MIC2940A and MIC2941A

1.25A Low Drop Out Voltage Regulator

Preliminary Information–Production Q1 '94

General Description

The MIC2940A and MIC2941A are "bulletproof" efficient voltage regulators with very low dropout voltage (typically 40mV at light loads and 280mV at 1A), and very low quiescent current (90μA typical). The quiescent current of the MIC2940A increases only slightly in dropout, thus prolonging battery life. Key MIC2940A features include protection against reversed battery, fold-back current limiting, and automotive "load dump" protection (60V positive transient).

The MIC2940 is available in both fixed voltage and adjustable voltage configurations. The MIC2940A-xx devices are three pin fixed voltage regulators. A logic-compatible shutdown input is provided on the adjustable MIC2941A, which enables the regulator to be switched on and off.

Features

- High output voltage accuracy
- Guaranteed 1.2A output
- Low quiescent current
- Low dropout voltage
- Extremely tight load and line regulation
- Very low temperature coefficient
- Current and thermal limiting
- Input can withstand –20V reverse battery and +60V positive transients
- Logic-controlled electronic shutdown
- Output programmable from 1.24V to 26V(MIC2941A)
- Available in TO-220, TO-263, TO-220-5, TO-263-5, TO-3, and TO-3-4 packages.

Applications

- Battery Powered Equipment
- Cellular Telephones
- Laptop, Notebook, and Palmtop Computers
- PCMCIA V_{CC} and V_{PP} Regulation/Switching
- Bar Code Scanners
- Automotive Electronics
- SMPS Post-Regulator/ DC to DC Modules
- Voltage Reference
- High Efficiency Linear Power Supplies

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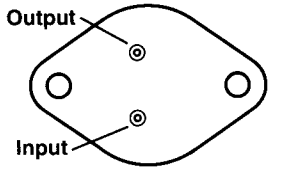
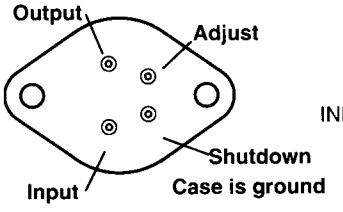
Pin Configuration



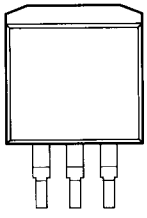
TO-3 Package
(MIC2940A-xxBK)



TO-3-5 Package
(MIC2941ABK)

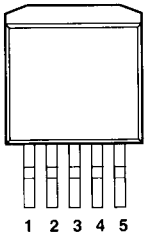
MIC2941A Pinout

1) **Adjust**
2) **Shutdown**
3) **Ground**
4) **Input**
5) **Output**

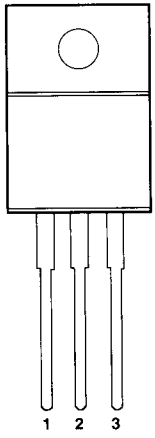


INPUT GROUND OUTPUT

TO-263 Package
(MIC2940A-xxBU)

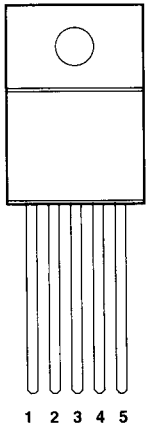


TO-263-5 Package
(MIC2941ABU)



INPUT GROUND OUTPUT

TO-220 Package
(MIC2940A-xxBT)



TO-220-5 Package
(MIC2941ABT)

Tab is Ground on TO-220 and TO-263 packages

Ordering Information

Part Number	Voltage	Temperature Range*	Package
MIC2940A-3.3BK	3.3	–40°C to +125°C	TO-3
MIC2940A-3.3BT	3.3	–40°C to +125°C	TO-220
MIC2940A-3.3BU	3.3	–40°C to +125°C	TO-263
MIC2940A-5.0BK	5.0	–40°C to +125°C	TO-3
MIC2940A-5.0BT	5.0	–40°C to +125°C	TO-220
MIC2940A-5.0BU	5.0	–40°C to +125°C	TO-263
MIC2940A-12BK	12	–40°C to +125°C	TO-3
MIC2940A-12BT	12	–40°C to +125°C	TO-220
MIC2940A-12BU	12	–40°C to +125°C	TO-263
MIC2941ABK	Adj	–40°C to +125°C	TO-3-4
MIC2941ABT	Adj	–40°C to +125°C	TO-220-5
MIC2941ABU	Adj	–40°C to +125°C	TO-263-5

* Junction temperatures

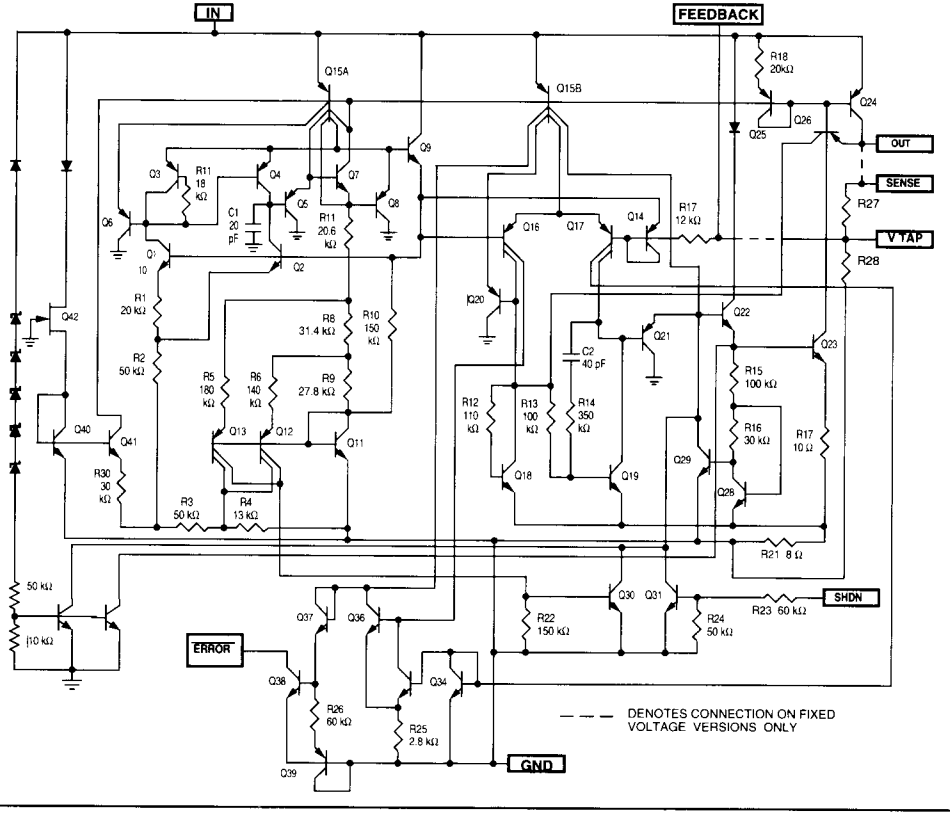
Absolute Maximum Ratings

If Military/Aerospace specified devices are required, contact your local Micrel representative/distributor for availability and specifications.

Power Dissipation (Note 1)	Internally Limited
Lead Temperature (Soldering, 5 seconds)	260°C
Storage Temperature Range	–65°C to +150°C
Operating Junction Temperature Range	–40°C to +125°C
Input Supply Voltage	–20V to +60V
Operating Input Supply Voltage	2V† to 26V
Adjust Input Voltage (Notes 9 and 10)	–1.5V to +26V
Shutdown Input Voltage	–0.3V to +30V
Error Comparator Output Voltage	–0.3V to +30V
ESD Rating	>±2000V

† Across the full operating temperature, the minimum input voltage range for full output current is 4.3V to 26V. Output will remain in-regulation at lower output voltages and low current loads down to an input of 2V at 25°C.

Schematic Diagram



Electrical Characteristics

Limits in standard typeface are for T_J = 25°C and limits in **boldface** apply over the full operating temperature range. Unless otherwise specified, $V_{IN} = V_{OUT} + 1V$, I_L = 1000mA, C_L = 10µF. The MIC2941A is programmed to output 5V and has $V_{SHUTDOWN} \leq 0.6V$.

Symbol	Parameter	Conditions	Min	Typical	Max	Units
V_O	Output Voltage (5.0 or adjustable versions)		4.950	5.00	5.050	V
			4.900		**5.100**	
		5 mA ≤ I_L ≤ 1A	**4.880**	**5.00**	**5.120**	
	Output Voltage Accuracy	Variation from designed V_{OUT}	–1		1	%
			–2		**2**	
		5 mA ≤ I_L ≤ 1A	**–2.5**		**2.5**	
$\frac{\Delta V_O}{\Delta T}$	Output Voltage Temperature Coef.	(Note 2)		**20**	**100**	ppm/°C
$\frac{\Delta V_O}{V_O}$	Line Regulation	$V_{IN} = V_{OUT} + 1V$ to 26V		0.03	0.10	%
					0.40	
$\frac{\Delta V_O}{V_O}$	Load Regulation	I_L = 5mA to 1A		0.04	0.16	%
					0.20	
		(Note 3)				
$V_{IN} - V_O$	Dropout Voltage (Note 4)	I_L = 5mA		60	100	mV
					150	
		I_L = 250mA		150	200	
					320	
		I_L = 1000mA		280	450	
					600	
		I_L = 1250mA		300		
I_{GND}	Ground Pin Current (Note 5)	I_L = 5mA		90	150	µA
					180	
		I_L = 250mA		3	4.5	mA
					6	
		I_L = 1000mA		22	35	
					45	
		I_L = 1250mA		35		
I_{GNDDO}	Ground Pin Current at Dropout (Note 5)	V_{IN} = 0.5V less than designed V_{OUT} ($V_{OUT} \geq 3.3V$)		180	**300**	µA
I_{LIMIT}	Current Limit	V_{OUT} = 0V (Note 6)		1.6	2	A
					2.4	
$\frac{\Delta V_O}{\Delta P_D}$	Thermal Regulation	(Note 7)		0.05	0.2	%/W
e_n	Output Noise Voltage (10Hz to 100kHz) I_L = 100mA	C_L = 10µF		400		µV RMS
		C_L = 33µF		260		

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Electrical Characteristics (MIC2941A Only)

Parameter	Conditions	Min	Typical	Max	Units
Reference Voltage		1.210 **1.200**	1.235	1.260 **1.270**	V V max
Reference Voltage	(Note 9)	**1.185**		**1.285**	V
Adjust Pin Bias Current			20	40 **60**	nA
Reference Voltage Temperature Coefficient	(Note 8)		20		ppm/°C
Adjust Pin Bias Current Temperature Coefficient			0.1		nA/°C
Shutdown Input					
Input Logic Voltage	Low (ON) High (OFF)	 **2.0**	1.3	**0.7**	V
Shutdown Pin Input Current	$V_{SHUTDOWN}$ = 2.4V		30	50 **100**	µA
	$V_{SHUTDOWN}$ = 30V		450	600 **750**	µA
Regulator Output Current in Shutdown	(Note 11)		3	10 **20**	µA

Note 1: Absolute maximum ratings indicate limits beyond which damage to the component may occur. Electrical specifications do not apply when operating the device outside of its rated operating conditions. The maximum allowable power dissipation is a function of the maximum junction temperature, $T_{J(MAX)}$, the junction-to-ambient thermal resistance, θ_{JA}, and the ambient temperature, T_A. The maximum allowable power dissipation at any ambient temperature is calculated using: $P_{(MAX)} = (T_{J(MAX)} - T_A)/\theta_{JA}$ Exceeding the maximum allowable power dissipation will result in excessive die temperature, and the regulator will go into thermal shutdown.

Note 2: Output voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature range.

Note 3: Regulation is measured at constant junction temperature using low duty cycle pulse testing. Changes in output voltage due to heating effects are covered by the thermal regulation specification.

Note 4: Dropout Voltage is defined as the input to output differential at which the output voltage drops 100 mV below its nominal value measured at 1V differential. At low values of programmed output voltage, the minimum input supply voltage of 4.3V over temperature must be taken into account.

Note 5: 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.

Note 6: The MIC2940A features fold-back current limiting. The short circuit (V_{OUT} = 0V) current limit is less than the maximum current with normal output voltage.

Note 7: 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 a 200mA load pulse at V_{IN} = 20V (a 4W pulse) for T = 10ms.

Note 8: $V_{REF} \le V_{OUT} \le (V_{IN} - 1\ V)$, $4.3V \le V_{IN} \le 26V$, $5mA < I_L \le 1.25A$, $T_J \le T_{J\,MAX}$.

Note 9: 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 95 mV x 5V/1.235 V = 384 mV. Thresholds remain constant as a percent of VOUT as VOUT is varied, with the dropout warning occurring at typically 5% below nominal, 7.5% guaranteed.

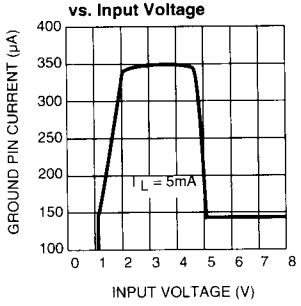
Note 10: Circuit of Figure 3 with R1 ≥ 150kΩ. $V_{SHUTDOWN} \ge 2$ V and $V_{IN} \le 26$ V, $V_{OUT} = 0$.

Note 11: 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.

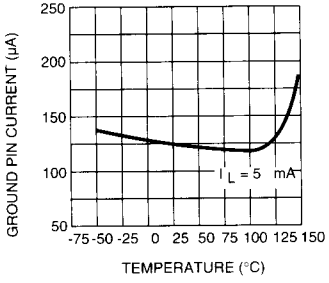
Note 12: Maximum positive supply voltage of 60 V must be of limited duration (< 100 ms) and duty cycle (≤ 1%). The maximum continuous supply voltage is 26V.

Typical Characteristics

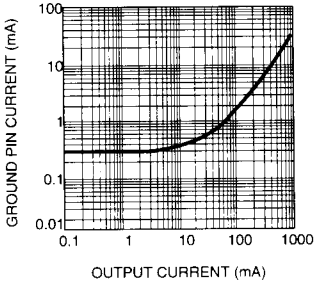
Ground Pin Current vs. Input Voltage



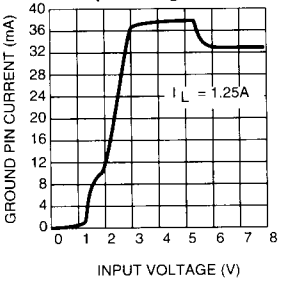
Ground Pin Current vs. Temperature



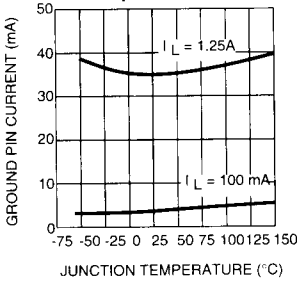
Ground Pin Current vs. Load



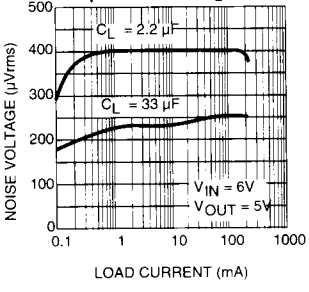
Ground Pin Current vs. Input Voltage



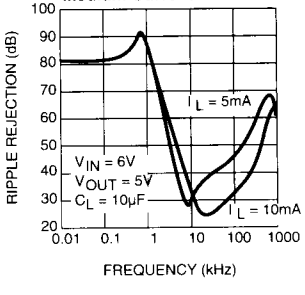
Ground Pin Current vs. Temperature



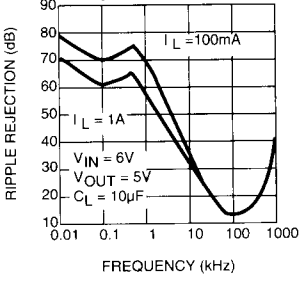
Output Noise Voltage



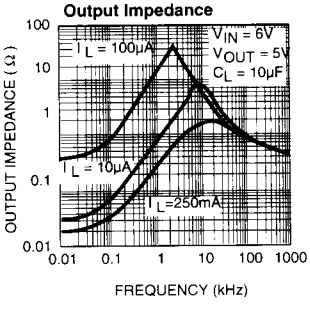
Ripple Rejection vs. Frequency at Medium Current



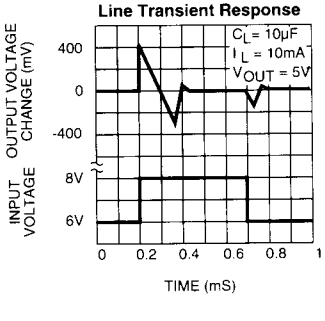
Ripple Rejection vs. Frequency at High Current



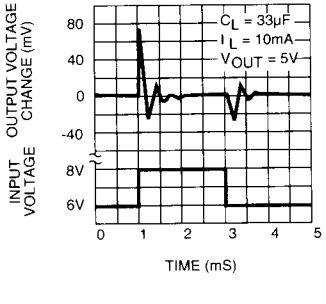
Output Impedance



Line Transient Response



Line Transient Response



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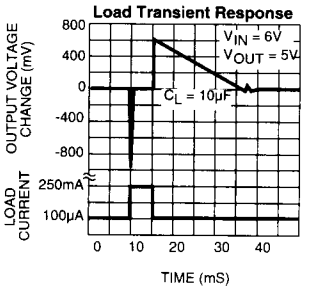
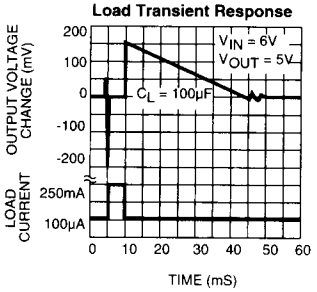
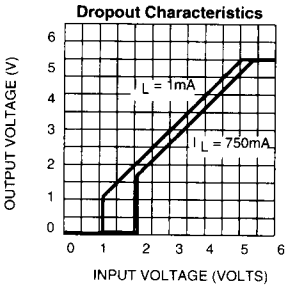
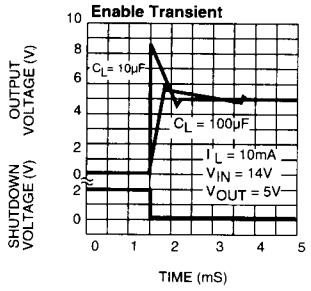
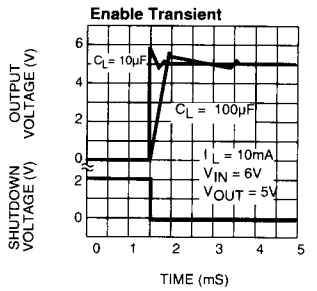
Typical Characteristics, Continued

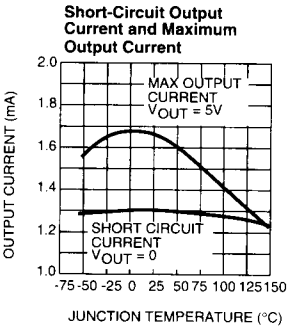


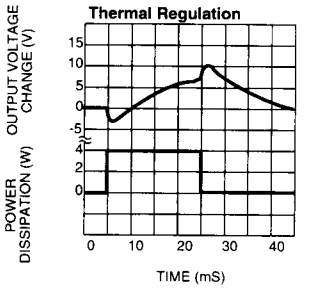


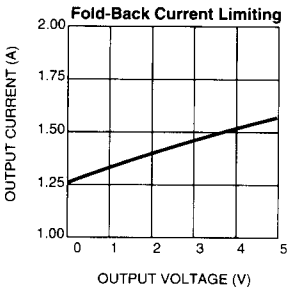


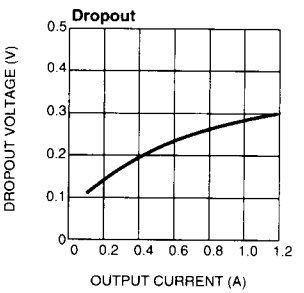












Applications Information

External Capacitors

A 10µF (or greater) capacitor is required between the MIC2940A output and ground to prevent oscillations due to instability. Most types of tantalum or aluminum electrolytics will be adequate; film types will work, but are costly and therefore not recommended. Many aluminum electrolytics have electrolytes that freeze at about –30°C, so solid tantalums are recommended for operation below –25°C. The important parameters of the capacitor are an effective series resistance of about 5Ω or less and a resonant frequency above 500kHz. The value of this capacitor may be increased without limit.

At lower values of output current, less output capacitance is required for output stability. The capacitor can be reduced to 3.3µF for current below 100mA or 2.2µF for currents below 10 mA. Adjusting the MIC2941A/29403 to voltages below 5V runs the error amplifier at lower gains so that more output capacitance is needed. For the worst-case situation of a 1.25A load at 1.23V output (Output shorted to Adjust) a 22µF (or greater) capacitor should be used.

The MIC2940A will remain stable and in regulation with no load in addition to the internal voltage divider, unlike many other voltage regulators. This is especially important in CMOS RAM keep-alive applications. When setting the output voltage of the MIC2941A version with external resistors, a minimum load of 1mA is recommended.

A 0.22µF capacitor should be placed from the MIC2940A input to ground if there is more than 10 inches of wire between the input and the AC filter capacitor or if a battery is used as the input.

Stray capacitance to the MIC2941A Adjust terminal can cause instability. This may especially be a problem when using high value external resistors to set the output voltage. Adding a 100pF capacitor between Output and Adjust and increasing the output capacitor to at least 22µF will remedy this.

Programming the Output Voltage (MIC2941A/ MIC29403)

The MIC2941A may be programmed for any output voltage between its 1.235V reference and its 26V maximum rating. An external pair of resistors is required, as shown in Figure 3.

The complete equation for the output voltage is

$$V_{OUT} = V_{REF} \times \{ 1 + R_1/R_2 \} + I_{FB} R_1$$

where V_{REF} is the nominal 1.235 reference voltage and I_{FB} is the Adjust pin bias current, nominally 20nA. The minimum recommended load current of 1 µA forces an upper limit of 1.2MΩ on the value of R_2, if the regulator must work with no load (a condition often found in CMOS in standby), I_{FB} will produce a 2% typical error in V_{OUT} which may be eliminated at room temperature by trimming R_1. For better accuracy, choosing R_2 = 100k reduces this error to 0.17% while increasing the resistor program current to 12 µA. Since the MIC2941A typically draws 100 µA at no load with SHUTDOWN open-circuited, this is a negligible addition.

Reducing Output Noise

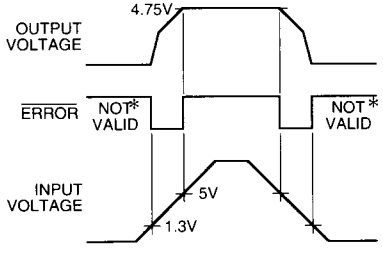
In reference applications it may be advantageous to reduce the AC noise present at the output. One method is to reduce the regulator bandwidth by increasing the size of the output capacitor. This is relatively inefficient, as increasing the capacitor from 1 µF to 220 µF only decreases the noise from 430µV to 160μV_{RMS} for a 100kHz bandwidth at 5V output. Noise can be reduced by a factor of four with the MIC2941A by adding a bypass capacitor across R_1, since it reduces the high frequency gain from 4 to unity. Pick

$$C_{BYPASS} \cong \frac{1}{2\pi R_1 \bullet 200\ Hz}$$

or about 0.01 µF. When doing this, the output capacitor must be increased to 22 µF to maintain stability. These changes reduce the output noise from 430 µV to 100 µV rms for a 100 kHz bandwidth at 5V output. With the bypass capacitor added, noise no longer scales with output voltage so that improvements are more dramatic at higher output voltages.

Automotive Applications

The MIC2940A is ideally suited for automotive applications for a variety of reasons. It will operate over a wide range of input voltages with very low dropout voltages (40mV at light loads), and very low quiescent currents (90µA typical). These features are necessary for use in battery powered systems, such as automobiles. It is a "bulletproof" device with the ability to survive both reverse battery (negative transients up to 20V below ground), and load dump (positive transients up to 60V) conditions. A wide operating temperature range with low temperature coefficients is yet another reason to use these versatile regulators in automotive designs.



* SEE APPLICATIONS INFORMATION

Figure 1. $\overline{\text{ERROR}}$ Output Timing

Typical Applications

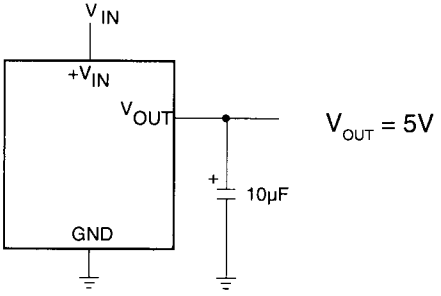


Figure 2. MIC2940A-5.0 Fixed +5V Regulator

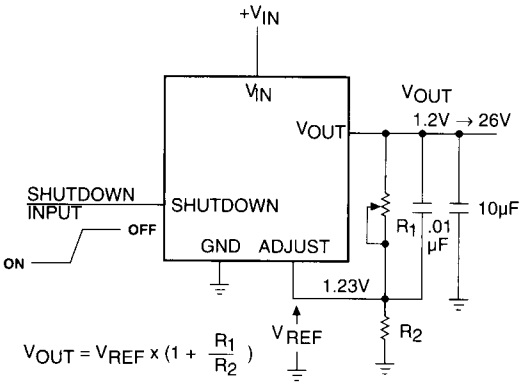
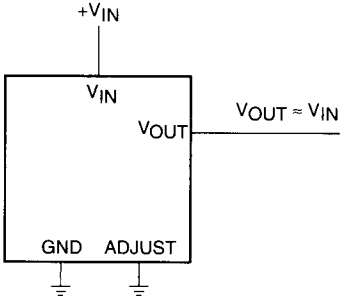
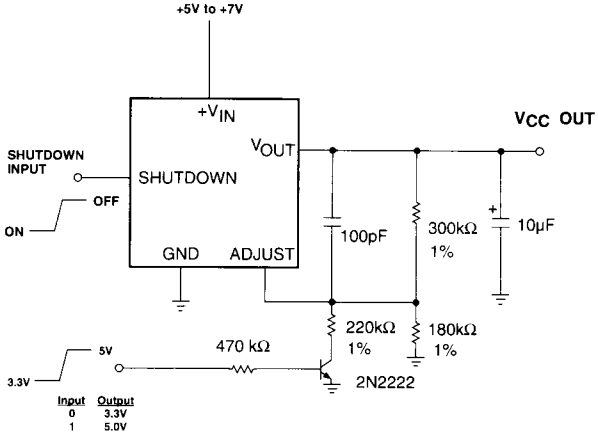


Figure 3. MIC2941A Adjustable Regulator



*MINIMUM INPUT-OUTPUT VOLTAGE RANGES FROM 40mV TO 400mV, DEPENDING ON LOAD CURRENT.

Figure 4. MIC2941A Wide Input Voltage Range Current Limiter



ADJUST PIN LOW= ENABLE OUTPUT. Q1 ON = 3.3V, Q1 OFF = 5.0V.

Figure 5. MIC2941A 5.0V or 3.3V Selectable Regulator with Shutdown.