



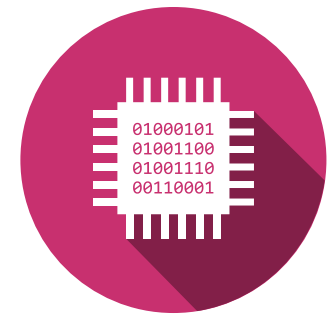
# Digitales Design (DiD)

## Synchrone Zähler

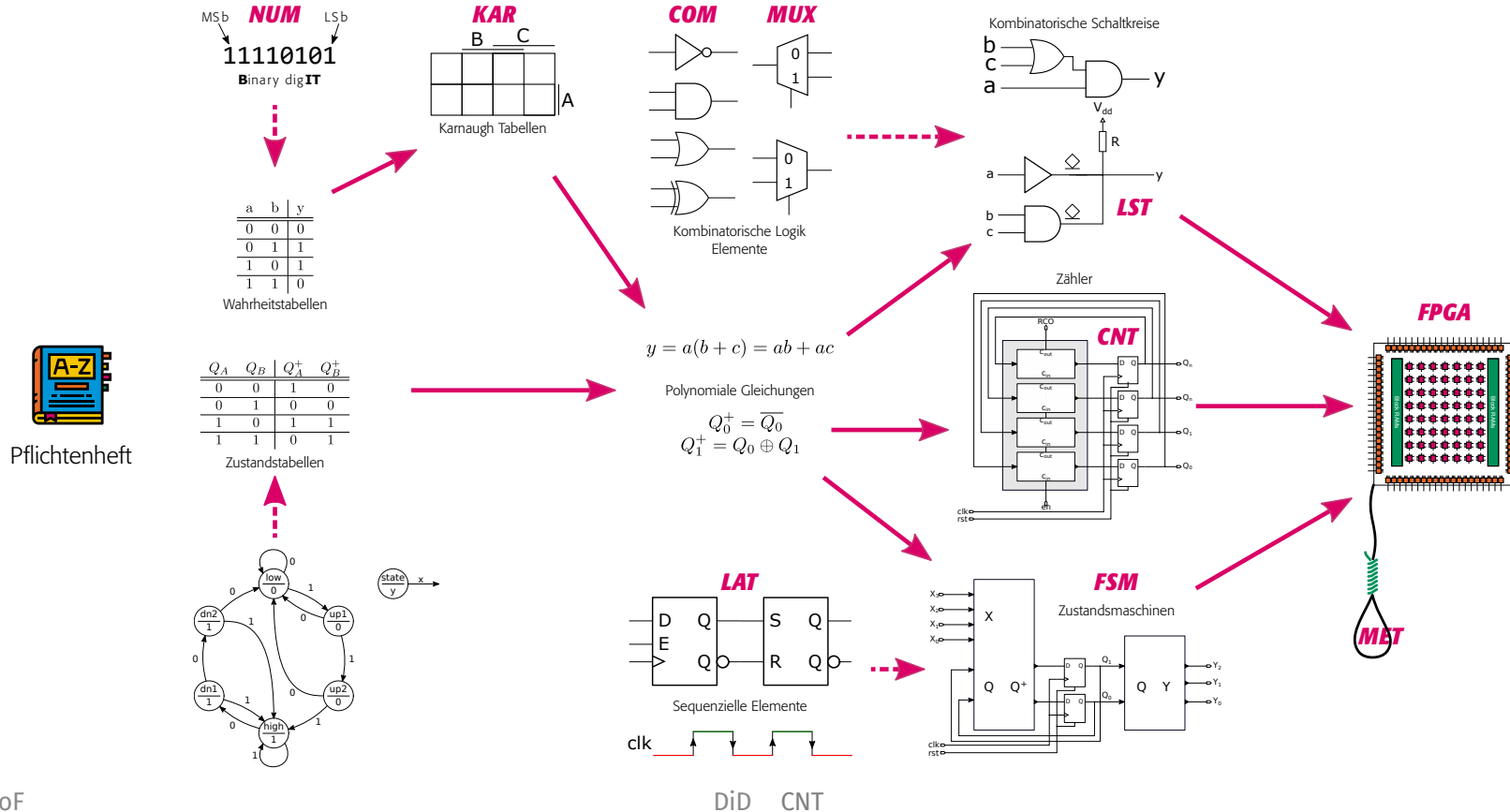
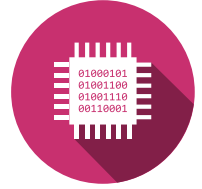
### CNT

Studiengang Systemtechnik  
Studiengang Energie und Umwelttechnik  
Studiengang Informatik und Kommunikationssysteme

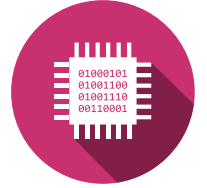
Silvan Zahno [silvan.zahno@hevs.ch](mailto:silvan.zahno@hevs.ch)  
Christophe Bianchi [christophe.bianchi@hevs.ch](mailto:christophe.bianchi@hevs.ch)  
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# Aktueller Inhalt des Themas im Kurs



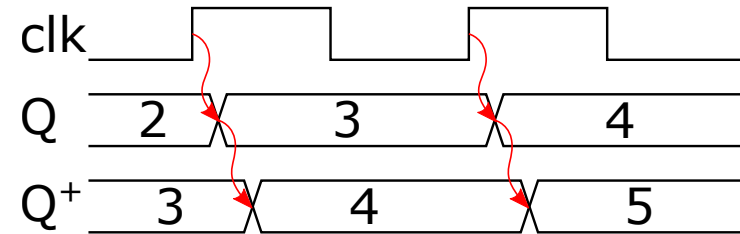
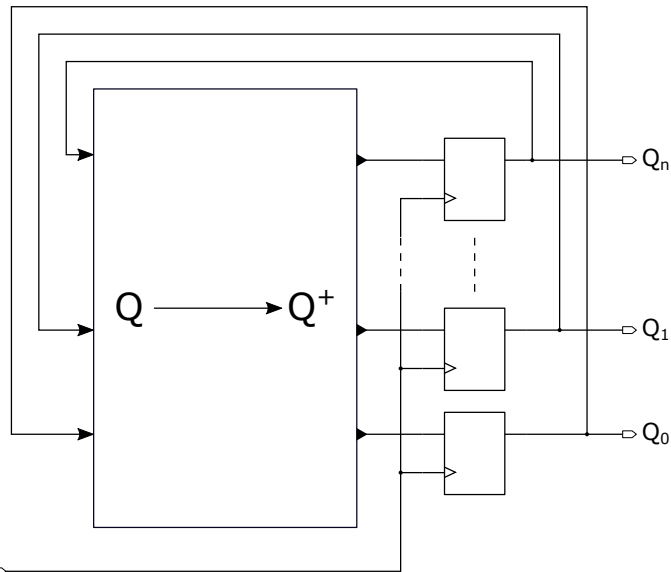
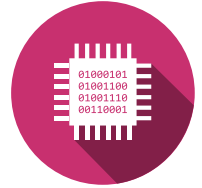
# Inhalt



- **Aufbau der Synchronzähler**
- Zähler mit Zweierpotenz
- Zähler mit ungeordneter Sequenz
- Iterative Schaltkreise

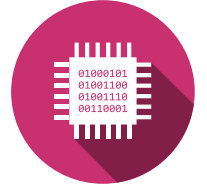
# Synchronzähler

## Architektur



- Synchroner Zähler:
- Eine Logikschaltung berechnet den nachfolgenden Wert
- Dieser Wert wird beim nächsten Taktschlag in die Flip-Flops geladen.
- Die Logikschaltung berechnet erneut den nachfolgenden Wert

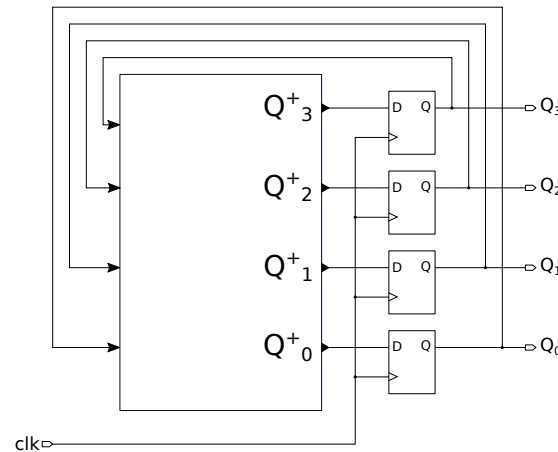
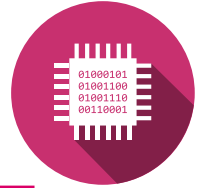
# Inhalt



- Aufbau der Synchronzähler
- **Zähler mit Zweierpotenz**
  - Mit D-FlipFlops
  - Mit anderen FlipFlop Typen
- Zähler mit ungeordneter Sequenz
- Iterative Schaltkreise

# Synchronzähler

## Zähler auf 16 ( $2^4$ ) mit D-FlipFlops

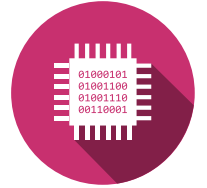


$$\begin{array}{lll}
 D_0 = Q_0^+ & D_0 = Q_0 \oplus 1 & D_0 = \overline{Q_0} \\
 D_1 = Q_1^+ & D_1 = Q_1 \oplus Q_0 & \\
 D_2 = Q_2^+ & D_2 = Q_2 \oplus Q_1 Q_0 & \\
 D_3 = Q_3^+ & D_3 = Q_3 \oplus Q_2 Q_1 Q_0 & 
 \end{array}$$

$Q_3$	$Q_2$	$Q_1$	$Q_0$	$Q_3^+$	$Q_2^+$	$Q_1^+$	$Q_0^+$
0	0	0	0	0	0	0	1
0	0	0	1	0	0	1	0
0	0	1	0	0	0	1	1
0	0	1	1	0	1	0	0
0	1	0	0	0	1	0	1
0	1	0	1	0	1	1	0
0	1	1	0	0	1	1	1
0	1	1	1	1	0	0	0
1	0	0	0	1	0	0	1
1	0	0	1	1	0	1	0
1	0	1	0	1	0	1	1
1	0	1	1	1	1	0	0
1	1	0	0	1	1	0	1
1	1	0	1	1	1	1	0
1	1	1	0	1	1	1	1
1	1	1	1	0	0	0	0

## Aufgabe 1.1 (cnt/pow2-01)

### Abwärtszähler



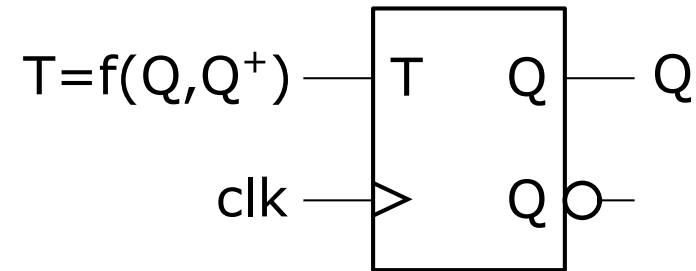
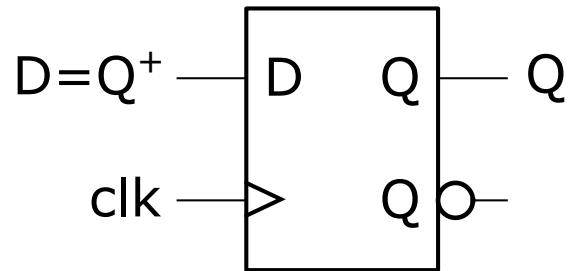
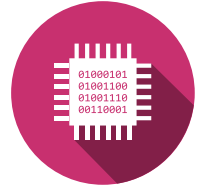
Erstellen Sie mit Hilfe von D-Flipflops und von kombinatorischen Logikgattern einen synchronen Abwärtszähler mit der Sequenz:

15 – 14 – 13 – 12 – ... – 3 – 2 – 1 – 0 – 15 – ...

Zeichnen Sie das vollständige Schema

# Synchronzähler

## Zähler anderen FlipFlop Typen



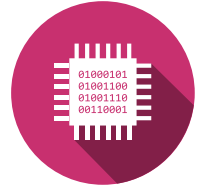
Q	Q <sup>+</sup>	D	T	E	D
0	0	0	0	0	-
0	1	1	1	1	1
1	0	0	1	1	0
1	1	1	0	0	-
				1	1

DiD CNT



# Synchronzähler

## Zähler mit T-FlipFlops



$Q_3$	$Q_2$	$Q_1$	$Q_0$	$Q_3^+$	$Q_2^+$	$Q_1^+$	$Q_0^+$	$T_3$	$T_2$	$T_1$	$T_0$
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	1	1	0	1	0	0	0	1
1	1	0	1	1	1	1	0	0	0	1	1
1	1	1	0	1	1	1	1	0	0	0	1
1	1	1	1	0	0	0	0	1	1	1	1

$$T_0 = 1$$

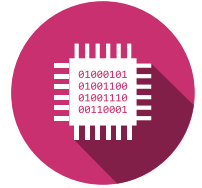
$$T_1 = Q_0$$

$$T_2 = Q_1 Q_0$$

$$T_3 = Q_2 Q_1 Q_0$$

## Aufgabe 1.2 (cnt/pow2-02)

### Abwärtszähler

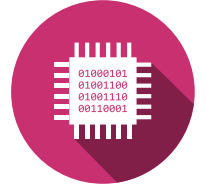


Erstellen Sie mit Hilfe von T-Flipflops und von NAND-Gattern einen synchronen Abwärtszähler mit der Sequenz:

7 – 6 – ... – 3 – 2 – 1 – 0 – 7 – ...

Zeichnen Sie das vollständige Schema

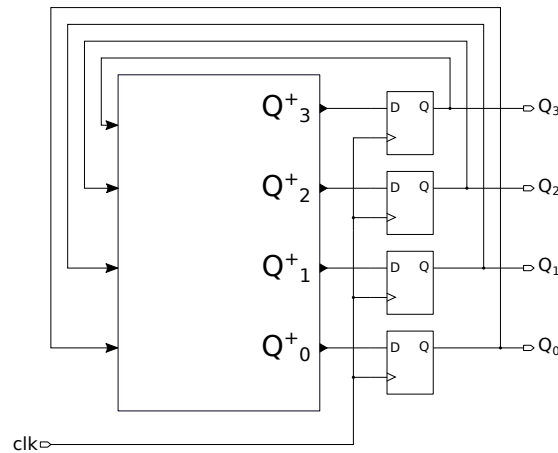
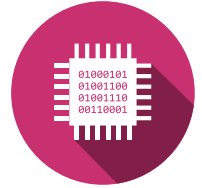
# Inhalt



- Aufbau der Synchronzähler
- Zähler mit Zweierpotenz
- **Zähler mit ungeordneter Sequenz**
  - Realisierung
  - Verifikation
- Iterative Schaltkreise

# Synchronzähler

## Realisierung eines Modulo 10 Zählers



$$D_0 = \overline{Q_0}$$

$$D_1 = Q_1 \overline{Q_0} + \overline{Q_3} \overline{Q_1} Q_0$$

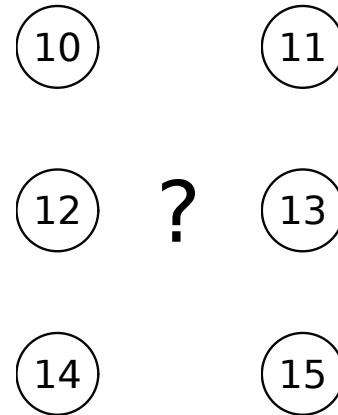
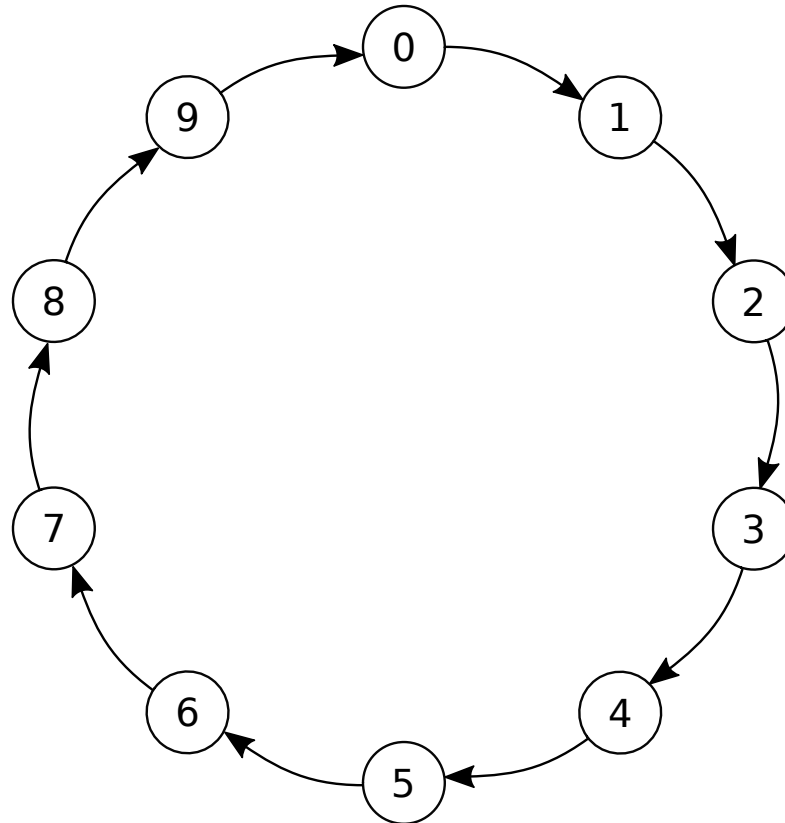
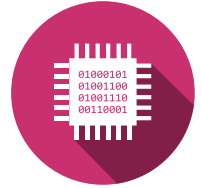
$$D_2 = Q_2 \overline{Q_1} + Q_2 \overline{Q_0} + \overline{Q_2} Q_1 Q_0$$

$$D_3 = Q_3 \overline{Q_0} + Q_2 Q_1 Q_0$$

$Q_3$	$Q_2$	$Q_1$	$Q_0$	$Q^+_3$	$Q^+_2$	$Q^+_1$	$Q^+_0$
0	0	0	0	0	0	0	1
0	0	0	1	0	0	1	0
0	0	1	0	0	0	1	1
0	0	1	1	0	1	0	0
0	1	0	0	0	1	0	1
0	1	0	1	0	1	1	0
0	1	1	0	0	1	1	1
0	1	1	1	1	0	0	0
1	0	0	0	1	0	0	1
1	0	0	1	0	0	0	0
1	0	1	0	-	-	-	-
1	0	1	1	-	-	-	-
1	1	0	0	-	-	-	-
1	1	0	1	-	-	-	-
1	1	1	0	-	-	-	-
1	1	1	1	-	-	-	-

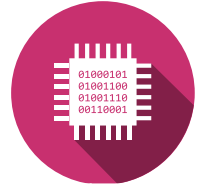
# Synchronzähler

## Verifikation – Zustandsgraph der Zählers



# Synchronzähler

## Verifikation – Nicht definierte Zustände



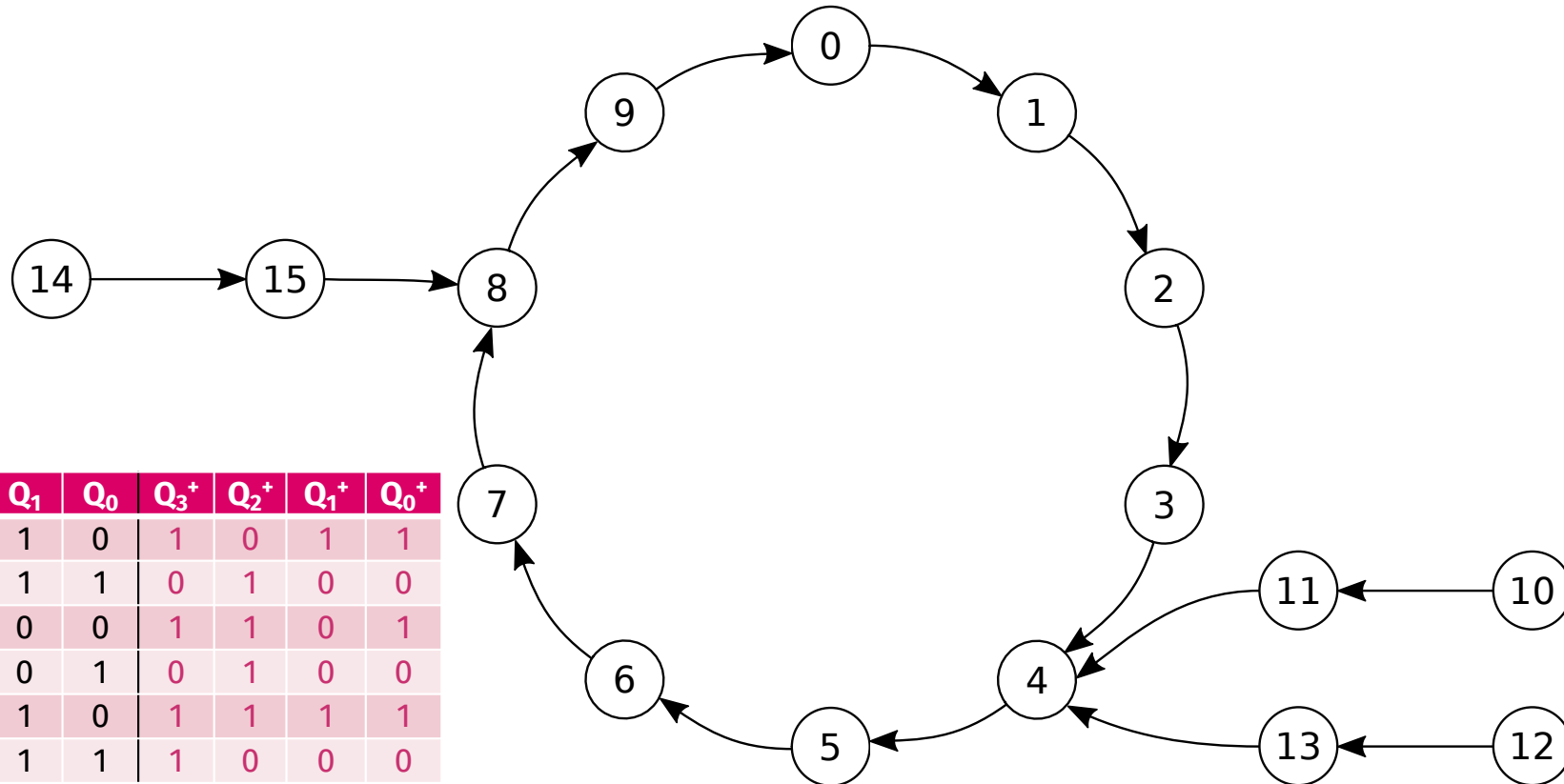
$$\begin{aligned}
 D_0 &= \overline{Q_0} \\
 D_1 &= Q_1 \overline{Q_0} + \overline{Q_3} \overline{Q_1} Q_0 \\
 D_2 &= Q_2 \overline{Q_1} + Q_2 \overline{Q_0} + \overline{Q_2} Q_1 Q_0 \\
 D_3 &= Q_3 \overline{Q_0} + Q_2 Q_1 Q_0
 \end{aligned}$$



$Q_3$	$Q_2$	$Q_1$	$Q_0$	$Q_3^+$	$Q_2^+$	$Q_1^+$	$Q_0^+$
0	0	0	0	0	0	0	1
0	0	0	1	0	0	1	0
0	0	1	0	0	0	1	1
0	0	1	1	0	1	0	0
0	1	0	0	0	1	0	1
0	1	0	1	0	1	1	0
0	1	1	0	0	1	1	1
0	1	1	1	1	0	0	0
1	0	0	0	1	0	0	1
1	0	0	1	0	0	0	0
1	0	1	0	1	0	1	1
1	0	1	1	0	1	0	0
1	1	0	0	1	1	0	1
1	1	0	1	0	1	0	0
1	1	1	0	1	1	1	1
1	1	1	1	1	0	0	0

# Synchronzähler

## Verifikation – Kompletierter Graph



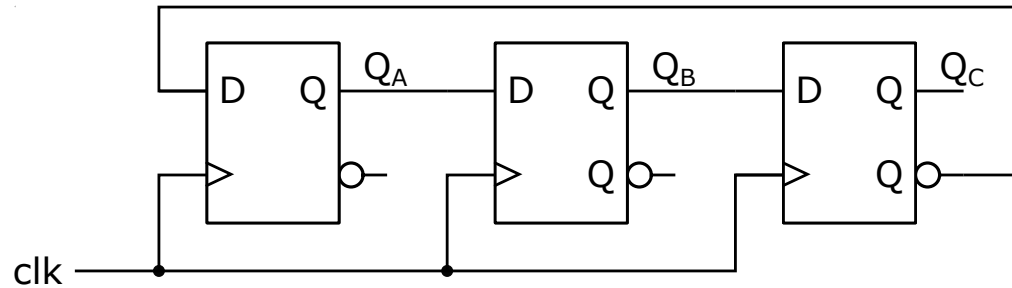
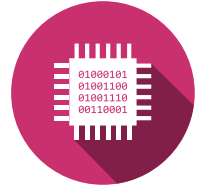
$Q_3$	$Q_2$	$Q_1$	$Q_0$	$Q_3^+$	$Q_2^+$	$Q_1^+$	$Q_0^+$
1	0	1	0	1	0	1	1
1	0	1	1	0	1	0	0
1	1	0	0	1	1	0	1
1	1	0	1	0	1	0	0
1	1	1	0	1	1	1	1
1	1	1	1	1	0	0	0

ZaS, BiC, CoF

DiD CNT

# Synchronzähler

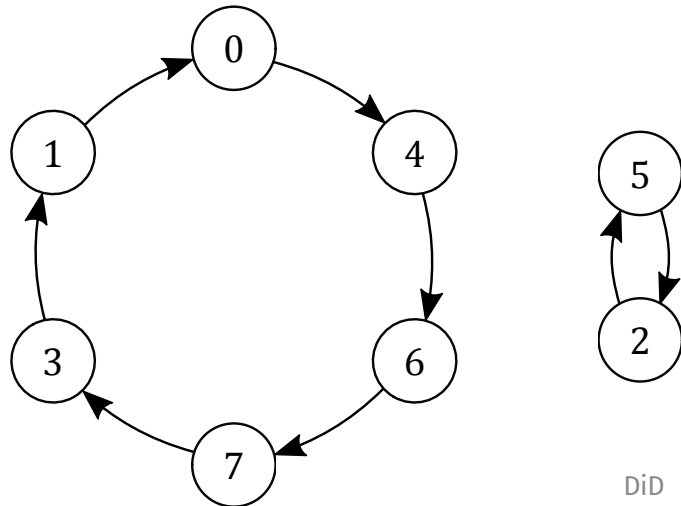
## Johnson Zähler



$$D_A = Q_A^+ = \overline{Q_C}$$

$$D_B = Q_B^+ = Q_A$$

$$D_C = Q_C^+ = Q_B$$

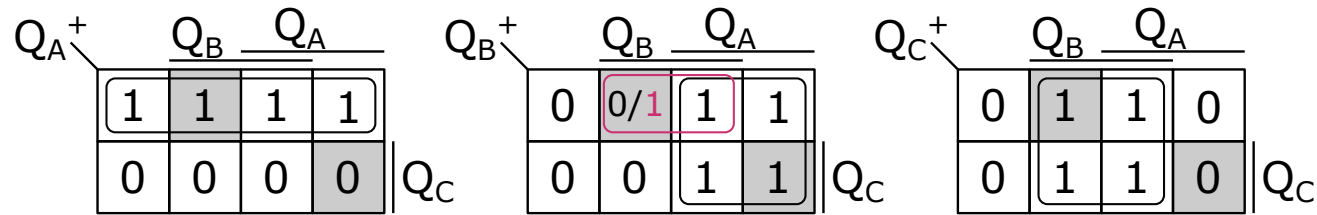
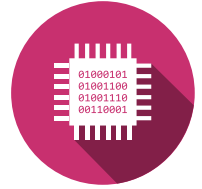


$Q_A$	$Q_B$	$Q_C$	$Q_A^+$	$Q_B^+$	$Q_C^+$
0	0	0	1	0	0
0	0	1	0	0	0
0	1	0	1	0	1
0	1	1	0	0	1
1	0	0	1	1	0
1	0	1	0	1	0
1	1	0	1	1	1
1	1	1	0	1	1



# Synchronzähler

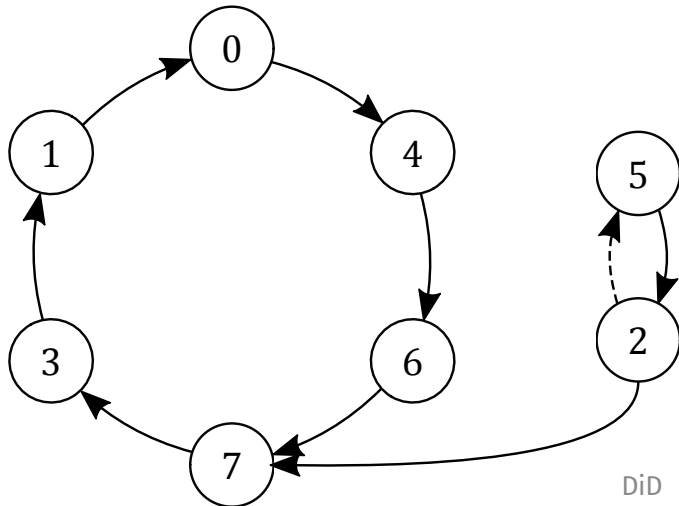
## Johnson Zähler



$$D_A = Q_A^+ = \overline{Q_C}$$

$$D_B = Q_B^+ = Q_A + Q_B \overline{Q_C}$$

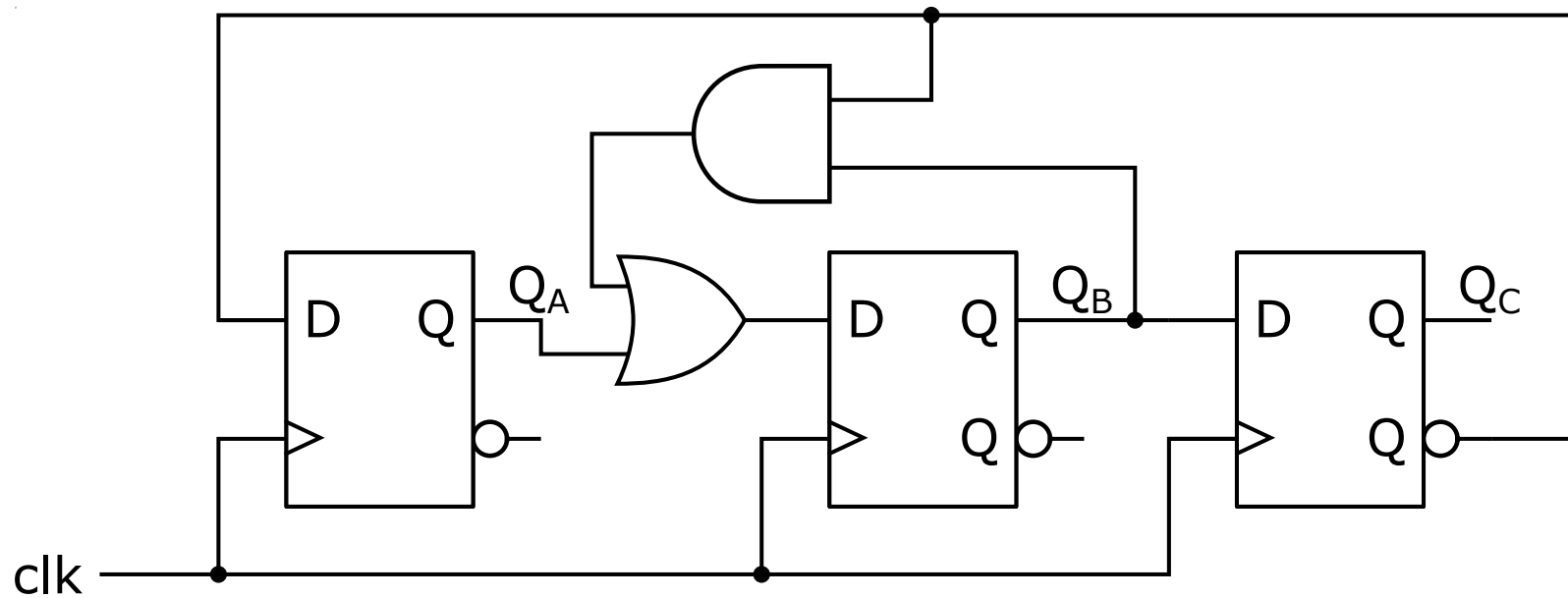
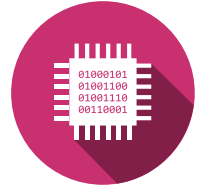
$$D_C = Q_C^+ = Q_B$$



$Q_A$	$Q_B$	$Q_C$	$Q_A^+$	$Q_B^+$	$Q_C^+$
0	0	0	1	0	0
0	0	1	0	0	0
0	1	0	1	1	1
0	1	1	0	0	1
1	0	0	1	1	0
1	0	1	0	1	0
1	1	0	1	1	1
1	1	1	0	1	1

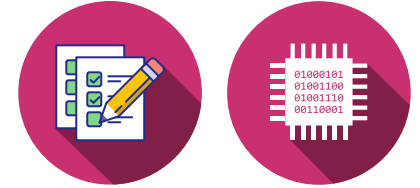
# Synchronzähler

## Johnson Zähler



## Aufgabe 2.1 (cnt/cnt-01)

### Abwärtszähler



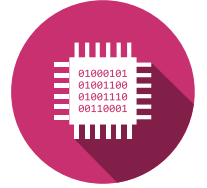
Erstellen Sie mit Hilfe von D-Flipflops und von NAND-Gattern einen Modulo-10 synchronen Abwärtszähler mit der Sequenz:

9 – 8 – 7 – ... – 3 – 2 – 1 – 0 – 9 – ...

Zeichnen Sie das vollständige Schema.

Zeichnen Sie des Zustandsgraph mit allen Zuständen, auch mit denjenigen ausserhalb der Hauptschleife.

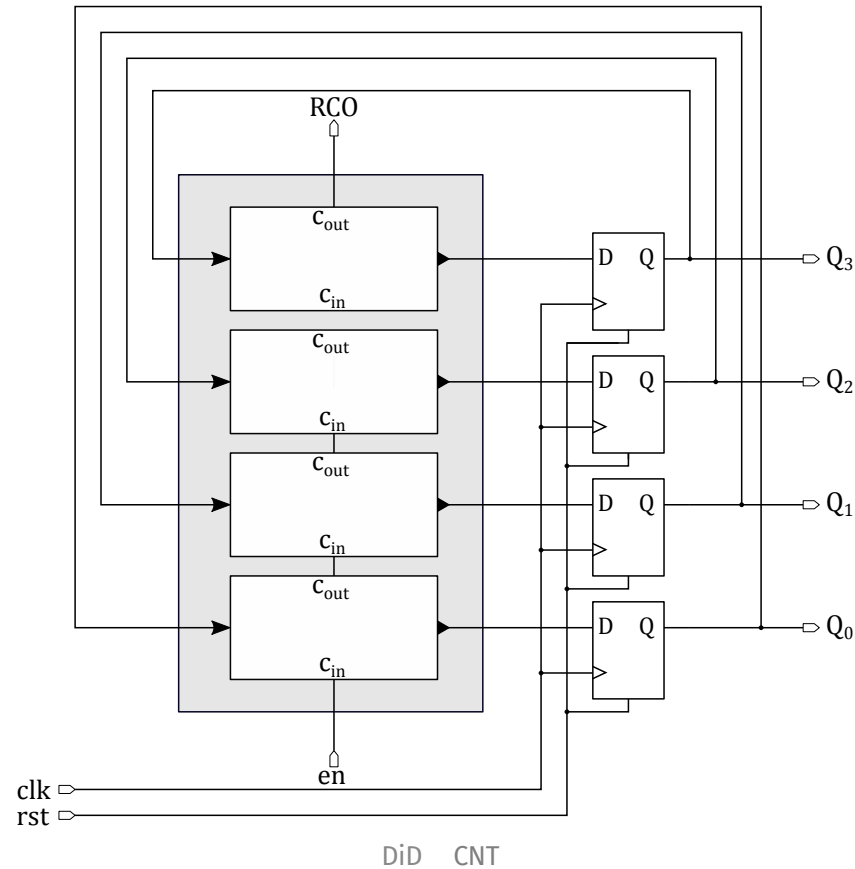
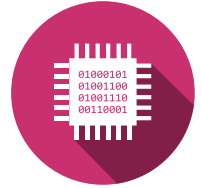
# Inhalt



- Aufbau der Synchronzähler
- Zähler mit Zweierpotenz
- Zähler mit ungeordneter Sequenz
- **Iterative Schaltkreise**
  - Iterativer Zähler

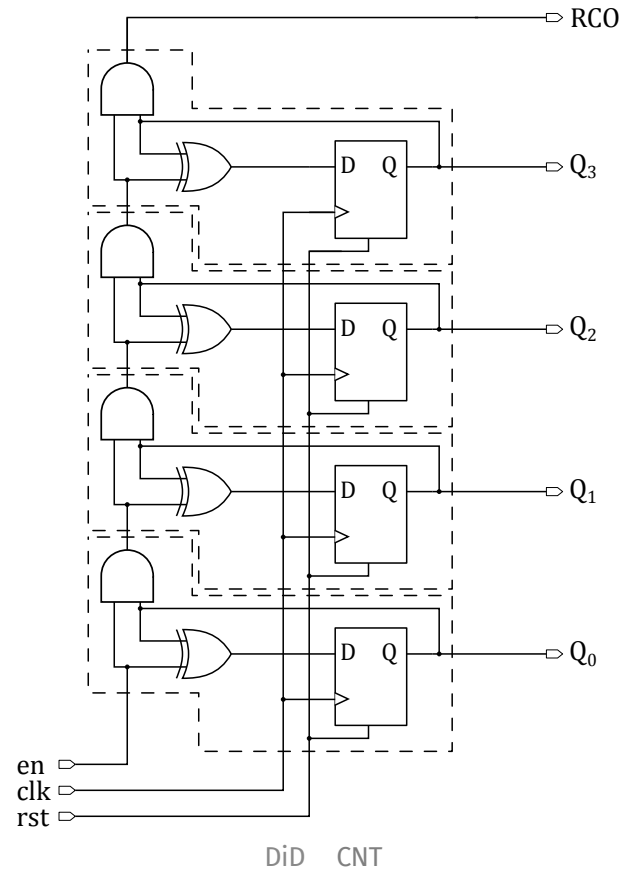
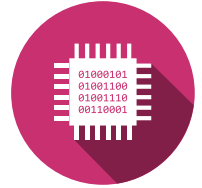
# Synchrone Zähler

## Iterativer Zähler - Architektur



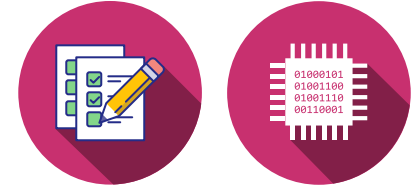
# Synchrone Zähler

## Iterativer Zähler - Schaltung



## Aufgabe 3.3 (cnt/cnt-iterative-03)

### Auf- und Abwärtszähler

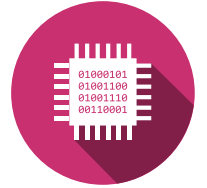


Erstellen Sie einen 4-Bit Aufwärts-Abwärtszähler mit Hilfe von D-Flipflops und von Logikgattern.

Der Aufwärts-Abwärtszähler hat einen Steuereingang up/down.

- Ist up/down = '1', so zählt die Schaltung aufwärts.
- Ist up/down = '0', so zählt die Schaltung abwärts.

# Referenzen



- [Kün97] (Deutsch)
  - Vollständig
  - Elektronikbeispiele
  - Zähler basierend auf Schieberegister
- [Wak00] (Englisch)
  - Iterative Schaltungen, Standard integrierte Schaltungen
- [Man78] (Französisch)
  - Gute Präsentation, korrigierte Übungen



WHY ARE THERE MIRRORS ABOVE BEDS

WHY DO I SAY UH

WHY IS SEA SALT BETTER

WHY ARE THERE TREES IN THE MIDDLE OF FIELDS

WHY IS THERE NOT A POKEMON MMO

WHY IS THERE LAUGHING IN TV SHOWS

WHY ARE THERE DOORS ON THE FREEWAY

WHY ARE THERE SO MANY SUCHOST-EXE RUNNING

WHY AREN'T ANY COUNTRIES IN ANTARCTICA

WHY ARE THERE SCARY SOUNDS IN MINECRAFT

WHY IS THERE KICKING IN MY STOMACH

WHY ARE THERE TWO SLASHES AFTER HTTP

WHY ARE THERE CELEBRITIES

WHY DO SNAKES EXIST

WHY DO OYSTERS HAVE PEARLS

WHY ARE DUCKS CALLED DUCKS

WHY DO THEY CALL IT THE CLAP

WHY ARE KYLE AND CARTMAN FRIENDS

WHY IS THERE AN ARROW ON AANG'S HEAD

WHY ARE TEXT MESSAGES BLUE

WHY ARE THERE MUSTACHES ON CLOTHES

WHY WUBA LUBBA DUB DUB MEANING

WHY IS THERE A WHALE AND A POT FALLING

WHY ARE THERE SO MANY BIRDS IN SWISS

WHY IS THERE SO LITTLE RAIN IN WALLIS

WHY IS WALLIS WEATHER FORECAST ALWAYS WRONG

WHY ARE THERE MALE AND FEMALE BIKES

WHY ARE THERE BRIDESMAIDS

WHY DO DYING PEOPLE REACH UP

HOW FAST IS LIGHTSPEED

WHY ARE OLD KLINGONS DIFFERENT

WHY ARE THERE SQUIRRELS

WHY ARE THERE TINY SPIDERS IN MY HOUSE

WHY DO SPIDERS COME INSIDE

WHY ARE THERE HUGE SPIDERS IN MY HOUSE

WHY ARE THERE LOTS OF SPIDERS IN MY HOUSE

WHY ARE THERE SPIDERS IN MY ROOM

WHY ARE THERE SO MANY SPIDERS IN MY ROOM

WHY DO SPYDER BITES ITCH

WHY IS DYING SO SCARY

WHY IS THERE NO GPS IN LAPTOPS

WHY DO KNEES CLICK

WHY IS THERE CAFFEINE IN MY SHAMPOO

WHY HAVE DINOSAURS NO FUR

WHY DO IGUANAS DIE

WHY AREN'T ECONOMISTS RICH

WHY DO AMERICANS CALL IT SOCCER

WHY ARE MY EARS RINGING

WHY IS 42 THE ANSWER TO EVERYTHING

WHY CAN'T NOBODY ELSE LIFT THORS HAMMER

WHY IS MARVIN ALWAYS SO SAD

WHY ARE THERE ANTS IN MY LAPTOP

WHY IS EARTH TILTED

WHY IS SPACE BLACK

WHY IS OUTER SPACE SO COLD

WHY ARE THERE PYRAMIDS ON THE MOON

WHY IS NASA SHUTTING DOWN

WHY ARE THERE GHOSTS

WHY IS THERE AN OWL IN MY BACKYARD

WHY IS THERE AN OWL OUTSIDE MY WINDOW

WHY IS THERE AN OWL ON THE DOLLAR BILL

WHY DO OWLS ATTACK PEOPLE

WHY ARE FPGA's EVERYWHERE

WHY ARE THERE HELICOPTERS CIRCLING MY HOUSE

WHY ARE THERE GODS

WHY ARE THERE TWO SPOCKS

WHY ARE MY BOOBS ITCHY

WHY ARE CIGARETTES LEGAL

WHY ARE THERE DUCKS IN MY POOL

WHY IS JESUS WHITE

WHY IS THERE LIQUID IN MY EAR

WHY DO Q TIPS FEEL GOOD

WHY DO PEOPLE DIE

WHY AREN'T THERE GUNS IN

WHY ARE THERE DOGS AFRAID OF FIRE

WHY IS THERE NO KING IN E

WHY ARE THERE NO GUNS IN

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# QUESTIONS

CAN BE ASKED BY ANYONE ANYTIME

WHY AREN'T MY  
ARMS GROWING



WHY ARE THERE  
GHOSTS



WHY IS THERE AN OWL IN MY BACKYARD

WHY IS THERE AN OWL OUTSIDE MY WINDOW

WHY IS THERE AN OWL ON THE DOLLAR BILL

WHY DO OWLS ATTACK PEOPLE

WHY ARE FPGA's EVERYWHERE

WHY ARE THERE HELICOPTERS CIRCLING MY HOUSE

WHY ARE THERE GODS

WHY ARE THERE TWO SPOCKS

WHY ARE MY BOOBS ITCHY

WHY ARE CIGARETTES LEGAL

WHY ARE THERE DUCKS IN MY POOL

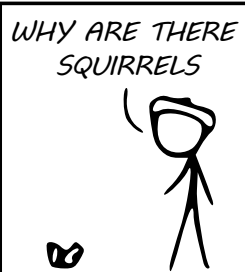
WHY IS JESUS WHITE

WHY IS THERE LIQUID IN MY EAR

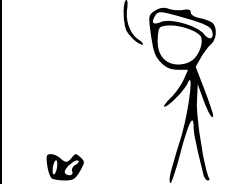
WHY DO Q TIPS FEEL GOOD

WHY DO PEOPLE DIE

WHY AREN'T  
THERE GUNS IN



WHY ARE THERE  
SQUIRRELS



B

WHY IS HTTPS CROSSED OUT IN RED  
WHY IS THERE A LINE THROUGH HTTPS  
WHY IS THERE A RED LINE THROUGH HTTPS ON TWITTER  
WHY IS HTTPS IMPORTANT

WHY ARE THERE WEEKS  
WHY DO I FEEL DIZZY

WHY ARE THERE SO MANY CROWS IN ROCHESTER

WHY IS TO BE OR NOT TO BE FUNNY

WHY DO CHILDREN GET CANCER

WHY IS POSEIDON ANGRY WITH ODYSSEUS

WHY IS THERE ICE IN SPACE

WHY ARE THERE DOGS AFRAID OF FIRE

WHY IS THERE NO KING IN E

WHY ARE THERE NO GUNS IN

WHY ARE THERE NO GUNS IN

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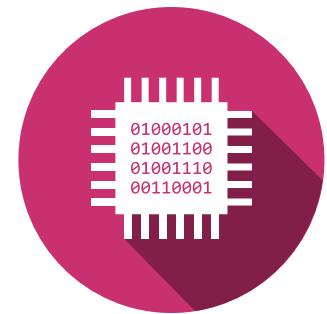
WHY ARE THERE NO GUNS IN



**Hes·so**  **VALAIS  
WALLIS**



**Haute Ecole d'Ingénierie**  
**Hochschule für Ingenieurwissenschaften**



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