Sequential Circuits Cheat Sheet (Theory Only)

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1. Introduction to Sequential Circuits

Sequential Circuits → Digital circuits where output depends on **both present inputs and past states** (memory is involved).

Two main components:

- **Combinational Logic (Logic Gates).**
- **Storage Elements (Latches, Flip-Flops).**

Types of Sequential Circuits:

- **Synchronous** → Clock-controlled.
- **Asynchronous** → Output changes immediately with input.

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2. Latches

Latches are basic memory elements that store **1-bit data**.
They are **level-triggered** (change state based on input).

(A) SR Latch (Set-Reset Latch)

Inputs: S (Set) and R (Reset).
Outputs: Q and Q' (complement of Q).
Operation:

- S = 1, R = 0 → Q = 1 (Set).
- S = 0, R = 1 → Q = 0 (Reset).
- S = 0, R = 0 → No change (Previous State).
- S = 1, R = 1 → **Invalid State**.

SR Latch Truth Table:

S	R	Q (Next State)	Q'
0	0	No Change	-
0	1	0 (Reset)	1
1	0	1 (Set)	0
1	1	Invalid	-

(B) D Latch (Data Latch)

Eliminates the invalid state of the SR latch.
Single input (D) and Clock (C).
Operation:

- D = 1 → Q = 1 (Set).
- D = 0 → Q = 0 (Reset).

Truth Table:
| D | Clock | Q (Next State) | |---|------|---------------| | 0 | 1 | 0 (Reset) | | 1 | 1 | 1 (Set) | | X | 0 | No Change |

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3. Flip-Flops

Flip-Flops are **edge-triggered storage elements** (change state only on the clock edge).
Types of Flip-Flops:

(A) RS Flip-Flop (Edge-Triggered SR Latch)

Works like SR Latch but with a clock signal.
Truth Table:

S	R	Q (Next State)
0	0	No Change
0	1	0 (Reset)
1	0	1 (Set)
1	1	Invalid

(B) JK Flip-Flop

Improves RS Flip-Flop (No invalid state).
Truth Table:

J	K	Q (Next State)
0	0	No Change
0	1	0 (Reset)
1	0	1 (Set)
1	1	Toggle

Toggle condition (J=1, K=1) changes state every clock cycle.

(C) D Flip-Flop (Data Flip-Flop)

Stores one-bit data (Prevents glitches).
Truth Table:

D	Clock	Q (Next State)
0	↑	0 (Reset)
1	↑	1 (Set)

(D) T Flip-Flop (Toggle Flip-Flop)

Toggles (Flips) output every clock pulse.
Truth Table:

T	Clock	Q (Next State)
0	↑	No Change
1	↑	Toggle

Used in Counters.

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4. Excitation Table of Flip-Flops

Used to design sequential circuits (reverse engineering truth tables).

Flip-Flop	Current State (Q)	Next State (Q_{n+1})	Input Needed
RS	0 → 0	No Change	S=0, R=0
RS	0 → 1	Set	S=1, R=0

Flip-Flop	Current State (Q)	Next State (Q_{n+1})	Input Needed
RS	1 → 0	Reset	S=0, R=1
JK	0 → 1	Set	J=1, K=0
JK	1 → 0	Reset	J=0, K=1
JK	Toggle	Toggle	J=1, K=1
D	0 → 1	Load 1	D=1
T	Toggle	Flip State	T=1

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5. Counters

Counters store and count values on clock pulses.
Types:

(A) Asynchronous Counters (Ripple Counters)

Each Flip-Flop toggles the next one.
Slower due to propagation delay.

(B) Synchronous Counters

All Flip-Flops change at the same time (faster).

(C) MOD Counters

Counts up to n states (MOD-n counter).
Example: **MOD-4 counter counts 0 → 1 → 2 → 3 → 0.**

(D) Johnson Counter

Modified ring counter with feedback.
Generates **2n unique states using n Flip-Flops.**

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6. Shift Registers

Stores and shifts data in bit sequences.
Types of Shift Registers:

Type	**Function**
SISO (Serial In Serial Out)	Shifts data **one bit at a time**
SIPO (Serial In Parallel Out)	Serial input, Parallel readout
PISO (Parallel In Serial Out)	Parallel input, Serial readout
PIPO (Parallel In Parallel Out)	Parallel input & Parallel output
Universal Shift Register	**Can perform all operations (SISO, SIPO, PISO, PIPO)**

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7. Ripple Counter

A type of Asynchronous Counter where the flip-flop output acts as the clock for the next flip-flop.
Example: 4-bit Ripple Counter (counts 0000 to 1111).

Comparison of Sequential Circuits

Feature	Latches	Flip-Flops	Counters	Shift Registers
Triggering	Level	Edge	Edge	Edge
Storage	1-bit	1-bit	Multiple bits	Multiple bits
Uses	Simple memory	Storage & Timing	Counting & Frequency Division	Data Transfer

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Key Takeaways

Sequential Circuits have memory (store past states).
Latches (SR, D) store bits based on input levels.
Flip-Flops (RS, JK, D, T) are edge-triggered storage devices.
Counters (Async/Sync, MOD, Johnson) are used for counting events.
Shift Registers shift bits in multiple configurations.

This **Sequential Circuits Cheat Sheet** covers **latches, flip-flops, excitation tables, counters, and shift registers**. Let me know if you need further explanations!