Analog Output Subsystem:

OPA192 & OPA197 Integration

# 1. Introduction

This document presents a detailed design for the analog output stage of a Data Acquisition (DAQ) system, ensuring accurate signal conditioning, stability, and robustness.

The DAQ outputs are classified into two voltage stages:

* DAC0-3 (3.3V Stage)
  + Uses OPA192 as the buffer op-amp.
  + Output range: 0V to 3.3V.
* DAC4-7 (±12V Stage)
  + Uses OPA197 for high-voltage amplification.
  + Output range: -12V to +12V.

## 1.1. Design Objectives

The core objectives of this design include:

1. Accurate DAC output scaling
2. Ensuring stability with capacitive loads
3. Consistent bandwidth (~100 kHz) across both stages
4. Minimized voltage drop across R\_ISO
5. Optimized resistor values for precise scaling

# 2. DAC8568 Output Scaling for 3.3V and ±12V Stages

The DAC8568 generates a 0V to 2.5V output, which must be amplified and shifted to match the respective voltage stages.

## 2.1. Output Calculation

For a generalized output scaling formula, the output voltage is given by:

Where:

* DAC output voltage (0 to 2.5V)
* 2.5V DAC reference
* Feedback resistor
* Gain resistors

The resistor network is designed separately for each voltage stage.

# 3. DAC8568 Output Scaling for 3.3V Stage

The 3.3V stage (DAC0-3) uses OPA192 in a non-inverting amplifier configuration.

## 3.1. Gain Calculation

The gain is:

## 3.2. Resistor Selection

For a non-inverting amplifier, the gain is:

Choosing :

## 3.3. Output Resolution Calculation

* DAC resolution:
* Scaled output resolution:

## 3.4. Final Resistor Values

| **Component** | **Value** |
| --- | --- |
| **​** |  |
| **​** |  |

# 4. DAC8568 Output Scaling for ±12V Stage

The ±12V stage (DAC4-7) uses OPA197 to achieve high-voltage amplification.

## 4.1. Gain Calculation

The gain is:

## 4.2. Resistor Selection

For a non-inverting amplifier, the gain is:

Choosing :

## 4.3. Output Resolution Calculation

Scaled output resolution:

## 4.4. Final Resistor Values

| **Component** | **Value** |
| --- | --- |
| **​** |  |
| **​** |  |

# 5. Stability Considerations

## 5.1. OPA192 (3.3V Stage)

* Low-power op-amp with 1 MHz GBW.
* Requires for stability with higher capacitive loads.
* Chosen values:

## 5.2. OPA197 (±12V Stage)

* Precision op-amp with 2.5 MHz GBW.
* Stabilized by R\_ISO for capacitive loads.
* Chosen values:

# 6. Load Stability & Voltage Drop Analysis

The cutoff frequency for stability is:

For the 3.3V stage:

For the ±12V stage:

Voltage drop across :

For 5mA output current:

* OPA192 (3.3V Stage, )
* OPA197 (±12V Stage, )

# 7. Final Optimized Circuit

## 7.1. Parameter Summary

| DAC Channel | Op-Amp | Supply Voltage | Output Voltage Range |  |  | Cutoff Frequency (kHz) |
| --- | --- | --- | --- | --- | --- | --- |
| DAC0-3 | OPA192 | 5V | 0V to 3.3V | 68Ω | 20nF | 117 kHz |
| DAC4-7 | OPA197 | ±12V | -12V to +12V | 110Ω | 12nF | 120 kHz |

A képen diagram, szöveg, sor, Diagram látható

Előfordulhat, hogy a mesterséges intelligencia által létrehozott tartalom helytelen.

A képen diagram, szöveg, sor, Tervrajz látható

Előfordulhat, hogy a mesterséges intelligencia által létrehozott tartalom helytelen.

# 8. Purpose of the 10kΩ Pulldown Resistors

The pulldown resistors serve a critical role in ensuring signal stability by preventing the op-amp’s inverting input from floating if the DAC output becomes high impedance (tri-stated or powered down). A floating inverting input can result in:

* Op-amp instability or oscillations
* Increased noise sensitivity
* Unexpected voltage drift due to leakage currents

To evaluate whether the 10kΩ resistors are necessary, we analyze their voltage effect and impact on circuit stability for both the 3.3V and ±12V output stages.

## 8.1. Voltage Division & Leakage Current Analysis

If the DAC output enters high impedance mode (open circuit), the pulldown resistor determines the voltage at the op-amp's inverting input.

## 8.2. Calculation for the 3.3V Stage (OPA192)

* Op-amp: OPA192 (low-power, rail-to-rail, 5V single-supply)
* Pulldown resistor:
* DAC reference voltage:
* Op-amp bias current (typical):
* Leakage current estimate (conservative assumption)

Voltage at the inverting input when DAC is in high-Z mode:

## 8.3. Calculation for the ±12V Stage (OPA197)

* Op-amp: OPA197 (precision, ±12V supply)
* Pulldown resistor:
* DAC reference voltage:
* Op-amp bias current (typical):
* Leakage current estimate

Voltage at the inverting input when DAC is in high-Z mode:

## 8.4 Impact on Stability & Frequency Response

The inverting input is highly sensitive. Without the pulldown resistor:

* Any residual charge on the PCB traces could cause voltage drift.
* Leakage currents from the DAC or op-amp could accumulate, shifting the voltage.
* Noise from adjacent signals could capacitively couple into the floating node, leading to oscillations.

Adding prevents floating and keeps the circuit deterministic even if the DAC is disabled.

## 8.5. Power Dissipation Analysis

For continuous operation, power consumption due to the pulldown resistors is:

The 3.3V Stage:

The ±12V Stage: