This is a non-inverting amplifier with a gain of $G = 1 + \frac{479}{1.12} = 428.7$. With such a large gain, it will saturate when $V_i = \pm 10 V / G = \pm 0.023 V$.

Times when $|V_i| < 0.023$, $V_o$ are:

$T_1 = \pm \frac{0.1 - 0.023}{5 V / 100 ms} = \pm 1.540 ms.$
$T_2 = \pm \frac{0.1 + 0.023}{5 V / 100 ms} = \pm 2.460 ms.$

- Sketch $V_o$.
  1) From start to $-2.460$ ms, $V_o = -10 V$
  2) From $-2.460$ ms to $-1.540$ ms, $V_o$ = transitions from $-10 V$ to $+10 V$
  3) From $-1.540$ ms to 0 ms, $V_o = +10 V$
  4) From 0 ms to $+1.540$ ms, $V_o = -10 V$
  5) From $+1.540$ ms to $+2.460$ ms, $V_o$ = transitions from $-10 V$ to $+10 V$
  6) From $+2.460$ ms to end, $V_o = +10 V$

- At what times does $V_o$ reach $\pm 10 V$?
  1) From start to $-2.460$ ms, $V_o = -10 V$
  3) From $-1.540$ ms to 0 ms, $V_o = +10 V$
  4) From 0 ms to $+1.540$ ms, $V_o = -10 V$
  6) From $+2.460$ 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 $\pm 10 \, \text{V}$?

• 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 $\pm \frac{1.60 \, \text{k}\Omega}{544+1.60 \, \text{k}\Omega} \times 10 \, \text{V} = \pm 0.029 \, \text{V}$.

Conditions:
1) If $V_i < V_+ \implies V_o = +10 \, \text{V}$ and $V_+ = +0.029 \, \text{V}$.
2) If $V_i > V_+ \implies V_o = -10 \, \text{V}$ 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 $+0.029 \, \text{V}$, then $V_o = -10$ and $V_+ = -0.029 \, \text{V}$
  3) when $V_i$ crosses $-0.029 \, \text{V}$, then $V_o = +10$ and $V_+ = +0.029 \, \text{V}$
  4) when $V_i$ crosses $+0.029 \, \text{V}$, then $V_o = -10$ and $V_+ = -0.029 \, \text{V}$

• At what times does $V_o$ reach $\pm 10 \, \text{V}$?
  Transitions at $\pm \frac{0.1-0.029}{5 \, \text{V}/100 \, \text{ms}} = \pm 1.42 \, \text{ms}$.
  1) Beginning until $-1.42 \, \text{ms} \implies V_o = +10 \, \text{V}$.
  2) $-1.42 \, \text{ms}$ until $0 \, \text{ms} \implies V_o = -10 \, \text{V}$.
  3) $0 \, \text{ms}$ until $+2.58 \, \text{ms} \implies V_o = +10 \, \text{V}$.
  4) $+2.58 \, \text{ms}$ 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 $G = -\frac{573 \text{k}\Omega}{10.1 \text{k}\Omega} = -56.73$.
With such a large gain, it will saturate when $V_i = \pm 10 \text{ V}/G = \pm 0.176 \text{ V}$.
The time constant is $\tau = 573 \text{k}\Omega \times 337 \text{nF} = 193.1 \text{ ms}$.

- At what times does $V_o$ reach $\pm 10 \text{ V}$?
  Transitions at $\pm \frac{0.1 + 0.176}{5 \text{ V}/100 \text{ ms}} = \pm 5.5 \text{ ms}$.
  Thus: 1) Beginning until $-5.5 \text{ ms} \Rightarrow V_o = +10 \text{ V}$.
  2) +5.5 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 $-5.5 \text{ ms} \Rightarrow V_o = +10 \text{ V}$. Then, from +5.5 ms until $-5.5 \text{ ms}$ 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 +5.5 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 $RC = 193.1 \text{ ms}$. 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.