This is a non-inverting amplifier with a gain of \( G = 1 + \frac{497}{1.35} = 369.1 \). With such a large gain, it will saturate when \( V_i = \pm 10 V/G = \pm 0.027 V \).

Times when \( |V_i| < 0.027 \), \( V \), are
\[
T_1 = \pm \frac{0.1-0.027}{5 V/100 \text{ms}} = \pm 1.460 \text{ ms}.
\]
\[
T_2 = \pm \frac{0.1+0.027}{5 V/100 \text{ms}} = \pm 2.540 \text{ ms}.
\]

**Sketch \( V_o \).**

1) From start to \(-2.540 \text{ ms} \), \( V_o = -10 V \)
2) From \(-2.540 \text{ ms} \) to \(-1.460 \text{ ms} \), \( V_o = \text{transitions from} -10 V \) to \(+10 V \)
3) From \(-1.460 \text{ ms} \) to \(0 \text{ ms} \), \( V_o = +10 V \)
4) From \(0 \text{ ms} \) to \(+1.460 \text{ ms} \), \( V_o = -10 V \)
5) From \(+1.460 \text{ ms} \) to \(+2.540 \text{ ms} \), \( V_o = \text{transitions from} -10 V \) to \(+10 V \)
6) From \(+2.540 \text{ ms} \) to end, \( V_o = +10 V \)

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

1) From start to \(-2.540 \text{ ms} \), \( V_o = -10 V \)
3) From \(-1.460 \text{ ms} \) to \(0 \text{ ms} \), \( V_o = +10 V \)
4) From \(0 \text{ ms} \) to \(+1.460 \text{ ms} \), \( V_o = -10 V \)
6) From \(+2.540 \text{ ms} \) to end, \( V_o = +10 V \)

**Does this circuit suffer from multiple transitions?**

Yes
• Sketch $V_o$.
• At what times does $V_o$ reach $\pm 10\, V$?
• 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)

Thresholds at $\pm \frac{1.66\, k\Omega}{508+1.66\, k\Omega} \times 10\, V = \pm 0.033\, V$.

Conditions:
1) If $V_i < V_+ \implies V_o = +10\, V$ and $V_+ = +0.033\, V$.
2) If $V_i > V_+ \implies V_o = -10\, V$ and $V_+ = -0.033\, V$.

• Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.033\, V$
  2) when $V_i$ crosses $+0.033\, V$, then $V_o = -10$ and $V_+ = -0.033\, V$
  3) when $V_i$ crosses $-0.033\, V$, then $V_o = +10$ and $V_+ = +0.033\, V$
  4) when $V_i$ crosses $+0.033\, V$, then $V_o = -10$ and $V_+ = -0.033\, V$

• At what times does $V_o$ reach $\pm 10\, V$?
  Transitions at $\pm \frac{0.1-0.033}{5V/100\, ms} = \pm 1.34\, ms$.
  1) Beginning until $-1.34\, ms \implies V_o = +10\, V$.
  2) $-1.34\, ms$ until $0\, ms \implies V_o = -10\, V$.
  3) $0\, ms$ until $+2.66\, ms \implies V_o = +10\, V$.
  4) $+2.66\, ms$ until end $\implies V_o = -10\, V$.

• Does this circuit suffer from multiple transitions?
  Yes
This is a low pass filter with a gain of $G = \frac{562 \text{k}\Omega}{12.5 \text{k}\Omega} = -44.96$. With such a large gain, it will saturate when $V_i = \pm 10 \text{ V}$.

The time constant is $\tau = 562 \text{k}\Omega \times 406 \text{nF} = 228.2 \text{ ms}$.

- At what times does $V_o$ reach $\pm 10 \text{ V}$?
  Transitions at $\pm 0.1 + 0.222 = \pm 6.4 \text{ ms}$.
  Thus: 1) Beginning until $-6.4 \text{ ms} \implies V_o = +10 \text{ V}$.
  2) $+6.4 \text{ ms}$ 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 $-6.4 \text{ ms} \implies V_o = +10 \text{ V}$. Then, from $+6.4 \text{ ms}$ until $-6.4 \text{ ms}$ 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 $+6.4 \text{ ms}$ 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 $RC = 228.2 \text{ ms}$. 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.