This is a non-inverting amplifier with a gain of \( G = 1 + \frac{432}{164} = 264.4 \).
With such a large gain, it will saturate when \( V_i = \pm 10 V/G = \pm 0.038 V \).
Times when \( |V_i| < 0.038 \), are
\[
T_1 = \pm \frac{0.1 - 0.038}{5V/100ms} = \pm 1.240 \text{ ms}.
\]
\[
T_2 = \pm \frac{0.1 + 0.038}{5V/100ms} = \pm 2.760 \text{ ms}.
\]
• Sketch \( V_o \).

1) From start to \(-2.760 \text{ ms} \), \( V_o = -10 \text{ V} \)
2) From \(-2.760 \text{ ms} \) to \(-1.240 \text{ ms} \), \( V_o = \text{ transitions from } -10 \text{ V to } +10 \text{ V} \)
3) From \(-1.240 \text{ ms} \) to \(0 \text{ ms} \), \( V_o = +10 \text{ V} \)
4) From \(0 \text{ ms} \) to \(+1.240 \text{ ms} \), \( V_o = -10 \text{ V} \)
5) From \(+1.240 \text{ ms} \) to \(+2.760 \text{ ms} \), \( V_o = \text{ transitions from } -10 \text{ V to } +10 \text{ V} \)
6) From \(+2.760 \text{ ms} \) to end, \( V_o = +10 \text{ V} \)

• At what times does \( V_o \) reach \( \pm 10 \text{ V} \)?
1) From start to \(-2.760 \text{ ms} \), \( V_o = -10 \text{ V} \)
3) From \(-1.240 \text{ ms} \) to \(0 \text{ ms} \), \( V_o = +10 \text{ V} \)
4) From \(0 \text{ ms} \) to \(+1.240 \text{ ms} \), \( V_o = -10 \text{ V} \)
6) From \(+2.760 \text{ ms} \) 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 $\pm 10$ 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 $\pm \frac{1.44 \text{k}\Omega}{461 + 1.44 \text{k}\Omega} \times 10 \text{V} = \pm 0.031 \text{V}$.  

Conditions:
1) If $V_i < V_+ \implies V_o = +10 \text{V}$ and $V_+ = +0.031 \text{V}$.
2) If $V_i > V_+ \implies V_o = -10 \text{V}$ and $V_+ = -0.031 \text{V}$.

- Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.031 \text{V}$
  2) when $V_i$ crosses $+0.031 \text{V}$, then $V_o = -10$ and $V_+ = -0.031 \text{V}$
  3) when $V_i$ crosses $-0.031 \text{V}$, then $V_o = +10$ and $V_+ = +0.031 \text{V}$
  4) when $V_i$ crosses $+0.031 \text{V}$, then $V_o = -10$ and $V_+ = -0.031 \text{V}$

- At what times does $V_o$ reach $\pm 10$ V?
  Transitions at $\pm \frac{0.1 - 0.031}{5 \text{V}/100 \text{ms}} = \pm 1.38 \text{ms}$.
  1) Begining until $-1.38 \text{ms} \implies V_o = +10 \text{V}$.
  2) $-1.38 \text{ms}$ until $0 \text{ms} \implies V_o = -10 \text{V}$.
  3) $0 \text{ms}$ until $+2.62 \text{ms} \implies V_o = +10 \text{V}$.
  4) $+2.62 \text{ms}$ 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 \( G = \frac{575 \text{k}\Omega}{12.8 \text{k}\Omega} = -44.92 \).
With such a large gain, it will saturate when \( V_i = \pm 10 \text{V} / G = \pm 0.223 \text{V} \).
The time constant is \( \tau = 575 \text{k}\Omega \times 491 \text{nF} = 282.3 \text{ms} \).

- At what times does \( V_o \) reach \( \pm 10 \text{V} \)?
  Transitions at \( \pm \frac{0.1 + 0.223}{5 \text{V}/100 \text{ms}} = \pm 6.5 \text{ms} \).
  Thus: 1) Beginning until \( -6.5 \text{ms} \implies V_o = +10 \text{V} \).
    2) +6.5 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)
  Beginning until \(-6.5 \text{ms} \implies V_o = +10 \text{V} \). Then, from +6.5 ms until -6.5 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 +6.5 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 \( RC = 282.3 \text{ms} \). 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.