

# TFE4101

## KRETS- OG DIGITALTEKNIKK

Regneformer (del 2) og kombinatoriske kretser (utvalg)

Gajski:

- Kap. 2.7: Binær multiplikasjon
- Kap. 2.8: Binær divisjon
- Kap. 5: Kombinatoriske komponenter  
(Et utvalg. Les resten selv)

# Binær multiplikasjon

Desimalt:

$$\begin{array}{r}
 \text{Multiplikand (md)} \\
 \downarrow \\
 14 \times 13 \\
 \hline
 42 \quad (\text{md} \times 10^0 \times 3) \\
 14 \quad (\text{md} \times 10^1 \times 1) \\
 \hline
 182
 \end{array}$$

Binært:

$$\begin{array}{r}
 1110 \times 1101 \\
 \hline
 \begin{array}{r}
 1110 \quad (\text{md} \times 2^0 \times 1) \\
 0000 \quad (\text{md} \times 2^1 \times 0) \\
 1110 \quad (\text{md} \times 2^2 \times 1) \\
 1110 \quad (\text{md} \times 2^3 \times 1)
 \end{array} \\
 \hline
 10110110 \quad (182_{10})
 \end{array}$$

# Binær multiplikasjon

- Alternativ: adder partielt produkt (pp) underveis

$$\begin{array}{r}
 \text{1110} \times \text{1101} \\
 \hline
 \begin{array}{r}
 0000 \quad (\text{nullstilt pp}) \\
 1110 \quad (\text{md} \times 2^0 \times \text{1}) \\
 \hline
 1110 \quad (\text{pp}) \\
 0000 \quad (\text{md} \times 2^1 \times \text{0}) \\
 \hline
 01110 \quad (\text{pp}) \\
 1110 \quad (\text{md} \times 2^2 \times \text{1}) \\
 \hline
 1000110 \quad (\text{pp}) \\
 1110 \quad (\text{md} \times 2^3 \times \text{1}) \\
 \hline
 10110110 \quad (182_{10}) \\
 \hline
 \hline
 \end{array}
 \end{array}$$

- Svaret har  $m+n$  bit ( $m = \# \text{bit i mp}$ ,  $n = \# \text{bit i md}$ )

# Binær multiplikasjon med 2's kompl.

- Multiplikasjon av tall på fortegn-tallverdi form er enkelt
  - Sammenlikn fortegn:
    - Like fortegn gir positivt resultat
    - Ulike fortegn gir negativt resultat
  - Multipliser tallverdi ved hjelp av addisjon og skift
- Multiplikasjon av tall på 2's komplement form mer komplekst
  - Fortsatt multiplikasjon ved addisjon og skift
  - Multiplikand og partielt produkt må fortegnutvides
  - Fortegnsbit må inverteres

# Binær multiplikasjon med 2's kompl.

$10010 \times 10011$	$((-14) \times (-13))$
000000	(utvidet nullstilt pp)
110010	(utvidet $md$ x $2^0$ x 1)
1110010	(utvidet pp)
110010	(utvidet $md$ x $2^1$ x 1)
<del>1</del> 1010110	(utvidet pp)
000000	(utvidet $md$ x $2^2$ x 0)
111010110	(utvidet pp)
000000	(utvidet $md$ x $2^3$ x 0)
1111010110	(utvidet pp)
001110	(utvidet invertert $md$ x $2^4$ x 1)
<del>1</del> 0010110110	$(182_{10})$

# Gruppeoppgave 5 min.

- Multipliser på 2's komplementform tallene 3 og  $-2$  ( $3 \times -2$ )
- Kontroller at svaret stemmer

# Binær divisjon

Desimalt:

$$\begin{array}{r}
 \text{Dividend (dd)} \\
 \downarrow \\
 186 : 14 = 13 \\
 \hline
 14 \phantom{00} \quad \text{Skiftet dv: } 1 \times 10^1 \times \text{dv} \\
 \hline
 46 \phantom{00} \quad \text{Redusert dividend} \\
 42 \phantom{00} \quad \text{Skiftet dv: } 3 \times 10^0 \times \text{dv} \\
 \hline
 4 \phantom{00} \quad \text{Rest}
 \end{array}$$

# Binær divisjon

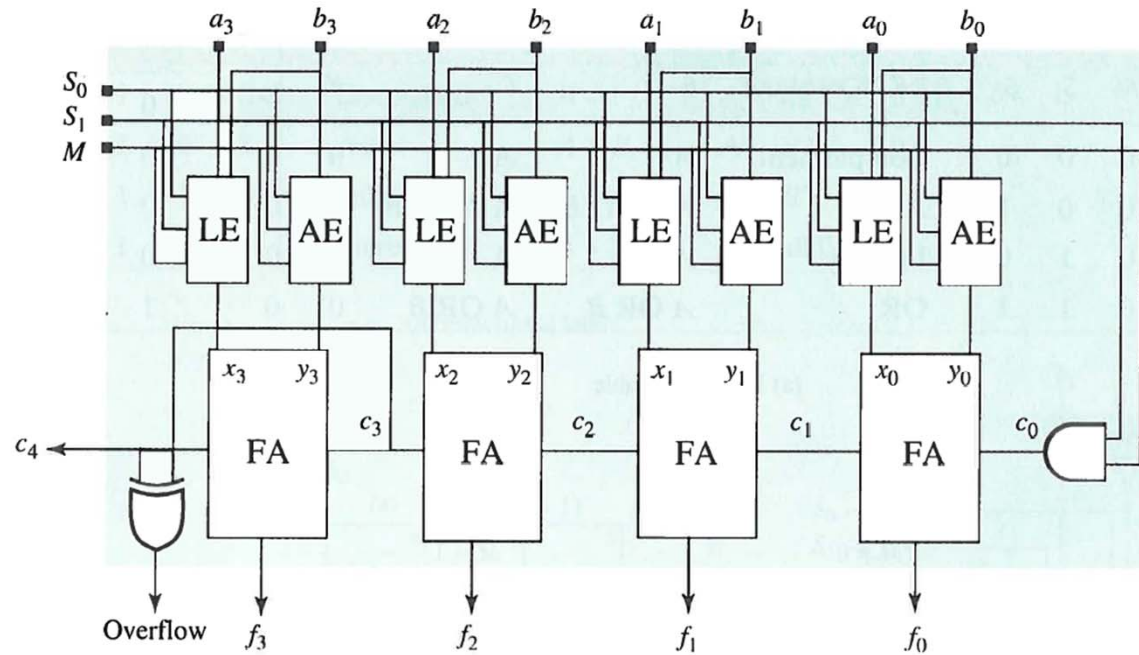
Binært:

$$\begin{array}{r}
 10111010 : 1110 = 1101 \\
 \hline
 1110 \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \\
 \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \\
 \hline
 10010 \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \\
 1110 \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \\
 \hline
 01001 \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \\
 0000 \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \\
 \hline
 010010 \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \\
 1110 \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \\
 \hline
 100 \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \phantom{0000} \\
 \hline
 \end{array}$$

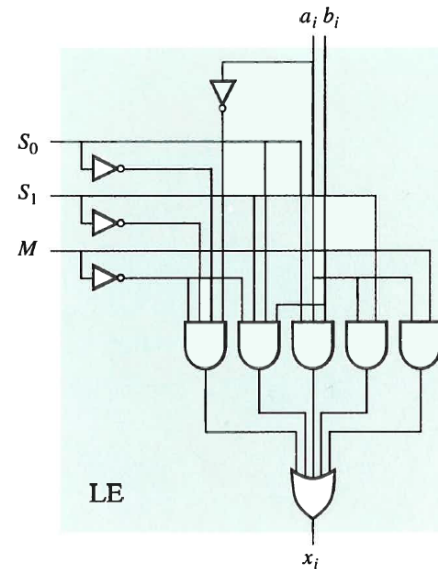
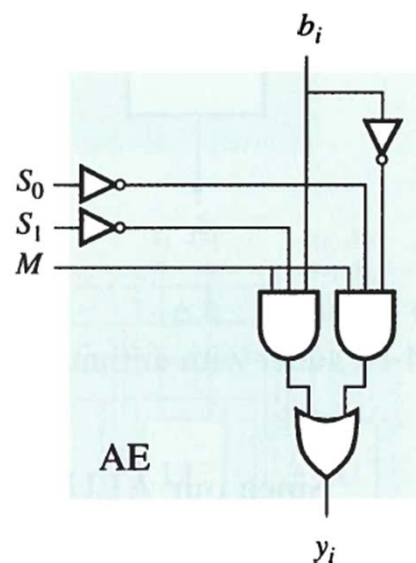
Skiftet dv  
Redusert dd  
Skiftet dv  
Redusert dd  
Skiftet dv (x0)  
Redusert dd  
Skiftet dv  
Rest



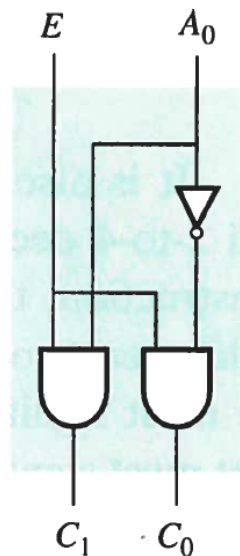
# Kap 5: Kombinatoriske kretser



ALU:  
Aritmetisk-  
logisk  
enhet

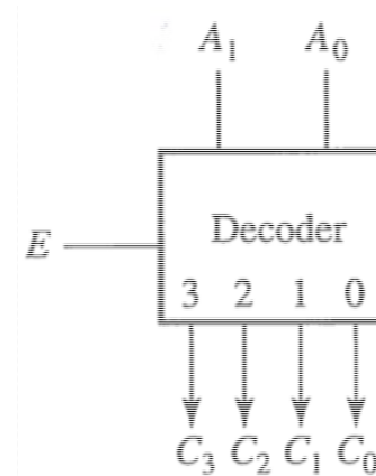


# Dekoder (demultiplexer)

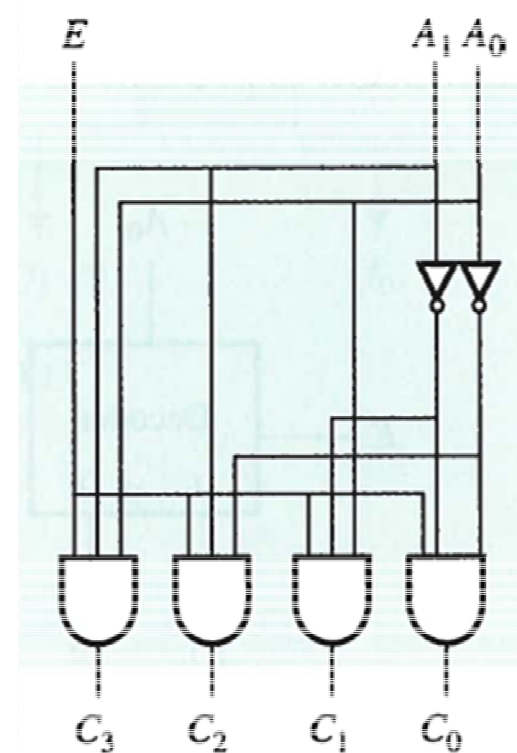


$E$	$A_0$	$C_1$	$C_0$
1	0	0	1
1	1	1	0
0	X	0	0

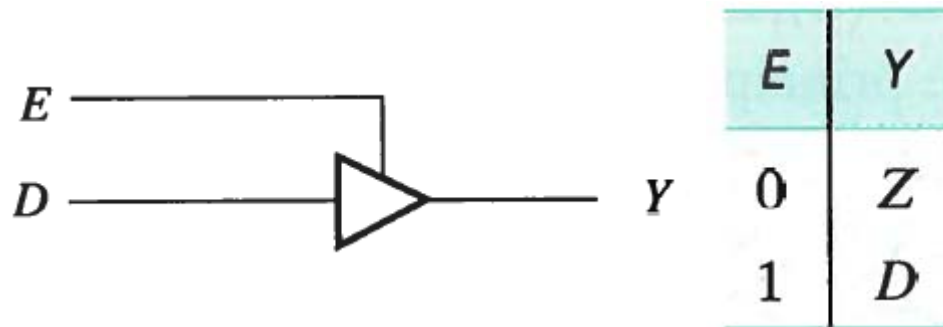
1-2 dekoder



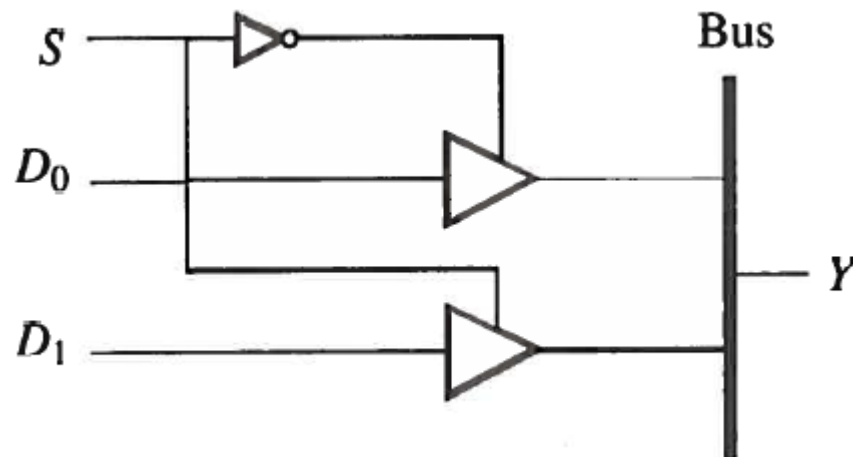
2-4  
dekoder



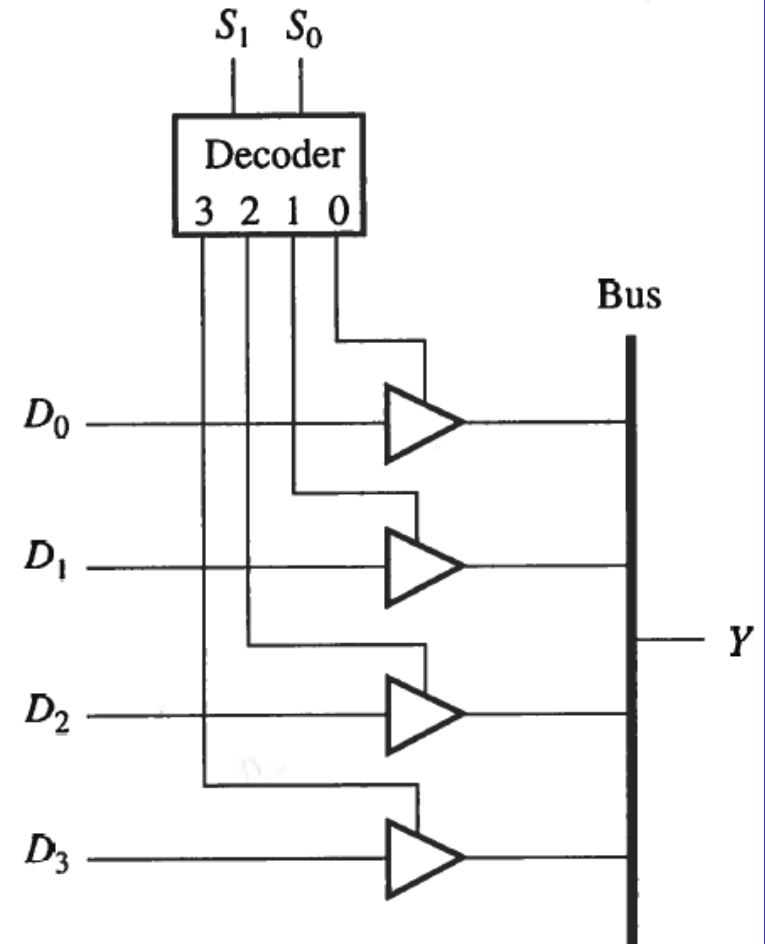
# Buss



Tristate driver

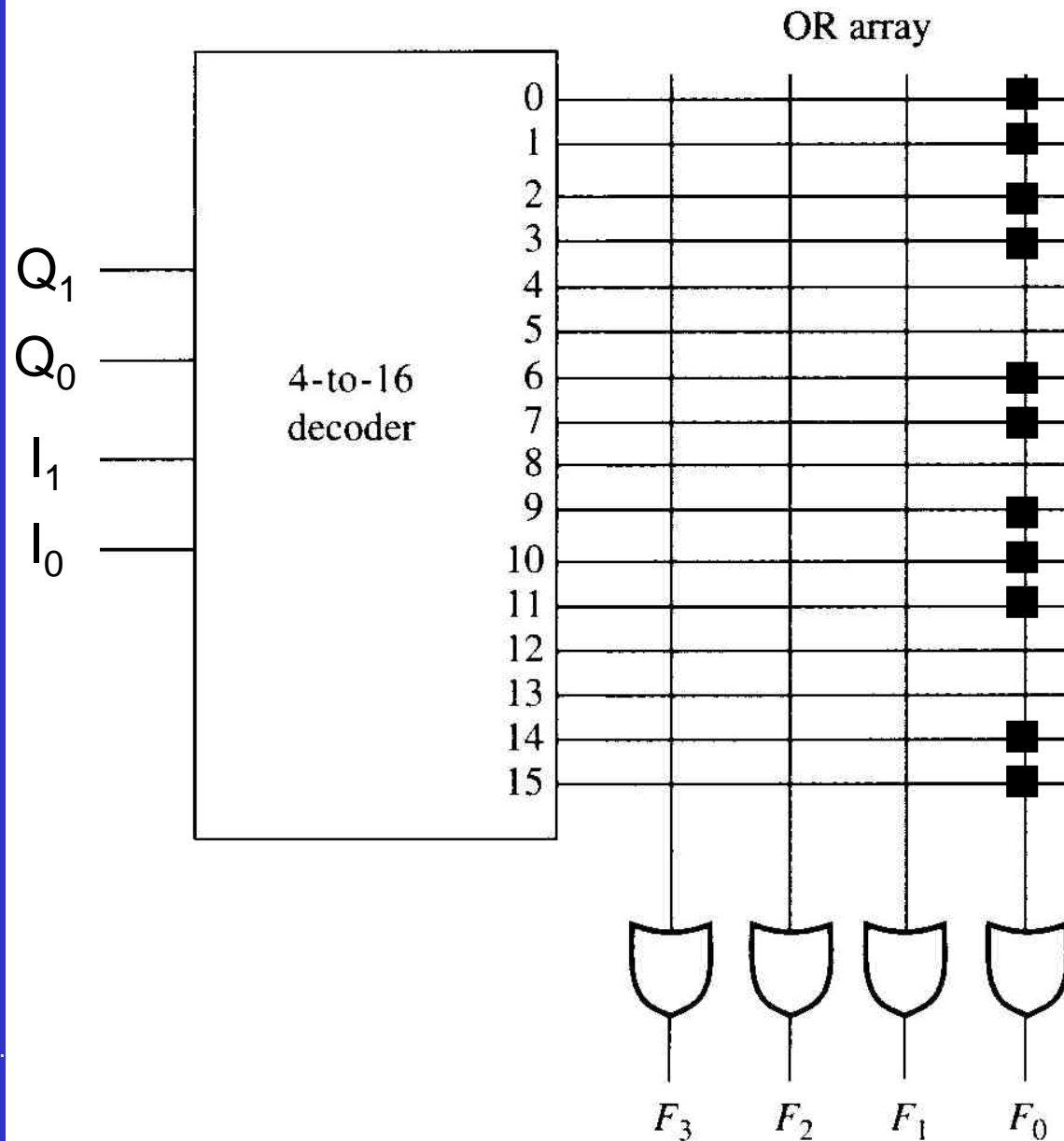


2-inngangs buss



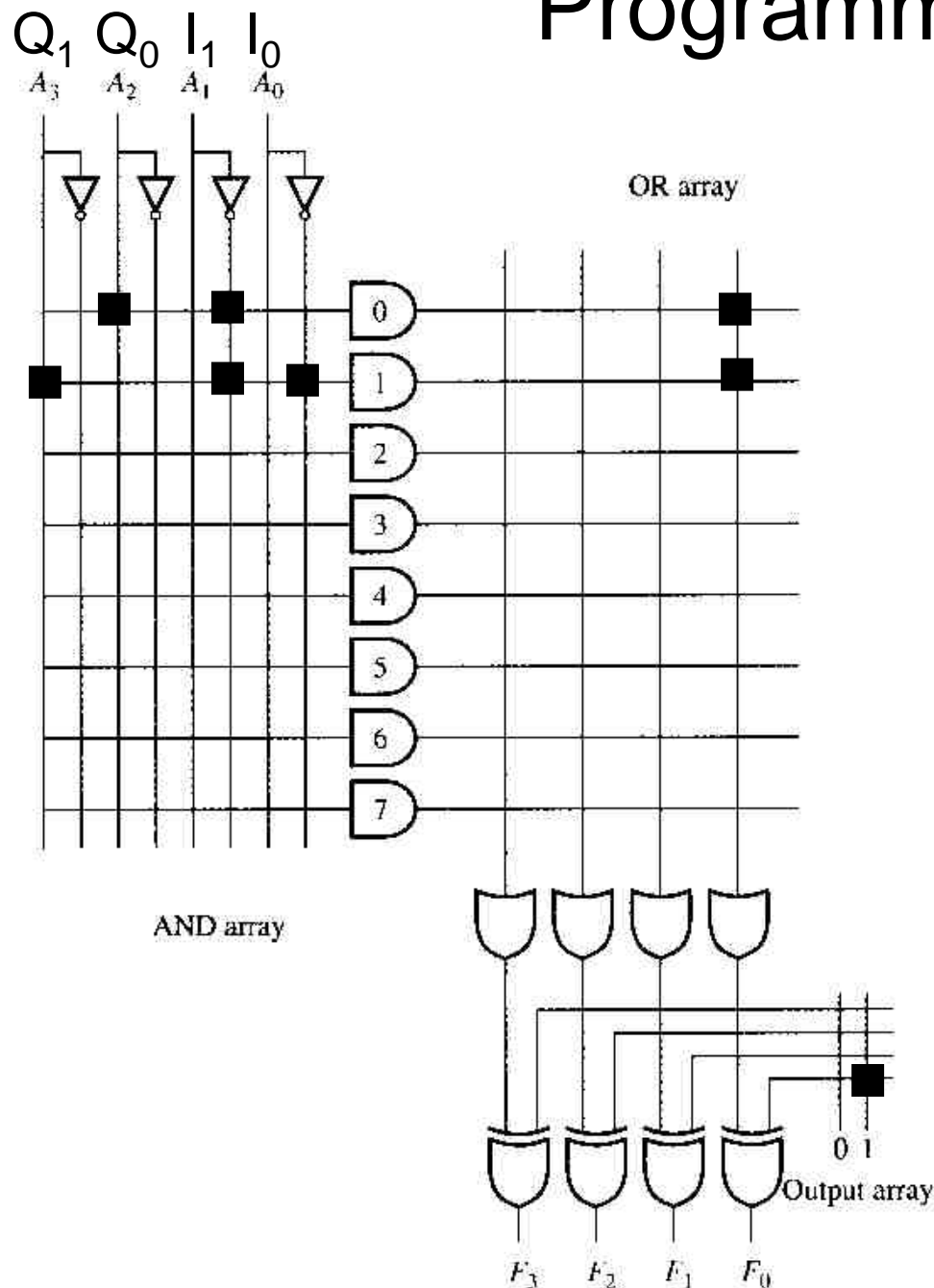
4-inngangs buss

# (Programmable) Read Only Memory



$Q_1$	$Q_0$	$I_1$	$I_0$	$F_0$
0	0	0	0	1
0	0	0	1	1
0	0	1	0	1
0	0	1	1	1
0	1	0	0	0
0	1	0	1	0
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1
1	1	0	0	0
1	1	0	1	0
1	1	1	0	1
1	1	1	1	1

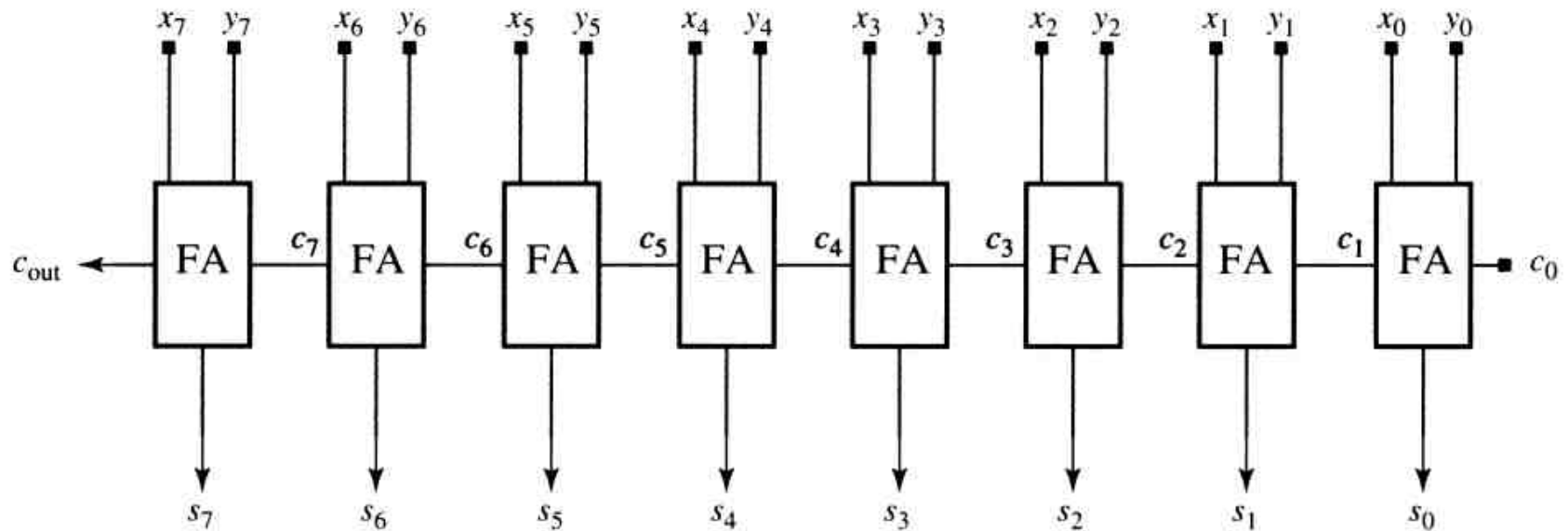
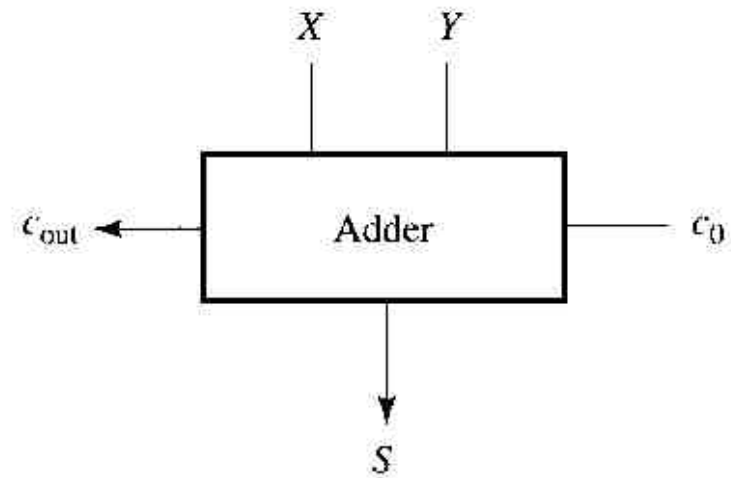
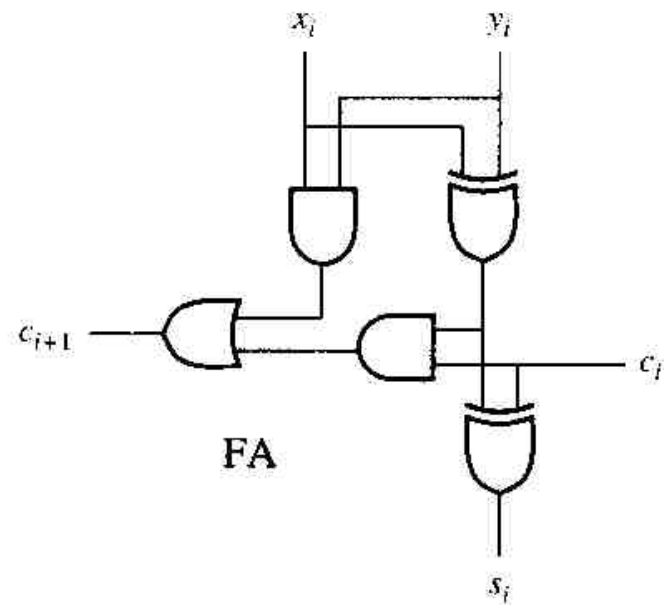
# Programmable Logic Array



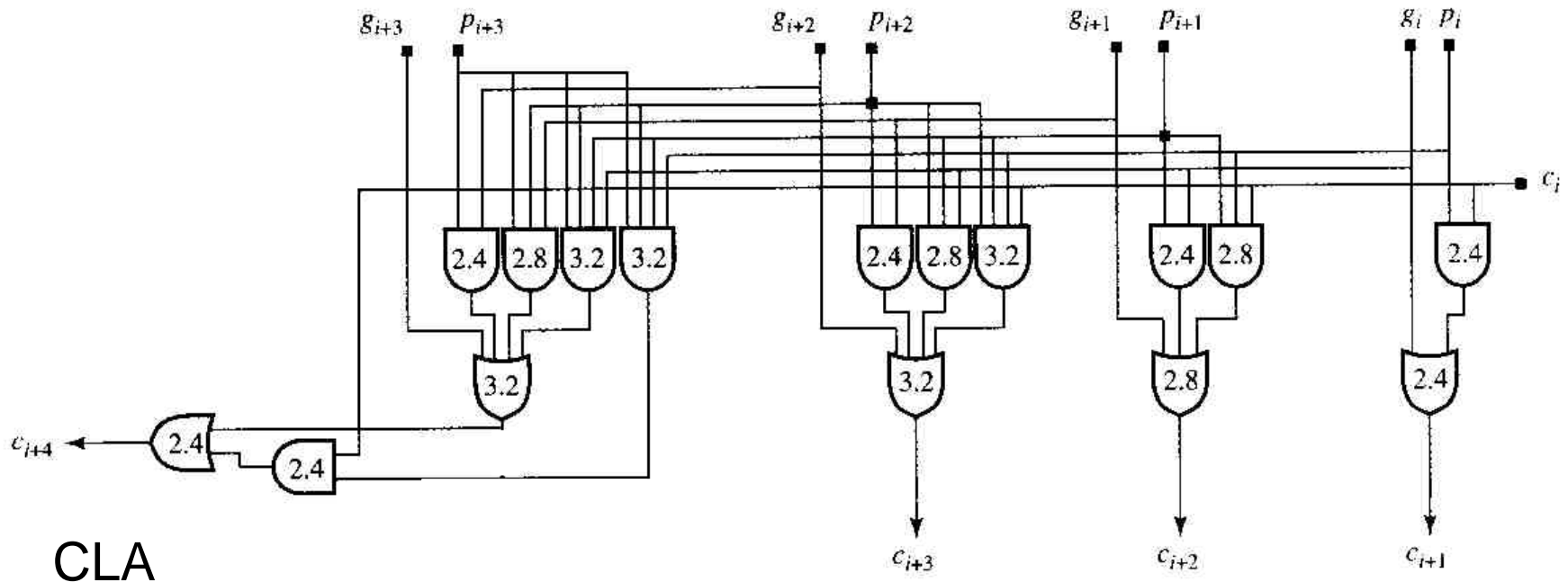
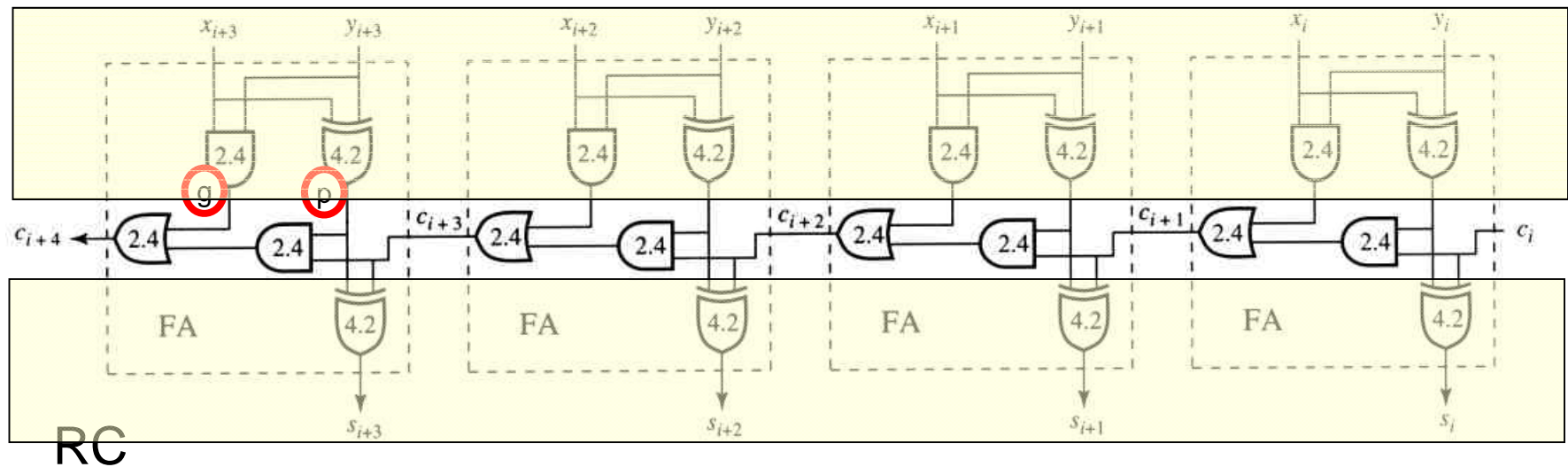
$Q_1$	$Q_0$	$I_1$	$I_0$	$F_0$
0	0	0	0	1
0	0	0	1	1
0	0	1	0	1
0	0	1	1	1
0	1	0	0	0
0	1	0	1	0
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1
1	1	0	0	0
1	1	0	1	0
1	1	1	0	1
1	1	1	1	1

$$F_0' = Q_0 I_1' + Q_1 I_1' I_0'$$

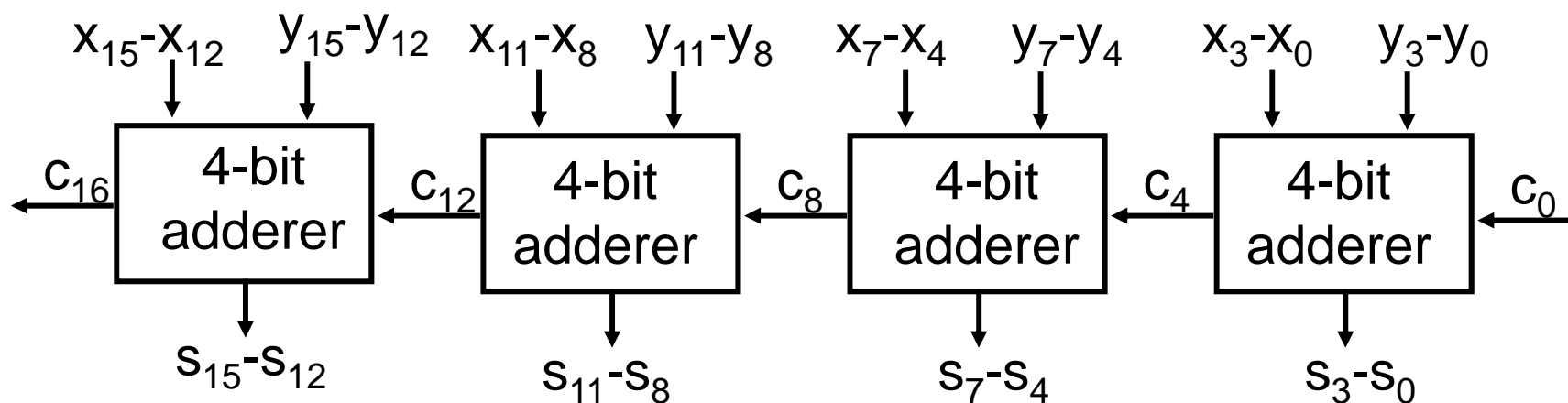
# "Ripple-Carry" Adder



# "Carry Look Ahead" Adder



# Forsinkelse i adderere



Mentesti	RC adderer	En-nivå CLA	To-nivå CLA
$c_0 (x_0, y_0)$ to $c_4$	19,2 (23,4)	4,8 (13,0)	4,8 (13,0)
$c_0 (x_0, y_0)$ to $c_{16}$	76,8 (81,0)	19,2 (27,4)	4,8 (19,4)