Differential Amplifier

Current sensor

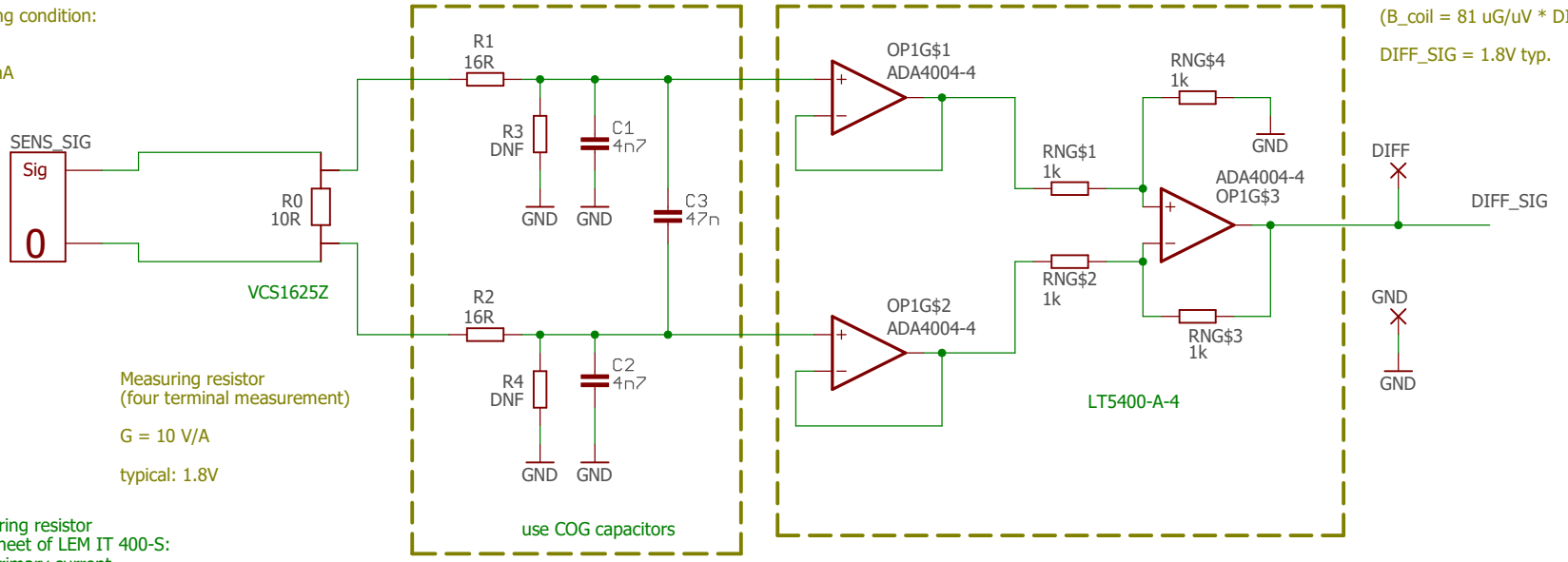
e.g. LEM-IT 400
G = 0.003
(conversion factor 1/2000 * 6 turns around sensor)

typical operating condition:
B_coil = 146G
I_coil = 60A
I_sens = 180mA

total transfer function:
DIFF_SIG = 0.03 V/A * I_coil

(B_coil = 81 uG/uV * DIFF_SIG)

DIFF_SIG = 1.8V typ.



Measuring resistor
(four terminal measurement)

G = 10 V/A

typical: 1.8V

Maximum measuring resistor
acc. to the datasheet of LEM IT 400-S:
9ohms at 360A primary current
only for max. temperature and min. supply voltage;
ok for our application (priv. communication)

use COG capacitors

lowpass filter
common-mode bandwidth: 2.1 MHz
differential bandwidth: 100 kHz

Unity-gain instrumentation amplifier

R3 and R4 provide ground connection
in case the sensor is disconnected.
But input current noise of OP1
requires low resistor values...

when R3 and R4 are not fitted,
make sure the sensor is connected
before powering the circuit

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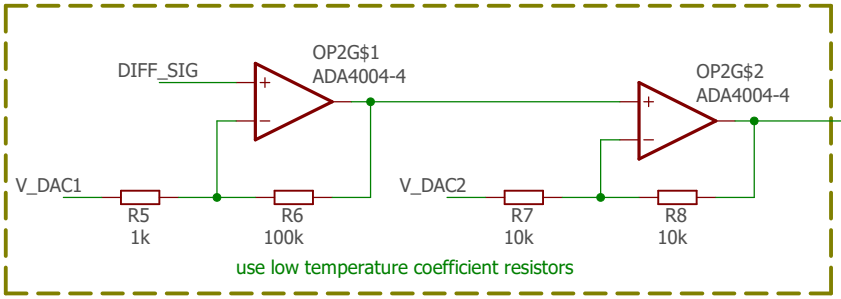
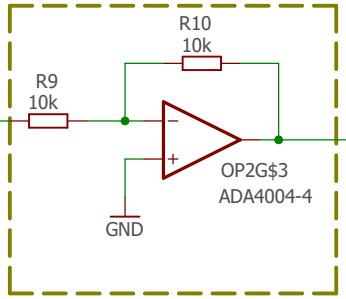
Reference Subtraction

DIFF_SIG = 1.8 V typ.
V_DAC1 = 2.048 V max.
V_DAC2 = 2.048 V max.



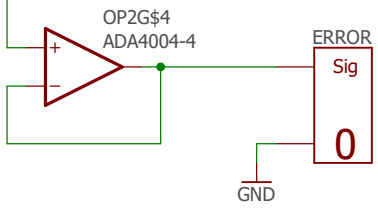
Subtract coarse DAC (1) and fine DAC (2) references



Inverting unity-gain buffer

ERR

ERR = 200 V_DAC1 + V_DAC2 - 202 DIFF_SIG



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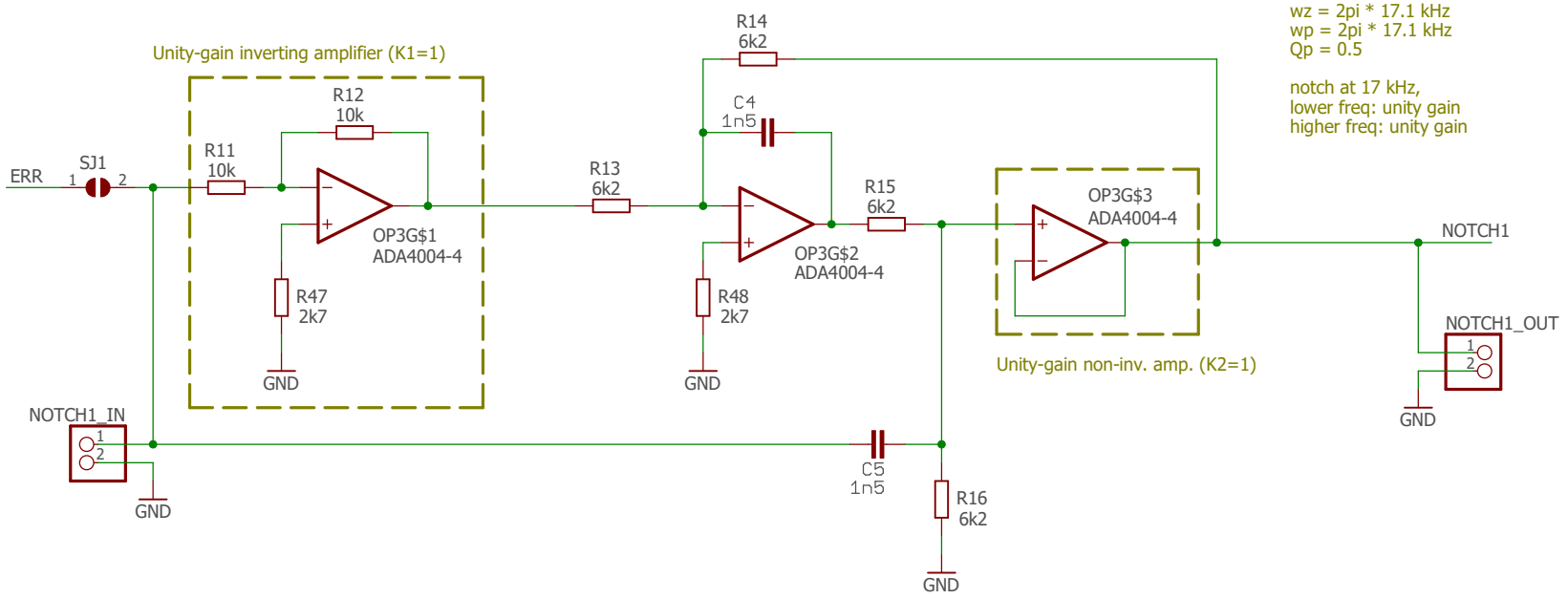
Narrow Notch Filter (17 kHz)

Bainter design



G = (s^2+wz^2) / (s^2+s*wp/Qp+wp^2)

wz = 2pi * 17.1 kHz
wp = 2pi * 17.1 kHz
Qp = 0.5

notch at 17 kHz,
lower freq: unity gain
higher freq: unity gain

opamp output at low frequencies:
1) - NOTCH1_IN
2) 2 * NOTCH1_IN <- check here for saturation
3) NOTCH1_IN

J. Bainter: "Active filter has stable notch,
and response can be regulated"
Electronics, October/2, 1975

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Low-Pass Notch Filter

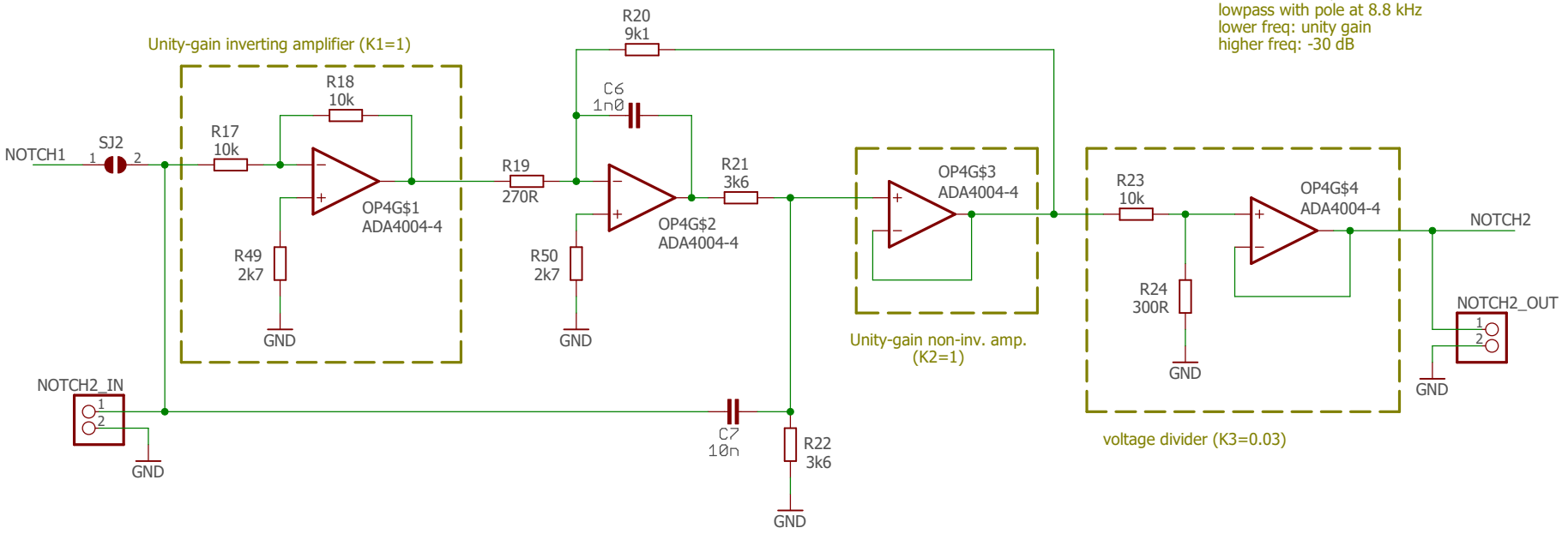
Bainter design

double-pole at 8.8 kHz
double-zero at 51 kHz

G = K3 * (s^2+wz^2) / (s^2+s*wp/Qp+wp^2)

wz = 2pi * 51 kHz
wp = 2pi * 16 kHz
Qp = 0.99

notch at 51 kHz,
lowpass with pole at 8.8 kHz
lower freq: unity gain
higher freq: -30 dB



opamp output at low frequencies:
1) - NOTCH2_IN
2) 67.4 * NOTCH2_IN <- check here for saturation
3) 33.7 * NOTCH2_IN
4) NOTCH2_IN

max. input: 0.1 V rms

J. Bainter: "Active filter has stable notch,
and response can be regulated"
Electronics, October/2, 1975

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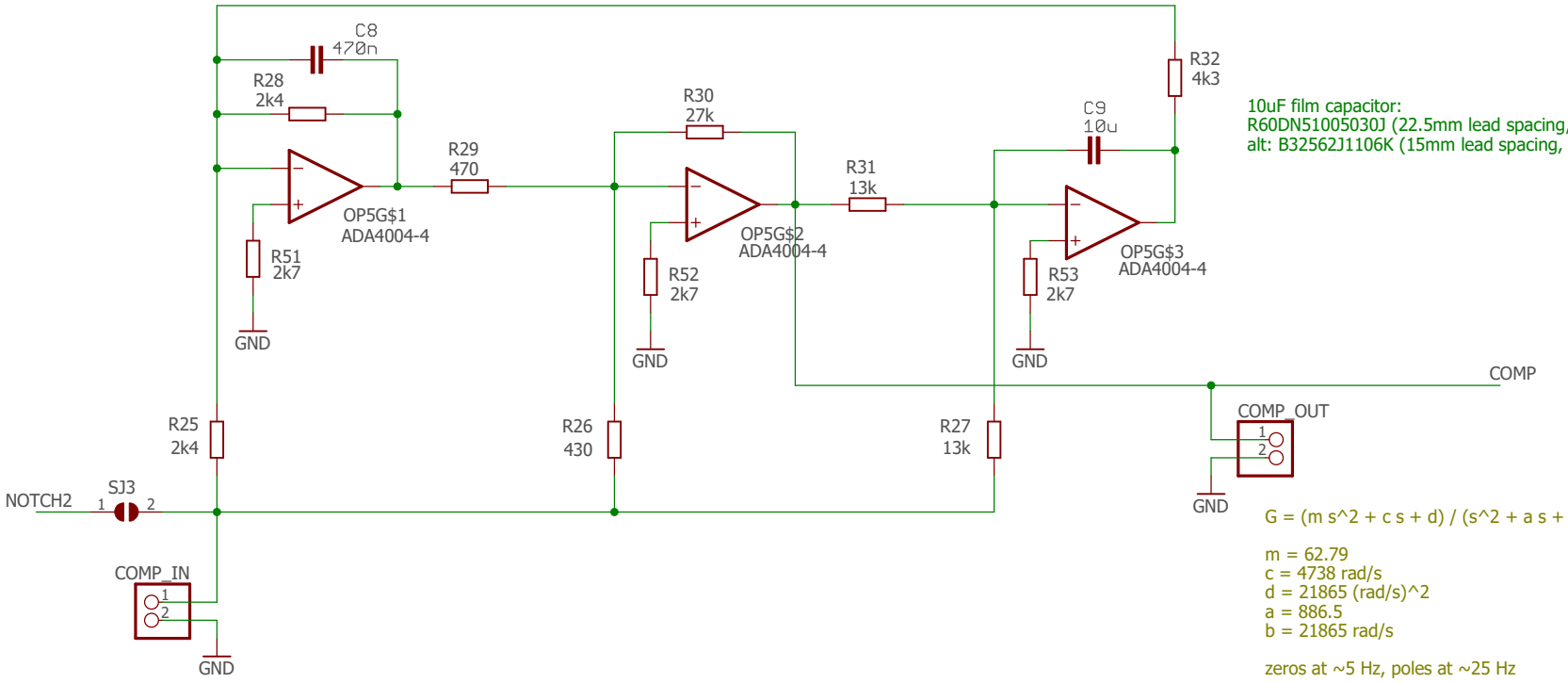
Compensator

Biquad Active All-Pass Filter
(Tow-Thomas Design)



10uF film capacitor:
R60DN51005030J (22.5mm lead spacing, 5% tol.)
alt: B32562J1106K (15mm lead spacing, 10% tol.)

G = (m s^2 + c s + d) / (s^2 + a s + b)

m = 62.79
c = 4738 rad/s
d = 21865 (rad/s)^2
a = 886.5
b = 21865 rad/s

zeros at ~5 Hz, poles at ~25 Hz

maximum opamp output:
1) NOTCH2 (lowpass)
2) 10 * NOTCH2 (compensator) <- check COMP_OUT for saturation
3) NOTCH2 (bandpass)

P. E. Fleischer and J. Tow:
"Design Formulas for Biquad Active Filters
Using Three Operational Amplifiers"
Proc. IEEE, 662, May 1973

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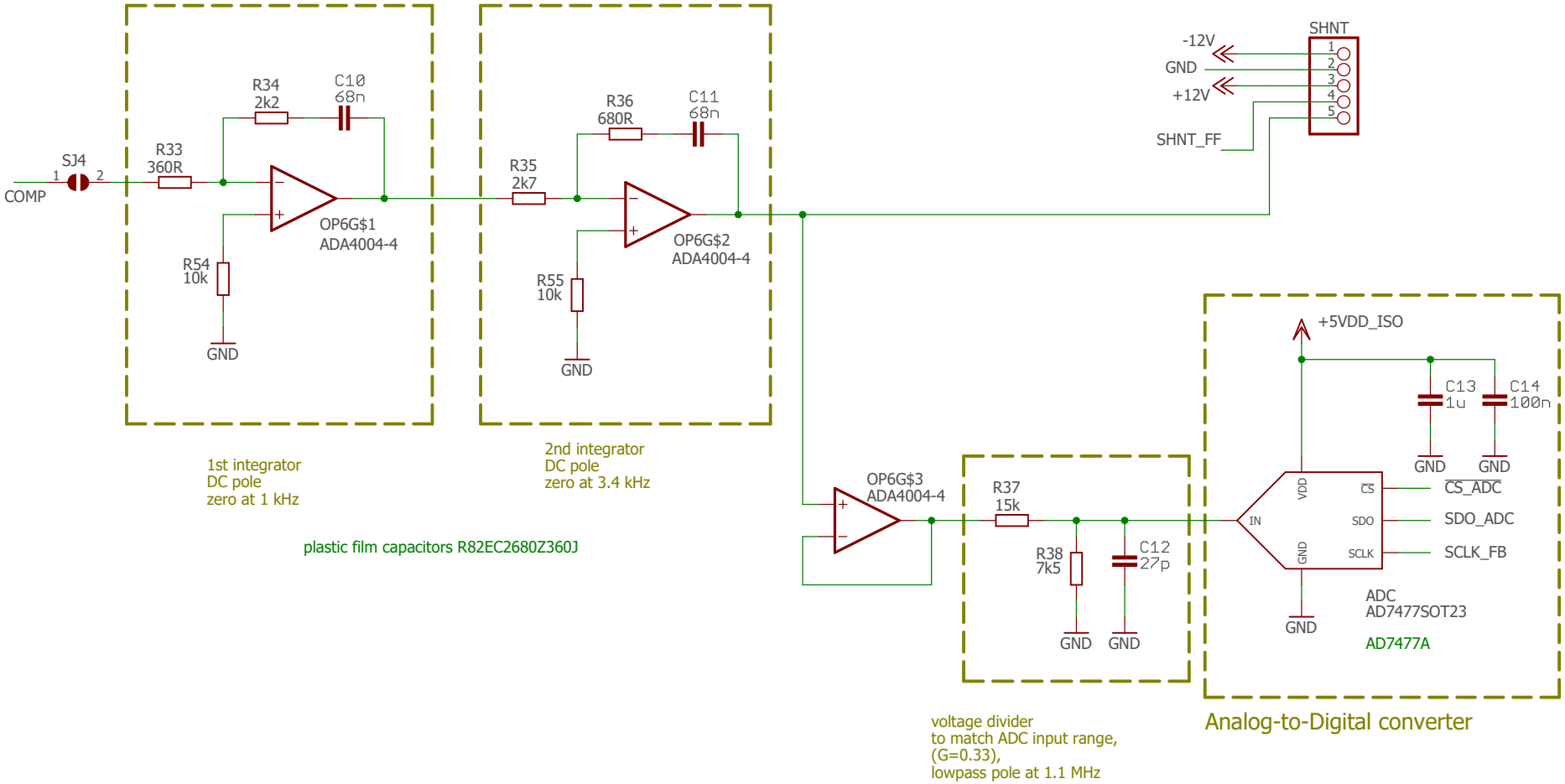
Type II - Loop Filter



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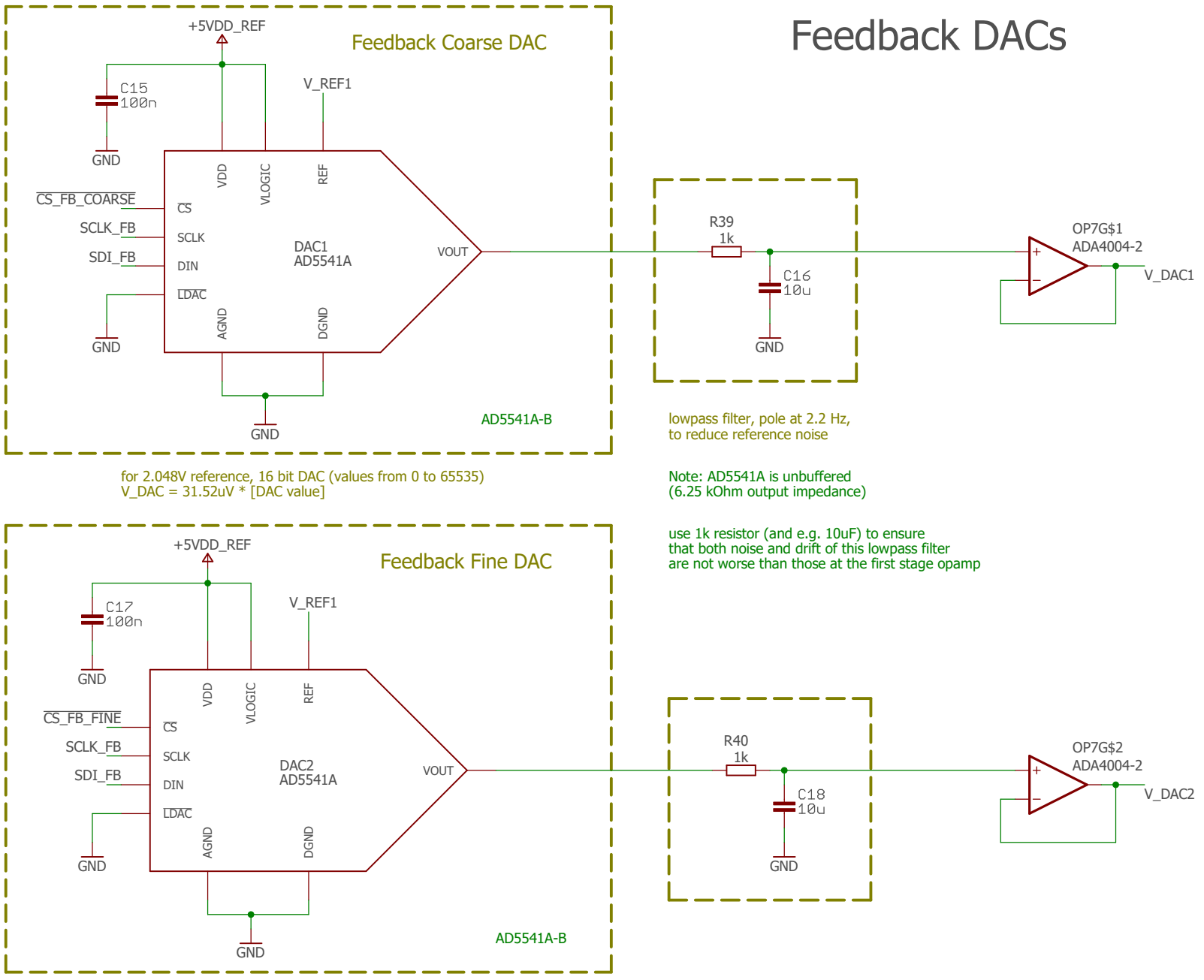
Feedback DACs



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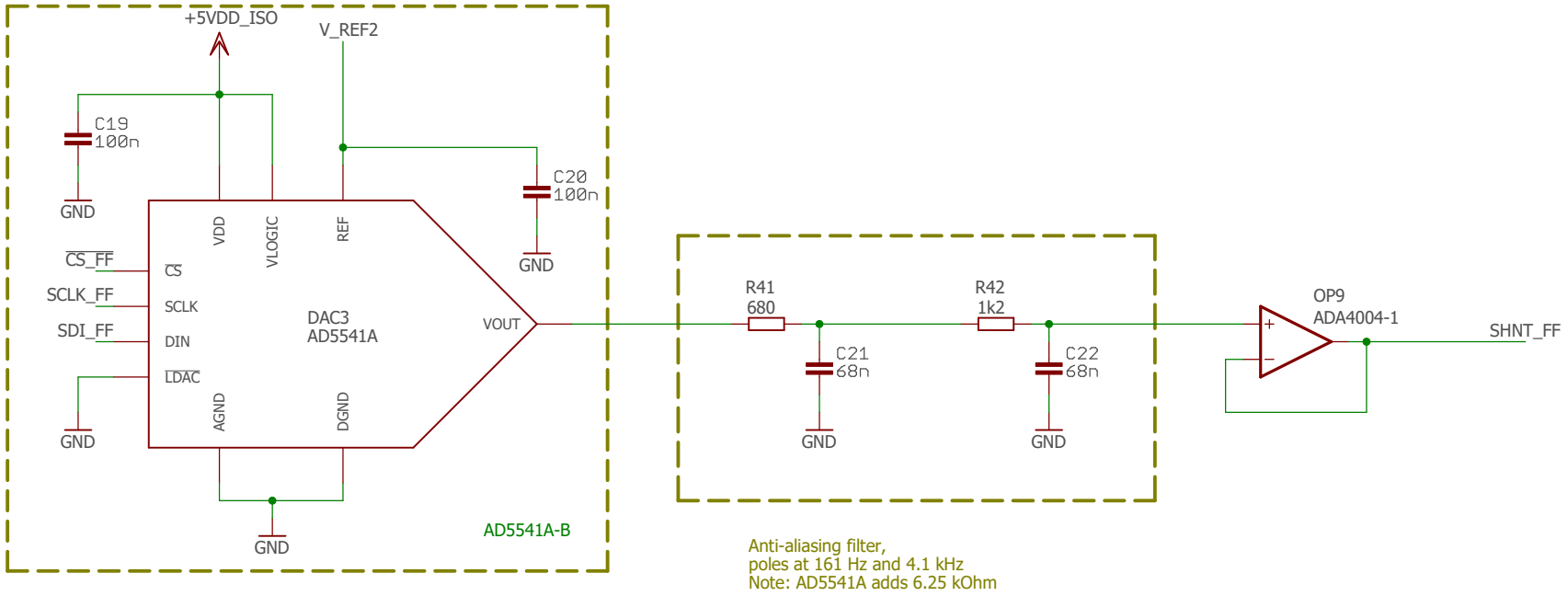
Feedforward DAC



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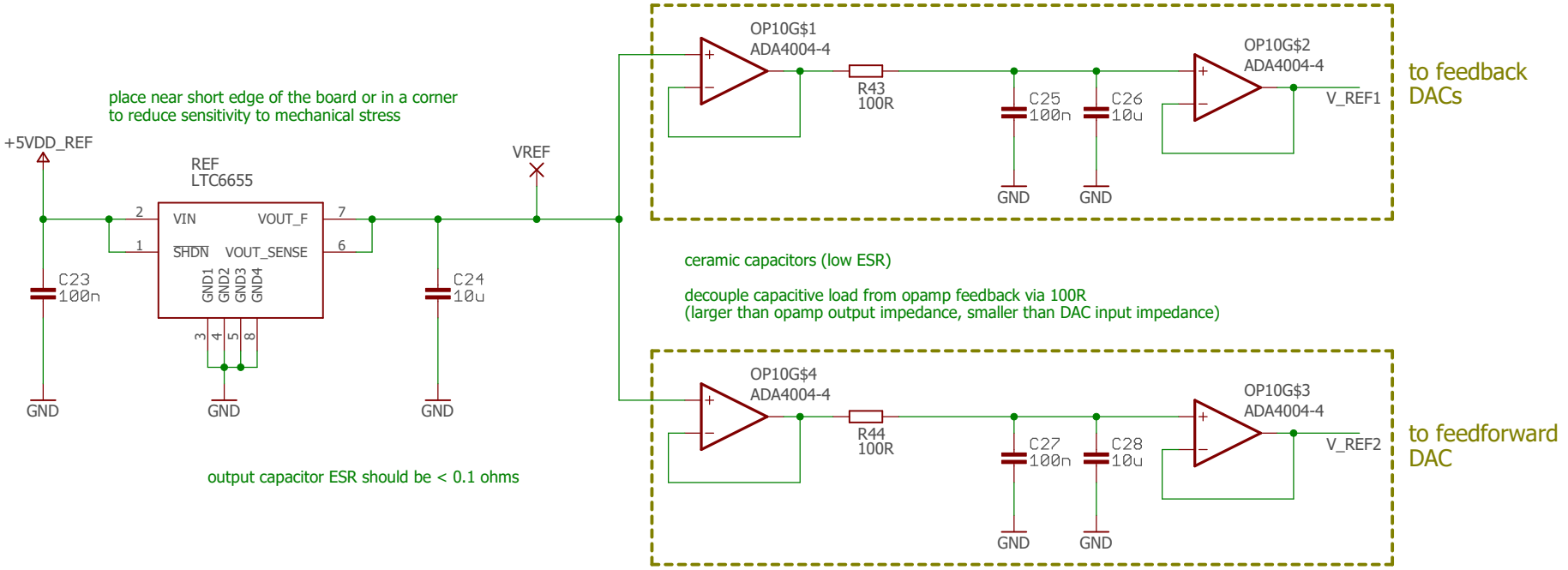
Voltage Reference

provides 2.048V reference for DACs



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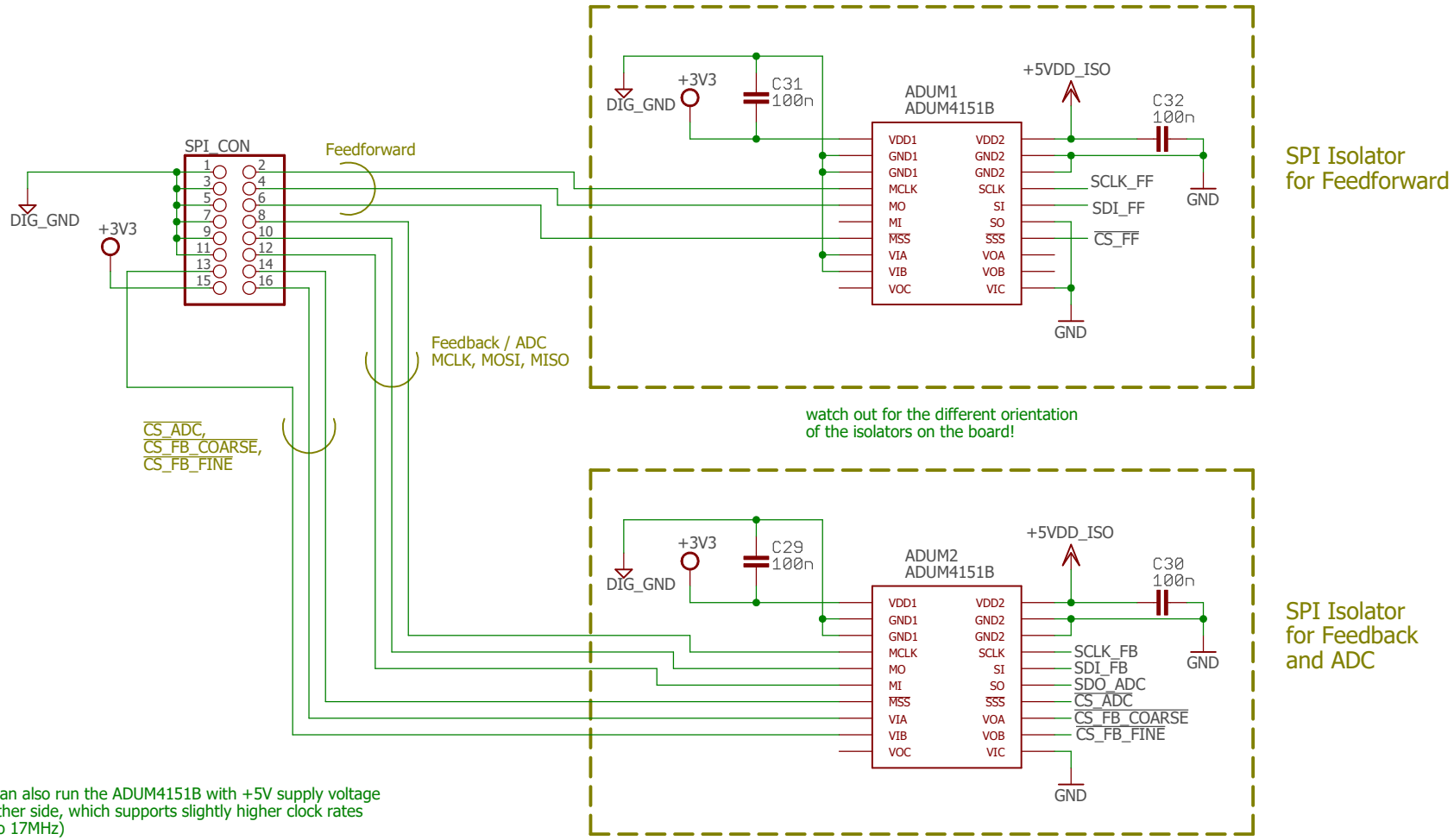
SPI Isolators



Note:
you can also run the ADUM4151B with +5V supply voltage
on either side, which supports slightly higher clock rates
(up to 17MHz)

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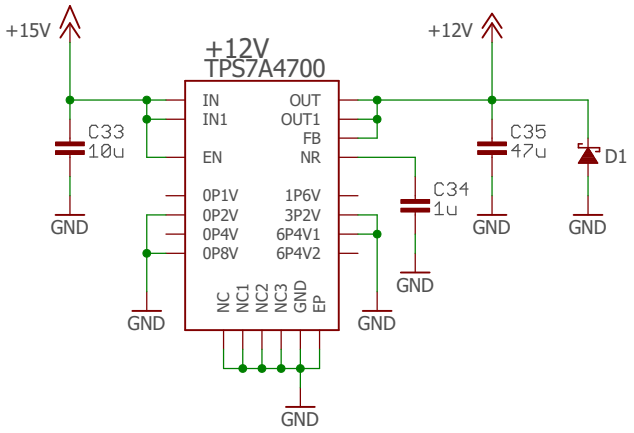
Voltage Regulators

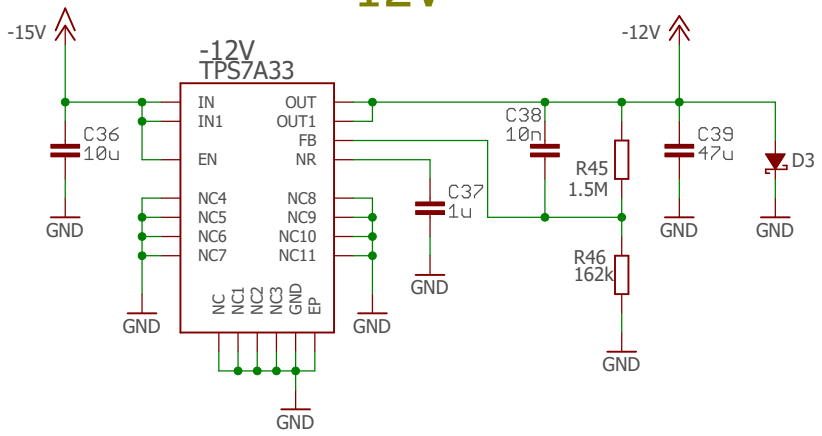
+12V, -12V for OpAmp Power Supply
+5V for DACs/ADC, SPI Isolators and Reference LTC6655 Power Supply

+12V



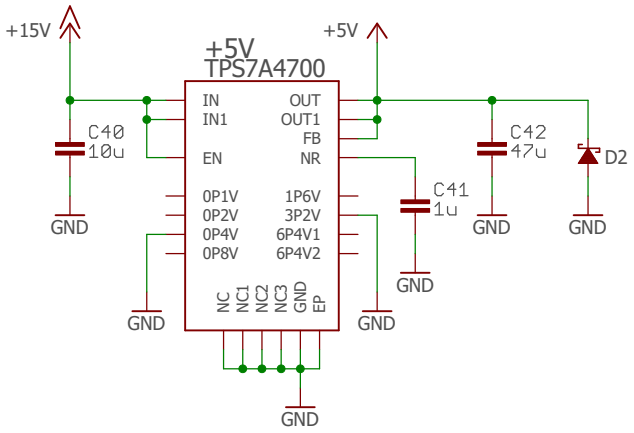
if output ringing occurs:
put 10uF tantalum capacitor (high ESR)
in parallel to the 10u ceramic input capacitor

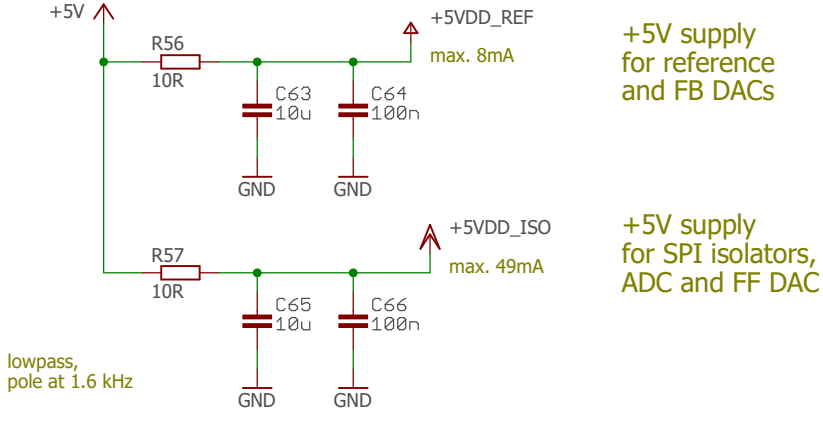
-12V



low ESR ceramic (X7R, or X5R) input/output capacitors

+5V





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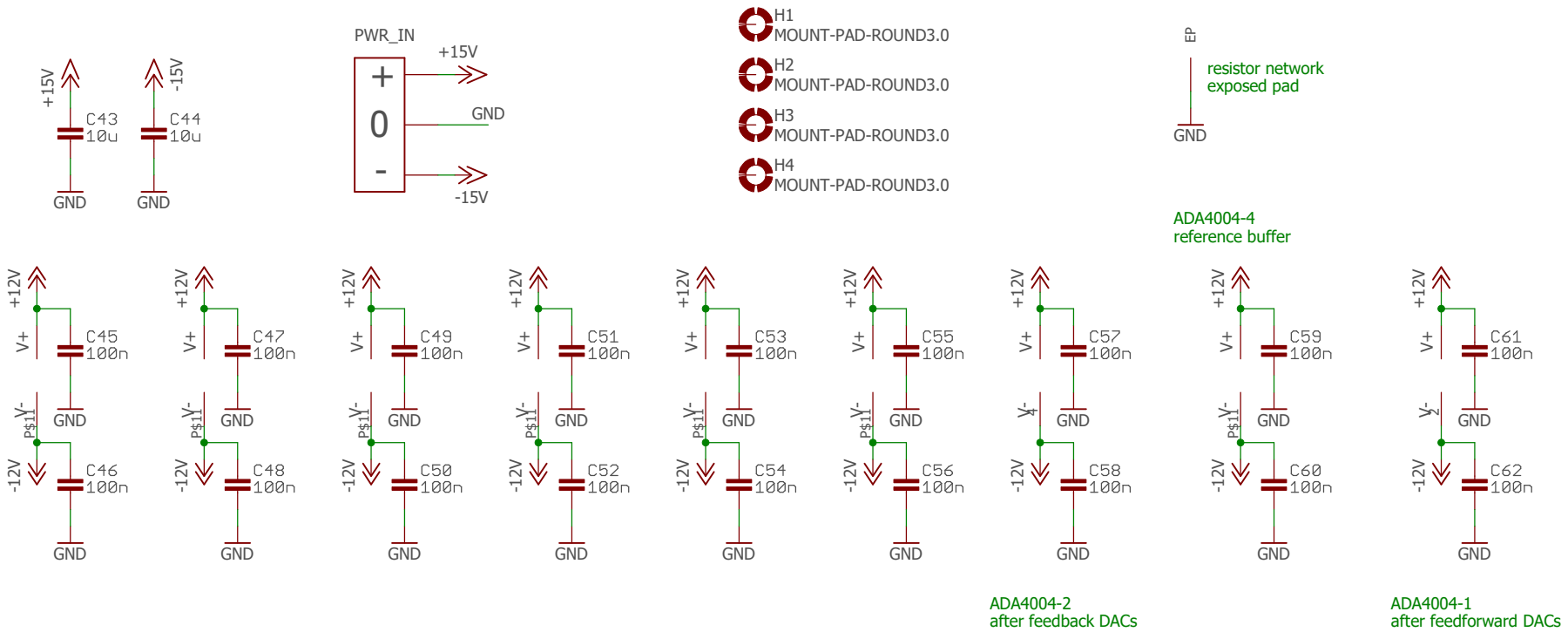

Decoupling capacitors

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