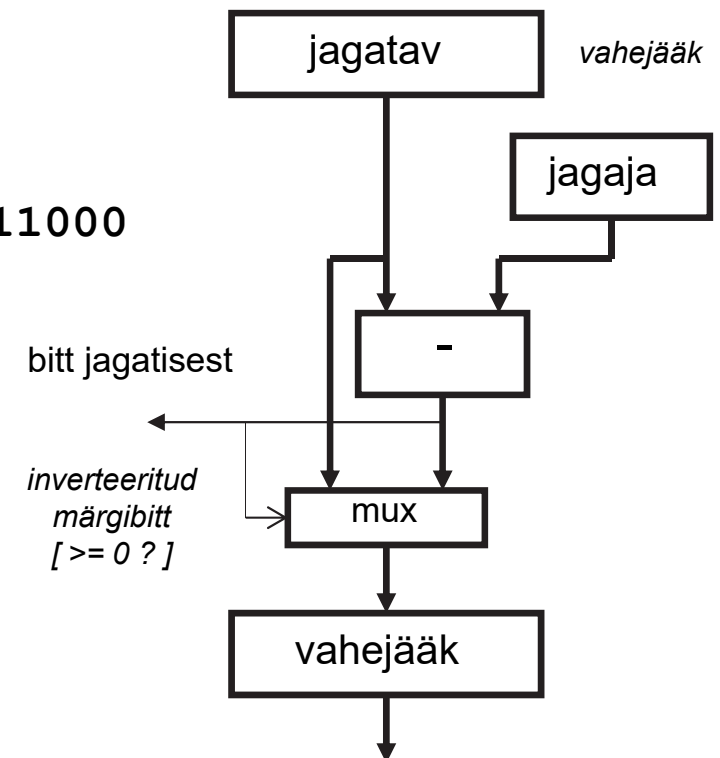


Jagamisalgoritmid

- 2-nd arvude jagamine
 - analoogne 10-nd arvude jagamisele

312 / 13 = 24	0100111000 / 01101 = 011000
26	- 01101
---	-----
52	01101
52	- 01101
---	-----
0	0000000000 [jääk]
===	=====



- Lahutamine, kontroll ja nihutamine
- Enamus arhitektuure põhineb sellel algoritmil
 - Kiirendusvõtted kombineerivad eri variante

Jagamisalgoritmid

$$23/5=4 \text{ j } 3$$

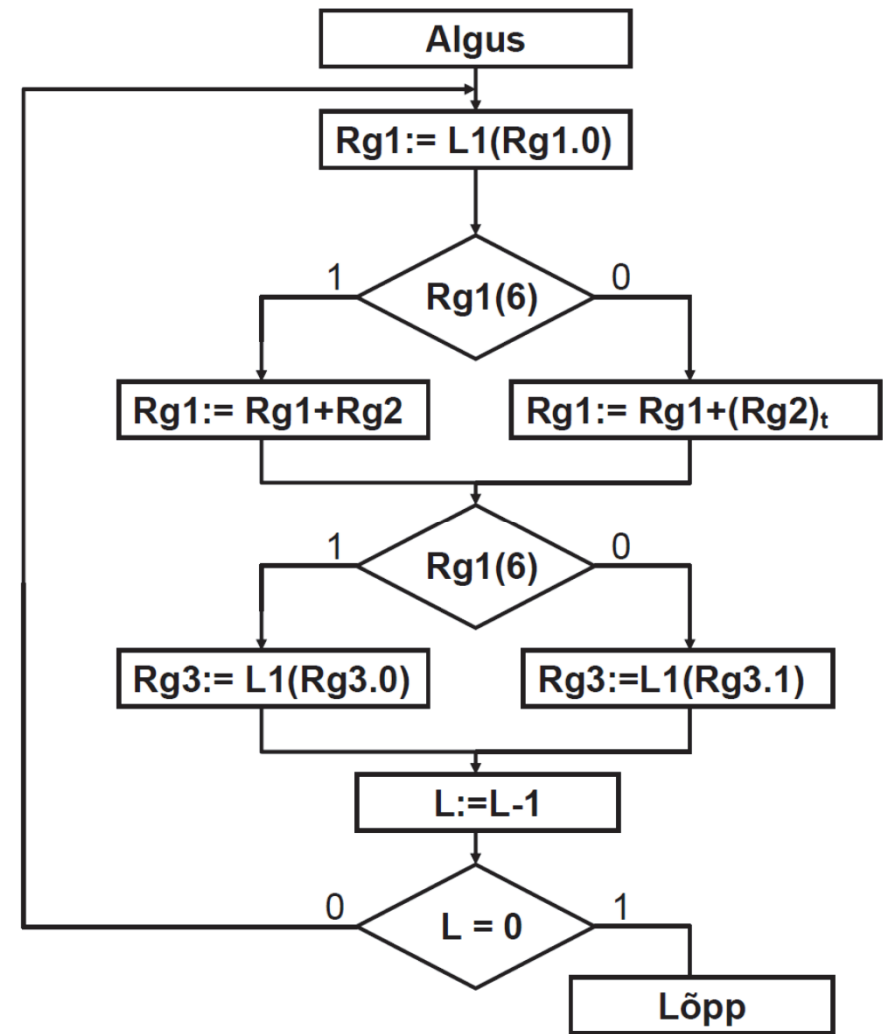
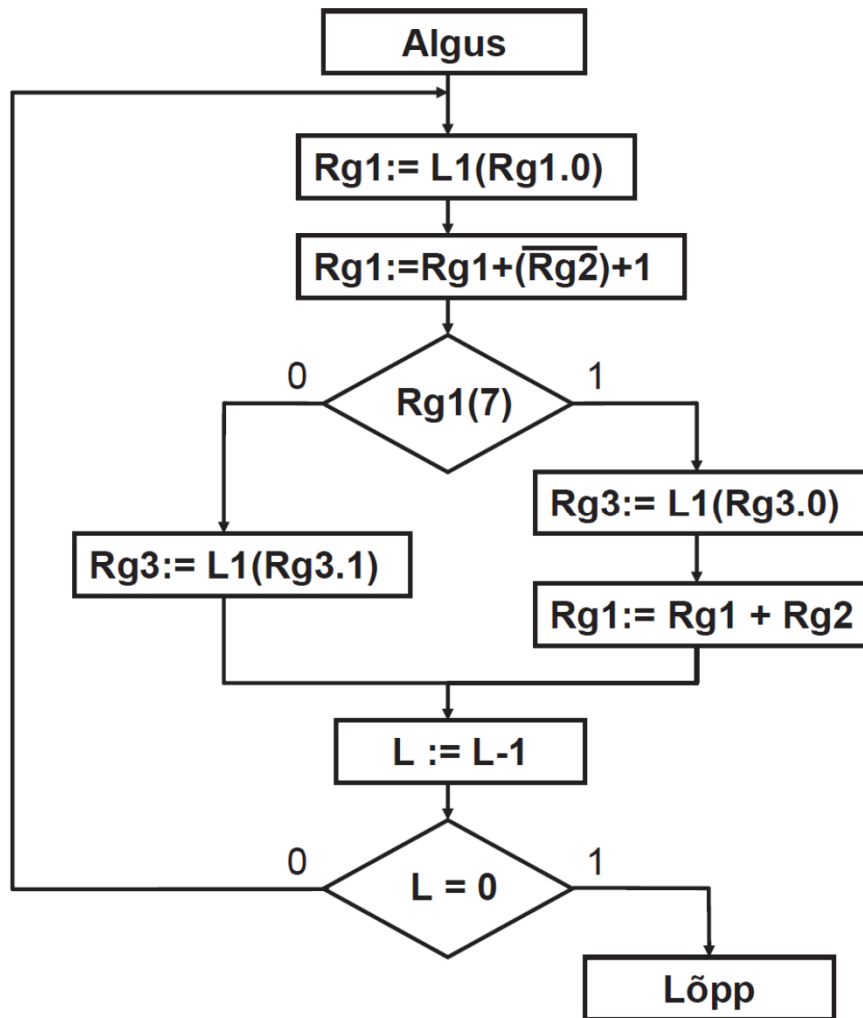
$$\begin{array}{r} 00010111 / 00000101 == 100 \text{ jääk } 11 \\ -0101 \\ \hline 11 \end{array}$$

$$20/3=6 \text{ j } 2$$

$$\begin{array}{r} 00010100 / 00000011 == 110 \text{ j. } 10 \\ -011 \\ \hline 1000 \\ -011 \\ \hline 10 \end{array}$$

- Jagamisel on oluline alustada “õigest” kohast
- Erinevad algoritmid käsitlevad negatiivseid arve erinevalt

Jagamisalgoritmid



- Margus Kruus – Jagamisalgoritmid

Ujukoma-arvud – tehted

- Märk 1; eksponent k ja mantiss m bitti
 - $\pm(N/2^m)*2^K$; $1 > N \geq 0.5$ ja $2^{k-1} > K \geq -2^{k-1}$
 - $1,5 = 0,75*2^1 = 0|0001|11000000$
 - Võimalik ka märgiga mantiss ja eksponendi variandid
- Liitmine & lahutamine
 - $a+b = (A*2^{AE})+(B*2^{BE}) = (A*2^{AE})+(B*2^{AE-x}) = (A+B/2^x)*2^{AE}$
 - $AE > BE$ (e. $AE=BE+x$) ja $1 > \text{mantiss} > 0$
 - eel- ja järelkorrektsioonid võivad olla vajalikud!
- Korrutamine & jagamine
 - $a*b = (A*2^{AE})*(B*2^{BE}) = (A*B)*2^{AE+BE}$
- Normaliseerimine enne/pärast tehteid

Ujukoma-arvud – tehted

- Liitmine / lahutamine

- Astendajad peavad olema võrdsed

- $2,7 - 1,3 \equiv 0,675 \cdot 2^2 - 0,65 \cdot 2^1 =$
 $0,675 \cdot 2^2 - 0,325 \cdot 2^2 = (0,675 - 0,325) \cdot 2^2 =$
 $0,35 \cdot 2^2 = 0,7 \cdot 2^1 \equiv 1,4$

- Korrutamine

- $1,3 \cdot 1,9 \equiv 0,65 \cdot 2^1 \cdot 0,95 \cdot 2^1 = 0,6175 \cdot 2^2 \equiv 2,47$

- Jagamine

- $2,7 / 1,3 \equiv 0,675 \cdot 2^2 / 0,65 \cdot 2^1 =$
 $1,038461... \cdot 2^1 = 0,519230... \cdot 2^2 \equiv 2,076923...$

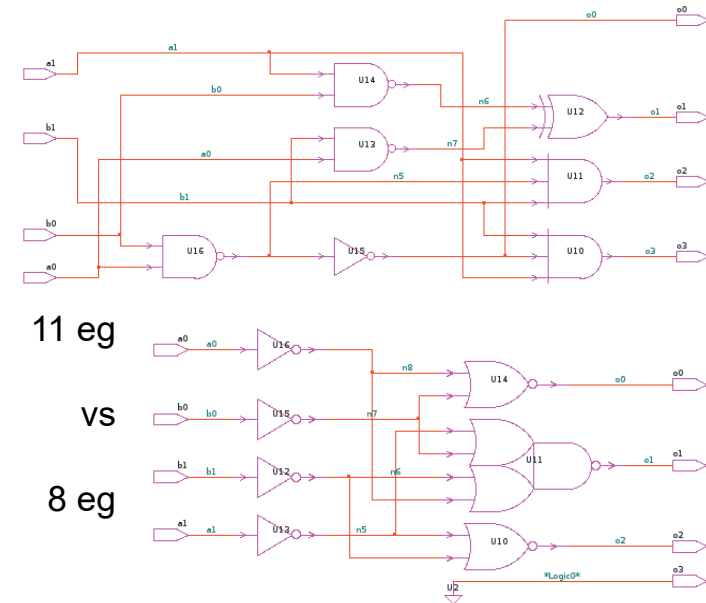
Ujukoma-arvud – muud formaadid

- Erinevad formaadid ja tehted
 - <https://ati.ttu.ee/~lrv/ujukoma.html>
 - IEEE 754 standard
 - https://en.wikipedia.org/wiki/IEEE_754
 - Märk, astendaja, mantiss
 - Normeeritud mantiss – 1,0...2,0
 - Vanim bitt alati 1 – ei kasutata
 - Astendaja nn kõrvalekaldega (bias)
- Posit
 - IEEE 754 asendus / täiendus
 - <https://www.sigarch.org/posit-a-potential-replacement-for-ieee-754/>
 - [https://en.wikipedia.org/wiki/Unum_\(number_format\)](https://en.wikipedia.org/wiki/Unum_(number_format))

Ligikaudne arvutamine

- Arvutustäpsus polegi nii oluline
 - Närvivõrgud (NN) – 8 bitti täitsa OK 😊
 - Korrutamistel noorimad järgud vähemtähtsad
- Lihtstatud korrutaja – 2x2 bitti

A x B	00	01	10	11
00	000	000	000	000
01	000	001	010	011
10	000	010	100	110
11	000	011	110	111



Aritmeetikatehete simulaator

<http://www.ecs.umass.edu/ece/koren/arith/simulator/>

Restoring Division

X:

D:

bin ☒ dec ☐

Number of bits:

X = 0.4375, D = 0.6875

$r_0 = X$	.0 1 1 1 0 0
$2r_0$	0 .1 1 1 0 0 0 set $q_1 = 1$
Add -D +	1 .0 1 0 1 0 0
r_1	0 .0 0 1 1 0 0
$2r_1$	0 .0 1 1 0 0 0 set $q_2 = 0$
$r_2 = 2r_1$	0 .0 1 1 0 0 0
$2r_2$	0 .1 1 0 0 0 0 set $q_3 = 1$
Add -D +	1 .0 1 0 1 0 0
r_3	0 .0 0 0 1 0 0
$2r_3$	0 .0 0 1 0 0 0 set $q_4 = 0$
$r_4 = 2r_3$	0 .0 0 1 0 0 0
$2r_4$	0 .0 1 0 0 0 0 set $q_5 = 0$
$r_5 = 2r_4$	0 .0 1 0 0 0 0
$2r_5$	0 .1
$r_6 = 2r_5$	0 .1

Q = 0.101000 = 0.625
 $R = r_6 2^{-6} = 0.0078$

SRT Radix-2 Division

X:

D:

bin ☒ dec ☐

Number of bits:

Floating Point Add/Subtract

A:

B:

hex ☐ dec ☒

add ☐ sub ☒

single ☒ double ☐

A + 1.01011001100110011001100 * $2^1 = 2.6999998092651367$
B + 1.01001100110011001100110 * $2^0 = 1.2999999523162842$

Alignment Step

A + 1.01011001100110011001100|000 * 2^1
B + 0.10100110011001100110011|000 * 2^1

A-B + 0.10110011001100110011001|000 * 2^1

Postnormalization Step

A-B + 1.01100110011001100110010|00 * 2^0

Round to Zero

A-B + 1.01100110011001100110010 * $2^0 = 1.3999998569488525$

Round to Nearest Even

A-B + 1.01100110011001100110010 * $2^0 = 1.3999998569488525$

Round to Plus Infinity

A-B + 1.01100110011001100110010 * $2^0 = 1.3999998569488525$

Round to Minus Infinity

A-B + 1.01100110011001100110010 * $2^0 = 1.3999998569488525$

$r_0 = X$ 0.0 1 1 1 0
 $2r_0$ 0.1 1 1 0 0 $\geq 1/2$ set $q_1 = 1$
Add -D + 1.0 1 0 1 0

r_1 0.0 0 1 1 0
 $2r_1 \Rightarrow r_2$ 0.0 1 1 0 0 $< 1/2$ set $q_2 = 0$
 $2r_2$ 0.1 1 0 0 0 $\geq 1/2$ set $q_3 = 1$
Add -D + 1.0 1 0 1 0

r_3 0.0 0 0 1 0
 $2r_3 \Rightarrow r_4$ 0.0 0 1 0 0 $< 1/2$ set $q_4 = 0$
 $2r_4 \Rightarrow r_5$ 0.0 1 0 0 0 $< 1/2$ set $q_5 = 0$

Q = 0.10100 = 0.625