LM3102 Demonstration Board Reference Design

National Semiconductor
Application Note 1646
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Introduction

The LM3102 Step Down Switching Regulator features all required functions to implement a cost effective, efficient buck power converter capable of supplying 2.5A to loads. The Constant On-Time (COT) regulation scheme requires no loop compensation, results in a fast load transient response and simple circuit implementation which allows a low component count, and consequently very small overall board space is required for a typical application. The regulator can function properly even with an all ceramic output capacitor network, and does not rely on the output capacitor's ESR for stability. The operating frequency remains constant with line variations due to the inverse relationship between the input voltage and the on-time. Protection features include output over-voltage protection, thermal shutdown, V_{CC} under-voltage lock-out, gate drive under-voltage lock-out. The LM3102 is available in the thermally enhanced eTSSOP-20 package.

This application note details the design of a demonstration board which provides a 3.3V output voltage with 2.5A load capability for a wide input voltage range from 8V to 42V. The demonstration board schematic, PCB layout, Bill of Materials, and circuit design descriptions are shown. Typical performance and operating waveforms are also provided for reference.

Demonstration Board Schematic and PCB

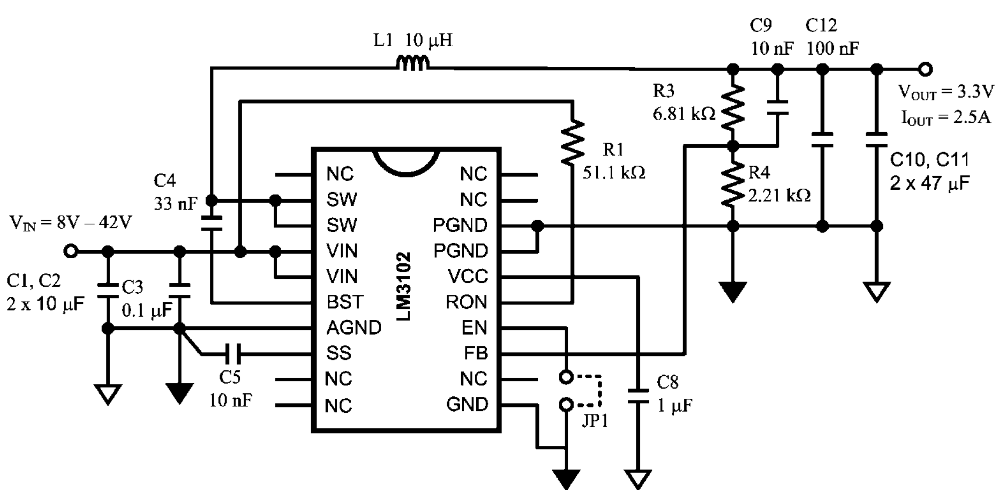

FIGURE 1. LM3102 Demonstration Board Schematic

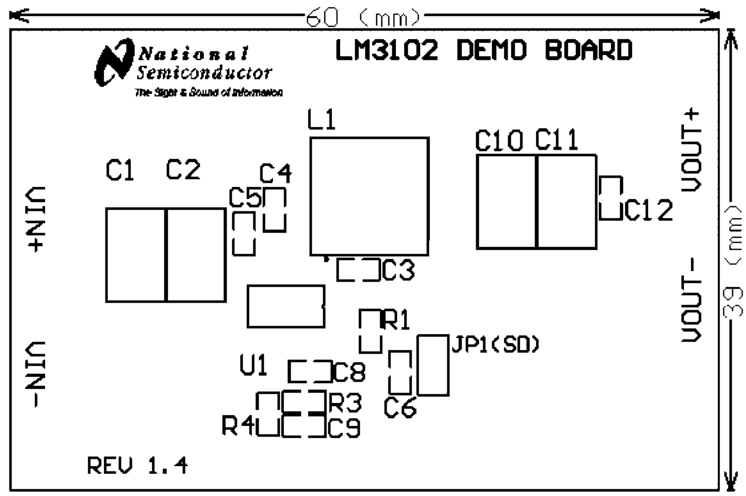

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FIGURE 2. LM3102 Demonstration Board PCB Top Overlay

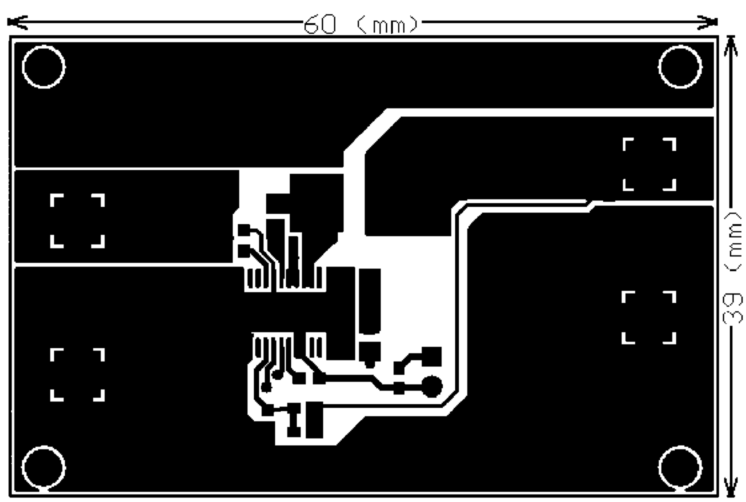

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FIGURE 3. LM3102 Demonstration Board PCB Top View

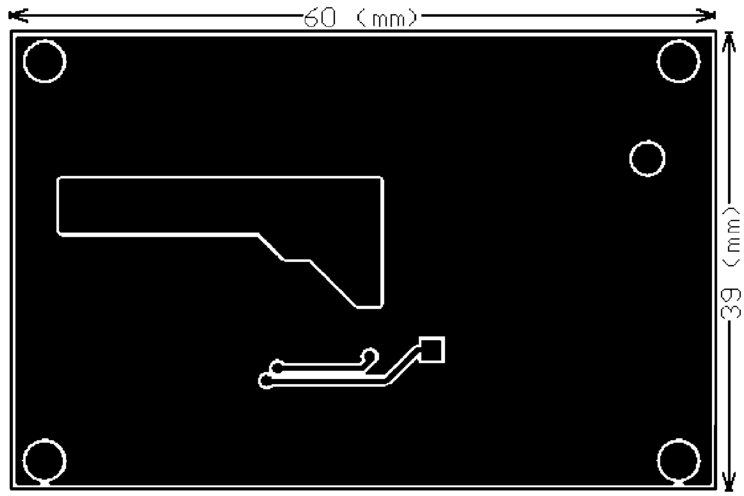


FIGURE 4. LM3102 Demonstration Board PCB Bottom View

Demonstration Board Quick Setup Procedures

Step	Description	Notes
1	Connect a power supply to VIN terminals	V_{IN} range: 8V to 42V
2	Connect a load to VOUT terminals	I_{OUT} range: 0A to 2.5A
3	SD (JP1) should be left open for normal operation. Short this jumper to shutdown	
4	Set V_{IN} = 18V, with 0A load applied, check V_{OUT} with a voltmeter	Nominal 3.3V
5	Apply 2.5A load and check V_{OUT}	Nominal 3.3V
6	Short output terminals and check the short circuit current with an ammeter	Nominal 2.95A
7	Short SD (JP1) to check the shutdown function	

Demonstration Board Performance Characteristic

Description	Symbol	Condition	Min	Typ	Max	Unit
Input Voltage	V_{IN}		8	18	42	V
Output Voltage	V_{OUT}		3.2	3.3	3.4	V
Output Current	I_{OUT}		0	-	2.5	A
Output Voltage Ripple	V_{OUT}(Ripple)		-	-	50	mVp-p
Output Voltage Regulation	ΔV_{OUT}	ALL V_{IN} and I_{OUT} Conditions	-3		3	%
Efficiency		V_{IN} = 8V	84		92	%
		V_{IN} = 24V	73		85	
		V_{IN} = 42V (I_{OUT} = 0.1A to 2.5A)	62		79	
Output Short Current Limit	I_{LIM-SC}			2.95		A

Design Procedure

The LM3102 is easy to use compared with other devices available on the market because it integrates all key components, including both the main and synchronous power MOSFETs, in a single package and requires no loop compensation owing to the use of the Constant On-Time (COT) hysteretic control scheme. The design of the demonstration board in this application note is detailed below.

Design Parameters:

V_{IN} = 8V to 42V, typical 18V

V_{OUT} = 3.3V

I_{OUT} = 2.5A

Step 1: Calculate the feedback resistors

The ratio of the feedback resistors can be calculated from the following equation:

$$\frac{R3}{R4} = \frac{V_{OUT}}{0.8} - 1$$

As a general practice, R3 and R4 should be chosen from standard 1% resistor values in the range of 1.0 kΩ to 10 kΩ satisfying the above ratio. Now, select R4 = 2.21 kΩ, with V_{OUT} = 3.3V,

$$R3 = 2.21\ k\Omega \left(\frac{V_{OUT}}{0.8} - 1\right) = 6.91\ k\Omega$$

Step 2: Calculate the on-time setting resistor

The switching frequency f_{SW} of the demonstration board is affected by the on-time t_{on} of the LM3102, which is determined by R1. If f_{SW} and V_{OUT} are determined, R1 can be calculated as follows:

$$R1 = \frac{V_{OUT}}{1.3 \times 10^{-10} \times f_{SW}}$$

For this demonstration board design, V_{OUT} = 3.3V and f_{SW} = 500 kHz are chosen. As a result, R1 = 50.8 kΩ. To ensure that the on-time is larger than the minimum limit, which is 150 ns, the value of R1 must satisfy the following equation:

$$R1 \geq \frac{V_{IN(MAX)} \times 150\ ns}{1.3 \times 10^{-10}}$$

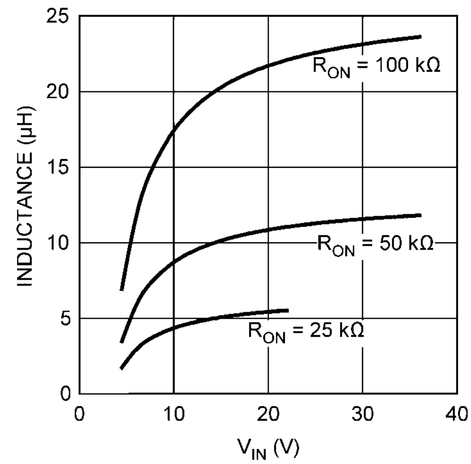
Now the maximum V_{IN} is 42V, the calculated R1 satisfies the above equation.

Step 3: Determine the inductance

The main parameter affected by the inductor is the amplitude of the inductor current ripple I_{LR}. Once I_{LR} is selected, L can be determined by:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{I_{LR} \times f_{SW} \times V_{IN}}$$

For this demonstration board design, I_{LR} = 0.5A is selected. Now V_{IN} = 18V, V_{OUT} = 3.3V, and f_{SW} = 500 kHz. As a result, L = 10.78 µH.



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Inductor Selection for V_{OUT} = 3.3V

Step 4: Determine the value of other components

C1 and C2: The function of the input capacitor is to supply most of the main MOSFET current during the on-time, and limit the voltage ripple at the VIN pin, assuming that the voltage source feeding to the VIN pin has finite output impedance. If the voltage source's dynamic impedance is high (effectively a current source), the input capacitor supplies the average input current, but not the ripple current. At maximum load current, when the main MOSFET turns on, the current to the VIN pin suddenly increases from zero to the lower peak of the inductor's ripple current and ramps up to the higher peak value. It then drops to zero at turn-off. The average current during the on-time is the load current. For a worst case calculation, the input capacitor must be capable of supplying this average load current during the maximum on-time. The input capacitor is calculated from:

$$C_{IN} = \frac{I_{OUT} \times t_{on}}{\Delta V_{IN}}$$

where C_{IN} = C1 + C2 is the input capacitor, I_{OUT} is the load current, t_{on} is the maximum on-time, and ΔV_{IN} is the allowable ripple voltage at V_{IN}. In this demonstration board, two 10 µF capacitors connecting in parallel are used.

C3: C3's purpose is to help avoid transients and ringing due to long lead inductance at the VIN pin. A low ESR 0.1 µF ceramic chip capacitor located close to the LM3102 is used in this demonstration board.

C4: A 33 nF high quality ceramic capacitor with low ESR is used for C4 since it supplies a surge current to charge the main MOSFET gate driver at turn-on. Low ESR also helps ensure a complete recharge during each off-time.

C5: The capacitor at the SS pin determines the soft-start time, i.e. the time for the reference voltage at the regulation comparator and the output voltage to reach their final value. The time is determined from the following equation:

$$t_{SS} = \frac{C5 \times 0.8V}{8\ \mu A}$$

In this demonstration board, a 10 nF capacitor is used, and the corresponding soft-start time is about 1 ms.

C8: The capacitor on the V_{CC} output provides not only noise filtering and stability, but also prevents false triggering of the V_{CC} UVLO at the main MOSFET on/off transitions. C8 should be no smaller than 680 nF for stability, and should be a good quality, low ESR, ceramic capacitor. In this demonstration board, a 1 µF capacitor is used.

C9: If the output voltage is higher than 1.6V, C9 is needed in the Discontinuous Conduction Mode to reduce the output ripple. In this demonstration board, a 10 nF capacitor is used.

C10 and C11: The output capacitor should generally be no smaller than 10 µF. Experimentation is usually necessary to determine the minimum value for the output capacitor, as the nature of the load may require a larger value. A load which creates significant transients requires a larger output capacitor than a fixed load. In this demonstration board, two 47 µF capacitors are connected in parallel to provide a low output ripple.

C12: C12 is a small value ceramic capacitor located close to the LM3102 to further suppress high frequency noise at V_{OUT}. A 100 nF capacitor is used in this demonstration board.

PC Board Layout

The LM3102 regulation, over-voltage, and current limit comparators are very fast so they will respond to short duration noise pulses. Layout is therefore critical for optimum performance. It must be as neat and compact as possible, and all external components must be as close to their associated pins of the LM3102 as possible. The loop formed by the input capacitors (C1 and C2), the main and synchronous MOSFET internal to the LM3102, and the PGND pin should be as small as possible. The connection from the PGND pin to the input capacitors should be as short and direct as possible. Vias should be added to connect the ground of the input capacitors to a ground plane, located as close to the capacitor as possible. The bootstrap capacitor C4 should be connected as close to the SW and BST pins as possible, and the connecting traces should be thick. The feedback resistors and capacitor R3, R4, and C9 should be close to the FB pin. A long trace running from V_{OUT} to R3 is generally acceptable since this is a low impedance node. Ground R4 directly to the AGND pin (pin 7). The output capacitor C10, C11 should be connected close to the load and tied directly to the ground plane. The inductor L1 should be connected close to the SW pin with as short a trace as possible to reduce the potential for EMI (electromagnetic interference) generation. If it is expected that the internal dissipation of the LM3102 will produce excessive junction temperature during normal operation, making good use of the PC board's ground plane can help considerably to dissipate heat. The exposed pad on the bottom of the LM3102 IC package can be soldered to the ground plane, which should extend out from beneath the LM3102 to help dissipate heat. The exposed pad is internally connected to the LM3102 IC substrate. Additionally the use of thick traces, where possible, can help conduct heat away from the LM3102. Using numerous vias to connect the die attached pad to the ground plane is a good practice. Judicious positioning of the PC board within the end product, along with the use of any available air flow (forced or natural convection) can help reduce the junction temperature.

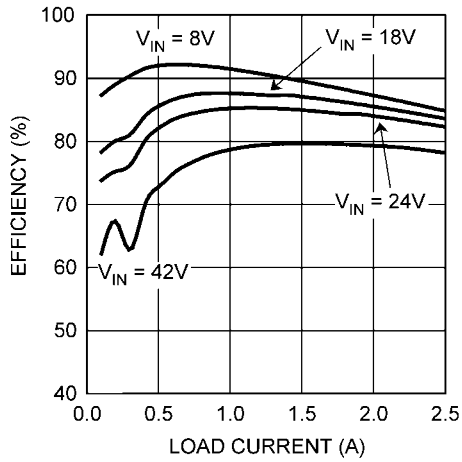
Bill of Materials

Designation	Description	Size	Manufacturer Part #	Vendor
C1, C2	Cap 10µF 50V Y5V	1210	GRM32DF51H106ZA01L	muRata
C3	Cap MLCC 0.1µF 50V X7R	0603	ECJ1VB1H104K	Panasonic
C4	0603/X7R/33000pF/25V	0603	GRM188R71E333KA01B	muRata
C5, C9	0603/X7R/10000pF/50V	0603	GRM188R71H103KA01B	muRata
C8	0603/X5R/1µF/10V	0603	GRM188R61A105KA61B	muRata
C10, C11	Cap MLCC 47µF 6.3V X5R	1210	ECJ4YB0J476M	Panasonic
C12	0603/X7R/0.1µF/25V	0603	GRM188R71E104KA01B	muRata
R1	Resistor Chip 51.1kΩ F	0603	CRCW06035112F	Vishay
R3	Resistor Chip 6.81kΩ F	0603	CRCW06036811F	Vishay
R4	Resistor Chip 2.21kΩ F	0603	CRCW06032211F	Vishay
L1	Inductor 10µH 4.40A POWER-CHOKE	10.3×10.5×4	CDRH104RNP-100NC	Sumida
	SMD-Power Choke WE-TPC 3.6A Type XLH	10×10×3.8	744066100	Wurth
U1	IC LM3102	eTSSOP-20	LM3102MH	National
PCB	LM3102 demo board			National

Typical Performance and Waveforms

All curves and waveforms are taken at V_{IN} = 18V with the demonstration board and T_A = 25°C unless otherwise specified.

Efficiency vs Load Current (V_{OUT} = 3.3V)



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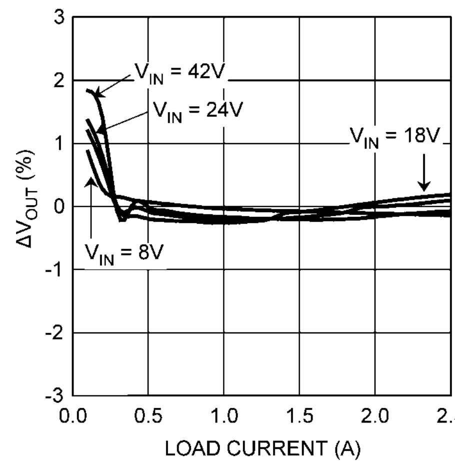
V_{OUT} Regulation vs Load Current (V_{OUT} = 3.3V)



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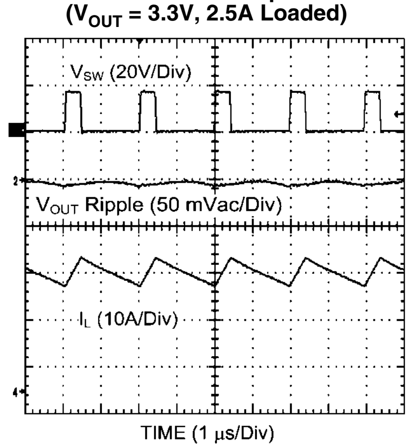
Continuous Mode Operation (V_{OUT} = 3.3V, 2.5A Loaded)



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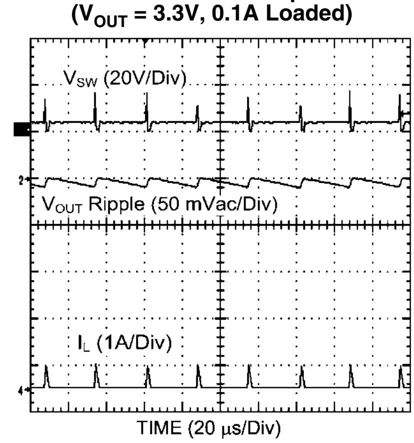
Discontinuous Mode Operation (V_{OUT} = 3.3V, 0.1A Loaded)



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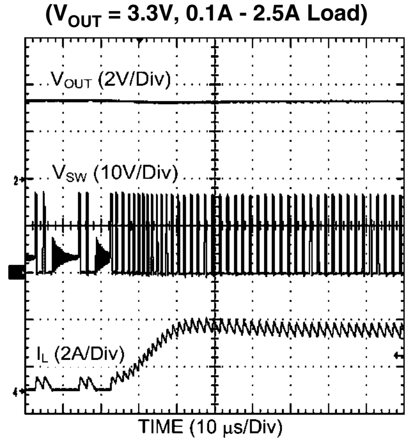
DCM to CCM Transition (V_{OUT} = 3.3V, 0.1A - 2.5A Load)



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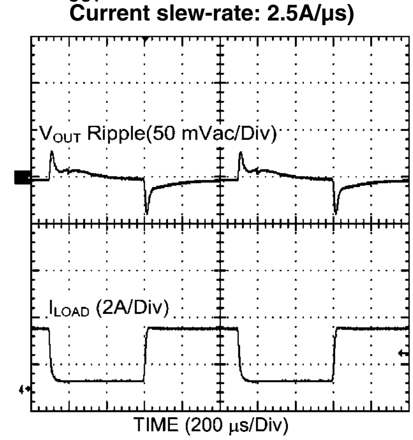
Load Transient (V_{OUT} = 3.3V, 0.25A - 2.5A Load, Current slew-rate: 2.5A/µs)



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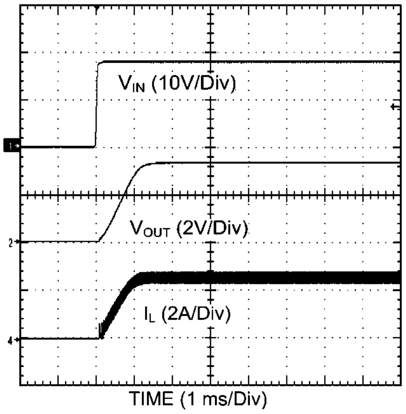
Power Up (V_{OUT} = 3.3V, 2.5A Loaded)



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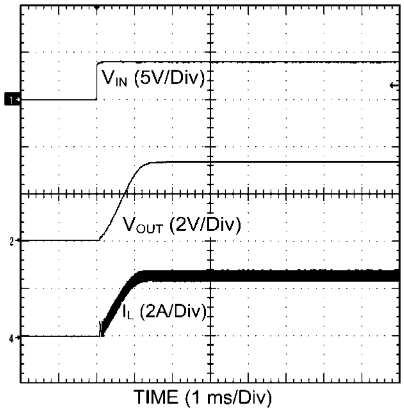
Enable Transient (V_{OUT} = 3.3V, 2.5A Loaded)



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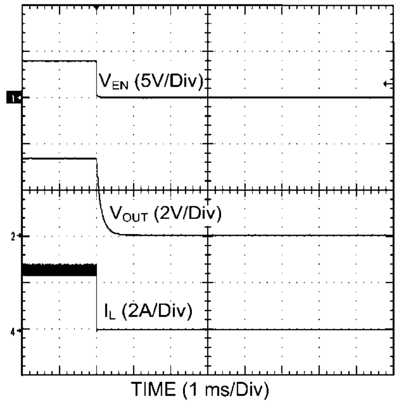
Shutdown Transient (V_{OUT} = 3.3V, 2.5A Loaded)



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Notes

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