This is a non-inverting amplifier with a gain of $G = 1 + \frac{396}{150} = 265.0$. With such a large gain, it will saturate when $V_i = \pm 10 V / G = \pm 0.038 V$.

Times when $|V_i| < 0.038$, $V_o$, are

$T_1 = \pm \frac{0.1 - 0.038}{5 V / 100 \text{ms}} = \pm 1.240 \text{ ms}$.  
$T_2 = \pm \frac{0.1 + 0.038}{5 V / 100 \text{ms}} = \pm 2.760 \text{ ms}$.  

- 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 $5 V / 100 \text{ms}$. Op amps are ideal)

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

- At what times does $V_o$ reach $\pm 10 V$?  
  1) From start to $-2.760 \text{ ms}$, $V_o = -10 V$  
  3) From $-1.240 \text{ ms}$ to $0 \text{ ms}$, $V_o = +10 V$  
  4) From $0 \text{ ms}$ to $+1.240 \text{ ms}$, $V_o = -10 V$  
  6) From $+2.760 \text{ ms}$ 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 $\pm \frac{1.32\,k\Omega}{337+1.32\,k\Omega} \times 10\,V = \pm 0.039\,V$.

Conditions:
1) If $V_i < V_+ \implies V_o = +10\,V$ and $V_+ = +0.039\,V$.
2) If $V_i > V_+ \implies V_o = -10\,V$ and $V_+ = -0.039\,V$.

• Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.039\,V$
  2) when $V_i$ crosses $+0.039\,V$, then $V_o = -10$ and $V_+ = -0.039\,V$
  3) when $V_i$ crosses $-0.039\,V$, then $V_o = +10$ and $V_+ = +0.039\,V$
  4) when $V_i$ crosses $+0.039\,V$, then $V_o = -10$ and $V_+ = -0.039\,V$

• At what times does $V_o$ reach $\pm 10\,V$?
  Transitions at $\pm \frac{0.1-0.039}{5V/100\,ms} = \pm 1.22\,ms$.
  1) Beginning until $-1.22\,ms \implies V_o = +10\,V$.
  2) $-1.22\,ms$ until $0\,ms \implies V_o = -10\,V$.
  3) $0\,ms$ until $+2.78\,ms \implies V_o = +10\,V$.
  4) $+2.78\,ms$ 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 $G = -\frac{442 \text{k}\Omega}{15.2 \text{k}\Omega} = -29.08$.

With such a large gain, it will saturate when $V_i = \pm 10 \text{ V} / G = \pm 0.344 \text{ V}$.

The time constant is $\tau = 442 \text{k}\Omega \times 449 \text{nF} = 198.5 \text{ ms}$.

- At what times does $V_o$ reach $\pm 10 \text{ V}$?
  
  Transitions at $\pm 0.1 \pm 0.344 \text{ V}/100 \text{ ms} = \pm 8.9 \text{ ms}$.
  
  Thus: 1) Beginning until $-8.9 \text{ ms} \implies V_o = +10 \text{ V}$.
  
  2) $+8.9 \text{ ms}$ 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 $-8.9 \text{ ms} \implies V_o = +10 \text{ V}$. Then, from $+8.9 \text{ ms}$ until $-8.9 \text{ ms}$ the will go from $+10 \text{ V}$ 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 $+8.9 \text{ ms}$ 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 $+/-.1 \text{V}$ 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 $RC = 198.5 \text{ ms}$. 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.