# Phase 02: Sequential part

## J-K Flip Flop

**Truth Table:**

| J-K Inputs | | | | | | | | Clk | Outputs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **JA** | **KA** | **JB** | **KB** | **JC** | **KC** | **JD** | **KD** | | **QA*** | **QB*** | **QC*** | **QD*** |
| X | X | X | X | X | X | X | X | 0 | 0 | 0 | 0 | 0 |
| 0 | X | 0 | X | 0 | X | 1 | X | 1 | 0 | 0 | 0 | 1 |
| 0 | X | 0 | X | 1 | X | X | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | X | 0 | X | X | 0 | 1 | X | 1 | 0 | 0 | 1 | 1 |
| 0 | X | 1 | X | X | 1 | X | 1 | 1 | 0 | 1 | 0 | 0 |
| 0 | X | X | 0 | 0 | X | 1 | X | 1 | 0 | 1 | 0 | 1 |
| 0 | X | X | 0 | 1 | X | X | 1 | 1 | 0 | 1 | 1 | 0 |
| 0 | X | X | 0 | X | 0 | 1 | X | 1 | 0 | 1 | 1 | 1 |
| 1 | X | X | 1 | X | 1 | X | 1 | 1 | 1 | 0 | 0 | 0 |
| X | 0 | 0 | X | 0 | X | 1 | X | 1 | 1 | 0 | 0 | 1 |
| X | 0 | 0 | X | 1 | X | X | 1 | 1 | 1 | 0 | 1 | 0 |
| X | 0 | 0 | X | X | 0 | 1 | X | 1 | 1 | 0 | 1 | 1 |
| X | 0 | 1 | X | X | 1 | X | 1 | 1 | 1 | 1 | 0 | 0 |
| X | 1 | X | 1 | 0 | X | 0 | X | 1 | 0 | 0 | 0 | 0 |

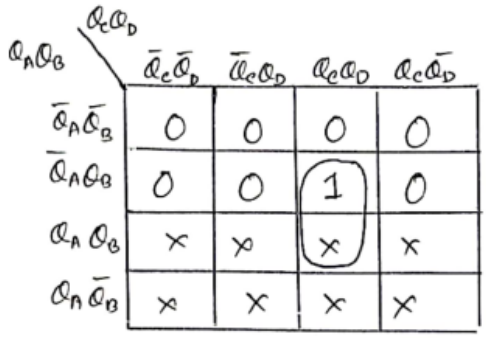
**Characteristic Table:**

| Present | | | | J-K Inputs | | | | | | | | Next | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **QA** | **QB** | **QC** | **QD** | **JA** | **KA** | **JB** | **KB** | **JC** | **KC** | **JD** | **KD** | **QA*** | **QB*** | **QC*** | **QD*** |
| 0 | 0 | 0 | 0 | 0 | X | 0 | X | 0 | X | 1 | X | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 1 | 0 | X | 0 | X | 1 | X | X | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | X | 0 | X | X | 0 | 1 | X | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 1 | 0 | X | 1 | X | X | 1 | X | 1 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | X | X | 0 | 0 | X | 1 | X | 0 | 1 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 | X | X | 0 | 1 | X | X | 1 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | X | X | 0 | X | 0 | 1 | X | 0 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | X | X | 1 | X | 1 | X | 1 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | X | 0 | 0 | X | 0 | X | 1 | X | 1 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | X | 0 | 0 | X | 1 | X | X | 1 | 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | X | 0 | 0 | X | X | 0 | 1 | X | 1 | 0 | 1 | 1 |
| 1 | 0 | 1 | 1 | X | 0 | 1 | X | X | 1 | X | 1 | 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 0 | X | 1 | X | 1 | 0 | X | 0 | X | 0 | 0 | 0 | 0 |

**Excitation Table:**

| Present | | | | Next | | | | J-K Inputs | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **QA** | **QB** | **QC** | **QD** | **QA*** | **QB*** | **QC*** | **QD*** | **JA** | **KA** | **JB** | **KB** | **JC** | **KC** | **JD** | **KD** |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | X | 0 | X | 0 | X | 1 | X |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | X | 0 | X | 1 | X | X | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | X | 0 | X | X | 0 | 1 | X |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | X | 1 | X | X | 1 | X | 1 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | X | X | 0 | 0 | X | 1 | X |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | X | X | 0 | 1 | X | X | 1 |
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | X | X | 0 | X | 0 | 1 | X |
| 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | X | X | 1 | X | 1 | X | 1 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | X | 0 | 0 | X | 0 | X | 1 | X |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | X | 0 | 0 | X | 1 | X | X | 1 |
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | X | 0 | 0 | X | X | 0 | 1 | X |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | X | 0 | 1 | X | X | 1 | X | 1 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | X | 1 | X | 1 | 0 | X | 0 | X |

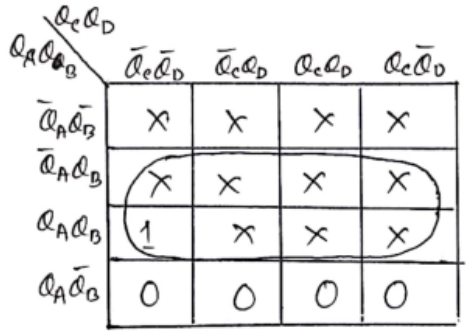
**K-Maps for J-K flip flop:**



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | 0 | 0 | 0 | 0 |
| $\bar{Q}_A Q_B$ | 0 | 0 | 1 | 0 |
| $Q_A Q_B$ | × | × | × | × |
| $Q_A\bar{Q}_B$ | × | × | × | × |

K-Map for $J_A$

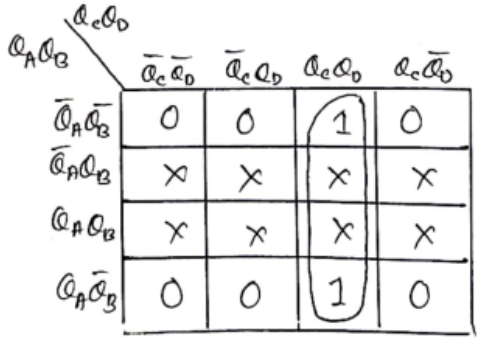
$J_A = Q_B Q_C Q_D$



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | × | × | × | × |
| $\bar{Q}_A Q_B$ | × | × | × | × |
| $Q_A Q_B$ | 1 | × | × | × |
| $Q_A\bar{Q}_B$ | 0 | 0 | 0 | 0 |

K-Map for $K_A$

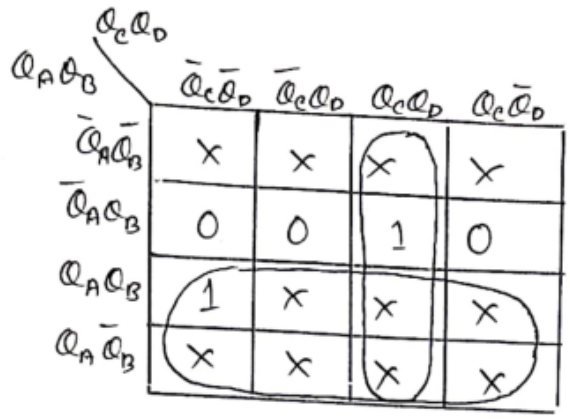
$K_A = Q_B$



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | 0 | 0 | 1 | 0 |
| $\bar{Q}_A Q_B$ | × | × | × | × |
| $Q_A Q_B$ | × | × | × | × |
| $Q_A\bar{Q}_B$ | 0 | 0 | 1 | 0 |

K-Map for $J_B$

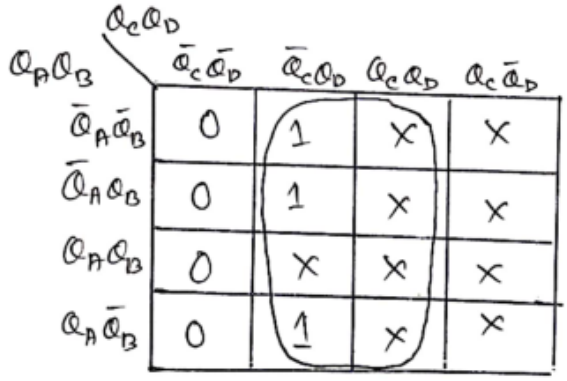
$J_B = Q_C Q_D.$



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | X | X | X | X |
| $\bar{Q}_A Q_B$ | 0 | 0 | 1 | 0 |
| $Q_A Q_B$ | 1 | X | X | X |
| $Q_A\bar{Q}_B$ | X | X | X | X |

K-Map for $K_B$

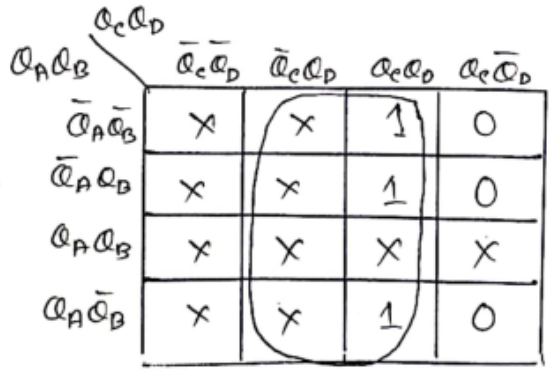
$K_B = Q_C Q_D + Q_A$



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | 0 | 1 | X | X |
| $\bar{Q}_A Q_B$ | 0 | 1 | X | X |
| $Q_A Q_B$ | 0 | X | X | X |
| $Q_A\bar{Q}_B$ | 0 | 1 | X | X |

K-Map for $J_C$

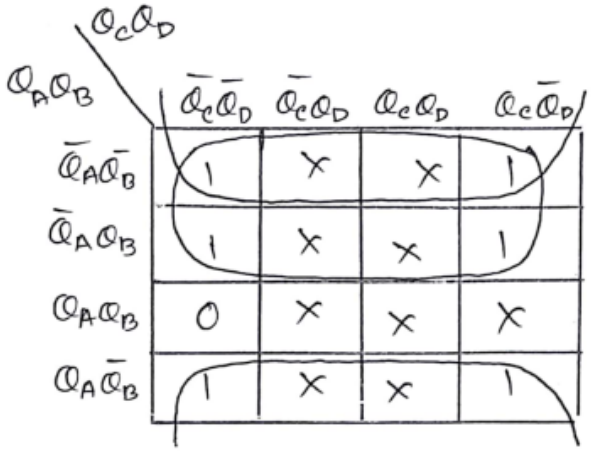
$J_C = Q_D$



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | X | X | 1 | 0 |
| $\bar{Q}_A Q_B$ | X | X | 1 | 0 |
| $Q_A Q_B$ | X | X | X | X |
| $Q_A\bar{Q}_B$ | X | X | 1 | 0 |

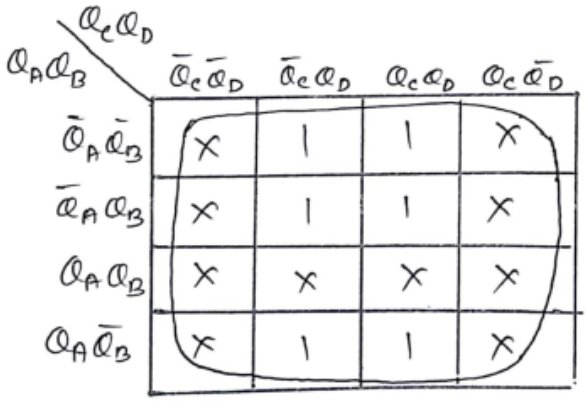
K-Map for $K_C$

$K_C = Q_D$




K-Map for $J_D$

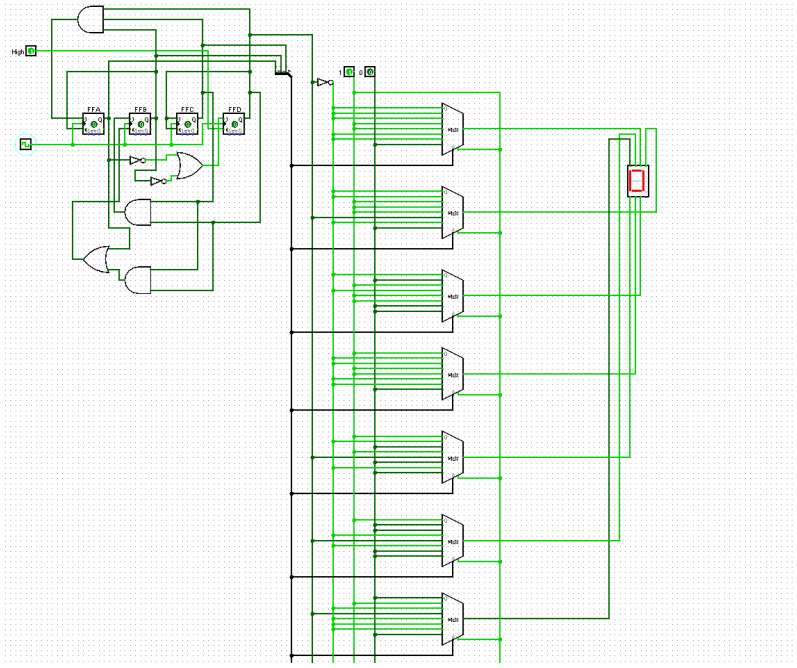
$J_D = \bar{Q}_A + \bar{Q}_B$



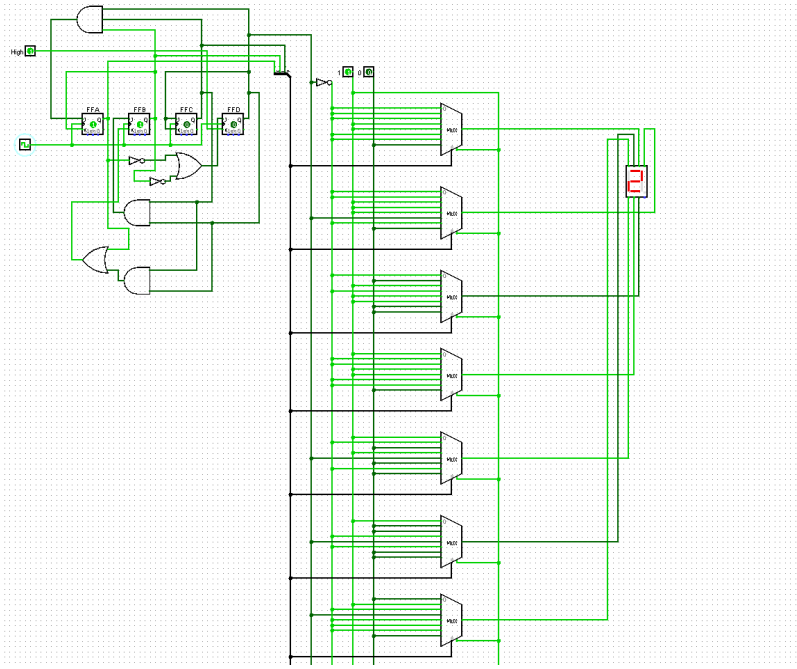

K-Map for $K_D$

$K_D = 1$

## Logisim Simulation



**Screenshot 1:** State - 0000 Displaying - "**D**"



**Screenshot 2:** State - 1100 Displaying - "**2**"

**Note:** We can avoid the NOT gates in the flip flop part because it's built-in.

# T Flip Flop

**Truth Table:**

| T Inputs | | | | Clk | Outputs | | | |
|---|---|---|---|---|---|---|---|---|
| **TA** | **TB** | **TC** | **TD** | | **QA*** | **QB*** | **QC*** | **QD*** |
| X | X | X | X | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 |
| 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

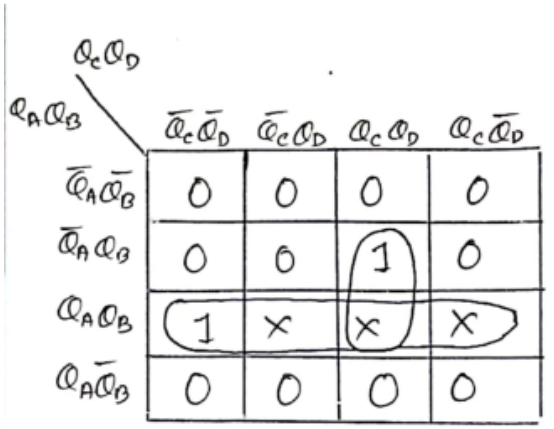
**Characteristic Table:**

| Present | | | | T Inputs | | | | Next | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **QA** | **QB** | **QC** | **QD** | **TA** | **TB** | **TC** | **TD** | **QA*** | **QB*** | **QC*** | **QD*** |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

**Excitation Table:**

| Present | | | | Next | | | | T Inputs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **QA** | **QB** | **QC** | **QD** | **QA*** | **QB*** | **QC*** | **QD*** | **TA** | **TB** | **TC** | **TD** |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |

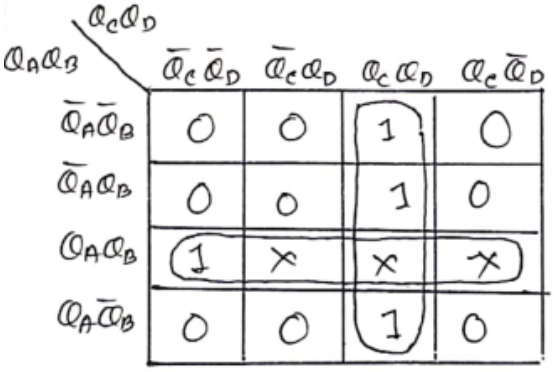
**K-Maps for T flip flop:**



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | 0 | 0 | 0 | 0 |
| $\bar{Q}_A Q_B$ | 0 | 0 | 1 | 0 |
| $Q_A Q_B$ | 1 | × | × | × |
| $Q_A\bar{Q}_B$ | 0 | 0 | 0 | 0 |

K-Map for $T_A$

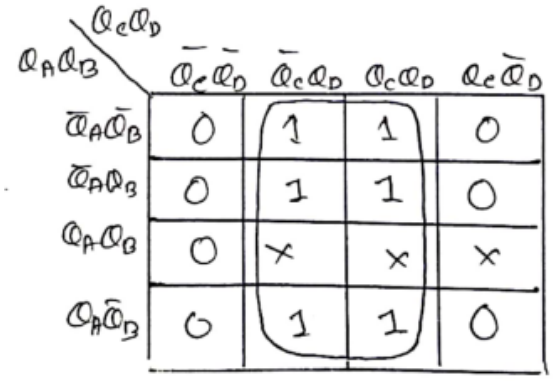
$T_A = Q_A Q_B + Q_B Q_C Q_D$



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | 0 | 0 | 1 | 0 |
| $\bar{Q}_A Q_B$ | 0 | 0 | 1 | 0 |
| $Q_A Q_B$ | 1 | × | × | × |
| $Q_A\bar{Q}_B$ | 0 | 0 | 1 | 0 |

K-Map for $T_B$

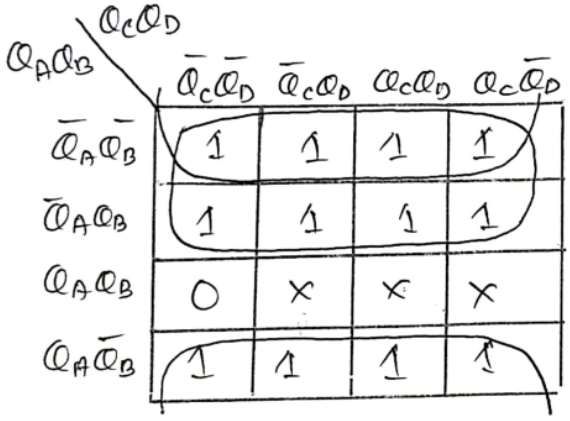
$T_B = Q_A Q_B + Q_C Q_D$.



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | 0 | 1 | 1 | 0 |
| $\bar{Q}_A Q_B$ | 0 | 1 | 1 | 0 |
| $Q_A Q_B$ | 0 | × | × | × |
| $Q_A\bar{Q}_B$ | 0 | 1 | 1 | 0 |

K-Map for $T_C$

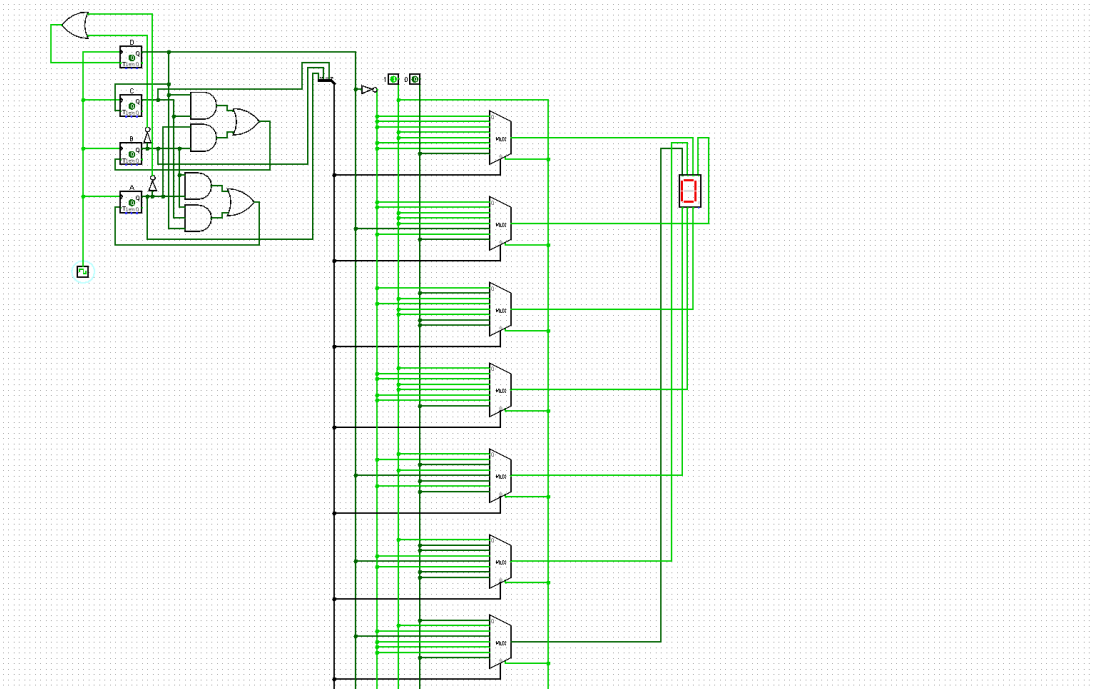
$T_C = Q_D$.



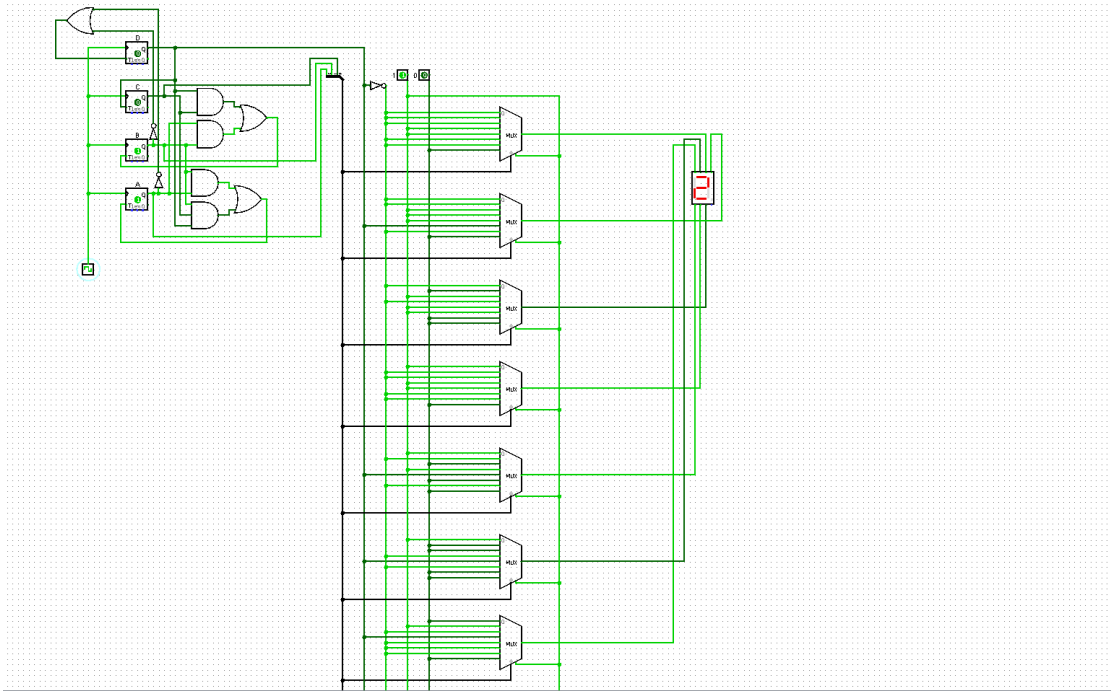

K-Map for $T_D$

$T_D = \bar{Q}_A + \bar{Q}_B$

## Logisim Simulation



**Screenshot 1:** State - 0000 Displaying - "**D**"



**Screenshot 2:** State - 1100 Displaying - "**2**"

**Note:** We can avoid the NOT gates in the flip flop part because it's built-in.

# D Flip Flop

**Truth Table:**

| D Inputs | | | | Clk | Next | | | |
|---|---|---|---|---|---|---|---|---|
| **DA** | **DB** | **DC** | **DD** | | **QA*** | **QB*** | **QC*** | **QD*** |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

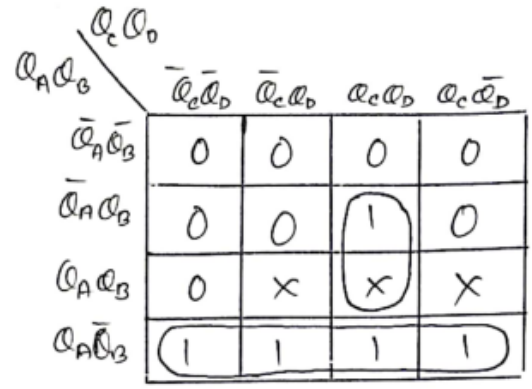
**Characteristic Table:**

| Present | | | | D Inputs | | | | Next | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **QA** | **QB** | **QC** | **QD** | **DA** | **DB** | **DC** | **DD** | **QA*** | **QB*** | **QC*** | **QD*** |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Excitation Table:**

| Present | | | | Next | | | | D Inputs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **QA** | **QB** | **QC** | **QD** | **QA*** | **QB*** | **QC*** | **QD*** | **DA** | **DB** | **DC** | **DD** |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

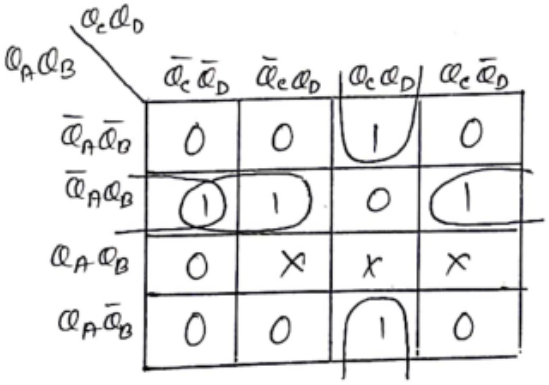
**K-Maps for D flip flop:**



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | 0 | 0 | 0 | 0 |
| $\bar{Q}_A Q_B$ | 0 | 0 | 1 | 0 |
| $Q_A Q_B$ | 0 | × | × | × |
| $Q_A\bar{Q}_B$ | 1 | 1 | 1 | 1 |

K-Map for $D_A$

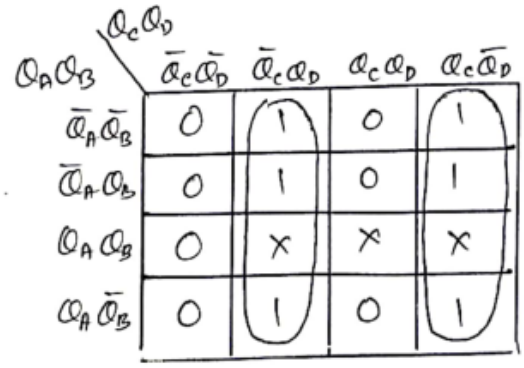
$D_A = Q_A\bar{Q}_B + Q_B Q_C Q_D$.



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | 0 | 0 | 1 | 0 |
| $\bar{Q}_A Q_B$ | 1 | 1 | 0 | 1 |
| $Q_A Q_B$ | 0 | × | × | × |
| $Q_A\bar{Q}_B$ | 0 | 0 | 1 | 0 |

K-Map for $D_B$

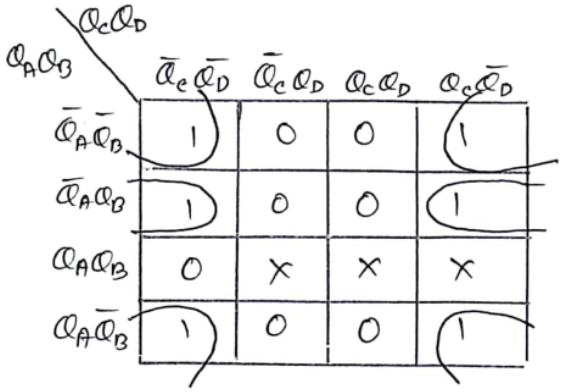
$D_B = \bar{Q}_A Q_D\bar{Q}_C + \bar{Q}_A Q_B\bar{Q}_D + \bar{Q}_B Q_C Q_D$



| $Q_A Q_B$ \ $Q_C Q_D$ | $\bar{Q}_C\bar{Q}_D$ | $\bar{Q}_C Q_D$ | $Q_C Q_D$ | $Q_C\bar{Q}_D$ |
|---|---|---|---|---|
| $\bar{Q}_A\bar{Q}_B$ | 0 | 1 | 0 | 1 |
| $\bar{Q}_A Q_B$ | 0 | 1 | 0 | 1 |
| $Q_A Q_B$ | 0 | × | × | × |
| $Q_A\bar{Q}_B$ | 0 | 1 | 0 | 1 |

K-Map for $D_C$

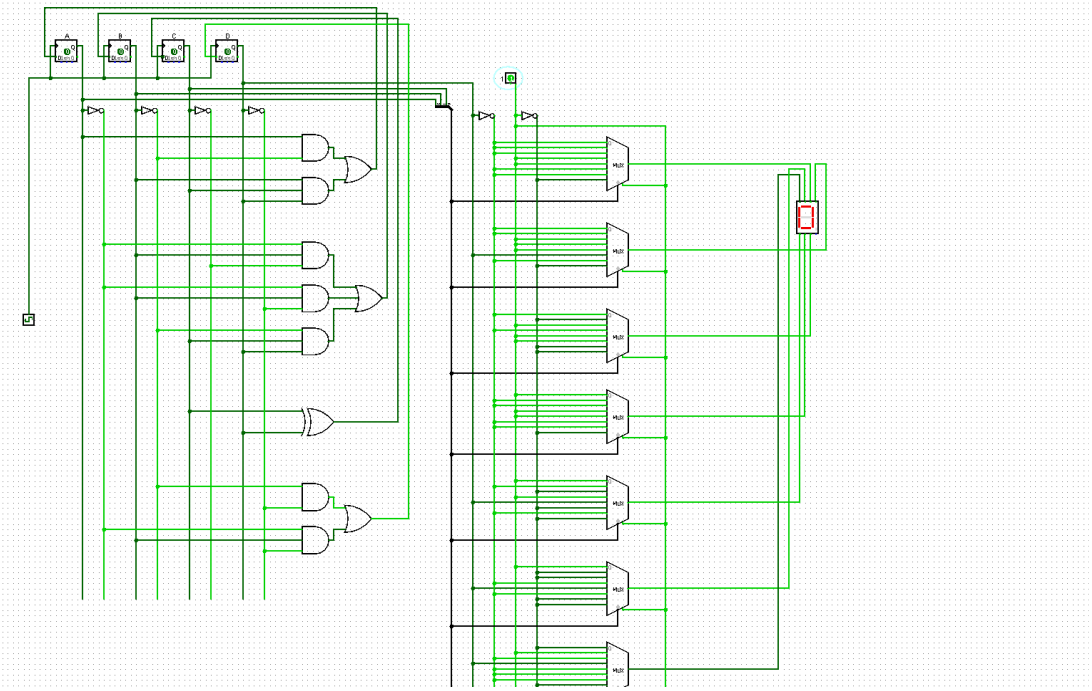
$D_C = \bar{Q}_C Q_D + Q_C\bar{Q}_D$



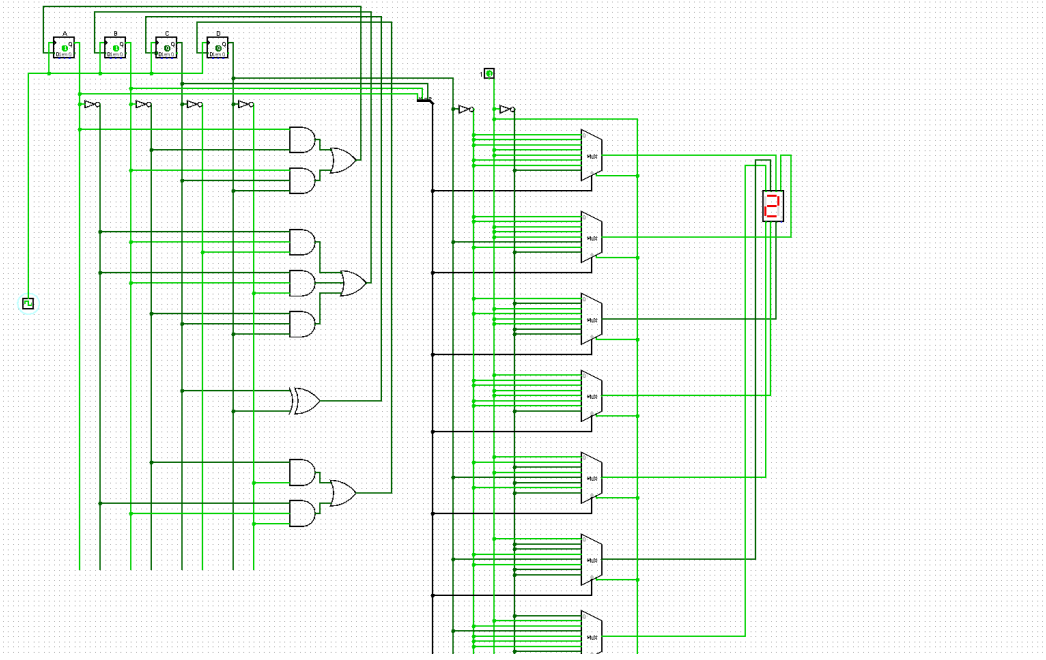

K-Map for $D_D$

$$D_D = \bar{Q}_B \bar{Q}_D + \bar{Q}_A Q_B \bar{Q}_D$$

## Logisim Simulation



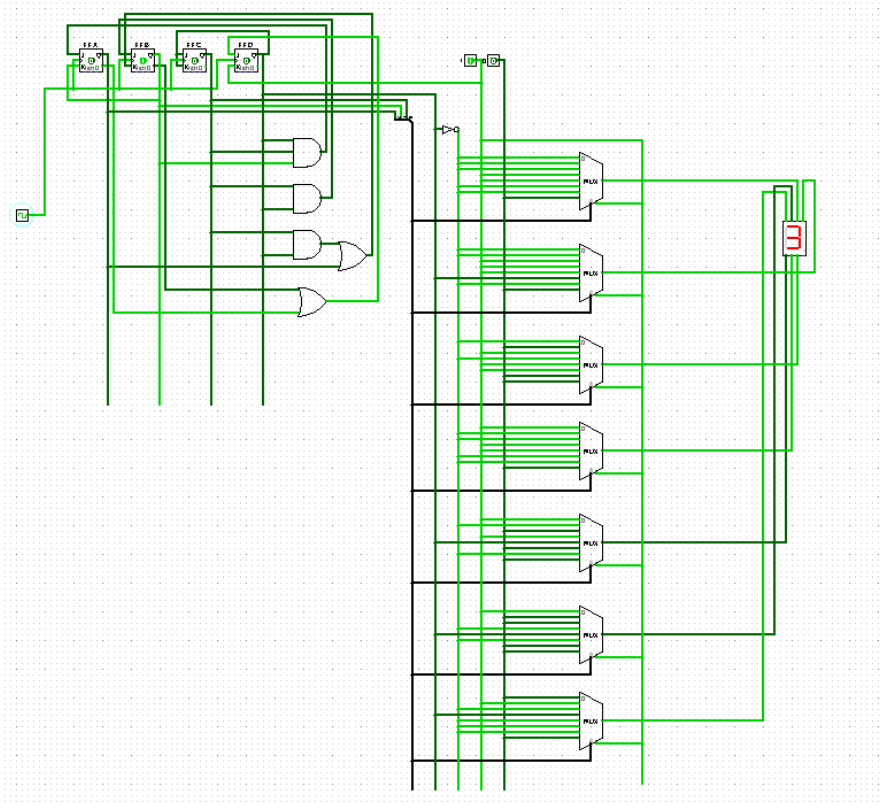
**Screenshot 1:** State - 0000 Displaying - “D”



**Screenshot 2:** State - 1100 Displaying - “2”

**Note:** We can avoid the NOT gates in the flip flop part because it's built-in.

**The optimized flip flop for the project:**



The **J-K Flip Flop** is the optimized one because for our project we can see that this flip flop configuration required the least amount of gates and complexity. Whereas D and T Flip Flops require more gates.

Unlike other flip-flop types, JK flip-flops do not have invalid or forbidden states. They can be in any of the four possible states (00, 01, 10, 11), which simplifies state analysis and reduces the risk of unintended behavior. When configured as a toggle flip-flop, a JK flip-flop typically requires fewer gates than other flip-flop types designed for toggling. This can result in a more compact and efficient design.

Thus J-K Flip Flop is the most optimized one for this project.

**Budget for the project:**

As we are using Multiplexer to display “**DL2-31D230S12**”, we require

1-Cathode 7-Segment Display = 12 Tk
7-IC 74HC151N (8:1 MUX) = 224 Tk
1-IC NOT 7404 (2-input NOT) = 26 Tk
1-IC 7408 (2-input AND) = 31 Tk
1-IC 7432 (2-input OR) = 28 Tk
2-IC 4027 (Dual J-k Flip-Flop) = 70 Tk
1-IC 555 Timer = 18 Tk
5 Breadboards = 650
13 resistors = 20 Tk
1 capacitor = 5 Tk
Jumper cables = 300 Tk

**Total Cost = 1384 Tk**