Circuitos Digitais

Prof. Ricardo Pedroni
ricardopedroni@utfpr.edu.br
www.rpedroni.com.br

Registradores

Prof. Ricardo Pedroni
ricardopedroni@utfpr.edu.br
www.rpedroni.com.br

Ementa

- Lembre!
  - Análise e Projeto de Circuitos Combinacionais
  - Módulos Combinacionais Padrão
    - Mux, Demux, etc.
  - Circuitos Combinacionais x Sequenciais

Ementa

- Registradores
- Sinal de Sincronia ~ Clock
- Latch
- Flip Flop

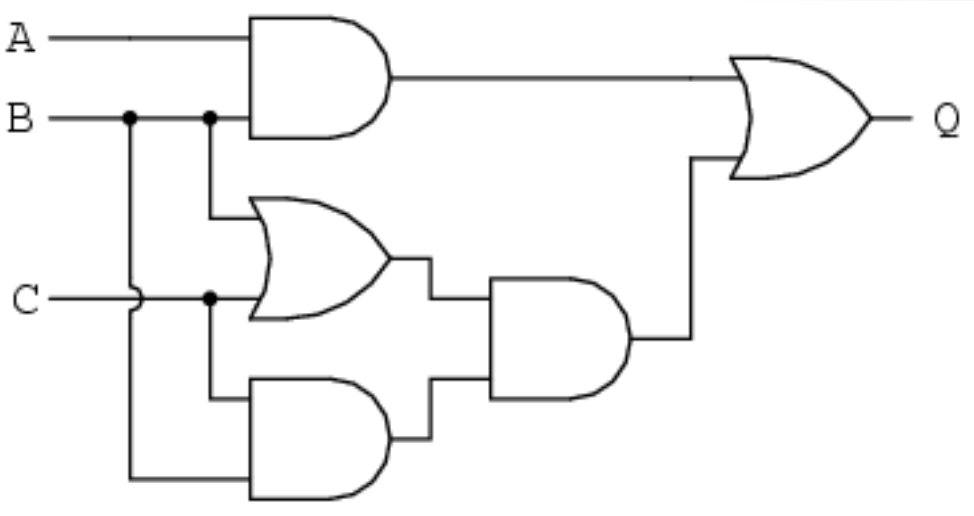
Registradores

Registradores

- O que define um Circuito Combinacional?
- Qual a diferença entre um Circuito Combinacional de um Circuito Sequencial?
- Qual o conceito básico que diferencia os dois?

Registradores

- Análise de Circuito
  - Mesmas entradas geram mesmas saídas (só importa a **combinação** da entrada)

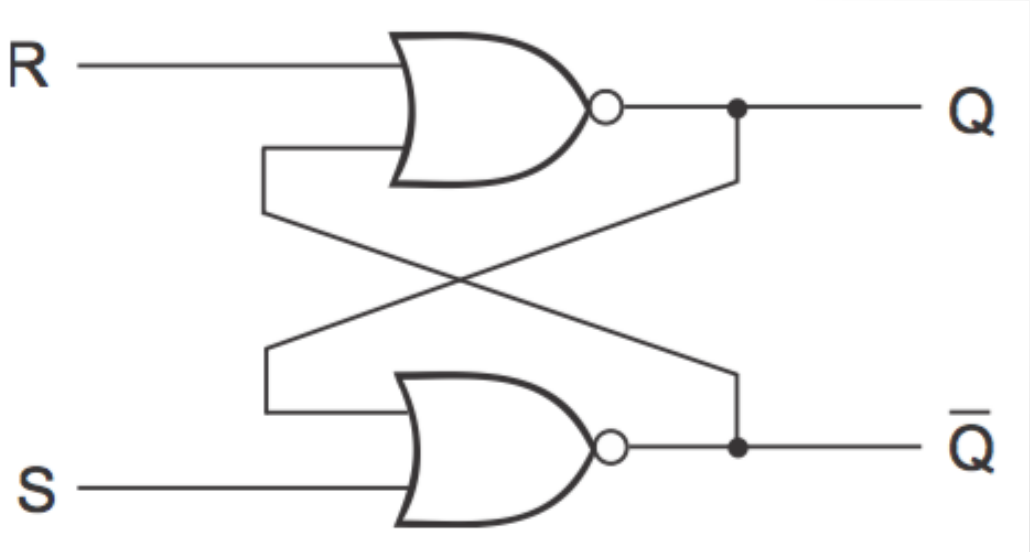


→A saída do circuito depende apenas das entradas <u>naquele instante</u>

Registradores

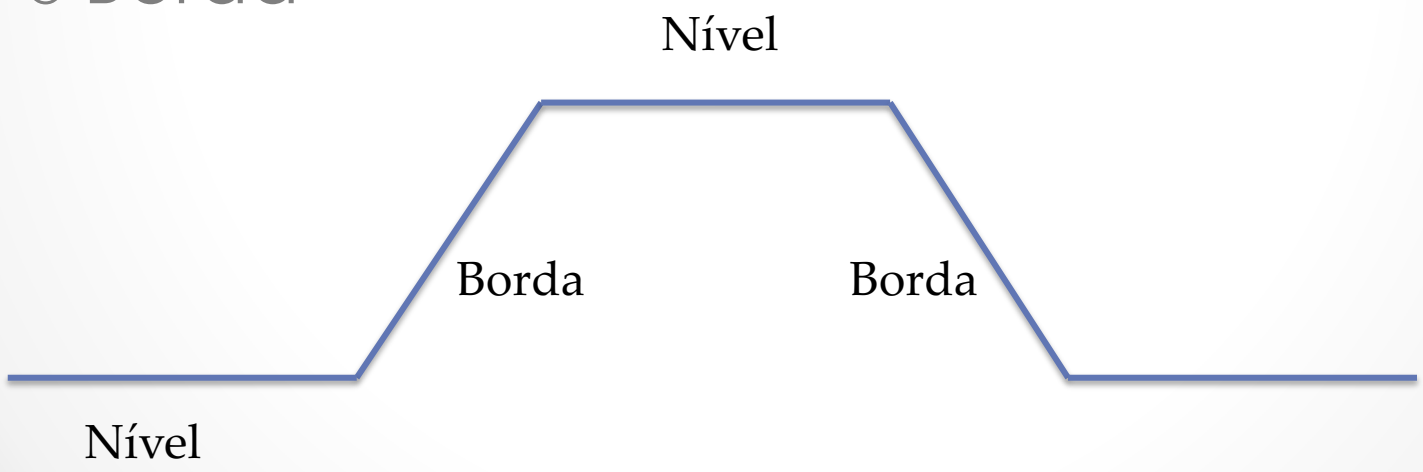
- Análise de Circuito
  - Mesmas entradas podem gerar saídas diferentes (a **sequência** importa)

→A saída do circuito depende das entradas naquele instante e valores prévios



Nível x Borda

- Um sinal digital é composto por dois momentos de existência
  - Nível
  - Borda



Nível x Borda

- Nível é qualquer valor estável, alto ou baixo, de um sinal

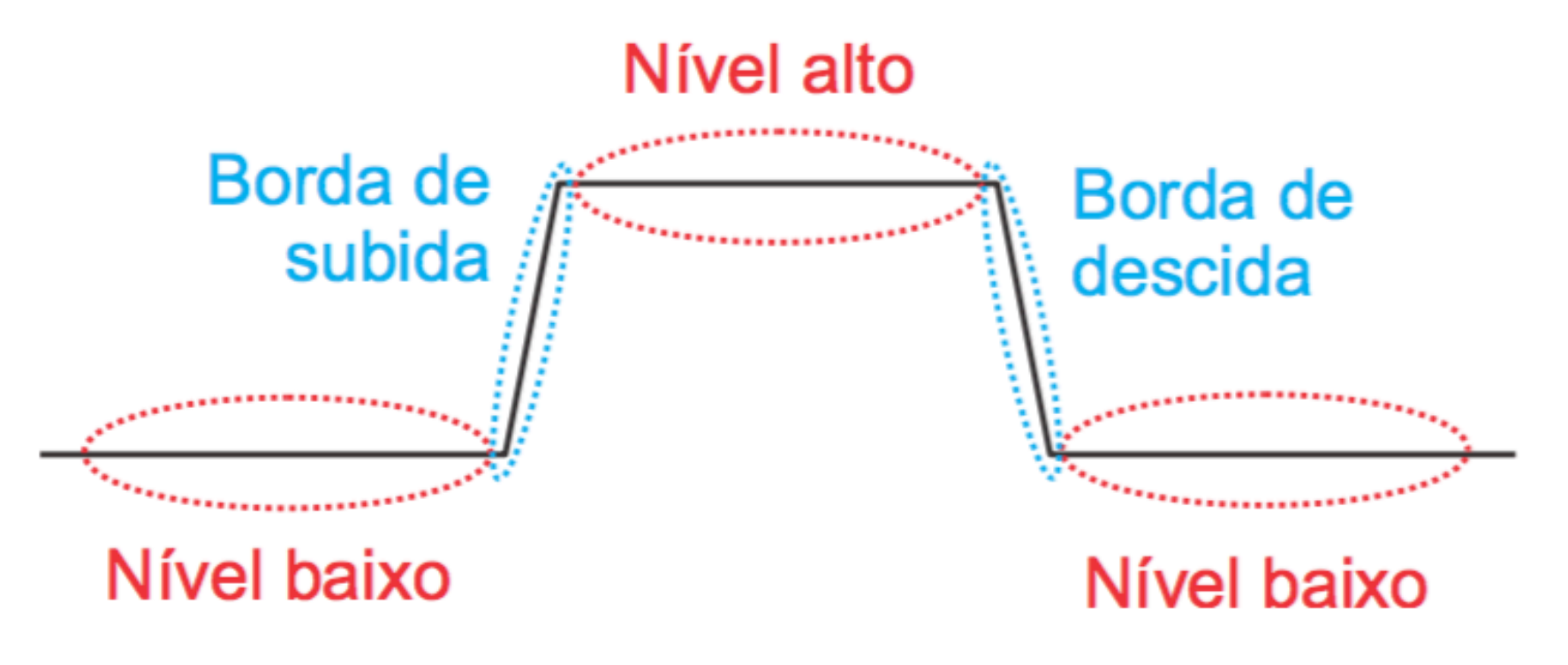
- Borda é a (ou momento de) transição de um valor baixo para um valor alto e vice versa

Nível x Borda

- Nível Alto (Positivo) → '1'
- Nível Baixo (Negativo) → '0'
- Borda de Subida (Positiva) →
- Borda de Descida (Negativa) →

Nível x Borda

- Resumindo



Nível x Borda

- A distinção dos dois é relevante
- Nível → Janela de tempo, depende da período do sinal
- Borda → Momento específico e muito curto, independe da período (mas o número de ocorrências depende!)

Nível x Borda

- Os registradores são quebrados em dois sub-grupos

- Qualquer circuito que responde ou tem atividade em:
  - Nível → **é um <u>Latch</u>**
  - Borda → **é um <u>Flip Flop</u> (FF)**

Sinal de Sincronia Clock

Sinal de Sincronia

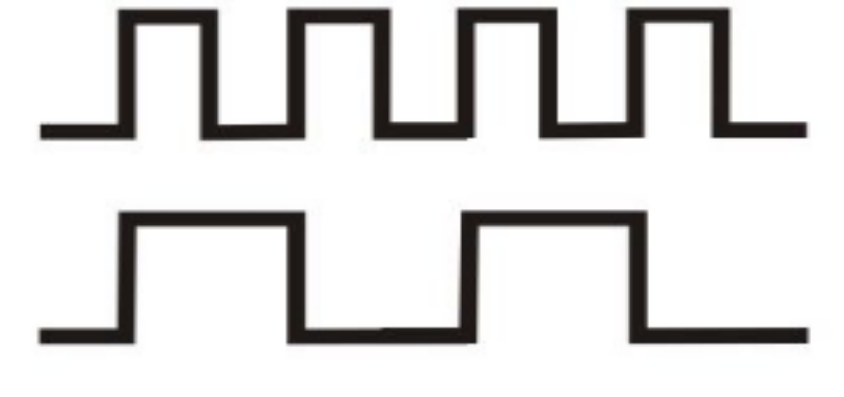
- A maioria dos registradores utiliza um sinal especificamente para dar sincronia ao circuito

- Sincronização ("trabalhar num momento específico") dá possibilidade a funções impossíveis de se realizar em circuitos combinacionais
  - Temporização
  - Contagem
  - Etc.

Sinal de Sincronia

- Esse sinal de sincronia é comumente chamado de ***clock***

- Clock é tipicamente um sinal quadrado, cuja frequência determina a taxa de operação de um circuito ou sistema



Sinal de Sincronia

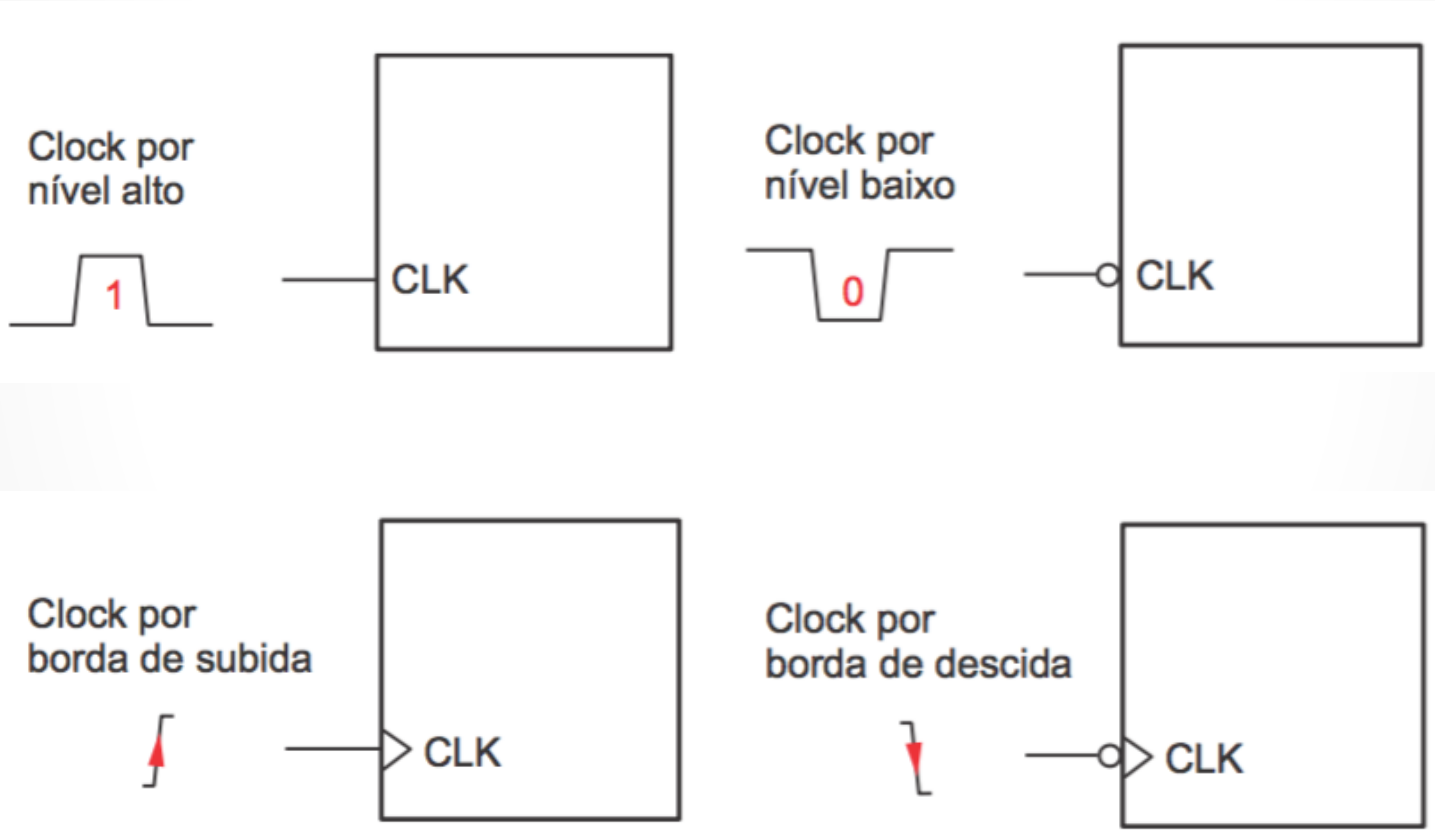
- Clock, como todo sinal digital, tem níveis e bordas
- Se todas as partes sequenciais de um circuito utilizam o mesmo clock, chamamos o circuito de *síncrono*
- Um circuito pode ser considerado *assíncrono* mesmo possuindo um clock
  - i.e. Possui mais de uma fonte de sincronia!

Sinal de Sincronia

- A entrada de clock é a entrada de comando, também chamada de trigger (gatilho) de um registrador

- Mais uma vez, se o circuito trabalha com:
  - Nível → Latch
  - Borda → Flip flop

Sinal de Sincronia



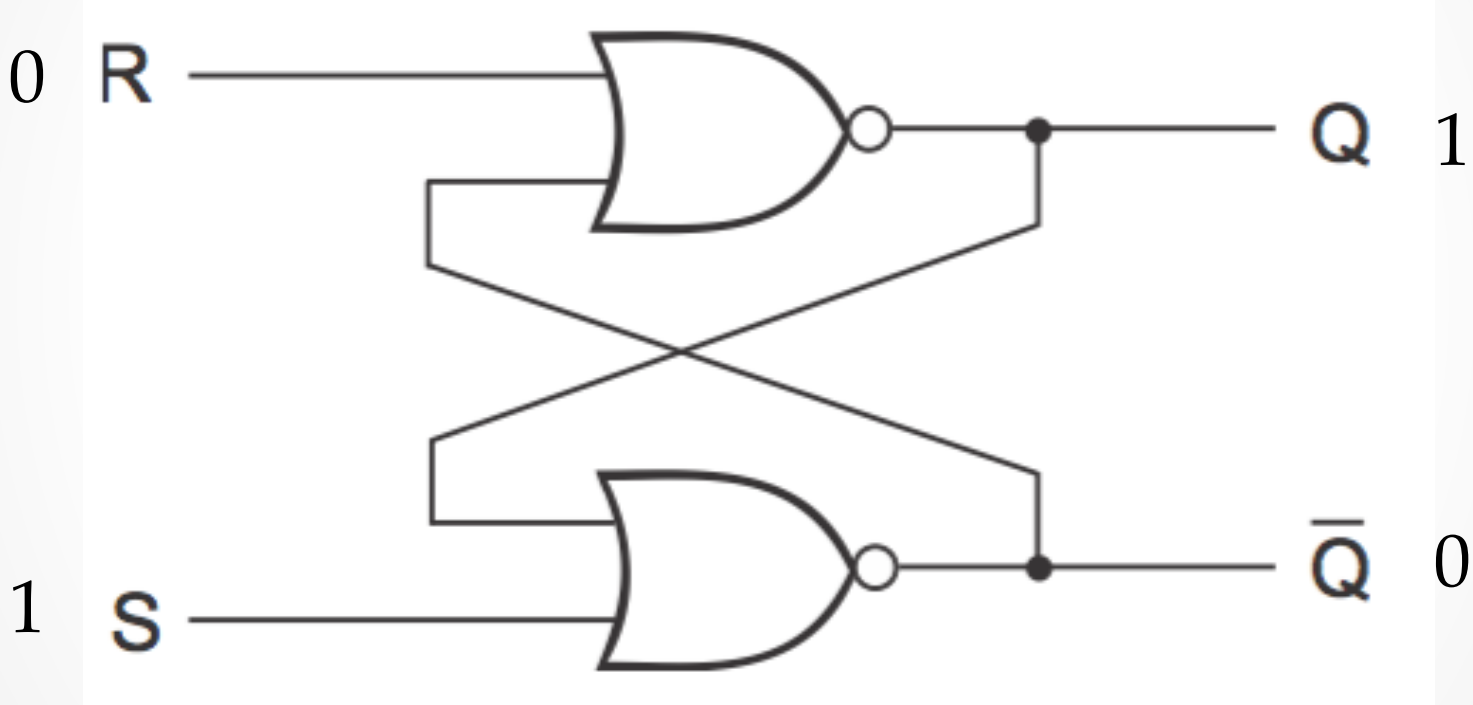
Registradores: Latches

Latches

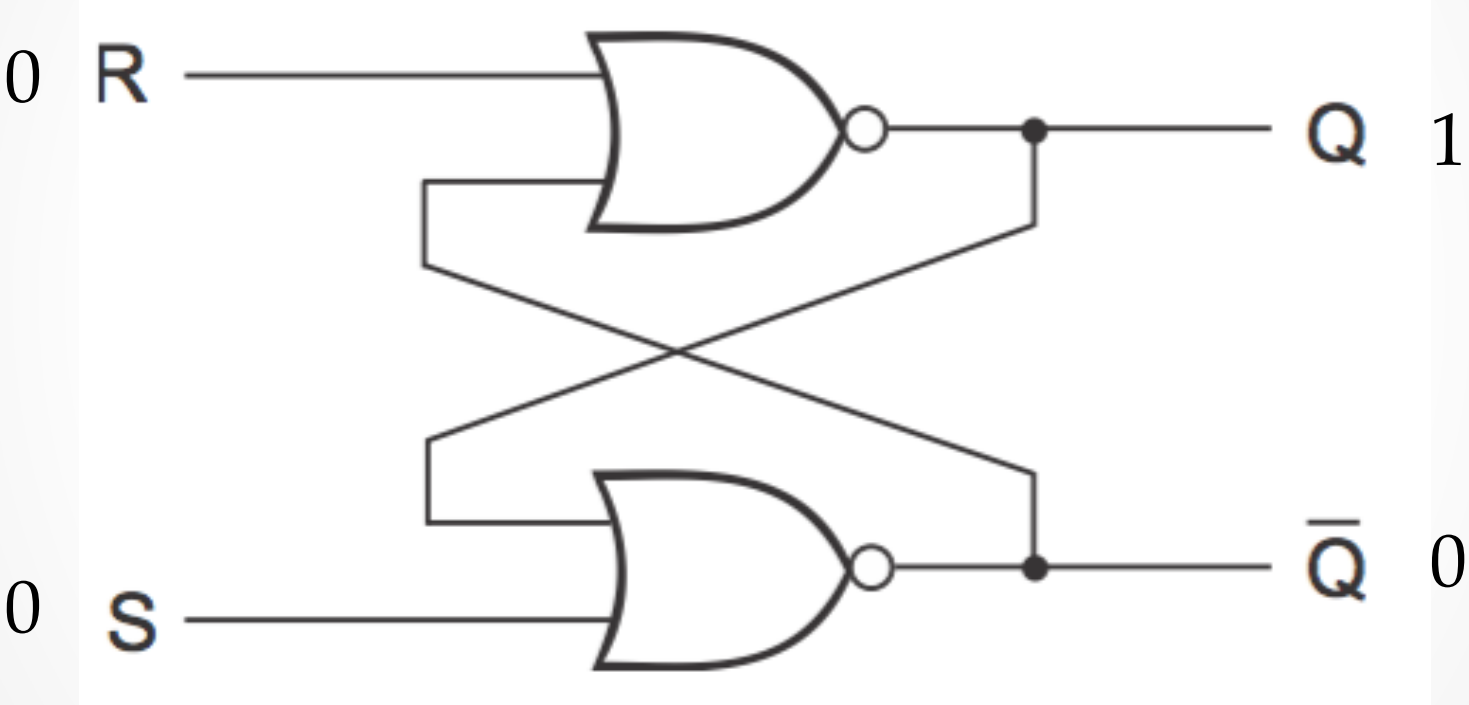
- Latches trabalham com os **NÍVEIS** do sinal/sinais de entrada

- Tipos de Latches:
  - SR Latch (SRL)
  - D Latch (DL)

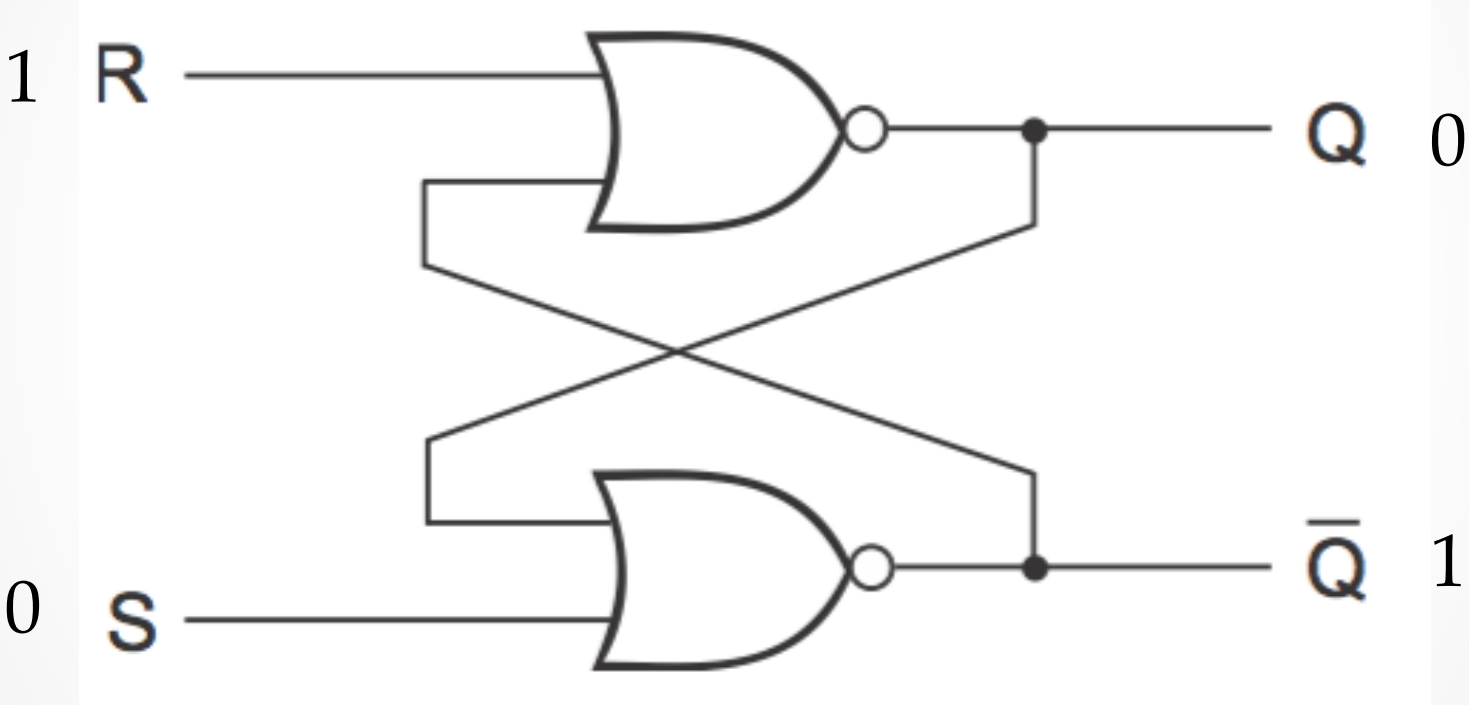
SR Latch



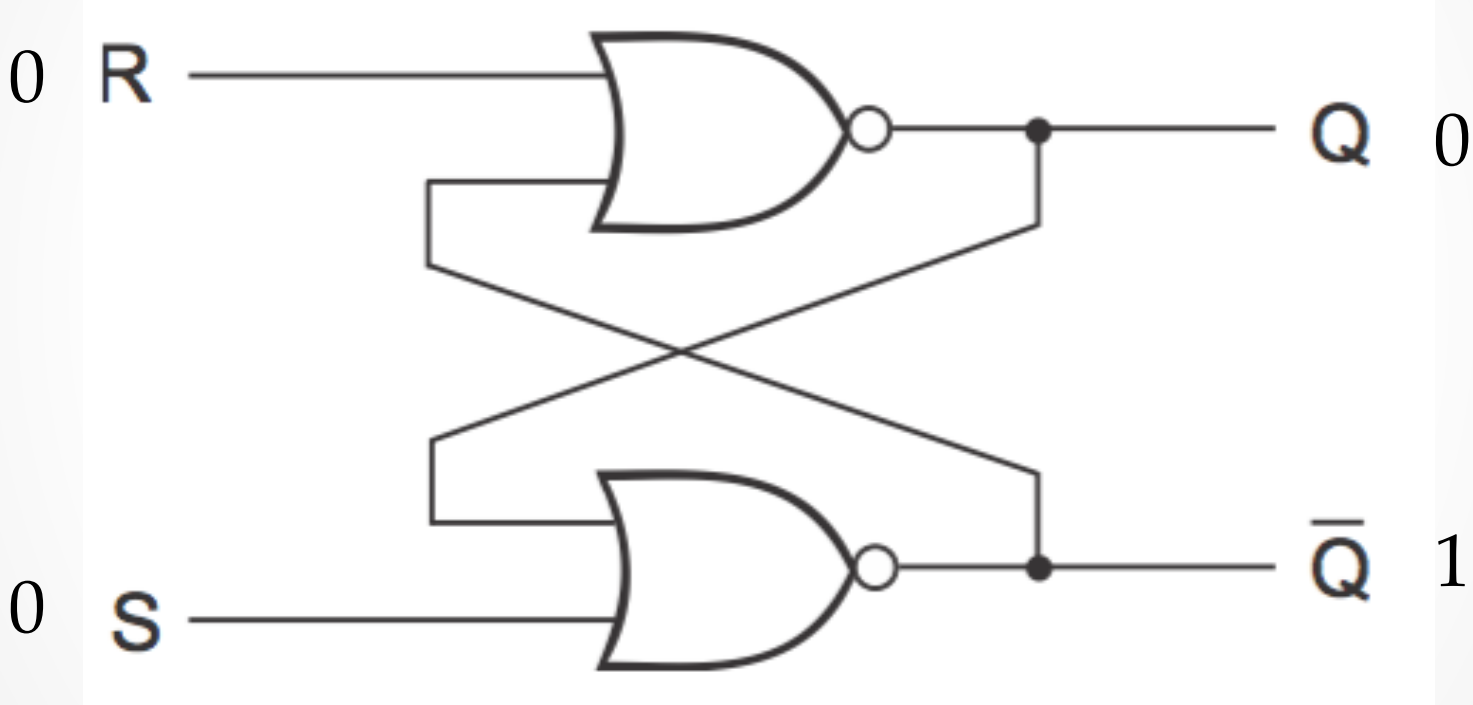
SR Latch



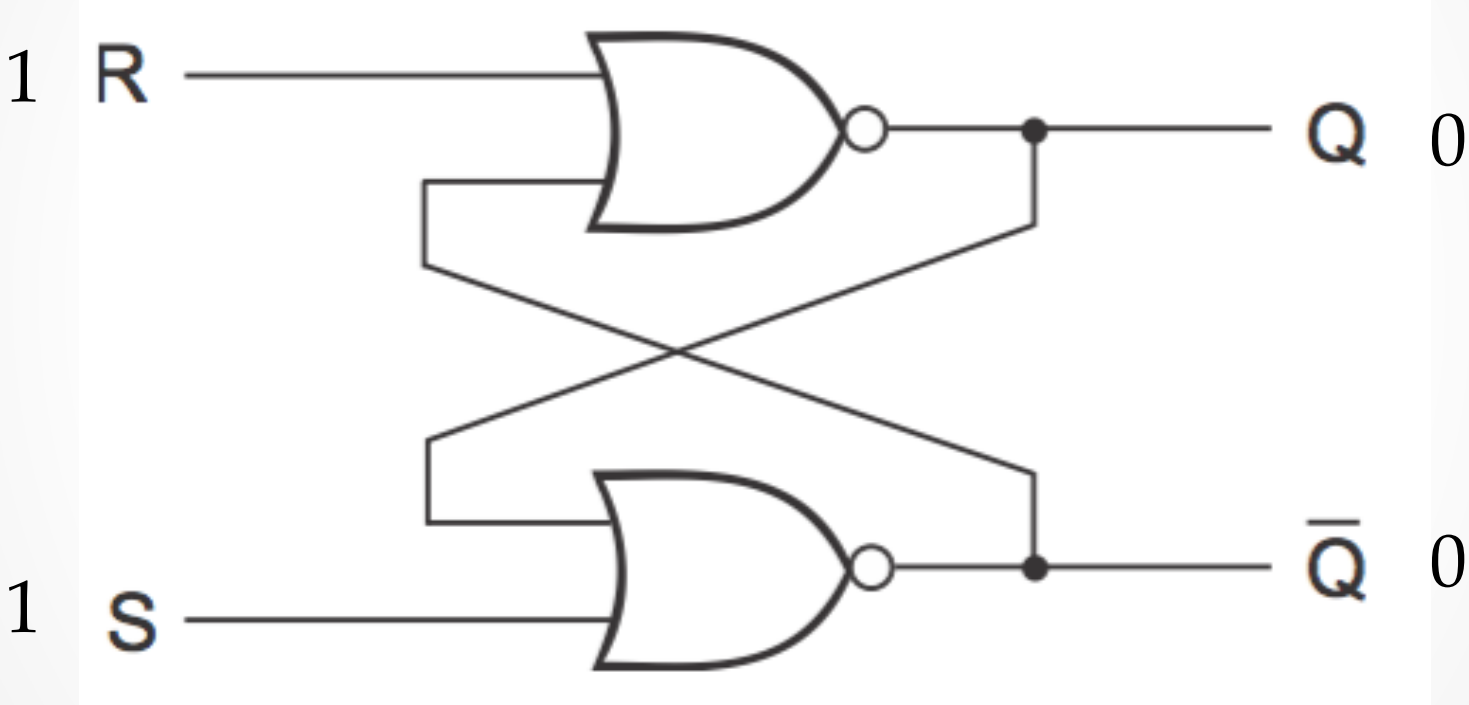
SR Latch



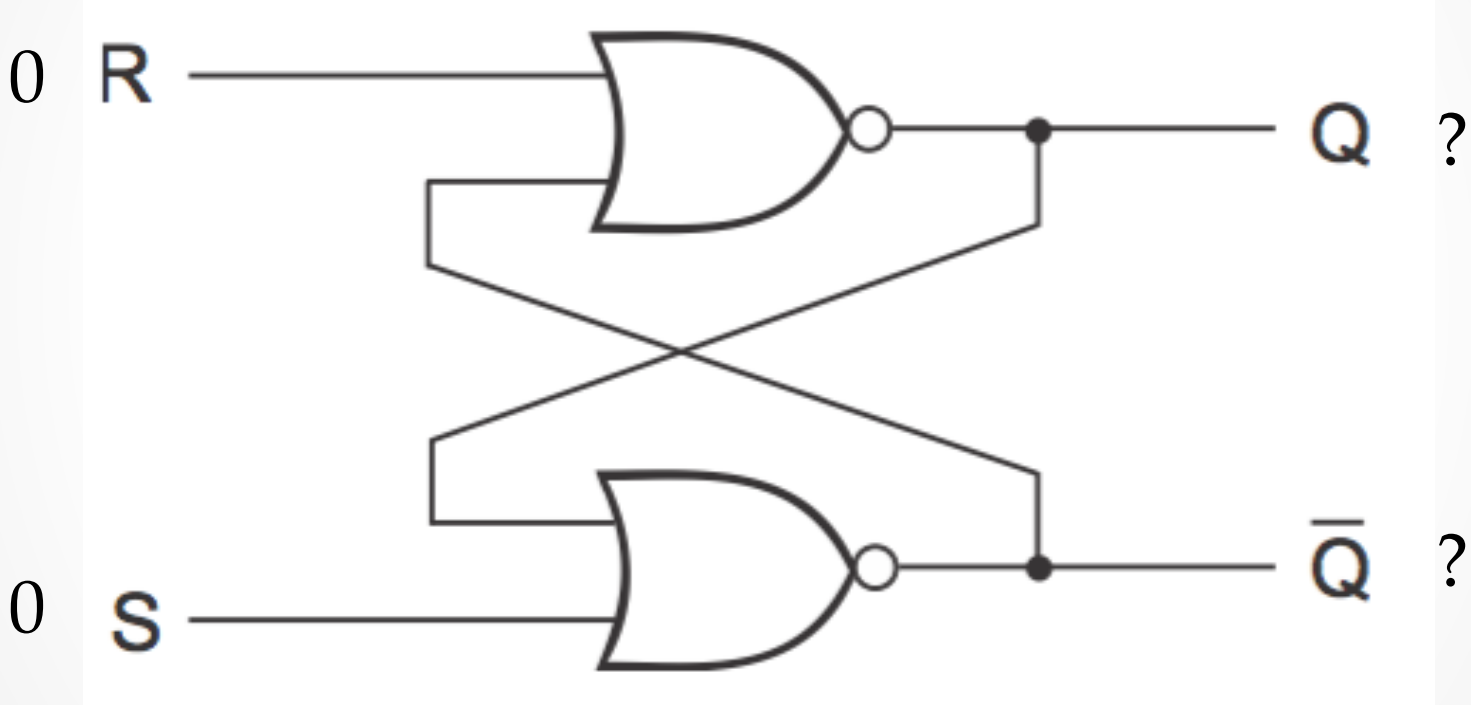
SR Latch



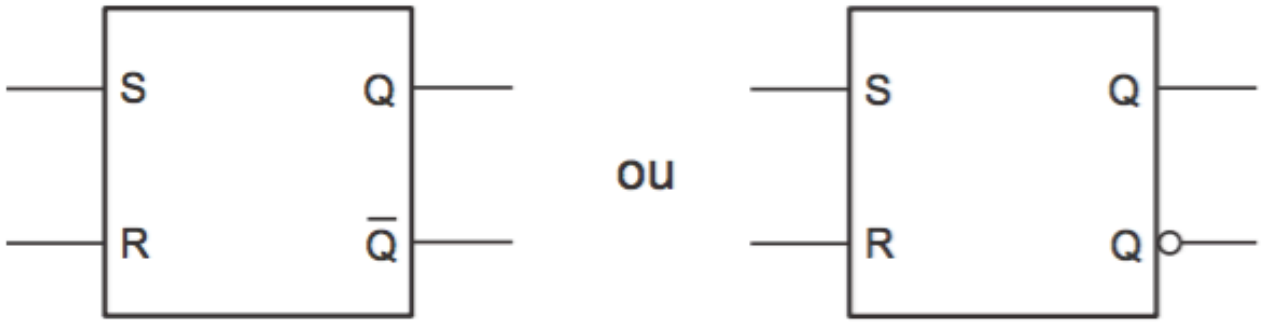
SR Latch



SR Latch



SR Latch

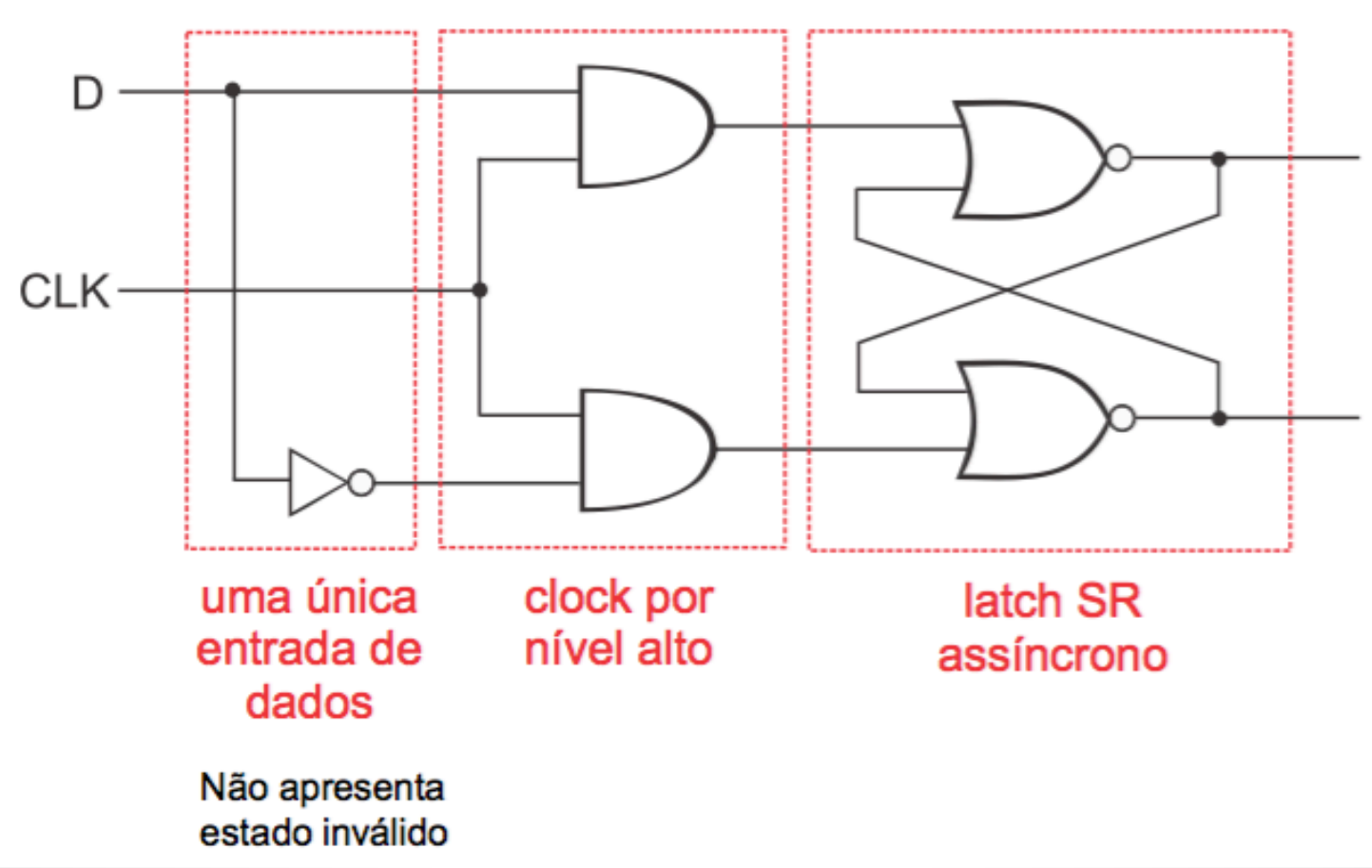


S	R	Q	$\overline{Q}$	
0	0	Q_0	$\overline{Q}_0$	
0	1	0	1	
1	0	1	0	
1	1	0	0	Inválido

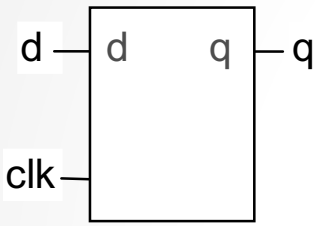
D Latch

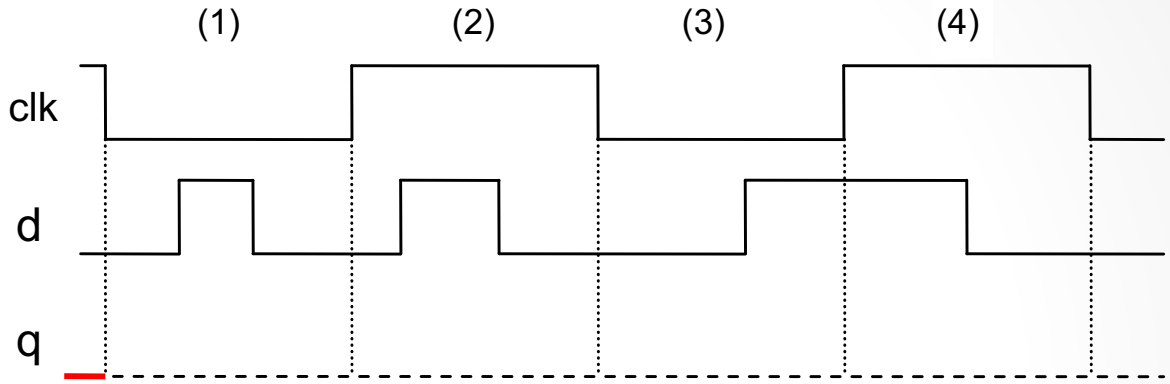
- D Latch é parecido com o SR Latch com um bloco a mais
- O SR possuia apenas as entradas S e R, já o D tem as entradas D e o sinal de sincronia, *clock*
- Bastante utilizado

D Latch


D
CLK
uma única entrada de dados
clock por nível alto
latch SR assíncrono
Não apresenta estado inválido

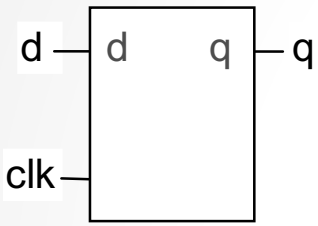
D Latch

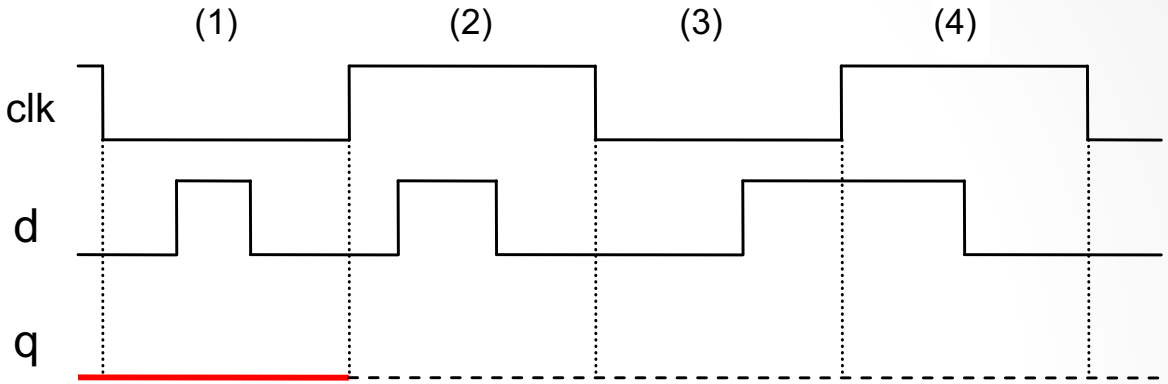




(1) = transparent or opaque?

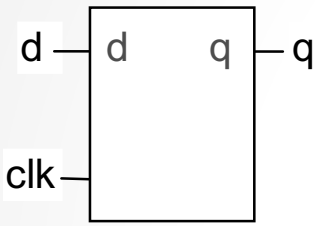
D Latch

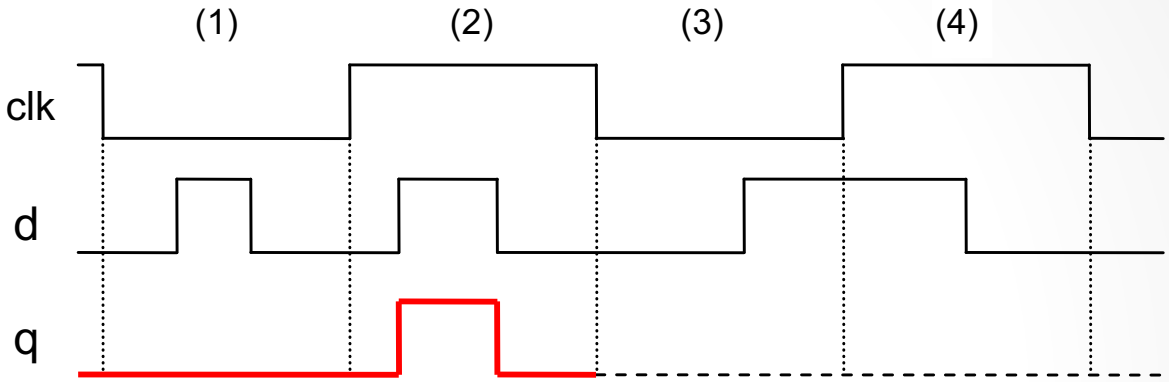




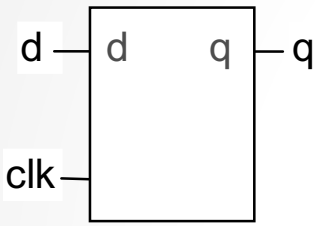
(2) = transparent or opaque?

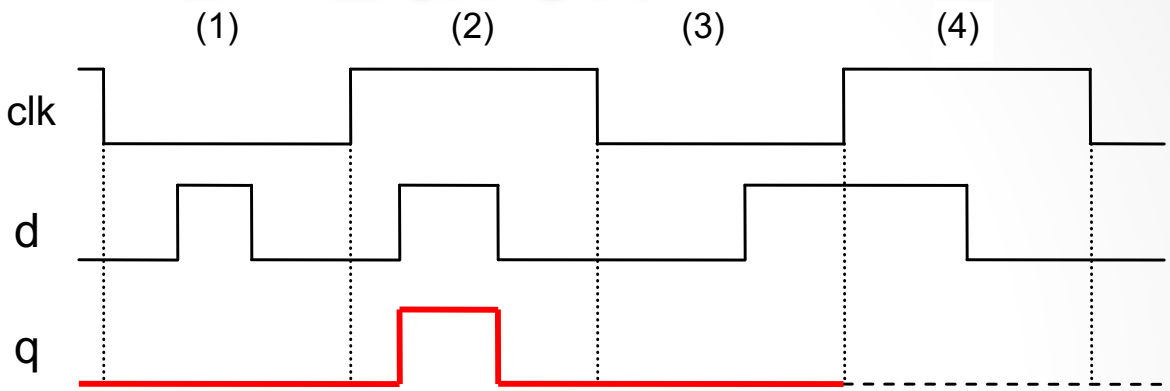
D Latch



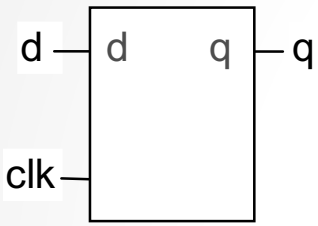


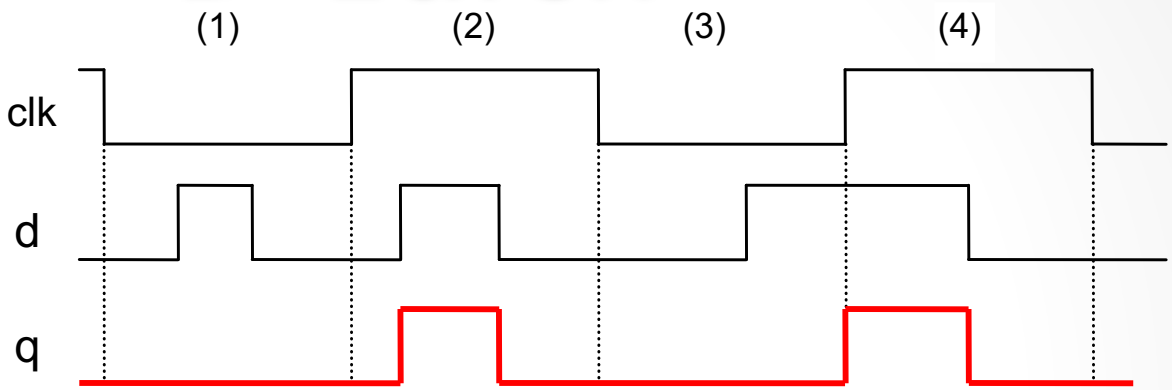
D Latch



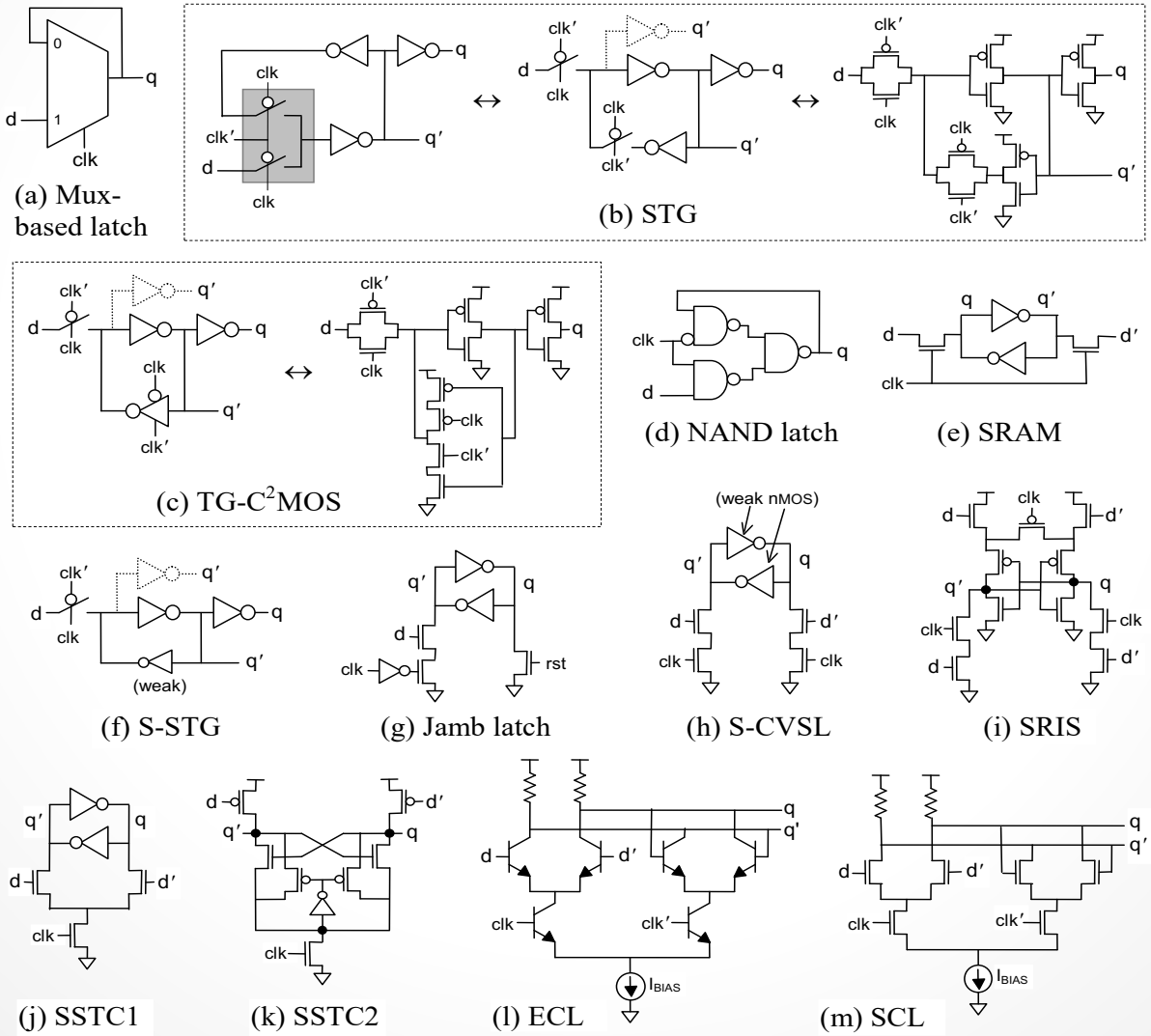


D Latch

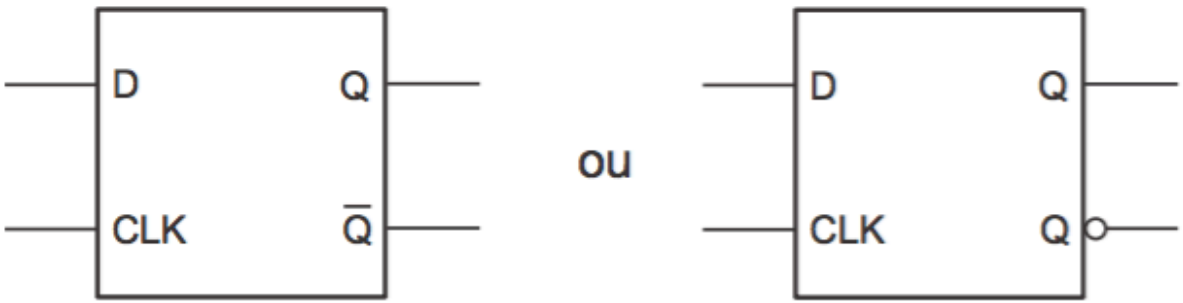




D Latch


(a) Mux-based latch
(b) STG
(c) TG-C²MOS
(d) NAND latch
(e) SRAM
(weak)
(f) S-STG
(g) Jamb latch
(weak nMOS)
(h) S-CVSL
(i) SRIS
(j) SSTC1
(k) SSTC2
(l) ECL
(m) SCL

D Latch



CLK	D	Q	$\overline{Q}$	
0	X	Q_0	$\overline{Q}_0$	← Opaco (mantém)
1	0	0	1	Transparente
1	1	1	0	

Registradores: Flip Flops

Flip Flops

- Flip Flops trabalham com as **BORDAS** dos sinais de entrada (quase sempre esse sinal é o clock)

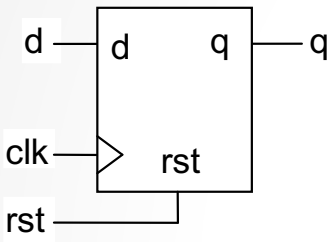
- Tipos de Flip Flops:
  - SR Flip Flop (SRFF)
  - D Flip Flop (DFF)
  - T Flip Flop (TFF)
  - JK Flip Flop (JKFF)

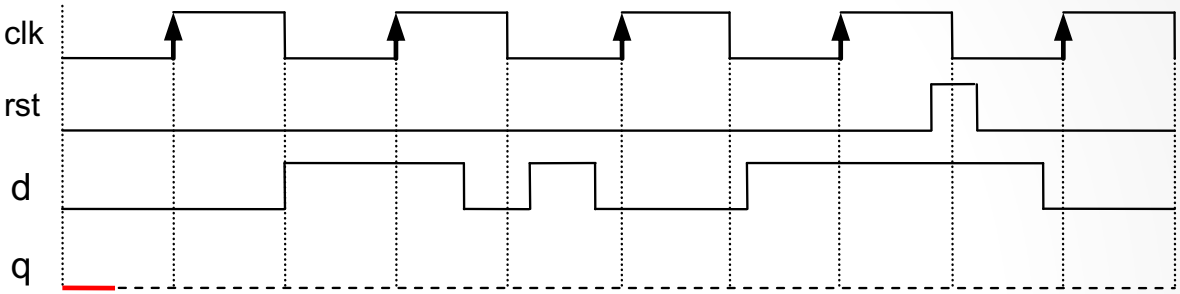
Flip Flops

- Flip flops são muito mais utilizados do que latches por causa da sua natureza de trabalhar com bordas → **amostrar** um sinal ou **ter atividade** em um momento específico

- Entre latches e flip flops, o mais útil e produzido é o **DFF**

DFF





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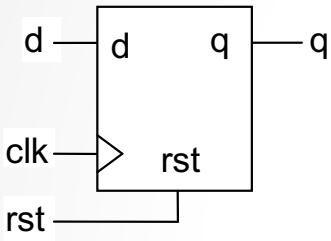

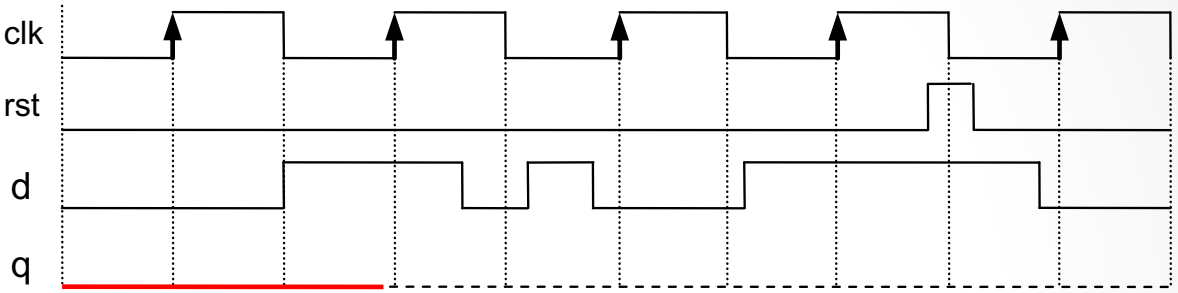

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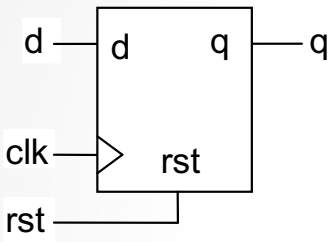

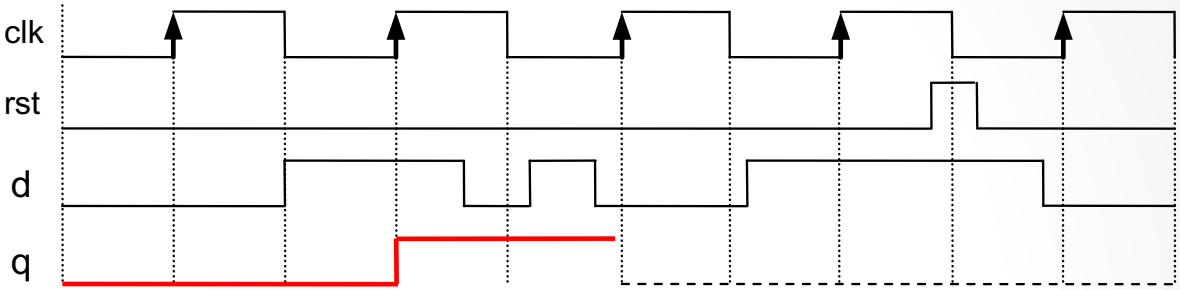

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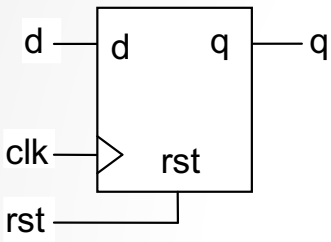

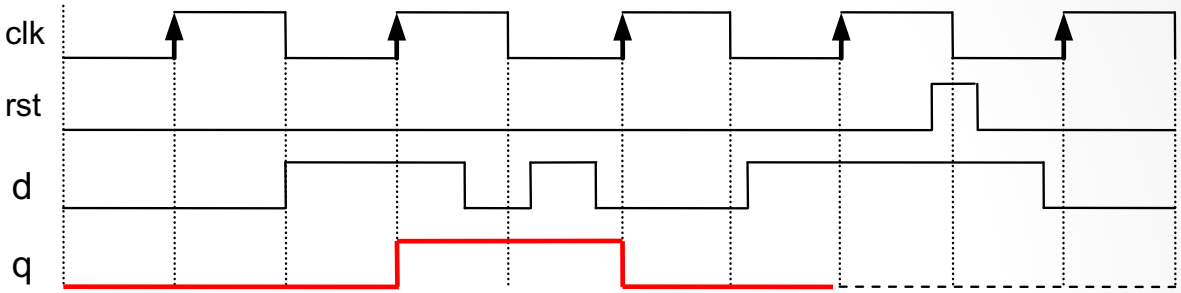

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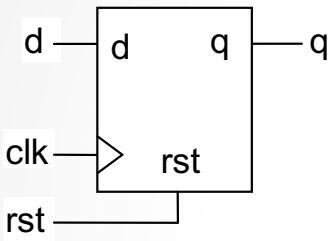

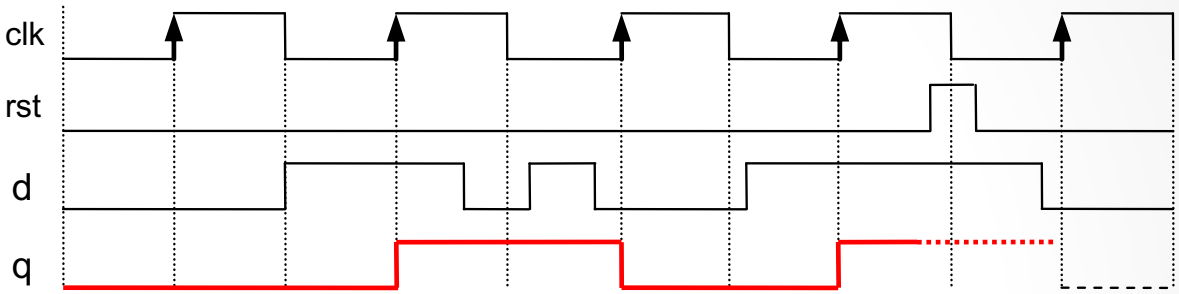

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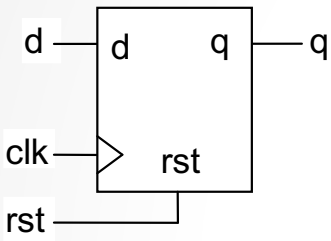

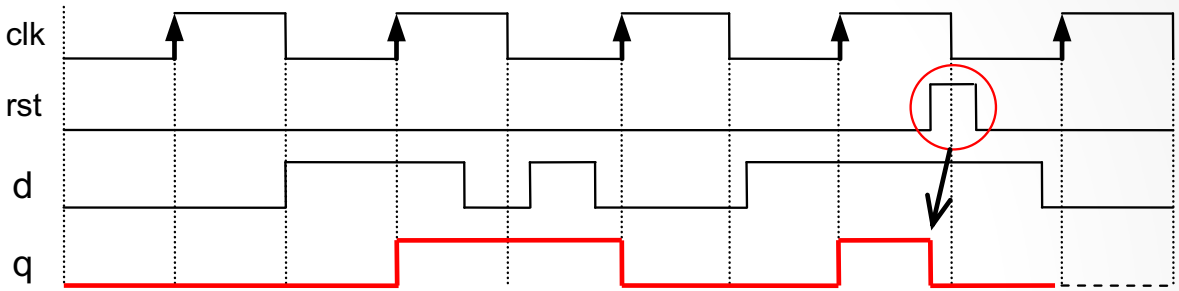

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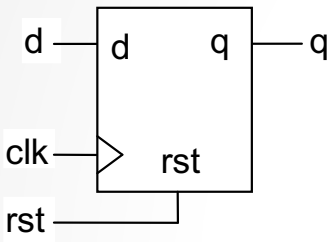

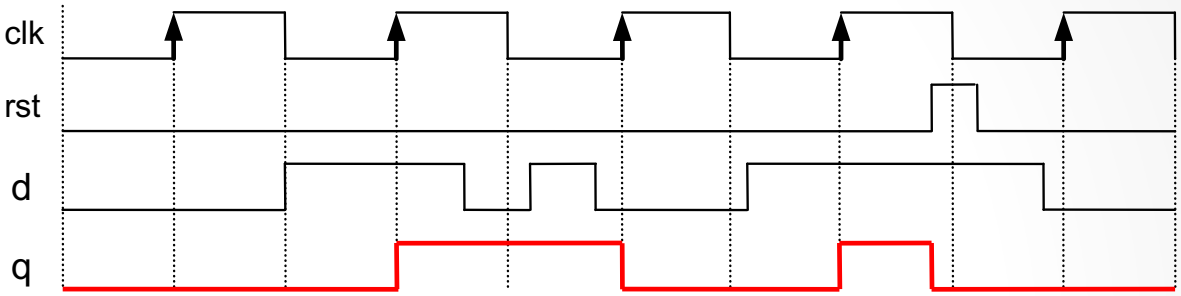

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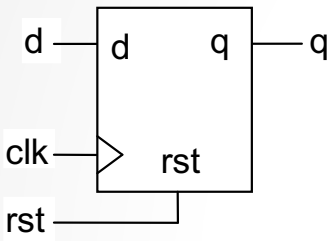
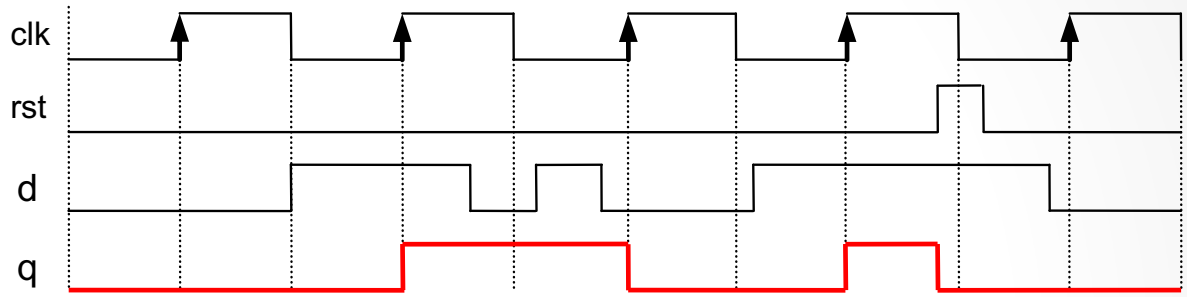
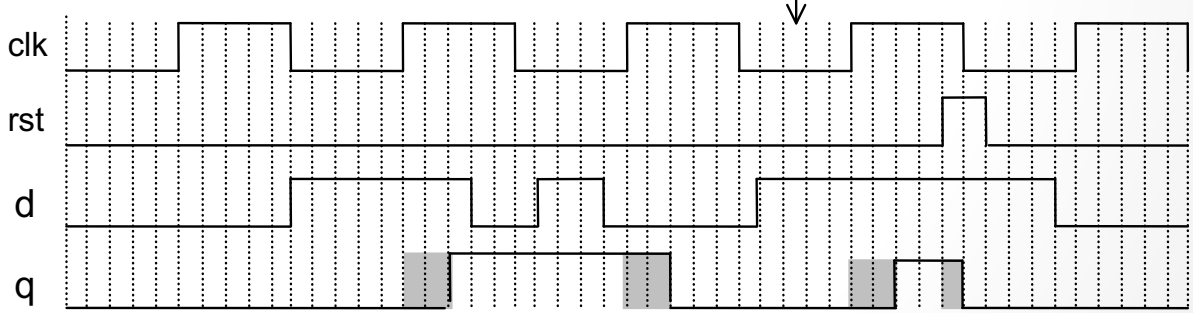




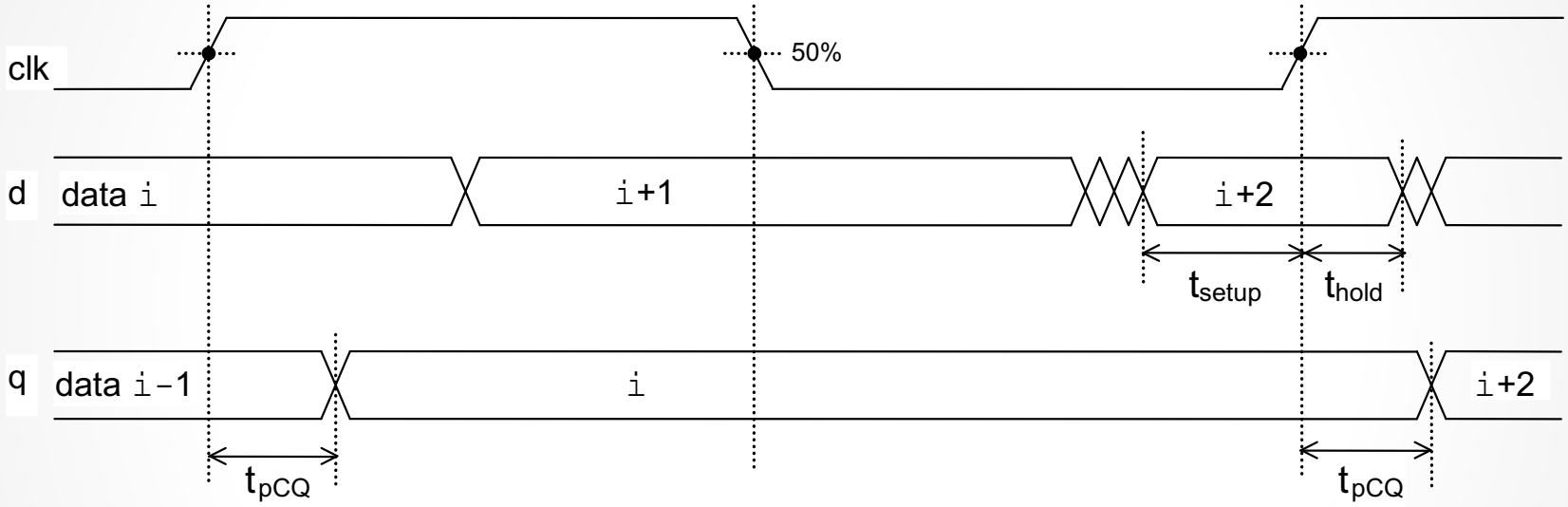
Propagation delay: t_{pCQ} = 2 ns

Time slot = 1 ns



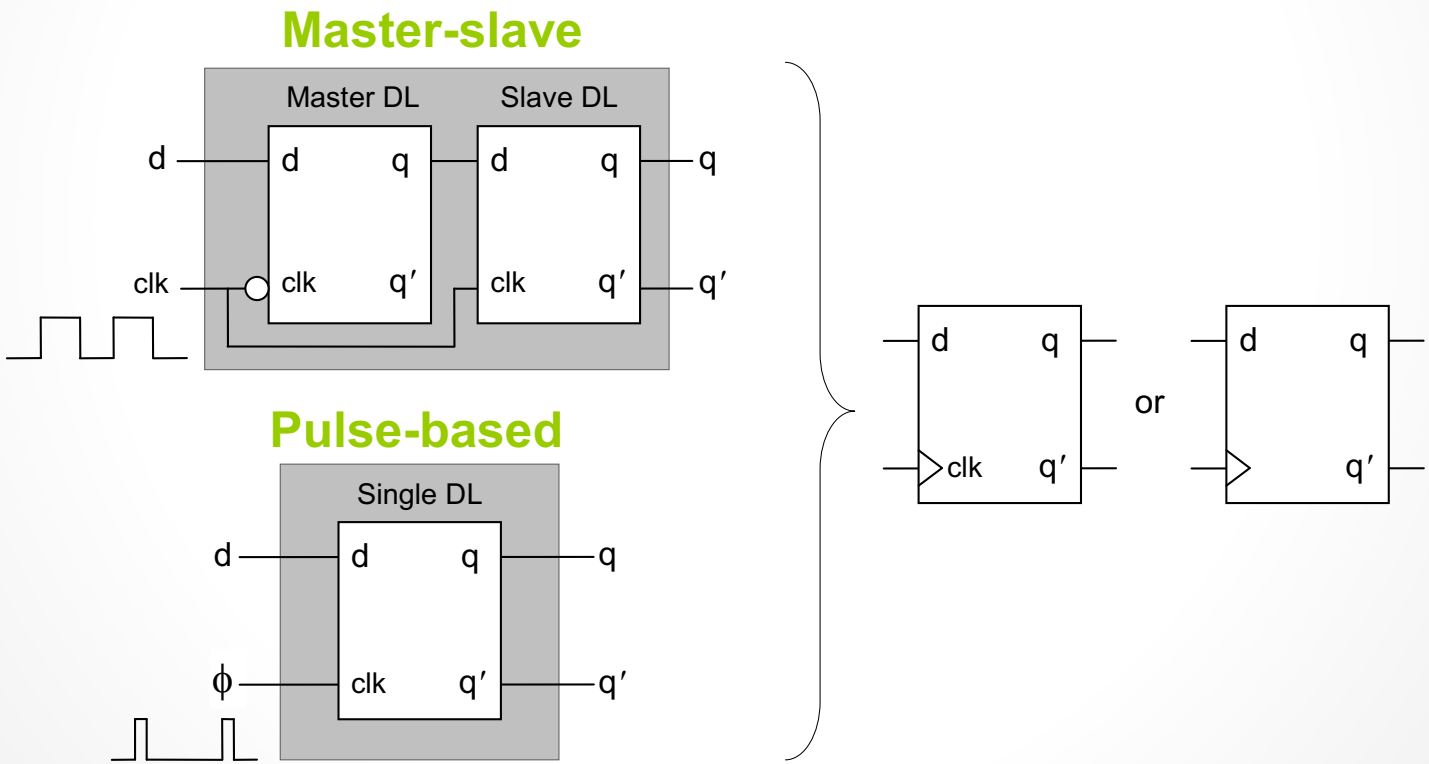
Analysis type?

DFF



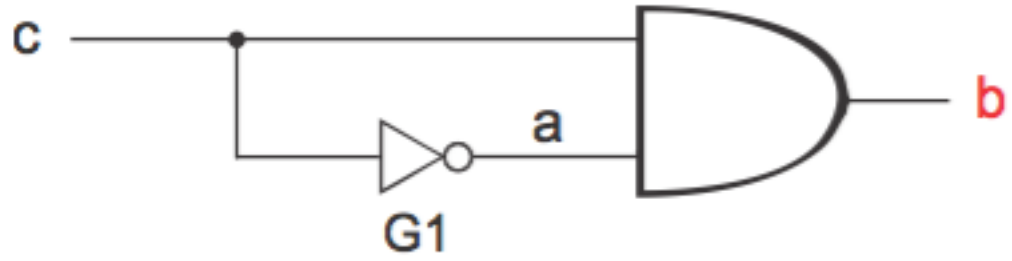
DFF

- Construção

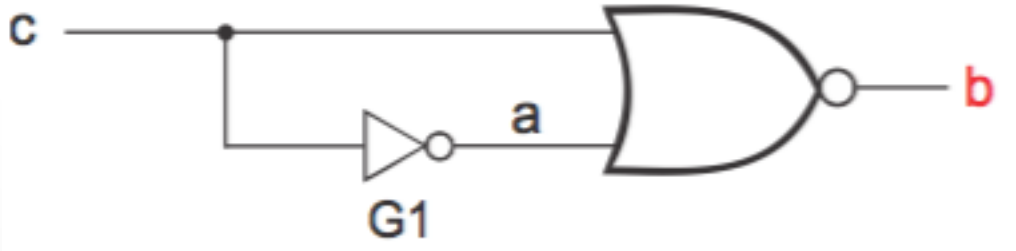


DFF

- Para identificar uma borda de subida

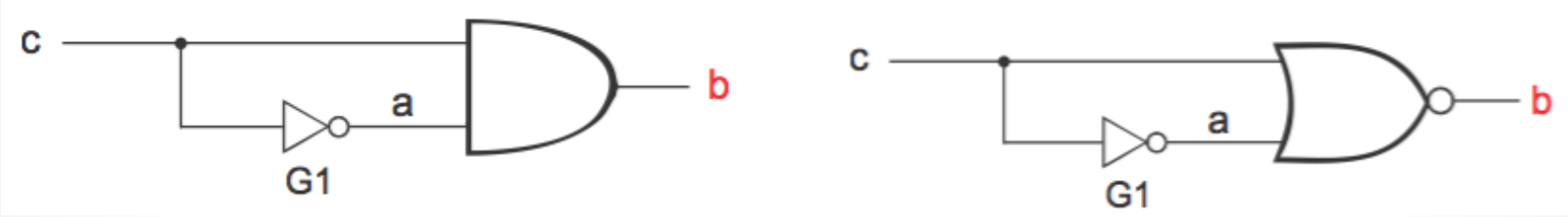


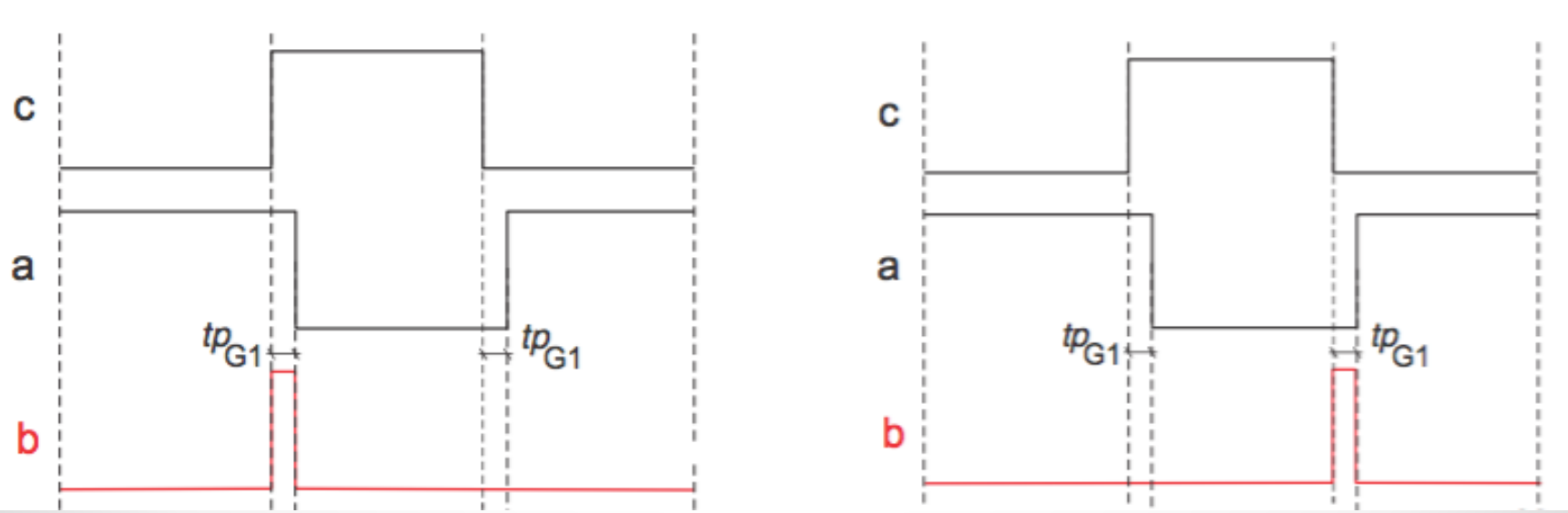
- Para identificar uma borda de descida



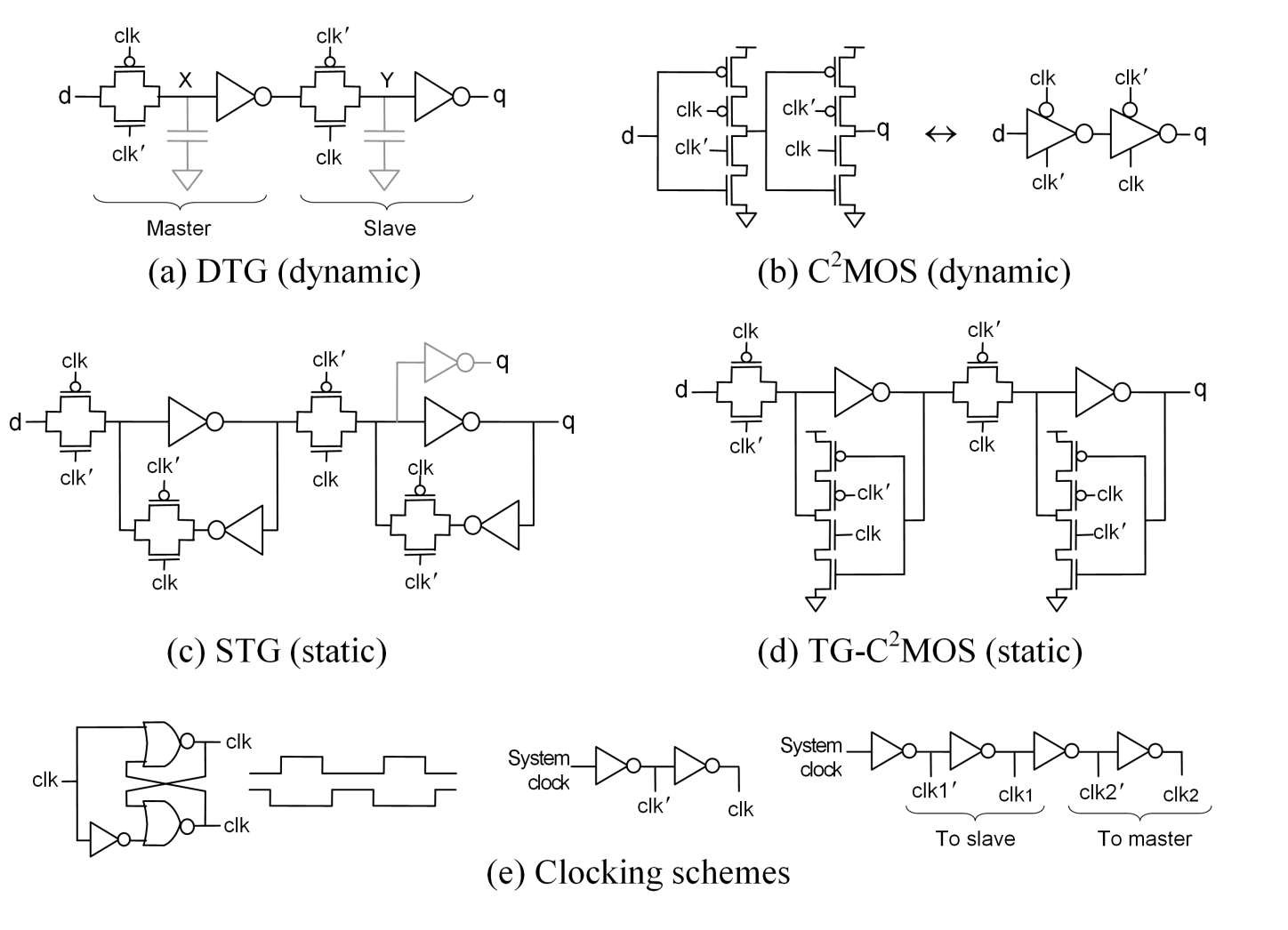
DFF

- Para identificar uma borda de subida



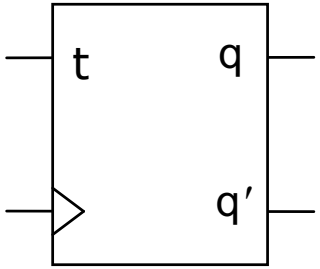


DFF


clk
clk′
d
X
Y
q
Master
Slave
(a) DTG (dynamic)
(b) C2MOS (dynamic)
(c) STG (static)
(d) TG-C2MOS (static)
System clock
clk1′
clk1
clk2′
clk2
To slave
To master
(e) Clocking schemes

TFF

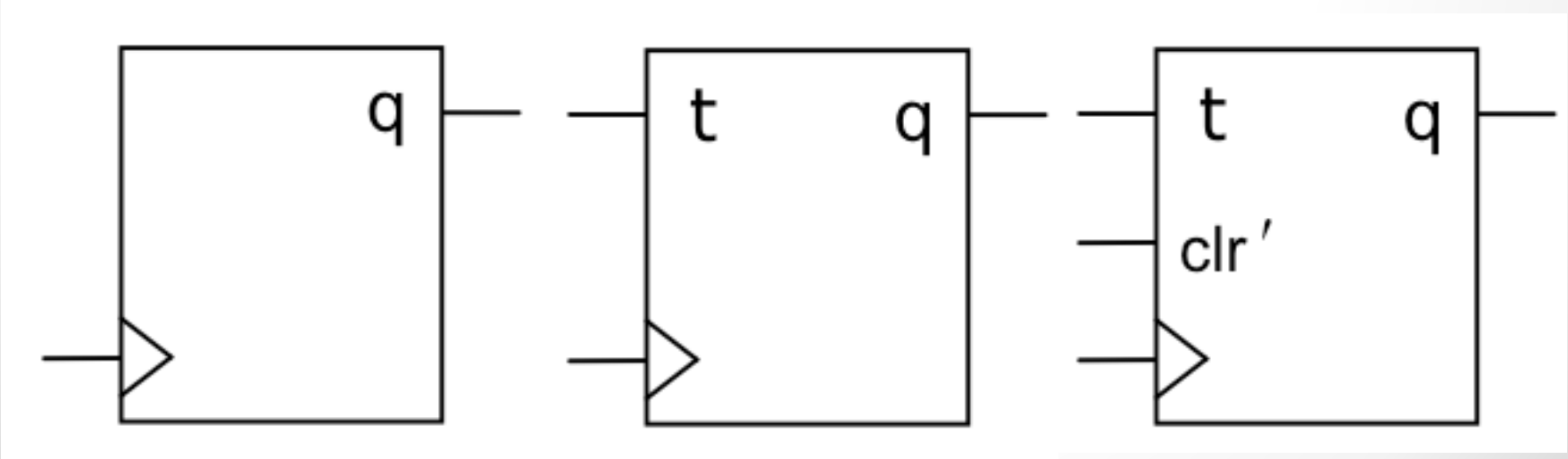
- Outro flip flop de grande utilidade é o TFF
  - T → Toggle



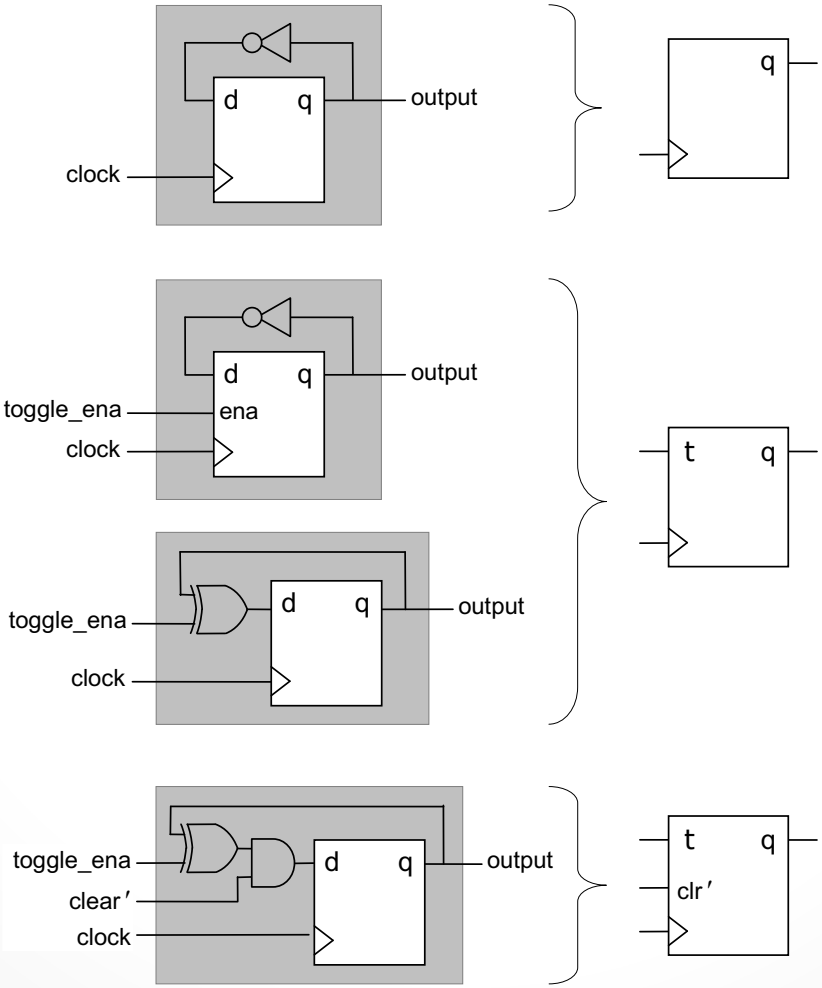
t	clk	q+
0	X	q
1	↑	q′

TFF

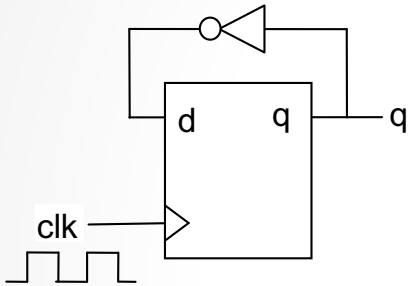
- É possível construir um T baseado em um D. Como construir os próximos TFFs?

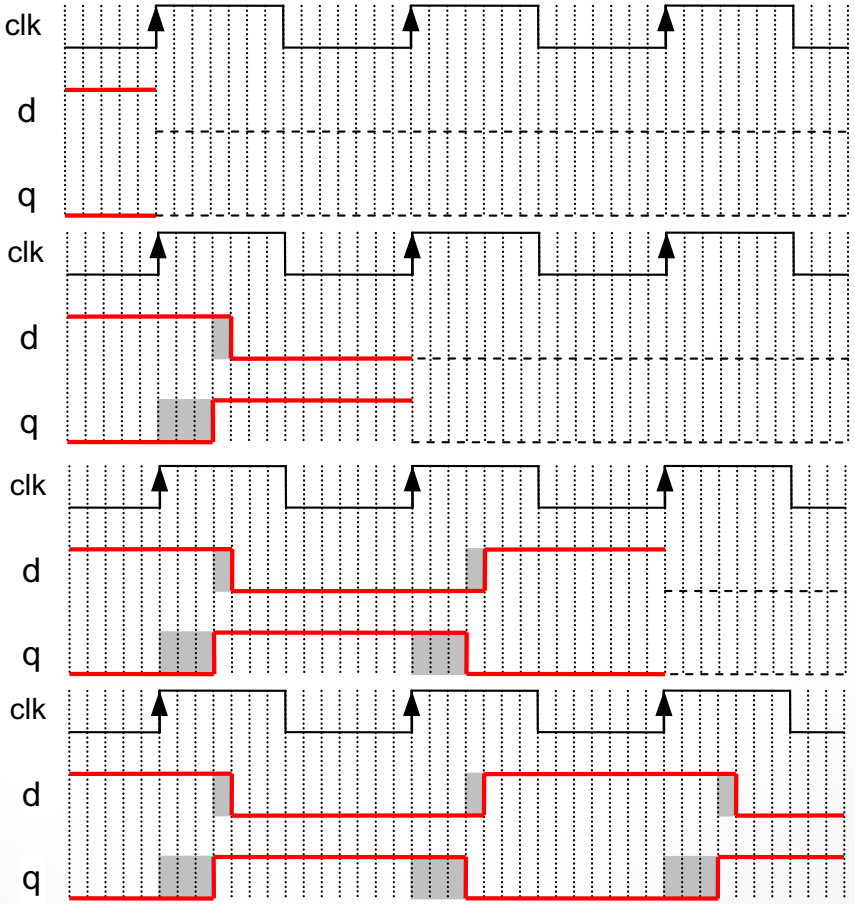


TFF


d
q
output
clock
q
d
q
output
toggle_ena
ena
clock
t
q
d
q
output
toggle_ena
clock
d
q
output
toggle_ena
clear′
clock
t
q
clr′

TFF

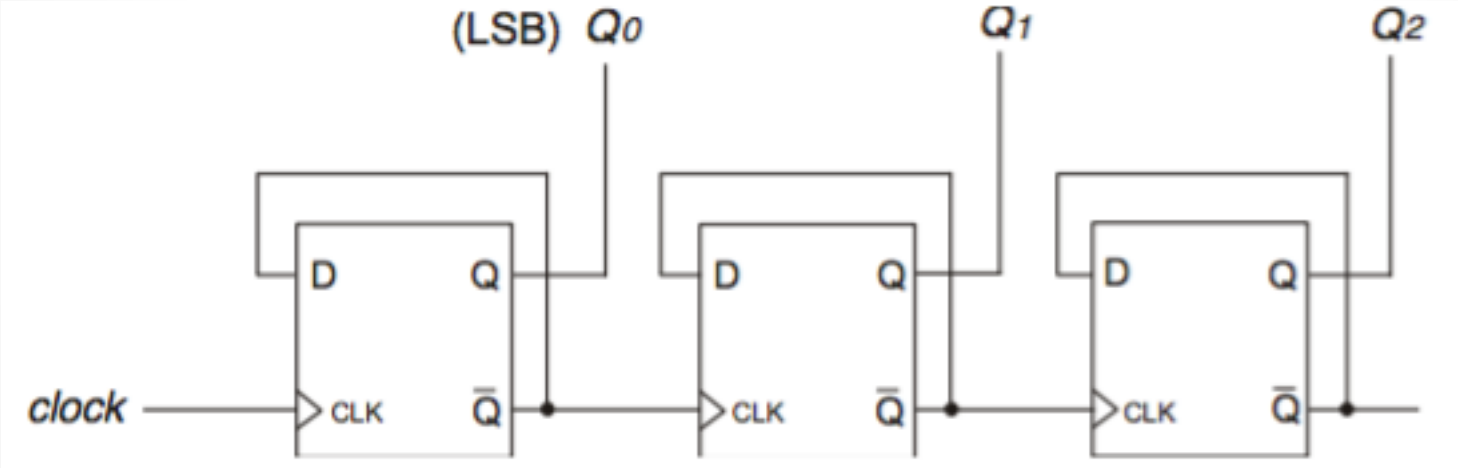




Qual o valor de f_{CLK}?

TFF

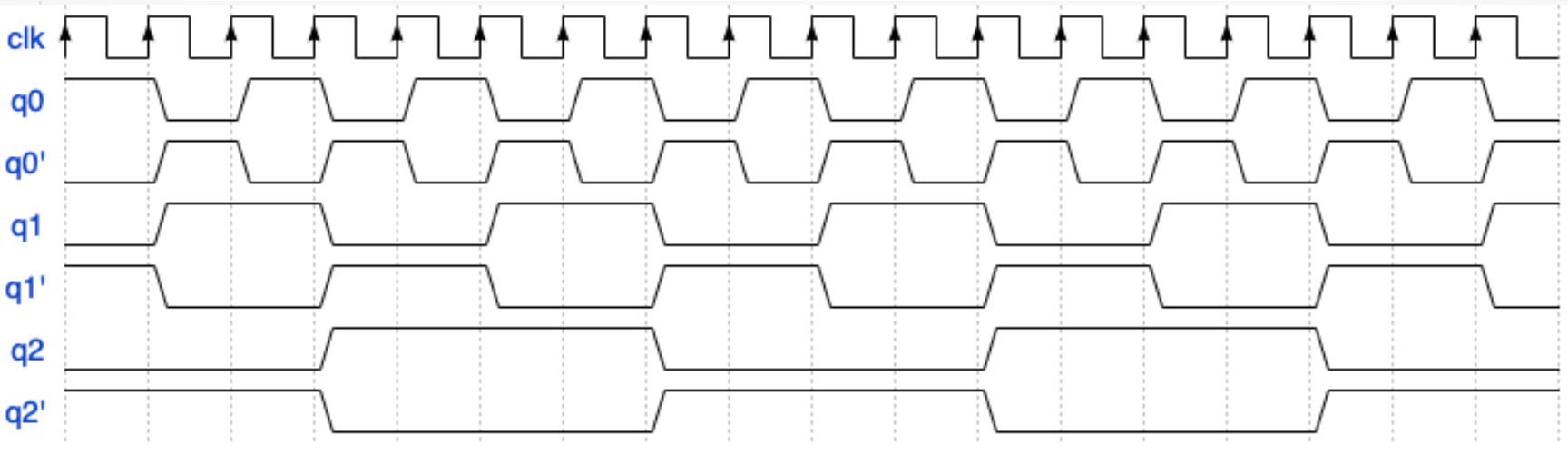
- O que seria o sinal de saída (Q) de uma série de TFFs construído dessa maneira?



- Circuito <u>síncrono</u> x <u>assíncrono</u>

TFF

- Repare os valores $q_2q_1q_0$ juntos



- 000, 001, 010, … 111, 000, 001 …

Flip Flops

- É comum FF terem pinos adicionais
- O que fazem varia para cada FF mas seguem tipicamente o comportamento abaixo

- **Enable (EN)**
  - Habilita o funcionamento normal do FF quando ativado, desabilita caso contrário

- **Preset (PR)**
  - *Preseta* assincromanete o valor da saída (Q = 1)

Flip Flops

- **Reset (RST)**
  - *Reseta* assincronamente o valor da saída (Q = 0)

- **Clear (CLR)**
  - *Reseta* sincronamente o valor da saída (Q = 0 na borda do clock)

* Atenção ao uso síncrono/assíncrono de cada uma dessas entradas

Flip Flops

- Ainda existem o FF JK e SR (pouco utilizados → pesquisem os dois! "matéria dada")

- Como as portas lógicas, registradores são a base de construção os circuitos sequenciais

- Portas lógicas → Circuitos combinacionais e registradores
- Registradores → Circuitos sequenciais

Conclusão

Conclusão

- Registradores → Memória
- Latches x Flip Flops
- Sinal de Sincronização
- Tipos de Latches e Flip Flops

O Fim.

Perguntas? Não?
Então palmas para o professor.

Desafio do Dia
Cleópatra & Marco Aurélio