CS4304P/8P DAC Output Summing Guide

Introduction

The CS4304P/8P high-performance DAC devices provide a differential current-mode output that require external components for current-to-voltage (I-to-V) conversion and out-of-band noise filtering. The CS4304P/8P supports the option to combine the DAC signal paths in groups of two, four or a single group of eight channels (eight channels only supported on CS4308P).

This App Note describes the selection of external components for the I-to-V output buffer stage, and the performance improvements that can be achieved using the output-summing configuration.

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1 DAC Output Summing

The CS4304P/8P supports the option to combine the DAC outputs in groups of two, four, or a single group of eight (CS4308P only); this can be used to achieve enhanced dynamic-range performance on the respective paths. A six-channel summing mode is also supported, with DAC1–DAC4 operating in pairs, with DAC5–DAC8 operating individually (CS4308P only).

In the summing configuration, the signal paths are routed and controlled differently to normal operation. The input signals are routed to groups of two or more DACs (depending on the selected configuration), and the grouped paths are each controlled as a single channel.

The DAC output summing is configured using the OUT_SUM_MODE field, as described in the CS4304P/8P datasheet (Section 4.5.3). The summing configurations for CS4304P are described in Table 1.

Table 1 CS4304P DAC Output Summing

Configuration	Description	OUT_SUM_MODE	Output Summing Configuration	Summed Channel Number
Default	4-channel	0x0	OUT1–OUT4 as individual outputs	1–4
DACs combined in groups of two	2-channel input	0x1	OUT1+OUT2 OUT3+OUT4	1 2
DACs combined in groups of four	1-channel input	0x2	OUT1+OUT2+OUT3+OUT4	1

The summing configurations for CS4308P are described in Table 2.

Table 2 CS4308P DAC Output Summing

Configuration	Description	OUT_SUM_MODE	Output Summing Configuration	Summed Channel Number
Default	8-channel	0x0	OUT1–OUT8 as individual outputs	1–8
DACs combined in groups of two	4-channel input	0x1	OUT1+OUT2 OUT3+OUT4 OUT5+OUT6 OUT7+OUT8	1 2 3 4
DACs combined in groups of four	2-channel input	0x2	OUT1+OUT2+OUT3+OUT4 OUT5+OUT6+OUT7+OUT8	1 2
DACs combined in groups of eight	1-channel input	0x3	OUT1+OUT2+OUT3+OUT4+OUT5+OUT6+OUT7+OUT8	1
Four DACs combined in groups of two	6-channel input	0x4	OUT1+OUT2 OUT3+OUT4 OUT5–OUT8 as individual outputs	1 2 3-6

In summing configuration, the respective analog output connections must be combined externally to achieve the performance enhancement. The analog outputs are current-mode outputs; the external combining of these outputs results in the summing of the respective output signals.

Note that the increased current in the summing configuration affects the choice of components for the output buffer, as described in the following section.

1.1 External Components

The analog output paths are supported using an external I-to-V output buffer/filter circuit. The recommended external components for the CS4304P/8P output buffer/filter circuit are shown in Figure 1; this circuit produces a 2 V_{RMS} differential output from a full-scale (0 dBFS) digital input.
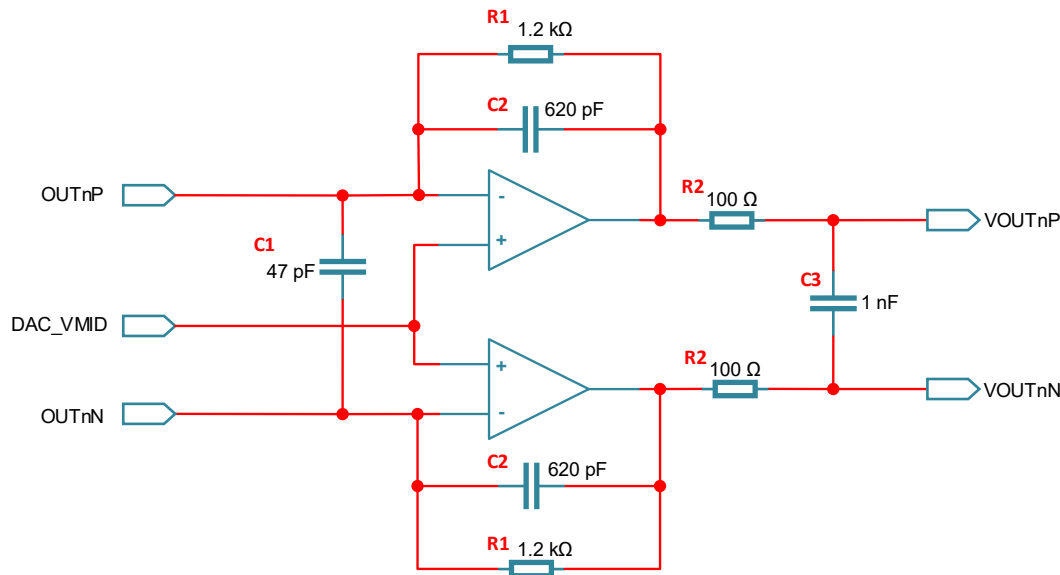

Figure 1: Typical CS4304P/8P Differential Output Buffer/Filter Circuit

The full-scale output voltage is determined by the feedback resistor R1. The required value of R1 also depends on whether the outputs are configured in a summing configuration. The value of R1 can be calculated using the following equation:

$$R_1(k\Omega) = \frac{Full\_scale\ output\ voltage\ (V_{RMS})}{(Numer\ of\ outputs\ summed\ x\ 1.66)}$$

Note: The number of outputs summed is 1, 2, 4, or 8 depending on the applicable summing configuration.

The required value of R1 is shown in Table 3 for a range of typical operating configurations. The THD+N performance may be degraded with increased full-scale output voltage. It must also be considered that low resistance (e.g., 150 Ω) may be incompatible with some op-amp devices.

Table 3 Feedback Resistor (R1) Selection

Configuration	Full-Scale Output Voltage		
	2 V_{RMS}	4 V_{RMS}	8 V_{RMS}
No Summing	1.2 kΩ	2.4 kΩ	4.8 kΩ
2 outputs summed	600 Ω	1.2 kΩ	2.4 kΩ
4 outputs summed	300 Ω	600 Ω	1.2 kΩ
8 outputs summed	150 Ω	300 Ω	600 Ω

A low-pass filter is provided using R1 and C2. The filter should be designed to provide a flat passband for the audio bandwidth, while attenuating out-of-band noise. The –3 dB cut-off frequency (F_C) can be calculated using the following equation:

$$F_C = \frac{1}{2\pi R_1 C_2}$$

The recommended value of C2 is shown in Table 4 for different values of R1. The recommended configuration provides a –3 dB cut-off around 220 Hz.

Table 4 Feedback Capacitor (C2) Selection

Resistor	Capacitor	-3 dB Cutoff
4.8 kΩ	150 pF	221 kHz
2.4 kΩ	300 pF	221 kHz
1.2 kΩ	620 pF	214 kHz
600 Ω	1.2 nF	221 kHz
300 Ω	2.4 nF	221 kHz
150 Ω	4.7 nF	226 kHz

Additional filtering is provided using R2 and C3. The recommended components attenuate out-of-band noise, while minimizing the capacitive loading on the op-amp device. Using the values shown, the –3 dB cut-off frequency (F_C) can be calculated using the following equation:

$$F_C = \frac{1}{2\pi R_2 2 C_3} = \frac{1}{2 \times \pi \times 100 \times 2 \times 1 \times 10^{-9}} = 795.8 \, kHz$$

The recommended value of C1 is 47 pF, assuming output summing is not used. If the outputs are configured in a summing configuration, C1 should be increased to 100 pF.

Table 5 C1 Capacitor Selection

Configuration	Capacitor
No Summing	47 pF
2 outputs summed	100 pF
4 outputs summed	100 pF
8 outputs summed (CS4308P only)	100 pF

1.2 Recommended Components

To achieve the specified performance characteristics, the choice of external components should observe the following recommendations:

- Capacitors should be stable dielectric types, such as C0G (NP0) or electrolytic.
- Resistors should be low value where possible, to minimize thermal noise.
- Low-noise op-amps should be used, such as Texas Instruments OP1656. The op-amps should meet the minimum performance requirements noted in Table 6.

Table 6 Op-Amp Specification

Parameter	Specification
Input Noise	5 nV/√Hz
Unity Gain bandwidth (G = 1)	15 MHz
Slew Rate	5 V/µs
THD+N	-128 dB

1.3   DACs Combined in Groups of 2

If the DAC outputs are summed in groups of 2 (OUT_SUM_MODE = 0x1), the respective groups of analog outputs from the CS4304P/8P must be linked to provide a single output.

The recommended external components for the CS4304P/8P output buffer/filter circuit, when combining 2 DAC outputs, are shown in Figure 2. Note that the circuit is configured for 8 V_{RMS} full-scale output (0 dBFS) to maximize dynamic range.
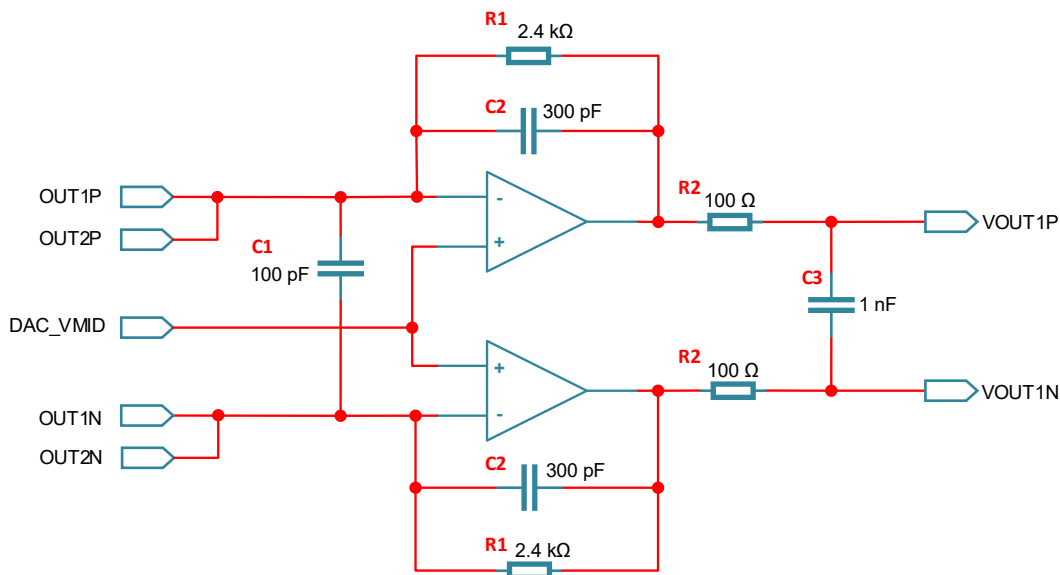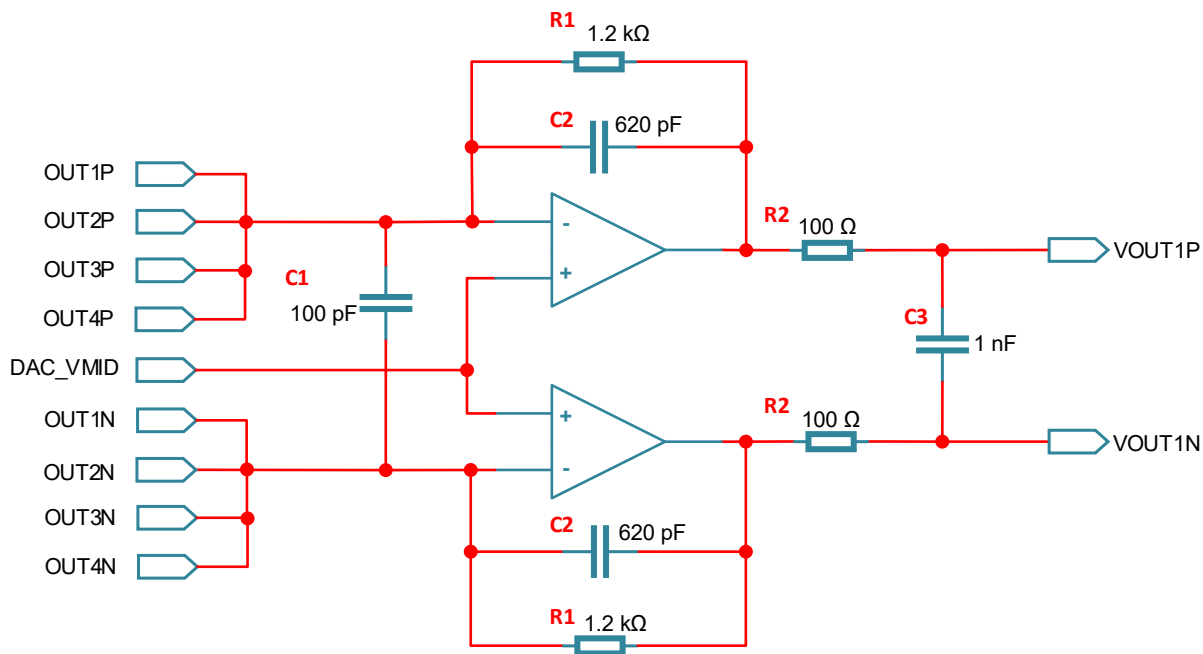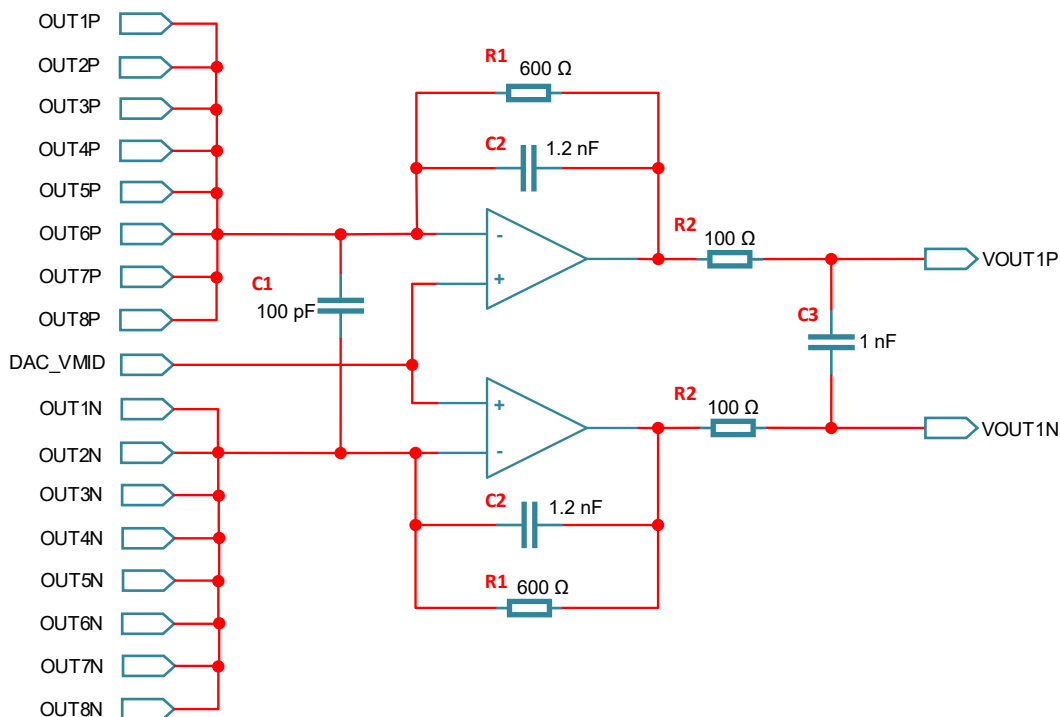

Figure 2: Output Buffer/Filter Circuit - DACs Combined in Groups of 2

The key performance metrics for this summing configuration are shown in Table 7. Comparative figures for the typical no-summing configuration (see Section 1.1) are also shown.

Table 7: Performance Measurements - DACs Combined in Groups of 2

Measurement	No Summing (2V full-scale output)	DACs Combined in Groups of 2 (8V full-scale output)
Signal to Noise Ratio	121 dB	123 dB
THD +N Ratio at 0 dBFS	-115 dB	-115 dB
Dynamic Range A-weighted	123 dB	125 dB

1.4 DACs Combined in Groups of 4

If the DAC outputs are summed in groups of 4 (OUT_SUM_MODE = 0x2), the respective groups of analog outputs from the CS4304P/8P must be linked to provide a single output.

The recommended external components for the CS4304P/8P output buffer/filter circuit, when combining 4 DAC outputs, are shown in Figure 3. Note that the circuit is configured for 8 V_{RMS} full-scale output (0 dBFS) to maximize dynamic range.

Figure 3: Output Buffer/Filter Circuit - DACs Combined in Groups of 4

The key performance metrics for this summing configuration are shown in Table 8. Comparative figures for the typical no-summing configuration (see Section 1.1) are also shown.

Table 8: Performance Measurements - DACs Combined in Groups of 4

Measurement	No Summing (2V full-scale output)	DACs Combined in Groups of 4 (8V full-scale output)
Signal to Noise Ratio	121 dB	125 dB
THD +N Ratio at 0 dBFS	-115 dB	-115 dB
Dynamic Range A-weighted	123 dB	127 dB

1.5 DACs Combined in a Group of 8 (CS4308P only)

If the DAC outputs are summed in a group of 8 (OUT_SUM_MODE = 0x3), the respective groups of analog outputs from the CS4308P must be linked to provide a single output.

The recommended external components for the CS4308P output buffer/filter circuit, when combining 8 DAC outputs, are shown in Figure 4. Note that the circuit is configured for 8 V$_{RMS}$ full-scale output (0 dBFS) to maximize dynamic range.

Figure 4: Output Buffer/Filter Circuit - DACs Combined in a Group of 8

The key performance metrics for this summing configuration are shown in Table 9. Comparative figures for the typical no-summing configuration (see Section 1.1) are also shown.

Table 9: Performance Measurements - DACs Combined in a Group of 8

Measurement	No Summing (2V full scale output)	DACs Combined in a Group of 8 (8V full-scale output)
Signal to Noise Ratio	121 dB	127 dB
THD +N Ratio at -1dBFS	-115 dB	-115 dB
Dynamic Range A-weighted	123 dB	129 dB

2 Revision History

Revision	Changes
R1 AUG 2025	• Initial version.

Contacting Cirrus Logic Support

For all product questions and inquiries, contact a Cirrus Logic Sales Representative.

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