ADPL31610

1.2MHz/2.2MHz Inverting DC/DC Converters in ThinSOT

FEATURES

- Fixed Frequency 1.2MHz/2.2MHz Operation
- Very Low Noise: $1mV_{P-P}$ Output Ripple
- –5V at 350mA from 5V Input
- –12V at 150mA from 5V Input
- Uses Small Surface Mount Components
- Wide Input Range: 2.6V to 16V
- Low Shutdown Current: 2µA (max)
- Low V_{CESAT} Switch: 400mV at 1A
- Low Profile (1mm) ThinSOT™ Package

APPLICATIONS

- Disk Drive MR Head Bias
- Digital Camera CCD Bias
- LCD Bias
- GaAs FET Bias
- Local Low Noise/Low Impedance Negative Supply

GENERAL DESCRIPTION

The ADPL31610A/ADPL31610B are the industry's highest power inverting SOT-23 current mode DC/DC converters. Both parts include a 1A integrated switch allowing high current outputs to be generated in a small footprint. The ADPL31610A switches at 1.2MHz, while the ADPL31610B switches at 2.2MHz. These high speeds enable the use of tiny, low-cost capacitors and inductors. The ADPL31610A is capable of generating –5V at 350mA or –12V at 150mA from a 5V supply, while the ADPL31610B can generate –5V at 300mA using significantly smaller inductors.

The ADPL31610A/ADPL31610B operate in a dual inductor inverting topology that filters both the input side and output side current. Very low output voltage ripple approaching $1mV_{P-P}$ can be achieved when ceramic output capacitors are used. Fixed frequency switching ensures a clean output free from low frequency noise typically present with charge pump solutions. The low impedance output remains within 1% of nominal during large load steps. The 34V switch allows V_{IN} to V_{OUT} differential of up to 32V.

The ADPL31610A/ADPL31610B are available in the 5-lead ThinSOT package.

TYPICAL APPLICATION

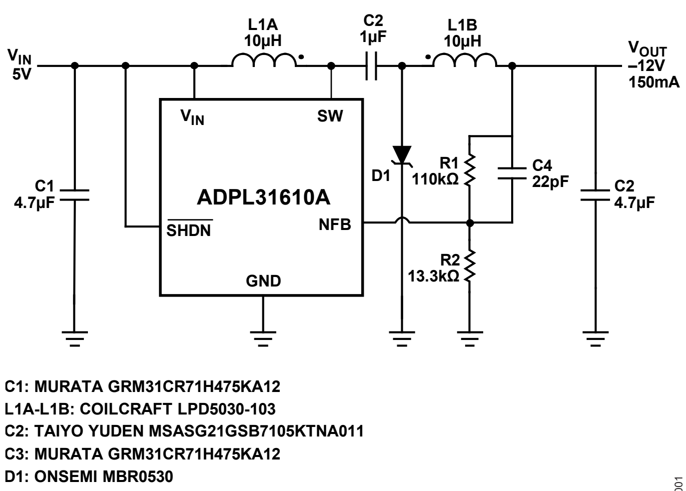


Figure 1. 5V to –12V, 150mA Inverting DC/DC Converter

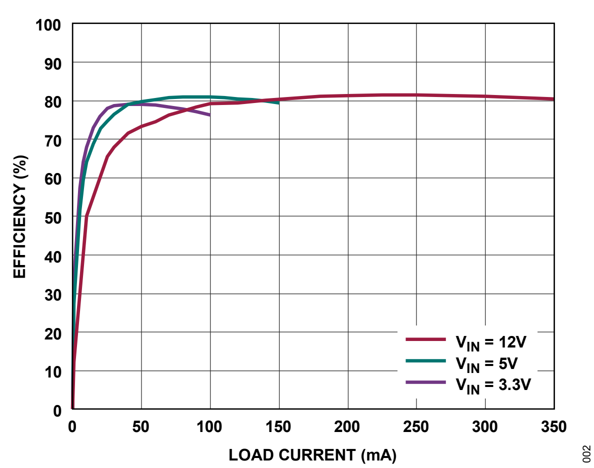


Figure 2. Efficiency vs. Load Current

One Analog Way, Wilmington, MA 01887-2356, U.S.A. | Tel: 781.329.4700

SPECIFICATIONS

Table 1. Electrical Characteristics

(Specifications are at T_A = 25°C. V_{IN} = 3V, $V_{\overline{SHDN}}$ = V_{IN}, unless otherwise noted. ([2]))

PARAMETER	CONDITIONS	ADPL31610A			ADPL31610B			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Minimum Operating Voltage			2.45	2.6		2.45	2.6	V
Maximum Operating Voltage				16			16	V
Feedback Voltage	-40°C ≤ T_J ≤ 85°C	-1.280	-1.255	-1.230	-1.280	-1.255	-1.230	V
NFB Pin Bias Current	V_{NFB} = –1.255V 40°C ≤ T_J ≤ 85°C		5	10		10	20	µA
Quiescent Current	$V_{\overline{SHDN}}$ = 2.4V, Not Switching		4.2	7.2		5.8	9.6	mA
Quiescent Current in Shutdown	$V_{\overline{SHDN}}$ = 0V, V_{IN} = 3V		0.01	2		0.01	2	µA
Reference Line Regulation	2.6V ≤ V_{IN} ≤ 16V		0.012	0.06		0.012	0.06	%/V
Switching Frequency	-40°C ≤ T_J ≤ 85°C	0.85	1.2	1.6	1.6	2.2	2.9	MHz
Maximum Duty Cycle	-40°C ≤ T_J ≤ 85°C	84	90		75	82		%
Switch Current Limit	([3])	1	1.2	2	1	1.2	2.5	A
Switch V_{CESAT}	I_{SW} = 1A		400	675		400	675	mV
Switch Leakage Current	V_{SW} = 5V		0.01	1.2		0.01	1.2	µA
$\overline{SHDN}$ Input Voltage, High		2.4			2.4			V
$\overline{SHDN}$ Input Voltage, Low				0.5			0.5	V
$\overline{SHDN}$ Pin Bias Current	$V_{\overline{SHDN}}$ = 3V		16	34		34	70	µA
	$V_{\overline{SHDN}}$ = 0V		0	0.1		0	0.1	µA

[1] Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

[2] Specifications over the –40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls. ADPL31610A/ADPL31610B are guaranteed over the –40°C to 85°C temperature range.

[3] Current limit guaranteed by design and/or correlation to static test.

ABSOLUTE MAXIMUM RATINGS

T_A = 25°C, unless otherwise specified.

Table 2. Absolute Maximum Ratings

PARAMETER	RATING
V_{IN} Voltage	16V
SW Voltage	–0.4V to 34V
NFB Voltage	-2V
Current Into NFB Pin	±1mA
$\overline{\text{SHDN}}$ Voltage	16V
Maximum Junction Temperature	125°C
Operating Temperature Range (2)	-40°C to 85°C
Storage Temperature Range	–65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS

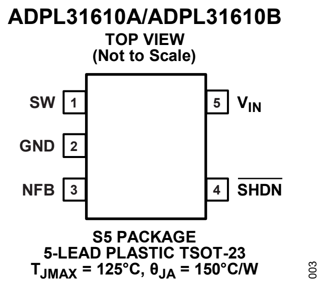


Figure 3. ADPL31610A/B Pin configuration

Pin Descriptions

Table 3. Pin Descriptions

PIN	NAME	DESCRIPTION
1	SW	Switch Pin. Connect inductor/diode here. Minimize trace area at this pin to keep EMI down.
2	GND	Ground. Tie directly to local ground plane.
3	NFB	Feedback Pin. Reference voltage is –1.255V. Connect resistive divider tap here. Minimize trace area. The NFB bias current flows out of the pin. Set R1 and R2 according to: $$\text{For ADPL31610A: R1} = \frac{\lvert V_{OUT}\rvert - 1.255}{\frac{1.255}{R2} + (4 \times 10^{-6})}$$ $$\text{For ADPL31610B: R1} = \frac{\lvert V_{OUT}\rvert - 1.255}{\frac{1.255}{R2} + (8 \times 10^{-6})}$$
4	$\overline{SHDN}$	Shutdown Pin. Tie to 2.4V or more to enable device. Ground to shut the device down.
5	V_{IN}	Input Supply Pin. Must be locally bypassed.

TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, unless otherwise noted.

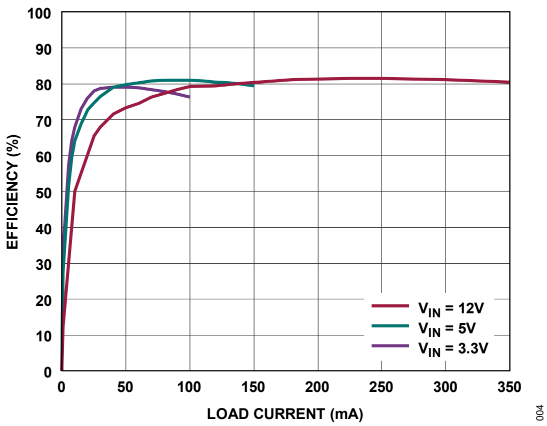


Figure 4. Efficiency vs. Load Current (Reference to Figure 1 Circuit)

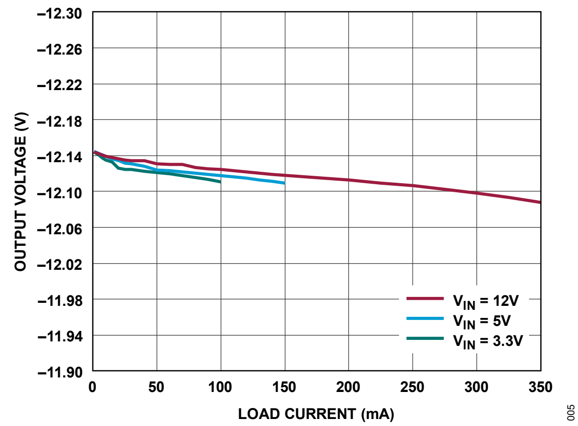


Figure 5. Output Voltage vs. Load Current (Reference to Figure 1 Circuit)

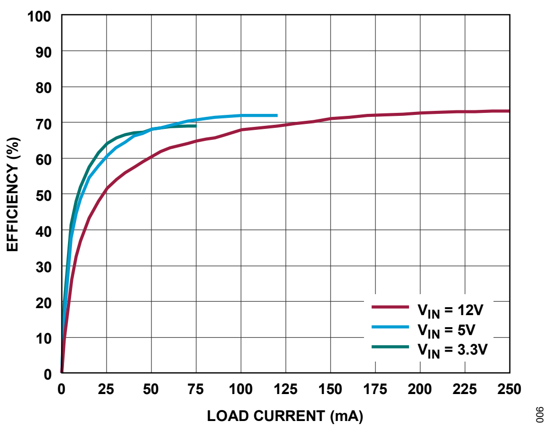


Figure 6. Efficiency vs. Load Current (Reference to Figure 32 Circuit)

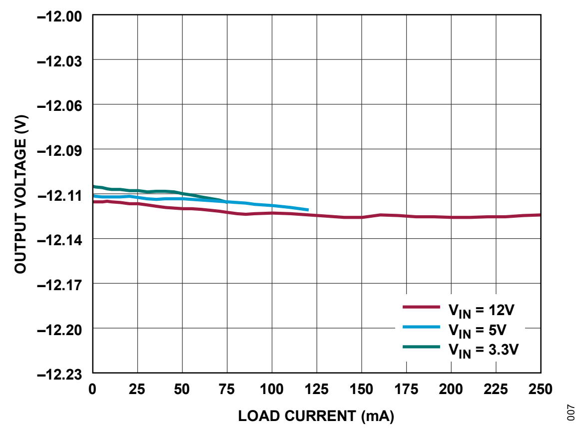


Figure 7. Output Voltage vs. Load Current (Reference to Figure 32 Circuit)

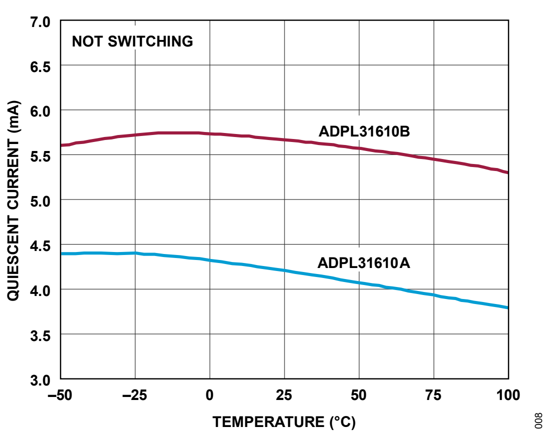


Figure 8. Quiescent Current

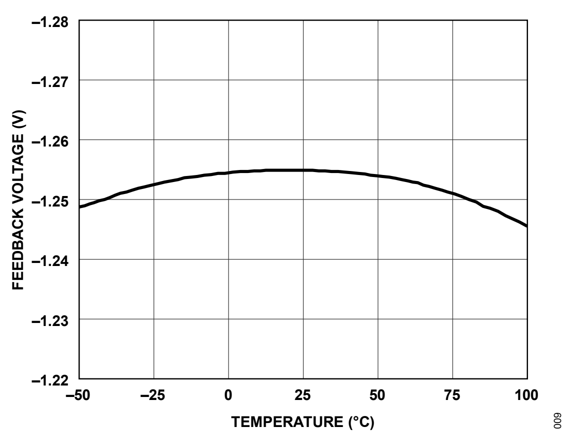


Figure 9. Feedback Pin Voltage

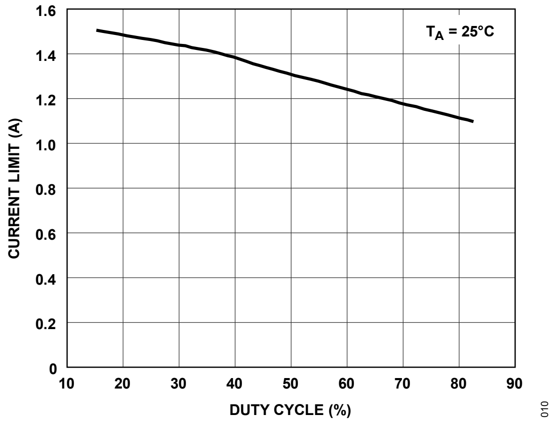


Figure 10. Current Limit

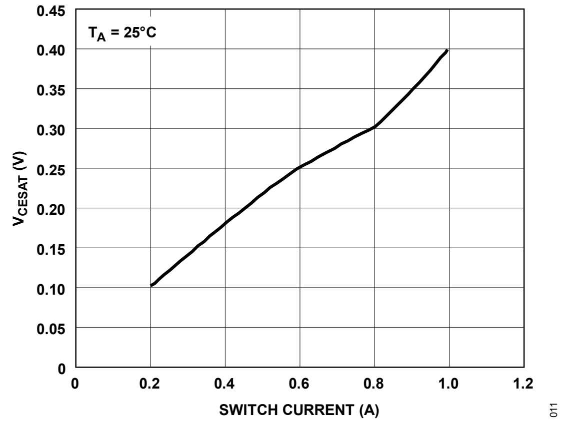


Figure 11. Switch Saturation Voltage

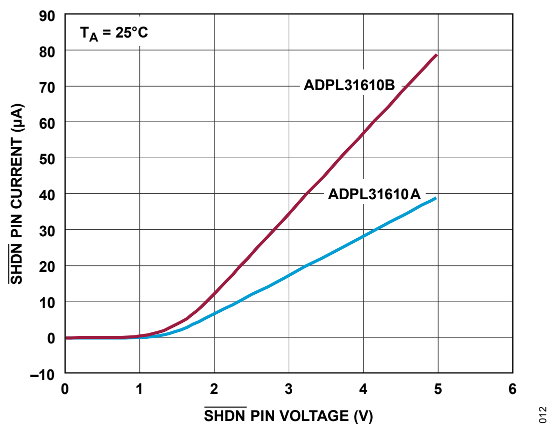


Figure 12. Shutdown Pin Current

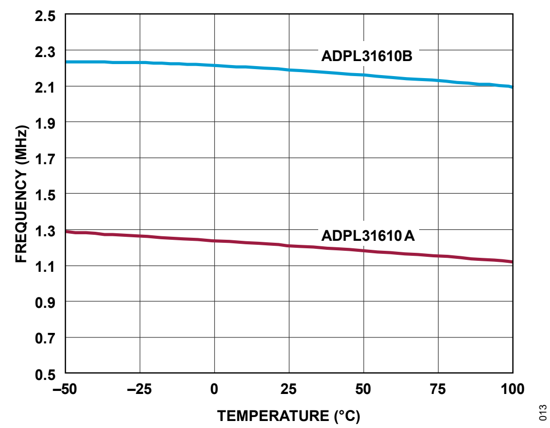


Figure 13. Oscillator Frequency

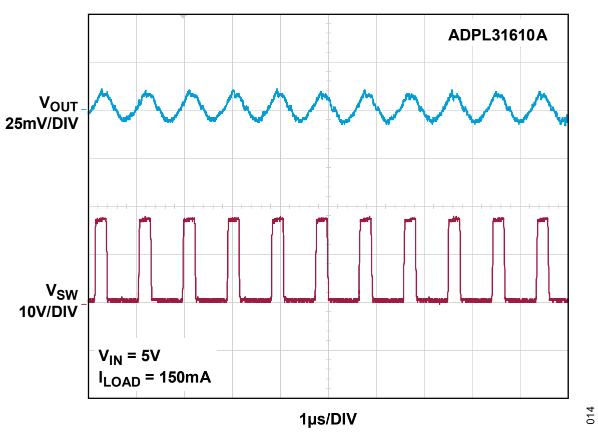


Figure 14. Switching Waveform (Reference to Figure 1 Circuit)

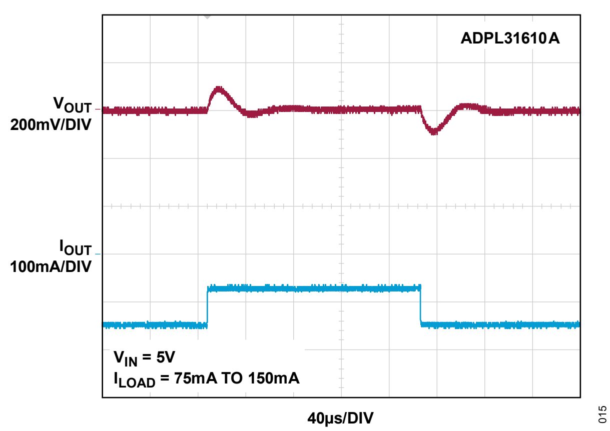


Figure 15. Transient Response (Reference to Figure 1 Circuit)

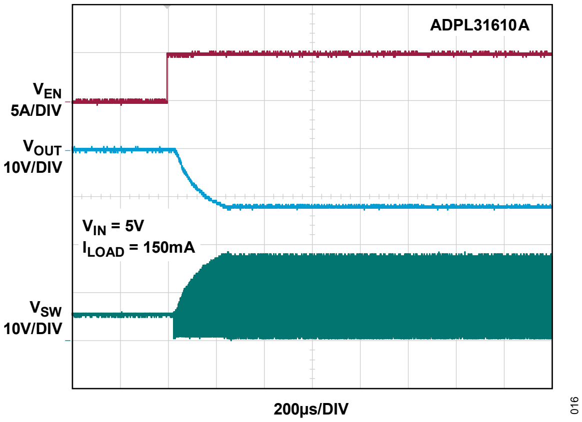


Figure 16. Startup waveform (Reference to Figure 1 Circuit)

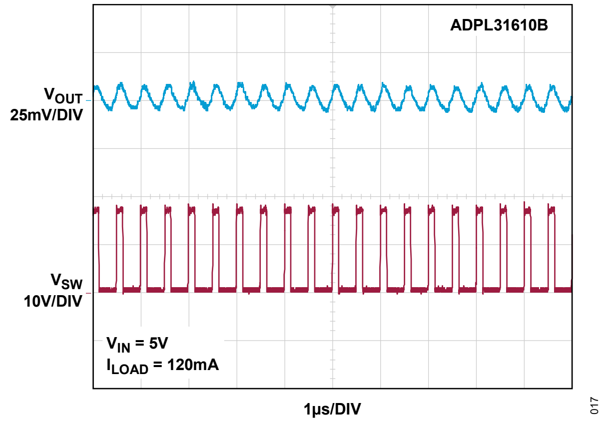


Figure 17. Switching Waveform (Reference to Figure 32 Circuit)

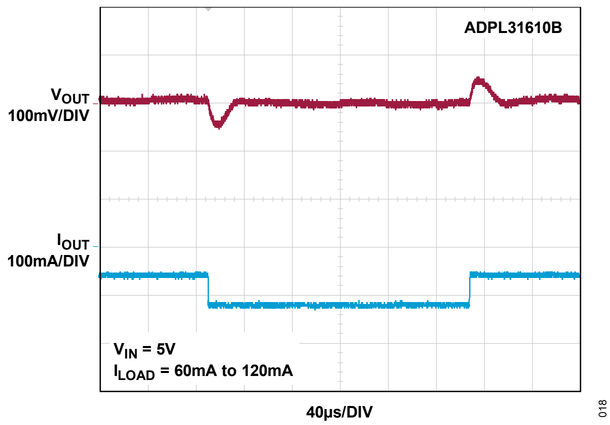


Figure 18. Transient Response (Reference to Figure 32 Circuit)

BLOCK DIAGRAM

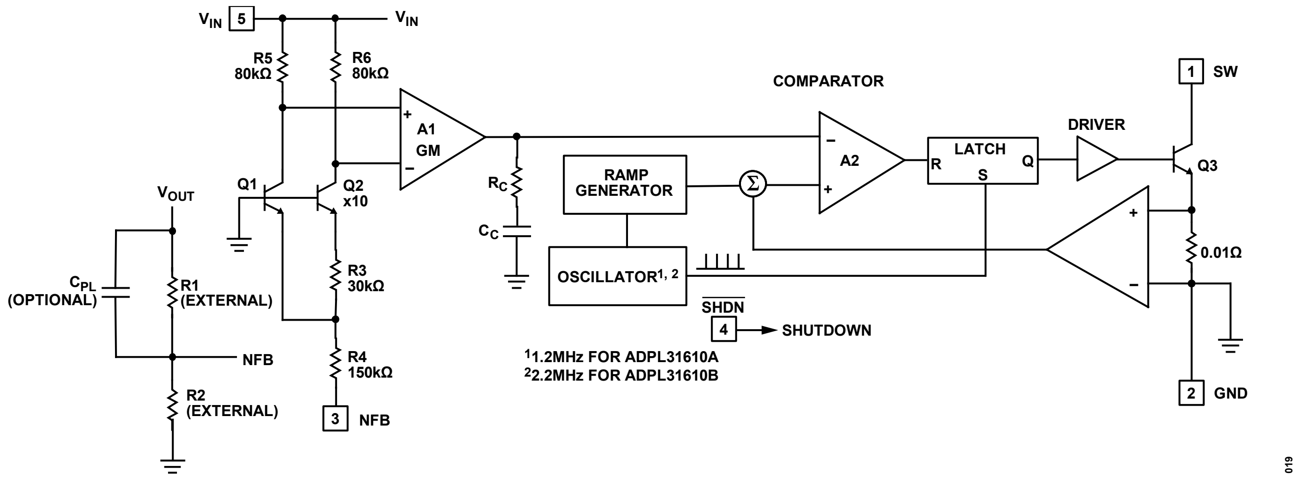


Figure 19. Block Diagram

THEORY OF OPERATION

The ADPL31610A uses a constant frequency, current-mode control scheme to provide excellent line and load regulation. For a better understanding of the operation, see the block diagram in *Figure 19.* At the start of each oscillator cycle, the SR latch is set, turning on the power switch Q3. A voltage proportional to the switch current is added to a stabilizing ramp and the resulting sum is fed into the positive terminal of the PWM comparator A2. When this voltage exceeds the level at the negative input of A2, the SR latch is reset, turning off the power switch. The level at the negative input of A2 is set by the error amplifier (g_m) and is simply an amplified version of the difference between the feedback voltage and the reference voltage of –1.255V. In this manner, the error amplifier sets the correct peak current level to keep the output in regulation. If the error amplifier's output increases, more current is taken from the output; if it decreases, less current is taken. One function not shown in Figure 19 is the current limit. The switch current is constantly monitored and not allowed to exceed the nominal value of 1.2A. If the switch current reaches 1.2A, the SR latch is reset regardless of the state of comparator A2. This current limit protects the power switch as well as various external components connected to the ADPL31610A.

The block diagram for the ADPL31610B is identical except that the oscillator is 2.2MHz and resistors R3 to R6 are one-half of the ADPL31610A values.

APPLICATIONS INFORMATION

ADPL31610B and ADPL31610A Differences:

Switching Frequency

The key difference between the ADPL31610B and ADPL31610A is the faster switching frequency of the ADPL31610B. At 2.2MHz, the ADPL31610B switches at nearly twice the rate of the ADPL31610A. Care must be taken in deciding which part to use. The high switching frequency of the ADPL31610B allows smaller, cheaper inductors and capacitors to be used in a given application, but with a slight decrease in efficiency and maximum output current when compared to the ADPL31610A. Generally, if efficiency and maximum output current are critical, the ADPL31610A should be used. If application size and cost are more important, the ADPL31610B will be the better choice. In many applications, tiny inexpensive chip inductors can be used with the ADPL31610B, reducing solution cost.

Duty Cycle

The maximum duty cycle (DC) of the ADPL31610B is 75% compared to 84% for the ADPL31610A. The duty cycle for a given application using the dual inductor inverting topology is given by:

$$DC = \frac{|V_{OUT}|}{|V_{IN}| + |V_{OUT}|}$$

For a 5V to −5V application, the DC is 50% indicating that the ADPL31610B can be used. A 5V to −16V application has a DC of 76.2% making the ADPL31610A the right choice. The ADPL31610B can still be used in applications where the DC, as calculated above, is above 75%. However, the part must be operated in the discontinuous conduction mode so that the actual duty cycle is reduced.

Inductor Selection

Several inductors that work well with the ADPL31610A are listed in *Table 4* and those for the ADPL31610B are listed in *Table 5*. Besides these, there are many other inductors that can be used. Consult each manufacturer for detailed information and for their entire selection of related parts. Ferrite core inductors should be used to obtain the best efficiency, as core losses at frequencies above 1MHz are much lower for ferrite cores than for powdered-iron units. When using coupled inductors, choose one that can handle at least 1A of current without saturating, and ensure that the inductor has a low DCR (copper-wire resistance) to minimize I^2R power losses. If using uncoupled inductors, each inductor need only handle one-half of the total switch current so that 0.5A per inductor is sufficient. A 4.7µH to 15µH coupled inductor or a 15µH to 22µH uncoupled inductor will usually be the best choice for most ADPL31610A designs. For the ADPL31610B, a 2.2µH to 4.7µH coupled inductor or a 3.3µH to 10µH uncoupled inductor will usually suffice. In certain applications such as the charge pump inverting DC/DC converter, only a single inductor is used. In this case, the inductor must carry the entire 1A switch current.

The inductors shown in *Table 5* for use with the ADPL31610B were chosen for their small size. For better efficiency, use similar valued inductors with a larger volume. For instance, the Sumida CR43 series, in values ranging from 3.3µH to 10µH, will give a ADPL31610B application a few percentage points increase in efficiency.

Capacitor Selection

Low ESR (equivalent series resistance) capacitors should be used at the output to minimize the output ripple voltage. Multilayer ceramic capacitors are an excellent choice, as they have an extremely low ESR and are available in very small packages. X5R dielectrics are preferred, followed by X7R, as these materials retain their capacitance over wide voltage and temperature ranges. A 10µF to 22µF output capacitor is sufficient for most ADPL31610A applications while a 4.7µF to 10µF capacitor will suffice for the ADPL31610B. Solid tantalum capacitors can be used, but they will occupy more board area than a ceramic and will have a higher ESR. Always use a capacitor with a sufficient voltage rating.

Ceramic capacitors also make a good choice for the input decoupling capacitor, which should be placed as close as possible to the ADPL31610A/ADPL31610B. A 1μF to 4.7μF input capacitor is sufficient for most applications. *Table 6* shows a list of several ceramic capacitor manufacturers. Consult the manufacturers for detailed information on their entire selection of ceramic parts.

Table 4. Recommended Inductors—ADPL31610A

PART	L(μH)	SIZE (L × W × H) mm	VENDOR
LPS3030-103	10	3 × 3 × 3	Coilcraft *www.coilcraft.com*
LPS4018-103	10	4 × 4 × 1.8	
LPD5030-103	10	4.8 x 4.8 x 2.9	
LPS5030-153	15	5 x 5 x 3	
LPS4018-153	15	4 × 4 × 1.8	
LPS5030-223	22	5 x 5 x 3	
LPS4018-223	22	4 × 4 × 1.8	
74405042100	10	4 × 3.7 × 2	Würth Elektronik *www.we-online.com*
78438357100	10	4.1 x 4.1 x 3.1	
74438336100	10	3 × 3 × 2	
74404063150	15	6 x 6 x 2.8	
74404043150A	15	4 x 4 x 2.5	
LQH43CN100K03L	10	4.5 × 3.2 × 2.8	Murata *www.murata.com*
LQH43CN150K03L	15	4.5 × 3.2 × 2.8	

Table 5. Recommended Inductors—ADPL31610B

PART	L(μH)	SIZE (L × W × H) mm	VENDOR
LPS3015-332	3.3	3.15 × 3.15 × 1.5	Coilcraft *www.coilcraft.com*
LPS3015-472	4.7	3.15 × 3.15 × 1.5	
74438334047	4.7	2.5 × 2 × 1	Würth Elektronik *www.we-online.com*
74438323033	3.3		
LQH3NPH4R7MMEL	4.7	3 x 3 x 1.5	Murata *www.murata.com*
LQH43CN100K03L	10	4.5 × 3.2 × 2.8	

Table 6. Ceramic Capacitor Suppliers

SUPPLIER	WEBSITE
Taiyo Yuden	*www.yuden.com*
AVX	*www.kyocera-avx.com*
Murata	*www.murata.com*

The decision to use either low ESR (ceramic) capacitors or the higher ESR (tantalum or OS-CON) capacitors can affect the stability of the overall system. The ESR of any capacitor, along with the capacitance itself, contributes a zero to the system. For the tantalum and OS-CON capacitors, this zero is located at a lower frequency due to the higher value of the ESR, while the zero of a ceramic capacitor is at a much higher frequency and can generally be ignored.

A phase lead zero can be intentionally introduced by placing a capacitor (C4) in parallel with the resistor (R1) between V_{OUT} and V_{NFB} as shown in *Figure 1*. The frequency of the zero is determined by the following equation.

$$fz = \frac{1}{2\pi \cdot R1 \cdot C4}$$

By choosing the appropriate values for the resistor and capacitor, the zero frequency can be designed to improve the phase margin of the overall converter. The typical target value for the zero frequency is between 20kHz to 60kHz. *Figure 20* shows the transient response of the inverting converter from *Figure 23* without the phase lead capacitor C4. The phase margin is reduced as evidenced by more ringing in both the output voltage and inductor current. A 220pF capacitor for C4 results in better phase margin, which is revealed in *Figure 21* as a more damped response and less overshoot.

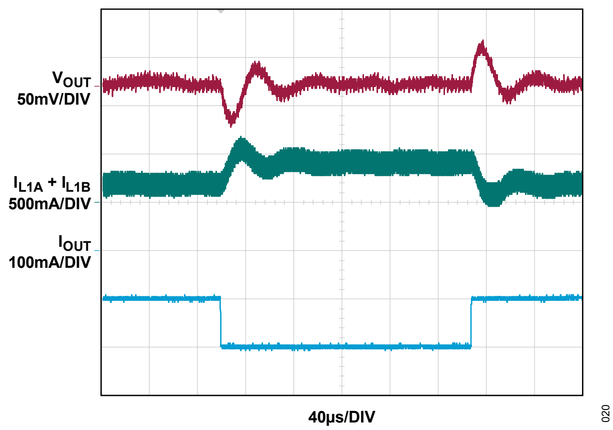


Figure 20. Transient Response of Inverting Converter Without Phase Lead Capacitor

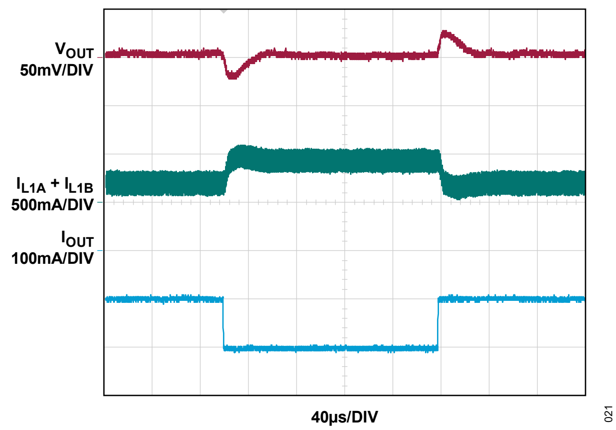


Figure 21. Transient Response of Inverting Converter with 220pF Phase Lead Capacitor

Start-Up/Soft-Start

For most ADPL31610A/ADPL31610B applications, the start-up in rush current can be high. This is an inherent feature of switching regulators in general since the feedback loop is saturated due to V_{OUT} being far from its final value. The regulator tries to charge up the output capacitor as quickly as possible, which results in a large inrush current. *Figure 22* shows a typical oscillograph of the start-up waveform for the application of *Figure 23* starting into a load of 33Ω. The first waveform shows $\overline{\text{SHDN}}$ being pulsed from 0V to 5V. The third waveform shows the input current, which reaches as high as 0.8A. The total time required for the output to reach its final value is approximately ~400µs. For some applications, this initial inrush current may not be acceptable. If a longer start-up time is acceptable, a soft-start circuit consisting of R_{SS} and C_{SS}, as shown in *Figure 23*, can be used to limit inrush current to a lower value. *Figure 24* shows the relevant waveforms with R_{SS} = 15k and C_{SS} = 33nF. Input current, measured at V_{IN}, is limited to a peak value of 0.7A as the time required to reach final value increases to ~1ms.

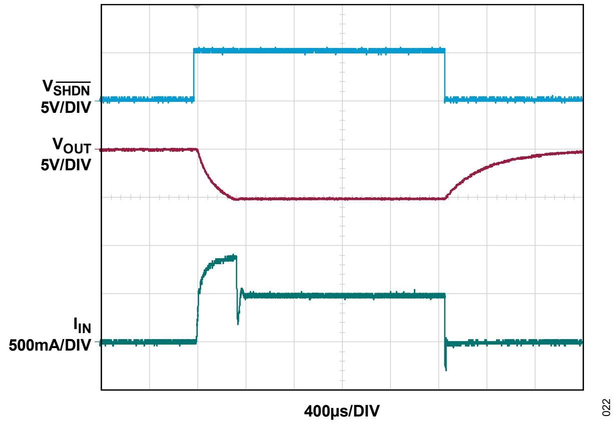


Figure 22. Start-Up Waveforms for 5V to –5V Application (Figure 23).
No Soft-Start Circuit. V_{OUT} Reaches –5V in 500µs; Input Current Peaks at 800mA

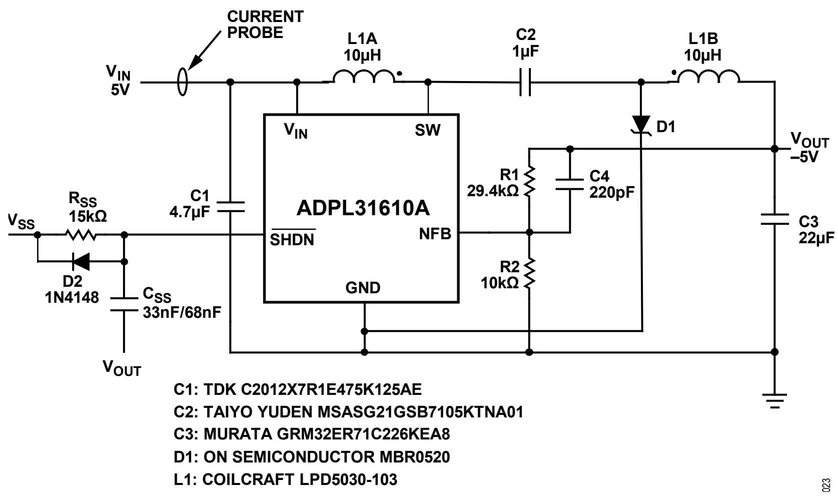


Figure 23. R_{SS} and C_{SS} at $\overline{SHDN}$ Pin Provide Soft-Start to ADPL31610A Inverting Converter

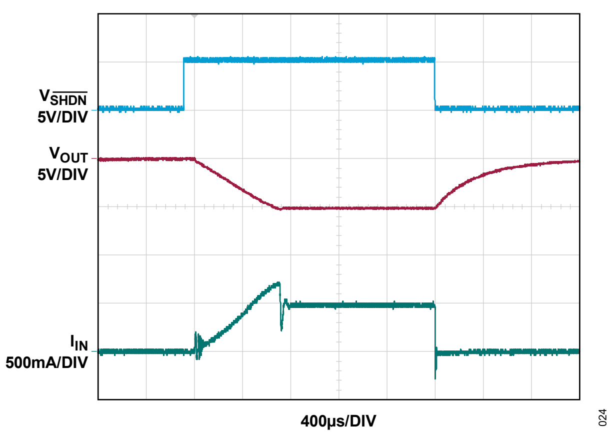


Figure 24. R_{SS} = 15k, C_{SS} = 33nF; V_{OUT} Reaches –5V in 0.8ms; Input Current Peaks at 700mA

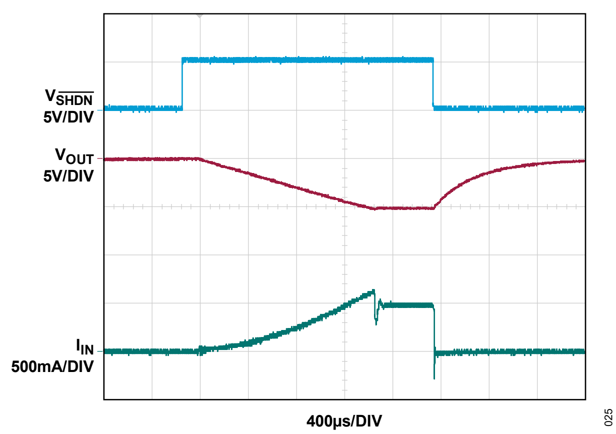


Figure 25. R_{SS} = 15k, C_{SS} = 68nF; V_{OUT} Reaches –5V in 1.5ms; Input Current Peaks at 600mA

In *Figure 23*, C_{SS} has increased to 68nF, resulting in a lower peak input current of 600mA with a V_{OUT} ramp time of 1.6ms. C_{SS} or R_{SS} can be increased further for an even slower ramp, if desired. Diode D2 serves to quickly discharge C_{SS} when V_{SS} is driven low to shut down the device. D2 can be omitted, resulting in a soft-stop slow discharge of the output capacitor.

Diode Selection

A Schottky diode is recommended for use with the ADPL31610A/ADPL31610B. The Onsemi MBR0520 is a very good choice. Where the input to output voltage differential exceeds 20V, use the MBR0530 (a 30V diode). These diodes are rated to handle an average forward current of 0.5A.

Layout Hints

The high-speed operation of the ADPL31610A/ADPL31610B demands careful attention to board layout. It will not achieve the advertised performance with a careless layout. *Figure 26* shows the recommended component placement. The ground cut at the cathode of D1 is essential for low noise operation.

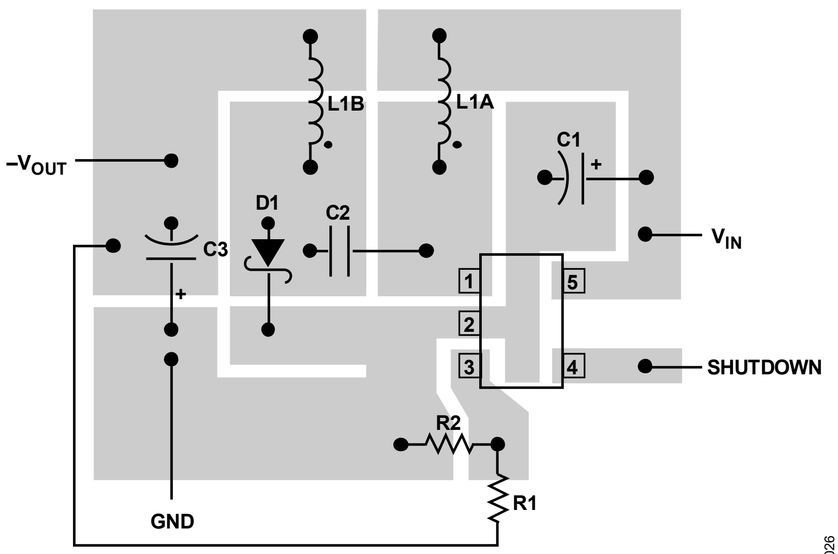


Figure 26. Suggested Component Placement. Note Cut in Ground Copper at D1's Cathode

TYPICAL APPLICATION

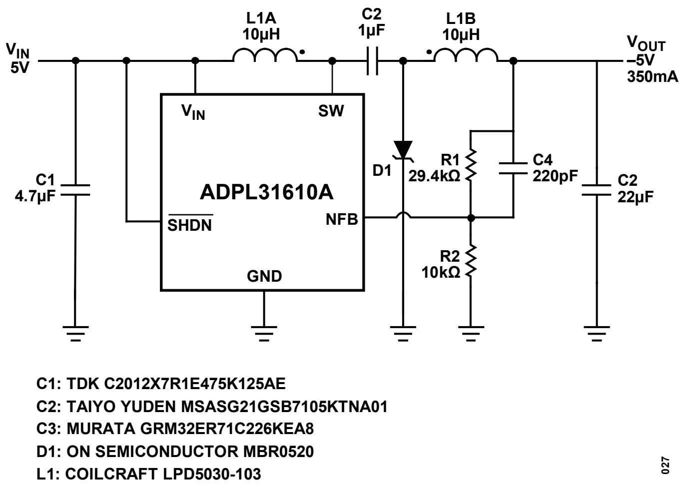


Figure 27. 5V to -5V Inverting Converter

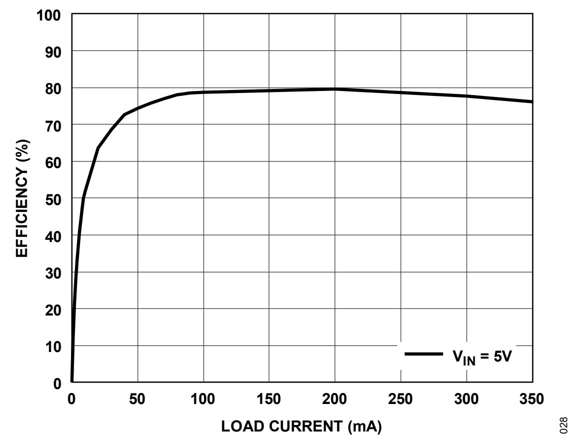


Figure 28. Efficiency

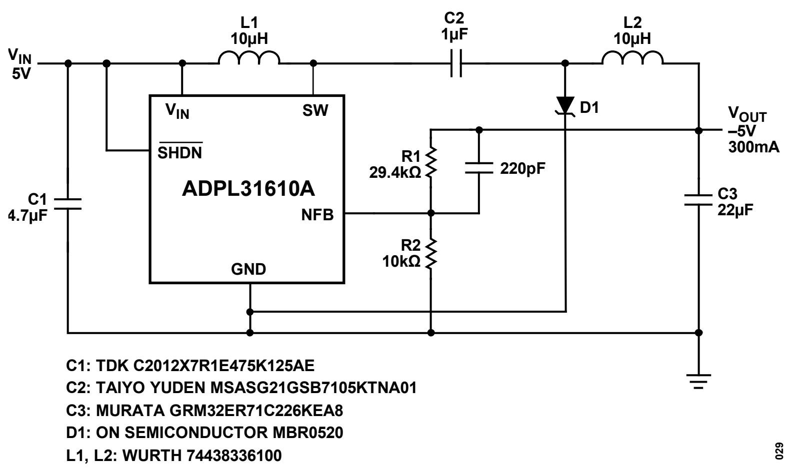


Figure 29. 5V to –5V Inverting Converter Using Uncoupled Inductors

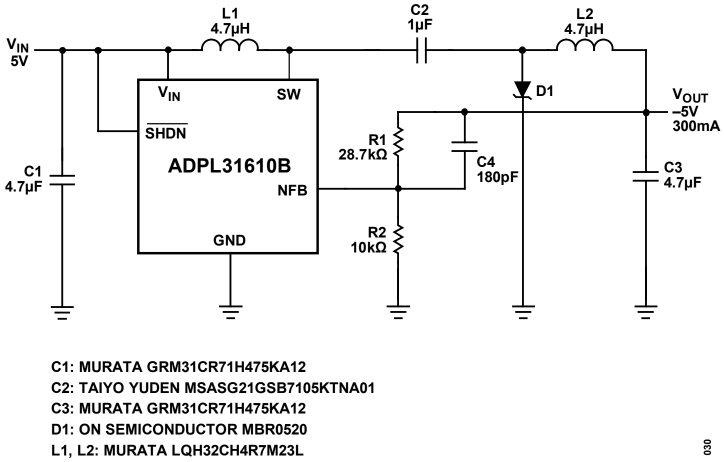


Figure 30. 2.2MHz, 5V to –5V Inverting Converter

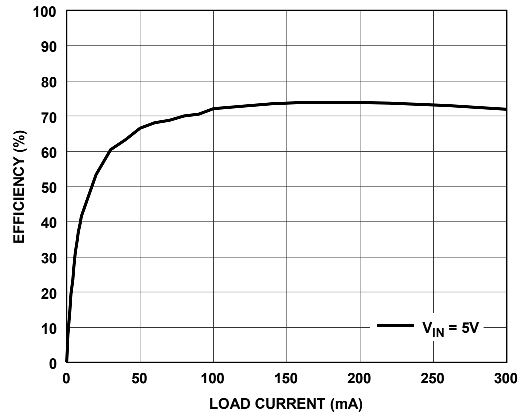


Figure 31. Efficiency

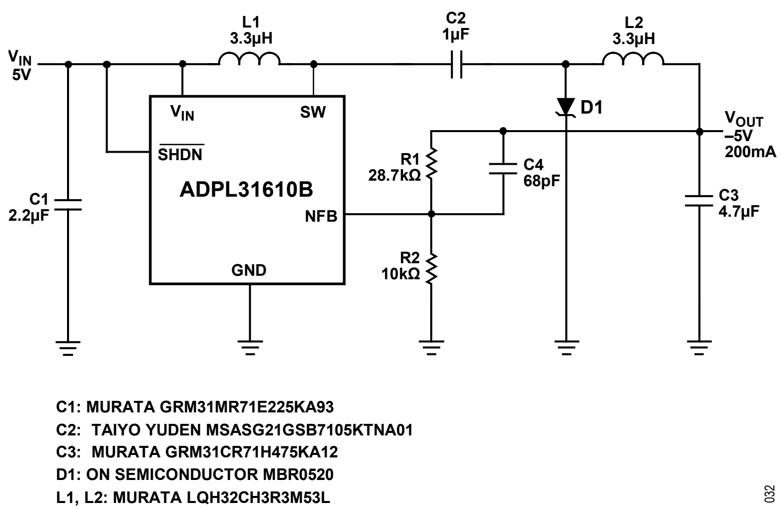


Figure 32. 2.2MHz, 5V to –12V Converter Uses Tiny Chip Inductors

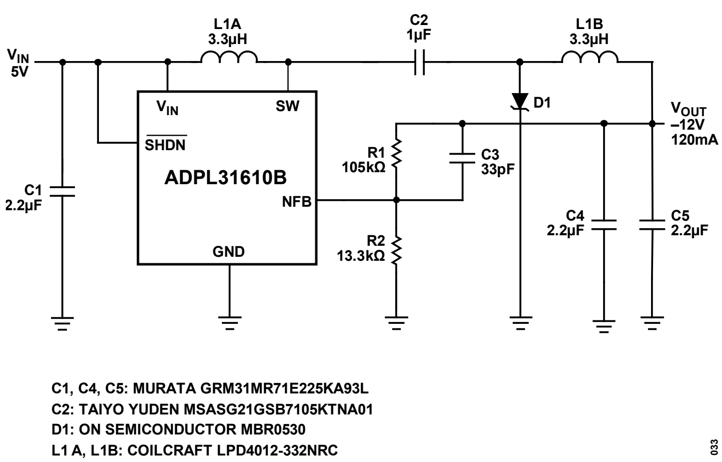


Figure 33. 2.2MHz, 5V to –5V Converter Uses Tiny Chip Inductors

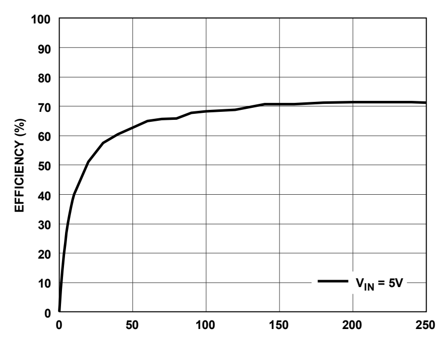


Figure 34. Efficiency

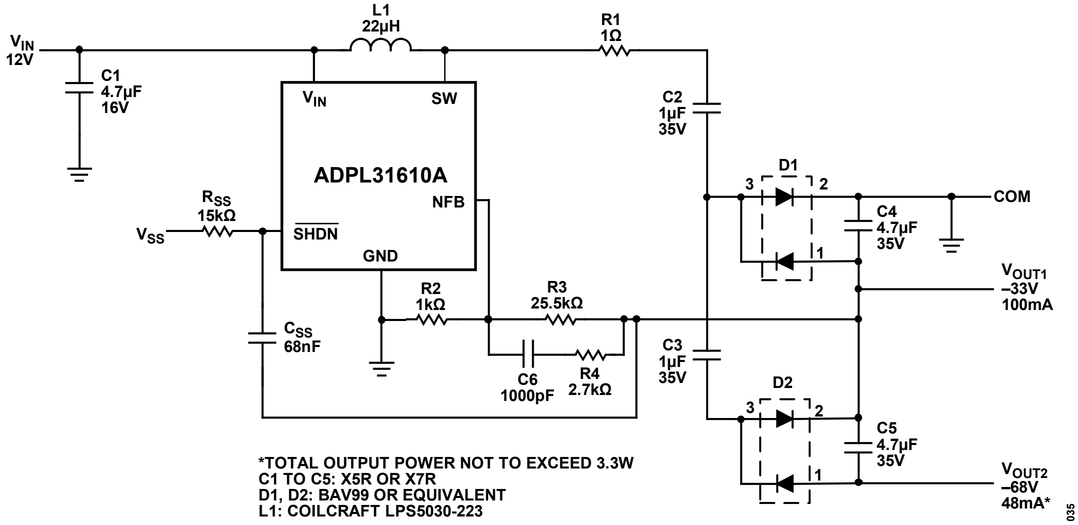


Figure 35. SLIC Power Supply with –33V and –68V Outputs, Uses Soft-Start

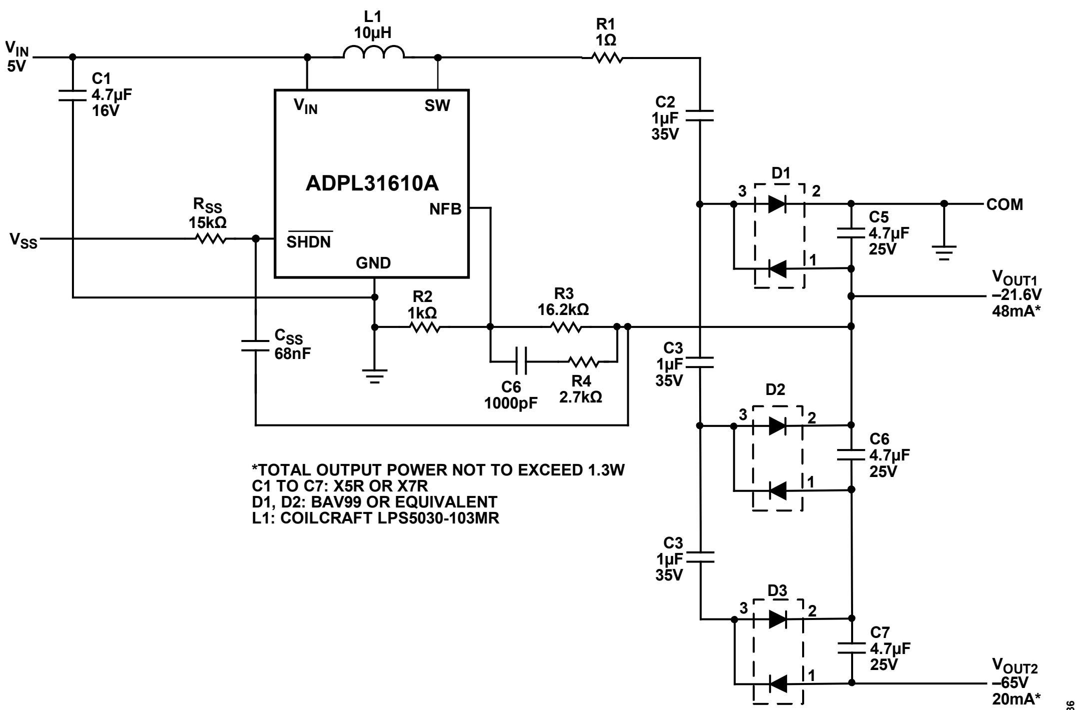
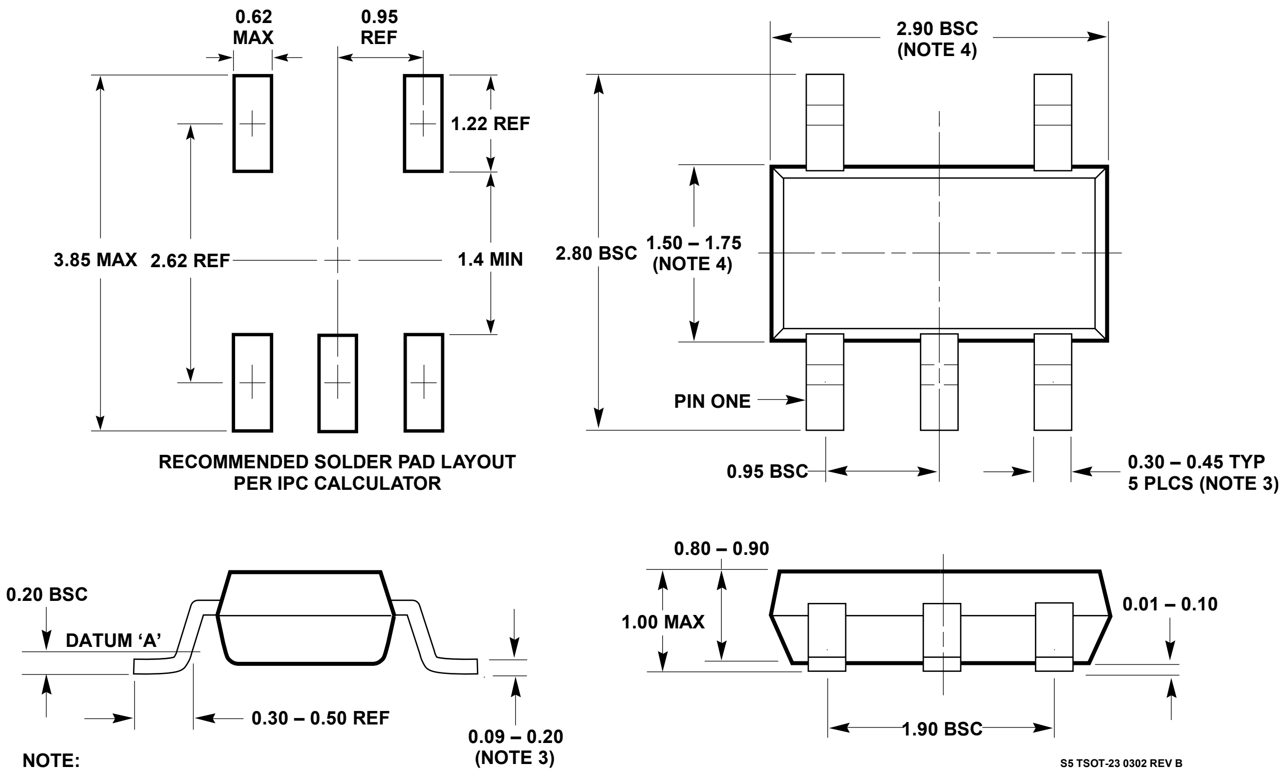


Figure 36. SLIC Power Supply with –21.6V and –65V Outputs, Uses Soft-Start

PACKAGE DESCRIPTION



NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
2. DRAWING NOT TO SCALE
3. DIMENSIONS ARE INCLUSIVE OF PLATING
4. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
5. MOLD FLASH SHALL NOT EXCEED 0.254 mm
6. JEDEC PACKAGE REFERENCE IS MO-193

ORDERING GUIDE

Table 7. Ordering Guide

TAPE AND REEL	PART MARKING*	PACKAGE DESCRIPTION	TEMPERATURE RANGE
ADPL31610AUJZ-RL	LTBZG	S5 PACKAGE 5-LEAD PLASTIC SOT-23	−40°C to 85°C
ADPL31610BUJZ-RL	LTBZF	S5 PACKAGE 5-LEAD PLASTIC SOT-23	−40°C to 85°C

*The temperature grade is identified by a label on the shipping container.

Tape and reel specifications.

Table 8. Evaluation Boards

PART NUMBER	DESCRIPTION
EVAL-ADPL31610-AZ	Evaluates ADPL31610A and ADPL31610B in -12V Output Voltage Application

REVISION HISTORY

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGE NUMBER
0	01/26	Initial Release	—
1	01/26	Updated data sheet title from ADPL31610A/ADPL31610B to ADPL31610	1-19