This is a non-inverting amplifier with a gain of \( G = 1 + \frac{469}{115} = 408.8 \).

With such a large gain, it will saturate when \( V_i = \pm 10 V / G = \pm 0.024 V \).

Times when \(|V_i| < 0.024, \) are
\[
T_1 = \pm \frac{0.1-0.024}{5 V/100 ms} = \pm 1.520 ms.
\]
\[
T_2 = \pm \frac{0.1+0.024}{5 V/100 ms} = \pm 2.480 ms.
\]

- 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)

\[
\begin{align*}
1) & \text{From start to } -2.480 \text{ ms, } V_o = -10 V \\
2) & \text{From } -2.480 \text{ ms to } -1.520 \text{ ms, } V_o = \text{transitions from } -10 V \text{ to } +10 V \\
3) & \text{From } -1.520 \text{ ms to } 0 \text{ ms, } V_o = +10 V \\
4) & \text{From } 0 \text{ ms to } +1.520 \text{ ms, } V_o = -10 V \\
5) & \text{From } +1.520 \text{ ms to } +2.480 \text{ ms, } V_o = \text{transitions from } -10 V \text{ to } +10 V \\
6) & \text{From } +2.480 \text{ ms to end, } V_o = +10 V
\end{align*}
\]

- At what times does \( V_o \) reach \( \pm 10 V \)?
  1) From start to \(-2.480 \text{ ms, } V_o = -10 V \)
  3) From \(-1.520 \text{ ms to } 0 \text{ ms, } V_o = +10 V \)
  4) From \(0 \text{ ms to } +1.520 \text{ ms, } V_o = -10 V \)
  6) From \(+2.480 \text{ ms to end, } V_o = +10 V \)

- 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 $\pm \frac{1.56 \text{k}\Omega}{542 + 1.56 \text{k}\Omega} \times 10 \text{ V} = \pm 0.029 \text{ V}$.

Conditions:
1) If $V_i < V_+$ $\Rightarrow$ $V_o = +10 \text{ V}$ and $V_+ = +0.029 \text{ V}$.
2) If $V_i > V_+$ $\Rightarrow$ $V_o = -10 \text{ V}$ and $V_+ = -0.029 \text{ V}$.

- Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.029 \text{ V}$
  2) when $V_i$ crosses +0.029 V, then $V_o = -10$ and $V_+ = -0.029 \text{ V}$
  3) when $V_i$ crosses −0.029 V, then $V_o = +10$ and $V_+ = +0.029 \text{ V}$
  4) when $V_i$ crosses +0.029 V, then $V_o = -10$ and $V_+ = -0.029 \text{ V}$

- At what times does $V_o$ reach ±10 V?
  Transitions at $\pm \frac{0.1 - 0.029}{5 \text{ V/100 ms}} = \pm 1.42 \text{ ms}$.
  1) Beginning until $-1.42 \text{ ms} \Rightarrow V_o = +10 \text{ V}$.
  2) $-1.42 \text{ ms}$ until $0 \text{ ms} \Rightarrow V_o = -10 \text{ V}$.
  3) $0 \text{ ms}$ until $+2.58 \text{ ms} \Rightarrow V_o = +10 \text{ V}$.
  4) $+2.58 \text{ ms}$ until end $\Rightarrow V_o = -10 \text{ V}$.

- Does this circuit suffer from multiple transitions?
  Yes
This is a low pass filter with a gain of $G = -\frac{342 \text{k}\Omega}{19.8 \text{k}\Omega} = -17.27$. With such a large gain, it will saturate when $V_i = \pm 10 \text{V} / G = \pm 0.579 \text{V}$. The time constant is $\tau = 342 \text{k}\Omega \times 346 \text{nF} = 118.3 \text{ms}$.

- At what times does $V_o$ reach $\pm 10 \text{V}$?
  Transitions at $\pm \frac{0.1 + 0.579}{5 \text{V} / 100 \text{ms}} = \pm 13.6 \text{ms}$.
  Thus: 1) Beginning until $-13.6 \text{ms} \implies V_o = +10 \text{V}$.
    2) $+13.6 \text{ms}$ until end $\implies V_o = -10 \text{V}$.

- Sketch $V_o$ (this is difficult because of the exponential – indicate the main features of the curve)
  Begining until $-13.6 \text{ms} \implies V_o = +10 \text{V}$. Then, from $+13.6 \text{ms}$ until $-13.6 \text{ms}$ the will go from $+10$ to $-10 \text{V}$, 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 $+13.6 \text{ms}$ until end $\implies V_o = -10 \text{V}$.

- 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 $RC = 118.3 \text{ms}$. 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.