This is a non-inverting amplifier with a gain of \( G = 1 + \frac{364}{155} = 235.8 \).
With such a large gain, it will saturate when \( V_i = \pm 10 \text{V}/G = \pm 0.042 \text{V}. \)

Times when \( |V_i| < 0.042, \text{V} \), are
\[
T_1 = \pm \frac{0.1-0.042}{5\text{V}/100\text{ms}} = \pm 1.160 \text{ms}.
\]
\[
T_2 = \pm \frac{0.1+0.042}{5\text{V}/100\text{ms}} = \pm 2.840 \text{ms}.
\]

- Sketch \( V_o \).
- At what times does \( V_o \) reach ±10 V?
- Does this circuit suffer from multiple transitions?

(Notes: voltage axis not to scale. The slope of the voltage may be approximated as 5 V/100 ms. Op amps are ideal)

- Sketch \( V_o \).
  1) From start to −2.840 ms, \( V_o = -10 \text{V} \)
  2) From −2.840 ms to −1.160 ms, \( V_o = \) transitions from −10 V to +10 V
  3) From −1.160 ms to 0 ms, \( V_o = +10 \text{V} \)
  4) From 0 ms to +1.160 ms, \( V_o = -10 \text{V} \)
  5) From +1.160 ms to +2.840 ms, \( V_o = \) transitions from −10 V to +10 V
  6) From +2.840 ms to end, \( V_o = +10 \text{V} \)

- At what times does \( V_o \) reach ±10 V?
  1) From start to −2.840 ms, \( V_o = -10 \text{V} \)
  3) From −1.160 ms to 0 ms, \( V_o = +10 \text{V} \)
  4) From 0 ms to +1.160 ms, \( V_o = -10 \text{V} \)
  6) From +2.840 ms to end, \( V_o = +10 \text{V} \)

- Does this circuit suffer from multiple transitions?
  [Yes]
• Sketch $V_o$.

• At what times does $V_o$ reach ±10 V?

• Does this circuit suffer from multiple transitions?

(Notes: voltage axis not to scale. The slope of the voltage may be approximated as 5 V/100 ms. Op amps are ideal)

Thresholds at $±\frac{1.21\,\text{kΩ}}{\frac{251\,\text{kΩ}}{1.21\,\text{kΩ}}} \times 10\,\text{V} = ±0.022\,\text{V}$.

Conditions:
1) If $V_i < V_+ \implies V_o = +10\,\text{V}$ and $V_+ = +0.022\,\text{V}$.
2) If $V_i > V_+ \implies V_o = -10\,\text{V}$ and $V_+ = -0.022\,\text{V}$.

• Sketch $V_o$.

1) Initially, $V_o = +10$ and $V_+ = +0.022\,\text{V}$
2) when $V_i$ crosses +0.022 V, then $V_o = -10$ and $V_+ = -0.022\,\text{V}$
3) when $V_i$ crosses -0.022 V, then $V_o = +10$ and $V_+ = +0.022\,\text{V}$
4) when $V_i$ crosses +0.022 V, then $V_o = -10$ and $V_+ = -0.022\,\text{V}$

• At what times does $V_o$ reach ±10 V?

Transitions at $±\frac{0.1-0.022}{5\,\text{V}/100\,\text{ms}} = ±1.56\,\text{ms}$.

1) Beginning until −1.56 ms $\implies V_o = +10\,\text{V}$.
2) −1.56 ms until 0 ms $\implies V_o = -10\,\text{V}$.
3) 0 ms until +2.44 ms $\implies V_o = +10\,\text{V}$.
4) +2.44 ms until end $\implies V_o = -10\,\text{V}$.

• Does this circuit suffer from multiple transitions?

[Yes]
This is a low pass filter with a gain of \( G = -\frac{599 \text{k}\Omega}{14.1 \text{k}\Omega} = -42.48 \). With such a large gain, it will saturate when \( V_i = \pm 10 \text{ V} / G = \pm 0.235 \text{ V} \). The time constant is \( \tau = 599 \text{k}\Omega \times 464 \text{nF} = 277.9 \text{ ms} \).

- At what times does \( V_o \) reach \( \pm 10 \text{ V} \)?
  Transitions at \( \pm 0.1 + 0.235 \frac{5 \text{ V}}{100 \text{ ms}} = \pm 6.7 \text{ ms} \).
  Thus: 1) Beginning until \(-6.7 \text{ ms} \Rightarrow V_o = +10 \text{ V} \).
  2) +6.7 ms until end \( \Rightarrow V_o = -10 \text{ V} \).

- Sketch \( V_o \) (this is difficult because of the exponential – indicate the main features of the curve)
  Begining until \(-6.7 \text{ ms} \Rightarrow V_o = +10 \text{ V} \). Then, from +6.7 ms until -6.7 ms the will go from +10 to -10 V, following the flipped the blue line (with gain) but with a slight delay. However, it will only deviate slightly at the zigzag. The time constant \( \tau \) is longer than the gap in the zigzag. Finally, from +6.7 ms until end \( \Rightarrow V_o = -10 \text{ V} \).

- Does this circuit suffer from multiple transitions?
  [No]

**Explanation:** In the above case, the response is linear throughout the +/-0.1V transition of the input signal. The addition of the capacitor turns the circuit into a “lossy integrator”. Its step response would be an exponential with time constant \( RC = 277.9 \text{ ms} \). We don’t have exactly a step at the input; however, if the input transitions are short compared to the time constant we can approximate the output as an exponential (perhaps with a “bump” \( V_i \) briefly changes sign). assuming the input transitions are short compared to \( RC \), then \( V_o \) will NOT suffer from multiple transitions.