Imperial College London

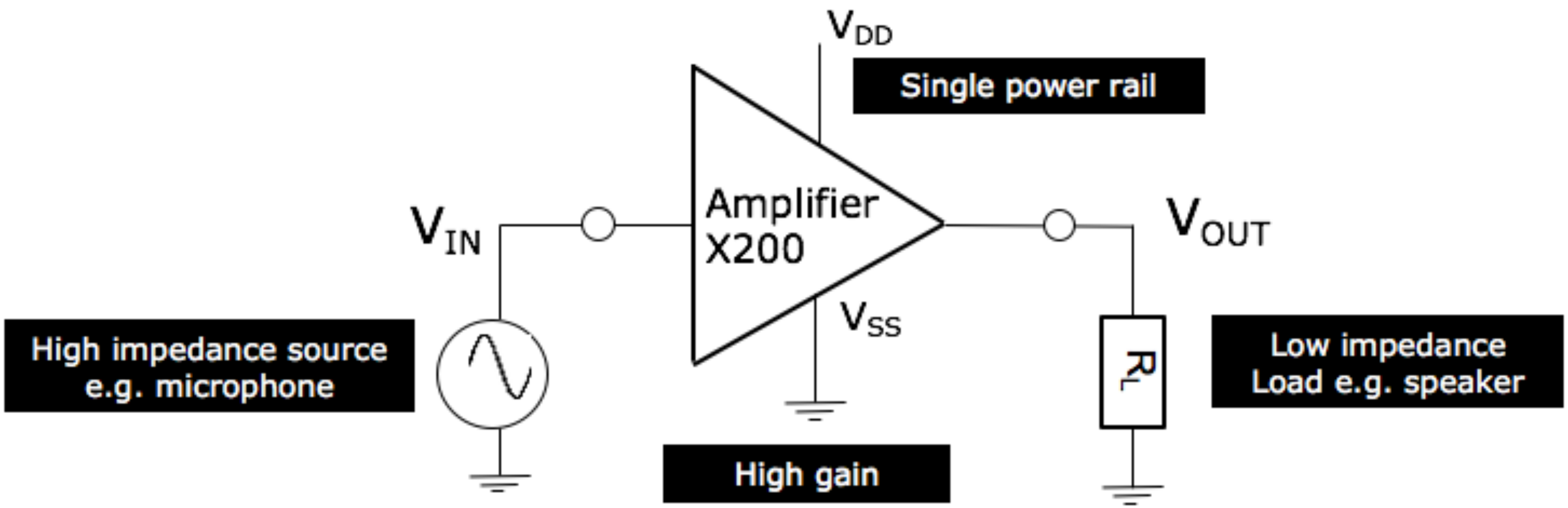
Lecture 2

Amplification and Single-rail Op-amp

Prof Peter YK Cheung
Imperial College London

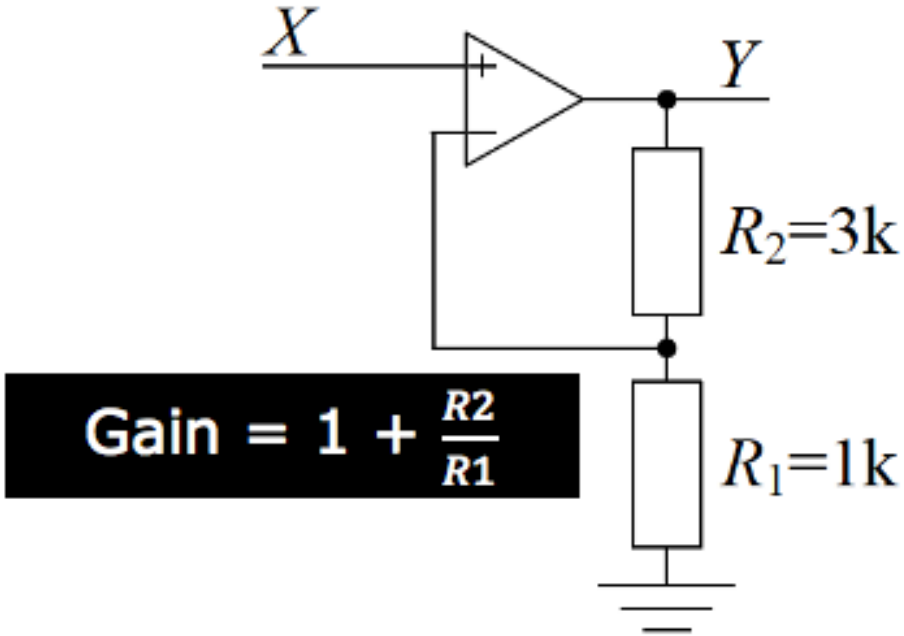
URL: www.ee.ic.ac.uk/pcheung/teaching/EE2_CAS/
E-mail: p.cheung@imperial.ac.uk

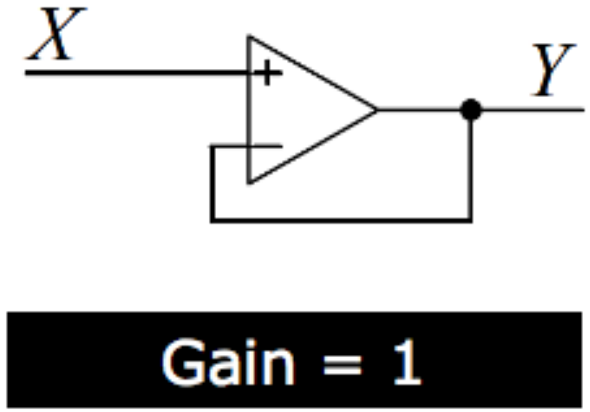
What you will learn in Lectures 2 and 3?



- Small input signal
- High gain amplification
- Working with single power supply rail
- Low impedance load (next Lecture)

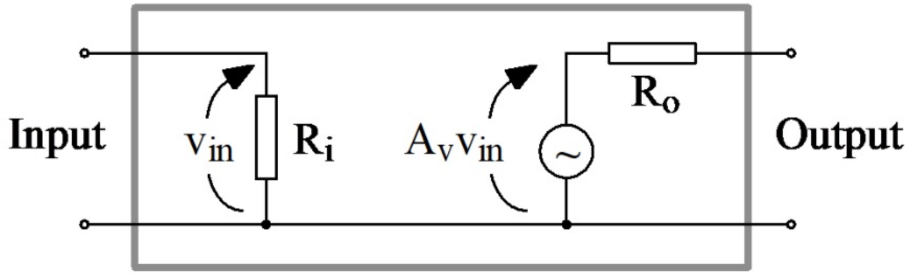
Non-inverting Amplifier & Voltage Follower





- Year 1 circuits module, part 1, lecture 9, slides 11 and 12
- Non-inverting amplifier using op-amp, Gain x4
- Special case: R2 = 0, R1 = ∞, Gain = 1
  - Voltage follower or unity gain buffer

MCP6001/2/4 as a near ideal op-amp



- Ideal op-amp
  - $R_i \rightarrow \infty$
  - $A_v \rightarrow \infty$
  - $R_o \rightarrow 0$

✓ Z_{in} of MCP6001 is very large

Common Mode Input Impedance	Z_{CM}	$10^{13}\|\|6$	Ω||pF
Differential Input Impedance	Z_{DIFF}	$10^{13}\|\|3$	Ω||pF

✓ Input current is negligible

Input Bias Current:	I_B	±1.0	pA	
Industrial Temperature	I_B	19	pA	T_A = +85°C
Extended Temperature	I_B	1100	pA	T_A = +125°C

✓ Gain is near infinite (true at low frequency)

DC Open-Loop Gain (Large Signal)	A_{OL}	112 >1 x10^5	dB

✓ Output impedance is low (specified as I_{SC})

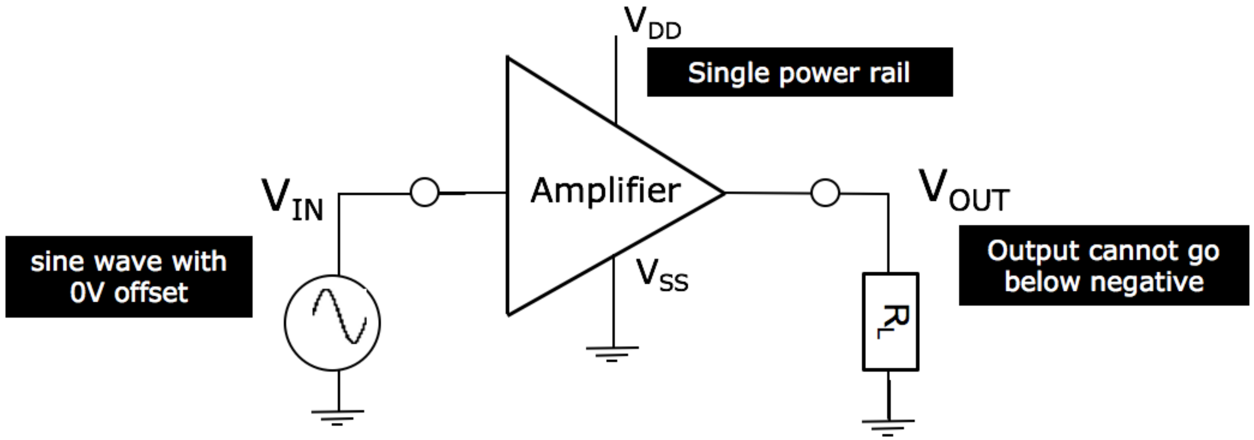
Output Short Circuit Current	I_{SC}	±6	mA	V_{DD} = 1.8V
		±23	mA	V_{DD} = 5.5V

Problem with single supply rail

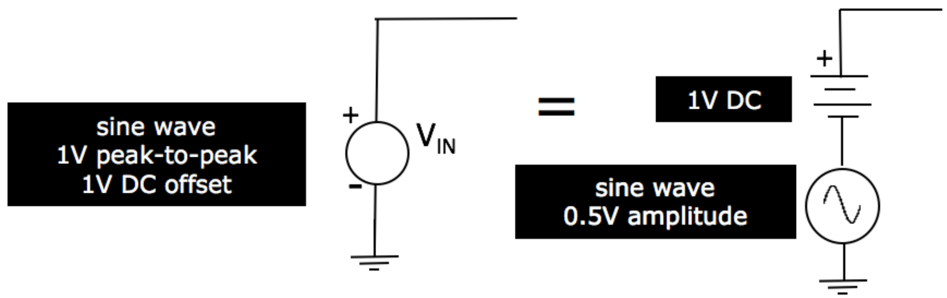
- Output swing limited to rail voltages

Maximum Output Voltage Swing	V_{OL}, V_{OH}	V_{SS} + 25 V_{DD} – 25	mV

- Input cannot be a sinewave with 0V DC offset

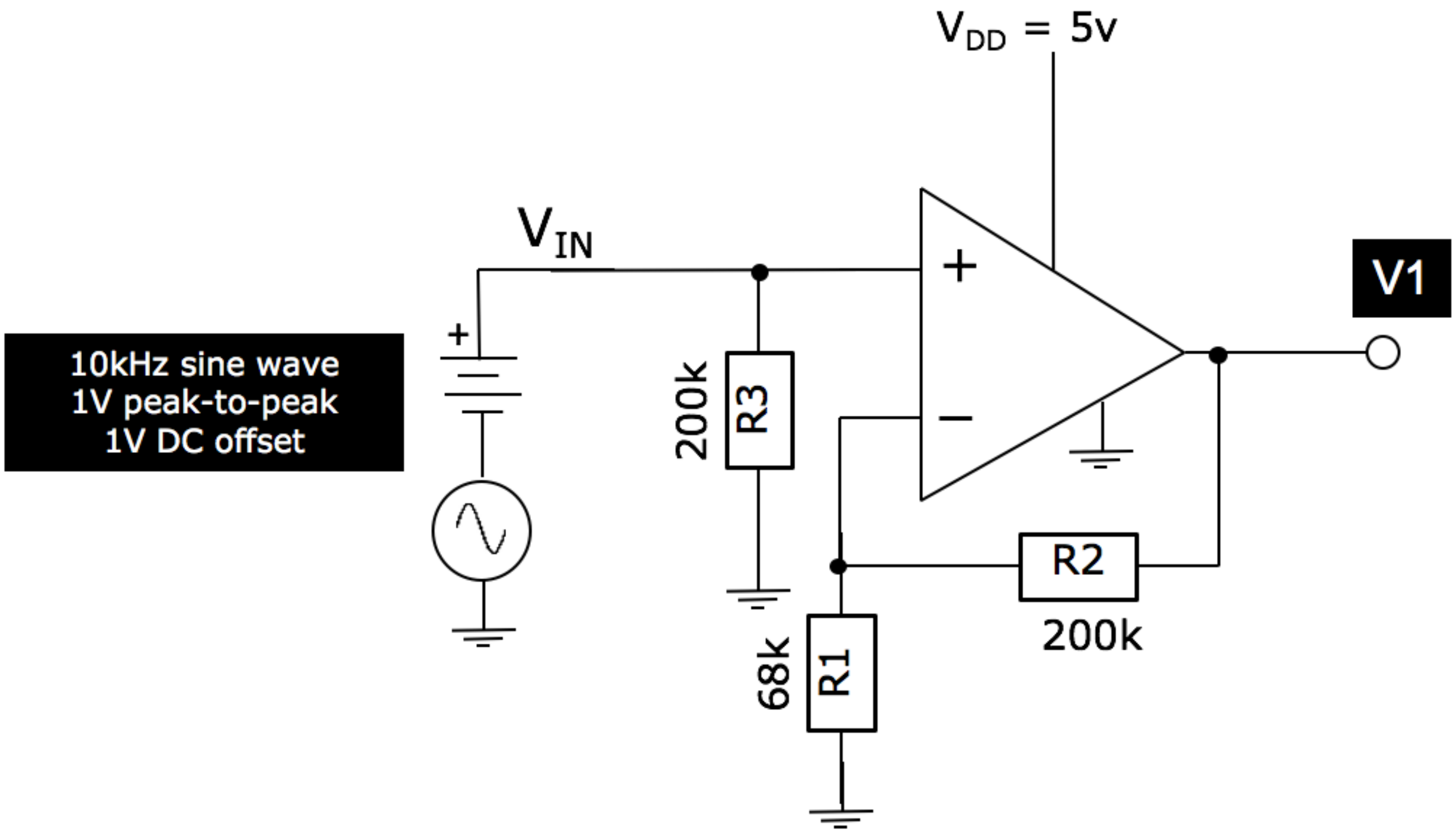


- Need to add DC offset to input



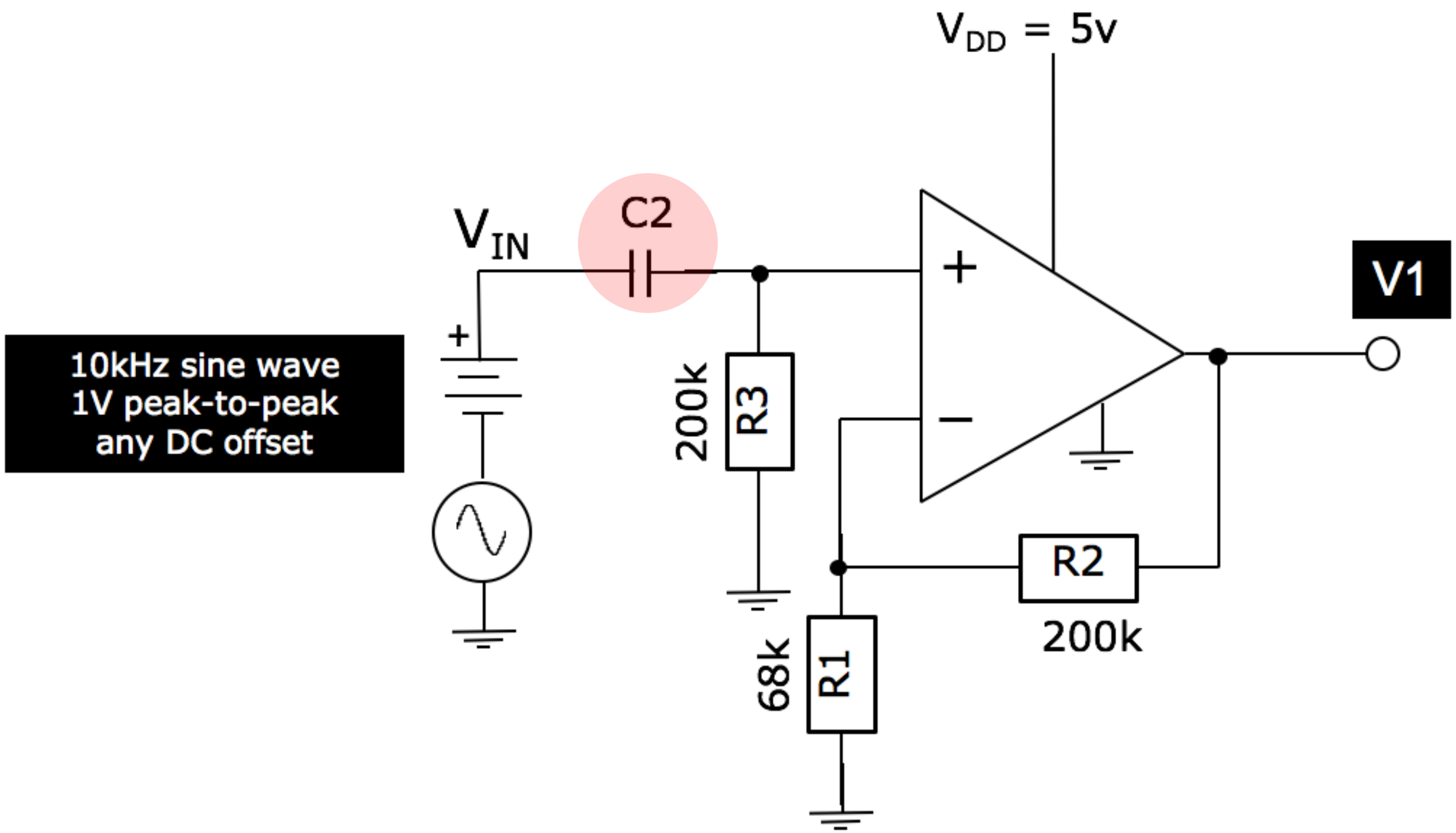
X4 amplifier fail

- Amplifier Gain = +4, output swing = 2V to 6V – not possible



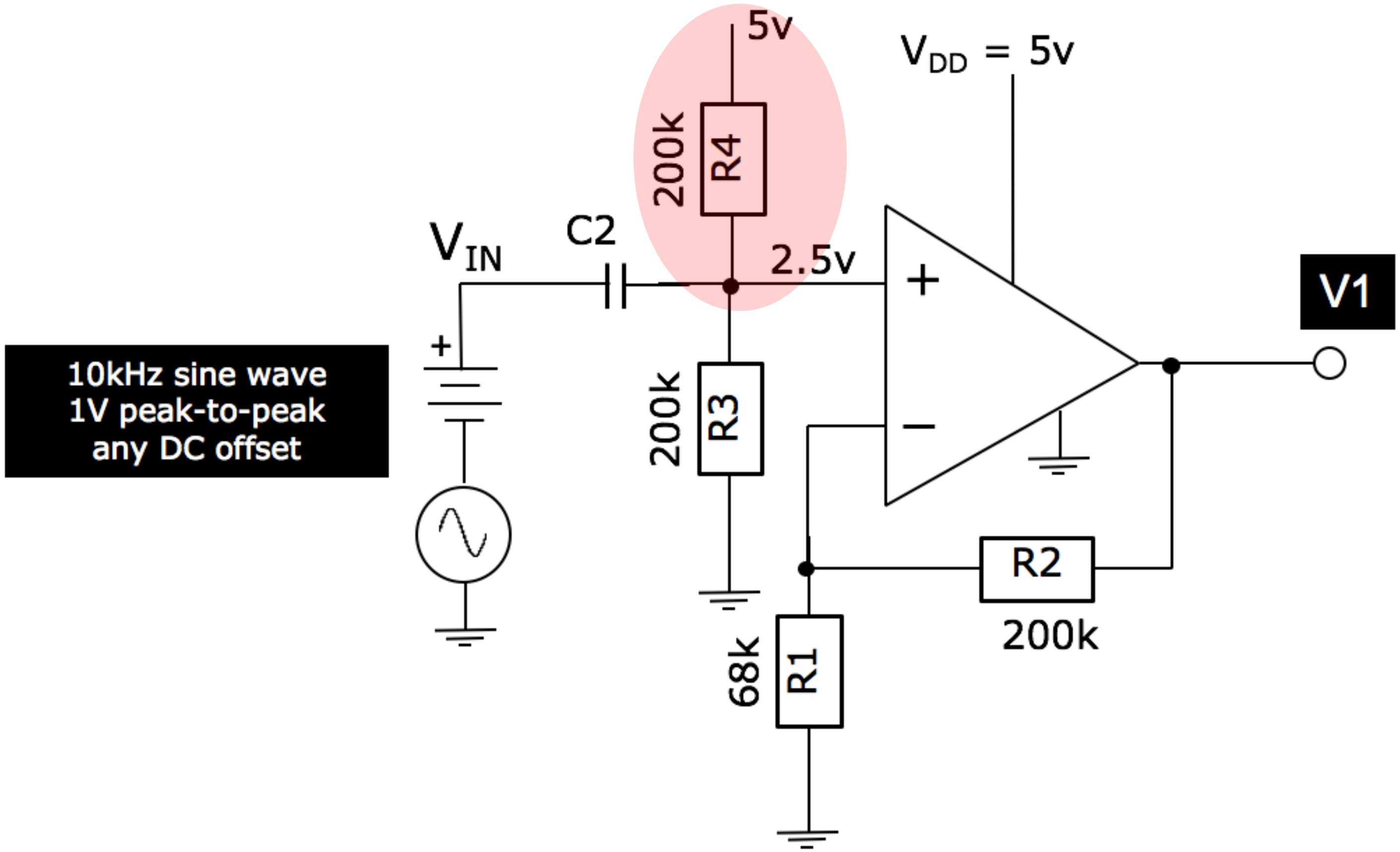
Attempt 1 – AC coupling signal

- AC couple input signal – block DC offset to amplifier
- Does not work for single supply op-amp



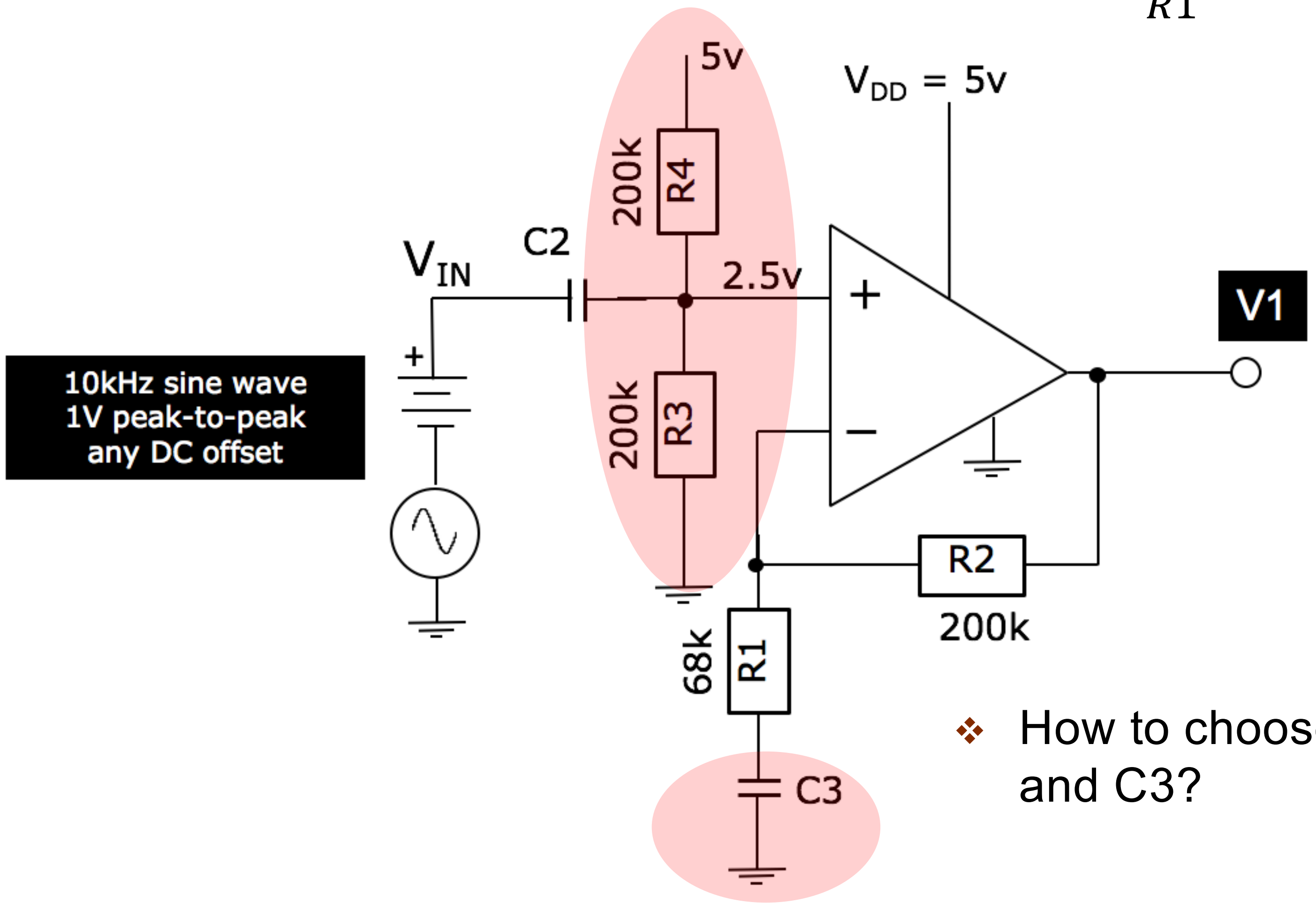
Attempt 2 – Add bias to V+ input

- Bias input V+ to half of power supply rail voltage
  - Maximize input voltage swing
  - Still not working – bias voltage is now the unwanted DC offset!



Final working solution

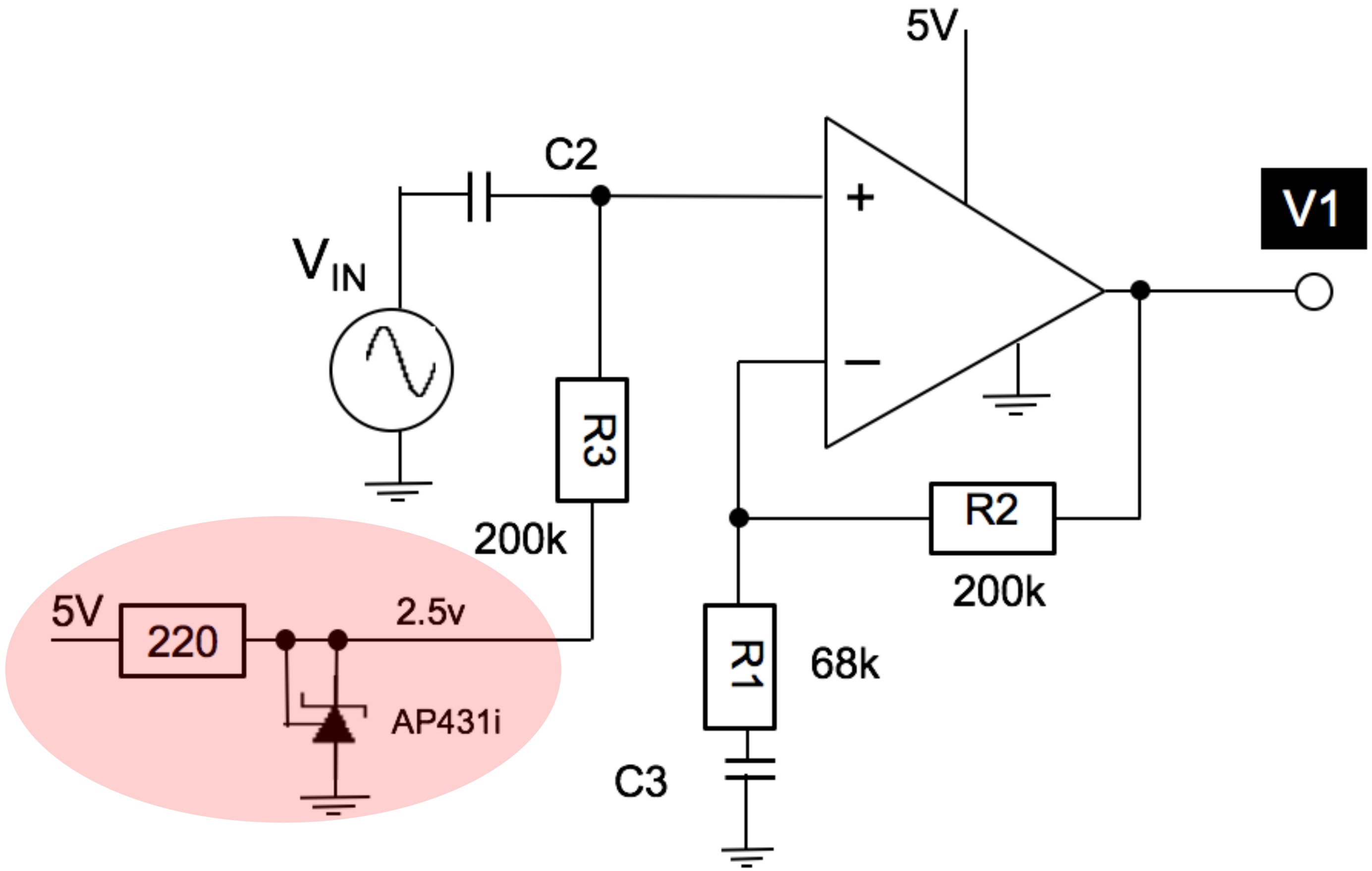
- Final solution: Add C3 such that gain of op-amp = 1 at 0 Hz (DC)
- Gain of op-amp at valid signal frequency is $G = 1 + \frac{R2}{R1}$



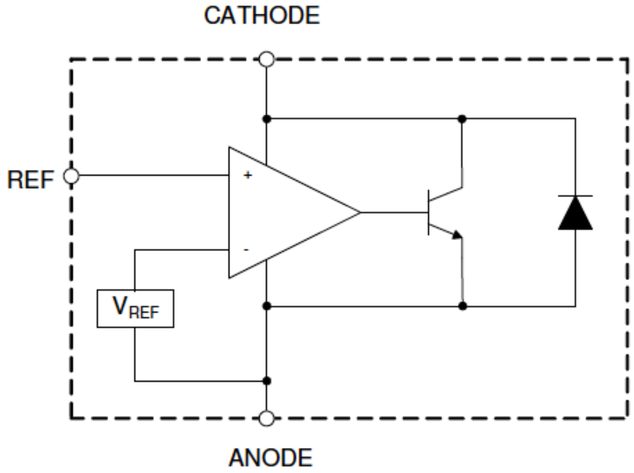
- How to choose values for C2 and C3?

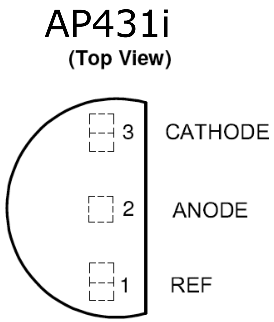
Better Bias Circuit

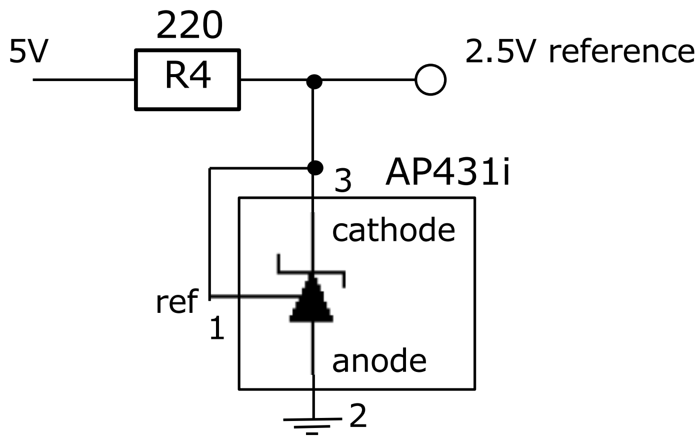
- Generate bias voltage using a voltage reference circuit, e.g. AP431i
- Bias voltage NOT susceptible to noise on 5V supply



AP431i voltage reference in detail





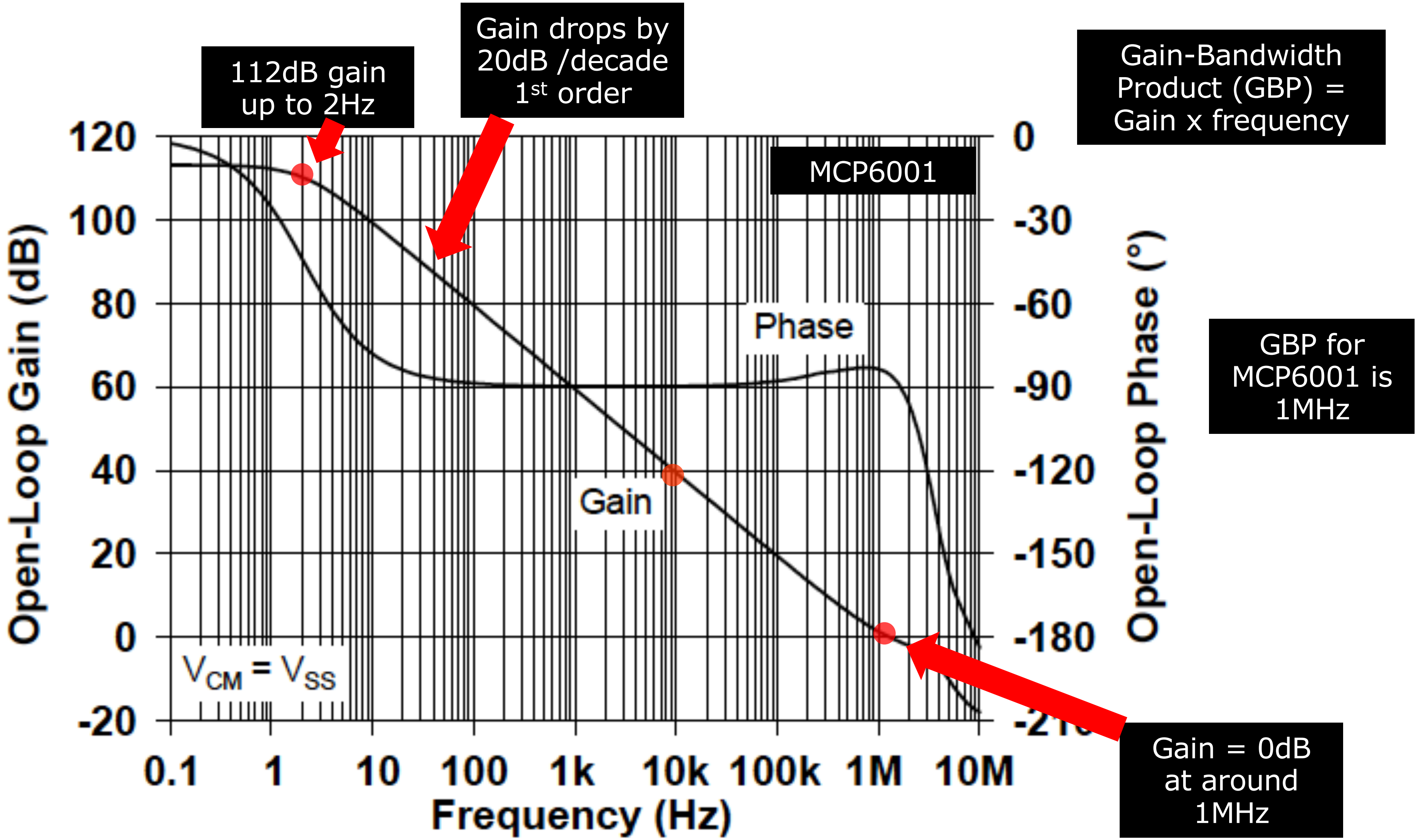


		Min	Max	
I_{KA}	Cathode Current	0.1	100	mA

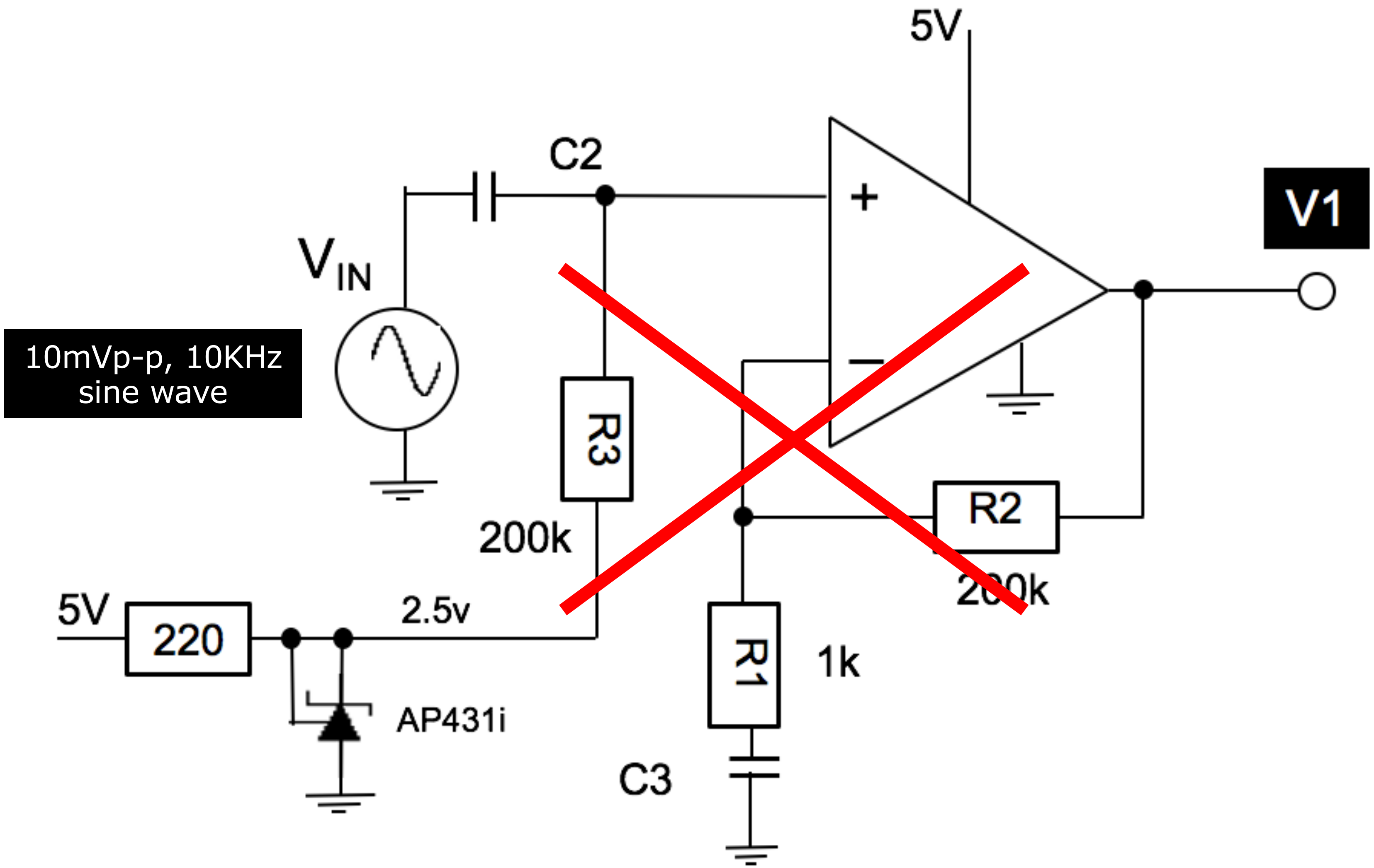
			Min	Typical	Max	
V_{REF} 1%	Reference Voltage	$V_{KA} = V_{REF}$, $I_{KA} = 1mA$	2.475	2.500	2.525	V

			Typical	Max	
Z_{KA}	Dynamic Impedance	$V_{KA} = V_{REF}$, $I_{KA} = 1$ to 100mA, $f \leq 1.0kHz$	0.1	0.3	Ω

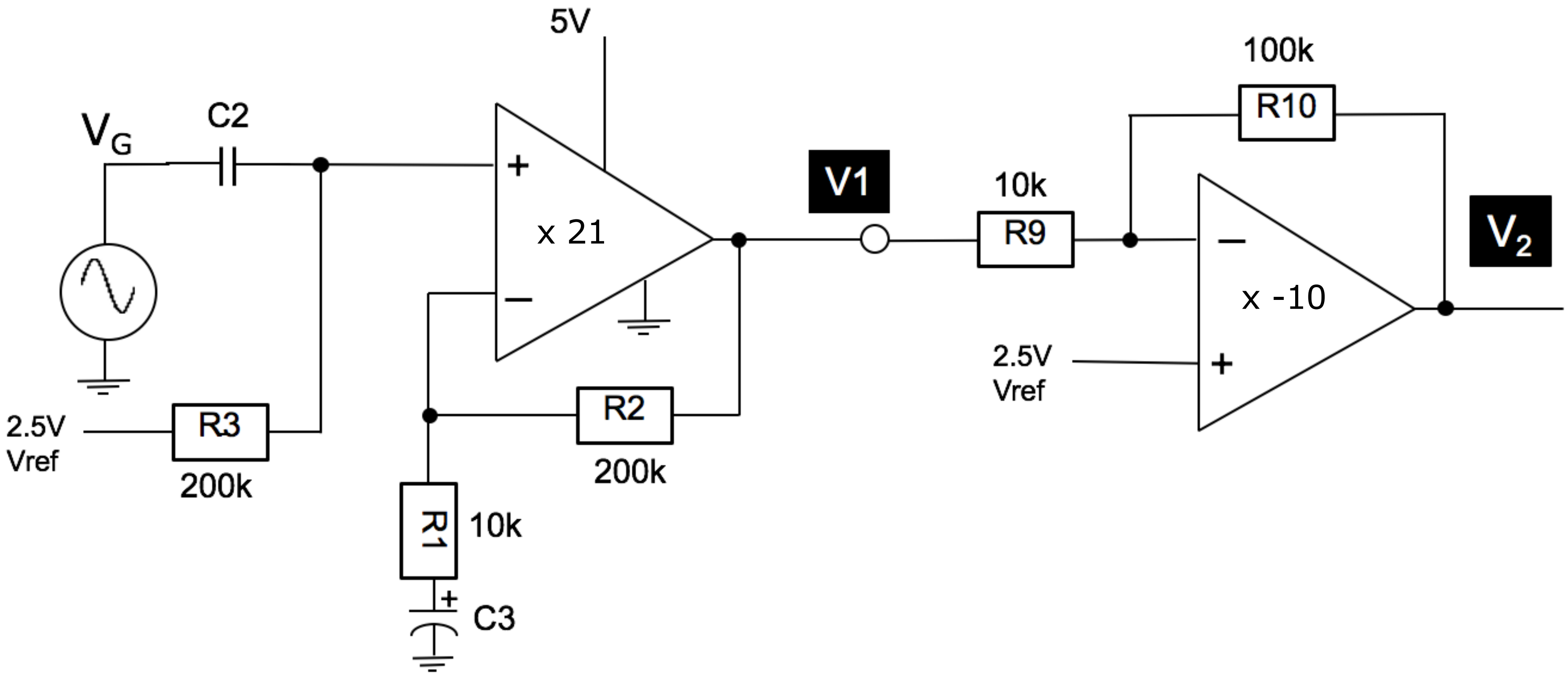
Open-loop Gain vs Frequency for MCP6001



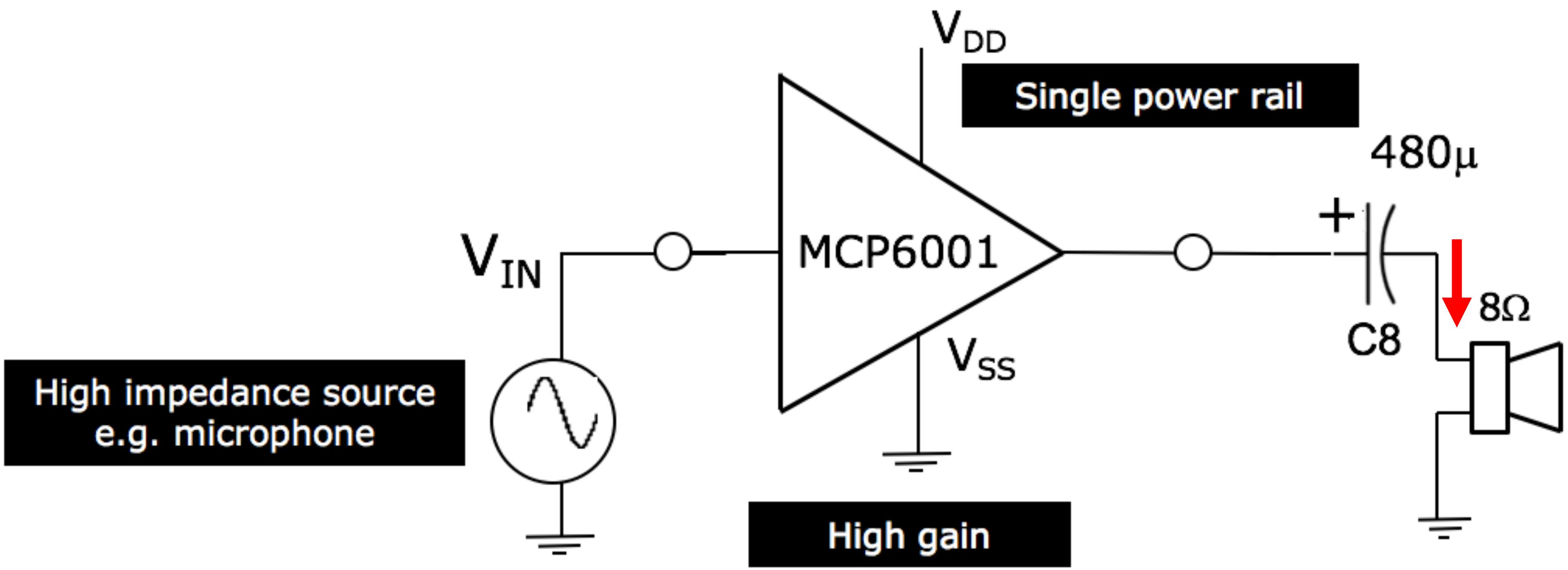
Amplify 10kHz signal with Gain of 200



Solution - Two stage amplification



Problem with driving low impedance load



Output Short Circuit Current	I_{SC}	±6	mA	V_{DD} = 1.8V
		±23	mA	V_{DD} = 5.5V

- Needs AC coupling due to output bias voltage of 2.5V
- Maximum current is over 600mA!
- MCP6001 cannot drive 8Ω speaker