LDO Regulator TCR3UG Series Application for Power Supply of IoT Devices

Reference Guide

RD037-RGUIDE-02

TOSHIBA ELECTRONIC DEVICES & STORAGE CORPORATION

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1. Overview

- Introduction

Systems requiring power management generally reduce their average power consumption by controlling power supplies according to their power use. Various functions such as sensing and wireless communication are built in IoT devices. For battery operation, it is necessary to save power in order to extend battery operating time.

Battery-powered IoT devices generally provide two modes: an active operating mode in which they consume several milliwatts to several hundreds of milliwatts during sensing and data communication and a standby or sleep mode in which power consumption is reduced to several microwatts to several tens of microwatts by disabling power-consuming functions. IoT devices remain in standby or sleep mode for as long as possible to reduce overall system power consumption.

- Issues concerning the selection of power supply ICs for IoT devices

It is necessary to select power supply ICs that accommodate the requirements for both the active and standby/sleep modes of an IoT device.

(1) Stable operation of a power supply IC in active mode

In active mode, the output power provided by a power supply IC is expected to fluctuate from several milliwatts to several hundreds of milliwatts during stable data communication or high-precision sensing. For example, a radio-frequency (RF) IC and a power amplifier, in particular, consume much power to transmit sensing and other data. During a transmit operation, the output current from the power supply IC also fluctuates from several milliamperes to several hundreds of milliamperes. Generally, the output voltage of a power supply IC is fluctuated when its output current changes rapidly in a few microseconds. This phenomenon is called a load transient response. The maximum output voltage variation caused by the load transient response must be within the active operating voltage range of the data communication and sensing ICs.

(2) Low supply current of a power supply IC in standby/sleep mode

The standby/sleep mode of a power supply IC is divided into the following three states:

a. State in which no input voltage is being applied to a power supply IC: No supply current flows in the IC.

b. State in which a power supply IC is off, with the input voltage being applied: Standby current flows in the IC.

c. State in which a power supply IC operates with an output current of several microamperes to several tens of microamperes: Bias current flows in the IC.

Generally, there is a trade-off between the load transient response in active mode and the supply current (standby and bias currents) in standby/sleep mode. It is difficult to find an optimum power supply IC that meets both these requirements.

- Solution using the TCR3UG LDO regulator series

The TCR3UG low-dropout (LDO) regulator IC series is designed to solve this issue. The TCR3UG series features an output voltage fluctuation of the load transient response as small as ±60mV typical. Therefore, the TCR3UG series maintains the regulated voltage even in the event of a rapid change in the output current. In addition, the TCR3UG series provides a typical standby current of 0.03μA as well as a bias current of 0.34 to 0.4μA over the output current range of 0 to 20μA, which values are less than 50% of those of Toshiba's previous TCR2L series (released for volume production in November 2013). Therefore, the TCR3UG series helps to extend the operating time of battery-powered devices.

Figure 1.1 compares the TCR3UG and TCR2L series in terms of the bias current and load transient response characteristics.

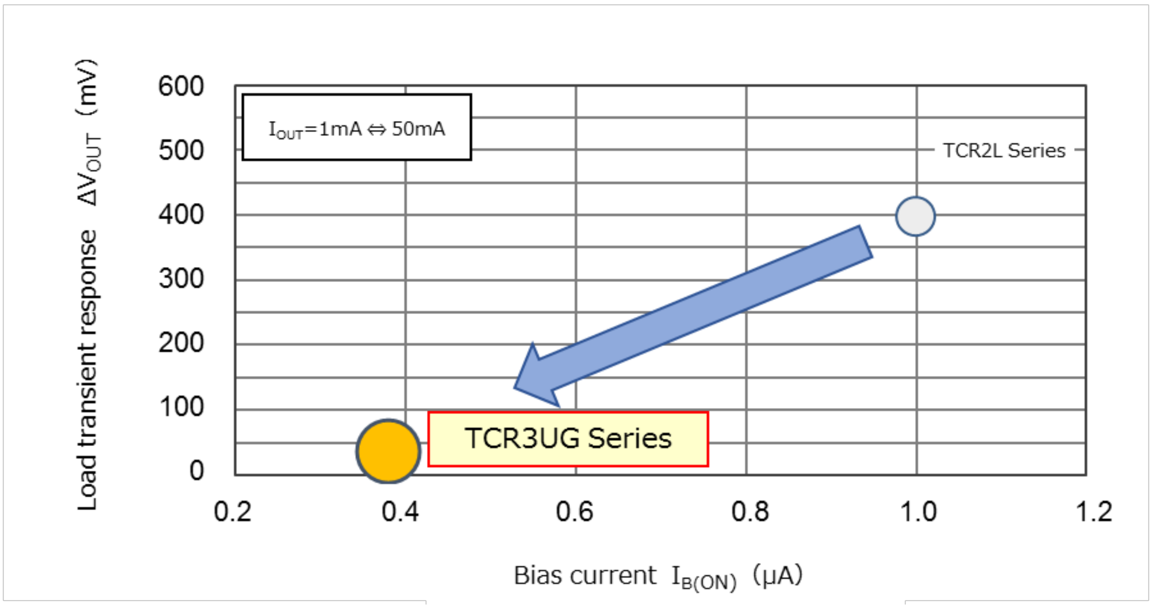


Figure 1.1 Bias current vs. load transient response

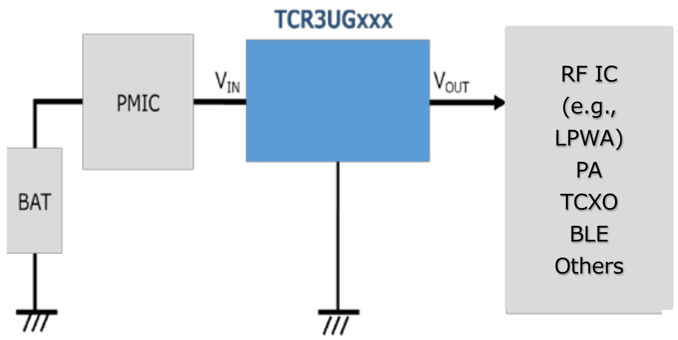
As shown above, the TCR3UG ultra-small LDO regulator series feature both low supply current (standby and bias currents) and fast load transient response. The TCR3UG series incorporates overcurrent protection, thermal shutdown, and inrush current reduction circuits and optionally provides an auto output discharge function. In addition, the TCR3UG series is available with 31 different output voltages from 0.8 to 5.0V, allowing you to select LDO regulators with the optimum output voltage for the battery-powered IoT device.

To download the datasheet for the TCR3UG series→ Click Here

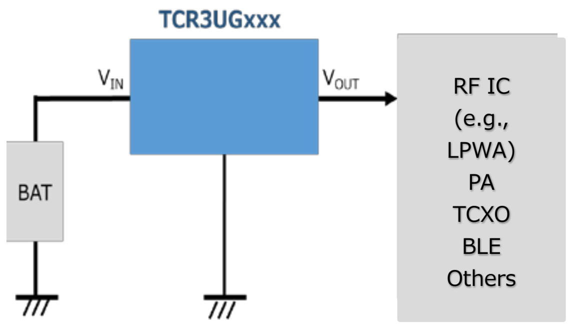
1.1. Target applications

- Power supplies for battery-powered IoT devices

Circuit example 1:
When a power management IC (PMIC) is used



Circuit example 2:
When an LDO regulator is directly connected to a battery



RF- IC: Radio-Frequency Integrated Circuit
LPWA: Low-Power Wide-Area
PA: Power Amplifier
TCXO: Temperature-Compensated Crystal Oscillator
BLE: Bluetooth Low Energy

2. Application circuit example and its bill of materials

2.1. Application circuit example

Figure 2.1 shows an example of a power supply circuit for an IoT device using TCR3UG LDO regulator series.

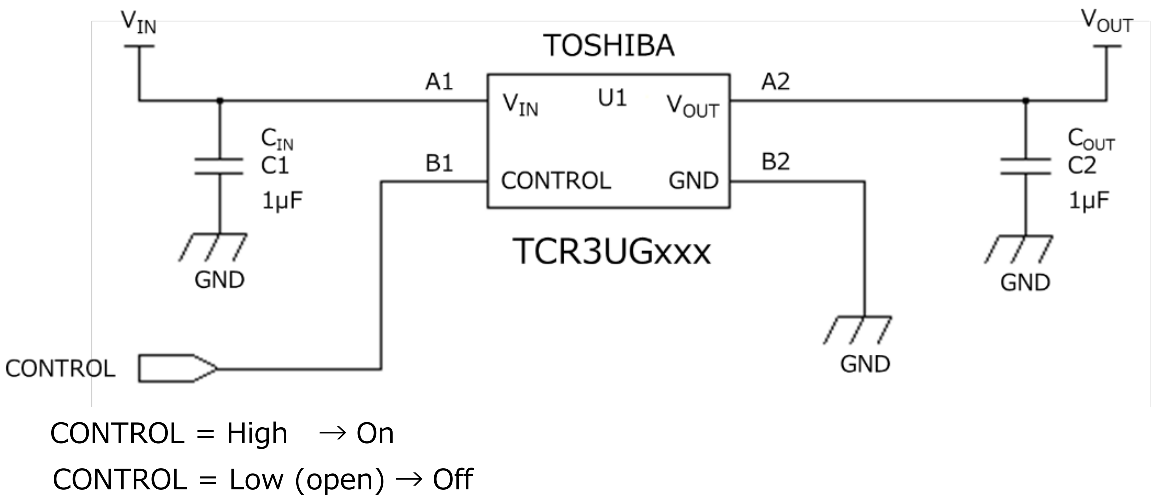


Figure 2.1 Power supply circuit for an IoT device using TCR3UG LDO regulator series

2.2. Bill of materials

Table 2.1 Bill of materials

No.	Ref.	Qty.	Value	Part Number	Manufacturers	Description	Packaging	Typical Dimensions in mm (inches)
1	C1, C2	2	1μF	—	—	Ceramic, 6.3V, ±10%	—	0.6 x 0.3 (0201)
2	U1	1	—	TCR3UGxxx	TOSHIBA		WCSP4F	0.645 x 0.645

3. Typical characteristics of the LDO regulator for IoT device applications

3.1. Output voltage stability in active mode (load transient response)

When an IoT module transmits sensing and other data, an RF IC and a power amplifier, in particular, consume much power. When an LDO regulator is used as a power supply IC, it is subject to a rapid change, of between several milliamperes and several hundreds of milliamperes, in the output current. Therefore, the load transient response performance, which represents the output voltage fluctuation for a change in the output current, is important. Figure 3.1 shows an image of the load transient response characteristics. The smaller the output voltage fluctuation, the better.

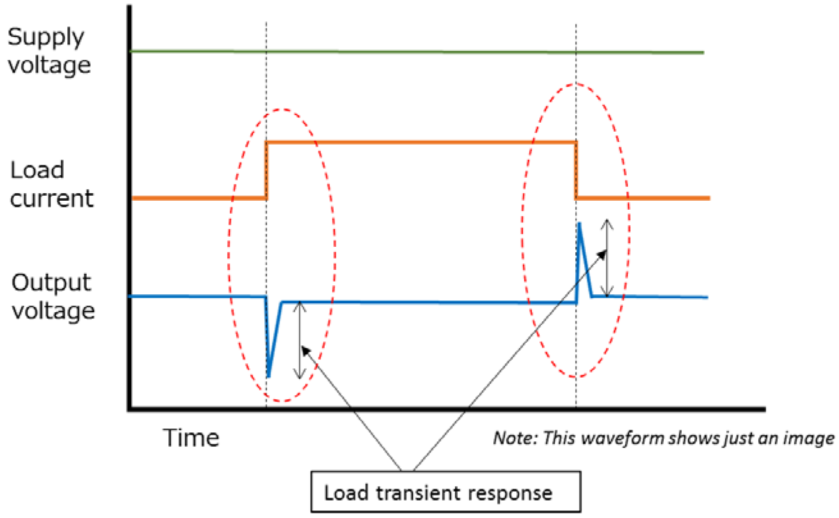


Figure 3.1　Load transient response characteristics

The output voltage fluctuation of TCR3UG series is only ±60mV (typical) for an output current change of between 1mA and 50mA. For example, the TCR3UG33A with an output voltage of 3.3V has a voltage fluctuation of ±5% and therefore provides a stable voltage supply (see Figure 3.2).

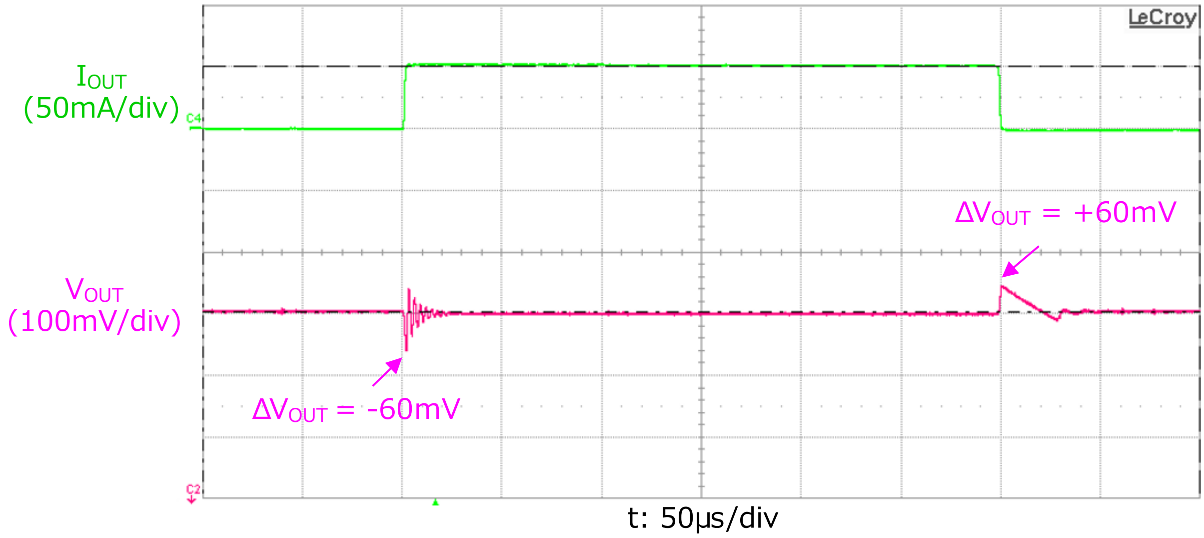


Figure 3.2 Load transient response (TCR3UG33A)

3.2. Low supply current in standby/sleep mode (dependency on the output current)

IoT modules remain in standby or sleep mode for a long period of time to reduce system power consumption. The bias current of the TCR3UG series is only 0.34 to 0.4µA over an output current of 0 to 20µA (see Figure 3.3).

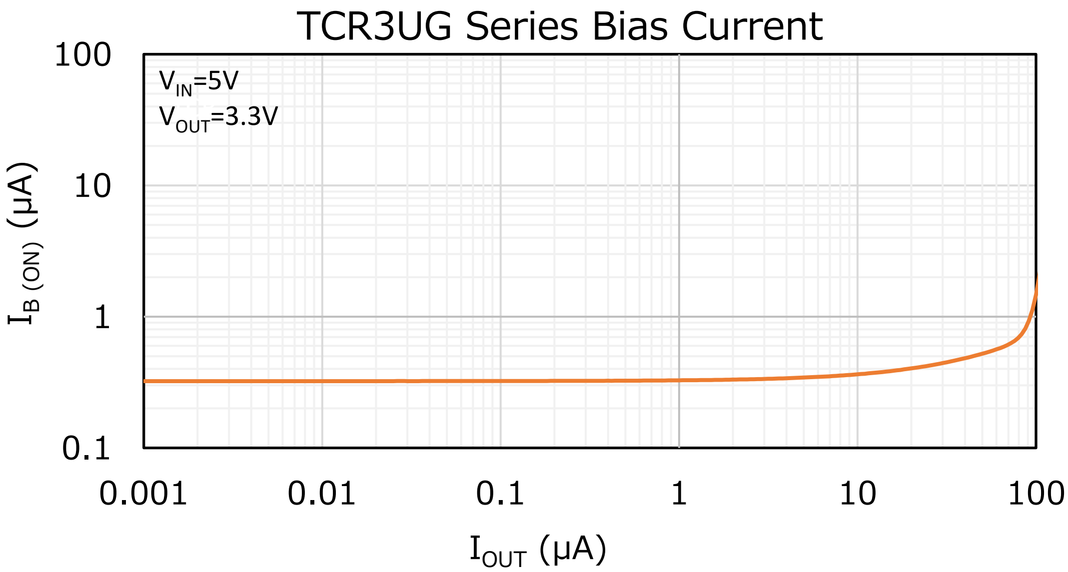


Figure 3.3 Bias current vs. output current

3.3. Low supply current in standby/sleep mode (dependency on the input voltage)

When the input voltage is lower than the rated output voltage (e.g., 3.3V in the case of the TCR3UG33A), bias current of conventional LDO regulators is bigger compared with when they are regulated at the rated output voltage. In contrast, the TCR3UG series provides low bias current even in the low-input-voltage region because of the improved circuit. Therefore, the TCR3UG series can operate with low bias current even when its input voltage is lower than the rated output voltage. Figure 3.4 compares the bias current curves of the TCR3UG and TCR2L series.

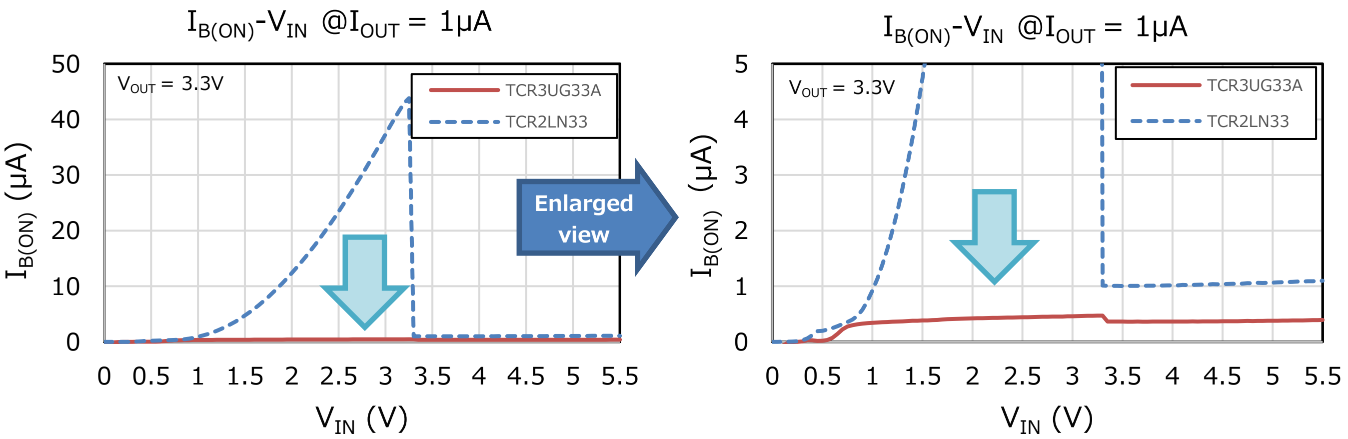


Figure 3.4 Comparison of bias current

Because of its low bias current, the TCR3UG series can also be used as a load switch for overvoltage protection, which provides the rated output voltage when the input voltage is higher than the rated output voltage and passes the input voltage to the output when the input voltage is lower than the rated output voltage. This feature is called the bypass mode. For example, the TCR3UG series can be used as a switch with low supply current even when the battery voltage of an IoT device drops below the rated output voltage. The minimum input voltage of bypass mode operation of the TCR3UG series is 1.5V. Figure 3.5 shows the V_{IN}-V_{OUT} and V_{IN}-$I_{B(ON)}$ waveforms of the TCR3UG series.

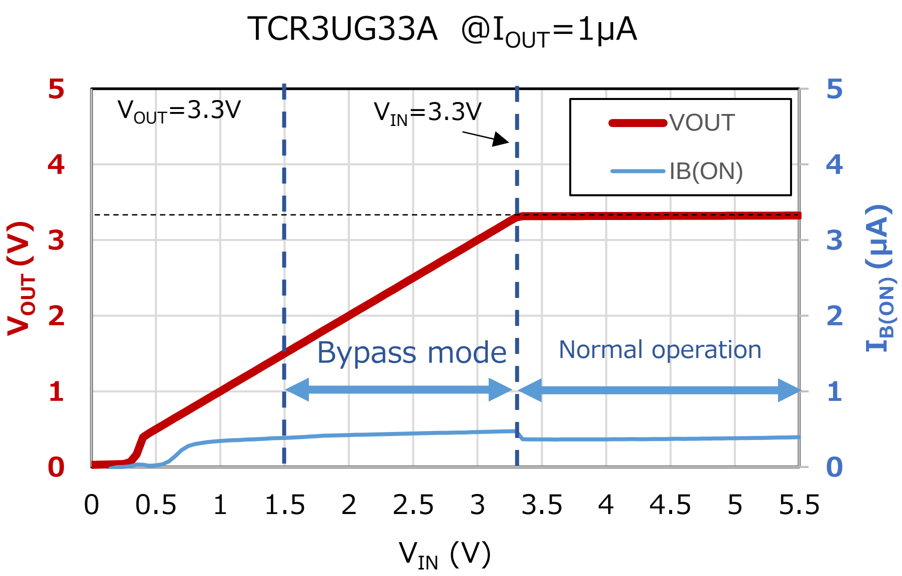


Figure 3.5 V_{IN}-V_{OUT} waveform and bias current

To download the datasheet for the TCR3UG series → Click Here

4. Design considerations

- Input ,Output capacitor

  Ceramic capacitors can be used for these devices. However, because of the type of the capacitors, there might be unexpected thermal features. Please consider application condition for selecting capacitors. And Toshiba recommend the equivalent series resistance (ESR) of ceramic capacitor is under 1 Ω. For stable operation, we recommend over 1 μF.

- Mounting

  For stable power supply, input output capacitor need to mount near IC as much as possible. Also VIN and GND pattern need to be large and make the wire impedance small as possible.

- Permissible loss

  Please have enough design patterns for expected maximum permissible loss. And under consideration of ambient temperature, input voltage, and output current etc.

- Overcurrent protection and thermal shutdown

  Overcurrent protection and Thermal shutdown are designed in these products, but these are not designed to constantly ensure the suppression of the device within operation limits.

5. Product overview

5.1. TCR3UG series

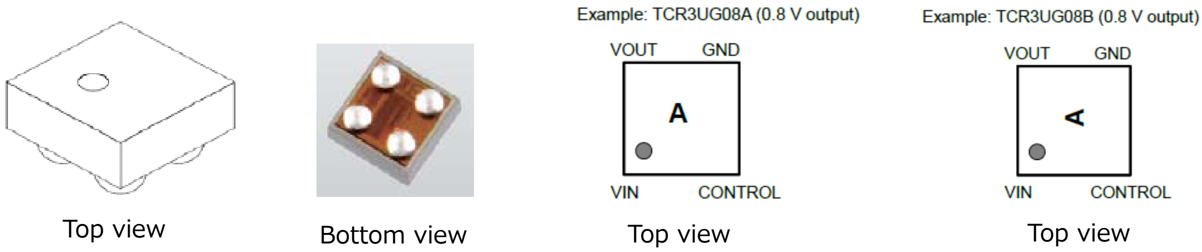
5.1.1 Features

The TCR3UG series is single-output CMOS LDO regulator with a control pin featuring ultra-low quiescent bias current and a low dropout voltage. The TCR3UG series is available with a fixed output voltage between 0.8V and 5.0V and is capable of supplying an output current of up to 300mA. Despite an ultra-small package, the TCR3UG series features a low dropout voltage of 155mV (at an output voltage of 3.3V and an I_{OUT} of 300mA).

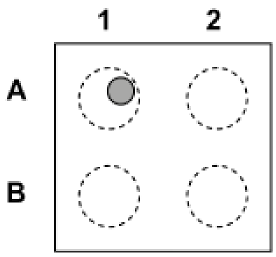
- Ultra-small package: WCSP4F (0.645mm x 0.645mm (typical); t: 0.33mm (maximum))
- Low quiescent bias current: I_B=0.34μA (typical) at I_{OUT}=0mA (an output voltage of up to 1.5V)
- High ripple rejection ratio: R.R = 70dB (typical) at 0.8V output
- Fast load transient response: ± 60mV at 0.8V output and I_{OUT}=1mA ⇔ 50mA
- Low dropout voltage: V_{DO} = V_{IN}-V_{OUT}= 155mV typical at 3.3V output and I_{OUT} = 300mA
- Product lineup with a wide range of output voltage: V_{OUT}=0.8 to 5.0V (V_{IN}=1.5 to 5.5V)
- High output voltage accuracy: ±1.0% (V_{OUT} ≥ 1.8V)
- TCR3UGxxA series with an auto output discharge function and TCR3UGxxB series without an auto output discharge function
- Overcurrent protection circuit
- Thermal shutdown circuit
- Inrush current reduction circuit

5.1.2 External view and pin assignment

External view and marking



Pin assignment (Top view)



	1	2
A	VIN	VOUT
B	CONTROL	GND

Figure 5.1 External view, marking, and pin assignment of the TCR3UG series

5.1.3 Product list

Table 5.1 Product list

Product No.	Output voltage(V)	Auto dis-charge	Marking	Product No.	Output voltage(V)	Auto dis-charge	Marking**
TCR3UG08A	0.8	Yes	A	TCR3UG08B	0.8	No	A
TCR3UG085A	0.85		B	TCR3UG085B	0.85		B
TCR3UG09A	0.9		C	TCR3UG09B	0.9		C
TCR3UG095A	0.95		D	TCR3UG095B	0.95		D
TCR3UG10A	1.0		E	TCR3UG10B	1.0		E
TCR3UG105A	1.05		F	TCR3UG105B	1.05		F
TCR3UG11A	1.1		H	TCR3UG11B	1.1		H
TCR3UG115A	1.15		J	TCR3UG115B	1.15		J
TCR3UG12A	1.2		K	TCR3UG12B	1.2		K
TCR3UG13A	1.3		L	TCR3UG13B	1.3		L
TCR3UG135A	1.35		M	TCR3UG135B	1.35		M
TCR3UG15A	1.5		N	TCR3UG15B	1.5		N
TCR3UG175A	1.75		P	TCR3UG175B	1.75		P
TCR3UG18A	1.8		R	TCR3UG18B	1.8		R
TCR3UG185A	1.85		S	TCR3UG185B	1.85		S
TCR3UG19A	1.9		T	TCR3UG19B	1.9		T
TCR3UG25A	2.5		U	TCR3UG25B	2.5		U
TCR3UG26A	2.6		V	TCR3UG26B	2.6		V
TCR3UG27A	2.7		W	TCR3UG27B	2.7		W
TCR3UG28A	2.8		X	TCR3UG28B	2.8		X
TCR3UG285A	2.85		Y	TCR3UG285B	2.85		Y
TCR3UG30A	3.0		0	TCR3UG30B	3.0		0
TCR3UG31A	3.1		1	TCR3UG31B	3.1		1
TCR3UG32A	3.2		2	TCR3UG32B	3.2		2
TCR3UG33A	3.3		3	TCR3UG33B	3.3		3
TCR3UG35A	3.5		4	TCR3UG35B	3.5		4
TCR3UG36A	3.6		5	TCR3UG36B	3.6		5
TCR3UG41A	4.1		9	TCR3UG41B	4.1		9
TCR3UG42A	4.2		6	TCR3UG42B	4.2		6
TCR3UG45A	4.5		7	TCR3UG45B	4.5		7
TCR3UG50A	5.0		8	TCR3UG50B	5.0		8

** The marking is rotated left by 90 degrees.

5.1.4 Pin description

Table 5.2 Pin description

Pin	Name	Description
A1	V_{IN}	Power supply input. The maximum V_{IN} voltage is 5.5V. For stable operation, use an input capacitor of 1μF or higher (with an equivalent series resistance of 1Ω or less) to the V_{IN} pin.
B1	CONTROL	Output on/off control pin. A High on this input turns on the output. A Low on this input turns off the output. The CONTROL pin is internally connected to GND via a pulldown resistor.
A2	V_{OUT}	Output. For stable operation, use an output capacitor of 1μF or higher (with an equivalent series resistance of 1Ω or less) to the V_{OUT} pin.
B2	GND	Ground

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