

2019-2

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INF01107 – Introdução à Arquitetura e Organização de Computadores



AULA 11 e 12



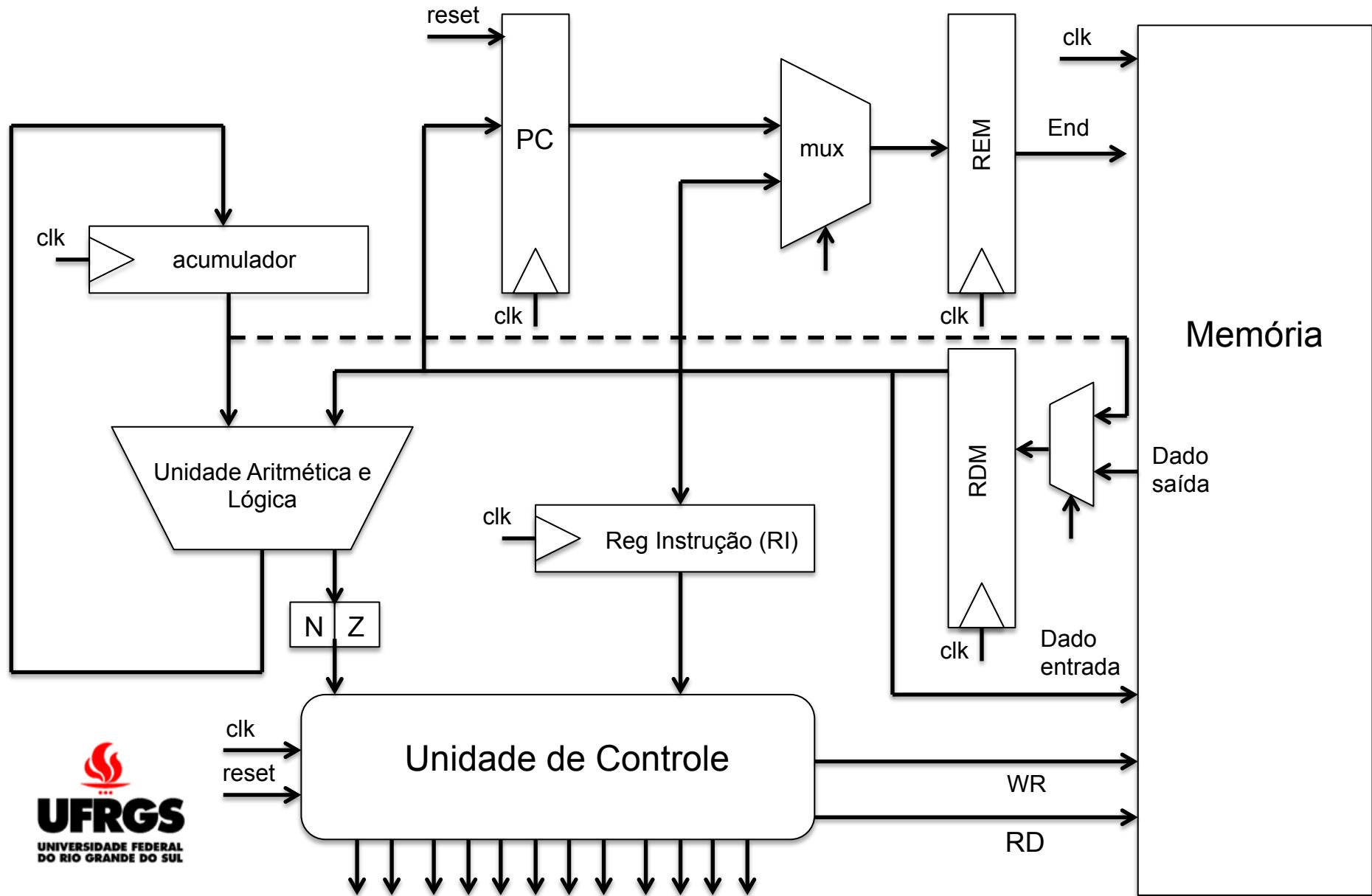
Instruções Neander

Instrução	Comentário
NOP	nenhuma operação
STA end	$\text{MEM}(\text{end}) \leftarrow \text{AC}$
LDA end	$\text{AC} \leftarrow \text{MEM}(\text{end})$
ADD end	$\text{AC} \leftarrow \text{MEM}(\text{end}) + \text{AC}$
OR end	$\text{AC} \leftarrow \text{MEM}(\text{end}) \text{ OR } \text{AC}$
AND end	$\text{AC} \leftarrow \text{MEM}(\text{end}) \text{ AND } \text{AC}$
NOT	$\text{AC} \leftarrow \text{NOT AC}$
JMP end	$\text{PC} \leftarrow \text{end}$
JN end	IF $\text{N}=1$ THEN $\text{PC} \leftarrow \text{end}$
JZ end	IF $\text{Z}=1$ THEN $\text{PC} \leftarrow \text{end}$

O Conjunto de instruções de um processador irá definir sua organização interna, os recursos de hardware necessários.



Qual é o Hardware necessário?





Registrador

- Acumulador
- Registrador de Instrução
- Registrador de endereço de memória REM
- Registrador de dados de memória (RDM)
- Contador de programa (PC)

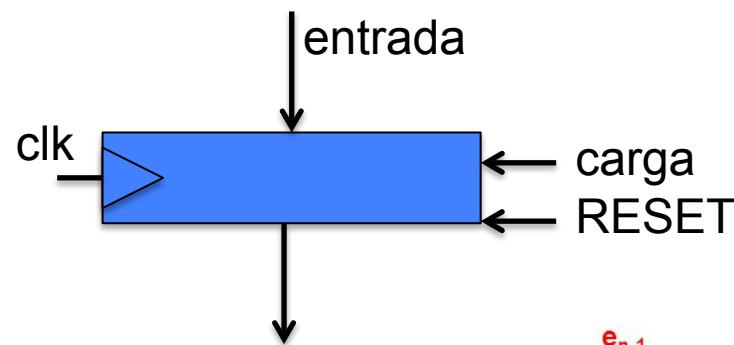


O que é um registrador?

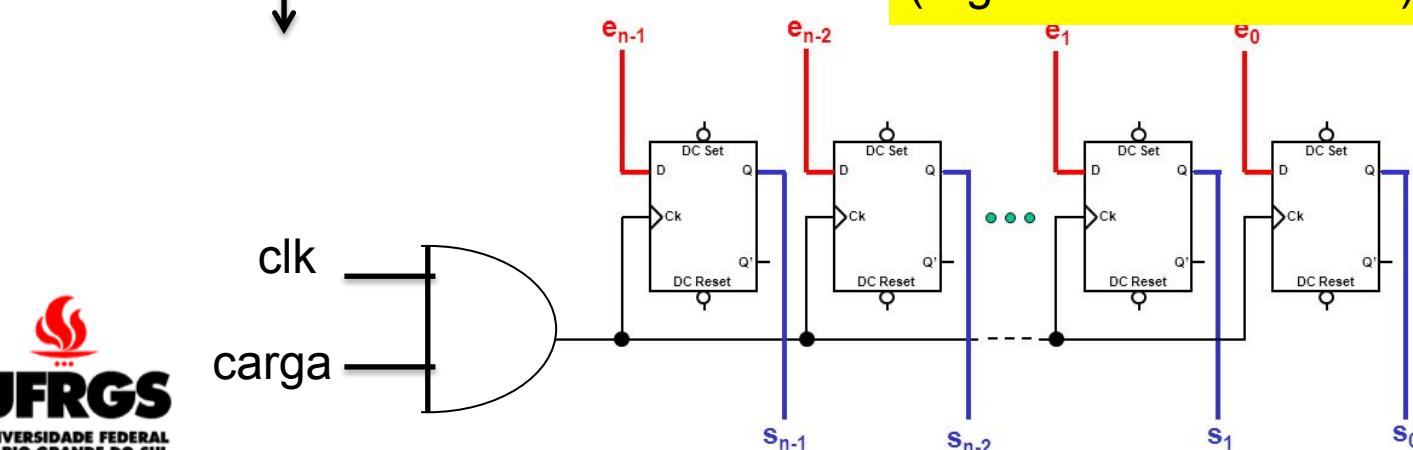
Registrador é um elemento de memória capaz de armazenar n bits de informação.

Ele é composto por um conjunto de n flip-flops (elemento de armazenamento básico, unitário) do tipo D.

Um registrador pode ser sinal que habilita a carga neste registrador, reset, e outras funcionalidades.

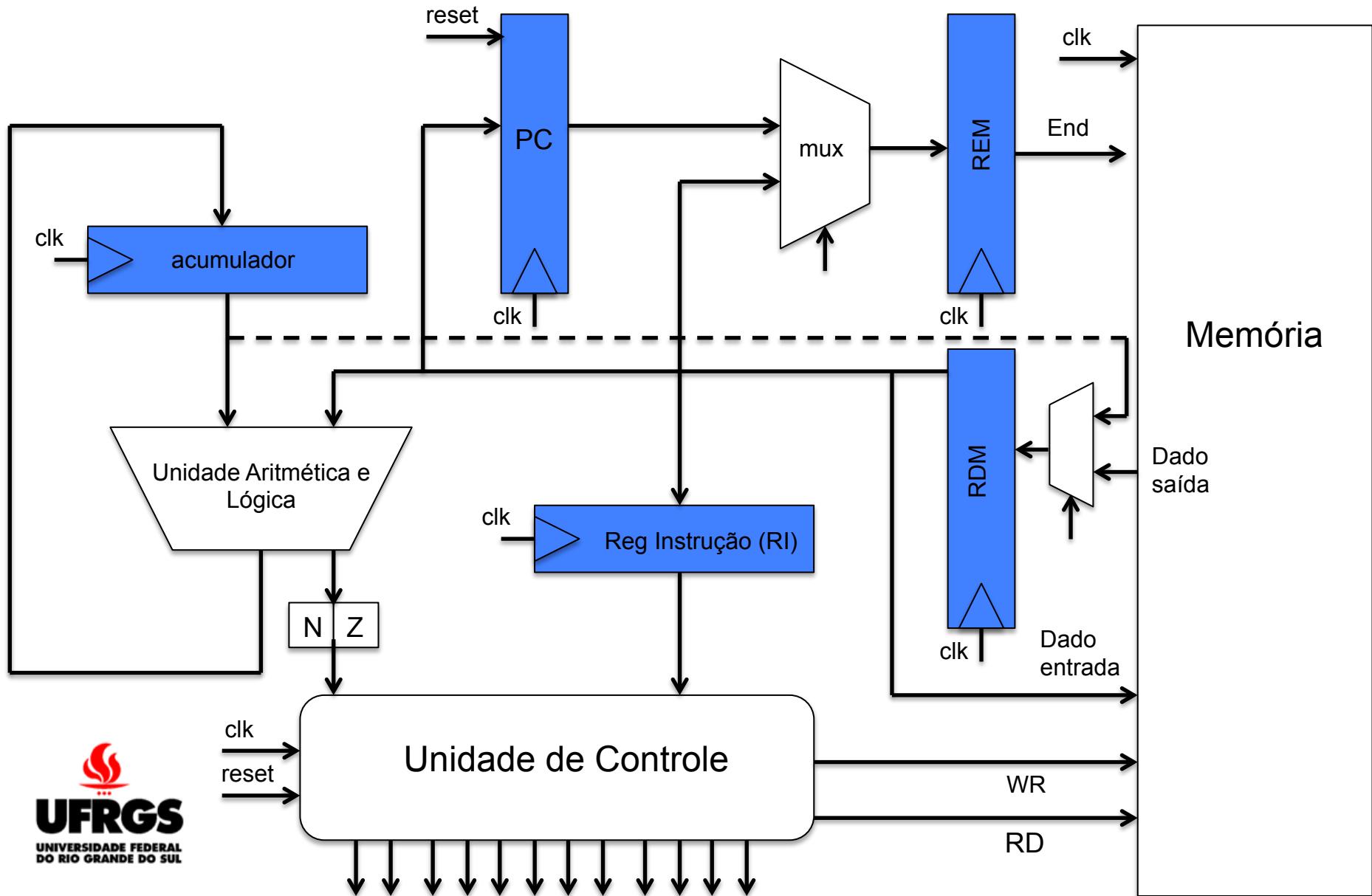


Quando reset = 1, registrador é inicializado com valor inicial, quando carga = 1 e a borda de subida do relogio (clk) acontece, então o registrador armazena um novo valor (registrador \leq entrada)





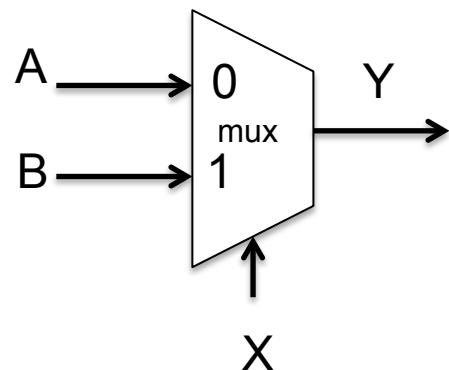
Qual é o Hardware necessário?



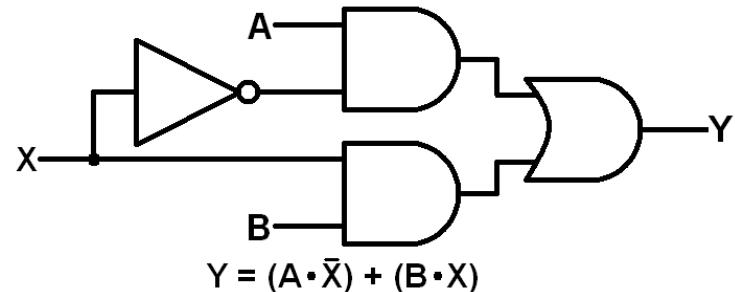


Multiplexador (MUX)

- Elemento lógico, combinacional, capaz de escolher, selecionar entradas para uma saída.
- Existem multiplexadores de 2:1, 4:1, 8:1, 16:1 e assim por diante.
- Os multiplexadores são compostos por porta lógica básica: not, and e or. (inversor, E e OU).

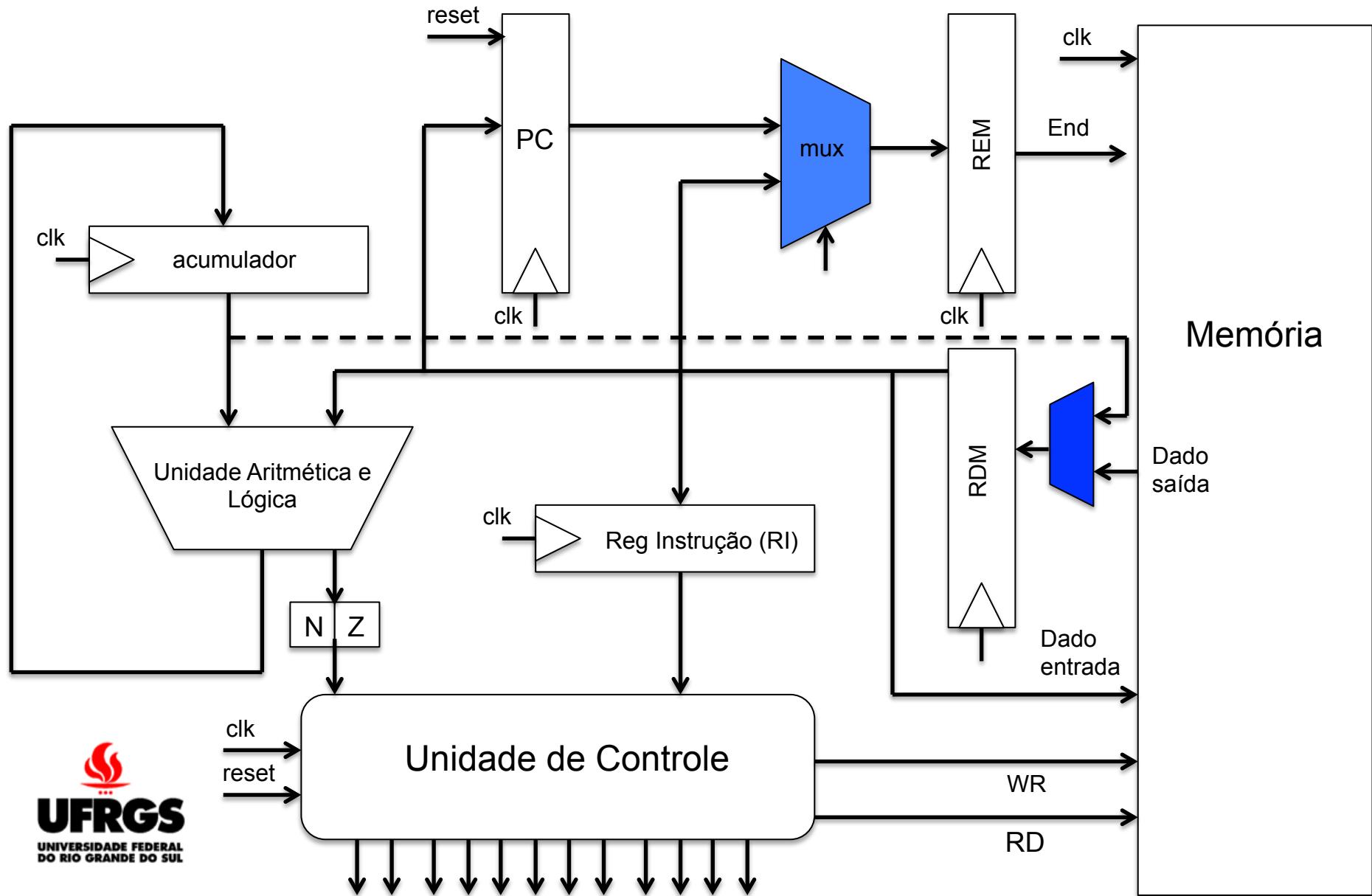


XAB	Y
000	0
001	0
010	1
011	1
100	0
101	1
110	0
111	1





Qual é o Hardware necessário?



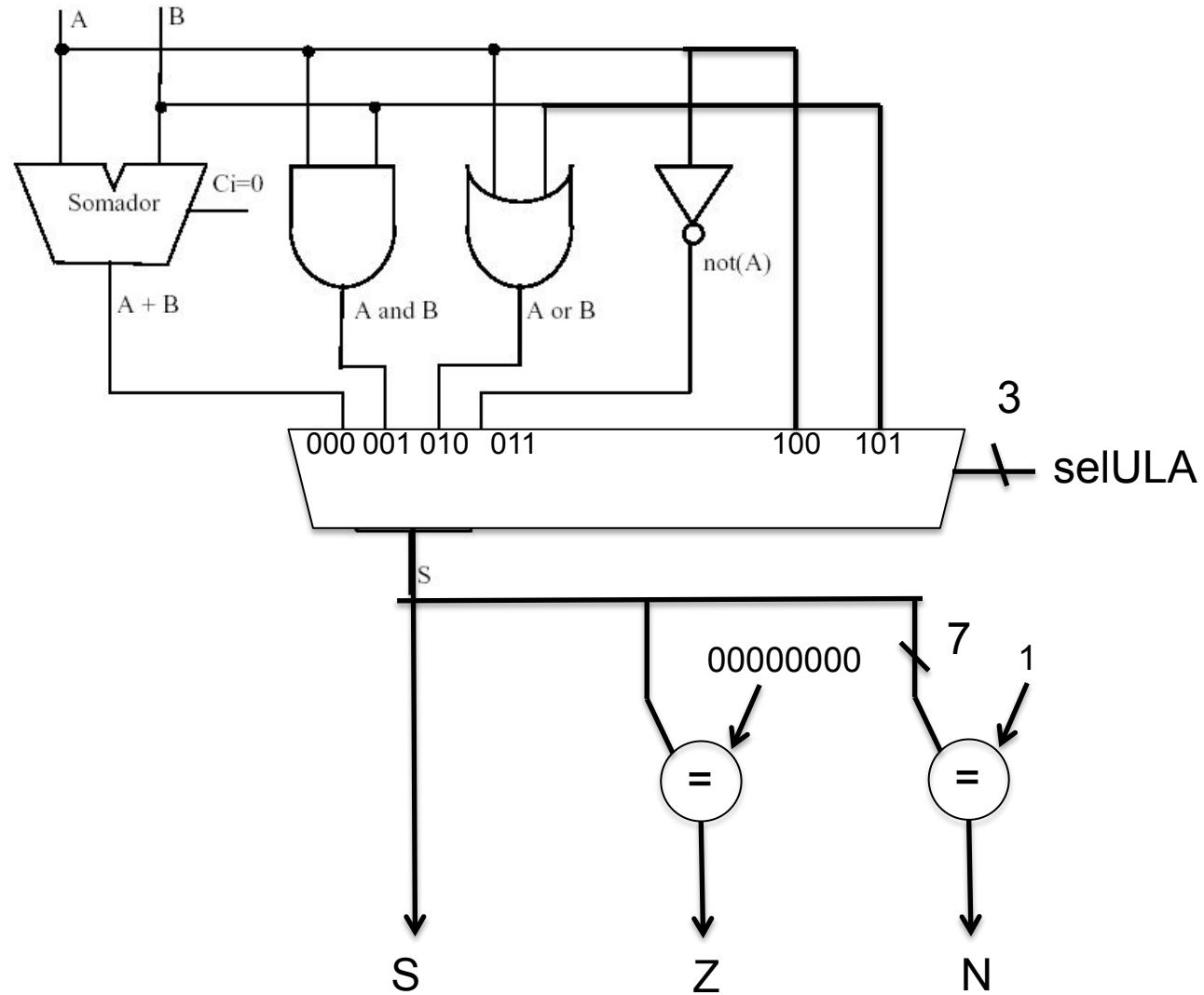


Unidade Aritmética e Lógica (ULA)

- Elemento lógico, combinacional, capaz de realizar um conjunto de operações lógicas e aritméticas.
- Um multiplexador normalmente escolhe qual das operações a saída da ULA irá receber e o tamanho do MUX depende de quantas operações a ULA pode realizar. No Neander há um multiplexador 4:1.
- As funções da ULA no Neander são:
 - SOMA,
 - E,
 - OU
 - inversão
 - *Reconhecer Acumulador = 0, ou dado a ser gravado no acumulador = 0 (Z)*
 - *Reconhecer Acumulador negativo ou dado a ser escrito no acumulador como negativo (N)*

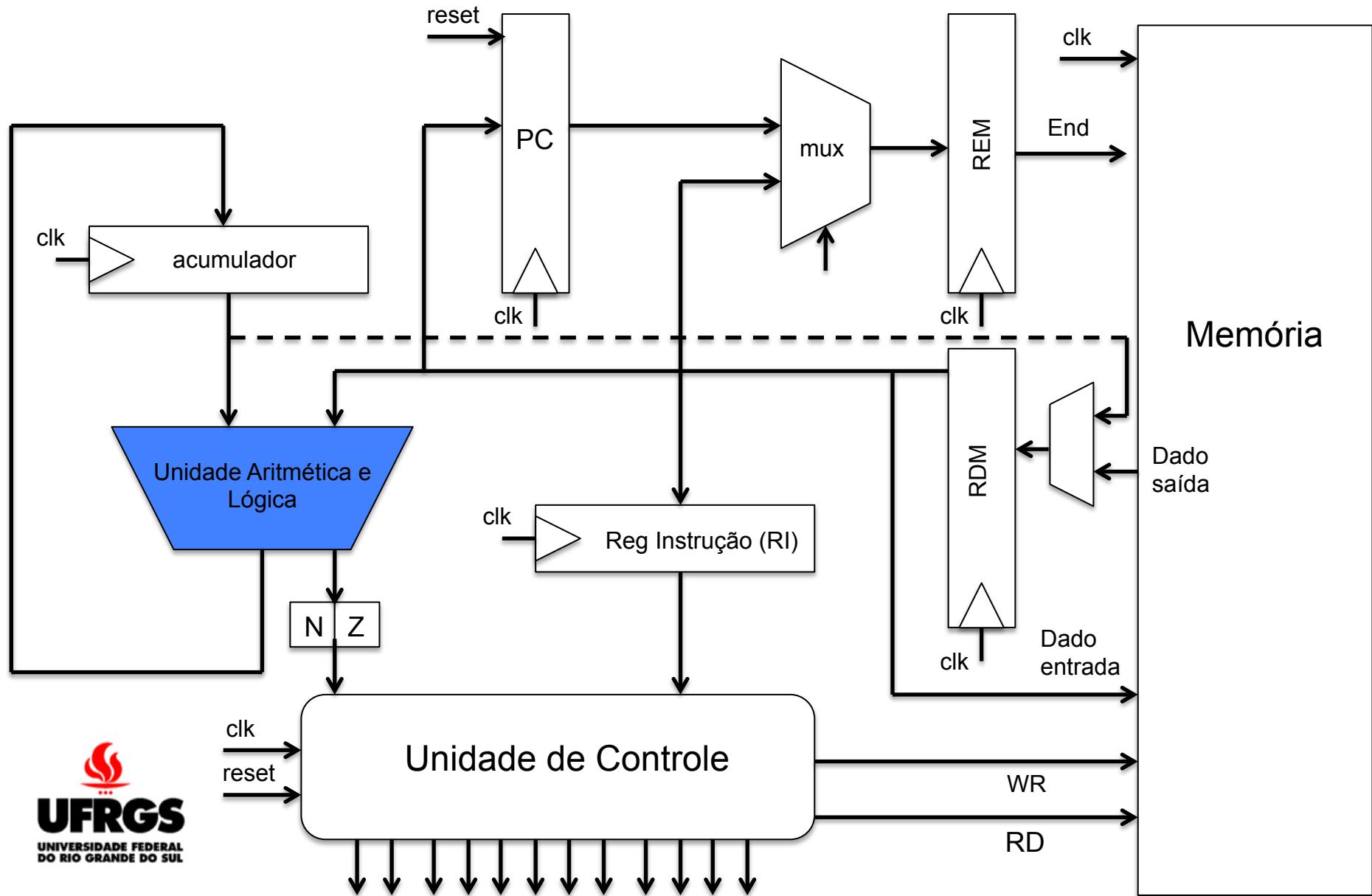


ULA NEANDER





Qual é o Hardware necessário?



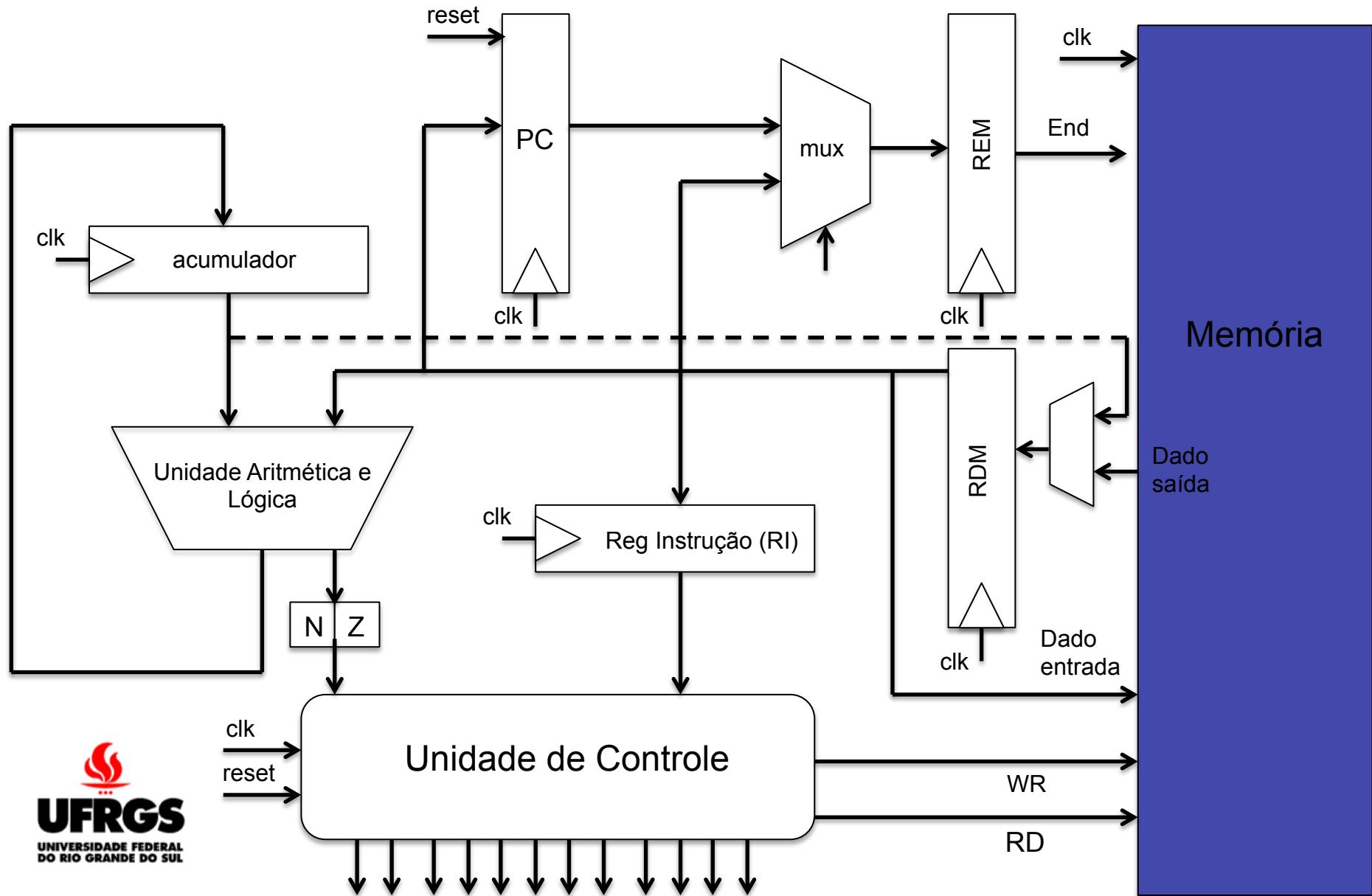


Memória

- Array de registradores regular, organizado para que cada registrador possa ser acessado por um determinado endereço.
- No Neander a memória tem 256 endereços e cada endereço tem um registro de 8 bits de largura (1 Byte).
- A memoria tem uma interface de endereço, dado de entrada, dado de saída, sinal de leitura (RD) e de escrita (WR).

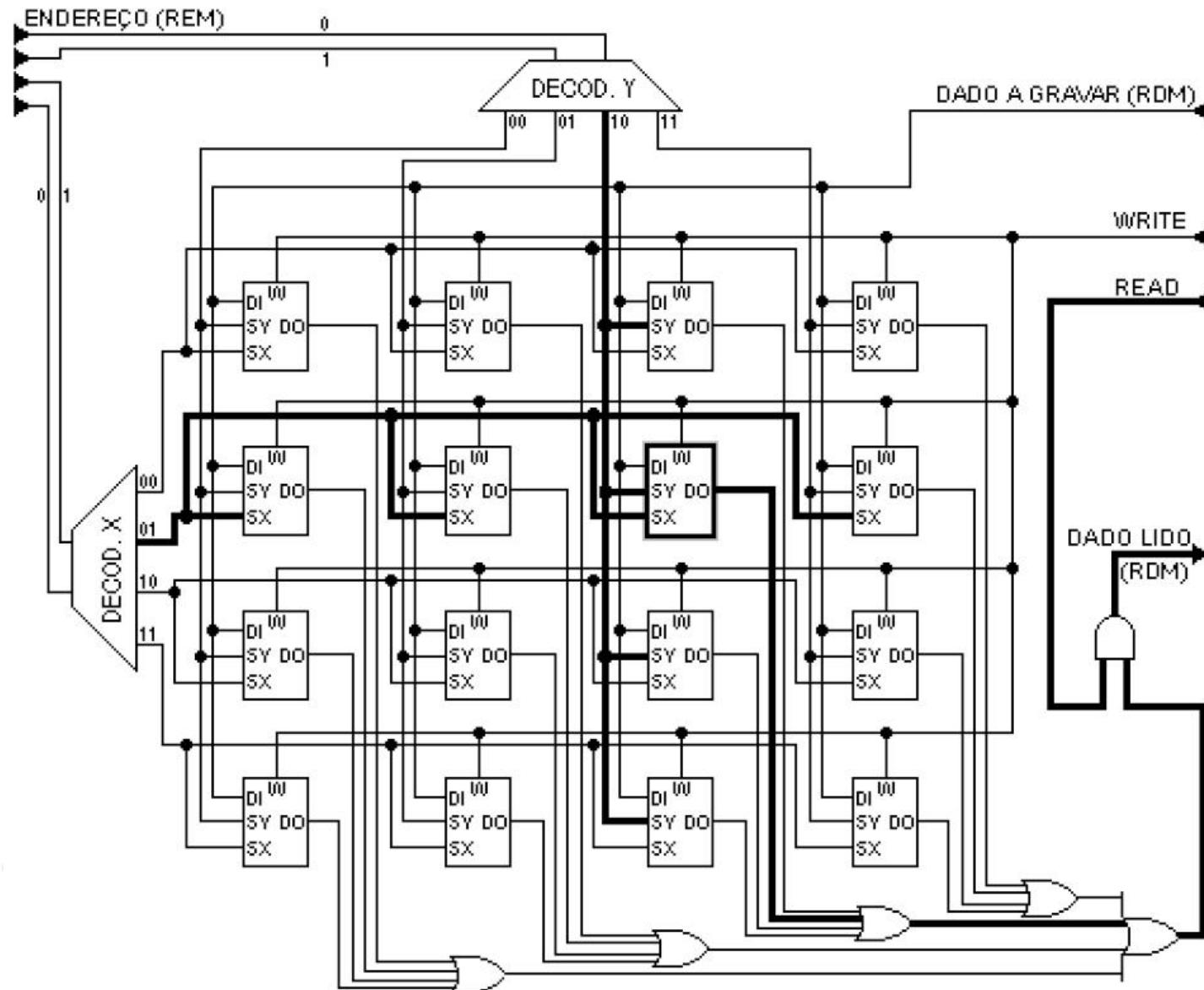


Qual é o Hardware necessário?





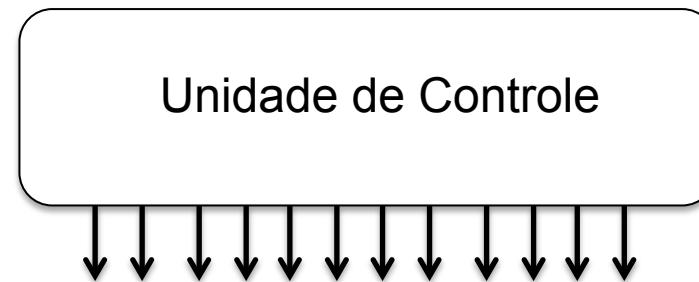
Memória



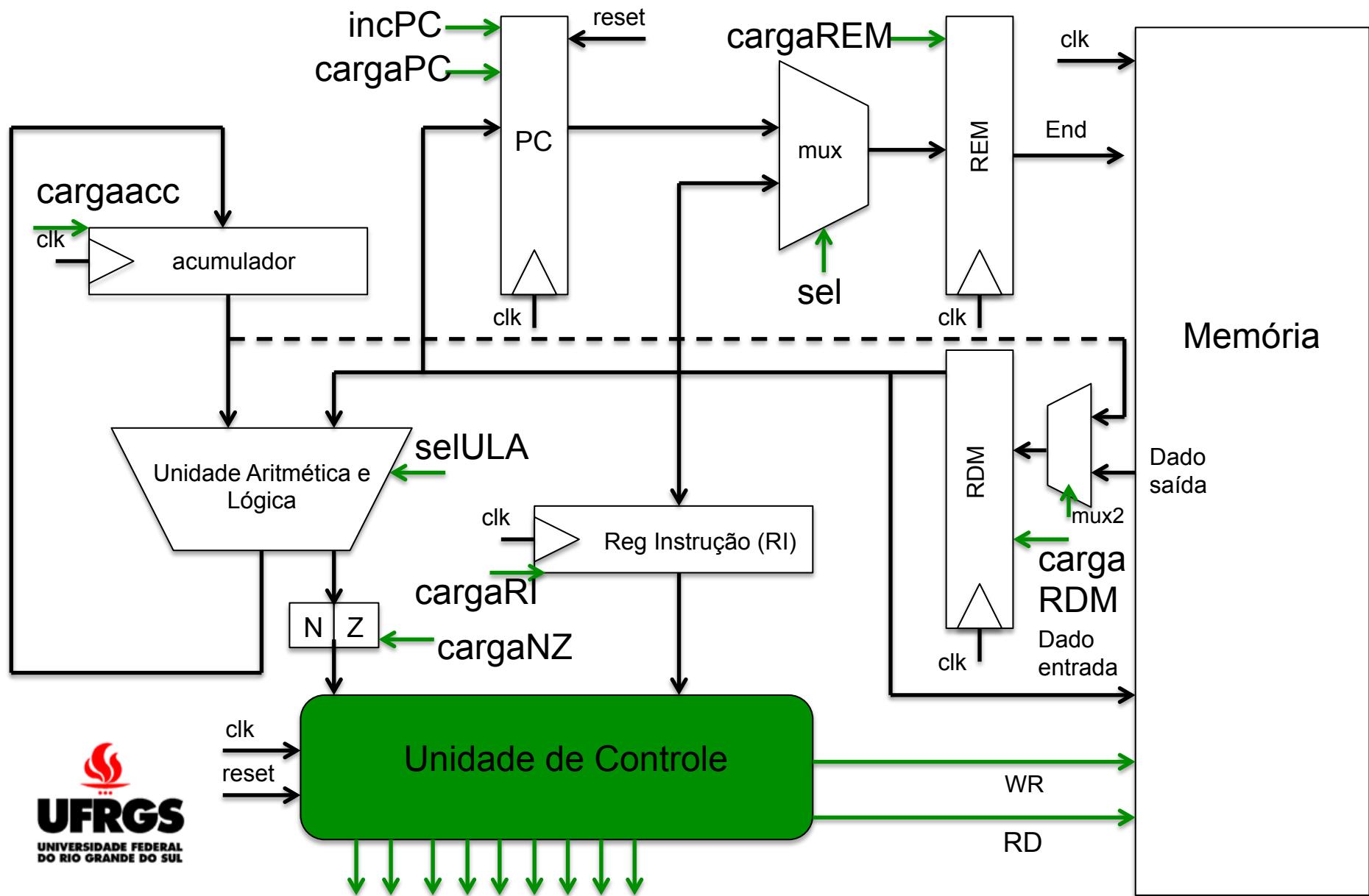


Quem controla as passagens dos dados?

- Unidade de controle que é uma grande máquina de estados que controla a passagem dos dados na parte operativa.



Esses são os conjuntos de sinais que controlam a carga dos registradores, os multiplexadores, o controle da ULA e a leitura e escrita na memória.





Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	

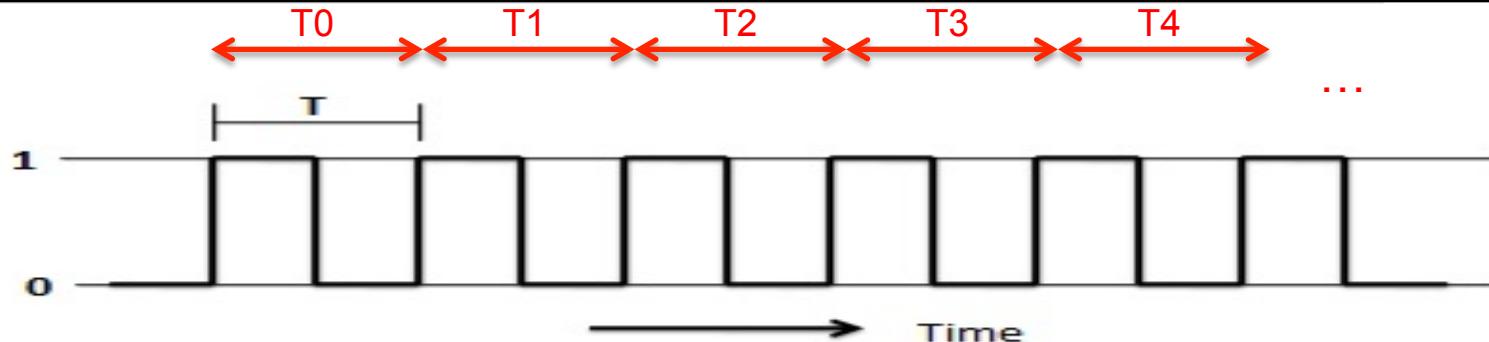


Unidade de Controle

tempo	JMP	JN, N=1	JN, N=0	JZ, Z=1	JZ, Z=0	NOP	HLT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	incrementa PC, goto t0	sel=0, carga REM	incrementa PC, goto t0	goto t0	Halt
t4	Read	Read		Read			
t5	carga PC, goto t0	carga PC, goto t0		carga PC, goto t0			
t6							
t7							



O que é o tempo T0 T7...



T = periodo do relógio.

Cada ciclo do relogio, ou periodo do relógio, a maquina de estados que implementa a Unidade de Controle do Processador gera diferentes valores para os sinais de controle de carga de registradores, seleção dos mux, ULA e leitura e escrita da memoria.

As instruções mais complexas demoram 8 ciclos de relógio para serem lidas e executadas.

As instruções mais simples como NOT, NOP e HLT demoram 4 ciclos de relógio.



Unidade de Controle

- Note que em cada ciclo de relógio Tx a máquina de controle da Unidade de Controle define valores 1 e 0 para os sinais de controle (sinais verdes da figura).
- E quando vem a borda de subida do relógio (clk) os valores são armazenados nos registradores e memória (conforme a habilitação dos sinais de controle).
- IMPORTANTE: um registrador e memoria só são atualizados quando vem a borda de subida do relógio e o sinal de carga/habilita/load ou WR estão habilitados.



Instruções Neander

Instrução	Comentário
NOP	nenhuma operação
STA end	$\text{MEM}(\text{end}) \leftarrow \text{AC}$
LDA end	$\text{AC} \leftarrow \text{MEM}(\text{end})$
ADD end	$\text{AC} \leftarrow \text{MEM}(\text{end}) + \text{AC}$
OR end	$\text{AC} \leftarrow \text{MEM}(\text{end}) \text{ OR } \text{AC}$
AND end	$\text{AC} \leftarrow \text{MEM}(\text{end}) \text{ AND } \text{AC}$
NOT	$\text{AC} \leftarrow \text{NOT AC}$
JMP end	$\text{PC} \leftarrow \text{end}$
JN end	IF $\text{N}=1$ THEN $\text{PC} \leftarrow \text{end}$
JZ end	IF $\text{Z}=1$ THEN $\text{PC} \leftarrow \text{end}$



Instrução de LOAD

LDA end

Busca:

RI <= mem (PC)

PC <= PC + 1

Execução:

end <= mem (PC)

PC <= PC + 1

AC <= mem (end), atualiza N e Z

LDA end

Busca:

REM <= PC

Read; PC <= PC + 1

RI <= RDM

Execução:

REM <= PC

Read; PC <= PC + 1

REM <= RDM

Read

AC <= RDM; atualiza N e Z

Código	Instrução
0000	NOP
0001	STA end
0010	LDA end
0011	ADD end
0100	OR end
0101	AND end
0110	NOT
1000	JMP end
1001	JN end
1010	JZ end
1111	HLT

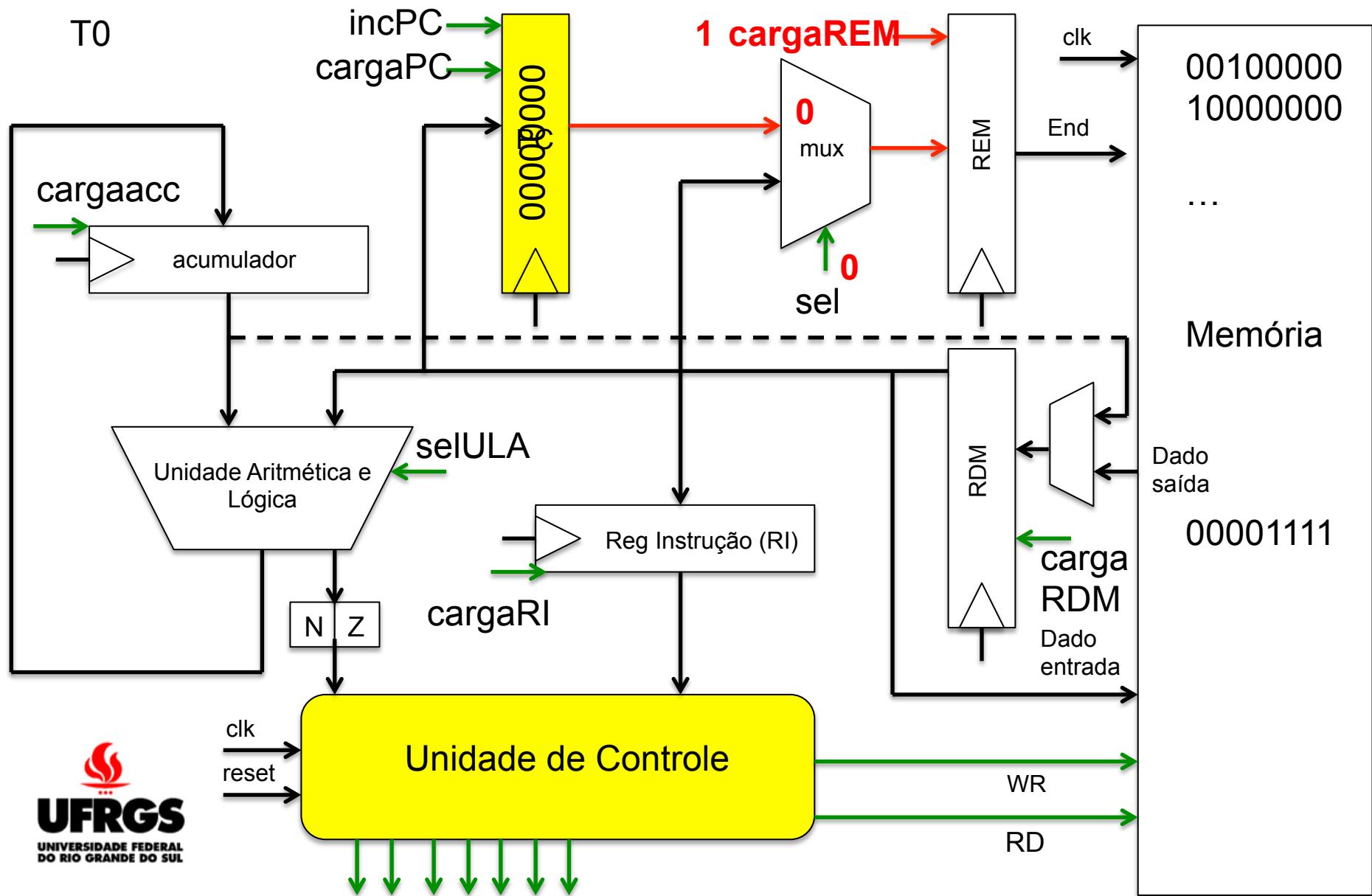


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: LDA end



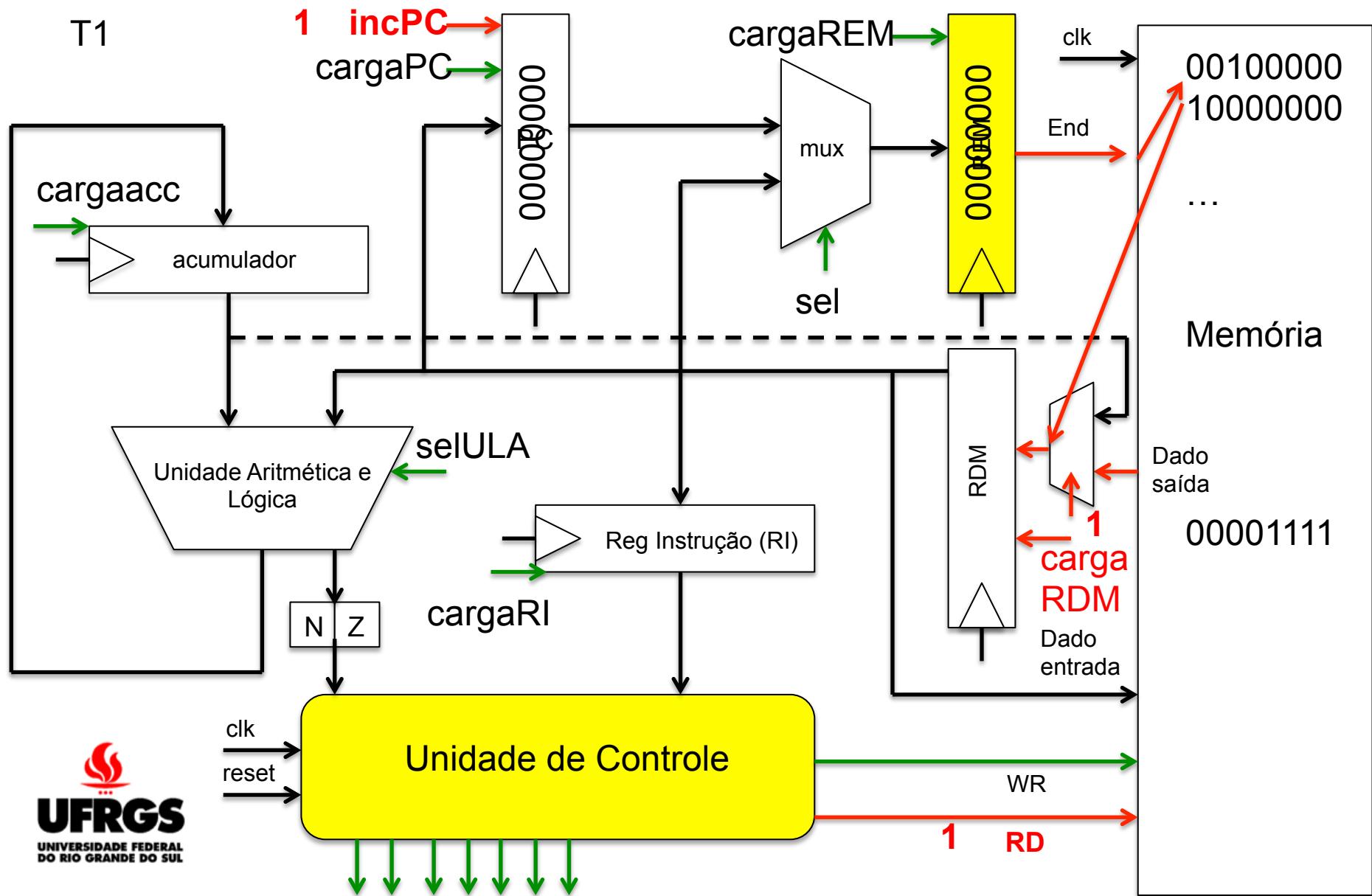


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: LDA end



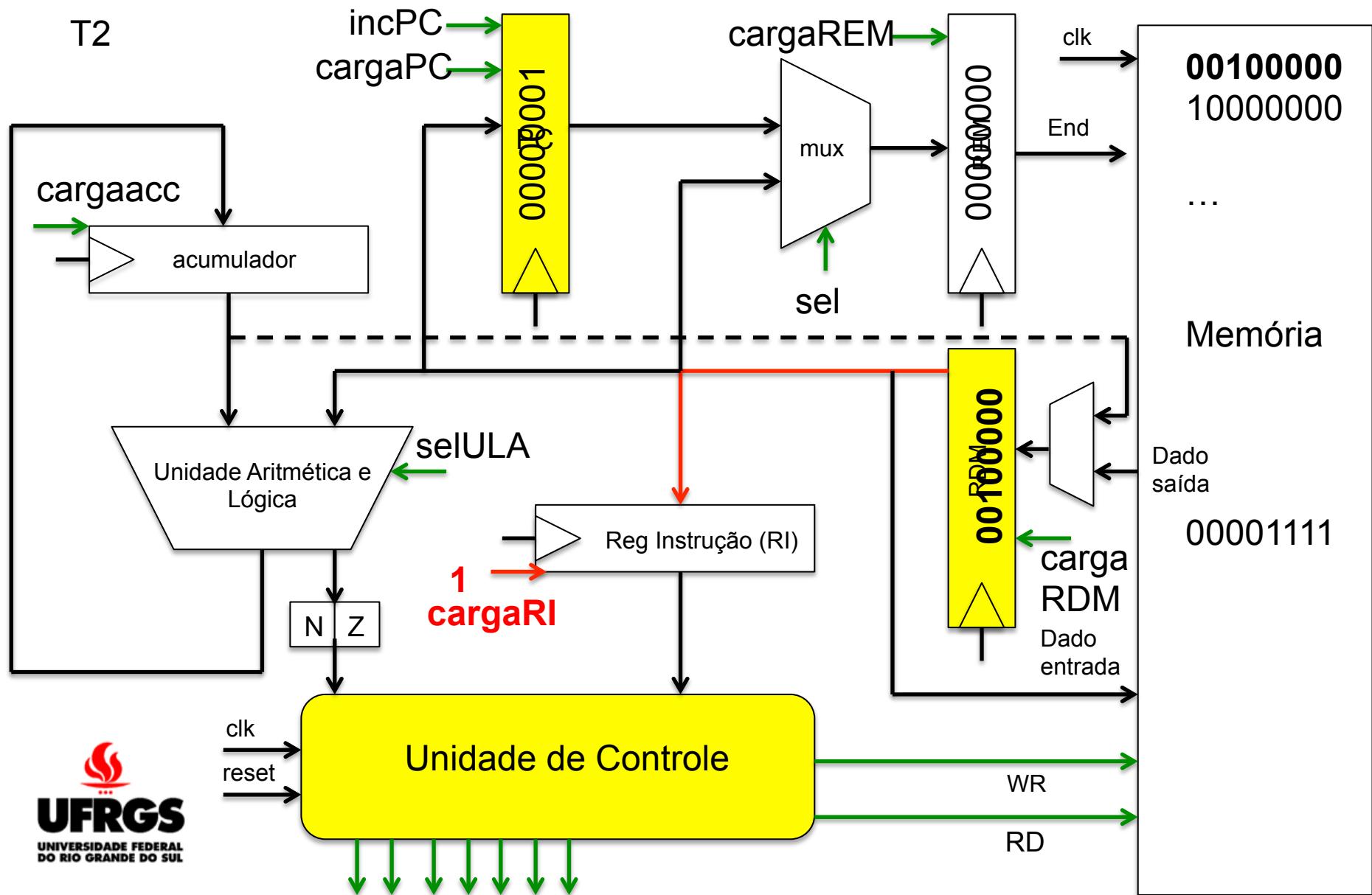


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: LDA end



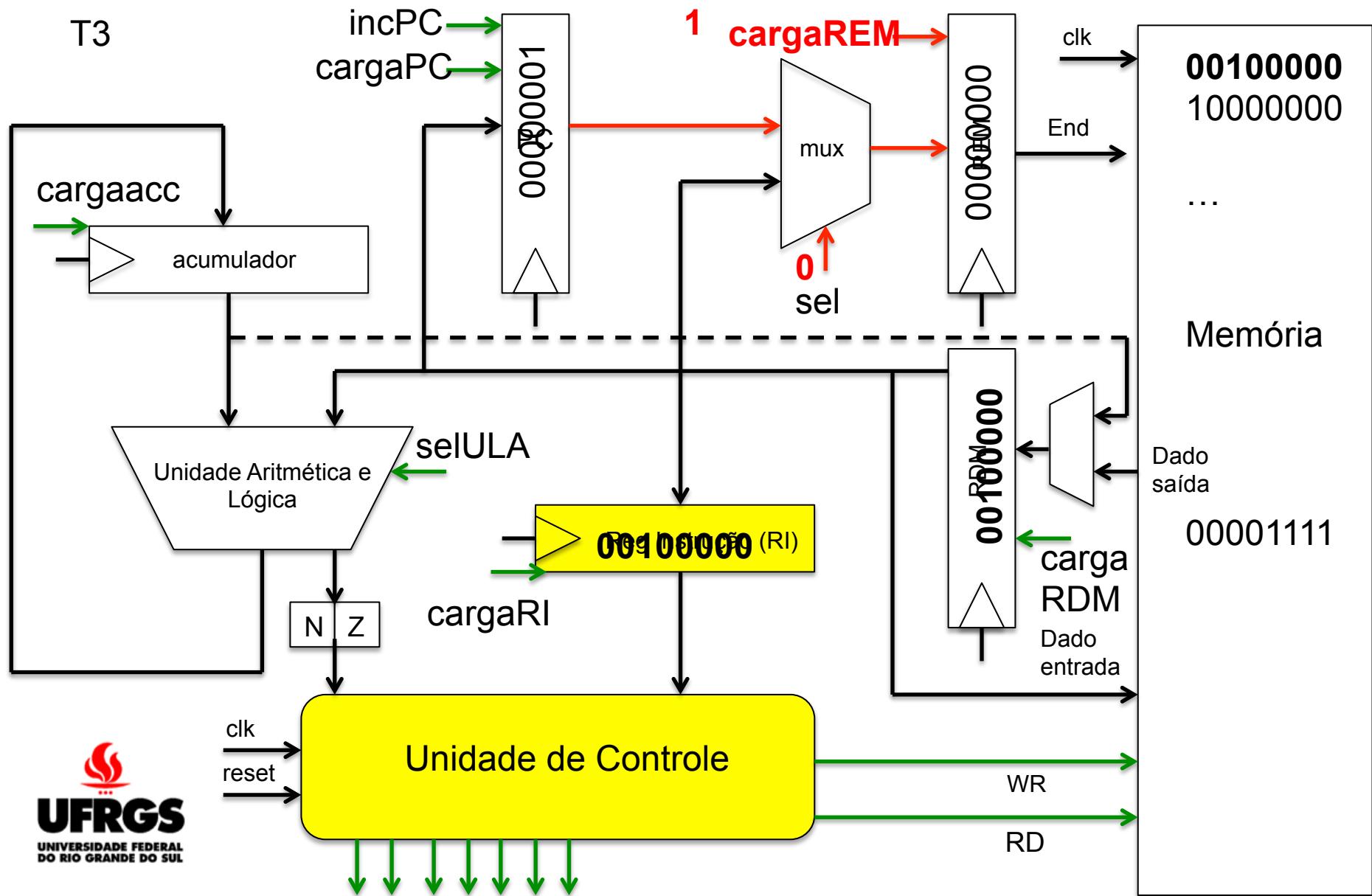


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: LDA end



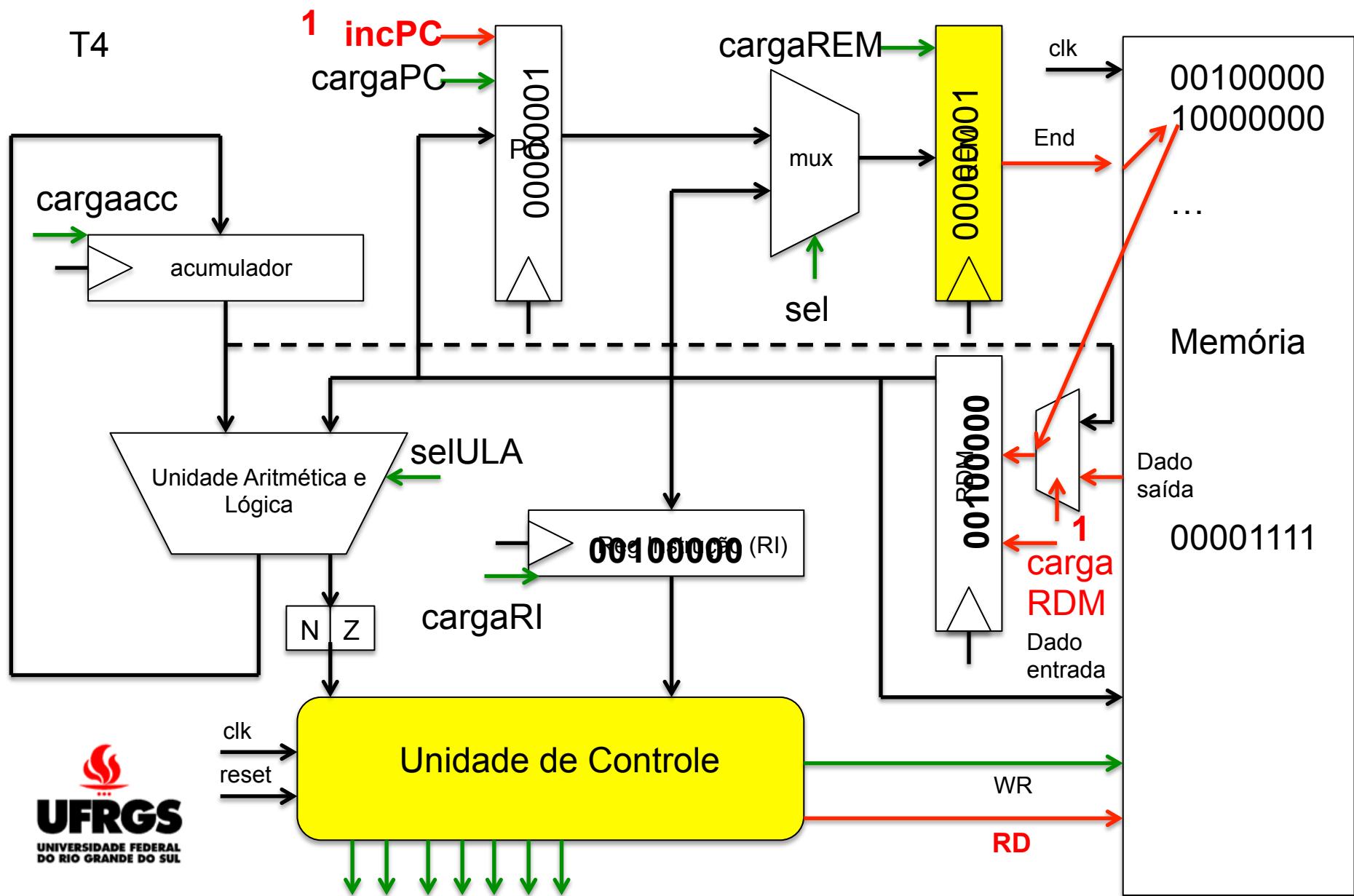


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: LDA end



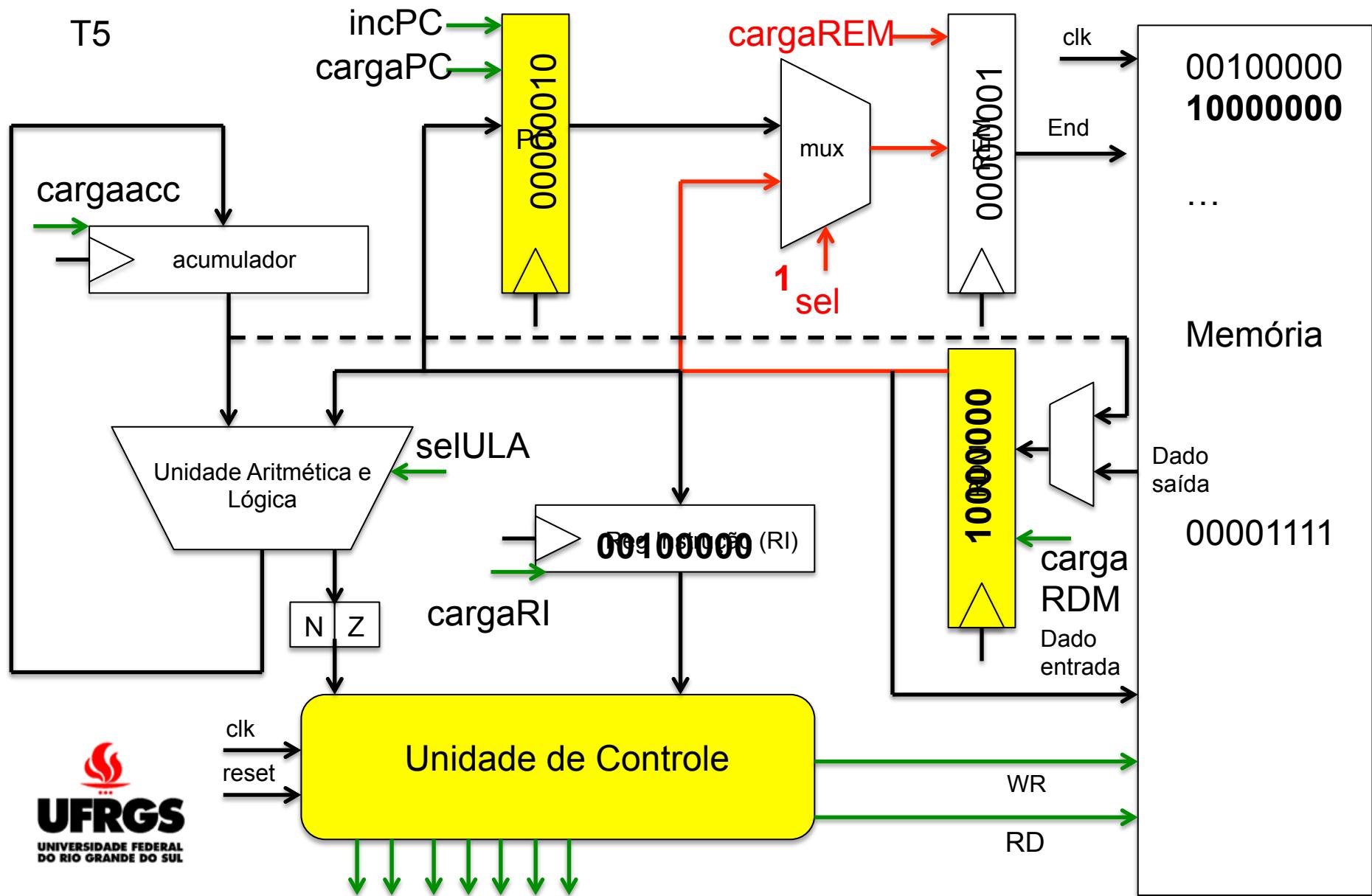


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: LDA end



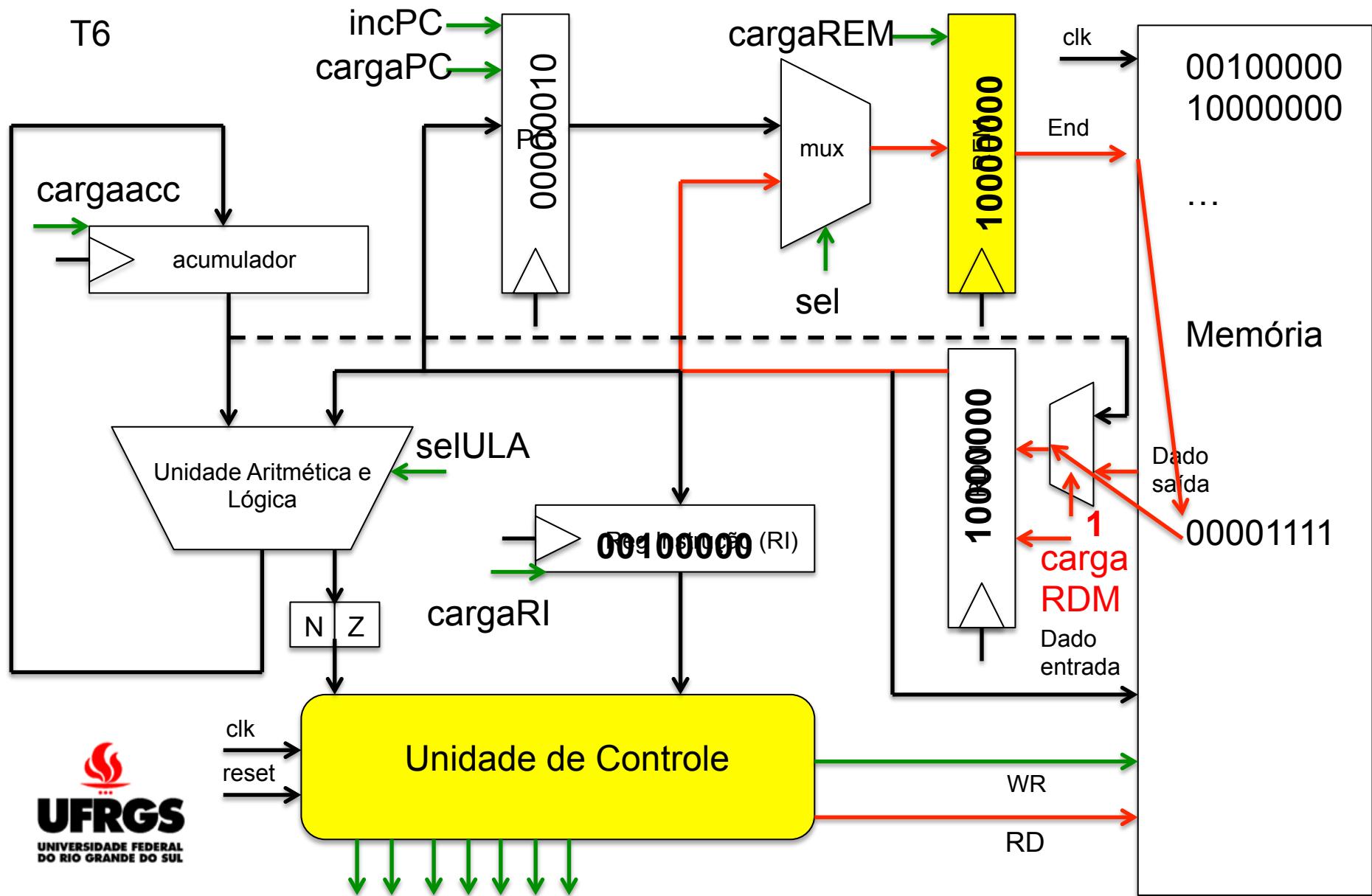


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: LDA end



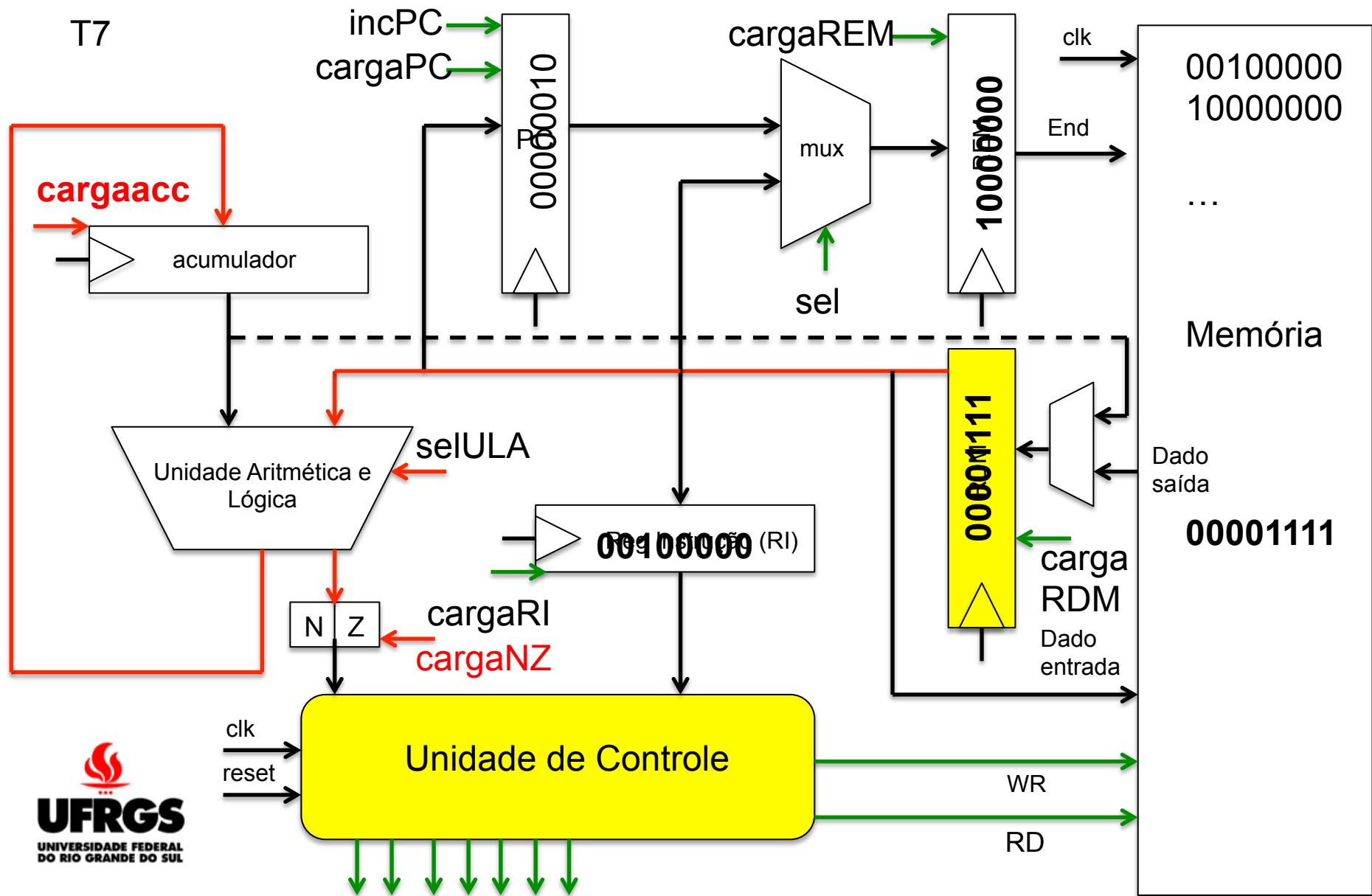


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	

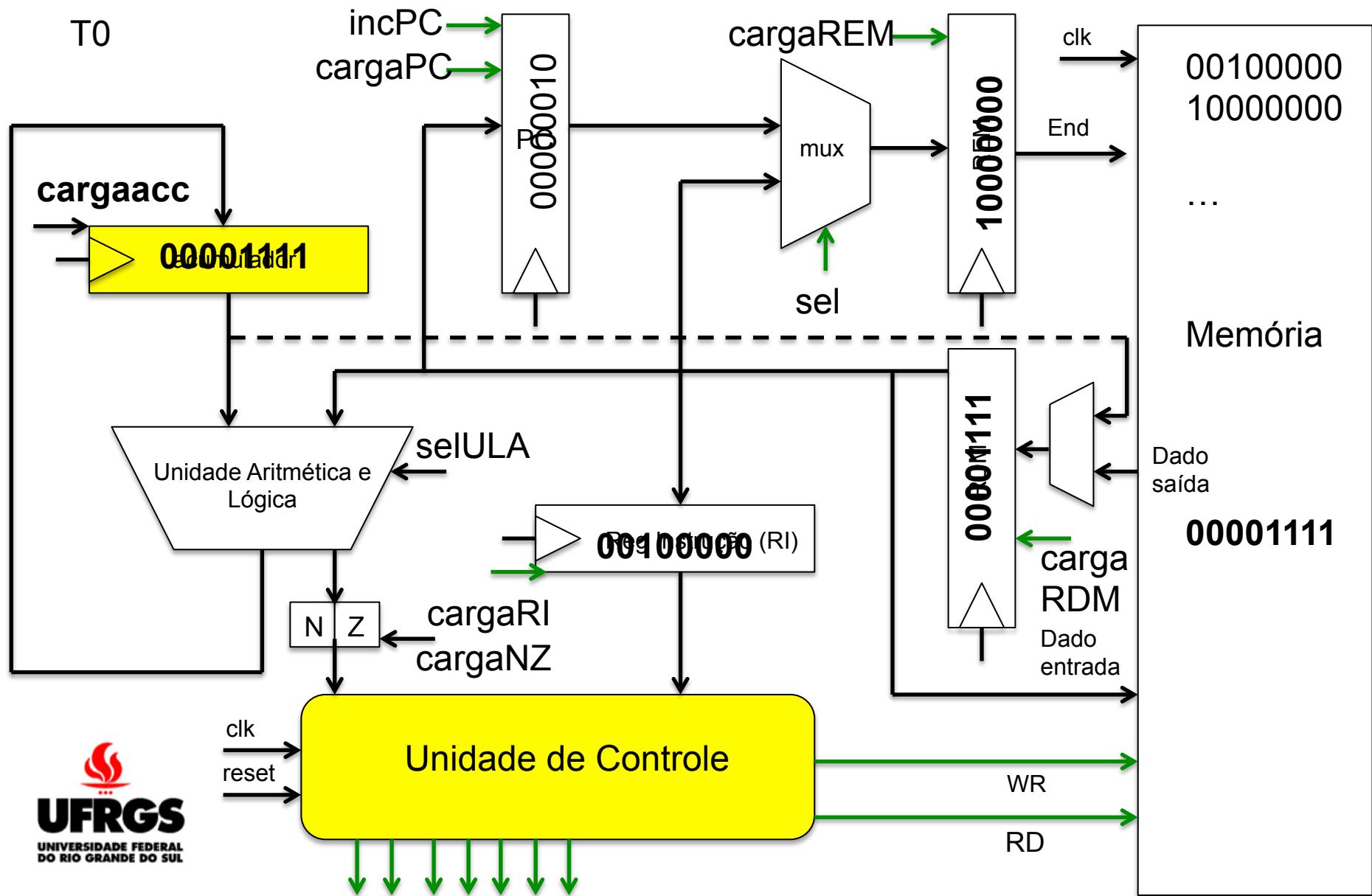


Neander: LDA end





Neander: LDA end





Instrução de STORE

STA end

Busca:

RI \leq mem (PC)

PC \leq PC + 1

Execução:

end \leq mem (PC)

PC \leq PC + 1

mem (end) \leq AC

STA end

Busca:

REM \leq PC

Read; PC \leq PC + 1

RI \leq RDM

Execução:

REM \leq PC

Read; PC \leq PC + 1

REM \leq RDM

RDM \leq AC

Write

Código	Instrução
0000	NOP
0001	STA end
0010	LDA end
0011	ADD end
0100	OR end
0101	AND end
0110	NOT
1000	JMP end
1001	JN end
1010	JZ end
1111	HLT

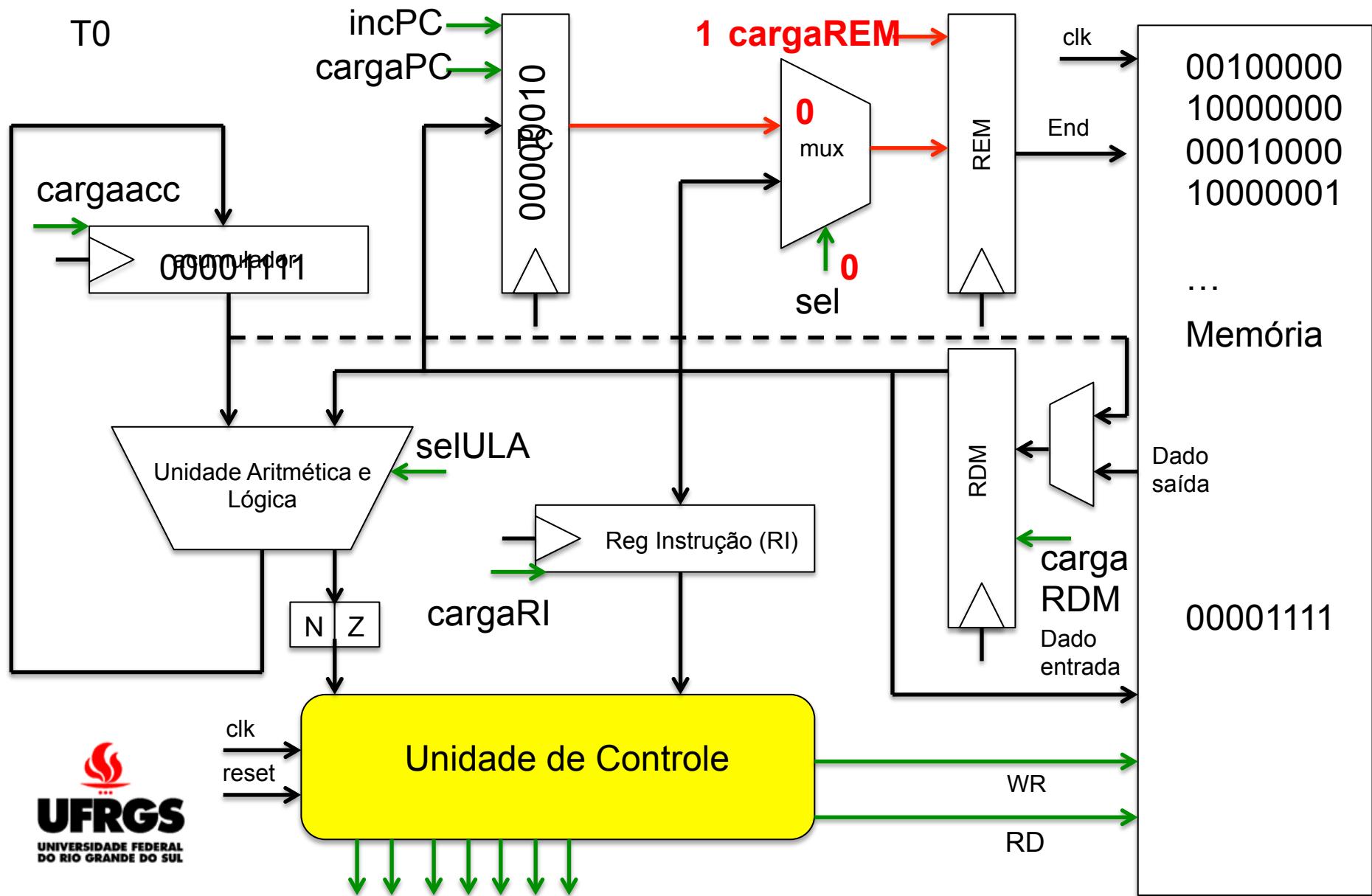


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: STA end



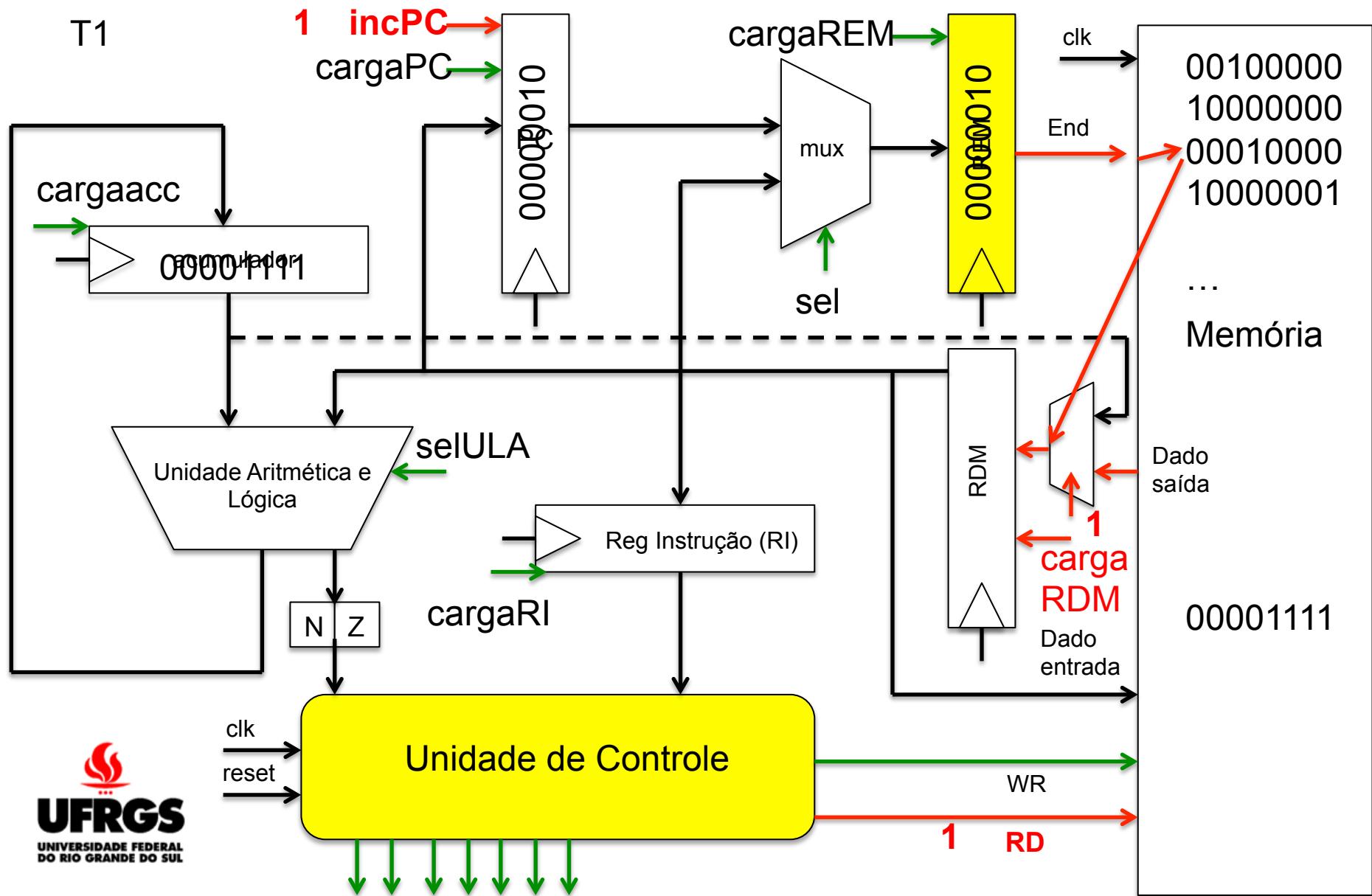


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: STA end



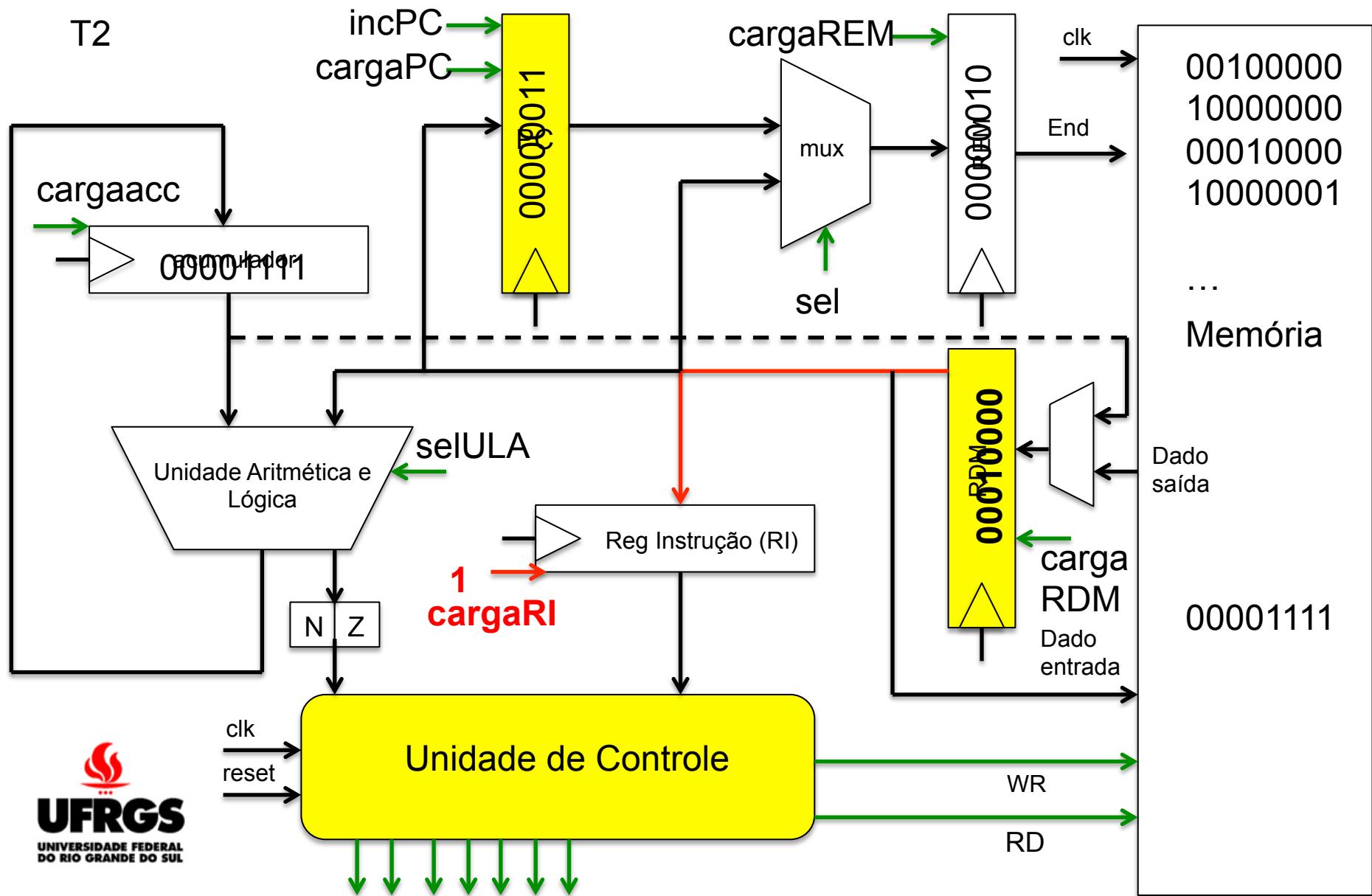


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: STA end



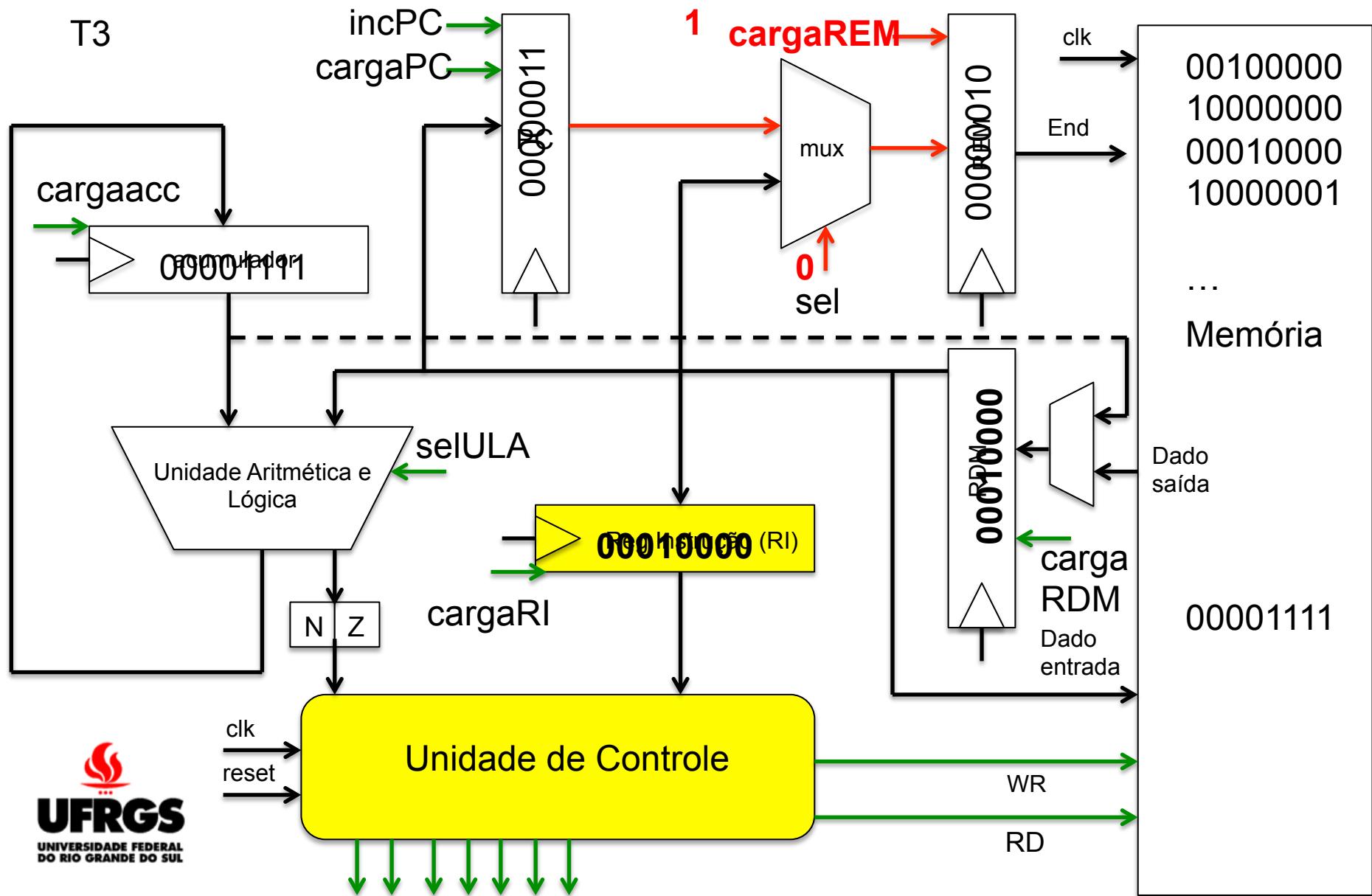


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: STA end



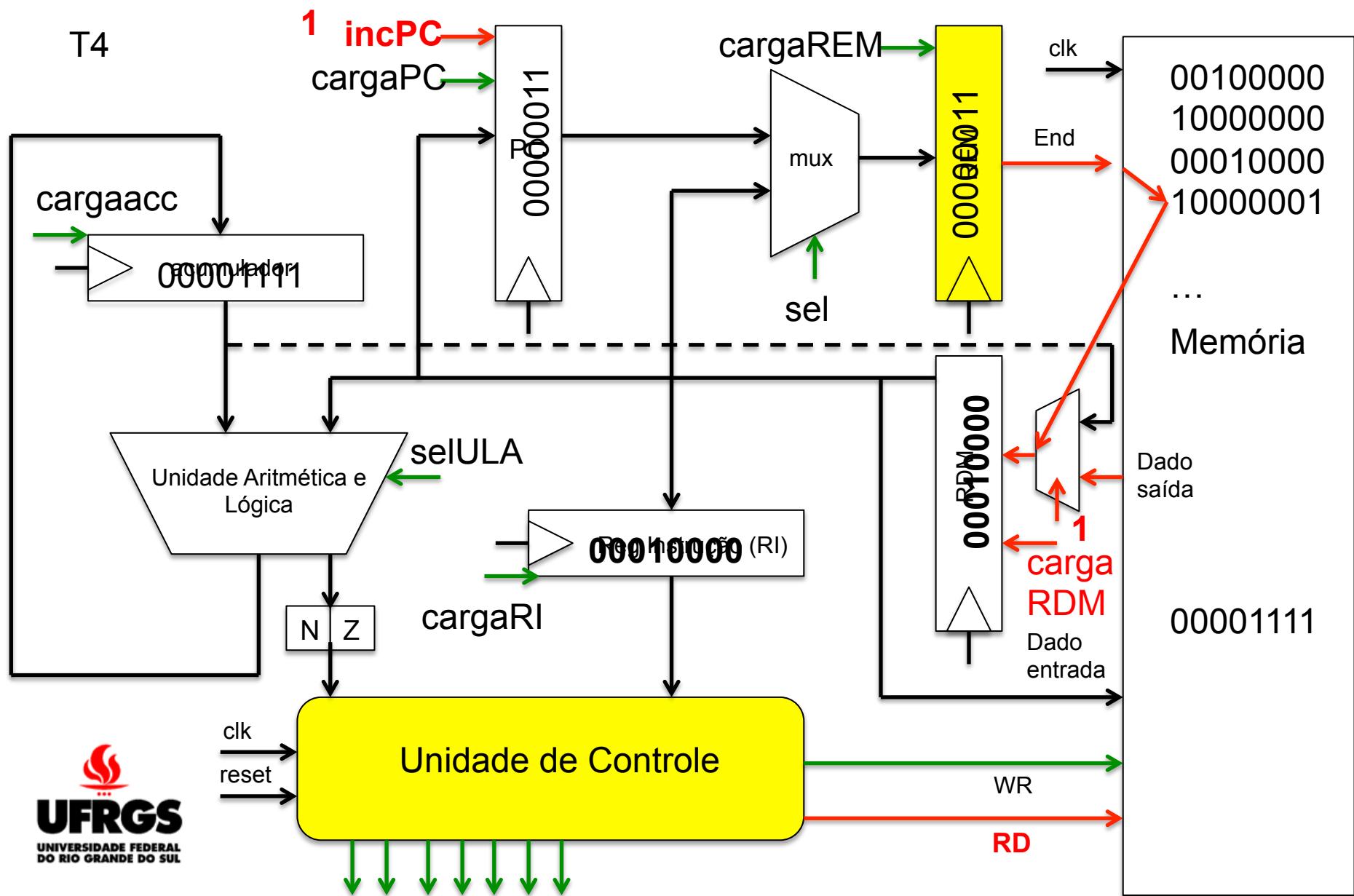


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: STA end



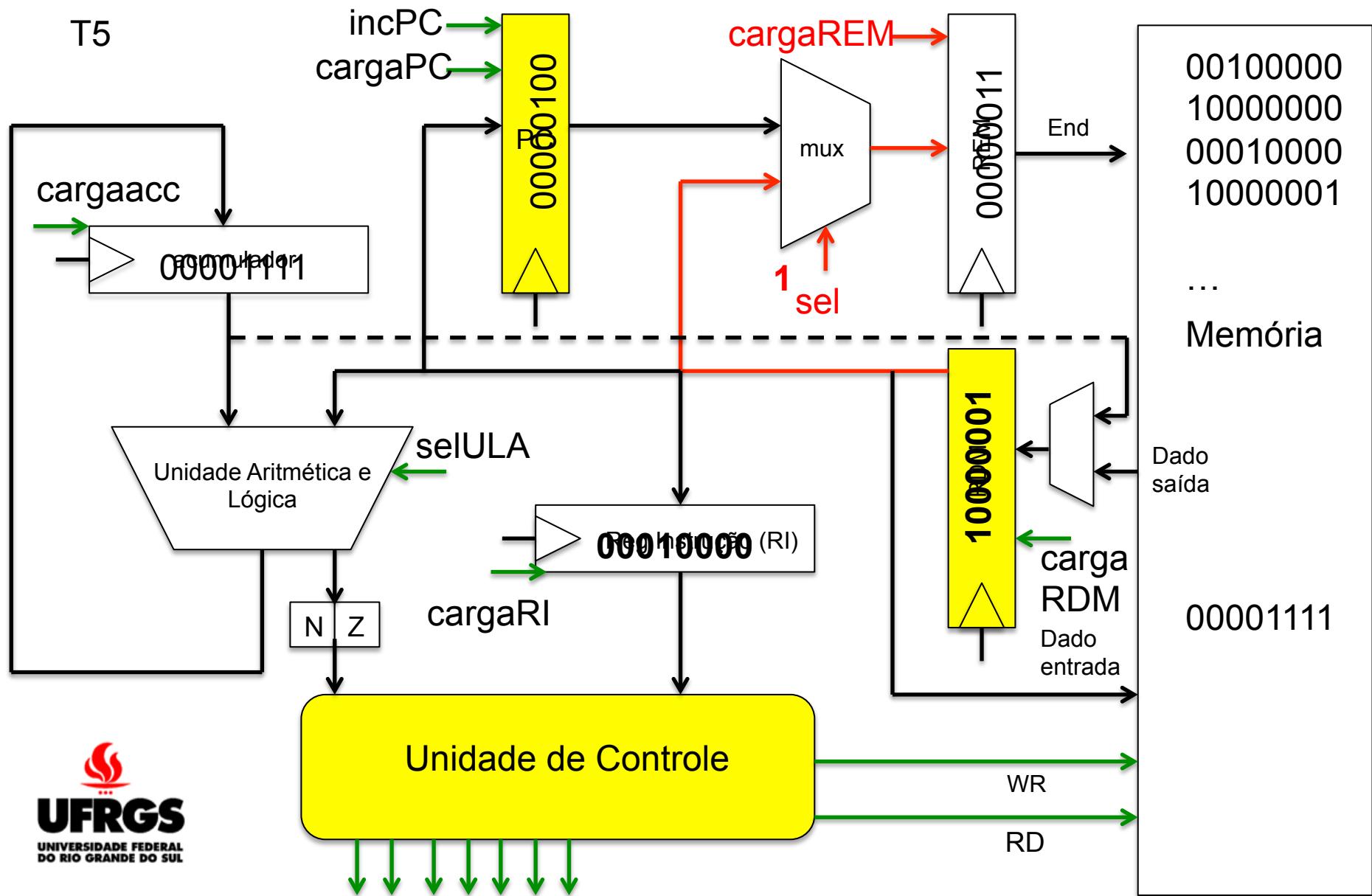


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: STA end



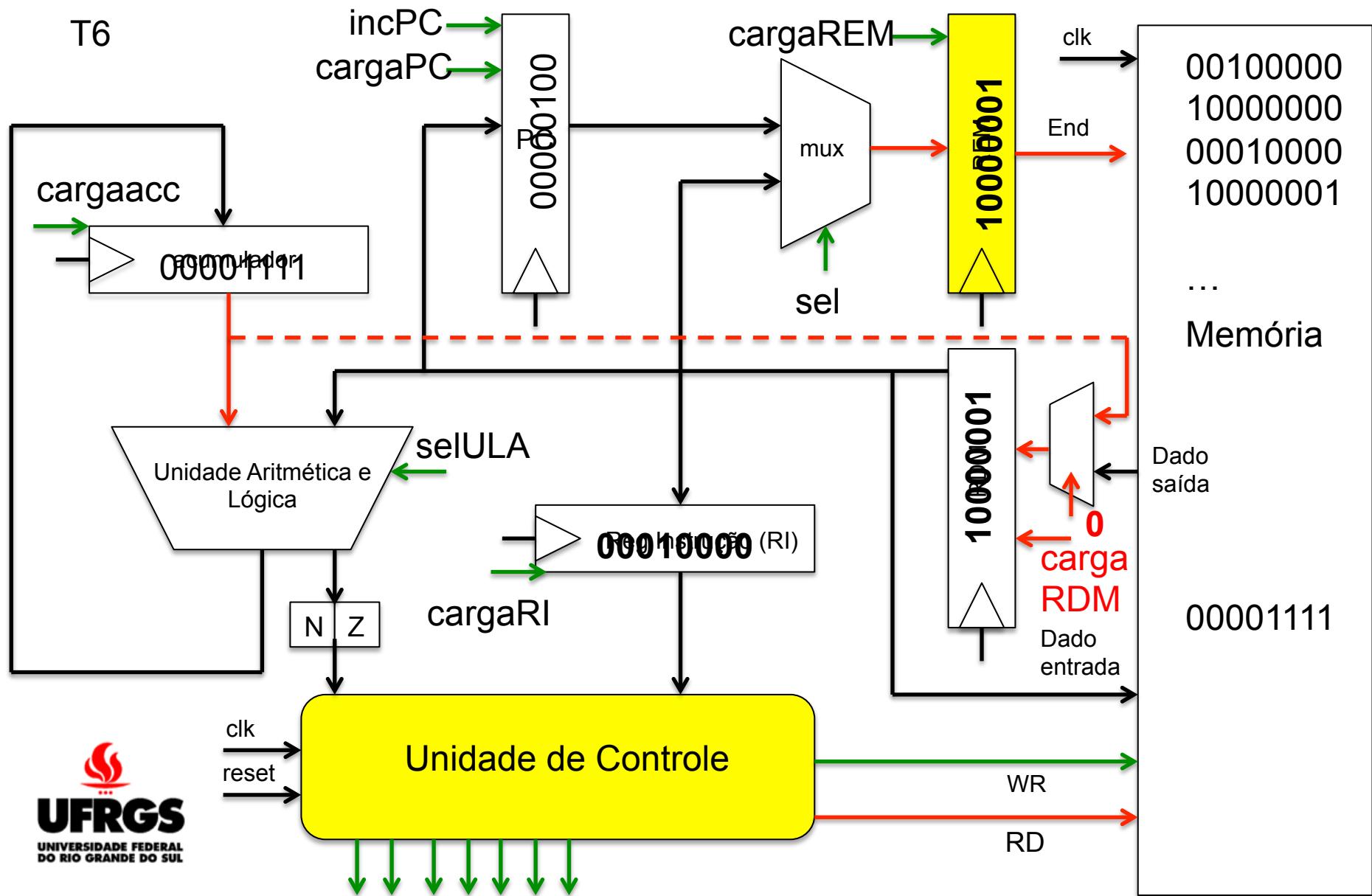


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	



Neander: STA end



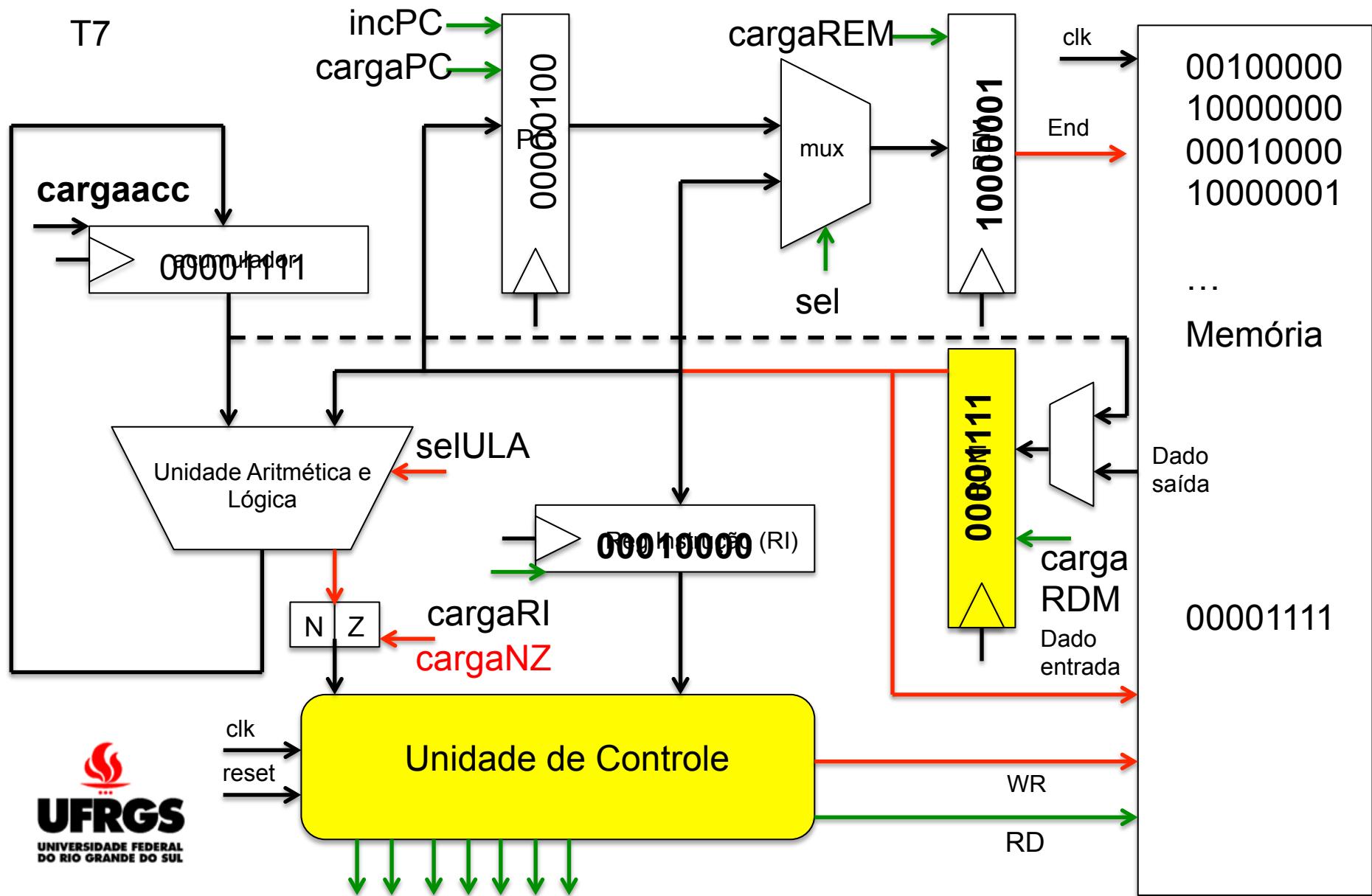


Unidade de Controle

tempo	STA	LDA	ADD	OR	AND	NOT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	UAL(NOT), carga AC, carga NZ, goto t0
t4	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	
t5	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	sel=1, carga REM	
t6	carga RDM	Read	Read	Read	Read	
t7	Write, goto t0	UAL(Y), carga AC, carga NZ, goto t0	UAL(ADD), carga AC, carga NZ, goto t0	UAL(OR), carga AC, carga NZ, goto t0	UAL(AND, carga AC, carga NZ, goto t0	

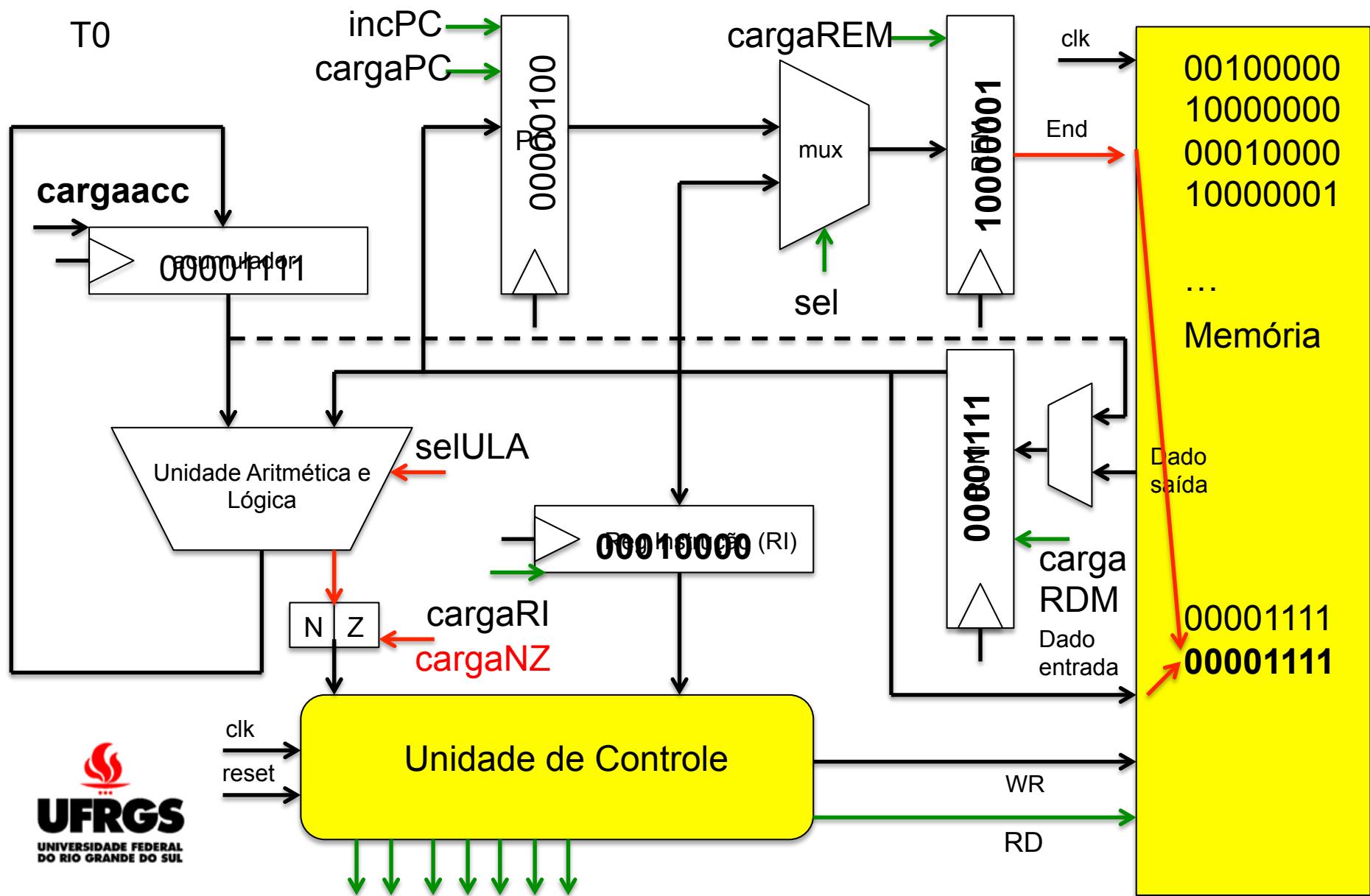


Neander: STA end





Neander: STA end





Resumo

- A sequencia de slides apresentada mostrou

LDA 128

STA 128

Onde a posição de memoria 128 contem 00001111. Logo o programa copiou esse valor para a posição 129.

Quantos ciclos de relógio demorou para realizar essas duas instruções?

$8 + 8 = 16$ e no ciclo 17 o valor 00001111 está gravado na memoria.



Instrução de NOP

NOP

Busca:

RI \leq mem (PC)

PC \leq PC + 1

Execução:

Nenhuma operação

NOP

Busca:

REM \leq PC

Read; PC \leq PC + 1

RI \leq RDM

Execução:

Nenhuma operação

Código	Instrução
0000	NOP
0001	STA end
0010	LDA end
0011	ADD end
0100	OR end
0101	AND end
0110	NOT
1000	JMP end
1001	JN end
1010	JZ end
1111	HLT

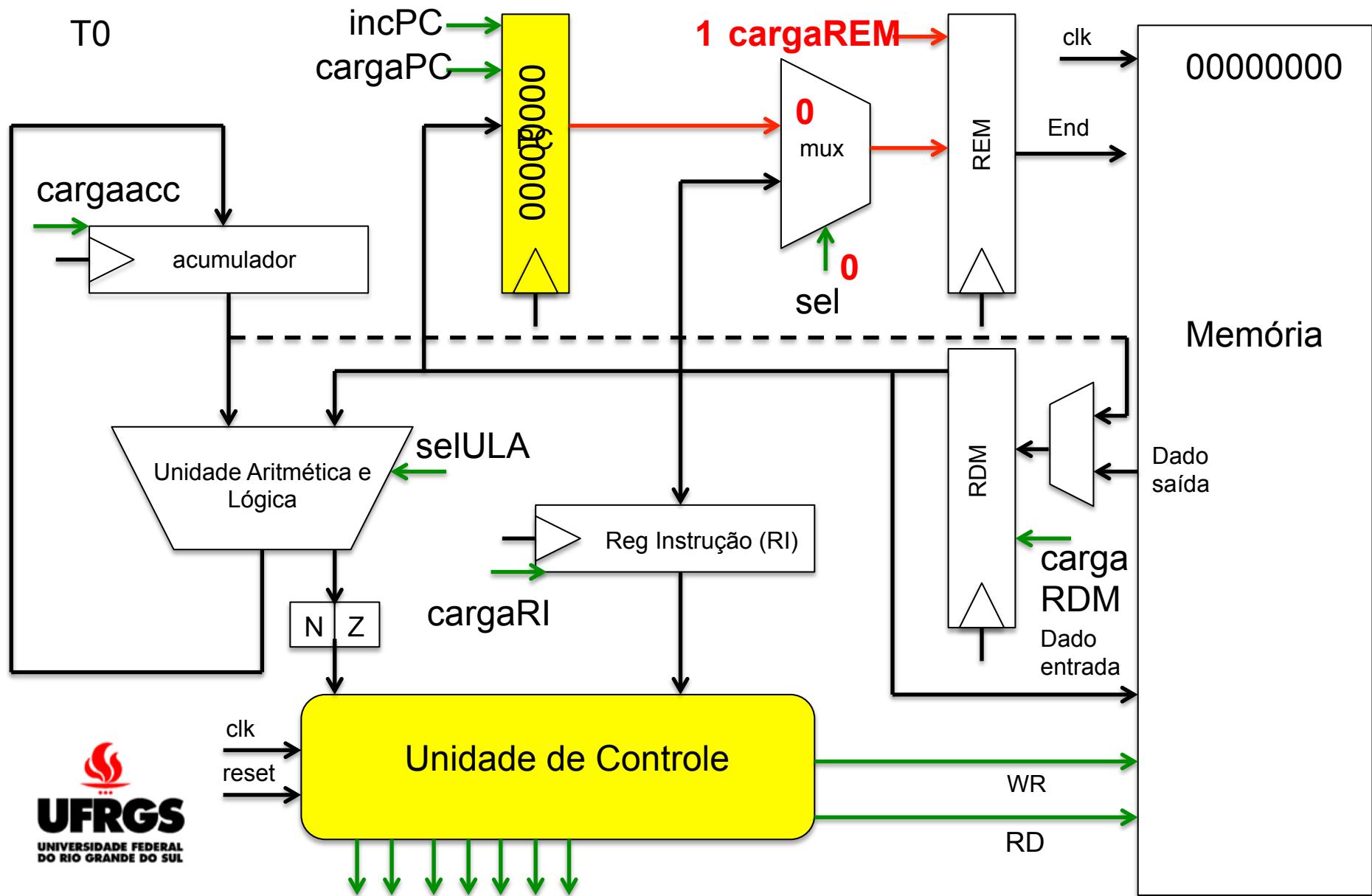


Unidade de Controle

tempo	JMP	JN, N=1	JN, N=0	JZ, Z=1	JZ, Z=0	NOP	HLT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	incrementa PC, goto t0	sel=0, carga REM	incrementa PC, goto t0	goto t0	Halt
t4	Read	Read		Read			
t5	carga PC, goto t0	carga PC, goto t0		carga PC, goto t0			
t6							
t7							



Neander: NOP



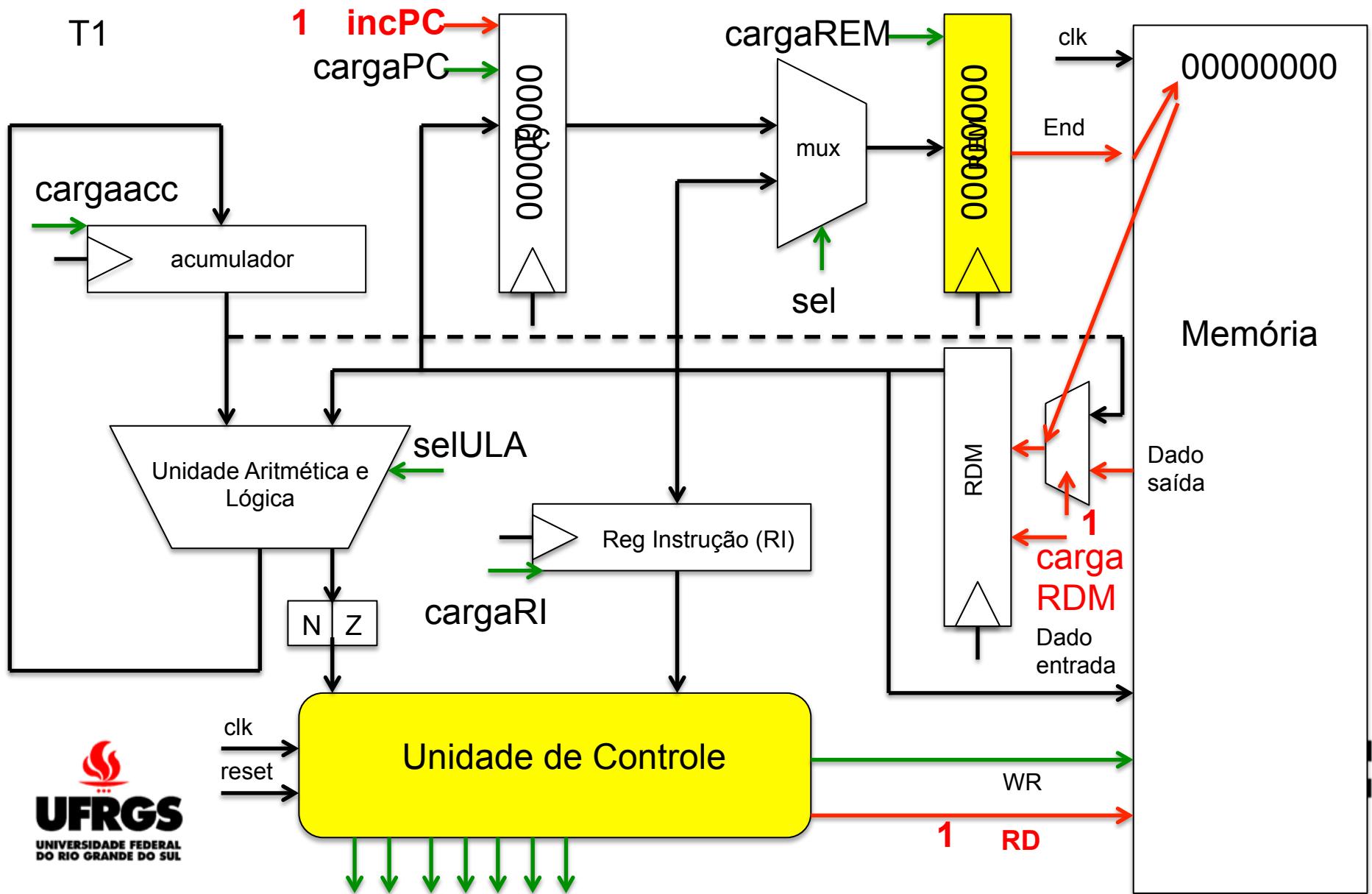


Unidade de Controle

tempo	JMP	JN, N=1	JN, N=0	JZ, Z=1	JZ, Z=0	NOP	HLT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	incrementa PC, goto t0	sel=0, carga REM	incrementa PC, goto t0	goto t0	Halt
t4	Read	Read		Read			
t5	carga PC, goto t0	carga PC, goto t0		carga PC, goto t0			
t6							
t7							

N

Neander: NOP



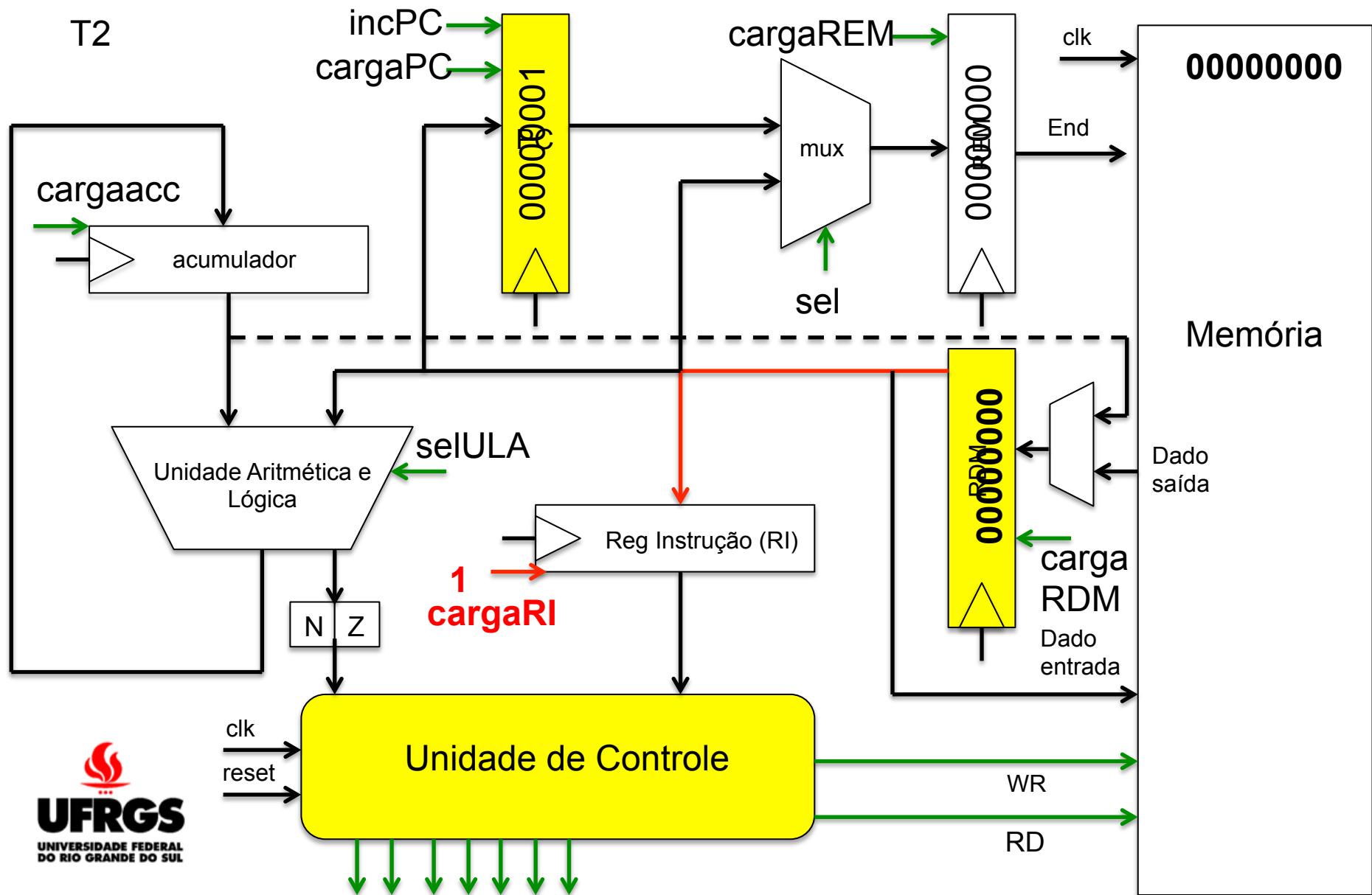


Unidade de Controle

tempo	JMP	JN, N=1	JN, N=0	JZ, Z=1	JZ, Z=0	NOP	HLT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	incrementa PC, goto t0	sel=0, carga REM	incrementa PC, goto t0	goto t0	Halt
t4	Read	Read		Read			
t5	carga PC, goto t0	carga PC, goto t0		carga PC, goto t0			
t6							
t7							



Neander: NOP



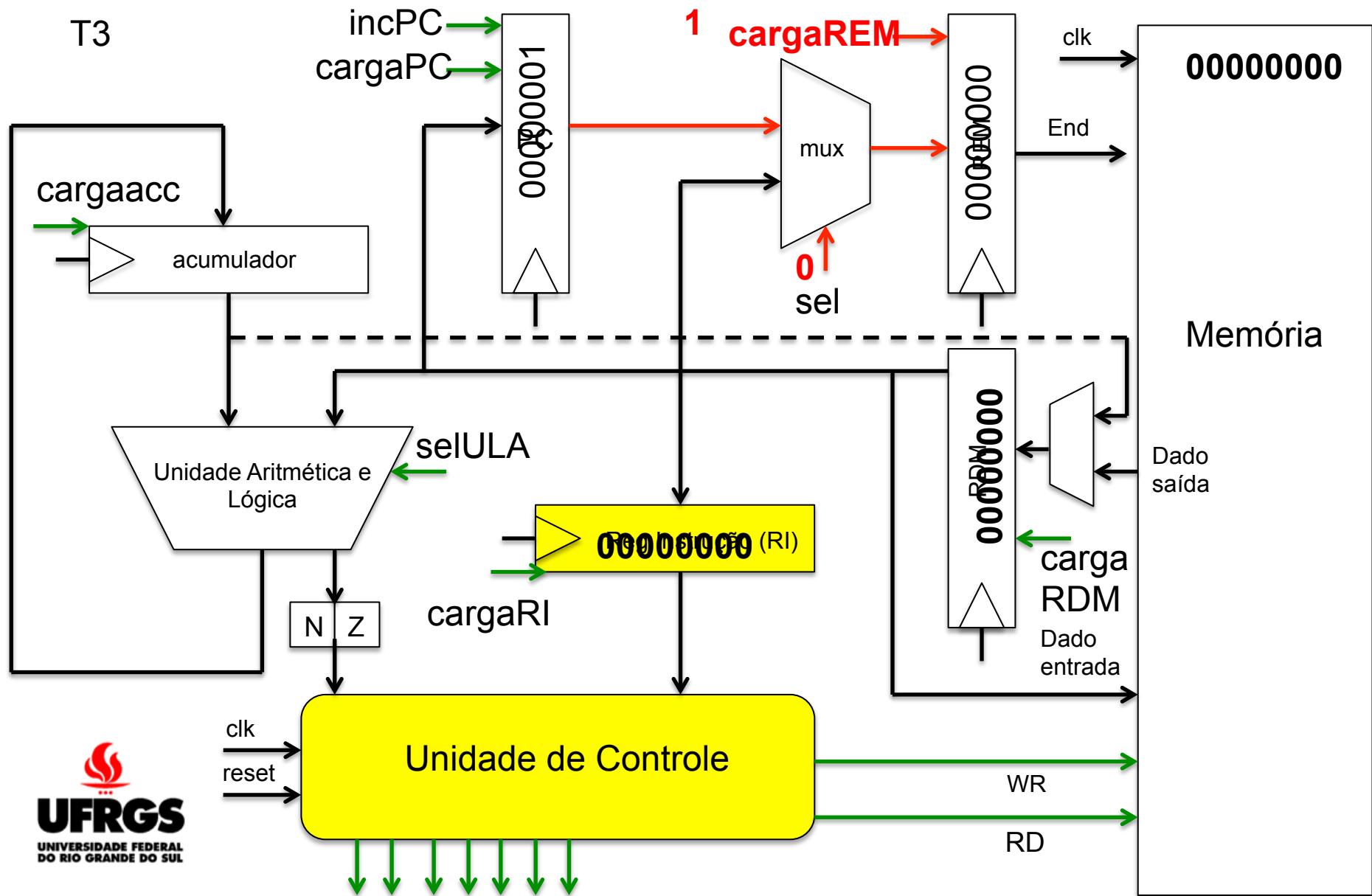


Unidade de Controle

tempo	JMP	JN, N=1	JN, N=0	JZ, Z=1	JZ, Z=0	NOP	HLT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	incrementa PC, goto t0	sel=0, carga REM	incrementa PC, goto t0	goto t0	Halt
t4	Read	Read		Read			
t5	carga PC, goto t0	carga PC, goto t0		carga PC, goto t0			
t6							
t7							



Neander: NOP





Instrução de ADD (Exercício)

ADD end

Busca:

RI \leq mem (PC)

PC \leq PC + 1

Execução:

End \leq mem(PC)

PC \leq PC+1

AC \leq AC + mem (end),
atualiza N e Z

ADD end

Busca:

REM \leq PC

Read; PC \leq PC + 1

RI \leq RDM

Execução:

REM \leq PC

Read; PC \leq PC+1

REM \leq RDM

Read

AC \leq AC + RDM

Atualize N e Z

Código	Instrução
0000	NOP
0001	STA end
0010	LDA end
0011	ADD end
0100	OR end
0101	AND end
0110	NOT
1000	JMP end
1001	JN end
1010	JZ end
1111	HLT



Instrução JZ end

- Caso Z=1

Busca:

RI <= mem(PC)

PC <= PC + 1

Execução:

end <= mem(PC)

PC <= end

- Caso Z=0

Busca:

RI <= mem(PC)

PC <= PC + 1

Execução:

end <= mem(PC)

PC <= PC + 1

- Caso Z=1

Busca:

REM <= PC

Read; PC<= PC+1

RI <= RDM

Execução:

REM <= PC

Read

PC <= RDM

- Caso Z=0

Busca:

REM <= PC

Read; PC<= PC+1

RI <= RDM

Execução:

REM <= PC

Read

PC <= PC + 1

Código	Instrução
0000	NOP
0001	STA end
0010	LDA end
0011	ADD end
0100	OR end
0101	AND end
0110	NOT
1000	JMP end
1001	JN end
1010	JZ end
1111	HLT

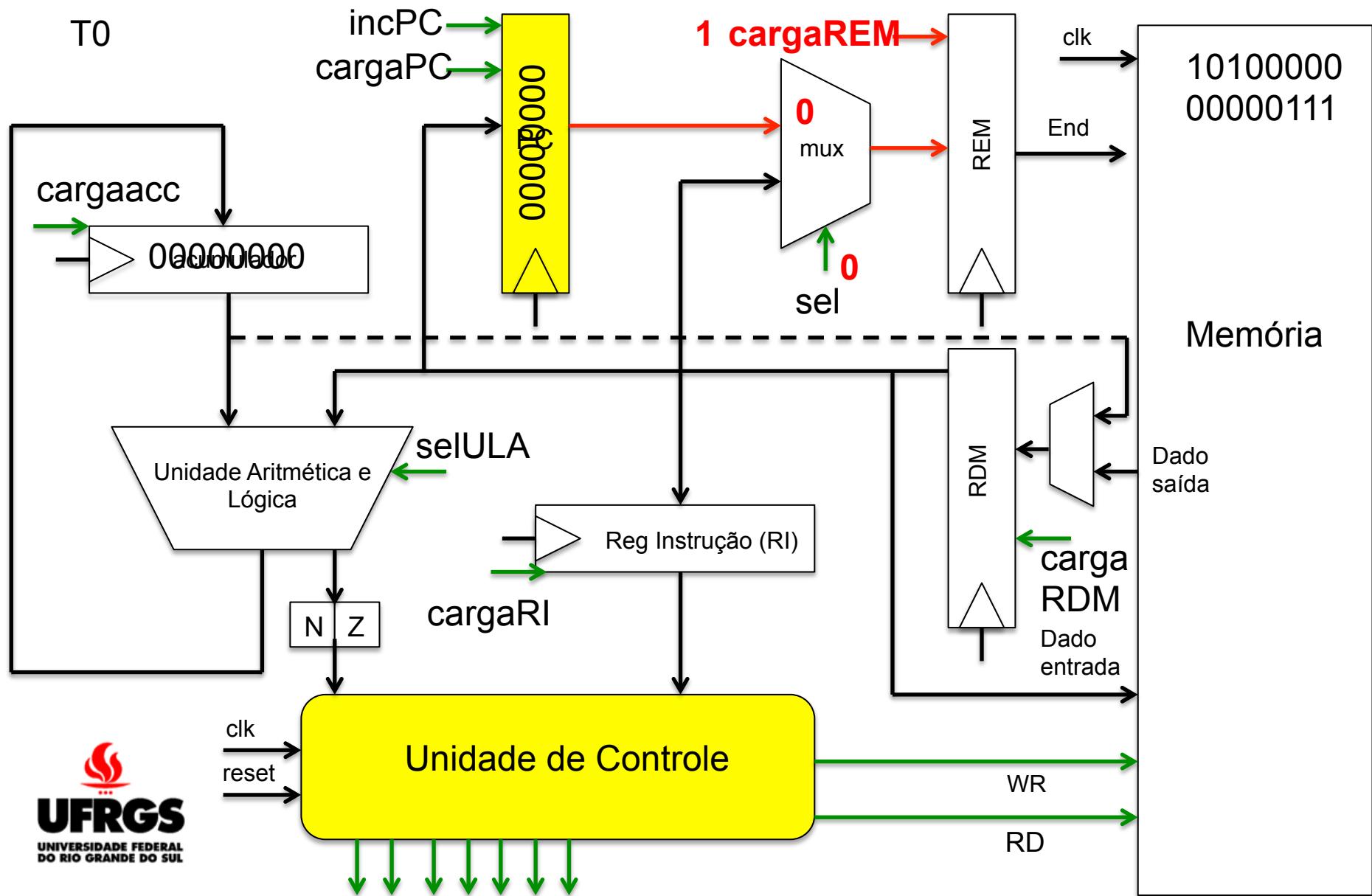


Unidade de Controle

tempo	JMP	JN, N=1	JN, N=0	JZ, Z=1	JZ, Z=0	NOP	HLT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	incrementa PC, goto t0	sel=0, carga REM	incrementa PC, goto t0	goto t0	Halt
t4	Read	Read		Read			
t5	carga PC, goto t0	carga PC, goto t0		carga PC, goto t0			
t6							
t7							



Neander: JZ end



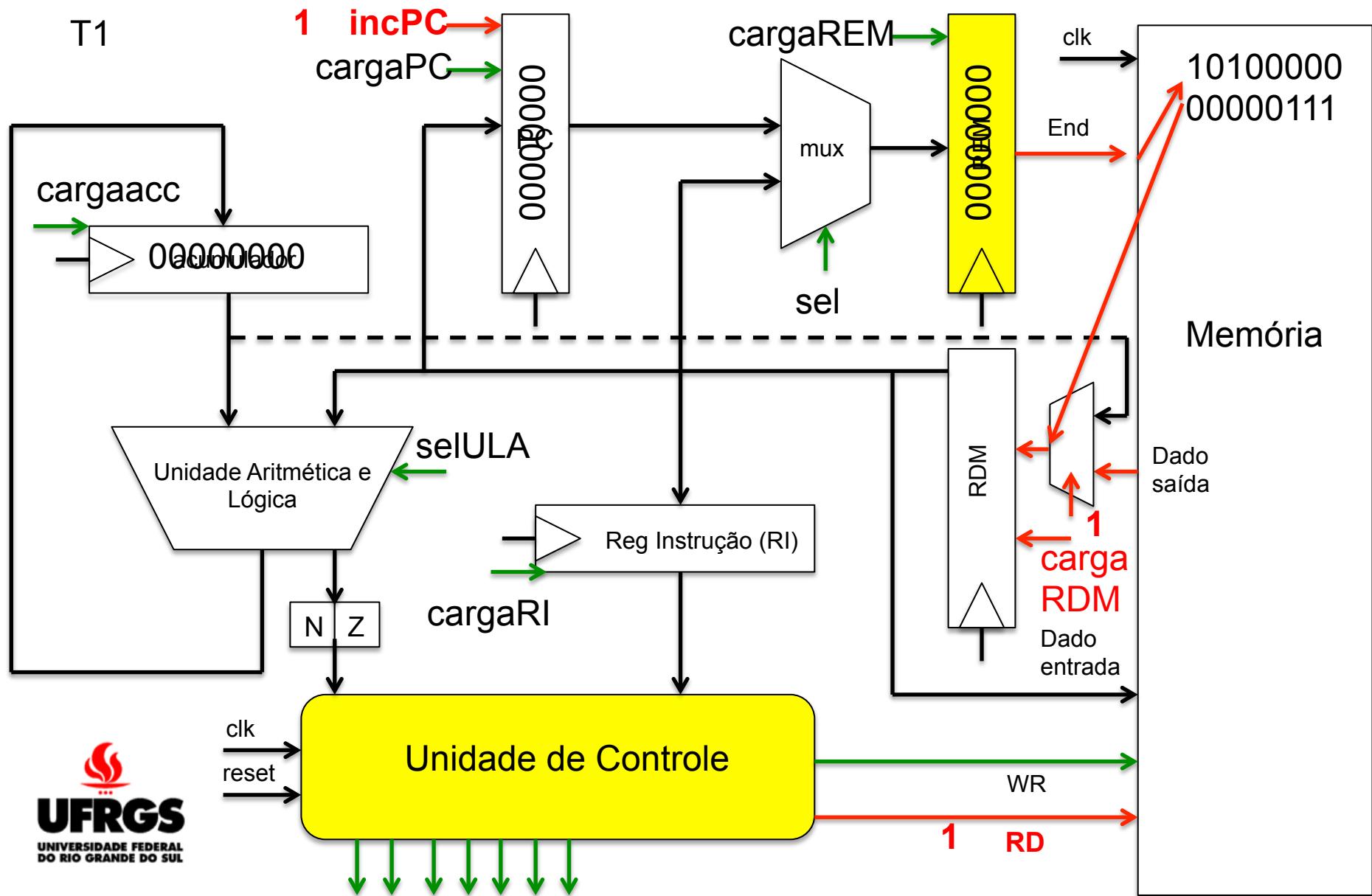


Unidade de Controle

tempo	JMP	JN, N=1	JN, N=0	JZ, Z=1	JZ, Z=0	NOP	HLT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	incrementa PC, goto t0	sel=0, carga REM	incrementa PC, goto t0	goto t0	Halt
t4	Read	Read		Read			
t5	carga PC, goto t0	carga PC, goto t0		carga PC, goto t0			
t6							
t7							



Neander: JZ end



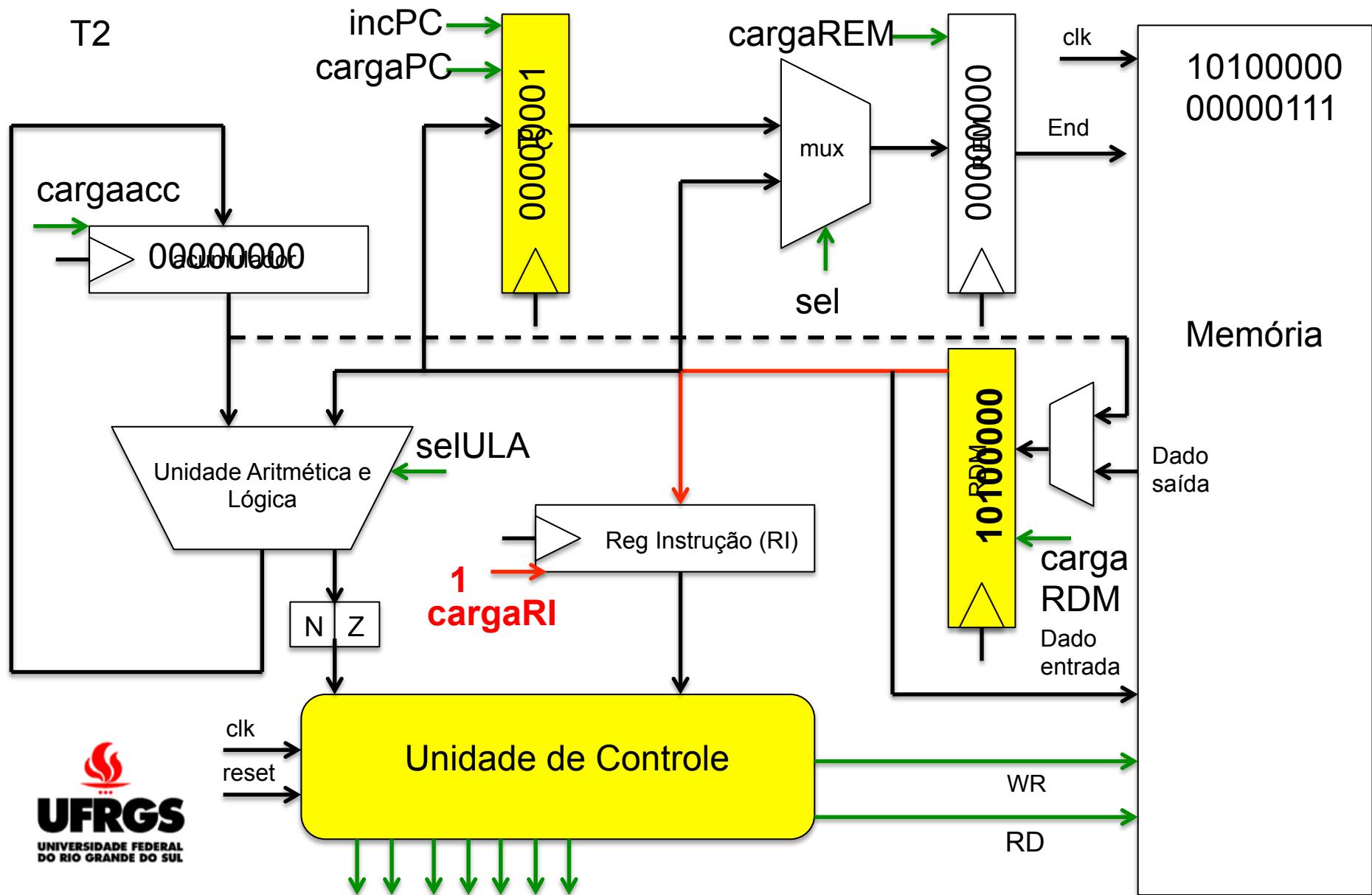


Unidade de Controle

tempo	JMP	JN, N=1	JN, N=0	JZ, Z=1	JZ, Z=0	NOP	HLT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	incrementa PC, goto t0	sel=0, carga REM	incrementa PC, goto t0	goto t0	Halt
t4	Read	Read		Read			
t5	carga PC, goto t0	carga PC, goto t0		carga PC, goto t0			
t6							
t7							



Neander: JZ end



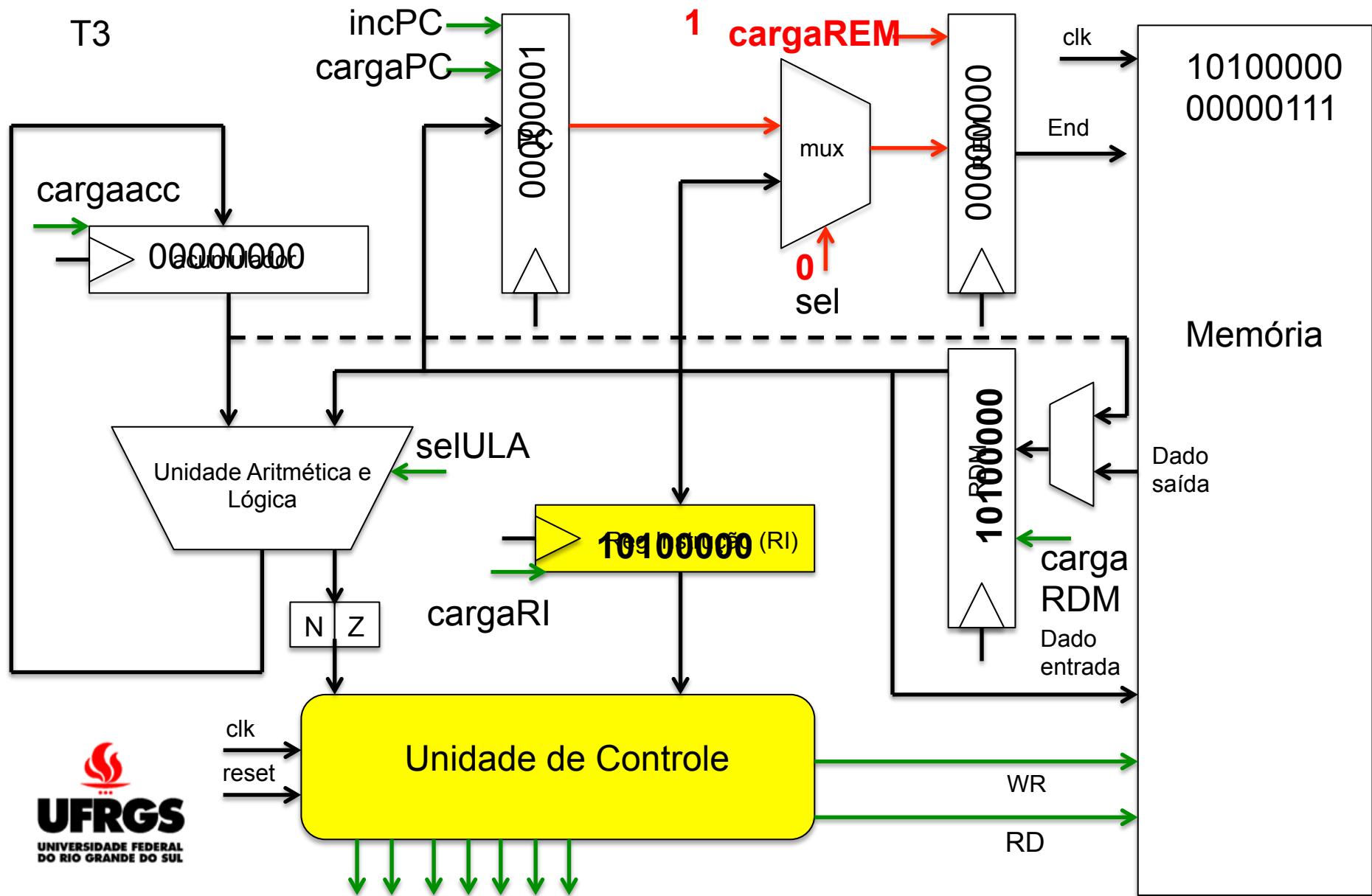


Unidade de Controle

tempo	JMP	JN, N=1	JN, N=0	JZ, Z=1	JZ, Z=0	NOP	HLT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	incrementa PC, goto t0	sel=0, carga REM	incrementa PC, goto t0	goto t0	Halt
t4	Read	Read		Read			
t5	carga PC, goto t0	carga PC, goto t0		carga PC, goto t0			
t6							
t7							



Neander: JZ end



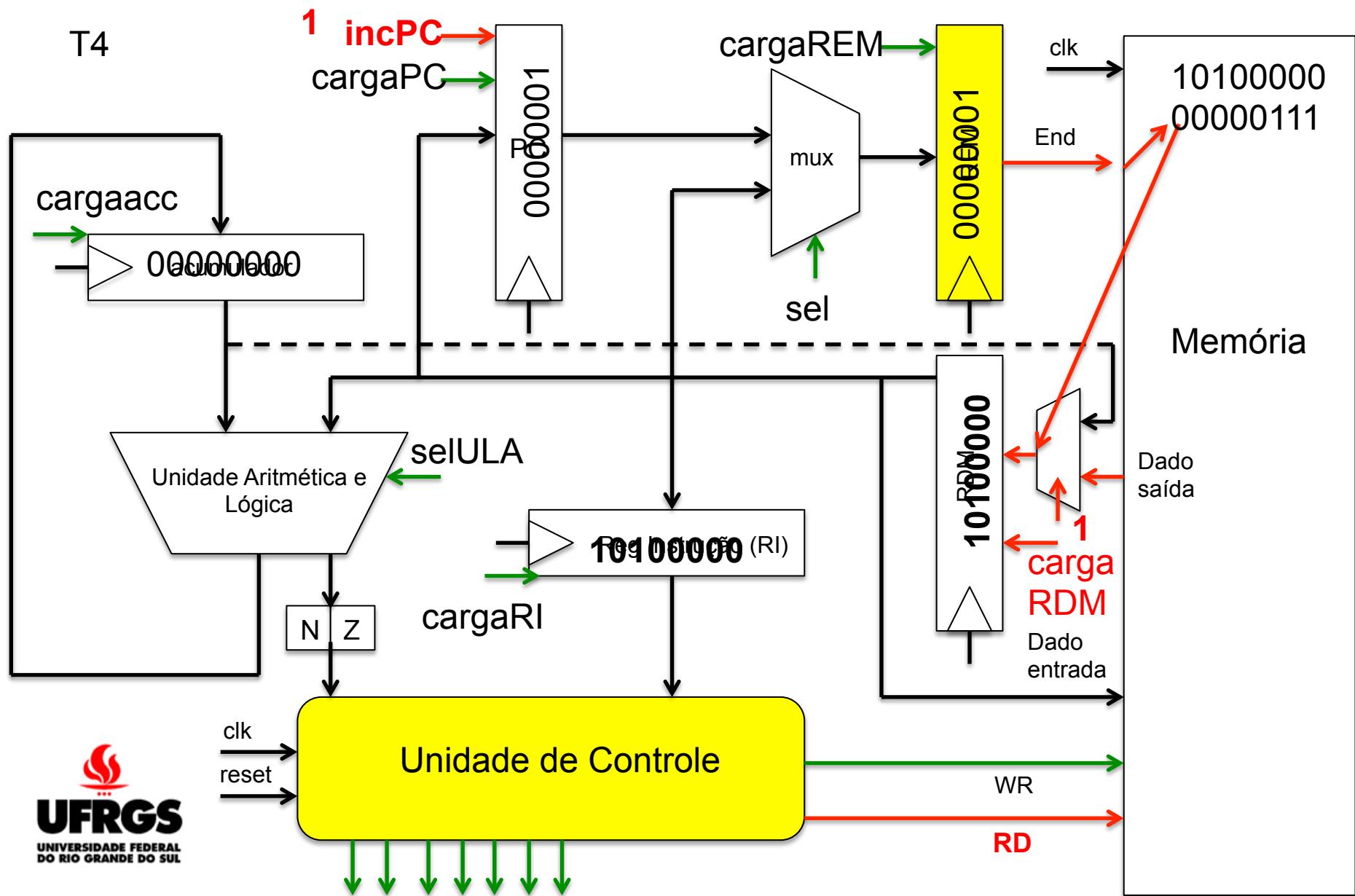


Unidade de Controle

tempo	JMP	JN, N=1	JN, N=0	JZ, Z=1	JZ, Z=0	NOP	HLT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	incrementa PC, goto t0	sel=0, carga REM	incrementa PC, goto t0	goto t0	Halt
t4	Read	Read		Read			
t5	carga PC, goto t0	carga PC, goto t0		carga PC, goto t0			
t6							
t7							



Neander: LDA end



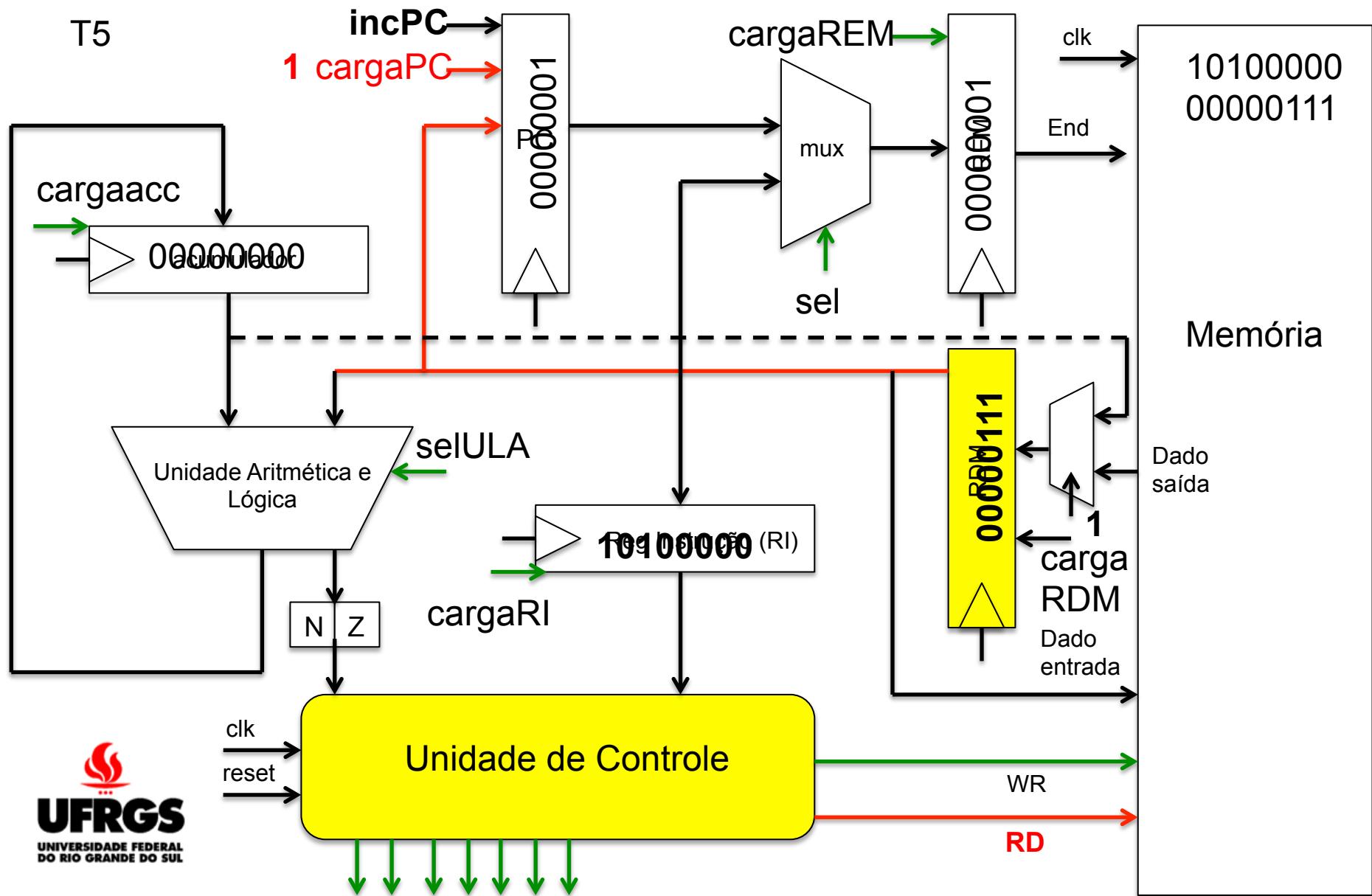


Unidade de Controle

tempo	JMP	JN, N=1	JN, N=0	JZ, Z=1	JZ, Z=0	NOP	HLT
t0	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM	sel=0, carga REM
t1	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC	Read, incrementa PC
t2	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI	carga RI
t3	sel=0, carga REM	sel=0, carga REM	incrementa PC, goto t0	sel=0, carga REM	incrementa PC, goto t0	goto t0	Halt
t4	Read	Read		Read			
t5	carga PC, goto t0	carga PC, goto t0		carga PC, goto t0			
t6							
t7							

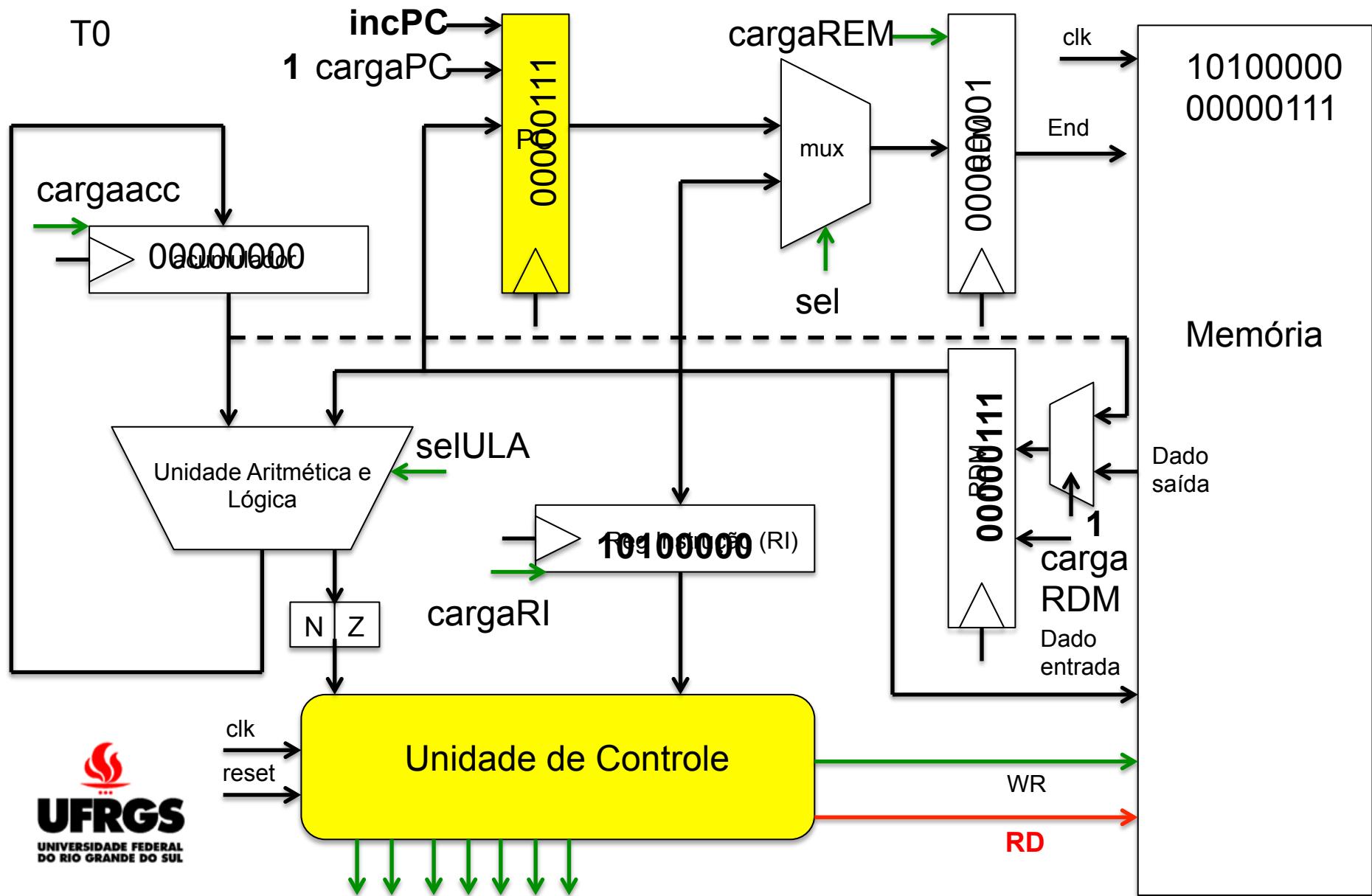


Neander: JZ end





Neander: JZ end





Instrução: AND end (exercício)

Busca:

REM <= PC

Read; PC<= PC+1

RI <= RDM

Execução:

REM <= PC

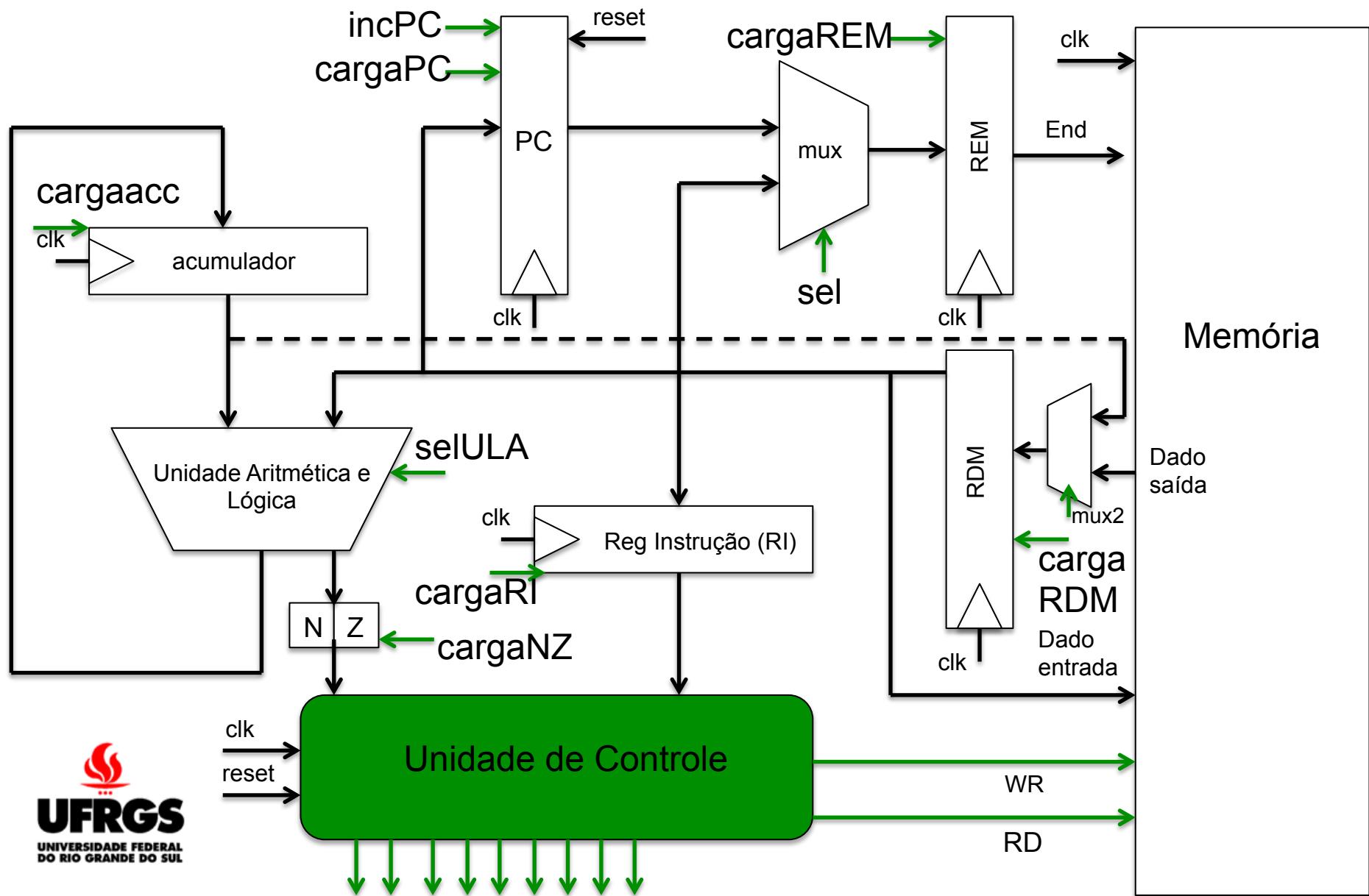
Read; PC <= PC + 1

REM <= RDM

Read

AC <= AC and RDM; atualiza N e Z

Código	Instrução
0000	NOP
0001	STA end
0010	LDA end
0011	ADD end
0100	OR end
0101	AND end
0110	NOT
1000	JMP end
1001	JN end
1010	JZ end
1111	HLT





ULA NEANDER

