TCR3EMxxA/3DMxxA/3LMxxA Series LDO Regulators With 300mA Output in Small DNF4D Package for Power Supply Circuit Applications

Reference Guide

RD251-RGUIDE-01

Toshiba Electronic Devices & Storage Corporation

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1. Introduction

A low drop out (LDO) regulator is a linear regulator that outputs a constant voltage lower than the input voltage and can operate even with a small input/output voltage difference. It is widely used in a variety of electronic devices, including mobile devices such as smartphones and tablets that require a compact and lightweight design, stable output voltage, and power savings.

1.1. Advantages of LDO Regulators Compared to Switching Regulators

The difference between a switching regulator and an LDO regulator is that a switching regulator outputs a constant voltage by controlling the on/off time of the switching element (MOSFET, etc.), while an LDO regulator outputs a constant voltage by controlling the on-resistance of the switching element. Due to this difference in control methods, each has its own advantages and disadvantages. Table 1.1 compares switching and LDO regulators. Compared to switching regulators, LDO regulators have the advantages of lower noise, fewer external components, easier circuit design, and smaller circuit size and area.

Table 1.1 Comparison of LDO Regulators and Switching Regulators

Electrical Characteristics	LDO Regulators (Linear Regulators)	Switching Regulators
Operation (output voltage)	Step-down	Buck, boost, buck-boost, and reversible
Efficiency	Depends on V_{out}/V_{in}	~95% (generally high)
Output current	Relatively small	Relatively large
Noise	Small	Large
External components	Few	Many
Design	Simple	Complex
Circuit size and area	Small	Large

1.2. LDO Regulator Internal Operation

By adjusting the on-resistance (R_{ON}) of the control element (MOSFET), the output voltage (V_{OUT}) is kept constant even when the input voltage (V_{IN}) or load (R_L) changes. The internal configuration and controls are described here. Fig. 1.1 shows an example of an LDO reference circuit.

The reference voltage circuit creates a reference voltage to determine whether the required output voltage is high or low.

A feedback resistance is connected between the output pin and ground (GND). The output voltage (V_{OUT}) divided by resistors R1 and R2 to get the feedback voltage (V_{FB}) and is output to the error amplifier. The error amplifier compares the reference voltage (V_{REF}) output from the reference voltage circuit with the feedback voltage (V_{FB}) divided by the feedback resistors to control the output voltage (V_{OUT}) so that it becomes the set voltage.

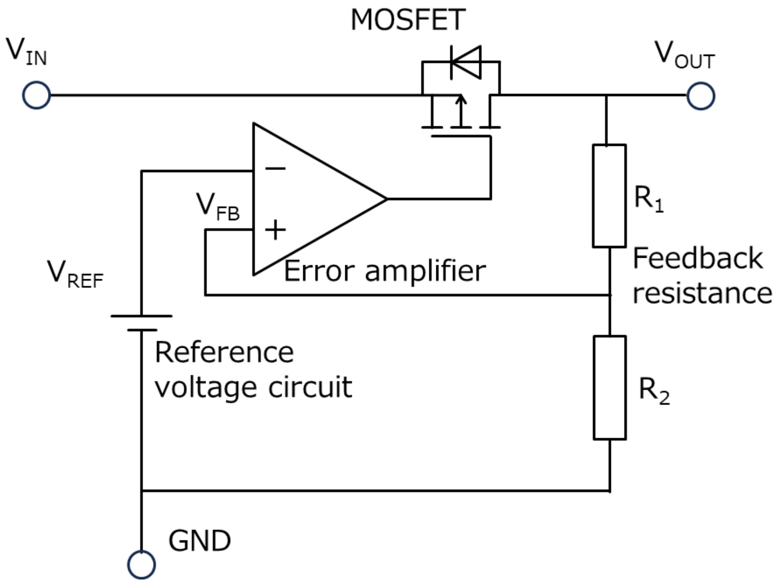


Fig. 1.1 LDO Internal Circuit

2. TCR3EMxxA/3DMxxA/3LMxxA Series Characteristics

The TCR3EMxxA/3DMxxA/3LMxxA series LDO regulators feature output currents of up to 300mA and are available in the ultra-small DFN4D (1.0mm x 1.0mm x 0.37mm (Typ.)) package. The output voltage ranges are 0.8V to 5.0V (TCR3EMxxA series), 1.0V to 4.5V (TCR3DMxxA series), 0.8V to 5.0V (TCR3LMxxA series). These are ideal for applications that require high-density mounting, such as mobile devices. Regulators of TCR3EMxxA series are of standard type, TCR3DMxxA series are of low dropout voltage type, and TCR3LMxxA series are of low current consumption type (low bias current). Table 2.1 shows a comparison of the dropout voltage and bias current for each series.

Table 2.1 Comparison of Drop Voltage and Bias Current of Each Series

	Dropout Voltage (Typ.) V_{DO}	Bias Current (Typ.) $I_{B(ON)}$
TCR3EMxxA series (Standard type)	160mV @V_{OUT} = 2.5V, I_{OUT} = 150mA	35μA @I_{OUT} = 0mA, V_{IN} = 5.5V
	330mV @V_{OUT} = 2.5V, I_{OUT} = 300mA	
TCR3DMxxA series (Low dropout voltage type)	297mV @V_{OUT} = 1.8V, I_{OUT} = 300mA	86μA @I_{OUT} = 0mA, V_{IN} = 5.5V, V_{OUT} = 4.5V
	216mV @V_{OUT} = 2.5V, I_{OUT} = 300mA	
	175mV @V_{OUT} = 3.3V, I_{OUT} = 300mA	
	148mV @V_{OUT} = 4.5V, I_{OUT} = 300mA	
TCR3LMxxA series (Low current consumption type)	297mV @V_{OUT} = 1.8V, I_{OUT} = 200mA	1.2μA @V_{CT} = 0mA, I_{IN} = 5.5V
	216mV @V_{OUT} = 2.5V, I_{OUT} = 200mA	
	175mV @V_{OUT} = 3.3V, I_{OUT} = 200mA	
	148mV @V_{OUT} = 4.5V, I_{OUT} = 200mA	

In addition, each series has a built-in overcurrent protection circuit, thermal shutdown circuit, inrush current suppression circuit, and auto-discharge function. Please refer to the data sheet for details of the TCR3EMxxA/3DMxxA/3LMxxA series.

TCR3EMxxA Series (Standard Type)

This series contains standard type regulators with output current of 300mA (Max.), compact DFN4D package, and are ideal for applications that require high-density mounting, such as portable devices.

TCR3DMxxA Series (Low Dropout Voltage Type)

This series contains low dropout voltage type regulators with high ripple rejection ratio. The dropout voltage is the differential between the minimum input operating voltage and the output voltage required for the regulator IC to keep the output voltage in regulation. If the input voltage drops and the voltage difference between the output voltage and the input voltage becomes greater than the dropout voltage, the specified output voltage cannot be obtained. These regulators with low dropout voltages can maintain the desired output voltage even if the battery voltage drops due to battery discharge in battery-powered applications. In addition, even with a low input voltage, it is possible to obtain an output voltage with large current, and high power-supply efficiency can be achieved by reducing power consumption. In addition, since the power consumption can be expressed roughly as "|input voltage - output voltage | x output current", and the dropout voltage of these LDO regulators is small, which makes the power consumption during operation small, and therefore the heat generation is also small. For this reason, it is possible to reduce the effect of heat generation on the components around the board when mounted.

Ripple rejection ratio is a characteristic that expresses the ripple voltage that appears in the output voltage when the ripple voltage component (noise) is superimposed on the input voltage as a ratio of the input ripple voltage to the output ripple voltage. The higher this value, the smaller the output ripple component. These regulators also features a low output noise voltage (V_{NO}). Due to their high ripple rejection ratio, they have the characteristic of greatly reducing ripple (switching noise), which is a noise source that causes operation failures due to the influence of external noise from switching regulators, etc., of external power supplies, and are ideal for power supplies of weak noise immunity devices like sensors, RF modules, etc.

TCR3LMxxA Series (Low Current Consumption Type)

Battery-powered IoT devices and wearable devices are becoming increasingly sophisticated and require long-term operation. In order to meet this demand, it is necessary to devise ways to reduce the average power consumption during the standby (sleep) period. The TCR3LMxxA series LDO regulators features low bias current to meet this requirement.

The bias current ($I_{B(ON)}$) is the current that flows to the input of the LDO regulator when no output current is flowing and is required to operate the LDO regulator itself. The output of the LDO regulator is used to power various functional blocks such as sensing and data communication, but these functions are not always in operation and may not be in operation for some periods. At this time, only the bias current flows from the battery, so this characteristic is important for reducing current consumption.

3. Application Circuit

3.1. Example of Application Circuit

Fig. 3.1 shows an example of an LDO regulator application circuit. Capacitors are connected to the V_{IN} and V_{OUT} pins for stable operation (ceramic capacitors can be used).

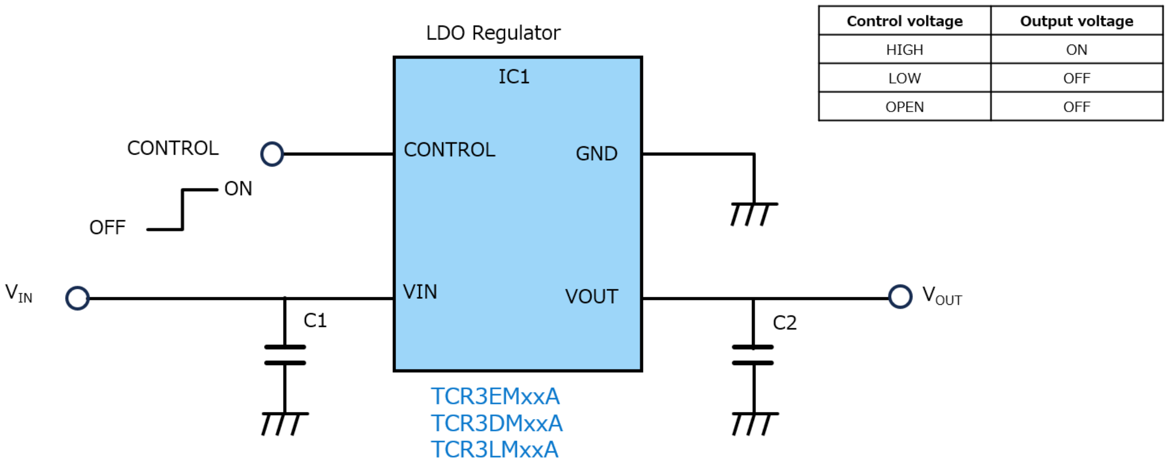


Fig. 3.1 TCR3EMxxA/3DMxxA/3LMxxA Series Application Circuit Example

3.2. Examples of Components Used

Table 3.1 shows the examples of components used.

Table 3.1 Bill of Materials

IC1 (LDO)	TCR3EMxxA (*) Output current: 300mA Package: DFN4D Standard dimensions: 1.0 x 1.0mm	TCR3DMxxA (*) Output current: 300mA Package: DFN4D Standard dimensions: 1.0 x 1.0mm	TCR3LMxxA (*) Output current: 300mA Package: DFN4D Standard dimensions: 1.0 x 1.0mm
C1	1.0μF Ceramic 6.3V ±2% Standard dimensions: 0.6×0.3mm	1.0μF Ceramic 6.3V ±20% Standard dimensions: 0.6×0.3mm	0.47μF Ceramic 6.3V ±20% Standard dimensions: 0.6×0.3mm
C2	1.0μF Ceramic 6.3V ±20% Standard dimensions: 0.6×0.3mm	1.0μF Ceramic 6.3V ±20% Standard dimensions: 0.6 x 0.3mm	0.47μF Ceramic 6.3V ±20% Standard dimensions: 0.6 x 0.3mm

* In the circuit diagram and bill of materials, xx part of the product name contains a number indicating the output voltage.

e.g.) Regulators with V_{OUT} = 1.2V are TCR3EM12A/TCR3DM12A/TCR3LM12A

4. Circuit and Board Design

4.1. Important Points for Design

This section explains the important points for designing circuits and boards using the TCR3EMxxA/3DMxxA/3LMxxA series regulators.

- About External Capacitors

The capacitor used not only remove noise and ripple, but also greatly affects the performance of the power supply in terms of load response characteristics and oscillation. In addition, depending on the type of capacitor, there may be a large variation in capacitance with respect to temperature. A capacitor must be selected very carefully. For stable operation, the recommended capacitors for TCR3EMxxA/3DMxxA series are 1.0μF or more for the V_{IN} pin and 1.0μF or more for the V_{OUT} pin, and for TCR3LMxxA series are 0.47μF or more for the V_{IN} pin and 0.47μF or more for the V_{OUT} pin.

- Mounting on Printed Circuit Board

External conditions, such as the pattern of the printed circuit board and the usage environment, can cause oscillation under the influence of wiring resistance and wiring inductance.

As a general precaution, the V_{IN}, V_{OUT}, and GND wiring should be widened as much as possible to reduce wiring resistance. In addition, special attention should be paid to routing the path through which the input and output currents flow.

If the output capacitor is far from the V_{OUT} pin, it is susceptible to the impedance of the wiring resistance and the inductive component. For more stable power supply operation, the output capacitor should be mounted as close to the V_{OUT} pin as possible (preferably at the base of the pin), so that the common impedance can be minimized between the wiring that carries the output current to the output capacitor and the wiring that carries the output current to the load. In the unlikely event that oscillation occurs, take measures by optimizing the value and position of the capacitor while checking the output waveform with the actual device. Please refer to Fig. 4.1 for an example of the evaluation board as described above, and Fig. 4.2 for an example of routing the wiring pattern.

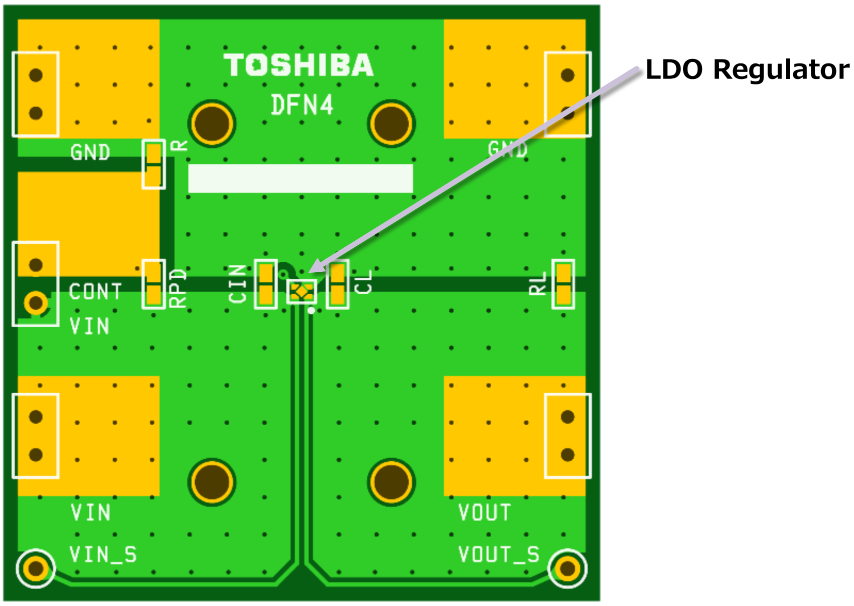


Fig. 4.1 Example of LDO Regulator Evaluation Board (Front Side)

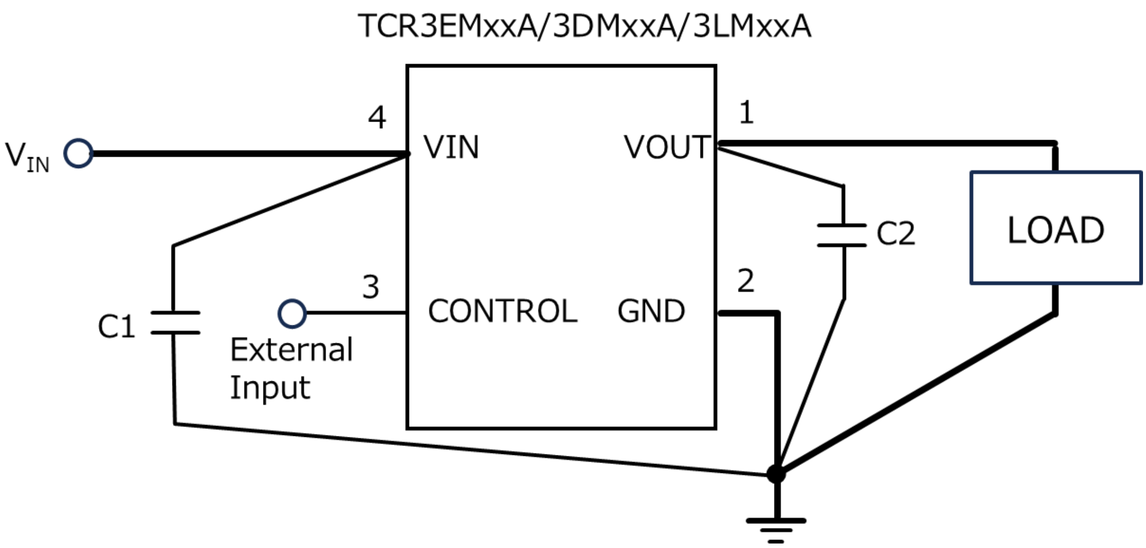


Fig. 4.2 Example of Routing of Wiring Pattern

- Power Dissipation

Design the board pattern with as much margin as possible for the maximum power dissipation expected under actual use conditions. In addition, in actual use, please consider parameters such as ambient temperature, input voltage, output current, etc., and consider an appropriate derating (generally 70% to 80% of the maximum value) for the maximum power dissipation.

- Overcurrent Protection Circuit and Thermal Shutdown Circuit

The TCR3EMxxA/3DMxxA/3LMxxA series regulators have overcurrent protection circuit and thermal shutdown circuit with foldback characteristics, but they do not guarantee that the regulator will always operate within its maximum rating. Please note that depending on the operating conditions, the product deterioration and the reliability may be affected. In addition, we do not guarantee that this product will not be destroyed under any circumstances. There is a risk of damage if the output pin and the GND pin gets shorted even with low impedance connection.

When using the TCR3EMxxA/3DMxxA/3LMxxA series, please refer to the absolute maximum ratings described above and in Toshiba's "Semiconductor Reliability Handbook" and in data sheets, and be careful not to exceed the absolute maximum ratings and take appropriate derating into consideration. It is recommended that sufficient safety measures such as fail-safe must be applied to the set.

- Output Voltage V_{OUT} Rise Time (TCR3EMxxA Series)

The TCR3EMxxA series has an inrush current suppression circuit, and the output rise time varies depending on the operating conditions, peripheral circuits, and ambient temperature. For example, under the condition of C_{OUT} = 1.0μF and Ta = 25°C, the output voltage stabilizes after about 200μs after the control voltage is applied.

- Bias Current Characteristics (TCR3LMxxA Series)

The bias current $I_{B(ON)}$ of the TCR3LMxxA series is controlled by the output current, I_{OUT}. If I_{OUT} is small, TCR3LMxxA series operates at low $I_{B(ON)}$, but in this state the load transient response is inferior to normal. The switching of $I_{B(ON)}$ by I_{OUT} is controlled with hysteresis characteristics. When I_{OUT} increases and $I_{B(ON)}$ becomes large, it exhibits good load transient response. This characteristic is maintained until I_{OUT} becomes small and switches $I_{B(ON)}$ to low.

4.2. Dropout Voltage: V_{DO}

The dropout voltage (minimum input-to-output voltage difference) is the minimum difference between the input voltage and the output voltage required for the LDO regulator to output a stable output voltage. The minimum input-to-output voltage difference of an LDO using a MOSFET in the output stage is when the MOSFET is operating in the linear region, and the minimum input-to-output voltage difference depends on the on-resistance characteristics of the LDO regulator and the output current. The data sheet specifies this as the minimum difference between the input voltage and the output voltage required to output a given voltage. The lower this number, the lower the input voltage for which the desired output voltage can be obtained, and the lower will be the power consumption due to the loss caused by the voltage difference. It is important to note that if the voltage difference between the input and output is smaller than the dropout voltage, the expected output voltage cannot be obtained.

TCR3EMxxA Series: 144mV (Typ.) @3.3V output, I_{OUT} = 150mA
TCR3DMxxA Series: 175mV (Typ.) @3.3V output, I_{OUT} = 300mA
TCR3LMxxA Series: 177mV (Typ.) @3.3V output, I_{OUT} = 200mA

The dropout voltage to output current characteristics (reference values) of the TCR3EMxxA/3DMxxA/3LMxxA series are shown below. Refer these when using these regulators.

TCR3EMxxA Series

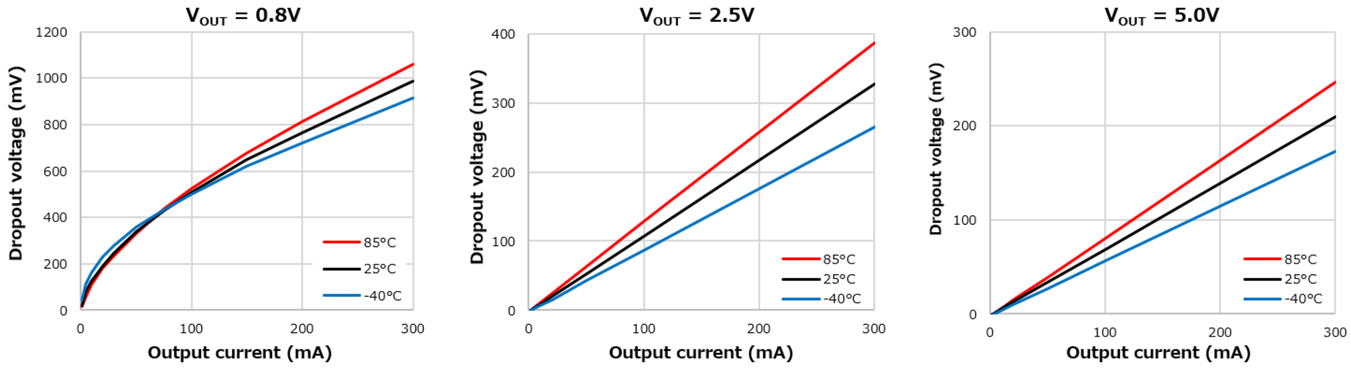


Fig. 4.3 Dropout Voltage Characteristics of TCR3EMxxA Series

TCR3DMxxA Series

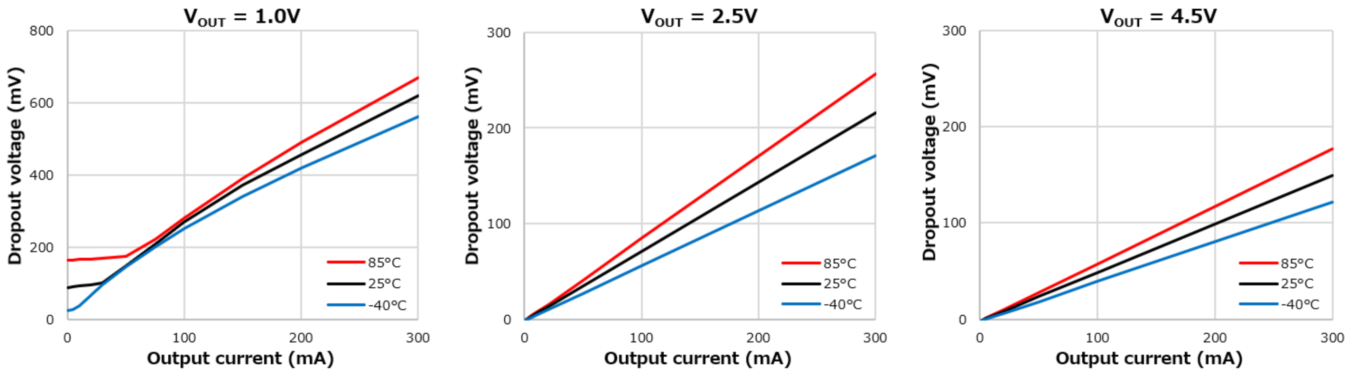


Fig. 4.4 Dropout Voltage Characteristics of TCR3DMxxA Series

TCR3LMxxA Series

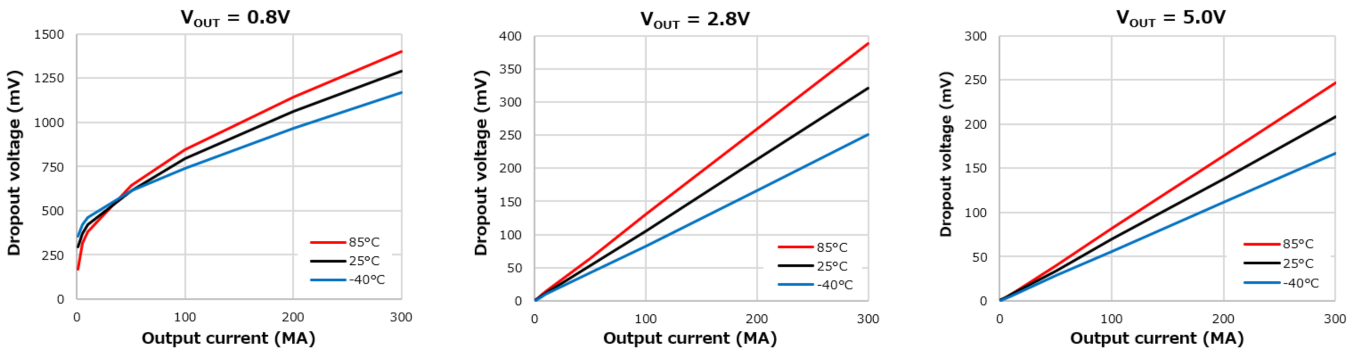


Fig. 4.5 Dropout Voltage Characteristics of TCR3LMxxA series

4.3. Load Transient Response: ΔV_{OUT}

The negative transient response characteristic is the undershoot and overshoot that occurs in the output voltage when the output current changes in a steep step. LDO regulators with poor load response characteristics have a large fluctuation in the output voltage when the output current changes abruptly, and then take a long time to return to the normal output voltage, increasing the risk of affecting the operation of the ICs or circuits connected to the output. Since the size of the load connected to the output of the LDO regulator is not constant, the output current fluctuates accordingly, however TCR3EMxxA/3DMxxA/3LMxxA series regulators have an excellent response to sudden current changes and provide a stable constant voltage operation.

The load transient response characteristics of the TCR3EMxxA/3DMxxA/3LMxxA series regulators are shown below (reference values). Refer to these when using these regulators.

<u>TCR3EMxxA Series</u>

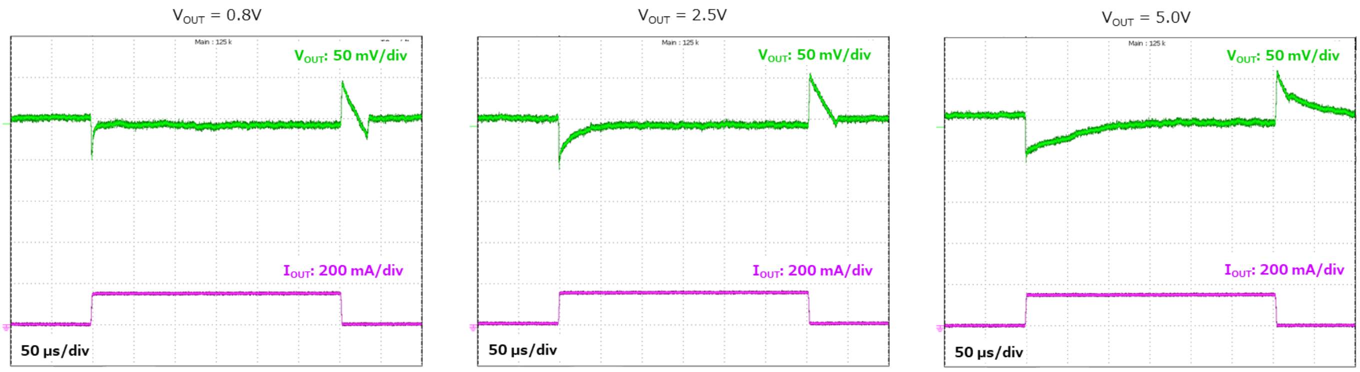
Measurement conditions

@C_{IN} = 1.0μF, C_{OUT} = 1.0μF,

V_{IN} = 2.5V (V_{OUT} = 0.8V) or 3.5V (V_{OUT} = 2.5V) or 5.5V (V_{OUT} = 5.0V),

t_r = 1.5μs, t_f = 1.5μs, Ta = 25°C

- I_{OUT} = 1mA to 150mA



- I_{OUT} = 1mA to 300mA

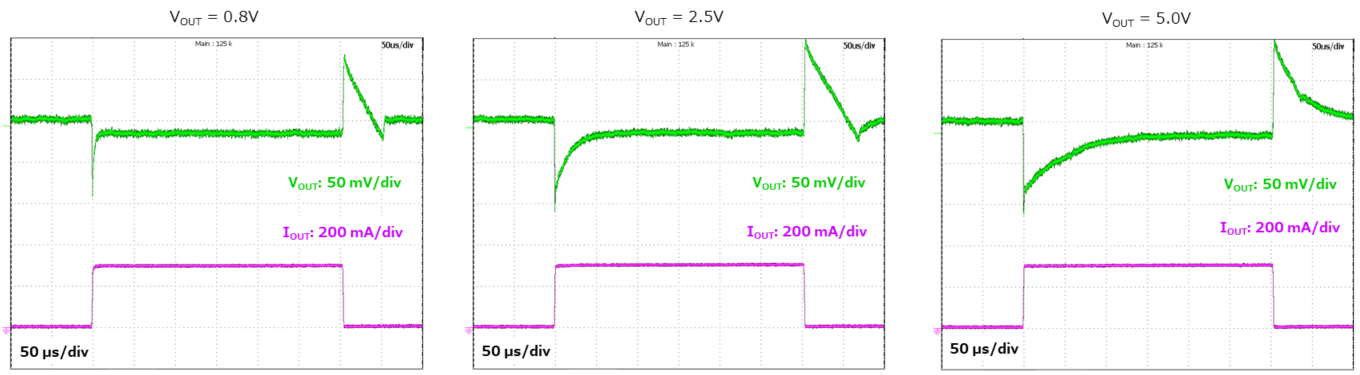


Fig. 4.6 TCR3EMxxA Series Load Transient Response

TCR3DMxxA Series

Measurement conditions

@C_{IN} = 1.0µF, C_{OUT} = 1.0µF,

V_{IN} = V_{OUT} + 1.0V, I_{OUT} = 1mA to 300mA,

t_r = 1.0µs, t_f = 1.0µs, Ta = 25°C

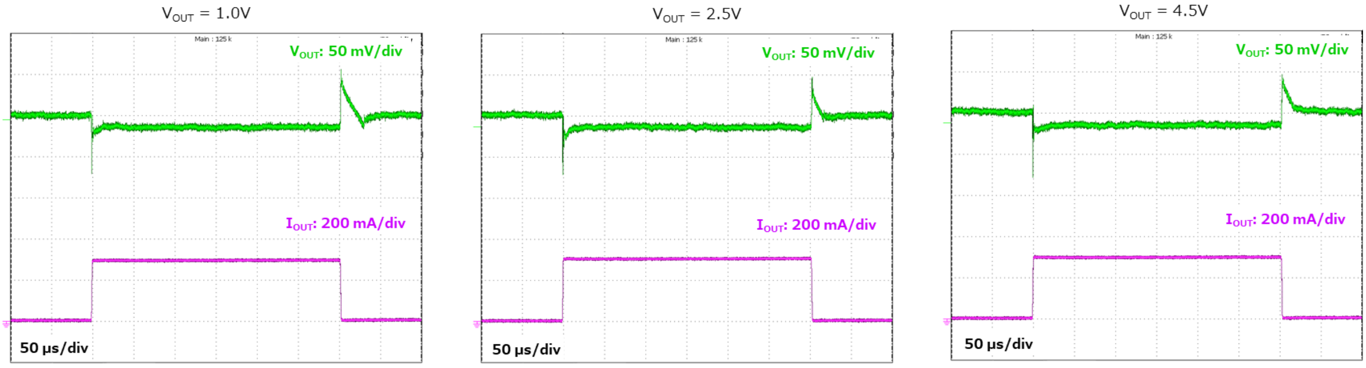


Fig. 4.7 TCR3DMxxA Series Load Transient Response

TCR3LMxxA Series

Measurement conditions

@C_{IN} = 0.47µF, C_{OUT} = 0.47µF,

V_{IN} = 2.5V (V_{OUT} = 0.8V) or 3.8V (V_{OUT} = 2.8V) or 5.5V (V_{OUT} = 5.0V),

t_r = 1.0µs, t_f = 1.0µs, Ta = 25°C

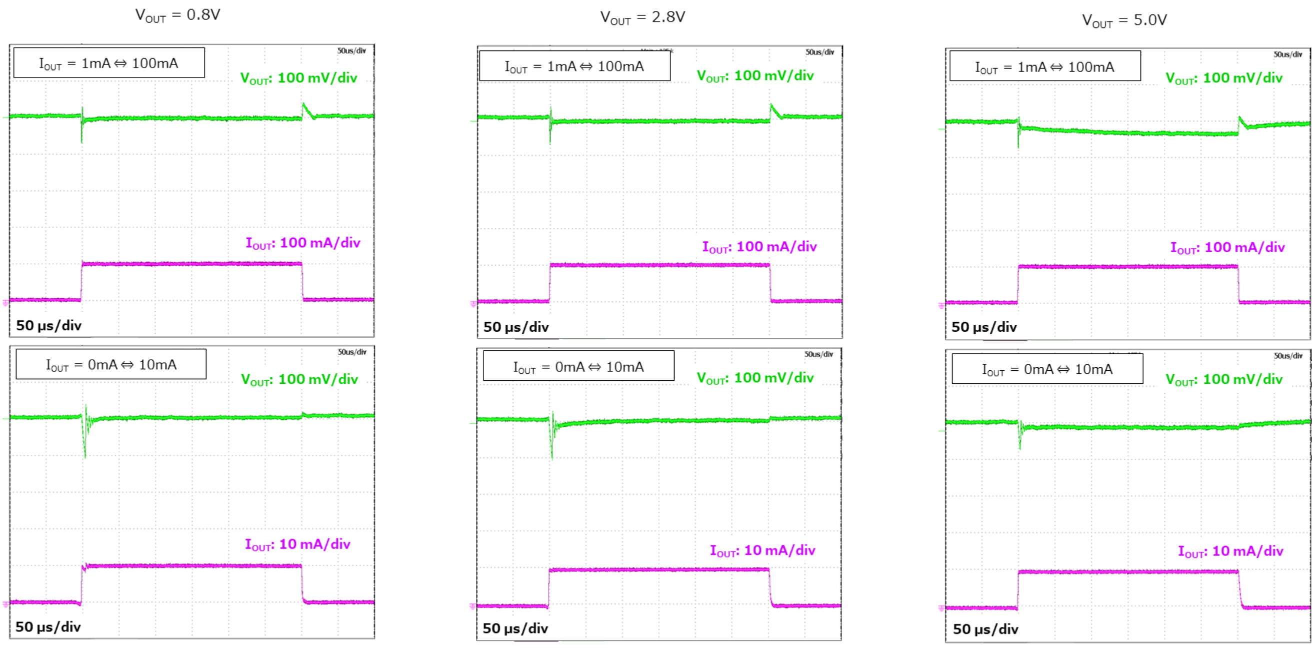


Fig. 4.8 TCR3LMxxA Series Load Transient Response

4.4. Ripple Rejection Ratio: R.R

It shows the ratio of the ripple voltage component superimposed on the input voltage to the ripple voltage component that appears in the output voltage at that time. The higher this value, the smaller the ripple component that appears in the output, but it may be displayed as negative by swapping the denominator and numerator, in which case the smaller is better.

The degree of ripple rejection ratio (R.R.) is given by the following equation. R.R.has a frequency response, and if a switching regulator is connected in front of the LDO regulator, the higher the R.R. value, the more ripple voltage components superimposed on the input voltage can be removed. This makes it an indicator for using an LDO to power sensor circuits and analog circuits that are sensitive to noise.

$$R.R = 20 \times Log \frac{V_{IN\ ripple}}{V_{OUT\ ripple}} \quad (dB)$$

$V_{IN\ ripple}$: ripple voltage (V) of input voltage V_{IN}
$V_{OUT\ ripple}$: ripple voltage(V) of output voltage V_{OUT}

The ripple rejection ratio vs. frequency characteristics of the TCR3EMxxA/3DMxxA/3LMxxA series are shown below (reference values). For TCR3EMxxA/3DMxxA series regulators, the characteristic curve is shown when there is no external capacitance C_{IN} and C_{OUT} is 1.0μF, and for TCR3LMxxA series regulators the characteristic curve is shown when there is no external capacitance C_{IN} and C_{OUT} is 0.47μF. Refer to these when using these regulators.

TCR3EMxxA

Measurement conditions
@C_{IN} = none, C_{OUT} = 1.0μF,
V_{IN} = 2.5V (V_{OUT} = 0.8V) or 3.5V (V_{OUT} = 2.5V) or 5.5V (V_{OUT} = 5.0V),
$V_{IN\ Ripple}$ = 500mV_{p-p}, I_{OUT} = 10mA, Ta = 25°C

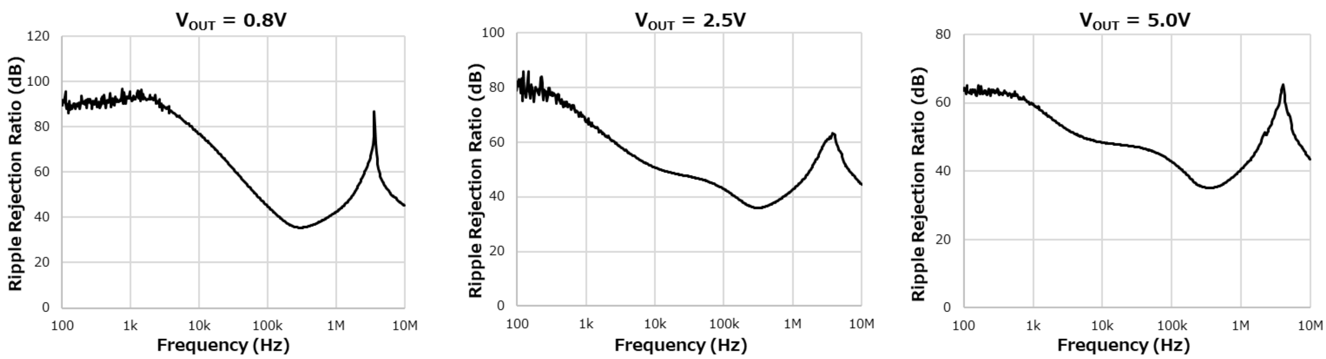


Fig. 4.9 Ripple Rejection Ratio vs. Frequency Response of TCR3EMxxA Series

TCR3DMxxA

Measurement conditions

@C_{IN} = none, C_{OUT} = 1.0µF,

V_{IN} = V_{OUT} +1.0V,

$V_{IN\ Ripple}$ = 500mV_{p-p}, I_{OUT} = 10mA, Ta = 25°C

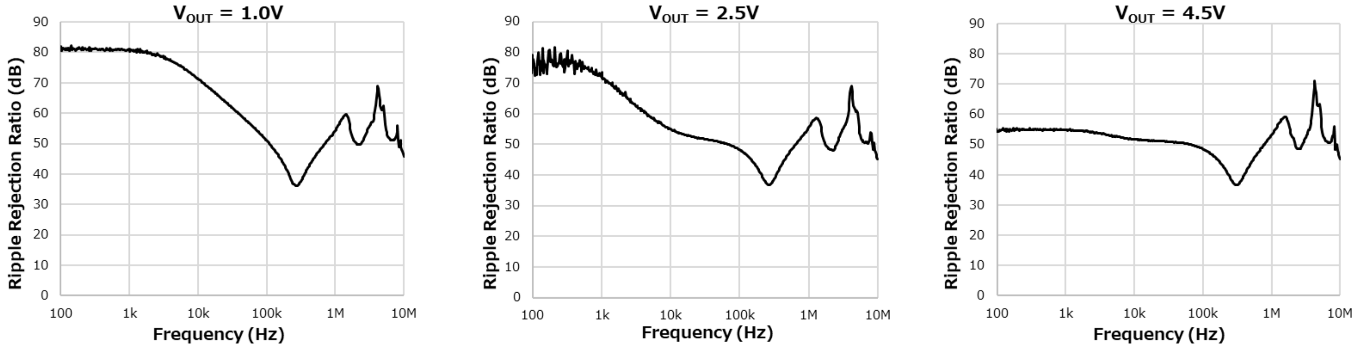


Fig. 4.10 Ripple Rejection Ratio vs. Frequency Response of TCR3DMxxA series

TCR3LMxxA

Measurement conditions

@C_{IN} = none, C_{OUT} = 0.47µF,

V_{IN} = 2.5V (V_{OUT} = 0.8V) or 3.8V (V_{OUT} = 2.8V) or 5.5V (V_{OUT} = 5.0V),

$V_{IN\ Ripple}$ = 200mVp-p, I_{OUT} = 10mA, Ta = 25°C

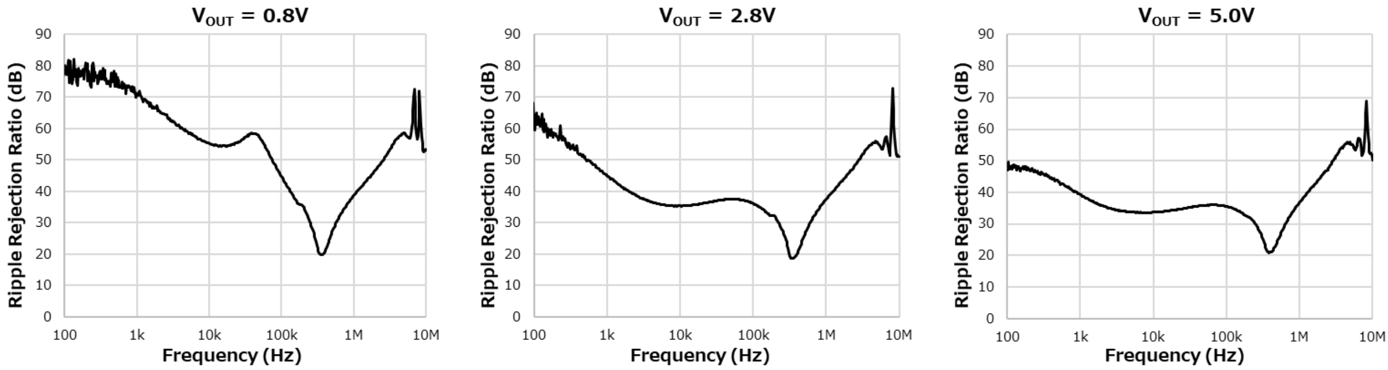


Fig. 4.11 Rejection Ratio vs. Frequency Response of TCR3LMxxA Series

4.5. Other Electrical Characteristics

In addition to the three items described in the previous section, various electrical characteristics are described in the data sheet. These are also briefly explained below. The data sheet lists the values when the temperature condition is Tj = 25°C, but some items describe values in the range of Tj = -40°C to 85°C.

- Output Voltage Accuracy: V_{OUT}

  The output voltage is distributed within a certain range with the set value in the center due to factors such as variations in the internal circuit elements. This item has a maximum and a minimum value that indicates the variation in the output voltage. The TCR3EMxxA/3DMxxA/3LMxxA series regulators are available by the output voltage values, but the voltage accuracy standard is displayed as a voltage value if the output voltage is less than 1.8V, and as a ratio to the output voltage when the output voltage is 1.8V or more.

- Line Regulation: Reg･line

  This value indicates the range of fluctuations in the output voltage within the range of input voltage. If the value of Reg･line is small, even if V_{IN} changes, the amount of change in V_{OUT} is small and a stable voltage can be obtained. For applications with a wide input voltage range, it is necessary to select an LDO regulator with a low Reg･line.

- Load Regulation: Reg･load

  This value indicates the range of fluctuations in the output voltage within the range of the output current (load). This is an indication of a variation in the regular voltage, which is different from the load transient response. If the LDO regulator has a small Reg･load value, even if IOUT changes, the amount of V_{OUT} change is small and a stable voltage can be obtained. For applications with large changes in output current, it is necessary to select an LDO regulator with a low Reg･load.

- Bias Current: $I_{B(ON)}$

  It is the current consumption of the internal circuit when the LDO regulator is operating under the measurement conditions specified in the data sheet. It is the current value obtained by subtracting the control pull down current (I_{CT}) flowing into the control pin from the from the current flowing out of the GND pin. The bias current, $I_{B(ON)}$, is specified at no load (I_{OUT}=0A).

- Standby Current: $I_{B(OFF)}$

  When the LDO regulator is in standby mode (V_{CT} = 0V), it is the current value obtained by subtracting the control pull down current (I_{CT}) flowing to the control pin from the current flowing out of the GND pin. In LDO regulators used in battery equipment, this standby current is consumed from the battery when the equipment is in a standby state, so it is an important standard for managing battery life.

- Control Pull Down Current: I_{CT}
  This is the current value flowing into the control pin when the control pin is set high.

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

- Output Current Limit: I_{CL}
  This indicates the value of the output current at which the overcurrent protection operates. The output current limit value is specified as the output current when the overcurrent protection circuit is activated and the output voltage drops to 0.9 times of the typical value. Fort the wiring through which output current flows, ensure that there is a minimum wiring width sufficient to handle this current without any problems.

- Thermal Shutdown Threshold: T_{SDH}, T_{SDL}
  Thermal shutdown (TSD) function protects the device by detecting a specified junction temperature. At this junction temperature the output is turned off to prevent deterioration or destruction of the LDO regulator when the junction temperature rises due to self-heating of the device itself, such as when the ambient temperature rises rapidly or if the LDO regulator load is shorted, or if the V_{OUT} pin is shorted to GND. When the thermal shutdown is activated, the output is turned off, which reduces power consumption and lowers the junction temperature. When the junction temperature drops to the set value, the thermal protection operation is deactivated, and the output is automatically turned on. The thermal shutdown operation is activated at T_{SDH} temperature, and is deactivated at T_{SDL} temperature.

- Control Pin Threshold Voltage: V_{CTH}, V_{CTL}
  Indicates the range of voltages that can be applied to the control pin to turn the LDO regulator on or off. This indicates that the LDO regulator is securely turned on within the control pin input voltage (ON) range and that it is securely turned off within the control pin input voltage (OFF) range. Please note that it does not indicate the distribution of the threshold for ON/OFF switching thresholds. Be sure to set the HIGH signal voltage and the LOW signal voltage applied to the control pin to be within the respective voltage ranges.

- Output Discharge On-Resistance: R_{SD}
  Fig. 4.12 shows the resistance value (discharge-on resistance) that discharges the charge stored in the output capacitor when the output voltage of the LDO regulator is turned off. The discharge on-resistance is the on-resistance value of the N-channel MOSFET inside the LDO which is used to discharge of the output capacitor connected to the V_{OUT} and GND pins. When the output of the LDO switches from the on state to the off state, the N-channel MOSFET for discharging is turned on, and the output capacitor starts discharging. The integrated discharge MOSFETs allow for shorter discharge times even when using high-capacitance output capacitor, making it easier to set up system power sequencing.

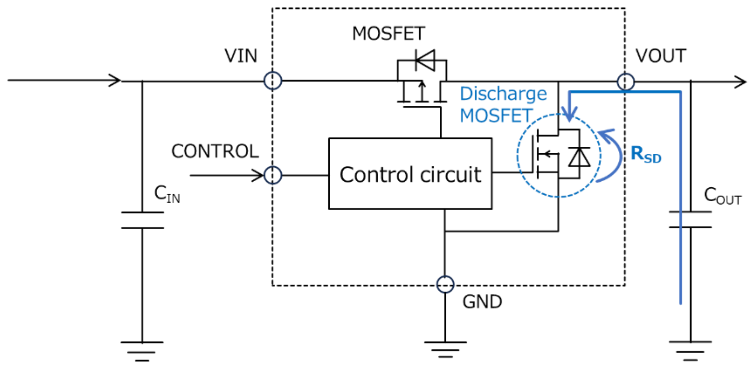


Fig. 4.12 Output Discharge Circuit

4.6. Built-In Circuits and Functions

The TCR3EMxxA/3DMxxA/3LMxxA series regulators include the following circuits and functions:

- Overcurrent Protection Circuit

  If the output current exceeds the current limit due to a load abnormality or a short circuit, the output voltage will begin to decrease and the output current will also decrease, thereby reducing the power consumption during the abnormality. The protection operation is performed with foldback characteristic. This is called “foldback characteristic" because under a short-circuit load condition, foldback reduces IOUT as VOUT decreases. When VOUT has dropped to zero, it keeps the output current at a limited constant level. When the overcurrent condition has disappeared, VOUT returns to the normal level automatically.

- Thermal Shutdown Circuit

  If the temperature of the LDO regulator exceeds the set value due to the continuous flow of a large current due to an short circuit at the load, a protective action is performed to turn off the output to prevent degradation or destruction of the LDO regulator.

- Inrush Current Suppression Loop

  When the output is turned on, the output capacitor charge current flows, but if this current is too large, the overcurrent protection circuit may malfunction and the start up may fail, or the output voltage may be overshoot. In order to prevent this, the output voltage is slowly increased, and while suppressing the inrush current.

- Auto Discharge Function

  This function discharges the residual charge of the output capacitor when the output is turned off by control of the control pin.

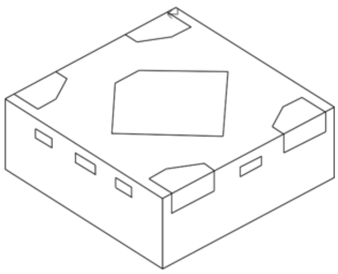
5. Product Details

5.1. TCR3EMxxA/3DMxxA/3LMxxA Series Features

The TCR3EMxxA/3DMxxA/3LMxxA series LDO regulators feature output currents of up to 300mA and are available in the ultra-small DFN4D (1.0mm x 1.0mm x 0.37mm (Typ.)) package. These are ideal for applications that require high-density mounting, such as mobile devices. Regulators of TCR3EMxxA series are of standard type, TCR3DMxxA series are of low dropout voltage type, and TCR3LMxxA series are of low current consumption type (low bias current).

Appearance and Pin Arrangement

Appearance of DFN4D package



Pin Arrangement (Top view)

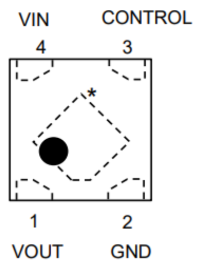


Fig. 5.1 Appearance and Pin Arrangement of TCR3EMxxA/3DMxxA/3LMxxA Series

Table 5.4 Pin Description of TCR3EMxxA/3DMxxA/3LMxxA Series

Pin Number	Pin Name	Pin Description
1	VOUT	Output pin
2	GND	Ground pin
3	CONTROL	Output ON/OFF control pin
4	VIN	Power supply input pin

5.1.1. TCR3EMxxA Series

Key features of the TCR3EMxxA series include:

Features

- Wide range output voltage lineup (V_{OUT} = 1.0V to 4.5V)
- Low dropout voltage
  V_{DO} = 175mV (Typ.) @3.3V output, I_{OUT} = 300mA
  V_{DO} = 216mV (Typ.) @2.5V output, I_{OUT} = 300mA
  V_{DO} = 297mV (Typ.) @1.8V output, I_{OUT} = 300mA
- Low output noise voltage (V_{NO} = 38μVrms (Typ.) @10Hz ≦ f ≦ 100kHz)
- High ripple rejection ratio (72dB (Typ.) @2.5V output, I_{OUT} = 10mA, f = 1kHz)
- Fast load transient response (±80mV (Typ.) @2.5V output, I_{OUT} = 1mA to 300mA)
- Overcurrent protection
- Thermal shutdown
- Auto-discharge
- Pull down connection between CONTROL and GND
- Ceramic capacitors can be used (C_{IN} = 1.0μF, C_{OUT} = 1.0μF)

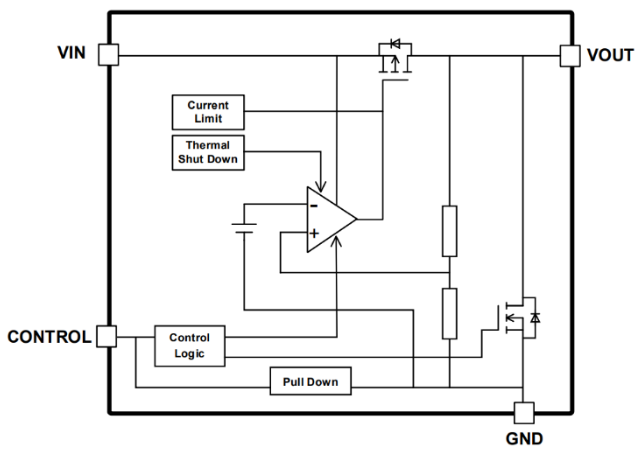


Fig. 5.2 Internal Circuit Block Diagram of TCR3EMxxA Series

5.1.2. TCR3DMxxA Series

Key features of the TCR3DMxxA series include:

Features

- Wide range output voltage line up (V_{OUT} = 1.0 to 4.5V)
- Low dropout voltage
  V_{DO} = 175mV (Typ.) @3.3V output, I_{OUT} = 300mA
  V_{DO} = 216mV (Typ.) @2.5V output, I_{OUT} = 300mA
  V_{DO} = 297mV (Typ.) @1.8V output, I_{OUT} = 300mA
- Low output noise voltage (V_{NO} = 38μVrms (Typ.) @10Hz ≦ f ≦ 100kHz)
- High ripple rejection ratio(72dB (Typ.) @2.5V output, I_{OUT} = 10mA, f = 1kHz)
- Fast load transient response (±80mV (Typ.) @2.5V output, I_{OUT} = 1mA to 300mA)
- Overcurrent protection
- Thermal shutdown
- Inrush current suppression
- Auto-discharge
- Pull down connection between CONTROL and GND
- Ceramic capacitors can be used (C_{IN} = 1.0μF, C_{OUT} = 1.0μF)

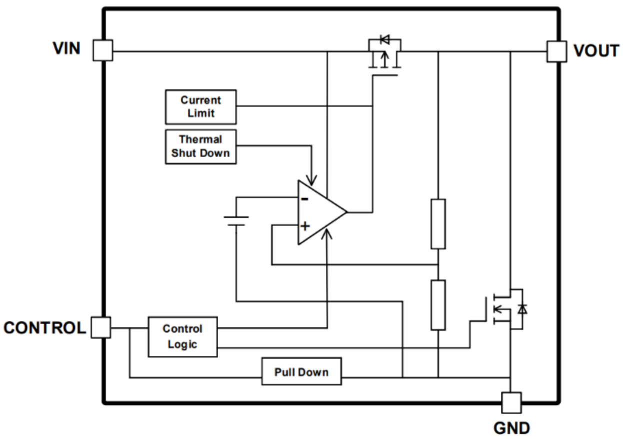


Fig. 5.3 Internal Circuit Block Diagram of TCR3DMxxA Series

5.1.3. TCR3LMxxA Series

Key features of the TCR3LMxxA series include:

Features

- Low bias current ($I_{B(ON)}$ = 1.2μA (Typ.) @I_{OUT} = 0mA)
- High ripple rejection ratio (74dB (Typ.) @100Hz, 0.8V output)
- Fast load transient response (-70/+35mV @2.8V output, I_{OUT} = 1mA to 100mA)
- Low dropout voltage (V_{DO} = 213mV (Typ.) @2.8V output, I_{OUT} = 200mA)
- Wide range output voltage line up (V_{OUT} = 0.8V to 5.0V)
- Overcurrent protection
- Thermal shutdown
- Auto-discharge
- Pull down connection between CONTROL and GND
- Ceramic capacitors can be used (C_{IN} = 0.47μF, C_{OUT} = 0.47μF)

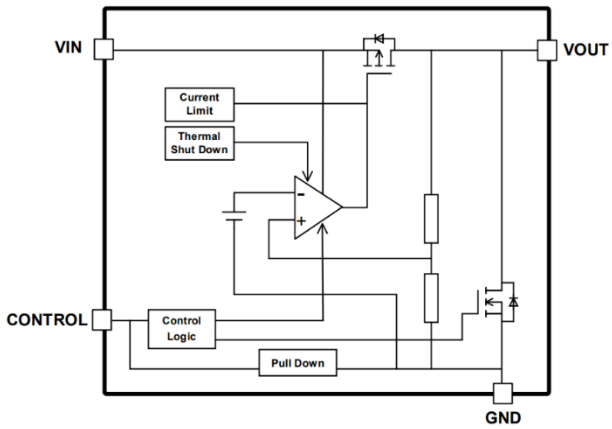


Fig. 5.4 Internal Circuit Block Diagram of TCR3LMxxA Series

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