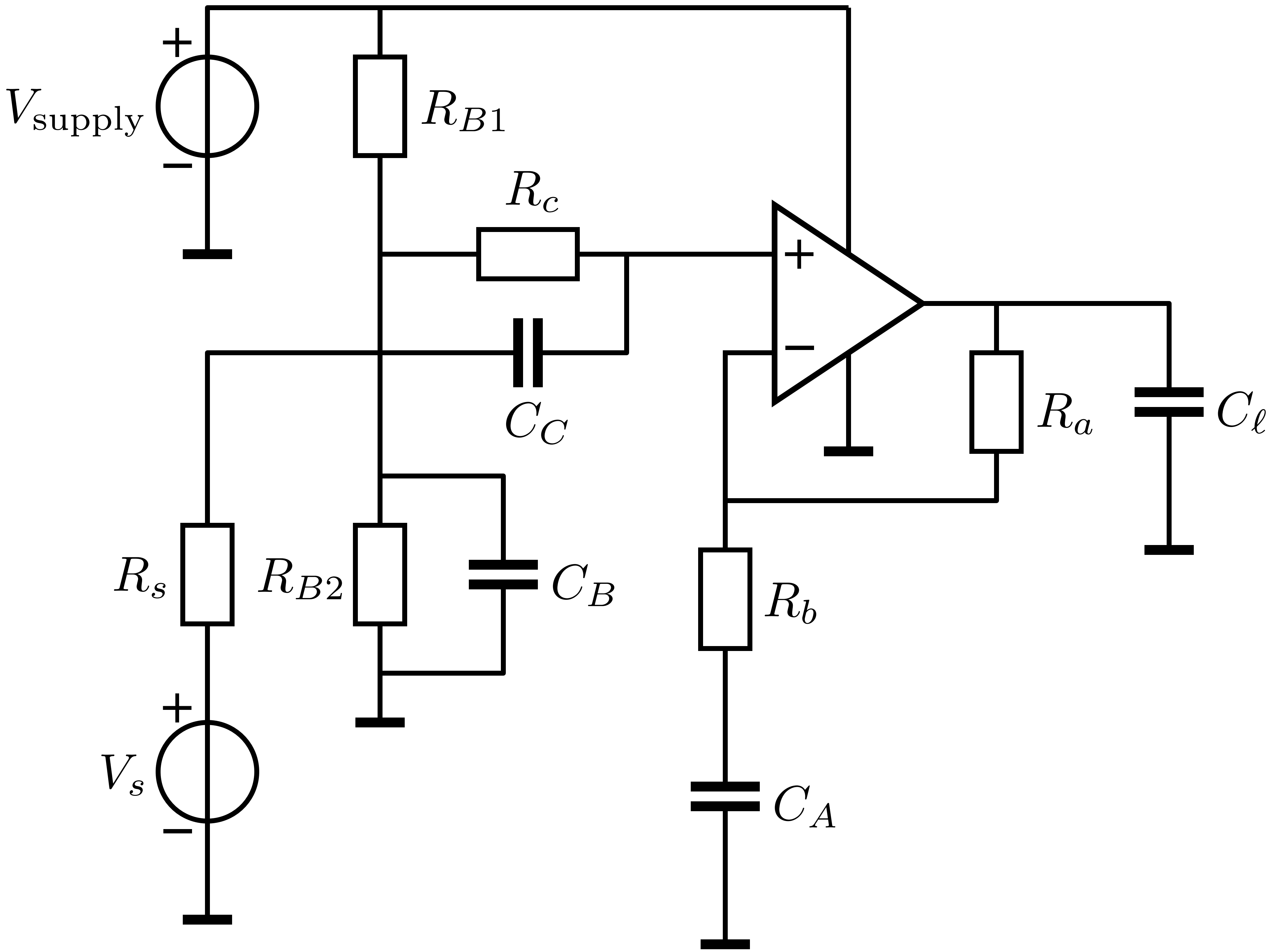
Component selection

Component selection



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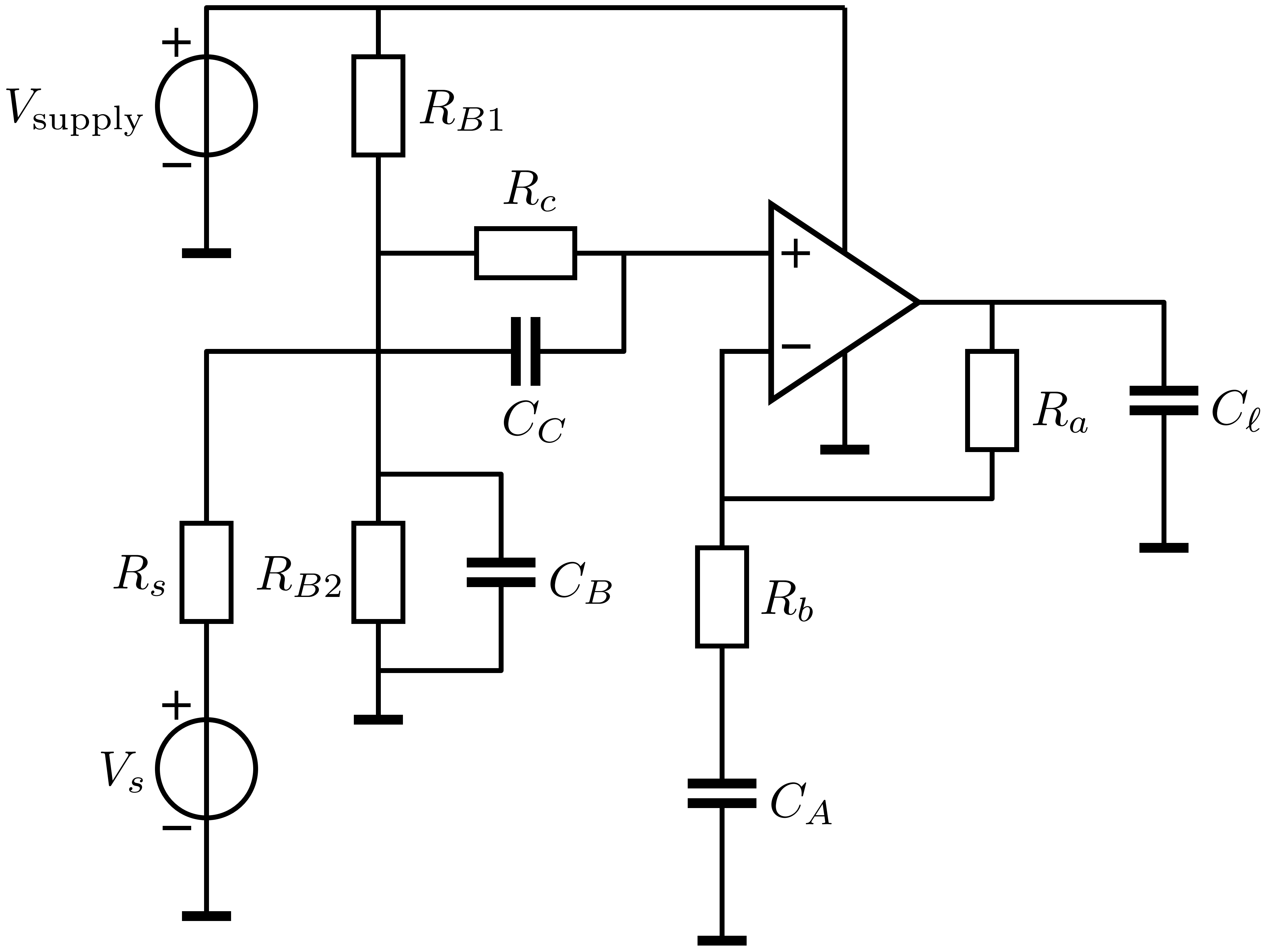
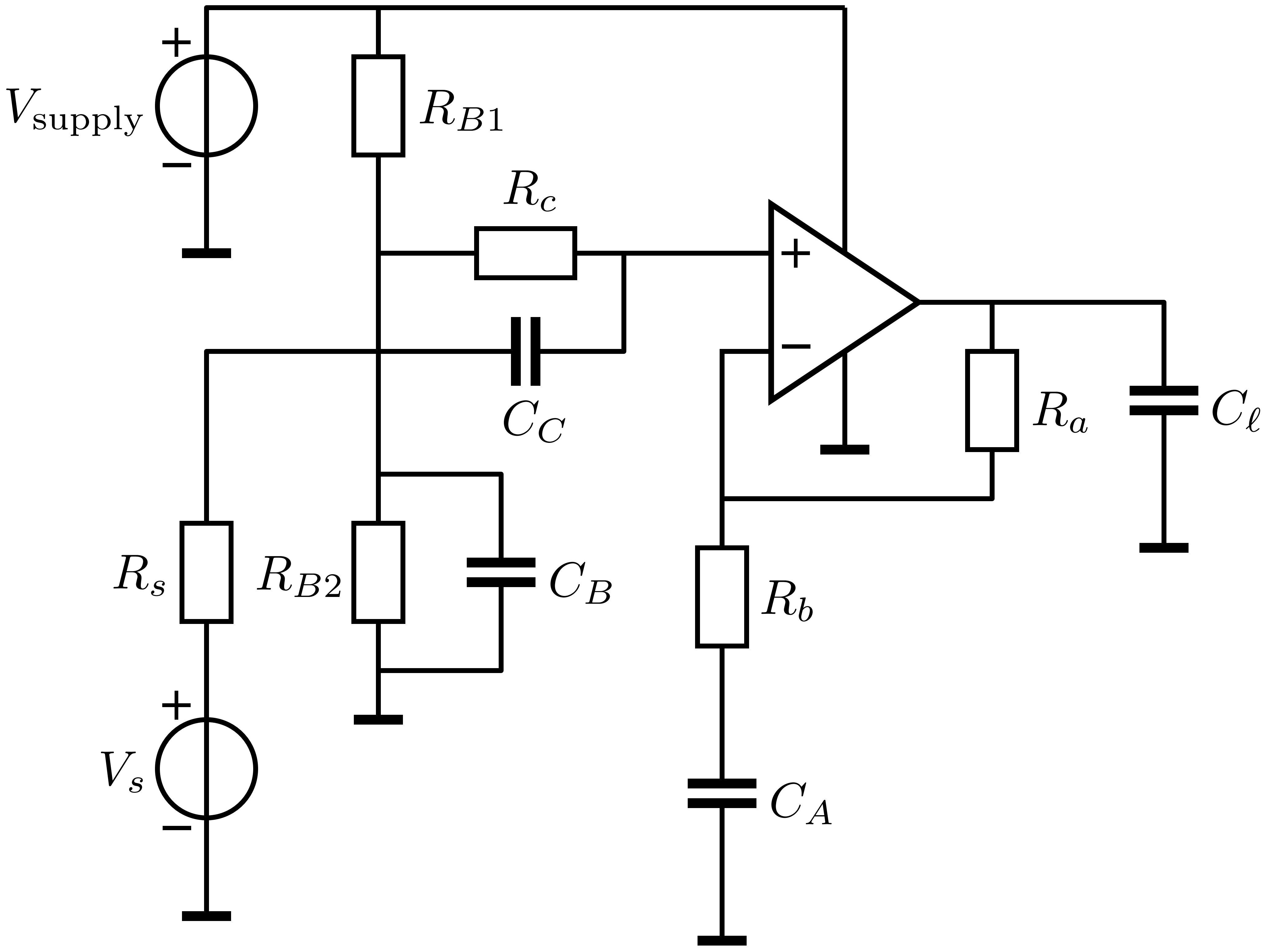


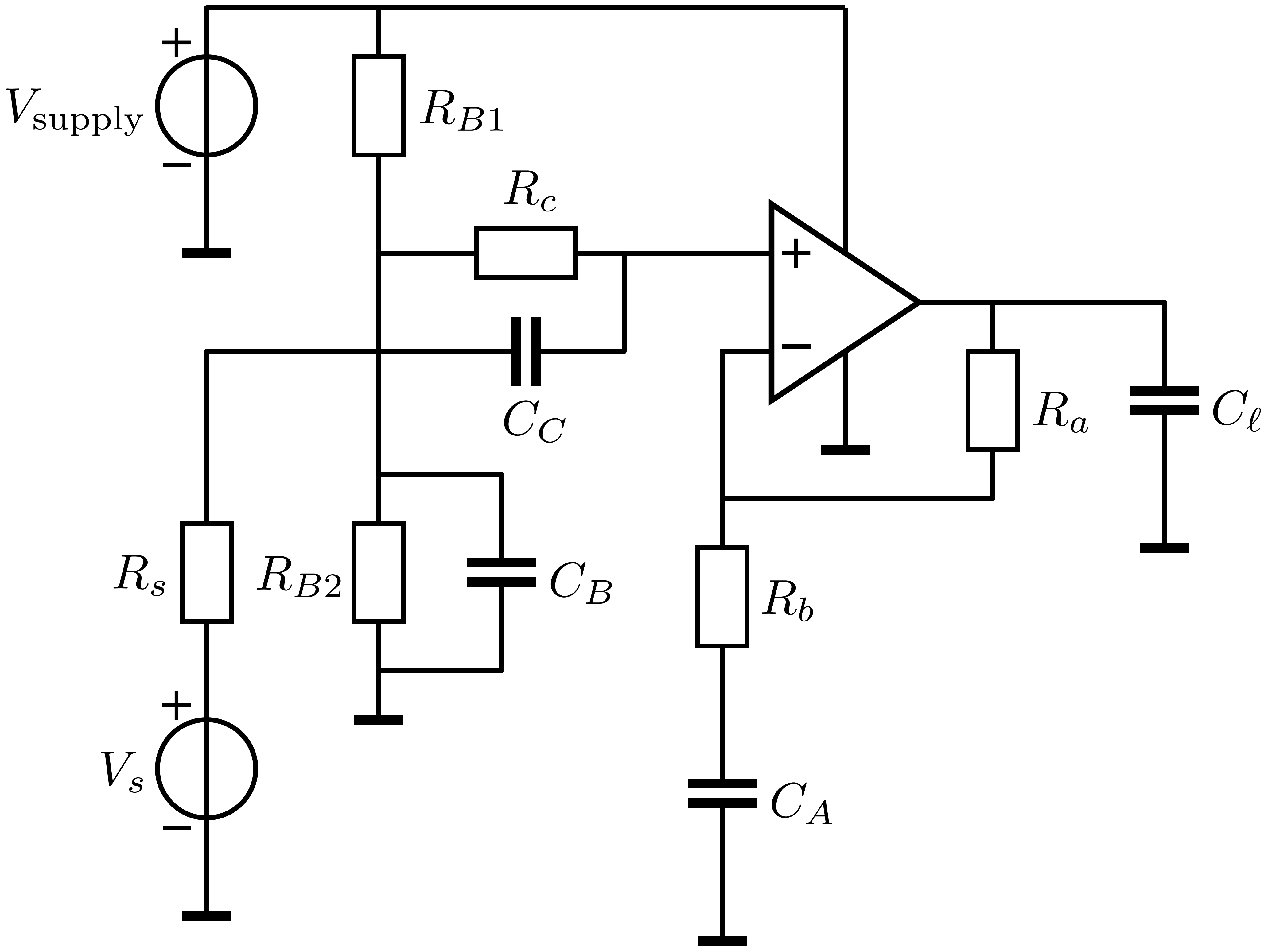
- Noise:

Component selection



- Noise: $R_b < 600\Omega$,
  $R_c \gg 600\Omega$,
  $\frac{1}{2\pi f C_C} \ll R_s$,
  $S_{V_n} < 3.15\frac{\text{nV}}{\sqrt{\text{Hz}}}$
  $S_{I_n} < 5.25\frac{\text{pA}}{\sqrt{\text{Hz}}}$

Component selection



- Noise: $R_b < 600\Omega,$
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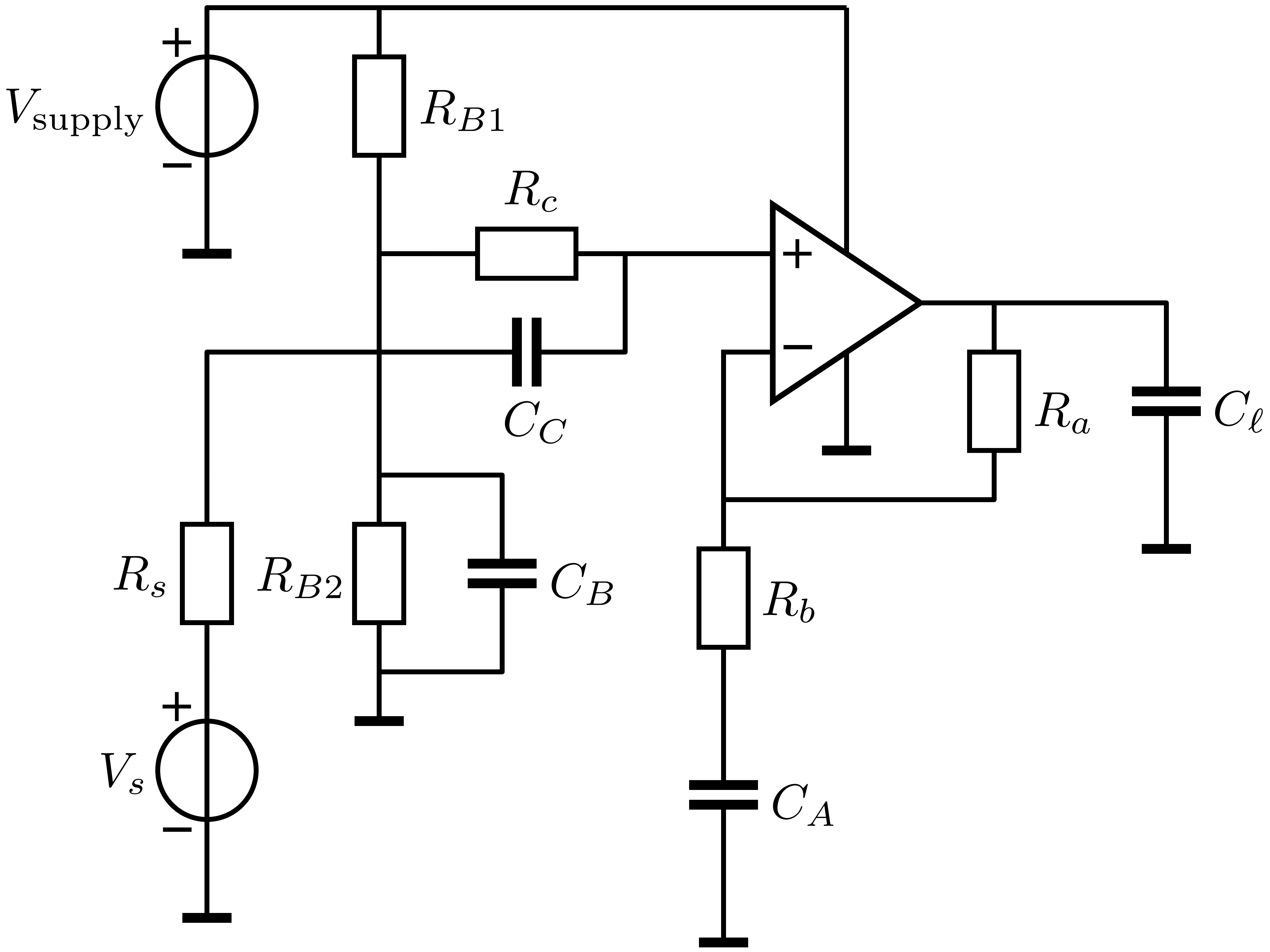
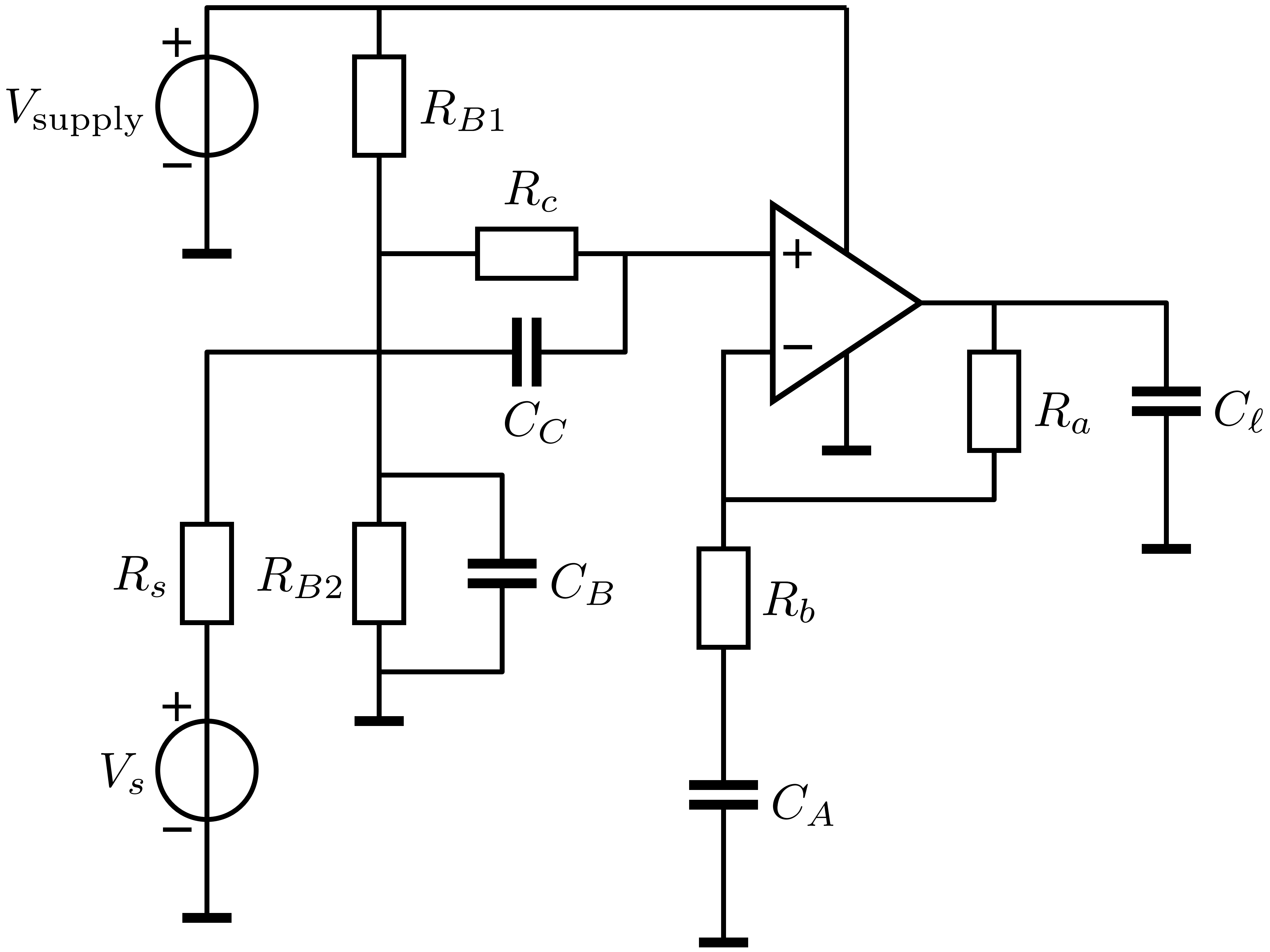
  $\frac{1}{2\pi f C_C} \ll R_s,$
  $S_{V_n} < 3.15 \frac{\text{nV}}{\sqrt{\text{Hz}}}$
  $S_{I_n} < 5.25 \frac{\text{pA}}{\sqrt{\text{Hz}}}$
- Bandwidth: $\frac{1}{2\pi f_{\text{low}} C_A} \leq R_b$
  $\text{GB} > 45\ \text{MHz}$
  $\frac{1}{2\pi f_{\text{low}} C_A} \leq R_b$

Component selection



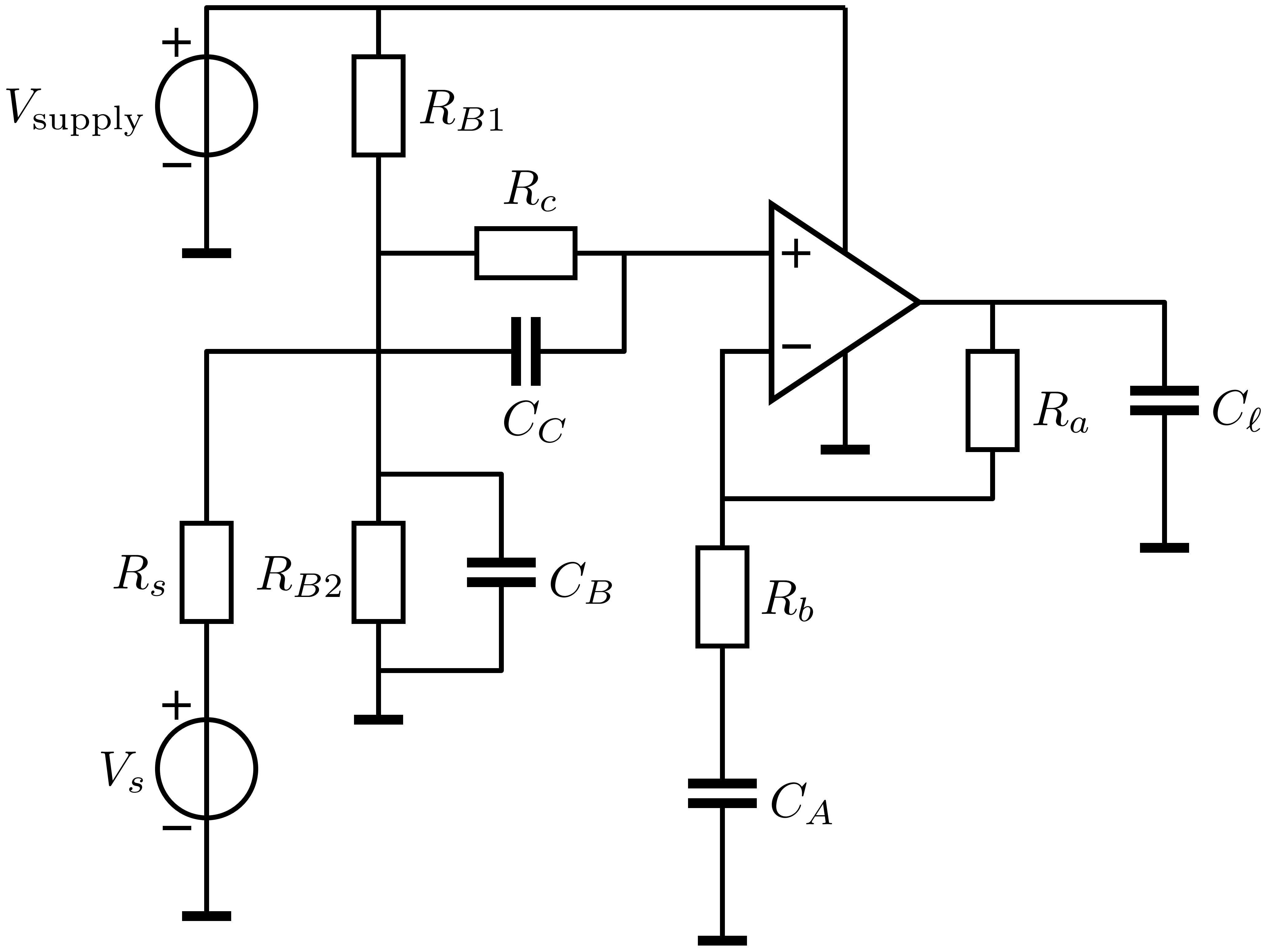
- Noise: $R_b < 600\Omega$, $R_c \gg 600\Omega$, $\frac{1}{2\pi f C_C} \ll R_s$, $S_{V_n} < 3.15\frac{\text{nV}}{\sqrt{\text{Hz}}}$, $S_{I_n} < 5.25\frac{\text{pA}}{\sqrt{\text{Hz}}}$
- Bandwidth: $\frac{1}{2\pi f_{\text{low}} C_A} \leq R_b$, $\text{GB} > 45\ \text{MHz}$, $\frac{1}{2\pi f_{\text{low}} C_A} \leq R_b$
- Accuracy: $R_c \gg R_s$, $A_0 \gg 33 \times 90 \approx 3000$

Component selection



- Noise: $R_b < 600\Omega$, $R_c \gg 600\Omega$, $\frac{1}{2\pi f C_C} \ll R_s$, $S_{V_n} < 3.15 \frac{\text{nV}}{\sqrt{\text{Hz}}}$ $S_{I_n} < 5.25 \frac{\text{pA}}{\sqrt{\text{Hz}}}$
- Bandwidth: $\frac{1}{2\pi f_{\text{low}} C_A} \leq R_b$ $\text{GB} > 45 \text{ MHz}$ $\frac{1}{2\pi f_{\text{low}} C_A} \leq R_b$
- Accuracy: $R_c \gg R_s$ $A_0 \gg 33 \times 90 \approx 3000$
- Drive capability:

Component selection



- Noise: $R_b < 600\Omega$,
  $R_c \gg 600\Omega$,
  $\frac{1}{2\pi f C_C} \ll R_s$,
  $S_{V_n} < 3.15 \frac{\text{nV}}{\sqrt{\text{Hz}}}$
  $S_{I_n} < 5.25 \frac{\text{pA}}{\sqrt{\text{Hz}}}$
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  $\text{GB} > 45\ \text{MHz}$
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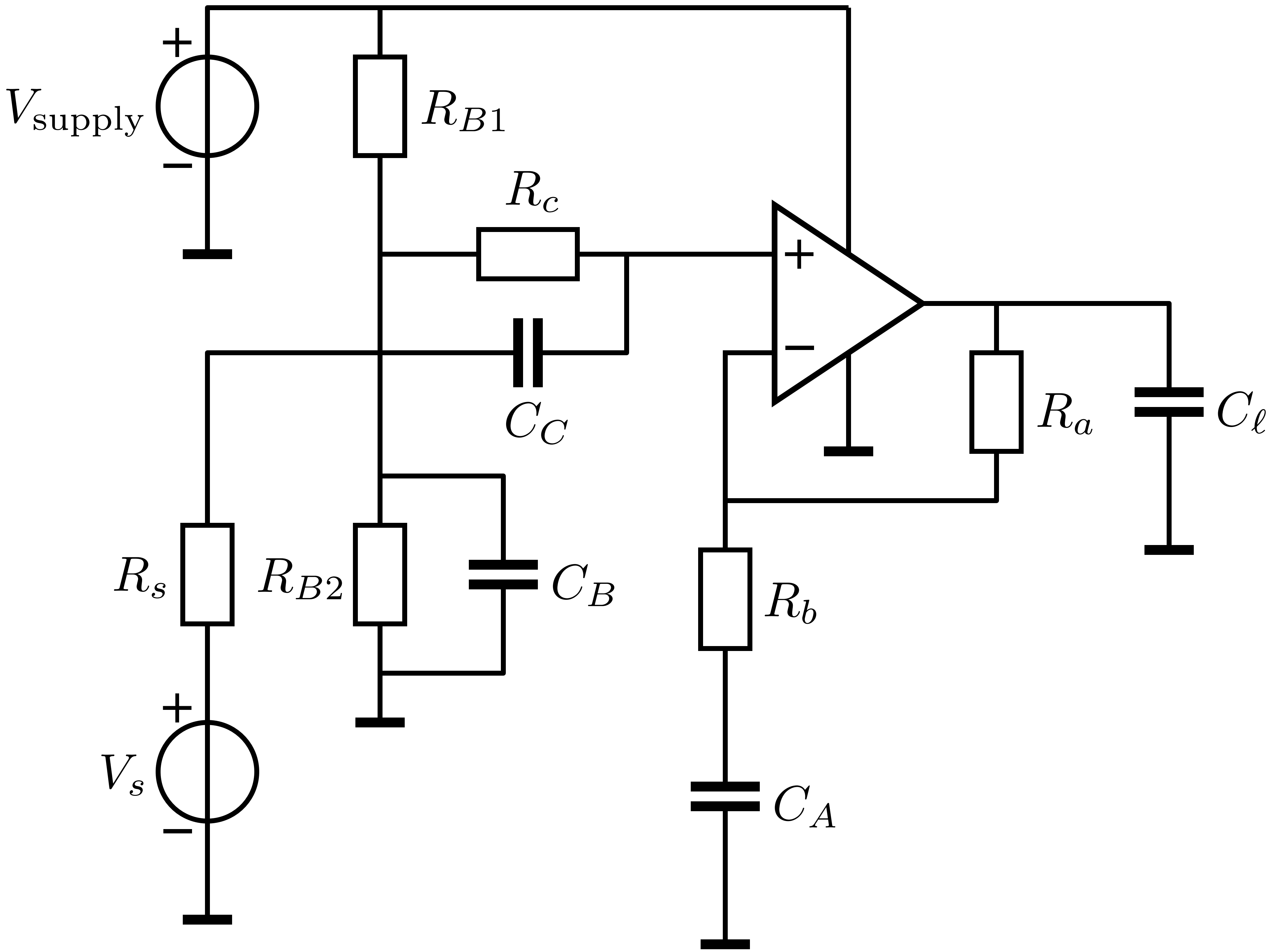
- Accuracy: $R_c \gg R_s$
  $A_0 \gg 33 \times 90 \approx 3000$
- Drive capability:
  $I_{\text{source,sink}} > 5\ \text{mA}$
  $\text{SR} > 1.5\ \text{V}/\mu\text{s}$
  $V_{\text{sat}} < 0.25\ \text{V}$

Component selection



- Noise: $R_b < 600\Omega$,
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  $S_{V_n} < 3.15 \frac{\text{nV}}{\sqrt{\text{Hz}}}$
  $S_{I_n} < 5.25 \frac{\text{pA}}{\sqrt{\text{Hz}}}$
- Bandwidth: $\frac{1}{2\pi f_{\text{low}} C_A} \leq R_b$
  $\text{GB} > 45 \text{ MHz}$
  $\frac{1}{2\pi f_{\text{low}} C_A} \leq R_b$
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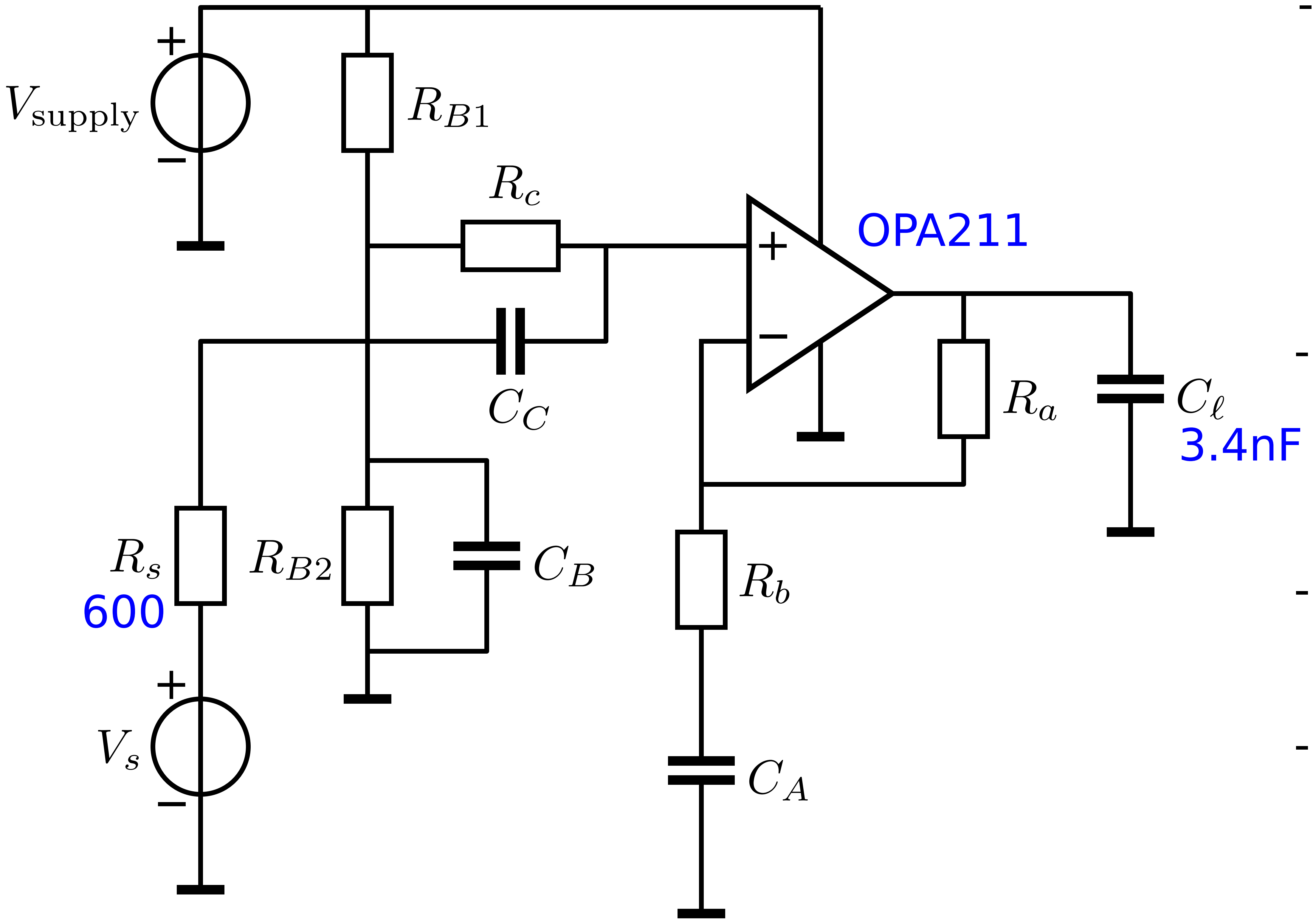
Component selection



- Noise: $R_b < 600\Omega$, $R_c \gg 600\Omega$, $\frac{1}{2\pi f C_C} \ll R_s$, $S_{V_n} < 3.15 \frac{\text{nV}}{\sqrt{\text{Hz}}}$, $S_{I_n} < 5.25 \frac{\text{pA}}{\sqrt{\text{Hz}}}$
- Bandwidth: $\frac{1}{2\pi f_{\text{low}} C_A} \leq R_b$, $\text{GB} > 45 \text{ MHz}$, $\frac{1}{2\pi f_{\text{low}} C_A} \leq R_b$
- Accuracy: $R_c \gg R_s$, $A_0 \gg 33 \times 90 \approx 3000$
- Drive capability:
  $I_{\text{source,sink}} > 5 \text{ mA}$
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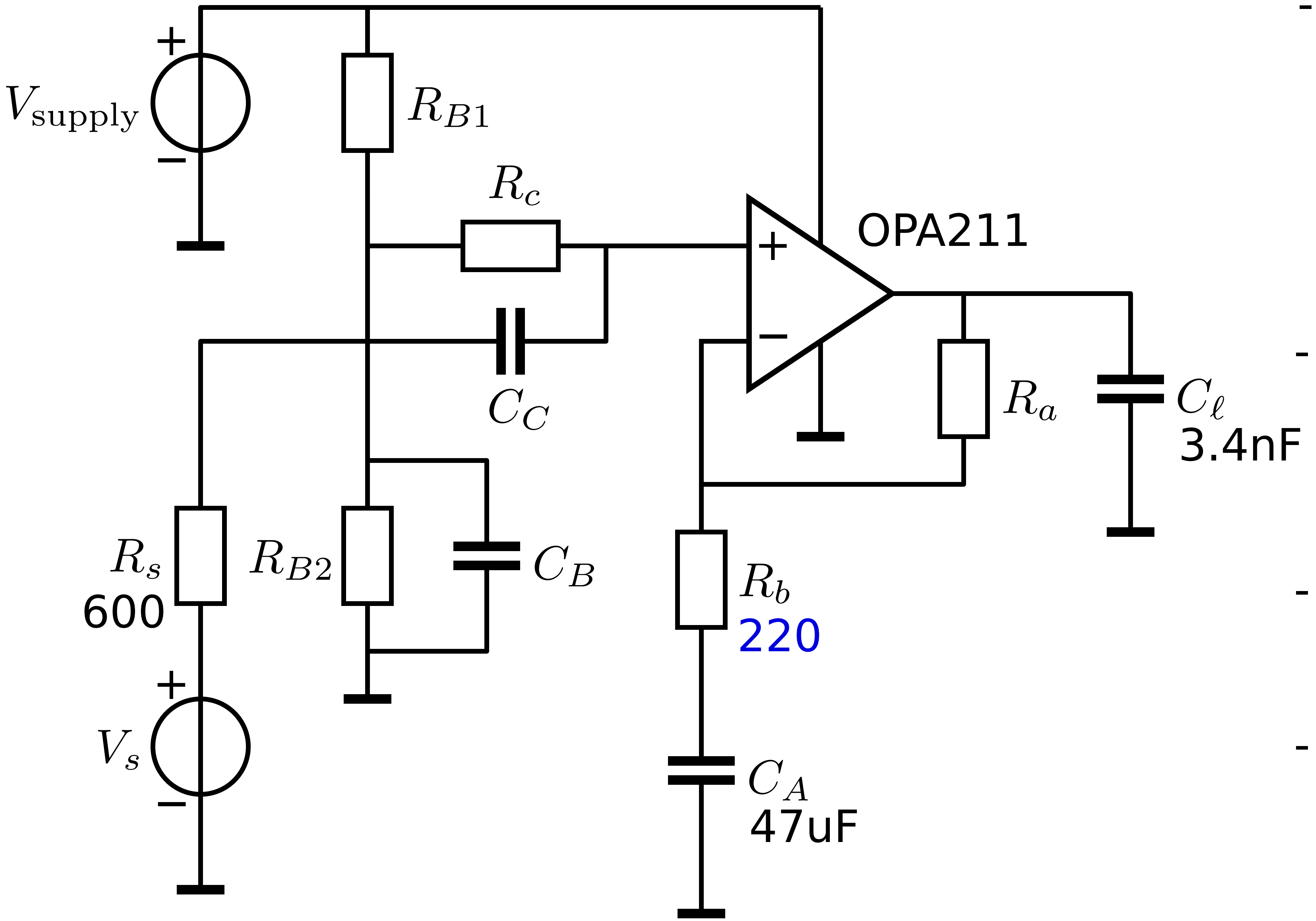
Component selection



- Noise: $R_b < 600\Omega$,
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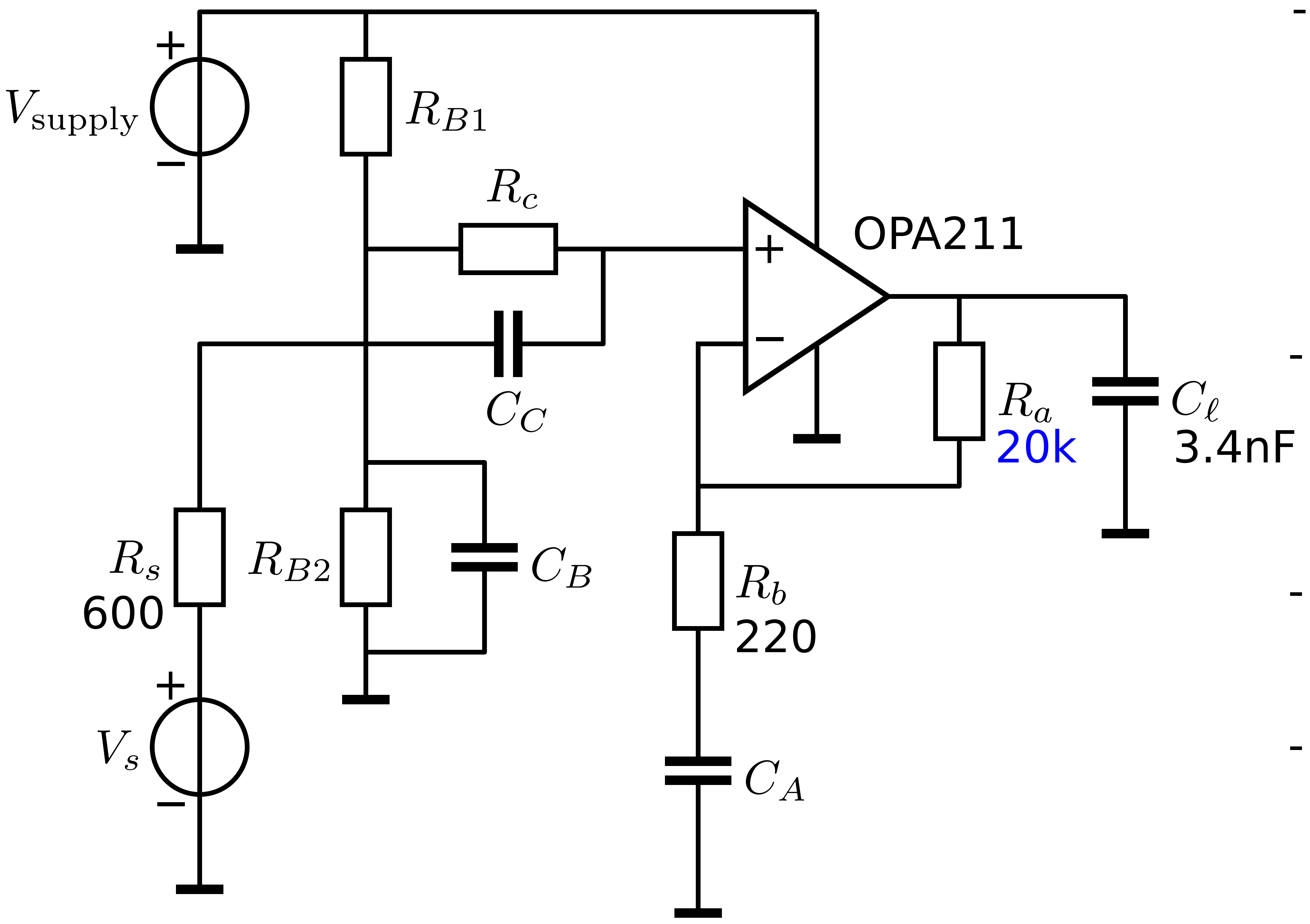

- Noise: $R_b < 600\Omega$, $R_c \gg 600\Omega$, $\frac{1}{2\pi f C_C} \ll R_s$, $S_{V_n} < 3.15 \frac{\rm nV}{\sqrt{\rm Hz}}$, $S_{I_n} < 5.25 \frac{\rm pA}{\sqrt{\rm Hz}}$
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  $\text{GB} > 45 \text{ MHz}$

  $\frac{1}{2\pi f_{\rm low} C_A} \leq R_b$
- Accuracy: $R_c \gg R_s$

  $A_0 \gg 33 \times 90 \approx 3000$
- Drive capability:

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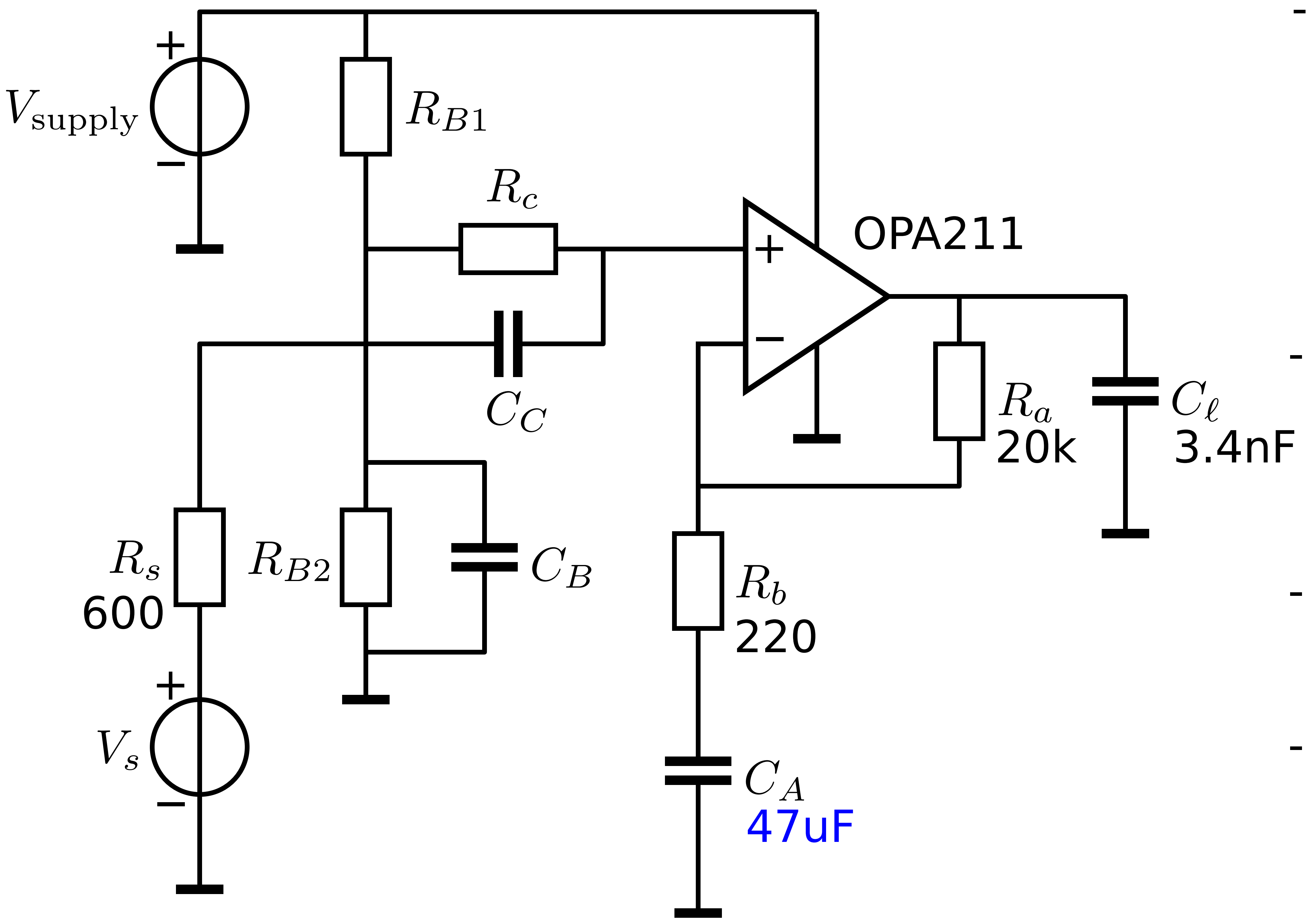
  $\text{SR} > 1.5 \text{ V}/\mu\text{s}$

  $V_{\rm sat} < 0.25 \text{ V}$

Component selection



- Noise:
  $R_b < 600\Omega,$
  $R_c \gg 600\Omega,$
  $\frac{1}{2\pi f C_C} \ll R_s,$
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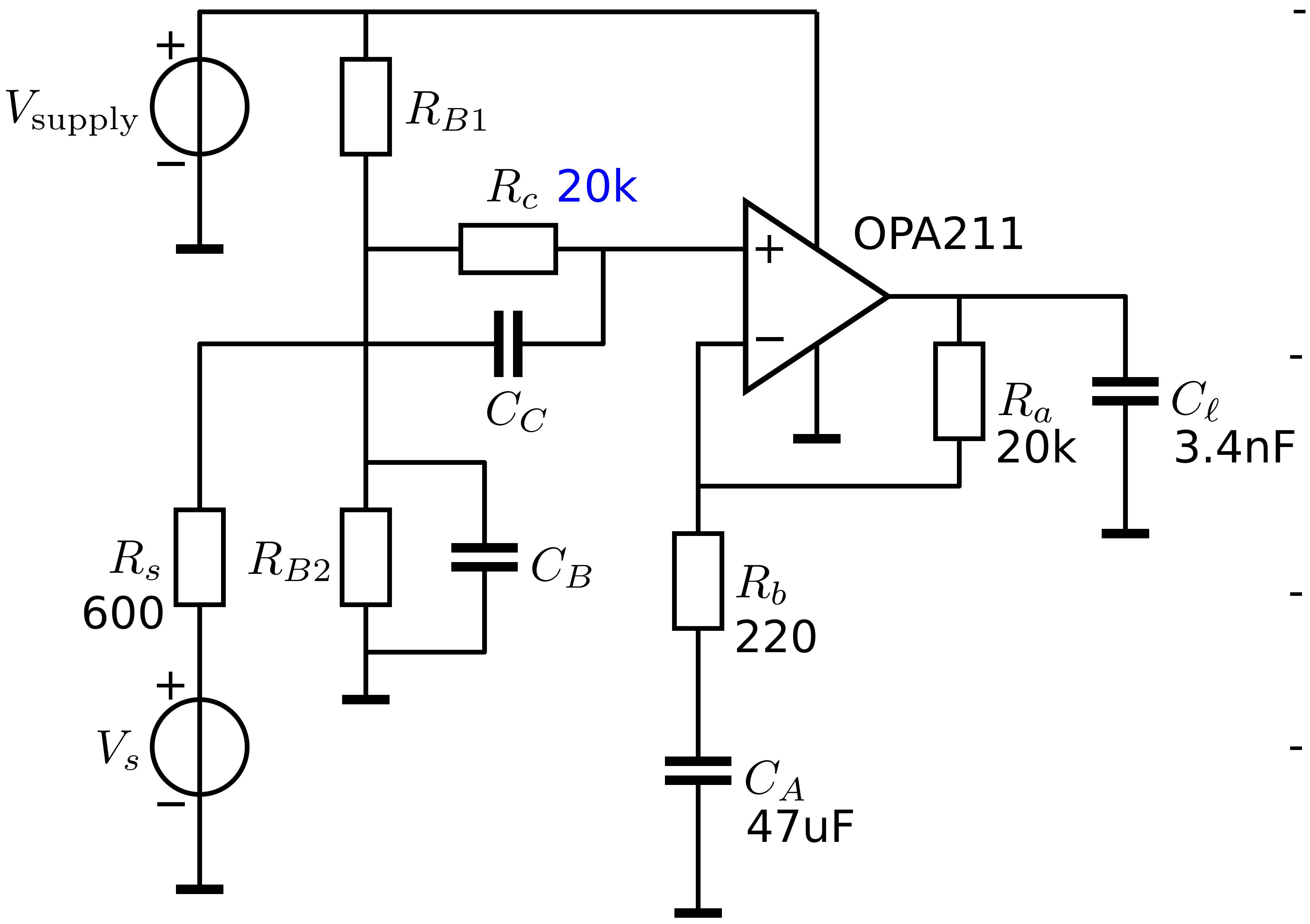
Component selection



- Noise: $R_b < 600\Omega$, $R_c \gg 600\Omega$, $\frac{1}{2\pi f C_C} \ll R_s$, $S_{V_n} < 3.15 \frac{\text{nV}}{\sqrt{\text{Hz}}}$, $S_{I_n} < 5.25 \frac{\text{pA}}{\sqrt{\text{Hz}}}$
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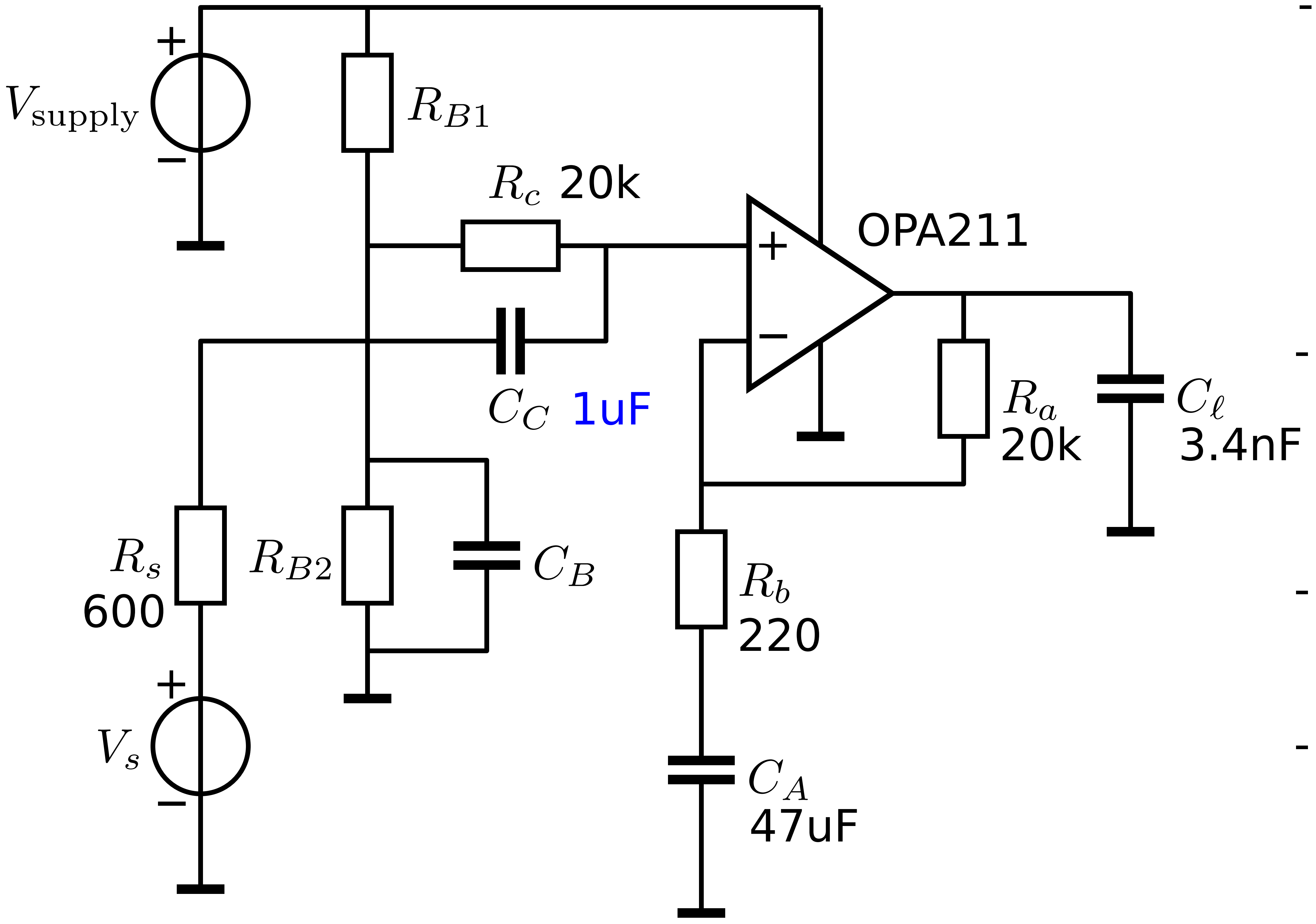

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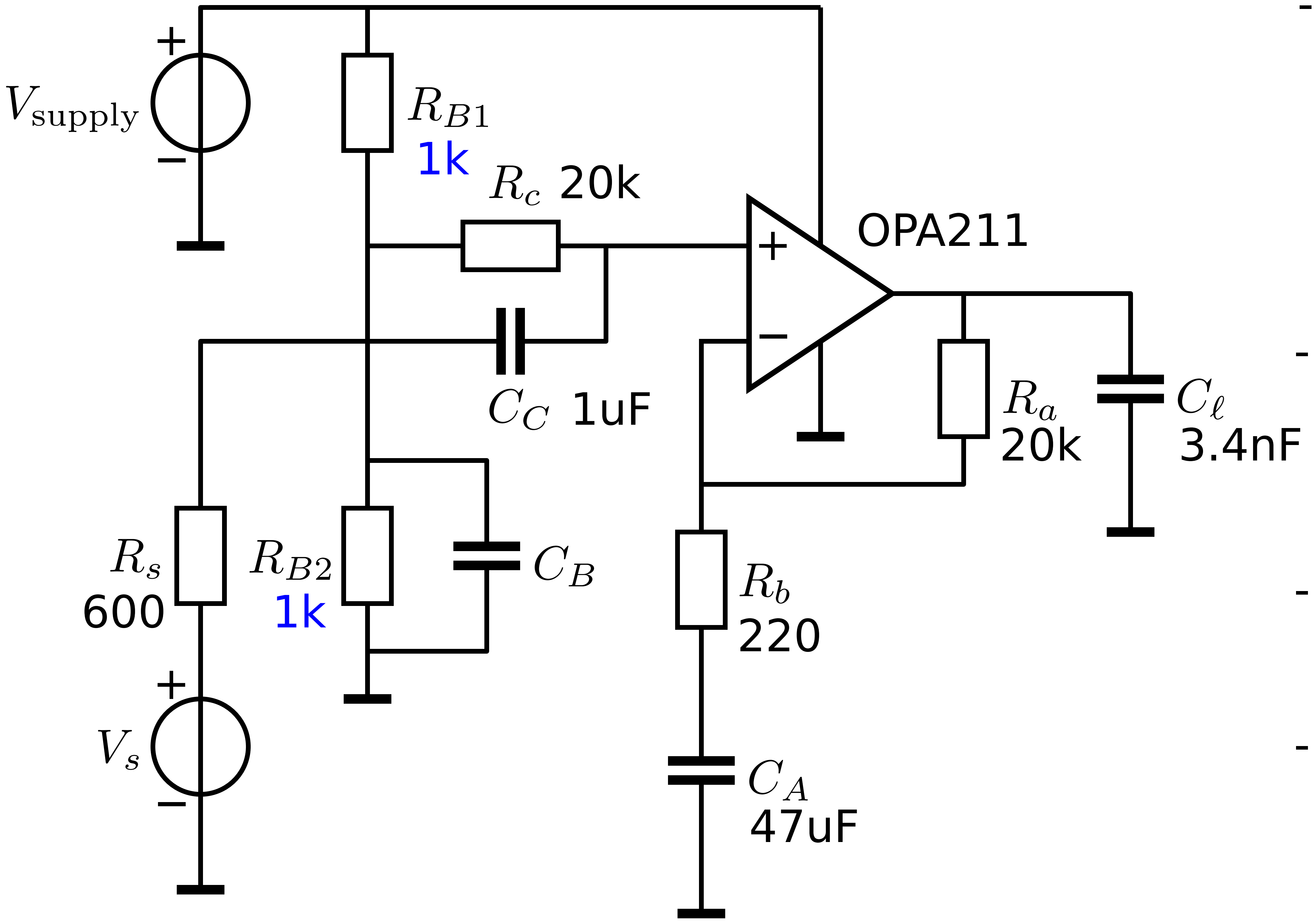

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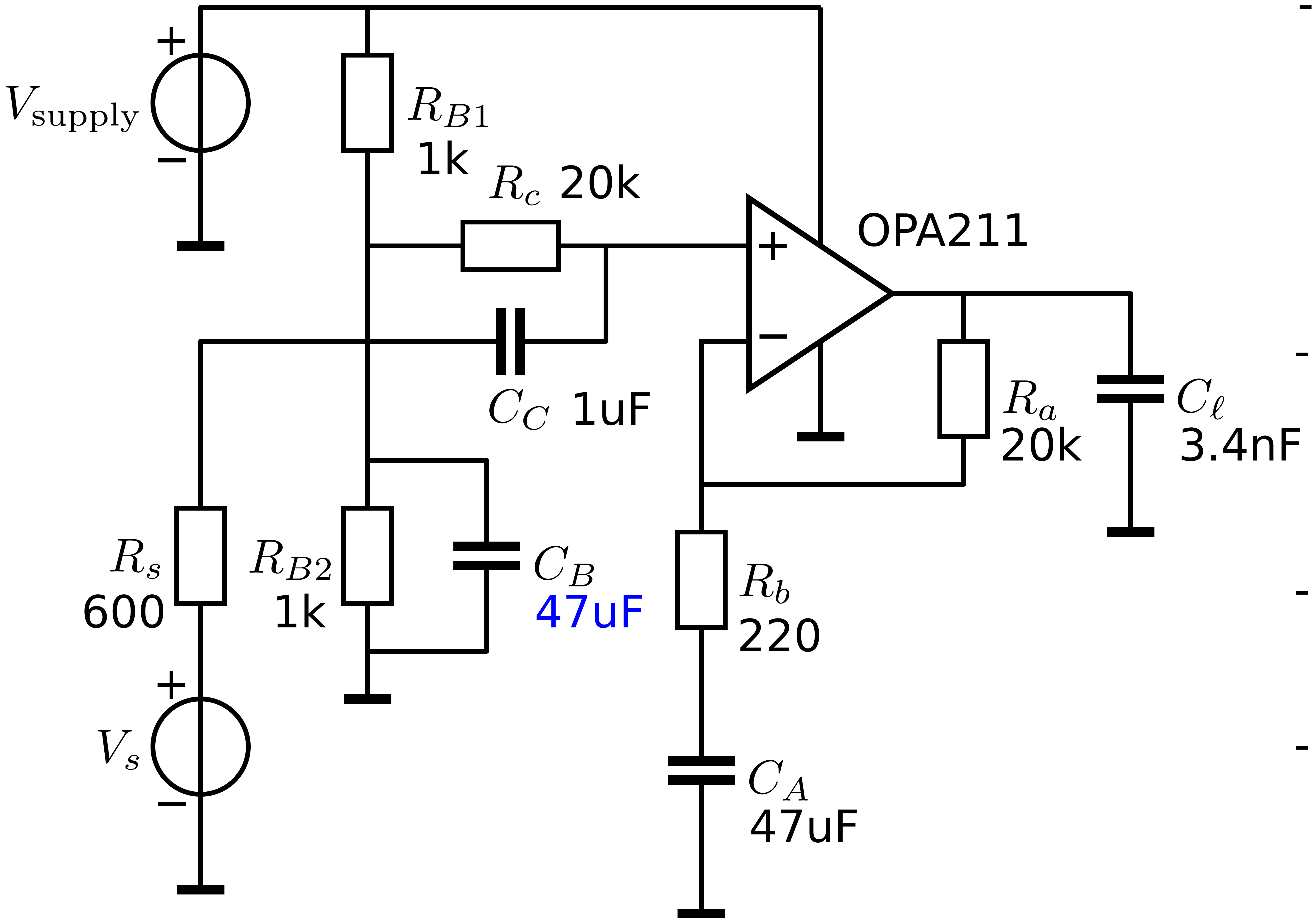
Component selection



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  $\frac{1}{2\pi f C_C} \ll R_s$,
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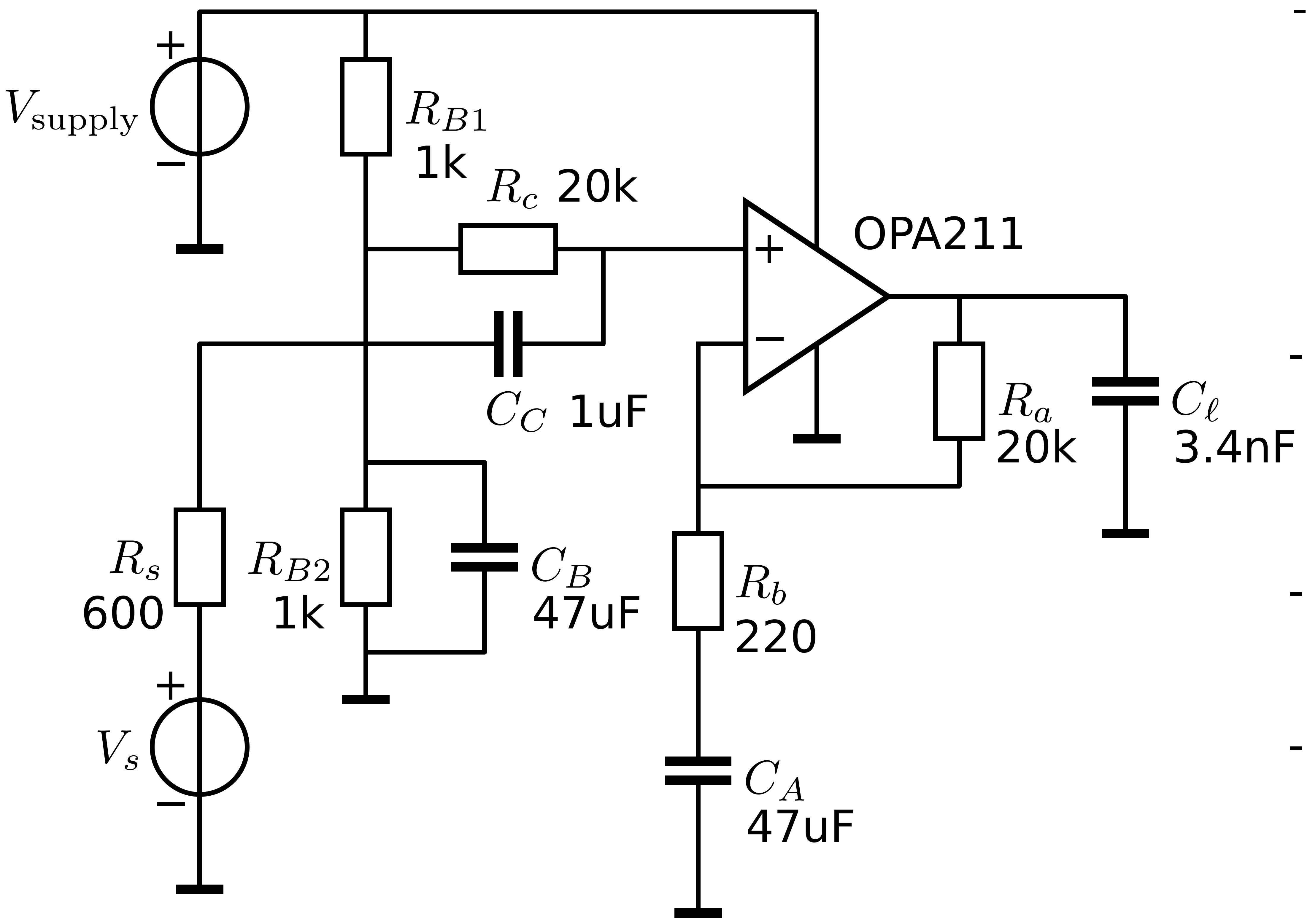

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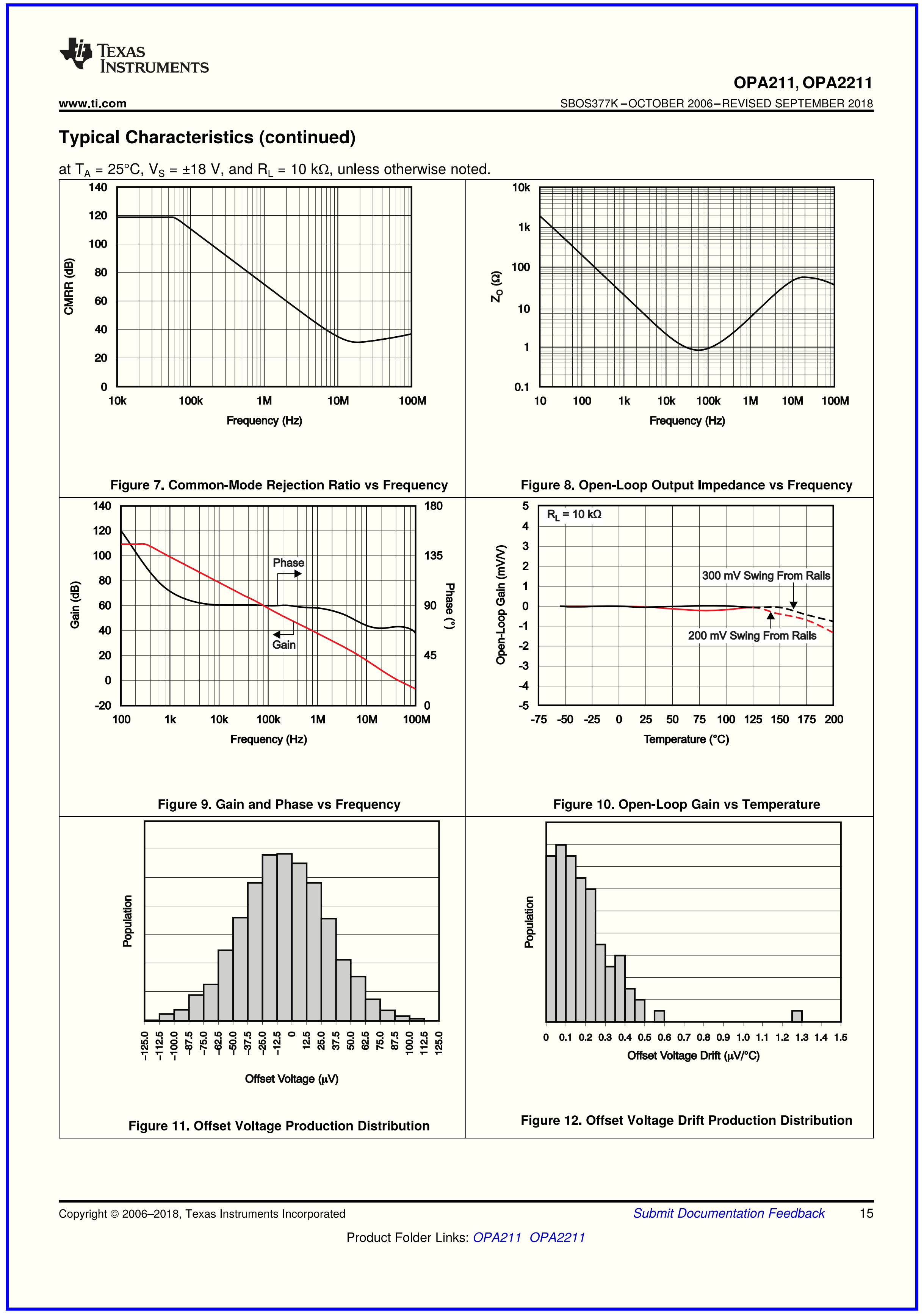
- Accuracy: $R_c \gg R_s$ $A_0 \gg 33 \times 90 \approx 3000$
- Drive capability: $I_{\text{source,sink}} > 5\ \text{mA}$ $\text{SR} > 1.5\ \text{V}/\mu\text{s}$ $V_{\text{sat}} < 0.25\ \text{V}$

Modeling OpAmp

Small-signal dynamic behavior OPA211

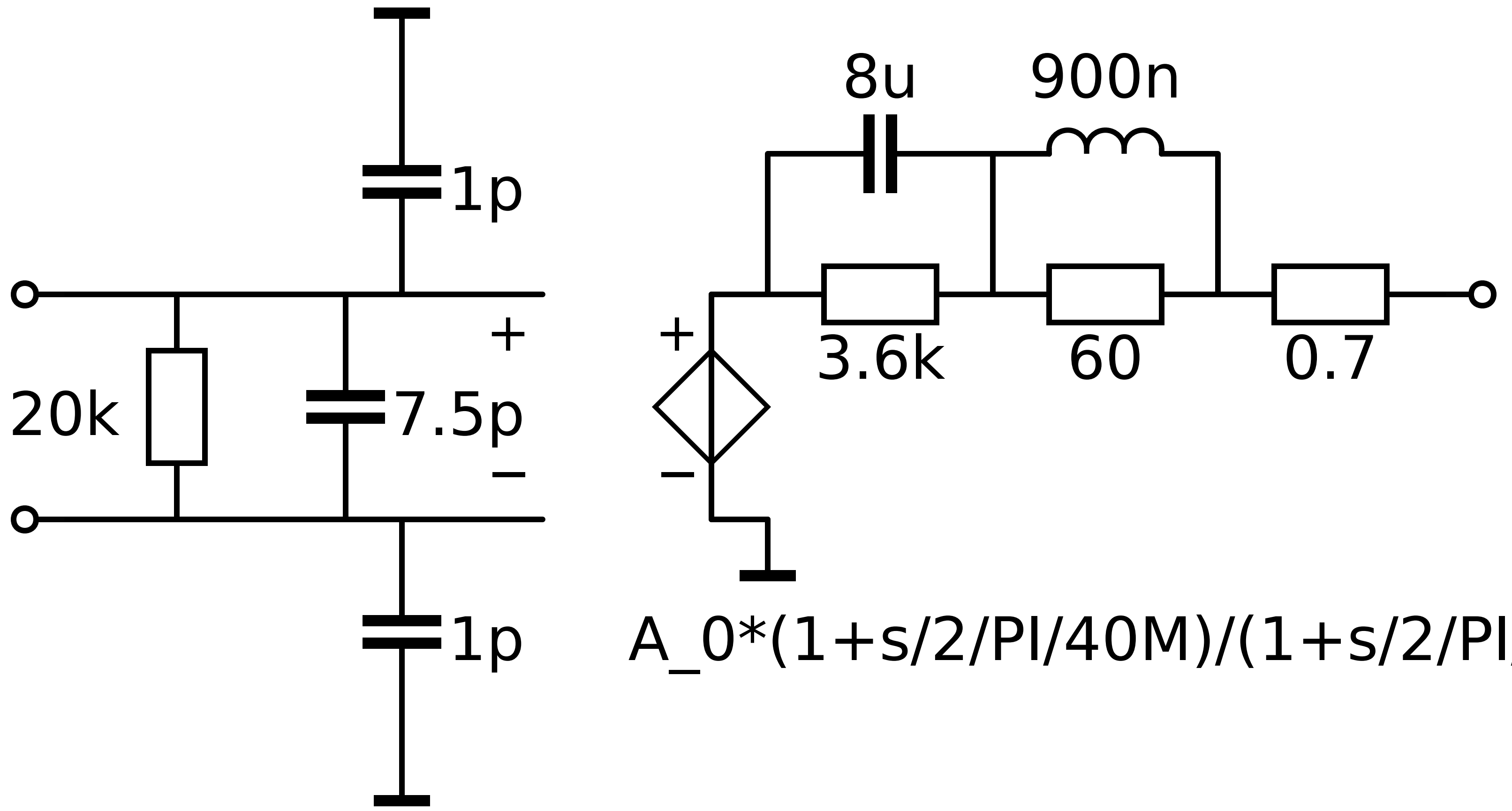
Modeling OpAmp

Small-signal dynamic behavior OPA211

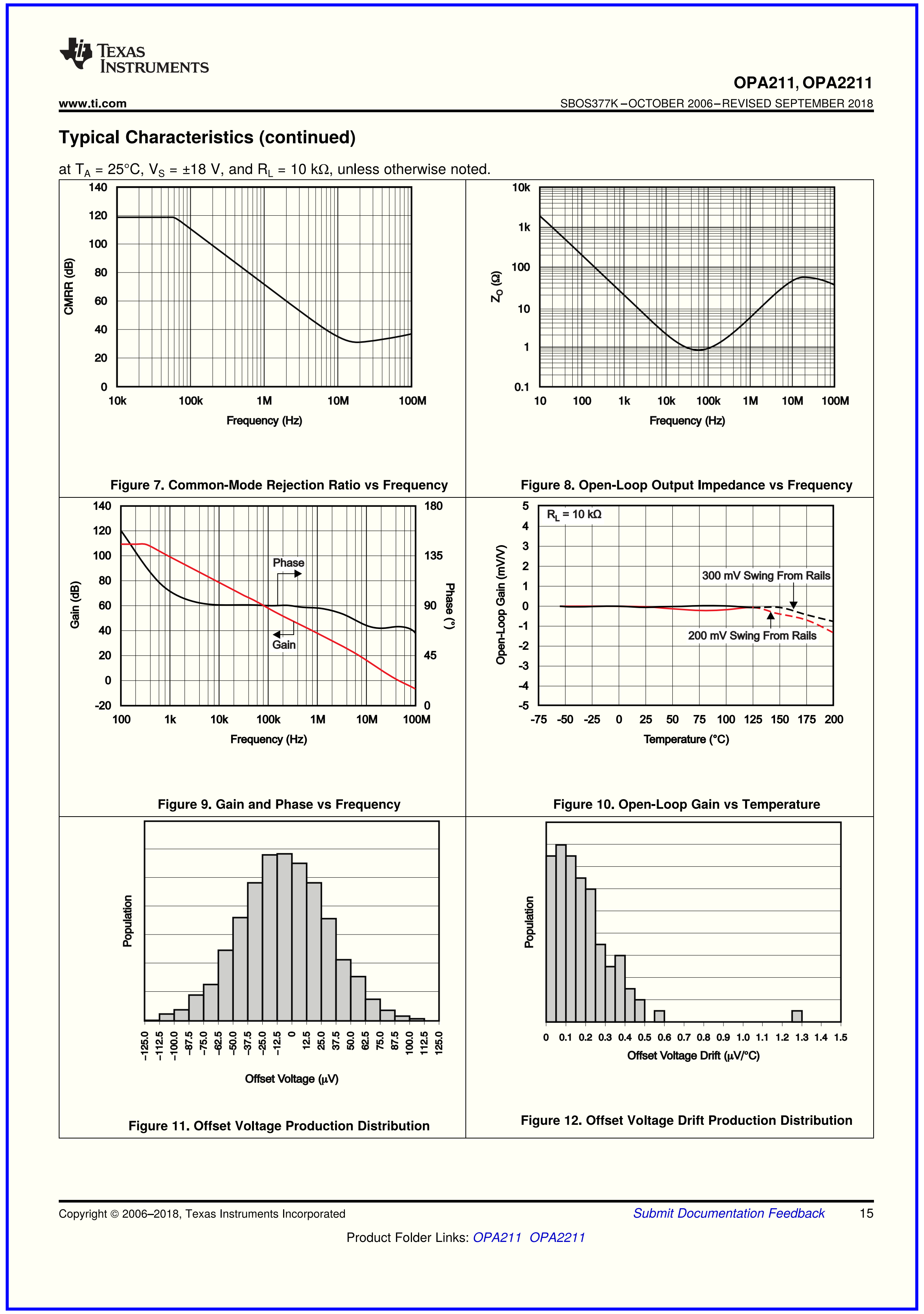


Modeling OpAmp

Small-signal dynamic behavior OPA211

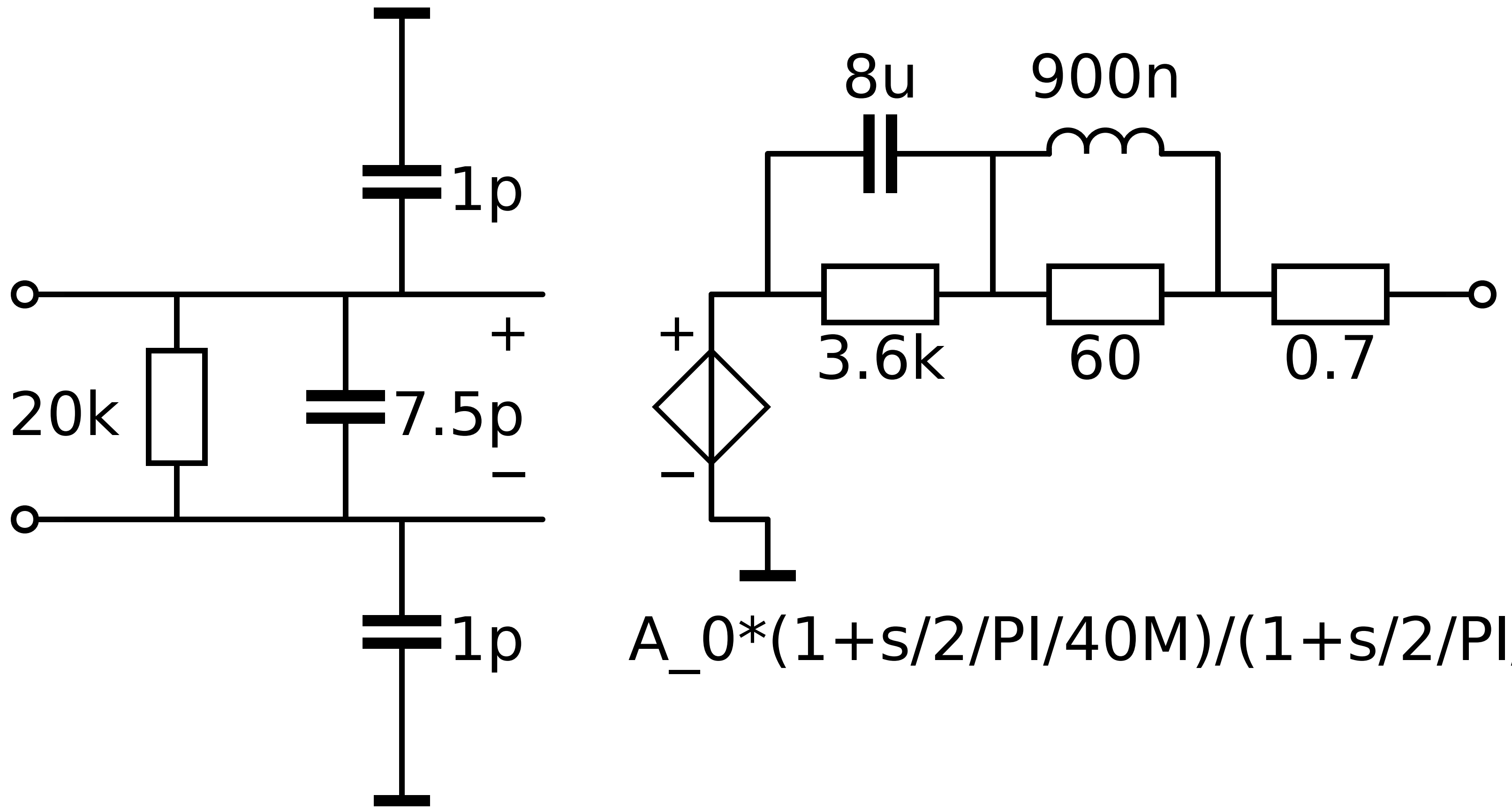


A_0*(1+s/2/PI/40M)/(1+s/2/PI/120)/(1+2/2/PI/20M)



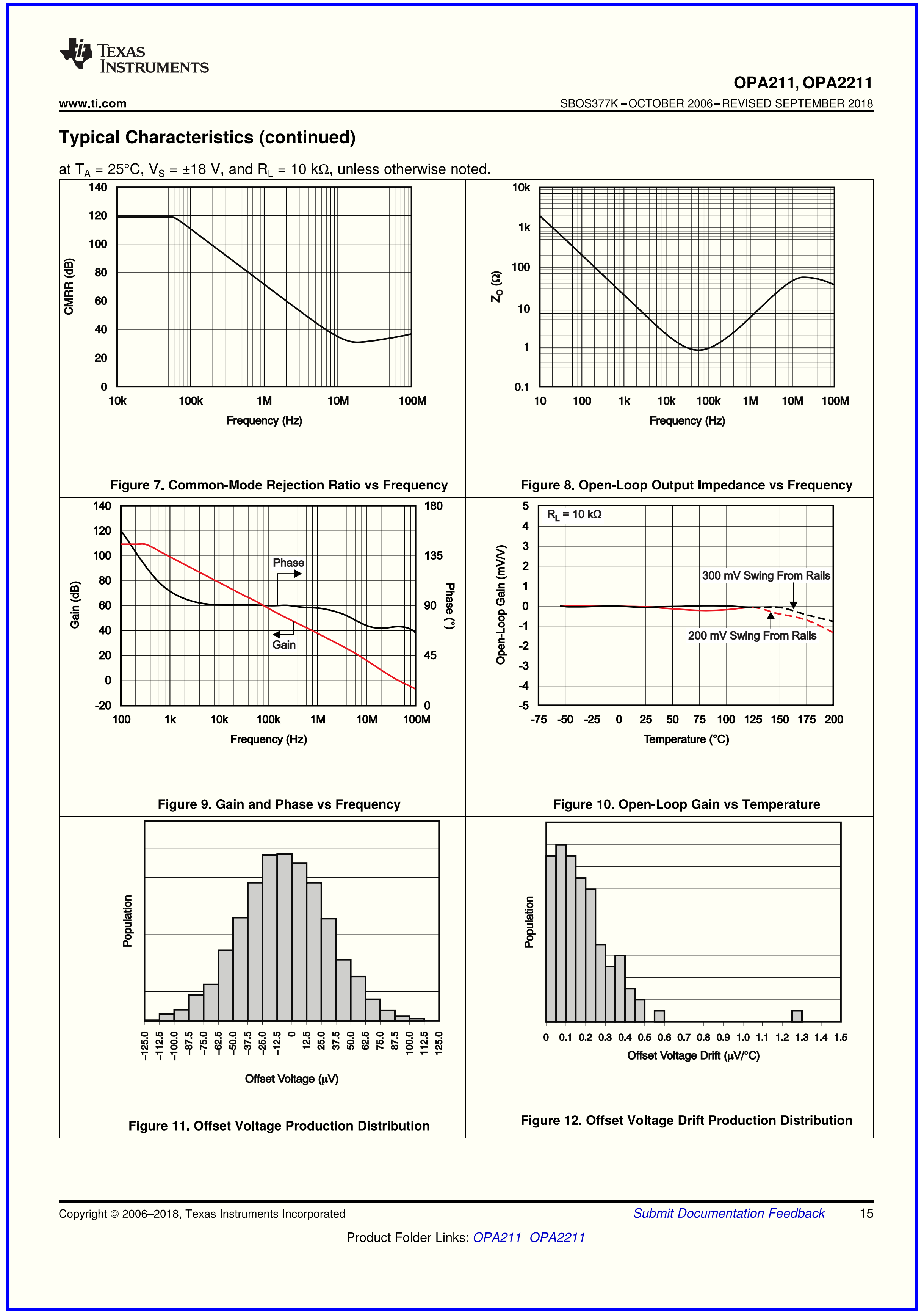
Modeling OpAmp

Small-signal dynamic behavior OPA211



A_0*(1+s/2/PI/40M)/(1+s/2/PI/120)/(1+2/2/PI/20M)

```
.model OPA211_A0 OV
+ cd = 8p  ; differential-mode input capacitance
+ gd = 50u ; differential-mode input conductance
+ cc = 2p  ; common-mode input capacitance
+ av = {A_0*(1+s/2/PI/40M)/(1+s/2/PI/120)/(1+s/2/PI/20M)}   ; voltage gain
+ zo = {3.6k/(1+s*3.6k*8u) + 0.7 + s*900n*60/(60+s*900n)}   ; output impedance
```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Typical Characteristics (continued)

at T_A = 25°C, V_S = ±18 V, and R_L = 10 kΩ, unless otherwise noted.

Figure 7. Common-Mode Rejection Ratio vs Frequency

Figure 8. Open-Loop Output Impedance vs Frequency

Figure 9. Gain and Phase vs Frequency

Figure 10. Open-Loop Gain vs Temperature

Figure 11. Offset Voltage Production Distribution

Figure 12. Offset Voltage Drift Production Distribution

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SLiCAP noise and bias models

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6.6 Electrical Characteristics: V_S = ±2.25 to ±18 V (OPAx211)

at T_A = 25°C, R_L = 10 kΩ connected to midsupply, V_{CM} = V_{OUT} = midsupply, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage	OPA211: V_S = ±15 V		±30	±125	μV
		OPA2211: V_S = ±15 V		±50	±150	μV
dV_{OS}/dT	Input offset drift	V_S = ±15 V, T_A = –40°C to +125°C		±0.35	±1.5	μV/°C
PSRR	Input offset voltage vs power supply	T_A = 25°C		0.1	1	μV/V
		T_A = –40°C to +125°C			3	μV/V
INPUT BIAS CURRENT						
I_B	Input bias current	V_{CM} = 0 V		±60	±175	nA
		OPA211: V_{CM} = 0 V, T_A = –40°C to +125°C			±200	nA
		OPA2211: V_{CM} = 0 V, T_A = –40°C to +125°C			±250	nA
I_{OS}	Input offset current	V_{CM} = 0 V		±25	±100	nA
		V_{CM} = 0 V, T_A = –40°C to +125°C			±150	nA
NOISE						
e_n	Input voltage noise	f = 0.1 to 10 Hz		80		nV_{PP}
	Input voltage noise density	f = 10 Hz		2		nV/√Hz
		f = 100 Hz		1.4		nV/√Hz
		f = 1 kHz		1.1		nV/√Hz
I_n	Input current noise density	f = 10 Hz		3.2		pA/√Hz
		f = 1 kHz		1.7		pA/√Hz
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	V_S ≥ ±5 V	(V–) + 1.8		(V+) – 1.4	V
		V_S < ±5 V	(V–) + 2		(V+) – 1.4	V
CMRR	Common-mode rejection ratio	V_S ≥ ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	114	120		dB
		V_S < ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	110	120		dB
INPUT IMPEDANCE						
	Differential			20 || 8		kΩ || pF
	Common-mode			10 || 2		GΩ || pF
OPEN-LOOP GAIN						

SLiCAP noise and bias models

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6.6 Electrical Characteristics: V_S = ±2.25 to ±18 V (OPAx211)

at T_A = 25°C, R_L = 10 kΩ connected to midsupply, V_{CM} = V_{OUT} = midsupply, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage	OPA211: V_S = ±15 V		±30	±125	μV
		OPA2211: V_S = ±15 V		±50	±150	μV
dV_{OS}/dT	Input offset drift	V_S = ±15 V, T_A = –40°C to +125°C		±0.35	±1.5	μV/°C
PSRR	Input offset voltage vs power supply	T_A = 25°C		0.1	1	μV/V
		T_A = –40°C to +125°C			3	μV/V
INPUT BIAS CURRENT						
I_B	Input bias current	V_{CM} = 0 V		±60	±175	nA
		OPA211: V_{CM} = 0 V, T_A = –40°C to +125°C			±200	nA
		OPA2211: V_{CM} = 0 V, T_A = –40°C to +125°C			±250	nA
I_{OS}	Input offset current	V_{CM} = 0 V		±25	±100	nA
		V_{CM} = 0 V, T_A = –40°C to +125°C			±150	nA
NOISE						
e_n	Input voltage noise	f = 0.1 to 10 Hz		80		nV_{PP}
	Input voltage noise density	f = 10 Hz		2		nV/√Hz
		f = 100 Hz		1.4		nV/√Hz
		f = 1 kHz		1.1		nV/√Hz
I_n	Input current noise density	f = 10 Hz		3.2		pA/√Hz
		f = 1 kHz		1.7		pA/√Hz
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	V_S ≥ ±5 V	(V–) + 1.8		(V+) – 1.4	V
		V_S < ±5 V	(V–) + 2		(V+) – 1.4	V
CMRR	Common-mode rejection ratio	V_S ≥ ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	114	120		dB
		V_S < ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	110	120		dB
INPUT IMPEDANCE						
	Differential			20 || 8		kΩ || pF
	Common-mode			10 || 2		GΩ || pF
OPEN-LOOP GAIN						

SLiCAP noise and bias models

SLiCAP O_dcvar
nullor with offset and bias

Modeling OpAmp

OPA211, OPA2211
SBOS377K – OCTOBER 2006 – REVISED SEPTEMBER 2018 — TEXAS INSTRUMENTS — www.ti.com

6.6 Electrical Characteristics: V_S = ±2.25 to ±18 V (OPAx211)

at T_A = 25°C, R_L = 10 kΩ connected to midsupply, V_{CM} = V_{OUT} = midsupply, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage	OPA211: V_S = ±15 V		±30	±125	μV
		OPA2211: V_S = ±15 V		±50	±150	μV
dV_{OS}/dT	Input offset drift	V_S = ±15 V, T_A = –40°C to +125°C		±0.35	±1.5	μV/°C
PSRR	Input offset voltage vs power supply	T_A = 25°C		0.1	1	μV/V
		T_A = –40°C to +125°C			3	μV/V
INPUT BIAS CURRENT						
I_B	Input bias current	V_{CM} = 0 V		±60	±175	nA
		OPA211: V_{CM} = 0 V, T_A = –40°C to +125°C			±200	nA
		OPA2211: V_{CM} = 0 V, T_A = –40°C to +125°C			±250	nA
I_{OS}	Input offset current	V_{CM} = 0 V		±25	±100	nA
		V_{CM} = 0 V, T_A = –40°C to +125°C			±150	nA
NOISE						
e_n	Input voltage noise	f = 0.1 to 10 Hz		80		nV_{PP}
	Input voltage noise density	f = 10 Hz		2		nV/√Hz
		f = 100 Hz		1.4		nV/√Hz
		f = 1 kHz		1.1		nV/√Hz
I_n	Input current noise density	f = 10 Hz		3.2		pA/√Hz
		f = 1 kHz		1.7		pA/√Hz
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	V_S ≥ ±5 V	(V–) + 1.8		(V+) – 1.4	V
		V_S < ±5 V	(V–) + 2		(V+) – 1.4	V
CMRR	Common-mode rejection ratio	V_S ≥ ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	114	120		dB
		V_S < ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	110	120		dB
INPUT IMPEDANCE						
	Differential			20 || 8		kΩ || pF
	Common-mode			10 || 2		GΩ || pF
OPEN-LOOP GAIN						

SLiCAP noise and bias models

SLiCAP O_dcvar
nullor with offset and bias

Standard deviation offset voltage $svo = 40 \times 10^{-6}$

Modeling OpAmp

TEXAS INSTRUMENTS

OPA211, OPA2211

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6.6 Electrical Characteristics: V_S = ±2.25 to ±18 V (OPAx211)

at T_A = 25°C, R_L = 10 kΩ connected to midsupply, V_{CM} = V_{OUT} = midsupply, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage	OPA211: V_S = ±15 V		±30	±125	μV
		OPA2211: V_S = ±15 V		±50	±150	μV
dV_{OS}/dT	Input offset drift	V_S = ±15 V, T_A = –40°C to +125°C		±0.35	±1.5	μV/°C
PSRR	Input offset voltage vs power supply	T_A = 25°C		0.1	1	μV/V
		T_A = –40°C to +125°C			3	μV/V
INPUT BIAS CURRENT						
I_B	Input bias current	V_{CM} = 0 V		±60	±175	nA
		OPA211: V_{CM} = 0 V, T_A = –40°C to +125°C			±200	nA
		OPA2211: V_{CM} = 0 V, T_A = –40°C to +125°C			±250	nA
I_{OS}	Input offset current	V_{CM} = 0 V		±25	±100	nA
		V_{CM} = 0 V, T_A = –40°C to +125°C			±150	nA
NOISE						
e_n	Input voltage noise	f = 0.1 to 10 Hz		80		nV_{PP}
	Input voltage noise density	f = 10 Hz		2		nV/√Hz
		f = 100 Hz		1.4		nV/√Hz
		f = 1 kHz		1.1		nV/√Hz
I_n	Input current noise density	f = 10 Hz		3.2		pA/√Hz
		f = 1 kHz		1.7		pA/√Hz
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	V_S ≥ ±5 V	(V–) + 1.8		(V+) – 1.4	V
		V_S < ±5 V	(V–) + 2		(V+) – 1.4	V
CMRR	Common-mode rejection ratio	V_S ≥ ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	114	120		dB
		V_S < ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	110	120		dB
INPUT IMPEDANCE						
	Differential			20 || 8		kΩ || pF
	Common-mode			10 || 2		GΩ || pF
OPEN-LOOP GAIN						

SLiCAP noise and bias models

SLiCAP O_dcvar
nullor with offset and bias

Standard deviation offset voltage $svo = 40 \times 10^{-6}$

Standard deviation offset current $sio = 30 \times 10^{-9}$

Modeling OpAmp

OPA211, OPA2211

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Texas Instruments

6.6 Electrical Characteristics: V_S = ±2.25 to ±18 V (OPAx211)

at T_A = 25°C, R_L = 10 kΩ connected to midsupply, V_{CM} = V_{OUT} = midsupply, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage	OPA211: V_S = ±15 V		±30	±125	µV
		OPA2211: V_S = ±15 V		±50	±150	µV
dV_{OS}/dT	Input offset drift	V_S = ±15 V, T_A = –40°C to +125°C		±0.35	±1.5	µV/°C
PSRR	Input offset voltage vs power supply	T_A = 25°C		0.1	1	µV/V
		T_A = –40°C to +125°C			3	µV/V
INPUT BIAS CURRENT						
I_B	Input bias current	V_{CM} = 0 V		±60	±175	nA
		OPA211: V_{CM} = 0 V, T_A = –40°C to +125°C			±200	nA
		OPA2211: V_{CM} = 0 V, T_A = –40°C to +125°C			±250	nA
I_{OS}	Input offset current	V_{CM} = 0 V		±25	±100	nA
		V_{CM} = 0 V, T_A = –40°C to +125°C			±150	nA
NOISE						
e_n	Input voltage noise	f = 0.1 to 10 Hz		80		nV_{PP}
	Input voltage noise density	f = 10 Hz		2		nV/√Hz
		f = 100 Hz		1.4		nV/√Hz
		f = 1 kHz		1.1		nV/√Hz
I_n	Input current noise density	f = 10 Hz		3.2		pA/√Hz
		f = 1 kHz		1.7		pA/√Hz
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	V_S ≥ ±5 V	(V–) + 1.8		(V+) – 1.4	V
		V_S < ±5 V	(V–) + 2		(V+) – 1.4	V
CMRR	Common-mode rejection ratio	V_S ≥ ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	114	120		dB
		V_S < ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	110	120		dB
INPUT IMPEDANCE						
	Differential			20 || 8		kΩ || pF
	Common-mode			10 || 2		GΩ || pF
OPEN-LOOP GAIN						

SLiCAP noise and bias models

SLiCAP O_dcvar
nullor with offset and bias

Standard deviation offset voltage $svo = 40 \times 10^{-6}$

Standard deviation offset current $sio = 30 \times 10^{-9}$

Mean value bias current $iib = 0$

Modeling OpAmp

OPA211, OPA2211

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TEXAS INSTRUMENTS

6.6 Electrical Characteristics: V_S = ±2.25 to ±18 V (OPAx211)

at T_A = 25°C, R_L = 10 kΩ connected to midsupply, V_{CM} = V_{OUT} = midsupply, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage	OPA211: V_S = ±15 V		±30	±125	μV
		OPA2211: V_S = ±15 V		±50	±150	μV
dV_{OS}/dT	Input offset drift	V_S = ±15 V T_A = –40°C to +125°C		±0.35	±1.5	μV/°C
PSRR	Input offset voltage vs power supply	T_A = 25°C		0.1	1	μV/V
		T_A = –40°C to +125°C			3	μV/V
INPUT BIAS CURRENT						
I_B	Input bias current	V_{CM} = 0 V		±60	±175	nA
		OPA211: V_{CM} = 0 V T_A = –40°C to +125°C			±200	nA
		OPA2211: V_{CM} = 0 V T_A = –40°C to +125°C			±250	nA
I_{OS}	Input offset current	V_{CM} = 0 V		±25	±100	nA
		V_{CM} = 0 V T_A = –40°C to +125°C			±150	nA
NOISE						
e_n	Input voltage noise	f = 0.1 to 10 Hz		80		nV_{PP}
	Input voltage noise density	f = 10 Hz		2		nV/√Hz
		f = 100 Hz		1.4		nV/√Hz
		f = 1 kHz		1.1		nV/√Hz
I_n	Input current noise density	f = 10 Hz		3.2		pA/√Hz
		f = 1 kHz		1.7		pA/√Hz
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	V_S ≥ ±5 V	(V–) + 1.8		(V+) – 1.4	V
		V_S < ±5 V	(V–) + 2		(V+) – 1.4	V
CMRR	Common-mode rejection ratio	V_S ≥ ±5 V (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V T_A = –40°C to +125°C	114	120		dB
		V_S < ±5 V (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V T_A = –40°C to +125°C	110	120		dB
INPUT IMPEDANCE						
	Differential			20 || 8		kΩ || pF
	Common-mode			10 || 2		GΩ || pF
OPEN-LOOP GAIN						

SLiCAP noise and bias models

SLiCAP O_dcvar
nullor with offset and bias

Standard deviation offset voltage $svo = 40 \times 10^{-6}$

Standard deviation offset current $sio = 30 \times 10^{-9}$

Mean value bias current $iib = 0$

Standard deviation bias current $sib = 60 \times 10^{-9}$

Modeling OpAmp

TEXAS INSTRUMENTS

OPA211, OPA2211

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6.6 Electrical Characteristics: V_S = ±2.25 to ±18 V (OPAx211)

at T_A = 25°C, R_L = 10 kΩ connected to midsupply, V_{CM} = V_{OUT} = midsupply, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage	OPA211: V_S = ±15 V		±30	±125	μV
		OPA2211: V_S = ±15 V		±50	±150	μV
dV_{OS}/dT	Input offset drift	V_S = ±15 V, T_A = –40°C to +125°C		±0.35	±1.5	μV/°C
PSRR	Input offset voltage vs power supply	T_A = 25°C		0.1	1	μV/V
		T_A = –40°C to +125°C			3	μV/V
INPUT BIAS CURRENT						
I_B	Input bias current	V_{CM} = 0 V		±60	±175	nA
		OPA211: V_{CM} = 0 V, T_A = –40°C to +125°C			±200	nA
		OPA2211: V_{CM} = 0 V, T_A = –40°C to +125°C			±250	nA
I_{OS}	Input offset current	V_{CM} = 0 V		±25	±100	nA
		V_{CM} = 0 V, T_A = –40°C to +125°C			±150	nA
NOISE						
e_n	Input voltage noise	f = 0.1 to 10 Hz		80		nV_{PP}
	Input voltage noise density	f = 10 Hz		2		nV/√Hz
		f = 100 Hz		1.4		nV/√Hz
		f = 1 kHz		1.1		nV/√Hz
I_n	Input current noise density	f = 10 Hz		3.2		pA/√Hz
		f = 1 kHz		1.7		pA/√Hz
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	V_S ≥ ±5 V	(V–) + 1.8		(V+) – 1.4	V
		V_S < ±5 V	(V–) + 2		(V+) – 1.4	V
CMRR	Common-mode rejection ratio	V_S ≥ ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	114	120		dB
		V_S < ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	110	120		dB
INPUT IMPEDANCE						
	Differential			20 || 8		kΩ || pF
	Common-mode			10 || 2		GΩ || pF
OPEN-LOOP GAIN						

SLiCAP noise and bias models

SLiCAP O_dcvar
nullor with offset and bias

Standard deviation offset voltage $svo = 40 \times 10^{-6}$

Standard deviation offset current $sio = 30 \times 10^{-9}$

Mean value bias current $iib = 0$

Standard deviation bias current $sib = 60 \times 10^{-9}$

SLiCAP O_noise
nullor with equivalent input noise sources

Modeling OpAmp

OPA211, OPA2211

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6.6 Electrical Characteristics: V_S = ±2.25 to ±18 V (OPAx211)

at T_A = 25°C, R_L = 10 kΩ connected to midsupply, V_{CM} = V_{OUT} = midsupply, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage	OPA211: V_S = ±15 V		±30	±125	µV
		OPA2211: V_S = ±15 V		±50	±150	µV
dV_{OS}/dT	Input offset drift	V_S = ±15 V, T_A = –40°C to +125°C		±0.35	±1.5	µV/°C
PSRR	Input offset voltage vs power supply	T_A = 25°C		0.1	1	µV/V
		T_A = –40°C to +125°C			3	µV/V
INPUT BIAS CURRENT						
I_B	Input bias current	V_{CM} = 0 V		±60	±175	nA
		OPA211: V_{CM} = 0 V, T_A = –40°C to +125°C			±200	nA
		OPA2211: V_{CM} = 0 V, T_A = –40°C to +125°C			±250	nA
I_{OS}	Input offset current	V_{CM} = 0 V		±25	±100	nA
		V_{CM} = 0 V, T_A = –40°C to +125°C			±150	nA
NOISE						
e_n	Input voltage noise	f = 0.1 to 10 Hz		80		nV_{PP}
	Input voltage noise density	f = 10 Hz		2		nV/√Hz
		f = 100 Hz		1.4		nV/√Hz
		f = 1 kHz		1.1		nV/√Hz
I_n	Input current noise density	f = 10 Hz		3.2		pA/√Hz
		f = 1 kHz		1.7		pA/√Hz
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	V_S ≥ ±5 V	(V–) + 1.8		(V+) – 1.4	V
		V_S < ±5 V	(V–) + 2		(V+) – 1.4	V
CMRR	Common-mode rejection ratio	V_S ≥ ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	114	120		dB
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INPUT IMPEDANCE						
	Differential			20 || 8		kΩ || pF
	Common-mode			10 || 2		GΩ || pF
OPEN-LOOP GAIN						

SLiCAP noise and bias models

SLiCAP O_dcvar
nullor with offset and bias

Standard deviation offset voltage	$svo = 40 \times 10^{-6}$
Standard deviation offset current	$sio = 30 \times 10^{-9}$
Mean value bias current	$iib = 0$
Standard deviation bias current	$sib = 60 \times 10^{-9}$

SLiCAP O_noise
nullor with equivalent input noise sources

Spectral density noise voltage $sv = 1.2 \times 10^{-18}$

Modeling OpAmp

OPA211, OPA2211

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TEXAS INSTRUMENTS

6.6 Electrical Characteristics: V_S = ±2.25 to ±18 V (OPAx211)

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PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage	OPA211: V_S = ±15 V		±30	±125	μV
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dV_{OS}/dT	Input offset drift	V_S = ±15 V, T_A = –40°C to +125°C		±0.35	±1.5	μV/°C
PSRR	Input offset voltage vs power supply	T_A = 25°C		0.1	1	μV/V
		T_A = –40°C to +125°C			3	μV/V
INPUT BIAS CURRENT						
I_B	Input bias current	V_{CM} = 0 V		±60	±175	nA
		OPA211: V_{CM} = 0 V, T_A = –40°C to +125°C			±200	nA
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I_{OS}	Input offset current	V_{CM} = 0 V		±25	±100	nA
		V_{CM} = 0 V, T_A = –40°C to +125°C			±150	nA
NOISE						
e_n	Input voltage noise	f = 0.1 to 10 Hz		80		nV_{PP}
	Input voltage noise density	f = 10 Hz		2		nV/√Hz
		f = 100 Hz		1.4		nV/√Hz
		f = 1 kHz		1.1		nV/√Hz
I_n	Input current noise density	f = 10 Hz		3.2		pA/√Hz
		f = 1 kHz		1.7		pA/√Hz
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	V_S ≥ ±5 V	(V–) + 1.8		(V+) – 1.4	V
		V_S < ±5 V	(V–) + 2		(V+) – 1.4	V
CMRR	Common-mode rejection ratio	V_S ≥ ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	114	120		dB
		V_S < ±5 V, (V–) + 2 V ≤ V_{CM} ≤ (V+) – 2 V, T_A = –40°C to +125°C	110	120		dB
INPUT IMPEDANCE						
	Differential			20 || 8		kΩ || pF
	Common-mode			10 || 2		GΩ || pF
OPEN-LOOP GAIN						

SLiCAP noise and bias models

SLiCAP O_dcvar
nullor with offset and bias

Standard deviation offset voltage $svo = 40 \times 10^{-6}$

Standard deviation offset current $sio = 30 \times 10^{-9}$

Mean value bias current $iib = 0$

Standard deviation bias current $sib = 60 \times 10^{-9}$

SLiCAP O_noise
nullor with equivalent input noise sources

Spectral density noise voltage $sv = 1.2 \times 10^{-18}$

Spectral density noise current $si = 2.9 \times 10^{-24}$

Modeling OpAmp

TEXAS INSTRUMENTS

OPA211, OPA2211

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6.6 Electrical Characteristics: V_S = ±2.25 to ±18 V (OPAx211)

at T_A = 25°C, R_L = 10 kΩ connected to midsupply, V_{CM} = V_{OUT} = midsupply, (unless otherwise noted)

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OFFSET VOLTAGE						
V_{OS}	Input offset voltage	OPA211: V_S = ±15 V		±30	±125	µV
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dV_{OS}/dT	Input offset drift	V_S = ±15 V, T_A = –40°C to +125°C		±0.35	±1.5	µV/°C
PSRR	Input offset voltage vs power supply	T_A = 25°C		0.1	1	µV/V
		T_A = –40°C to +125°C			3	µV/V
INPUT BIAS CURRENT						
I_B	Input bias current	V_{CM} = 0 V		±60	±175	nA
		OPA211: V_{CM} = 0 V, T_A = –40°C to +125°C			±200	nA
		OPA2211: V_{CM} = 0 V, T_A = –40°C to +125°C			±250	nA
I_{OS}	Input offset current	V_{CM} = 0 V		±25	±100	nA
		V_{CM} = 0 V, T_A = –40°C to +125°C			±150	nA
NOISE						
e_n	Input voltage noise	f = 0.1 to 10 Hz		80		nV_{PP}
	Input voltage noise density	f = 10 Hz		2		nV/√Hz
		f = 100 Hz		1.4		nV/√Hz
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I_n	Input current noise density	f = 10 Hz		3.2		pA/√Hz
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INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	V_S ≥ ±5 V	(V–) + 1.8		(V+) – 1.4	V
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INPUT IMPEDANCE						
	Differential			20 || 8		kΩ || pF
	Common-mode			10 || 2		GΩ || pF
OPEN-LOOP GAIN						

SLiCAP noise and bias models

SLiCAP O_dcvar
nullor with offset and bias

Standard deviation offset voltage $svo = 40 \times 10^{-6}$

Standard deviation offset current $sio = 30 \times 10^{-9}$

Mean value bias current $iib = 0$

Standard deviation bias current $sib = 60 \times 10^{-9}$

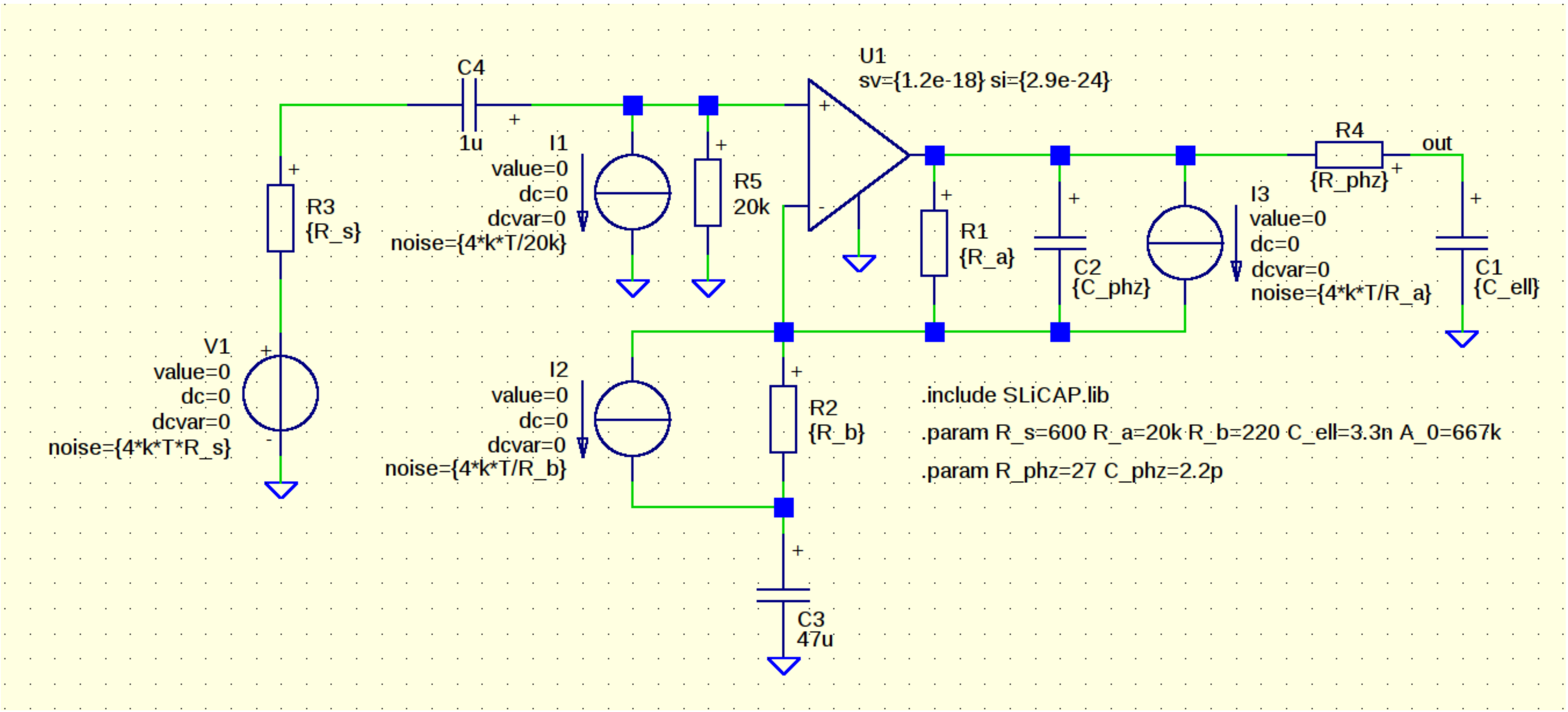
SLiCAP O_noise
nullor with equivalent input noise sources

Spectral density noise voltage $sv = 1.2 \times 10^{-18}$

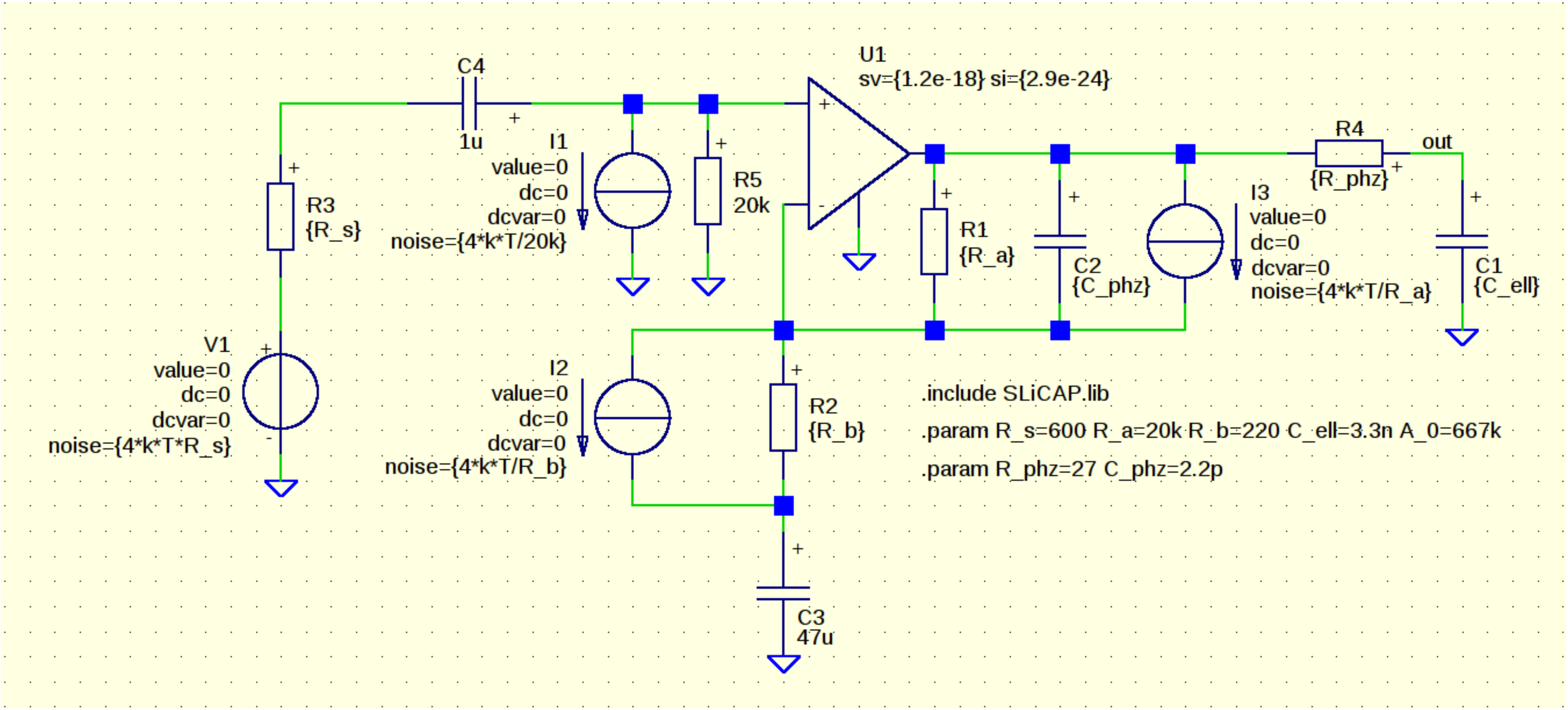
Spectral density noise current $si = 2.9 \times 10^{-24}$

SLiCAP noise verification

SLiCAP noise verification

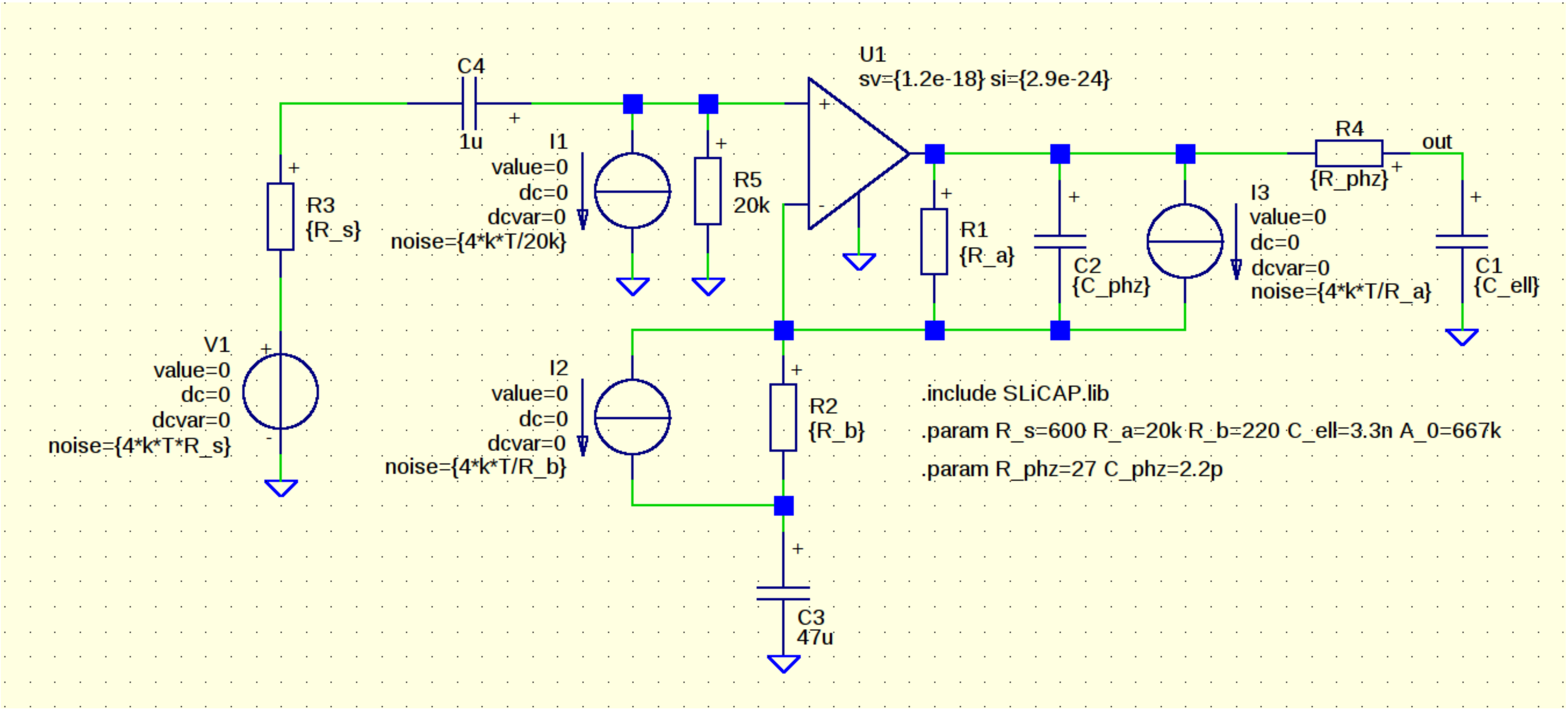


SLiCAP noise verification



Noise figure 2.4dB over 1.57x500kHz bandwidth.

SLiCAP noise verification



Noise figure 2.4dB over 1.57x500kHz bandwidth.

SLiCAP biasing verification

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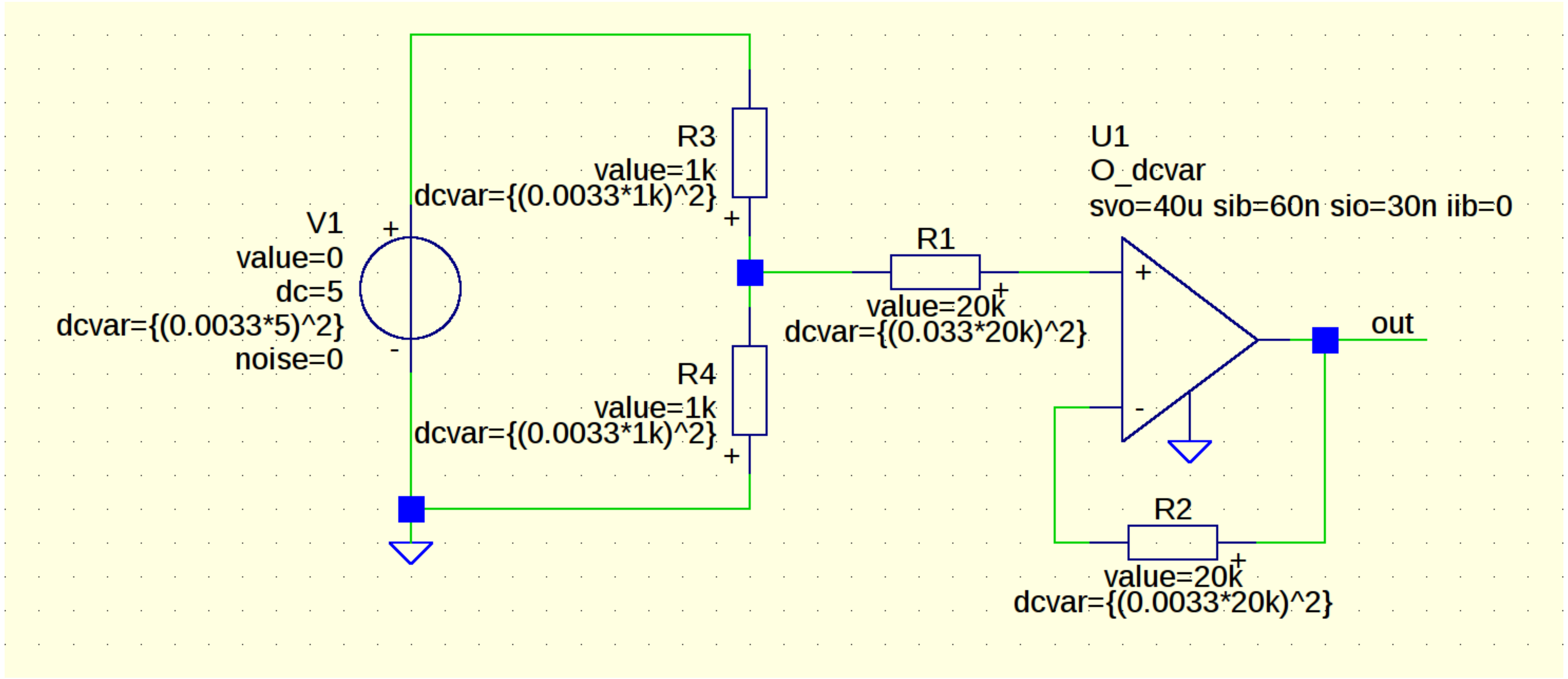
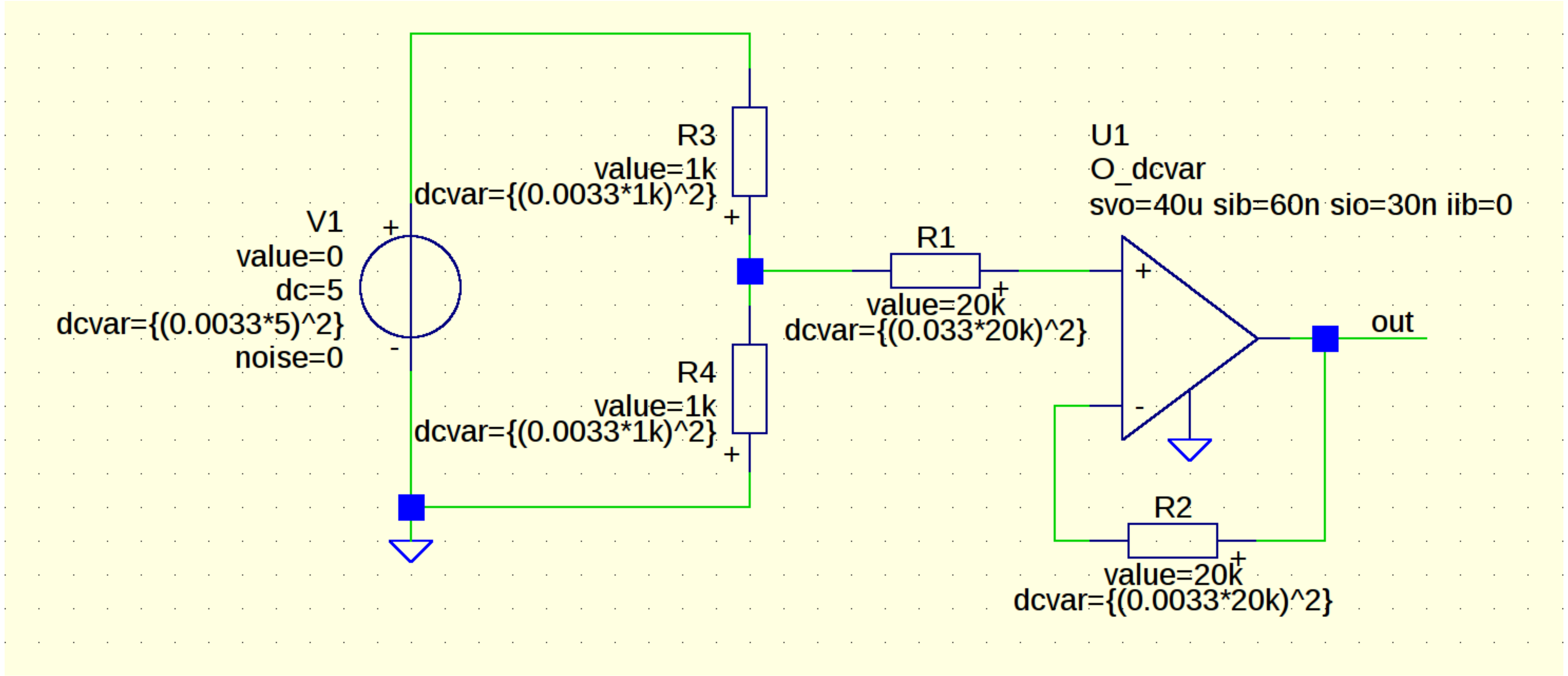
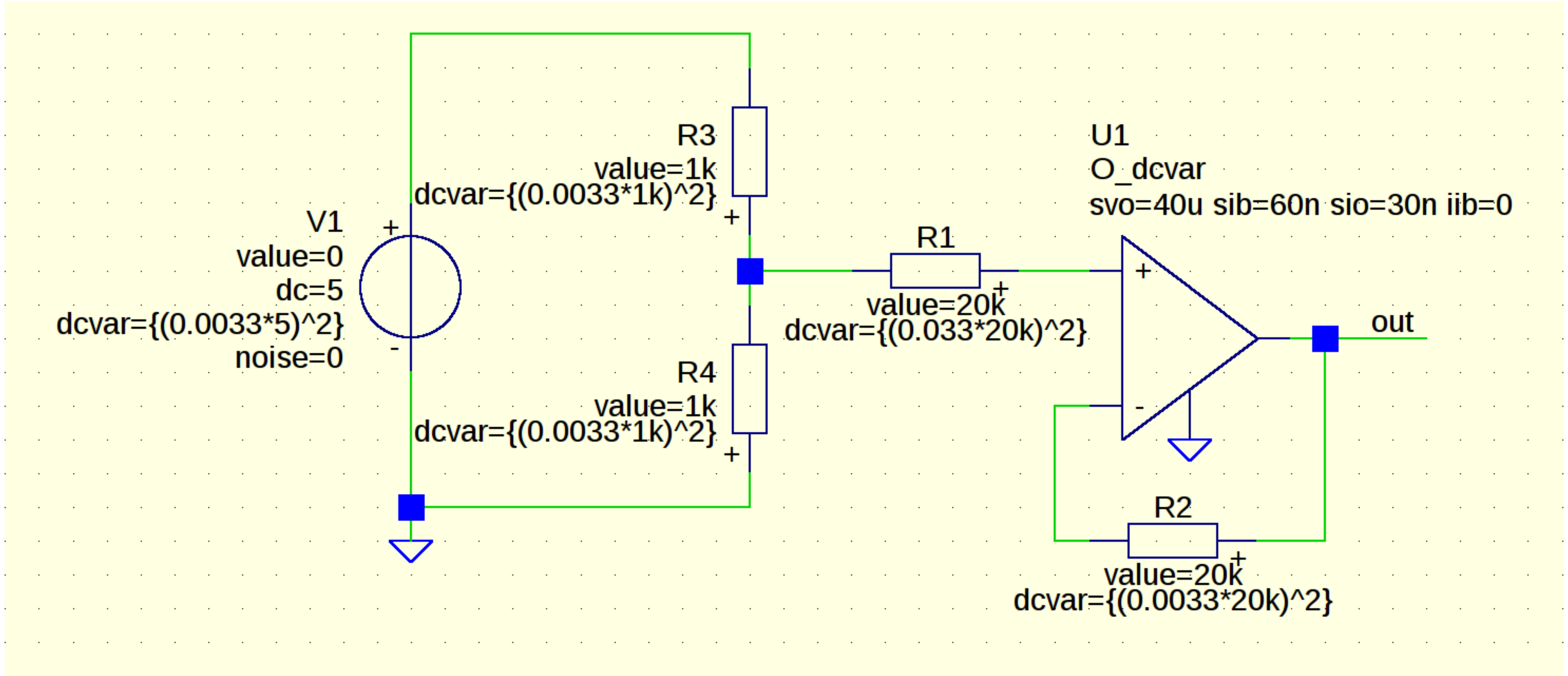


SLiCAP biasing verification



All component tolerances 1% (3-sigma)

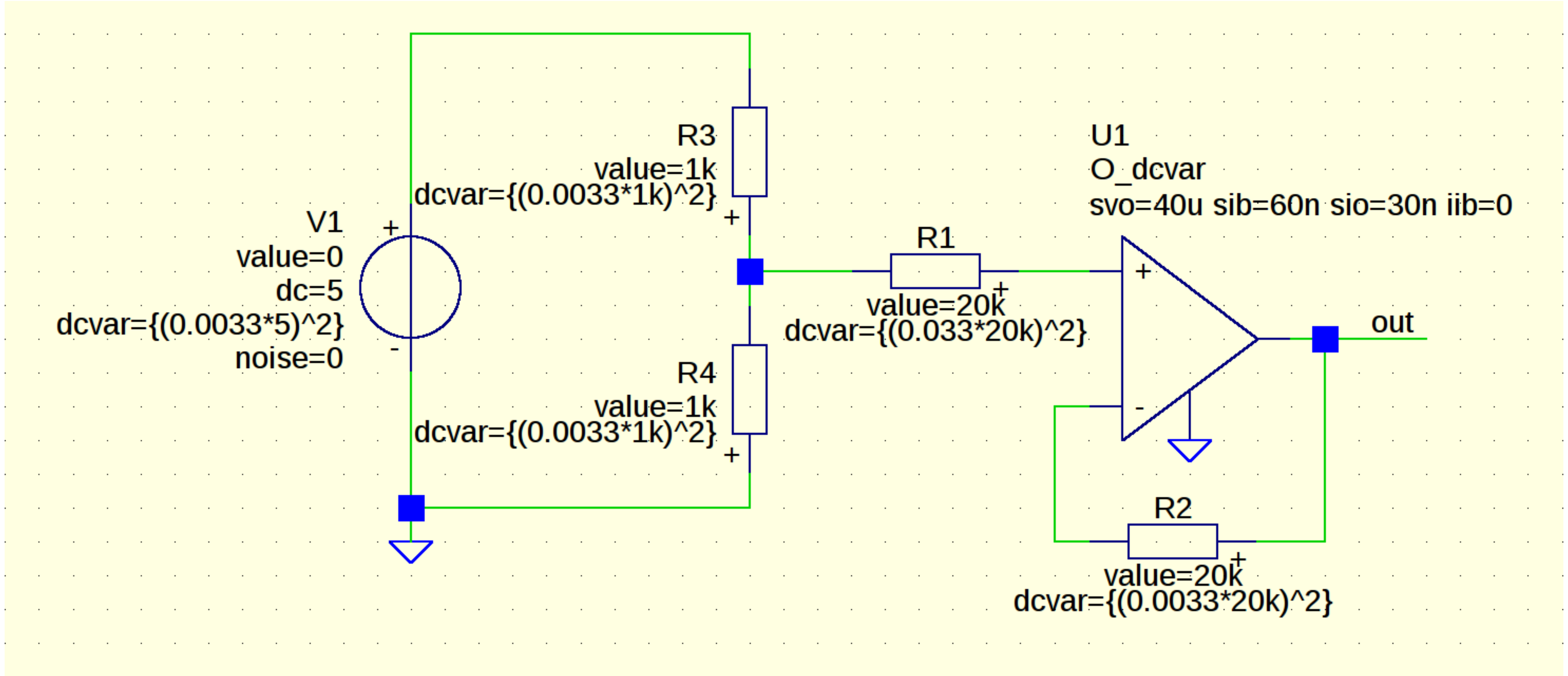
SLiCAP biasing verification



All component tolerances 1% (3-sigma)

Standard deviation of the output voltage: 10mV

SLiCAP biasing verification

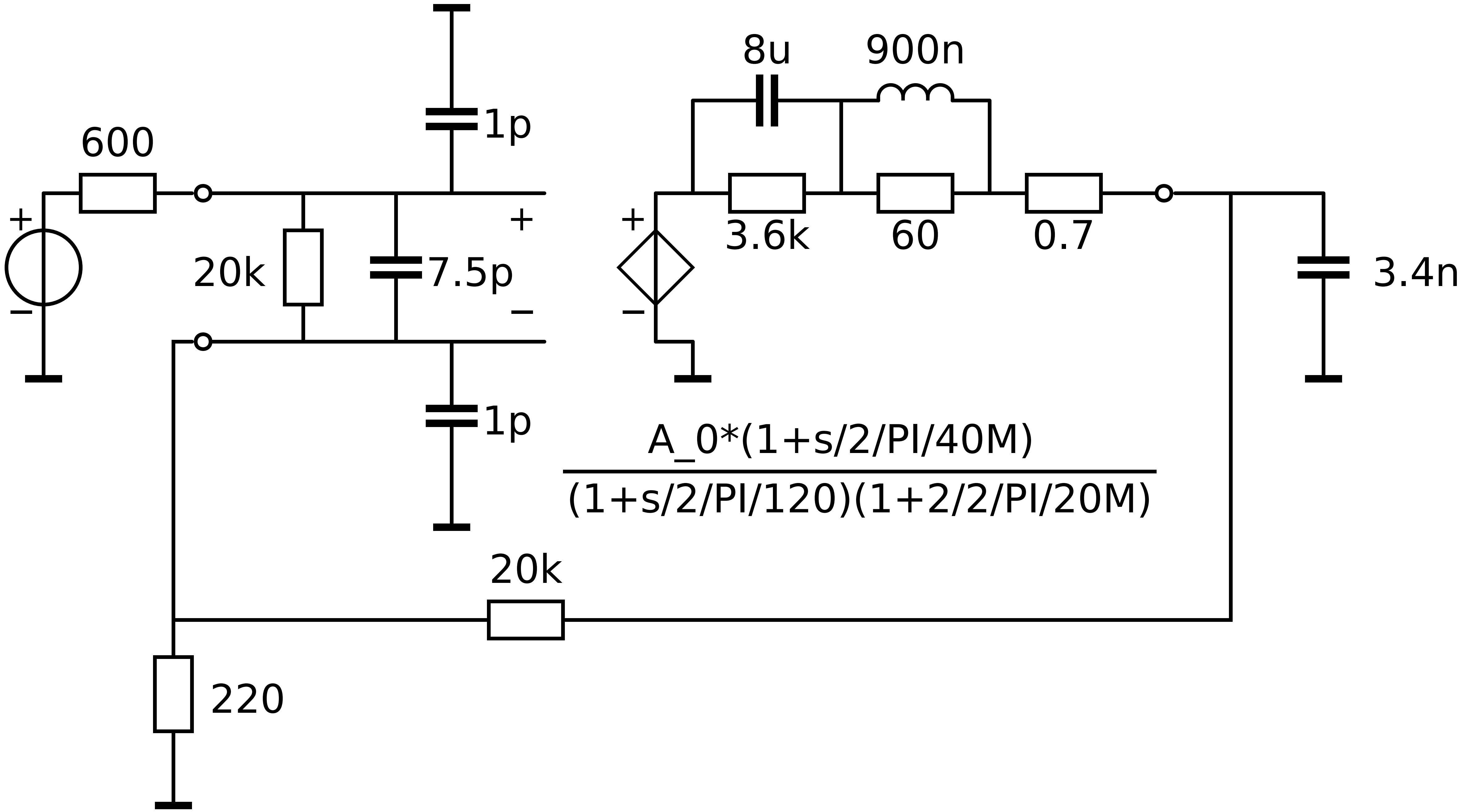


All component tolerances 1% (3-sigma)

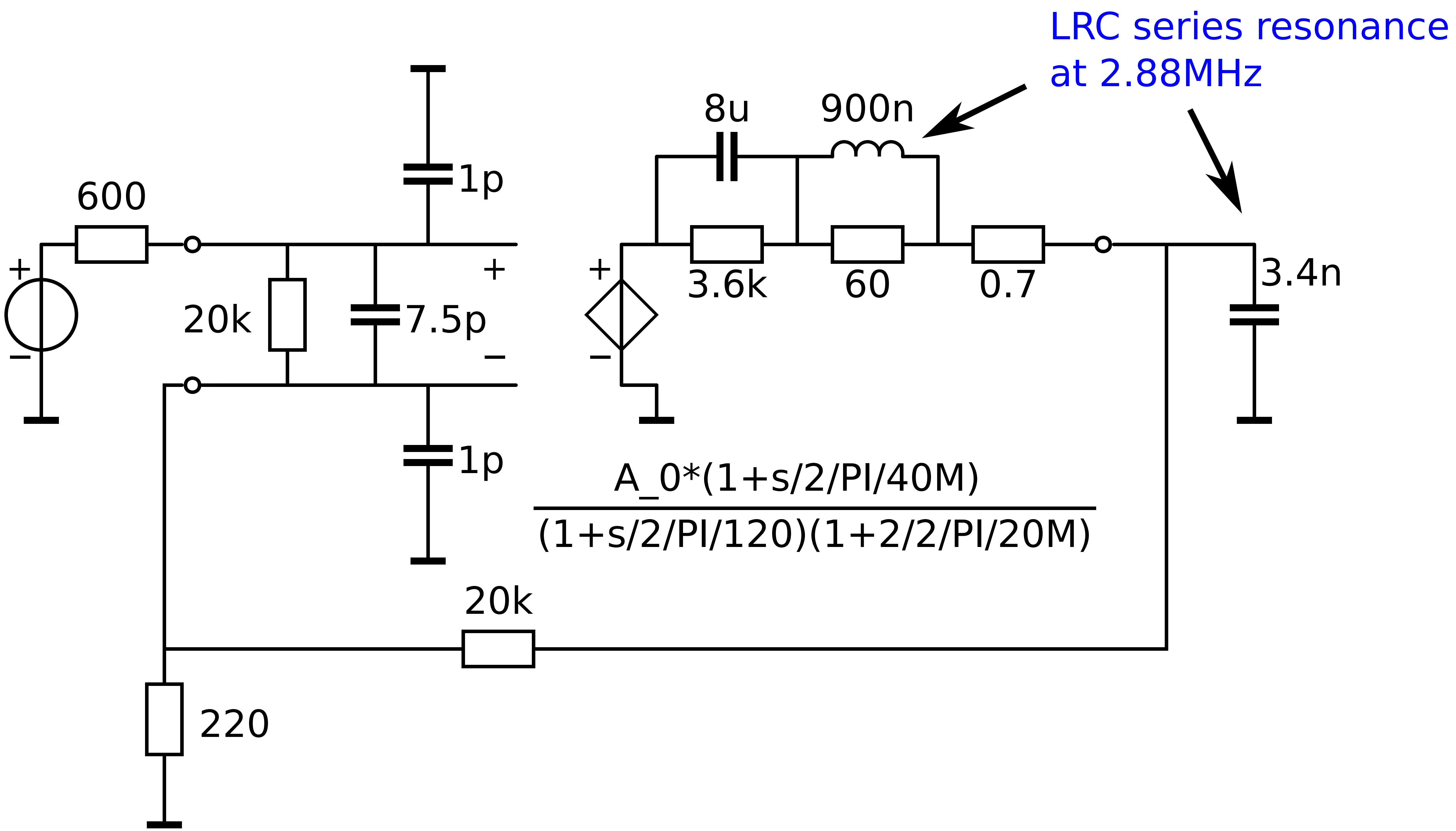
Standard deviation of the output voltage: 10mV

Frequency response

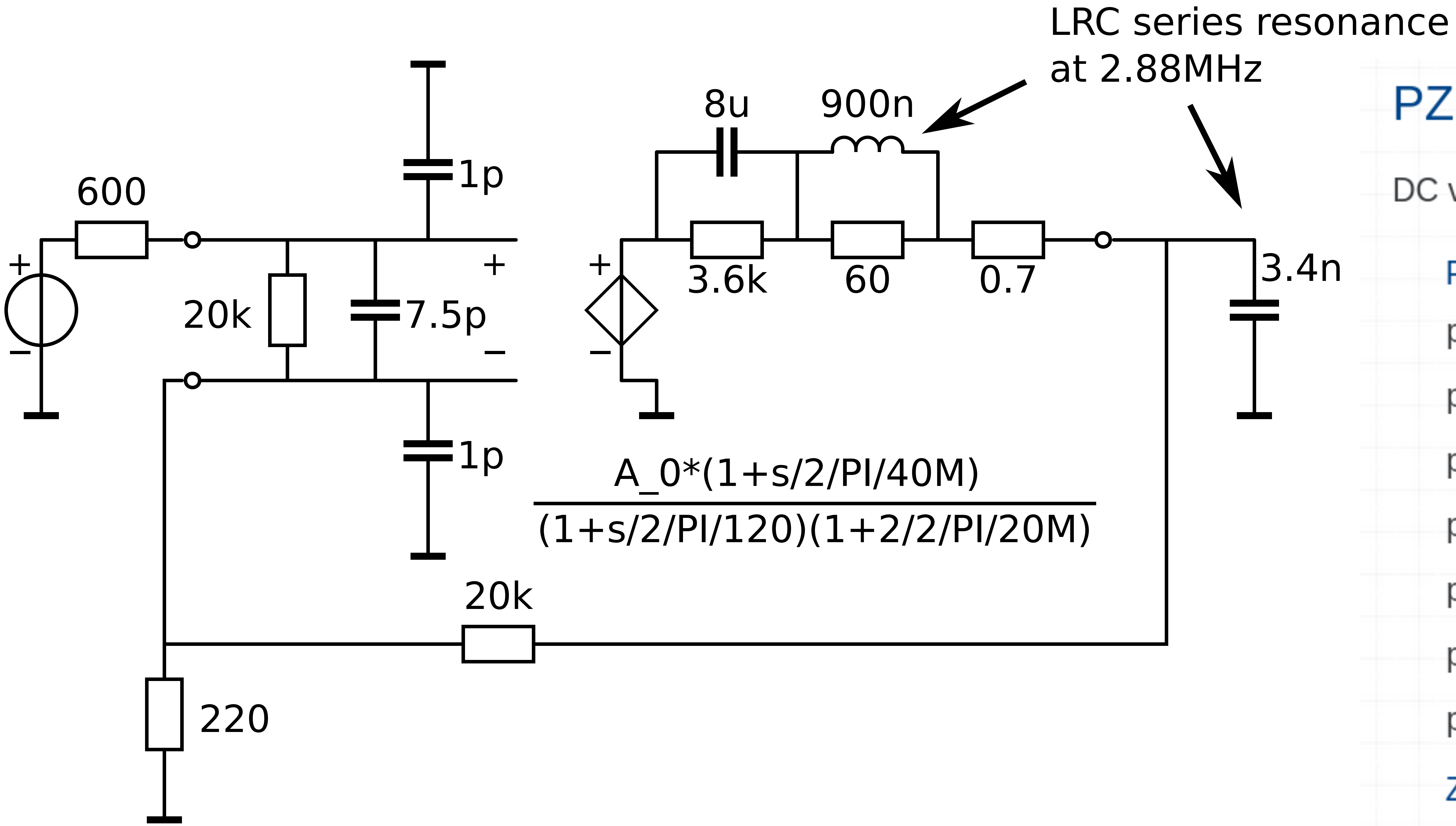
Frequency response



Frequency response



Frequency response



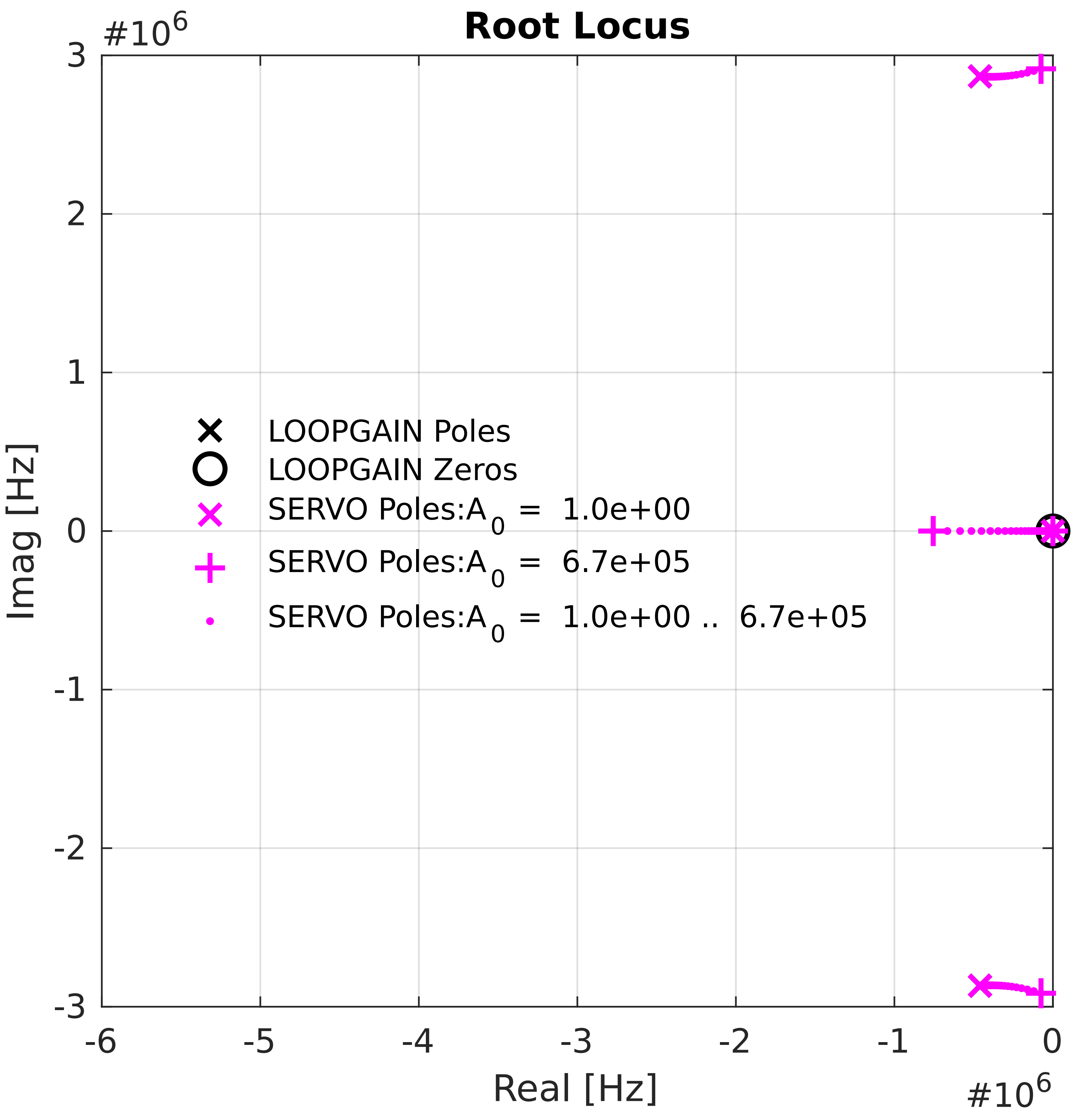
PZ analysis for: LOOPGAIN

DC value = -5918.0

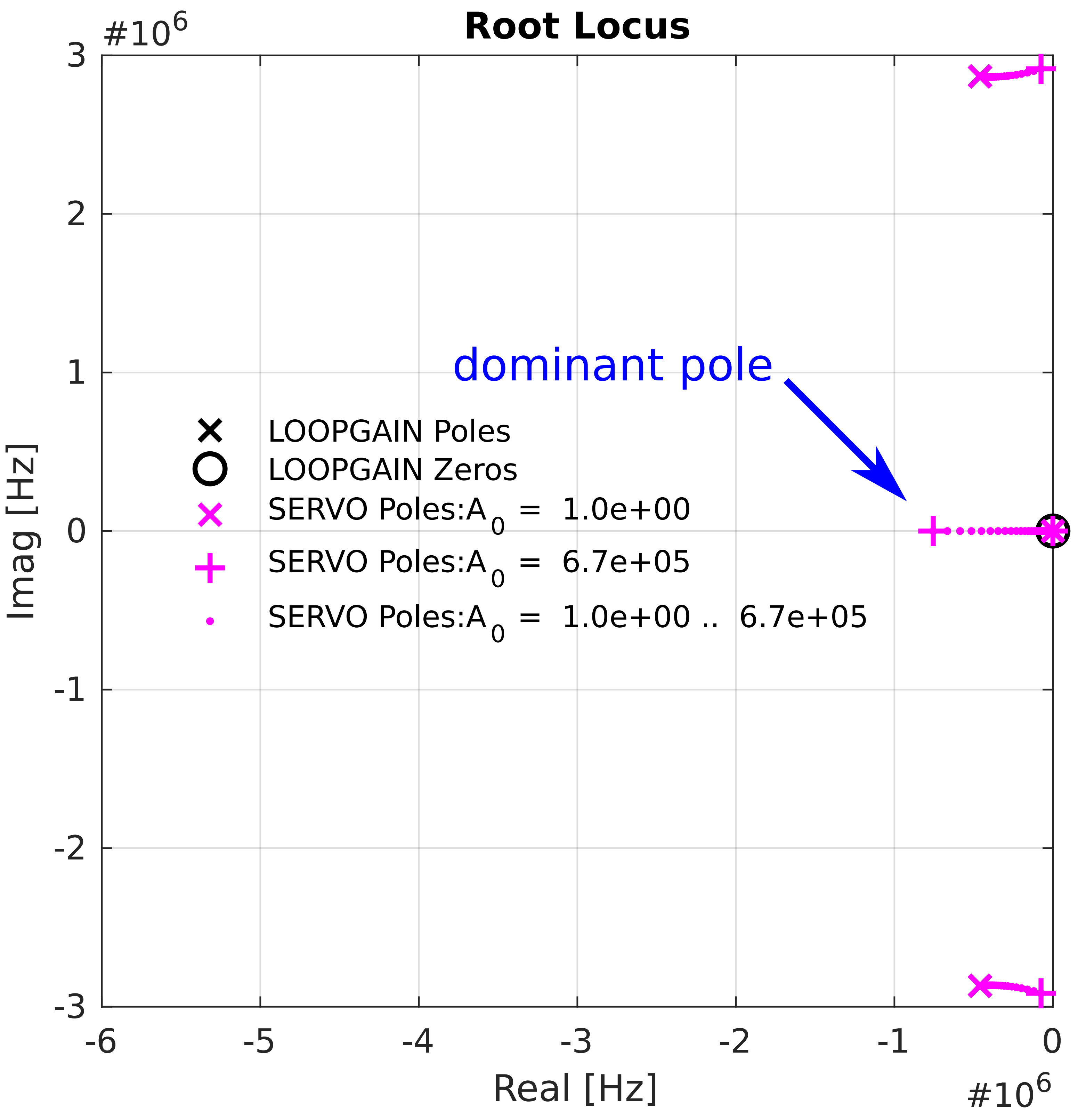
Poles	Re [Hz]	Im [Hz]	Mag [Hz]	Q [-]
p_1	-6.508	0.0	6.508	
p_2	-120.0	0.0	120.0	
p_3	-4.598e5	-2.868e6	2.904e6	3.158
p_4	-4.598e5	2.868e6	2.904e6	3.158
p_5	-2.0e7	0.0	2.0e7	
p_6	-2.352e7	0.0	2.352e7	
p_7	-5.051e8	0.0	5.051e8	

Zeros	Re [Hz]	Im [Hz]	Mag [Hz]	Q [-]
z_1	-5.526	0.0	5.526	
z_2	-1.061e7	0.0	1.061e7	
z_3	-4.0e7	0.0	4.0e7	
z_4	-2.653e8	0.0	2.653e8	

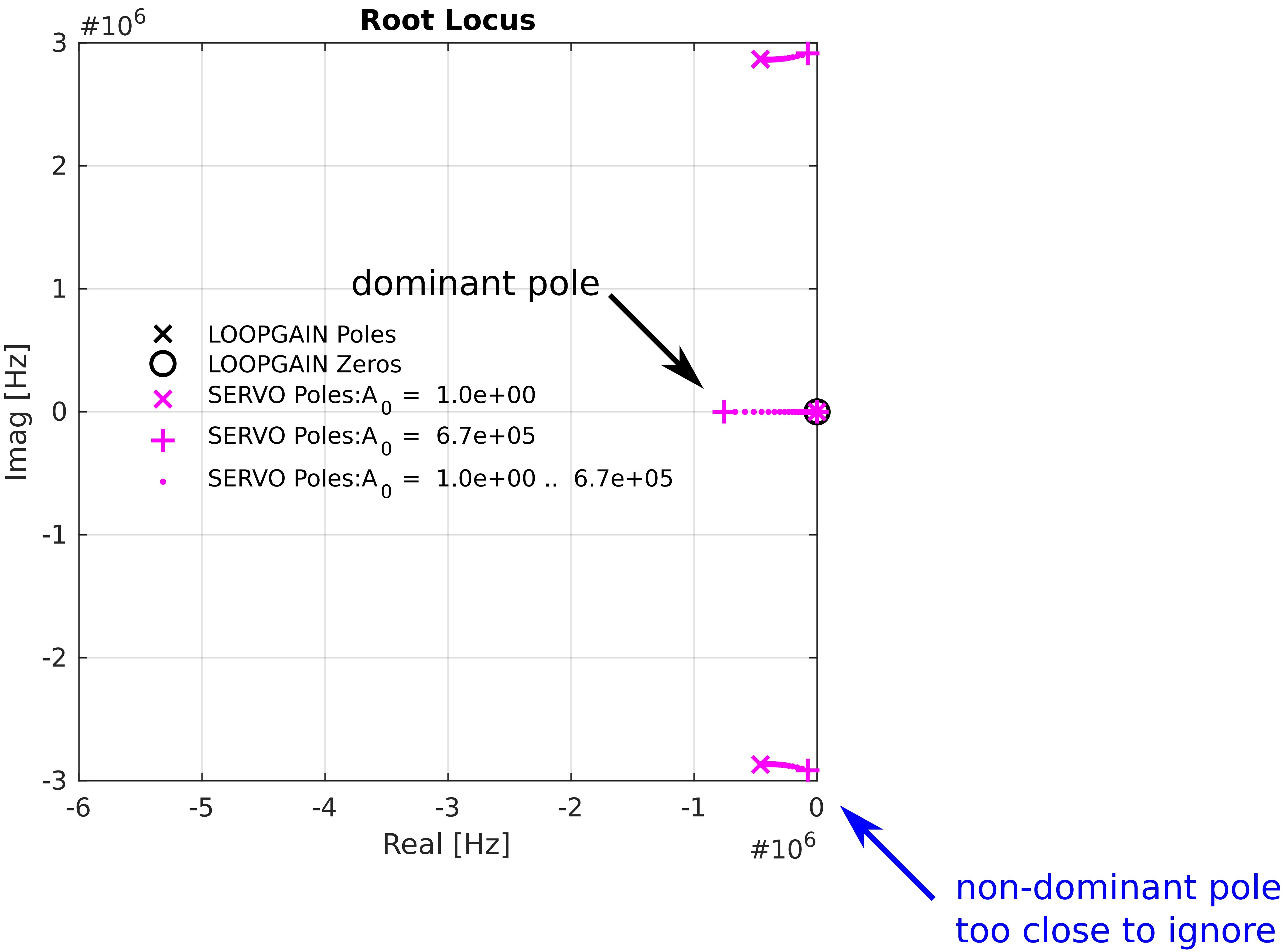
Frequency response



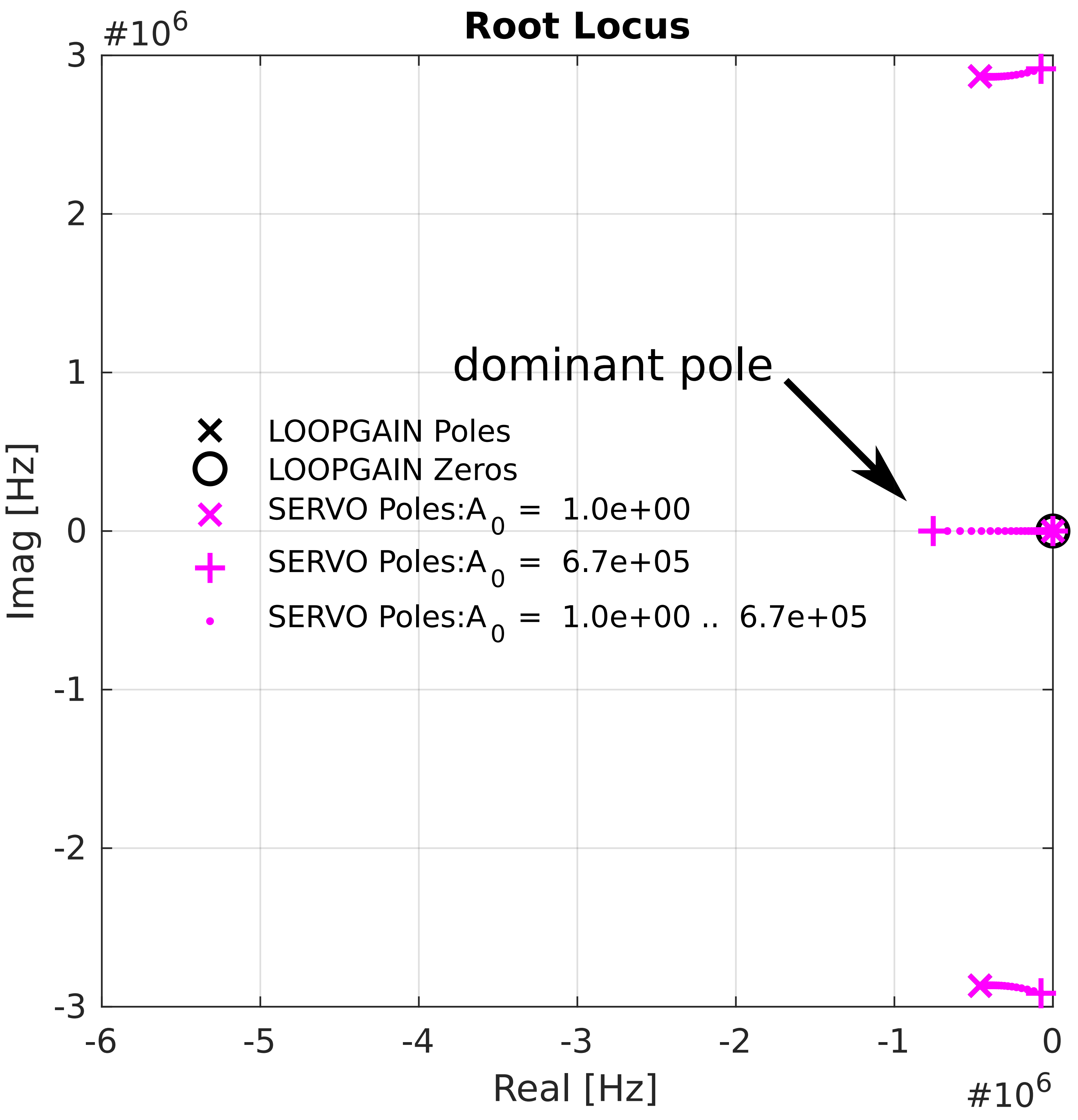
Frequency response



Frequency response



Frequency response



non-dominant pole
too close to ignore

PZ analysis for: GAIN

DC value = 91.89

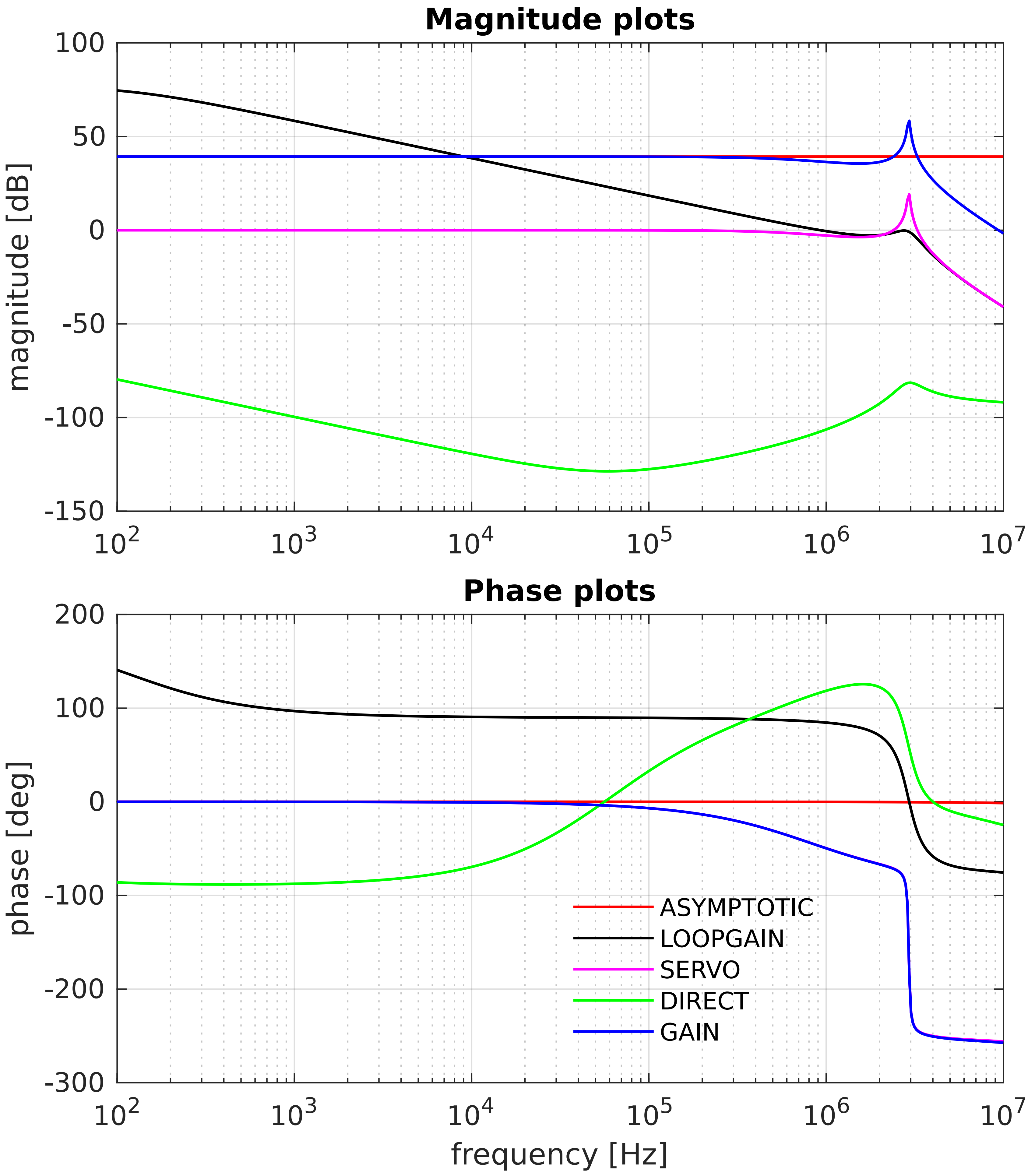
Poles	Re [Hz]	Im [Hz]	Mag [Hz]	Q [-]
p_1	-40300.0	2.926e6	2.926e6	36.3
p_2	-40300.0	-2.926e6	2.926e6	36.3
p_3	-8.232e5	0.0	8.232e5	
p_4	-2.005e7	0.0	2.005e7	
p_5	-2.348e7	0.0	2.348e7	
p_6	-5.051e8	0.0	5.051e8	

Zeros	Re [Hz]	Im [Hz]	Mag [Hz]	Q [-]
z_1	-1.061e7	0.0	1.061e7	
z_2	-3.996e7	0.0	3.996e7	
z_3	-8.094e8	-7.427e8	1.098e9	0.6786
z_4	-8.094e8	7.427e8	1.098e9	0.6786

Frequency response

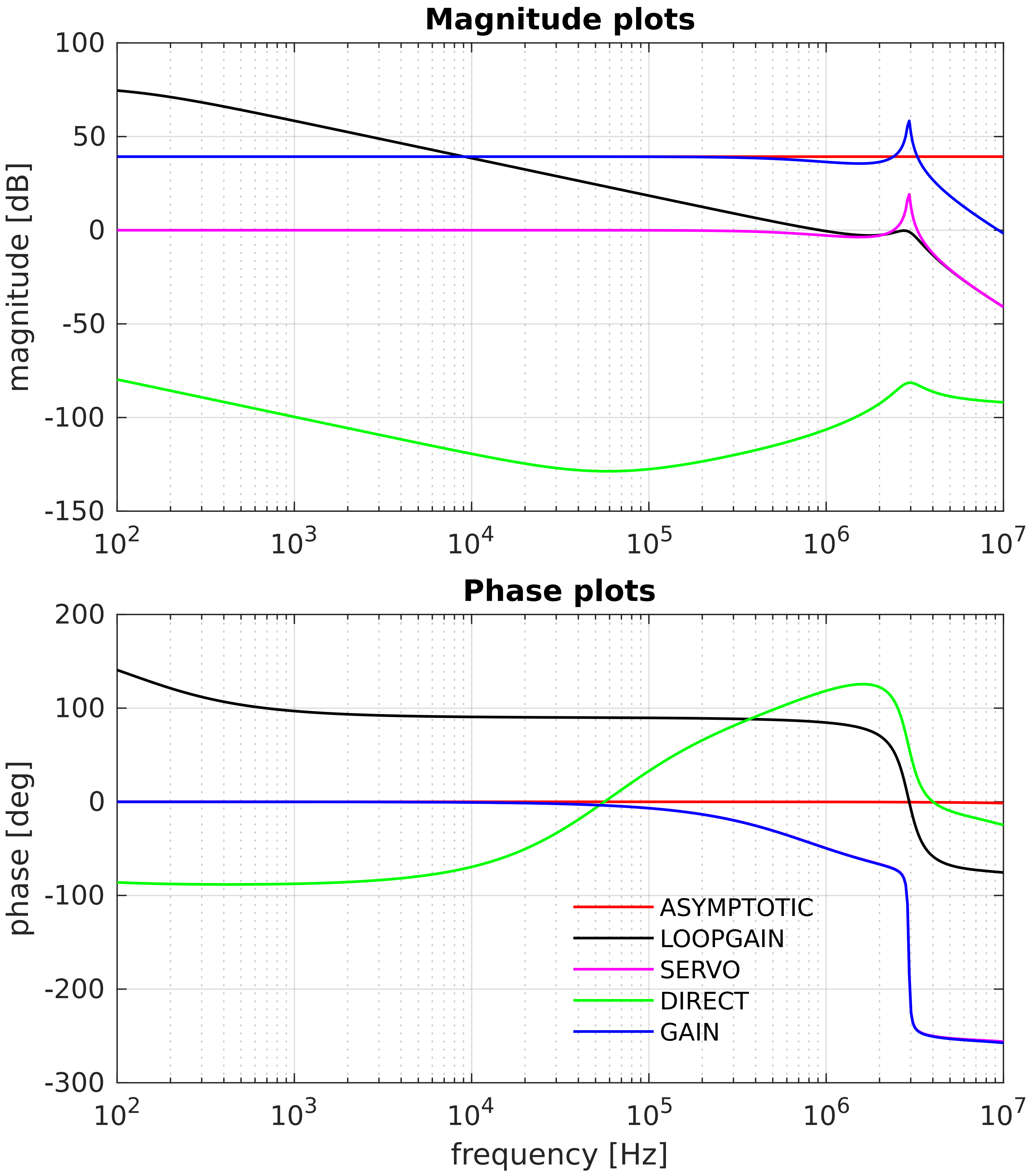
Uncompensated amplifier

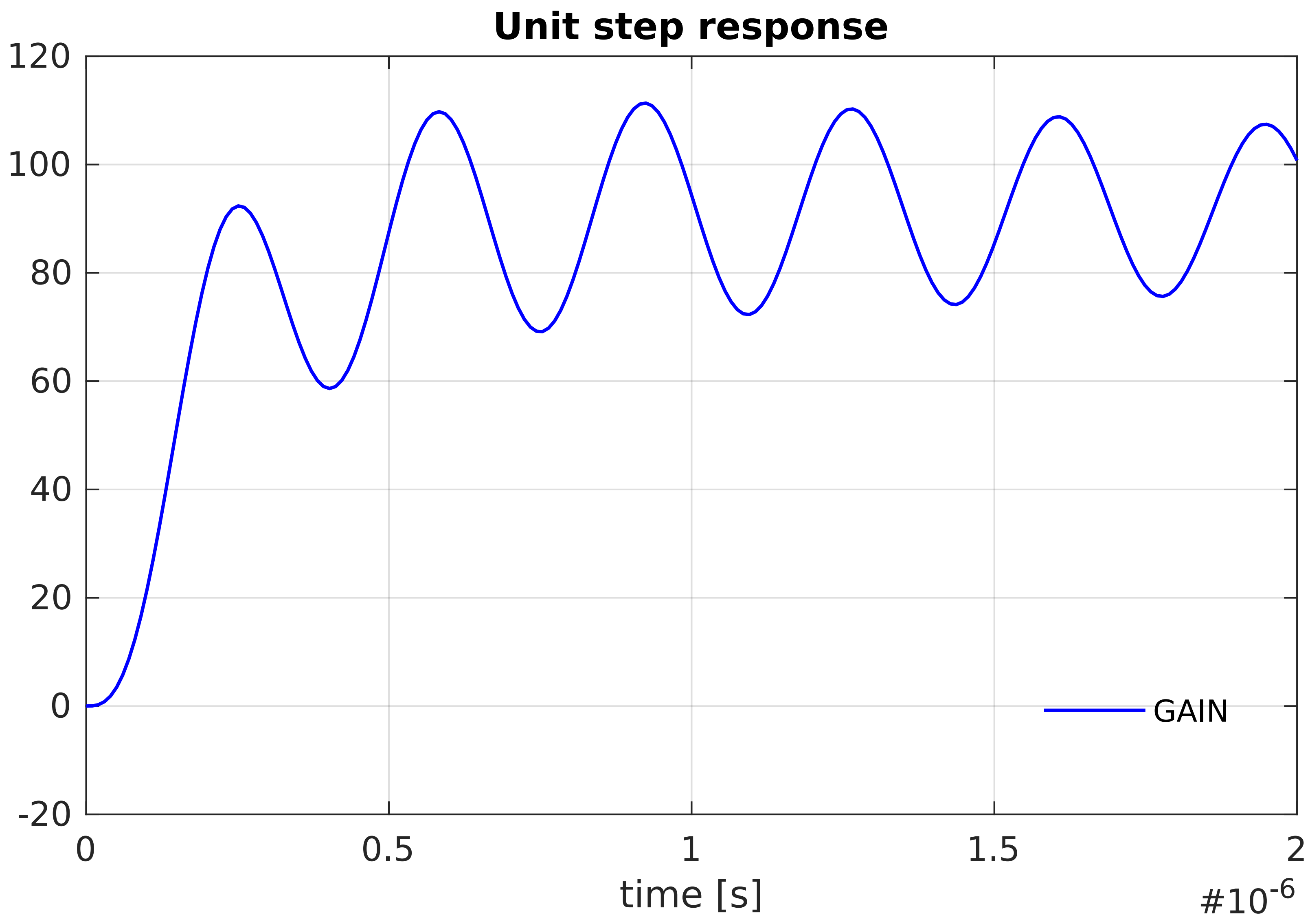
Frequency response



Uncompensated amplifier

Frequency response

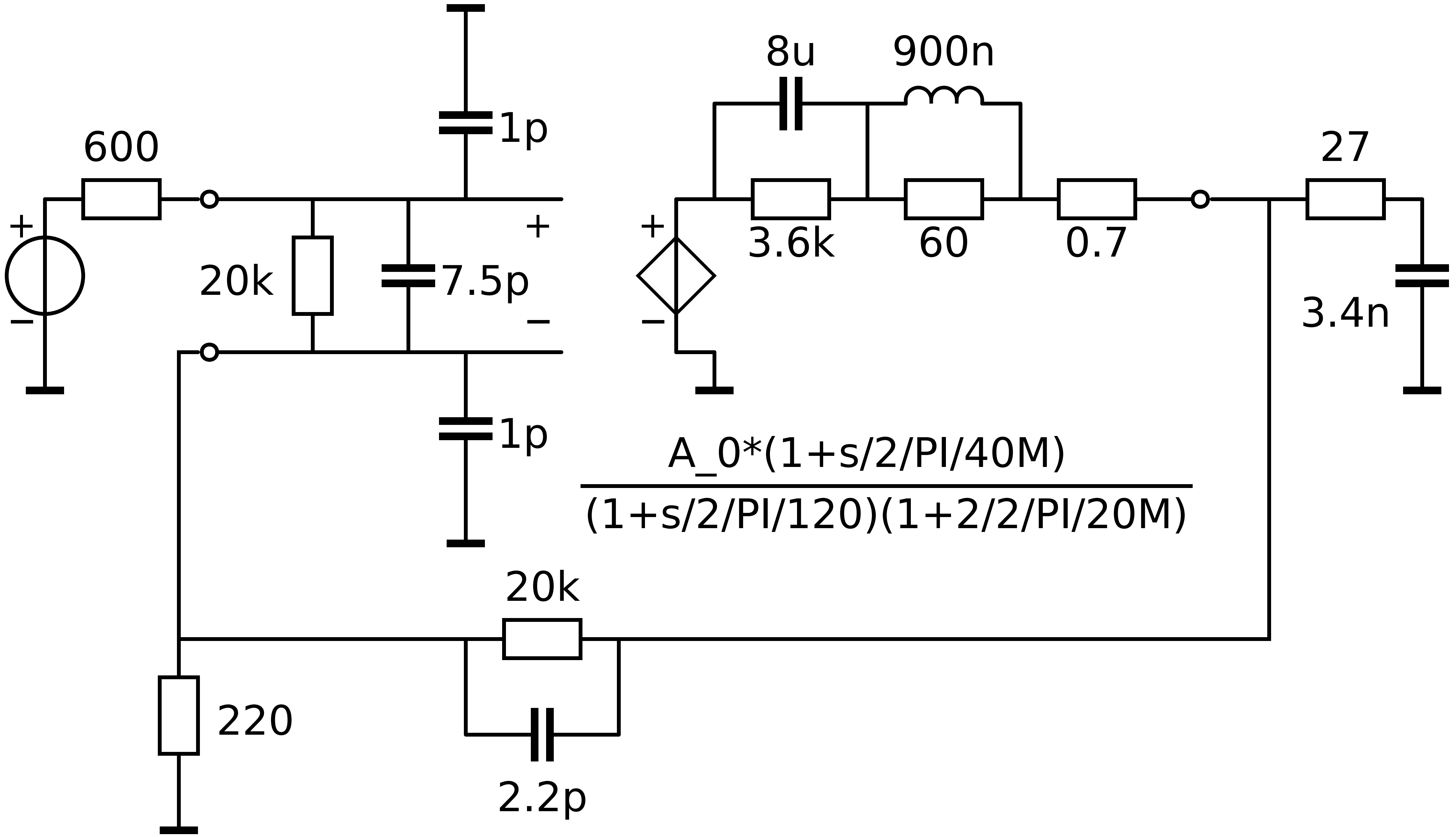




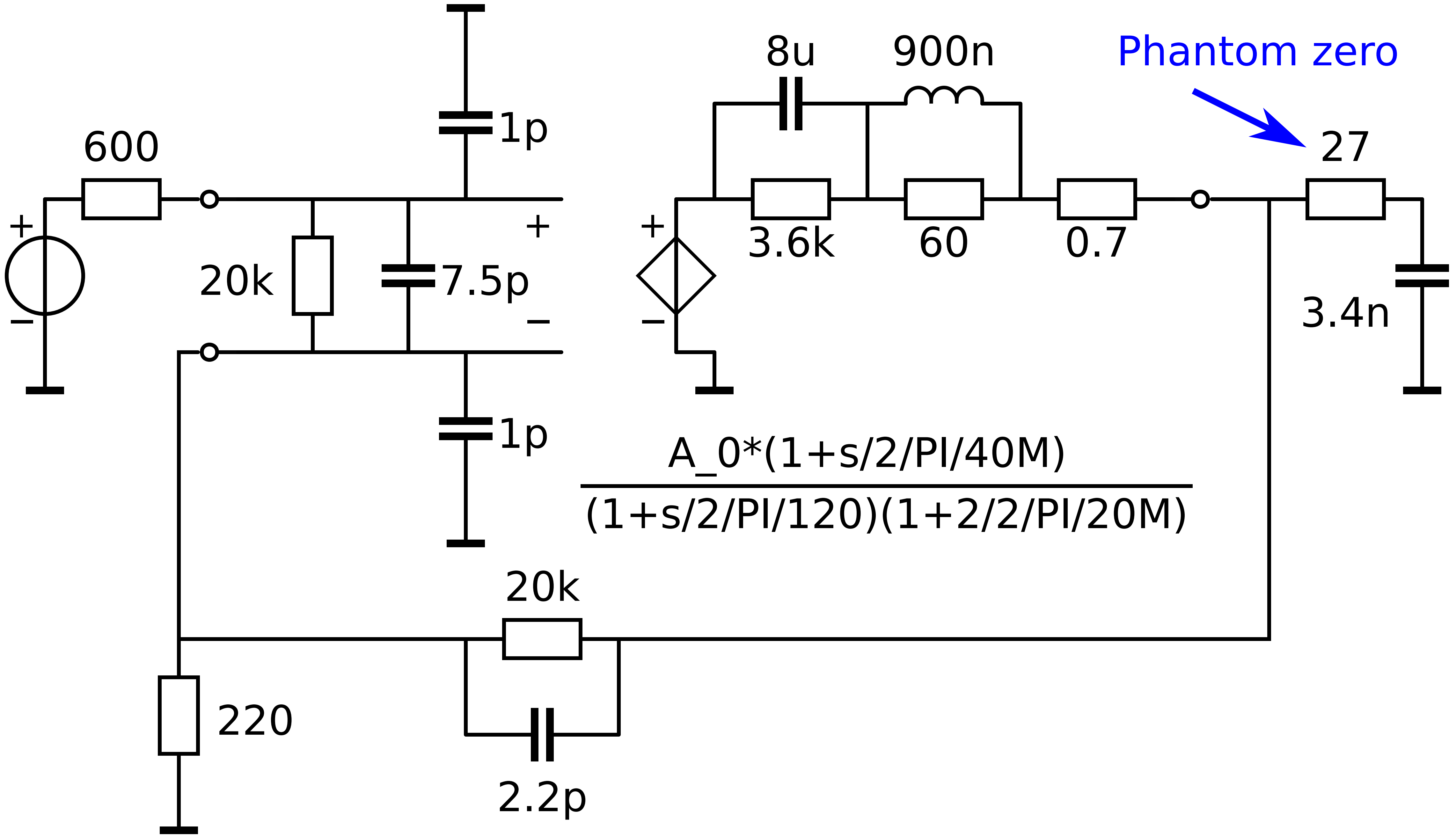
Uncompensated amplifier

Frequency compensation

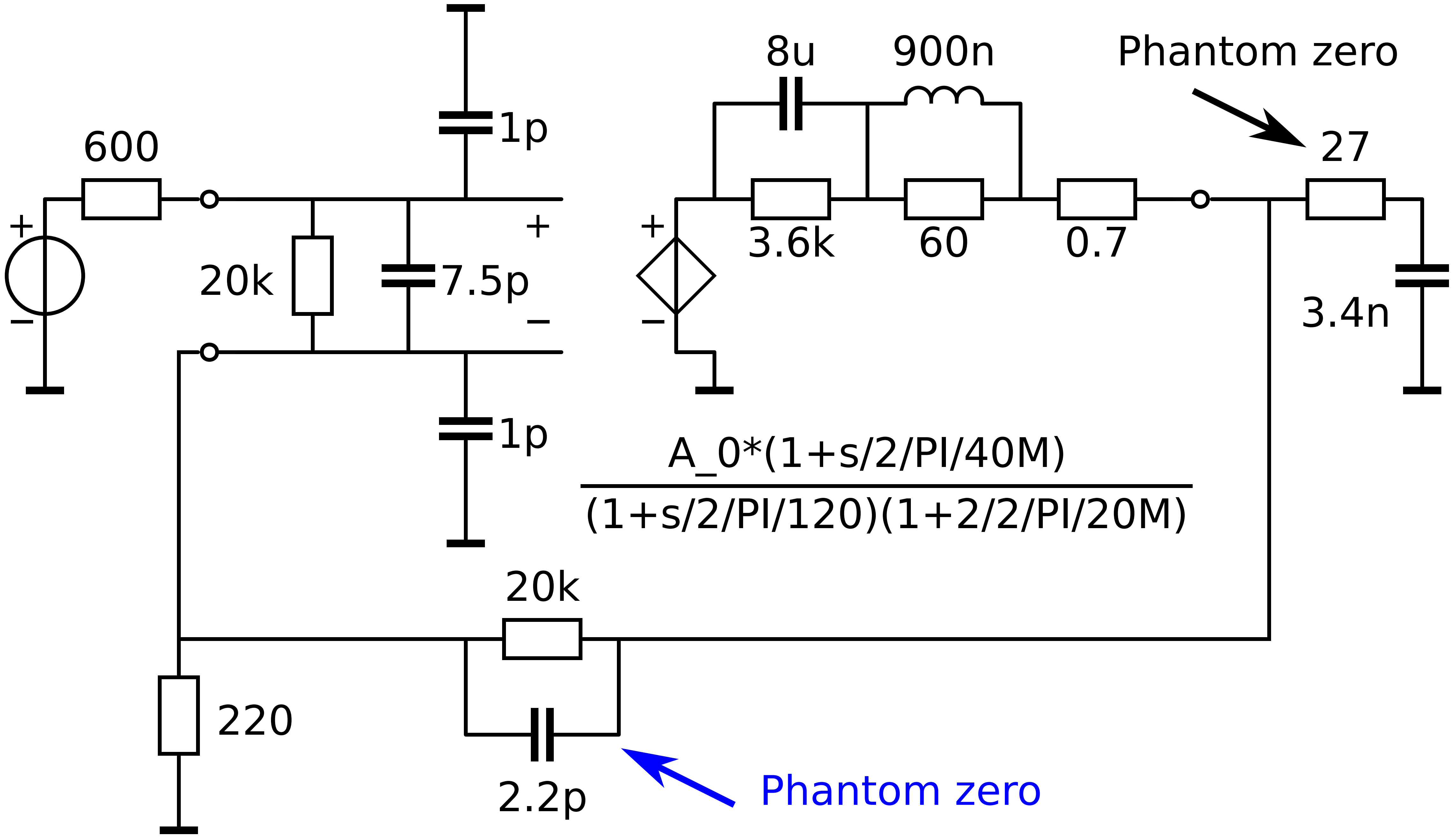
Frequency compensation



Frequency compensation



Frequency compensation



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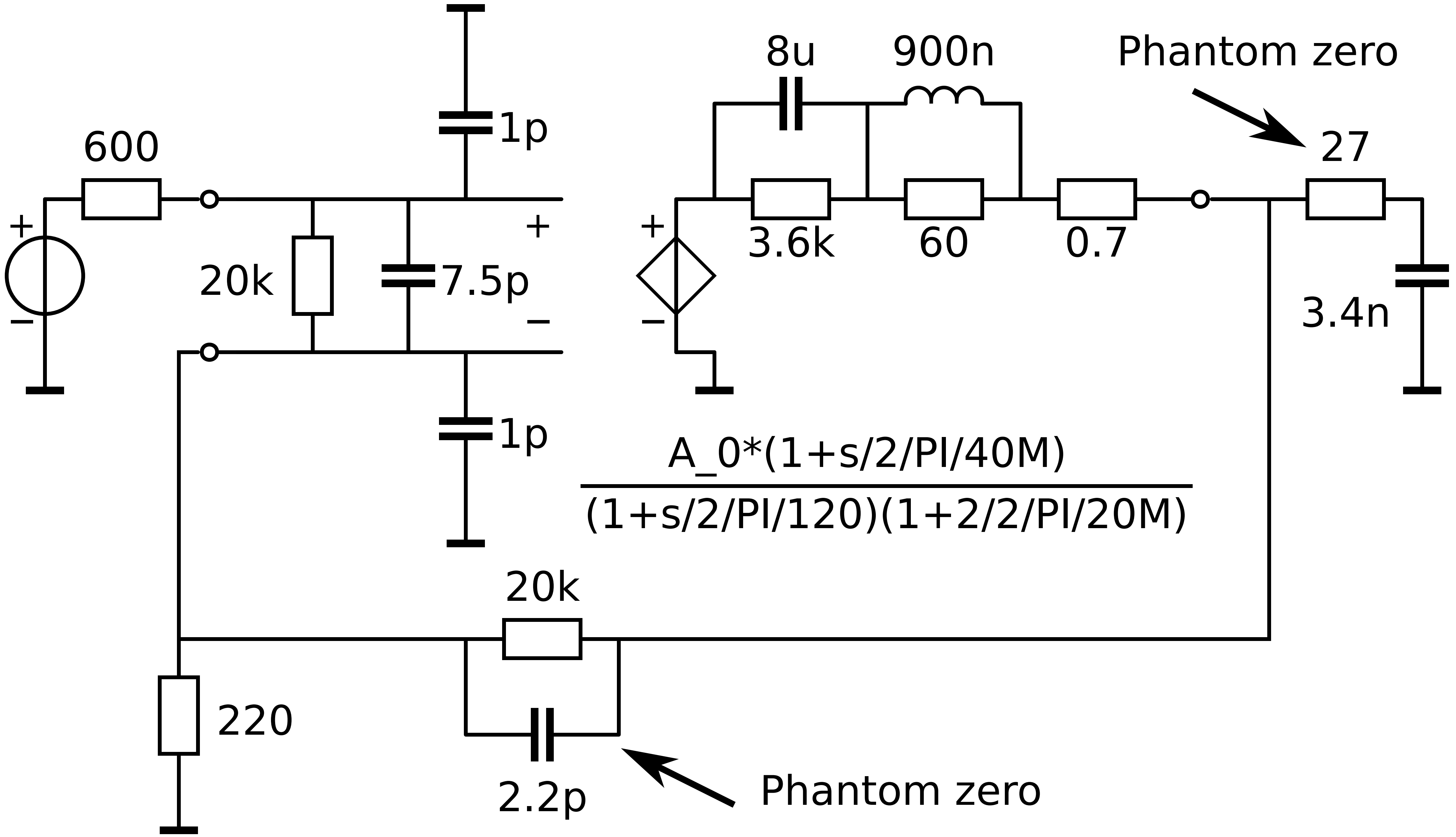

PZ analysis for: LOOPGAIN

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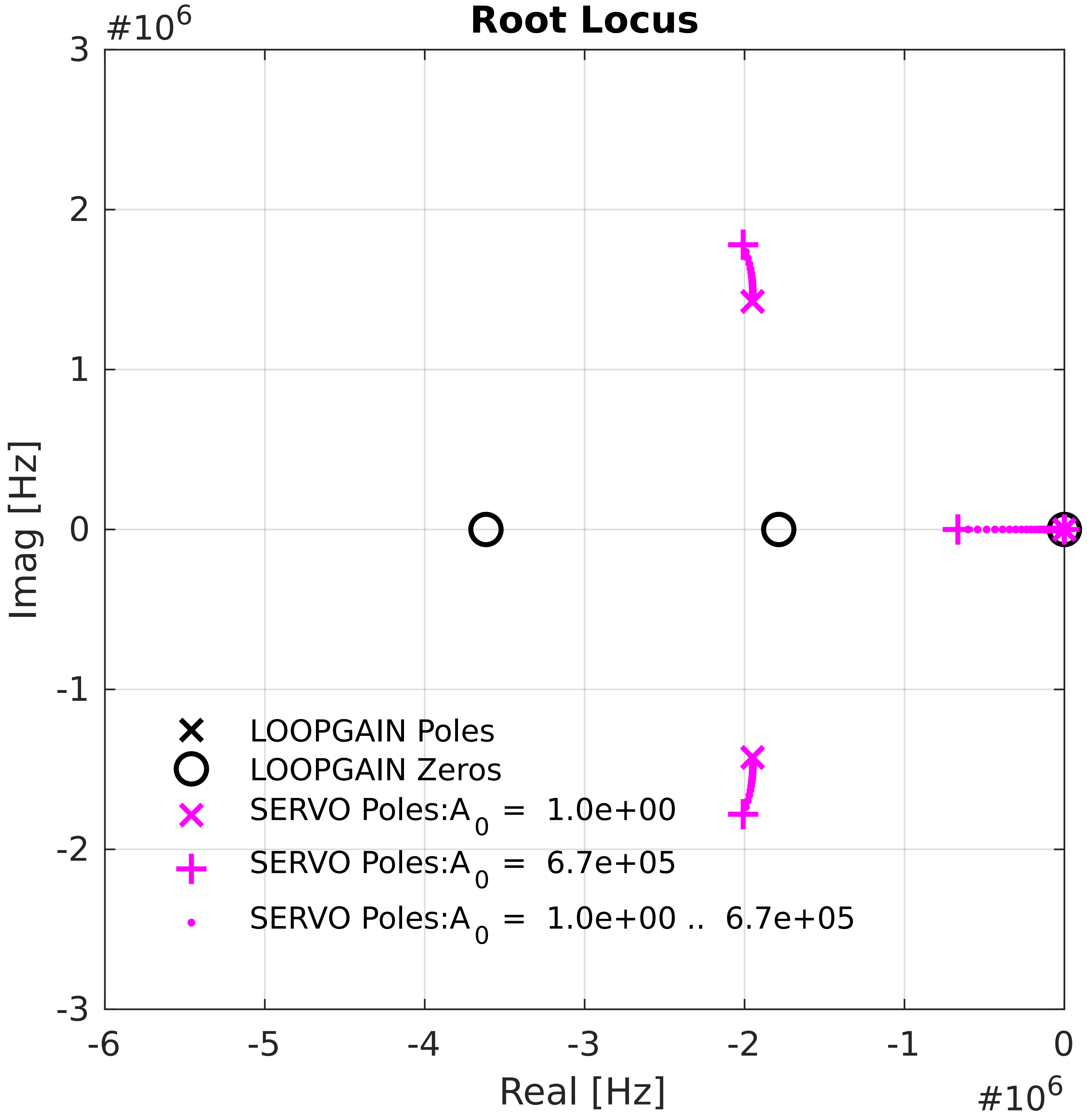
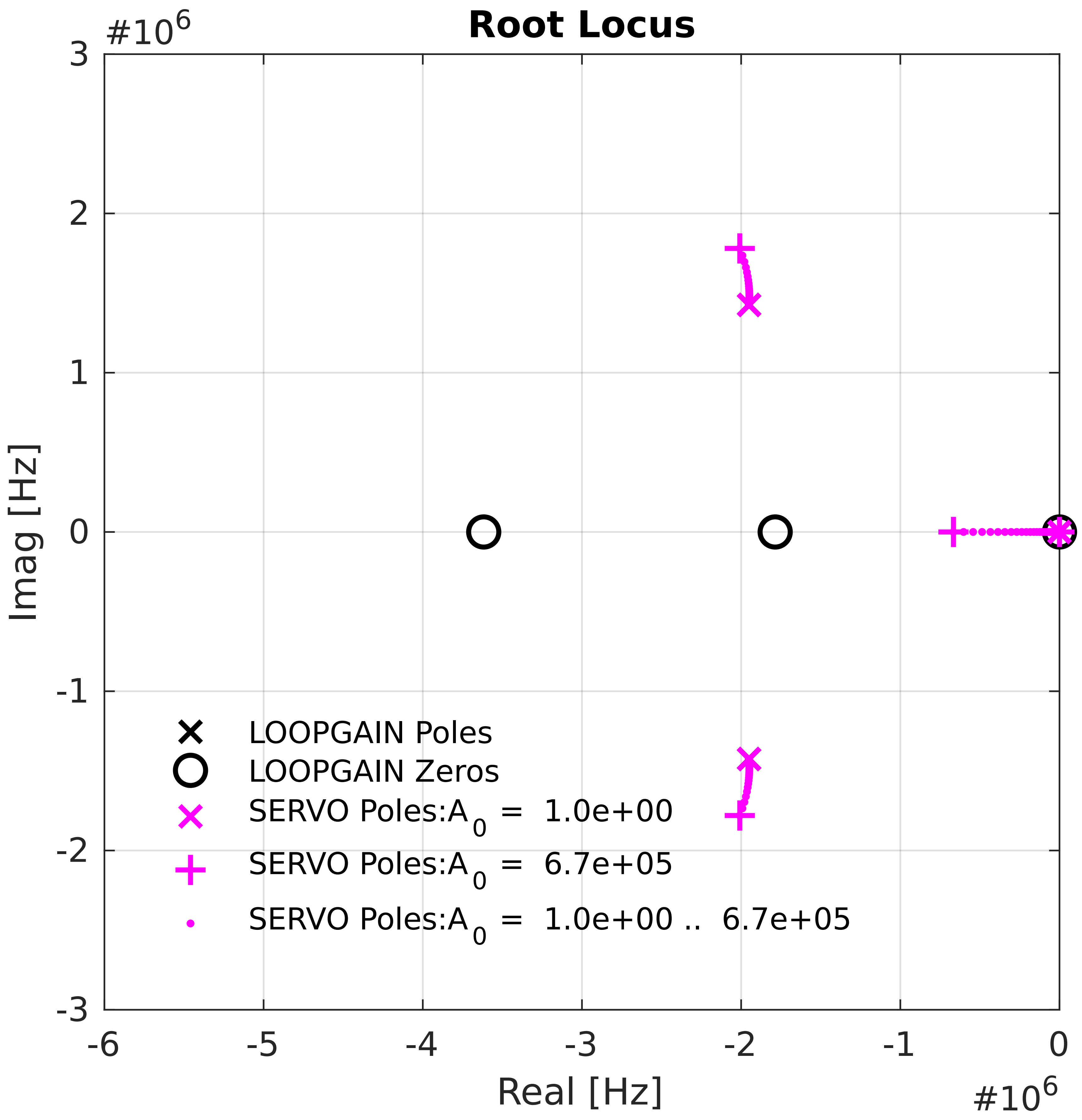
Poles	Re [Hz]	Im [Hz]	Mag [Hz]	Q [-]
p_1	-6.508	0.0	6.508	
p_2	-120.0	0.0	120.0	
p_3	-1.95e6	1.426e6	2.416e6	0.6194
p_4	-1.95e6	-1.426e6	2.416e6	0.6194
p_5	-2.0e7	0.0	2.0e7	
p_6	-2.311e7	0.0	2.311e7	
p_7	-2.3e8	0.0	2.3e8	
p_8	-8.653e9	0.0	8.653e9	

Zeros	Re [Hz]	Im [Hz]	Mag [Hz]	Q [-]
z_1	-5.526	0.0	5.526	
z_2	-1.786e6	0.0	1.786e6	
z_3	-3.617e6	0.0	3.617e6	
z_4	-1.061e7	0.0	1.061e7	
z_5	-4.0e7	0.0	4.0e7	
z_6	-2.653e8	0.0	2.653e8	

Frequency compensation



Frequency compensation



PZ analysis for: GAIN

DC value = 91.89

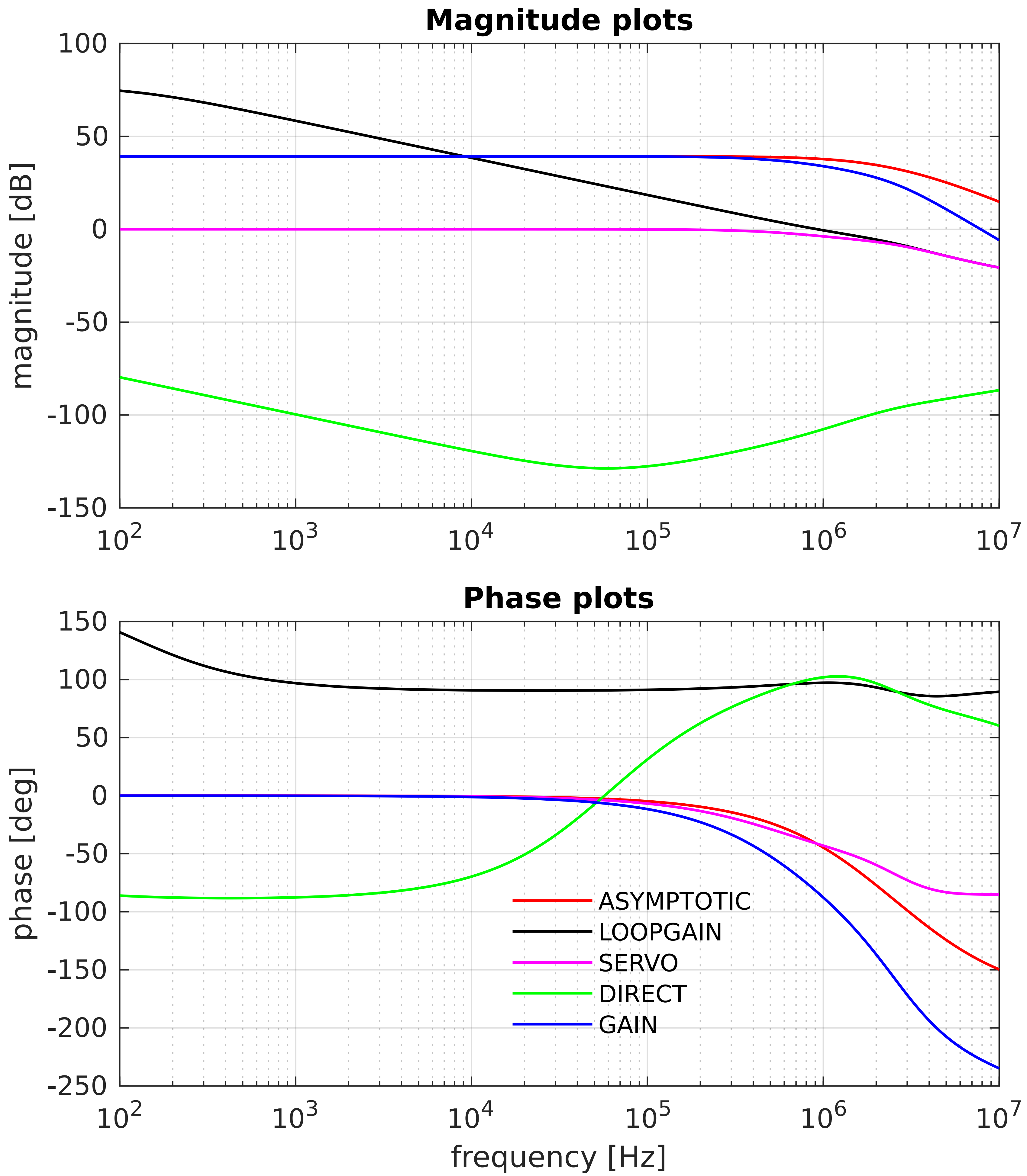
Poles	Re [Hz]	Im [Hz]	Mag [Hz]	Q [-]
p_1	-6.662e5	0.0	6.662e5	
p_2	-2.009e6	-1.78e6	2.684e6	0.6681
p_3	-2.009e6	1.78e6	2.684e6	0.6681
p_4	-2.157e7	2.221e6	2.169e7	0.5026
p_5	-2.157e7	-2.221e6	2.169e7	0.5026
p_6	-2.299e8	0.0	2.299e8	
p_7	-8.652e9	0.0	8.652e9	

Zeros	Re [Hz]	Im [Hz]	Mag [Hz]	Q [-]
z_1	7.165e7	-1.781e8	1.92e8	1.34
z_2	7.165e7	1.781e8	1.92e8	1.34
z_3	-1.061e7	0.0	1.061e7	
z_4	-4.045e7	0.0	4.045e7	
z_5	-1.17e8	0.0	1.17e8	

Frequency compensation

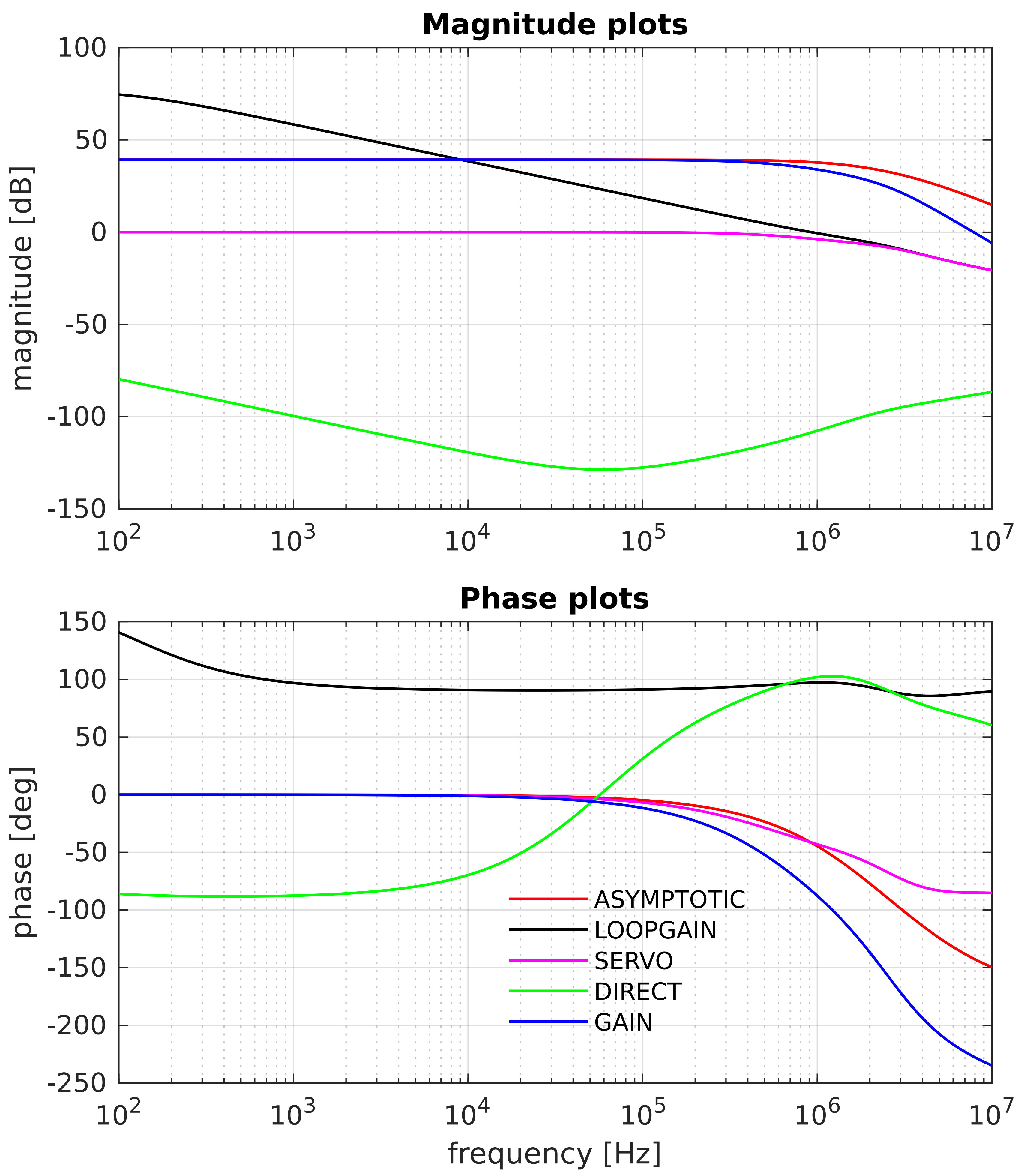
Compensated amplifier

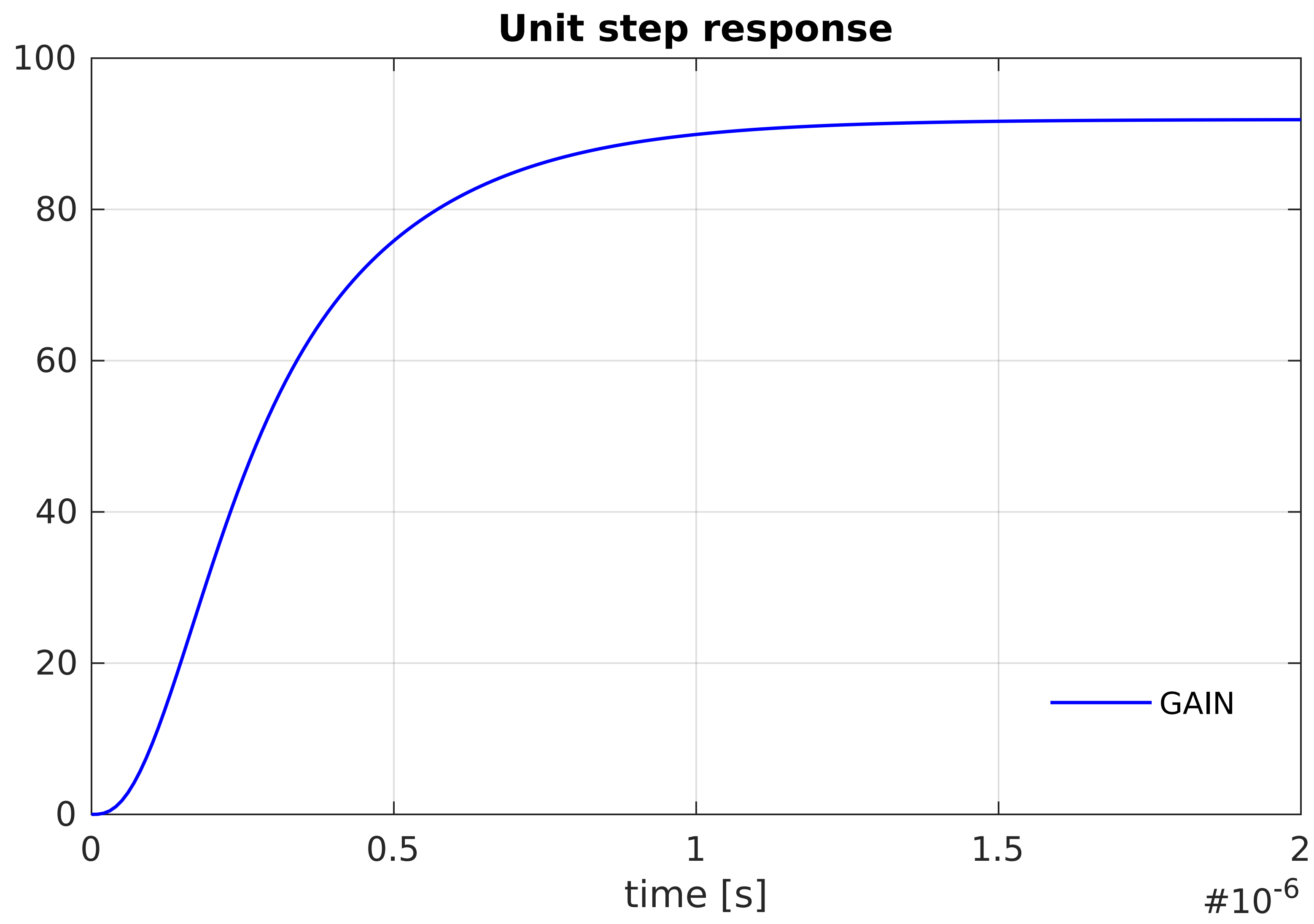
Frequency compensation



Compensated amplifier

Frequency compensation

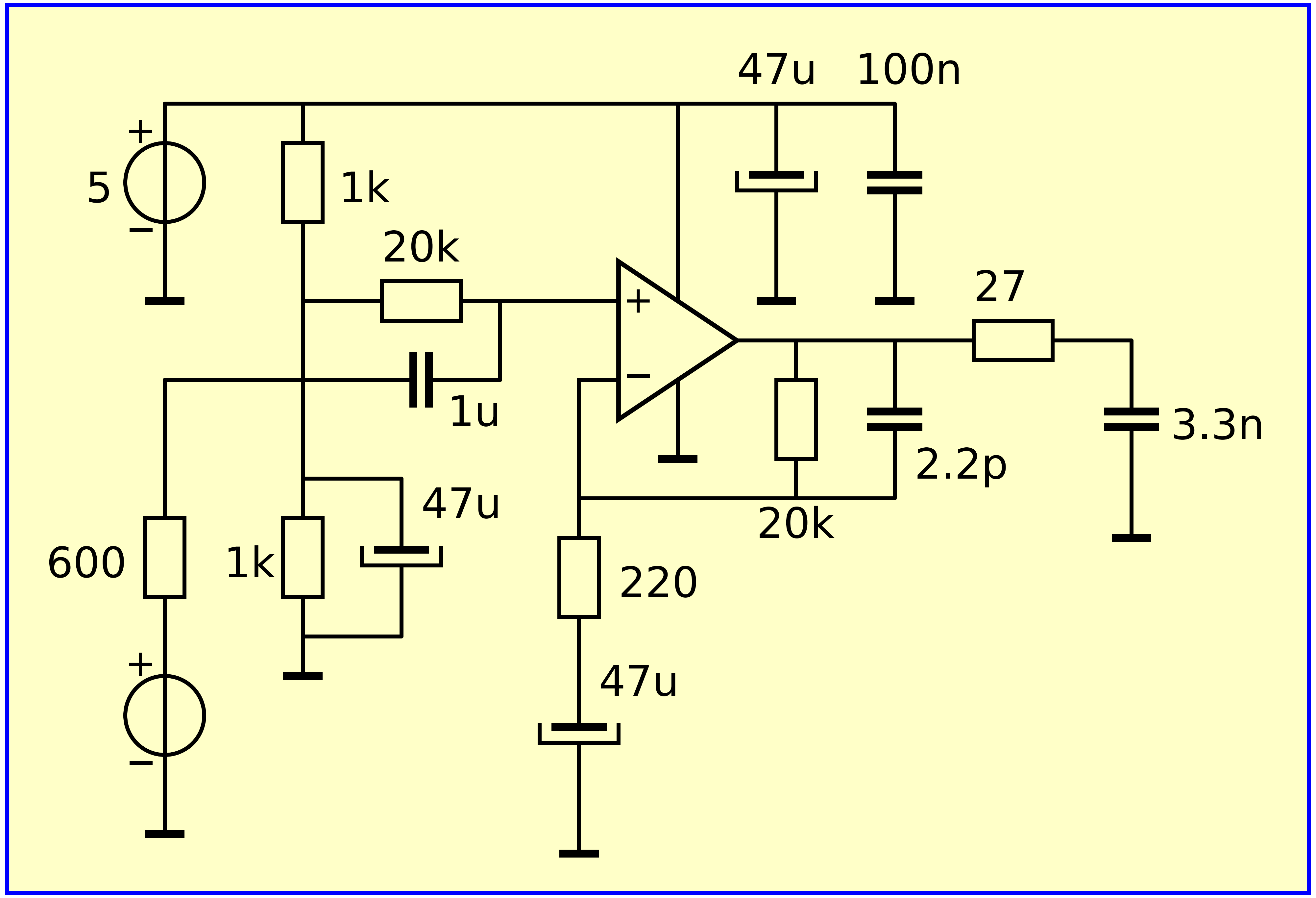




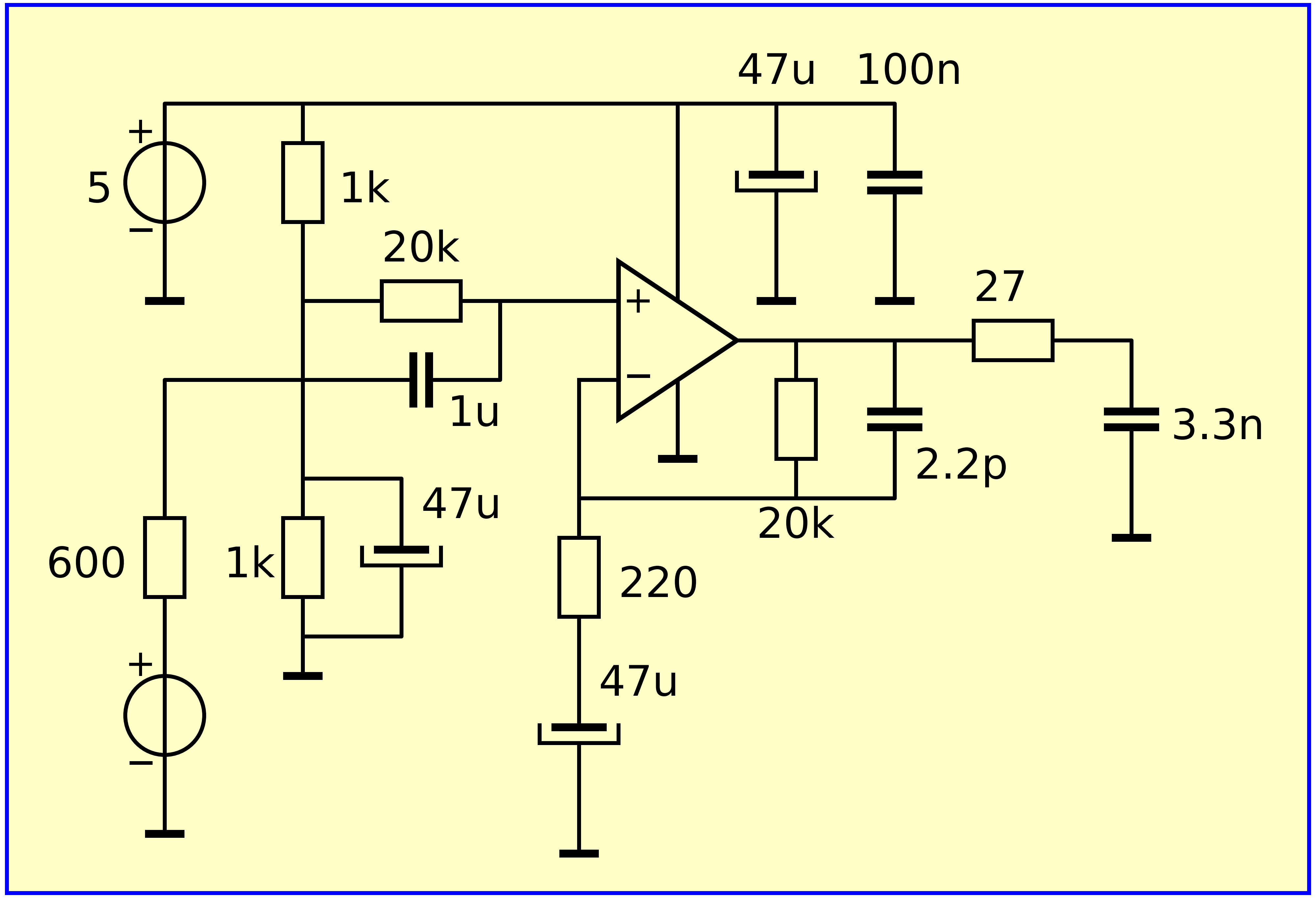
Compensated amplifier

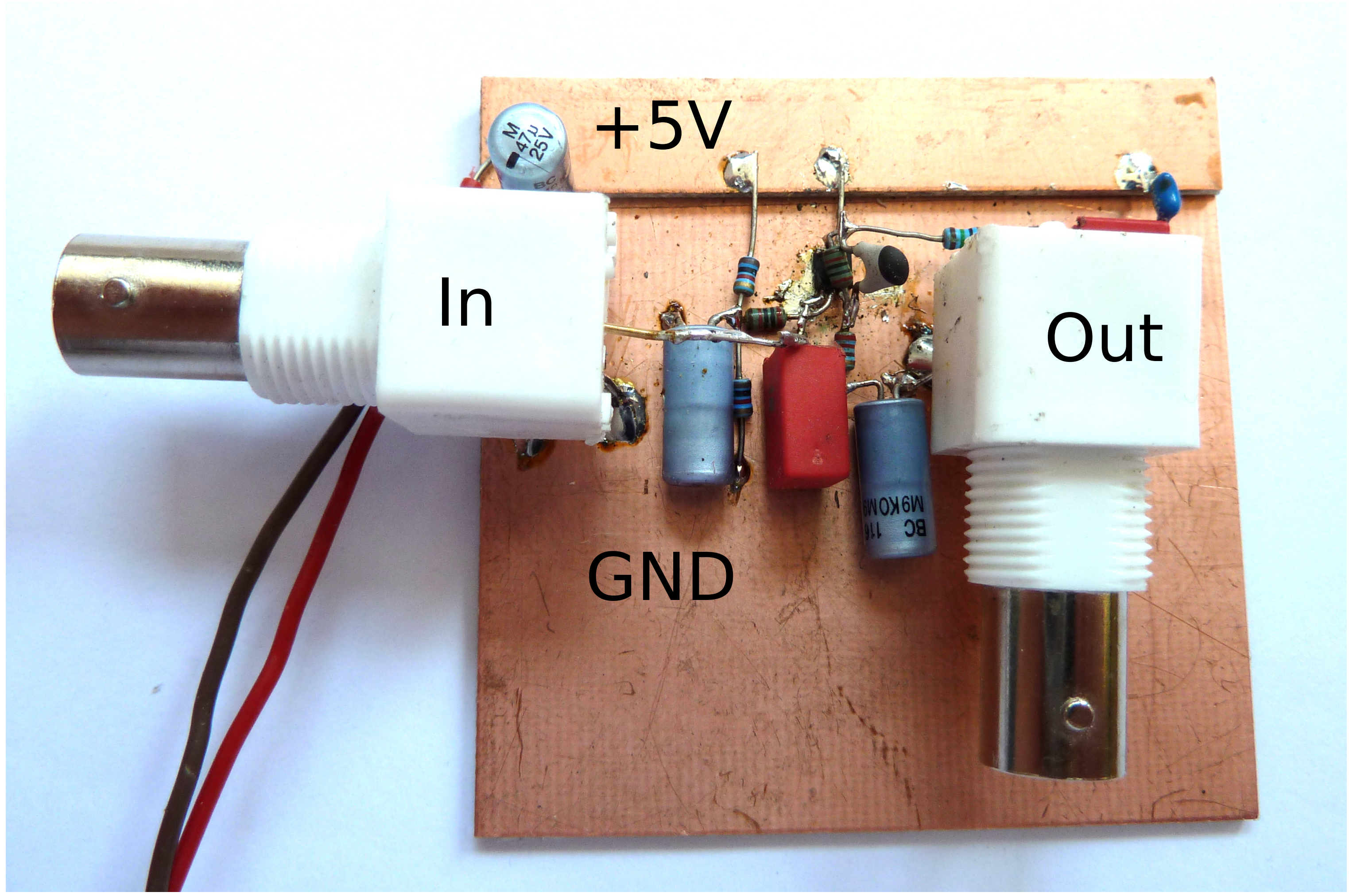
Construction

Construction

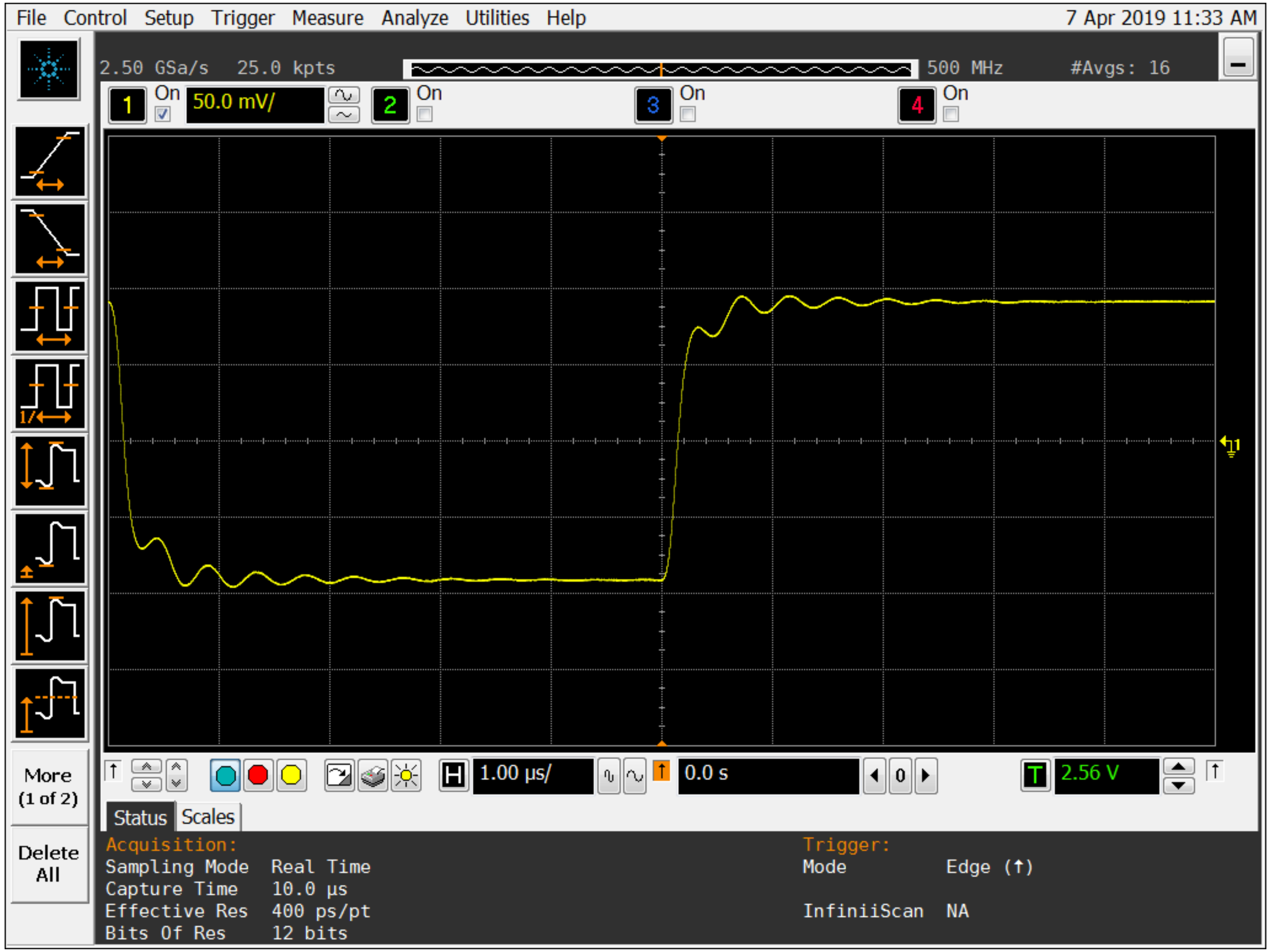


Construction





Test results

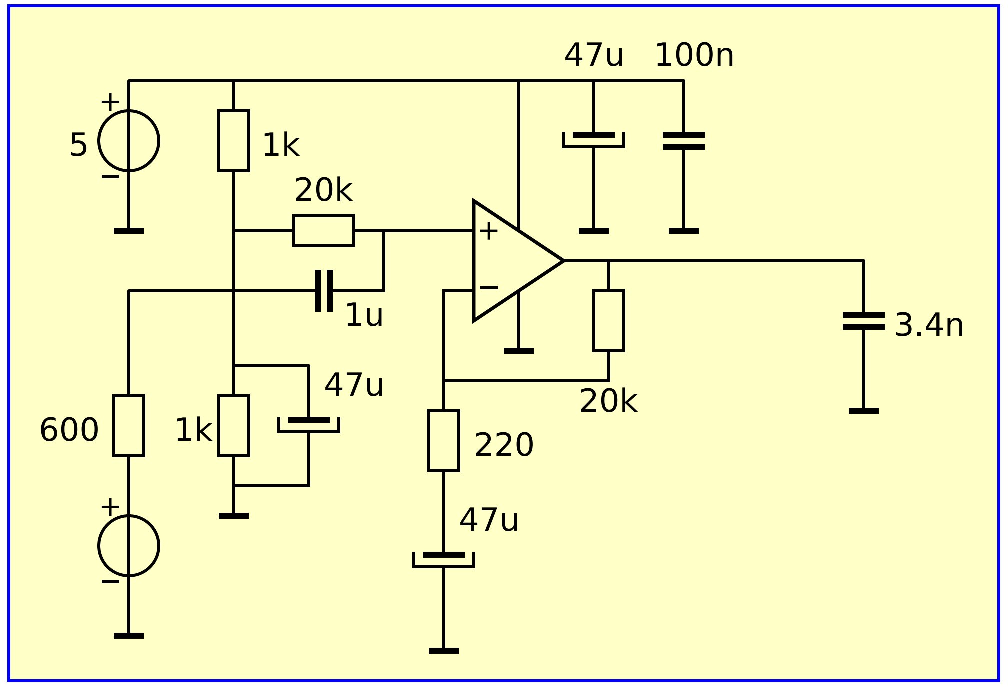


Small-signal step response

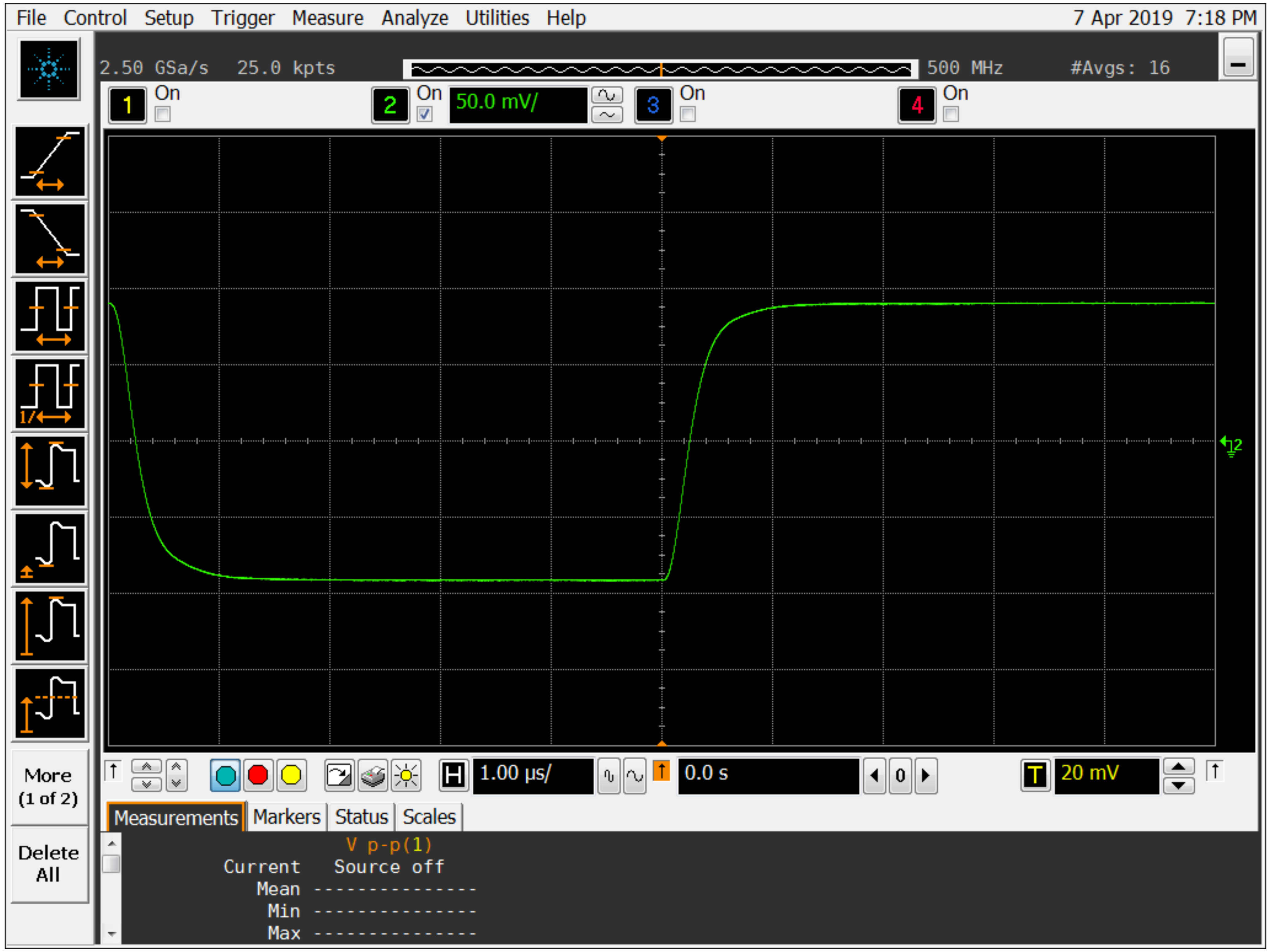
Source: $2mV_{pp}$, 100kHz, 50%

Uncompensated amplifier

Total load capacitance 3.4nF



Test results

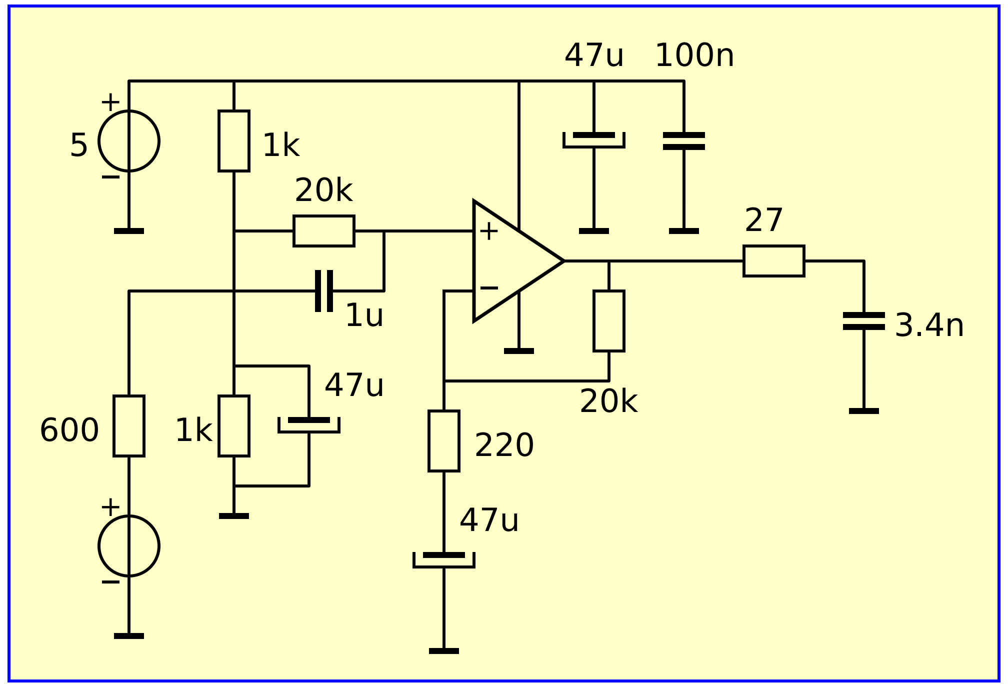


Small-signal step response

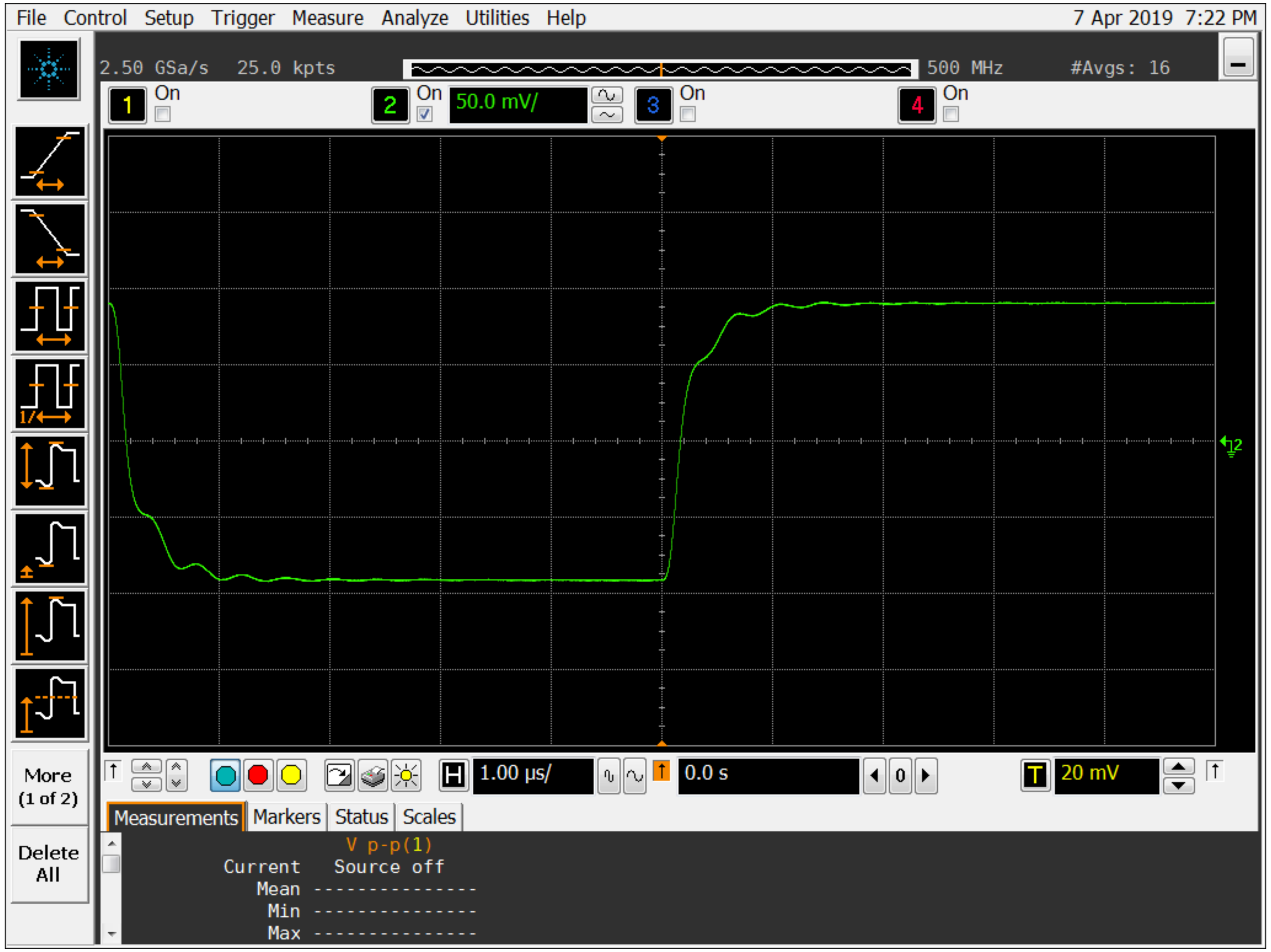
Source: 2mV$_{pp}$, 100kHz, 50%

Partly compensated amplifier

Total load capacitance 3.4nF



Test results



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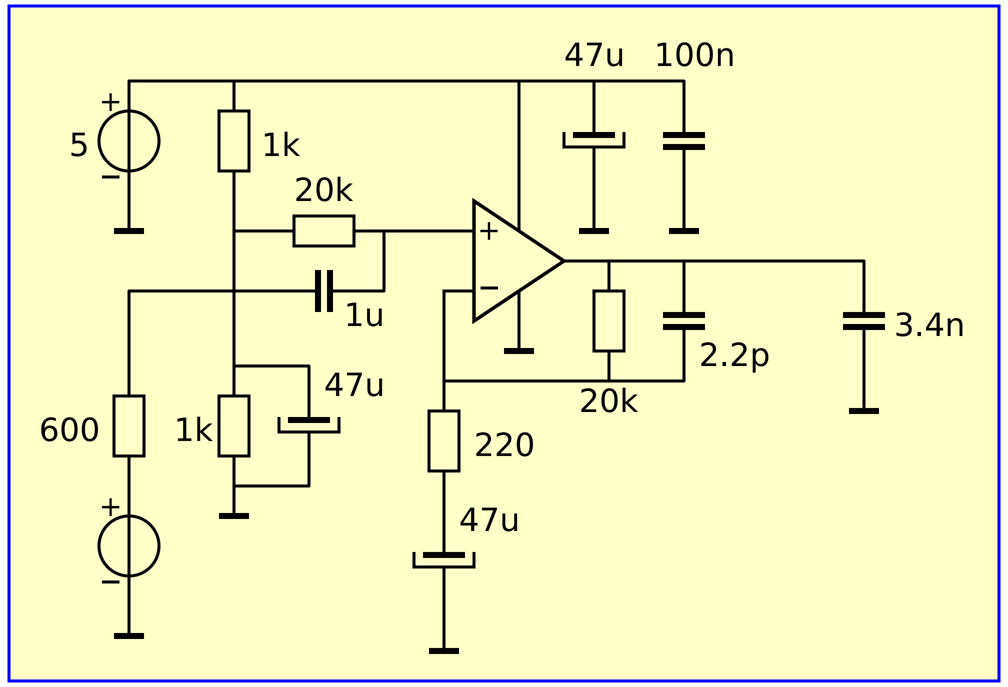
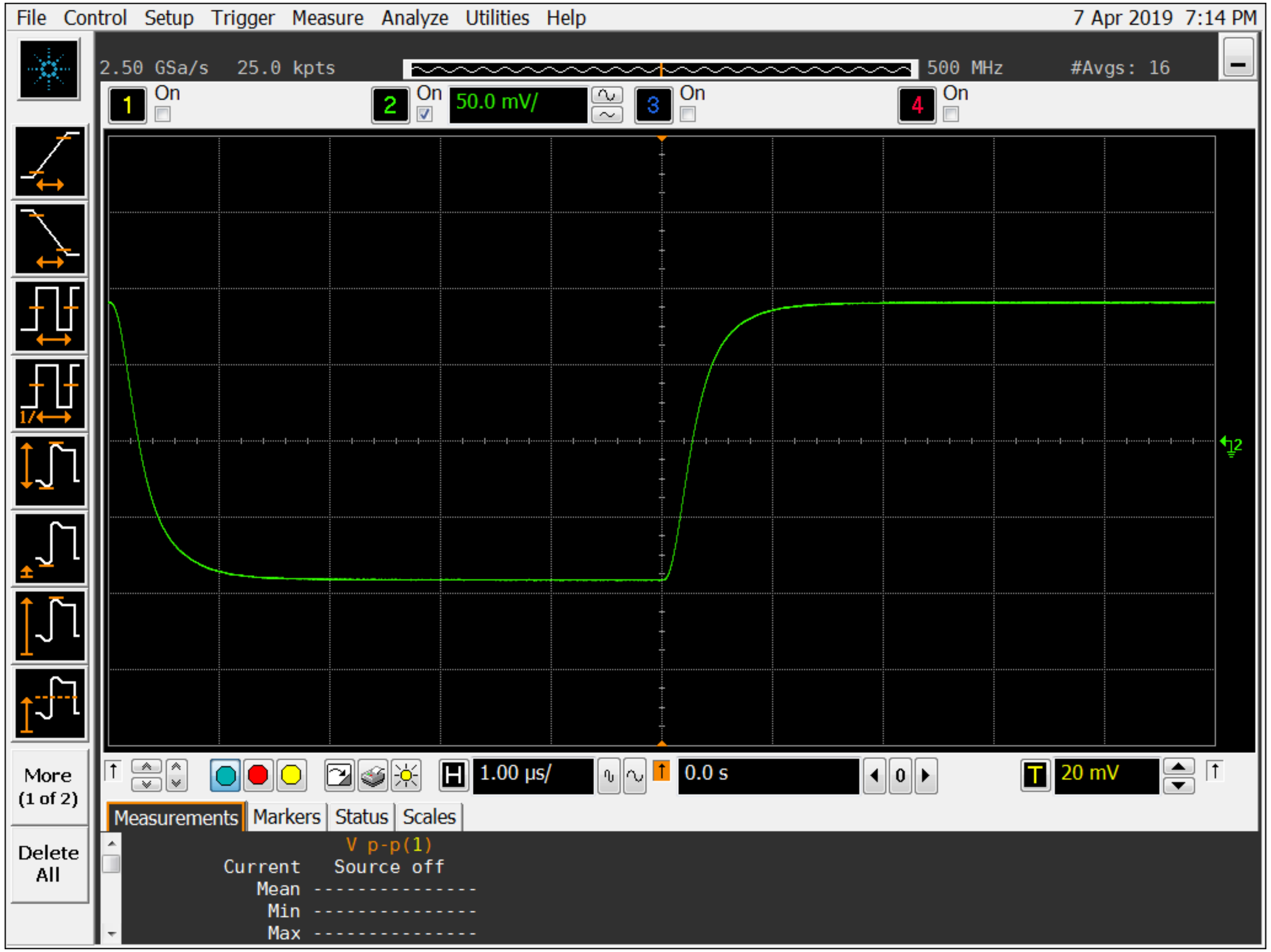
Source: $2mV_{pp}$, 100kHz, 50%

Partly compensated amplifier

Total load capacitance 3.4nF



Test results

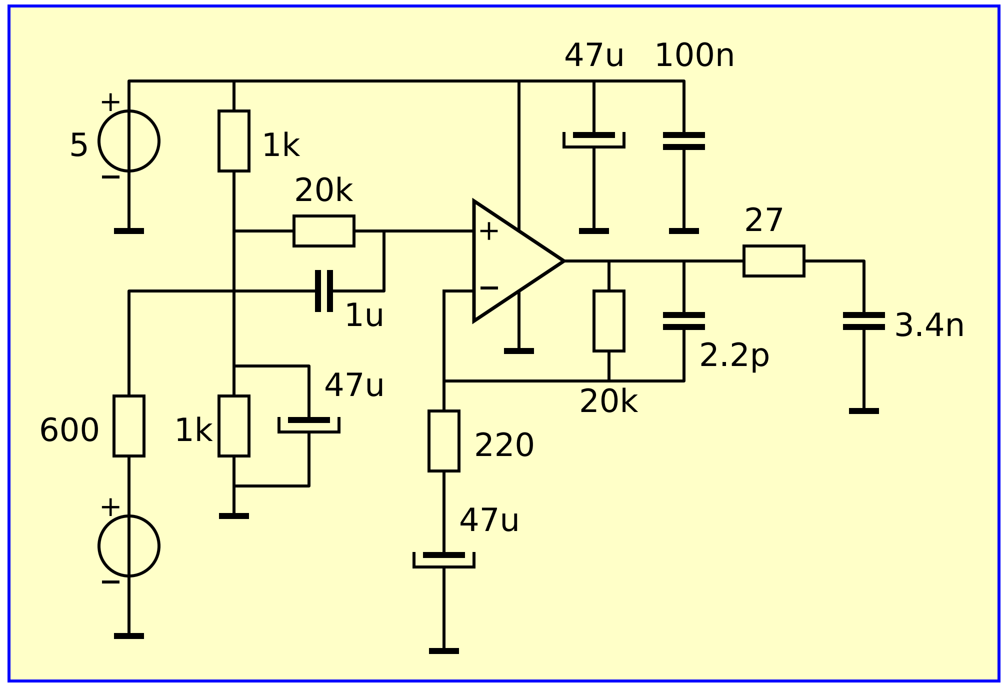


Small-signal step response

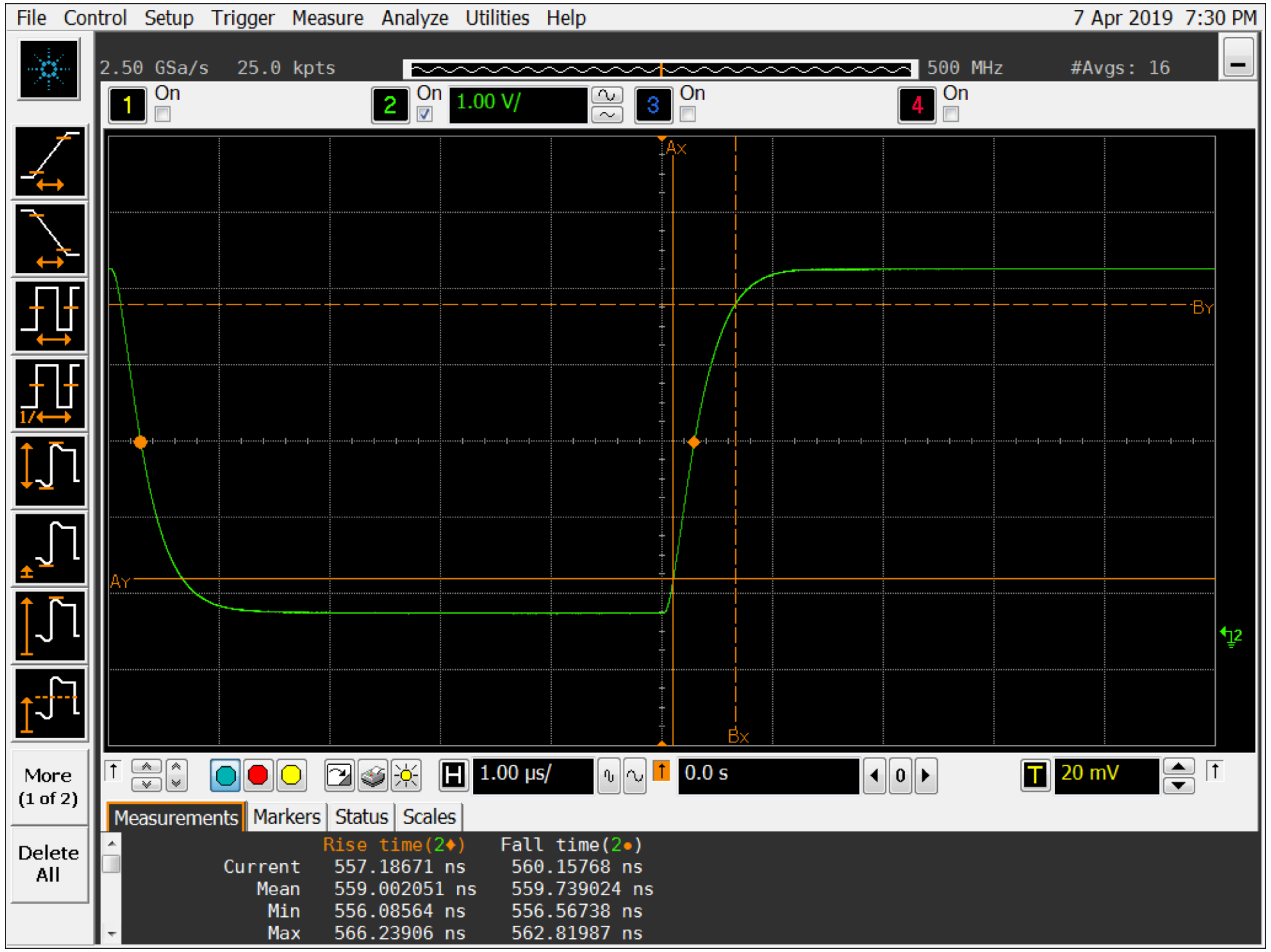
Source: $2mV_{pp}$, 100kHz, 50%

Compensated amplifier

Total load capacitance 3.4nF



Test results

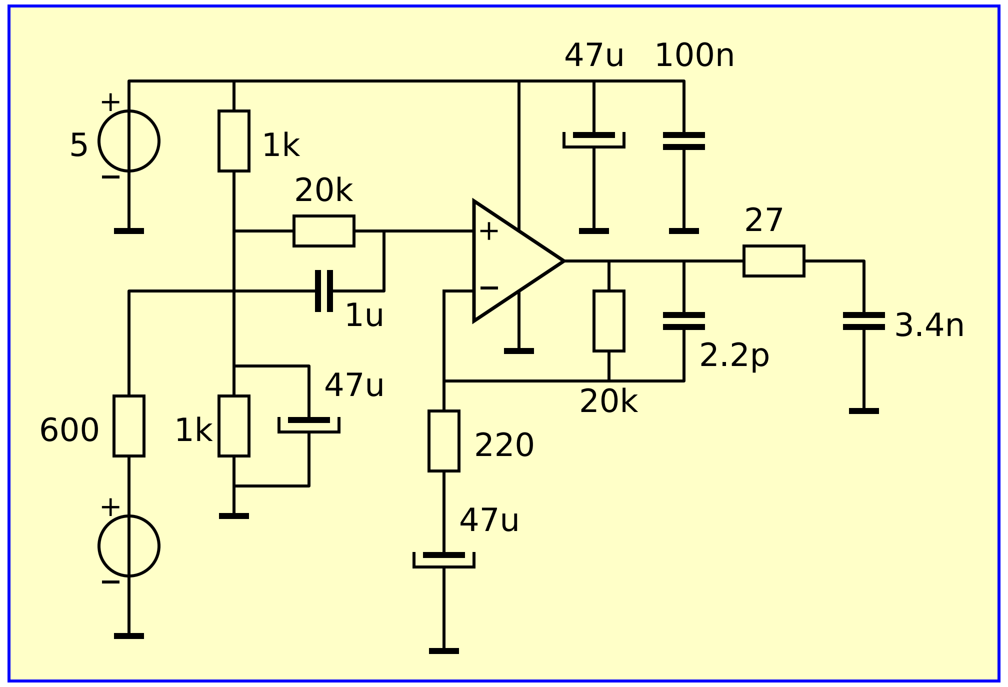


Large-signal step response

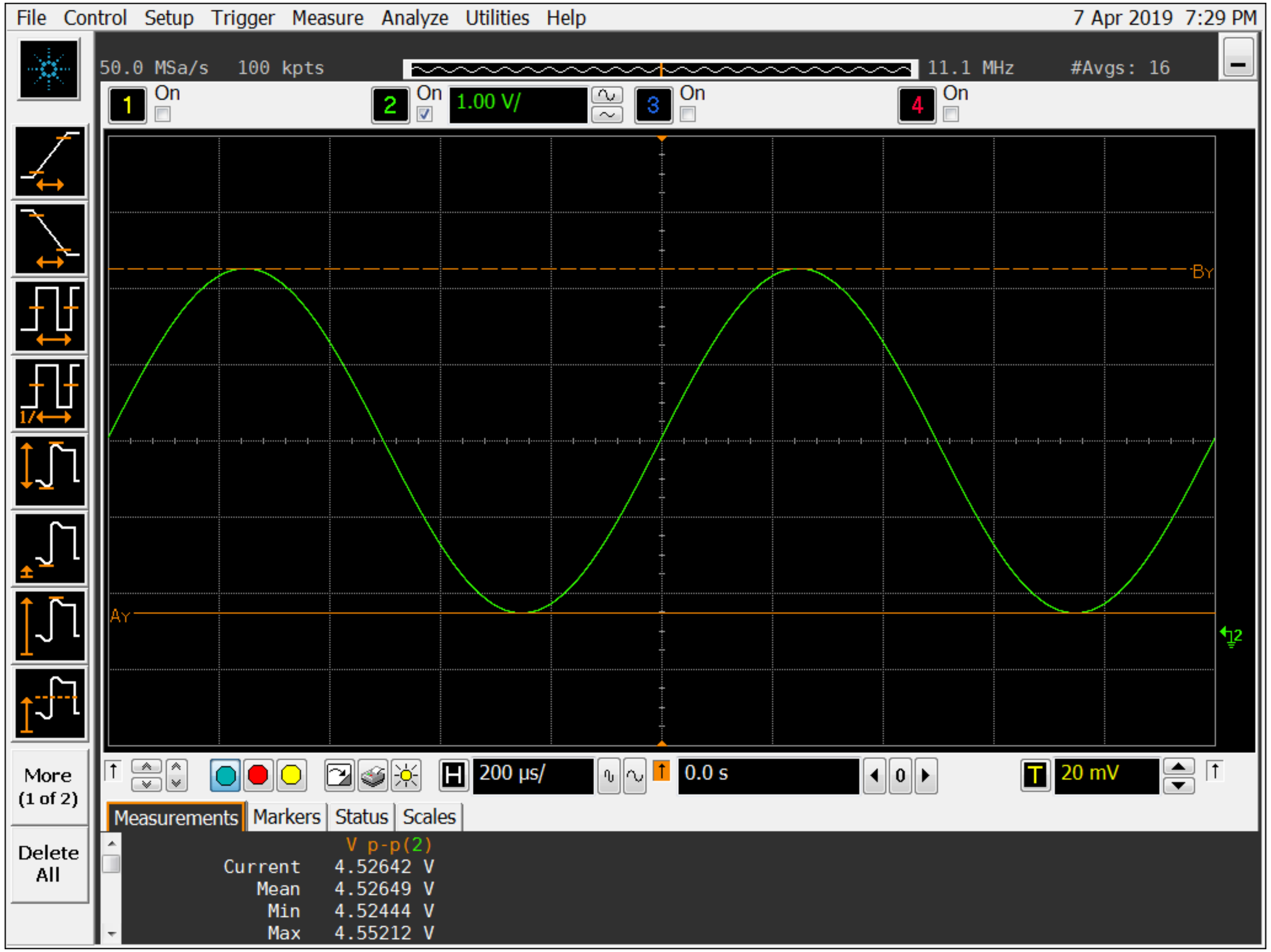
Source: 50mV$_{pp}$, 100kHz, 50%

Compensated amplifier

Total load capacitance 3.4nF



Test results

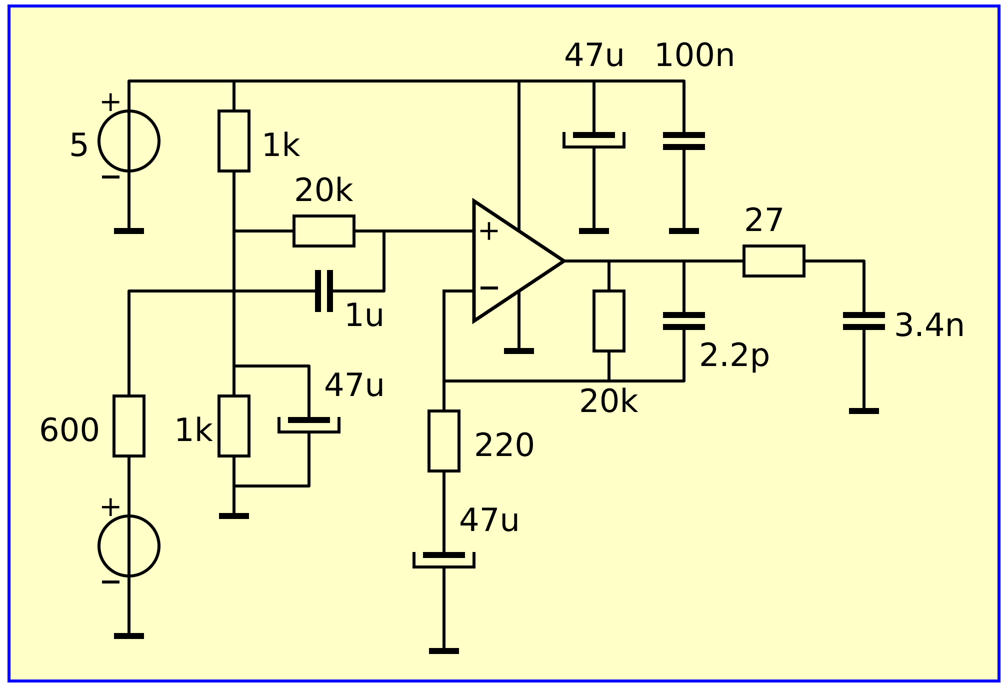


Large-signal sine response

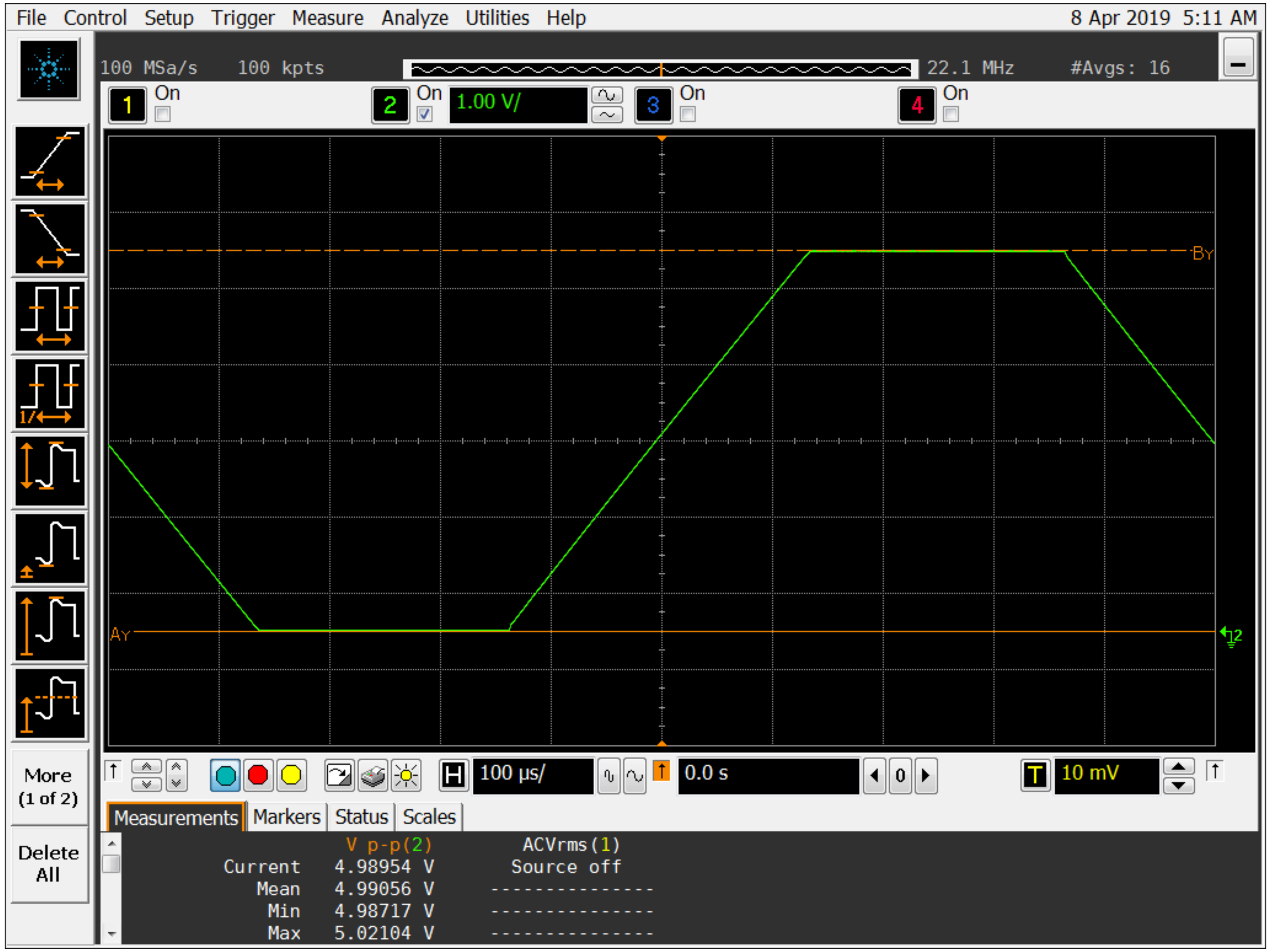
Source: 50mV$_{pp}$, 100kHz

Compensated amplifier

Total load capacitance 3.4nF



Test results



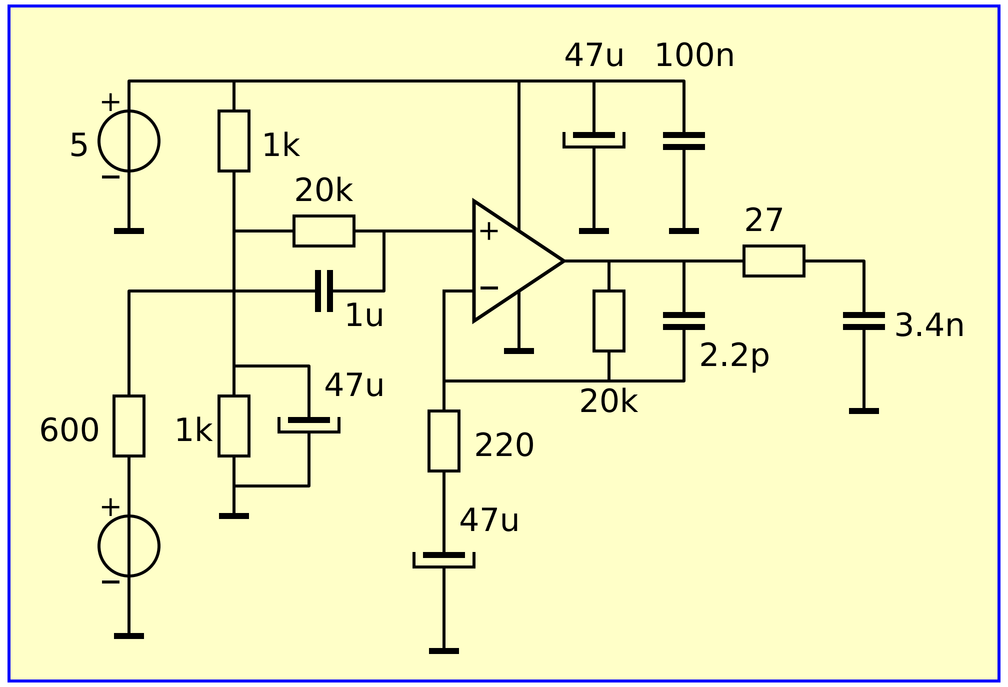
Large-signal overdrive

Source: 100mV$_{pp}$, 1kHz, triangle

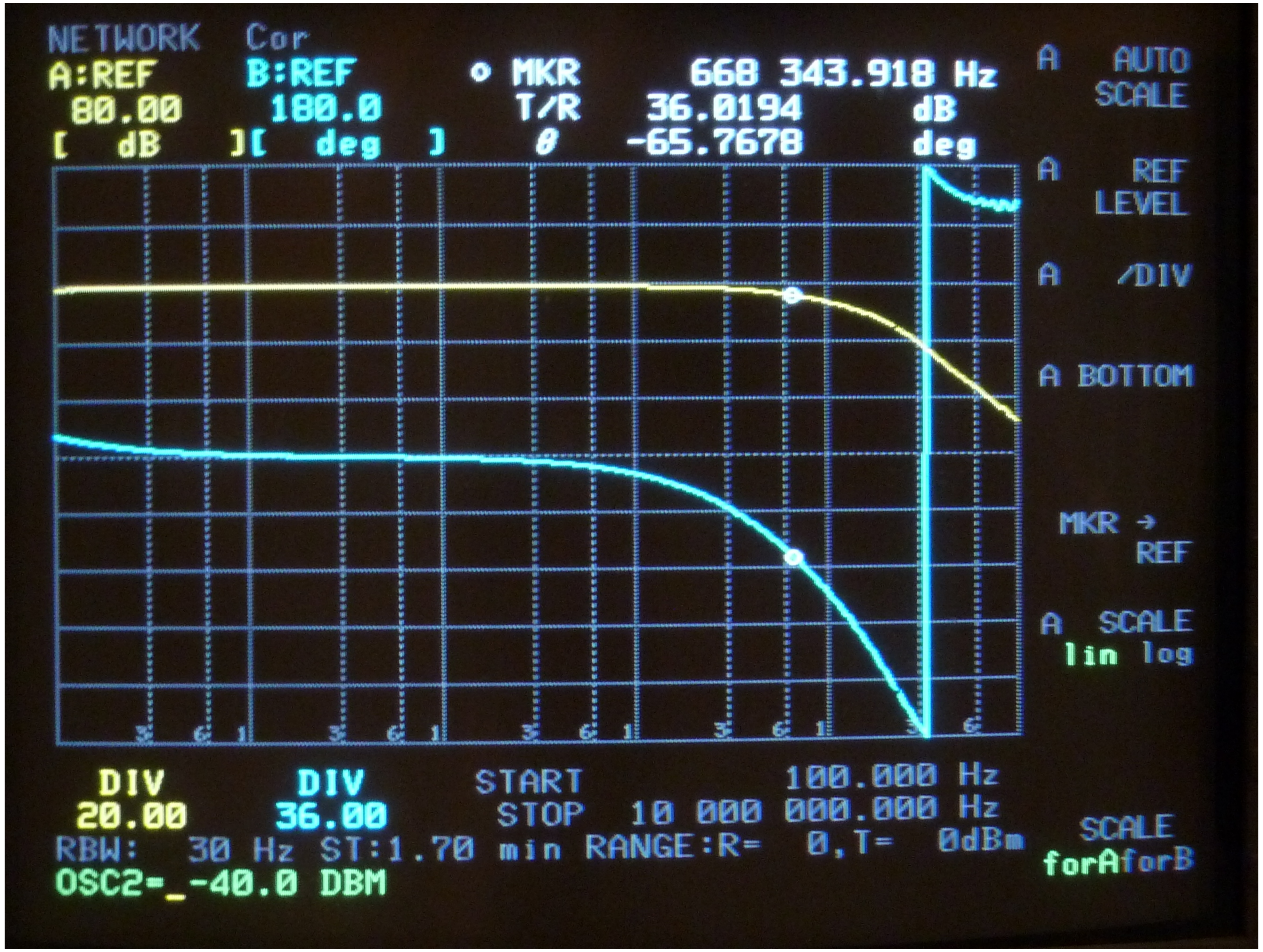
Compensated amplifier

Total load capacitance 3.4nF

Source/sink voltage drop < 10mV



Test results

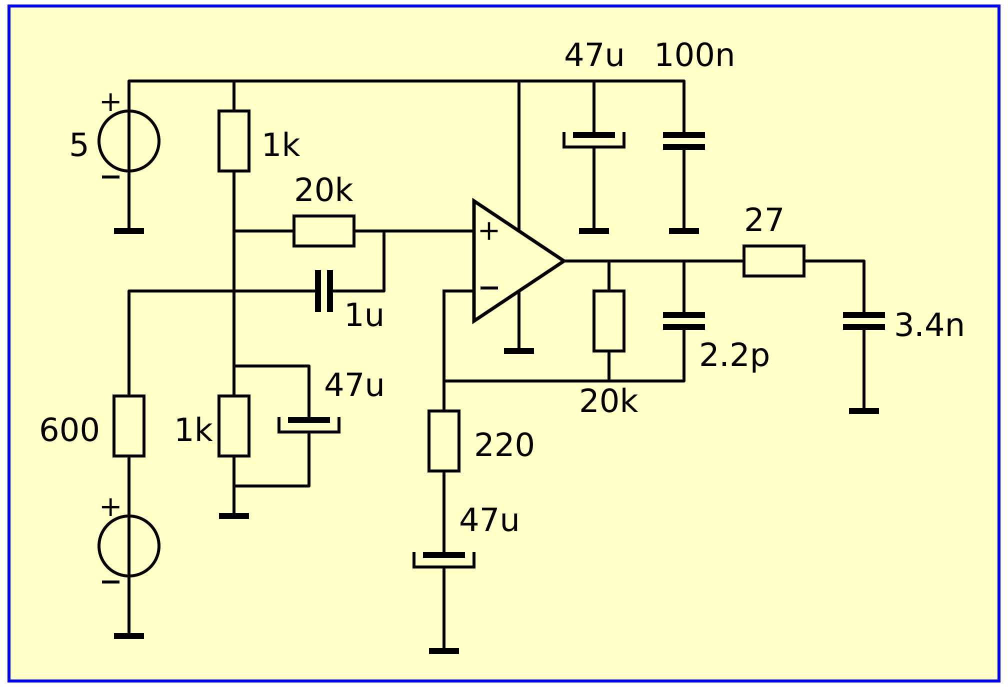


Small-signal transfer

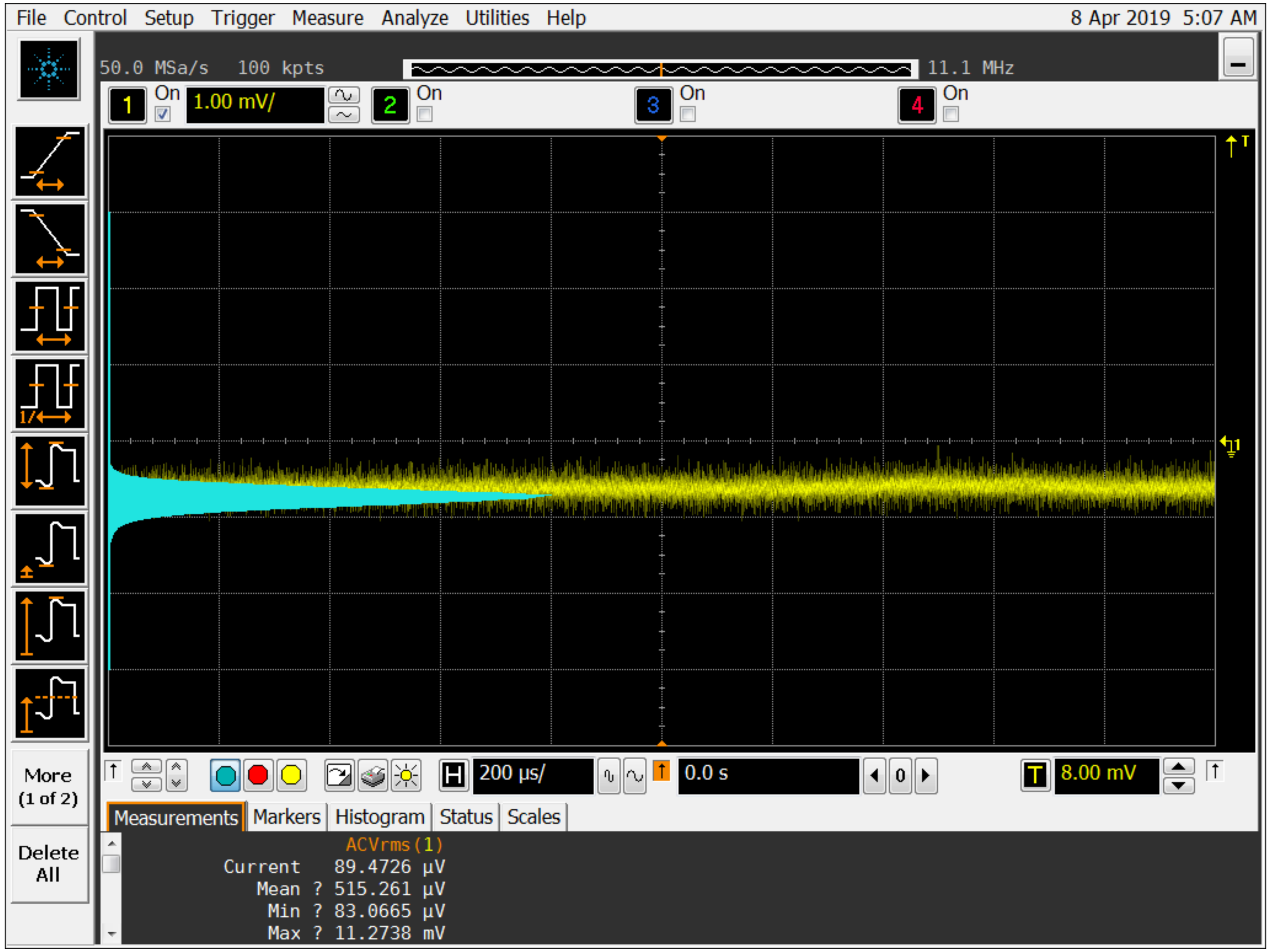
HP4195A, source -40dBm

Compensated amplifier

Total load capacitance 3.4nF



Test results

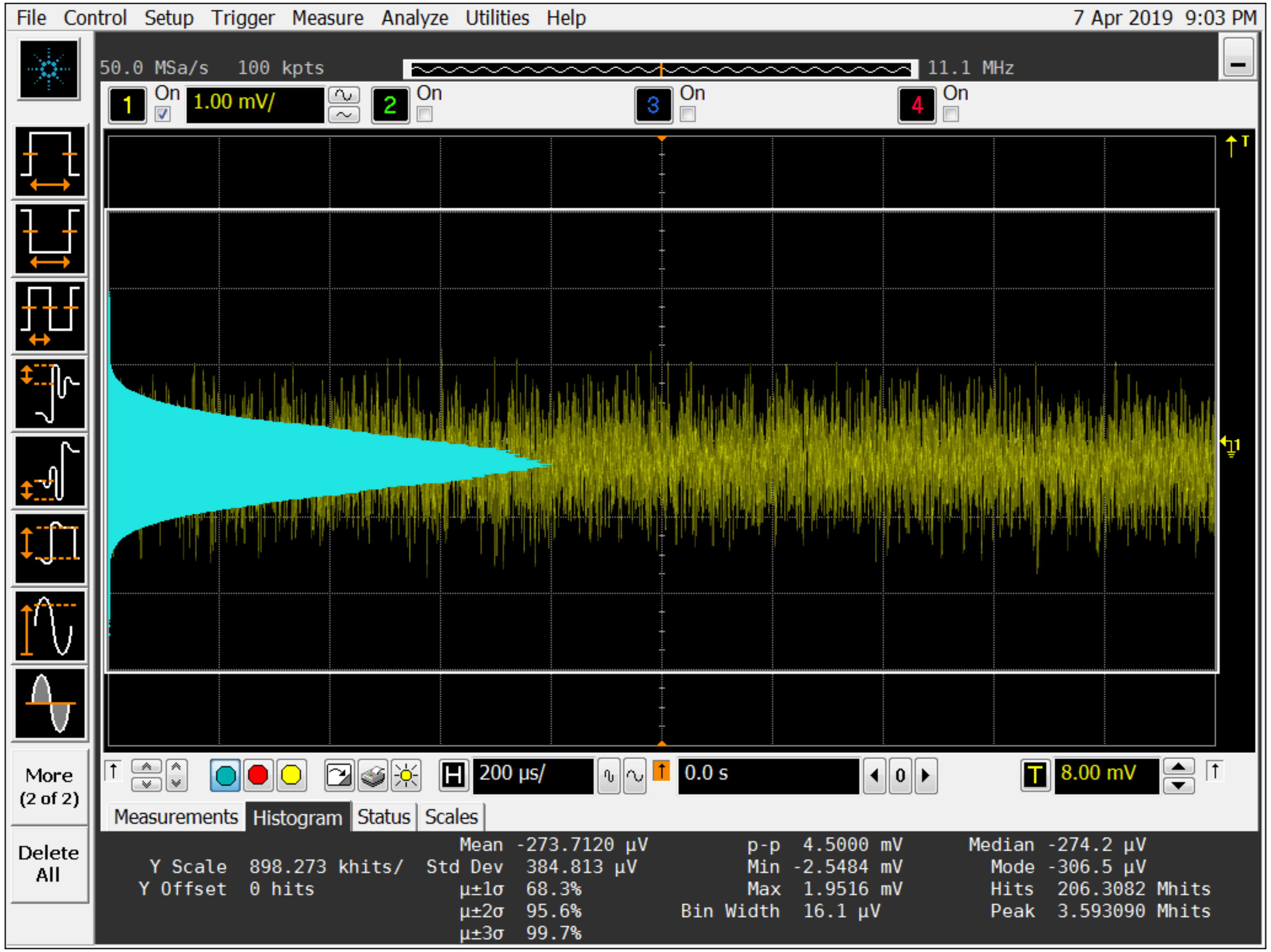


Oscilloscope noise

83uV RMS

Shorted input

Test results



Output noise

385uV RMS

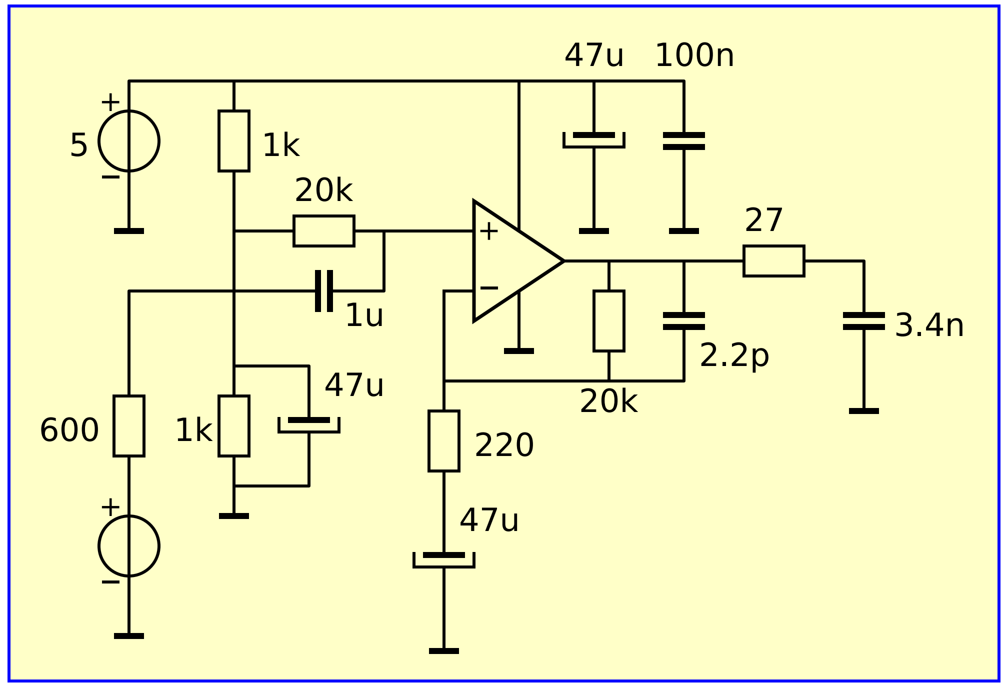
Compensated amplifier

Total load capacitance 3.4nF

Corrected for scope noise: 376uV

N=2.3dB @ 1MHz NBW

N=2.7dB @ 900kHz NBW



Conclusions and remarks

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