Analog Engineer's Circuit

Optimized Power-Supply Circuit Solution for DAC81416 High-Voltage Output

TEXAS INSTRUMENTS

Data Converters

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Design Objective

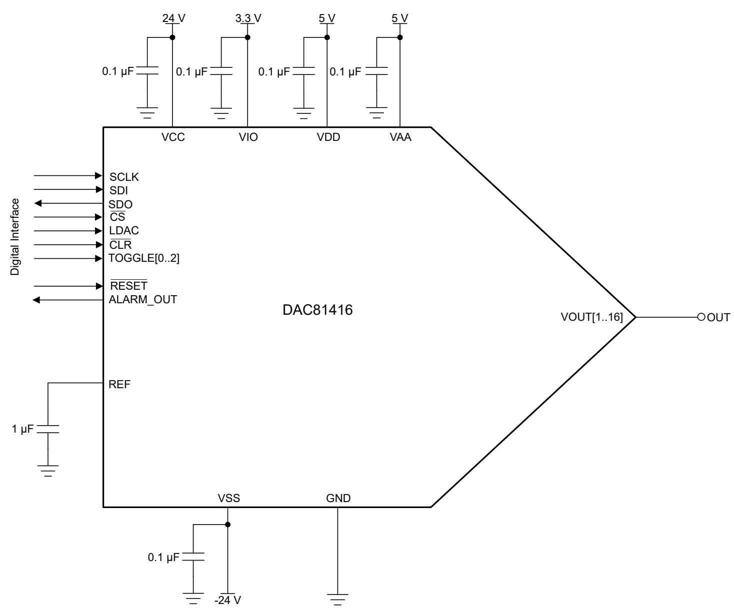
Key Input Parameter	Key Output Signal	Recommended Device
Supply Voltage: 11.5 V to 12 V Efficiency: ≥ 90%	Output Voltage: ±24 V at 500 mA	DAC81416, DAC81404, DAC61416, DAC61402, LM51571, LM25776

Objective: *Design a power-supply solution to optimize the output of DAC81416 high-voltage output.*

Design Description

This application note describes how to design a power supply to power the high voltage output of the DAC81416 using a single 12-V input. The proposed power supply is capable of providing 500 mA of current for a high-voltage output from the DAC. The DAC81416, DAC71416, and DAC61416 (DACx1416) are a pin-compatible family of 16-channel, buffered, high-voltage output digital-to analog converters (DACs) with 16-bit, 14-bit, and 12-bit resolution. A user-selectable output configuration enables full-scale bipolar output voltages of ±20 V, ±10 V, ±5 V or ±2.5 V, and full-scale unipolar output voltages of 40 V, 20 V, 10 V or 5 V.

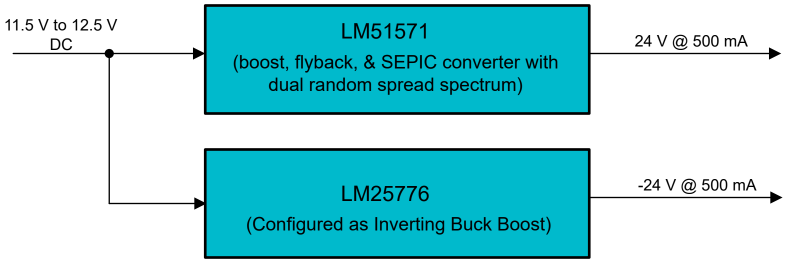
The DACx1416 requires five power-supply inputs: VIO, VDD, VAA, VCC, and VSS. VDD and VAA should be at the same level. For high-voltage output options like ±20 V, VCC and VSS should be ±24 V to account for the headroom and footroom requirements for the output buffer of the DAC81416. For unipolar output voltage (0 V to 40 V), the minimum VCC supply required is 42 V.



Power-Supply Scheme

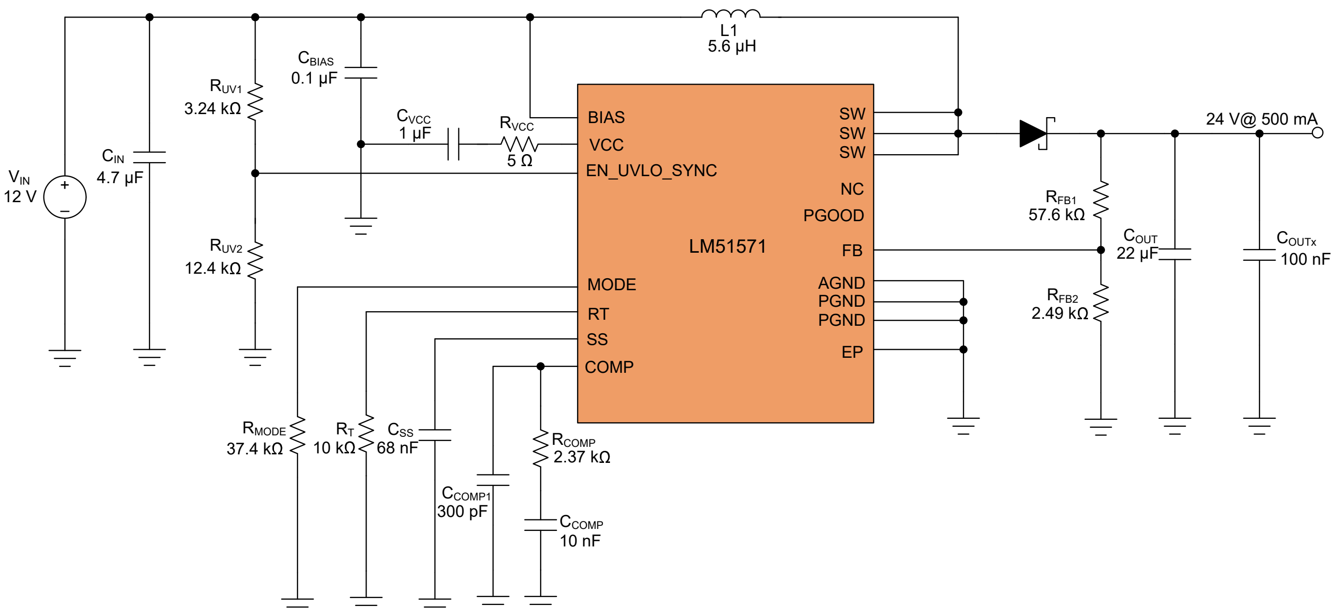
To generate the 24-V VCC supply, use LM51571 in boost configuration. The LM5157x-Q1 device is a wide input range, non-synchronous boost converter with integrated 50-V, 6.5-A (LM5157-Q1) or 50-V, 4.33-A (LM51571-Q1) power switch. The device can be used in boost, SEPIC, and flyback topologies.

The –24-V VSS supply is generated by using the LM25576 in an inverting buck boost configuration. Operating with an input voltage range of 6 V to 42 V, the LM25576 delivers 3 A of continuous output current with an integrated 170-mΩ N-Channel MOSFET



Detailed Design Procedure for LM51571

Custom Design With WEBENCH® Tools for LM51571



Click here to create a custom design using the device with the WEBENCH® Power Designer.

- Start by entering the input voltage (V_{IN}), output voltage (V_{OUT}), and output current (IOUT) requirements into WEBENCH® . For this design V_{IN} = 12 V (typical), V_{OUT} = 24 V, I_{OUT} = 500 mA
- Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial in WEBENCH Power Designer.
- Run electrical simulations to see important waveforms and circuit performance (If supported by the device). Otherwise download the spice model from website and simulate the circuit using PSpice® for TI

Design Notes for LM51571

- When selecting the inductor (L1), consider three key parameters: inductor current ripple ratio (RR), falling slope of the inductor current, and Right Half Plane (RHP) zero frequency (f_{RHP}). RR is selected to have a balance between core loss and copper loss. The falling slope of the inductor current must be low enough to prevent subharmonic oscillation at high duty cycle (additional RSL resistor is required, if not). Higher f_{RHP} (lower inductance) allows a higher crossover frequency and is always preferred when using a small value output capacitor. The inductance value can be selected to set the inductor current ripple between 30% and

70% of the average inductor current to achieve a good compromise between RR, f_{RHP}, and inductor falling slope

- To set the output regulation target, select the feedback resistor values as shown in the following equation:

$$V_{OUT} = V_{REF} \times {}^{R_{FB1}}/_{R_{FB2}} \tag{1}$$

where:

– V_{REF} = 1 V (typical)

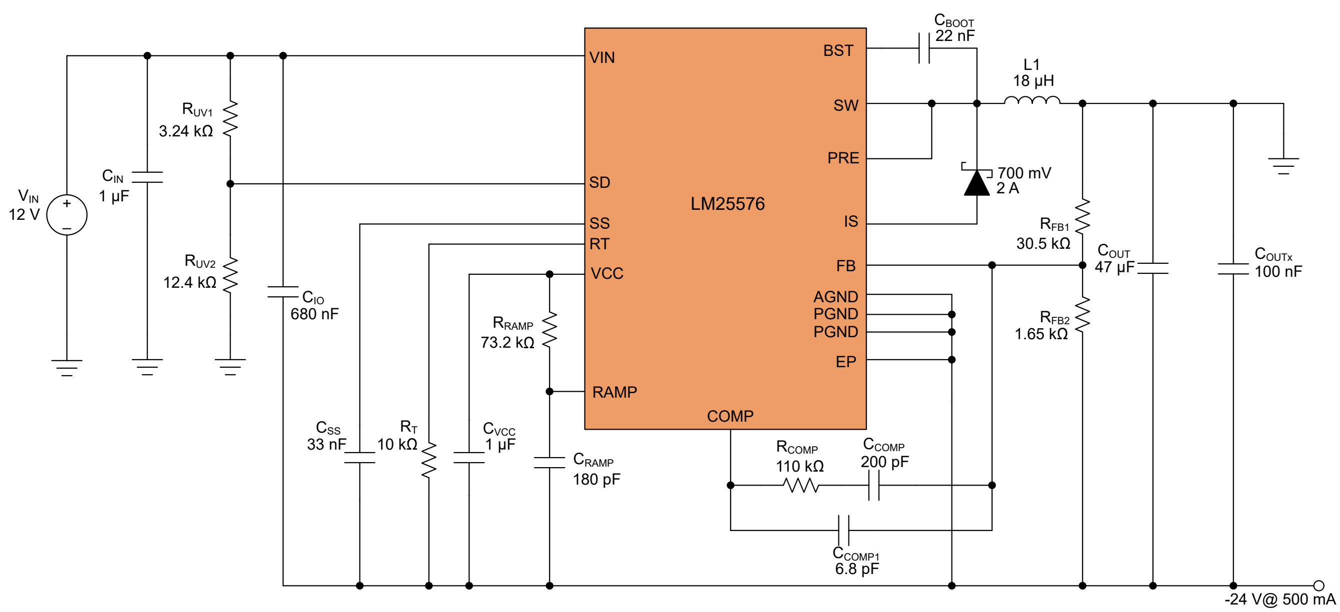
- There are a few ways to select the proper value of the output capacitor (C_{OUT}). Select the output capacitor value based on output voltage ripple, output overshoot, or undershoot due to load transient. The ripple current rating of the output capacitors must be enough to handle the output ripple current. By using multiple output capacitors, the ripple current can be split allowing for a capacitor with a lower ripple current to be chosen.
- A Schottky diode is the preferred type for a D1 diode due to its low forward voltage drop and small reverse recovery charge. Low reverse-leakage current is an important parameter when selecting the Schottky diode. The diode must be rated to handle the maximum output voltage plus any switching node ringing. Also, it must be able to handle the average output current.
- The switching frequency of the device can be set by a single resistor connected between RT and the GND pins using the following equation:

$$R_T = 2.21 \times 10^{10}/_{f_{RT(TYPICAL)}} - 955 \tag{2}$$

See the *How to Design a Boost Converter Using LM5155* application report for calculating compensation components or using WEBENCH Power Designer.

Detailed Design Procedure for LM25576

Custom Design With WEBENCH® Tools for LM25576



- RT sets the oscillator switching frequency. Generally, higher-frequency applications are smaller but have higher losses. Operation at 500 kHz was selected for this example as a reasonable compromise for both small size and high efficiency. RT is calculated using the following equation:

$$R_T = \left({}^{1}/_{f_S}\right) - 580 \times 10^{-9} \Big/ 135 \times 10^{-2} \tag{3}$$

- The inductor value is determined based on the operating frequency, load current, ripple current, and the minimum and maximum input voltage ($V_{IN(min)}$, $V_{IN(max)}$). To keep the circuit in continuous conduction mode

(CCM), the maximum ripple current (I_{RIPPLE}) should be less than twice the minimum load current, or 0.1 $A_{p\text{-}p}$. Using this value of ripple current, the value of inductor (L1) is calculated using the following equation:

$$L1 = V_{OUT} \times \left(V_{IN(MAX)} - V_{OUT}\right) / I_{RIPPLE} \times f_S \times V_{IN(MAX)} \quad (4)$$

- With the inductor value selected, the value of C_{RAMP} necessary for the emulation ramp circuit is calculated using the following equation:

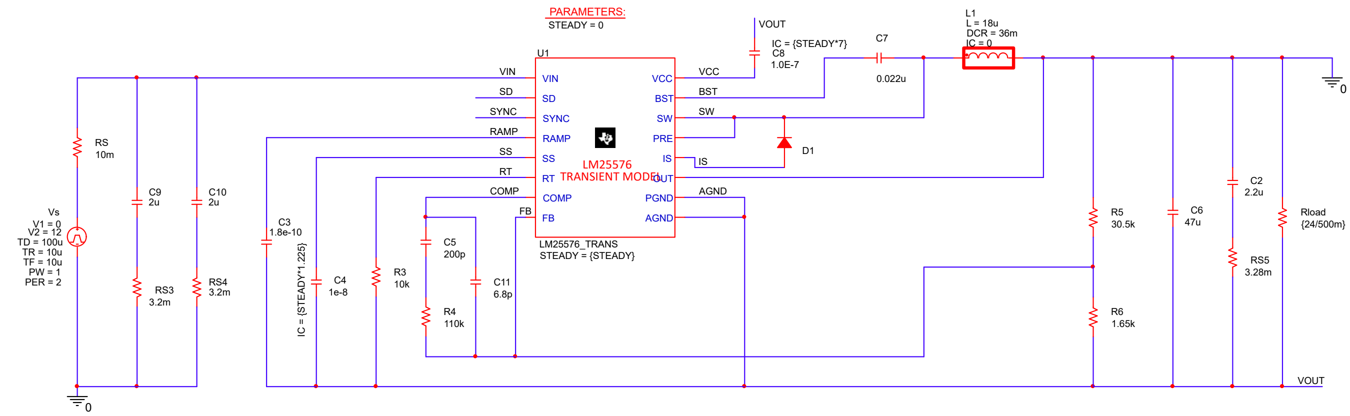
$$C_{RAMP} = L1 \times 10^{-5} \quad (5)$$

- A Schottky type re-circulating diode is required for all LM25576 applications. Ultra-fast diodes are not recommended and may result in damage to the device due to reverse recovery current transients. The near-ideal reverse recovery characteristics and low forward voltage drop are particularly important diode characteristics for high input voltage and low output voltage applications common to the LM25576. The reverse recovery characteristic determines how long the current surge lasts each cycle when the buck switch is turned on. The reverse recovery characteristics of Schottky diodes minimize the peak instantaneous power in the buck switch occurring during turn-on each cycle. The resulting switching losses of the buck switch are significantly reduced when using a Schottky diode. The reverse breakdown rating should be selected for the maximum V_{IN}, plus some safety margin.
- The regulator supply voltage has a large source impedance at the switching frequency. Low ESR ceramic input capacitors are necessary to limit the ripple voltage at the V_{IN} pin while supplying most of the switch current during the on-time. When the buck switch turns on, the current into the V_{IN} pin steps to the lower peak of the inductor current waveform, ramps up to the peak value, then drops to zero at turn-off.

For more information, see the *Working with Inverting Buck-Boost Converters* application report.

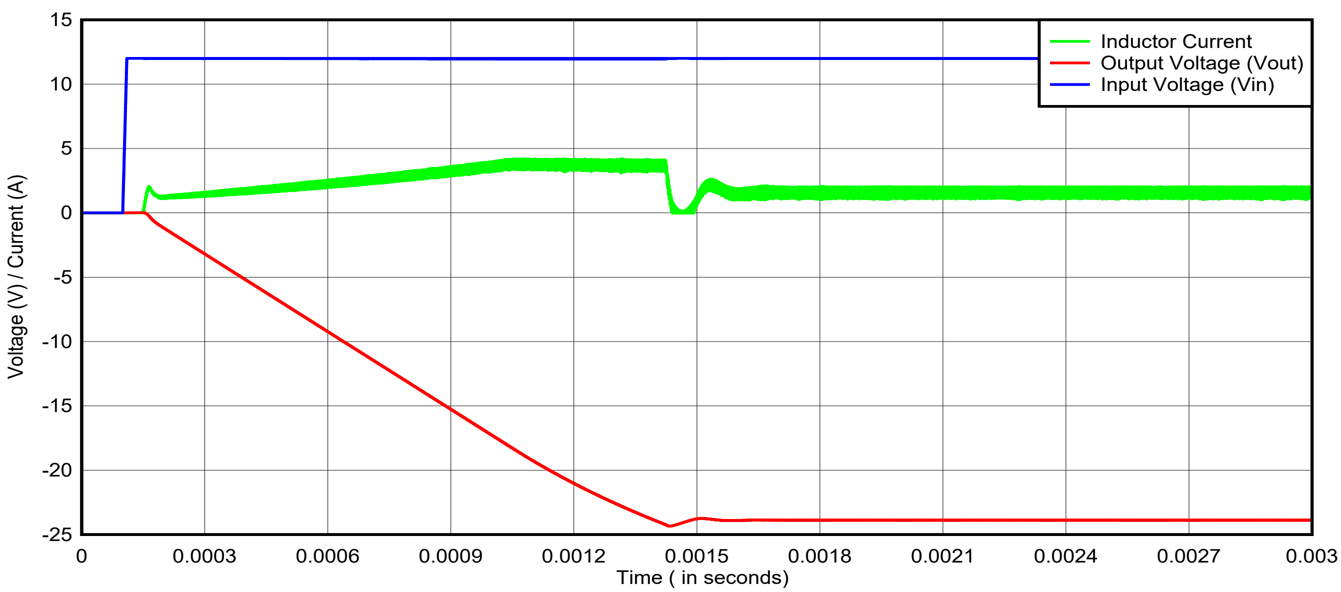
Design Simulations

The following schematic is used for the simulation of the LM25576 in inverting buck boost mode with the following conditions: V_{IN} = 12 V, V_{OUT} = –24 V, I_{OUT} = 500 mA. The LM25576 inverting transient model is used for this simulation.



Transient Simulation Results

This simulation shows the steady-state behavior of LM25576 in inverting buck boost configuration. The output voltage shown in the red curve settled to –24.1 V after approximately 2 ms. The peak inductor current is 3.3 A.



Design Featured Devices

Device	Key Features	Link
DAC81416	DACx1416 16-channel, 16-bit, 14-bit, and 12-bit high-voltage output DACs with internal reference	DAC81416
LM51571	4-A, 50-V, 2.2-MHz wide V_{IN} boost, flyback, and SEPIC converter with dual random spread Spectrum	LM51571-Q1
LM25576	4.5 V to 42 V, 3-A Step-Down Switching regulator	LM25576

Find other possible devices using the Parametric search tool.

Design References

See *Analog Engineer's Circuit Cookbooks* for TI's comprehensive circuit library.

Download the companion *LM25576 PSpice Model*

Download the companion *LM51571 PSpice Model*

Download *PSpice® for TI* to simulate the previously-mentioned circuits.

Additional Resources

- Texas Instruments, *DAC81416 Evaluation Module*
- Texas Instruments, *LM25576 Product Page*
- Texas Instruments, *LM51571-Q1 Evaluation Module*

For direct support from TI Engineers use the E2E community

e2e.ti.com