This is a non-inverting amplifier with a gain of $G = 1 + \frac{304}{114} = 267.7$. With such a large gain, it will saturate when $V_i = \pm 10 V/G = \pm 0.037 V$.

Times when $|V_i| < 0.037$, V, are

$T_1 = \pm \frac{0.1-0.037}{5 V/100 ms} = \pm 1.260 ms.$

$T_2 = \pm \frac{0.1+0.037}{5 V/100 ms} = \pm 2.740 ms.$

- Sketch $V_o$.
  1) From start to $-2.740 ms$, $V_o = -10 V$
  2) From $-2.740 ms$ to $-1.260 ms$, $V_o$ = transitions from $-10 V$ to $+10 V$
  3) From $-1.260 ms$ to $0 ms$, $V_o = +10 V$
  4) From $0 ms$ to $+1.260 ms$, $V_o = -10 V$
  5) From $+1.260 ms$ to $+2.740 ms$, $V_o$ = transitions from $-10 V$ to $+10 V$
  6) From $+2.740 ms$ to end, $V_o = +10 V$

- At what times does $V_o$ reach $\pm 10 V$?
  1) From start to $-2.740 ms$, $V_o = -10 V$
  3) From $-1.260 ms$ to $0 ms$, $V_o = +10 V$
  4) From $0 ms$ to $+1.260 ms$, $V_o = -10 V$
  6) From $+2.740 ms$ 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 $5\, \text{V}/100\, \text{ms}$. Op amps are ideal)

Thresholds at $\pm \frac{1.01\, \text{k}\Omega}{389 + 1.01\, \text{k}\Omega} \times 10\, \text{V} = \pm 0.026\, \text{V}$.

Conditions:
1) If $V_i < V_+$ $\implies V_o = +10\, \text{V}$ and $V_+ = +0.026\, \text{V}$.
2) If $V_i > V_+$ $\implies V_o = -10\, \text{V}$ and $V_+ = -0.026\, \text{V}$.

• Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.026\, \text{V}$
  2) when $V_i$ crosses $+0.026\, \text{V}$, then $V_o = -10$ and $V_+ = -0.026\, \text{V}$
  3) when $V_i$ crosses $-0.026\, \text{V}$, then $V_o = +10$ and $V_+ = +0.026\, \text{V}$
  4) when $V_i$ crosses $+0.026\, \text{V}$, then $V_o = -10$ and $V_+ = -0.026\, \text{V}$

• At what times does $V_o$ reach $\pm 10\, \text{V}$?
  Transitions at $\pm \frac{0.1 - 0.026\, \text{V}}{5\, \text{V}/100\, \text{ms}} = \pm 1.48\, \text{ms}$.
  1) Beginning until $-1.48\, \text{ms} \implies V_o = +10\, \text{V}$.
  2) $-1.48\, \text{ms}$ until $0\, \text{ms} \implies V_o = -10\, \text{V}$.
  3) $0\, \text{ms}$ until $+2.52\, \text{ms} \implies V_o = +10\, \text{V}$.
  4) $+2.52\, \text{ms}$ 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 $G = \frac{-400 \text{k}\Omega}{19.2 \text{k}\Omega} = -20.83$.

With such a large gain, it will saturate when $V_i = \pm 10 \text{V} / G = \pm 0.480 \text{V}$.

The time constant is $\tau = 400 \text{k}\Omega \times 341 \text{nF} = 136.4 \text{ms}$.

- At what times does $V_o$ reach $\pm 10 \text{V}$?
  
  Transitions at $\pm \frac{0.1 + 0.480}{5 \text{V}/100 \text{ms}} = \pm 11.6 \text{ms}$.
  
  Thus: 1) Beginning until $-11.6 \text{ms} \implies V_o = +10 \text{V}$.
  
  2) $+11.6 \text{ms}$ 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 $-11.6 \text{ms} \implies V_o = +10 \text{V}$. Then, from $+11.6 \text{ms}$ until $-11.6 \text{ms}$ 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 $+11.6 \text{ms}$ 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 $RC = 136.4 \text{ms}$. 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.