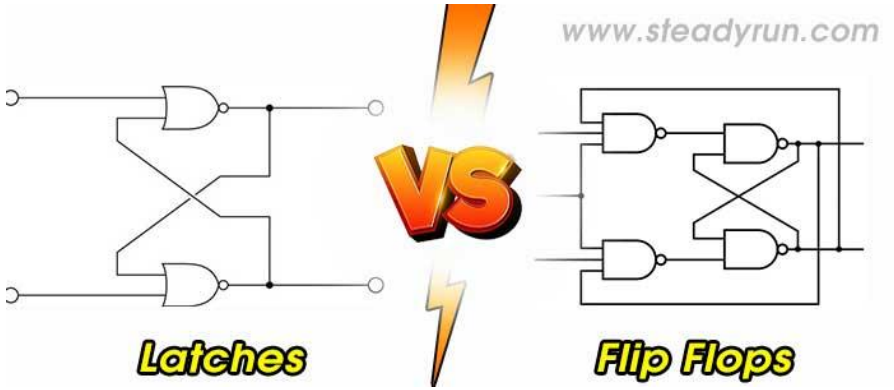
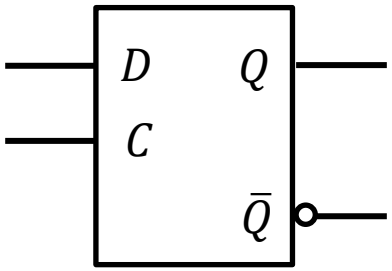
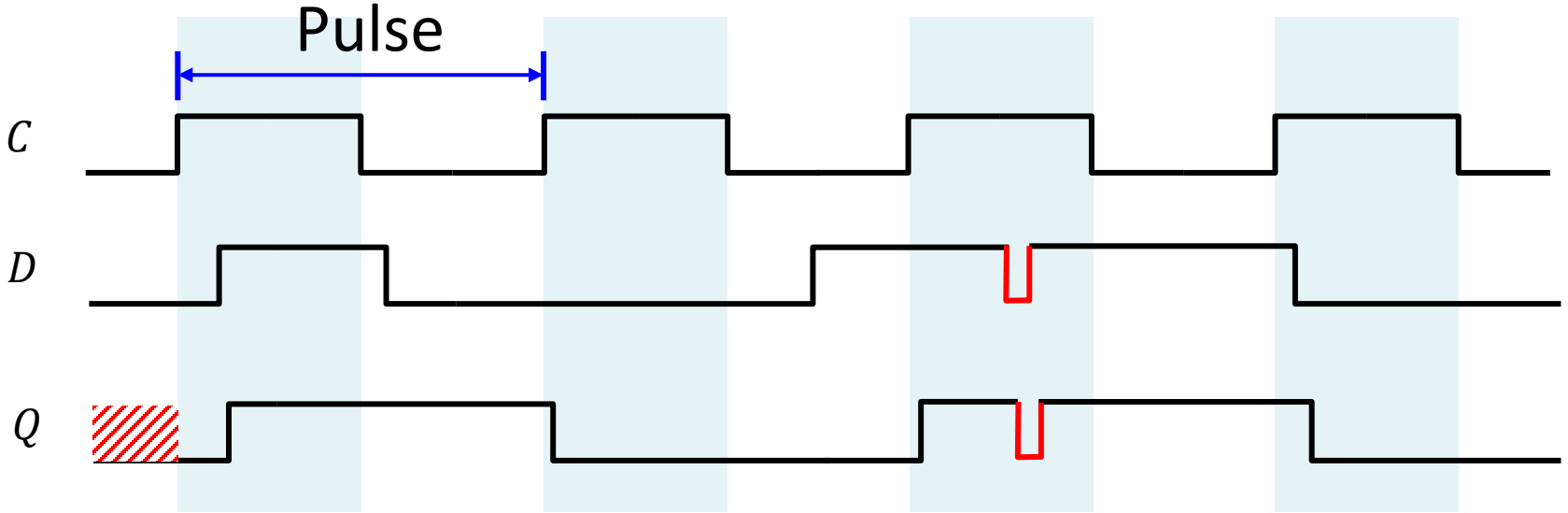
EE2000 Logic Circuit Design

Lecture 7 – Latch and Flip-Flop Circuits



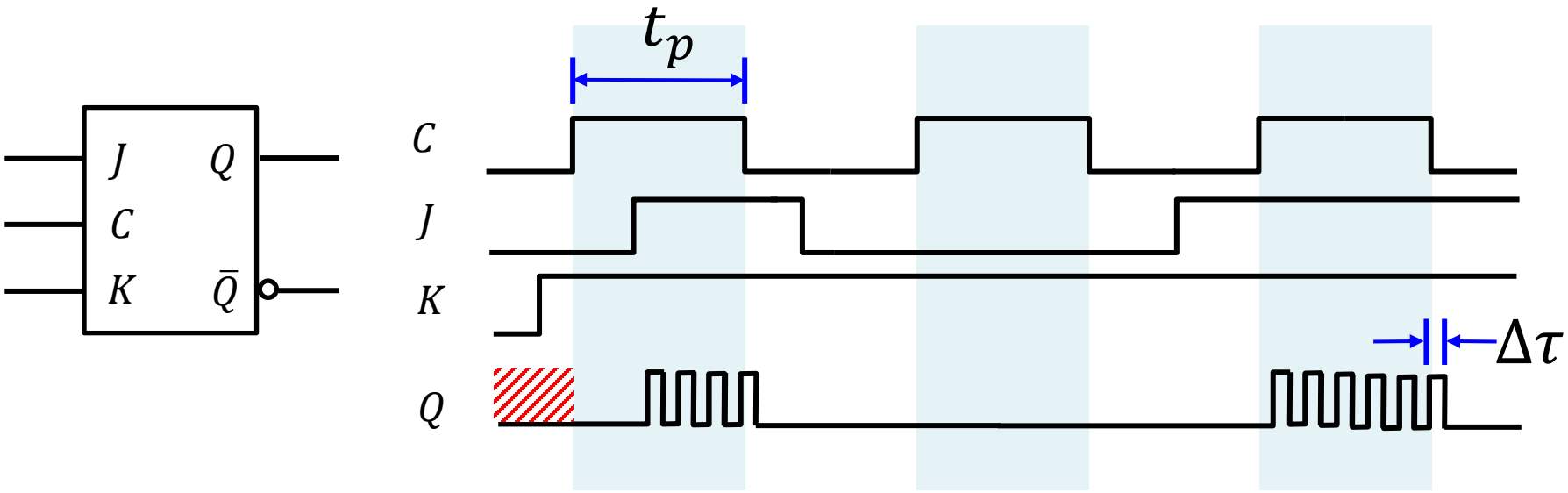
Transparency & Glitch





- FF is activated when C is HIGH (Pulse or Level triggered)
- Transparency: Input passes through directly to output
- Glitch: Undesired signal

Race Around Condition

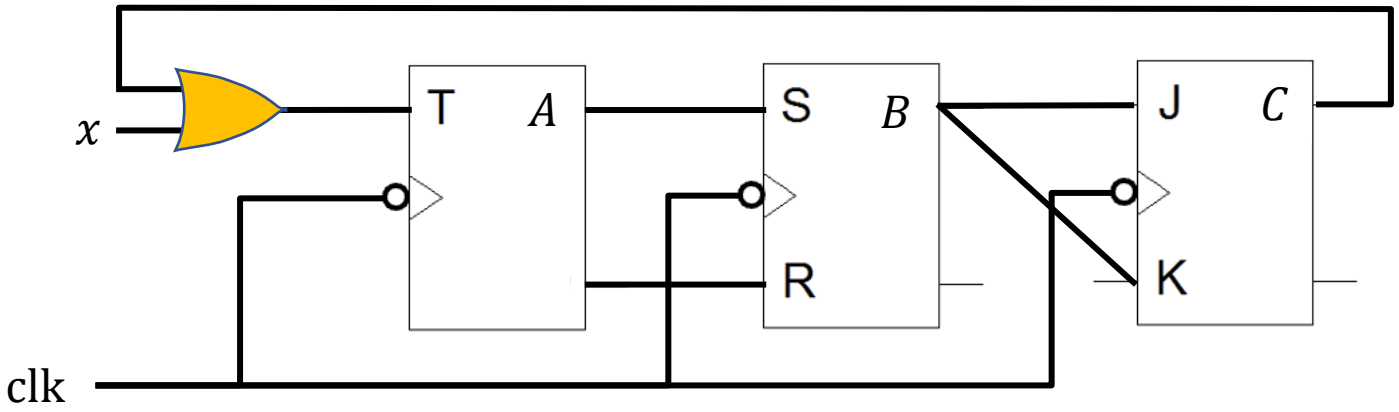


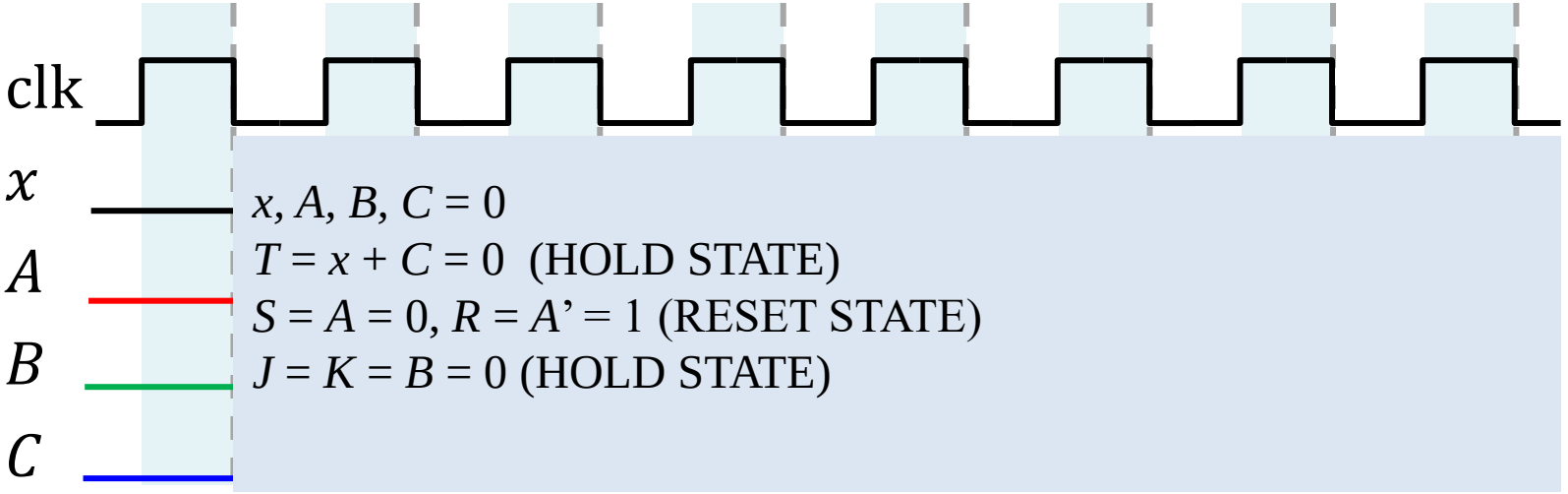
- When both J and K are HIGH, the output toggles continuously (racing) and becomes uncertain
- Unless propagation delay of the gates larger than the pulse width ($\Delta\tau > t_p$)

Exercise

$T = x + C \qquad S = A \qquad R = A'$

$J = K = B$





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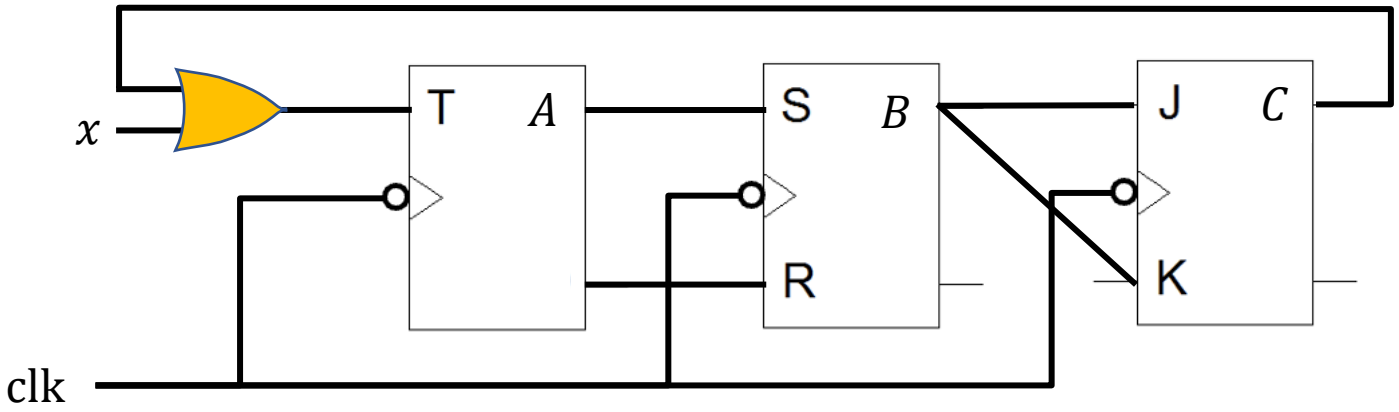
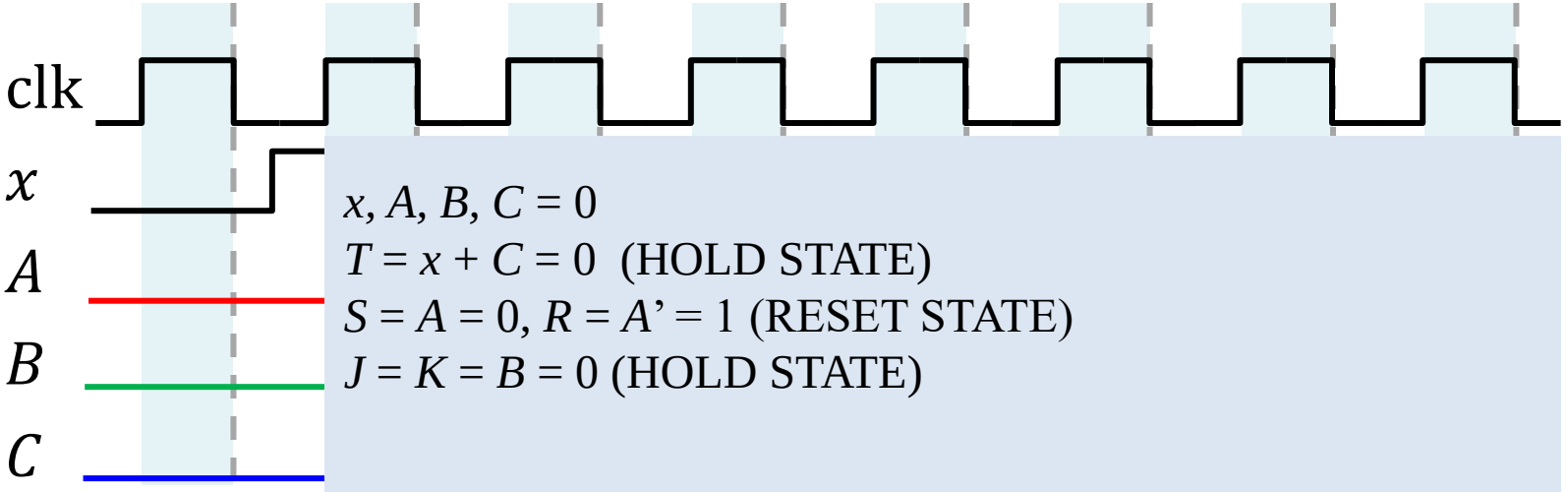




x, *A*, *B*, *C* = 0

T = *x* + *C* = 0 (HOLD STATE)

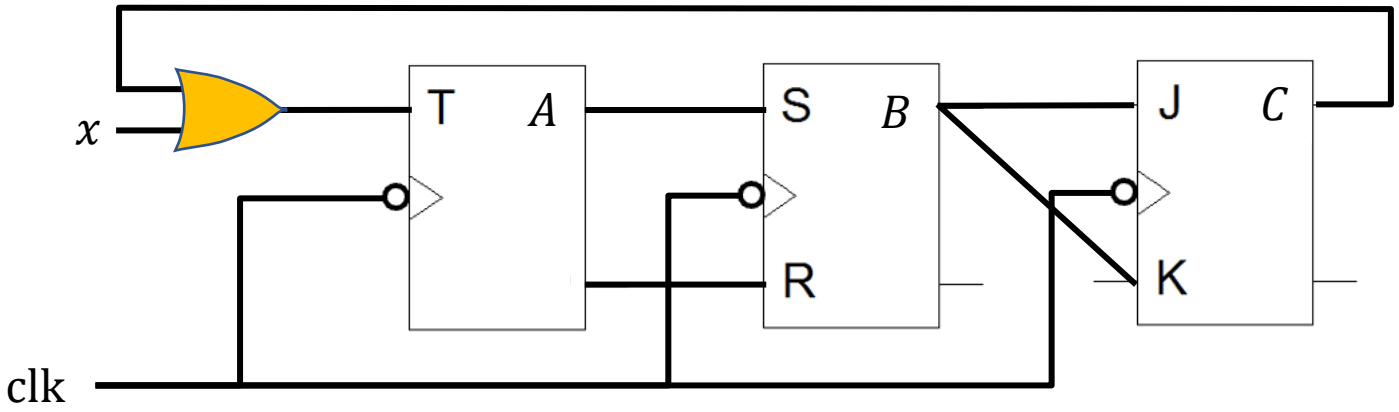
S = *A* = 0, *R* = *A*' = 1 (RESET STATE)

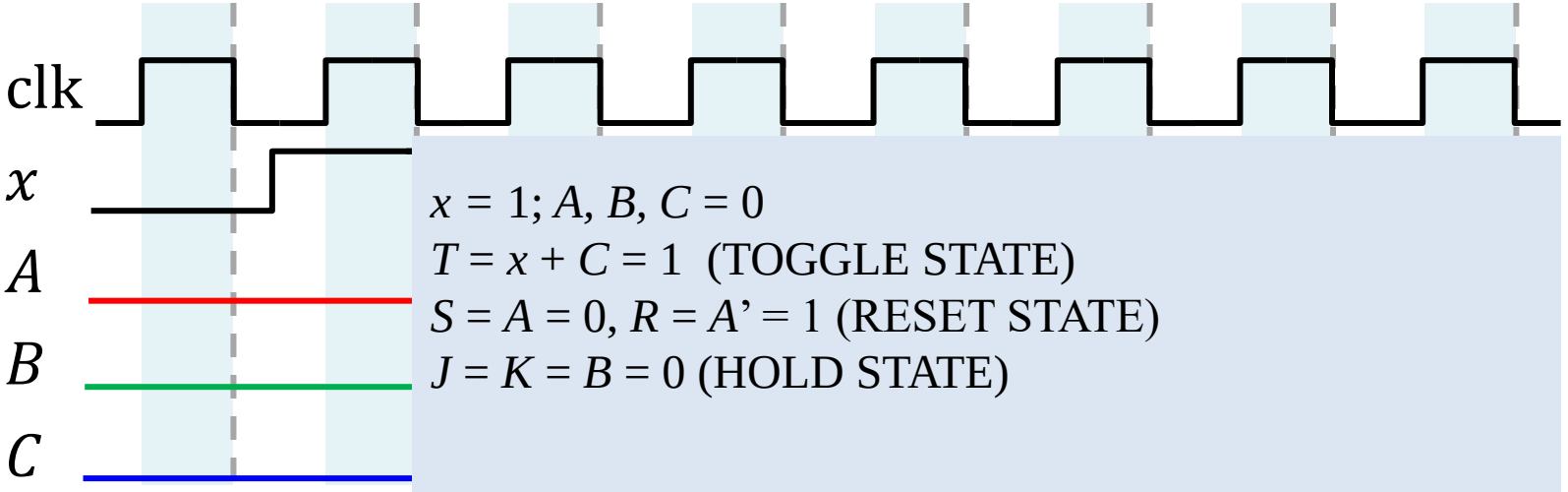
J = *K* = *B* = 0 (HOLD STATE)

Exercise

$T = x + C \qquad S = A \qquad R = A'$

$J = K = B$





Exercise

$T = x + C \qquad S = A \qquad R = A'$

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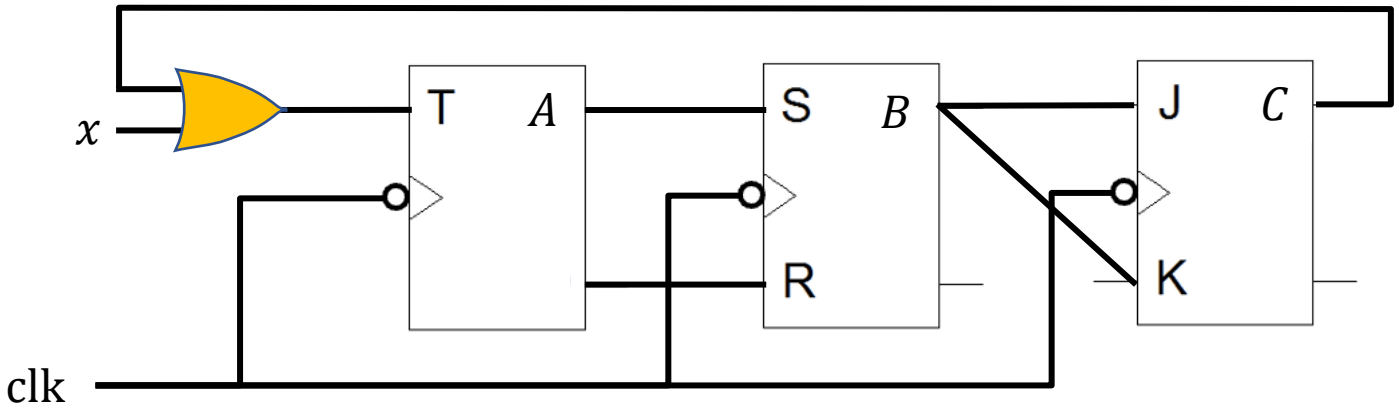
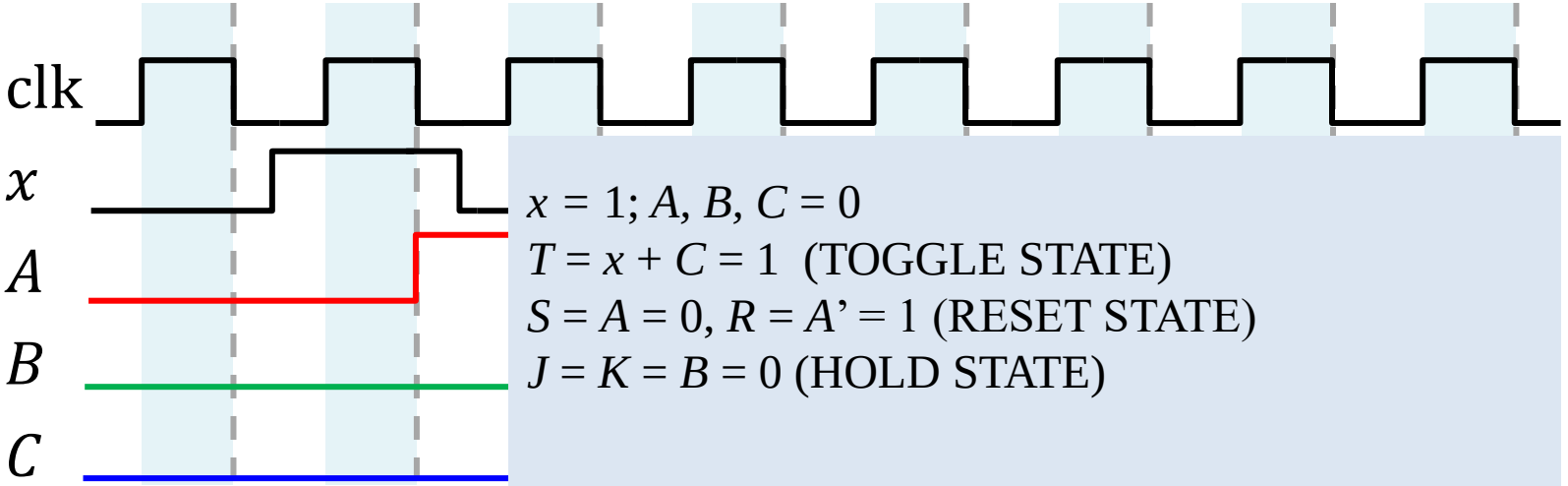




x = 1; A, B, C = 0

$T = x + C = 1$ (TOGGLE STATE)

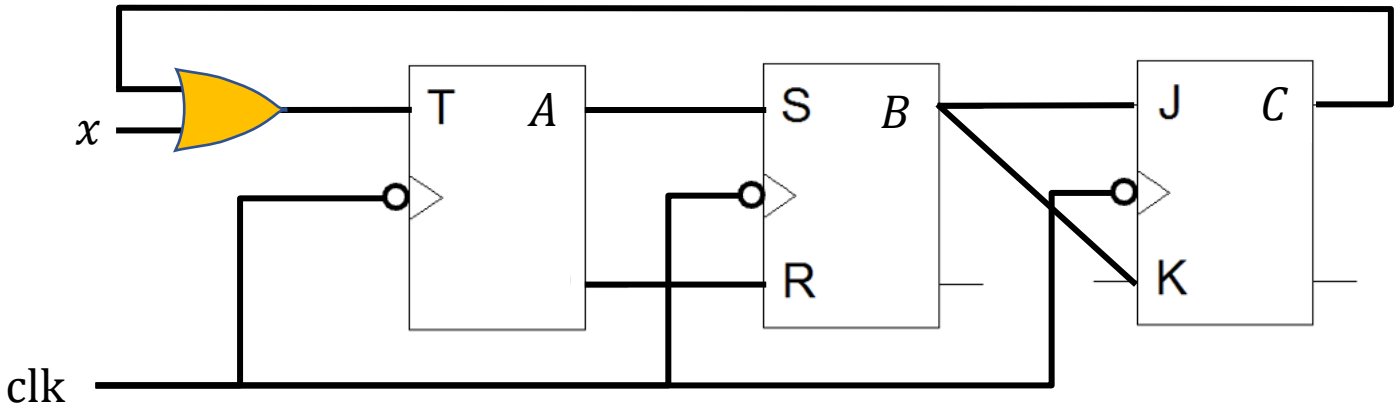
$S = A = 0$, $R = A' = 1$ (RESET STATE)

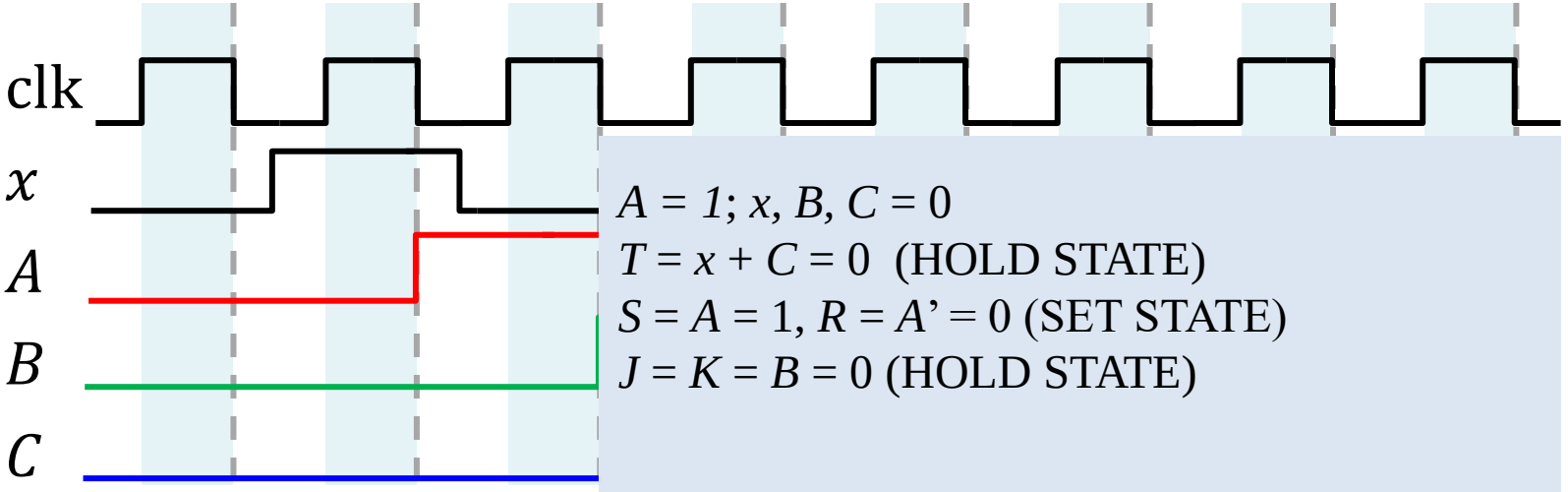
$J = K = B = 0$ (HOLD STATE)

Exercise

$T = x + C \qquad S = A \qquad R = A'$

$J = K = B$



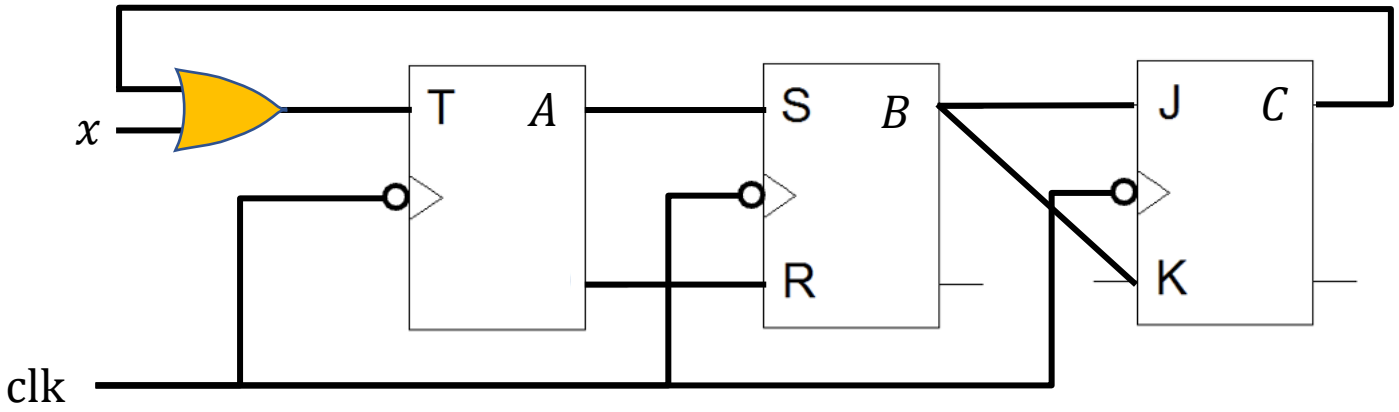


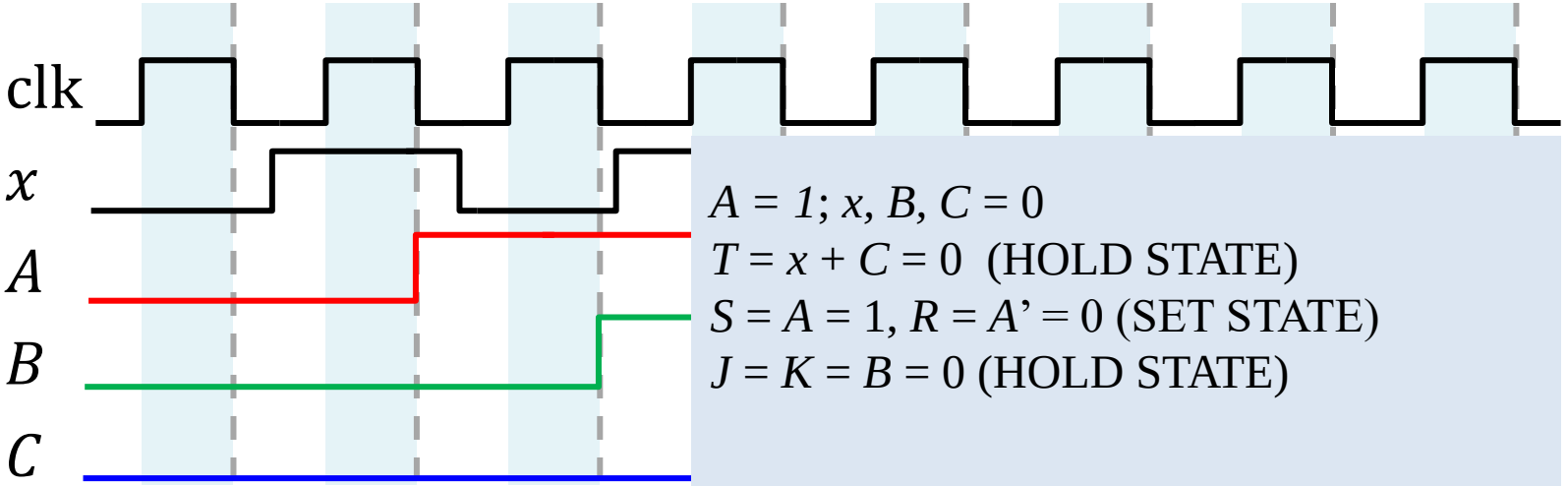
A = 1; x, B, C = 0
T = x + C = 0 (HOLD STATE)
S = A = 1, *R = A'* = 0 (SET STATE)
J = K = B = 0 (HOLD STATE)

Exercise

$T = x + C \qquad S = A \qquad R = A'$

$J = K = B$





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$T = x + C \qquad S = A \qquad R = A'$

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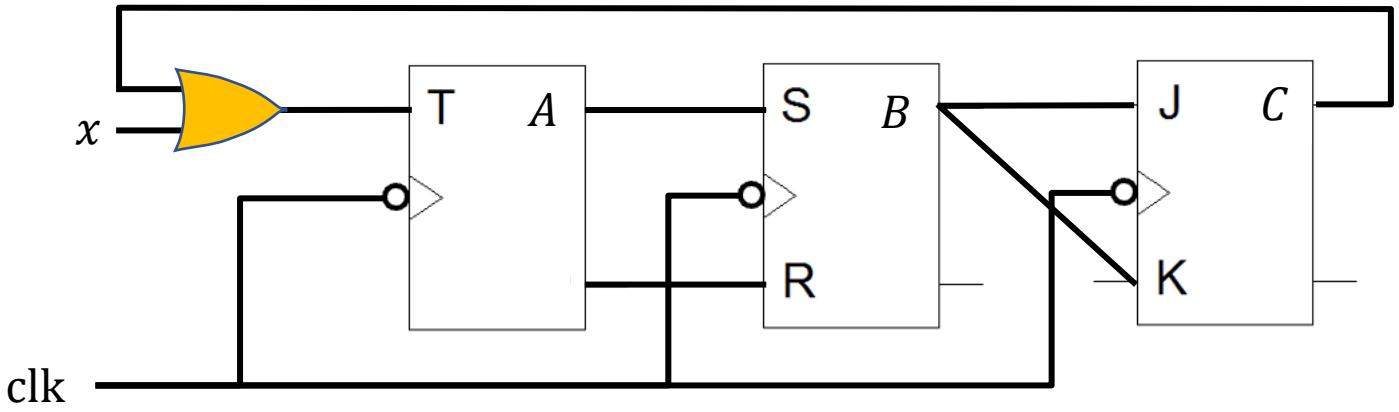
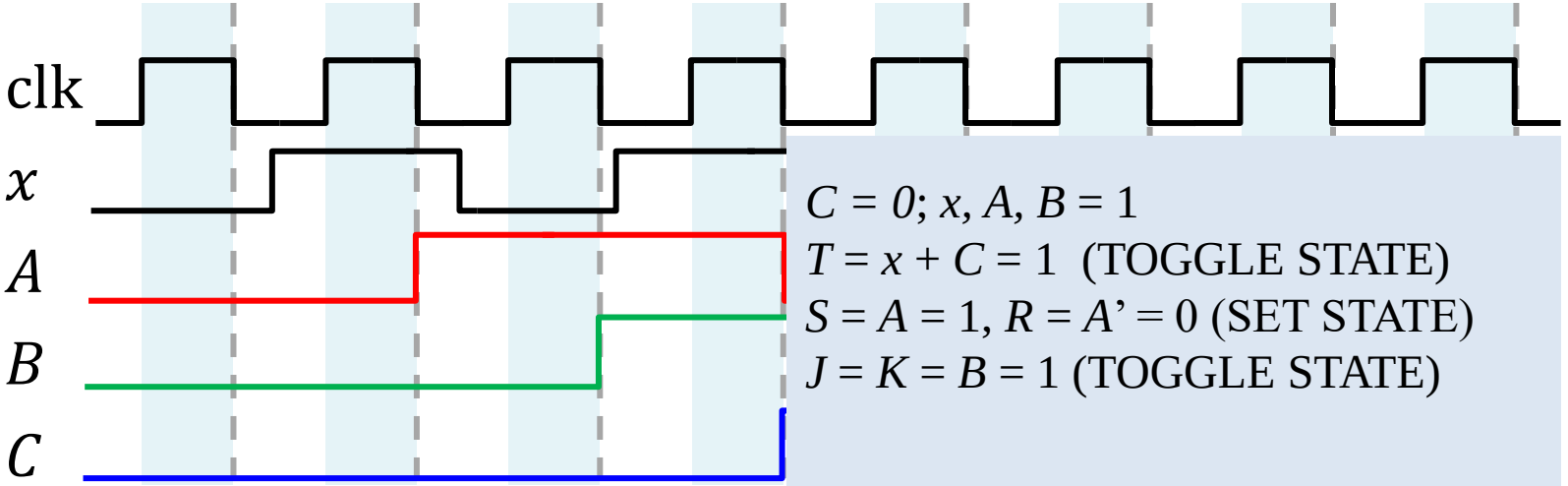




C = 0; *x*, *A*, *B* = 1

T = *x* + *C* = 1 (TOGGLE STATE)

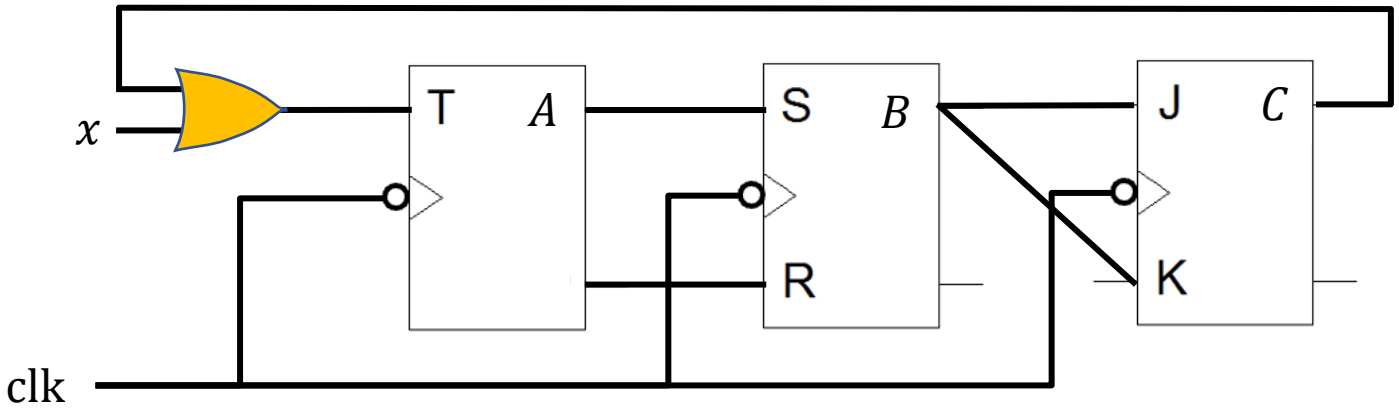
S = *A* = 1, *R* = *A*' = 0 (SET STATE)

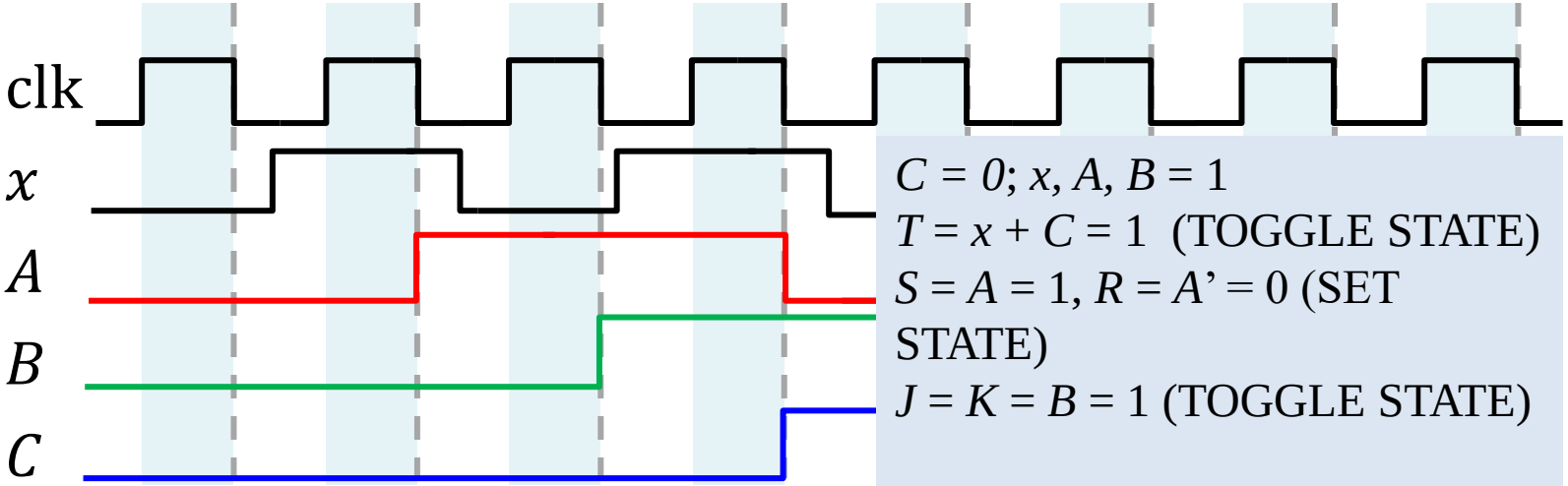
J = *K* = *B* = 1 (TOGGLE STATE)

Exercise

$T = x + C \qquad S = A \qquad R = A'$

$J = K = B$





C = *0*; *x*, *A*, *B* = 1
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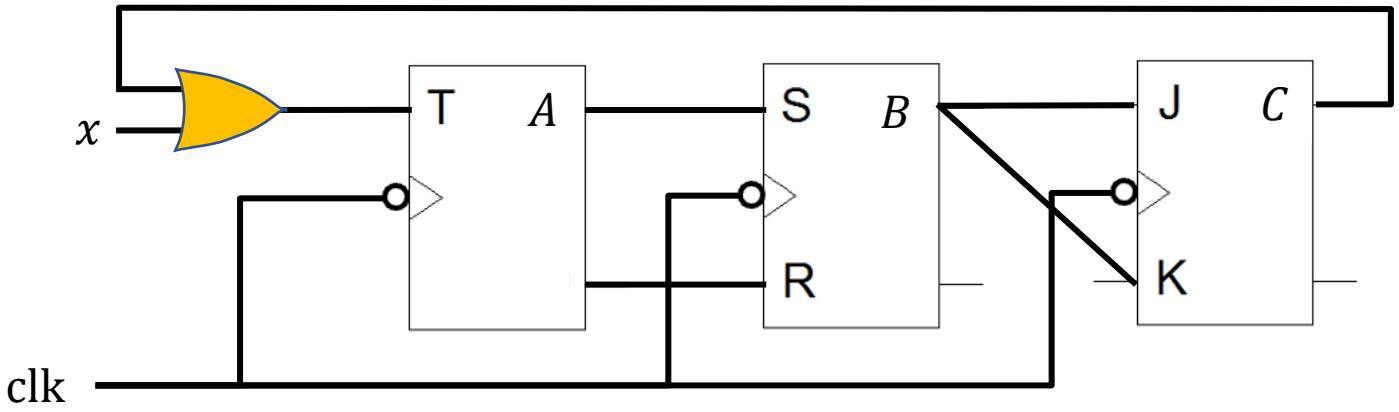
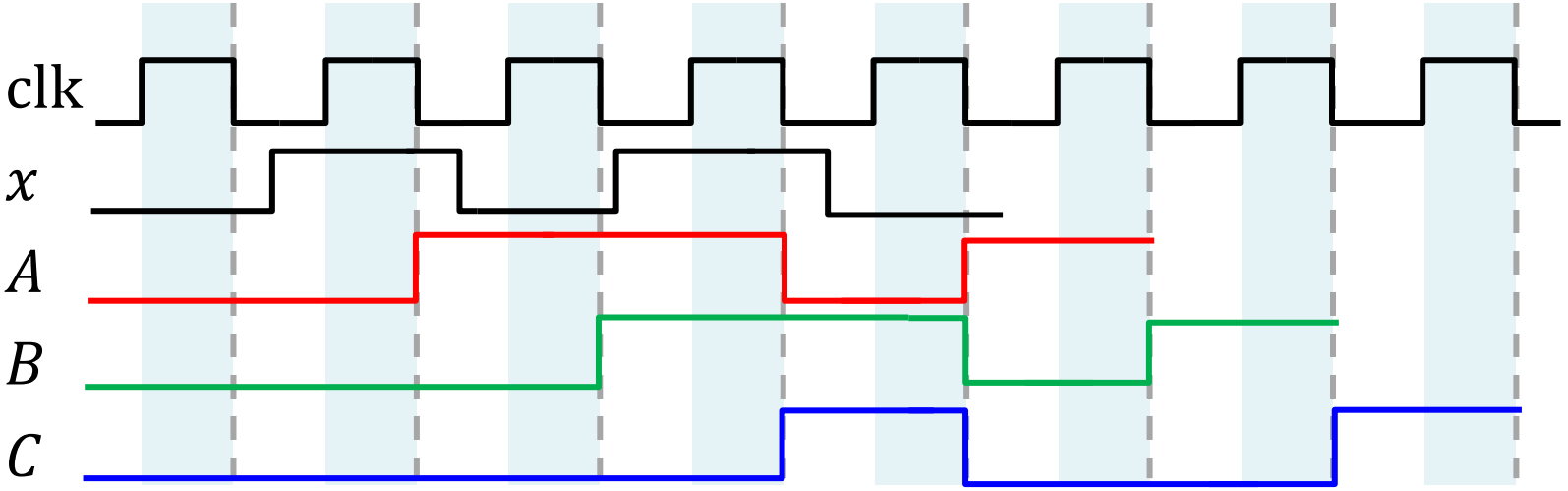
Exercise

$T = x + C \qquad S = A \qquad R = A'$

$J = K = B$





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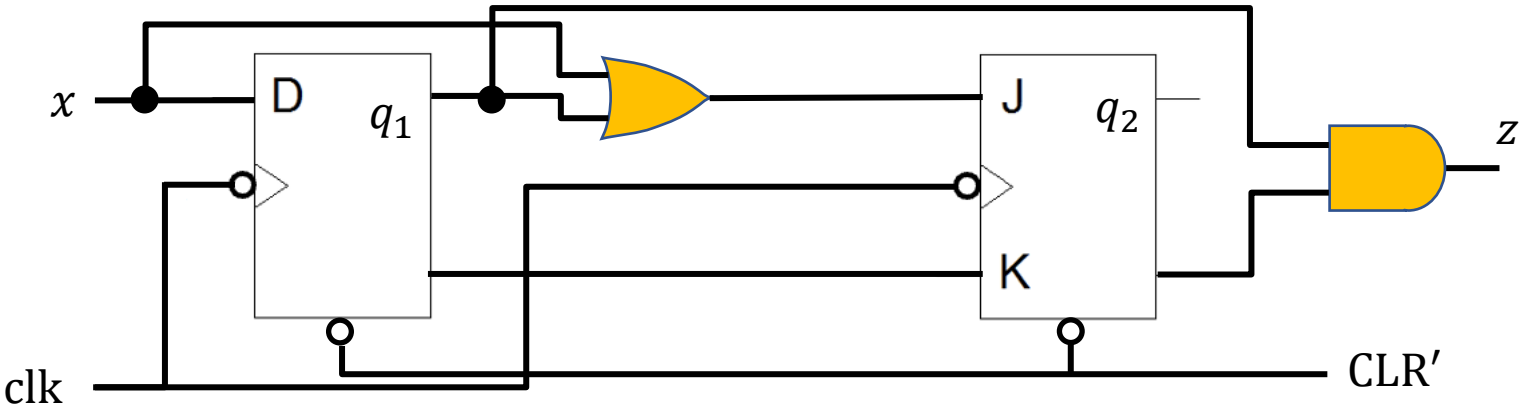
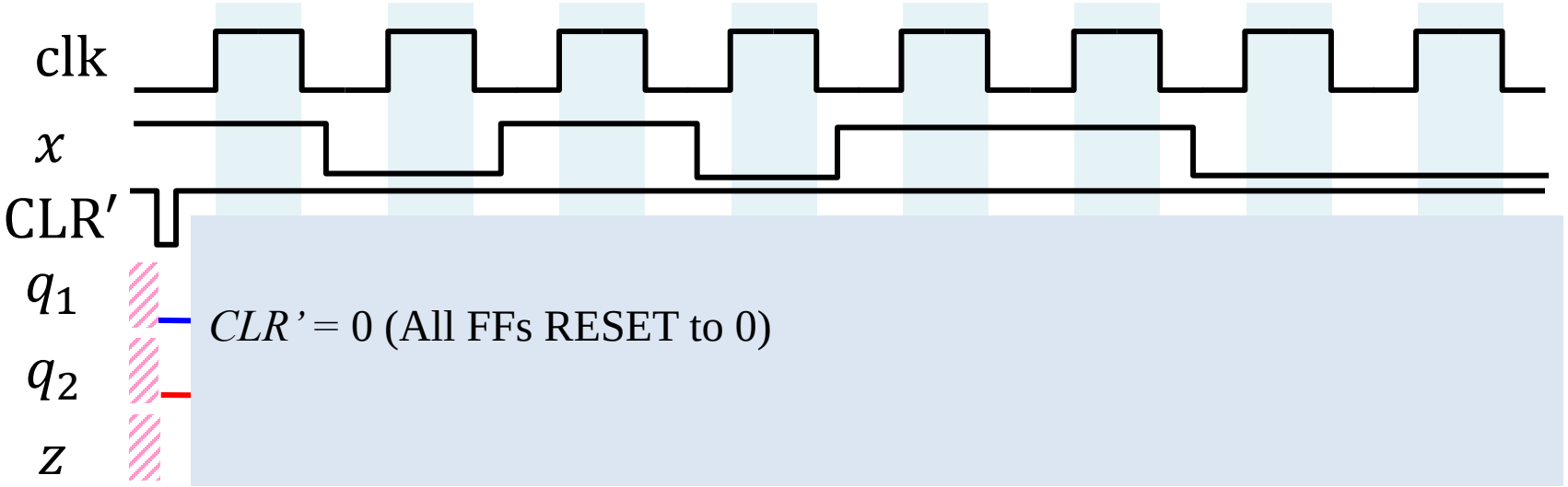
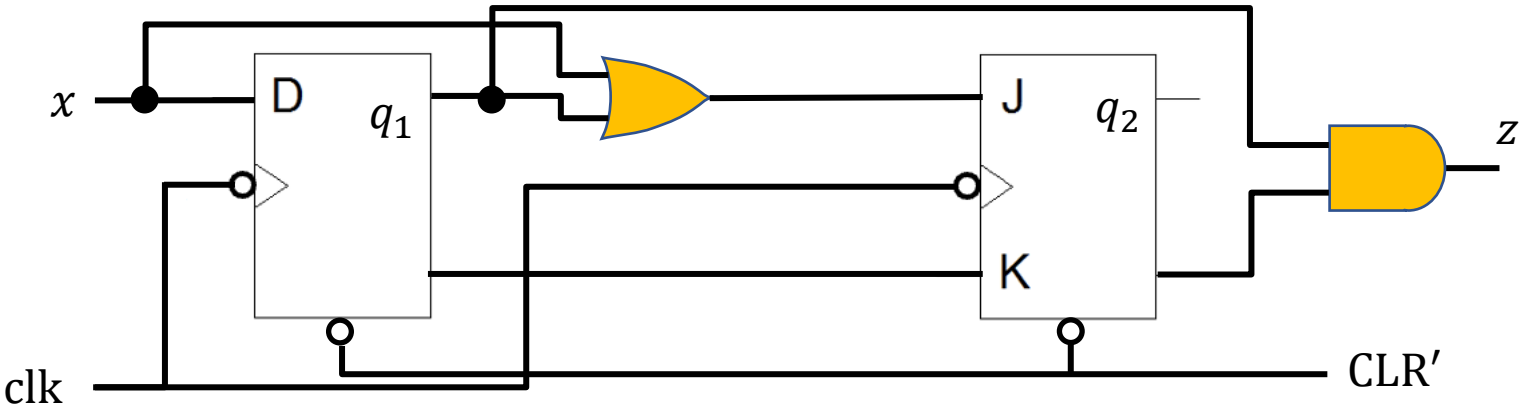


$$D = x$$
$$K = \overline{q_1}$$
$$J = x + q_1$$
$$z = q_1\overline{q_2}$$



Exercise

Ignore *z* first because *z* is a combinational circuit



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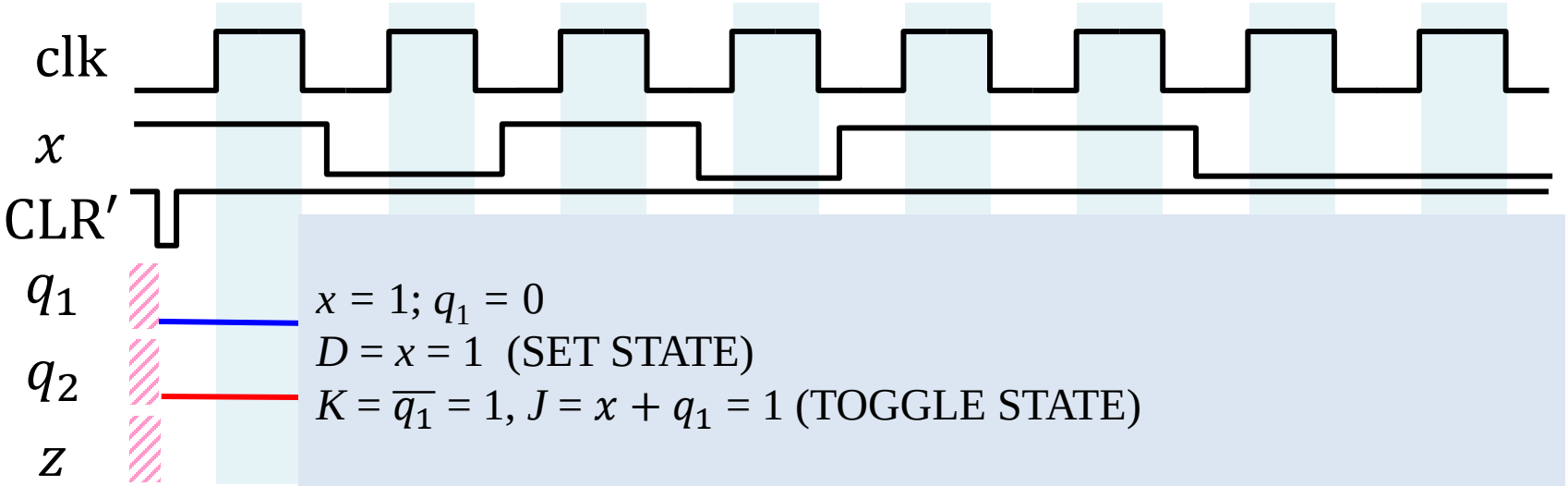

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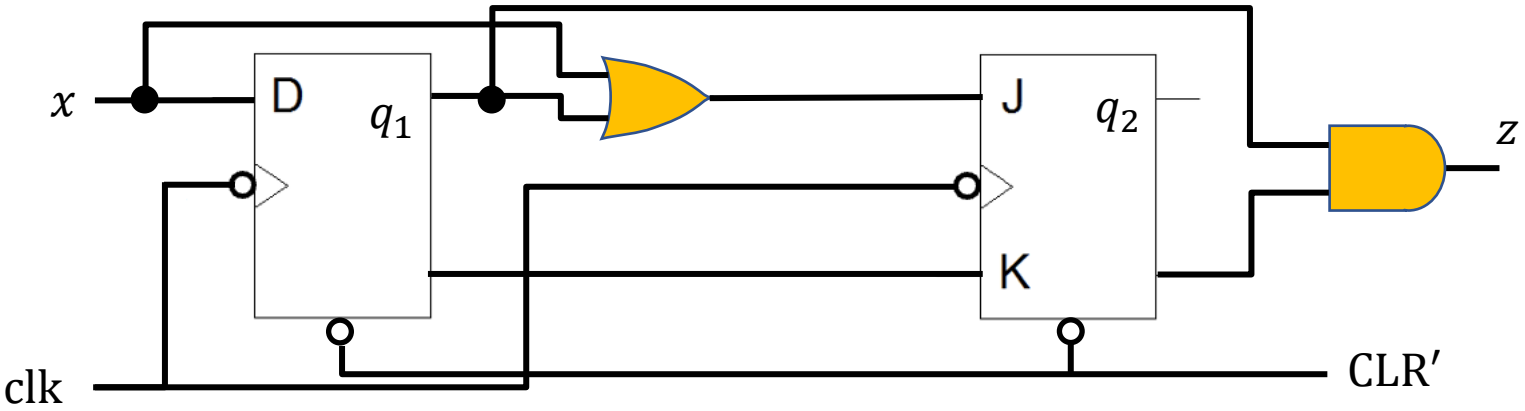

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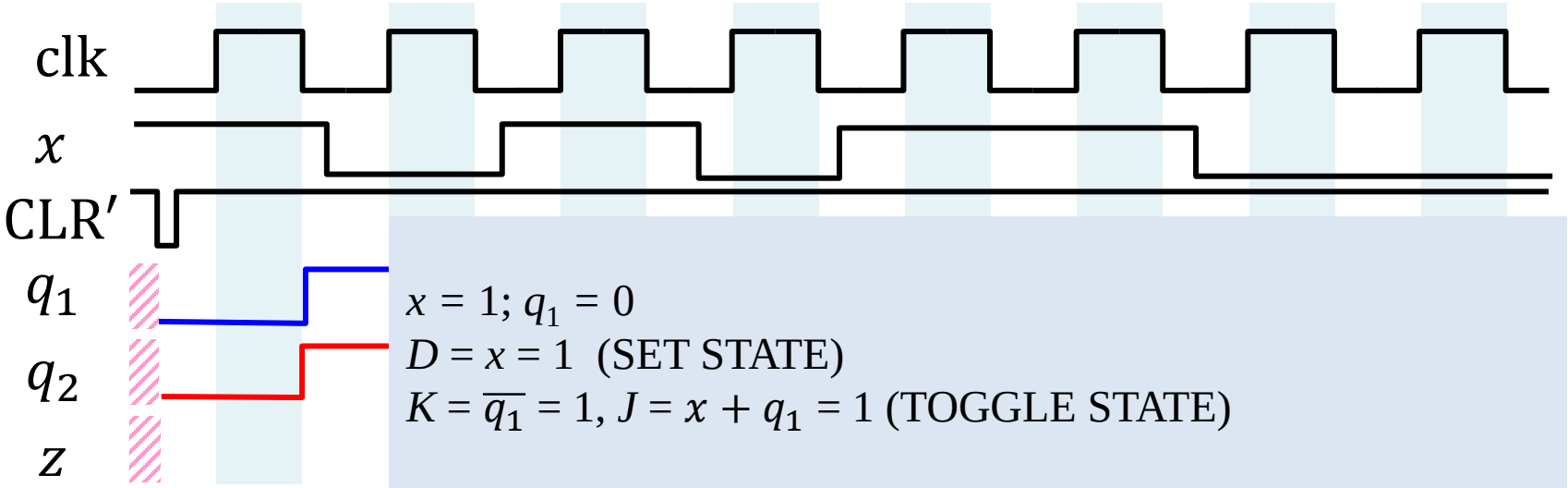
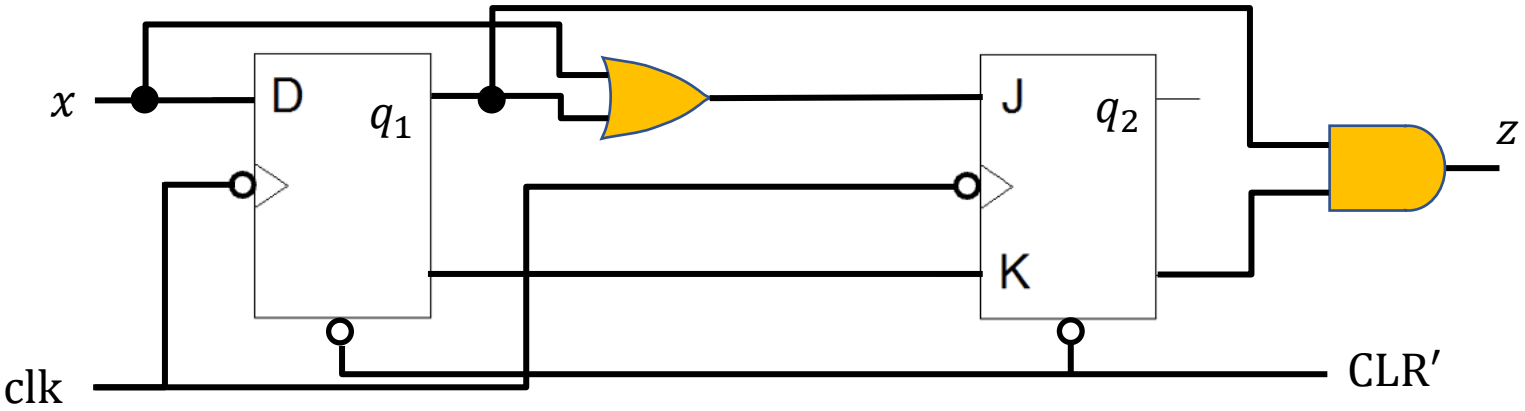


$x = 1$; $q_1 = 0$
$D = x = 1$ (SET STATE)
$K = \overline{q_1} = 1$, $J = x + q_1 = 1$ (TOGGLE STATE)

Exercise



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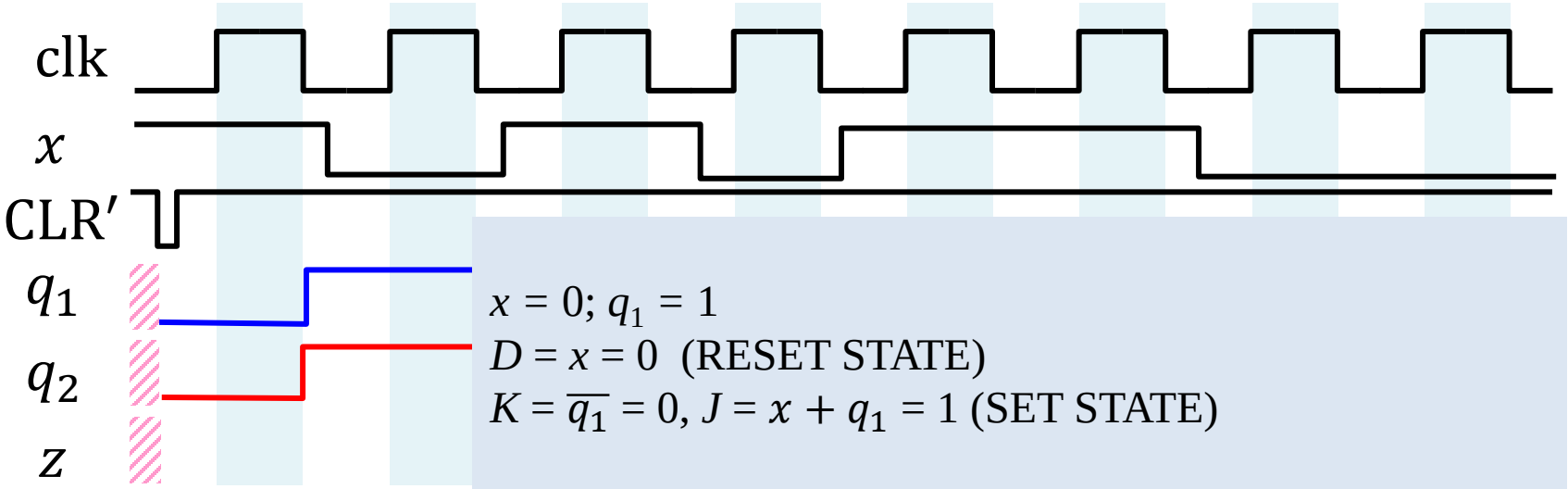

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$D = x = 0$ (RESET STATE)
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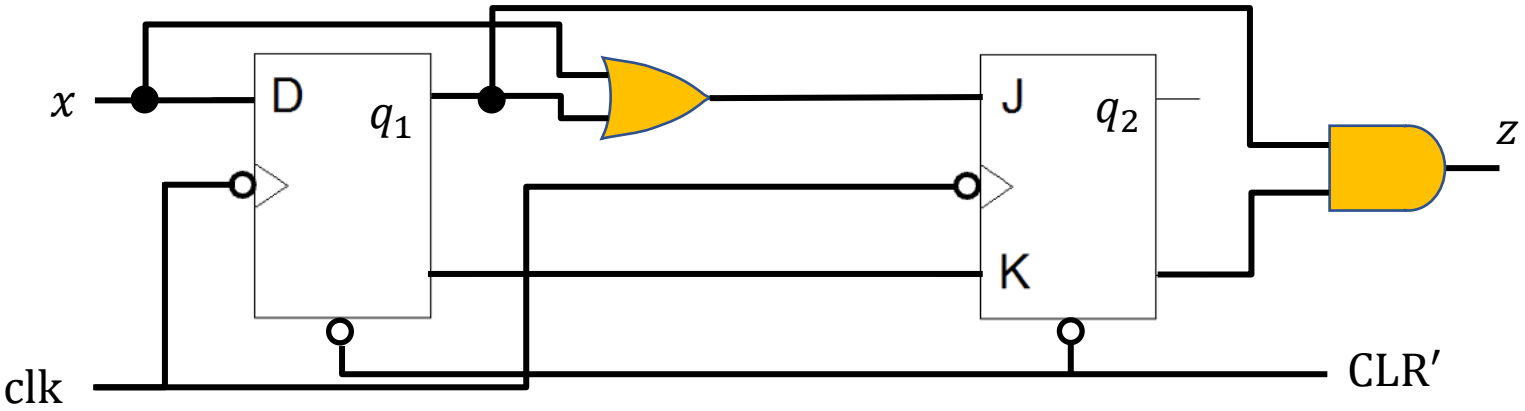
Exercise



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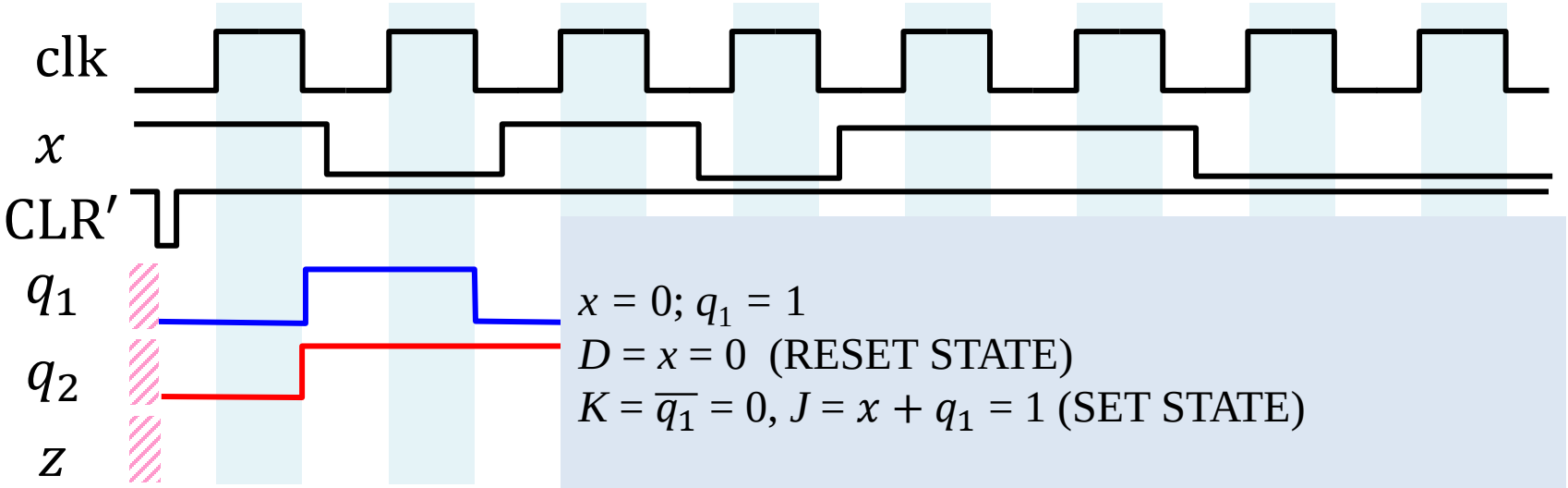

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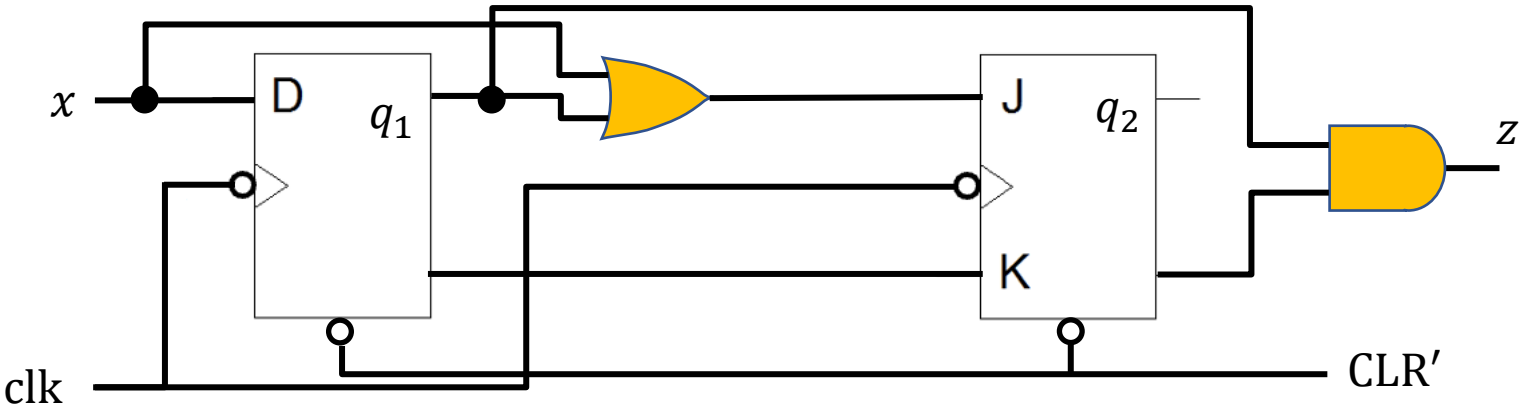

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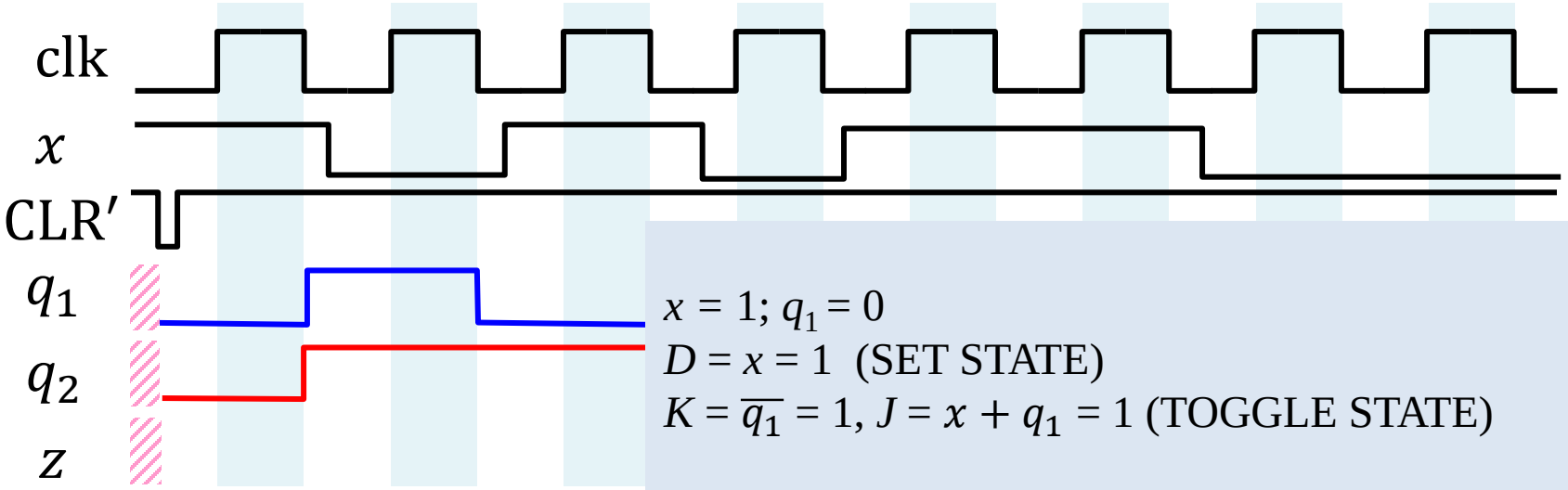

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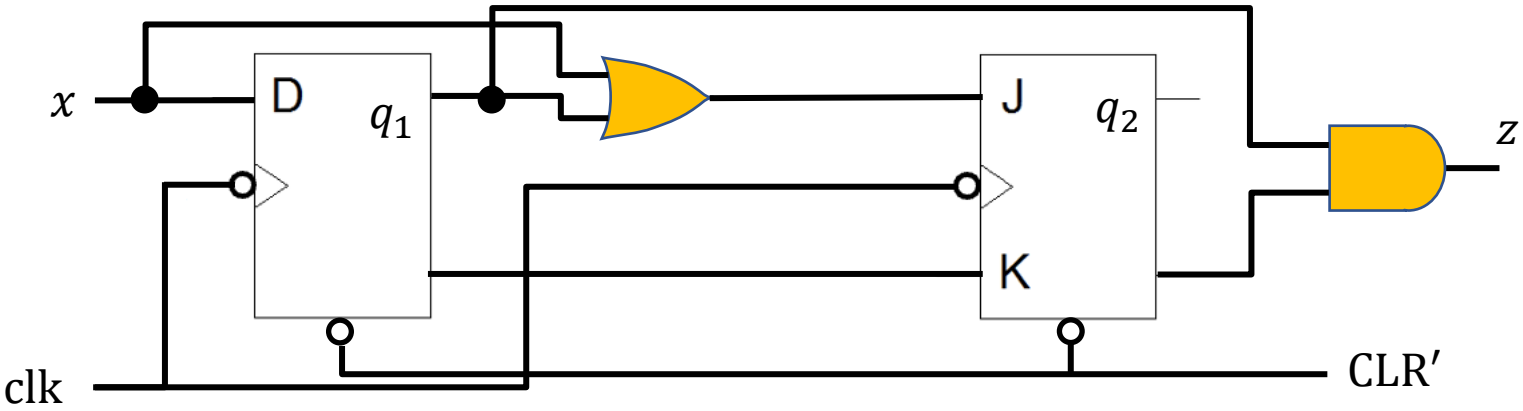

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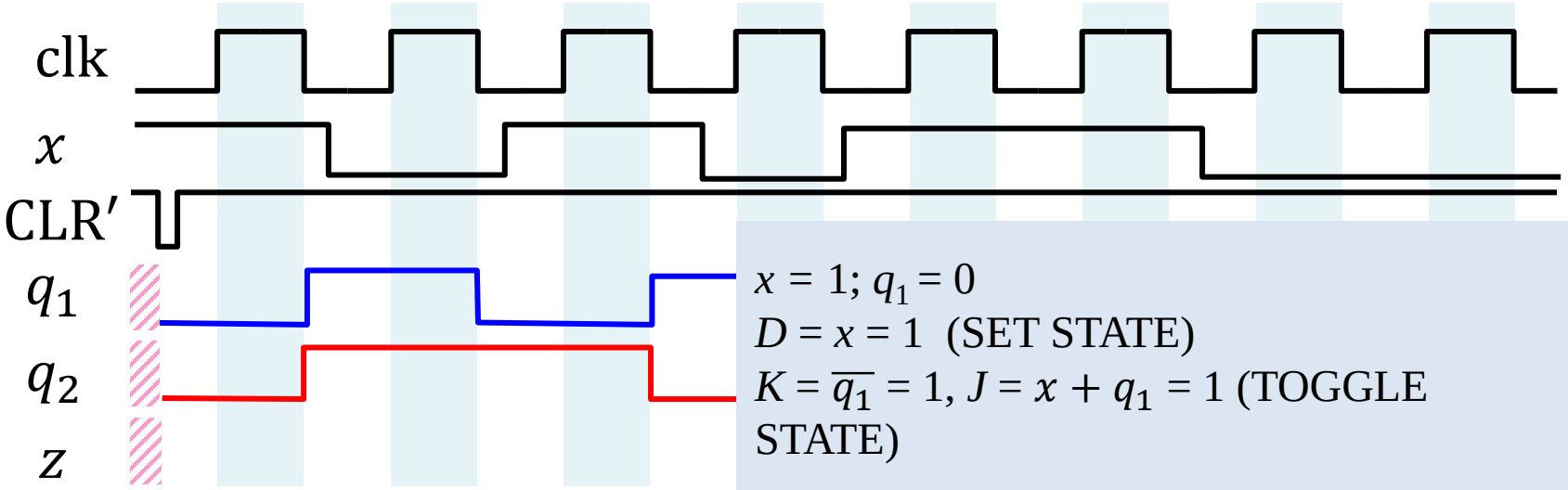

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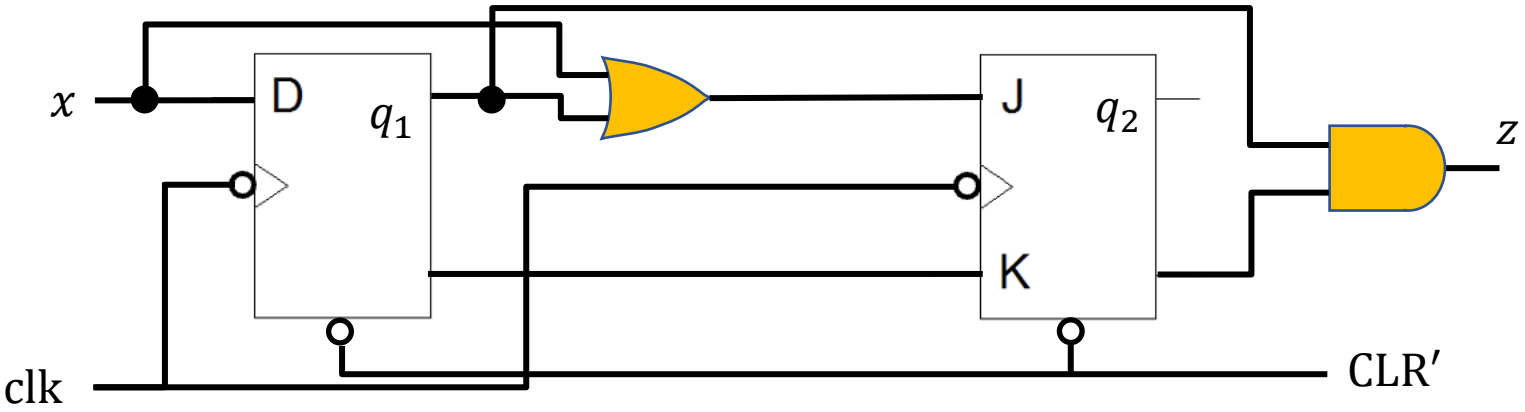

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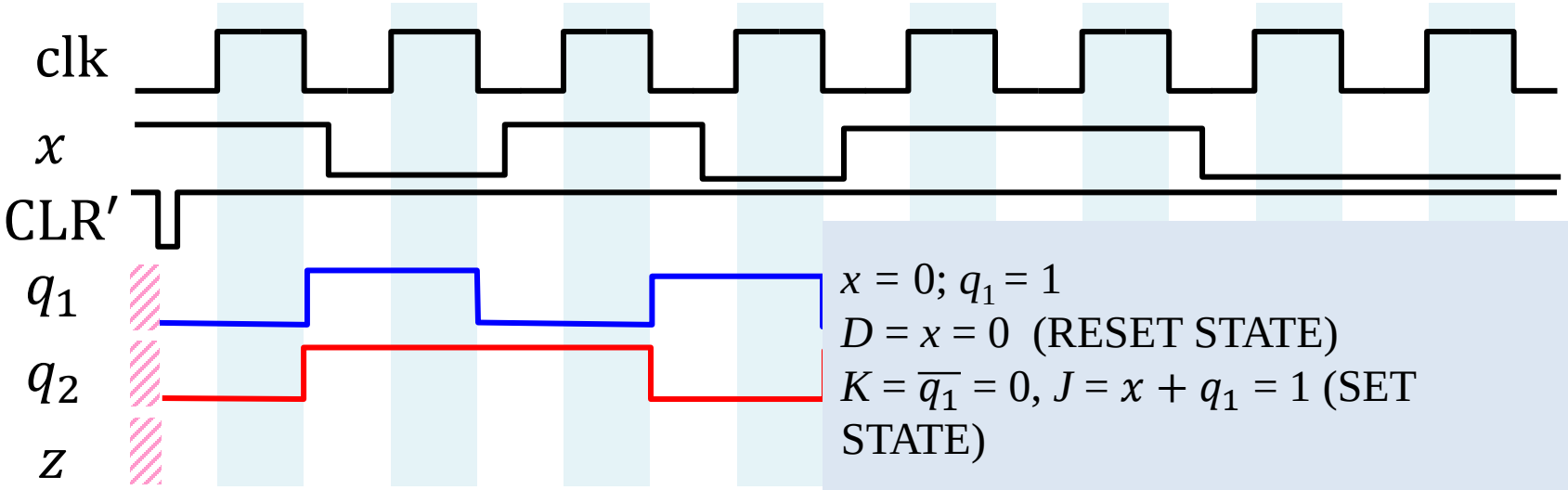

$x = 0$; $q_1 = 1$
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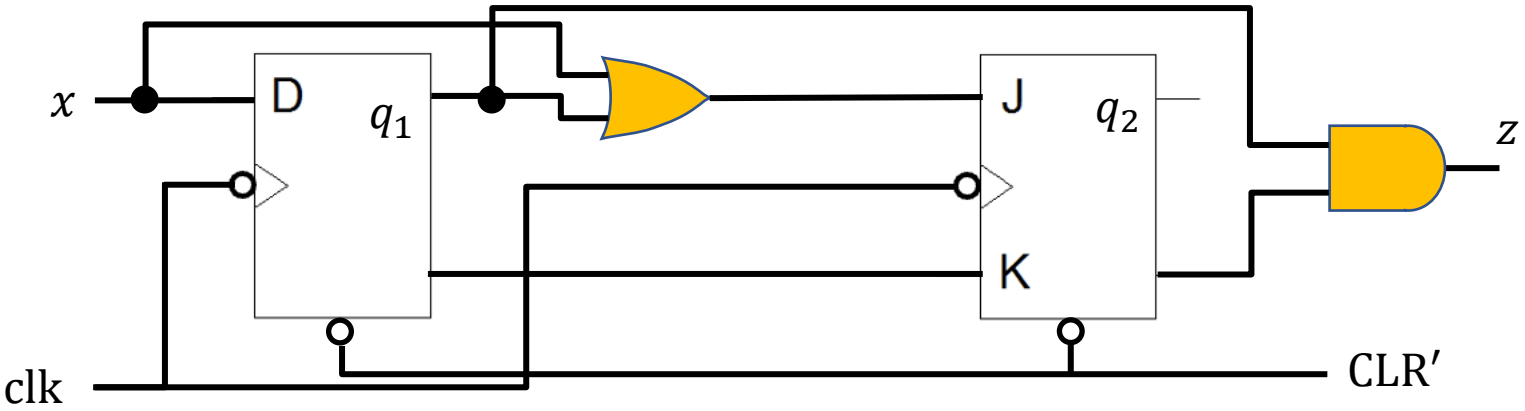
Exercise



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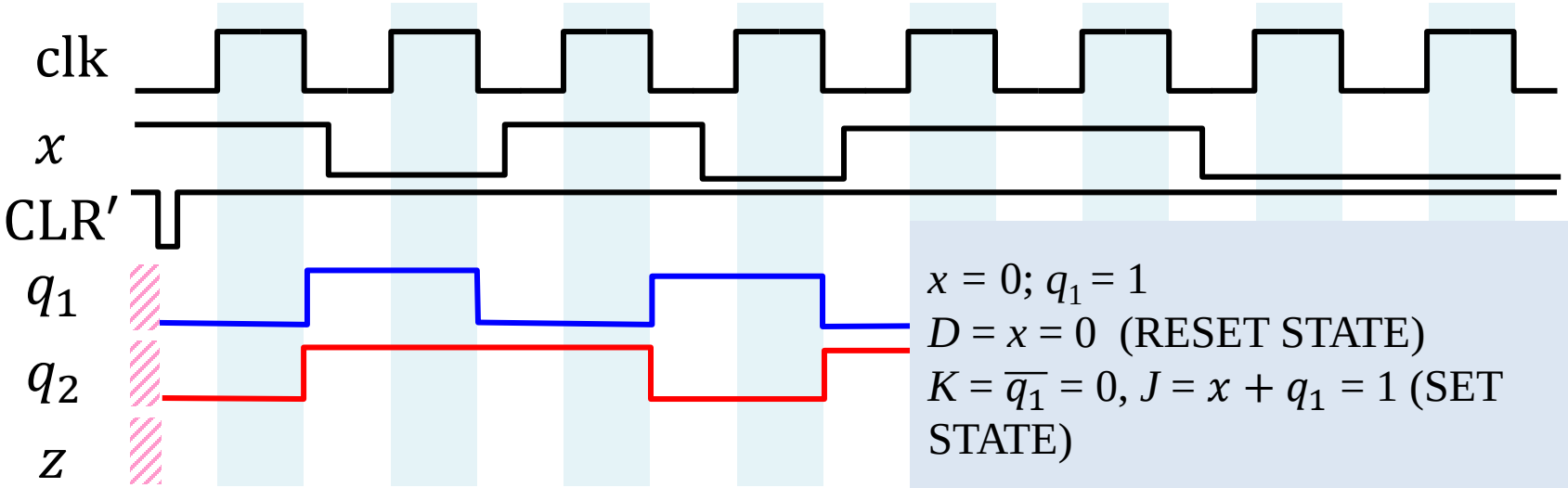

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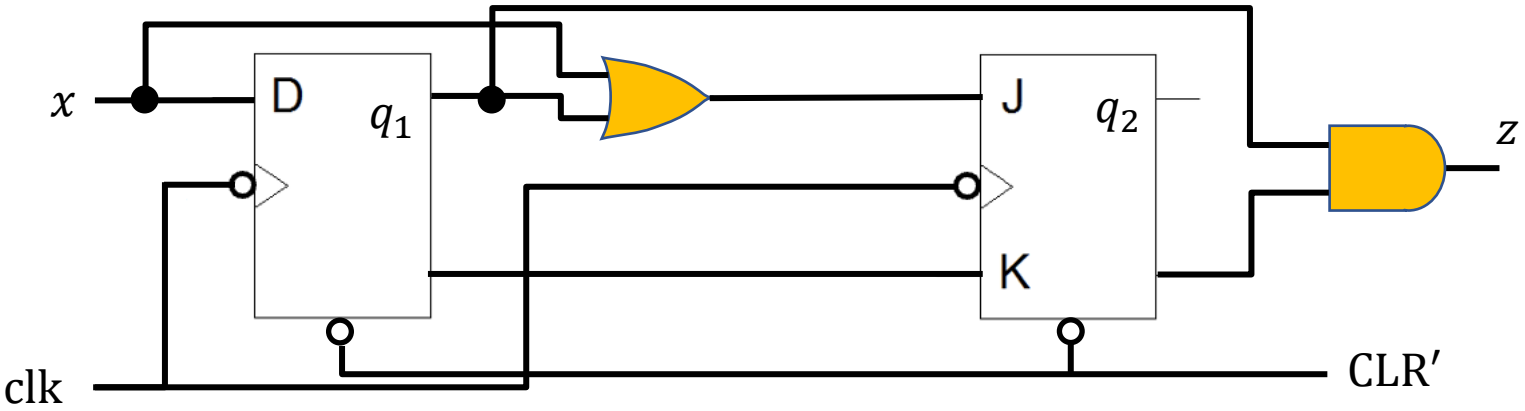
Exercise



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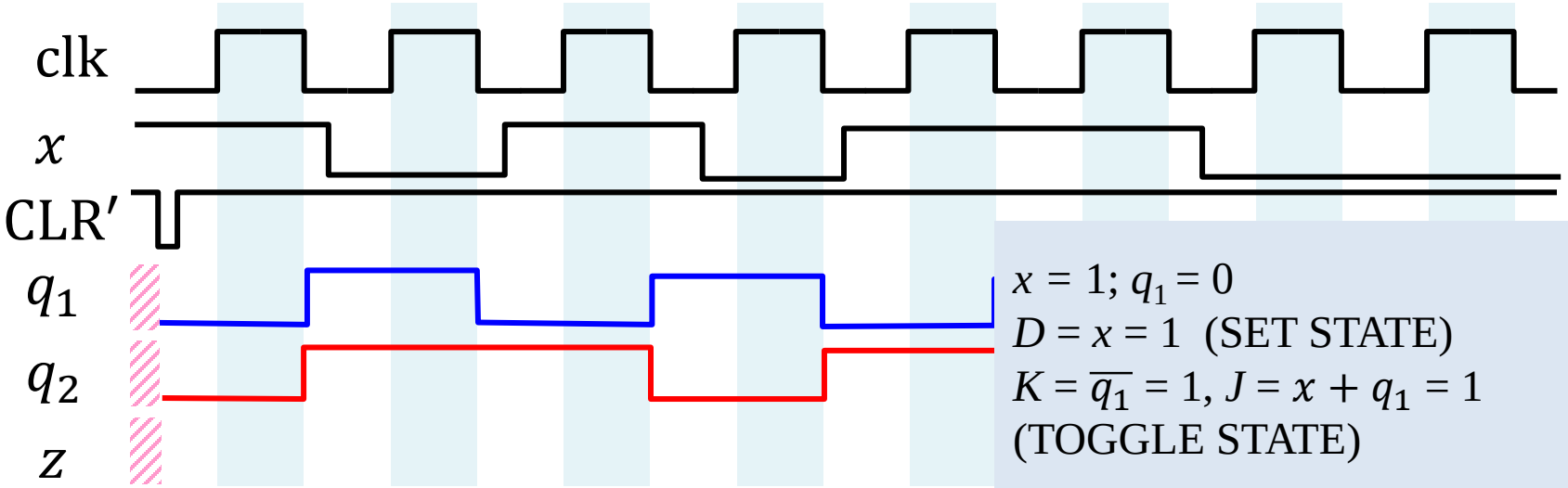

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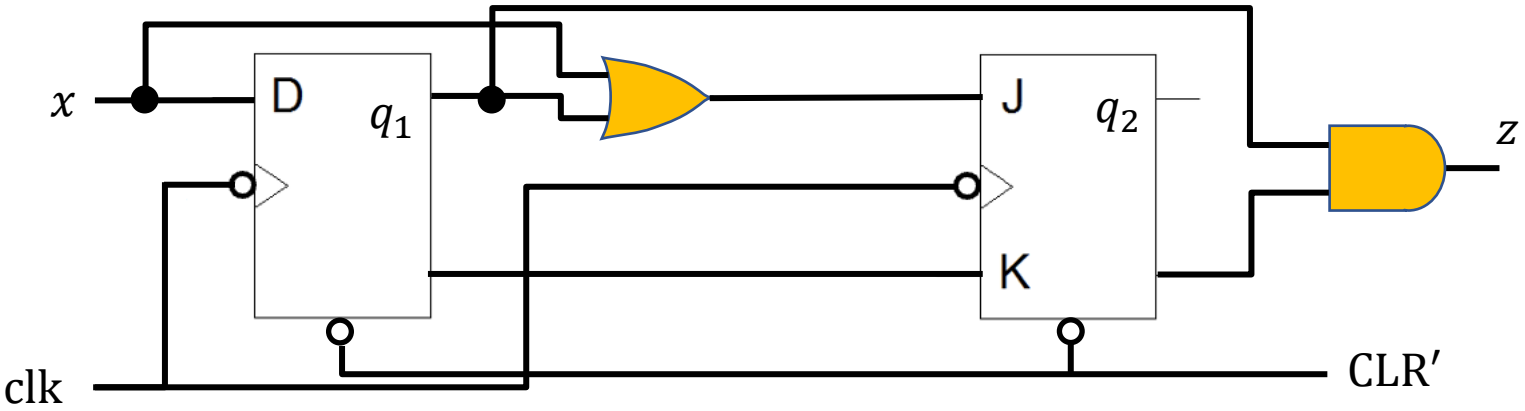

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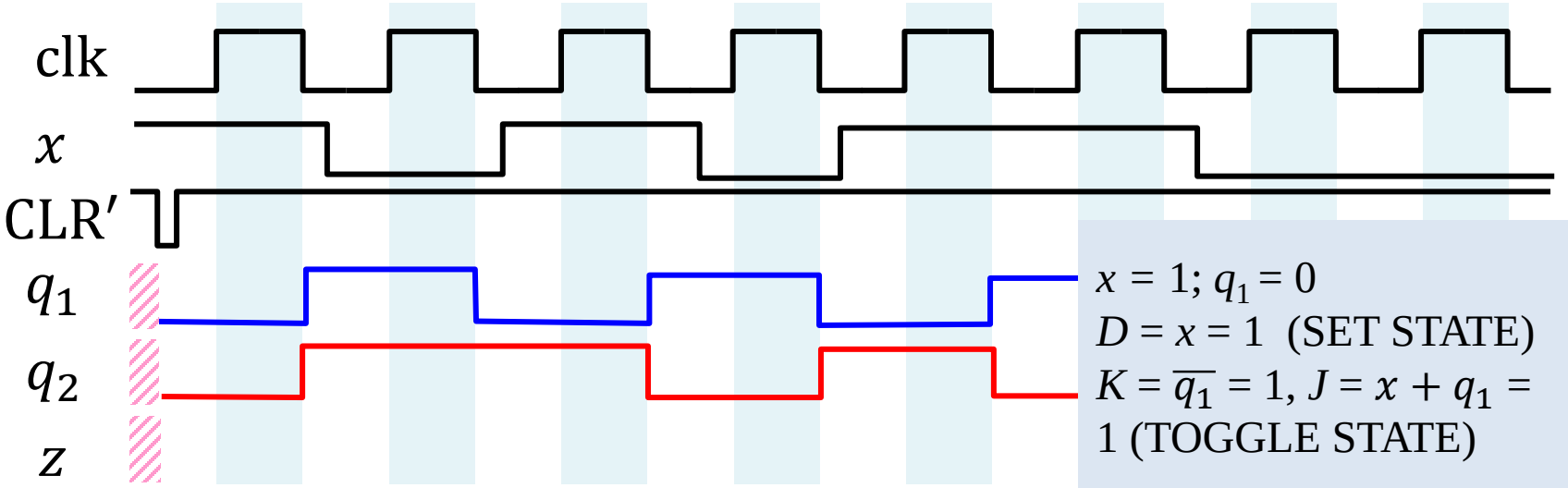

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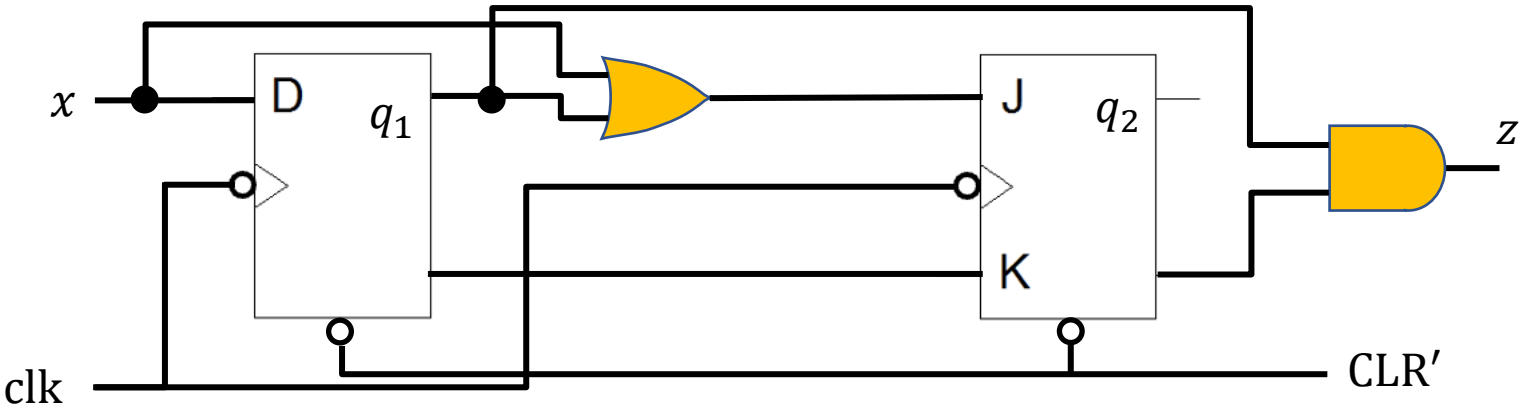

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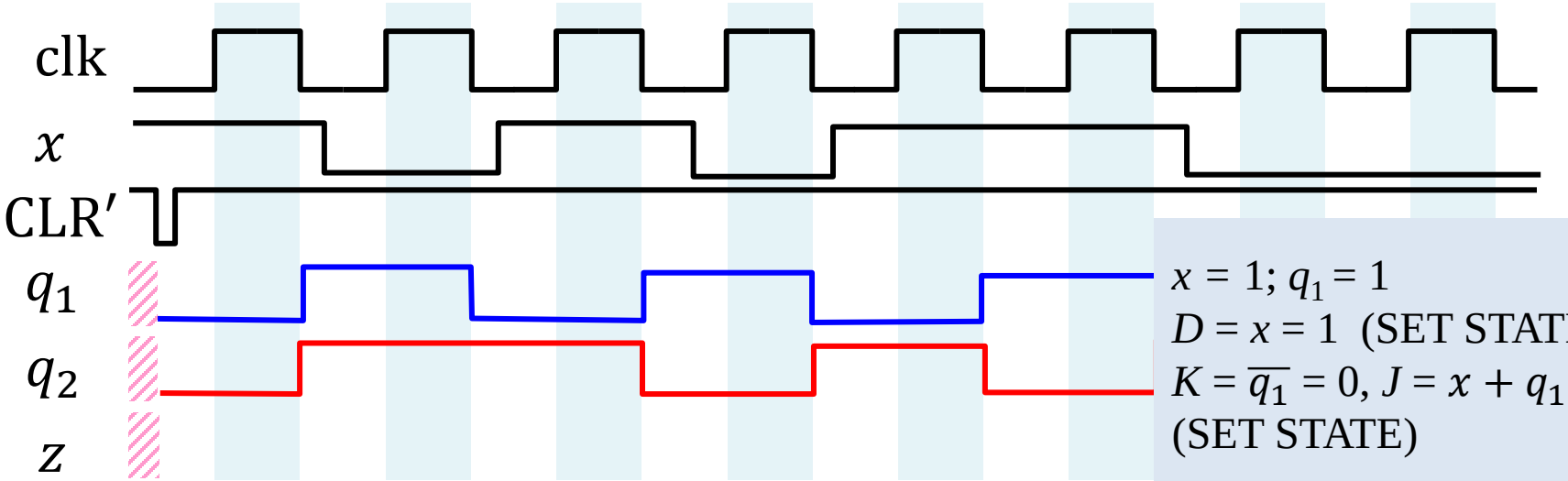
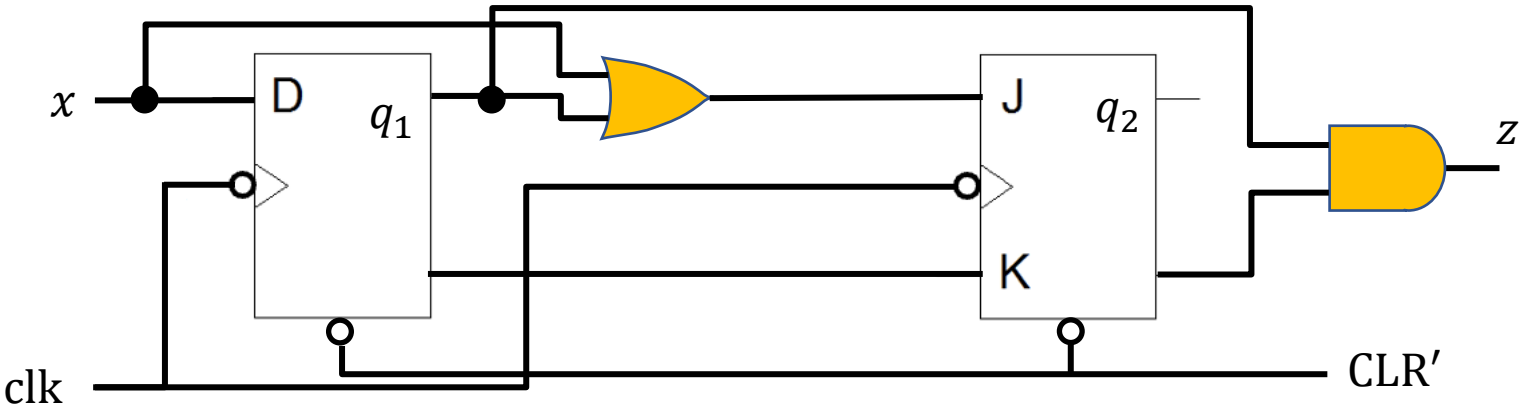
$$J = x + q_1$$
$$z = q_1\overline{q_2}$$

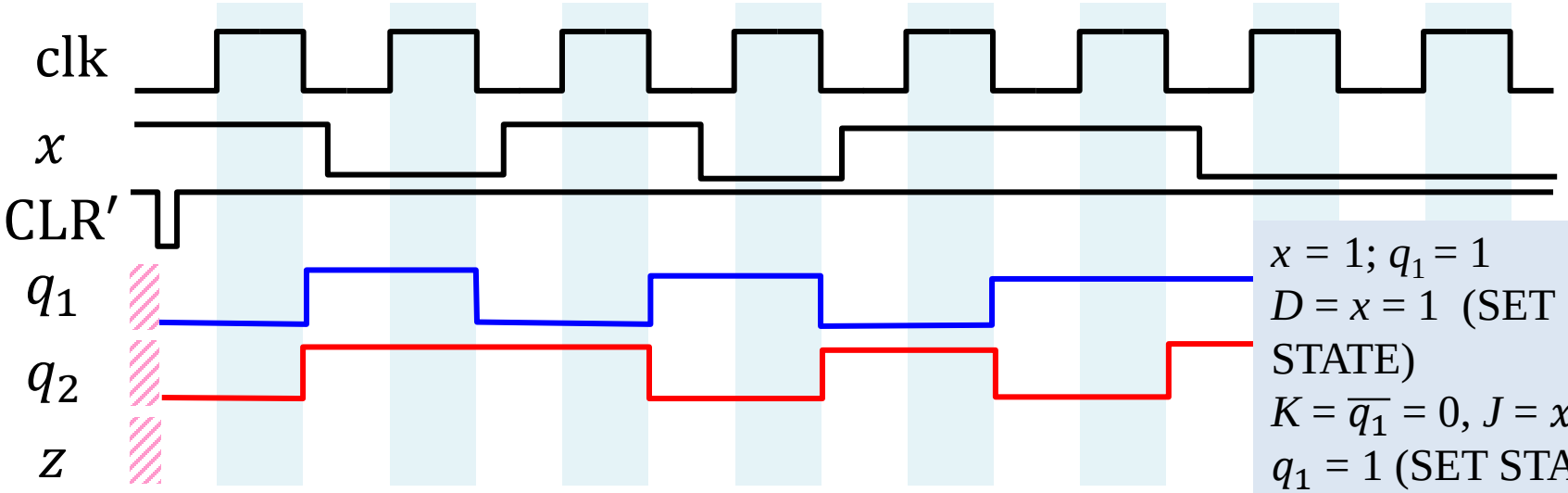


$x = 1$; $q_1 = 1$
$D = x = 1$ (SET STATE)
$K = \overline{q_1} = 0$, $J = x + q_1 = 1$
(SET STATE)

Exercise

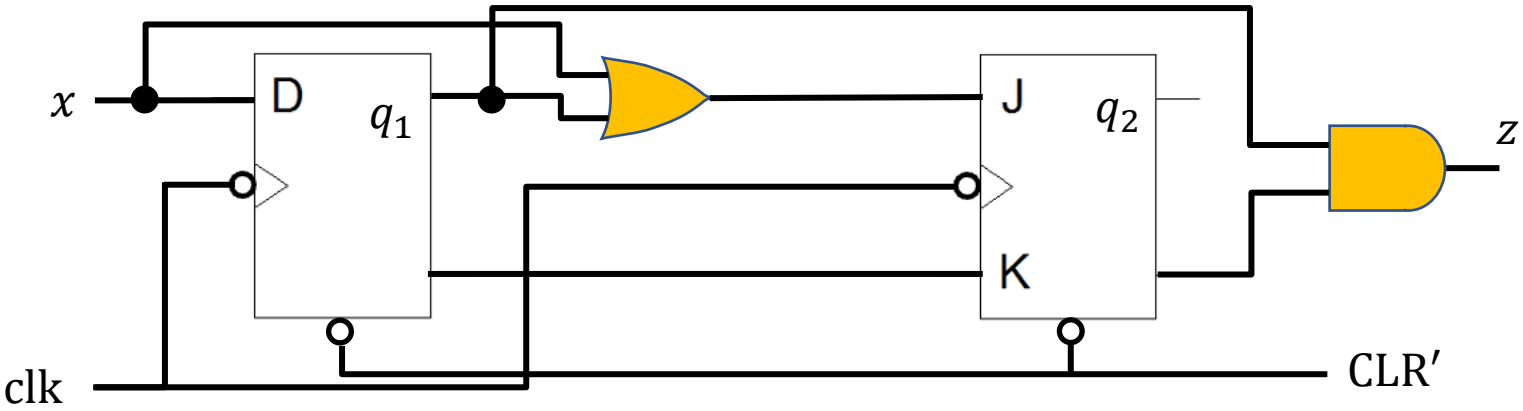


$$D = x$$
$$K = \overline{q_1}$$
$$J = x + q_1$$
$$z = q_1\overline{q_2}$$

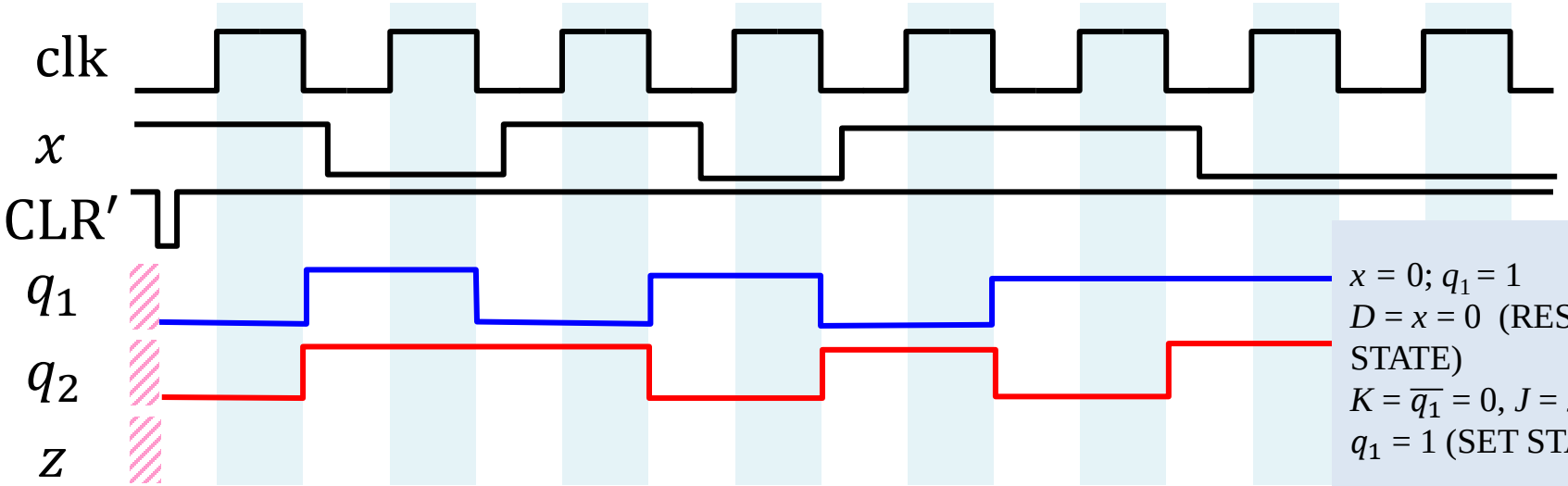


$x = 1$; $q_1 = 1$
$D = x = 1$ (SET STATE)
$K = \overline{q_1} = 0$, $J = x + q_1 = 1$ (SET STATE)

Exercise

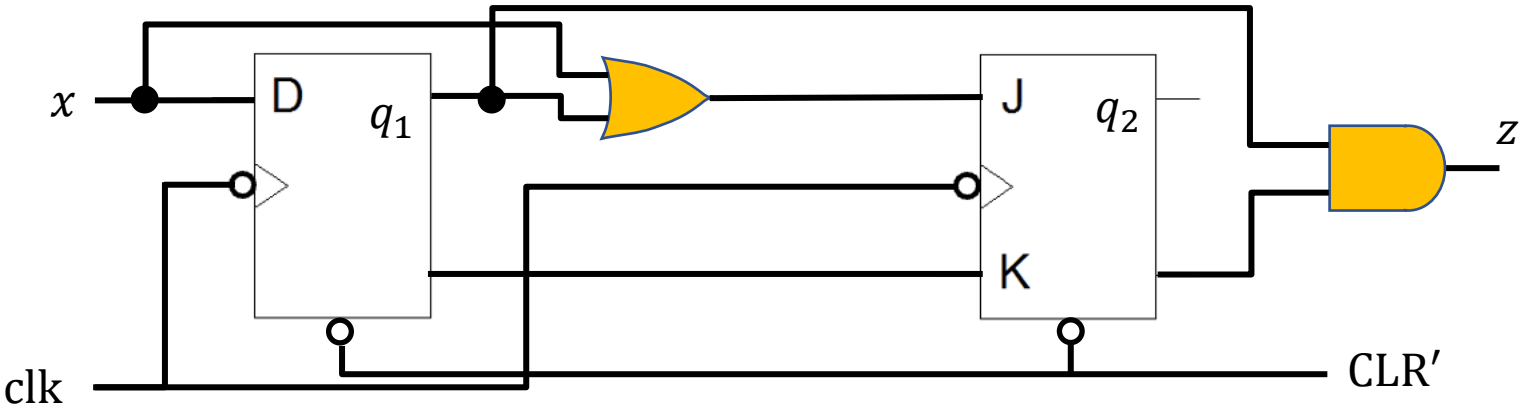


$$D = x$$
$$K = \overline{q_1}$$
$$J = x + q_1$$
$$z = q_1\overline{q_2}$$

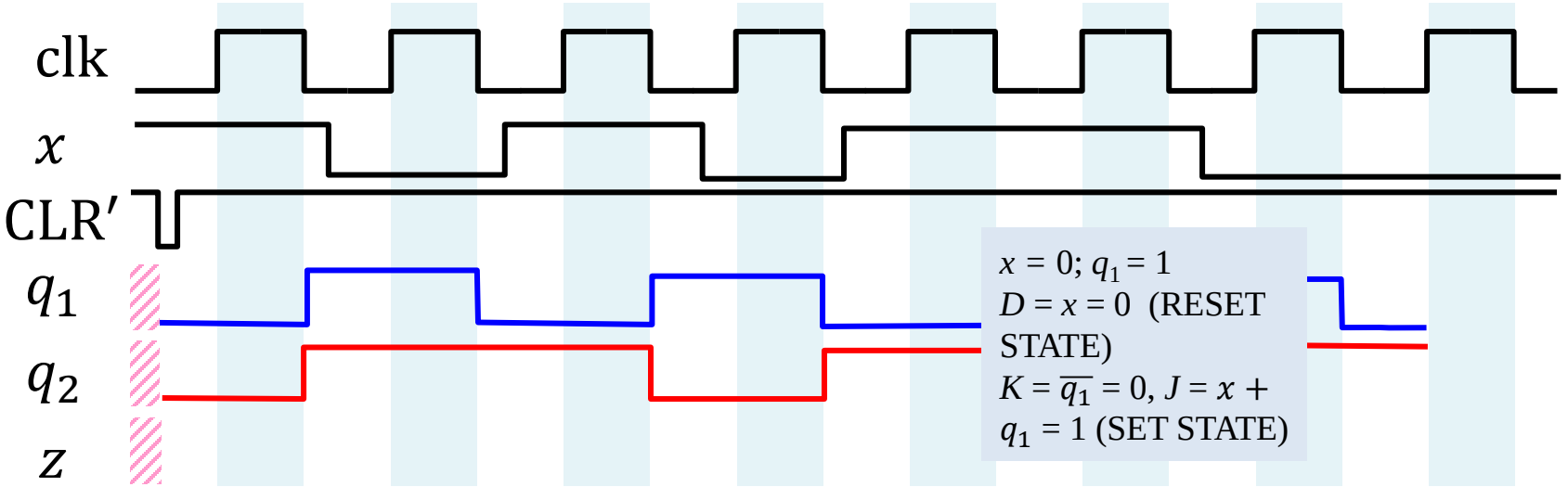


$x = 0$; $q_1 = 1$
$D = x = 0$ (RESET STATE)
$K = \overline{q_1} = 0$, $J = x + q_1 = 1$ (SET STATE)

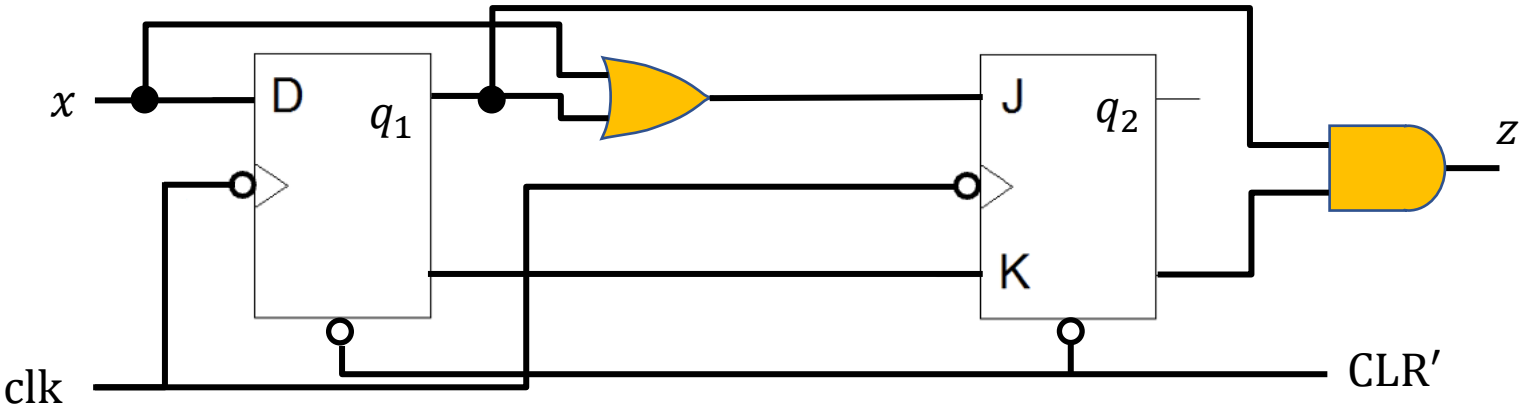
Exercise



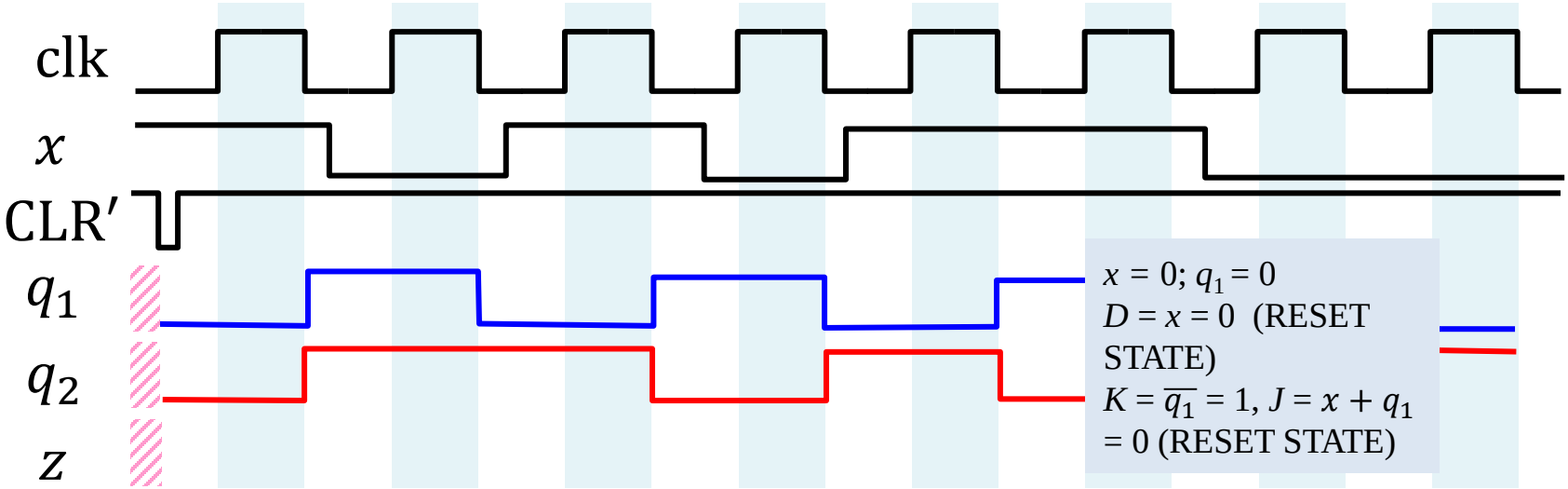
$$D = x$$
$$K = \overline{q_1}$$
$$J = x + q_1$$
$$z = q_1\overline{q_2}$$



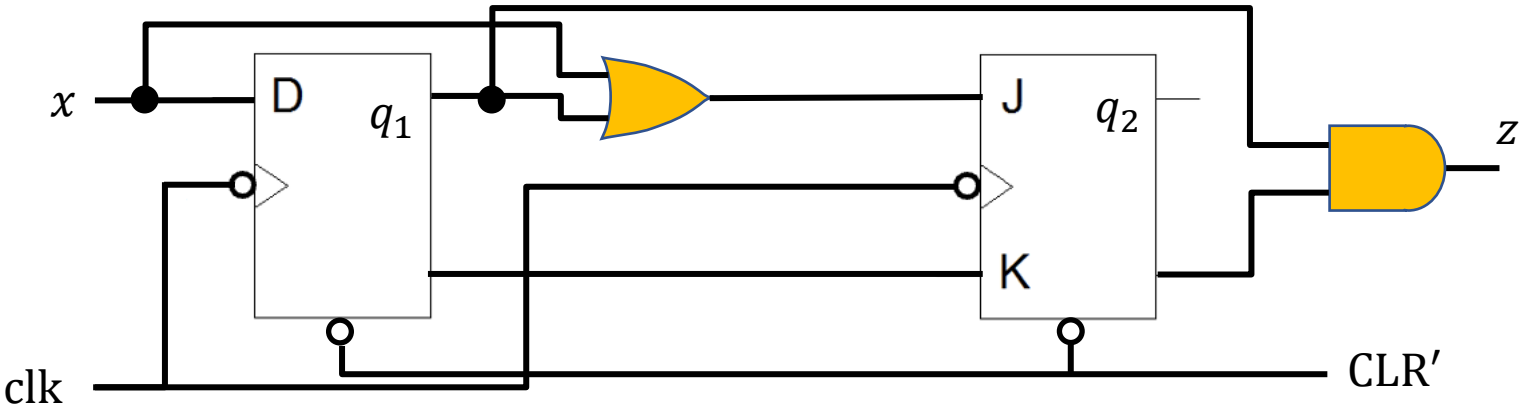
Exercise



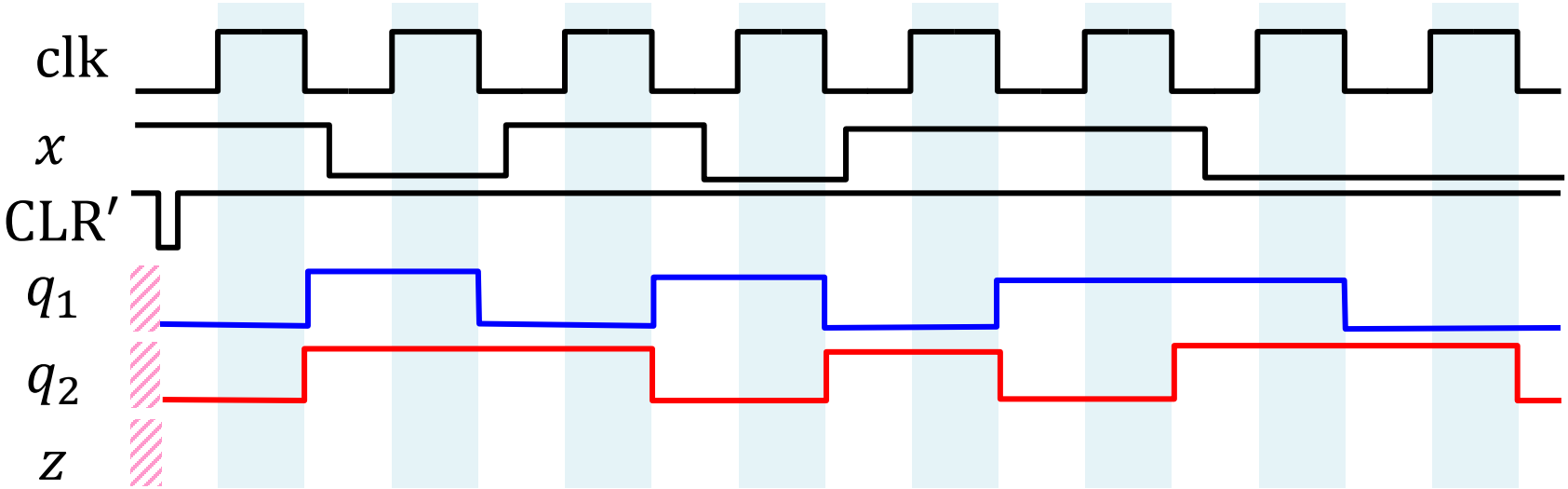
$$D = x$$
$$K = \overline{q_1}$$
$$J = x + q_1$$
$$z = q_1\overline{q_2}$$



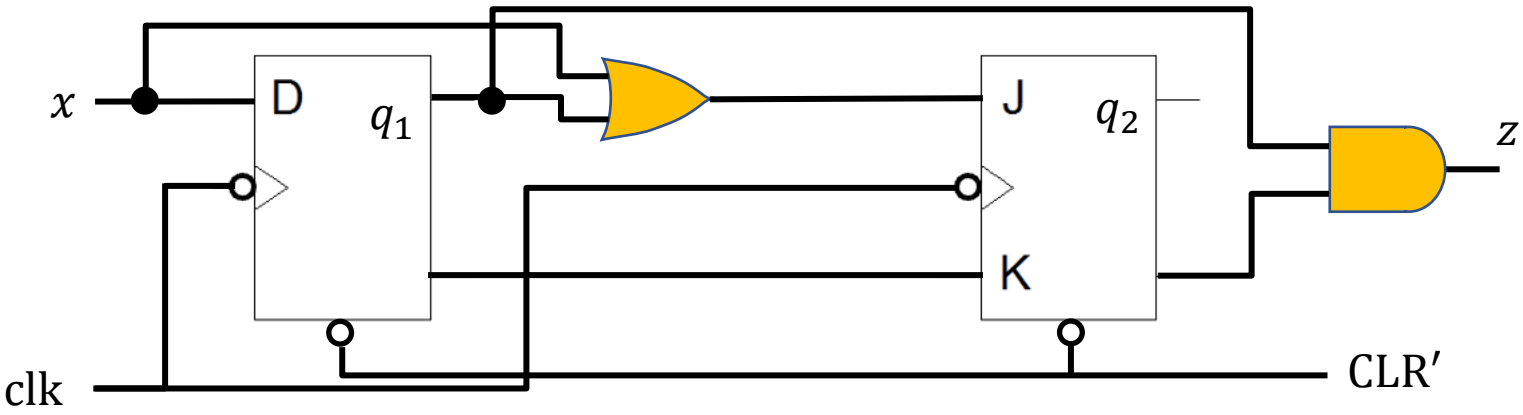
Exercise



$$D = x$$
$$K = \overline{q_1}$$
$$J = x + q_1$$
$$z = q_1\overline{q_2}$$



Exercise

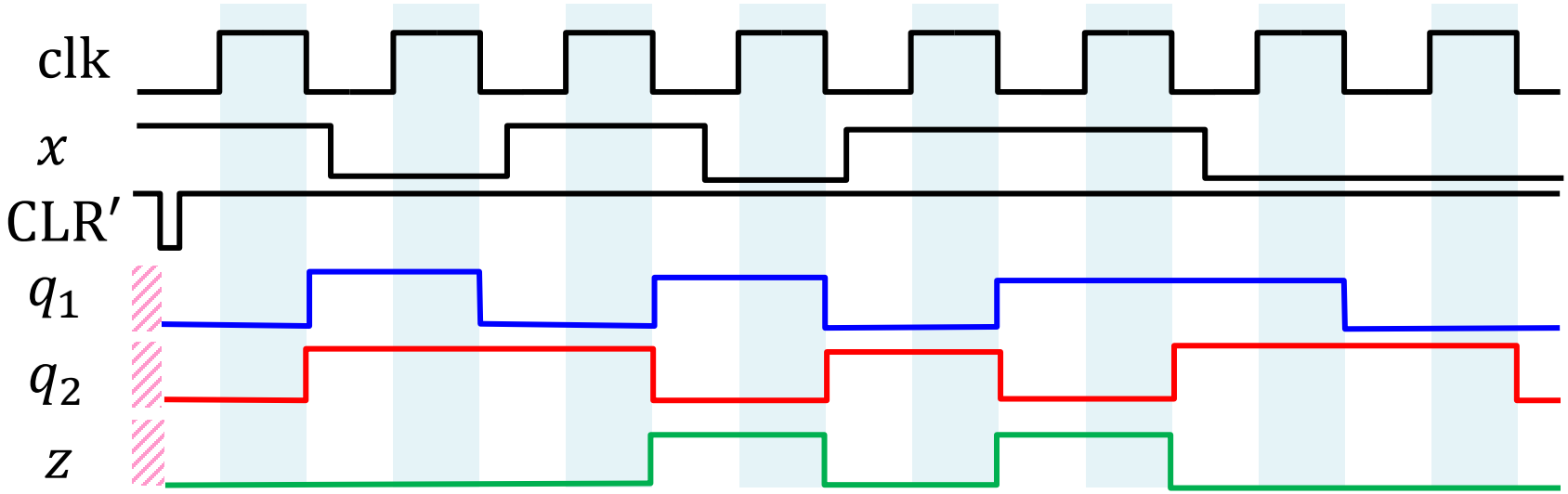


$D = x$

$K = \overline{q_1}$

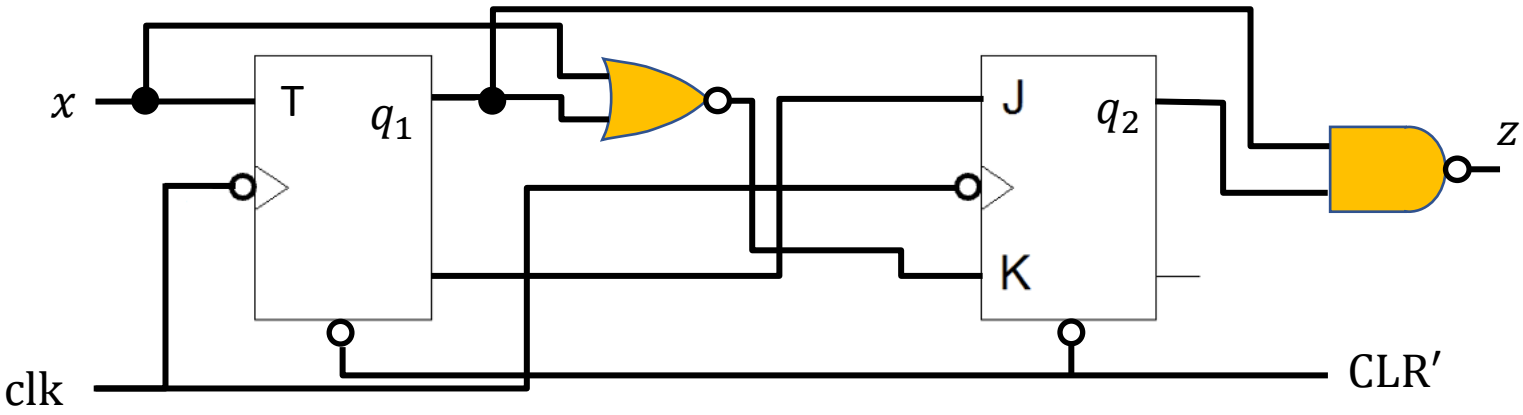
$z = q_1\overline{q_2}$

$J = x + q_1$



Final Step: Work out *z*

Exercise

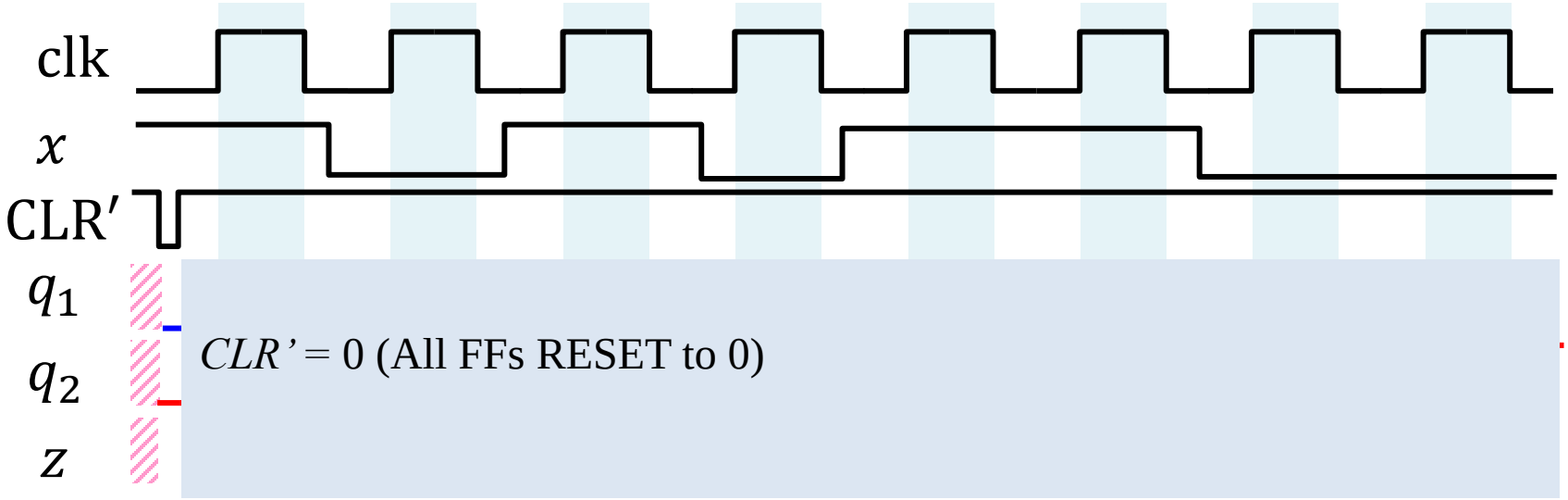


$$T = x$$

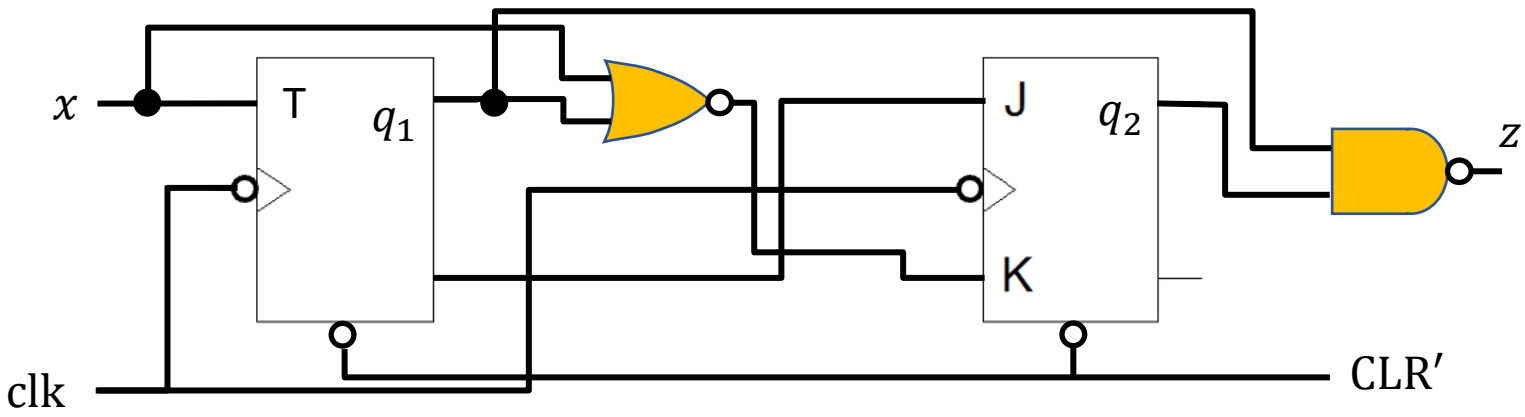
$$J = \overline{q_1}$$

$$K = \overline{x + q_1}$$

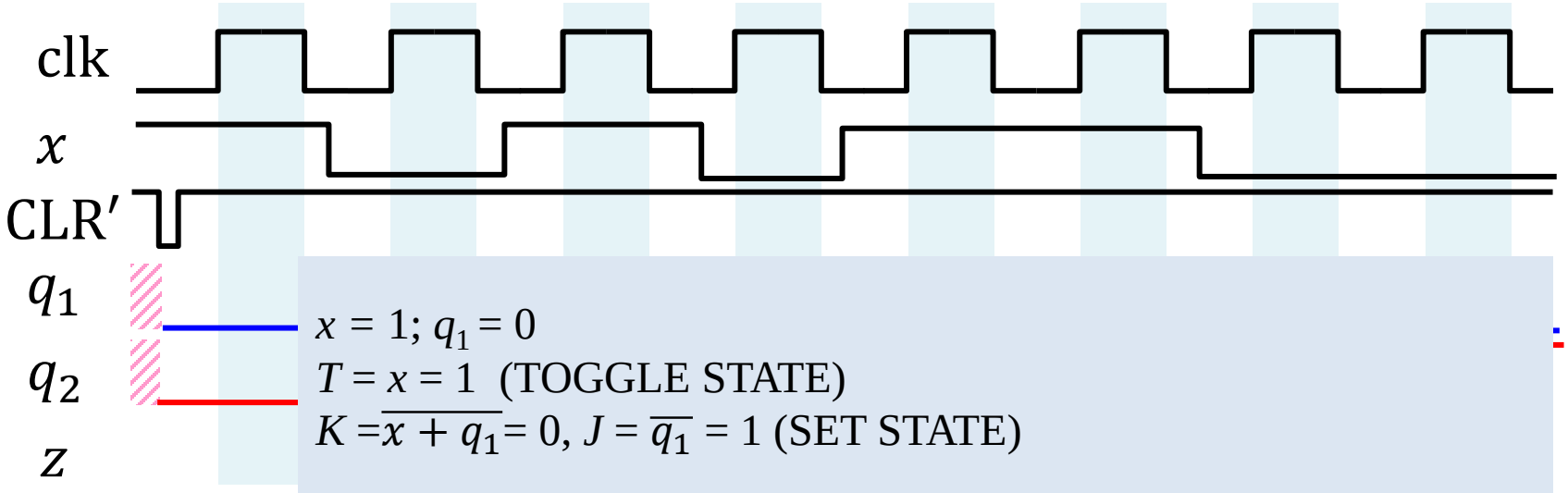
$$z = \overline{q_1 q_2}$$



Exercise

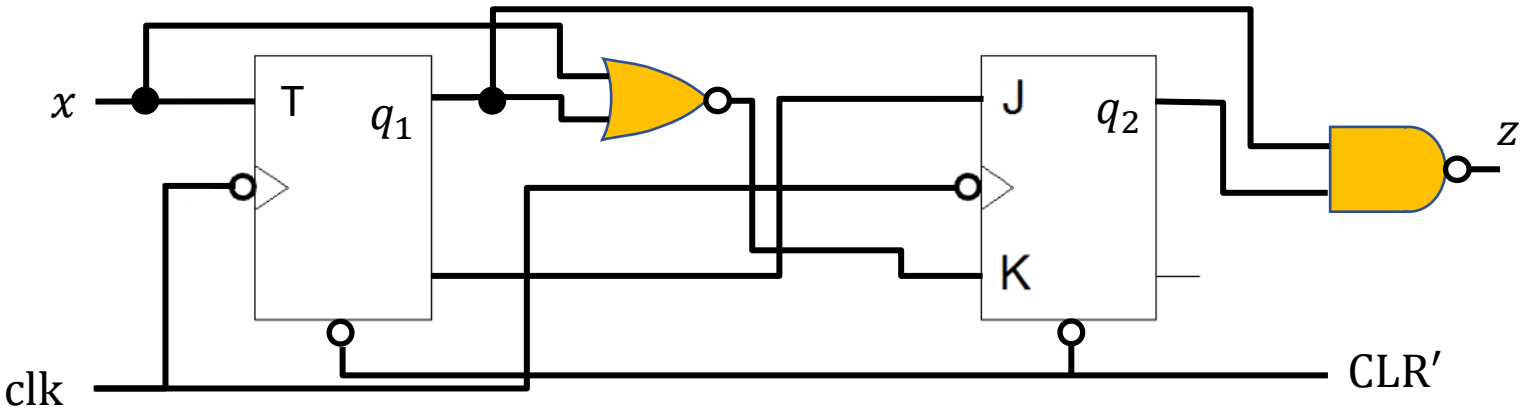


$$T = x$$
$$J = \overline{q_1}$$
$$K = \overline{x + q_1}$$
$$z = \overline{q_1 q_2}$$

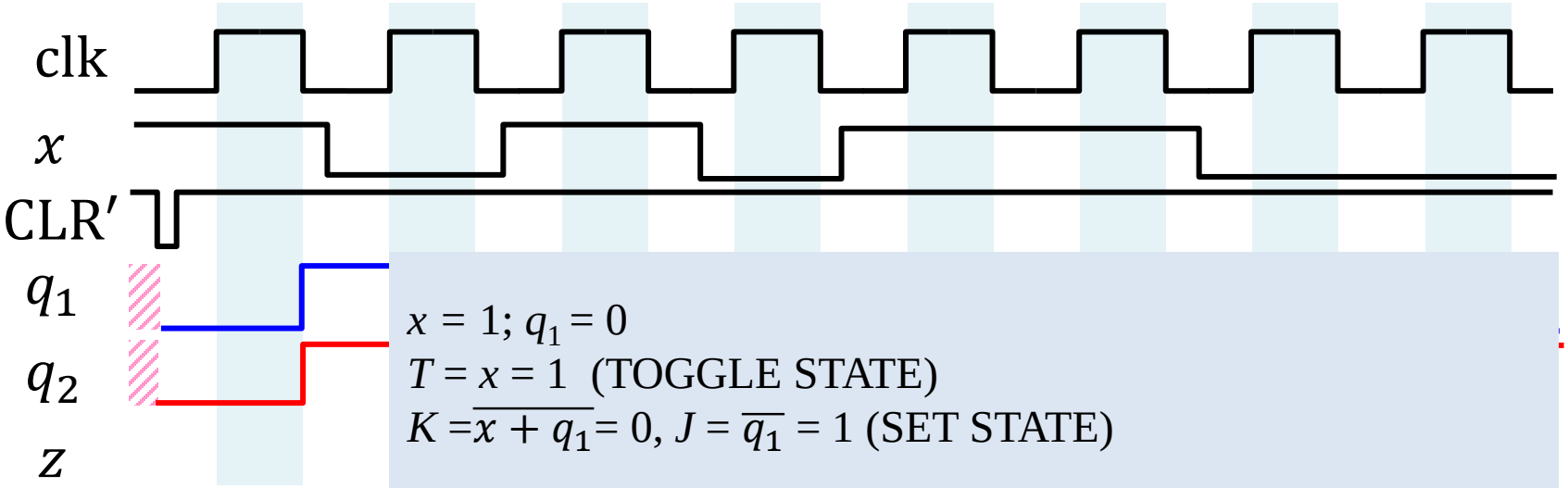


$x = 1$; $q_1 = 0$
$T = x = 1$ (TOGGLE STATE)
$K = \overline{x + q_1} = 0$, $J = \overline{q_1} = 1$ (SET STATE)

Exercise

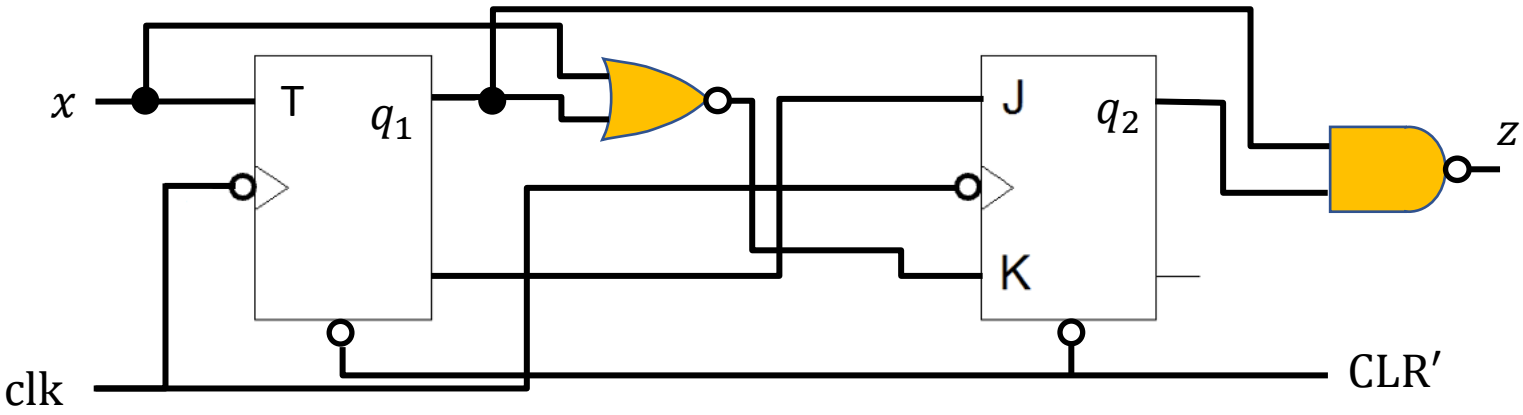


$$T = x$$
$$J = \overline{q_1}$$
$$K = \overline{x + q_1}$$
$$z = \overline{q_1 q_2}$$



$x = 1$; $q_1 = 0$
$T = x = 1$ (TOGGLE STATE)
$K = \overline{x + q_1} = 0$, $J = \overline{q_1} = 1$ (SET STATE)

Exercise



$$T = x$$
$$J = \overline{q_1}$$
$$K = \overline{x + q_1}$$
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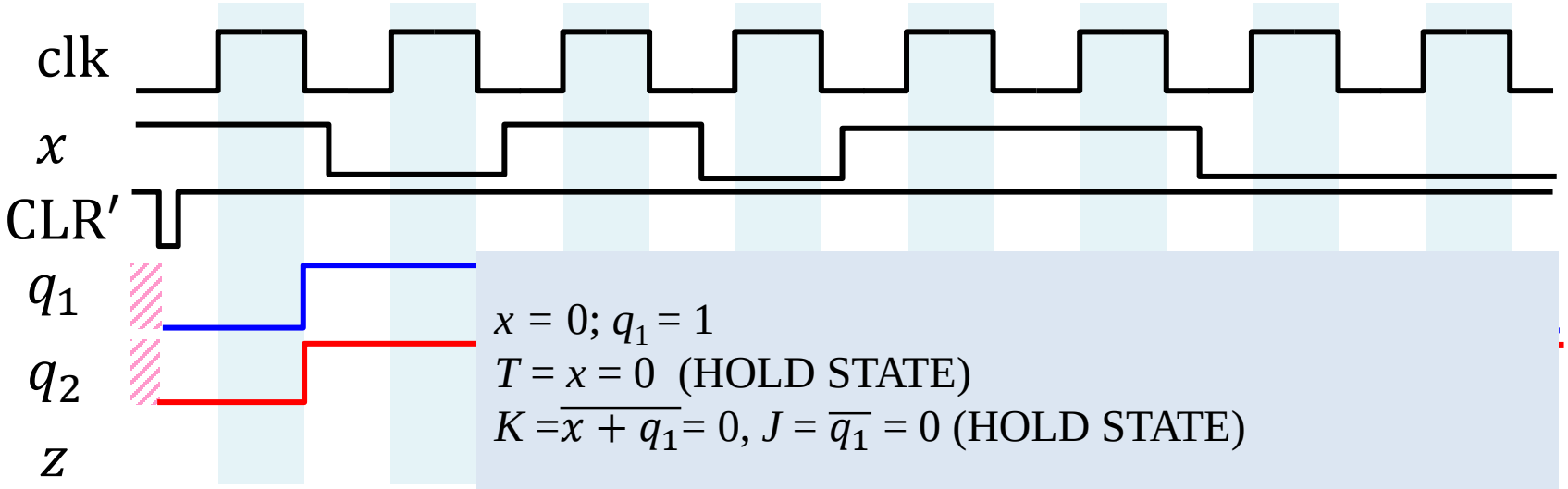
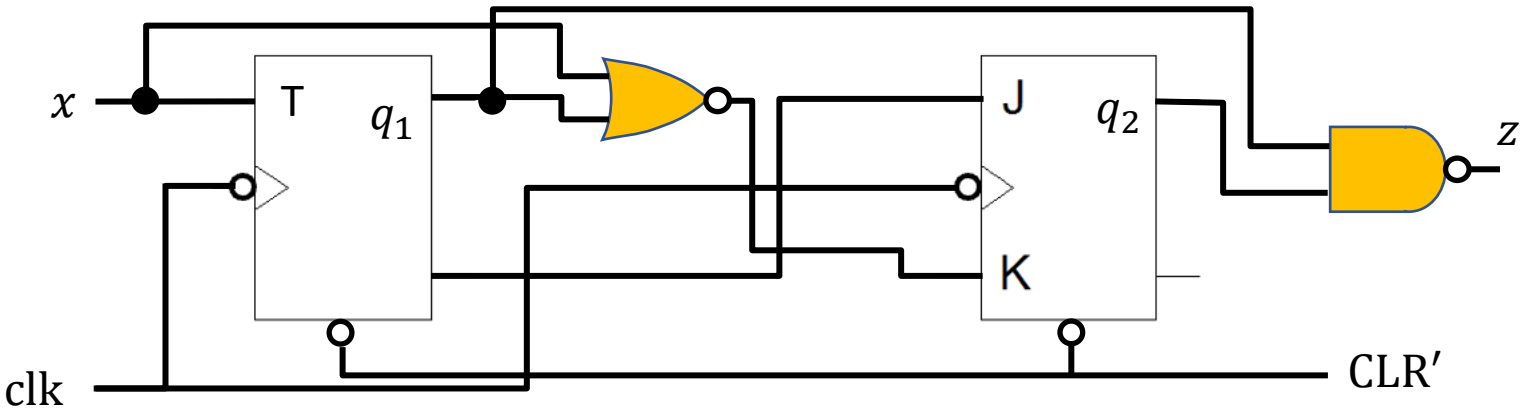
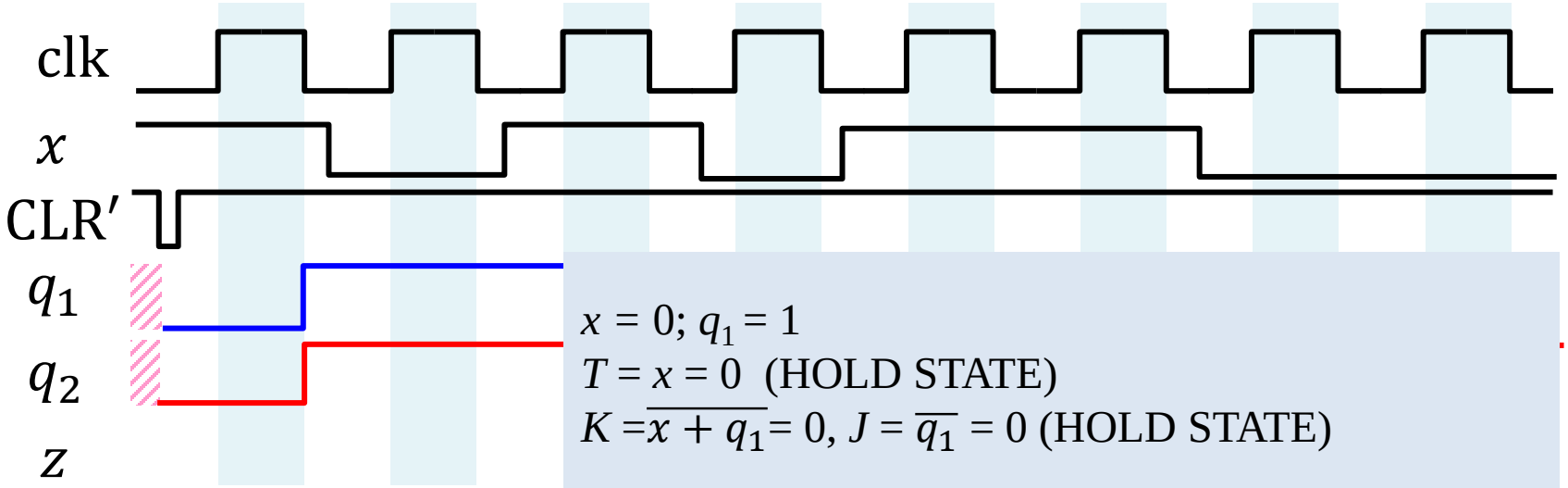


$x = 0$; $q_1 = 1$
$T = x = 0$ (HOLD STATE)
$K = \overline{x + q_1} = 0$, $J = \overline{q_1} = 0$ (HOLD STATE)

Exercise



$$T = x$$
$$J = \overline{q_1}$$
$$K = \overline{x + q_1}$$
$$z = \overline{q_1 q_2}$$



$x = 0$; $q_1 = 1$
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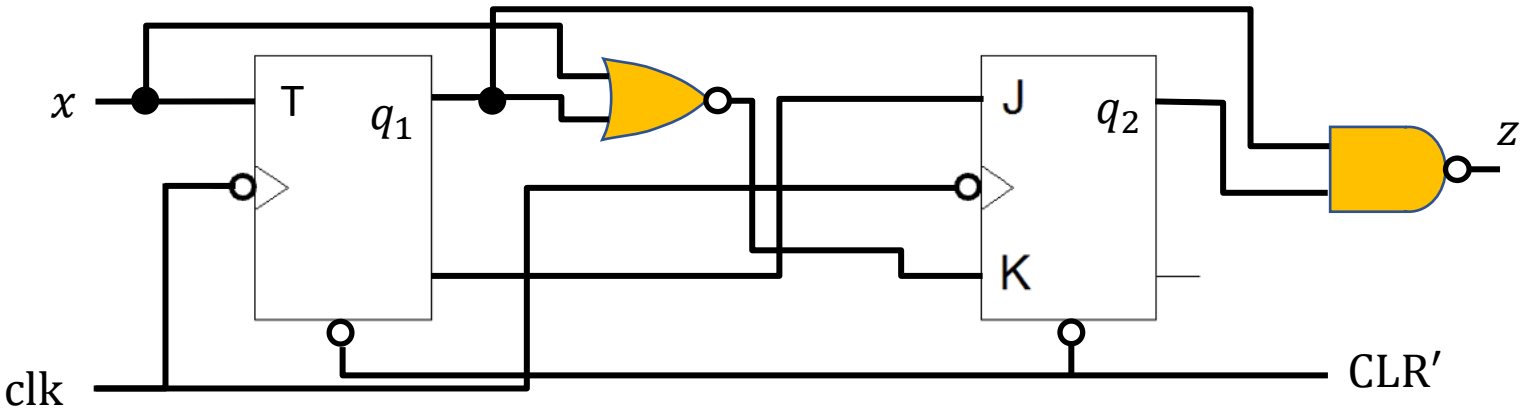
Exercise



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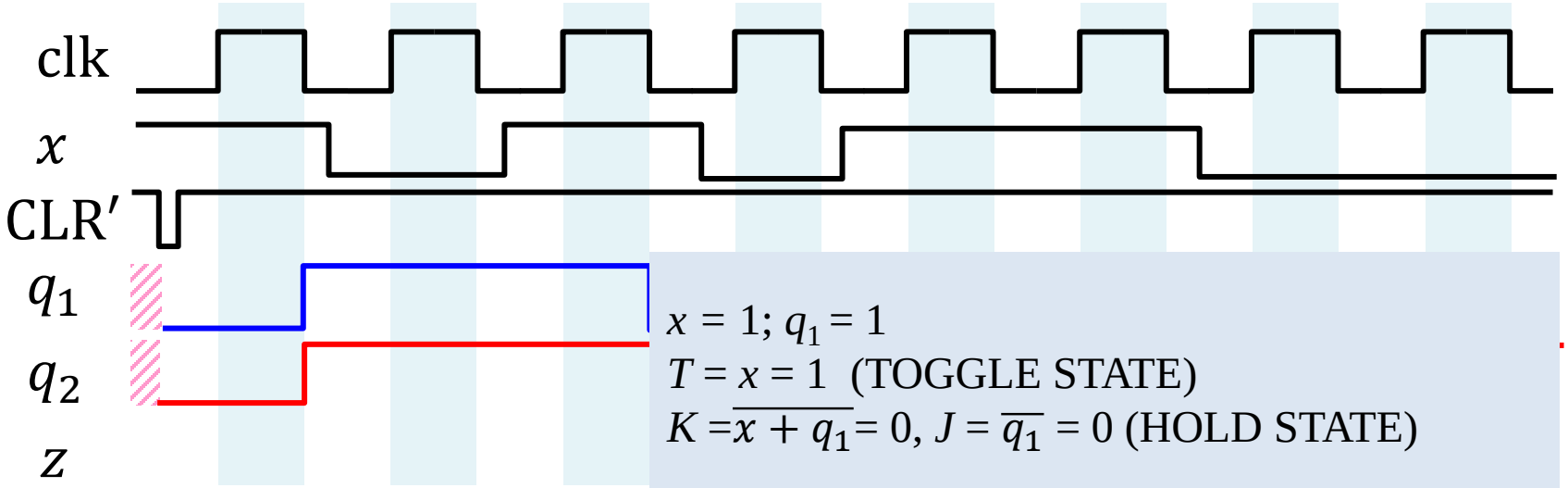
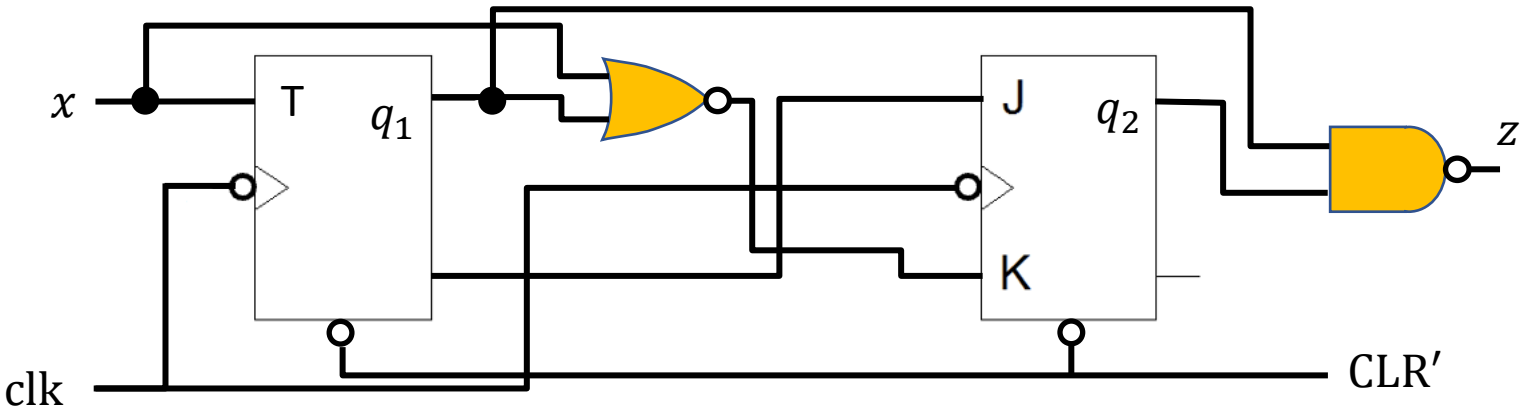


$x = 1$; $q_1 = 1$
$T = x = 1$ (TOGGLE STATE)
$K = \overline{x + q_1} = 0$, $J = \overline{q_1} = 0$ (HOLD STATE)

Exercise



$$T = x$$
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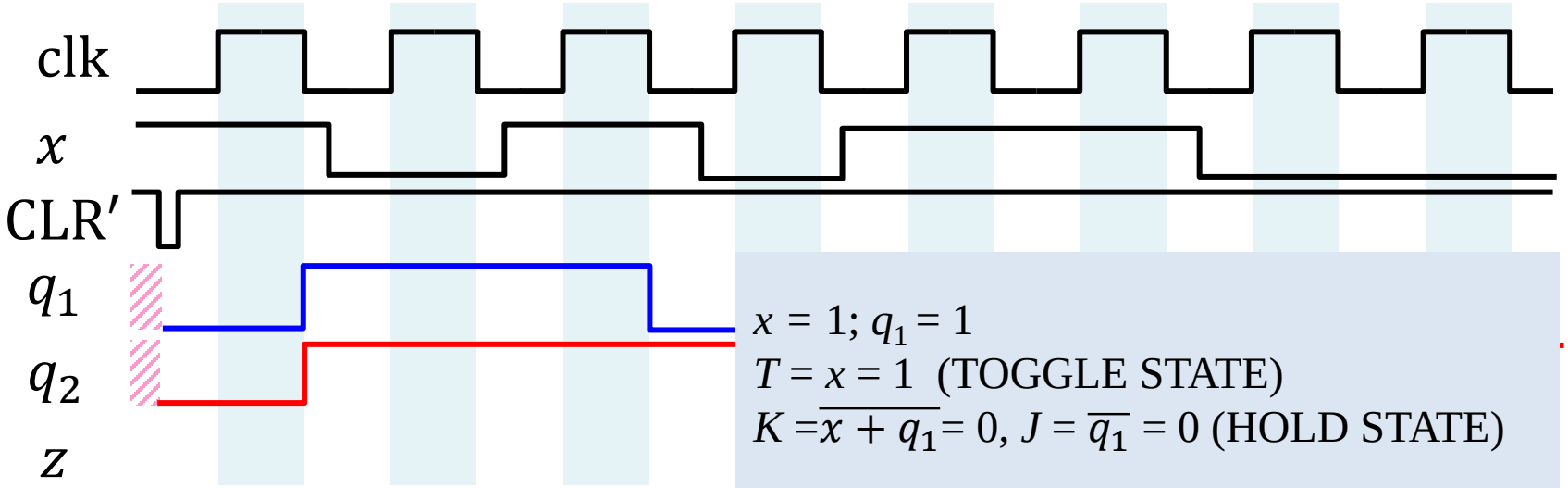

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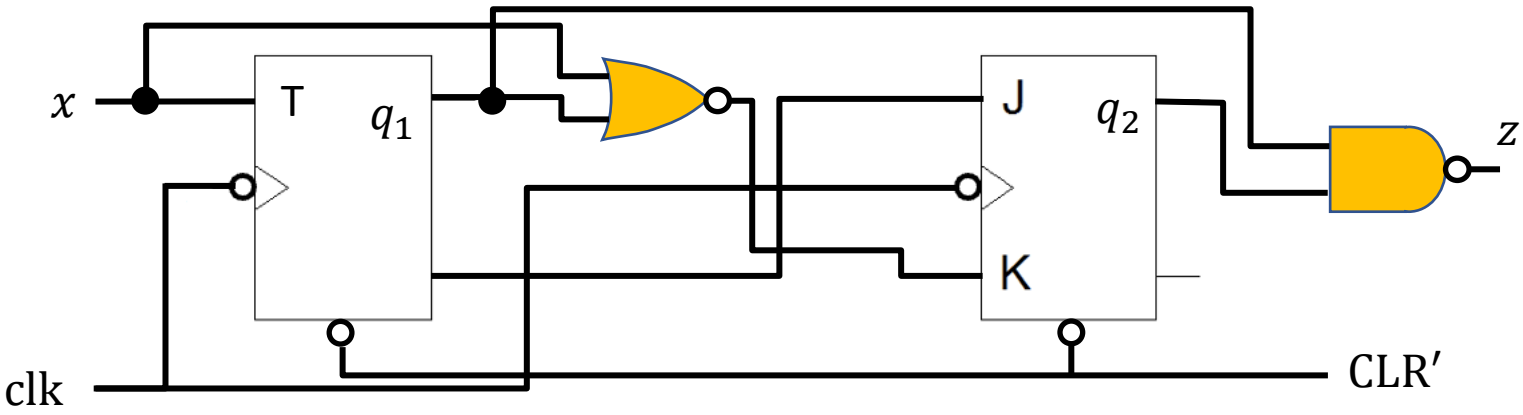
Exercise



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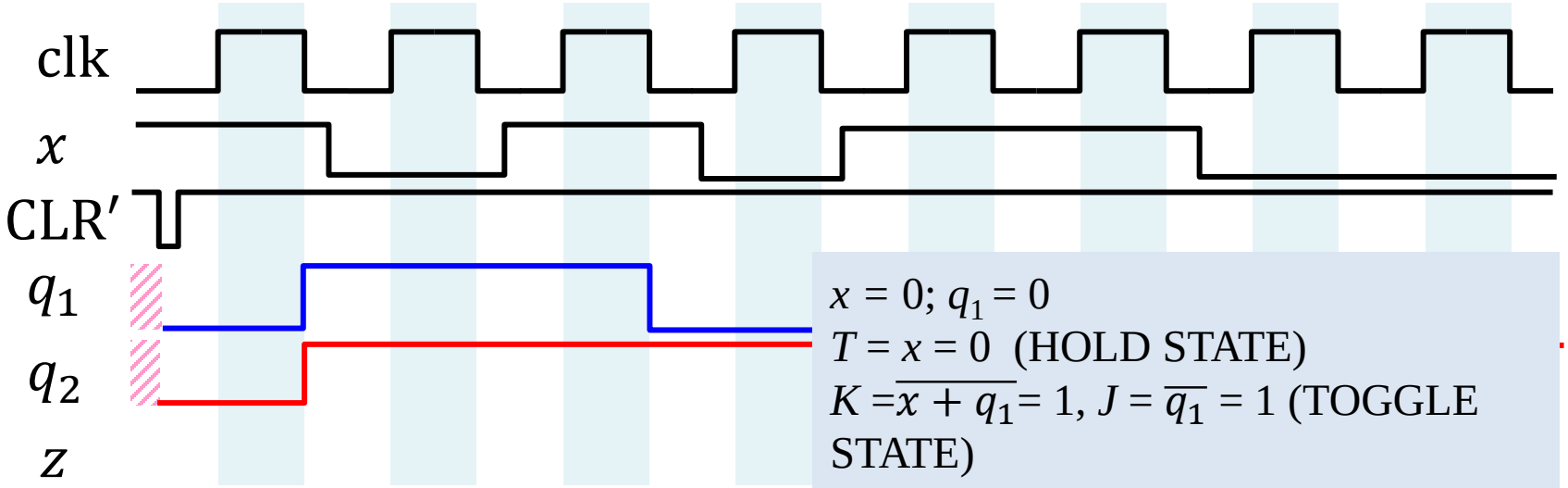

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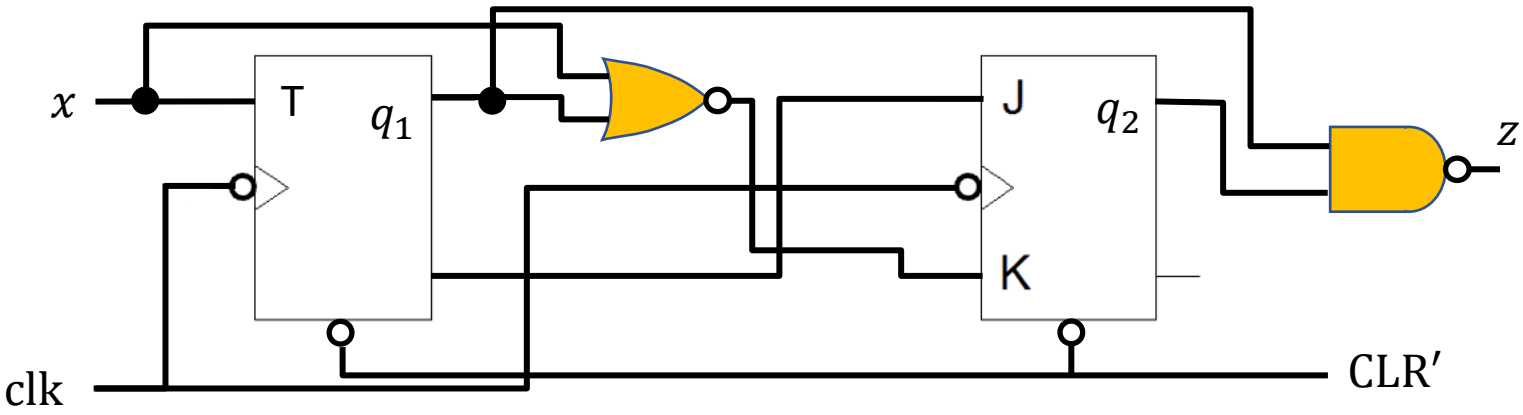
$T = x = 0$ (HOLD STATE)
$K = \overline{x + q_1} = 1$, $J = \overline{q_1} = 1$ (TOGGLE STATE)

Exercise



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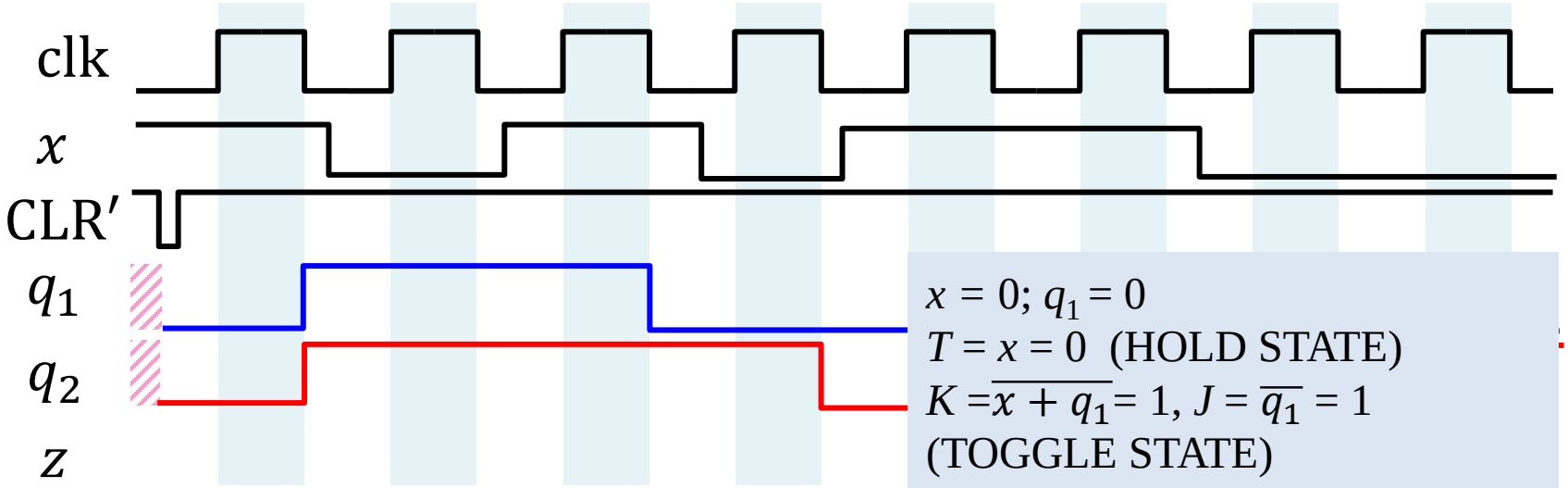
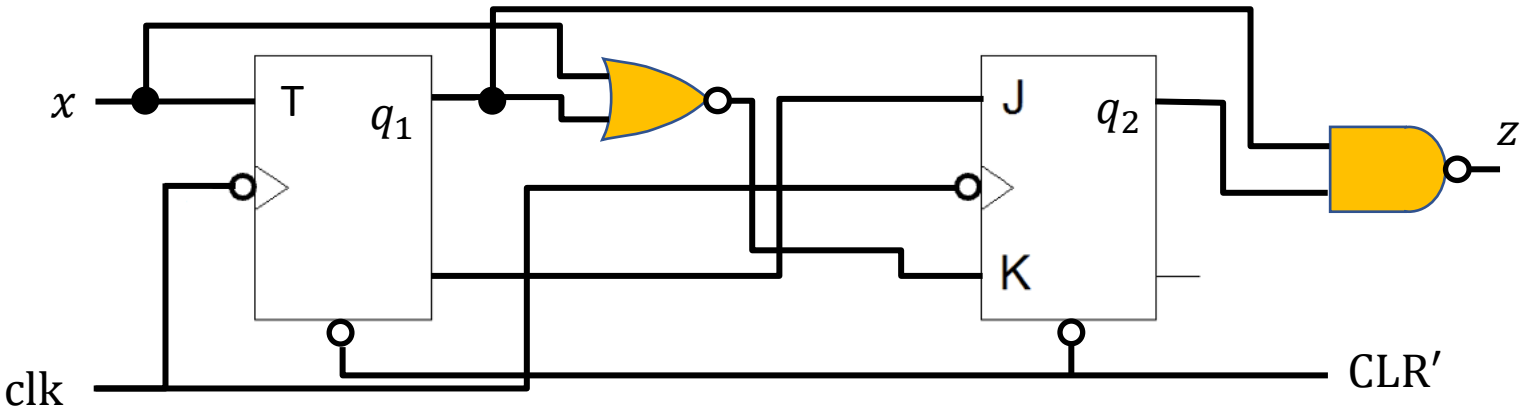


$x = 0$; $q_1 = 0$
$T = x = 0$ (HOLD STATE)
$K = \overline{x + q_1} = 1$, $J = \overline{q_1} = 1$
(TOGGLE STATE)

Exercise



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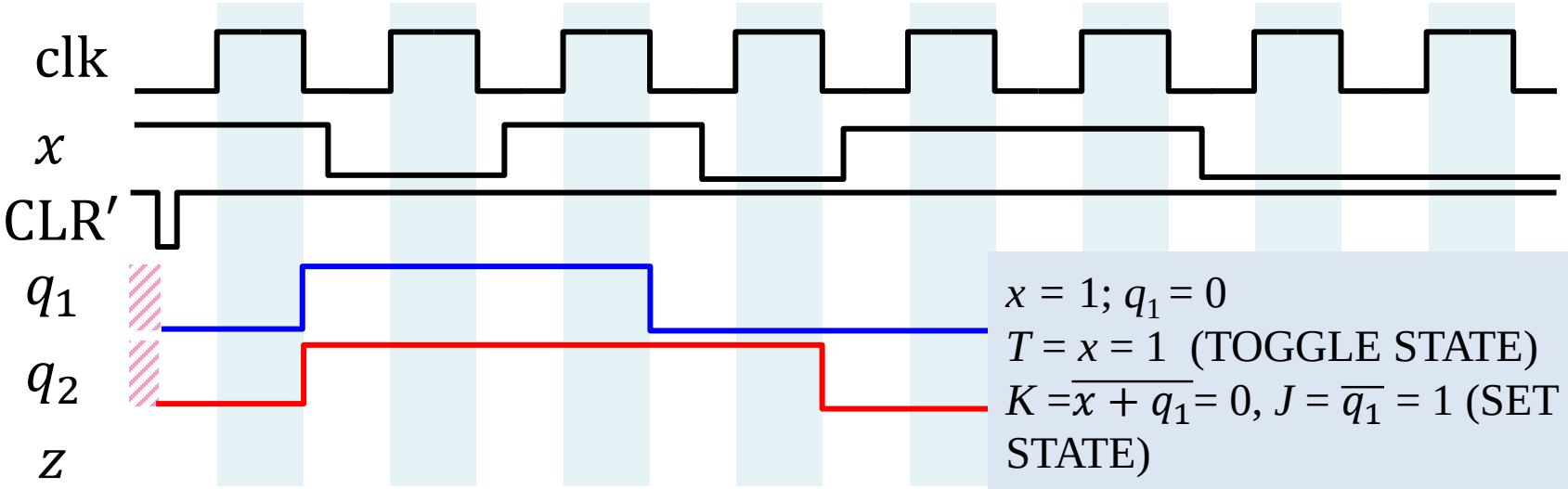
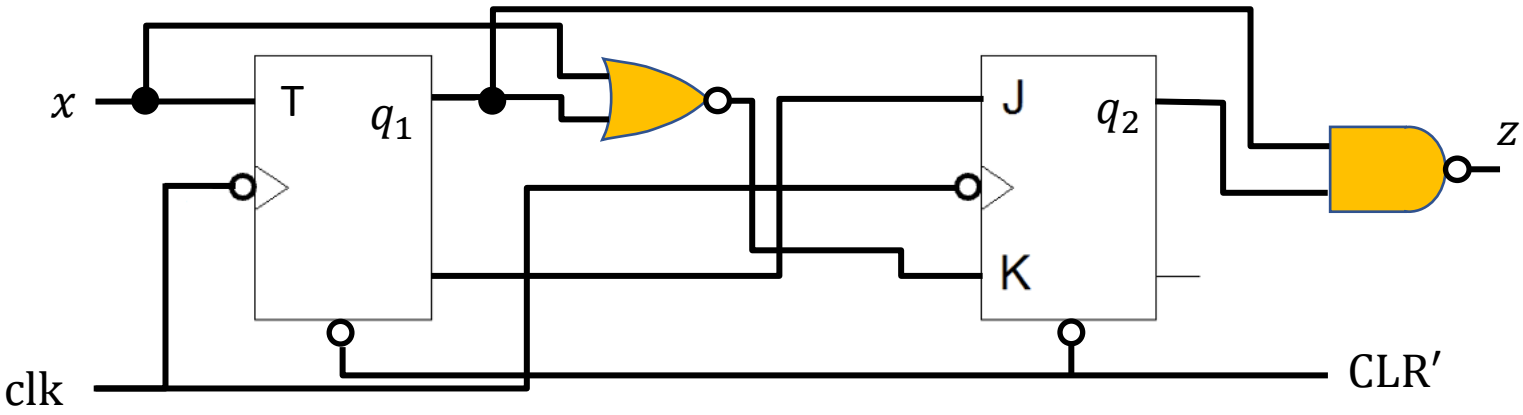


$x = 1$; $q_1 = 0$
$T = x = 1$ (TOGGLE STATE)
$K = \overline{x + q_1} = 0$, $J = \overline{q_1} = 1$ (SET STATE)

Exercise



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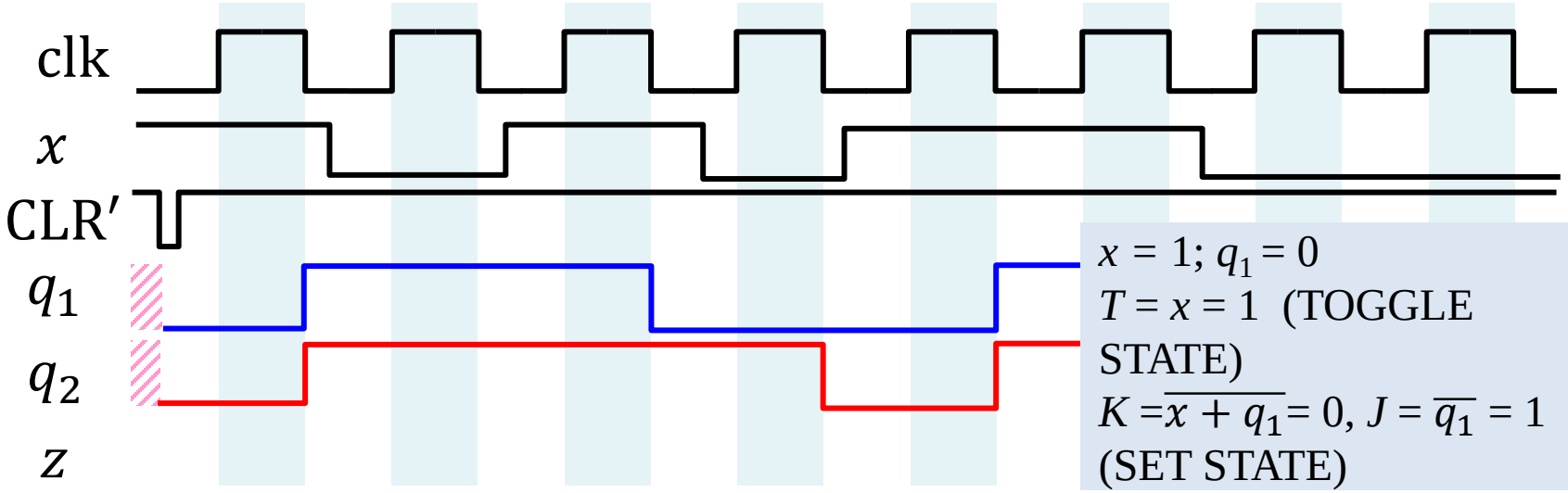

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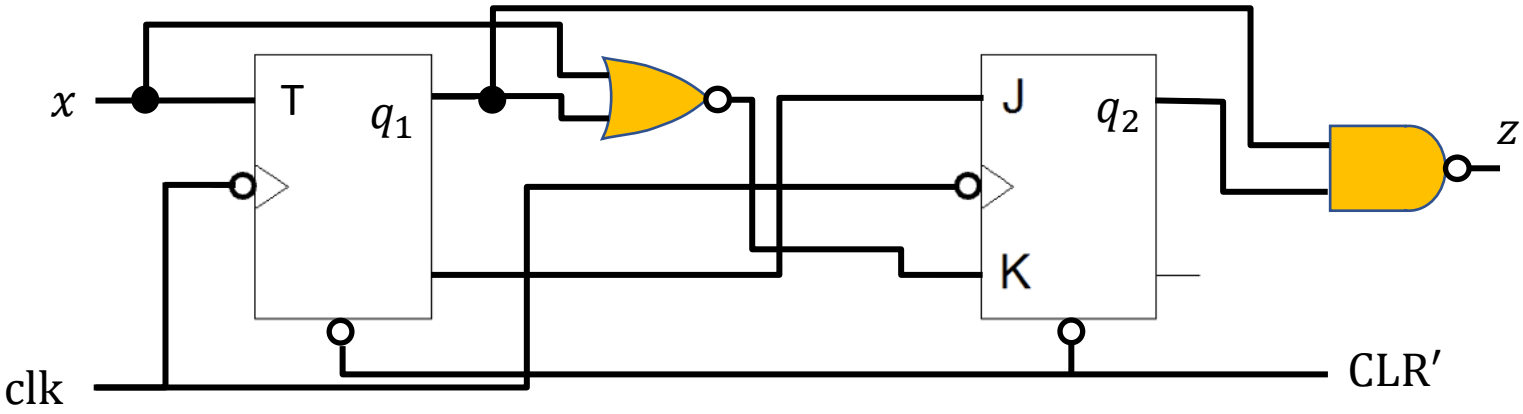
Exercise



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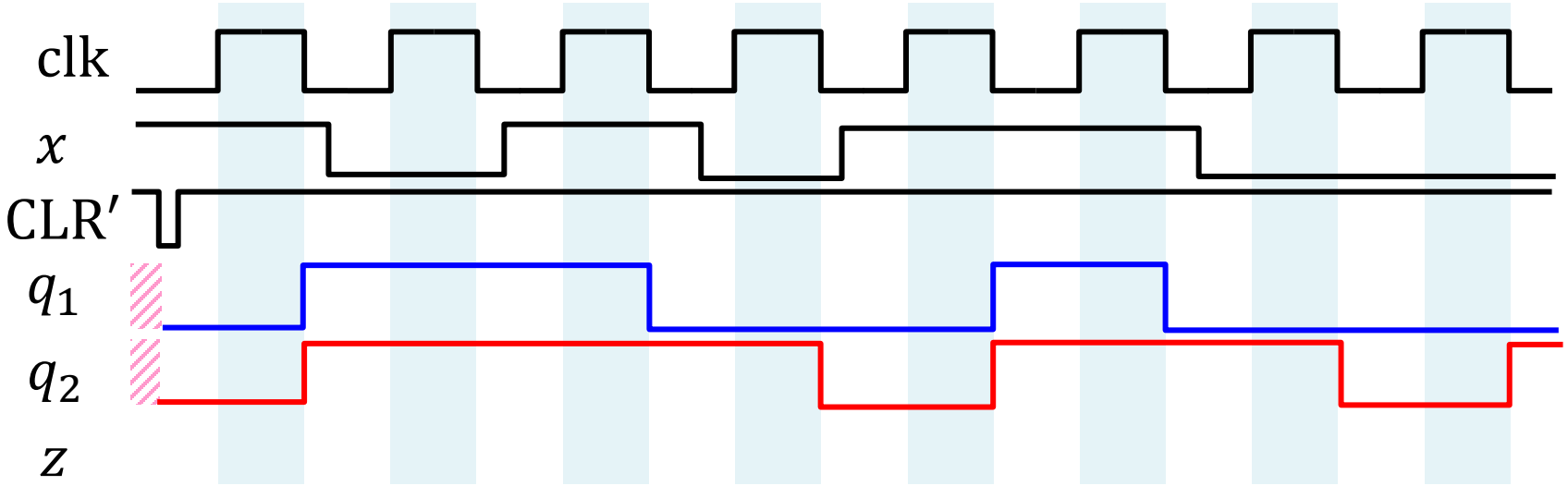
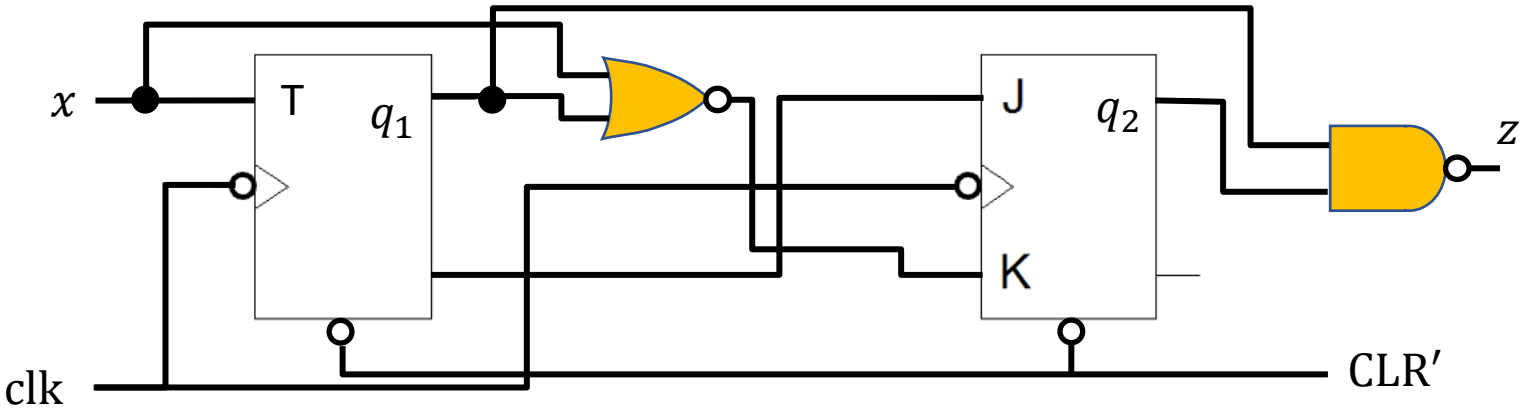


Exercise



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