Imperial College
London

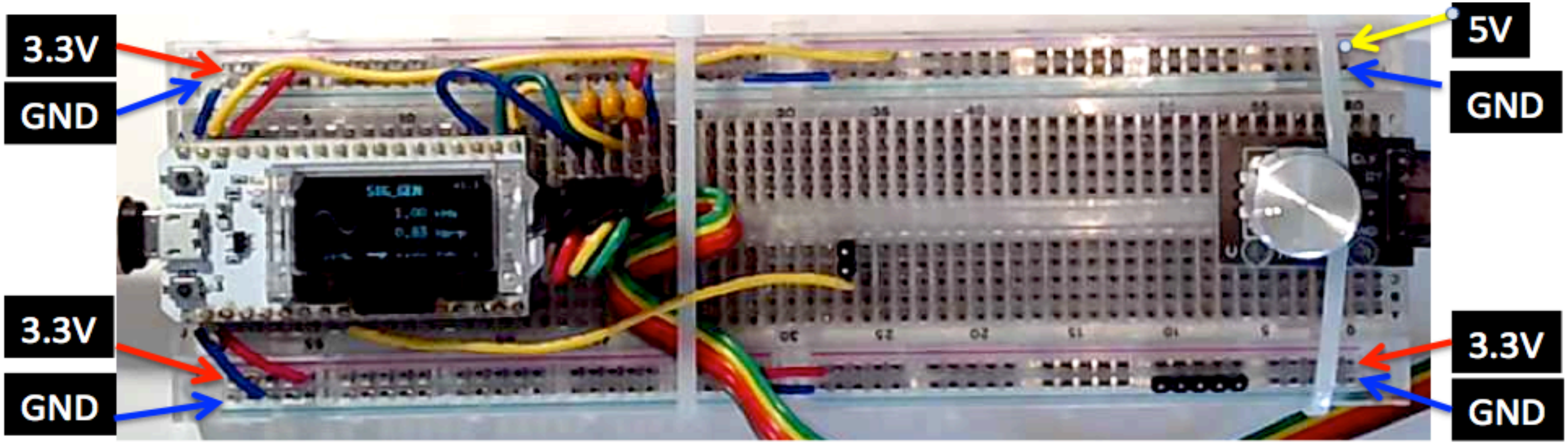
# Home Lab 3 Explained

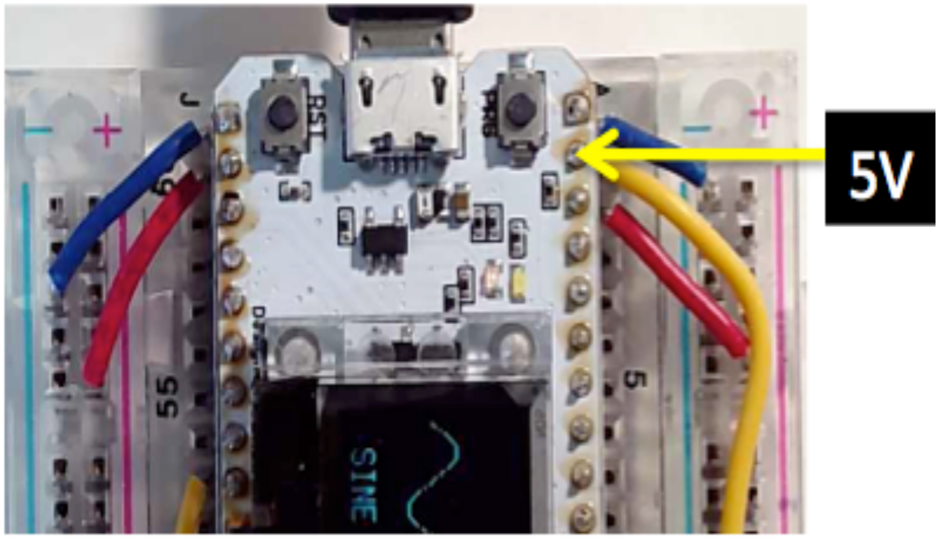
# Operational Amplifiers (op-amps)

Professor Peter YK Cheung
Dyson School of Design Engineering

URL: www.ee.ic.ac.uk/pcheung/teaching/DE1_EE/
E-mail: p.cheung@imperial.ac.uk

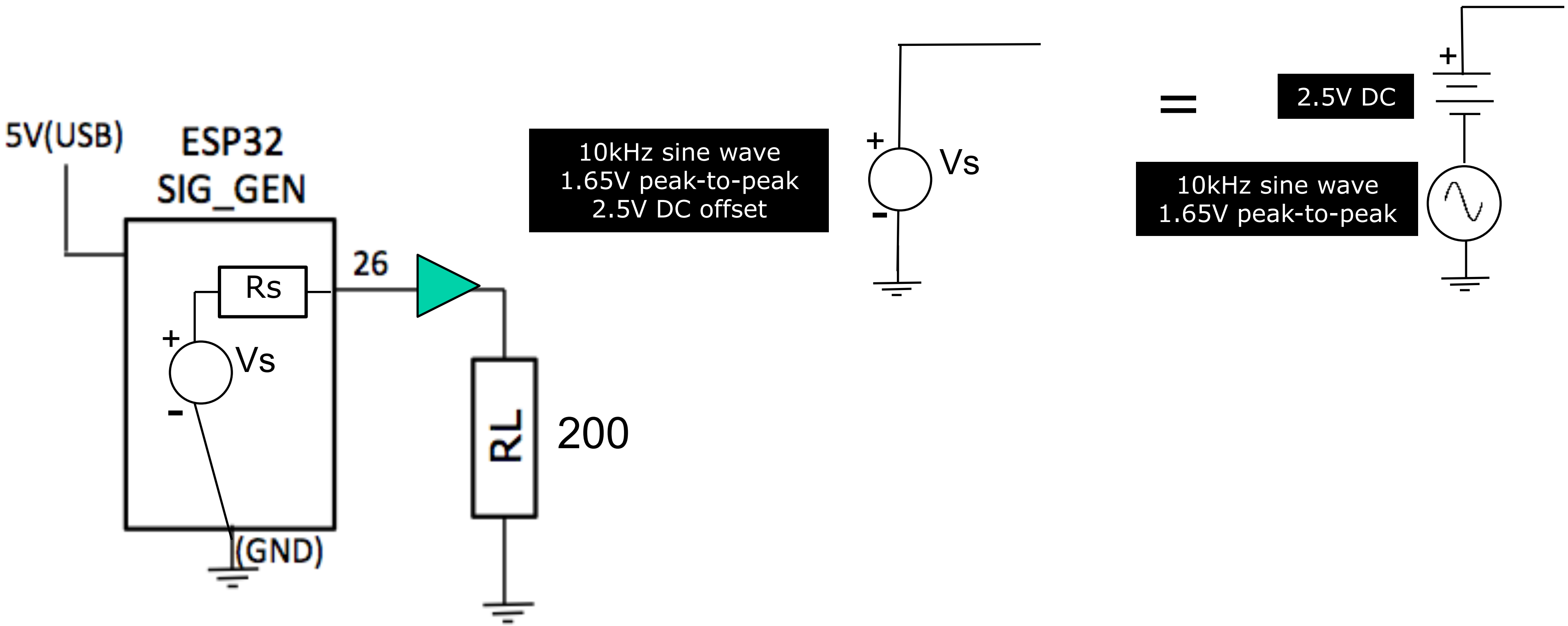
# Setting things up – 5V power supply



# Task 1 – Loading effect on SIG_GEN

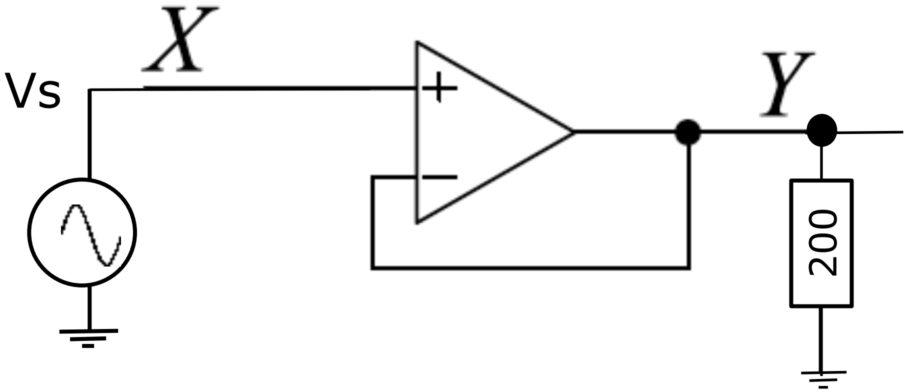
- Measure Vs without 200 ohm load – Vp-p should be around 1.65V
- Measure Vs again with 200 ohm load. You will see that Vp-p is reduced due to the internal source resistance of SIG_GEN



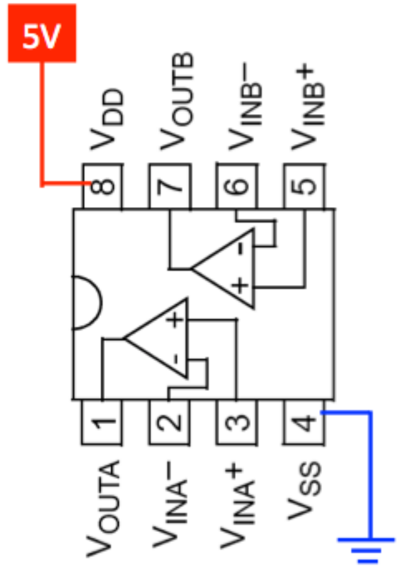
# Task 2 – Using a Unity Gain Amplifier (1)

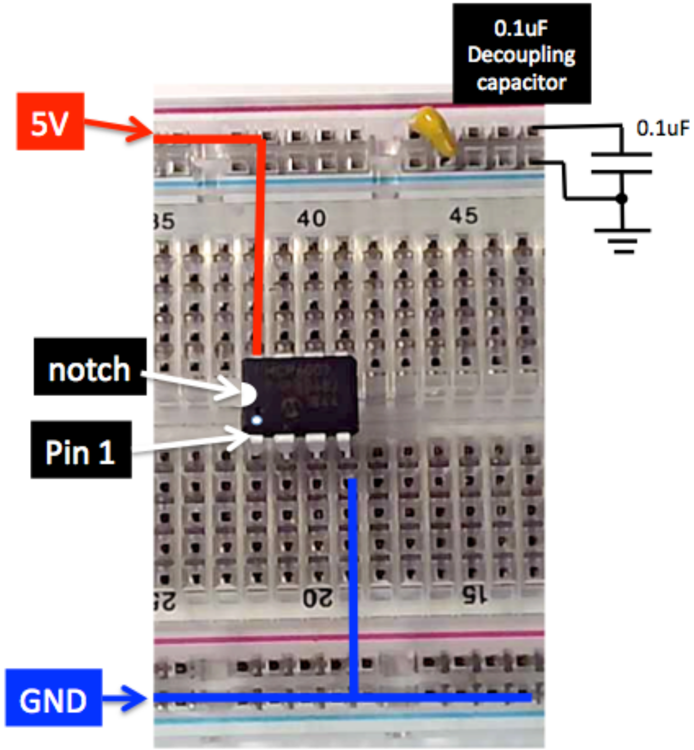
Topic 11 slide 4

10kHz sine wave
1.65V peak-to-peak
2.5V DC offset



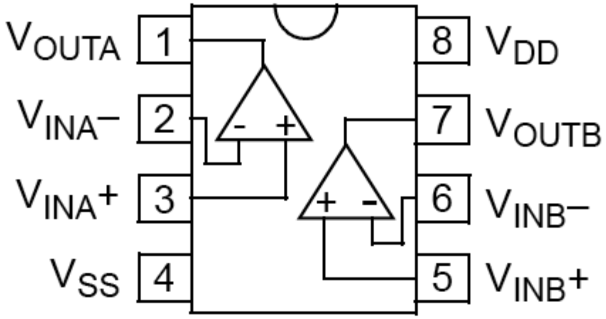

Y = X



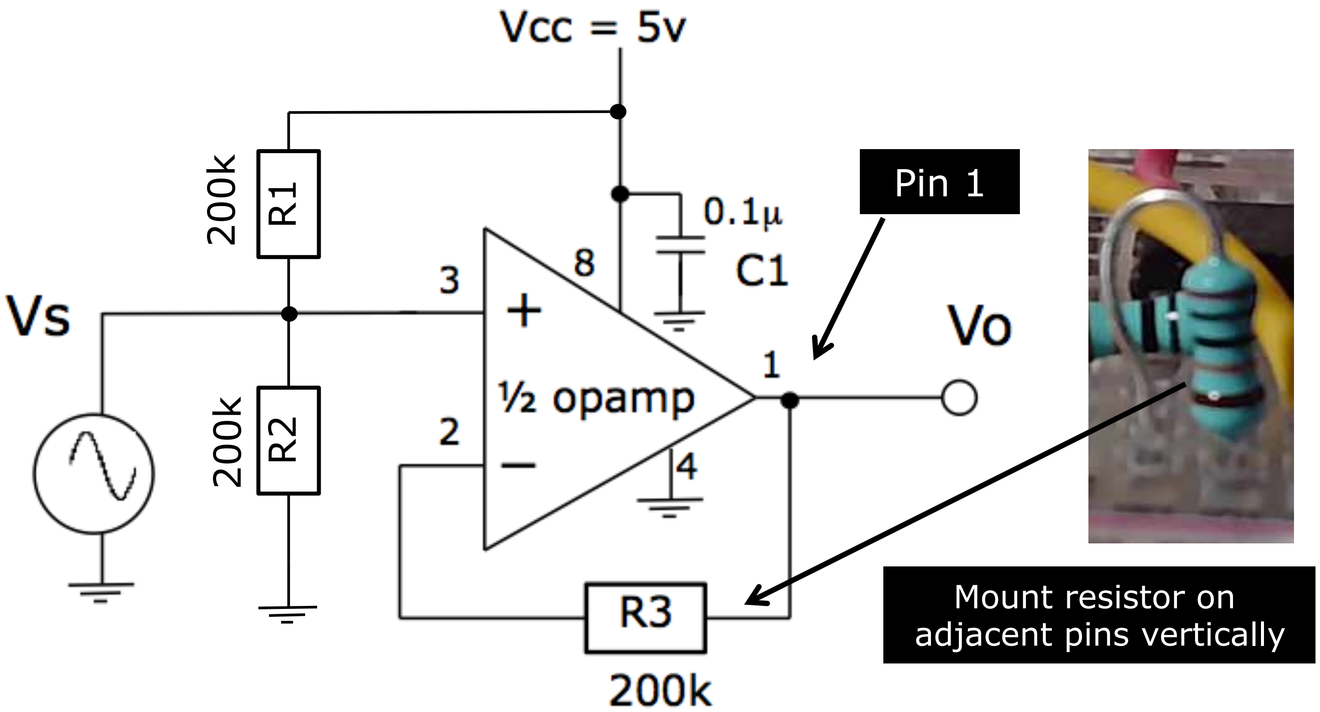



# Task 2 – Using a Unity Gain Amplifier (2)

- Add R3 (200k) – makes no difference, but ready for Task 3
- Add R1 and R2 to make Pin 3 sitting at 2.5Vdc offset (also ready for later tasks)

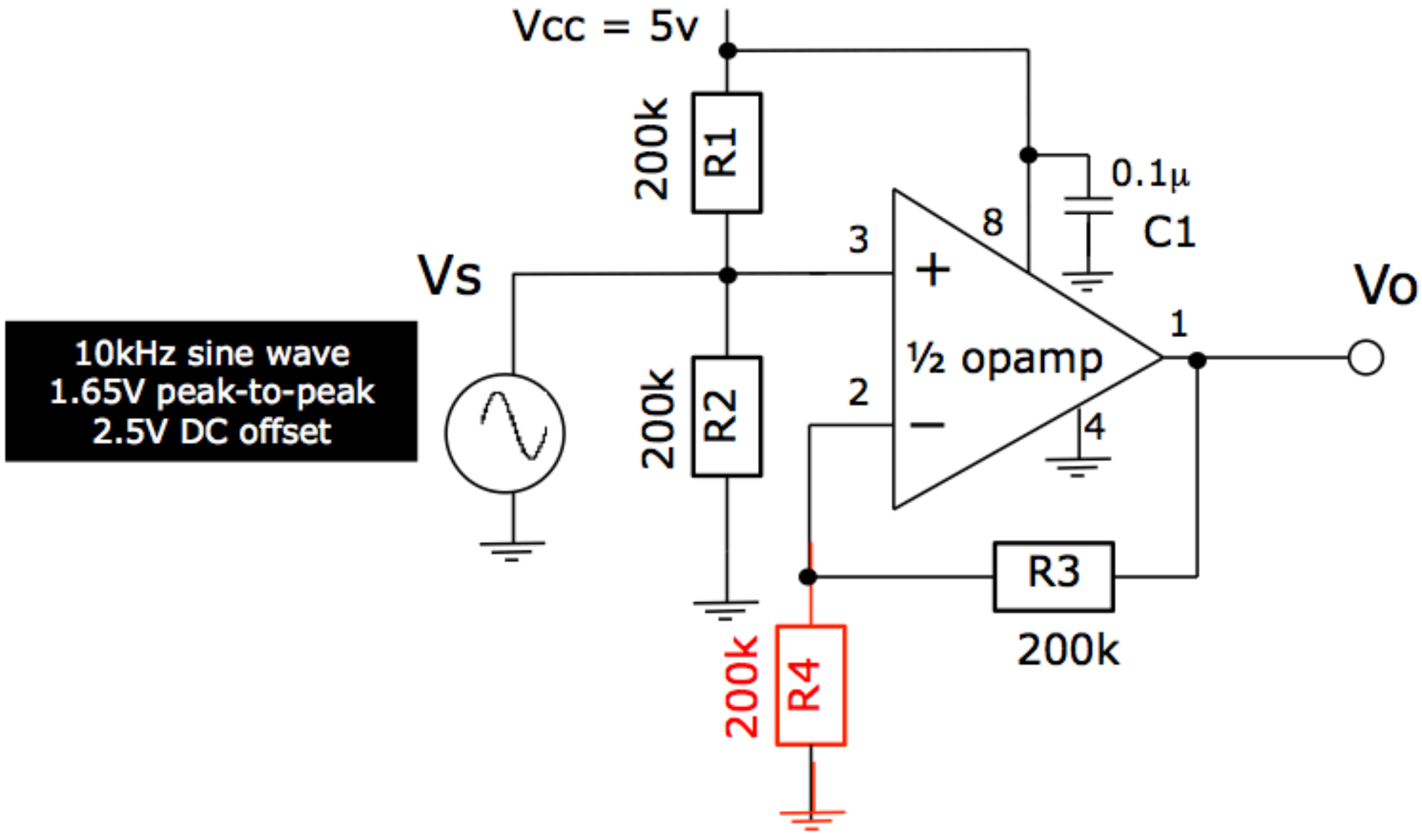



10kHz sine wave
1.65V peak-to-peak
2.5V DC offset



# Task 3 – x2 Amplifier Failure (1)

- Add R4 – See notes on Topic 11 slide 6. The gain of the amplifier should be x 2.
- However, you will see that Vo shows a sine wave with top of it “clipped”.

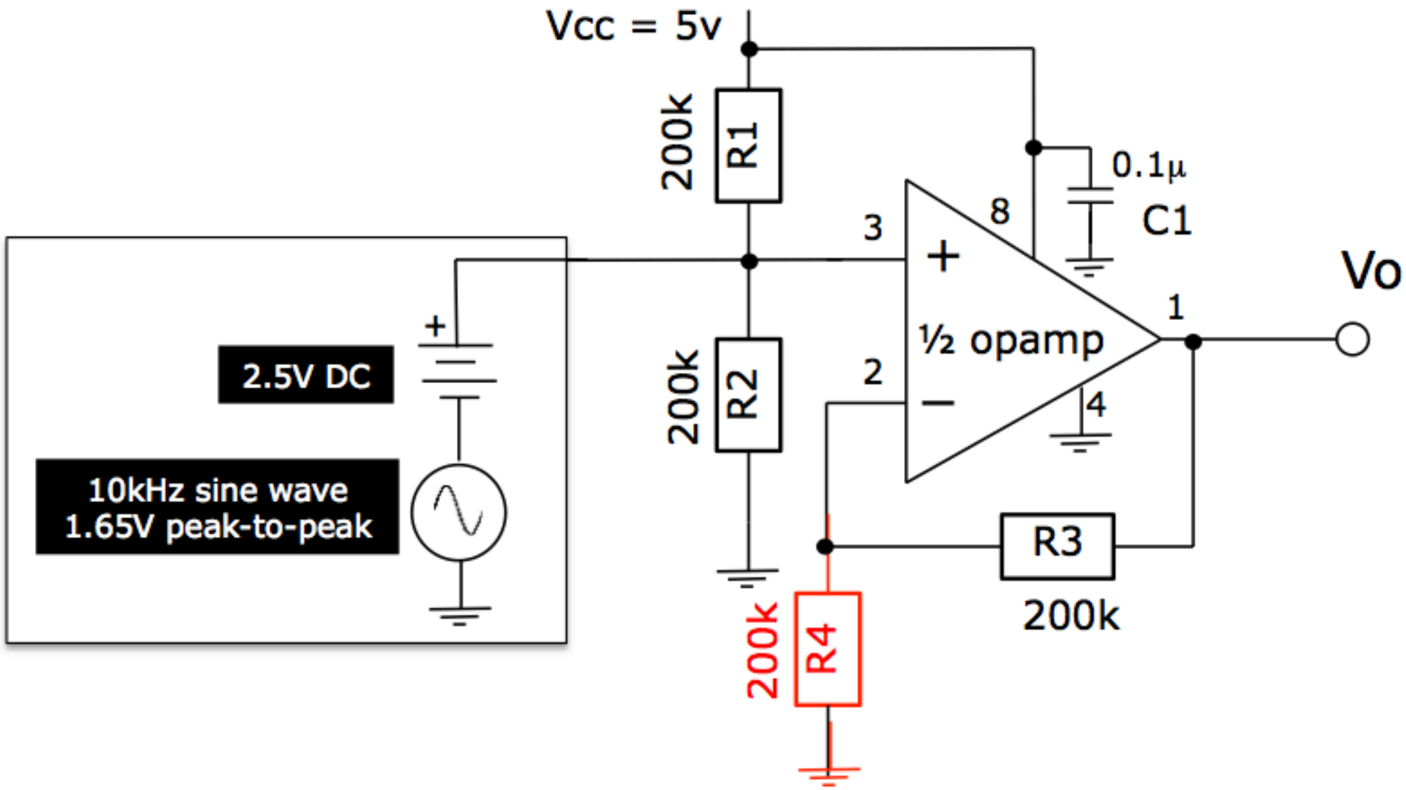



$$Gain = (1 + \frac{R3}{R4})$$

Topic 11 slide 6

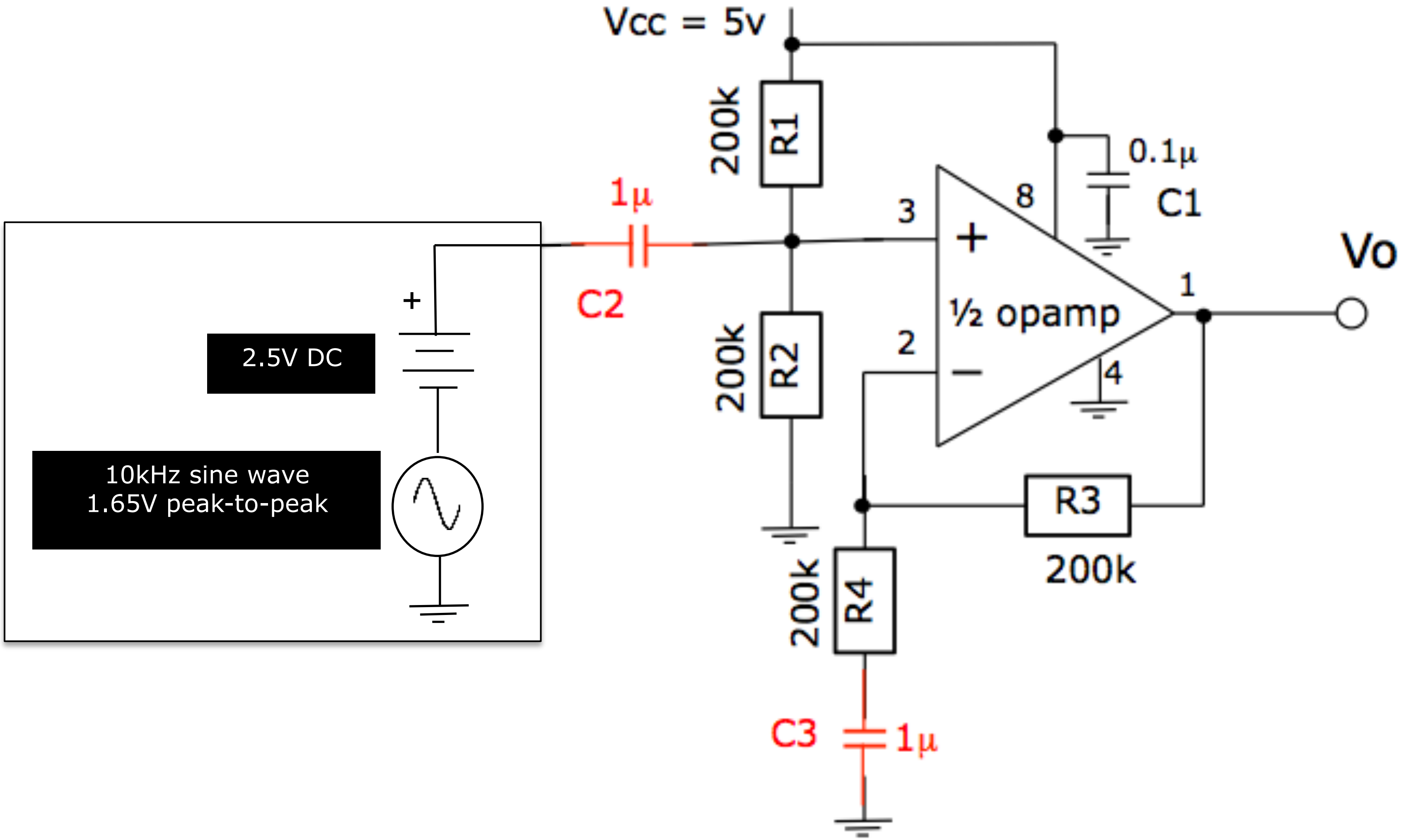
# Task 3 – x2 Amplifier Failure (2)

- Reason: x2 amplification applies both the 1.65Vp-p sine signal as well as the 2.5V DC offset. So, we will get a 3.3Vp-p sine wave sitting on a 5V offset
- Since power supply to op-amp is 5V, no output voltage can exceed this.



# Task 4 – x2 Amplifier Success (1)

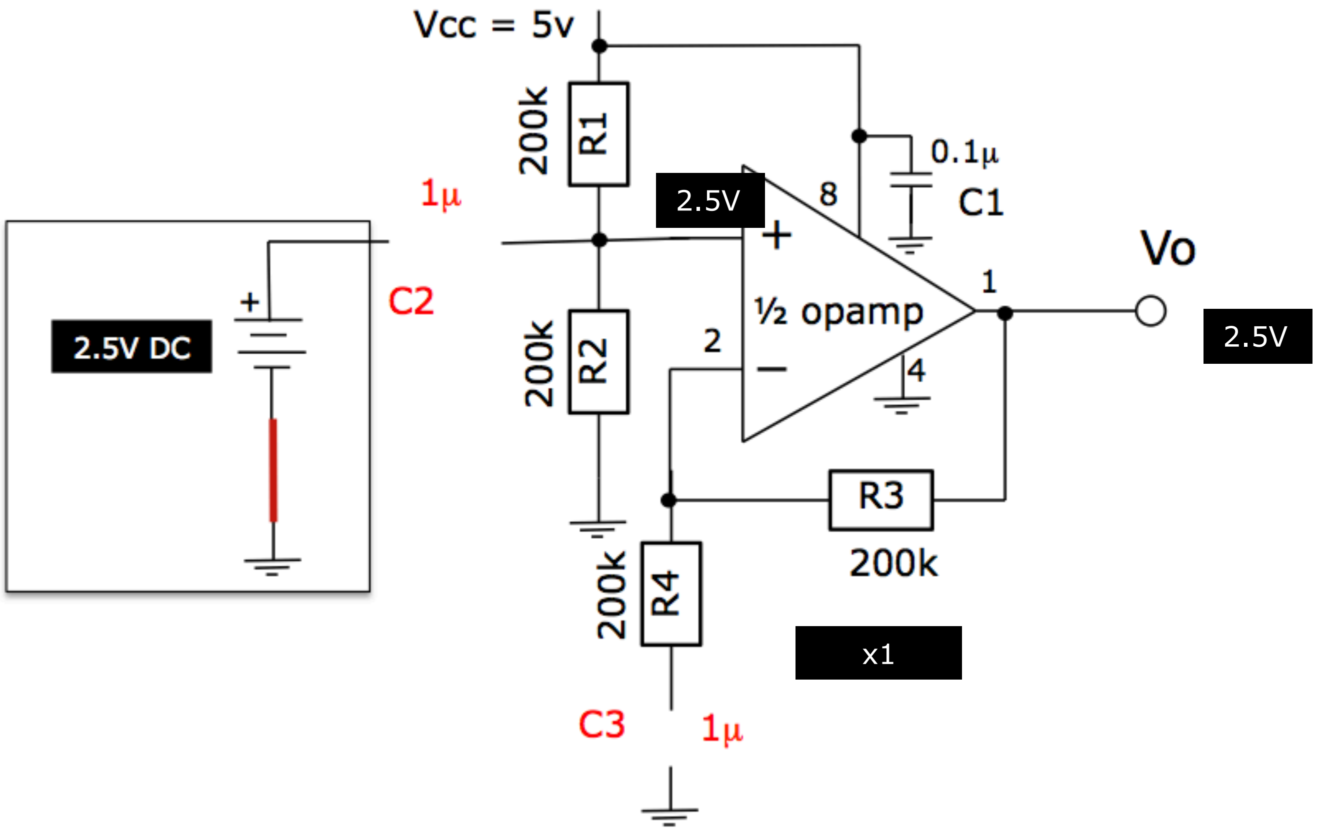
- Add C2 and C3, both 1uF. This will now work. Why?



# Task 4 – x2 Amplifier Success (2)

- Consider what happens at DC source (principle of superposition):

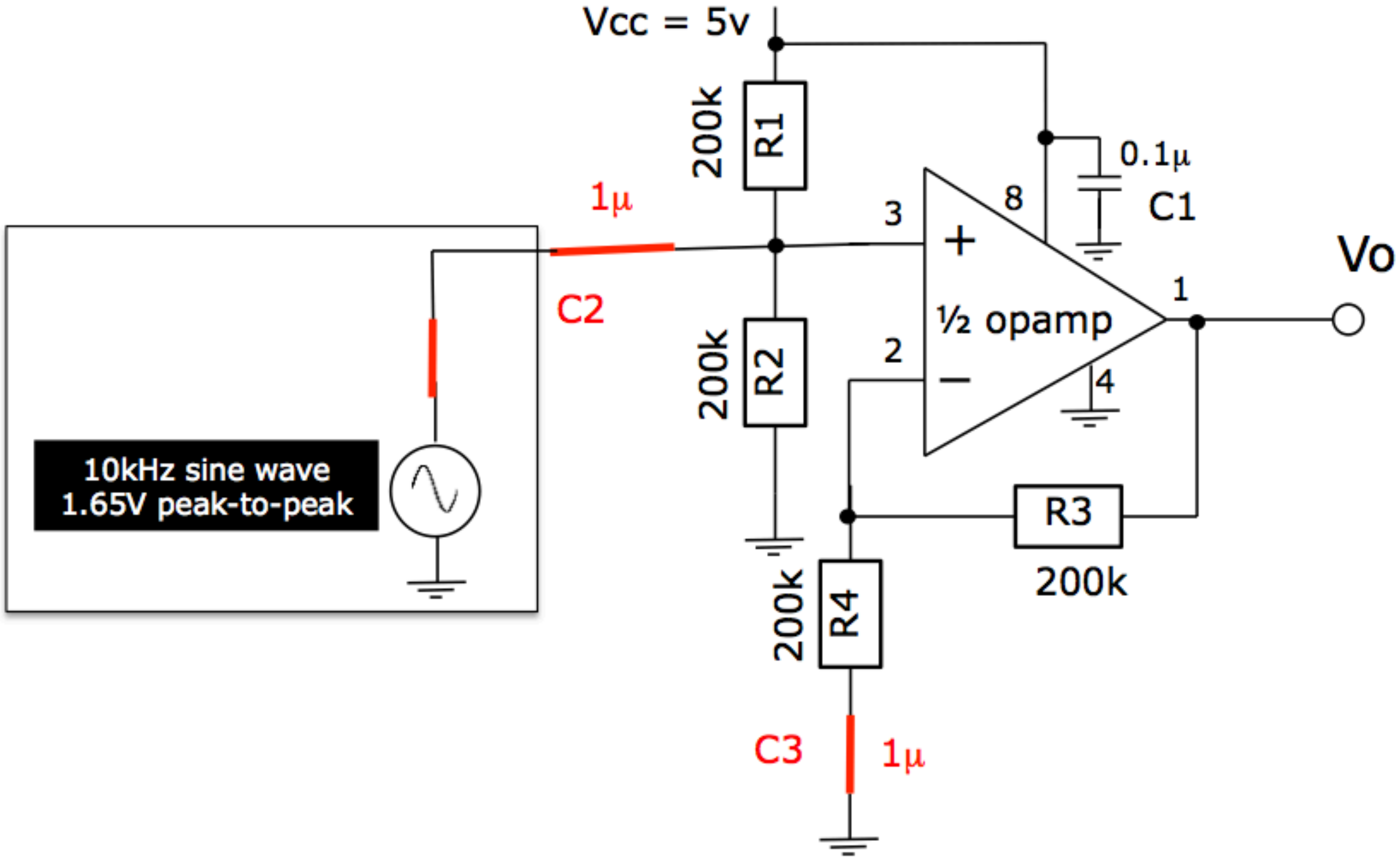
1. C2 is open-circuit, so 2.5V dc is blocked by C2. Instead, V+ is now at 2.5V because of R1 and R2 (voltage divider).
2. C3 is open-circuit. Therefore the op-amp is now a x1 amplifier as in Task 2.



# Task 4 – x2 Amplifier Success (3)

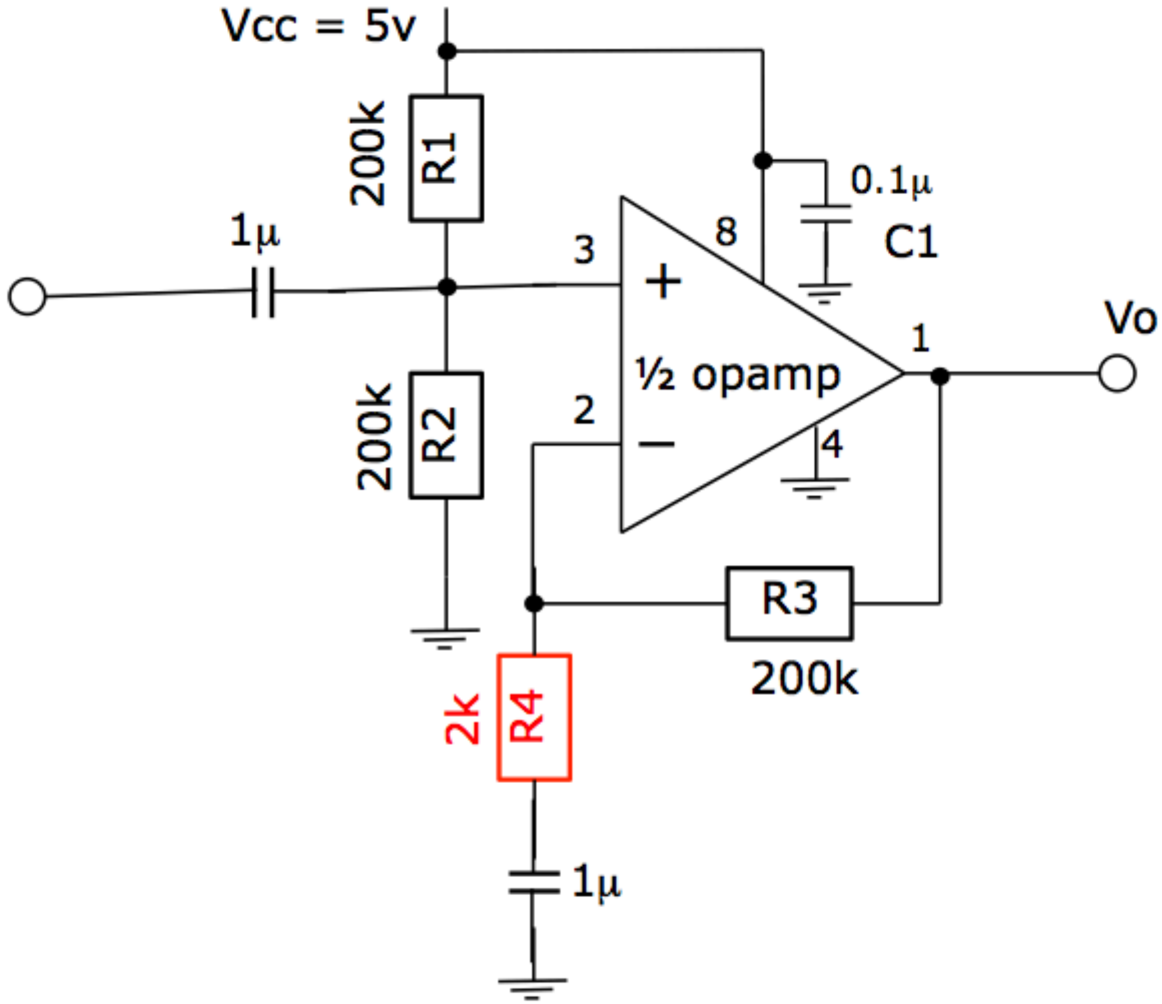
- Consider what happens at high frequency (e.g. 10kHz sine wave):

1. C2 is short-circuit, so Vs goes directly to V+.
2. C3 is short-circuit. Therefore the op-amp is now a x2 amplifier as in Task 3..



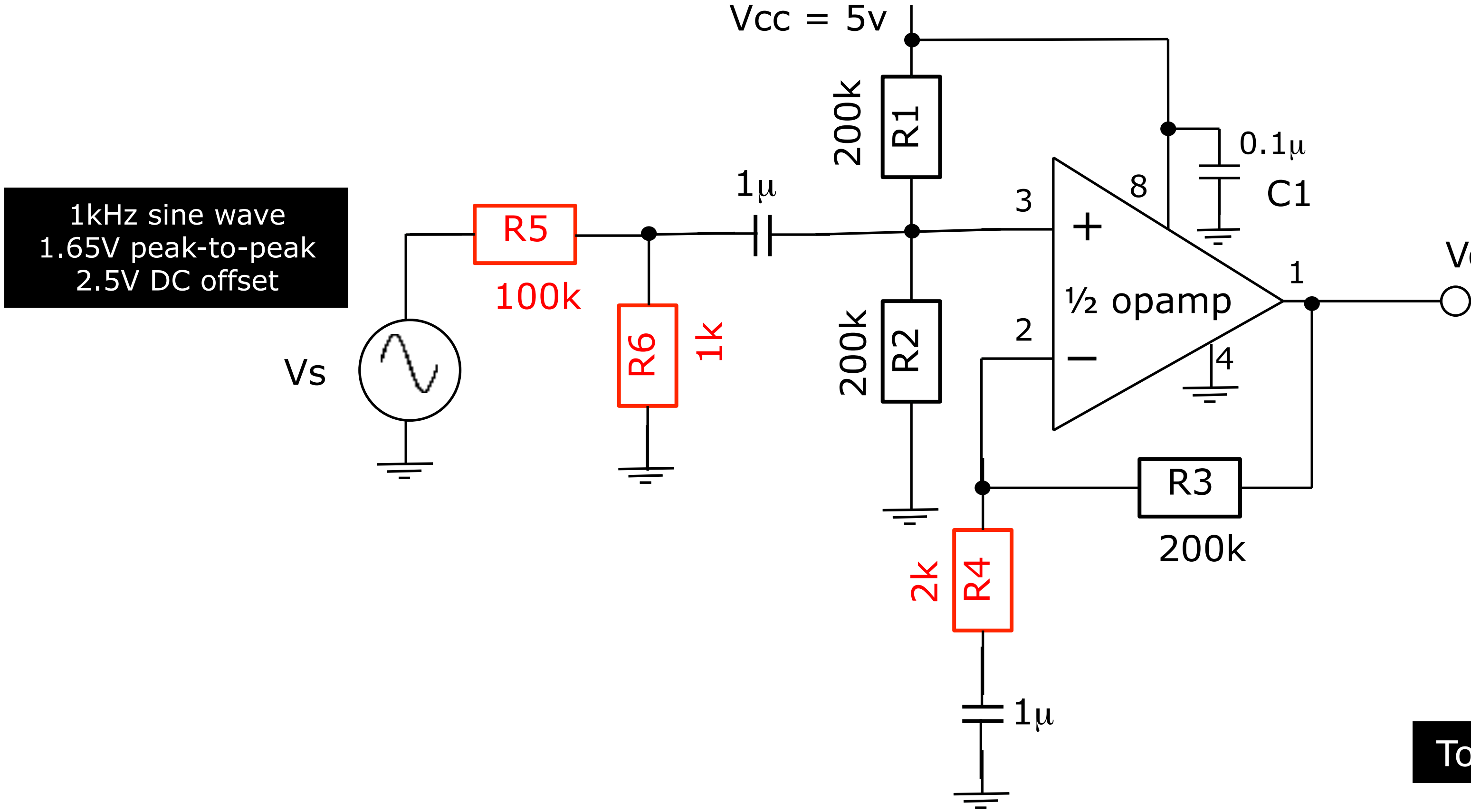
# Task 5 – x101 amplifier failure (1)

- Replace R4 with 2k ohm resistor. Gain = 1 + R3/R4 = 101



# Task 5 – High gain amplifier failure (2)

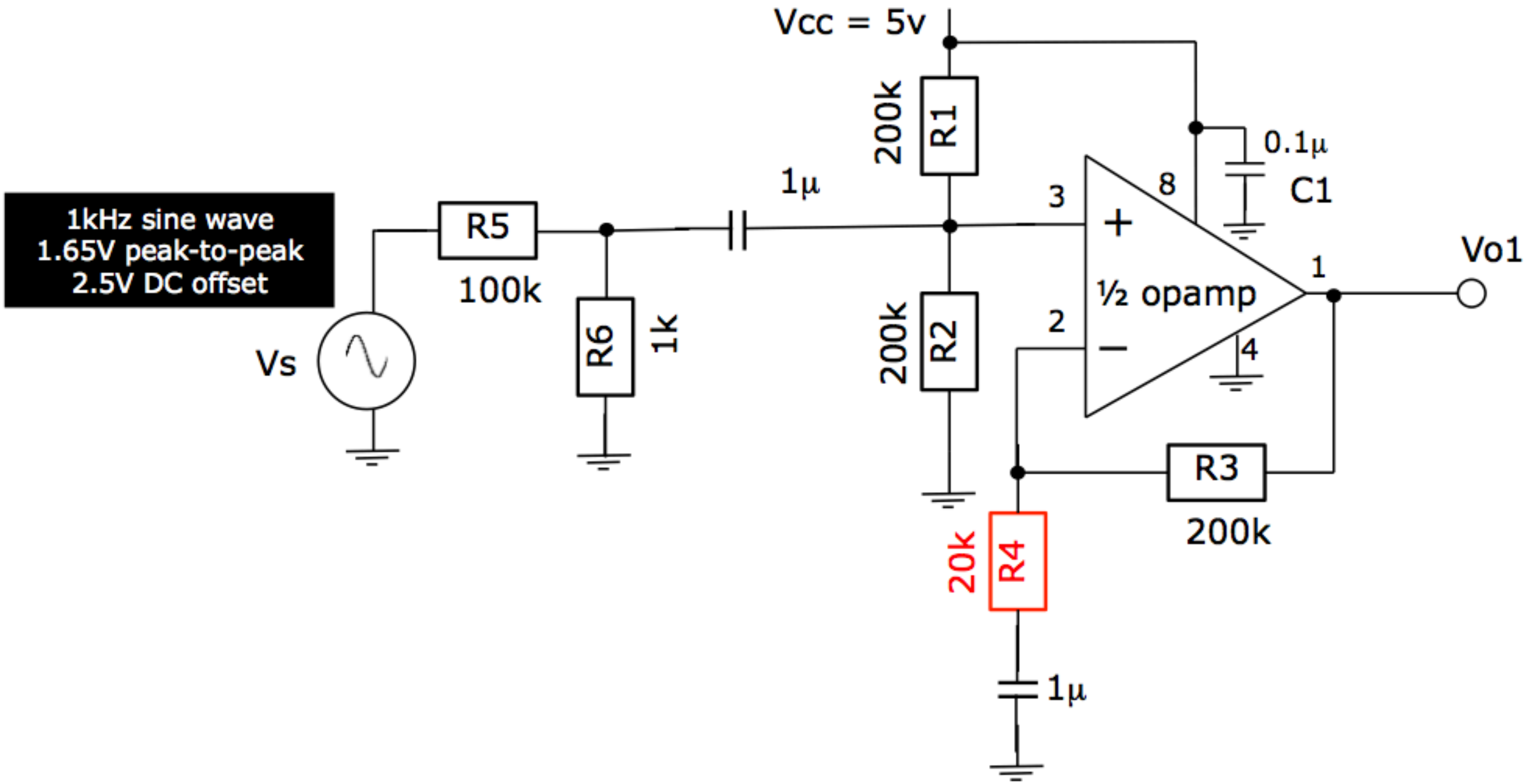
- Replace R4 with 2k ohm resistor. Gain = 1 + R3/R4 = 101
- Build a 1:101 voltage divider to reduce input signal to amplifier to ~16mV
- Change sine wave frequency from 1kHz to 100kHz – see gain of 101 NOT possible beyond 10kHz due to gain-bandwidth product limited to 1MHz.




Topic 11 slide 13

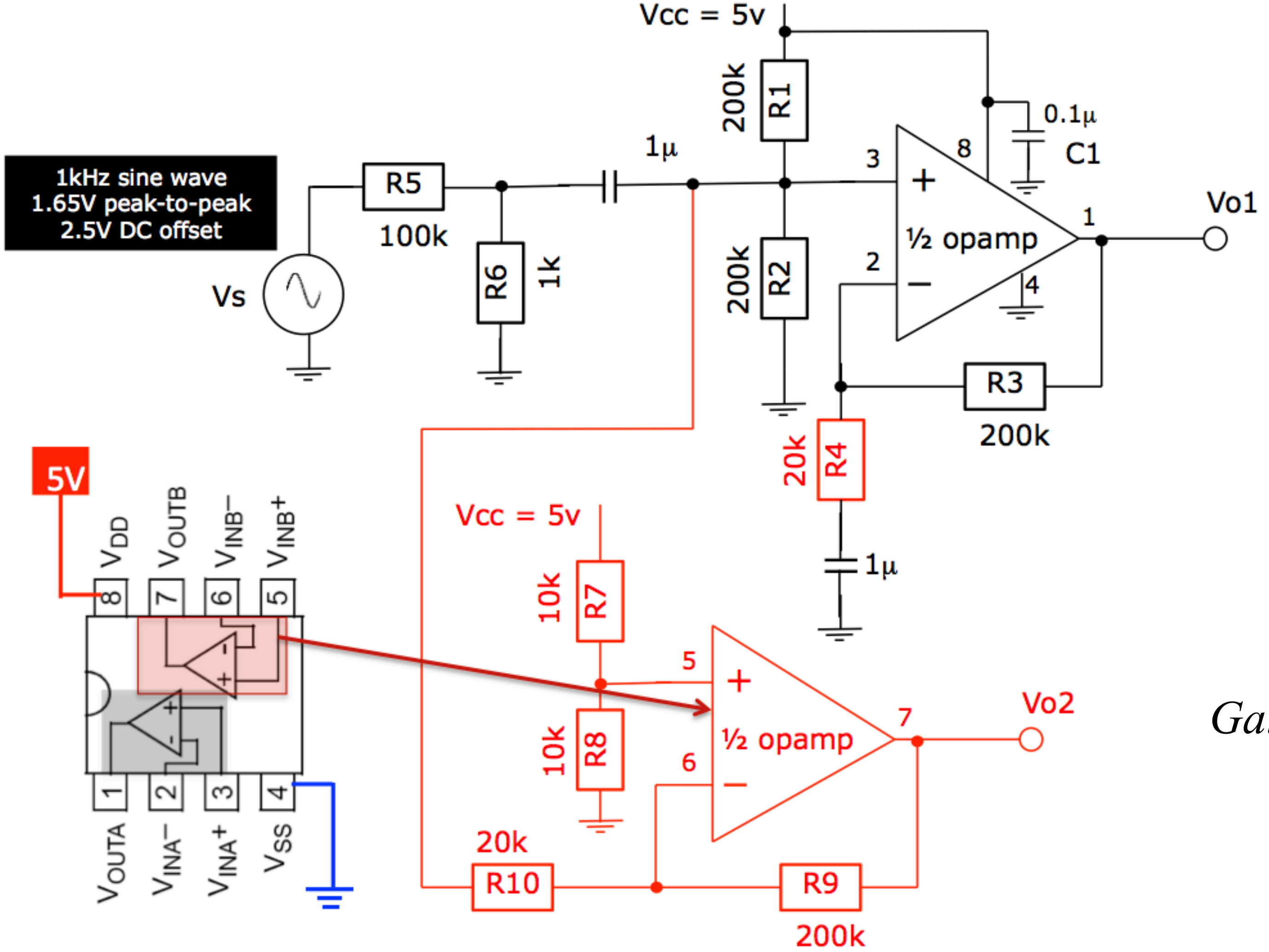
# Task 6 – High gain amplifier in 2 stages (1)

- Stage 1: non-inverting amplifier with GAIN = 11
- Replace R4 with a 20k ohm resistor.  Now gain is x11



# Task 6 – x101 amplifier in 2 stages (2)

- Stage 2: inverting amplifier with GAIN = -10 (circuit in RED)
- Now check Vo1 and Vo2

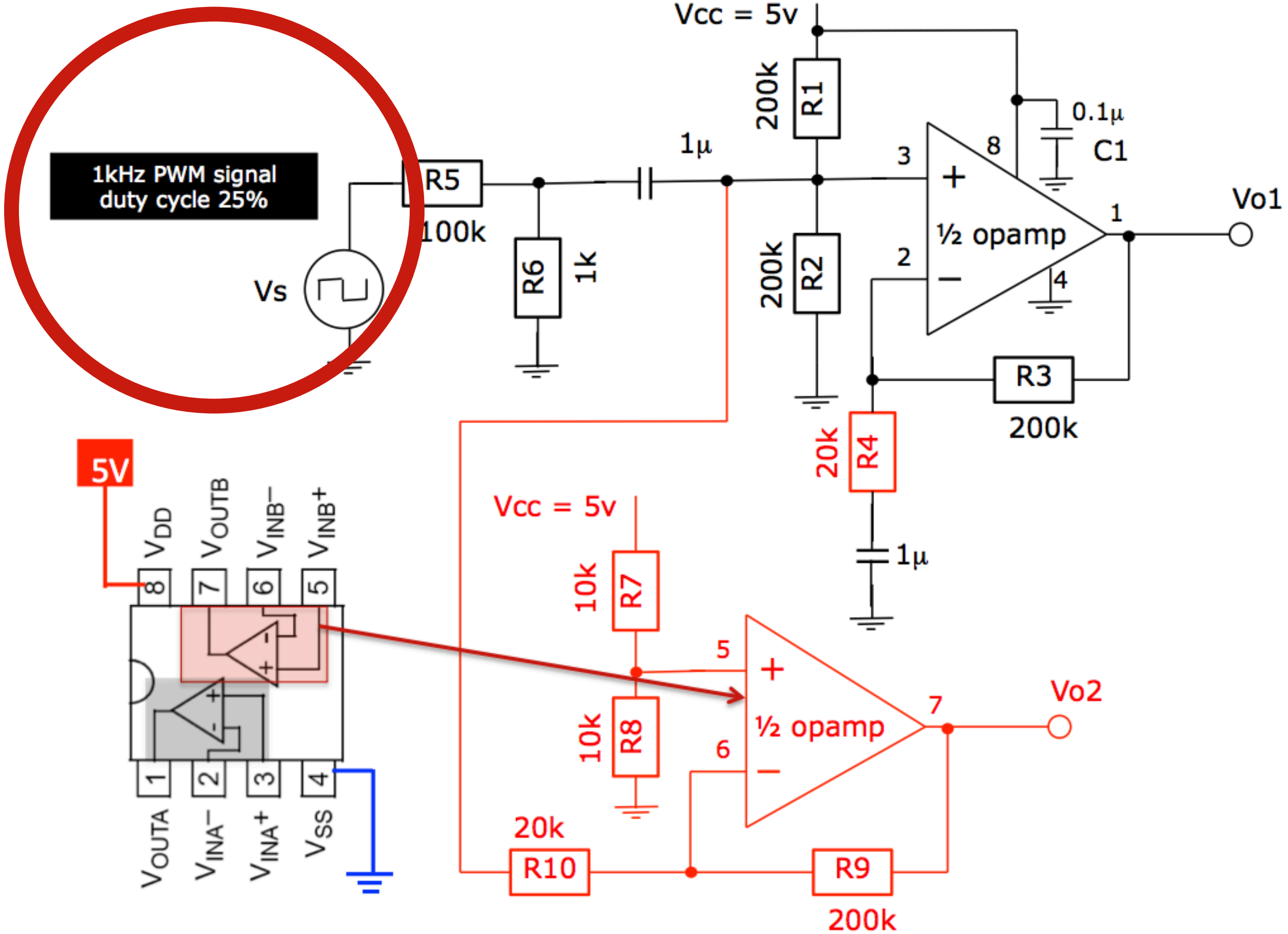



$$Gain = -\frac{R9}{R10}$$

Topic 11 slide 8

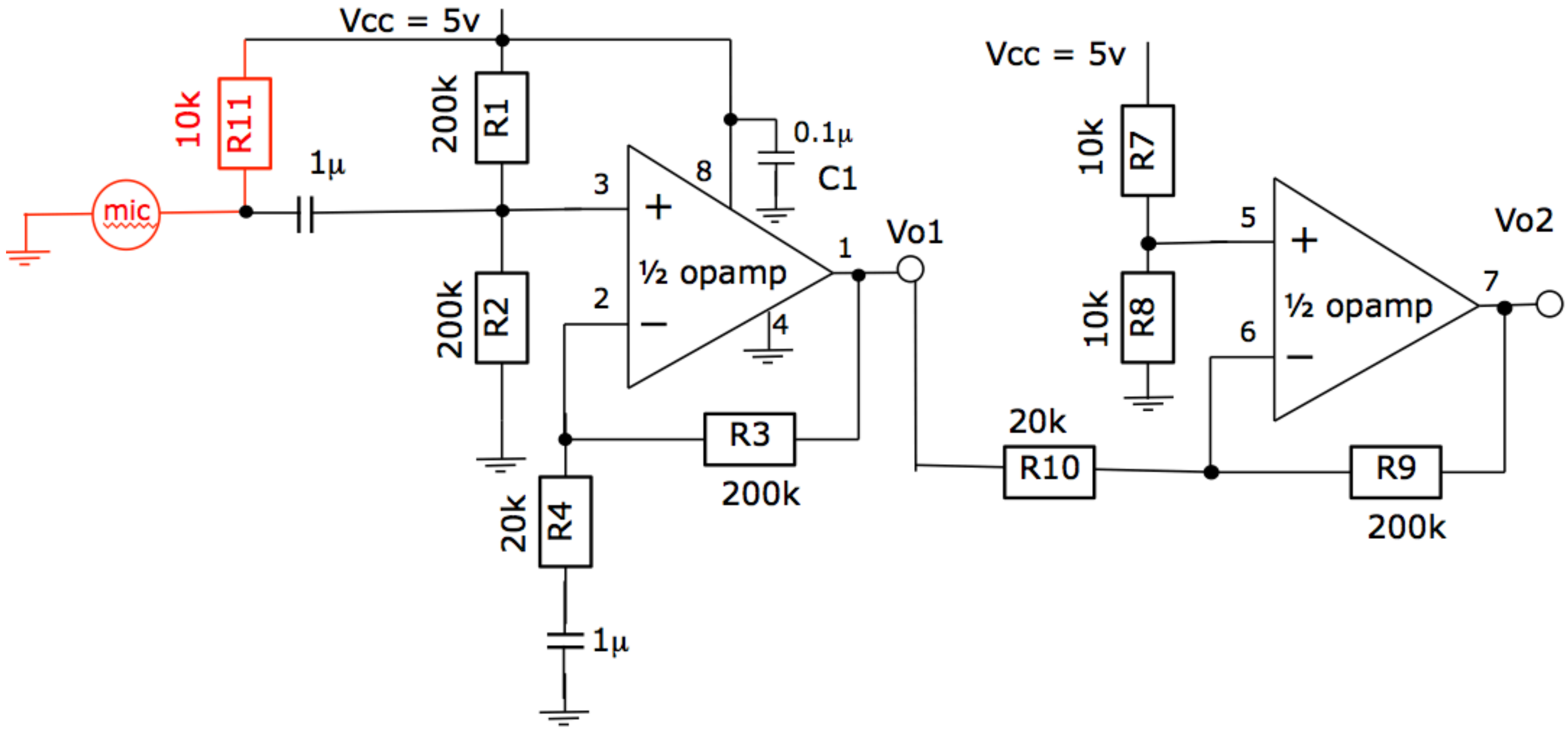
# Task 6 – x101 amplifier in 2 stages (3)

- Check that Vo1 and Vo2 have opposite phase (i.e. inverting amplifier DOES invert), use PWM signal instead of sine wave signal.



# Task 7 – Amplifying a real signal

- Connect the two amplifier in series (Vo1 becomes input to Vo2)
- Add microphone circuit shown.



# Task 8 – Audio Amplifier for 8 ohm speaker (optional)

- Op-amp only can only deliver at most 20mA current at its output
- Need special amplifier to drive 8 ohm speaker
- Use special amplifier for this purpose