

TOSHIBA CMOS Linear Integrated Circuit Silicon Monolithic

TCR15AG series

1.5 A CMOS Ultra Low Dropout, Ultra High ripple rejection ratio Regulator

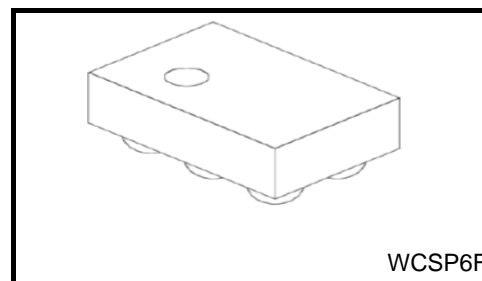
The TCR15AG series are CMOS single output voltage regulators with an on/off control input, featuring Ultra low dropout voltage, low inrush current and fast load transient response.

These voltage regulators are available in fixed output voltage type from 0.65 V to 3.6 V and adjustable output voltage type from 0.60 V to 3.6 V and capable of driving up to 1.5 A.

Other features include Overcurrent protection, Thermal shutdown, Inrush current reduction, Under voltage lockout and Auto-discharge.

The TCR15AG series are offered in the ultra-small package WCSP6F (0.8 mm x 1.2 mm (typ.), t: 0.33 mm (max))

As small ceramic input and output capacitors can be used with the TCR15AG series, these device are ideal for portable applications that require high-density board assembly such as cellular phones.



Weight : 0.61 mg (typ.)

Features

- Low Drop-Out voltage
- Wide range Output Voltage (Fixed Output Voltage 0.65 V to 3.6 V ,Adjustable Output Voltage 0.6 V to 3.6 V)
- Fast load transient response -100 / +115 mV (typ.)@ 0.01 A⇔1.5 A, C_{OUT} = 4.7 μF
- High Ripple rejection ratio 95 dB (typ.)@1 kHz
- Overcurrent protection
- Thermal shutdown
- Auto-discharge
- Inrush current reduction
- Output voltage soft start
- Under voltage lockout
- Pull down connection between CONTROL and GND
- Ultra Small package WCSP6F (0.8 mm x 1.2 mm (typ.), t: 0.33 mm (max))
- Stable with over 4.7 μF Input capacitor, 1.0 μF Bias capacitor and 4.7 μF output ceramic capacitor

Start of commercial production
2017-11

Absolute Maximum Ratings (Ta = 25°C)

| Characteristics | Symbol | Rating | Unit |
|---------------------------|--------------------|---------------------------------------|------|
| Bias voltage | V _{BIAS} | 6.0 | V |
| Input voltage | V _{IN} | 6.0 | V |
| Control voltage | V _{CT} | -0.3 to V _{BIAS} + 0.3 ≤ 6.0 | V |
| Adjustable voltage | V _{ADJ} | -0.3 to 6.0 | V |
| Sense voltage | V _{SENSE} | -0.3 to 6.0 | V |
| Output voltage | V _{OUT} | -0.3 to V _{IN} + 0.3 ≤ 6.0 | V |
| Power dissipation | P _D | 1.35 (Note 1) | W |
| Junction temperature | T _j | 150 | °C |
| Storage temperature range | T _{stg} | -55 to 150 | °C |

Note: Using continuously under heavy loads (e.g. the application of high temperature/current/voltage and the significant change in temperature, etc.) may cause this product to decrease in the reliability significantly even if the operating conditions (i.e. operating temperature/current/voltage, etc.) are within the absolute maximum ratings and the operating ranges.

Please design the appropriate reliability upon reviewing the Toshiba Semiconductor Reliability Handbook ("Handling Precautions"/"Derating Concept and Methods") and individual reliability data (i.e. reliability test report and estimated failure rate, etc).

Note1: Rating at mounting on a board
 (Glass epoxy board dimension : 40mm x 40mm , 4 layer
 Metal pattern ratio : approximately 70% each layer)

Operating Ranges

| Characteristics | Symbol | Rating | Unit |
|-----------------------|-------------------|--|---------------------------------|
| Bias voltage | V _{BIAS} | V _{OUT} ≤ 1.1 V, I _{OUT} = 1 mA | 2.5 to 5.5 |
| | | V _{OUT} > 1.1 V, I _{OUT} = 1 mA | V _{OUT} + 1.4 V to 5.5 |
| Input voltage | V _{IN} | V _{OUT} + V _{DO} to V _{BIAS} (Note 2) | V |
| Control voltage | V _{CT} | 0 to V _{BIAS} | V |
| Output voltage | V _{OUT} | 0.6 to 3.6 (Note 3) | V |
| Output current | I _{OUT} | 0 to 1.5 (Note 4) | A |
| Operation Temperature | T _{opr} | -40 to 85 | °C |
| Output Capacitance | C _{OUT} | ≥ 4.7μF | — |
| Input Capacitance | C _{IN} | ≥ 4.7μF | — |
| BIAS Capacitance | C _{BIAS} | ≥ 1.0μF | — |

Note2: I_{OUT} = 1 mA.

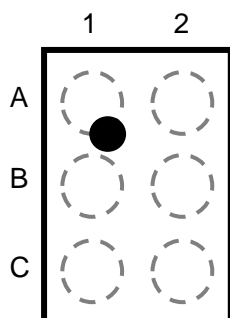
Please refer to Dropout Voltage (Page 7) and use it within Absolute Maximum Ratings Junction temperature and Operation Temperature Ranges.

Note3: For Output voltage adjustable type. Please refer to Application Note (Page 8).

Note4: Do not operate at or near the maximum recommended current and temperature ratings listed for extended periods of time. Exposure to such conditions may adversely impact product reliability and results in failures not covered by warranty. Maximum recommended DC current specification defined as lifetime average junction temperature of +45°C where max rated DC current = lifetime average current to avoid electro migration.

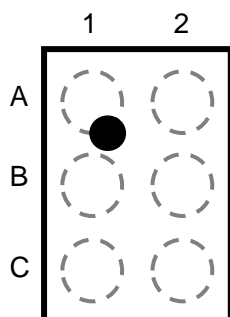
Pin Assignment (top view)

Fixed Output Voltage



| | 1 | 2 |
|---|-----------|------------|
| A | V_{OUT} | V_{IN} |
| B | SENSE | CONTROL |
| C | GND | V_{BIAS} |

Adjustable Output Voltage



| | 1 | 2 |
|---|-----------|------------|
| A | V_{OUT} | V_{IN} |
| B | V_{ADJ} | CONTROL |
| C | GND | V_{BIAS} |

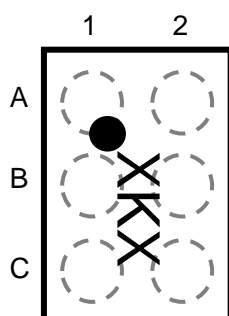
List of Products Number, Output voltage and Marking

| Product No. | V _{OUT} (V)(typ.) | Marking | Product No. | V _{OUT} (V)(typ.) | Marking |
|-------------|----------------------------|---------|-------------|----------------------------|---------|
| TCR15AG065* | 0.65 | 0KA | TCR15AG21* | 2.1 | 2K1 |
| TCR15AG07* | 0.7 | 0K7 | TCR15AG22* | 2.2 | 2K2 |
| TCR15AG075* | 0.75 | 0KB | TCR15AG23* | 2.3 | 2K3 |
| TCR15AG08* | 0.8 | 0K8 | TCR15AG24* | 2.4 | 2K4 |
| TCR15AG085* | 0.85 | 0KC | TCR15AG25 | 2.5 | 2K5 |
| TCR15AG09 | 0.9 | 0K9 | TCR15AG26* | 2.6 | 2K6 |
| TCR15AG095* | 0.95 | 0KF | TCR15AG27* | 2.7 | 2K7 |
| TCR15AG10 | 1.0 | 1K0 | TCR15AG275 | 2.75 | 0KP |
| TCR15AG105 | 1.05 | 0KH | TCR15AG28 | 2.8 | 2K8 |
| TCR15AG11 | 1.1 | 1K1 | TCR15AG285* | 2.85 | 0KR |
| TCR15AG115* | 1.15 | 0KJ | TCR15AG29* | 2.9 | 2K9 |
| TCR15AG12 | 1.2 | 1K2 | TCR15AG295* | 2.95 | 0KT |
| TCR15AG125* | 1.25 | 0KK | TCR15AG30 | 3.0 | 3K0 |
| TCR15AG13* | 1.3 | 1K3 | TCR15AG305* | 3.05 | 0KU |
| TCR15AG135* | 1.35 | 0KL | TCR15AG31* | 3.1 | 3K1 |
| TCR15AG14* | 1.4 | 1K4 | TCR15AG32* | 3.2 | 3K2 |
| TCR15AG15* | 1.5 | 1K5 | TCR15AG325* | 3.25 | 0KW |
| TCR15AG16* | 1.6 | 1K6 | TCR15AG33 | 3.3 | 3K3 |
| TCR15AG17* | 1.7 | 1K7 | TCR15AG335* | 3.35 | 0KX |
| TCR15AG175* | 1.75 | 0KM | TCR15AG34* | 3.4 | 3K4 |
| TCR15AG18 | 1.8 | 1K8 | TCR15AG35* | 3.5 | 3K5 |
| TCR15AG185 | 1.85 | 0KN | TCR15AG36* | 3.6 | 3K6 |
| TCR15AG19* | 1.9 | 1K9 | TCR15AGADJ | Adjustable | XXX |
| TCR15AG20* | 2.0 | 2K0 | | | |

* Please contact your local Toshiba representative if you are interested in products with * sign

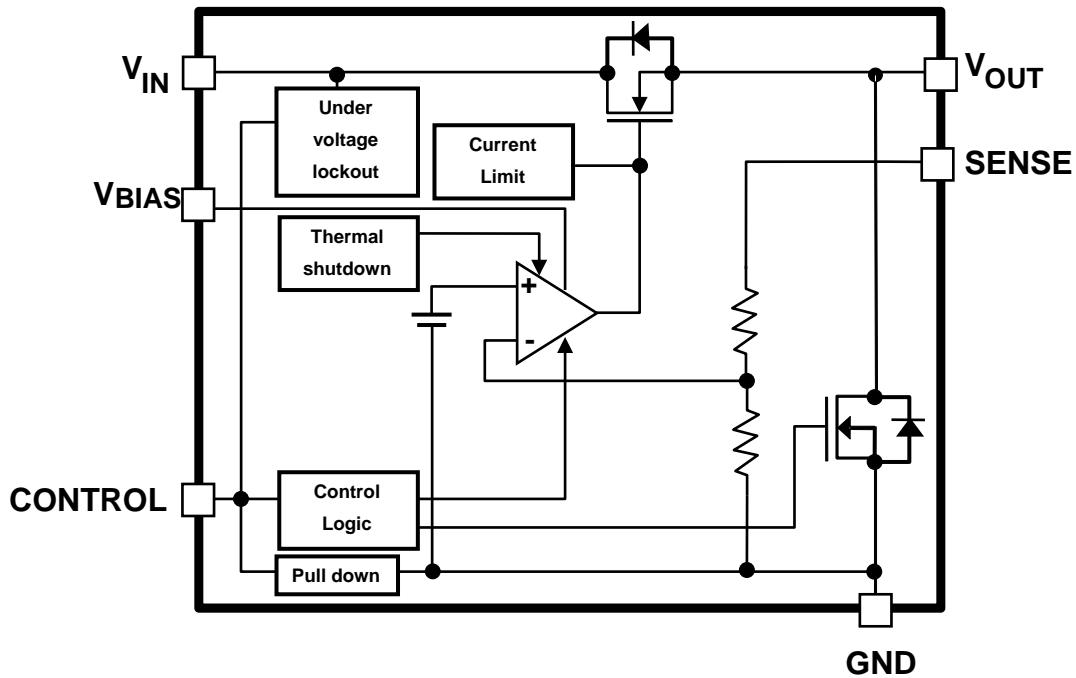
Top marking (top view)

Example: TCR15AGADJ (Adjustable output)

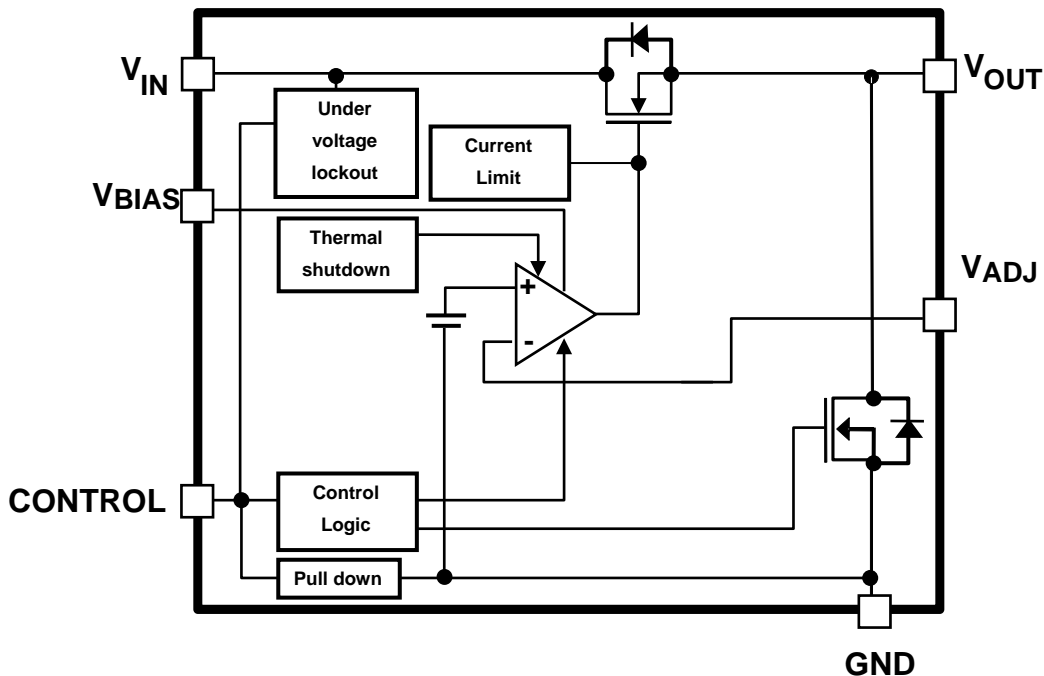


Block Diagram Operation Logic table

Fixed Output voltage



Ajustable Output voltage



Operation Logic table

| Control inputs | Output voltage(V) |
|----------------|-----------------------|
| High | VOUT |
| Low | 0V (Output discharge) |

Electrical Characteristics

(Unless otherwise specified, $V_{IN} = V_{OUT} + 0.5\text{ V}$, $I_{OUT} = 50\text{ mA}$, $C_{IN} = 4.7\text{ }\mu\text{F}$, $C_{BIAS} = 1.0\text{ }\mu\text{F}$, $C_{OUT} = 4.7\text{ }\mu\text{F}$)

| Characteristics | Symbol | Test Condition | $T_j = 25^\circ\text{C}$ | | | $T_j = -40\text{ to }85^\circ\text{C}$ (Note 9) | | Unit | |
|---|--------------------|---|-----------------------------|------|------------|--|------------|-----------------------|----|
| | | | Min | Typ. | Max | Min | Max | | |
| Output voltage accuracy (Fixed Output voltage) | V_{OUT} | $I_{OUT} = 50\text{ mA}$ (Note 5) | $V_{OUT} < 1.8\text{ V}$ | -18 | — | +18 | — | — | mV |
| | | | $1.8\text{ V} \leq V_{OUT}$ | -1.0 | — | +1.0 | — | — | % |
| Adjustable voltage (Adjustable Output voltage) | V_{ADJ} | TCR15AGADJ | 0.588 | 0.60 | 0.612 | — | — | V | |
| Bias voltage | V_{BIAS} | $V_{OUT} \leq 1.1\text{ V}$, $I_{OUT} = 1\text{ mA}$ | 2.5 | — | 5.5 | 2.5 | 5.5 | V | |
| | | $V_{OUT} > 1.1\text{ V}$, $I_{OUT} = 1\text{ mA}$ | $V_{OUT} + 1.4\text{ V}$ | — | 5.5 | $V_{OUT} + 1.4\text{ V}$ | 5.5 | V | |
| Input voltage | V_{IN} | $I_{OUT} = 0\text{ mA}$ (Note 6) | $V_{OUT} + V_{DO}$ | — | V_{BIAS} | $V_{OUT} + V_{DO}$ | V_{BIAS} | V | |
| Line regulation | Reg·line | $V_{OUT} + 0.5\text{ V} \leq V_{IN} \leq 5.5\text{ V}$ $I_{OUT} = 1\text{ mA}$ | — | 0 | 15 | — | — | mV | |
| Load regulation | Reg·load | $0.01\text{ A} \leq I_{OUT} \leq 1.5\text{ A}$ | — | 3 | — | — | — | mV | |
| Quiescent current | I_B | $I_{OUT} = 0\text{ mA}$ (Note 7) | — | 25 | — | — | 40 | μA | |
| ADJ pin current (Adjustable Output voltage) | I_{ADJ} | $V_{ADJ} = 0.6\text{ V}$ | — | 0 | 0.1 | — | — | μA | |
| Stand-by current | $I_{BIAS(OFF)}$ | $V_{CT} = 0\text{ V}$, | — | 0.04 | — | — | 1 | μA | |
| | $I_{IN(OFF)}$ | $V_{CT} = 0\text{ V}$ | — | 0 | 0.1 | — | — | μA | |
| Control pull down current | I_{CT} | — | — | 0.03 | — | — | — | μA | |
| Dropout voltage | V_{DO} | $I_{OUT} = 1.5\text{ A}$, $V_{BIAS} = 3.3\text{ V}$ (Note 8) | — | 120 | — | — | 216 | mV | |
| Under voltage lockout | V_{UVLO} | V_{IN} voltage | — | 0.5 | — | — | 0.65 | V | |
| Temperature coefficient | T_{CVO} | $-40^\circ\text{C} \leq T_{opr} \leq 85^\circ\text{C}$ | — | 60 | — | — | — | ppm/ $^\circ\text{C}$ | |
| Output noise voltage | V_{NO} | $V_{BIAS} = 3.3\text{ V}$, $V_{IN} = V_{OUT} + 1\text{ V}$ $I_{OUT} = 10\text{ mA}$, $V_{OUT} = 0.9\text{ V}$ $10\text{ Hz} \leq f \leq 100\text{ kHz}$, $T_a = 25^\circ\text{C}$ | — | 52 | — | — | — | μV_{rms} | |
| Ripple rejection ratio | R.R.(V_{IN}) | $V_{BIAS} = 3.3\text{ V}$, $V_{IN} = V_{OUT} + 1\text{ V}$ $I_{OUT} = 10\text{ mA}$, $V_{OUT} = 0.9\text{ V}$ $f = 1\text{ kHz}$, V_{IN} Ripple = 200 mV_{p-p} $T_a = 25^\circ\text{C}$, $C_{OUT} = 4.7\text{ }\mu\text{F}$ | — | 95 | — | — | — | dB | |
| | R.R.(V_{BIAS}) | $V_{BIAS} = 3.3\text{ V}$, $V_{IN} = V_{OUT} + 1\text{ V}$ $I_{OUT} = 10\text{ mA}$, $V_{OUT} = 0.9\text{ V}$ $f = 1\text{ kHz}$, V_{BIAS} Ripple = 200 mV_{p-p} $T_a = 25^\circ\text{C}$, $C_{OUT} = 4.7\text{ }\mu\text{F}$ | — | 60 | — | — | — | dB | |
| Load transient response | ΔV_{OUT} | $I_{OUT} = 0.01\text{ A} \rightarrow 1.5\text{ A}$ | — | -100 | — | — | — | mV | |
| | | $I_{OUT} = 1.5\text{ A} \rightarrow 0.01\text{ A}$ | — | +115 | — | — | — | mV | |
| Control voltage (ON) | $V_{CT(ON)}$ | — | 1.0 | — | 5.5 | 1.0 | 5.5 | V | |
| Control voltage (OFF) | $V_{CT(OFF)}$ | — | 0 | — | 0.4 | 0 | 0.4 | V | |
| Output discharge on resistance | R_{SD} | — | — | 10 | — | — | — | Ω | |

Note 5: Stable state with fixed I_{OUT} condition.

Note 6: Please refer to Dropout Voltage (Page 7) and use it within Absolute Maximum Ratings Junction temperature and Operation Temperature Ranges.

Note 7: Control pull down current and external resistors current not included in this parameter.

Note 8: This parameter is tested at $V_{OUT} = 0.9\text{ V}$ for Adjustable output. For other voltage, please refer to Dropout Voltage (Page 7).

Dropout voltage $V_{DO} = V_{IN1} - (V_{OUT1} - 100\text{ mV})$.

V_{OUT1} is the output voltage when $V_{IN} = V_{OUT} + 0.5\text{ V}$.

V_{IN1} is the input voltage at which the output voltage becomes 100 mV drop of V_{OUT1} after gradually decreasing the input voltage

Note 9: $T_j = -40\text{ to }85\text{ }^\circ\text{C}$. This parameter is warranted by design.

Dropout voltage

($C_{IN} = 4.7\text{ }\mu\text{F}$, $C_{BIAS} = 1.0\text{ }\mu\text{F}$, $C_{OUT} = 4.7\text{ }\mu\text{F}$, $T_j = 25\text{ }^\circ\text{C}$)

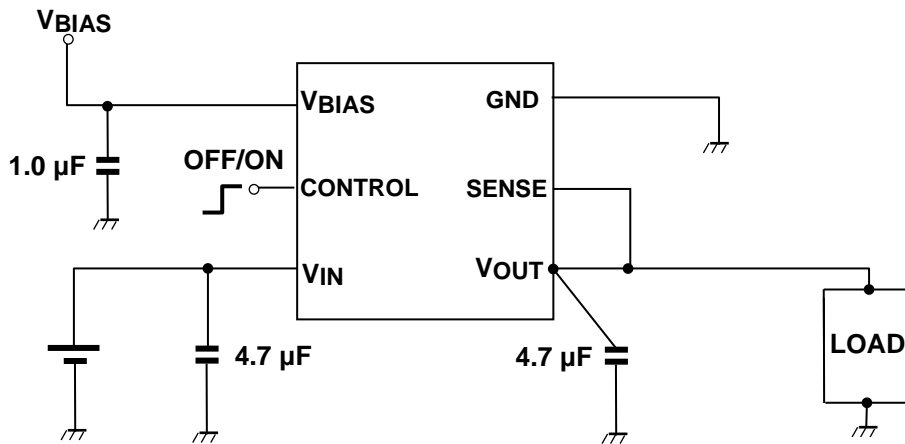
| Output voltages | V_{BIAS} input voltage | $I_{OUT} = 1000\text{ mA}$ | | | $I_{OUT} = 1500\text{ mA}$ | | | Unit |
|---|--------------------------|----------------------------|------|------------------|----------------------------|------|------------------|------|
| | | Min | Typ. | Max (Note 10) | Min | Typ. | Max (Note 10) | |
| $0.6\text{ V} \leq V_{OUT} < 0.7\text{ V}$ | 3.3 V | — | 73 | 133 | — | 110 | 199 | mV |
| $0.7\text{ V} \leq V_{OUT} < 0.8\text{ V}$ | 3.3 V | — | 75 | 135 | — | 112 | 203 | mV |
| $0.8\text{ V} \leq V_{OUT} < 0.9\text{ V}$ | 3.3 V | — | 77 | 139 | — | 115 | 208 | mV |
| $0.9\text{ V} \leq V_{OUT} < 1.0\text{ V}$ | 3.3 V | — | 80 | 144 | — | 120 | 216 | mV |
| $1.0\text{ V} \leq V_{OUT} < 1.1\text{ V}$ | 3.3 V | — | 83 | 152 | — | 125 | 228 | mV |
| $1.1\text{ V} \leq V_{OUT} < 1.2\text{ V}$ | 3.3 V | — | 89 | 160 | — | 134 | 240 | mV |
| $1.2\text{ V} \leq V_{OUT} < 1.3\text{ V}$ | 3.3 V | — | 94 | 171 | — | 141 | 257 | mV |
| 1.3 V | 3.3 V | — | 99 | 183 | — | 149 | 274 | mV |
| 1.4 V | 3.3 V | — | 107 | 197 | — | 161 | 295 | mV |
| 1.5 V | 3.3 V | — | 116 | 217 | — | 174 | 325 | mV |
| 1.6 V | $V_{OUT} + 1.7\text{ V}$ | — | 231 | 450 | — | 347 | 675 | mV |
| 1.7 V | $V_{OUT} + 1.7\text{ V}$ | — | 225 | 443 | — | 338 | 665 | mV |
| $1.8\text{ V} \leq V_{OUT} \leq 3.6\text{ V}$ | $V_{OUT} + 1.7\text{ V}$ | — | 221 | 432 | — | 332 | 648 | mV |

Note 10: $T_j = -40\text{ to }85\text{ }^\circ\text{C}$. This parameter is warranted by design.

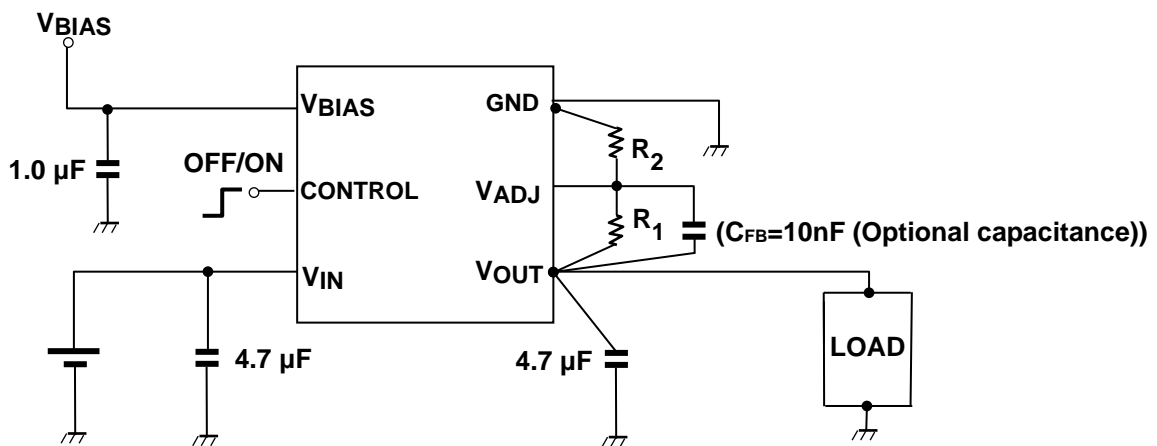
Application Note

1. Recommended Application Circuit

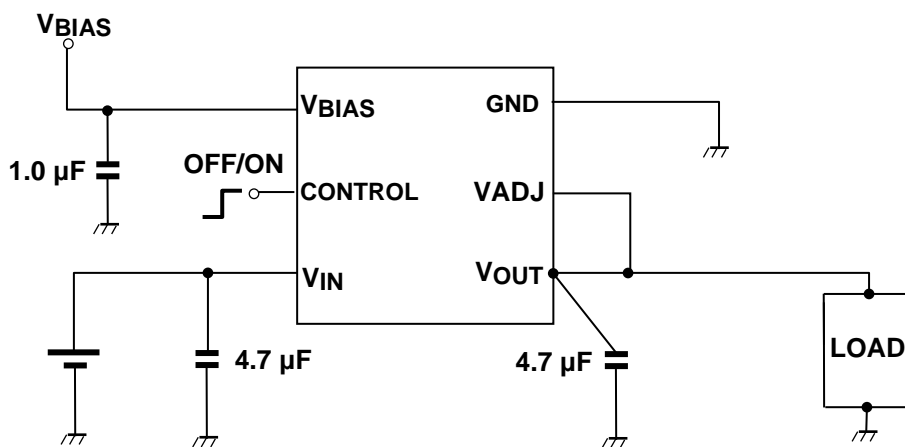
Fixed Output Voltage



Adjustable Output Voltage



Adjustable Output Voltage ($V_{OUT} = 0.6 \text{ V} : R_1 = 0 \Omega, R_2 = \text{Open}$)



The figure above shows the recommended configuration for using a Low-Dropout regulator. Insert a capacitor at VIN , VOUT and VBIAS pins for stable input/output operation. (Ceramic capacitors can be used).

Connect a capacitor with a capacitance value as much as 4.7µF or more between VIN and GND pin and 1.0 µF or more between VBIAS and GND, and as close as possible to the pins. But simple usage of large input capacitance is known to form unwanted LC resonance in combination with input wire inductance. So please check parameter with the actual device and circuit.

C_{FB} is optional capacitance that improve Transient response, Output noise, Oscillation resistance, PSRR and Overshoot. However, it does not necessarily need.

VADJ is the output voltage control pin. Typical VADJ value is 0.6 V. For best performance R1 and R2 should have similar temperature coefficients, otherwise output voltage accuracy will be compromised.

$$V_{OUT} = V_{ADJ} \times \left(1 + \frac{R1}{R2}\right)$$

Reference resistance table

This is reference data. Please check parameter with the actual device and circuit.

TCR15AGADJ : VADJ = 0.6 V (typ.).

| Output voltage (typ.) | R1 | R2 |
|-----------------------|--------|-------|
| 0.6 V | 0 Ω | Open |
| 0.65 V | 2 kΩ | 24 kΩ |
| 0.7 V | 4 kΩ | 24 kΩ |
| 0.8 V | 8 kΩ | 24 kΩ |
| 0.9 V | 12 kΩ | 24 kΩ |
| 1.0 V | 16 kΩ | 24 kΩ |
| 1.1 V | 20 kΩ | 24 kΩ |
| 1.2 V | 24 kΩ | 24 kΩ |
| 1.3 V | 28 kΩ | 24 kΩ |
| 1.8 V | 48 kΩ | 24 kΩ |
| 2.5 V | 76 kΩ | 24 kΩ |
| 3.0 V | 96 kΩ | 24 kΩ |
| 3.3 V | 108 kΩ | 24 kΩ |
| 3.6 V | 120 kΩ | 24 kΩ |

2. Power Dissipation

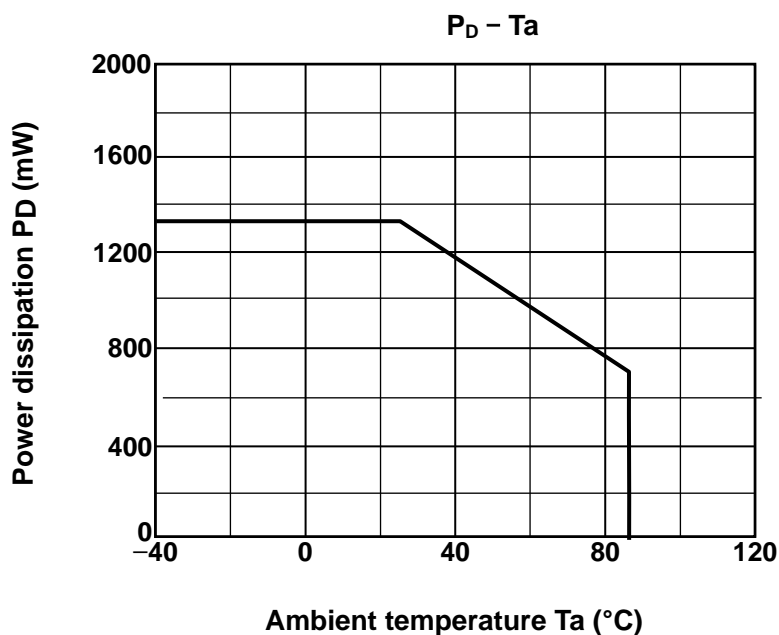
Board-mounted power dissipation ratings for TCR15AG series are available in the Absolute Maximum Ratings table. Power dissipation is measured on the board condition shown below.

[The Board Condition]

Board material: Glass epoxy (FR4)

Board dimension: 40 mm x 40 mm (4layer), t=1.8 mm

Metal pattern ratio: approximately 70% each layer



Please allow sufficient margin when designing a board pattern to fit the expected power dissipation. Also take into consideration the ambient temperature, input voltage, output current etc. and applying the appropriate derating for allowable power dissipation during operation.

Attention in Use

- **Capacitors(Output, Input, and Bias 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 ESR of ceramic capacitor is under 1.0 Ω . For stable operation, please use over 4.7 μF Input capacitor, 1.0 μF Bias capacitor and 4.7 μF output ceramic capacitor.
- **Mounting**

The long distance between IC and each capacitor might affect phase assurance by impedance in wire and inductor. For stable power supply, 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 surrounding temperature, input voltage, and output current etc, we recommend proper dissipation ratings for maximum permissible loss; in general maximum dissipation rating is 70 to 80 percent.
- **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. Depending on the condition during actual usage, it could affect the electrical characteristic specification and reliability. Also note that if output pins and GND pins are not completely shorted out, these products might be break down.

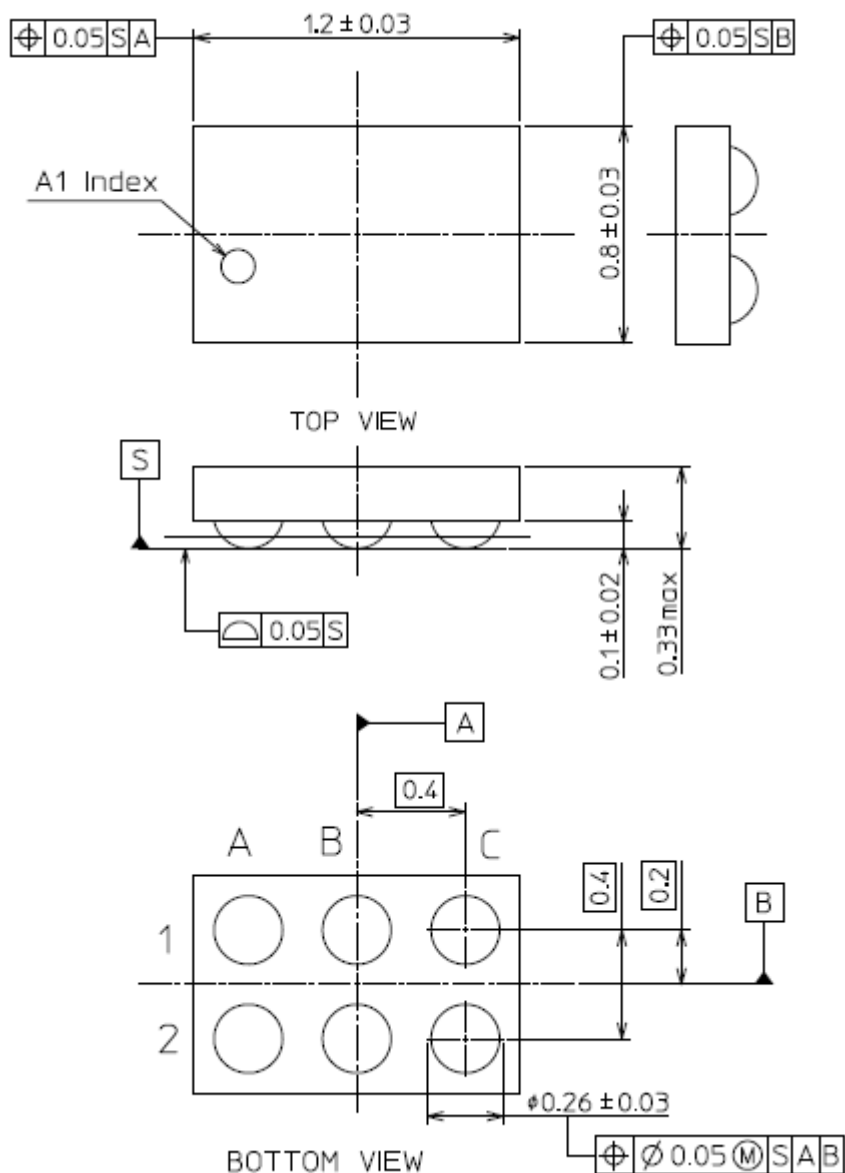
When using these products, please read through and understand the concept of dissipation for absolute maximum ratings from the above mention or our 'Semiconductor Reliability Handbook'. Then use these products under absolute maximum ratings in any condition. Furthermore, Toshiba recommend inserting failsafe system into the design.
- **Adjustable output voltage type**

TCR15AGADJ is adjustable output voltage type. VADJ is the output voltage control pin, please refer to recommended application circuit and reference resistance table. Please select the tolerance of the resistance value in accordance by the system. In addition, please assemble R1 and R2 to minimize common impedance. For VADJ assembly, please design PCB pattern as short as possible to avoid noise effect.

Package Dimensions

WCSP6F

Unit: mm



Weight : 0.61 mg (typ.)

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