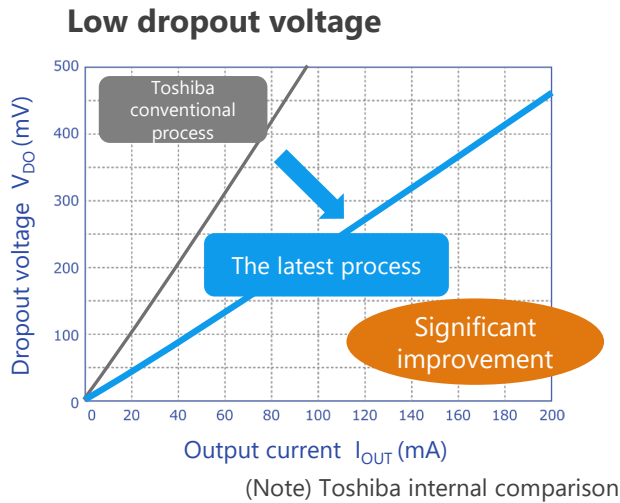
The originally developed latest process significantly improved the dropout voltage characteristics.

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)



Lineup

Part number	TCR15AG Series	TCR13AG Series	TCR8BM Series	TCR5BM Series	TCR5RG Series	TCR3RM Series	TCR3U Series	TCR2L Series	TAR5 Series
Features	Low dropout voltage High PSRR				High PSRR Low noise Low current consumption		Low current consumption		15 V Input voltage Bipolar type
I_{OUT} (Max) [A]	1.5	1.3	0.8	0.5		0.3		0.2	
PSRR (Typ.) [dB] @f = 1 kHz	95	90	98	98	100	100	70	-	70
I_B (Typ.) [μA]	25	56	20	19	7	7	0.34	1	170

[Return to Block Diagram TOP](#)

Value provided

Low current consumption type and low noise type operational amplifiers maximize the performance of system.

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 wearable equipment.

2 Low current consumption (TC75S102F) $I_{DD} = 0.27 \text{ } [\mu\text{A}] \text{ (Typ.)}$

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

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

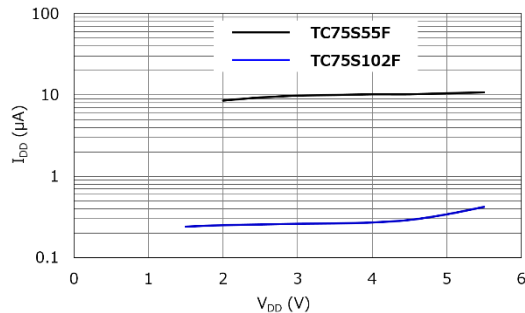
This CMOS operational amplifier can amplify minute signals detected by various sensors [Note] with very low noises. By optimizing the process, the equivalent input noise voltage has been reduced.

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

TC75S102F

Current Consumption Characteristic (Toshiba internal comparison)

Low current consumption product TC75S102F

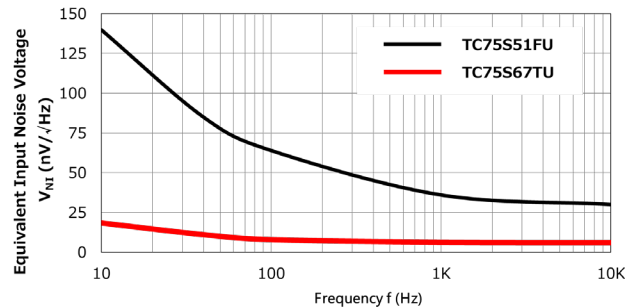


TC75S67TU



Noise Characteristic (Toshiba internal comparison)

Reduce 1/f noise (10 Hz) by 86 % from our normal products

$V_{NI} - f$ @ Ta=25 °C, V_{DD}=3.3 V



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](#)

Value provided

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

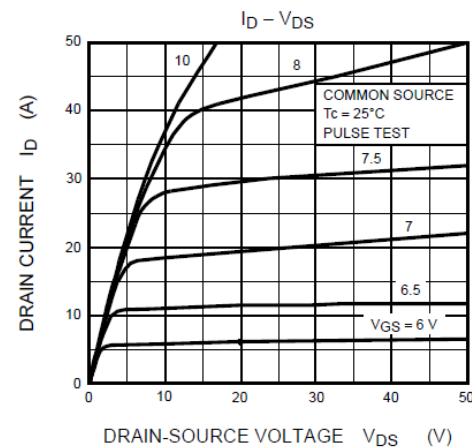
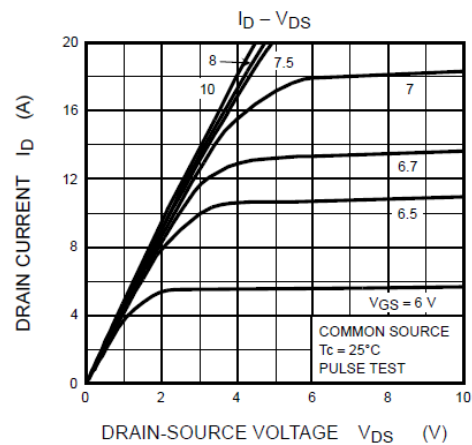
1 Low on-resistance

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: $I_{DSS} = 10 \mu\text{A}$ (Max) @ $V_{DS} = 500 \text{ V}$

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](#)

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 the new 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 our existing products. V_F is reduced by about 17%.

2 Improvement of power supply efficiency

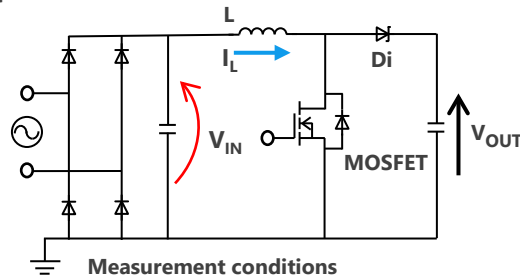
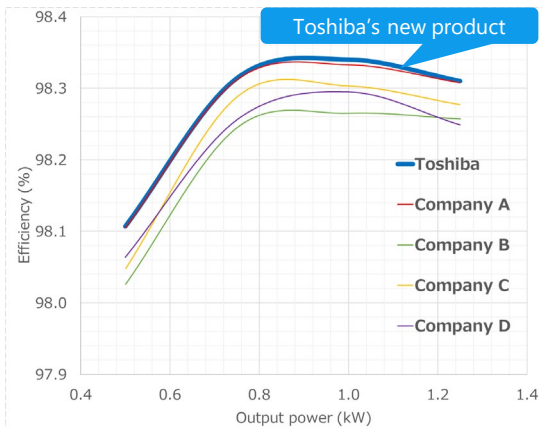
Compared with our existing products, the trade off of $V_F \times Q_C$ [Note2] of the new products have improved. About 0.1% of conversion efficiency improvement have also achieved under 800 W output condition in our test.

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 $V_F \times Q_C$ (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 new 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 November 2021)

Lineup

Part number	TRS12A65F	TRS24N65FB	TRS2E65H *	TRS12E65H *	TRS4V65H *	TRS12V65H *
Package	 TO-220F-2L	 TO-247 (Center tap)	 TO-220-2L			 DFN8x8
V_{RRM} [V]	650	650	650	650	650	650
$I_{F(DC)}$ [A]	12	12 / 24 **	2	12	4	12
I_{FSM} [A]	92	92 / 184 **	19	74	28	60
V_F (Typ.) [V]	1.45 @ $I_F = 12$ A	1.45 @ $I_F = 12$ A	1.2 @ $I_F = 2$ A	1.2 @ $I_F = 12$ A	1.2 @ $I_F = 4$ A	1.2 @ $I_F = 12$ A

*: New product

** : 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

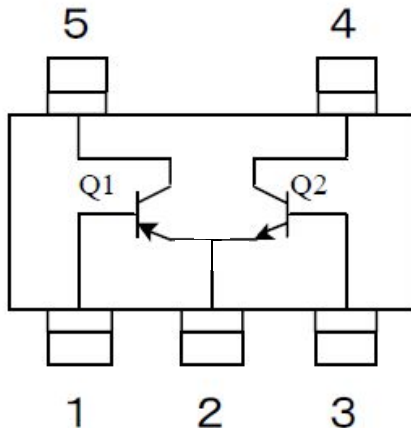
HN4B101J

$V_{CE(sat)} = -0.20 / 0.17$ 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

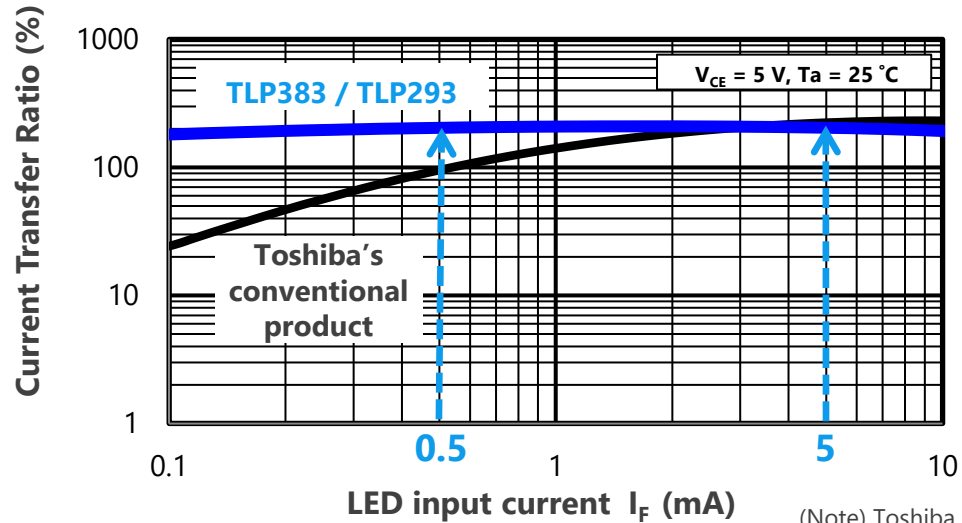
High CTR (Current Transfer Ratio) is realized even in low input current range ($I_F = 0.5 \text{ mA}$).

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 (@ $I_F = 0.5 \text{ mA}$) is realized.




2 High temperature operation

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



(Note) Toshiba internal comparison

Lineup

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

[Return to Block Diagram TOP](#)

Value provided

Suitable for power management switches and contributes to miniaturization.

1 Low voltage operation

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

2 Low on-resistance

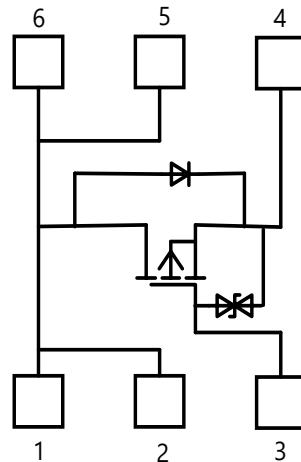
Heat generation and power dissipation can be kept low by keeping the on-resistance between the drain and source low.

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\text{ V}$	15.3	28	33	12	17.3

[Return to Block Diagram TOP](#)

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 $R_{ON} = 40 \text{ m}\Omega$ (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.

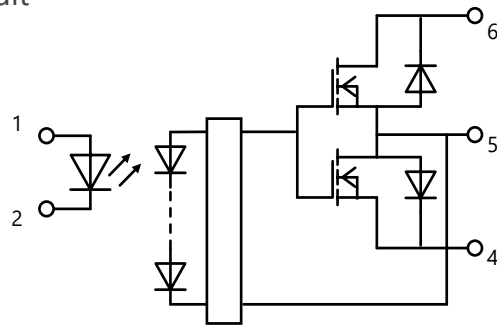
$I_{ON} = 4.0 \text{ A}$ (Max)
(TLP3107A: A connection) [Note]

3 Package

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



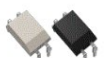
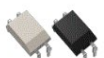


[Note] Please refer to the technical data sheet for connection.

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) [m Ω]	40	65	100	200	150	500
BV_S [Vrms]	1500	1500	2500	5000	2500	2500

[Return to Block Diagram TOP](#)

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.

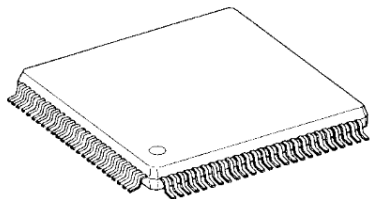
2 Suitable for sensing analog signal

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

3 Small package and low power consumption

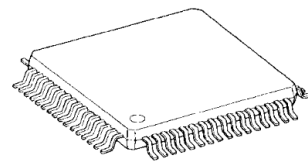
Cortex-M0 and original NANOFLASH™ technology bring to the small package and low power consumption. They contribute to reduce circuit board area and power consumption reduction.

TPM036FWFG



LQFP100-P-1414-0.50H

TPM037FWUG



LQFP64-P-1010-0.50E

Lineup

Part number	TPM036FWFG	TPM037FWUG
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 ² C	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.

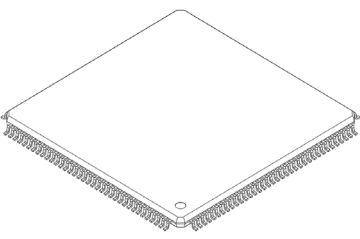
2 Compatible with HBS

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

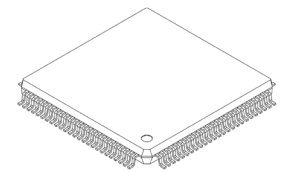
Several low power modes are available to support low power consumption. Package lineup of LQFP144 from small LQFP64 is provided.

TMPM3HQF*AFG



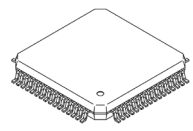
P-LQFP144-2020-0.50-002

TMPM3HNF*AFG



P-LQFP100-1414-0.50-002

TMPM3HLF*AUG



P-LQFP64-1010-0.50-003

Lineup

Part number	TMPM3HQFD/Z/YAFG	TMPM3HNFD/Z/YAFG TMPM3HNFD/Z/YADFG	TMPM3HLFD/Z/YAUG
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 ² C: 4ch, TSPI: 5ch	UART: 8ch, I ² C: 3ch, TSPI: 4ch	UART: 7ch, I ² C: 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

[Return to Block Diagram TOP](#)

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