MIC29152/29302/29502/29752 High-Current Low-Dropout Regulators

General Description

The MIC29150/29300/29500/29750 are high current, high accuracy, low-dropout voltage regulators. Using proprietary Super β eta PNP® process with a PNP pass element, these regulators feature 350mV to 425mV (full load) typical dropout voltages and very low ground current. Designed for high current loads, these devices also find applications in lower current, extremely low dropout-critical systems, where their tiny dropout voltage and ground current values are important attributes.

The MIC29150/29300/29500/29750 are fully protected against overcurrent faults, reversed input polarity, reversed lead insertion, overtemperature operation, and positive and negative transient voltage spikes. Five pin fixed voltage versions feature logic level ON/OFF control and an error flag which signals whenever the output falls out of regulation. Flagged states include low input voltage (dropout), output current limit, overtemperature shutdown, and extremely high voltage spikes on the input.

On the 29xx1 and 29xx2, the ENABLE pin may be tied to VIN if it is not required for ON/OFF control. The MIC29150/29300/29500 are available in 3-pin and 5-pin TO-220 and surface mount TO-263 (D^2Pak) packages. The 29750 7.5A regulators are available in 3-pin and 5-pin TO-247 packages. The 1.5A, adjustable output 29152 is available in a 5-pin power D-Pak (TO-252) package.

For applications with input voltage 6V or below, see HG37xxx LDOs.

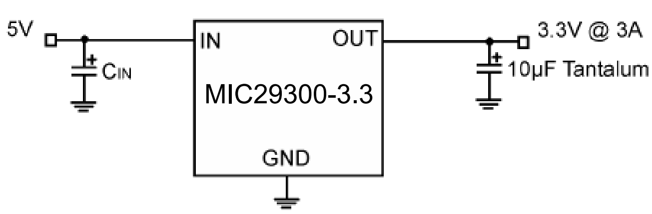
Features

- High current capability
  MIC29150/29151/29152/29153.................................1.5A
  MIC29300/29301/29302/29303....................................3A
  MIC29500/29501/29502/29503....................................5A
  MIC29750/29751/29752...7.5A
- Low-dropout voltage
- Low ground current
- Accurate 1% guaranteed tolerance
- Extremely fast transient response
- Reverse-battery and “Load Dump” protection
- Zero-current shutdown mode (5-pin versions)
- Error flag signals output out-of-regulation (5-pin versions)
- Also characterized for smaller loads with industry-leading performance specifications
- Fixed voltage and adjustable versions

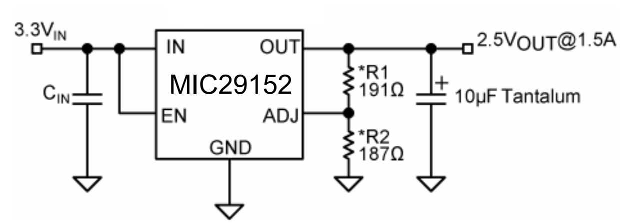
Applications

- Battery powered equipment
- High-efficiency “Green” computer systems
- Automotive electronics
- High-efficiency linear lower supplies
- High-efficiency lost-regulator for switching supply

Typical Application**



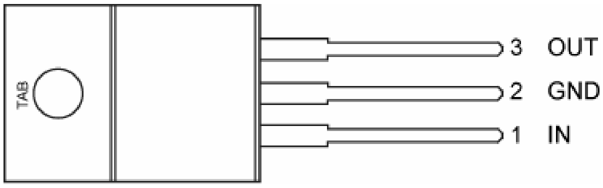
Fixed Output Voltage



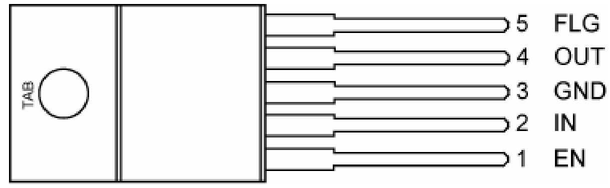
Adjustable Output Voltage

(*See Minimum Load Current Section)

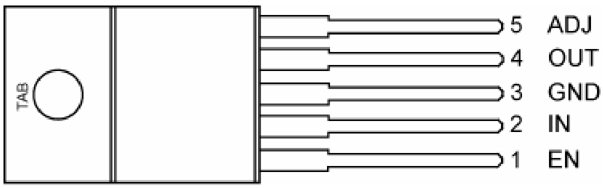
Pin Configuration



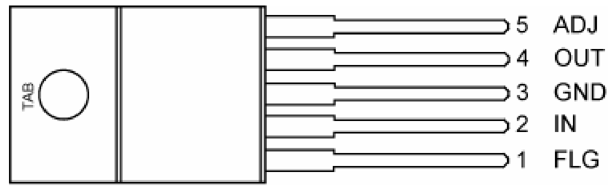
3-Pin TO-220 (T)
MIC29150/29300/29500



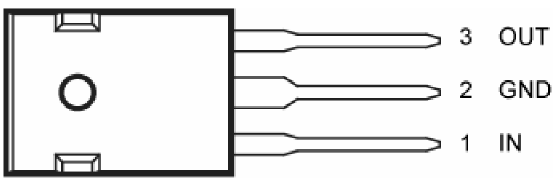
5-Pin TO-220 Fixed Voltage (T)
MIC29151/29301/29501/29751



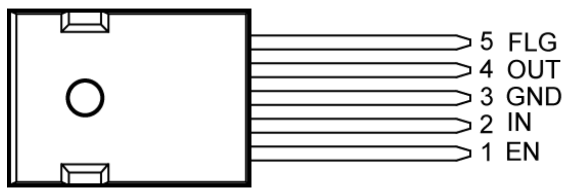
5-Pin TO-220 Adjustable Voltage (T)
MIC29152/29302/29502



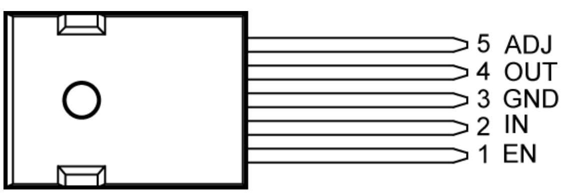
5-Pin TO-220 Adjustable with Flag (T)
MIC29153/29303/29503



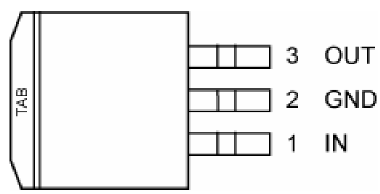
3-Pin TO-247 (WT)
MIC29750



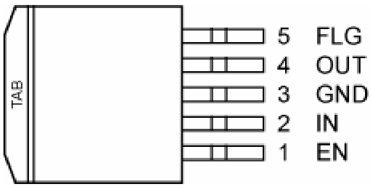
5-Pin TO-247 Fixed Voltage (WT)
MIC29751



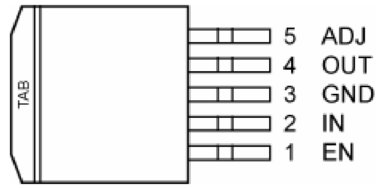
5-Pin TO-247 Adjustable Voltage (WT)
MIC29752



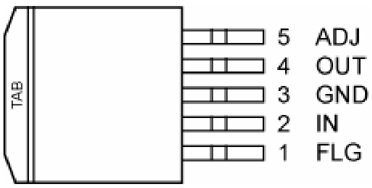
3-Pin TO-263 (D^2Pak) (UT)
MIC29150/29300



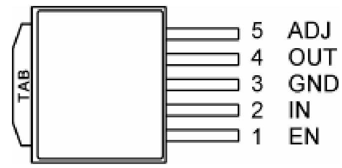
5-Pin TO-263 (D^2Pak) Fixed Voltage (U)
MIC29151/29301/29501



5-Pin TO-263 (D^2Pak) Adjustable Voltage (U)
MIC29302/29502



5-Pin TO-263 (D^2Pak) Adjustable with Flag (U)
MIC29153/29303/29503



5-Pin TO-252 (D-Pak) Adjustable Voltage (D)
MIC29152

Pin Description

Pin Number TO-220 TO-247 TO-263	Pin Name
1	INPUT: Supplies the current to the output power device
2	GND: TAB is also connected internally to the IC's ground on D-PAK.
3	OUTPUT: The regulator output voltage

Pin Description

Pin Number Fixed TO-220 TO-247 TO-263	Pin Number Adjustable TO-220 TO-247 TO-252 TO-263	Pin Number Adj. with Flag TO-220 TO-247 TO-263	Pin Name
1	1	—	ENABLE: CMOS compatible control input. Logic high = enable, logic low = shutdown.
2	2	2	INPUT: Supplies the current to the output power device
3, TAB	3, TAB	3, TAB	GND: TAB is also connected internally to the IC's ground on D-PAK.
4	4	4	OUTPUT: The regulator output voltage
—	5	5	ADJUST: Adjustable regulator feedback input that connects to the resistor voltage divider that is placed from OUTPUT to GND in order to set the output voltage.
5	—	1	FLAG: Active low error flag output signal that indicates an output fault condition

Absolute Maximum Ratings[1]

Input Supply Voltage (V_{IN})[1] .... –20V to +60V
Enable Input Voltage (V_{EN})............................... –0.3V to V_{IN}
Lead Temperature (soldering, 5sec.)......................... 260°C
Power Dissipation .... Internally Limited
Storage Temperature Range .... –65°C to +150°C
ESD Rating.. **Note 3**

Operating Ratings[2]

Operating Junction Temperature .... –40°C to +125°C
Maximum Operating Input Voltage 26V
Package Thermal Resistance
TO-220 (θ_{JC}).. 2°C/W
TO-263 (θ_{JC}).. 2°C/W
TO-247 (θ_{JC}) .... 1.5°C/W
TO-252 (θ_{JC}).. 3°C/W
TO-252 (θ_{JA}) .... 56°C/W

Electrical Characteristics[4,13]

$V_{IN} = V_{OUT} + 1V$; I_{OUT} = 10mA; T_J = 25°C, bold values indicate –40°C≤ T_J ≤ +125°C, unless noted.

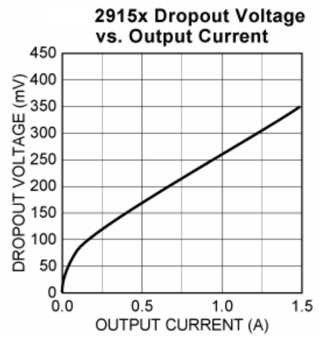
Parameter	Condition		Min	Typ	Max	Units
Output Voltage	I_{OUT} = 10mA		–1		1	%
	10mA ≤ I_{OUT} ≤ I_{FL}, (V_{OUT} + 1V) ≤ V_{IN} ≤26V (5)		–2		2	%
Line Regulation	I_{OUT} = 10mA, (V_{OUT} + 1V) ≤ V_{IN} ≤26V			0.06	0.5	%
Load Regulation	$V_{IN} = V_{OUT}$ + 5V, 10mA ≤ I_{OUT} ≤ 1.5A (5,9)			0.2	1	%
$\frac{\Delta V_O}{\Delta T}$	Output Voltage (9) Temperature Coefficient.			**20**	**100**	ppm/°C
Dropout Voltage	ΔV_{OUT} = -1% (6)					
	MIC29150	I_{OUT} = 100mA		80	**200**	mV
		I_{OUT} = 750mA		220		
		I_{OUT} = 1.5A		350	**600**	
	MIC29300	I_{OUT} = 100mA		80	**175**	
		I_{OUT} = 1.5A		250		
		I_{OUT} = 3A		370	**600**	
	MIC29500	I_{OUT} = 250mA		125	**250**	
		I_{OUT} = 2.5A		250		
		I_{OUT} = 5A		370	**600**	
	MIC29750	I_{OUT} = 250mA		80	**200**	
		I_{OUT} = 4A		270		
		I_{OUT} = 7.5A		425	750	
Ground Current	MIC29150	I_{OUT} = 750mA, $V_{IN} = V_{OUT}$ + 1V		8	**20**	mA
		I_{OUT} = 1.5A		22		
	MIC29300	I_{OUT} = 1.5A, $V_{IN} = V_{OUT}$ + 1V		10	**35**	mA
		I_{OUT} = 3A		37		
	MIC29500	I_{OUT} = 2.5A, $V_{IN} = V_{OUT}$ + 1V		15	**50**	mA
		I_{OUT} = 5A		70		
	MIC29750	I_{OUT} = 4A, $V_{IN} = V_{OUT}$ + 1V		35	**75**	mA
	Note 8	I_{OUT} = 7.5A		120		
I_{GRNDDO}Ground Pin Current at Droupout	V_{IN} = 0.5V less than specified V_{OUT} × I_{OUT} = 10mA					
	MIC29150			0.9		mA
	MIC29300			1.7		mA
	MIC29500			2.1		mA
	MIC29750			3.1		mA
Current Limit	MIC29150	V_{OUT} = 0V (7)		2.1	**3.5**	A
	MIC29300	V_{OUT} = 0V (7)		4.5	**5.0**	A
	MIC29500	V_{OUT} = 0V (7)		7.5	**10.0**	A
	MIC29750	V_{OUT} = 0V (7)		9.5	**15**	A

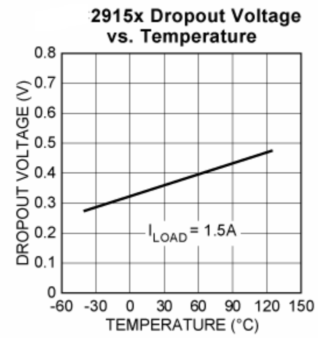
Parameter	Condition	Min	Typ	Max	Units
e_n, Output Noise Voltage (10Hz to 100kHz) I_L = 100mA	C_L = 10µF C_L = 33µF		400 260		µV (rms)
Ground Current in Shutdown	29150/1/2/3 only V_{EN} = 0.4V		2	10 **30**	µA µA
Reference	**MIC29xx2/29xx3**				
Reference Voltage		1.228 **1.215**	1.240	1.252 **1.265**	V V
Reference Voltage		**1.203**		**1.277**	V
Adjust Pin Bias Current			40	80 **120**	nA
Reference Voltage Temperature Coefficient	(10)		20		ppm/°C
Adjust Pin Bias Current Temperature Coefficient			0.1		nA/°C
Flag Output (Error Comparator) MIC29xx1/29xx3					
Output Leakage Current	V_{OH} = 26V		0.01	1.00 **2.00**	µA
Output Low Voltage	Device set for 5V, V_{IN} = 4.5V I_{OL} = 250µA		220	300 **400**	mV
Upper Threshold Voltage	Device set for 5V (11)	40 **25**	60		mV
Lower Threshold Voltage	Device set for 5V (11)		75	95 **140**	mV
Hysteresis	Device set for 5V (11)		15		mV
ENABLE Input	**MIC29xx1/29xx2**				
Input Logic Voltage Low (OFF) High (ON)		 **2.4**		 **0.8**	V
Enable Pin Input Current	V_{EN} = 26V		100	600 **750**	µA
	V_{EN} = 0.8V	0.7		2 **4**	µA
Regulator Output Current in Shutdown	(12)		10	**500**	µA

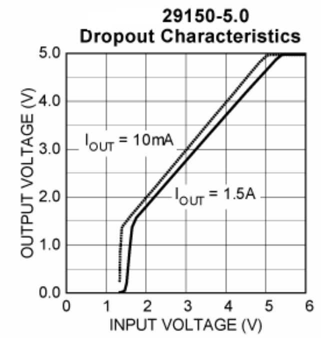
Notes:

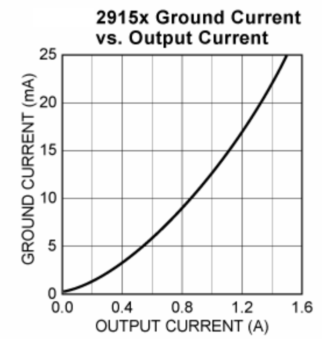
1. Maximum positive supply voltage of 60V must be of limited duration (<100msec) and duty cycle (≤1%). The maximum continuous supply voltage is 26V. Exceeding the absolute maximum rating may damage the device.
2. The device is not guaranteed to function outside its operating rating.
3. Devices are ESD sensitive. Handling precautions recommended.
4. Specification for packaged product only.
5. Full load current (I_{FL}) is defined as 1.5A for the MIC29150, 3A for the MIC29300, 5A for the MIC29500, and 7.5A for the MIC29750 families.
6. Dropout voltage is defined as the input-to-output differential when the output voltage drops to 99% of its normal value with V_{OUT} + 1V applied to V_{IN}.
7. V_{IN} = $V_{OUT\ (nominal)}$ + 1V. For example, use V_{IN} = 4.3V for a 3.3V regulator or use 6V for a 5V regulator. Employ pulse-testing procedures to pin current.
8. Ground pin current is the regulator quiescent current. The total current drawn from the source is the sum of the load current plus the ground pin current.
9. Output voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature range.
10. Thermal regulation is defined as the change in output voltage at a time T after a change in power dissipation is applied, excluding load or line regulation effects. Specifications are for a200mA load pulse at VIN = 20V (a 4W pulse) for T = 10ms.
11. Comparator thresholds are expressed in terms of a voltage differential at the Adjust terminal below the nominal reference voltage measured at 6V input. To express these thresholds in terms of output voltage change, multiply by the error amplifier gain = V_{OUT}/V_{REF} = (R1 + R2)/R2. For example, at a programmed output voltage of 5V, the Error output is guaranteed to go low when the output drops by 95mV x 5V/1.240V = 384mV. Thresholds remain constant as a percent of V_{OUT} as V_{OUT} is varied, with the dropout warning occurring at typically 5% below nominal, 7.7% guaranteed.
12. V_{EN} ≤ 0.8V and V_{IN} ≤ 26V, V_{OUT} = 0.
13. When used in dual supply systems where the regulator load is returned to a negative supply, the output voltage must be diode clamped to ground.

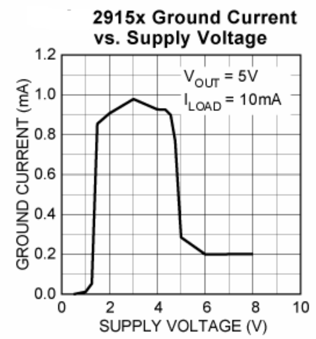
Typical Characteristics MIC2915x

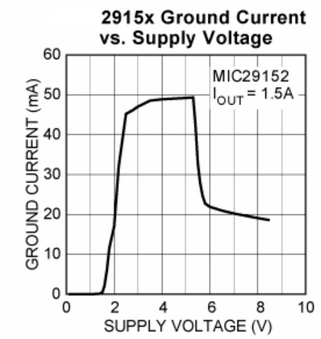


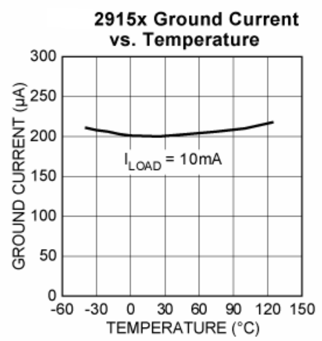


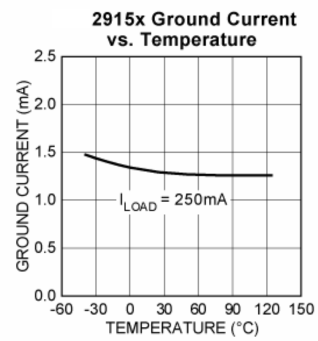


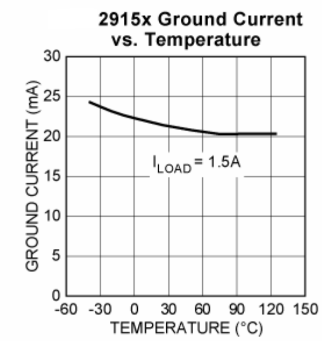


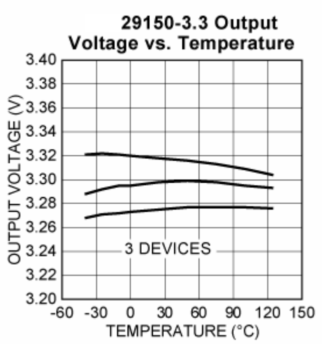


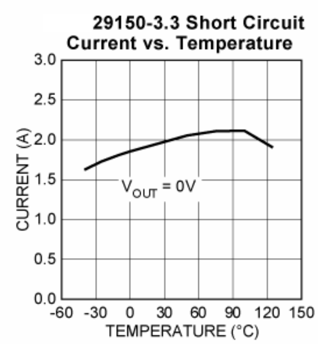


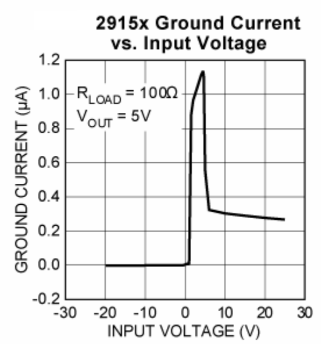


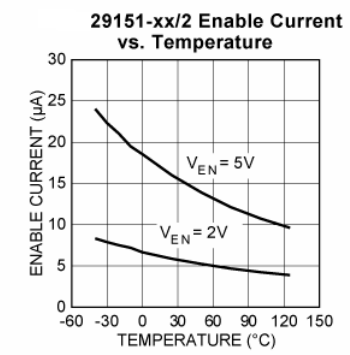


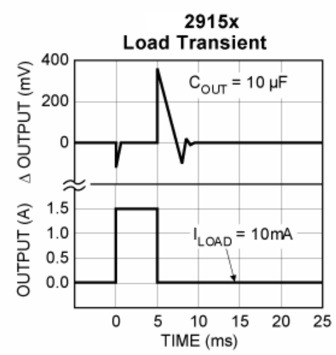


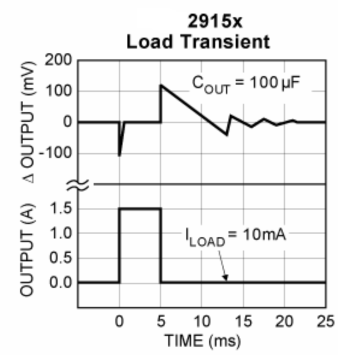


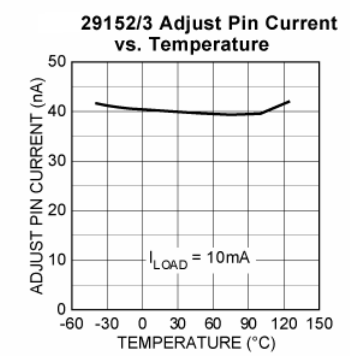


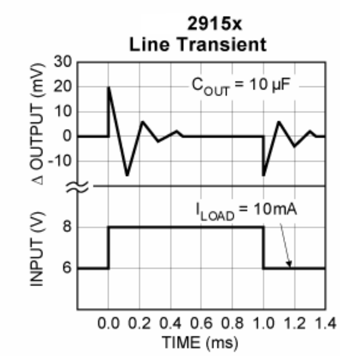


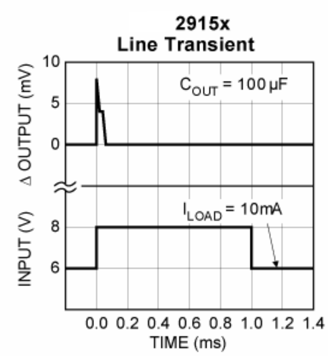

29151-xx/2 Enable Current vs. Temperature
ENABLE CURRENT (µA)
TEMPERATURE (°C)
V_{EN} = 5V
V_{EN} = 2V

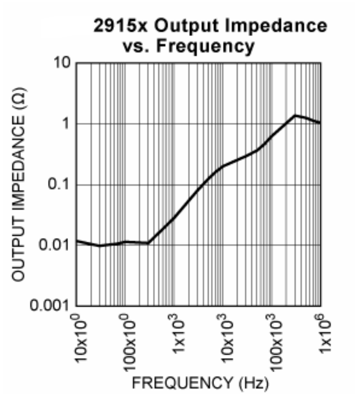

2915x Load Transient
Δ OUTPUT (mV)
OUTPUT (A)
C_{OUT} = 10 µF
I_{LOAD} = 10mA
TIME (ms)

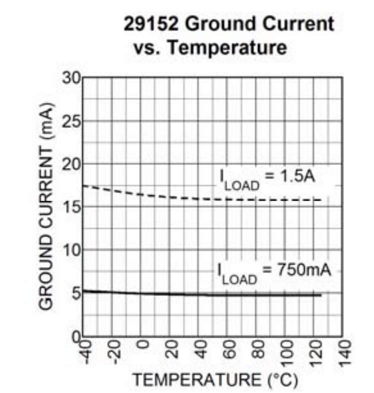

2915x Load Transient
Δ OUTPUT (mV)
OUTPUT (A)
C_{OUT} = 100 µF
I_{LOAD} = 10mA
TIME (ms)

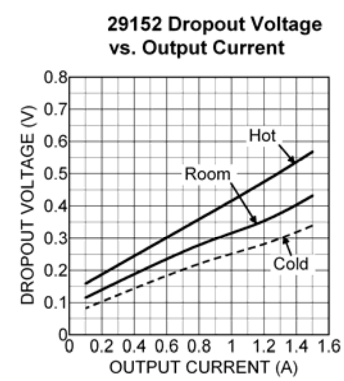

29152/3 Adjust Pin Current vs. Temperature
ADJUST PIN CURRENT (nA)
I_{LOAD} = 10mA
TEMPERATURE (°C)


2915x Line Transient
Δ OUTPUT (mV)
INPUT (V)
C_{OUT} = 10 µF
I_{LOAD} = 10mA
TIME (ms)


2915x Line Transient
Δ OUTPUT (mV)
INPUT (V)
C_{OUT} = 100 µF
I_{LOAD} = 10mA
TIME (ms)

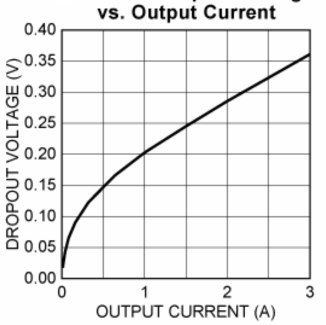

2915x Output Impedance vs. Frequency
OUTPUT IMPEDANCE (Ω)
FREQUENCY (Hz)


29152 Ground Current vs. Temperature
GROUND CURRENT (mA)
I_{LOAD} = 1.5A
I_{LOAD} = 750mA
TEMPERATURE (°C)

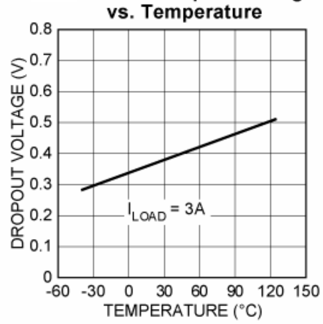

29152 Dropout Voltage vs. Output Current
DROPOUT VOLTAGE (V)
Hot
Room
Cold
OUTPUT CURRENT (A)

Typical Characteristics MIC2930x

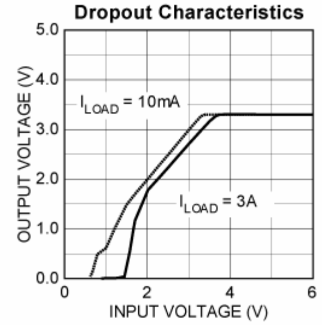
2930x Dropout Voltage vs. Output Current



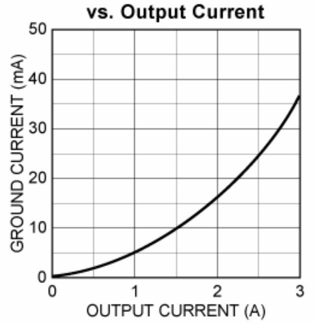
2930x Dropout Voltage vs. Temperature



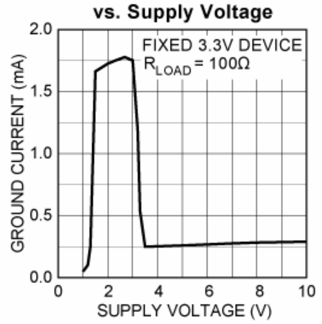
29300-3.3 Dropout Characteristics



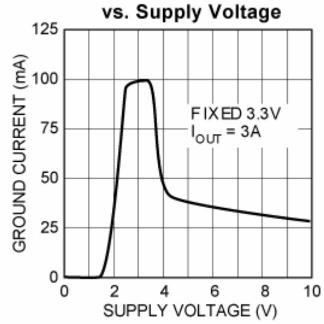
2930x Ground Current vs. Output Current



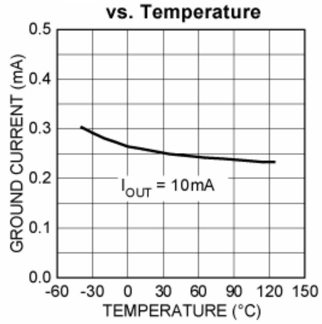
2930x Ground Current vs. Supply Voltage



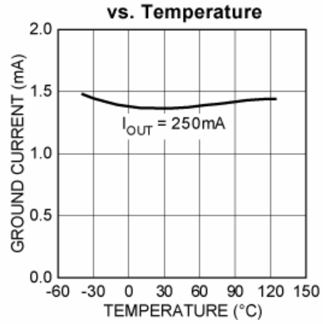
2930x Ground Current vs. Supply Voltage



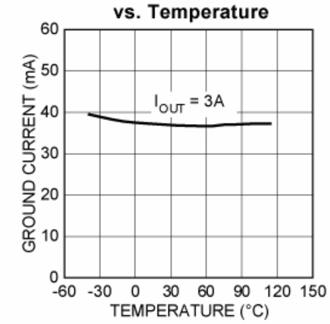
2930x Ground Current vs. Temperature



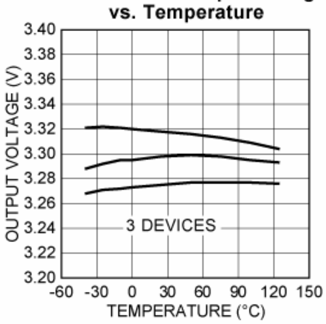
2930x Ground Current vs. Temperature



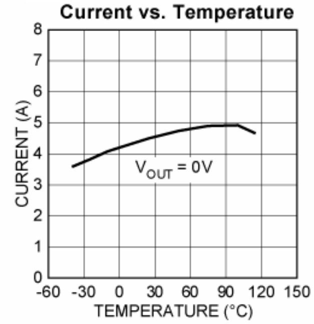
2930x Ground Current vs. Temperature



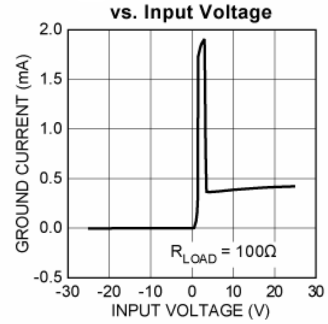
29300-3.3 Output Voltage vs. Temperature



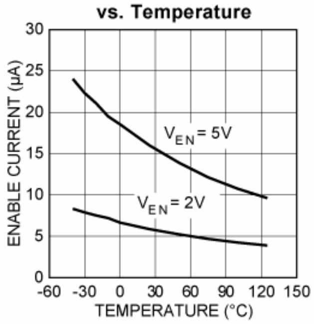
29300-5.0 Short Circuit Current vs. Temperature



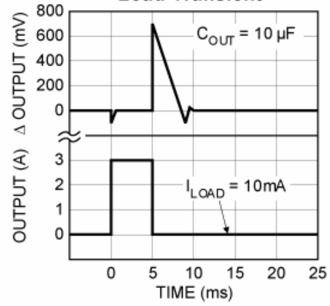
2930x Ground Current vs. Input Voltage



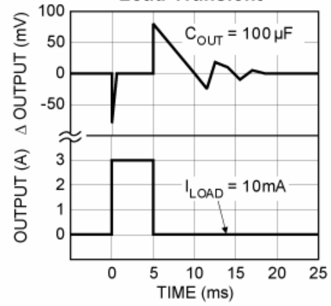
29301-xx/2 Enable Current vs. Temperature



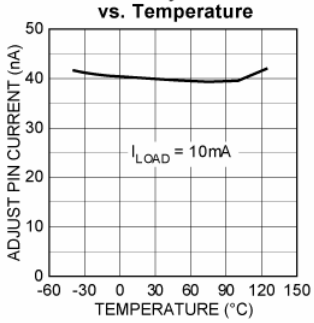
2930x Load Transient



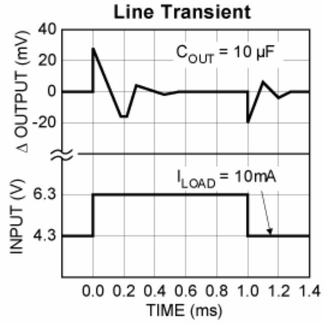
2930x Load Transient



29302/3 Adjust Pin Current vs. Temperature



2930x Line Transient



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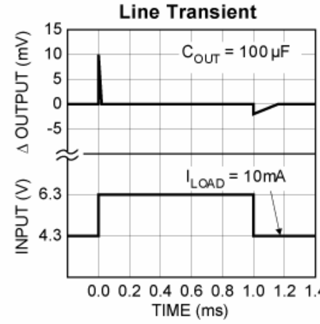
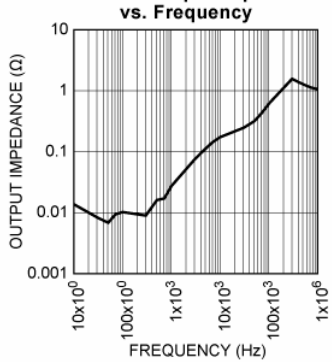
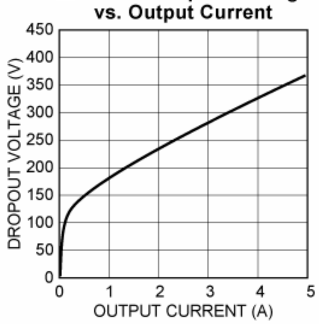


2930x Output Impedance vs. Frequency

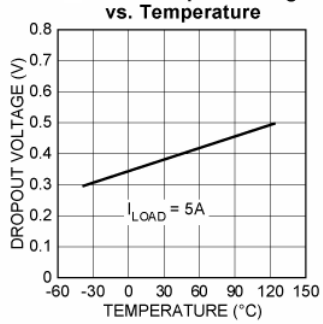


Typical Characteristics MIC2950x

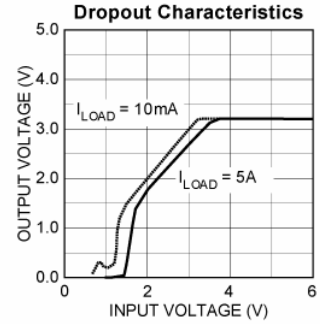
2950x Dropout Voltage vs. Output Current



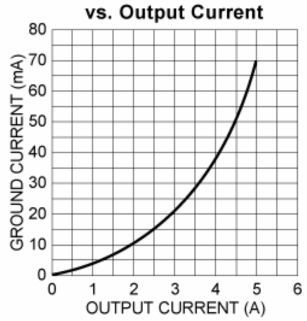
2950x Dropout Voltage vs. Temperature



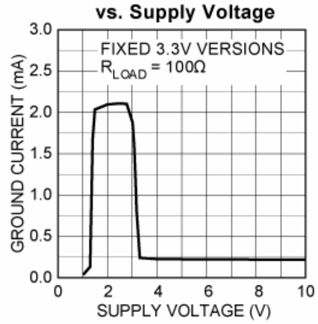
29500-3.3 Dropout Characteristics



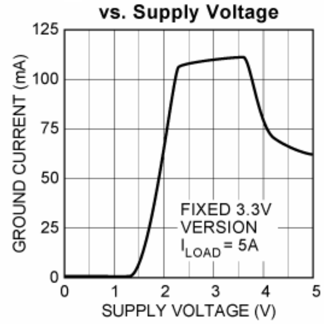
2950x Ground Current vs. Output Current



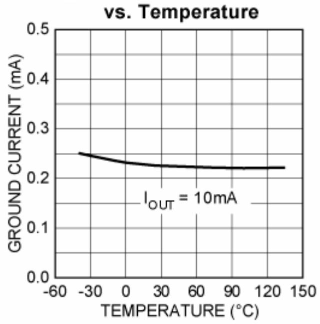
2950x Ground Current vs. Supply Voltage



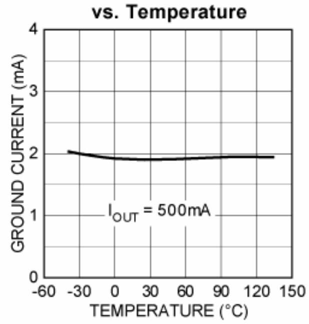
2950x Ground Current vs. Supply Voltage



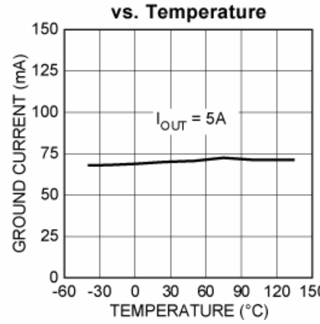
2950x Ground Current vs. Temperature



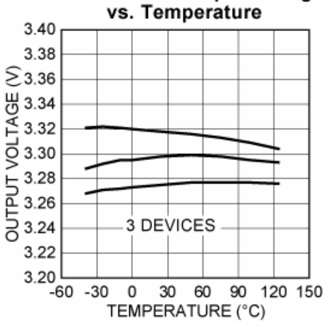
2950x Ground Current vs. Temperature



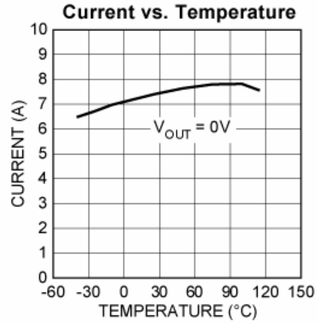
2950x Ground Current vs. Temperature



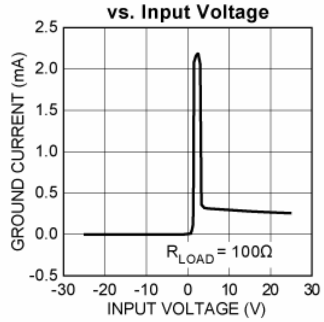
29500-3.3 Output Voltage vs. Temperature



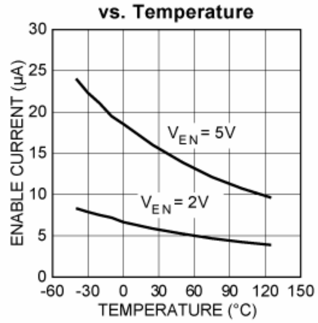
2950x-5.0 Short Circuit Current vs. Temperature



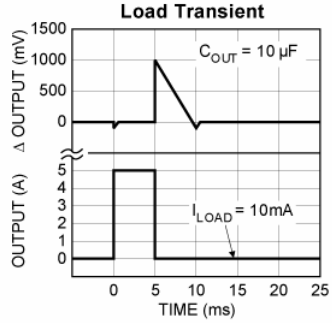
2950x Ground Current vs. Input Voltage



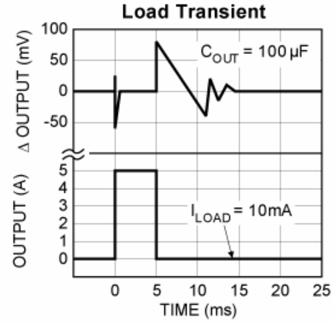
29501-xx/2 Enable Current vs. Temperature



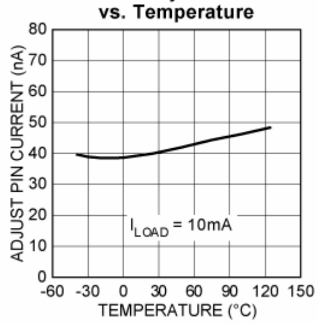
2950x Load Transient



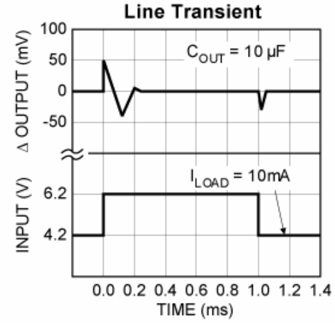
2950x Load Transient



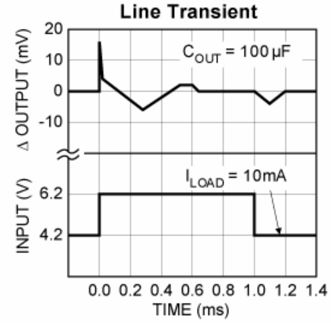
29502/3 Adjust Pin Current vs. Temperature



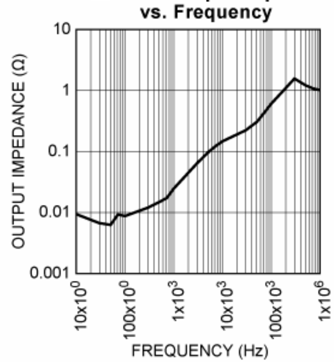
2950x Line Transient



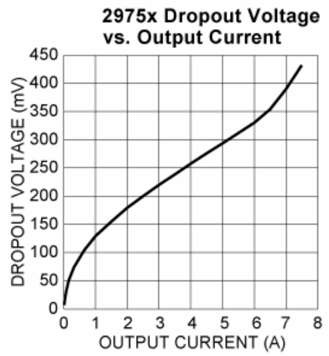
2950x Line Transient

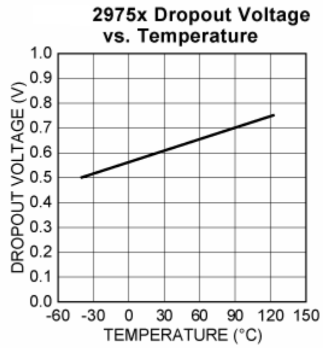


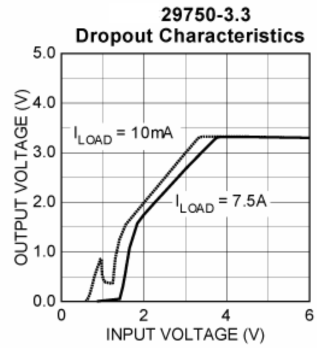
2950x Output Impedance vs. Frequency

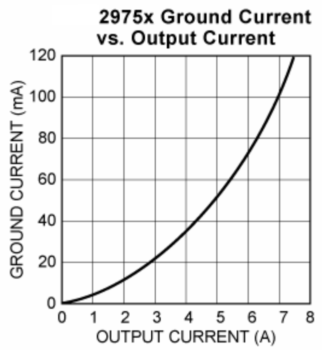


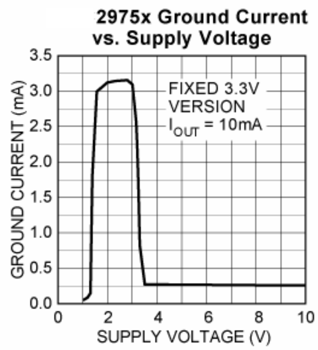
Typical Characteristics MIC2975x

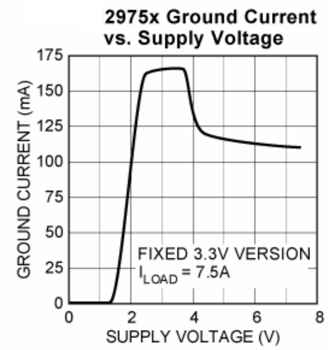


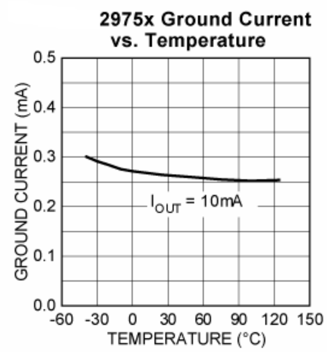


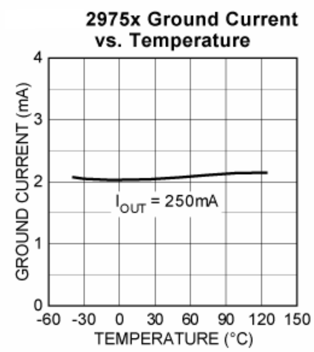


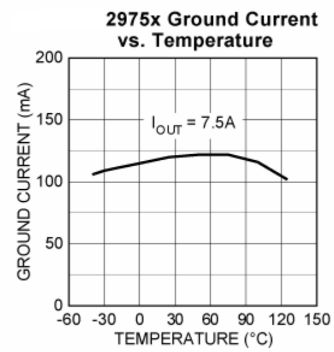


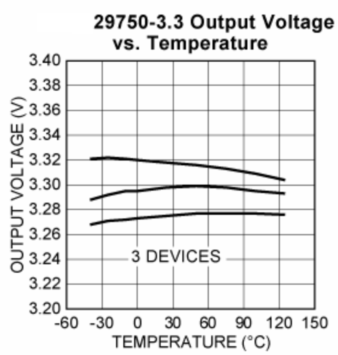


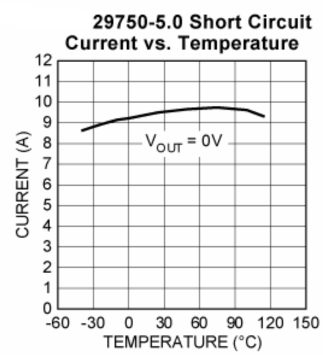


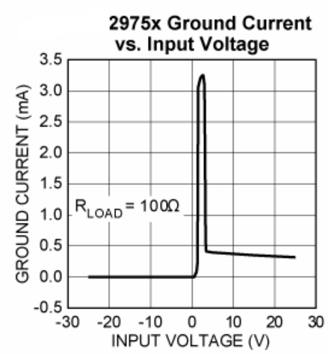




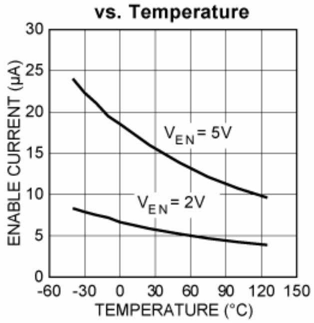




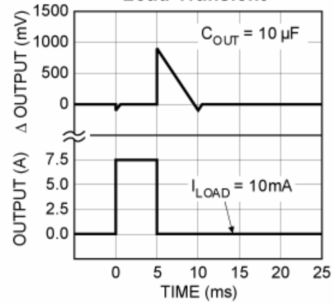




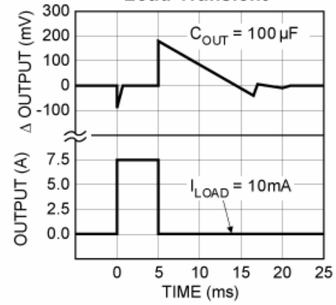
29751-xx/2 Enable Current vs. Temperature



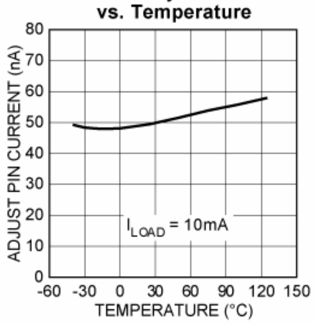
2975x Load Transient



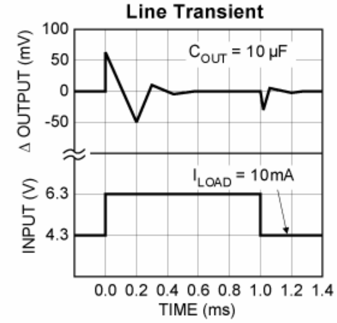
2975x Load Transient



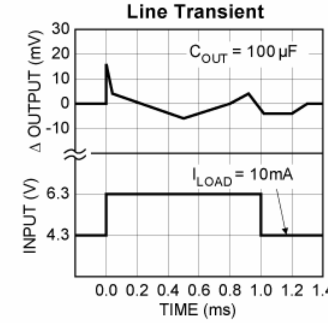
29752/3 Adjust Pin Current vs. Temperature



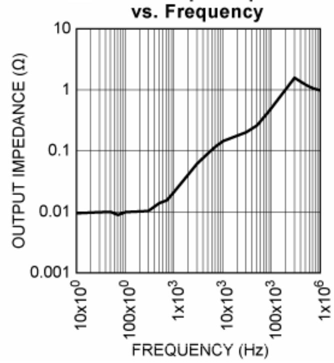
2975x Line Transient



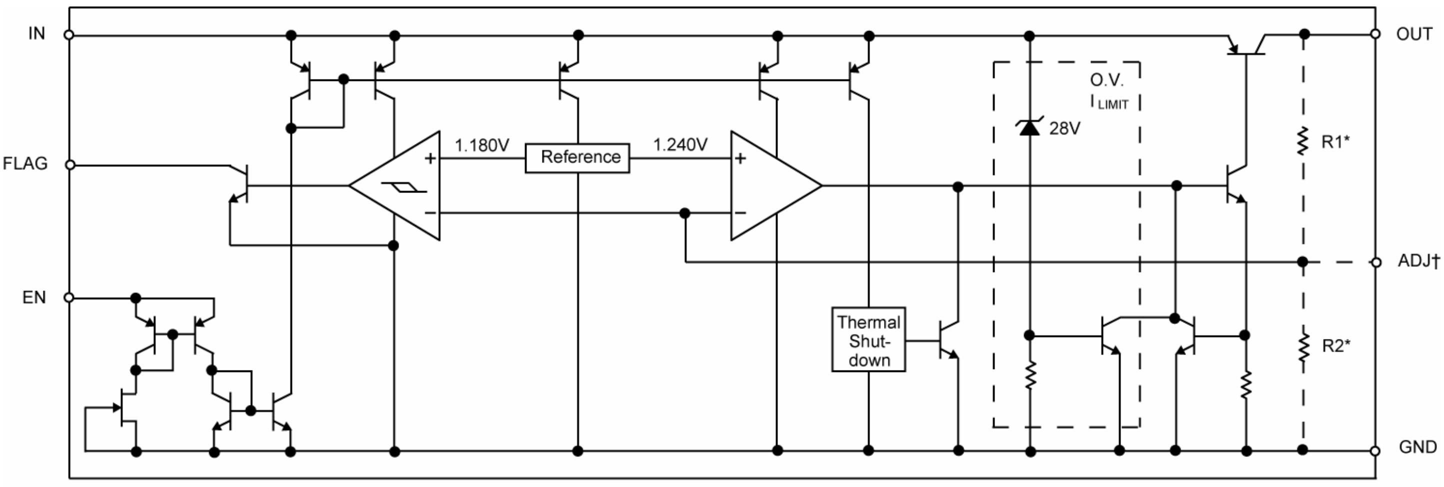
2975x Line Transient



2975x Output Impedance vs. Frequency



Functional Diagram



* Feedback network in fixed versions only
† Adjustable version only

Application Information

The MIC29150/29300/29500/29750 are high performance low-dropout voltage regulators suitable for all moderate to high-current voltage regulator applications. Their 350mV to 425mV typical dropout voltage at full load make them especially valuable in battery powered systems and as high efficiency noise filters in “post-regulator” applications. Unlike older NPN-pass transistor designs, where the minimum dropout voltage is limited by the base-emitter voltage drop and collector-emitter saturation voltage, dropout performance of the PNP output of these devices is limited merely by the low V_{CE} saturation voltage.

A trade-off for the low-dropout voltage is a varying base driver requirement. But Super ßeta PNP® process reduces this drive requirement to merely 1% of the load current.

The MIC29150/29300/29500/29750 family of regulators are fully protected from damage due to fault conditions. Current limiting is provided. This limiting is linear; output current under overload conditions is constant. Thermal shutdown disables the device when the die temperature exceeds the 125°C maximum safe operating temperature. Transient protection allows device (and load) survival even when the input voltage spikes between –20V and +60V. When the input voltage exceeds about 35V to 40V, the over voltage sensor temporarily disables the regulator. The output structure of these regulators allows voltages in excess of the desired output voltage to be applied without reverse current flow.MIC29xx1 and MIC29xx2 versions offer a logic level ON/OFF control: when disabled, the devices draw nearly zero current.

An additional feature of this regulator family is a common pinout: a design’s current requirement may change up or down yet use the same board layout, as all of these regulators have identical pinouts.

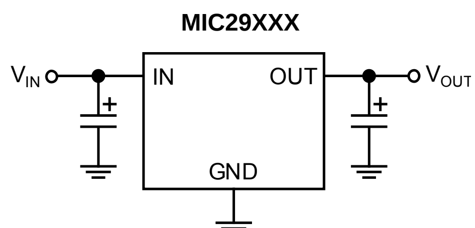


Figure 3. Linear regulators require only two capacitors for operation.

Thermal Design

Linear regulators are simple to use. The most complicated design parameters to consider are thermal characteristics. Thermal design requires the following application-specific parameters:

- Maximum ambient temperature, T_A
- Output Current, I_{OUT}
- Output Voltage, V_{OUT}
- Input Voltage, V_{IN}

First, we calculate the power dissipation of the regulator from these numbers and the device parameters from this datasheet.

$$P_D = I_{OUT}(1.01\,V_{IN} - V_{OUT})$$

Where the ground current is approximated by 1% of I_{OUT}. Then the heat sink thermal resistance is determined with this formula:

$$\theta_{SA} = \frac{T_{JMAX} - T_A}{P_D} - (\theta_{JC} + \theta_{CS})$$

Where $T_{JMAX} \le 125°C$ and θ_{CS} is between 0 and 2°C/W.

The heat sink may be significantly reduced in applications where the minimum input voltage is known and is large compared with the dropout voltage. Use a series input resistor to drop excessive voltage and distribute the heat between this resistor and the regulator. The low-dropout properties of Super ßeta PNP® regulators allow very significant reductions in regulator power dissipation and the associated heat sink without compromising performance. When this technique is employed, a capacitor of at least 0.1µF is needed directly between the input and regulator ground.

Please refer to Application Note 9 and Application Hint 17 for further details and examples on thermal design and heat sink specification.

With no heat sink in the application, calculate the junction temperature to determine the maximum power dissipation that will be allowed before exceeding the maximum junction temperature of the 29152. The maximum power allowed can be calculated using the thermal resistance (θ_{JA}) of the D-Pak adhering to the following criteria for the PCB design: 2 oz. copper and $100mm^2$ copper area for the 29152.

For example, given an expected maximum ambient temperature (T_A) of 75°C with V_{IN} = 3.3V, V_{OUT} = 2.5V, and I_{OUT} = 1.5A, first calculate the expected P_D using Equation (1);

P_D=(3.3V–2.5V)1.5A–(3.3V)(0.016A)=1.1472W

Next, calcualte the junction temperature for the expected power dissipation.

$T_J=(\theta_{JA}\times P_D)+T_A$=(56°C/W×1.1472W)+75°C=139.24°C

Now determine the maximum power dissipation allowed that would not exceed the IC’s maximum junction temperature (125°C) without the useof a heat sink by

$P_{D(MAX)}=(T_{J(MAX)}-T_A)/\theta_{JA}$=(125°C–75°C)/(56°C/W) =0.893W

Capacitor Requirements

For stability and minimum output noise, a capacitor on the regulator output is necessary. The value of this capacitor is dependent upon the output current; lower currents allow smaller capacitors.

This capacitor need not be an expensive low ESR type: aluminum electrolytics are adequate. In fact, extremely low ESR capacitors may contribute to instability. Tantalum capacitors are recommended for systems where fast load transient response is important.

Where the regulator is powered from a source with a high AC impedance, a 0.1µF capacitor connected between Input and GND is recommended. This capacitor should have good characteristics to above 250kHz.

Minimum Load Current

The MIC29150–29750 regulators are specified between finite loads. If the output current is too small, leakage currents dominate and the output voltage rises. The following minimum load current swamps any expected leakage current across the operating temperature range:

Device	Minimum Load
29150	5mA
29300	7mA
29500	10mA
29750	10mA

Adjustable Regulator Design

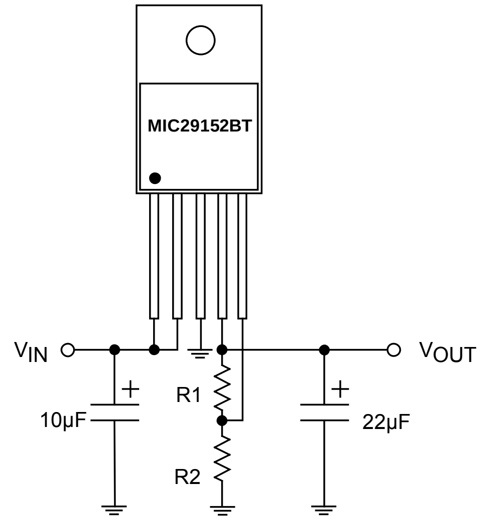


Figure 4. Adjustable Regulator with Resistors

The adjustable regulator versions, MIC29xx2 and MIC29xx3, allow programming the output voltage anywhere between 1.25V and the 25V. Two resistors are used. The resistor values are calculated by:

$$R_1 = R_2 \times \left(\frac{V_{OUT}}{1.240} - 1 \right)$$

where V_{OUT} is the desired output voltage. Figure 4 shows component definition. Applications with widely varying load currents may scale the resistors to draw the minimum load current required for proper operation (see “Minimum Load Current” section).

Error Flag

MIC29xx1 and MIC29xx3 versions feature an Error Flag, which looks at the output voltage and signals an error condition when this voltage drops 5% below its expected value. The error flag is an open-collector output that pulls low under fault conditions. It may sink 10mA. Low output voltage signifies a number of possible problems, including an overcurrent fault (the device is in current limit) and low input voltage. The flag output is inoperative during overtemperature shutdown conditions.

Enable Input

MIC29xx1 and MIC29xx2 versions feature an enable (EN) input that allows ON/OFF control of the device. Special design allows “zero” current drain when the device is disabled—only microamperes of leakage current flows. The EN input has TTL/CMOS compatible thresholds for simple interfacing with logic, or may be directly tied to ≤30V. Enabling the regulator requires approximately 20µA of current.