Application Circuits
of LDO Regulator TCR5BM/8BM Series
for MCU
Reference Guide

RD151-RGUIDE-01

Abstract

This reference guide explains the applications of the LDO-regulator TCR5BM/8BM series for battery-powered mobile devices to power supplies for MCUs, including the features and characteristics of these products. Please refer to this when designing a power supply for MCUs using TCR5BM/8BM Series.

TOSHIBA ELECTRONIC DEVICES & STORAGE CORPORATION

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1. Introduction

   LDOs (Low Drop Out) regulators are widely used in a variety of electronic devices, including mobile devices such as smartphones and tablets, which are strongly required to be compact and lightweight and to save power.

   TCR5BM/8BM series described in this guide divides the power supply line of the output drive circuit from the input terminal through which the output current flows to form an external bias terminal, and thus realizes extremely low dropout voltages (minimum voltage difference between input and output) of 100 mV (typical) in TCR5BM series, and of 170 mV (typical) in TCR8BM series, by setting a voltage higher than the input here. At the same time, it also ensures stable operation at low voltages and high output currents.

   The maximum output current is 500 mA (typical) in TCR5BM series, and 800 mA (typical) in TCR8BM series. Both series are fixed output voltage types, and a wide range of output voltages is available from 0.8 V to 3.6 V, so you can select the one with the most suitable output voltage for various applications. For the lineup of output voltages, refer to section 5.4 of this guide.

   Both products use small DFN5B packages (1.2 mm×1.2 mm×0.38 mm) to contribute to the miniaturization and thinning of the packages.

   Refer to the datasheet for details of TCR5BM/8BM series-related features. Also refer to the following link destination application note for details of the main characteristics of LDO.

To download the datasheet forTCR5BM Series	→	Click Here
To download the datasheet for TCR8BM Series	→	Click Here
About the power efficiency of the two-power LDOs	→	Click Here
About the load transients of LDOs	→	Click Here
About the ripple rejection	→	Click Here
About oscillations of LDOs	→	Click Here
About optimize thermal designs	→	Click Here

2. Characteristics Required for Power Supplies for MCUs

As shown in Fig. 2.1, the core power supply, the reference power supply, and the general-purpose power supply are generally supplied to the MCU, and the performance required for each type of power supply differs. This guide describes the applications of the LDO regulator TCR5BM/8BM series to core power supplies, which are particularly low-voltage, high-current loads.

The core power supply of the MCU is currently at around 1.0 to 1.2 V, but this voltage tends to be lower, and is expected to reach around 0.8 to 1.2 V in the future.

A characteristic of the MCU core power supply is that the load current of several hundred mA or more instantaneously increases or decreases as the peak current when the CPU performs heavy processing as the current consumption of the core part. If the output voltage fluctuates greatly in response to a sudden increase or decrease in the load current, a control logic malfunction, etc. may occur, causing the entire set to malfunction due to the malfunction of the MCU. For this reason, the load transient response characteristics are most important. In addition, to avoid logic malfunction due to noise, the core power supply must provide a stable low voltage and must be able to eliminate switching noise from PMIC and DC-DC converters, i.e., have a higher ripple rejection ratio.

Since the MCU itself generates heat, it is also necessary to reduce power dissipation to minimize the impact on the surroundings.

The low fluctuating load transients, high ripple rejection ratio, and low power dissipation required by the core power supplies of these MCUs can be achieved in a small area with the 2-input LDO regulator TCR5BM/8BM series. The specific circuit configuration is described below.

Depending on the expected output current, select TCR5BM series for 500 mA or less and TCR8BM series for 500 mA or more.
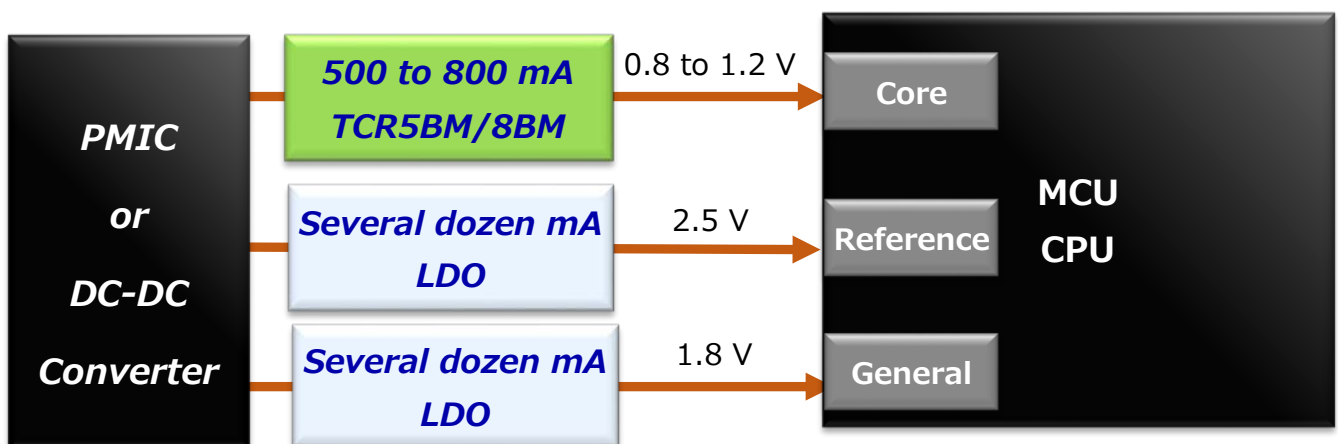

Fig.   2. 1 MCU Power Supply Configuration

3. Application Circuit
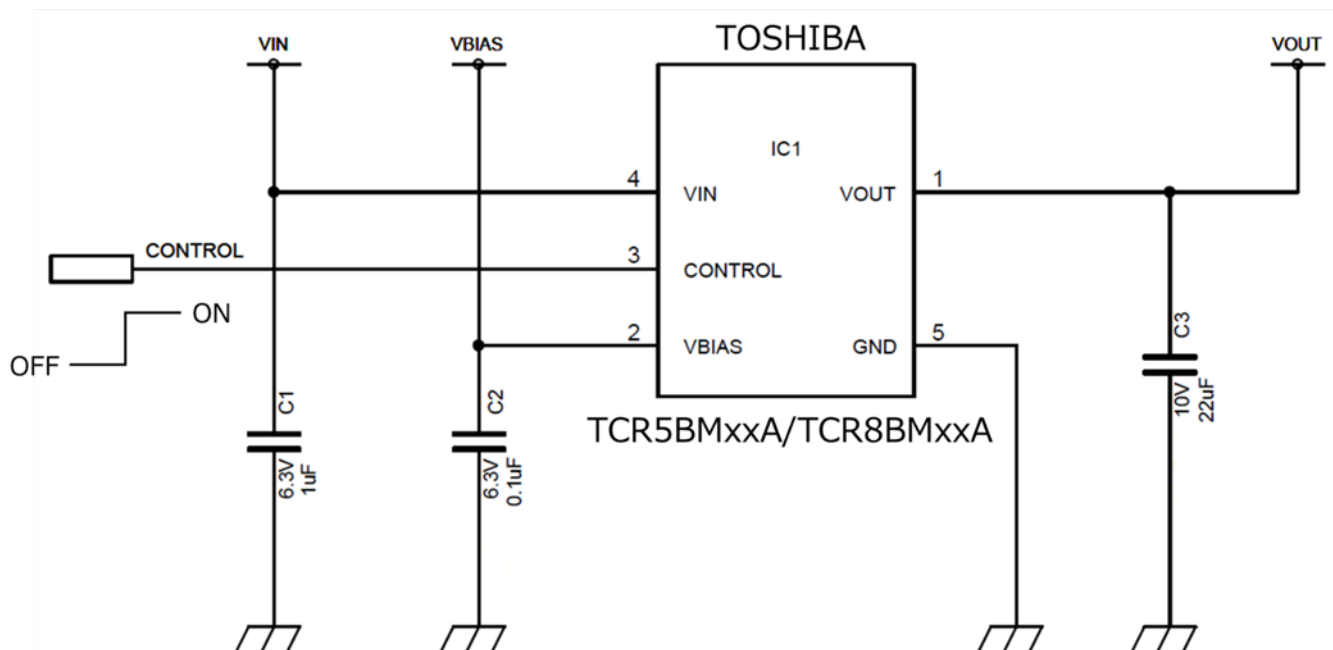
3.1. Typical Connection Diagram

Fig. 3.1 TCR5BM/TCR8BM Application Circuit for MCU

3.2. Bill of Materials

Table 3.1 Bill of Materials

Item	Part	Quantity	Manufacturer	Value	Product name	Description	Package name	Standard dimensions mm (inch)
1	IC1	1	TOSHIBA	-	TCR5BMxxA (*)	Output current 500 mA	DFN5B	1.2×1.2
					TCR8BMxxA (*)	Output current 800 mA		
2	C1	1		1 µF		Ceramic 6.3 V ±20 %	-	0.6×0.3 (0201)
3	C2	1		0.1 µF		Ceramic 6.3 V ±20 %	-	0.6×0.3 (0201)
4	C3	1		22 µF		Ceramic 10 V ±20 %	-	1.6×0.8 (0603)

* In the circuit diagram and the bill of materials, the xx part of the product name is a number indicating the output voltage.
  Ex.) When V_{OUT}=1.2 V, TCR5BM12A/TCR8BM12A

4. Circuit and Board Design

4.1. Points to Be Noted in Design

When using TCR5BM/8BM series-based core power supplies for MCU, the following describes the points to be noted in designing circuit and boards.

- About entering VBIAS

    VBIAS pin is used as a power supply for the circuit that drives the output elements. Input a voltage that is 2.5 V or higher and VOUT voltage +1.4 V or higher here. Use a stable power supply as much as possible for the external voltage input here. Noise may adversely affect the output voltage through the LDO drive circuit.

    The start-up sequence of the external power supply should be in the order of VBIAS → VIN → CONTROL.

- External Capacitors

    Ceramic capacitors can be used in TCR5BM/8BM series. However, some types may have very large thermal properties. When selecting a capacitor, carefully consider the operating environment. We also recommend using ceramic capacitors with ESR of 1.0 Ω or less. For stable operation, connect a capacitor of 1 µF or more to the VIN pin, 0.1 µF or more to VBIAS pin, and 2.2 µF or more to VOUT pin.

- Mounting on a Printed Circuit Board

    Although TCR5BM/8BM series is designed with sufficient consideration for oscillation, such as with a built-in phase compensation capacitance, oscillation may occur due to the effects of wiring resistors and L components, depending on external conditions such as the printed circuit board pattern and usage environment.

    As a general precaution, route the VIN and GND wires so that they do not form loops, and keep the wiring area as large as possible to reduce the wiring resistance. Pay special attention to routing of the path through which input/output current flows so that VIN and GND inside the LDO are not affected by the common impedance. Be careful not to route VBIAS wires too long, as they are more susceptible to noises.

    Also, if the output capacitor is far from VOUT terminal, it will be easily affected by the wiring resistor and L components. For more stable power supply operation, mount the output capacitor as close to VOUT terminal as possible. Separate the wiring to be connected as close to VOUT terminal as possible (where possible, at the base of the terminal) from the wiring to which the output current flows so that the resistance of the wiring does not become common-impedance. If oscillation occurs, optimize the value and position of the capacitor while checking the output waveform on the actual device.

    Refer to Fig. 4.1 for the wiring pattern routing image described above.
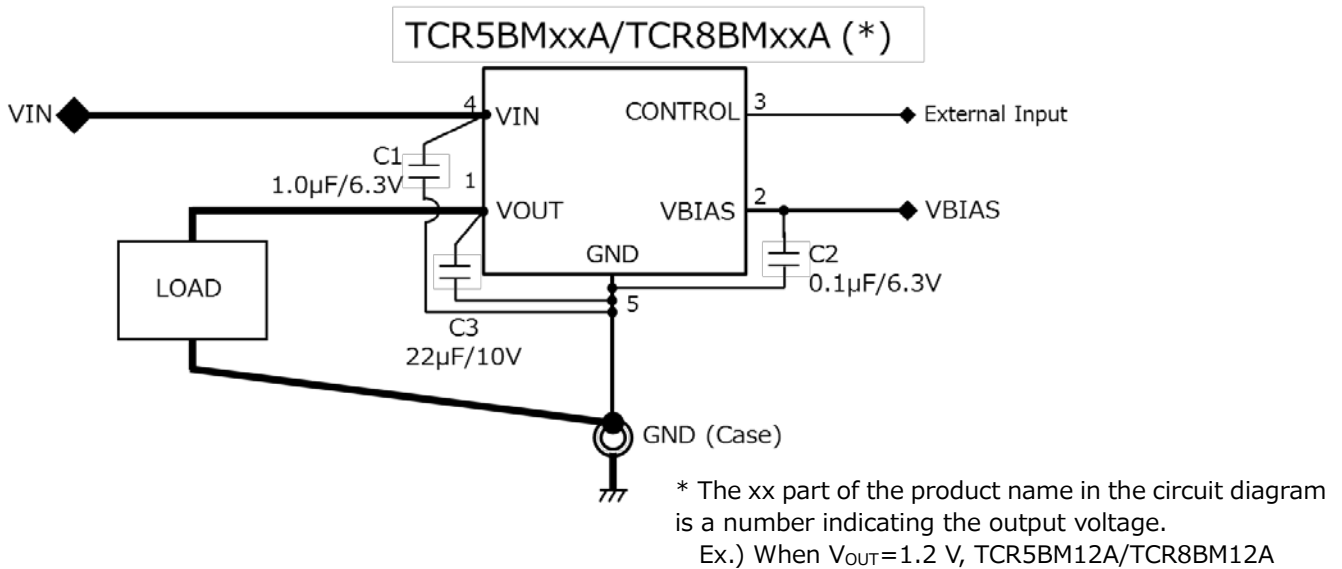
Fig. 4.1 Wiring Pattern Routing Image

● Allowable loss

Design the printed circuit board pattern with as much margin as possible against heat generation during maximum loss (power dissipation) assumed in actual use conditions. Take into account the worst case of each parameter such as ambient temperature, input voltage and output current in the actual environment to be used, and take derating of about 1.2 to 1.5 times for the maximum loss (power dissipation) assumed.

● Overcurrent protection circuit and overheat protection circuit

Although TCR5BM/8BM series has built-in foldback type overcurrent circuit and overheat protection circuit, these do not guarantee that the device's operation is constantly kept within its maximum ratings. Please note that the product may deteriorate and affect reliability depending on the operating conditions.

Nor does it warrant that the Product will not be destroyed in any event. Otherwise, the output terminal and GND terminal may be in an incomplete short mode, resulting in damage.

When using TCR5BM/8BM Series, please refer to the above and the absolute maximum ratings stated in our "Semiconductor Reliability Handbook" or data sheet, etc., and take appropriate derating into consideration so that the absolute maximum ratings will not be exceeded in any case. We recommend that you take adequate safety measures such as fail-safe in the set.

4.2. Dropout voltage: V_{DO}

The data sheet defines the minimum difference between the input and output voltages required to output a given voltage. It is sometimes referred to as the minimum input-output voltage difference. The lower this value, the less power is consumed.

In TCR5BM/8BM series, the power supply route to the gate drive circuit of the output element is separated from the input terminal (VIN), and a separate bias terminal (VBIAS) is provided to achieve low dropout voltage.

The drop-out voltage characteristics of TCR5BM/8BM series-products with V_{OUT}=0.8 to 1.2 V, which are suitable for power supplies of MCU, are shown below. Please refer to them for applications.
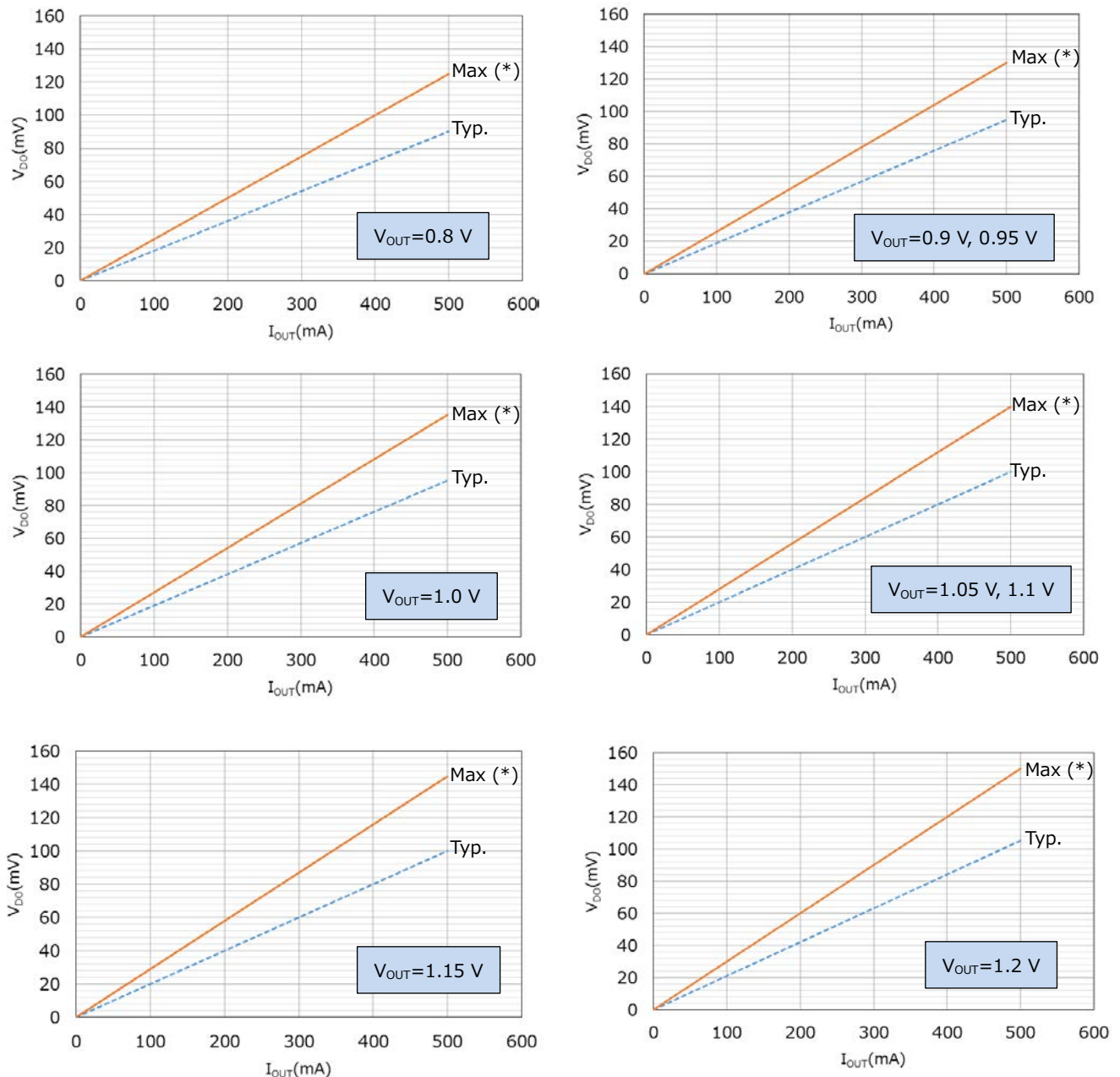

Fig. 4.2 Drop-out Voltage Characteristics of TCR5BM Series
(V_{BIAS}=3.3 V, V_{OUT}=0.8 to 1.2 V)

* The condition for the maximum value includes the total temperature range.

Fig. 4.3 Dropout Voltage Characteristics of TCR8BM Series

(V_{BIAS}=3.3 V, V_{OUT}=0.8 to 1.2 V)

* The condition for the maximum value includes the total temperature range.
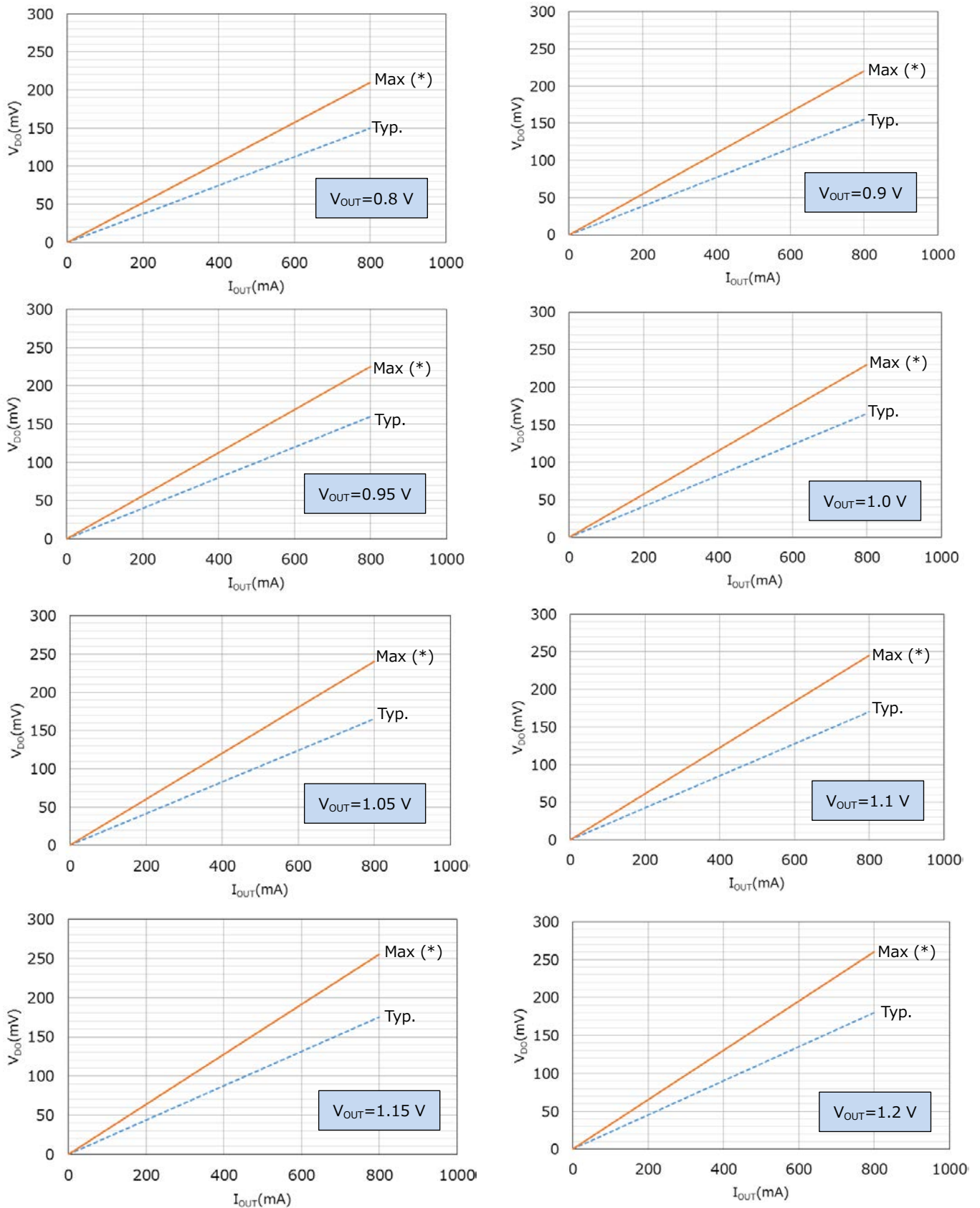
4.3. Load Transient Response: ΔV_{OUT}

Indicates the peak value of the fluctuation that instantaneously appears in the output voltage in response to a stepwise change in the load current.

Since the resistance value of the load connected to the output of the LDO is not constant, the output current also fluctuates accordingly, but TCR5BM/8BM Series has excellent response performance to sudden current changes and provides stable constant-voltage operation.

The following shows the load transient response characteristics of TCR5BM/8BM series. The appropriate V_{OUT} for the power supply of MCU is 0.8 to 1.2 V. Please refer to this section when applying the load transient response characteristics.
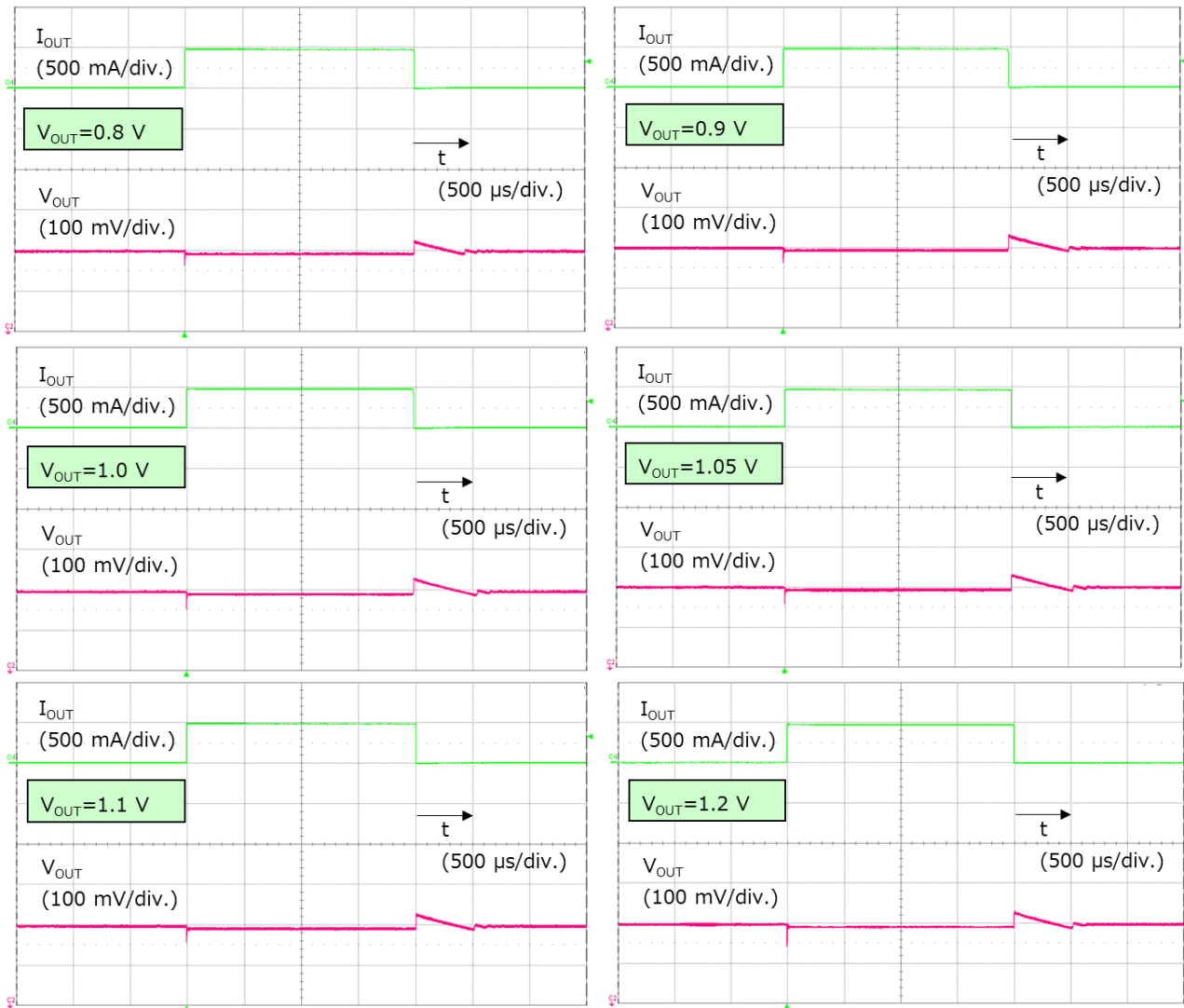

Fig. 4.4 Load Transient Response for TCR5BM Series
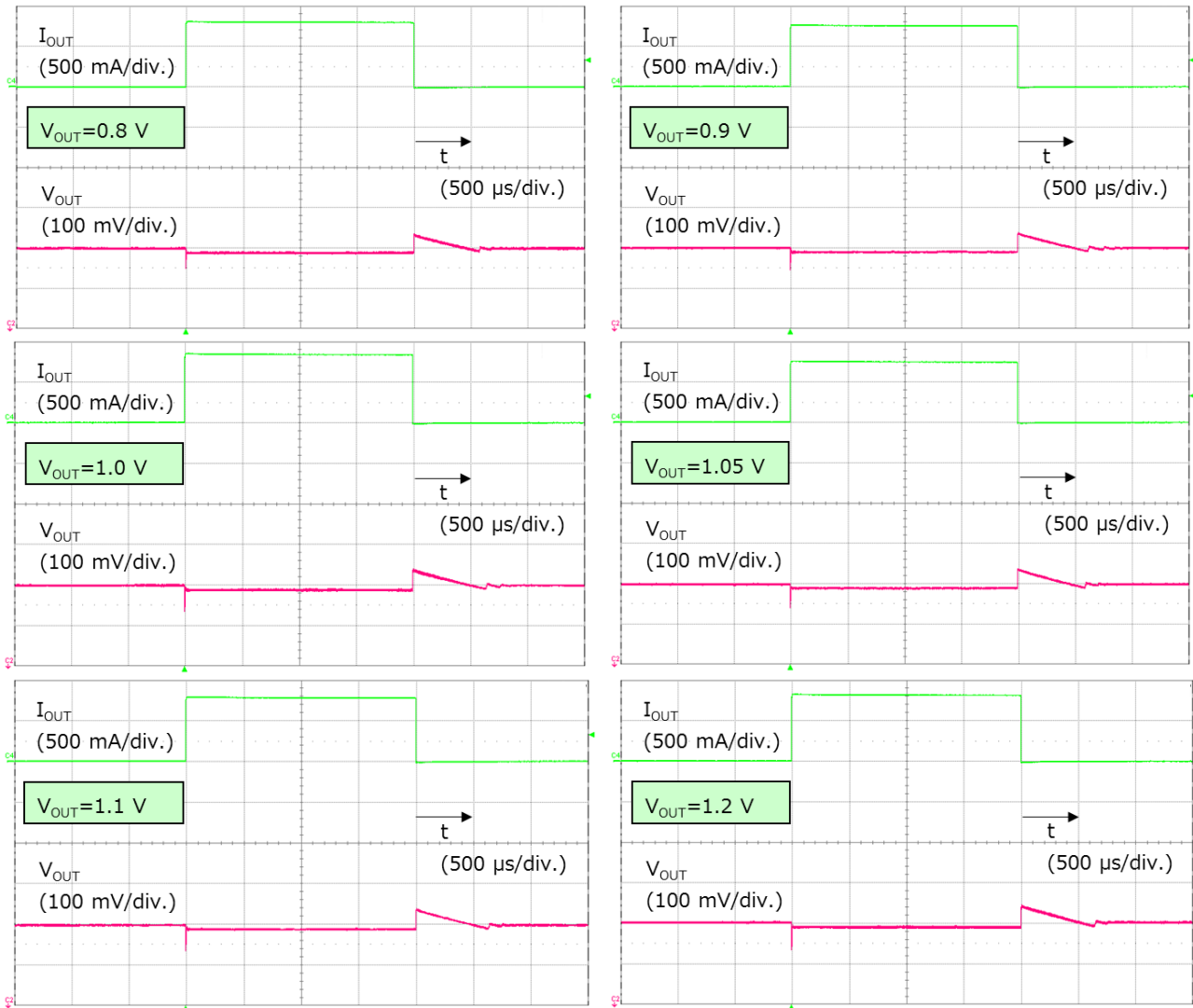**(V_{IN}=1.35 V, V_{BIAS}=3.3 V, I_{OUT}=1 mA-500 mA-1 mA, C_{OUT}=22 µF)**

Fig. 4.5 Load Transient Response for TCR8BM Series
(V_{IN}=V_{OUT}+0.3 V, V_{BIAS}=3.3 V, I_{OUT}=1 mA-800 mA-1 mA, C_{OUT}=22 µF)

4.4. Ripple Rejection Ratio: R.R

Also known as the ripple compression ratio or PSRR (Power Supply Rejection Ratio, it indicates the ratio of the ripple voltage component superimposed on the input voltage to the ripple voltage component appearing on the output voltage at that time. The larger this value, the smaller the ripple component appearing in the output. However, the denominator and numerator may be swapped and displayed as a minus value. In this case, the smaller the value is better.

To determine the impact of power supply noise on the load side, LDOs with low-voltage outputs are also highly sensitive to this characteristic.

The following shows the frequency characteristics of the ripple rejection ratio of TCR5BM/8BM series with V_{OUT}=0.8 to 1.2 V, which is suitable for the power supply of MCU. Characteristics when the output capacitance C_{OUT} is 2.2 µF and 22 µF are described. Please use them as a reference for determining external constants when applying.

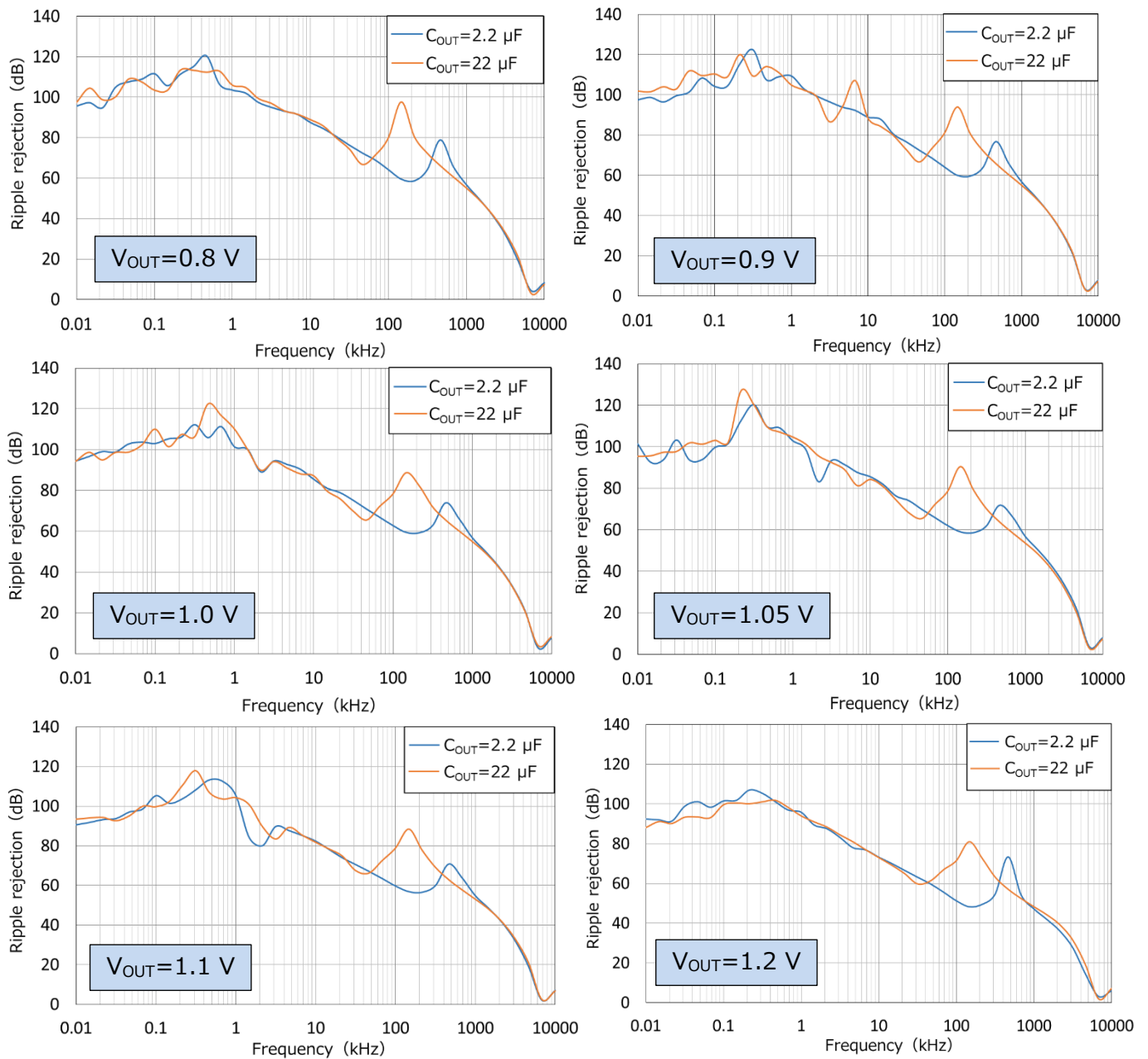**Fig. 4.6 Ripple Rejection Frequency Characteristics of TCR5BM Series**
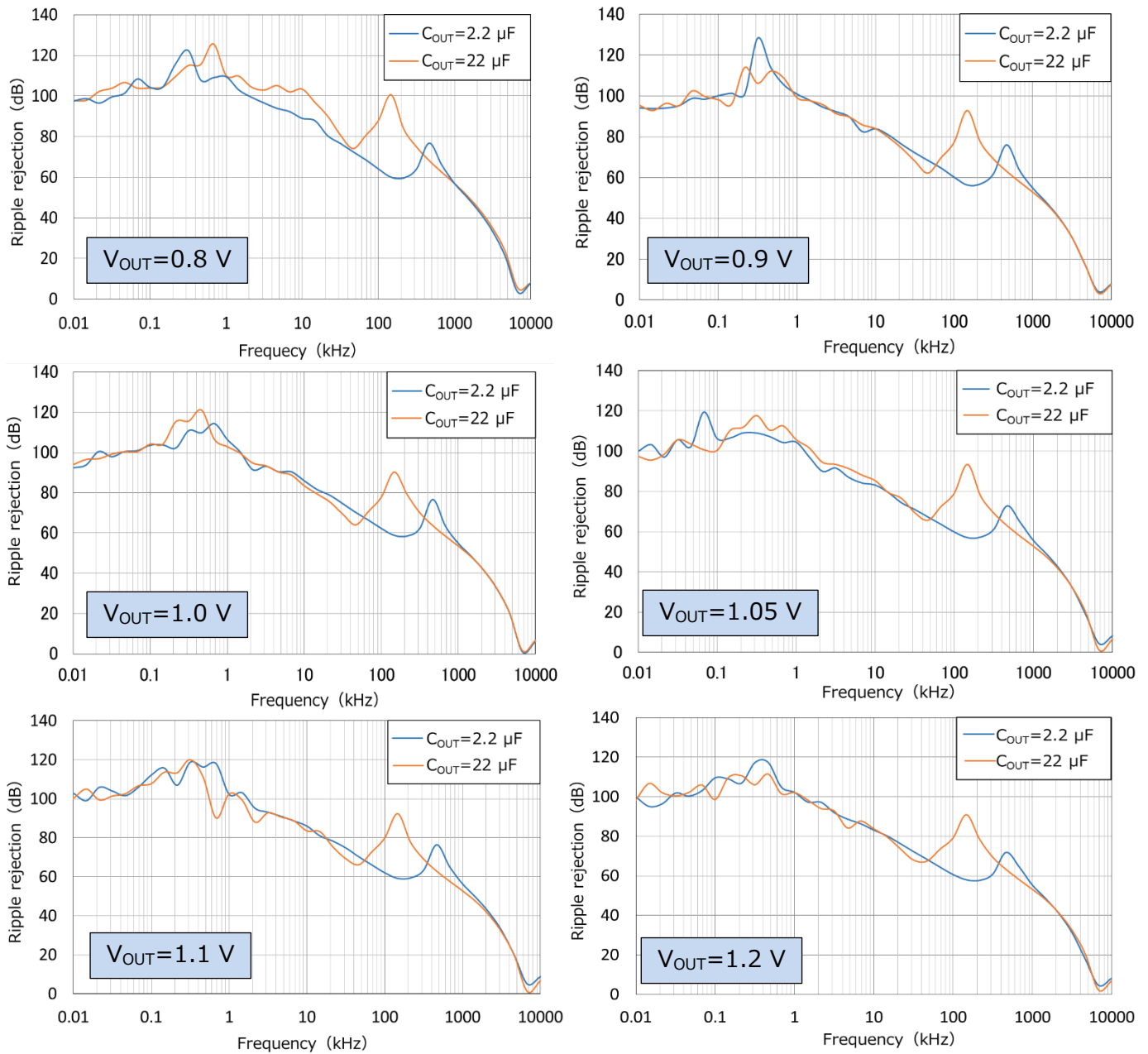**(V_{IN}=1.35 V, V_{BIAS}=3.3 V, I_{OUT}=10 mA)**

Fig. 4.7 Ripple Rejection Frequency Characteristics of TCR8BM Series
($V_{IN}=V_{OUT}+0.3$ V, $V_{BIAS}=3.3$ V, $I_{OUT}=10$ mA)

4.5. Other Electrical Characteristics

In addition to the three items described in the previous section, the datasheet contains various electrical characteristics. These are also briefly described below. The data sheet contains values when Ta (ambient temperature) =25 °C, but some items contain values within the range of Ta =-40 to 85 °C.

- Output-voltage accuracy: V_{OUT}
  The output voltage is distributed at a constant width with the set value as the center due to factors such as variations in internal circuit elements. This field is a width value indicating the maximum and minimum. TCR5BM/8BM series is lined up by the output voltage value, and when the output voltage is 1.8 V or less, it is displayed as a ratio to the output voltage, and when it is greater than 1.8 V, it is displayed as a voltage value.

- Line regulation: Reg·line
  This value indicates the fluctuation range of the steady output voltage within the range of the input voltage.

- Load regulation: Reg·load
  This value indicates the steady-state fluctuation range of the output voltage within the output current (load). This term indicates the fluctuation of the steady value. It is different from the load transient response.

- Quiescent current: $I_{BIAS(ON)}$, $I_{IN(ON)}$
  Indicates the current flowing to the VIN pin or VBIAS pin when the LDO is operated with no load connected to the output and no output current flowing. The smaller it is, the more efficient it is. Control pull-down current (below) is not included.

- Stand-by current: $I_{BIAS(OFF)}$, $I_{IN(OFF)}$
  Indicates the current that flows to the VIN pin or VBIAS pin while the LDO operation is stopped by the control pin. This current is the standby current for the set, which may cause the battery to drain. The smaller the current, the better the set.

- Control pull down current: I_{CT}
  This is the current that flows into the control terminal when the control terminal is set to HIGH.

- Under voltage lockout: V_{UVLO}
  Threshold value for the input voltage at which the undervoltage protection operation is performed.

- Temperature coefficient: T_{CVO}
  Temperature coefficient of the output voltage within the operating temperature range (-40 to

85 °C). Displays the change in output voltage when the temperature changes by 1 °C in ppm relative to the output voltage at normal temperature (25 °C).

● Output noise voltage: V_{NO}

This value indicates the magnitude of the noise component appearing in the output voltage.

● Control voltage: $V_{CT(ON)}$, $V_{CT(OFF)}$

Indicates the range of applied voltage to the control terminal that turns LDO ON or OFF. This indicates that the LDO is turned on securely within the control voltage (ON) range and turned off securely within the control voltage (OFF) range. Note that this does not indicate ON/OFF switching threshold. Be sure to set the voltage of HIGH signal to be applied to the control terminal and the voltage of the LOW signal to be within this voltage.

The threshold is distributed between the control voltage (ON) and the control voltage (OFF).

● Current limit: I_{CL}

Indicates the value of the output current at which overcurrent protection is activated. Wiring through which the output current flows should have a width such that there is no problem even if this current flows at a minimum.

● Output discharge on resistance: R_{SD}

Indicates the resistance value at which the charge stored in the output capacitor is discharged when the LDO is set to OFF.

4.6. Other Functions

TCR5BM/8BM series also has the following built-in functions.

● Overcurrent protection

If the output current exceeds the limit current due to a load error or short circuit, the output voltage begins to drop, and the output current also decreases. This protects the product from power dissipation when an error occurs. A circuit with such protection characteristics is called a foldback type.

● Thermal shutdown

If a large current continues to flow due to an incomplete short circuit in the load, etc., and the LDO temperature rises above the set value, the LDO is placed in the standby state to shut off the output to prevent damage.

● Inrush current reduction

When the output is turned on, the charging current of the output capacitor flows. If this current is too large, the overcurrent protection circuit may malfunction and become impossible to rise, or overshoot may occur in the output voltage. To prevent this, this function limits the current flowing through the output capacitor.

● Under voltage lockout

This function stops LDO operation to prevent malfunction when the input voltage drops below the operating range.

● Auto-discharge

This function discharges the remaining charge of the output capacitor when the output is turned off by control terminal control.

5. Product Overview

5.1. TCR5BM/8BM Series

The TCR5BM/8BM series are CMOS single-output voltage regulators with an on/off control input, featuring ultra low dropout voltage, high PSRR, low inrush current and fast load transient response.

A differentiating feature is the use of a secondary bias rail as a reference voltage that allows ultra low dropout of 100 mV (Typ.) at I_{OUT} = 500 mA (1.1 V output, V_{BIAS} = 3.3 V) in TCR5BM series, 170 mV (Typ.) at I_{OUT} = 500 mA (1.1 V output, V_{BIAS} = 3.3 V) in TCR8BM series.

These voltage regulators are available in fixed output voltages between 0.8 V and 3.6 V, and capable of driving up to 500 mA in TCR5BM series, up to 800 mA in TCR8BM series. Other features include overcurrent protection, thermal shutdown, and Auto-discharge.

Each series are offered in the ultra small plastic mold package DFN5B (1.2 mm x 1.2 mm; t 0.38 mm).

As small ceramic input and output capacitors can be used with the TCR5BM/8BM series, these devices are ideal for portable applications that require high-density board assembly such as cellular phones.

Features

- Low dropout voltage
  TCR5BM Series V_{DO} = 100 mV (typical) @ 1.1 V out, V_{BIAS} = 3.3 V, I_{OUT} = 500 mA
  TCR8BM Series V_{DO} = 170 mV (typical) @ 1.1 V out, V_{BIAS} = 3.3 V, I_{OUT} = 800 mA
- Low stand-by current
  TCR5BM/8BM Series $I_{BIAS(OFF)}$ = 1 µA (max.)
- Low quiescent current
  TCR5BM series $I_{BIAS(ON)}$ = 19 µA (typical) @ V_{BIAS} = 5.3 V, I_{OUT} = 0 mA)
  TCR8BM series $I_{BIAS(ON)}$ = 20 µA (typical) @ V_{BIAS} = 5.5 V, I_{OUT} = 0 mA)
- Wide output voltage line-up: (V_{OUT} = 0.8 to 3.6 V)
- Built-in overcurrent protection circuit
- Built-in thermal shutdown circuit
- Inrush current reduction circuit built-in
- Built-in low-voltage malfunction prevention circuit
- Built-in auto-discharge function
- CONTROL pin and GND pin are connected in a pull-down manner.
- Ultra-small-outline package: DFN 5 B (1.2 mm x 1.2 mm ; t 0.38 mm)

5.2. Appearance and Terminal Arrangement

BOTTOM VIEW ILLUSTRATION

VIN   CONTROL
4   5*   3

1   2
VOUT   VBIAS
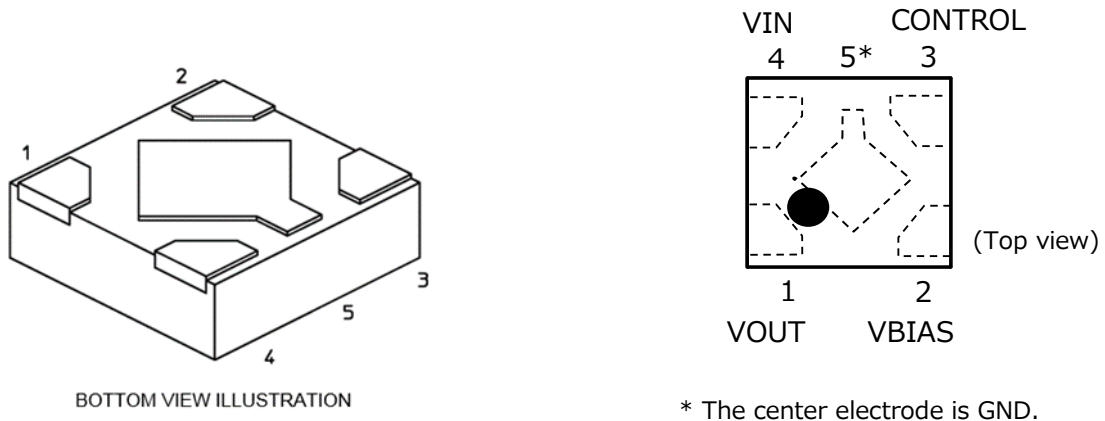
(Top view)

* The center electrode is GND.

Fig.   5.1 External View and Pin Layout of TCR5BM/8BM Series

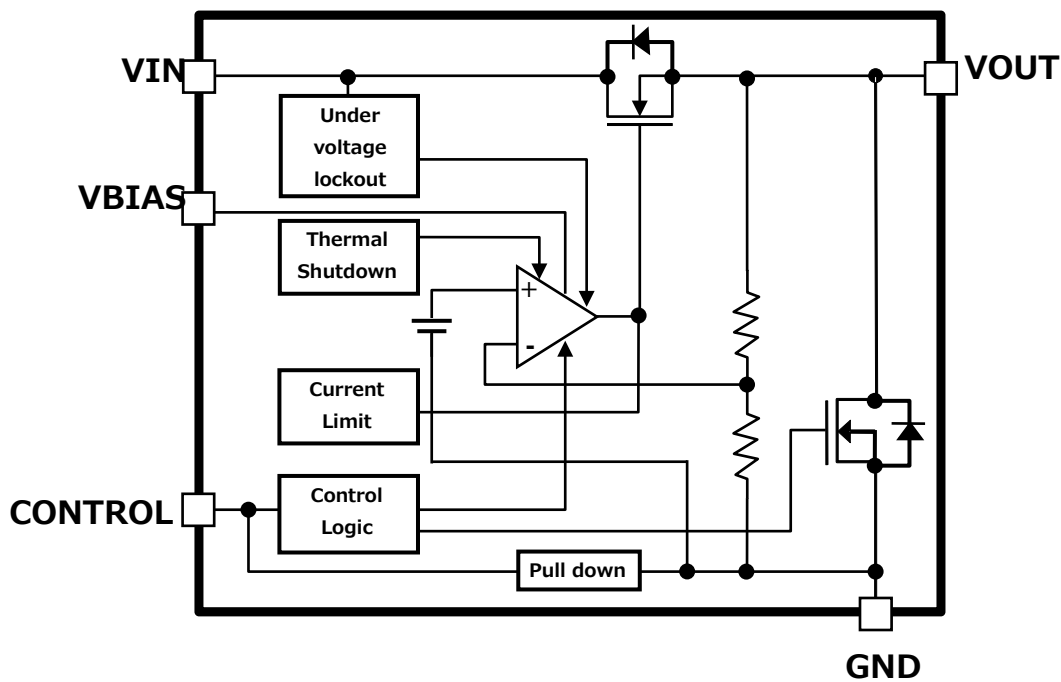## 5.3. Internal Circuit Block Diagram

Fig.   5.2 Internal Circuit Blocks for TCR5BM/8BM Series

5.4. Product List

• TCR5BM series

Table 5.1 List of TCR5BM Series/Product Labeling

Product name.	V_{OUT} (V)	Indication of	Product name.	V_{OUT} (V)	Indication of
TCR5BM08A	0.8	0N8	TCR5BM21A	2.1	2N1
TCR5BM085A	0.85	0NJ	TCR5BM22A	2.2	2N2
TCR5BM09A	0.9	0N9	TCR5BM23A	2.3	2N3
TCR5BM095A	0.95	0NK	TCR5BM24A	2.4	2N4
TCR5BM10A	1.0	1N0	TCR5BM25A	2.5	2N5
TCR5BM105A	1.05	1NA	TCR5BM26A	2.6	2N6
TCR5BM11A	1.1	1N1	TCR5BM27A	2.7	2N7
TCR5BM115A	1.15	1NB	TCR5BM28A	2.8	2N8
TCR5BM12A	1.2	1N2	TCR5BM285A	2.85	2NJ
TCR5BM125A	1.25	1NC	TCR5BM29A	2.9	2N9
TCR5BM13A	1.3	1N3	TCR5BM295A	2.95	2NK
TCR5BM14A	1.4	1N4	TCR5BM30A	3.0	3N0
TCR5BM15A	1.5	1N5	TCR5BM31A	3.1	3N1
TCR5BM16A	1.6	1N6	TCR5BM32A	3.2	3N2
TCR5BM17A	1.7	1N7	TCR5BM33A	3.3	3N3
TCR5BM18A	1.8	1N8	TCR5BM34A	3.4	3N4
TCR5BM19A	1.9	1N9	TCR5BM35A	3.5	3N5
TCR5BM20A	2.0	2N0	TCR5BM36A	3.6	3N6

• TCR8BM series

Table 5.2 List of TCR8BM Series/Product Labeling

Product name	V_{OUT} (V)	Indication of	Product name	V_{OUT} (V)	Indication of
TCR8BM08A	0.8	0P8	TCR8BM21A	2.1	2P1
TCR8BM085A	0.85	0PJ	TCR8BM22A	2.2	2P2
TCR8BM09A	0.9	0P9	TCR8BM23A	2.3	2P3
TCR8BM095A	0.95	0PK	TCR8BM24A	2.4	2P4
TCR8BM10A	1.0	1P0	TCR8BM25A	2.5	2P5
TCR8BM105A	1.05	1PA	TCR8BM26A	2.6	2P6
TCR8BM11A	1.1	1P1	TCR8BM27A	2.7	2P7
TCR8BM115A	1.15	1PB	TCR8BM28A	2.8	2P8
TCR8BM12A	1.2	1P2	TCR8BM285A	2.85	2PJ
TCR8BM125A	1.25	1PC	TCR8BM29A	2.9	2P9
TCR8BM13A	1.3	1P3	TCR8BM295A	2.95	2PK
TCR8BM14A	1.4	1P4	TCR8BM30A	3.0	3P0
TCR8BM15A	1.5	1P5	TCR8BM31A	3.1	3P1
TCR8BM16A	1.6	1P6	TCR8BM32A	3.2	3P2
TCR8BM17A	1.7	1P7	TCR8BM33A	3.3	3P3
TCR8BM18A	1.8	1P8	TCR8BM34A	3.4	3P4
TCR8BM19A	1.9	1P9	TCR8BM35A	3.5	3P5
TCR8BM20A	2.0	2P0	TCR8BM36A	3.6	3P6

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5.5. Terminal Description

Table 5.3 Pin Description of TCR5BM/8BM Series

Pin number	Pin name	Function
1	VOUT	Output terminal For stable operation, it is recommended to use a capacitor of 2.2 µF or more (ESR=1Ω or less).
2	VBIAS	Bias power supply input pin The maximum input voltage for this pin is 6 V. For stable operation, it is recommended to use a capacitor of 0.1 µF or more (ESR=1 Ω or less).
3	CONTROL	Output ON/OFF control terminal When this pin is set to "High", the output is turned ON, and when it is set to "Low", the output is turned OFF. This pin is pulled down internally. For OPEN, the output will be OFF.
4	VIN	Power input terminal The maximum input voltage for this pin is 6 V. For stable operation, it is recommended to use a capacitor of 1 µF or more (ESR=1 Ω or less).
5	GND	Ground terminal

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