70V, Low Dropout Voltage Linear Regulator

General Description

The RT9070B is a high voltage (70V operation), low quiescent current, low dropout linear regulator. The device supplies 20mA output current with a maximum dropout voltage of 230mV. Its low quiescent and shutdown currents (23μA operating and 3μA shutdown) are ideal for use in battery-powered and/or high voltage systems. Ground current is well-controlled in all conditions, including dropout.

The RT9070B operates with any reasonable output capacitors including 1μF low-ESR ceramic types. It features excellent line and load transient responses. Internal protection circuitry includes reverse-battery protection, current limiting, thermal shutdown, and reverse current protection.

The RT9070B has an adjustable output voltage (1.25V to 60V). It is available in the SOT-23-5 package.

Applications

- Low Current, High Voltage Regulators
- Battery Powered Applications
- Telecom and Datacom Applications
- Automotive Applications

Features

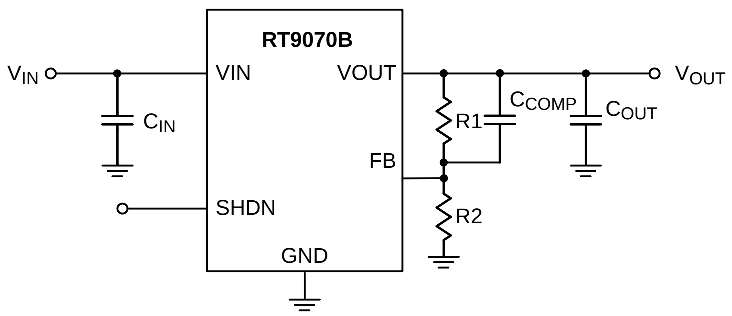
- **Wide Input Voltage Range: 4.5V to 70V**
- **Low Quiescent Current: 23μA Operating and 3μA Shutdown**
- **Low Dropout Voltage: 180mV (typical) at 20mA**
- **Adjustable (1.25V to 60V) Output Voltage**
- **±2% Initial Output Tolerance**
- **Stable with 1μF Output Capacitor**
- **Stable with Aluminum, Tantalum or Ceramic Capacitors**
- **No Reverse-Current Protection Diode Needed**
- **−70V Reverse-Battery Protection**
- **Internal Current Limit**
- **Internal Thermal Shutdown Protection**

Marking Information

6A=DNN

6A= : Product Code
DNN : Date Code

Simplified Application Circuit



Ordering Information

RT9070B□□

- Package Type
  B : SOT-23-5
- Lead Plating System
  G : Green (Halogen Free and Pb Free)

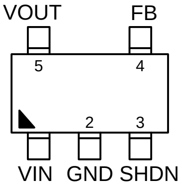
Note :

Richtek products are :

- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

Pin Configurations

(TOP VIEW)

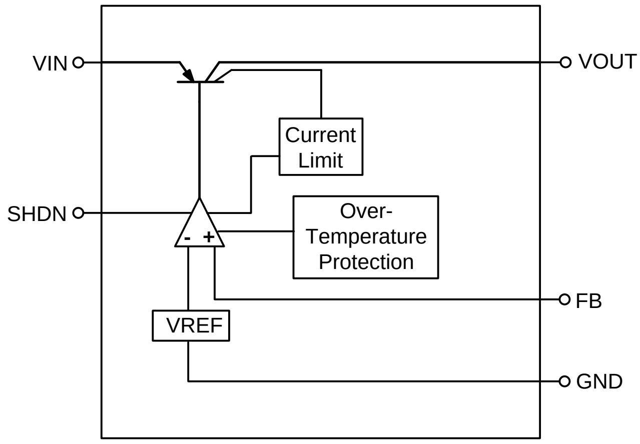


SOT-23-5

Functional Pin Description

Pin No.	Pin Name	Pin Function
5	VOUT	Output Voltage Pin. The VOUT pin supplies power to the load. A minimum output capacitor of 1μF is required for stable operation.
4	FB	Feedback Voltage Input. Connect to the center tap of a resistor divider for setting the output voltage.
2	GND	Ground.
3	SHDN	Shutdown Control Input. Connect SHDN of high to disable the output voltage and reduce the IC's quiescent current to 3μA (typical). Connect SHDN low to enable the output. SHDN is a high-voltage pin and can be connected directly to a high-voltage input less than 60V.
1	VIN	Power Input. Bypass VIN with a 0.18μF or larger capacitor with adequate voltage rating.

Function Block Diagram



Operation

The RT9070B is a high input-voltage linear regulator specifically designed to minimize external components. The input voltage range is from 4.5V to 70V. The device supplies 20mA of output current with a maximum dropout voltage of 230mV. Its 23μA quiescent and 3μA shutdown currents make it ideal for use in battery-powered applications. Unlike many PNP LDO regulators, ground current does not increase much in dropout conditions.

Output Transistor

The RT9070B includes a built-in PNP output transistor configured for low dropout voltage. The output transistor blocks the large reverse current from output to input node if the output voltage is held higher than the input voltage (such as in battery-backup applications), because there is no parasitic diode across VIN and VOUT directly.

Error Amplifier

The Error Amplifier compares the output feedback voltage at FB to an internal reference voltage and controls the PNP output transistor's base current to maintain output voltage regulation.

Current Limit Protection

The RT9070B provides a current limit function to prevent damage during output over-load or shorted-circuit conditions. The output current is detected by an internal current-sense transistor.

Over-Temperature Protection

The over-temperature protection function will turn off the PNP output transistor when the internal junction temperature exceeds 150°C (typ.). Once the junction temperature cools down by approximately 20°C, the regulator will automatically resume operation.

Reverse-Battery Protection

The RT9070B VIN can withstand reverse voltages as high as −70V. Both the IC and the load are protected and no negative voltage will appear at the output.

Reverse-Output Protection

The RT9070B protects against current flow to the input (VIN) when the output voltage exceeds VIN.

If the input is left open circuit or grounded, the FB pin will act like a resistor (typically 10k) in series with a diode when pulled above ground. If the FB pin is connected to a resistor divider now and the output voltage is held higher than the input voltage, a current will conduct from output via the resistor divider and FB node to ground. Because the current is limited by the resistor divider and FB internal resistor, no additional output blocking diode is needed if the limited current is acceptable.

Shutdown Control

The RT9070B SHDN input is an active-high input that turns off the output transistor and reduces the quiescent current to 3μA typical. Connect SHDN to a voltage below 0.4V for normal operation.

Absolute Maximum Ratings (Note 1)

- VIN Pin Voltage ---------- –70V to 80V
- SHDN Pin Voltage ---------- –0.3V to 60V
- VOUT to GND Voltage ---------- –70V to 70V
- VOUT to VIN Voltage ---------- –70V to 70V
- FB Pin Voltage ---------- –0.3V to 7V
- Power Dissipation, P_D @ T_A = 25°C

  SOT-23-5 ---------- 0.45W
- Package Thermal Resistance (Note 2)

  SOT-23-5, θ_{JA} ---------- 218.1°C/W

  SOT-23-5, θ_{JC} ---------- 28.5°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)

  HBM (Human Body Model) ---------- 2kV

  MM (Machine Model) ---------- 200V

Recommended Operating Conditions (Note 4)

- Supply Input Voltage ---------- 4.5V to 70V
- Ambient Temperature Range ---------- –40°C to 85°C
- Junction Temperature Range ---------- –40°C to 125°C

Electrical Characteristics

(4.5V < V_{IN} < 70V, V_{SHDN} = 0V , FB pin connected to VOUT pin, C_{OUT} = 1μF (ceramic), T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Voltage	V_{IN}	I_{LOAD} = 20mA	4.5	--	70	V
FB Pin Voltage	V_{FB}	V_{IN} = 12V, I_{LOAD} = 100μA	1.23	1.25	1.27	μV
		100μA < I_{LOAD} < 20mA	1.21	1.25	1.29	
Line Regulation	ΔV_{LINE}	ΔV_{IN} = 4.5V to 70V, I_{LOAD} = 100μA	--	1	10	mV
Load Regulation	ΔV_{LOAD}	V_{IN} = 12V, ΔI_{LOAD} = 100μA to 20mA	--	3	25	mV
Dropout Voltage	V_{DROP}	I_{LOAD} = 100μA	--	9	50	mV
		I_{LOAD} = 1mA	--	37	100	
		I_{LOAD} = 10mA	--	130	200	
		I_{LOAD} = 20mA	--	180	230	
GND Pin Current	I_{GND}	I_{LOAD} = 0mA	--	20	30	μA
		I_{LOAD} = 20mA	--	750	1200	
Output Voltage Noise	V_{ON}	C_{OUT} = 1μF, I_{LOAD} = 20mA, BW = 10Hz to 100kHz	--	120	--	μV_{RMS}

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
FB Pin Bias Current	I_{FB}		--	8	100	nA
Shutdown Threshold	V_{IH}	On to Off	--	--	2	V
	V_{IL}	Off to On	0.4	--	--	
SHDN Pin Current	I_{SHDN}	V_{SHDN} = 2V	--	0.4	2	μA
Quiescent Current in Shutdown	I_{SD}	V_{IN} = 6V, or V_{SHDN} = 0V	--	3	10	μA
Power Supply Rejection Rate	PSRR	V_{IN} = 7V (Avg), V_{RIPPLE} = 0.5 V_{P-P}, f_{RIPPLE} = 120Hz, I_{LOAD} = 20mA	--	75	--	dB
Output Current Limit	I_{LIM}	V_{IN} = 12V, V_{OUT} = 11V, V_{FB} = 1.2V	25	40	--	mA
Input Reverse Leakage Current	IV_{INr}	V_{IN} = –70V, V_{OUT} = 0V	--	--	6	mA
Reverse Output Current	IV_{OUTr}	FB connect to OUT, V_{OUT} = 1.27V, V_{IN} < 0V	--	19	40	μA
Over-Temperature Protection	T_{SD}		--	150	--	°C

Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. θ_{JA} is measured at T_A = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7.

Note 3. Devices are ESD sensitive. Handling precaution recommended.

Note 4. The device is not guaranteed to function outside its operating conditions.

Typical Application Circuit

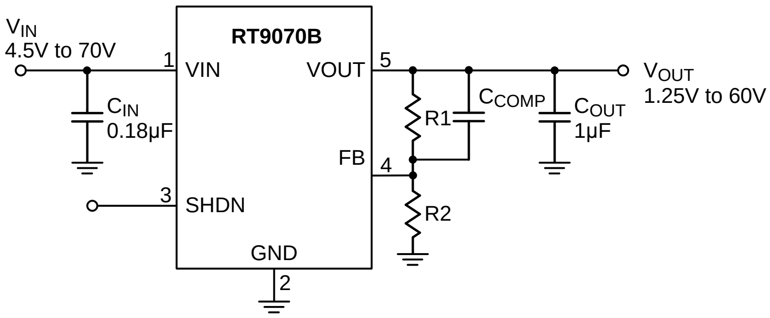


Figure 1. RT9070B Adjustable Output

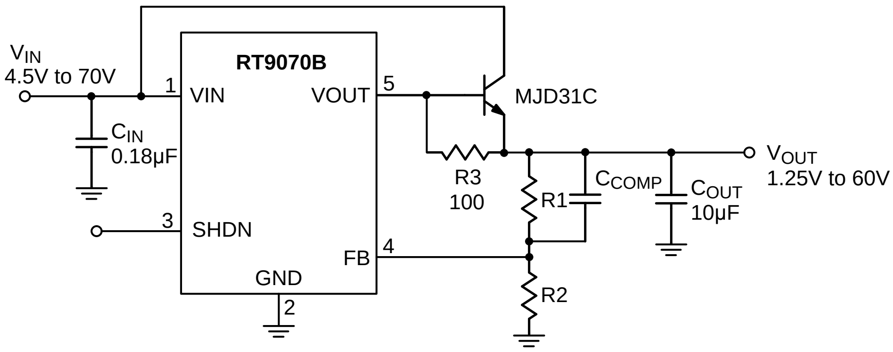
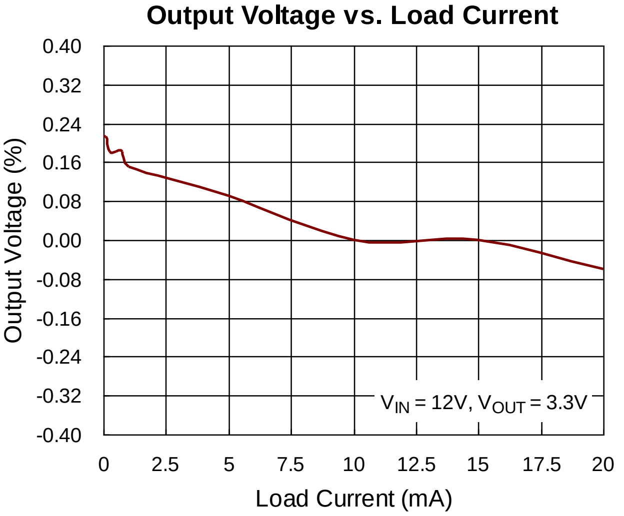
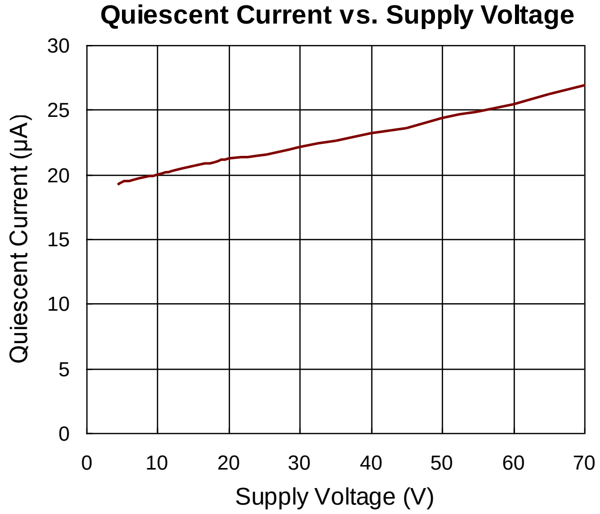
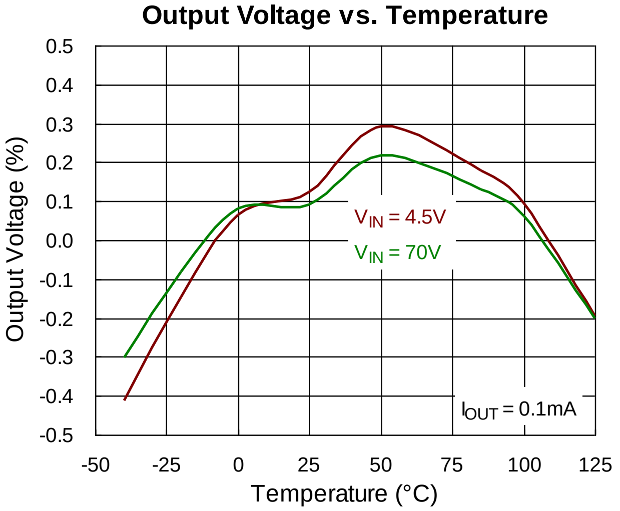


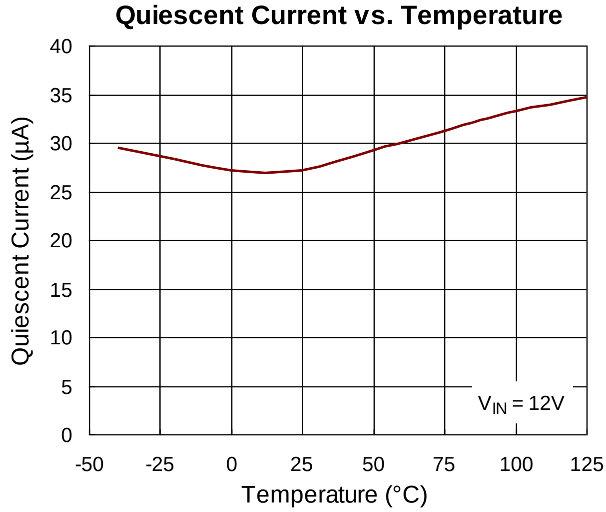
Figure 2. RT9070B External Transistor Application

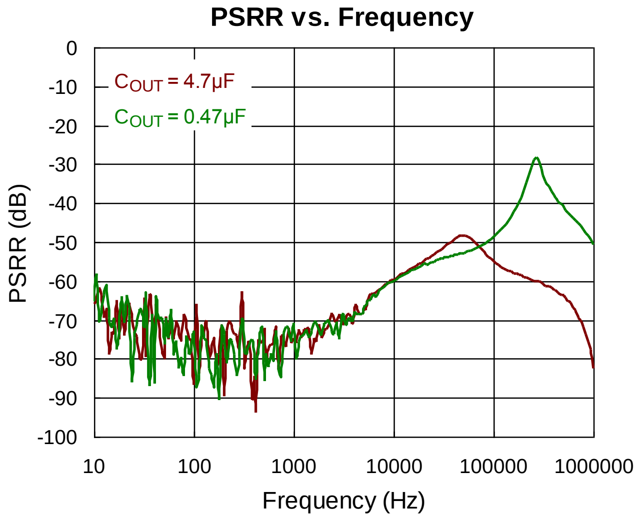
Typical Operating Characteristics

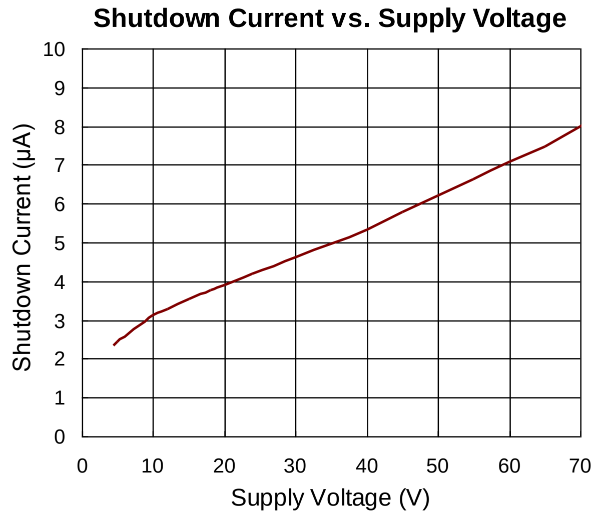




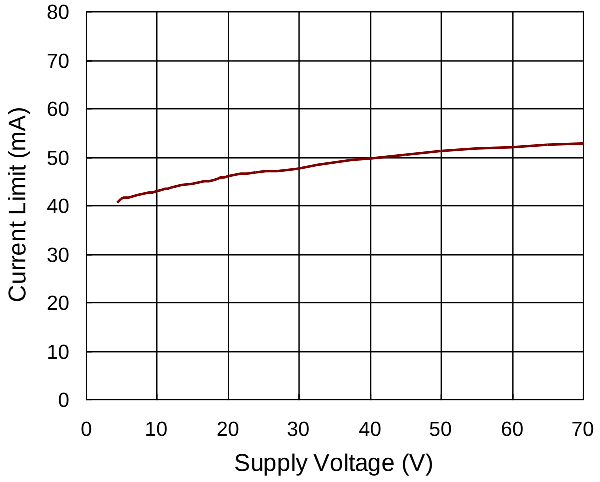




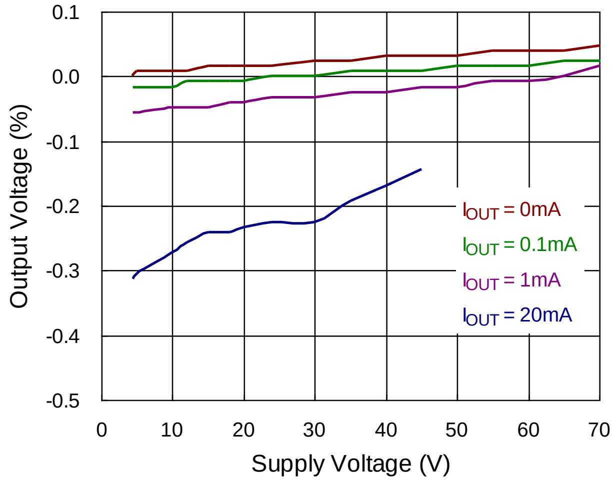




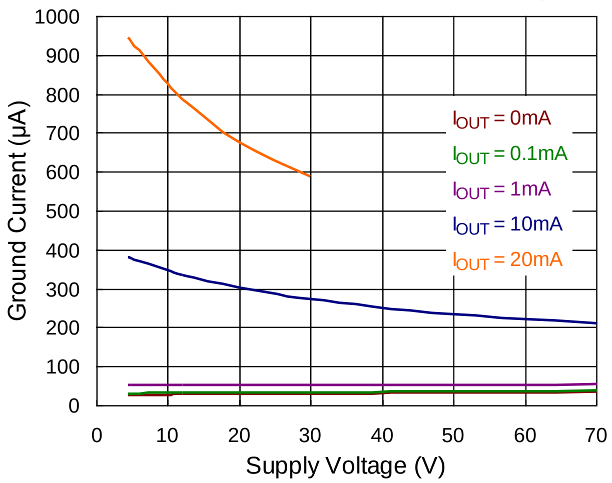
Current Limit vs. Supply Voltage



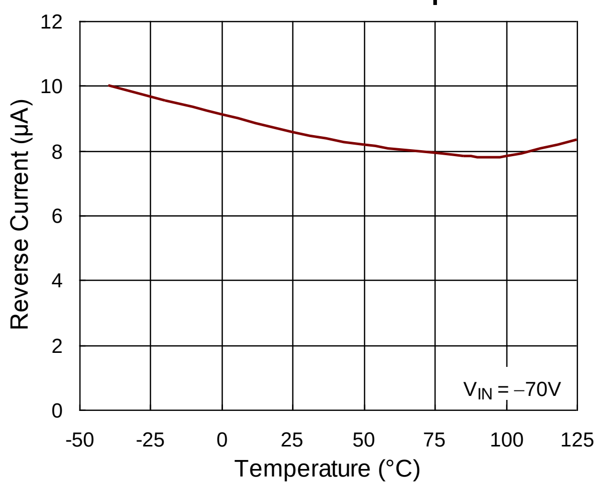
Output Voltage vs. Supply Voltage



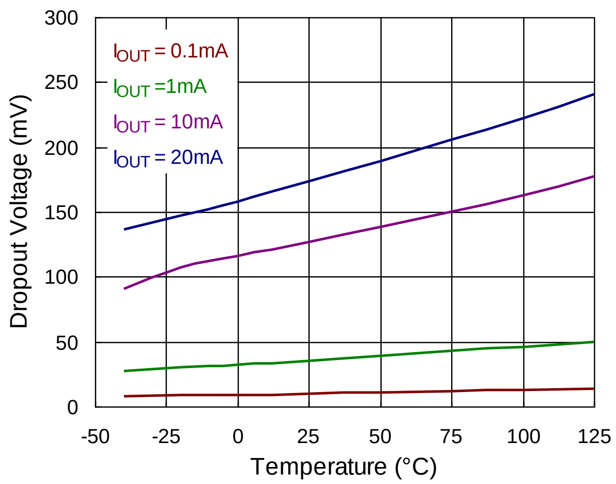
Ground Current vs. Supply Voltage



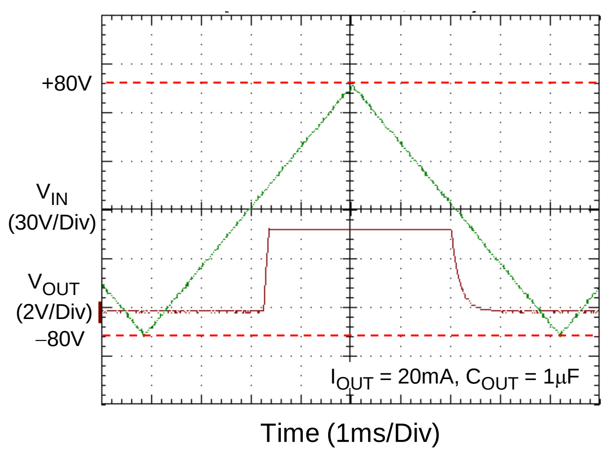
Reverse Current vs. Temperature



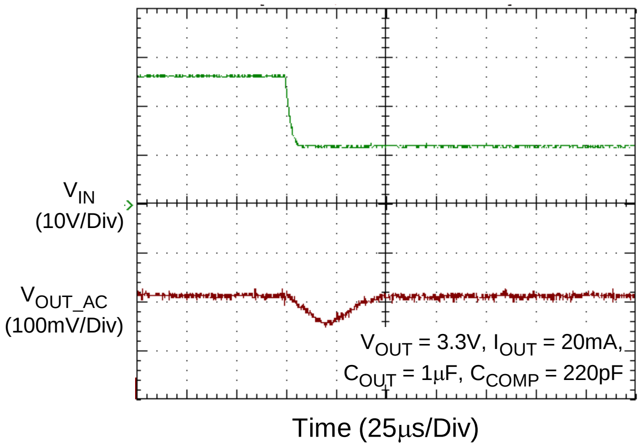
Dropout Voltage vs. Temperature



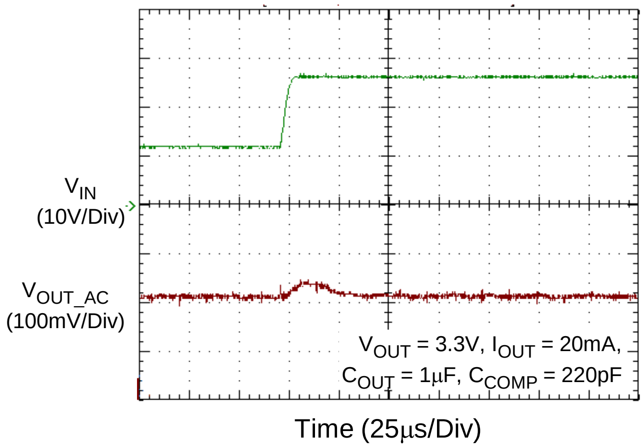
VOUT vs. VIN



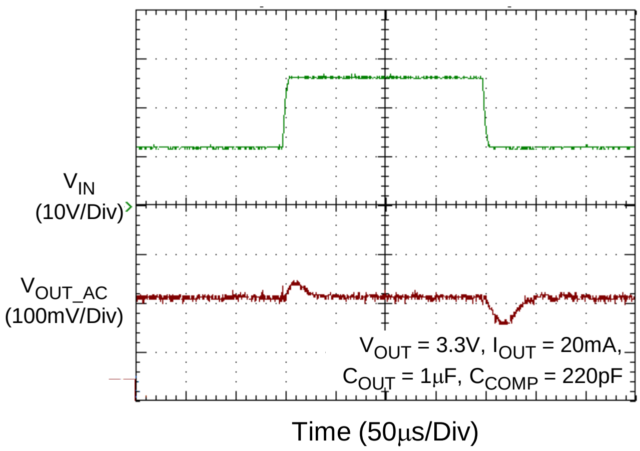
Line Transient Waveform Falling



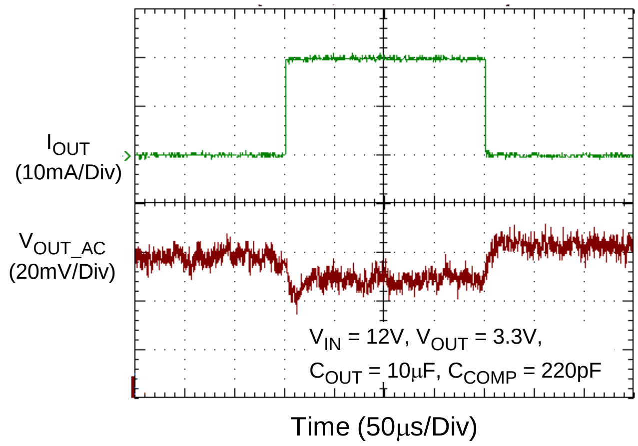
Line Transient Waveform Rising



Line Transient Waveform Full



Load Transient Waveform



Application Information

The RT9070B is a high input-voltage linear regulator specifically designed to minimize external components. The input voltage range is from 4.5V to 70V. The device supplies 20mA of output current with a maximum dropout voltage of 230mV.

Adjustable Output Voltage and Compensation

The adjustable output may be set to provide from 1.25V to 60V, using external feedback voltage divider resistors (Figure 1). To achieve the correct compensation (with your external FB divider, use a lower divider resistor (R2) value below 100kΩ. Calculate R1 according to the following formula : R2 = R1 / (V_{OUT} / 1.25V – 1). Then, calculate the compensation capacitor (C_{COMP}) value according to the following formula : C_{COMP} = 25μs/R1

Added External NPN for High-Current Applications

Higher output currents and/or increased power dissipation are possible using an external NPN output transistor. VOUT drives the base of the transistor and FB monitors the actual output voltage, as in normal applications. The output (Figure 2) can be used.

Component Selection

A low-ESR capacitor such as ceramic type must be connected between VIN and GND with short, wide traces to bypass input noise. RT9070B is designed to work with small input capacitor to reduce the cost from high-voltage low-ESR requirement. To guarantee a minimum 0.1μF input capacitance, a ceramic 0.18μF input capacitor with an appropriate voltage rating is recommended.

The RT9070B operates with any reasonable output capacitor including low-ESR ceramic types. Low-ESR aluminum and tantalum capacitor may also be used. A minimum of 1μF is recommended and much higher values are also acceptable. Connect the output capacitor between VOUT and GND with short, wide traces to keep the circuit stable.

Thermal Considerations

The RT9070B's high input-voltage capability and high output current capability require careful use to avoid over-heating the IC and activating the internal thermal protection. To avoid thermal shutdown, do not exceed the IC's maximum operating junction temperature range of 125°C.

For continuous operation, do not exceed absolute maximum junction temperature. The maximum power dissipation depends on the thermal resistance of the IC package, PCB layout, rate of surrounding airflow, and difference between junction and ambient temperature. The maximum power dissipation can be calculated by the following formula :

$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$

where $T_{J(MAX)}$ is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction to ambient thermal resistance.

For recommended operating condition specifications, the maximum junction temperature is 125°C. The junction to ambient thermal resistance, θ_{JA}, is layout dependent. For SOT-23-5 package, the thermal resistance, θ_{JA}, is 218.1°C/W on a standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at T_A = 25°C can be calculated by the following formula :

$P_{D(MAX)}$ = (125°C – 25°C) / (218.1°C/W) = 0.45W for SOT-23-5 package

The maximum power dissipation depends on the operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance, θ_{JA}. The derating curve in Figure 3 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

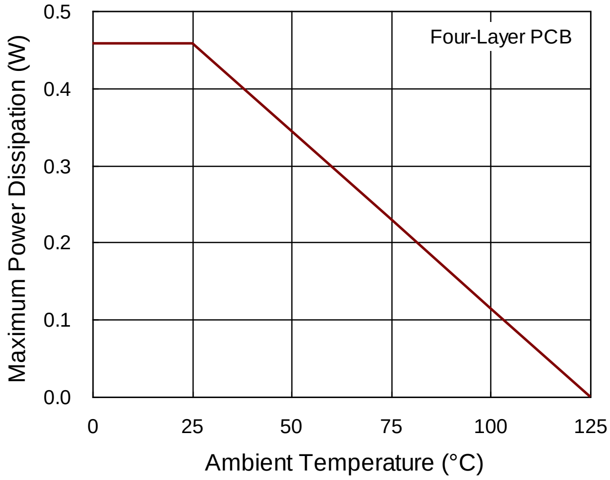
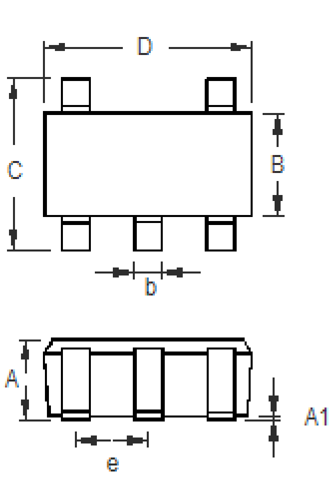


Figure 3. Derating Curve of Maximum Power Dissipation

Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.889	1.295	0.035	0.051
A1	0.000	0.152	0.000	0.006
B	1.397	1.803	0.055	0.071
b	0.356	0.559	0.014	0.022
C	2.591	2.997	0.102	0.118
D	2.692	3.099	0.106	0.122
e	0.838	1.041	0.033	0.041
H	0.080	0.254	0.003	0.010
L	0.300	0.610	0.012	0.024

SOT-23-5 Surface Mount Package

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