

# Space-Grade Unipolar Negative Voltage Source From Unipolar DAC Circuit



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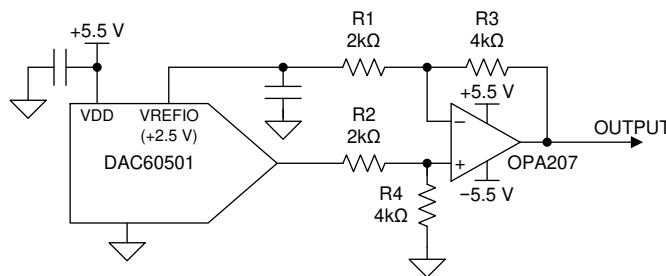
## Design Goals

DAC Supply Voltage	Amplifier Supply Voltage	DAC Output Range	Output Voltage Range	Output Current Capability	Power-On Reset Output
5.5V	±5.5V	0V to 2.5V	-5V to 0V	±20mA	-5V

## Design Description

This circuit shows how to convert a positive unipolar digital-to-analog (DAC) output to a negative unipolar output using only an external operational amplifier (op amp) and resistors. In many applications, such as [active antenna systems](#) (AAS) and [macro remote radio units](#) (RRU), a DAC output is used to bias the gate of gallium nitride (GaN) power amplifier (PA). For these amplifiers to be powered down, a negative potential must be applied to the gate. As such, it is beneficial to have the gate voltage be negative by default. PA biasing applications also require current output source and sink capability that usually exceeds that of most DACs.

These design goals are achieved by utilizing a voltage-output DAC that also features a reference. The DAC output and reference output are connected to differential amplifier with the reference connected to the inverting input. This enables the zero-scale output of the DAC to set the output of the amplifier to its negative full-scale value.



## Design Notes

1. At power-on, the DAC output will assume a default value. This value can be configured in some devices by connecting a reset-select pin to a high or low potential, which selects a start-up value of zero-scale or mid-scale. In [AAS](#) designs, it is beneficial to start at zero-scale to ensure the PA is disabled. Other applications may require a DAC to start at mid-scale.
2. The amplifier selected must provide the output current required by the application. Rail-to-rail outputs allow the op amp power supplies to be minimized without clipping the desired output range of the circuit. In [AAS](#) applications, there is usually a capacitive load on the output as well, so capacitive load stability is important to consider.
3. The op amp must feature a bipolar supply, as the op amp inputs will always be greater than or equal to 0V in operation. The negative supply must be low enough to allow the output to reach its most negative value.

## Design Steps

1. Select a DAC for the circuit based on initial on key requirements, such as the resolution, channel count, output accuracy, and power supply. These performance requirements are variable and application dependent. However, a few additional items must be considered as well.
  - The reference used to provide the offset of the differential amplifier will be required to source current. Current will flow from the reference through the resistors in the feedback network (R1 and R3) to the output of the amplifier. The maximum current would occur when the DAC output is at 0V and the output of the amplifier is at its most negative potential. The following equation shows how to calculate this current. If the current load is too great for the desired DAC reference, then a unity-gain buffer can be added to the circuit.

$$I_{\text{REF-MAX}} = \frac{V_{\text{REF}} - V_{\text{OUT-MIN}}}{R1 + R3}$$

- The output of DAC will also have to drive a resistive load, comprised of R2 and R4. The maximum required current drive capability is expressed in the following equation:

$$I_{\text{DAC-MAX}} = \frac{V_{\text{DAC-MAX}}}{R2 + R4}$$

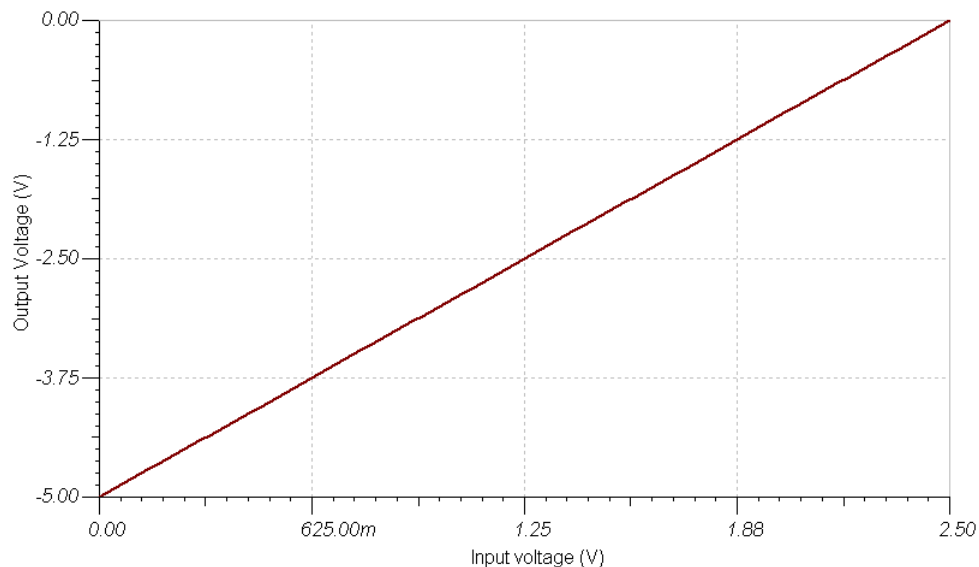
- DACs which have an output range from 0V to  $V_{\text{REF}}$  allow the resolution to be optimized for the negative output.
2. The output range of the system can be calculated using the following equation. This is assuming that R3 and R4 are equal and R1 and R2 are equal.

$$V_{\text{OUT}} = \frac{R3}{R1}(V_{\text{DAC}} - V_{\text{REF}})$$

3. Select resistor values to achieve a balance between output noise and power consumption. Lower resistor values will minimize the thermal noise of the resistors, but increase the power dissipation. The minimum resistance values are limited by the output drive capabilities of the DAC and reference output. The accuracy of the output transfer function is heavily dependent on the accuracy of the resistor ratios. High-accuracy resistors are recommended.

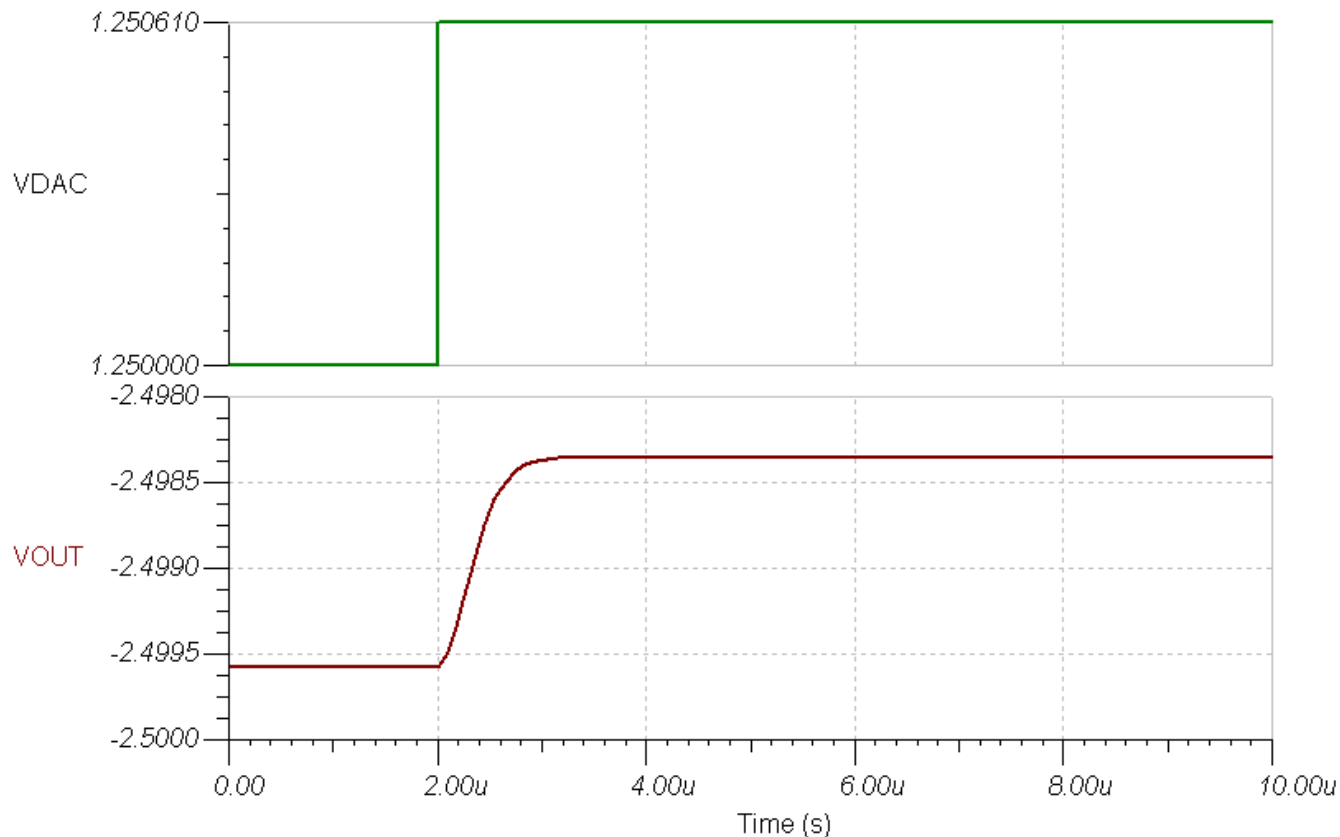
## DC Transfer Characteristics

The following simulation shows the output transfer function of the circuit:



## Small-Step Response

The following figure displays an LSB step response of the circuit with 15-pF load on the output.



## Design Featured Devices

Device	Key Features	Link	Other Possible Devices
DAC60501	12-bit, 1-LSB, voltage-output digital-to-analog converter with precision internal reference.	<a href="#">True 12-bit, 1-ch, SPI/I2C, voltage-output DAC in WSON package with precision internal reference</a>	<a href="#">Digital-to-analog converters (DACs)</a>
OPA207	Low-power, high-precision, low-noise, rail-to-rail output, operational amplifier	<a href="#">Low power (350µA), low noise (7.5nV/√Hz), high precision (100µV, 0.2µV/°C), bipolar RRO op amp</a>	<a href="#">Precision op amps (Vos&lt;1mV)</a>

## Design References

Texas Instruments, [companion simulation files for this circuit](#), software support

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