FRIDA PCB Analog Front-End

February 17, 2026

Constraints

- Sampling-rate target: 10 MS/s nominal, up to 50 MS/s.
- ADC analog rails: 0 V to 1.2 V.
- Required output common-mode range: 0.1 V to 1.1 V.
- Required differential output range: -1.2 V to +1.2 V (2.4 V total).
- 50 Ω source, 80 MHz generator: 33250A Keysight
- ADC input assumption: $R_{in} \approx 2$ kΩ, $C_{in,single} \approx 2$ pF.
- ADC quantization noise reference: $(1.2\ \mathrm{V}/2^{12})/\sqrt{12}$.
- Amplifier noise target: $< 20\%$ of ADC quantization noise.

Selected Driver: THS4541

- Fully differential amplifier for SE-to-diff conversion and ADC drive.
- Nominal BW class: 850 MHz (datasheet), with >500 MHz at gain of 2.
- Input voltage noise density: 2.2 $\mathrm{nV}/\sqrt{\mathrm{Hz}}$ ($f > 100$ kHz).
- Output linear swing headroom: about 0.2 V from each rail.
- `VOCM` loop range (approx):

$$V_{S-} + 0.91\ \mathrm{V} \leq V_{\mathrm{OCM}} \leq V_{S+} - 1.1\ \mathrm{V}$$

- Datasheet: TI THS4541
- App note: SNOA461A

Nyquist LPF Driver Requirements

Amplifier Specification	**Requirement**
Bandwidth (0.1 dB)	$\approx f_s/2$
H2 and H3	$\approx 20\log_{10}(1/2^N)$
Balance error	$\approx$ ADC LSB at $f_s/2$
Settling time	$\approx 0.5 \cdot (1/f_s)$
Noise	$\approx$ ADC floor, with amp 6 dB lower

Chosen Architecture and Equations

- Architecture: THS4541 differential driver + output RC anti-alias stage.
- Matched FDA differential gain:
$$A_{vd} \approx \frac{R_F}{R_G}$$
- Unity differential gain target: $R_F = R_G$ on both sides.
- First-order cutoff with differential capacitor across ADC inputs:
$$f_c \approx \frac{1}{2\pi(2R_O)\left(C_O + C_{in,diff}\right)}$$
- Per-side shunt form:
$$f_c \approx \frac{1}{2\pi R_O\left(C_{O,side} + C_{in,single}\right)}$$

Calculated Values: Gain and Interface

- Max sampling rate: $f_s = 50$ MS/s.
- Target anti-alias pole: $f_c \approx 25$ MHz.
- Unity-gain FDA: $R_F = R_G = 499\ \Omega$ (both sides).
- Input-shunt terminations are **R14** and **R15** (both 54.9 Ω), used as R_T.
- FDA gain network in this schematic: **R18**/**R19** as $R_G = 499\ \Omega$ and **R22**/**R23** as $R_F = 499\ \Omega$.
- First-order static estimate per input:

$$Z_{in} \approx R_T \parallel R_G \approx 54.9 \parallel 499 \approx 49.5\ \Omega$$

For a tighter 50-Ω static match, set R_T near **54.9** Ω.

Calculated Values: Output Filter

- Method reference: AN-1393 (SNOA461A).
- Output isolation/filter resistors: **R24**, **R25**; target $R_O = 56\ \Omega$ per side.
- 56 Ω is for ADC kickback isolation/stability, not 50-Ω source matching.
- Per-side solve ($f_c = 25$ MHz, $C_{in,single} = 2$ pF): $C_{O,side} = \frac{1}{2\pi R_O f_c} - C_{in,single} \approx 111.7$ pF. Use **110 pF** per side $\Rightarrow f_c \approx 25.4$ MHz.
- Differential solve: $C_{O,diff} = \frac{1}{2\pi(2R_O)f_c} - C_{in,diff} \approx 52.8$ pF. Use **51 pF** across OUT+/OUT- $\Rightarrow f_c \approx 25.7$ MHz.

100-Ω Differential Pair from Stackup

From the shown stackup (TOP over IN2 reference plane):

$$h = 140\ \mu\text{m}, \quad \varepsilon_r = 4.00, \quad t = 35\ \mu\text{m}$$

Core values from the image: $1200\ \mu\text{m}$, $\varepsilon_r = 4.60$.
Single-ended microstrip estimate:

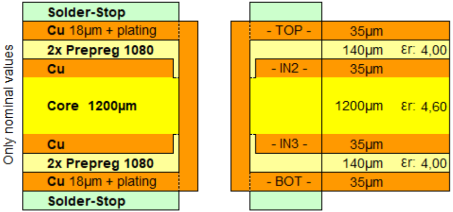
$$Z_0 \approx \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln\left(\frac{5.98h}{0.8W + t}\right)$$

Edge-coupled differential approximation:

$$Z_{\text{diff}} \approx 2Z_0\left(1 - 0.48e^{-0.96S/h}\right)$$

Use $W = 180\ \mu\text{m}$ and $S = 200\ \mu\text{m}$. With this stackup, the first-pass estimate is:

$$Z_0 \approx 58\ \Omega, \qquad Z_{\text{diff}} \approx 101\ \Omega$$



Source: from Multicb