

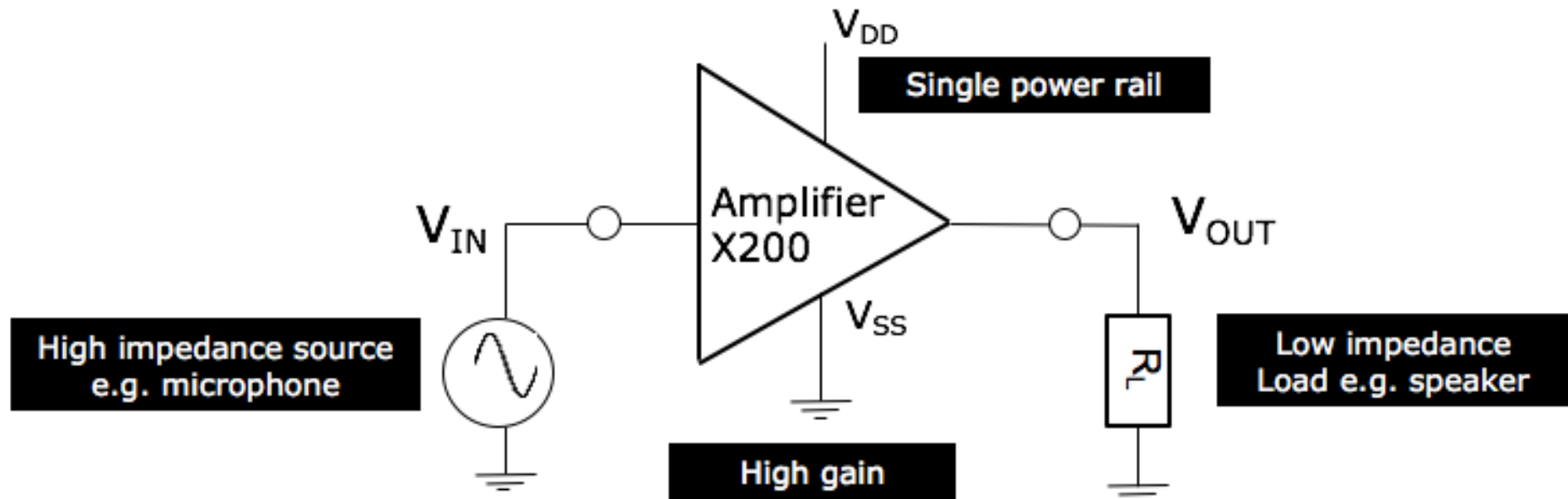
Lecture 2

Amplification and Single-rail Op-amp

Prof Peter YK Cheung
Imperial College London

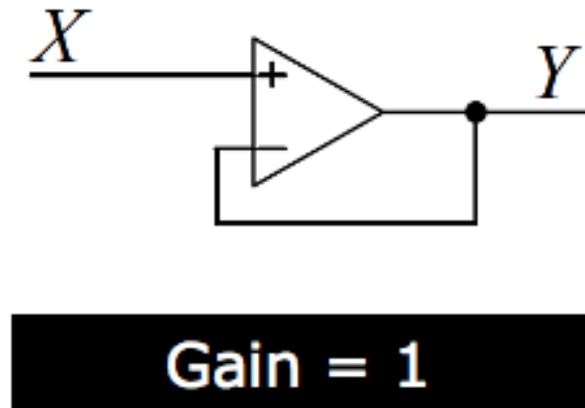
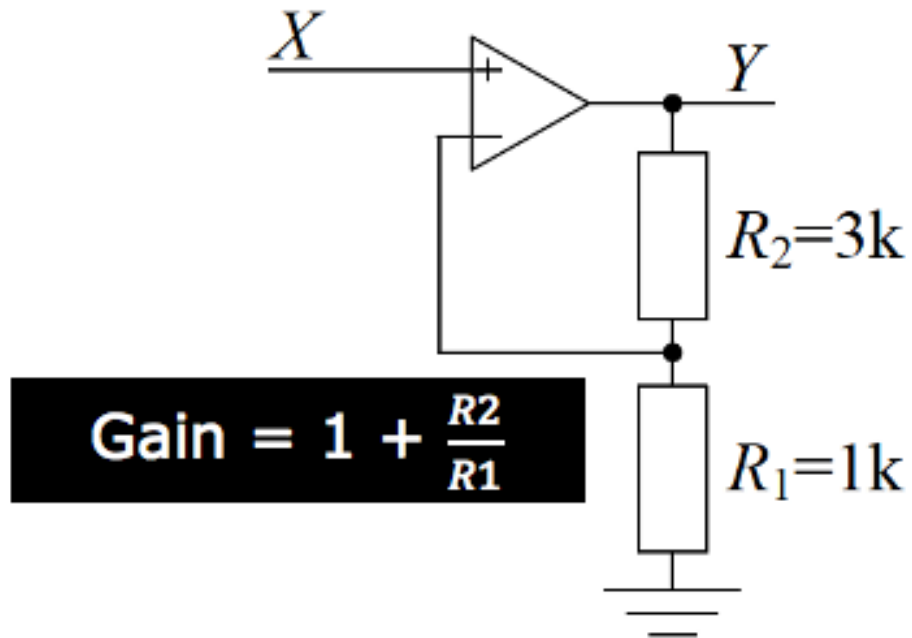
URL: www.ee.ic.ac.uk/pcheung/teaching/EE2_CAS/
E-mail: p.cheung@imperial.ac.uk

What you will learn in Lectures 2 and 3?



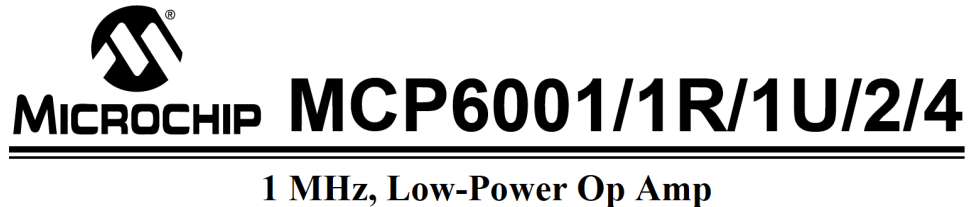
- ❖ Small input signal
- ❖ High gain amplification
- ❖ Working with single power supply rail
- ❖ Low impedance load (next Lecture)

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: $R_2 = 0$, $R_1 = \infty$, Gain = 1
 - Voltage follower or unity gain buffer

Real-life Op Amp

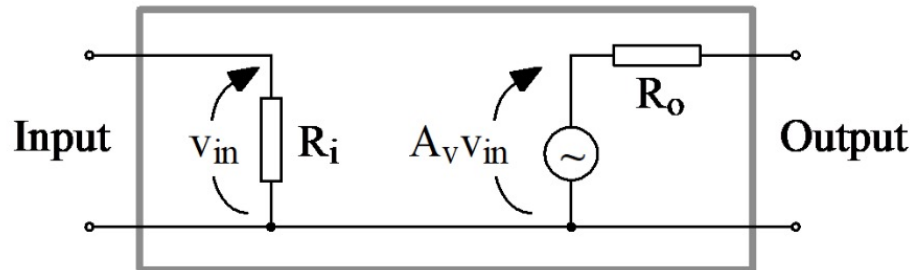


Description

The Microchip Technology Inc. MCP6001/2/4 family of operational amplifiers (op amps) is specifically designed for general-purpose applications. This family has a 1 MHz Gain Bandwidth Product (GBWP) and 90° phase margin (typical). It also maintains 45° phase margin (typical) with a 500 pF capacitive load. This family operates from a single supply voltage as low as 1.8V, while drawing 100 μ A (typical) quiescent current. Additionally, the MCP6001/2/4 supports rail-to-rail input and output swing, with a common mode input voltage range of $V_{DD} + 300$ mV to $V_{SS} - 300$ mV. This family of op amps is designed with Microchip's advanced CMOS process.

- ❖ Limited to 1MHz signal frequency (GBP) (not infinite gain at all frequencies)
- ❖ Stable under high capacitance load (linked to phase margin)
- ❖ **Single power supply operation**
- ❖ **Rail-to-rail input/output swing**
- ❖ Low supply current when idle
- ❖ Near rail-to-rail common mode input voltage

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



✓ Z_{in} of MCP6001 is very large

Common Mode Input Impedance	Z_{CM}	$10^{13} 6$	ΩpF
Differential Input Impedance	Z_{DIFF}	$10^{13} 3$	ΩpF

❖ Ideal op-amp

- $R_i \rightarrow \infty$
- $A_v \rightarrow \infty$
- $R_o \rightarrow 0$

✓ Input current is negligible

Input Bias Current:	I_B	± 1.0	pA	
Industrial Temperature	I_B	19	pA	$T_A = +85^\circ C$
Extended Temperature	I_B	1100	pA	$T_A = +125^\circ C$

✓ Gain is near infinite (true at low frequency)

DC Open-Loop Gain (Large Signal)	A_{OL}	112 >1 x10 ⁵	dB
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✓ Output impedance is low (specified as I_{SC})

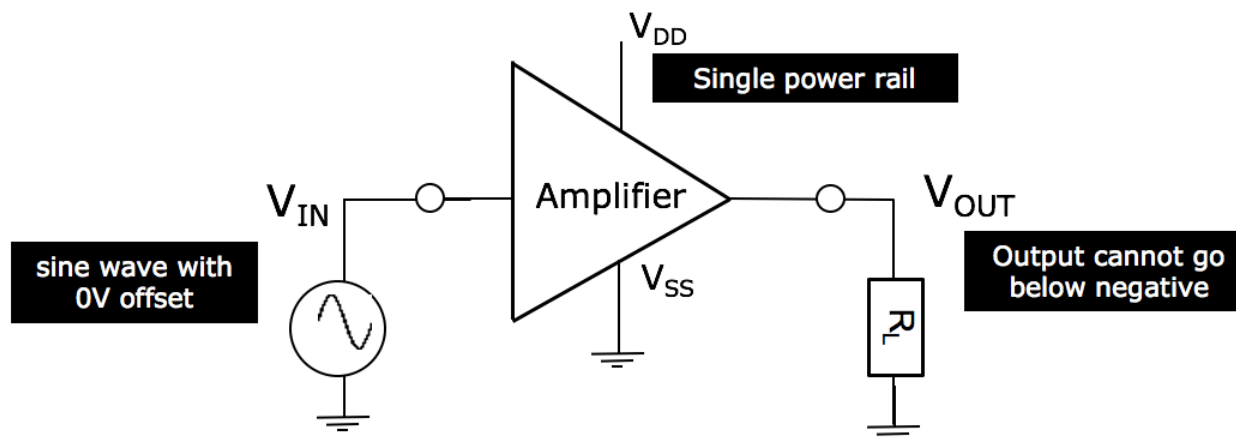
Output Short Circuit Current	I_{SC}	± 6	mA	$V_{DD} = 1.8V$
		± 23	mA	$V_{DD} = 5.5V$

Problem with single supply rail

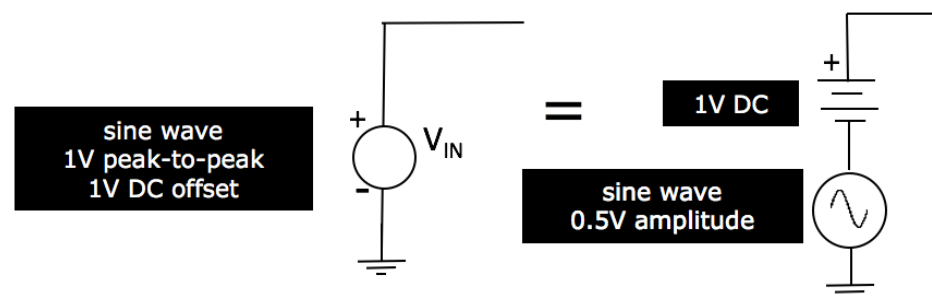
- ❖ Output swing limited to rail voltages

Maximum Output Voltage Swing	V_{OL}, V_{OH}	$V_{SS} + 25$ $V_{DD} - 25$	mV
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- ❖ Input cannot be a sinewave with 0V DC offset

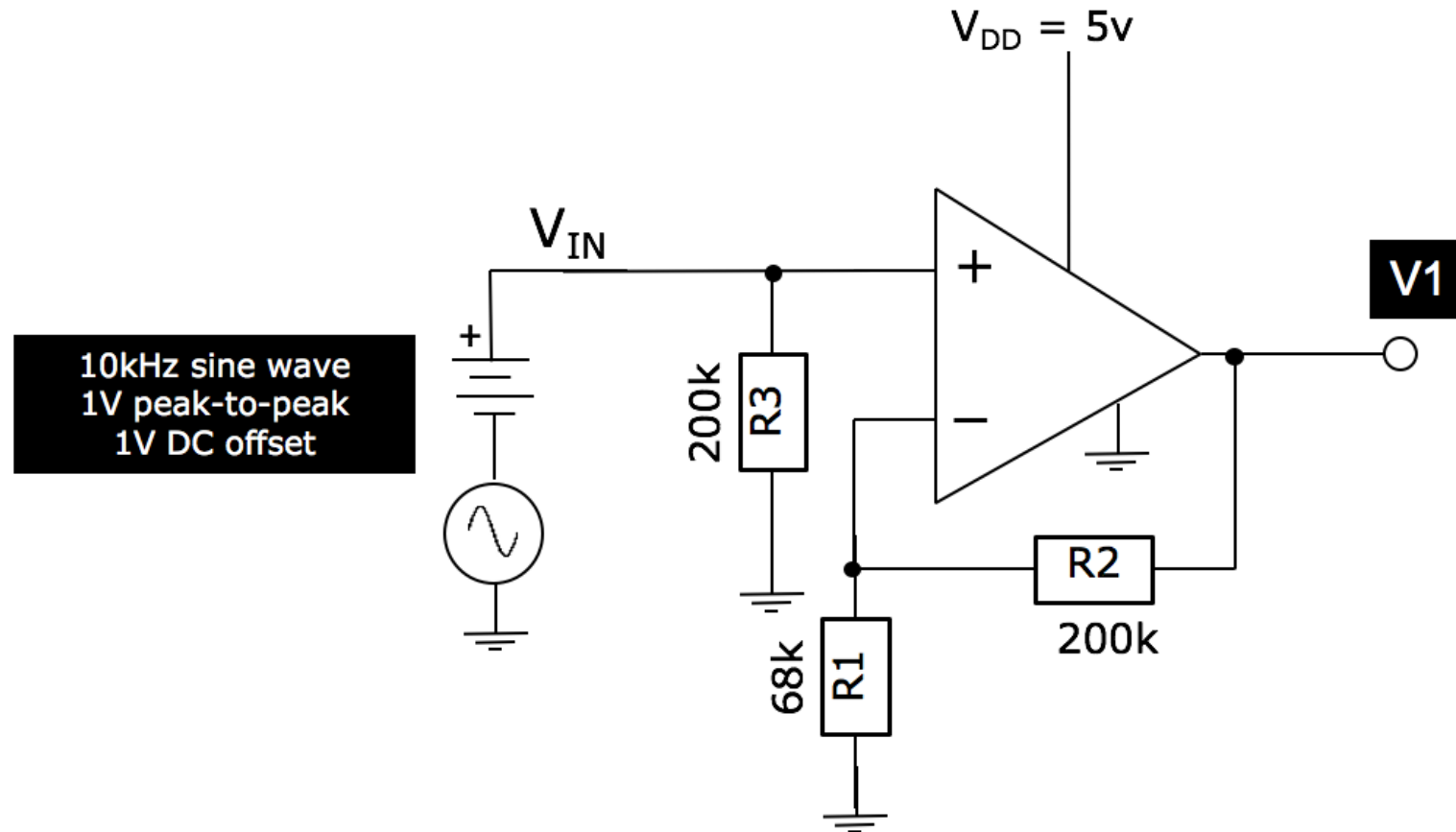


- ❖ Need to add DC offset to input



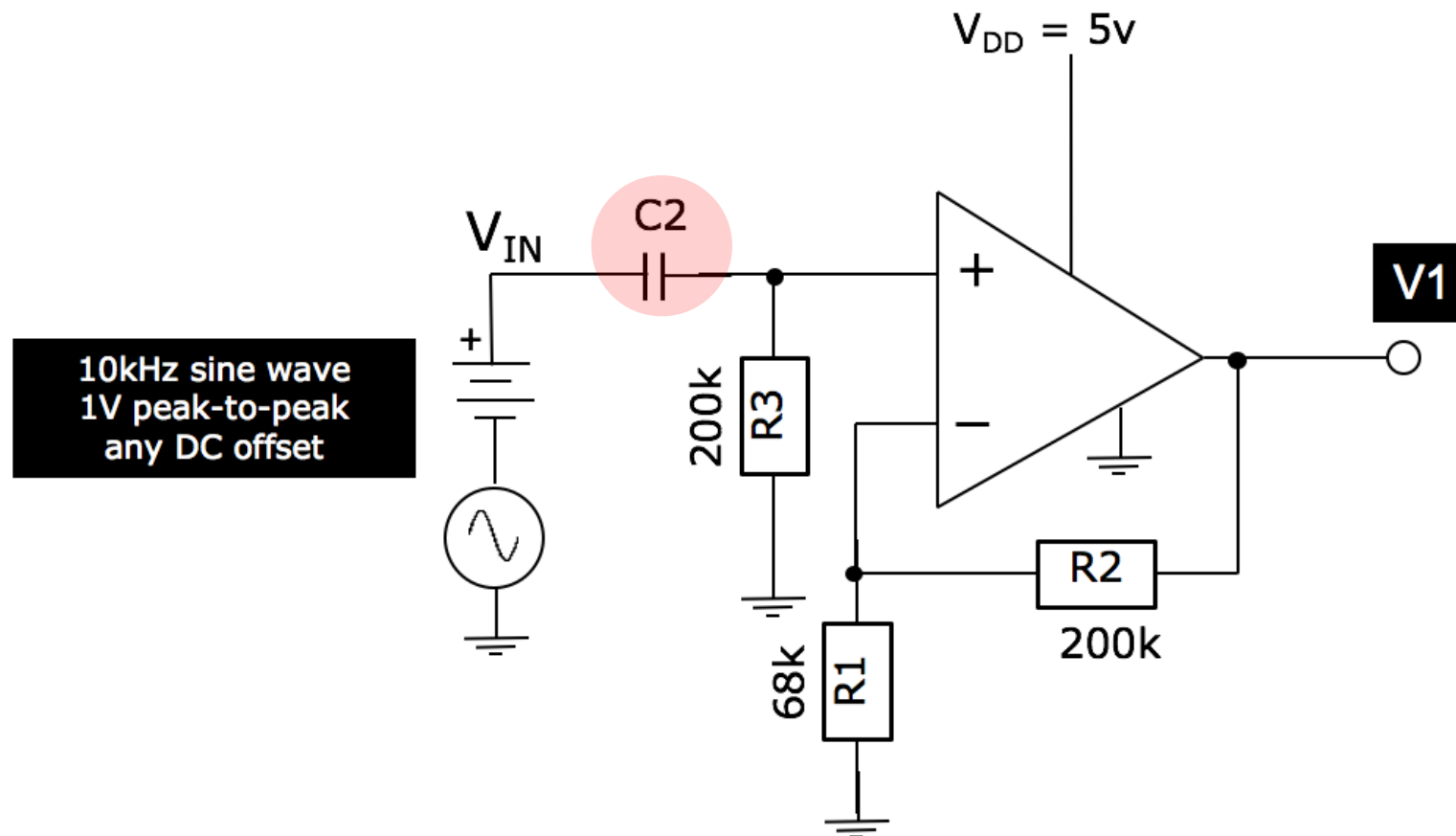
X4 amplifier fail

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



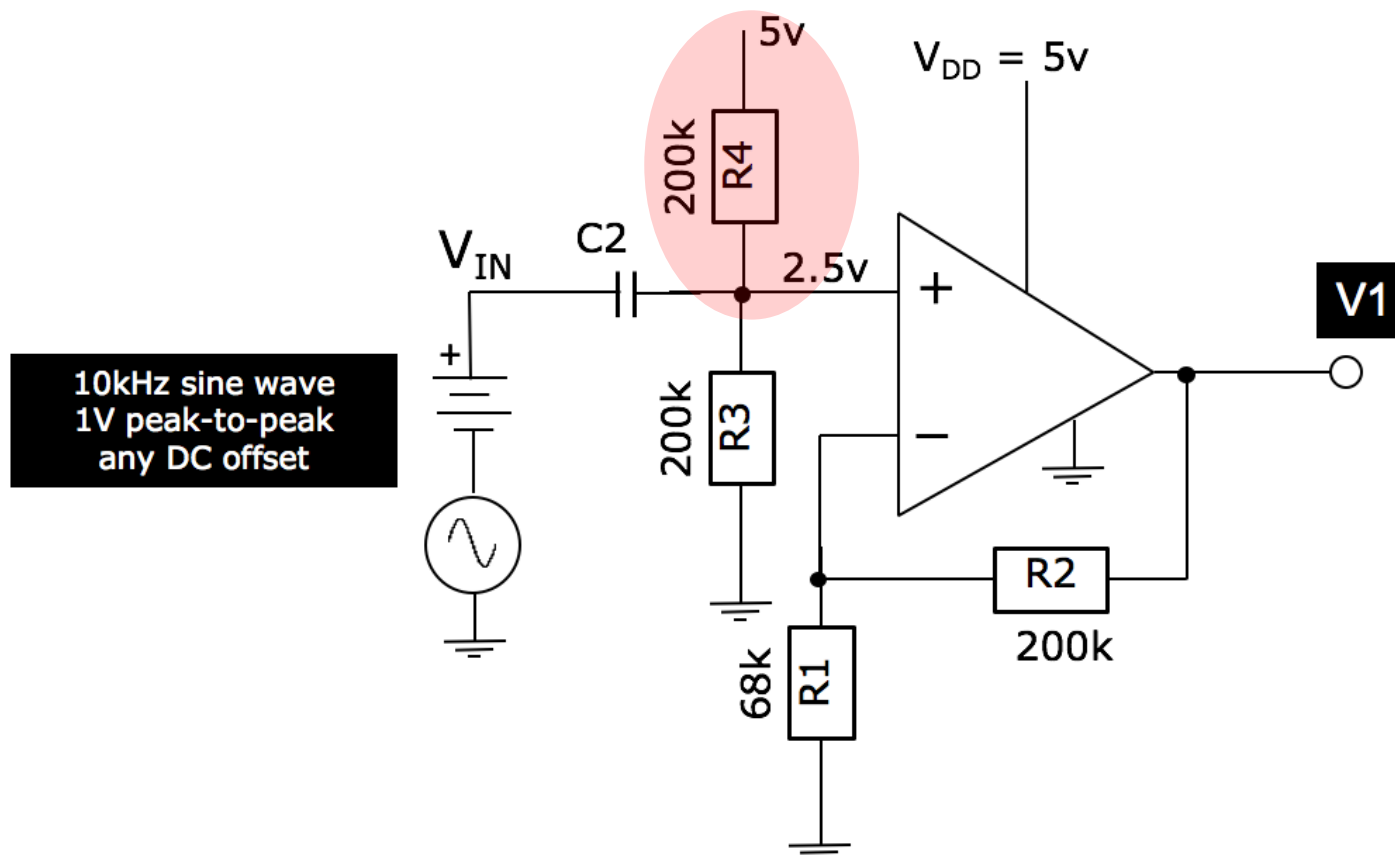
Attempt 1 – AC coupling signal

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



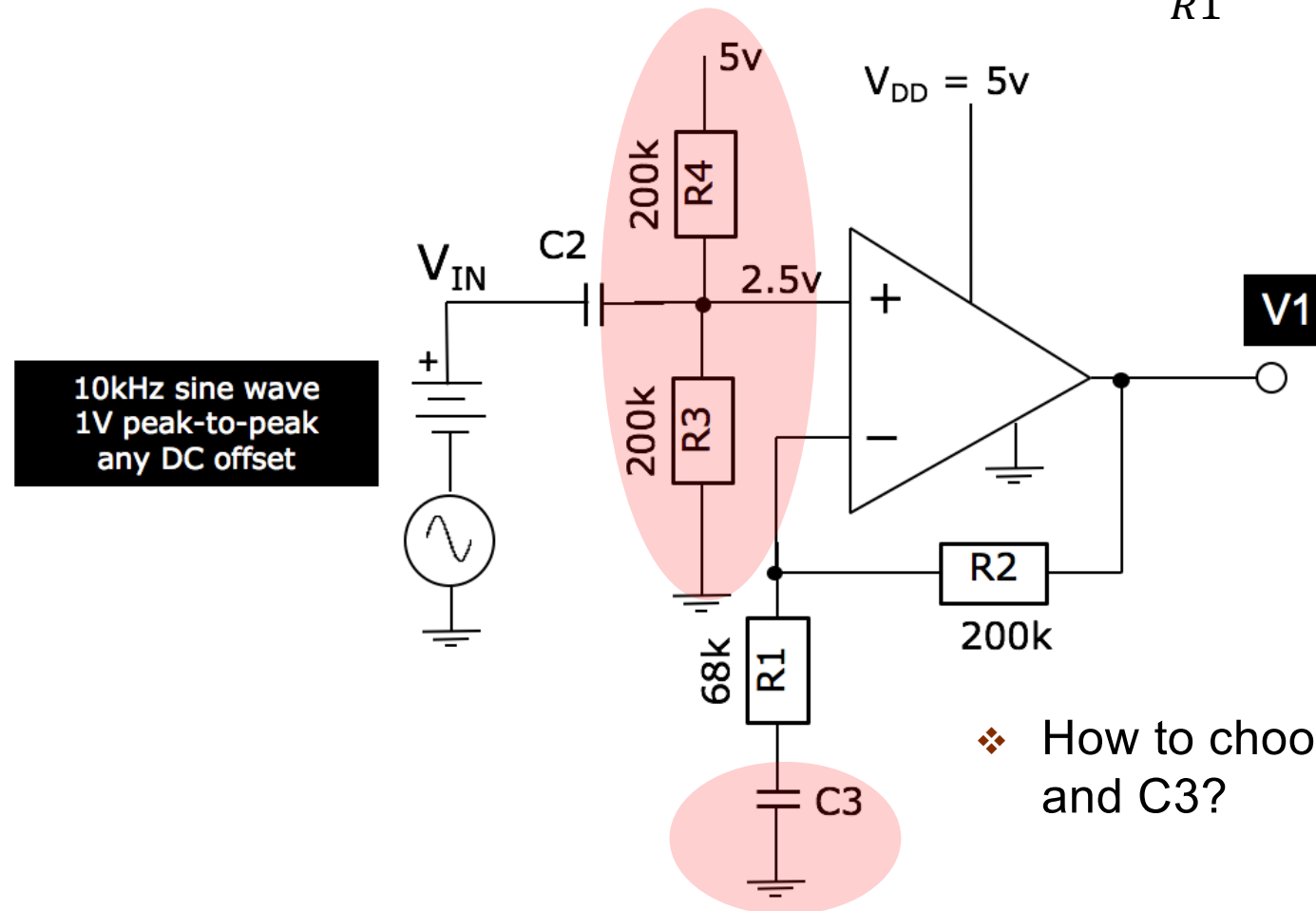
Attempt 2 – Add bias to V+ input

- ❖ 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

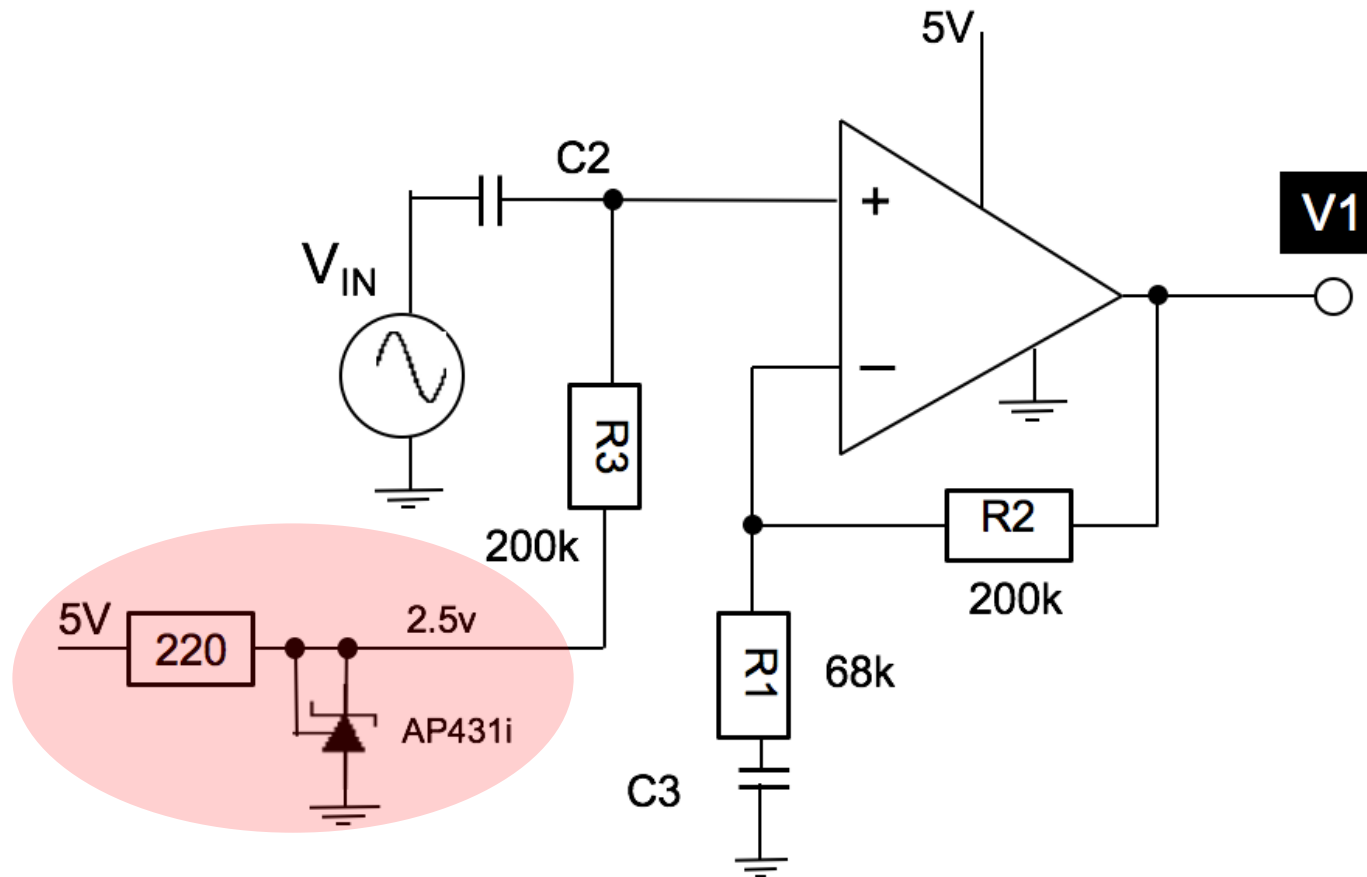
- ❖ Final solution: Add C3 such that gain of op-amp = 1 at 0 Hz (DC)
- ❖ Gain of op-amp at valid signal frequency is $G = 1 + \frac{R2}{R1}$



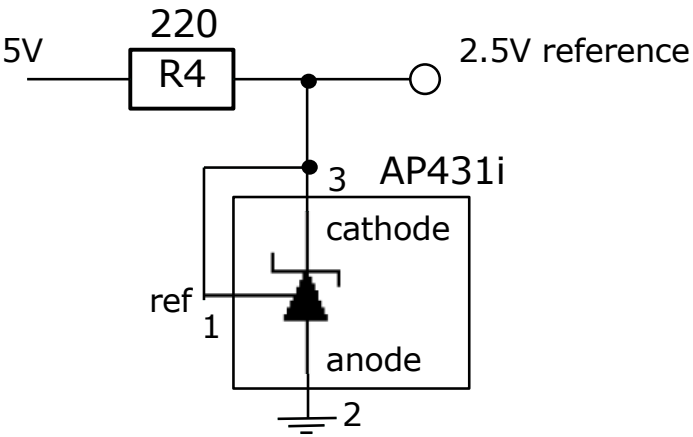
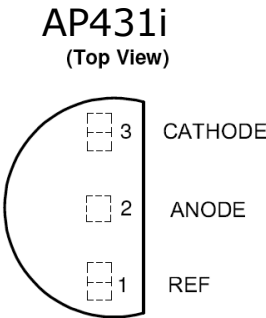
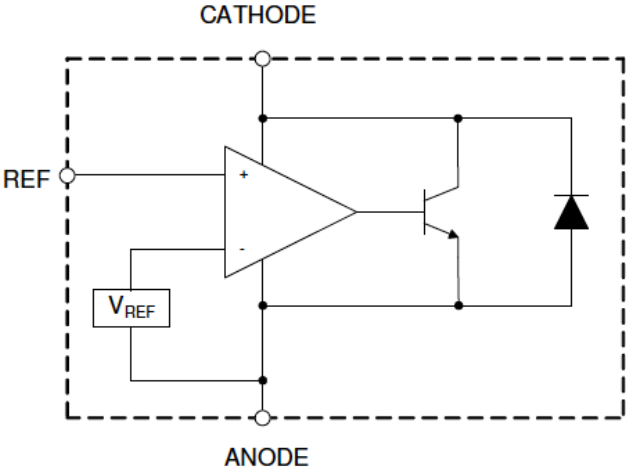
- ❖ How to choose values for C2 and C3?

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

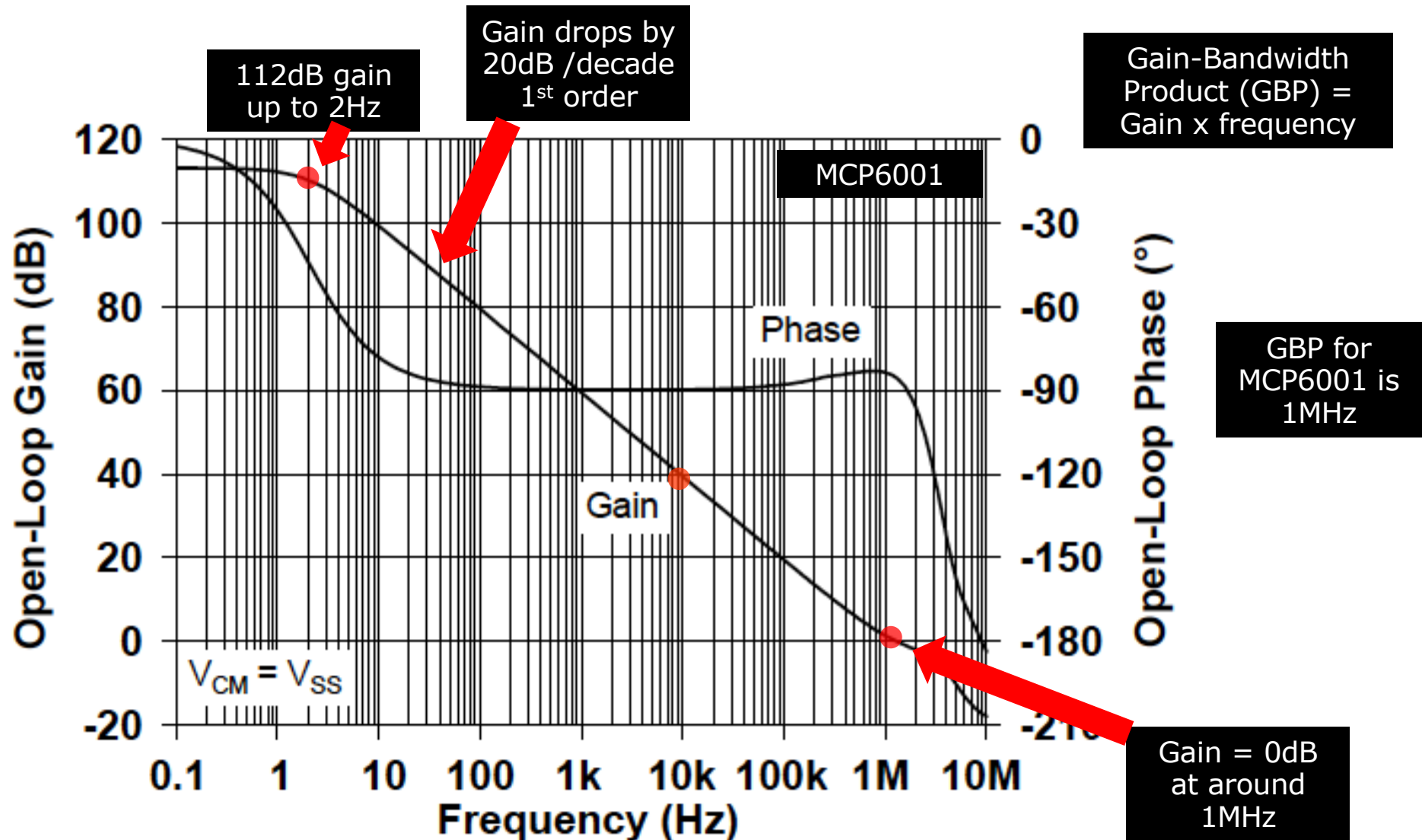


		Min	Max	
I_{KA}	Cathode Current	0.1	100	mA

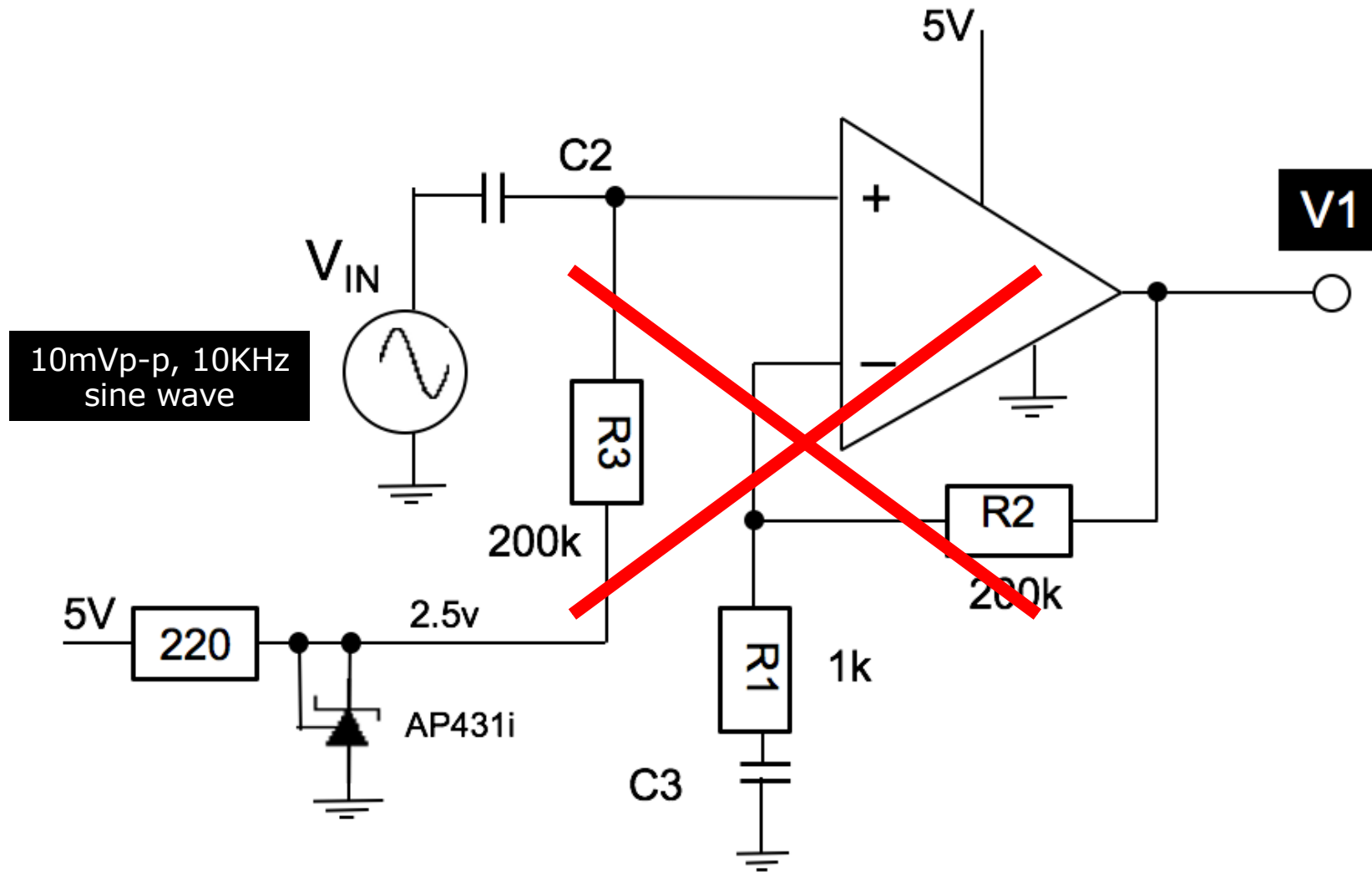
			Min	Typical	Max	
$V_{REF} \pm 1\%$	Reference Voltage	$V_{KA} = V_{REF}, I_{KA} = 1mA$	2.475	2.500	2.525	V

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

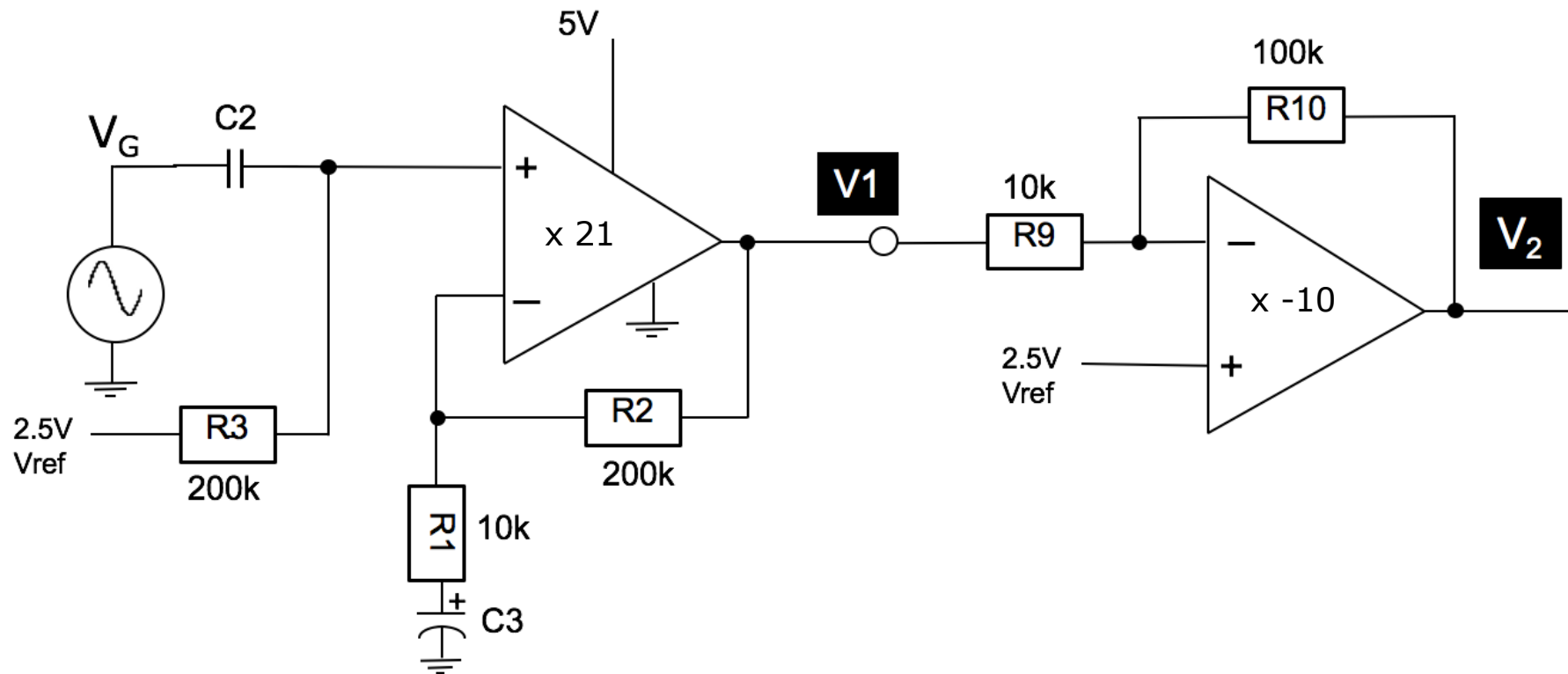
Open-loop Gain vs Frequency for MCP6001



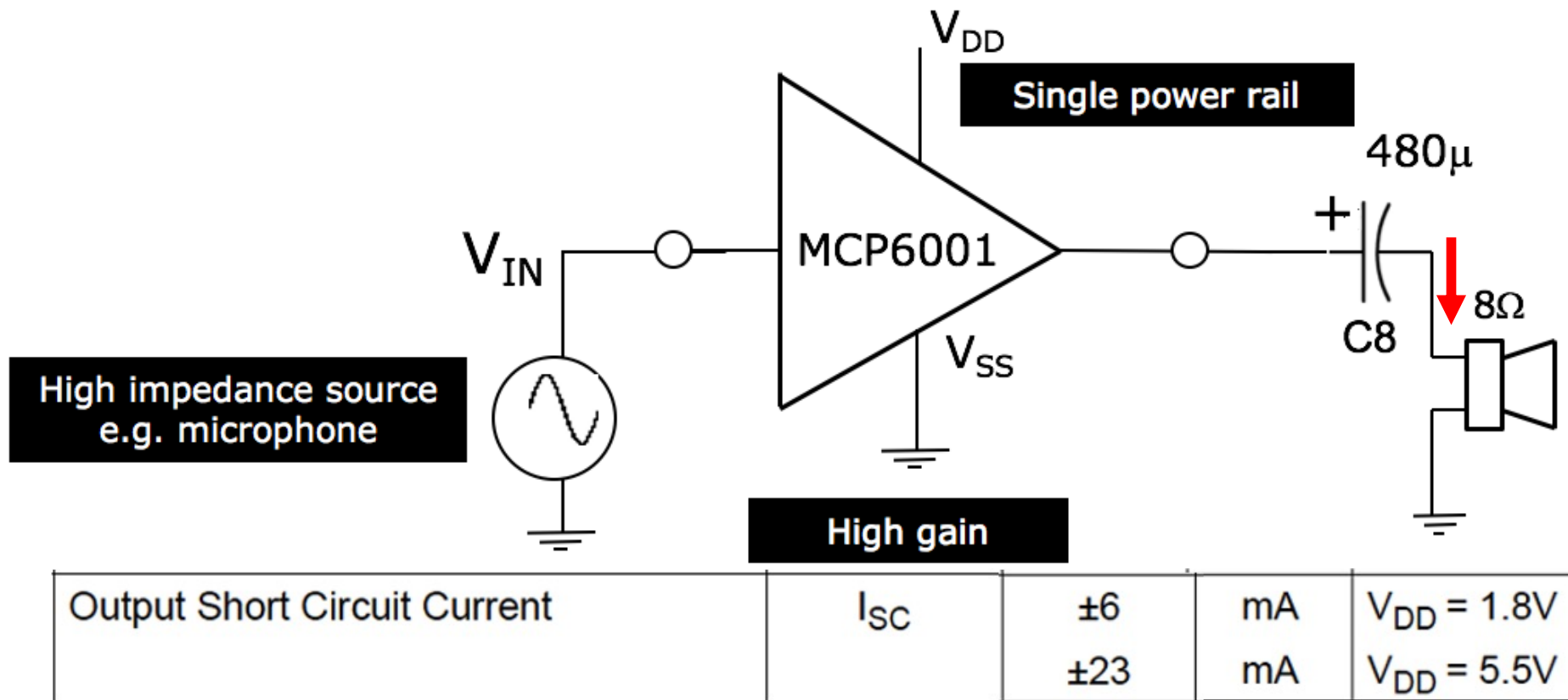
Amplify 10kHz signal with Gain of 200



Solution - Two stage amplification



Problem with driving low impedance load



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