This is a non-inverting amplifier with a gain of $G = 1 + \frac{546}{114} = 479.9$.
With such a large gain, it will saturate when $V_i = \pm 10 V / G = \pm 0.021 V$.

Times when $|V_i| < 0.021$, are

$T_1 = \pm \frac{0.1 - 0.021}{5V/100ms} = \pm 1.580 \text{ ms}$.

$T_2 = \pm \frac{0.1 + 0.021}{5V/100ms} = \pm 2.420 \text{ ms}$.

• Sketch $V_o$.

1) From start to $-2.420 \text{ ms}$, $V_o = -10 V$
2) From $-2.420 \text{ ms}$ to $-1.580 \text{ ms}$, $V_o$ = transitions from $-10 V$ to $+10 V$
3) From $-1.580 \text{ ms}$ to $0 \text{ ms}$, $V_o = +10 V$
4) From $0 \text{ ms}$ to $+1.580 \text{ ms}$, $V_o = -10 V$
5) From $+1.580 \text{ ms}$ to $+2.420 \text{ ms}$, $V_o$ = transitions from $-10 V$ to $+10 V$
6) From $+2.420 \text{ ms}$ to end, $V_o = +10 V$

• At what times does $V_o$ reach $\pm 10 V$?
1) From start to $-2.420 \text{ ms}$, $V_o = -10 V$
3) From $-1.580 \text{ ms}$ to $0 \text{ ms}$, $V_o = +10 V$
4) From $0 \text{ ms}$ to $+1.580 \text{ ms}$, $V_o = -10 V$
6) From $+2.420 \text{ ms}$ to end, $V_o = +10 V$

• Does this circuit suffer from multiple transitions?

[Yes]
**Question: B**

- Sketch $V_o$.
- At what times does $V_o$ reach $\pm 10$ V?
- Does this circuit suffer from multiple transitions?

(Note: voltage axis not to scale. The slope of the voltage may be approximated as 5 V/100 ms. Op amps are ideal)

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**Thresholds at** $\pm \frac{1.82 \, k\Omega}{502 + 1.82 \, k\Omega} \times 10$ V $= \pm 0.036$ V.

**Conditions:**
1) If $V_i < V_+$ $\implies V_o = +10$ V and $V_+ = +0.036$ V.
2) If $V_i > V_+$ $\implies V_o = -10$ V and $V_+ = -0.036$ V.

- Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.036$ V
  2) when $V_i$ crosses $+0.036$ V, then $V_o = -10$ and $V_+ = -0.036$ V
  3) when $V_i$ crosses $-0.036$ V, then $V_o = +10$ and $V_+ = +0.036$ V
  4) when $V_i$ crosses $+0.036$ V, then $V_o = -10$ and $V_+ = -0.036$ V

- At what times does $V_o$ reach $\pm 10$ V?
  Transitions at $\pm \frac{0.1 - 0.036}{5 \, V / 100 \, ms} = \pm 1.28$ ms.
  1) Beginning until $-1.28$ ms $\implies V_o = +10$ V.
  2) $-1.28$ ms until $0$ ms $\implies V_o = -10$ V.
  3) $0$ ms until $+2.72$ ms $\implies V_o = +10$ V.
  4) $+2.72$ 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 $G = -\frac{449 \text{k}\Omega}{11.2 \text{k}\Omega} = -40.09$. With such a large gain, it will saturate when $V_i = \pm 10 \text{ V}/G = \pm 0.249 \text{ V}$. The time constant is $\tau = 449 \text{k}\Omega \times 342 \text{nF} = 153.6 \text{ ms}$.

- At what times does $V_o$ reach $\pm 10 \text{ V}$?
  Transitions at $\pm 0.1 \pm 0.249 \frac{5 \text{ V}}{100 \text{ ms}} = \pm 7.0 \text{ ms}$.
  Thus: 1) Beginning until $-7.0 \text{ ms} \implies V_o = +10 \text{ V}$.
    2) $+7.0 \text{ ms}$ 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)
  Beginning until $-7.0 \text{ ms} \implies V_o = +10 \text{ V}$. Then, from $+7.0 \text{ ms}$ until $-7.0 \text{ ms}$ 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 $+7.0 \text{ ms}$ 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 $RC = 153.6 \text{ ms}$. 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.