
MSP1250

Power Converter 150kHz 3A Step-down Voltage Regulator

General Description

The MSP1250 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving a 3A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5V, 12V, and an adjustable output version.

Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation†, and a fixed-frequency oscillator.

The MSP1250 series operates at a switching frequency of 150 kHz thus allowing smaller sized filter components than what would be needed with lower frequency switching regulators. Available in a standard 5-lead TO-220 package with several different lead bend options, and a 5-lead TO-263 surface mount package. A standard series of inductors are available from several different manufacturers optimized for use with the MSP1250 series. This feature greatly simplifies the design of switch-mode power supplies.

Other features include a guaranteed $\pm 4\%$ tolerance on output voltage under specified input voltage and output load conditions, and $\pm 15\%$ on the oscillator frequency. External shutdown is included, featuring typically 80 μA standby current. Self-protection features include a two stage frequency reducing current limit for the output switch and an over temperature shutdown for complete protection under fault conditions.

Features

- ※ 3.3V, 5V, 12V, and adjustable output versions
- ※ Adjustable version output voltage range, 1.2V to 37V $\pm 4\%$ max over line and load conditions
- ※ Available in TO-220 and TO-263 packages
- ※ Guaranteed 3A output load current
- ※ Input voltage range up to 40V
- ※ Requires only 4 external components
- ※ Excellent line and load regulation specifications
- ※ 150 kHz fixed frequency internal oscillator
- ※ TTL shutdown capability
- ※ Low power standby mode, I_Q typically 80 μA
- ※ High efficiency
- ※ Uses readily available standard inductors
- Thermal shutdown and current limit protection

Applications

- ※ Simple high-efficiency step-down (buck) regulator
- ※ On-card switching regulators
- ※ Positive to negative converter

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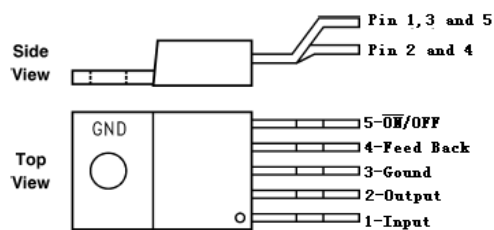
Power Converter 150kHz 3A

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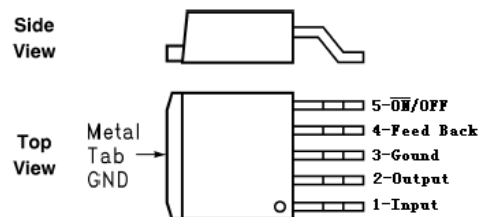
Connection Diagrams and Ordering Information

Bent and Staggered Leads, Through Hole

Package
5-Lead TO-220 (T)



Surface Mount Package
5-Lead TO-263 (S)



PIN FUNCTIONS

+VIN —This is the positive input supply for the IC switching regulator. A suitable input bypass capacitor must be present at this pin to minimize voltage transients and to supply the switching currents needed by the regulator.

Ground —Circuit ground.

Output —Internal switch. The voltage at this pin switches between $(+V_{IN} - V_{SAT})$ and approximately $-0.5V$, with a duty cycle of approximately V_{OUT}/V_{IN} . To minimize coupling to sensitive circuitry, the PC board copper area connected to this pin should be kept to a minimum.

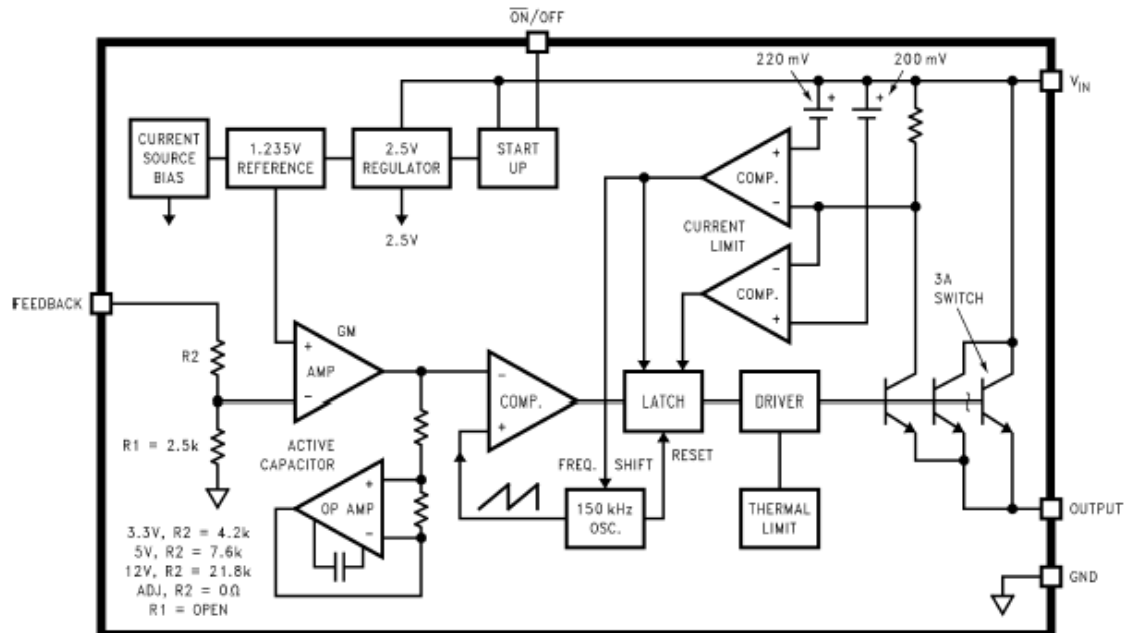
FeedBack —Senses the regulated output voltage to complete the feedback loop.

$\overline{\text{ON/OFF}}$ —Allows the switching regulator circuit to be shut down using logic level signals thus dropping the total input supply current to approximately $80 \mu A$. Pulling this pin below a threshold voltage of approximately $1.3V$ turns the regulator on, and pulling this pin above $1.3V$ (up to a maximum of $25V$) shuts the regulator down. If this shutdown feature is not needed, the $\overline{\text{ON/OFF}}$ pin can be wired to the ground pin or it can be left open, in either case the regulator will be in the ON condition.

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Block Diagram



Absolute Maximum Ratings (Note 1)

Parameter	Rating	Unit	
Maximum Supply Voltage	45	V	
ON/OFF Pin Input Voltage	-0.3~25	V	
Feedback Pin Voltage	-0.3~25	V	
Output Voltage to Ground (Steady State)	-1	V	
Power Dissipation	Internally limited	--	
Storage Temperature Range	-65~150	°C	
ESD Susceptibility (Human Body Model) (Note 2)		KV	
Conditions	Maximum Junction Temperature	150	°C
	Temperature Range	-40~125	°C
	Supply Voltage	4.5~40	V

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics.

Note 2: The human body model is a 100 pF capacitor discharged through a 1.5k resistor into each pin.

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Electrical Characteristics (Condition : $T_J = 25^{\circ}\text{C}$)

$V_O=3.3\text{V}$							
Symbol	Parameter	Conditions	MSP1250-- $V_O=3.3\text{V}$			Units	
			Min (Note 4)	Typ (Note 3)	Max (Note4)		
SYSTEM PARAMETERS (Note 5) Test Circuit Figure 1							
V_{OUT}	Output Voltage	4.75V V_{IN} 40V 0.2A I_{LOAD} 3A	3.135	3.3	3.465	V	
η	Efficiency	$V_{IN}=12\text{V}$, $I_{LOAD}=3\text{A}$	--	73	--	%	
$V_O=5\text{V}$							
Symbol	Parameter	Conditions	MSP1250-- $V_O=5.0\text{V}$			Units	
			Min (Note 4)	Typ (Note 3)	Max (Note4)		
SYSTEM PARAMETERS (Note 5) Test Circuit Figure 1							
V_{OUT}	Output Voltage	7V V_{IN} 40V 0.2A I_{LOAD} 3A	4.750	5.0	5.250	V	
η	Efficiency	$V_{IN}=12\text{V}$,	--	80	--	%	
$V_O=12\text{V}$							
Symbol	Parameter	Conditions	MSP1250-- $V_O=12.0\text{V}$			Units	
			Min (Note 4)	Typ (Note 3)	Max (Note4)		
SYSTEM PARAMETERS (Note 5) Test Circuit Figure 1							
V_{OUT}	Output Voltage	15V V_{IN} 40V 0.2A I_{LOAD} 3A	11.40	12.0	12.60	V	
η	Efficiency	$V_{IN}=25\text{V}$, $I_{LOAD}=3\text{A}$	--	80	---	%	
Vout is adjustable							
Symbol	Parameter	Conditions	MSP1250—ADJ			Units	
			Min (Note 4)	Typ (Note 3)	Max (Note4)		
SYSTEM PARAMETERS (Note 5) Test Circuit Figure 1							
V_{FB}	Feedback Voltage	4.5V V_{IN} 40V 0.2A I_{LOAD} 3A V_{OUT} programmed for 3V. Circuit of Figure 1	1.336	1.386	1.436	V	
η	Efficiency	$V_{IN}=12\text{V}$, $V_{OUT}=3\text{V}$, $I_{LOAD}=3\text{A}$	--	73	--	%	

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All Output Voltage Versions Electrical Characteristics (Condition :T_J = 25°C)

Symbol	Parameter	Conditions	MSP1250—XX			Units
			Min (Note 4)	Typ (Note 3)	Max (Note4)	
DEVICE PARAMETERS						
I _b	Feedback Bias Current	Adjustable Version Only, VFB = 1.3V	--	10	100	nA
f _o	Oscillator Frequency	(Note 6)	110	150	173	KHz
V _{SAT}	VSAT Saturation Voltage	I _{OUT} =3A(Notes 7, 8)	--	1.16	1.5	V
DC	Max Duty Cycle (ON)	(Note 8)	--	100	--	%
	Min Duty Cycle (OFF)	(Note 9)	--	0	--	%
I _{CL}	Current Limit	Peak Current (Notes 7, 8)	3.4	4.5	7.5	A
I _L	Output Leakage Current	Output = 0V (Notes 7, 9)	--	--	50	μA
		Output = -1V (Notes 10)	--	2	30	mA
I _Q	Quiescent Current	(Note 9)	--	5	10	mA
I _{STBY}	Standby Quiescent Current	ON/OFF pin = 5V (OFF) (Note 10)	--	80	250	μA
θ _{JC}	Thermal Resistance	TO-220 or TO-263 Junction to Case	--	2	--	°C/W
θ _{JA}		TO-220 Package, Junction to Ambient(Note 11)	--	50	--	°C/W
θ _{JA}		TO-263 Package, Junction to Ambient (Note 12)	--	50	--	°C/W
θ _{JA}		TO-263 Package, Junction to Ambient(Note 13)	--	30	--	°C/W
θ _{JA}		TO-263 Package, Junction to Ambient(Note 14)	--	20	--	°C/W
ON/OFF CONTROL Test Circuit Figure 1						
	ON /OFF Pin Logic Input		--	1.3	--	V
V _{IH}	Threshold Voltage	Low (Regulator on)	--	--	0.6	V
V _{IL}		High(Regulator off)	--	--	2.0	V
I _H	ON /OFF Pin Input Current	V _{LOGIC} =2.5V (Regulator OFF)	--	5	15	μA
I _L		V _{LOGIC} =0.5V (Regulator ON)	--	0.02	5	μA

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Note 3: Typical numbers are at 25°C and represent the most likely norm.

Note 4: All limits guaranteed at room temperature (standard type face) and at temperature extremes (bold type face). All room temperature limits are 100% production tested. All limits at temperature extremes are guaranteed via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

Note 5: External components such as the catch diode, inductor, input and output capacitors, and voltage programming resistors can affect switching regulator system performance.

Note 6: The switching frequency is reduced when the second stage current limit is activated.

Note 7: No diode, inductor or capacitor connected to output pin.

Note 8: Feedback pin removed from output and connected to 0V to force the output transistor switch ON.

Note 9: Feedback pin removed from output and connected to 12V for the 3.3V, 5V, and the ADJ. version, and 15V for the 12V version, to force the output transistor switch OFF.

Note 10: $V_{IN} = 40V$.

Note 11: Junction to ambient thermal resistance (no external heat sink) for the TO-220 package mounted vertically, with the leads soldered to a printed circuit board with (1 oz.) copper area of approximately 1 in².

Note 12: Junction to ambient thermal resistance with the TO-263 package tab soldered to a single printed circuit board with 0.5 in² of (1 oz.) copper area.

Note 13: Junction to ambient thermal resistance with the TO-263 package tab soldered to a single sided printed circuit board with 2.5 in² of (1 oz.) copper area.

Note 14: Junction to ambient thermal resistance with the TO-263 package tab soldered to a double sided printed circuit board with 3 in² of (1 oz.) copper area on the MSP1250 side of the board, and approximately 16 in² of copper on the other side of the p-c board.

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EXTERNAL COMPONENTS

INPUT CAPACITOR C_{IN} — A low ESR aluminum or tantalum bypass capacitor is needed between the input pin and ground pin. It must be located near the regulator using short leads. This capacitor prevents large voltage transients from appearing at the input, and provides the instantaneous current needed each time the switch turns on. Selecting an input capacitor requires consulting the manufacturers data sheet for maximum allowable RMS ripple current. For a maximum ambient temperature of 40°C, a general guideline would be to select a capacitor with a ripple current rating of approximately 50% of the DC load current. For ambient temperatures up to 70°C, a current rating of 75% of the DC load current would be a good choice for a conservative design. The capacitor voltage rating must be at least 1.25 times greater than the maximum input voltage, and often a much higher voltage capacitor is needed to satisfy the RMS current requirements.

FEEDFORWARD CAPACITOR (Adjustable Output Voltage Version) C_{FF} — A feed forward Capacitor C_{FF} , shown across R2 in Figure1 is used when the output voltage is greater than 10V or when C_{OUT} has a very low ESR. This capacitor adds lead compensation to the feedback loop and increases the phase margin for better loop stability.

OUTPUT CAPACITOR C_{OUT} — An output capacitor is required to filter the output and provide regulator loop stability. Low impedance or low ESR Electrolytic or solid tantalum capacitors designed for switching regulator applications must be used. When selecting an output capacitor, the important capacitor parameters are; the 100 kHz Equivalent Series resistance (ESR), the RMS ripple current rating, voltage rating, and capacitance value. For the output capacitor, the ESR value is the most important parameter. The output capacitor requires an ESR value that has an upper and lower limit. For low output ripple voltage, a low ESR value is needed. This value is determined by the maximum allowable output ripple voltage, typically 1% to 2% of the output voltage. But if the selected capacitor's ESR is extremely low, there is a possibility of an unstable feedback loop, resulting in an oscillation at the output.

CATCH DIODE D — Buck regulators require a diode to provide a return path for the inductor current when the switch turns off. This must be a fast diode and must be located close to the MSP1250 using short leads and short printed circuit traces. Because of their very fast switching speed and low forward voltage drop, Schottky diodes provide the best performance, especially in low output voltage applications (5V and lower). Ultra fast recovery, or High-Efficiency rectifiers are also a good choice, but some types with an abrupt turnoff characteristic may cause instability or EMI problems.

INDUCTOR SELECTION L — All switching regulators have two basic modes of operation; continuous and discontinuous. The difference between the two types relates to the inductor current, whether it is flowing continuously, or if it drops to zero for a period of time in the normal switching cycle. Each mode has distinctively different operating characteristics, which can affect the regulators performance and requirements. Most switcher designs will operate in the discontinuous mode when the load current is low. The MSP1250 (or any of the Simple Switcher family) can be used for both continuous and discontinuous modes of operation.

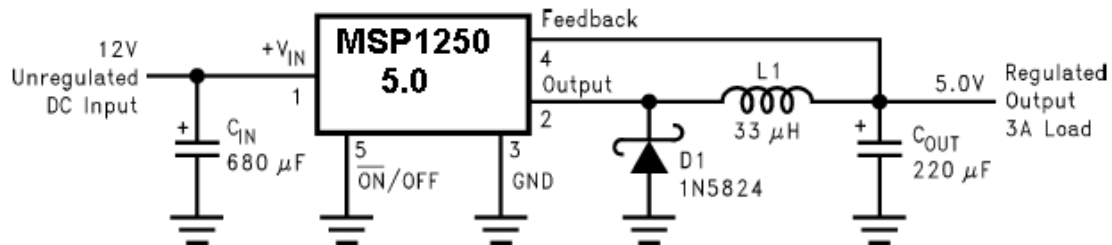
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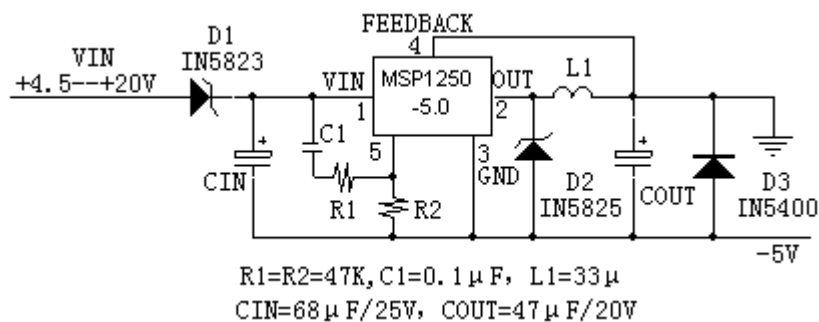
Typical Application

1. Fixed Output Voltage Versions



2. INVERTING REGULATOR

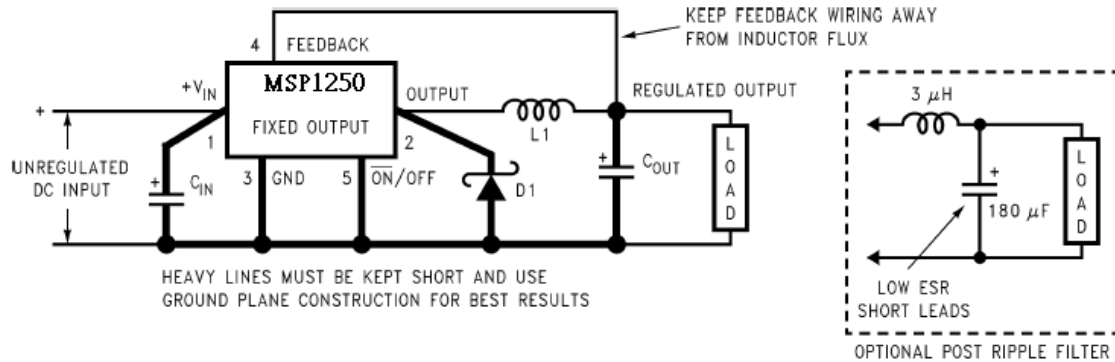
The circuit in Figure following converts a positive input voltage to a negative output voltage with a common ground. The circuit operates by bootstrapping the regulator's ground pin to the negative output voltage, and then grounding the feedback pin, the MSP1250 generate a negative output voltage. Since this regulator topology can produce an output voltage that is either greater than or less than the input voltage, the maximum output current greatly depends on both the input and output voltage. The maximum voltage appearing across the regulator is the absolute sum of the input and output voltage, and this must be limited to a maximum of 40V. Additional diodes are required in this regulator configuration. Diode D1 is used to solate input voltage ripple or noise from coupling through the C_{IN} capacitor to the output, under light or no load conditions. Without diode D3, when the input voltage is first applied, the charging current of C_{IN} can pull the output positive by several volts for a short period of time. Adding D3 prevents the output from going positive by more than a diode voltage.



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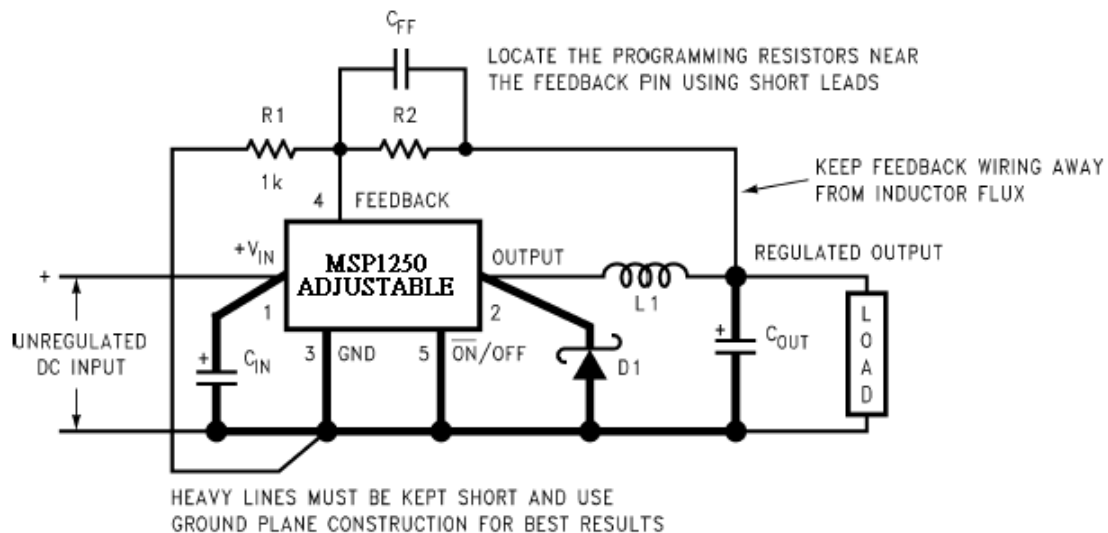
Test Circuit and Layout Guidelines

Fixed Output Voltage Versions



C_{IN} --470 μ F, 50V, Aluminum Electrolytic Nichicon "PL Series"
 C_{OUT} --220 μ F, 25V Aluminum Electrolytic, Nichicon "PL Series"
 D_1 --5A, 40V Schottky Rectifier, 1N5825
 L_1 --68 μ H, L38

Adjustable Output Voltage Versions



$$V_{OUT} = V_{REF} \left(1 + \frac{R_2}{R_1} \right)$$

where $V_{REF} = 1.23V$

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

Select R_1 to be approximately 1 k Ω , use a 1% resistor for best stability.

C_{IN} --470 μ F, 50V, Aluminum Electrolytic Nichicon "PL Series"

C_{OUT} --220 μ F, 35V Aluminum Electrolytic, Nichicon "PL Series"

D_1 --5A, 40V Schottky Rectifier, 1N5825

L_1 --68 μ H, L38

R_1 --1 k Ω , 1%

C_{FF} --See Application Information Section