NCV8501 Series

Advance Information

Micropower 150 mA LDO Linear Regulators with ENABLE, Delay, $\overline{\text{RESET}}$, and Monitor Flag

The NCV8501 is a family of precision micropower voltage regulators. Their output current capability is 150 mA. The family has output voltage options for adjustable, 2.5 V, 3.3 V, 5.0 V, 8.0 V, and 10 V.

The output voltage is accurate within ± 2.0% with a maximum dropout voltage of 0.6 V at 150 mA. Low quiescent current is a feature drawing only 70 μA with a 100 μA load. This part is ideal for any and all battery operated microprocessor equipment.

Microprocessor control logic includes an active $\overline{\text{RESET}}$ (with DELAY), and a flag monitor which can be used to provide an early warning signal to the microprocessor of a potential impending $\overline{\text{RESET}}$ signal. The use of the flag monitor allows the microprocessor to finish any signal processing before the $\overline{\text{RESET}}$ shuts the microprocessor down.

The active $\overline{\text{RESET}}$ circuit includes hysteresis, and operates correctly at an output voltage as low as 1.0 V. The $\overline{\text{RESET}}$ function is activated during the power up sequence or during normal operation if the output voltage drops outside the regulation limits.

The regulator is protected against reverse battery, short circuit, and thermal overload conditions. The device can withstand load dump transients making it suitable for use in automotive environments. The device has also been optimized for EMC conditions.

Features

- Output Voltage Options: Adjustable, 2.5 V, 3.3 V, 5.0 V, 8.0 V, 10 V
- ± 2.0% Output
- Low 70 μA Quiescent Current
- Fixed or Adjustable Output Voltage
- Active $\overline{\text{RESET}}$
- ENABLE
- 150 mA Output Current Capability
- Fault Protection
  - +60 V Peak Transient Voltage
  - –15 V Reverse Voltage
  - Short Circuit
  - Thermal Overload
- Early Warning through $\overline{\text{FLAG}}$/MON Leads

This document contains information on a new product. Specifications and information herein are subject to change without notice.

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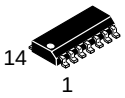
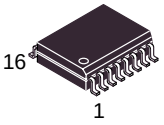
SO–8
D SUFFIX
CASE 751



SO–14
PD SUFFIX
CASE 751A



SOIC 16 LEAD
WIDE BODY
EXPOSED PAD
PDW SUFFIX
CASE 751R

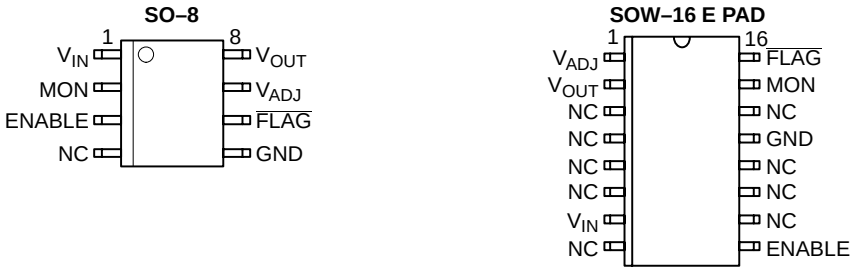
ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 933 of this data sheet.

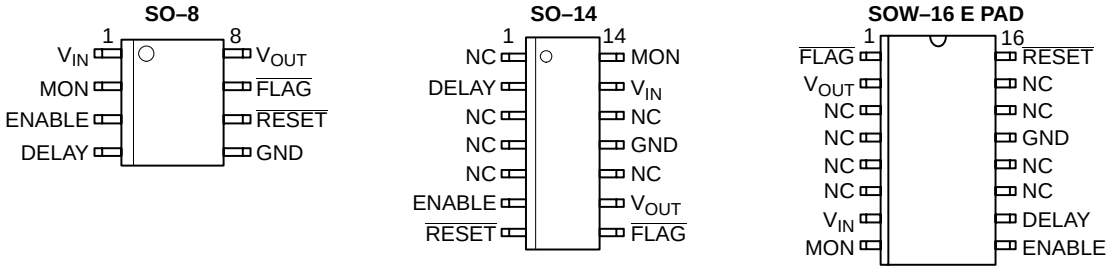
DEVICE MARKING INFORMATION

See general marking information in the device marking section on page 934 of this data sheet.

PIN CONNECTIONS, ADJUSTABLE OUTPUT



PIN CONNECTIONS, FIXED OUTPUT



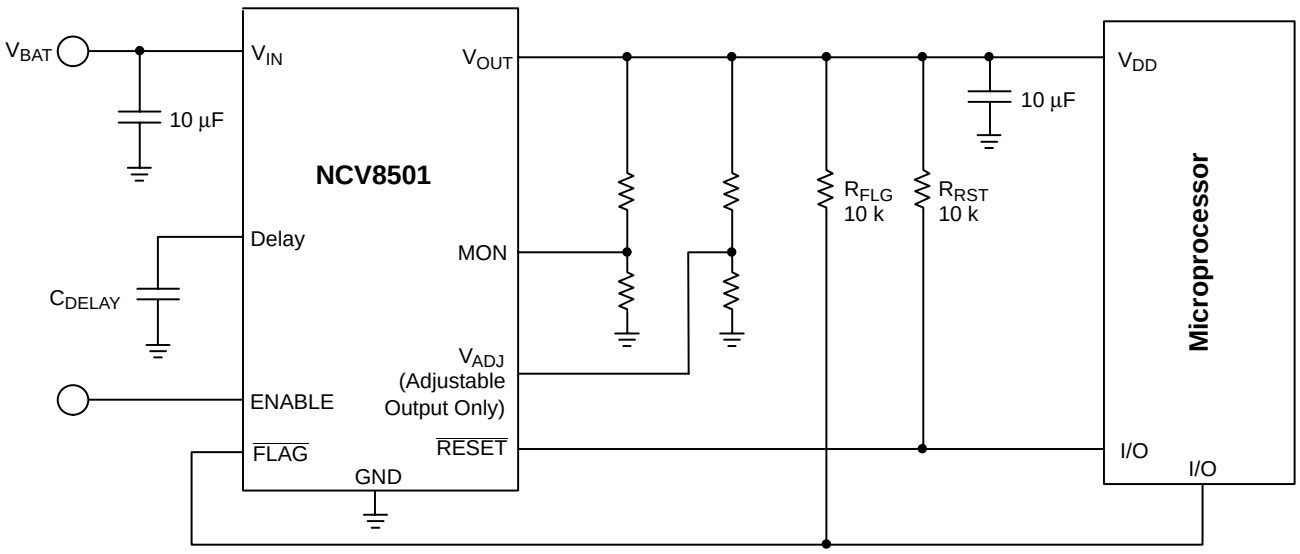


Figure 1. Application Diagram

MAXIMUM RATINGS*†

Rating	Value	Unit
V_{IN} (DC)	–15 to 45	V
Peak Transient Voltage (46 V Load Dump @ V_{IN} = 14 V)	60	V
Operating Voltage	45	V
Input Voltage Range ($\overline{RESET}$, $\overline{FLAG}$)	–0.3 to 10	V
Input Voltage Range (MON)	–0.3 to 45	V
Input Voltage Range (ENABLE)	60	V
ESD Susceptibility (Human Body Model)	2.0	kV
Junction Temperature, T_J	–40 to +150	°C
Storage Temperature, T_S	–55 to 150	°C
Package Thermal Resistance, SO–8: Junction–to–Case, $R_{\theta JC}$ Junction–to–Ambient, $R_{\theta JA}$	 45 165	 °C/W °C/W
Package Thermal Resistance, SO–14: Junction–to–Case, $R_{\theta JC}$ Junction–to–Ambient, $R_{\theta JA}$	 30 115	 °C/W °C/W
Package Thermal Resistance, SOW–16 E PAD: Junction–to–Case, $R_{\theta JC}$ Junction–to–Ambient, $R_{\theta JA}$	 1.0 36	 °C/W °C/W
Lead Temperature Soldering: Reflow: (SMD styles only) (Note 1)	230 peak	°C

1. 60 second maximum above 183°C.
*The maximum package power dissipation must be observed.
†During the voltage range which exceeds the maximum tested voltage of V_{IN}, operation is assured, but not specified. Wider limits may apply. Thermal dissipation must be observed closely.

ELECTRICAL CHARACTERISTICS (I_{OUT} = 1.0 mA, ENABLE = TBD, –40°C ≤ T_A ≤ 125°C; –40°C ≤ T_J ≤ 150°C; unless otherwise specified.)

Characteristic	Test Conditions	Min	Typ	Max	Unit
Output Stage					
Output Voltage for 2.5 V Option (4.5 V ≤ V_{IN} ≤ 26 V)	6.5 V < V_{IN} < 16 V, 100 μA ≤ I_{OUT} ≤ 150 mA 4.5 V < V_{IN} < 16 V, 100 μA ≤ I_{OUT} ≤ 150 mA	2.450 2.425	2.5 2.5	2.550 2.575	V V
Output Voltage for 3.3 V Option (4.5 V ≤ V_{IN} ≤ 26 V)	7.3 V < V_{IN} < 16 V, 100 μA ≤ I_{OUT} ≤ 150 mA 4.5 V < V_{IN} < 16 V, 100 μA ≤ I_{OUT} ≤ 150 mA	3.234 3.201	3.3 3.3	3.366 3.399	V V
Output Voltage for 5.0 V Option (6.0 V ≤ V_{IN} ≤ 26 V)	9.0 V < V_{IN} < 16 V, 100 μA ≤ I_{OUT} ≤ 150 mA 6.0 V < V_{IN} < 16 V, 100 μA ≤ I_{OUT} ≤ 150 mA	4.90 4.85	5.0 5.0	5.10 5.15	V V
Output Voltage for 8.0 V Option (9.0 V ≤ V_{IN} ≤ 26 V)	12 V < V_{IN} < 16 V, 100 μA ≤ I_{OUT} ≤ 150 mA 9.0 V < V_{IN} < 16 V, 100 μA ≤ I_{OUT} ≤ 150 mA	7.84 7.76	8.0 8.0	8.16 8.24	V V
Output Voltage for 10 V Option (11 V ≤ V_{IN} ≤ 26 V)	14 V < V_{IN} < 16 V, 100 μA ≤ I_{OUT} ≤ 150 mA 11 V < V_{IN} < 16 V, 100 μA ≤ I_{OUT} ≤ 150 mA	9.8 9.7	10 10	10.2 10.3	V V
Dropout Voltage (V_{IN} – V_{OUT}) (5.0 V, 8.0 V, 10 V Options Only)	I_{OUT} = 150 mA I_{OUT} = 100 μA	– –	400 100	600 150	mV mV
Load Regulation	V_{IN} = 14 V, 5.0 mA ≤ I_{OUT} ≤ 150 mA	–	5.0	30	mV
Line Regulation	[V_{OUT}(typ) + 1.0] < V < 26 V, I_{OUT} = 1.0 mA	–	5.0	40	mV
Quiescent Current, (I_Q) Active Mode	I_{OUT} = 100 μA, V_{IN} = 12 V, Delay = 3.0 V, MON = 3.0 V I_{OUT} = 75 mA, Delay = 3.0 V, MON = 3.0 V I_{OUT} ≤ 150 mA, Delay = 3.0 V, MON = 3.0 V	– – –	70 6.0 12	TBD 9.0 19	μA mA mA
Quiescent Current, (I_Q) Sleep Mode	ENABLE = 0 V	–	12	25	μA

ELECTRICAL CHARACTERISTICS (continued) (I_{OUT} = 1.0 mA, ENABLE = TBD, –40°C ≤ T_A ≤ 125°C; –40°C ≤ T_J ≤ 150°C; unless otherwise specified.)

Characteristic	Test Conditions	Min	Typ	Max	Unit
Output Stage					
Current Limit	–	160	300	–	mA
Short Circuit Output Current	V_{OUT} = 0 V	40	190	–	mA
Thermal Shutdown	(Guaranteed by Design)	150	180	–	°C
Reset Function ($\overline{RESET}$)					
$\overline{RESET}$ Threshold for 2.5 V Option HIGH (V_{RH}) LOW (V_{RL})	4.5 V ≤ V_{IN} ≤ 26 V (Note 2) V_{OUT} Increasing V_{OUT} Decreasing	 2.225 2.200	 2.350 2.300	 2.475 2.400	 V V
$\overline{RESET}$ Threshold for 3.3 V Option HIGH (V_{RH}) LOW (V_{RL})	4.5 V ≤ V_{IN} ≤ 26 V (Note 2) V_{OUT} Increasing V_{OUT} Decreasing	 2.937 2.904	 3.102 3.036	 3.267 3.168	 V V
$\overline{RESET}$ Threshold for 5.0 V Option HIGH (V_{RH}) LOW (V_{RL})	 V_{OUT} Increasing V_{OUT} Decreasing	 4.45 4.40	 4.70 4.60	 4.95 4.80	 V V
$\overline{RESET}$ Threshold for 8.0 V Option HIGH (V_{RH}) LOW (V_{RL})	 V_{OUT} Increasing V_{OUT} Decreasing	 7.12 7.04	 7.52 7.36	 7.92 7.68	 V V
$\overline{RESET}$ Threshold for 10 V Option HIGH (V_{RH}) LOW (V_{RL})	 V_{OUT} Increasing V_{OUT} Decreasing	 8.90 8.80	 9.40 9.20	 9.90 9.60	 V V
$\overline{RESET}$ Hysteresis	(HIGH – LOW)	–	100	–	mV
Output Voltage Low (V_{RLO}) Low ($V_{R(PEAK)}$)	 1.0 V ≤ V_{OUT} ≤ V_{RL}, $R_{\overline{RESET}}$ = 10 k V_{OUT}, Power up, Power down	 – –	 0.1 0.6	 0.4 1.0	 V V
Delay Switching Threshold (V_{DT})	–	1.4	1.8	2.2	V
Reset Delay Low Voltage	V_{OUT} < $\overline{RESET}$ Threshold Low(min)	–	–	0.1	V
Delay Charge Current	Delay = 1.0 V, V_{OUT} > V_{RH}	2.0	3.0	5.0	μA
Delay Discharge Current	Delay = 1.0 V, V_{OUT} = 1.5 V	10	–	–	mA
$\overline{FLAG}$/Monitor					
Monitor Threshold	–	TBD	1.28	TBD	V
Hysteresis	–	20	100	200	mV
Input Current	V_{MON} = 2.0 V	–1.0	0.1	1.0	μA
Output Saturation Voltage	V_{MON} = 0 V, I_{FLAG} = 1.0 mA	–	0.1	0.4	V
Voltage Adjust (Adjustable Output only)					
Threshold	–	TBD	1.28	TBD	V
Input Current	SENSE = 0 V	–	–20	TBD	μA
ENABLE					
Input Threshold	Low High	– TBD	– –	TBD –	V V
Input Current	ENABLE = 14 V	–	–	TBD	μA

2. For V_{IN} ≤ 4.5 V, a $\overline{RESET}$ = Low may occur with the output in regulation.

PACKAGE PIN DESCRIPTION, ADJUSTABLE OUTPUT

Package Pin Number		Pin Symbol	Function
SO–8	SOW–16 E PAD		
1	7	V_{IN}	Input Voltage.
2	15	MON	Monitor. Input for early warning comparator. If not needed connect to V_{OUT}.
3	9	ENABLE	ENABLE control for the IC. A high powers the device up.
4	3–6, 8, 10–12, 14	NC	No connection.
5	13	GND	Ground. All GND leads must be connected to Ground.
6	16	$\overline{FLAG}$	Open collector output from early warning comparator.
7	1	V_{ADJ}	Voltage Adjust. A resistor divider from V_{OUT} to this lead sets the output voltage.
8	2	V_{OUT}	±2.0%, 150 mA output.

NOTE: Tentative pinout for SOW–16 E Pad.

PACKAGE PIN DESCRIPTION, FIXED OUTPUT

Package Pin Number			Pin Symbol	Function
SO–8	SO–14	SOW–16 E PAD		
1	13	7	V_{IN}	Input Voltage.
2	14	8	MON	Monitor. Input for early warning comparator. If not needed connect to V_{OUT}.
3	6	9	ENABLE	ENABLE control for the IC. A high powers the device up.
4	2	10	DELAY	Timing capacitor for $\overline{RESET}$ function.
5	11	13	GND	Ground. All GND leads must be connected to Ground.
6	7	16	$\overline{RESET}$	Active reset (accurate to $V_{OUT} \geq 1.0$ V)
7	8	1	$\overline{FLAG}$	Open collector output from early warning comparator.
8	9	2	V_{OUT}	±2.0%, 150 mA output.
–	1, 3–5, 10, 12	3–6, 11, 12, 14, 15	NC	No connection.

NOTE: Tentative pinouts for SO–14 and SOW–16 E Pad. 5.0 V option only for SO–14.

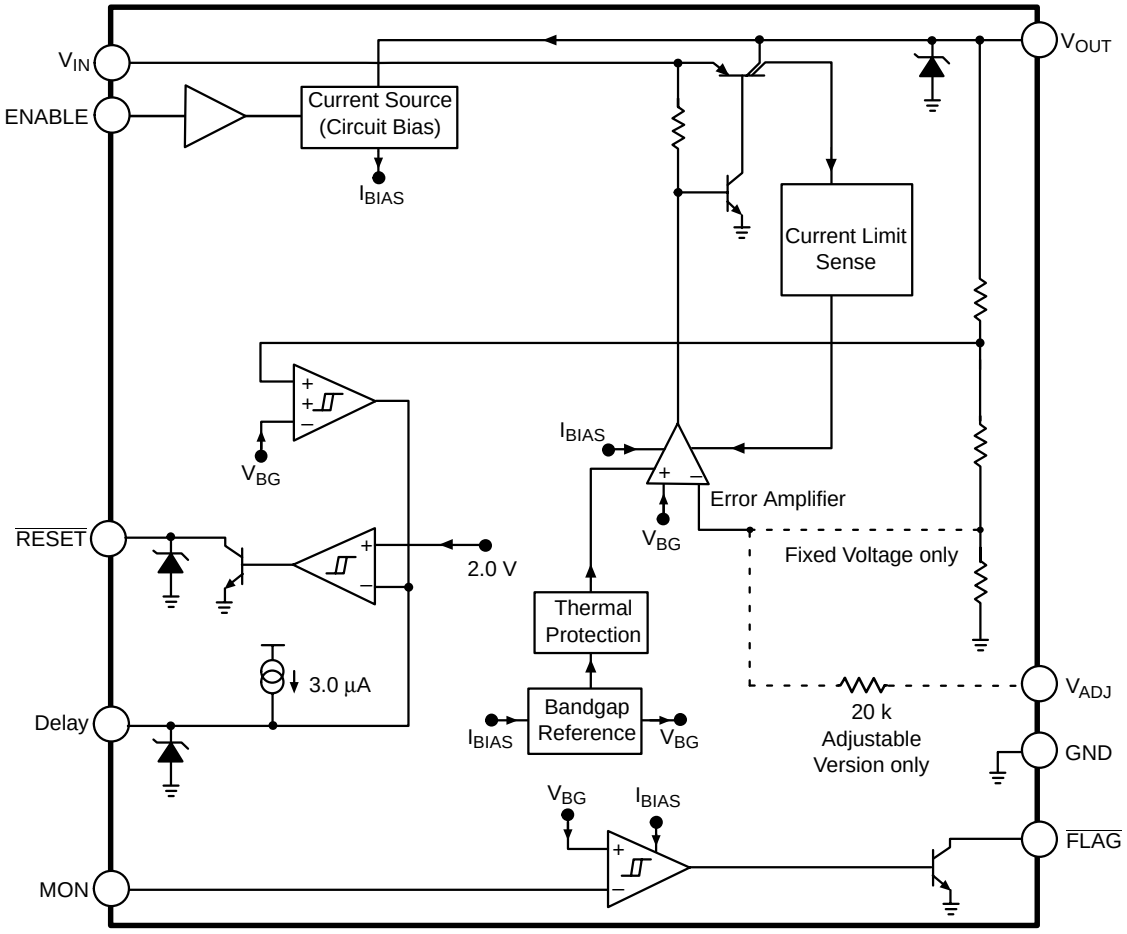


Figure 2. Block Diagram

CIRCUIT DESCRIPTION

REGULATOR CONTROL FUNCTIONS

The NCV8501 contains the microprocessor compatible control function $\overline{\text{RESET}}$ (Figure 3).

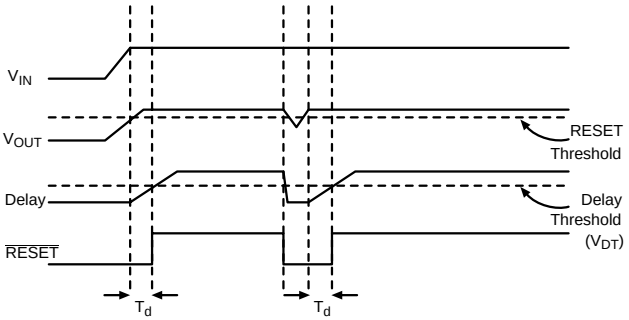


Figure 3. Reset and Delay Circuit Wave Forms

$\overline{\text{RESET}}$ Function

A $\overline{\text{RESET}}$ signal (low voltage) is generated as the IC powers up until V_{OUT} is within 6.0% of the regulated output voltage, or when V_{OUT} drops out of regulation,and is lower than 8.0% below the regulated output voltage. Hysteresis is included in the function to minimize oscillations.

The $\overline{\text{RESET}}$ output is an open collector NPN transistor, controlled by a low voltage detection circuit. The circuit is functionally independent of the rest of the IC thereby guaranteeing that the $\overline{\text{RESET}}$ signal is valid for V_{OUT} as low as 1.0 V.

ENABLE Function

The part stays in a low I_Q sleep mode when the ENABLE pin is held low. The part has an internal pull down if the pin is left floating. This is intended for failure modes only. An external connection (active pulldown, resistor, or switch) for normal operation is recommended.

The integrity of the ENABLE pin allows it to be tied directly to the battery line. It will withstand load dump potentials.

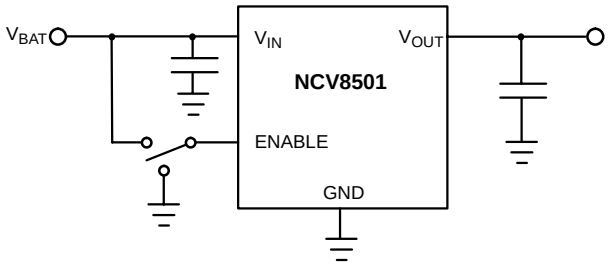


Figure 4. ENABLE Function

Delay Function

The reset delay circuit provides a programmable (by an external capacitor) delay on the $\overline{\text{RESET}}$ output lead. The delay lead provides source current (typically 3.0 μA) to the external delay capacitor only when the output voltage, V_{OUT}, has dropped below the reset threshold. Otherwise, the delay pin is always grounded through an internal NPN. If reset delay is not needed, this pin should be left open.

$\overline{\text{FLAG}}$/Monitor Function

An on–chip comparator is provided to perform an early warning to the microprocessor of a possible reset signal. The reset signal typically turns the microprocessor off instantaneously. This can cause unpredictable results with the microprocessor. The signal received from the FLAG pin will allow the microprocessor time to complete its present task before shutting down. This function is performed by a comparator referenced to the bandgap reference. The actual trip point can be programmed externally using a resistor divider to the input monitor (MON) (Figure 5).

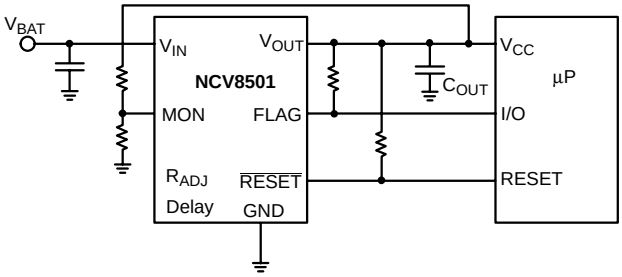


Figure 5. Flag/Monitor Function

Voltage Adjust

Figure 6 shows the device setup for a user configurable output voltage. The feedback to the V_{ADJ} pin is taken from a voltage divider referenced to the output voltage. The loop is balanced around the SENSE threshold (1.28 V typical).

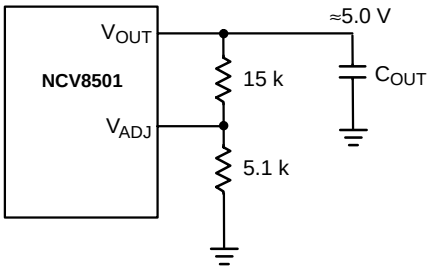


Figure 6. Adjustable Output Voltage

APPLICATION NOTES

FLAG MONITOR

Figure 7 shows the FLAG Monitor waveforms as a result of the circuit depicted in Figure 5. As the input voltage falls (V_{IN}), the Monitor threshold is crossed. This causes the voltage on the $\overline{\text{FLAG}}$ output to go low sending a warning signal to the microprocessor that a $\overline{\text{RESET}}$ signal may occur in a short period of time. $T_{WARNING}$ is the time the microprocessor has to complete the function it is currently working on and get ready for the $\overline{\text{RESET}}$ shutdown signal.

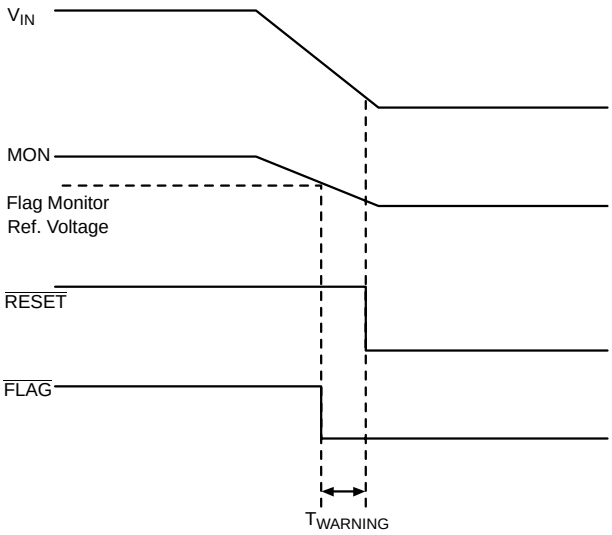


Figure 7. FLAG Monitor Circuit Waveform

SETTING THE DELAY TIME

The delay time is controlled by the Reset Delay Low Voltage, Delay Switching Threshold, and the Delay Charge Current. The delay follows the equation:

$$t_{DELAY} = \frac{[C_{DELAY}(V_{dt} - \text{Reset Delay Low Voltage})]}{\text{Delay Charge Current}}$$

Example:

Using C_{DELAY} = 33 nF.

Assume reset Delay Low Voltage = 0.

Use the typical value for V_{dt} = 1.8 V.

Use the typical value for Delay Charge Current = 3.0 μA.

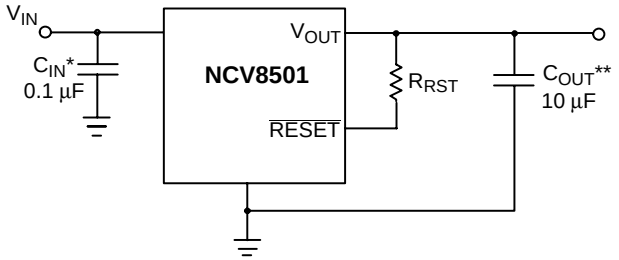
$$t_{DELAY} = \frac{[33\ nF(1.8 - 0)]}{3.0\ \mu A} = 19.8\ ms$$

STABILITY CONSIDERATIONS

The output or compensation capacitor helps determine three main characteristics of a linear regulator: start–up delay, load transient response and loop stability.

The capacitor value and type should be based on cost, availability, size and temperature constraints. A tantalum or aluminum electrolytic capacitor is best, since a film or ceramic capacitor with almost zero ESR can cause instability. The aluminum electrolytic capacitor is the least expensive solution, but, if the circuit operates at low temperatures (–25°C to –40°C), both the value and ESR of the capacitor will vary considerably. The capacitor manufacturers data sheet usually provides this information.

The value for the output capacitor C_{OUT} shown in Figure 8 should work for most applications, however it is not necessarily the optimized solution.



*C_{IN} required if regulator is located far from the power supply filter
**C_{OUT} required for stability. Capacitor must operate at minimum temperature expected

Figure 8. Test and Application Circuit Showing Output Compensation

CALCULATING POWER DISSIPATION IN A SINGLE OUTPUT LINEAR REGULATOR

The maximum power dissipation for a single output regulator (Figure 9) is:

$$P_{D(max)} = [V_{IN(max)} - V_{OUT(min)}]I_{OUT(max)} + V_{IN(max)}I_Q \quad (1)$$

where:

$V_{IN(max)}$ is the maximum input voltage,

$V_{OUT(min)}$ is the minimum output voltage,

$I_{OUT(max)}$ is the maximum output current for the application, and

I_Q is the quiescent current the regulator consumes at $I_{OUT(max)}$.

Once the value of $P_{D(max)}$ is known, the maximum permissible value of $R_{\Theta JA}$ can be calculated:

$$R_{\Theta JA} = \frac{150^\circ C - T_A}{P_D} \quad (2)$$

The value of $R_{\Theta JA}$ can then be compared with those in the package section of the data sheet. Those packages with $R_{\Theta JA}$'s less than the calculated value in equation 2 will keep the die temperature below 150°C.

In some cases, none of the packages will be sufficient to dissipate the heat generated by the IC, and an external heatsink will be required.

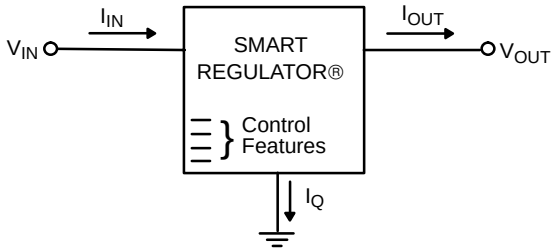


Figure 9. Single Output Regulator with Key Performance Parameters Labeled

HEAT SINKS

A heat sink effectively increases the surface area of the package to improve the flow of heat away from the IC and into the surrounding air.

Each material in the heat flow path between the IC and the outside environment will have a thermal resistance. Like series electrical resistances, these resistances are summed to determine the value of $R_{\Theta JA}$:

$$R_{\Theta JA} = R_{\Theta JC} + R_{\Theta CS} + R_{\Theta SA} \quad (3)$$

where:

$R_{\Theta JC}$ = the junction–to–case thermal resistance,

$R_{\Theta CS}$ = the case–to–heatsink thermal resistance, and

$R_{\Theta SA}$ = the heatsink–to–ambient thermal resistance.

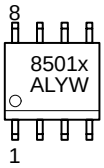
$R_{\Theta JC}$ appears in the package section of the data sheet. Like $R_{\Theta JA}$, it too is a function of package type. $R_{\Theta CS}$ and $R_{\Theta SA}$ are functions of the package type, heatsink and the interface between them. These values appear in heat sink data sheets of heat sink manufacturers.

ORDERING INFORMATION

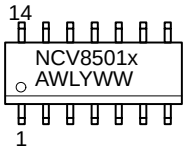
Device	Output Voltage	Package	Shipping
NCV8501DADJ	Adjustable	SO–8	95 Units/Rail
NCV8501DADJR2		SO–8	2500 Tape & Reel
NCV8501PDWADJ		SOW–16 Exposed Pad	46 Units/Rail
NCV8501PDWADJR2		SOW–16 Exposed Pad	1000 Tape & Reel
NCV8501D25	2.5 V	SO–8	95 Units/Rail
NCV8501D25R2		SO–8	2500 Tape & Reel
NCV8501PDW25		SOW–16 Exposed Pad	46 Units/Rail
NCV8501PDW25R2		SOW–16 Exposed Pad	1000 Tape & Reel
NCV8501D33	3.3 V	SO–8	95 Units/Rail
NCV8501D33R2		SO–8	2500 Tape & Reel
NCV8501PDW33		SOW–16 Exposed Pad	46 Units/Rail
NCV8501PDW33R2		SOW–16 Exposed Pad	1000 Tape & Reel
NCV8501D50	5.0 V	SO–8	95 Units/Rail
NCV8501D50R2		SO–8	2500 Tape & Reel
NCV8501PDW50		SOW–16 Exposed Pad	46 Units/Rail
NCV8501PDW50R2		SOW–16 Exposed Pad	1000 Tape & Reel
NCV8501PD50		SO–14	55 Units/Rail
NCV8501PD50R2		SO–14	2500 Tape & Reel
NCV8501D80	8.0 V	SO–8	95 Units/Rail
NCV8501D80R2		SO–8	2500 Tape & Reel
NCV8501PDW80		SOW–16 Exposed Pad	46 Units/Rail
NCV8501PDW80R2		SOW–16 Exposed Pad	1000 Tape & Reel
NCV8501D100	10 V	SO–8	95 Units/Rail
NCV8501D100R2		SO–8	2500 Tape & Reel
NCV8501PDW100		SOW–16 Exposed Pad	46 Units/Rail
NCV8501PDW100R2		SOW–16 Exposed Pad	1000 Tape & Reel

MARKING DIAGRAMS

SO–8



SO–14



SOW–16 E PAD

x = Voltage Ratings as Indicated Below:
- A = Adjustable
- 2 = 2.5 V
- 3 = 3.3 V
- 5 = 5.0 V
- 8 = 8.0 V
- 0 = 10 V

A = Assembly Location
WL, L = Wafer Lot
YY, Y = Year
WW, W = Work Week