EE 434

Lecture 43

Sequential Logic

Most useful circuits include a combination of combinational & sequential logic blocks

Observation:

- Multiple-input NAND or NOR gates are sufficient to build any combinational logic function
- Any clocked flip flop or storage element will be sufficient to add the sequential logic functionality to any system.

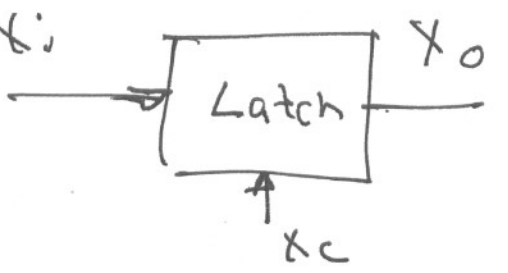
Memory Circuits / Elements

1) Latch

2) Flip Flop

3) Memory Cell

Latches:



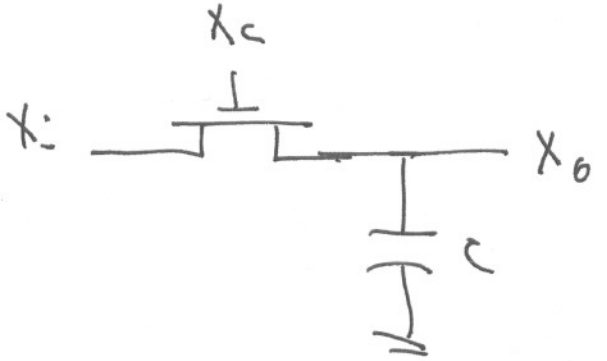
Terminology

Transparency: Input to Latch appears immediately on the latched output.

Opaque: Input to the Latch does not appear at the output while in the opaque state

Edge Triggered: Input to the latch at a control transition determines when the input is transferred to the latch output

Example:



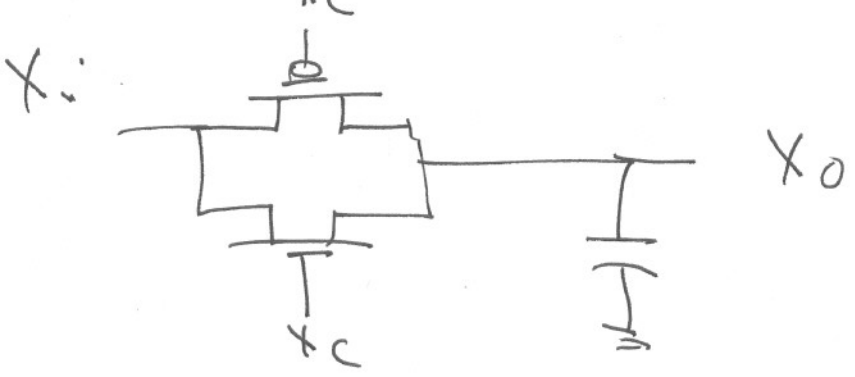
when Xc is high, output tracks Input

when Xc is low, latch is opaque

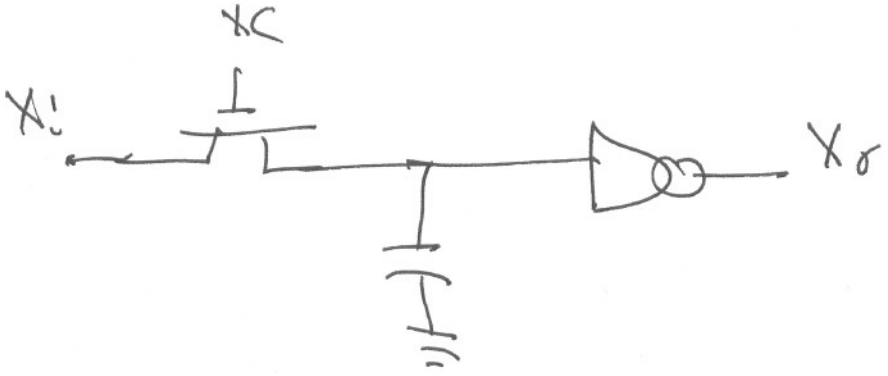
- very simple
- negative edge triggered.

Limitations:

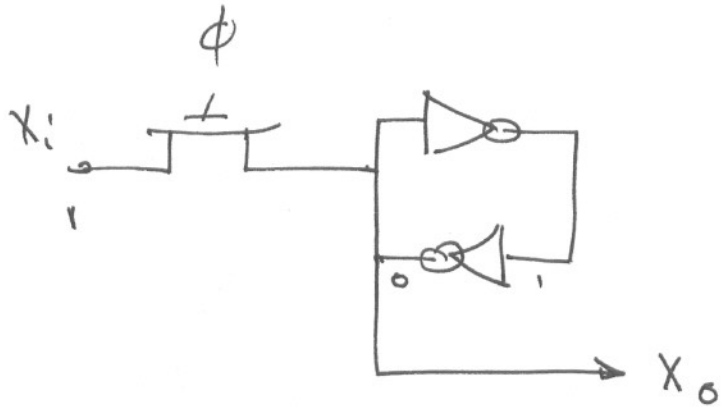
- X_O can get no closer to V_{DD} than V_{Tn}
- leakage of charge will occur when Xc is low
- any loads placed on Xc will further degrade signal



- rail to rail output
- leakage & loading problem
- more complexity

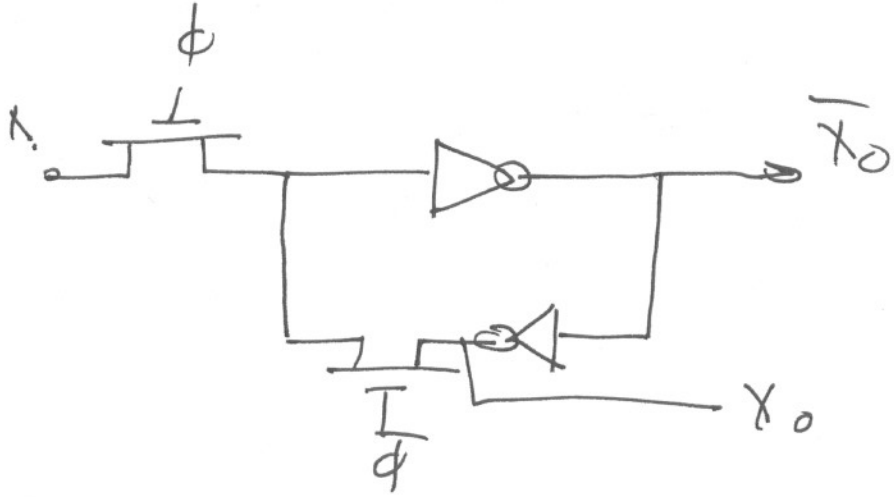


- removes loading problem



- removes the leakage problem.
- volatile
- load challenge

  load transistor must be stronger than the FB inverter.



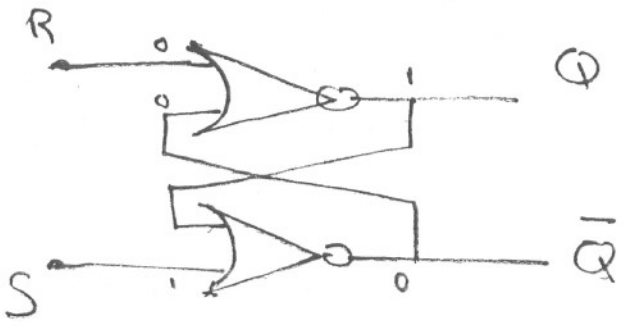
6- transistor solution

Flip Flops

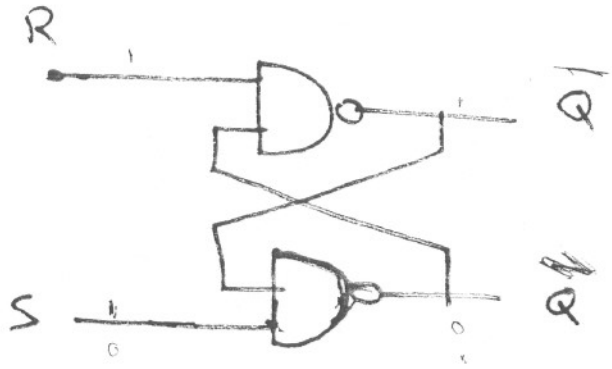
S-R
D
T
JK

} Master/Slave Version

S-R flip flop



Two cross-coupled NOR gates



Two cross-coupled NAND gates

R & S can not be high at the same time

R & S can not be low at the same time

If they are ever both simultaneously high, the state of the FF when both go low will be indeterminate

1 level of logic
2 transistors

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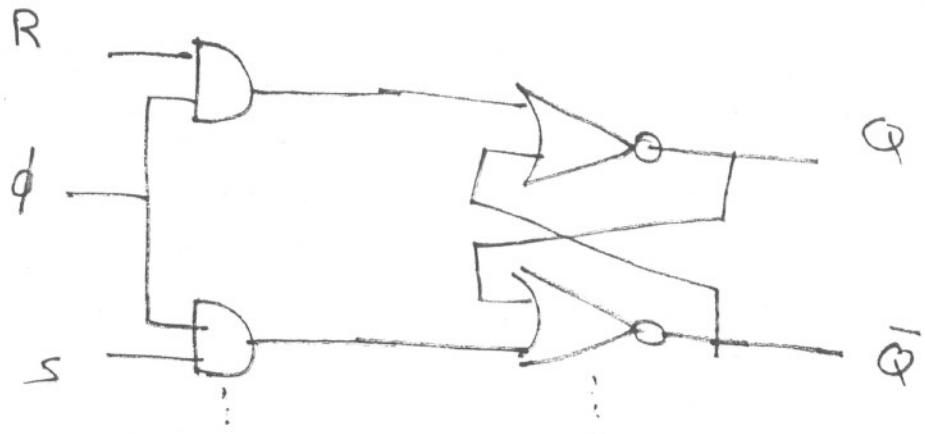
To obtain a clocked S-R flip flop



12 + 8 = 20

- output will not change when ϕ is low
- Output is immediate when ϕ is high

20 transistors 3 levels of logic

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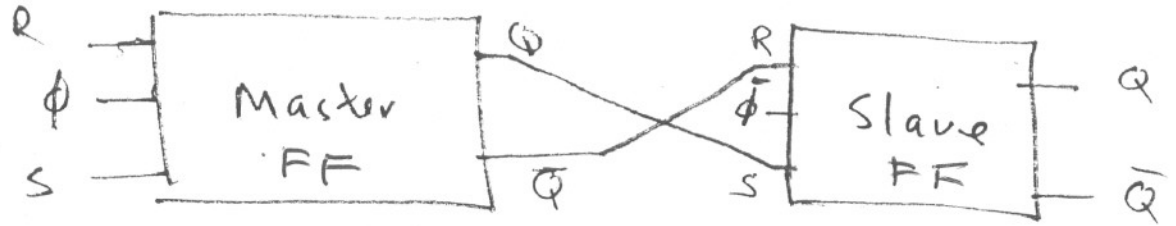
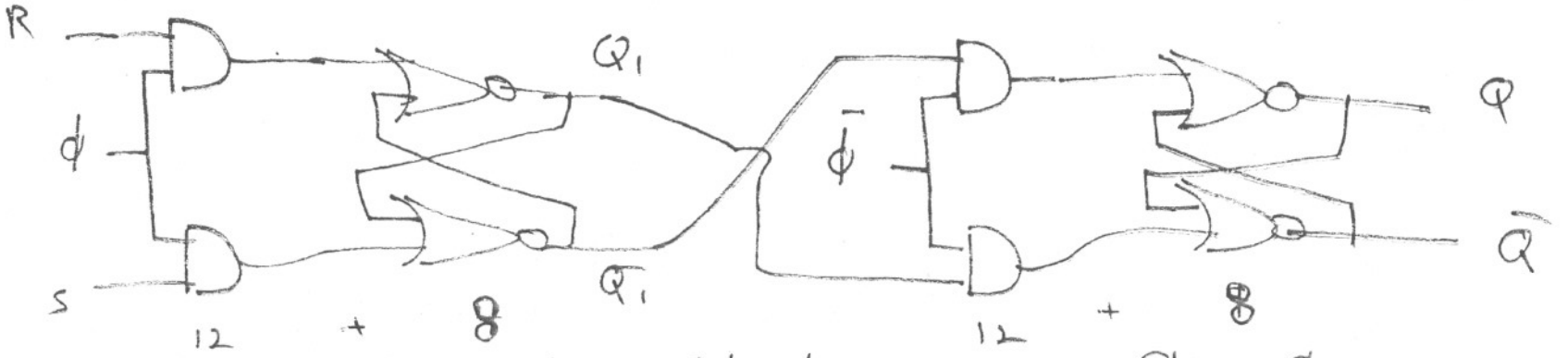


Master Slave Flip Flop



Master-Slave Clocked S-R flip flop
triggered on negative edge ϕ

40 transistors
6 levels of logic

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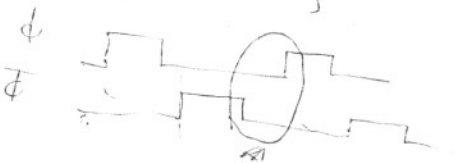
- output is not immune to either ϕ or ϕ̄
- avoid "shoot-through" when ϕ goes from LOW to HIGH



Or be sure ϕ̄ goes low before ϕ goes high