LDO Regulator Application to Power Supplies for High-Frequency Circuits

Overview

This application note describes the applications of the LDO regulator TCR5BM/8BM series for battery-powered mobile devices to power supplies for high-frequency circuits (RF blocks) in Wi-Fi® compatible mobile devices, including various features and characteristics of this product. Please refer to this document when designing a power supply for RF-blocks using TCR5BM/8BM Series.

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1. Introduction

Low-drop out regulator ICs (hereinafter"LDOs") are widely used inside various electronic devices, and in mobile devices such as smartphones and tablets they are particularly required to be smaller and lighter in size and save power.

By using an external bias pin separately from the input pin as the power supply line for the output drive, TCR5BM/8BM series achieves extremely low dropout characteristics of 100 mV (typical) for TCR5BM series and 170 mV (typical) for TCR8BM series, while ensuring stable operation at low voltages and high output currents.

Both series have a fixed output voltage lineup, ranging from 0.8 V to 3.6 V, and have a maximum output current of 500 mA (typical) for TCR5BM series and 800 mA (typical) for TCR8BM series, allowing you to use the optimum output voltage for power supplies for a wide range of applications.

DFN5B packages (1.2 mm×1.2 mm×0.38 mm) are also used, contributing to smaller and thinner sets.

Please refer to the datasheet for details of TCR5BM/8BM series, such as the characteristics of the series. For details of the main characteristics of the LDO, refer to the link destination below.

Downloading TCR5BM Series Data Sheets: -> Click Here

Downloading TCR8BM Series Data Sheets: -> Click Here

For the power efficiencies of the 2-power supply type LDOs -> Click Here

For the load transient responses of LDOs -> Click Here

For ripple rejection ratio-> Click Here

For oscillations of LDOs -> Click Here

For optimization of thermal designs -> Click Here

2. Required Characteristics for Power Supply for RF Block

As shown in Figure 2.1, the RF block generally consists of digital power supplies, analog power supplies, etc., and the required performance differs for each. This guide describes the applications of the LDO regulator TCR5BM/8BM series to low-voltage, high-current loads.

Digital power supplies for RF blocks currently use voltages of about 1.0 to 1.2 V. However, this voltage tends to be lower, and is expected to be in the range of 0.8 to 1.2 V in the future.

The RF-block digital power supply features instantaneous increase/decrease of load current of several hundred mA as peak current due to the power-enhancement of RF signals to improve communication quality, gain control of LNA (Low Noise Amplifier), and high throughput by MIMO (Multiple-Input and Multiple-Output) technology. If the output voltage fluctuates significantly with respect to a sudden increase or decrease in the load current, malfunction of the control logic, etc. may occur, causing operation abnormalities such as temporary communication disconnection or sound interruption. For this reason, load transient response characteristics are most important. In addition, it is important to reduce high-frequency noise, which has adverse effects such as RF signal interference. It is also necessary to have a high ripple rejection ratio, which is the ability to eliminate switching noise and other high-frequency noise components from DC-DC converters of PMIC that is the source of the noise.

In addition, the RF block is susceptible to heat and needs to be as low as possible in order to minimize the heat generated in the surrounding area, thus reducing power consumption.

The two-input LDO regulator TCR5BM/8BM offers the performance of low-fluctuation load transients, high ripple rejection ratio, and low power requirements of these RF-block digital power supplies in a small area. This section describes the specific circuit configuration.

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

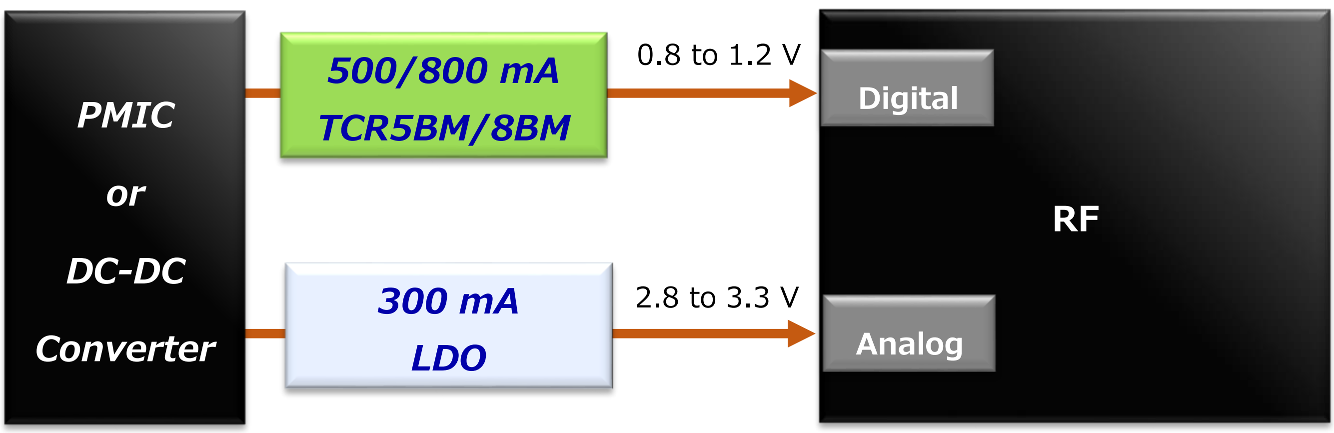


Figure 2.1 RF Block Power Configuration

3. Application circuit

3.1. Typical Connection Diagram

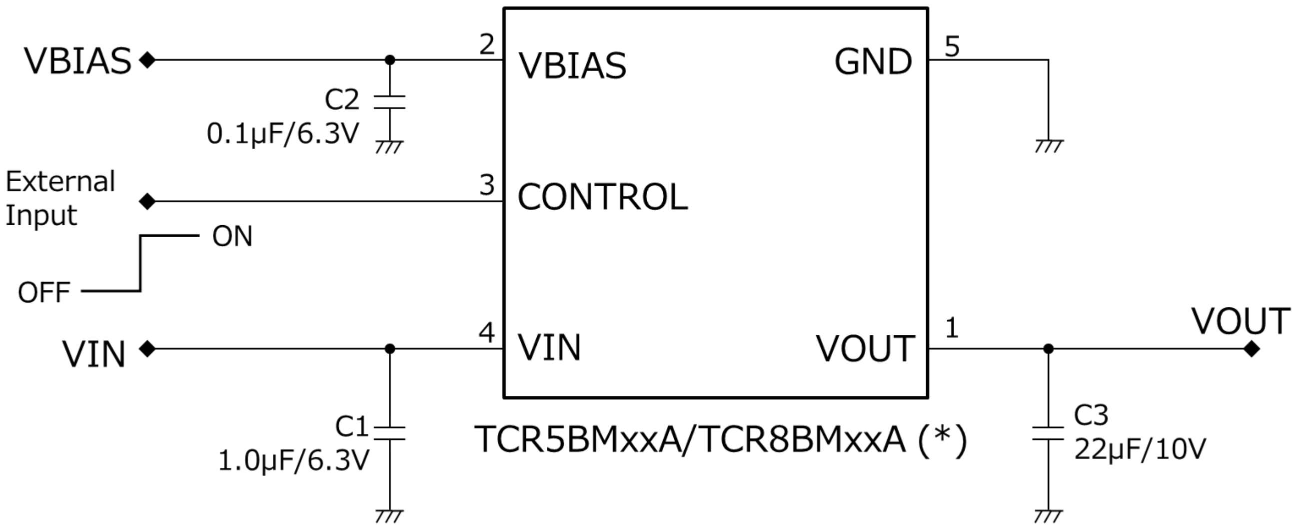


Figure 3.1 Applied Circuits for TCR5BM/TCR8BM Series RF Blocks

3.2. Parts list

Table 3.1 Bill of Materials

Item	Part	Quantity	Manufacturer	Value	Part 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 bill of materials, the xx part of the product name is a number indicating the output voltage.
e.g. TCR5BM12A/TCR8BM12A when V_{OUT}=1.2 V

4. Circuit and Board Design

4.1. Points to note in the design

This section describes the points to note in designing circuits and boards when configuring RF-block power supplies using TCR5BM/8BM Series.

- About VBIAS inputs

  VBIAS pin is the power supply for the circuits that drive the output elements. Therefore, input a voltage that is 2.5 V or higher and higher than VOUT voltage + 1.4 V higher, and use as stable a power supply as possible for the external voltage. Noise, etc., may adversely affect the output voltage through the drive circuit of this LDO.

  Also, set the power supply startup sequences in order of VBIAS -> VIN -> CONTROL.

- External Capacitors

  Ceramic capacitors can be used with this LDO, but depending on the type, they may have very large temperature characteristics. When selecting a capacitor, consider the operating environment thoroughly. We also recommend 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 the LDO is designed with sufficient consideration for oscillation such as built-in phase compensation capacitance, oscillation may occur due to the influence of wiring resistance and L component depending on the pattern of the printed circuit board and external conditions such as the operating environment.

  As a general precaution, route the wiring of VIN and GND so as not to form a loop, and make the wiring area as large as possible to reduce the wiring resistance. Pay special attention to the routing of the path through which I/O current flows so that VIN and GND inside the LDO are not affected by the common impedance. Be aware that VBIAS wiring is also susceptible to noises if it is routed too long.

  Generally, the influence of routing of wires can be solved by optimizing the value and position of the capacitor while checking the output waveform on the actual device. However, even if there is no influence, use a capacitor with a value larger than that shown in the previous section. When the output capacitor is apart from VOUT pin of the LDO, the output capacitor is easily affected by the wiring resistor and L-component. For more stable operation of the power supply, mount the output capacitor as close to the output terminal as possible, and separate the wiring to be connected from the wiring that carries the output current as close to VOUT terminal as possible (if possible, at the root of the terminal), so that the wiring resistance does not affect as a common impedance.

  Figure 4.1 shows an image of routing of the wiring pattern.

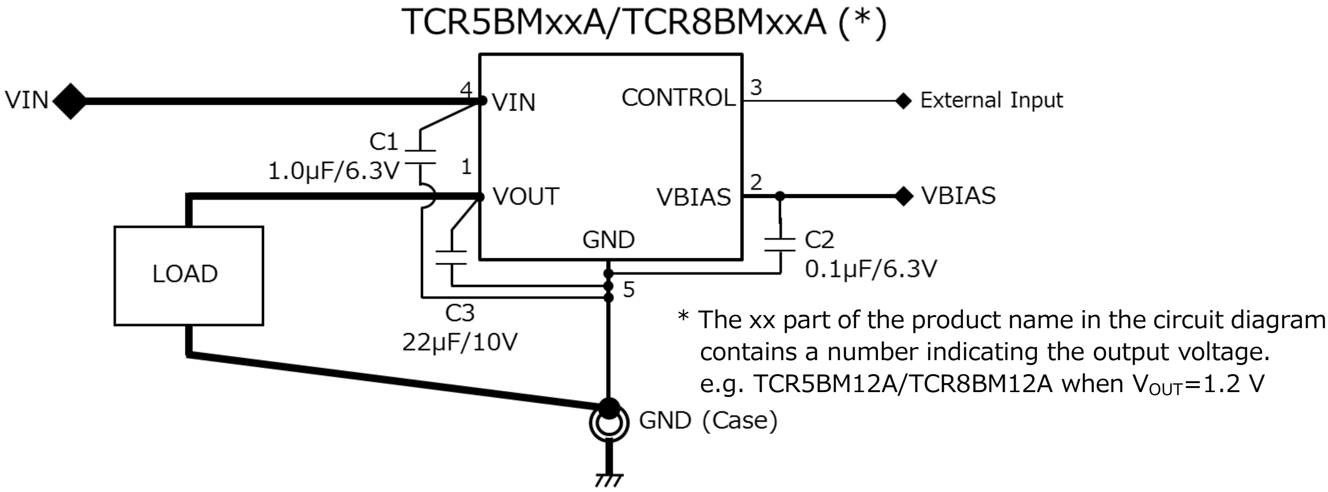


Figure 4.1 Routing Image of Wiring Pattern

- Allowable loss
  Design the printed circuit board pattern to have as much margin as possible for heat generation during maximum loss (power consumption) in LDO assumed in actual use conditions. Consider the worst case of each parameter such as ambient temperature, input voltage and output current in the actual operating environment, and design with a derating of approximately 1.2 to 1.5 times the assumed maximum loss (power consumption).

- Overcurrent protection circuit and overheat protection circuit
  This LDO has built-in foldback type overcurrent protection circuit and overheat protection circuit, but these do not guarantee that the operation of the device is always kept within the maximum rating. Depending on the conditions of use, deterioration and reliability of the product may be affected. Nor does it guarantee that LDO will not destroy in any case. If the output and GND terminals of this LDO are in the imperfect short mode, the LDO may be damaged.
  When using this LDO, please refer to the above and the absolute maximum ratings stated in our "Semiconductor Reliability Handbook" and data sheets, etc., and pay attention not to exceed the absolute maximum ratings in any case considering the appropriate derating.
  In addition, it is recommended that adequate safety measures such as fail-safe be implemented in the set.

4.2. Dropout voltage: V_{DO}

In the data sheet, it is specified as the minimum value of the difference between the input voltage and the output voltage required to output a predetermined voltage. It may also be referred to as the minimum voltage difference between input and output. Lower values consume less power.

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

V_{OUT} values show the drop-out voltage characteristics of TCR5BM/8BM series products suitable for RF-block digital power supplies. Please refer to them when applying.

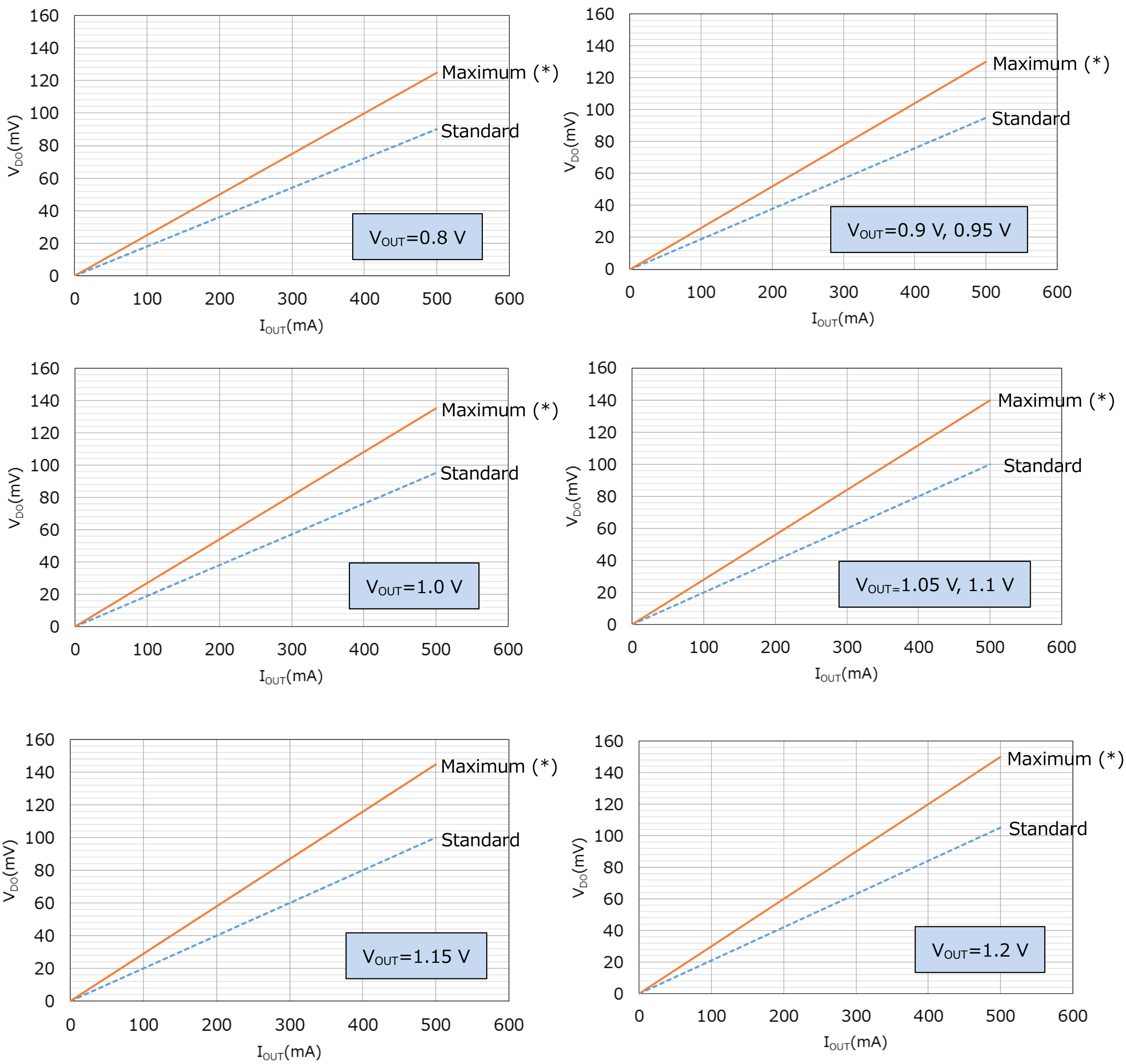


Figure 4.2 Dropout Voltage Characteristics of TCR5BM Series (V_{BIAS}=3.3 V, V_{OUT}=0.8 to 1.2 V)

* The maximum condition includes the full temperature range.

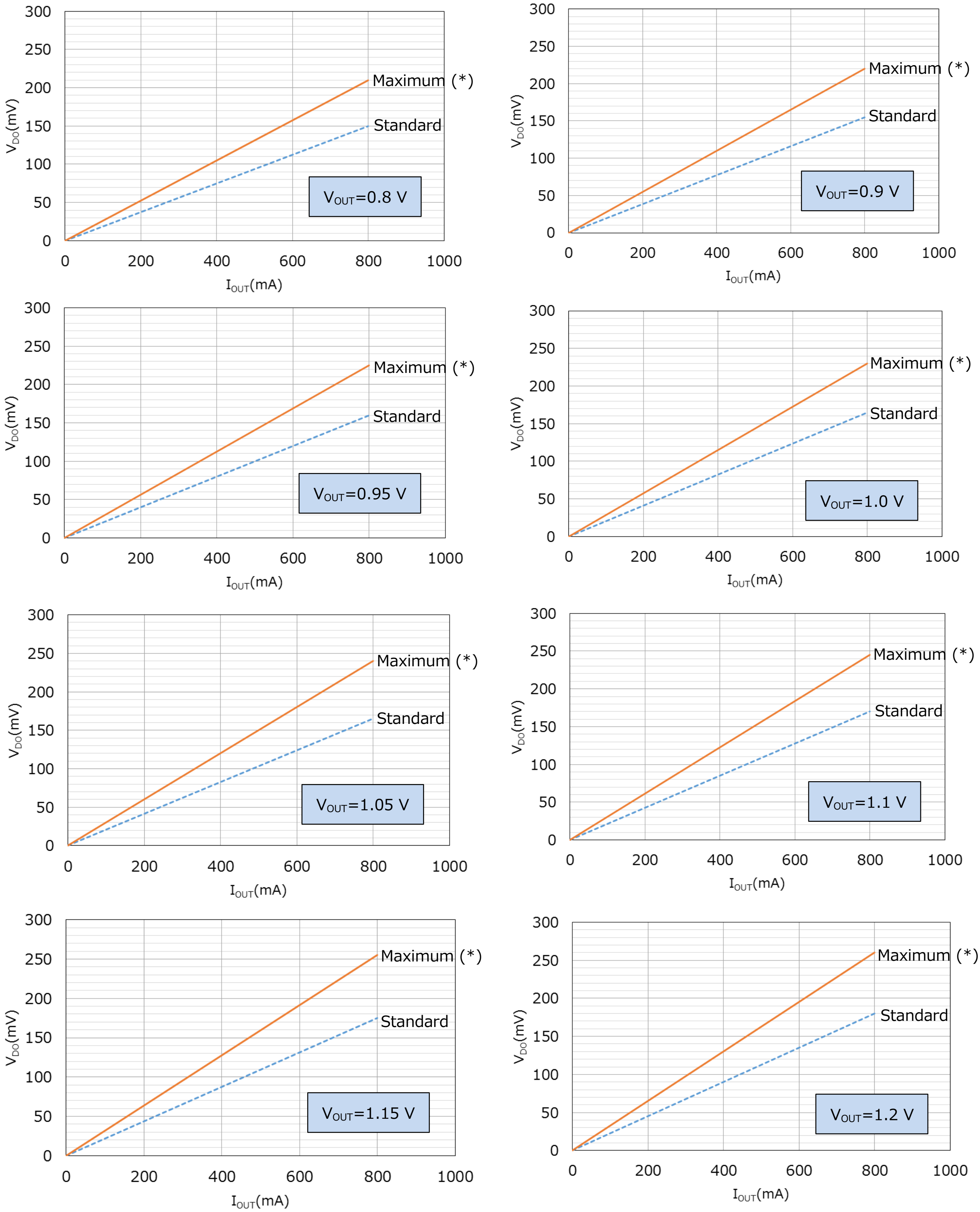


Figure 4.3 TCR8BM Series Dropout Voltage Characteristics (V_{BIAS}=3.3 V, V_{OUT}=0.8 to 1.2 V)

* The maximum condition includes the full temperature range.

4.3. Load transient response: Delta V_{OUT}

Indicates the peak value of the fluctuation instantaneously appearing in the output voltage for the step change in the load current.

Since the resistance of the load connected to the output of the LDO is not constant, the output current also fluctuates accordingly. However, TCR5BM/8BM series has excellent response performance against sudden current changes and performs stable constant voltage operation.

V_{OUT} values show the load-transient-response waveforms of TCR5BM/8BM series products suitable for RF-block digital power supplies. Please refer to them when applying them.

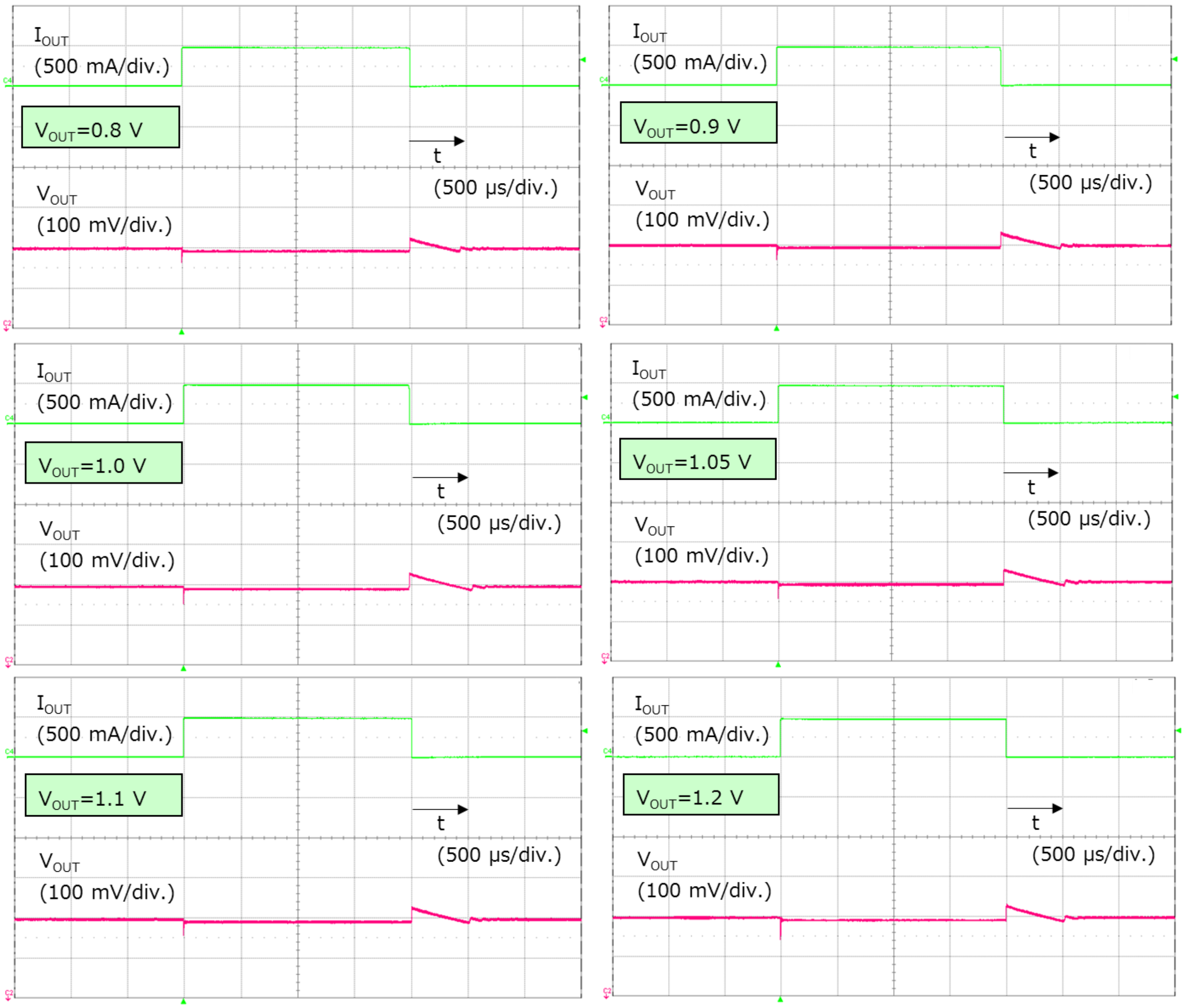


Figure 4.4 Load Transient Responses of TCR5BM Series
(V_{IN}=1.35 V, V_{BIAS}=3.3 V, I_{OUT}=1 mA-500 mA-1 mA, C_{OUT}=22 µF)

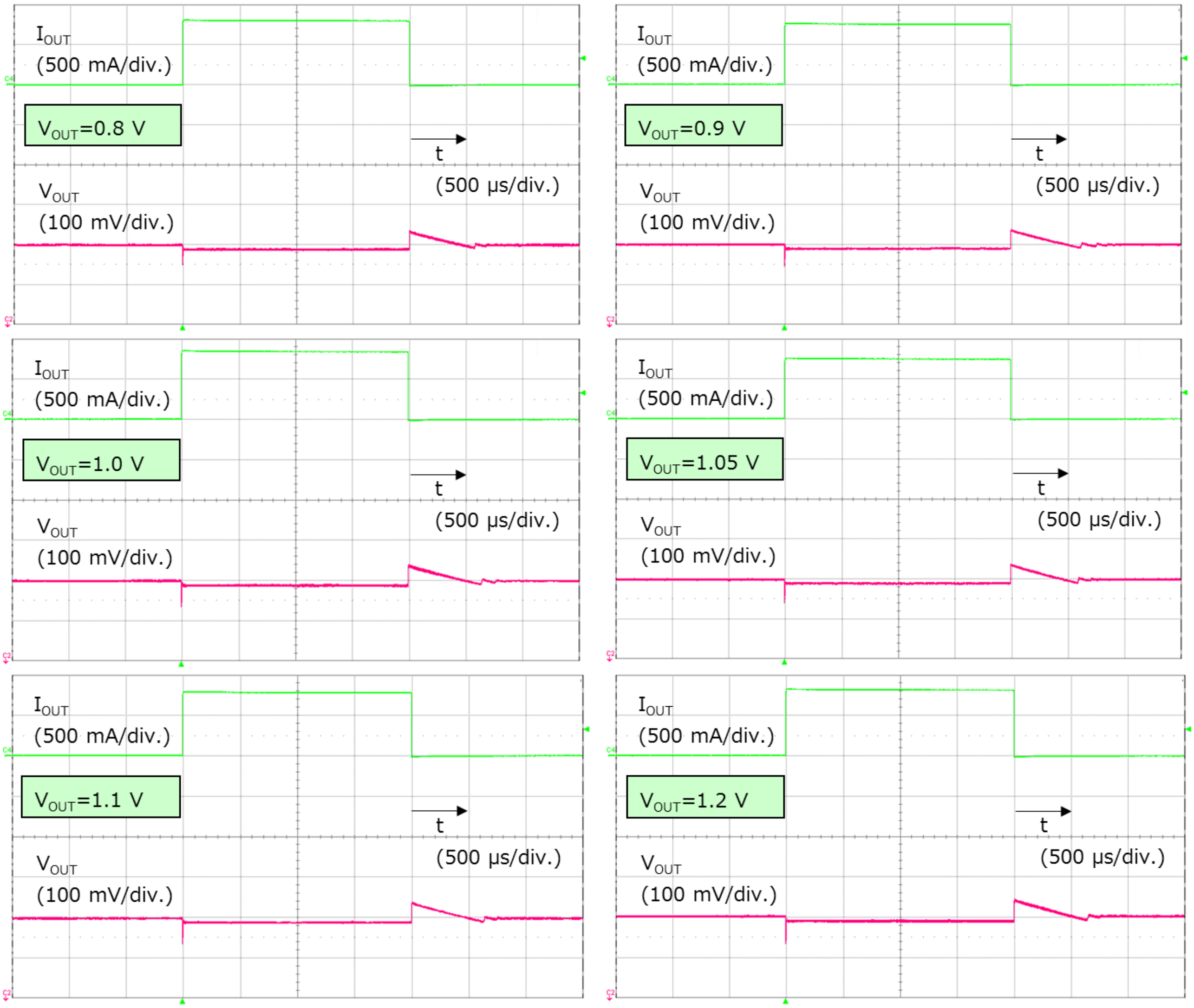


Figure 4.5 Load Transient Responses of TCR8BM Series
(V_{IN}=V_{OUT}+0.3 V, V_{BIAS}=3.3 V, I_{OUT}=1 mA-800 mA-1 mA, C_{OUT}=22 μF)

4.4. Ripple Rejection Ratio: R.R.

Also known as PSRR (Power Supply Rejection Ratio), this is the ratio of the ripple voltage component included in the input voltage to the ripple voltage component appearing at the output voltage. A larger value indicates a smaller ripple component that appears in the output, but in some cases the denominator and numerator are interchanged and displayed as a minus, in which case the smaller one is better.

In determining the influence of power supply noise on the load side, this characteristic is also very important for LDOs with low-voltage output.

The following shows the frequency characteristics of the ripple rejection ratio of TCR5BM/8BM series products whose V_{OUT} values are suitable for RF-block digital power supplies. This section describes the characteristics when C_{OUT} of outputs is 2.2 μF and 22 μF as a reference for determining external constants.

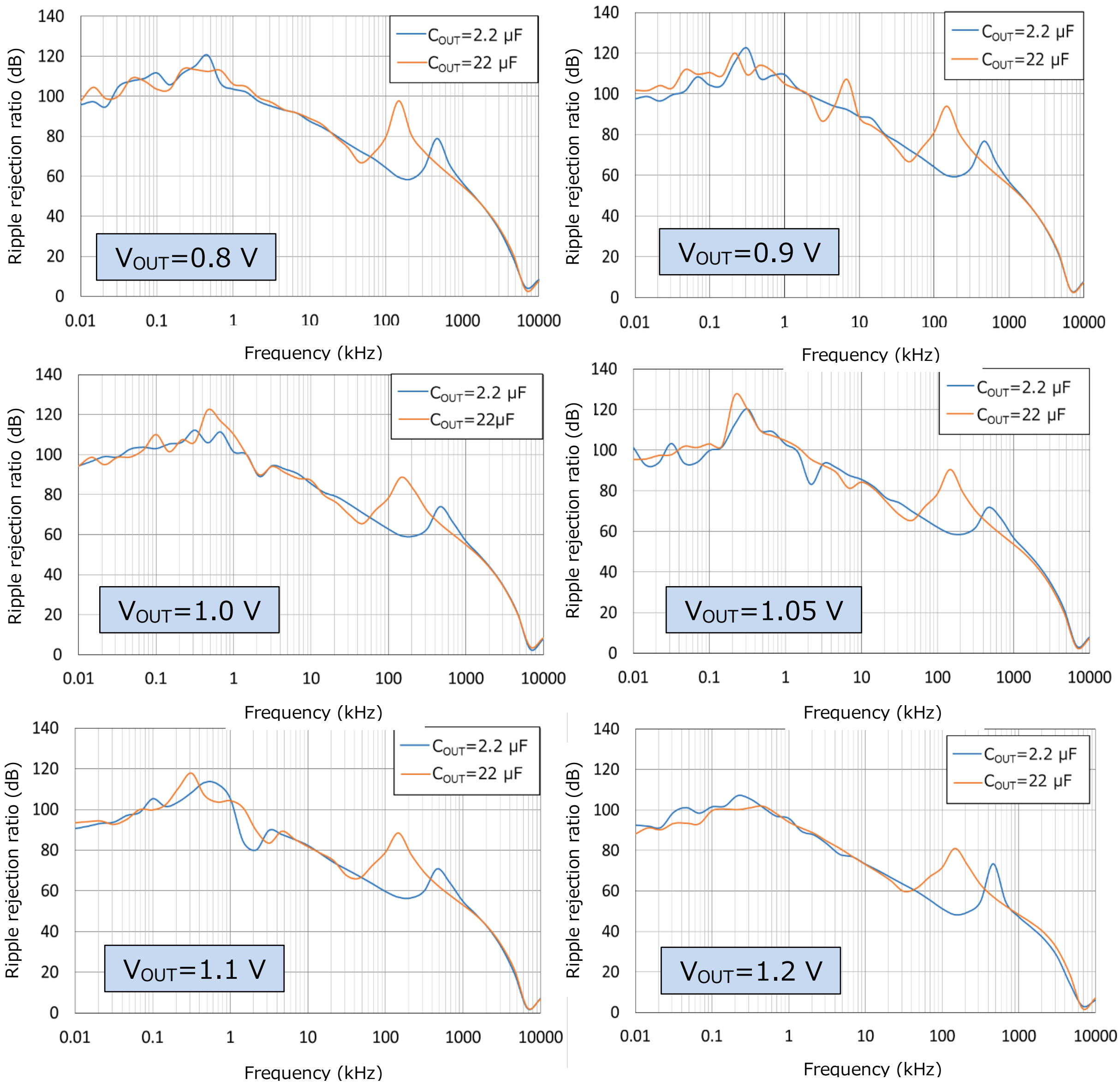


Figure 4.6 Ripple Rejection Ratio Frequency Characteristics of TCR5BM Series
(V_{IN}=1.35 V, V_{BIAS}=3.3 V, I_{OUT}=10 mA)

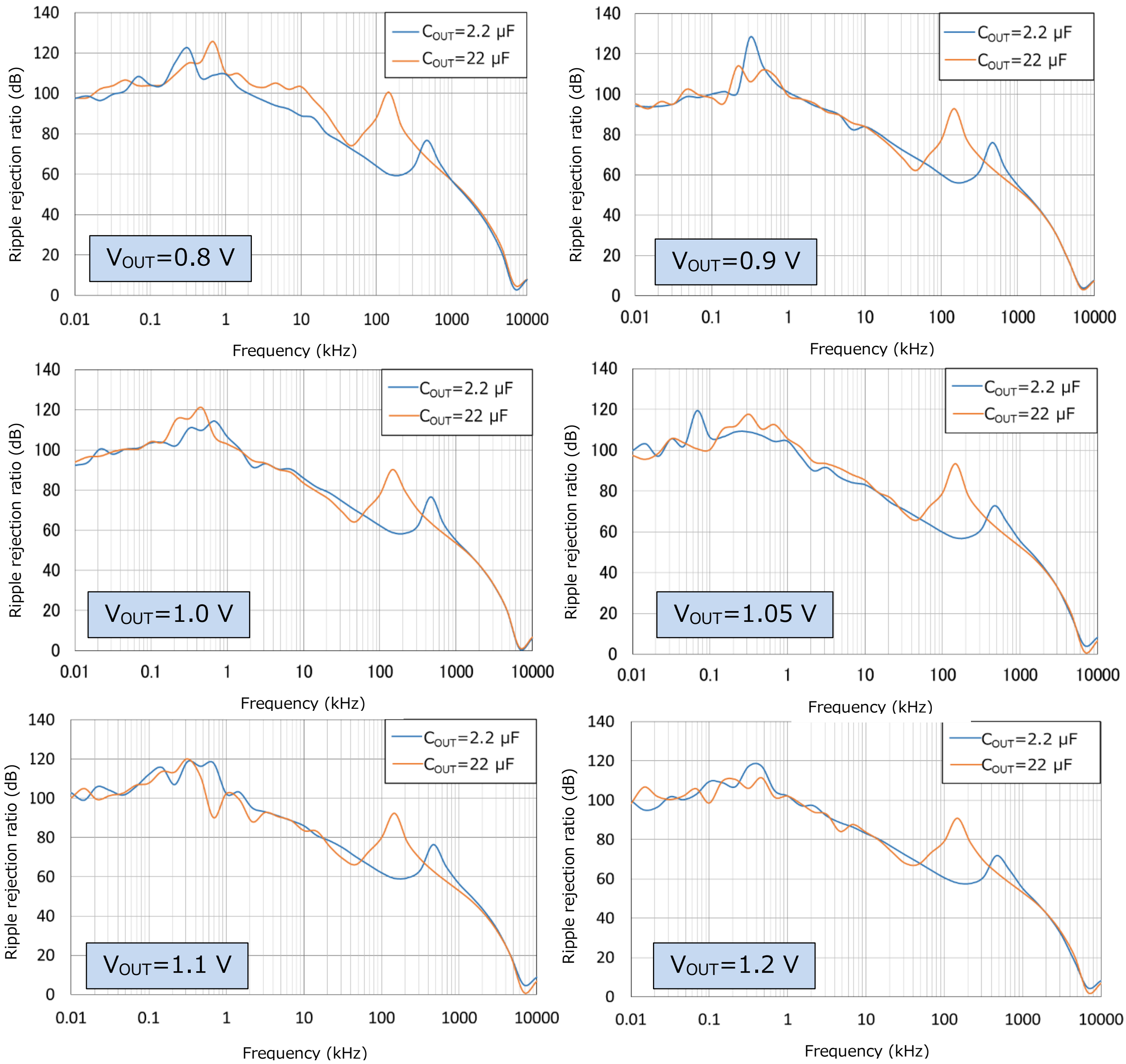


Figure 4.7 Ripple Rejection Ratio Frequency Characteristics of TCR8BM Series
(V_{IN}=V_{OUT}+0.3 V, V_{BIAS}=3.3 V, I_{OUT}=10 mA)

4.5. Other electrical characteristics

In addition to the three items described above, the data sheet also contains various electrical characteristics. These are also briefly described below. Data sheets contain values at 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 the internal circuit elements. VOUT shows the width, indicating maximum and minimum. TCR5BM/8BM series is lined up according to the output voltage value. If the output voltage is 1.8 V or less, VOUT is displayed as a ratio to the output voltage. If the output voltage is greater than 1.8 V, VOUT is displayed as a voltage value.

- Inputstability: Reg・line
  The amount of change of V_{OUT} with respect to V_{IN} when I_{OUT} is kept constant.

- Load-stability: Reg・load
  The amount of change of V_{OUT} with respect to I_{OUT} when V_{IN} is kept constant.This indicates the fluctuation of the steady-state value, and is different from the load transient response.

- Bias current: $I_{BIAS(ON)}$, $I_{IN(ON)}$
  This value indicates the current that flows to the VIN pin or VBIAS pin when the LDO is operated with no load connected to the output and no output current applied. The smaller the value, the better the efficiency will be. Control pull-down current (below) is not included.

- Standby current: $I_{BIAS(OFF)}$, $I_{IN(OFF)}$
  This value indicates the current flowing to the VIN pin or VBIAS pin when the LDO operation is stopped by the control pin. This current is the standby current in the set, which causes the battery to drain. The smaller the current is the desirable item.

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

- Undervoltage protection threshold voltage: V_{UVLO}
  Threshold value for the input voltage that performs undervoltage protection operation.

- Output-voltage thermal coefficient: T_{CVO}
  The temperature coefficient of the output voltage within the operating temperature range (-40 °C to 85 °C). Displays the change in output voltage when the temperature changes by 1 °C in ppm with respect to the output voltage at room temperature (25 °C).

- Output-Noise Voltage: V_{NO}
  This value indicates the magnitude of the noise component appearing in the output voltage.

- Control Voltages: $V_{CT(ON)}$, $V_{CT(OFF)}$
  Indicates the range of the applied voltage to the control terminals that turn LDO ON or OFF. This indicates that the LDO is ON within the control voltage (ON) range and OFF within the control voltage (OFF) range. Note that this does not indicate the distributions of ON/OFF switching thresholds. Be sure to set the voltage of HIGH signal 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).

- Limit current: I_{CL}
  Indicates the value of the output current at which the overcurrent protection operates. Wiring in which the output current flows should have a width that will not cause any problem even if this current flows at least.

- Output Discharge On Resistance: R_{SD}
  Indicates the resistance value that discharges the charge stored in the output capacitor when LDO is set to OFF.

4.6. Other Functions

The following functions are also built into TCR5BM/8BM series.

- Overcurrent protection function
  If the output current exceeds the limit current due to an abnormality or short-circuit in the load, the output voltage begins to drop and the output current also drops. This protects the unit from power consumption in the event of an abnormality. Circuits with such protective characteristics are called foldback types.

- Overheat protection function
  If a large current continues to flow due to semi-short-circuit of the load, etc., and the temperature of the LDO exceeds the set value, the LDO is placed in standby and the output is shut off to prevent damage.

- Inrush current suppression function
  When the output is turned on, the charging current of the output capacitor flows. However, if this current is too large, the overcurrent protection circuit may malfunction and rise may be disabled, or overshoot may occur in the output voltage. To prevent this, this function limits the current flowing through the output capacitor.

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

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

5. Product Overview

5.1. TCR5BM/8BM series

TCR5BM/8BM series are single-output LDO regulators of CMOS technology dropouts, fast load transients, high ripple rejection ratio, inrush current suppression circuits, and control terminals. By adopting a function to provide an external bias voltage separately from the power input, the dropout voltage is 100 mV (typical) (1.1 V output, I_{OUT} = 500 mA, V_{BIAS} = 3.3 V) for TCR5BM series and 170 mV (typical) (1.1 V output, I_{OUT}= 800 mA, V_{BIAS} = 3.3 V) for TCR8BM series.

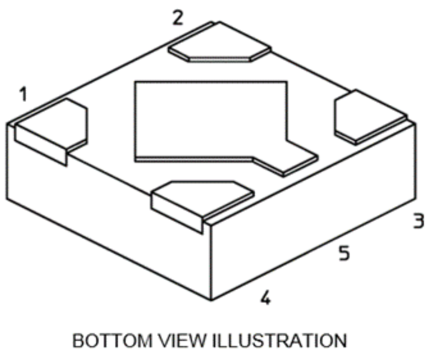
The output voltage can be selected from 0.8 V to 3.6 V with the voltage fixed type. The maximum output current of TCR5BM series is 500 mA and that of TCR8BM series is 800mA, and the overcurrent protection circuit, overheat protection circuit and auto discharge function are provided.

All products use an ultra-compact packaged DFN5B (1.2 mm x 1.2 mm ; t 0.38 mm) and small ceramic capacitors are applicable for inputs and outputs, making them ideal for applications requiring high-density mounting, such as portable devices.

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 standby current
  TCR5BM/8BM series $I_{BIAS(OFF)}$ = 1 μA (max)
- Low bias 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 Lineup: (V_{OUT} = 0.8 to 3.6 V)
- Built-in overcurrent protection circuit
- Built-in overheat protection circuit
- Inrush current suppression circuit built-in
- Built-in low-voltage malfunction prevention circuit
- Built-in auto discharge function
- Pull-down connections are provided between CONTROL and GND terminals.
- Ultra-small-outline package: DFN 5 B (1.2 mm x 1.2 mm ; t 0.38 mm)

5.2. Appearance and terminal arrangement



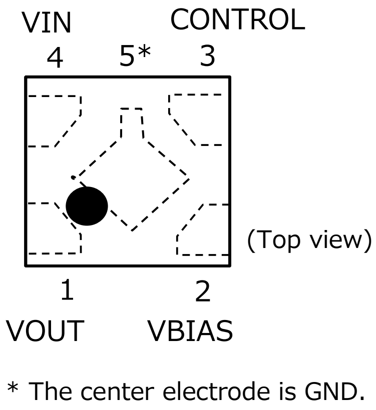


Figure 5.1 Appearance and Pin Layout of TCR5BM/8BM Series

5.3. Internal circuit block diagram

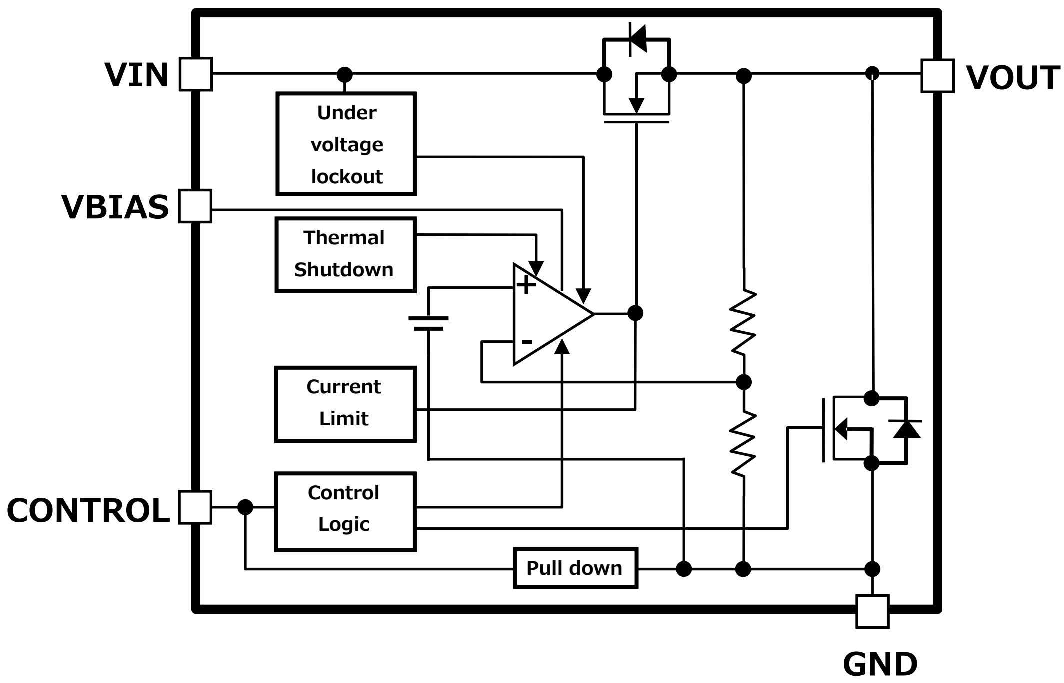


Figure 5.2 TCR5BM/8BM Series Internal Circuit Blocks

5.4. Product List

- **TCR5BM series**

Table 5.1 List of TCR5BM series products and actual products

Product name.	V_{OUT} (V) (Typical)	Actual product indication	Product name.	V_{OUT} (V) (Typical)	Actual product indication
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 products and actual products

Product name.	V_{OUT} (V) (Typical)	Actual product indication	Product name.	V_{OUT} (V) (Typical)	Actual product indication
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

5.5. Terminal Description

Table 5.3 TCR5BM/8BM Series Pin Descriptions

Pin number	Pin name	Function
1	VOUT	Output terminal It is recommended to use a capacitor of 2.2 μF or more (ESR=1Ω or less) for stable operation.
2	VBIAS	Bias power input pin The maximum input voltage of this pin is 6 V. It is recommended to use a capacitor of 0.1 μF or more (ESR=1 Ω or less) for stable operation.
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. If it is OPEN, the output is turned off.
4	VIN	Power input terminal The maximum input voltage of 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

6. Conclusion

The Toshiba LDO regulator uses a two-power circuit configuration, enabling high-power efficiency and low-loss, high-current, low-voltage output.
Furthermore, high-speed load transient response at high currents required for stable operation of the subsequent ICs and high ripple rejection ratio over a wide frequency range allow the ICs to be used as power supply ICs for high-frequency (RF) circuits. Refer to the data sheet for details of each characteristic.

Low-drop-out LDO products with two power supplies capable of high power efficiency

500mA LDO: Download TCR5BM datasheet from here -> Click Here
800mA LDO: Download TCR8BM datasheet from here -> Click Here
1.3A LDO : Download TCR13AGADJ datasheet from here -> Click Here
1.5A LDO : Download TCR15AG datasheet from here -> Click Here

For more information on using the LDO, see "Low Drop-Out (LDO) Regulator IC Application Notes".
Low Drop-Out (LDO) regulator IC application note from here -> Click Here

Other LDO product lineup is from here -> Click Here

RESTRICTIONS ON PRODUCT USE

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