This is a non-inverting amplifier with a gain of \( G = 1 + \frac{558}{1.92} = 291.6 \). With such a large gain, it will saturate when \( V_i = \pm 10 \) V/G = + \pm 0.034 V.

Times when \(|V_i| < 0.034\), V, are
\[
T_1 = \pm \frac{0.1 - 0.034}{5 \text{V/100ms}} = \pm 1.320 \text{ ms.}
\]
\[
T_2 = \pm \frac{0.1 + 0.034}{5 \text{V/100ms}} = \pm 2.680 \text{ ms.}
\]

- Sketch \( V_o \).
- At what times does \( V_o \) reach \( \pm 10 \) 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 \(-2.680\) ms, \( V_o = -10\) V
  2) From \(-2.680\) ms to \(-1.320\) ms, \( V_o \) = transitions from \(-10\) V to +10 V
  3) From \(-1.320\) ms to 0 ms, \( V_o = +10\) V
  4) From 0 ms to +1.320 ms, \( V_o = -10\) V
  5) From +1.320 ms to +2.680 ms, \( V_o \) = transitions from \(-10\) V to +10 V
  6) From +2.680 ms to end, \( V_o = +10\) V

- At what times does \( V_o \) reach \( \pm 10 \) V?
  1) From start to \(-2.680\) ms, \( V_o = -10\) V
  3) From \(-1.320\) ms to 0 ms, \( V_o = +10\) V
  4) From 0 ms to +1.320 ms, \( V_o = -10\) V
  6) From +2.680 ms to end, \( V_o = +10\) 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 $\pm \frac{1.86 \text{k}\Omega}{356 + 1.86 \text{k}\Omega} \times 10 \text{V} = \pm 0.052 \text{V}.$

Conditions:
1) If $V_i < V_+ \implies V_o = +10 \text{V}$ and $V_+ = +0.052 \text{V}$.
2) If $V_i > V_+ \implies V_o = -10 \text{V}$ and $V_+ = -0.052 \text{V}$.

• Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.052 \text{V}$
  2) when $V_i$ crosses +0.052 V, then $V_o = -10$ and $V_+ = -0.052 \text{V}$
  3) when $V_i$ crosses -0.052 V, then $V_o = +10$ and $V_+ = +0.052 \text{V}$
  4) when $V_i$ crosses +0.052 V, then $V_o = -10$ and $V_+ = -0.052 \text{V}$

• At what times does $V_o$ reach ±10 V?
  Transitions at $\pm \frac{0.1 - 0.052}{5 \text{V}/100 \text{ms}} = \pm 0.96 \text{ms}$.
  1) Beginning until $-0.96 \text{ms} \implies V_o = +10 \text{V}$.
  2) −0.96 ms until 0 ms $\implies V_o = -10 \text{V}$.
  3) 0 ms until +3.04 ms $\implies V_o = +10 \text{V}$.
  4) +3.04 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 \( G = -\frac{357 \, k\Omega}{16.4 \, k\Omega} = -21.77 \).

With such a large gain, it will saturate when \( V_i = \pm 10 \, V / G = \pm 0.459 \, V \).

The time constant is \( \tau = 357 \, k\Omega \times 576 \, nF = 205.6 \, ms \).

- At what times does \( V_o \) reach \( \pm 10 \, V \)?

Transitions at \( \pm \frac{0.1+0.459}{5V/100\,ms} = \pm 11.2 \, ms \).

Thus: 1) Begining until \(-11.2 \, ms \implies V_o = +10 \, V \).

2) \(+11.2 \, ms \) until end \( \implies V_o = -10 \, V \).

- Sketch \( V_o \) (this is difficult because of the exponential – indicate the main features of the curve)

Begining until \(-11.2 \, ms \implies V_o = +10 \, V \). Then, from \(+11.2 \, ms \) until \(-11.2 \, ms \) 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 \(+11.2 \, ms \) until end \( \implies V_o = -10 \, V \).

- 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 \( RC = 205.6 \, ms \). 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.