Unipolar voltage output DAC to bipolar voltage output circuit

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Design Goals

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<th>DAC Supply Voltage</th>
<th>Amplifier Supply Voltage</th>
<th>DAC Voltage</th>
<th>Output Voltage</th>
<th>Error</th>
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<td>5V</td>
<td>±15V</td>
<td>0V–2.5V</td>
<td>±10V</td>
<td>&lt;0.25% FSR</td>
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Design Description

The unipolar to bipolar output voltage circuit converts the voltage from a unipolar DAC into a bipolar voltage span. The circuit consists of a DAC, op amp, voltage reference, and 3 resistors to set the scale and span of the bipolar output voltage. This circuit is commonly used in PLC Analog Output Modules, Field Transmitters, and other applications requiring a programmable bipolar voltage.

Design Notes

1. Choose a DAC with low gain error, offset error, drift, and INL. A high-voltage op amp with low offset voltage and low offset voltage drift should be used.
2. Use precision 0.1% or better tolerance resistors with low temperature drift.
3. To minimize solution size a DAC with integrated reference may be used.
### Design Steps

1. The voltage output based on DAC voltage, reference voltage, and resistors is given by:

   \[ V_{OUT} = \left( 1 + \frac{R_{FB}}{R_{G1}} + \frac{R_{FB}}{R_{G2}} \right) V_{DAC} - \frac{R_{FB}}{R_{G1}} V_{REF} \]

2. Set the DAC voltage to zero to calculate ratio of \( R_{FB} \) and \( R_{G1} \) to create the desired negative full-scale output. Select standard resistor values to produce this gain.

   \[ \frac{V_{NegativeFS}}{V_{REF}} = \frac{R_{FB}}{R_{G1}} = \frac{10V}{2.5V} = \frac{33k\Omega}{8.25k\Omega} \]

3. Calculate \( R_{G2} \) based on the full-scale range required, in this case 20V to produce ±10V range.

   \[ R_{G2} = \frac{V_{FSR}}{V_{DAC}} \cdot \frac{R_{FB}}{R_{G1}} = \frac{20V}{33k\Omega} \cdot \frac{33k\Omega}{8.25k\Omega} = 11k\Omega \]

4. The output error can be approximated based on DAC TUE, amplifier offset voltage, resistor tolerance, and reference initial accuracy using root sum square (RSS) analysis.

   \[ \text{Output TUE(\% FSR)} = \sqrt{TUE_{DAC}^2 + \left( \frac{V_{diskAmplifier}}{FSR} \times 100 \right)^2 + T_{offsetDAC}^2 + T_{offsetGain}^2 + T_{offsetBias}^2 + \text{Accuracy_{Ref}}^2} = \sqrt{0.1^2 + \left( \frac{8uV}{2.5V} \times 100 \right)^2 + 3 \times 0.1^2 + 0.1^2} = 0.224\% \text{ FSR} \]
DC Transfer Characteristic

Small Signal Step Response
## Devices

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### Design References

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

### Links to Key Files

TI Design TIDP125, *Bipolar ±10V Output from a Unipolar DAC for Industrial Voltage Drivers.*


For direct support from TI Engineers use the E2E community:

[e2e.ti.com](http://e2e.ti.com)

### Other Links:

Precision DAC Learning Center

[http://www.ti.com/pdacs](http://www.ti.com/pdacs)
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